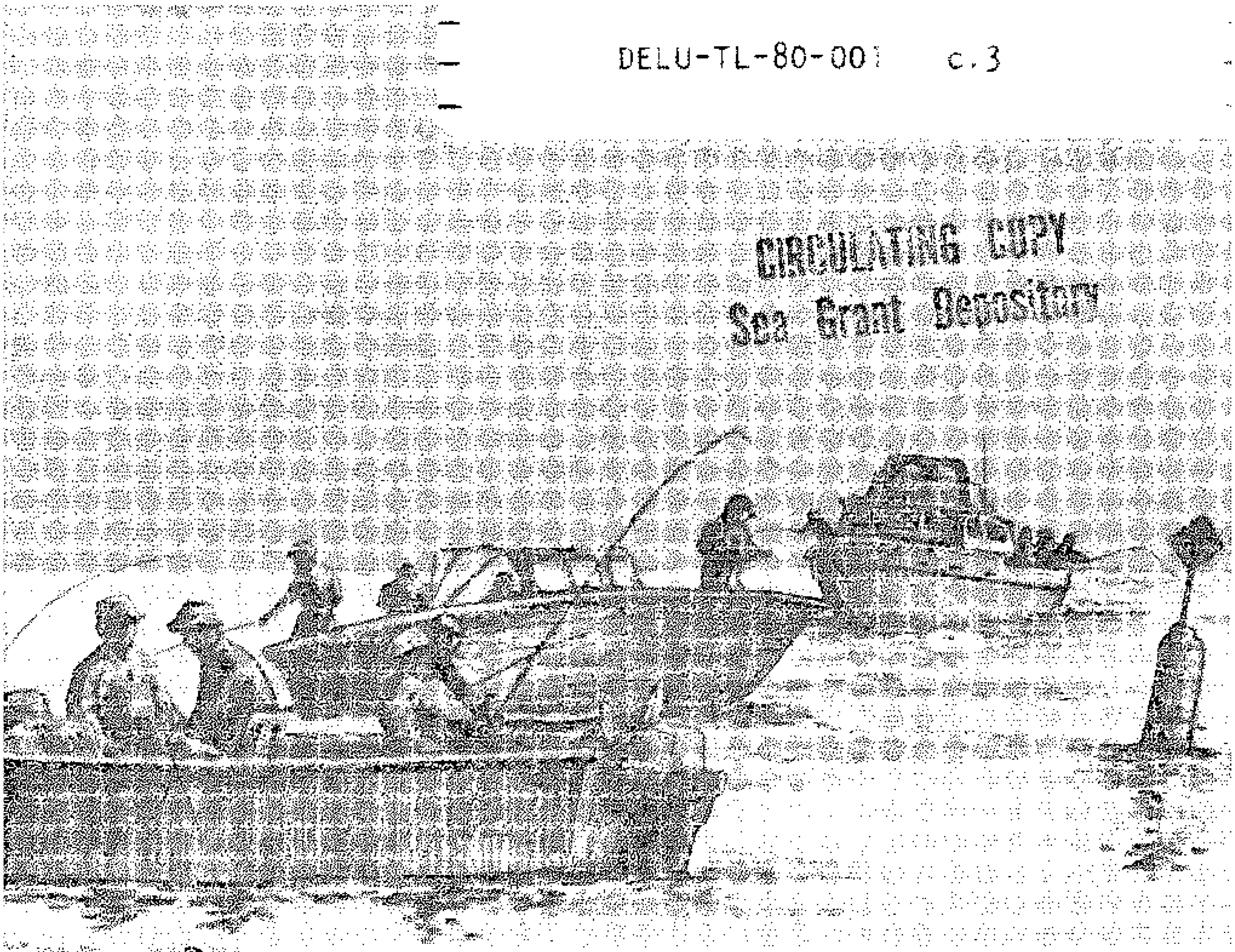

Artificial Reefs for Delaware?

Overview

- Artificial reefs have improved fishing in many coastal regions by concentrating fish in a smaller area through offering a good food supply and suitable habitat.
- In waters devoid of natural reefs and rock outcroppings—the case for Delaware, artificial reefs have attracted new sportfishing species by changing the environment beneficially.
- Many materials make good reefs—building rubble, scrap culvert, quarry rock, and concrete modules—but discarded automobile tires are probably most practical for Delaware because they are readily available, long lasting, and cost effective.
- Delaware discards about 500,000 tires annually, enough to build 20 acres or more of high-profile reef each year at an estimated cost of about $9,000 per acre. Cost of a low-profile reef could be as low as $2,000 per acre.
- Scrap tires are also a solid-waste-disposal problem for Delaware. Recognizing this, the Delaware Solid Waste Authority is willing to provide capital equipment for processing waste tires for reef construction.
- A worthwhile artificial-reef program for Delaware would cost between $100,000 and $200,000 per year and, to be most effective, should be operated by the state government.
- An artificial-reef program could attract additional out-of-state fishermen, and their expenditures in Delaware will benefit the local economy and increase state tax receipts. These continuing expenditures for the life of the reef give it an estimated value, based on tax revenue alone, of about $10,000 per acre.
- In view of the prospective benefits of artificial reefs—improved fishing, stimulation of the coastal economy, and clean disposal of scrap tires—Delaware should actively consider starting an artificial-reef program.

Artificial Reefs for Delaware?

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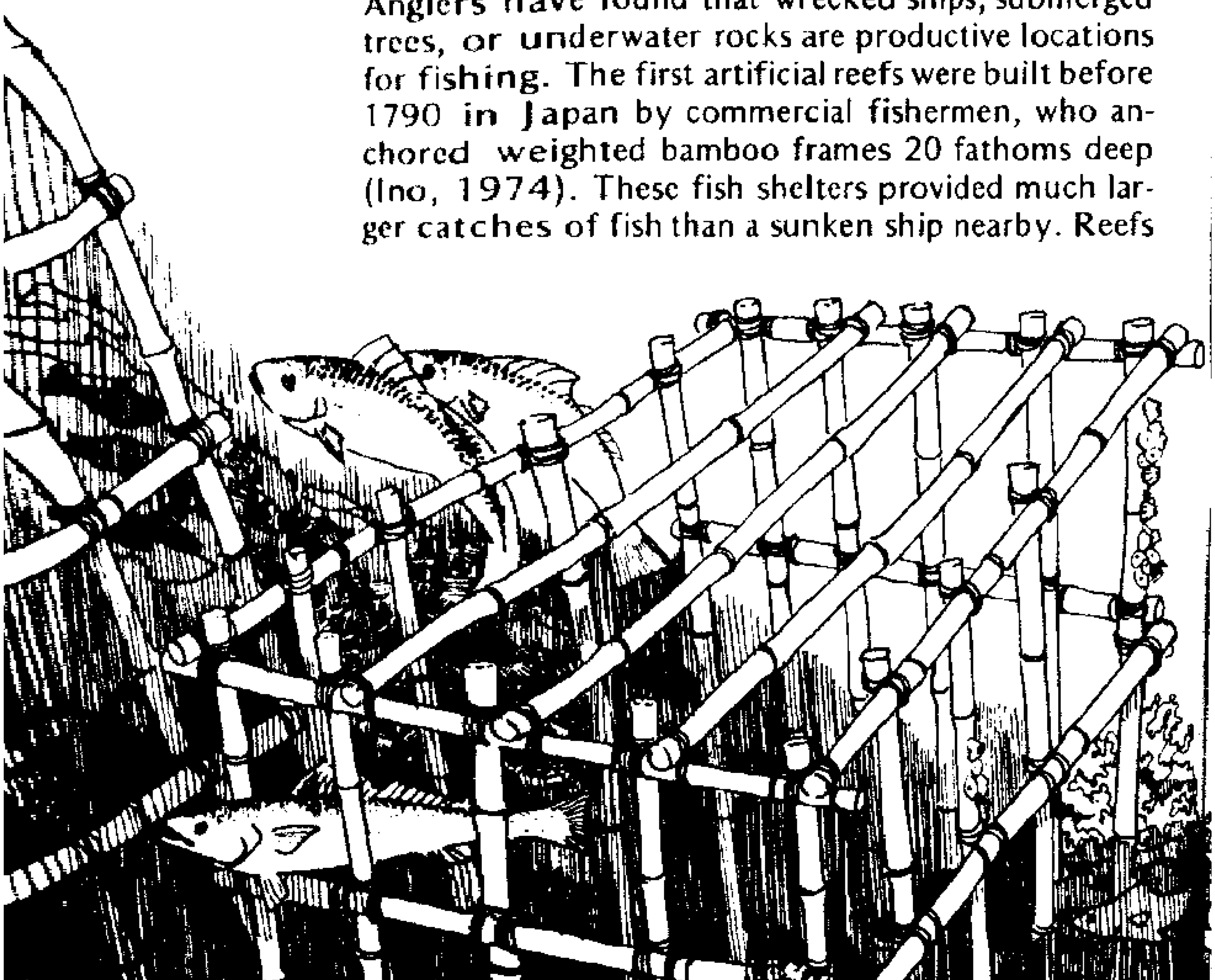
What are artificial reefs?

Artificial reefs are man-made underwater structures that provide a habitat for many types of fishes. Fish are attracted to artificial reefs because the reefs shelter the fish from predators and make good feeding sites. Barnacles, algae, smaller fish, and many other members of the aquatic food chain find a home within the reefs, as reported by Florida Sea Grant (1979). Thus, artificial reefs not only concentrate game fish within a smaller area, they also increase the total number of fish by offering an increased food supply.

The value of underwater reefs in providing larger catches of fish has long been recognized. Anglers have found that wrecked ships, submerged trees, or underwater rocks are productive locations for fishing. The first artificial reefs were built before 1790 in Japan by commercial fishermen, who anchored weighted bamboo frames 20 fathoms deep (Ino, 1974). These fish shelters provided much larger catches of fish than a sunken ship nearby. Reefs

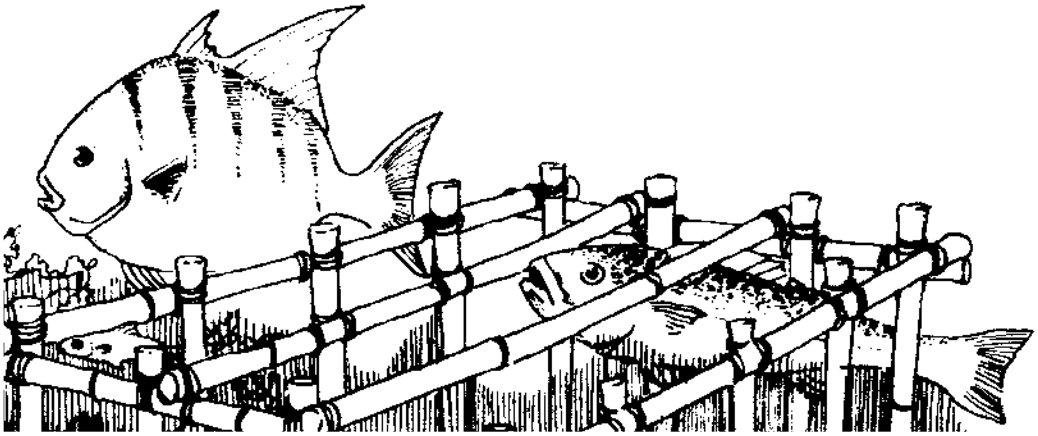


are still used by commercial fishermen in Japan, and the government there has granted subsidies for reef construction since 1930.

In South Carolina, artificial reefs were used as early as 1860 (Stone, 1974). Frames made from oak or pine logs and sunk offshore were inhabited by barnacles and fish in a few weeks. Stone cites numerous examples of later reef construction such as the use of concrete modules in Great South Bay, New York, in 1916 and the sinking of several vessels off Cape May, New Jersey, in 1935. In California, even offshore oil-well drilling platforms produce a notable increase in fish populations (Simpson, 1977).

Over 200 artificial reefs have been constructed to date along the U.S. coastline. Those along the Atlantic coast are especially helpful, because long stretches of the continental shelf have a sand or mud bottom with few rock outcroppings to concentrate marine life.

18th-century Japanese bamboo frames used as artificial reefs



How productive are artificial reefs?

The productivity of artificial reefs has been measured by various state and federal investigators in recent years. North Carolina's Division of Marine Fisheries reports that the state has ten reefs and plans to develop seven more (Van Buren and Tyler, 1977). Fishing has continually improved at the sites since the first reef was built in 1974. In Puerto Rico an artificial reef made from tires was colonized rapidly (Fast and Pagan, 1974). The weight of fish at one such reef was eight times that of fish taken from a natural reef of equal size.

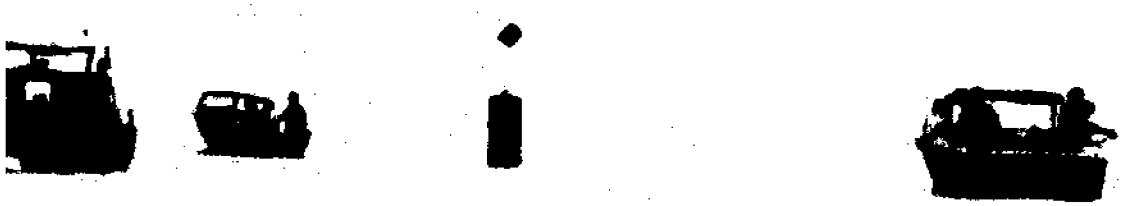
Clay pipe, tires, or brush greatly concentrated the fish population in freshwater lakes (Crumpton and Wilbur, 1974). Some types of fish move to an artificial reef within a few hours of its construction, although some reef materials may be preferred (Duffy, 1974). In this study, scuba divers estimated fish populations in reefs of equal volume and found the same number of fish per dive—826 to 870—in reefs made of quarry rock and old street cars. Concrete box shelters were somewhat better, showing more than 1,000 fish per dive.

Croaker

The artificial reef off Murrells Inlet, South Carolina, was extremely productive compared to a rocky bottom in the same area (Buchanan, 1974). Although anglers caught 2.4 fish per angler hour on the reef and 5.7 on the rocky bottom, fishing intensity (hours of fishing per square mile) for the artificial reef was *7,000 times* the rate for the rocky bottom. By these figures, fish caught per hour on the artificial reef greatly exceeded the number caught in the natural habitat.

Much closer to Delaware are three reefs built with scrap tires off Ocean City, Maryland. These reefs have been productive and are heavily fished. For example, a city official cited a day in August when fish were not biting offshore, except around the 27th Street reef. Here nearly 130 boats were "loading up" on croakers.

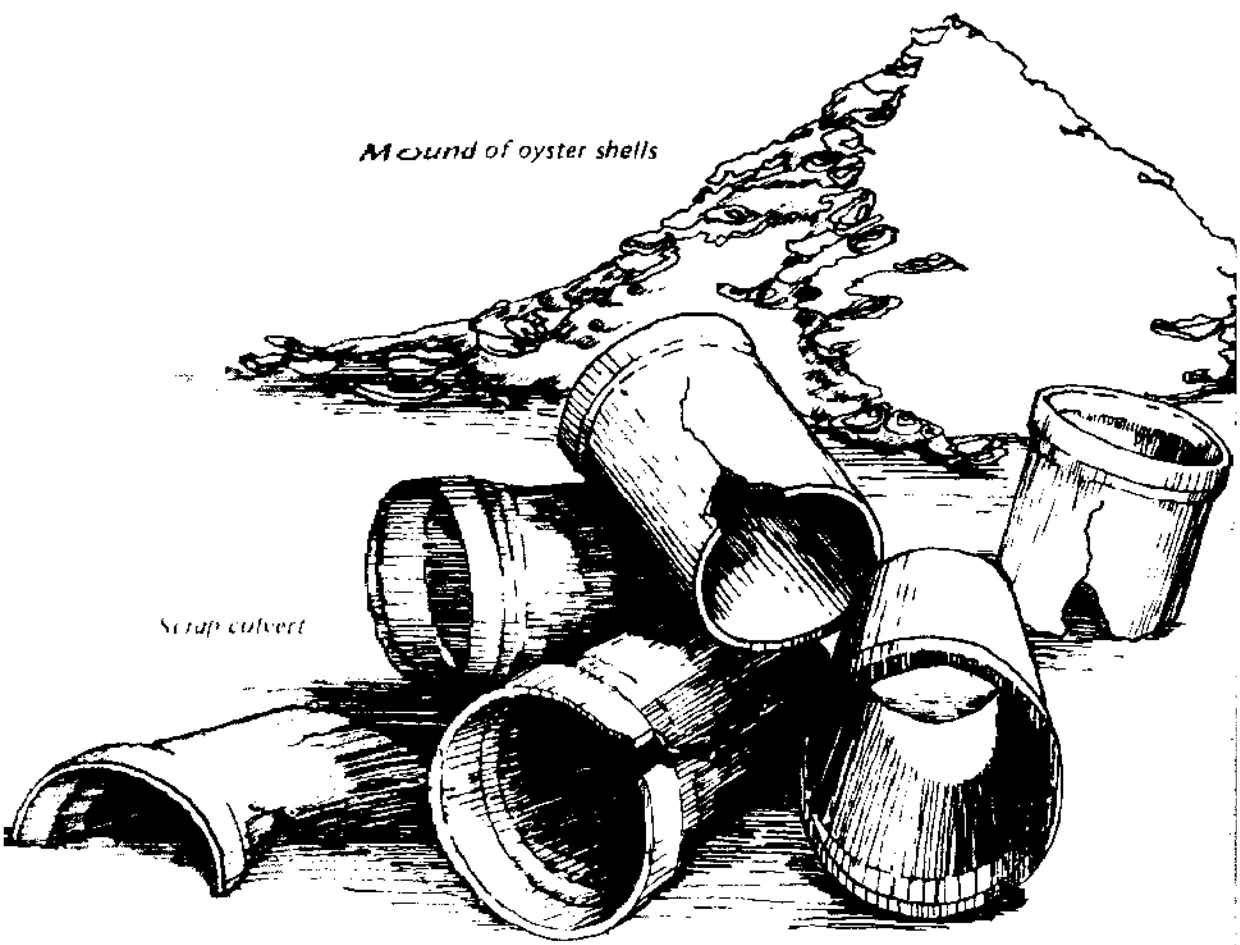
These successes show the results of good planning. As Florida Sea Grant (1979) points out, some reefs have been disappointing because of poor site selection or failure to provide a habitat attractive to indigenous species.



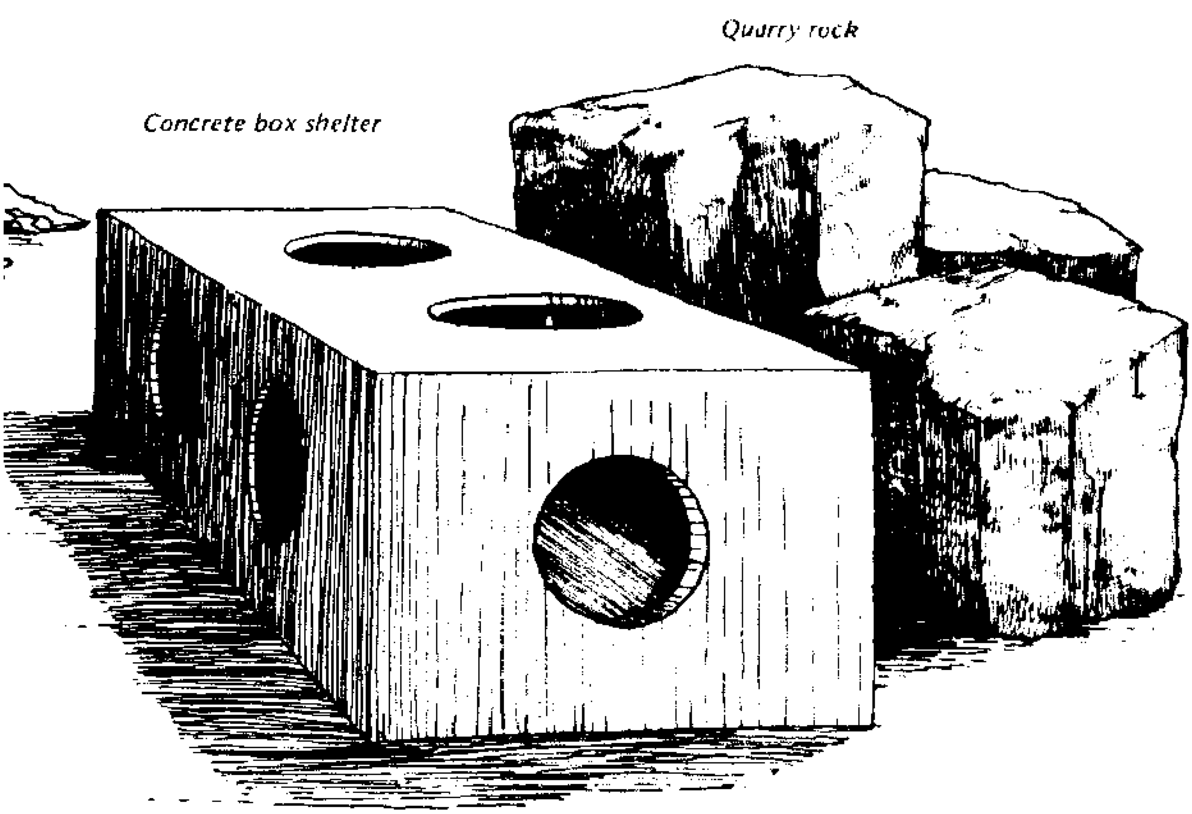
Boats "loading up" over baled-tire artificial reef off North Carolina

How are artificial reefs constructed?

Over the years, reefs have been made from various scrap products: abandoned ships, street cars, automobiles, household appliances, building rubble, and even baled municipal refuse (Loder, 1974). Materials such as quarry rock, concrete-box shelters, and concrete or terra cotta pipe have also been employed. Recently, many reefs have been built from scrap automobile tires.



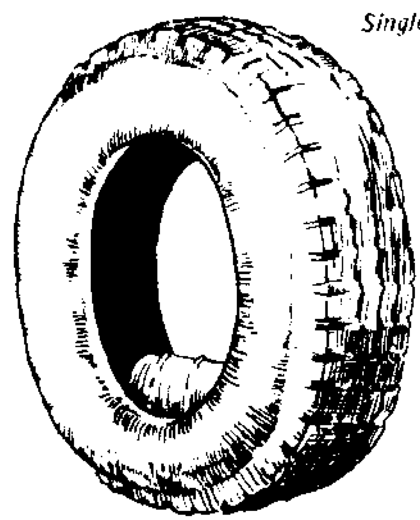
Authorities favor tires over other materials because of availability, low cost, and indestructibility (Parker, 1974). Old automobiles and household appliances have a short life—6 to 10 years—in corrosive seawater and add undesirable metals to the marine environment as they disintegrate. Ships and street cars have limited availability, and concrete boxes and other such structures are costly.



Various methods of using tires have been investigated:

- Submerging individual tires weighted with concrete ballast to prevent shifting during storms
- Positioning on end cylinders made by stacking 5 or 6 tires—low profile—or 12 to 15 tires—high profile—and baling with plastic rope; concrete ballast at the lower end is needed, and tire bodies must be vented by slashing or punching to let air escape
- Using cylinders similar to above, but compressed in a baler to give a smaller package for easier hauling
- Compressing about 60 tires into a high-density bale that requires no ballast or venting

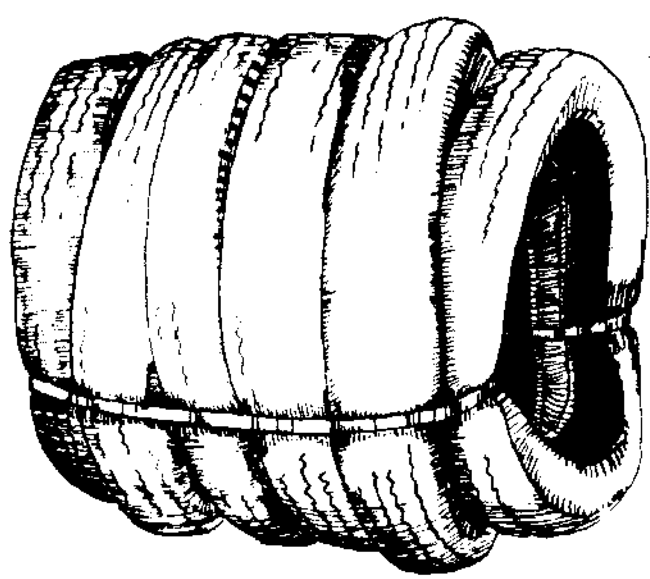
Single weighted tire



- Cutting tires in half and stringing the crescents on polyester strap to make 500-pound bundles that require no ballast

Compressed bales of tires are kept together with steel bands, and a heavy synthetic line is tied loosely through the bale; when the steel bands corrode in several months the tires can expand to a greater height off the bottom. The synthetic line will last almost indefinitely underwater when not exposed to sunlight or chafing.

The Ocean City, Maryland, reefs are the low-profile type. A low-profile reef accommodates more boats for the same number of tires. The city has added about 250,000 tires per year to the reefs since 1976, and the 27th Street reef currently has about 300,000 tires. When completed, each of these reefs will be about a mile long and a half mile wide.



Tire bale after compression

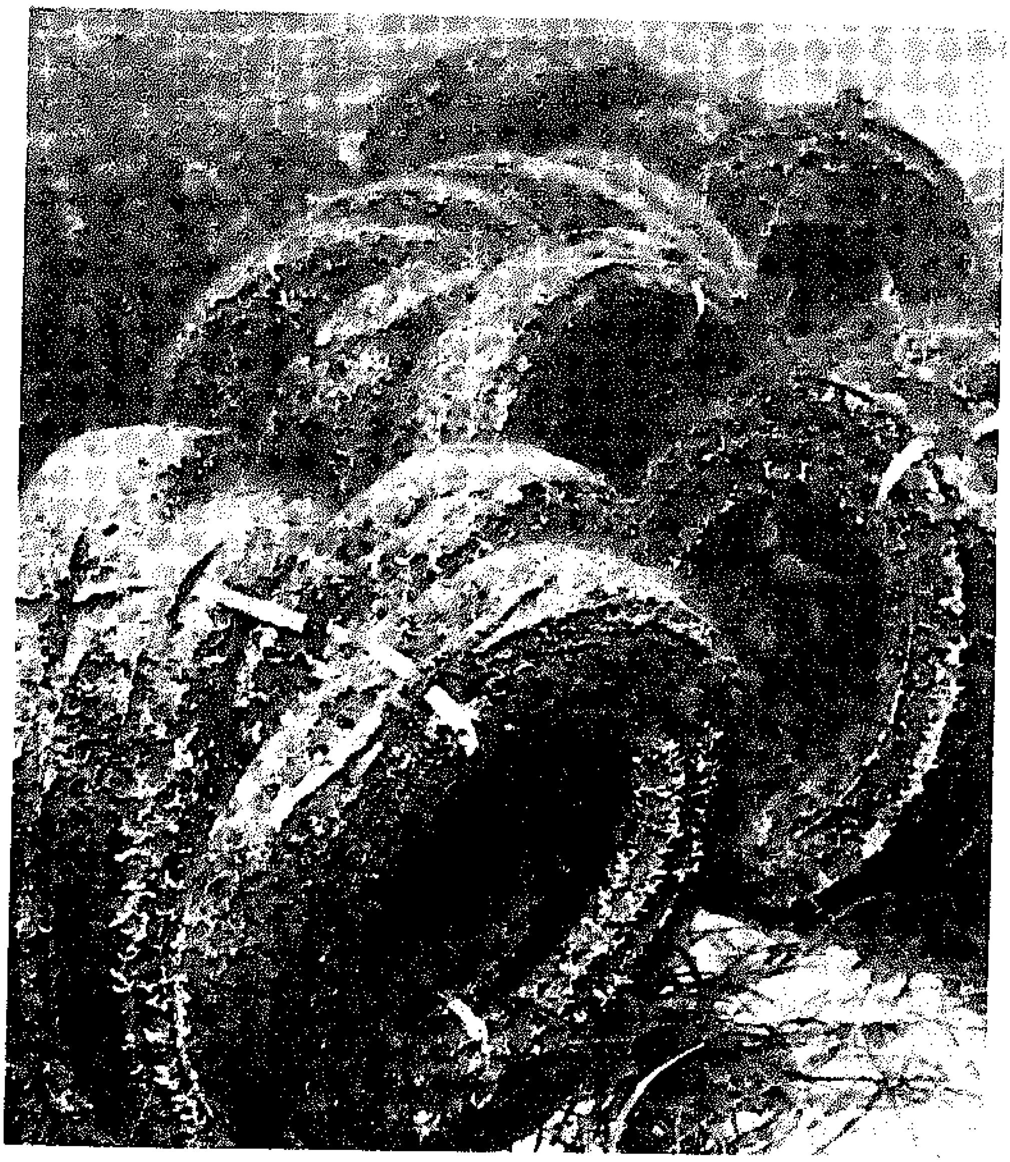
Will tire reefs harm the environment?

The Environmental Protection Agency reports there is no evidence that toxic materials leach from tires in reefs (Stone et al., 1974). Tires have good durability and resist chemical and bacterial breakdown, as well as physical destruction by boring organisms. When reefs are properly constructed there is no movement of tires on the seabed.

Proper construction of tire bundles and their placement on the seabed determine success of the venture. Tire bundles must have enough ballast to prevent shifting in severe storms and permanent plastic straps to hold the tires together. Iron or steel wire or strap is not enough.

Reefs should not be built in regions having strong subsurface currents. Furthermore, various writers have stressed the need to place tire bundles in water deeper than 50 feet to minimize the effect of storms. Generally, federal and state agencies also require a minimum depth of 50 feet for reef sites.

Both California and Florida have had tire bundles break up and shift off reef sites during storms. These states are curtailing the use of tires in reefs until better methods of tire deployment are found (Ryder, 1979). Ocean City, Maryland, also has had tires move from the reef onto the beach, which emphasizes the need to tie and ballast tire bundles securely. Perhaps much of Delaware's reef construction could be in Delaware Bay, which is sheltered from the worst of the Atlantic storms.



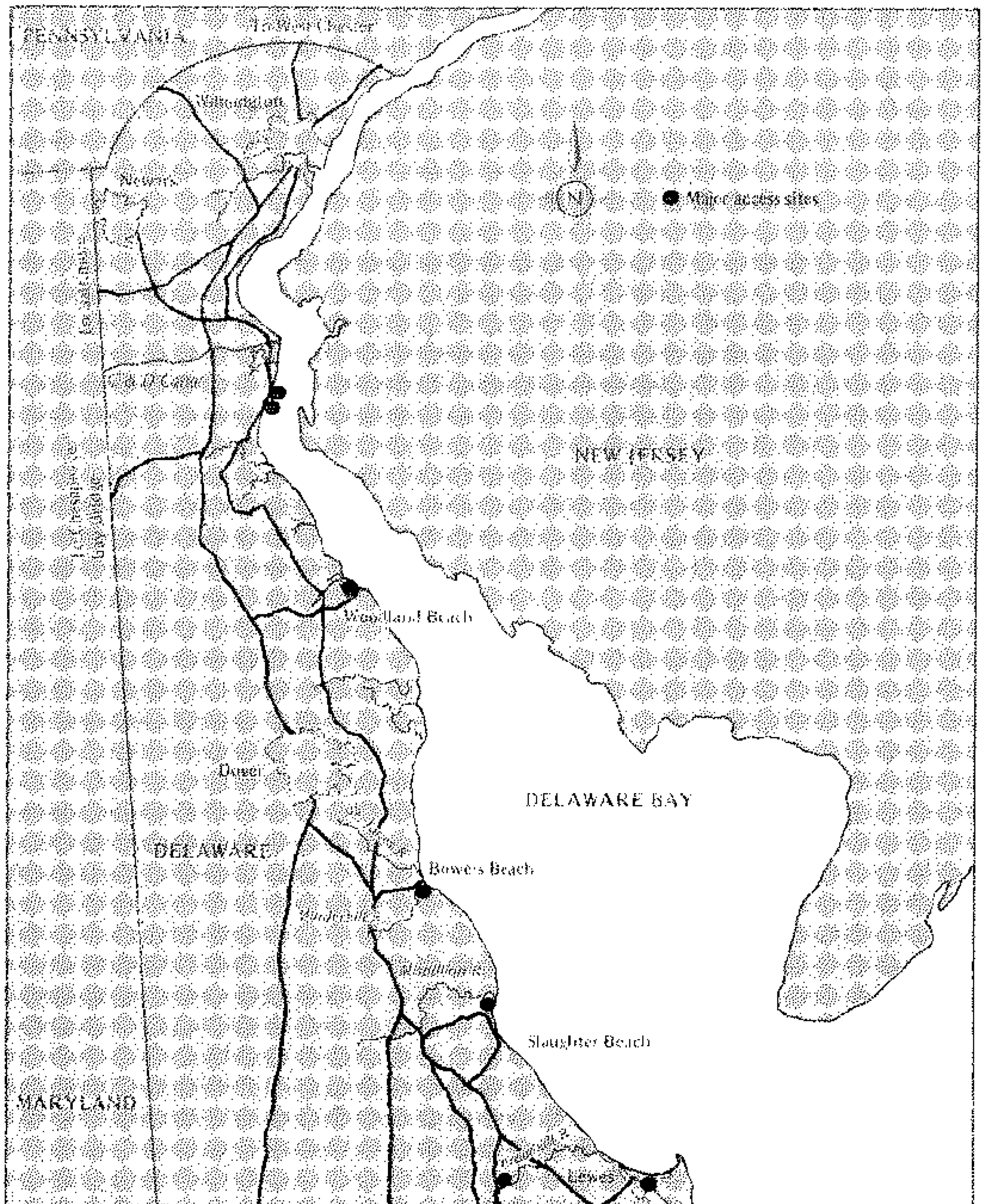
Marine growth rapidly occupies submerged tires and attracts many fish

Where should artificial reefs be located?

Artificial reefs can be placed wherever they will not obstruct navigation or activities such as commercial trawling or shellfishing. To be most effective, the reefs should be located on a smooth, sandy bottom where fishing is poor. (If there is already good fishing, why add a reef?) To be convenient to use . . . thereby benefitting more people and also conserving fuel by minimizing boat travel time . . . reefs should be near access points such as launching ramps and marinas. And, these access points should be capable of expanded use. Of course, building an artificial reef anywhere requires permits from both state and federal agencies. In addition, the reefs need marker buoys.

The map shows major access sites, and these suggest prospective locations for artificial reefs in Delaware. Locations should be selected on the basis of the proximity of access roads and launching ramps, and with the objective of decentralizing the heavy fishing activity in some locations and providing easier access to good fishing by more Delawareans. Because of the many factors involved in determining a site for an artificial reef, the decision may be made best by the Department of Natural Resources and Environmental Control with input by representatives from all groups concerned.

Any consideration of reef placement should be preceded by a study of bottom topography and currents and wave and storm action. The state, with assistance of the University, could identify suitable reef sites.



Delaware offers many suitable locations for artificial reefs

How much do artificial reefs cost?

The Broward County artificial reef, near Ft. Lauderdale, Florida, was made from 270,000 discarded tires at a cost of 20¢ per tire, or $54,000. But since this reef—like many others—was built with volunteer labor from sportsmen's clubs using equipment and material donated by local businesses, the expenses reported do not reflect the actual cost of reef construction. The cost of the Broward County reef would have been about 40¢ per tire if volunteer labor had not been available and there had been a charge for land and equipment (McIntosh, 1974).

The Ocean City, Maryland, reef-building program costs $65,000 per year, or 26¢ per tire. There, transportation cost is low because the reefs are within 3 miles of shore. The program uses paid employees, but land and equipment are donated by the county and state.

The cost of building reefs from bales of tires in the ocean runs from 27¢ to 39¢ per tire, depending on how far the bales have to be hauled (Myatt, 1974). Nevertheless, as far as the overall economy is concerned, building reefs from scrap tires processed through a mechanized system could be cheaper than other tire-disposal methods (Parker et al., 1974). Dealers in some areas now pay up to 15¢ per tire just to have them hauled away; costs of actual disposal are additional.

The table shows costs for various artificial-reef materials. Although any of these materials could be used, tires seem the most practical because of continued availability. They also compare favorably on a cost-per-acre basis with the other materials. Less-expensive materials are not practical. Junk cars are unsatisfactory because of their short life. Quarry rock would be more costly in this locality; the $5-per-ton cost in the table is for rock on Santa Catalina Island with the quarry at dockside. Oyster shell is not so good a reef material, as it provides a very low profile and has only small crevices to shelter fish. Concrete culvert, though cheaper than tires, is not readily available; that used in reef construction is flawed or broken sections from highway and industrial projects.

Annual cost of reef construction will depend on how many acres of reef are created. Small reefs—less than an acre in area—are not so successful as larger ones. Most likely, construction of 10 to 20 acres of reef per year is needed to build up new fishing areas rapidly. Based on tire costs from the table, this would entail spending $120,000 to $240,000 per year for reef construction.

COST OF REEF MATERIALS

Material	Unit	Cost per Unit ($)	Spacing Between Units on Seabed (ft)	Cost per Acre (1977 $)
Automobile tire	1	0.34	3	2,400
Concrete culvert	1-ton section	2.45 to 18.90	15	3,900
Junked automobile	1	10.45 to 100	25	6,100
Oyster shell	1-cu-yd mound	2.00 to 2.25	4	11,000
Sunken ship	1	0 to 15,000	-	11,000
Automobile tire	8-tire bale	2.00 to 6.00	4	12,000
Quarry rock	1-ton block	5.00	6	12,500
Concrete shelter	1	140	25	20,000

Source: Modified from Parker et al., 1974. For comparison, costs have been converted to a 1977 base by means of the annual Consumer Price Index inflation indicator.

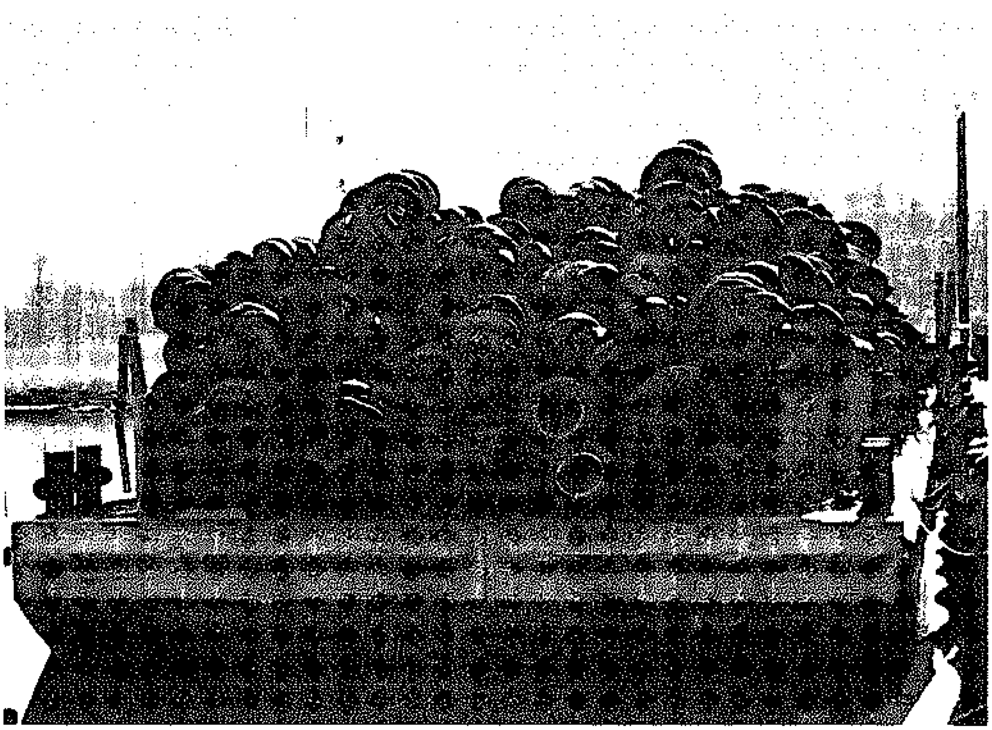
How have other areas paid for artificial reefs?

Most reef projects have been locally funded by donations from clubs and businesses, but several public agencies are funding and supervising reef construction. North Carolina has been active in funding reef construction, allocating until recently 1/8 of 1% of the gasoline tax for this purpose, or about $250,000 per year, approximately half the unrebated state marine-fuel tax (Shandle, 1976).

Pinellas County, Florida, has the most active reef program in the United States. This county on Florida's west coast spends more than $150,000 and additional state funds annually on reef construction and has built ten reefs since 1974. The program began with a budget of $20,000 per year.

Of the $65,000 per year spent for the reef program in Ocean City, Maryland, $25,000 comes from the state, $10,000 from the county, and $30,000 from the federal government in the form of CETA funds for salaries. The county and city have donated the land used for baling and loading, and the state has donated a tractor and barge for use in loading and hauling tires. These donated services, of course, help to keep costs low—26¢ per tire.

There is also the prospect of federal support for artificial-reef construction. Early in 1979, Senator Stone of Florida introduced a bill (S.B. 325) to support artificial-reef programs by appropriating $2.5 million for the next fiscal year. The funds



Baled tires loaded onto barge for deployment at reef site

would be available to cover 75% of the cost of approved state reef-building programs and would be disbursed through the National Marine Fisheries Service in the Department of Commerce. It is impossible to say when (or if) these federal funds will be available.

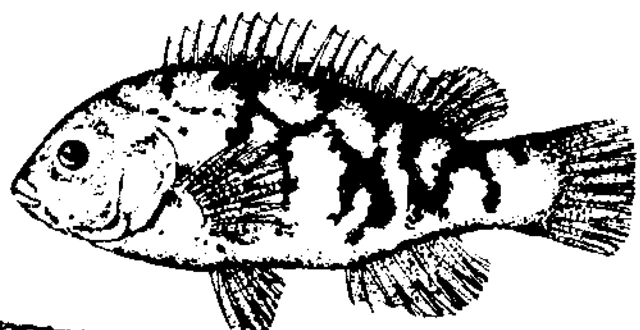
What would be the benefits of an artificial-reef program in Delaware?

On the basis of experience elsewhere, artificial reefs should provide a number of benefits for Delaware:

- Improved sportfishing
- Longer fishing season
- Acceptable disposal of waste tires
- Stimulation of local economy
- Increased tax revenue

The primary benefit of building artificial reefs in Delaware waters would be the improvement of sportfishing. As experienced elsewhere, artificial reefs yield larger and more dependable catches and a longer fishing season and thus contribute to a satisfying recreational experience . . . since fishermen *seem* happier when they catch fish! But increased fishing also benefits the entire state. Local economies are stimulated through increased purchases of goods and services, and state tax revenue is increased.

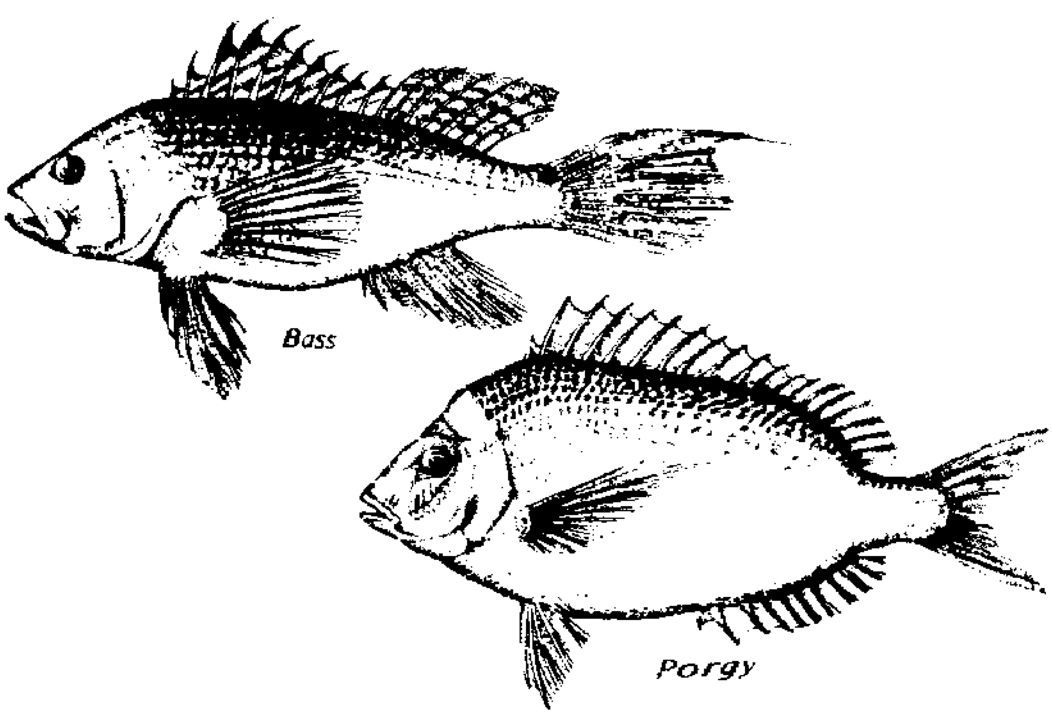
One of the ways in which artificial reefs could improve sportfishing is by increasing populations of fish species that are not abundant in Delaware



Tautog

Hake

waters. For example, while anglers catch a wide variety of fish over artificial reefs in the New York Bight, only four species make up 90% of the catch (Stone et al., 1974). These species—hake, black sea bass, porgy, and tautog—all prefer a rocky or rough bottom and are all (possibly with the exception of hake) actively sought by fishermen. The black sea bass and tautog can be fished heavily from September through December and to a lesser degree in early spring. Yet because of lack of a suitable habitat, populations of these fish in Delaware waters are small and are concentrated in just a few areas: wrecks, the breakwater walls at the mouth of the Bay, and to a lesser extent, the jetty at Indian River Inlet. New populations of these fish in artificial reefs at other sites would relieve the pressure on these overly congested areas, make the species available to other areas in the state, and extend the fishing season.



Another species, the croaker, can be fished from late July through September. The reefs off Ocean City, Maryland, have been able to attract especially abundant populations of this species once important to the mid-Atlantic region. If the croaker again became abundant in Delaware, it could divert some of the heavy summer fishing pressure from other species such as flounder and weakfish.

A reef-building program offers also a clean way to dispose of worn-out automobile tires. Tires create a major problem of solid-waste disposal, since they take up a great deal of space in landfills and decompose extremely slowly. With the advent of

steel-belted tires, it is no longer practical to cut them into pieces for burning as fuel. In short, the disposal of tires can be regarded as an additional benefit of artificial-reef construction.

Artificial reefs may provide another benefit by dispersing fishing more widely over state waters to reduce local congestion. For example, placing some artificial reefs in the upper Bay, closer to population centers, could encourage the use of existing launching ramps and the development of several potential sites for new or expanded marinas in the northern part of the state.

Crowded access ramps mean unhappy fishermen

It is not easy to calculate the economic benefits of artificial reefs because some factors are difficult to quantify. However, Liao of the South Carolina Department of Wildlife and Marine Resources (1978) estimated that in 1977 offshore anglers spent $22.3 million, of which $4.9 million was spent by anglers using artificial reefs. Using a multiplier of 2.29, Liao estimated that the total economic activity attributed to fishing artificial reefs was $10 million. No estimate of tax receipts was made, but since that state has a sales tax of 4%, reef fishing may have added as much as $400,000 to South Carolina's tax income.

If it is assumed that a program of any size in Delaware would require state funding, then the costs must be compared with the income the program would bring the state treasury. Based on certain conservative assumptions, an estimate of the value of reefs is possible:

- The fishing season will be lengthened by 60 days a year by increasing the catches of the early- or late-season anglers.
- On the average, 3 boats will use a 1-acre reef each day.
- With 3.3 anglers per boat, the 1-acre reef will add 600 man-days of fishing.
- Each angler will spend from $15 to $25 in Delaware for his day of fishing.
- Half the anglers will be from other states (300 man-days of fishing).

As noted, these assumptions are conservative. A productive reef would probably be used for the en-

Time well spent over a North Carolina artificial reef tire fishing season by all fishermen, but only the *extension* of the season and out-of-state fishermen are considered in the following estimate.

We estimate the 600 additional man-days of fishing per acre would produce a total expenditure of $15,000, of which $7,500 would come from outside the state. Money that comes from out of state is respent several times through the local economy, and economists use a multiplier to take this respending into account. Earning multipliers compiled by the U.S. Travel Data Center are 1.87 for Sussex County and 2.38 for New Castle County. A reasonable statewide recreational fishing multiplier might be 2.0.

The Theodore Parker *is sunk off North Carolina to make an artificial reef*

With the multiplier, the $7,500 income from out of state will produce $15,000 in Delaware economic activity for each acre of reef.

The tax income this will generate for the state depends on many variables—type of purchase, specific tax rate, whether the item purchased is a service or product made outside the state, for example. Bill Latham of the Department of Economics at the University of Delaware has estimated state tax income. Almost all businesses pay an occupation and business-license tax (mercantile tax); the tax varies from business to business but averages about 0.5%. Revenue is also generated by the personal income tax (effective state average 4%) or, for larger businesses, the corporate income tax rate of 8.5%. The motor-fuel tax is about 8%. In addition, taxes on alcohol and cigarettes go directly to the state treasury. Taking these taxes all together, Latham suggests that a reasonable, conservative, state tax income on recreational-fishing expenditures is 6%. Thus for a 1-acre reef, a conservative estimate of income to the state treasury is 6% of $15,000, or $900 per year just from out-of-state anglers.

Of course there are benefits other than direct tax revenues from a reef-building program; most important are tire disposal, improved recreational experience, and helping to alleviate crowding of water-access points by distributing fishing over a larger area. These values could turn out to be more important than the additional state revenue coming from out-of-state fishermen.

What would be the cost of an artificial-reef program in Delaware?

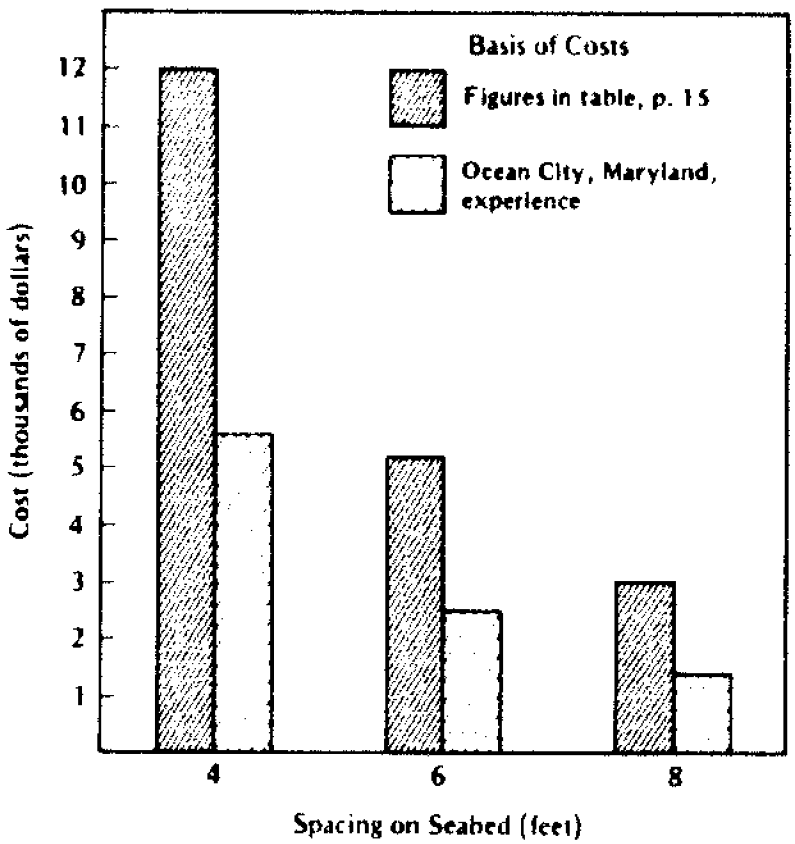
The facing chart shows the cost of reef construction to be $12,000 per acre (55¢ per tire) using 8-tire bales spaced 4 feet apart. At Ocean City the cost of tire placement has been considerably less, 26¢ per tire. At this lower rate, the cost would be about $5,600 per acre for the high-profile reef. Actually, Ocean City is building a low-profile reef with greater spacing of tires, and cost per acre is probably much less.

The optimal spacing and number of tires per acre are not known, but the good results at Ocean City suggest that tire density is not a critical factor. This in turn suggests that Delaware could expect good results from reefs costing as little as $1,500 per acre (at 26¢ per tire) or as much as $12,000 to per acre (at 55¢ per tire) with high tire density.

Since the major cost of an artificial reef is initial construction and the benefits should continue over its life span, it is necessary to convert these benefits to a present worth. If each acre of reef were to last 20 years and produce $900 per year for the state treasury, it would have a present worth (discounted at 5% per year) of $11,215. If the discount rate were 10% per year, the present worth of a 1-acre reef producing $900 per year for 20 years would be $7,663.

In addition to the cost of the reef, there will be the cost of markers, monitoring, obtaining federal permits, and general administration. These costs would vary considerably with the size and location of a reef but should not exceed 50% of the initial capital cost. On the basis of these estimates, it is evident that a suitable artificial-reef program in Delaware could be expected to pay for itself through increased tax revenue.

COST OF REEF CONSTRUCTION USING 8-TIRE BALES



What's the situation with scrap tires in Delaware?

The Delaware Solid Waste Authority estimates that approximately 500,000 tires are discarded in the state each year. A small percentage are resold as used tires or recapped, but most simply go to dumps in rural areas. There are currently 50,000 to 100,000 tires in Delaware sanitary landfills, but no rate of accumulation of tires has been calculated. Most tires don't go to landfills because the Authority charges $7 per ton (60 to 100 tires) for disposal. Some tire-disposal piles exist in the state and may be an eyesore but do not represent a public-health hazard.

Worn tires are usually collected from tire dealers by private haulers, who pay the dealers about 10¢ per tire. The hauler recovers the cost of tires, hauling, and storage by reselling recappable tires. Dealers who recap their own tires must pay to have unusable tires removed.

The present tire-collection system could be used if an artificial-reef program is implemented. Tire haulers would deliver tires to a central collection and baling site rather than to their usual dump areas. This would reduce the number of tire dumps and in some cases reduce hauling distances. Furthermore, by having the tires in a central location instead of scattered dumps in remote fields, it becomes more practical to consider baled tires for other uses such as certain types of foundation material or floating-tire breakwaters.

Artificial reefs can eliminate eyesores such as this

How can Delaware begin an artificial-reef program?

There are a number of possibilities. The first and least expensive option is a purely voluntary program. In some states local fishermen collect and bale their own scrap tires which they carry to a designated reef site on their own boats. These efforts encounter insurance and regulatory problems, and the volunteers eventually lose interest.

Experience from volunteer programs shows a need for a full-time coordinator and sufficient resources to fulfill permit and marking requirements. Even with this degree of support, a volunteer effort would be relatively small scale and slow. Such a program would tend to be local in scope and of limited size, not likely to alleviate fishing-related crowding or to use the large number of scrap tires available. Furthermore, tire bales would be limited to a size that could be lifted manually over the rail of a boat, further reducing efficiency. Finally, there might be problems with individual fishermen wanting to start their own secret reefs by dropping tires in unmarked areas.

A second option is to have a mechanized operation. This is not to discount the value of volunteers. They can and should be encouraged to make significant contributions. But to realize fully the potential benefits of a reef program, a large-scale operation with a heavy-duty tire baler would be necessary. Larger tire bales require a motorized hoist and other specialized equipment. One large operation appears to be more efficient than several smaller ones.

A large, efficient tire-baling and reef-construction program could be operated by county or state government or even by a private concern. The private operator would have to be reimbursed in some way by those who benefited from the service—fishermen and the fishing-related economy—and logically from a tax fund. Since the state tax system is designated to collect business and income taxes and the county tax system is not, it is logical that the state either operate the reef program or pay a contractor to do so.

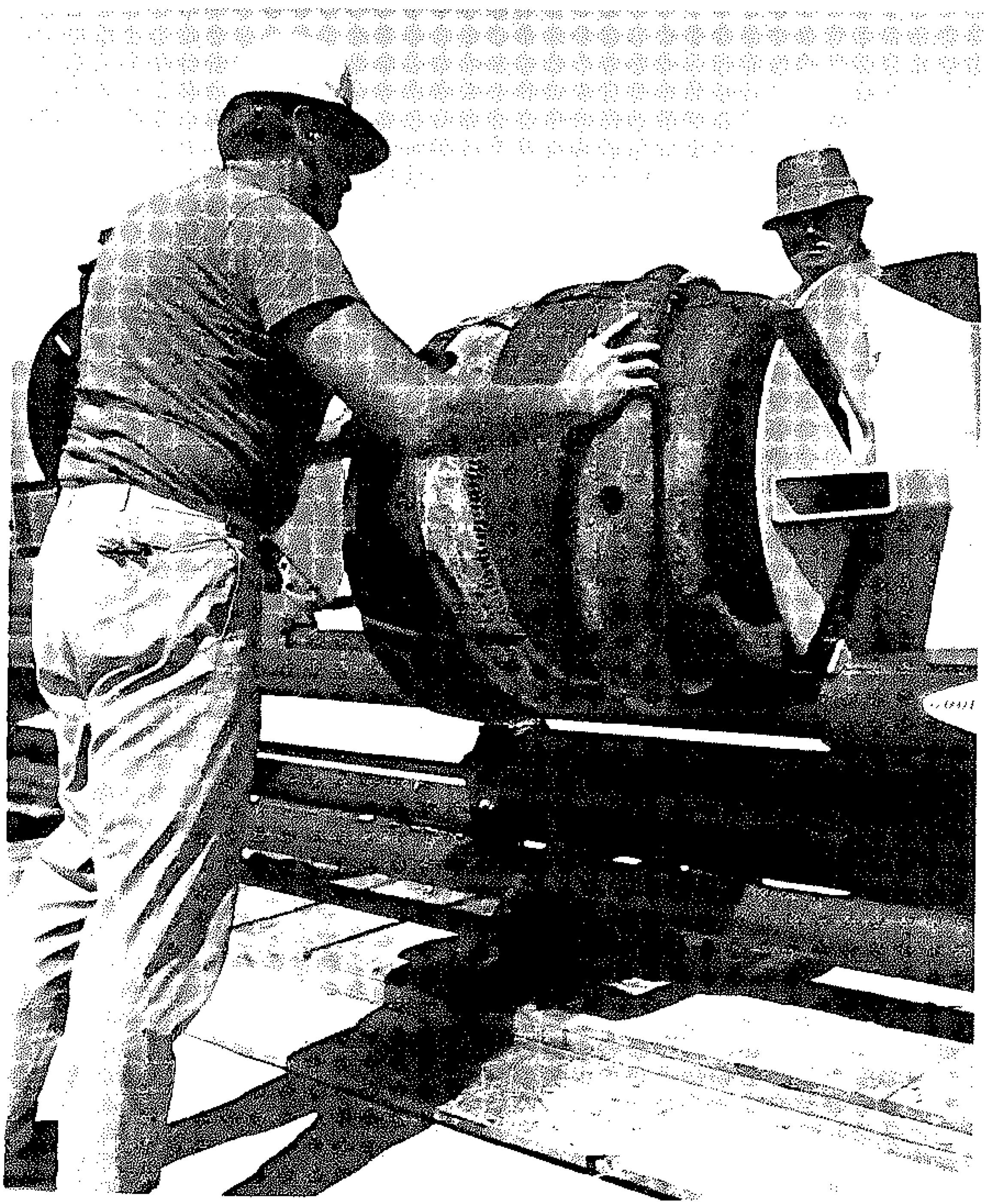
There are still options in the size of the program and how it will be funded. The upper limit to size is probably the number of tires scrapped in Delaware each year—about 500,000. A commercially available tire baler can handle this many tires with the crew working full time on baling. This output would be sufficient to build several large reefs in various locations. The actual area of the reefs would depend on bale size and how the tire bales were spaced.

If all of Delaware's 500,000 waste tires each year should go into reefs, they could provide about 23 acres of new reef annually by using the high-density spacing cited in the table. The cost, at $12,000 per acre, would be $276,000. Using the Ocean City low-profile plan would yield as much as 300 acres of reef from the same number of tires in 4-tire bales 10 feet apart. Cost would be $130,000 if the operation could achieve Ocean City's cost of 26¢ per tire. The area and type of reef to be installed each year must be decided, but it might be desirable to construct low-profile reefs initially to build up substantial acreage quickly.

After a number of years, a reef may become ineffective because it is either buried under sediment or completely encased in fouling organisms. If estimates of an expected life span of 20 years are reasonable, Delaware could maintain a large total reef area indefinitely by rebuilding old reefs after they become ineffective.

Building high-density reefs at the rate of 500,000 tires per year would cost in the range of $250,000 per year. If cost is a limiting factor and it is not necessary to use all of Delaware's scrap tires, reefs could be the low-profile type or constructed at a slower rate. Since the primary cost of reef construction is labor, the unit cost (per tire or acre of reef) will increase only slightly as the size of the reef-construction program is reduced. A lower limit to the rate of reef construction might be the point at which fixed capital investments (tire baler, truck, and crane) become an unreasonably large percentage of the costs, or when the cost per acre of reef greatly exceeds reef values based on anticipated revenues.

A final question is how to fund a program. One option is to make a direct appropriation from the general fund. While this would be the most straightforward approach, there would doubtless be problems, particularly if a request were made for a full-scale program (up to $250,000 per year). One problem is that while the program would appear to be a good investment, $250,000 per year is large in relation to current fisheries expenditures. Another problem is that even if an artificial-reef program generated the anticipated revenue, the revenue would go into the general fund. It would be very difficult to identify funds coming from a reef program, making it a problem to justify the program in lean years against competing budget pressures from schools, social services, and road repair.



A mechanical tire baler such as this is needed to compress tire bales

The general manager of the Delaware Solid Waste Authority is acutely aware that scrap tires present a waste-disposal problem and considers artificial reefs to be a solution to the problem. He has indicated his willingness to consider the purchase of a tire baler and to allow the use of the equipment in an approved reef-development program. In order to proceed with purchase and installation of the baler, the reef program would have to be approved by the Delaware Department of Natural Resources and Environmental Control, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and the U.S. Coast Guard.

In addition to the purchase of a tire baler, the state or counties could possibly provide land and equipment (truck, hoist, and barge) as is done in Ocean City. Provision of these items without cost to Delaware's program would reduce the amount needed each year from the general fund.

A suggestion has also been made to levy a tax of 25¢ on new tires to pay for their ultimate disposal. A tax of 25¢ per tire would amount to one-half to one percent of the typical new-tire retail cost and would generate approximately $125,000 per year in Delaware. This, along with capital equipment support from the Solid Waste Authority, would be sufficient for a program of reasonable scale.

After a reef is built, it should be monitored periodically for biomass growth, fish population, sportfishing success, and overall condition. This information will aid in the selection of future reef sites.

Summary

Artificial reefs have been proven effective in enhancing recreational fishing and stimulating the coastal economy. Based on results in other Atlantic coast states, scrap-tire reefs appear to be cost-effective means of improving fishing and disposing of waste tires. In addition, artificial reefs offer the potential to divert fishing pressure by encouraging fishing in the northern part of Delaware Bay, closer to population centers.

While an artificial-reef program in Delaware would not be cheap, several funding options appear viable. It is also entirely possible that an artificial-reef program could pay for itself solely through stimulation of the economy without counting benefits from tire disposal, improved recreational experience, or dispersing fishermen to less crowded areas. With these conditions, it appears that artificial reefs in Delaware are worth serious consideration.

Delaware Sea Grant neither supports nor rejects artificial-reef construction for Delaware. This publication deals with the history and technology of reef construction and points out policy considerations relevant to an artificial-reef program for Delaware.

References

Buchanan, C. C. 1974. Comparative study of the sport fishery over artificial and natural habitats off Murrells Inlet, S. C. p. 34.*

Crumpton, J. E., and Wilbur, R. L. 1974. Florida's fish attractor program. p. 39.*

Duffy, J. M. 1974. California's artificial reef experiences. p. 47.*

Fast, D. E., and Pagan, F. A. 1974. Comparative observations on an artificial tire reef and natural patch reefs off southwestern Puerto Rico. p. 49.*

Florida Marine Advisory Program. 1979. Artificial reef site selection and evaluation. Gainesville, FL: Marine Advisory Program, Univ. of Florida. MAFS-20.

Ino, T. 1974. Historical review of artificial reef activities in Japan. p. 21.*

Loder, T. C.; Rowe, G. T.; and Clifford, C. H. 1974. Experiments using baled urban refuse as artificial reef material. p. 56.*

Parker, R. O. Jr.; Stone, R. B.; Buchanan, C. C.; and Steimle, F. W. Jr. 1974. How to build marine artificial reefs. National Oceanic and Atmospheric Administration. Fishery Facts 10.

Ryder, L. S. 1979. Florida Department of Natural Resources; personal communication to authors.

Shandle, J. 1976. 20,000 tires under the sea. *Today*, Aug. 8.

Simpson, R. A. 1977. The biology of two offshore oil platforms. Inst. of Marine Resources, Univ. of California. IMR 76-13.

Stone, R. B. 1974. A brief history of artificial reef activities in the United States. p. 24.*

Stone, R. B.; Buchanan, C. C.; and Steimle, F. W. Jr. 1974. Scrap tires as artificial reefs. Environmental Protection Agency. Summary report SW-119.

Van Buren, J., and Tyler, J. 1977. Artificial reef project North Carolina. Div. of Marine Fisheries, State of North Carolina.

*In *Proceedings of an International Conference on Artificial Reefs*, ed. Laura Colunga and Richard Stone. Houston, Texas, Mar. 20-22, 1974. College Station, TX: Center for Marine Resources, Texas A&M University, 1974. TAMU-SG-74-103.

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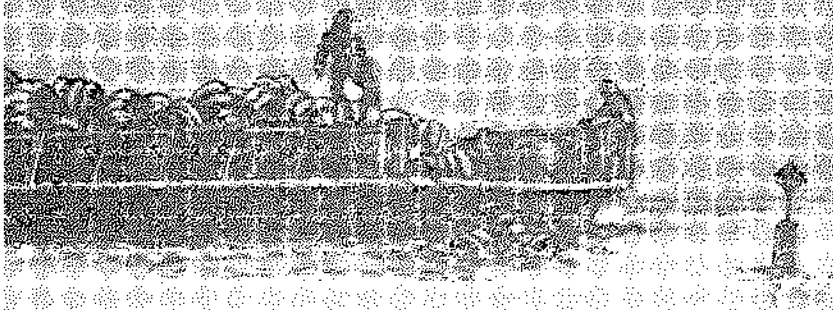

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