SCRAP TIRES
AS ARTIFICIAL REEFS

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MARINE SPORT FISHING is a billion dollar business. There are more than 5 million sport fishermen along the Atlantic coast alone, and each of these fishermen catch about 180 pounds of fish each year.[1] If this figure of almost 1 billion pounds is added to the approximately 1.7 billion pounds caught annually by commercial fishermen in the same area, it is easy to see that fishermen reap a large harvest. With projected population growth and increase in leisure time, we can expect the number of anglers to more than double by the year 2000.

The Atlantic Continental Shelf, that expanse of shallow ocean bottom stretching from the coast out to a depth of 600 feet, is the area inhabited by the majority of our valuable reef fishes. Much of this Shelf area, however, is relatively barren, consisting of a flat, sand, or mud bottom which slopes gently offshore, with little hard, irregular substrate. Areas of rough, hard bottom are necessary for encrusting organisms such as barnacles, hydroids, corals, and mussels, vital organisms in the food chain, to settle and complete their life cycles and are used as protective areas, food sources, spawning grounds, and visual reference points for many fishes. It is well known by fishermen that coral reefs, rock ledges, wrecks, and other areas of relief on the Shelf are productive fishing grounds.

If we are to meet and properly manage the future demands on our fishery resources, we must have effective management programs. We believe that artificial reefs, if used properly, can be a valuable management tool.

In March 1966, we started experimentally building artificial reefs from scrap materials in an attempt to increase the productivity of the marine environment. Test materials included junked automobiles, damaged concrete culverts, scrap tires, and derelict or obsolete ship hulls. From evaluations of data collected early in our studies, scrap tires appeared to be one of the most practical reef materials. In small-scale tests tires had been inexpensive to obtain and easy to handle on land. However, we needed to learn how tires could be handled efficiently in large numbers to develop many acres of ocean bottom.

The disposal of scrap tires is a problem national in scope. New and more efficient techniques are needed to handle this disposal problem. Scrap tires pose a menace to public health and add to the degradation of our landscape (Figure 1). The first effort should be to recycle this resource whenever possible. At present, only a few metropolitan areas can do this economically.

FIGURE 1. Over 200 million tires are discarded each year. Only a few of these are recycled, the majority create unsightly waste-disposal problems for many communities.

Since less than 10 percent of scrap rubber is reused, the remainder, more than 200 million scrap tires per year, continue to pile up around the countryside. If large numbers of scrap rubber tires could be used to develop coastal fishing reefs, this would offer at least a partial or temporary solution to the scrap tire disposal problem and benefit our fishery resources.

With this belief that scrap tire reefs could be effective for marine gamefish management, we entered into a cooperative agreement with the Solid Waste Management Program of the U.S. Environmental Protection Agency and the National Tire Dealers and Retreaders Association to study the possibility of using large numbers of scrap tires to build artificial reefs in the marine environment. This study phase began on October 1, 1968.

OBJECTIVES

The objectives of this investigation were to determine: (1) methods of assembling tires into units that would be inexpensive, easy to assemble and handle, and effective; (2) the cost, both to build the units and to transport them to the reef site; (3) how these reefs function in the marine environment; (4) the effect of reefs on angling success in the New York Bight; (5) the number of reefs that could be established, and the potential number of scrap tires that could be used effectively in the marine environment.

FUNCTIONS OF ARTIFICIAL REEFS

Artificial reefs are manmade 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. Through increasing the amount of reef habitat, artificial reefs provide the potential for increasing the stock sizes of reef fishes. Irrespective of the types of materials used to build reefs, the main features that appear to attract marine animals to these habitats are shelter, areas of calm water, visual reference points, and food. Artificial reefs also can provide some fishes access to new feeding grounds and open new territories for territorial fishes.

An obvious feature of reef habitat is the shelter provided by holes, ledges, and dark corners of the irregular substrate. In addition, organisms (e.g., algae, corals, and sponges) that attach to the reef provide additional shelter by increasing the complexity of the habitat. Since most fishes are subject to predation, their first recourse as prey is to conceal themselves.[2] Thus, the availability of shelter (Figure 2) can contribute significantly to their survival and growth.

FIGURE 2. Tires provide shelter from predators for many fishes. This can add significantly to the survival of these fishes.

The rough profile of a reef also provides areas of calm water or favorable currents, by damping or deflecting currents and wave surge. Fishes use the resultant calm areas, eddies, and upwellings to conserve their energy.[3] We have observed this phenomenon repeatedly on the Palm Beach artificial reef where the strong current of the Gulf Stream is over the reef much of the time. When the current is strong, the fishes are inside or close to the reef material (Figure 3). On days when the current is weak or absent the fishes are not crowded inside the shelter, but scattered around or above the material (Figure 4).

FIGURE 3. The rough profile of the artificial reef off Palm Beach provides areas of calm water or favorable currents by damping the strong current of the Gulf Stream. When the current is strong, the fishes will remain inside or close to the reef material.

FIGURE 4. On days when the current is weak or absent from the Palm Beach artificial reef the fishes will scatter around the reef material.

Features of the reef profile may be used as landmarks or visual reference points for fishes. These landmarks provide a spatial reference for fishes in an otherwise featureless environment.[4] Species that exhibit strong homing tendencies or those that inhabit a fixed territory may rely on landmarks to locate or define their territory. Visual reference appears to be important to fishes that make daily movements to feeding grounds; after feeding, many of these fishes return to specific sheltered areas.[5, 6] Thus, prominent landmarks on the reef profile may also be used by fishes for orientation in locating their feeding grounds and schooling areas.

Some fishes feed primarily on motile or encrusting organisms associated with reefs (Figure 5); however, the availability of food on or in the surrounding bottom is important to many fishes that depend on the reef for shelter but forage away from the reef (Figure 6). This food source may be invertebrates living in or on the sediment or grass beds and algae nearby. Randall found the availability of new feeding grounds was important to the initial success of artificial reefs in tropical waters.[7]

FIGURE 5. Many fishes, such as the ocean surgeon feed on organisms encrusting the reef material.

FIGURE 6. The availability of food on or in the surrounding bottom is important to many fishes that depend on the reef for shelter.

FIGURE 7. Artificial reefs, by providing new habitat, can create additional areas for fishes such as this sergeant major that establish territories.

Artificial reefs, by providing new habitat, can create additional areas for fishes that establish territories (Figure 7). The existing natural reef habitats can only satisfy the territorial needs of a limited number of fish, relative to the size of the habitat. The additional habitat provided by building artificial reefs affords the opportunity for more fishes to establish territories, potentially increasing both their distribution and abundance.

The design of an artificial reef can be an important determinant in the species of fishes attracted to the reef. The size of the holes in the reef material, for example, will determine the size of the fish using them; larger holes can shelter larger fish.[8,9]

Material producing high profile should attract more pelagic fishes than low profile material. The flexibility of artificial reefs (wide range of designs, locations, materials, etc.) makes them an important tool in the areas of fishery resource management and conservation.

RESEARCH REEF LOCATIONS

There are 114 artificial reef locations along the east coast of the United States.[10] During this study, we collected or received information from 20 of these sites (Figure 8). We limited our detailed studies to only six of these sites. Four of the sites are within the New York Bight, an area of extremely heavy fishing pressure. We conducted the sport fishing survey exclusively in

FIGURE 8. The National Marine Fisheries Service has been studying artificial reefs since 1966. Most of our research activities have been concentrated on 20 reefs along the east coast.

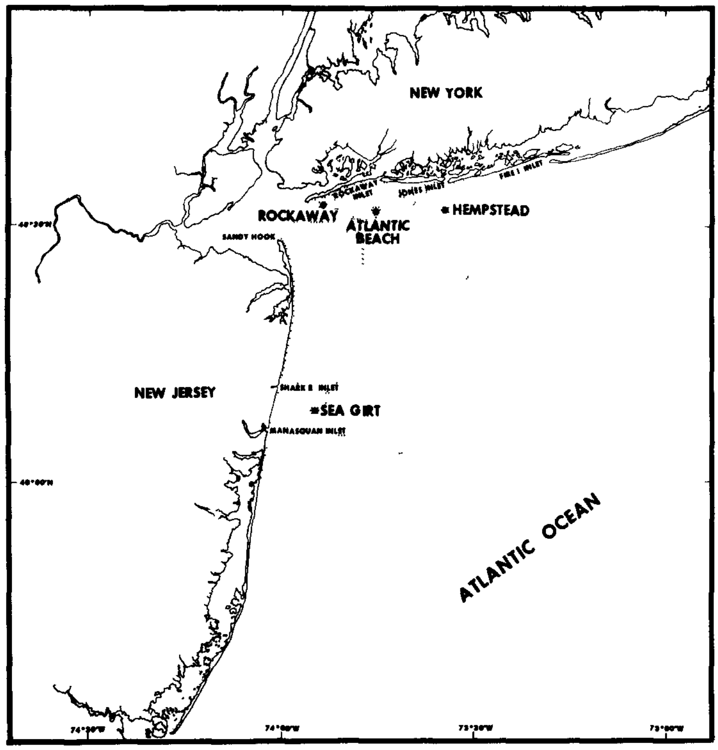

FIGURE 9. During 1970, we conducted a survey of sport fishery activities in the northwest section of the New York Bight. The purpose of our survey was to compare fishing success and effort over man made habitats to that over natural habitats. The four study reefs are shown by black dots.

this area (Figure 9). The fifth site is located off Murrells Inlet, S.C., and the sixth just north of Palm Beach, Fla. Only one of the reefs was constructed entirely of tires (Sea Girt, N.J.), the others are composite reefs consisting of a variety of materials, including tires, car bodies, scrap ships and barges, and concrete pipe and rubble.

DESIGNS AND COSTS

The use of scrap tires as reef material is not new. They have been used for many years in areas where other materials were either too expensive or not available. Little experimenting had gone into the design of these units. Most of the units were variations of a three-tire unit (Figure 10). We tested several new and current designs for their potential to provide an effective and durable habitat that would attract many fish species. A good design must also be relatively easy and inexpensive to assemble and handle.

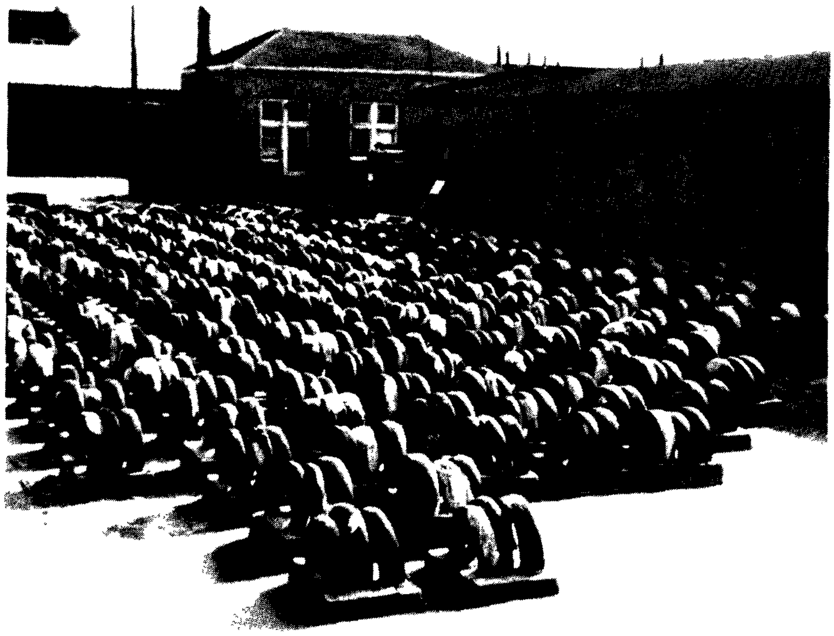

FIGURE 10. The concrete-base 3-tire unit consists of three tires standing side by side in a concrete base. Several thousand of the units were built by the New York State Department of Environmental Conservation and placed on reef sites off Long Island. This is an effective habitat but requires much more concrete than is necessary to ballast the unit. (Picture courtesy of Chester Zawacki, New York State Department of Environmental Conservation.)

We tested six different tire unit designs in this study and obtained data for two other tire units from State agencies and private groups (Table 1). For the eight units, the cost of materials ranged from \$0.07 to \$0.68 per tire; the cost of labor, from \$0.19 to \$2.05 per tire; and the cost of transportation, from \$0.08 to \$2.90 per tire. The cost of the majority of the designs fell in the lower end of the cost range. Only two units were relatively expensive.

TABLE 1

AVERAGE COSTS FOR EIGHT TIRE UNIT DESIGNS

Tire unit	Material/ tire*	Labor/tire	Transporta- tion/tire †	Remarks
12	0.49	0.75	2.90	Partial load of the test units accounts for high transportation costs. A full load would have reduced cost/tire about one-third.
Chain	—	—	—	Current cost for scrap chain is $40/ton. This amounts to a per-tire cost of $0.64. We received an estimate of $1.00 per tire for labor and transportation.
Band-8	0.17	0.20	0.14	
Rod-8	0.16	0.20	0.14	
Single	0.07	0.19	0.08	
Band-4	0.07	0.25	0.10	
Rod-3	0.11	0.89	0.56	
Concrete-3	0.68	2.05	1.35	

* Figures based on a no-cost delivery of donated tires to a dockside staging area. Last two unit cost figures obtained from private and state-supported reef projects.

† Transportation for barging to a reef site. Costs figured on a charge of $700 per day for use of a tow vessel. The concrete-3 estimate includes a large fraction for loading fees.

DATA

Twelve-Tire Unit. The 12-tire unit design consists of 12 tires in a triangular array, spaced on reinforcing rods, held together by bolts, and weighted with concrete (100 lbs.) for stability (Figure 11). We tested 20 such units on our Monmouth Beach, N.J., reef site. This unit provides an excellent habitat because it has a large surface area exposed for encrusting organisms, 5 to 6 feet of relief, and many crevices for fish shelter. The major drawbacks to this unit are that heavy equipment is required to move it and it is time consuming to build. Materials and labor for each unit cost about $15.

FIGURE 11. The 12-tire unit provides an excellent habitat for marine fauna, but was expensive to build and difficult to handle.

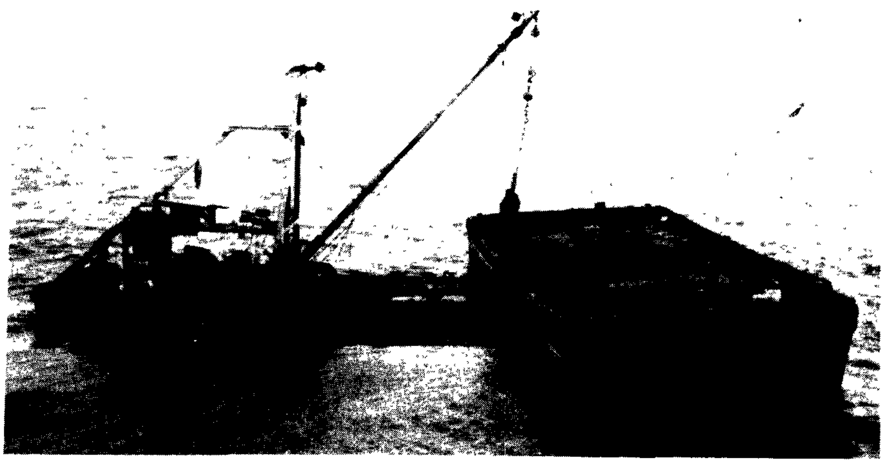

FIGURE 12. The chain-tire units, a string of tires on anchor chain, can only be built and placed on the reef site with the assistance of a crane. The cost and materials required eliminates this unit from consideration by most reef-building groups.

Chain-Tire Unit. The chain-tire unit is made by stringing car and truck tires on scrap anchor chain (Figure 12). Using these units, we placed 1,100 tires on a reef site 50 feet long and 25 feet wide and obtained 6 to 10 feet of elevation. Although chain is an effective ballast for tires, the supply of scrap chain is limited. Market purchase of chain results in a high material cost per tire. Another disadvantage of this unit is that it requires heavy equipment to move it.

Band 8-Tire Unit. The band 8-tire unit consists of a stack of tires held together by four stainless steel or plastic bands (Figure 13). A completed unit is about 3 feet high with a poured cement core. They were too difficult and time-consuming to assemble and too awkward to handle to be practical. South Carolina reef builders, along with several private groups on the east and Gulf coasts are using a modified version of this unit which is quite effective.[11] It is made by compressing ten or more tires into a stack with a tire baler.

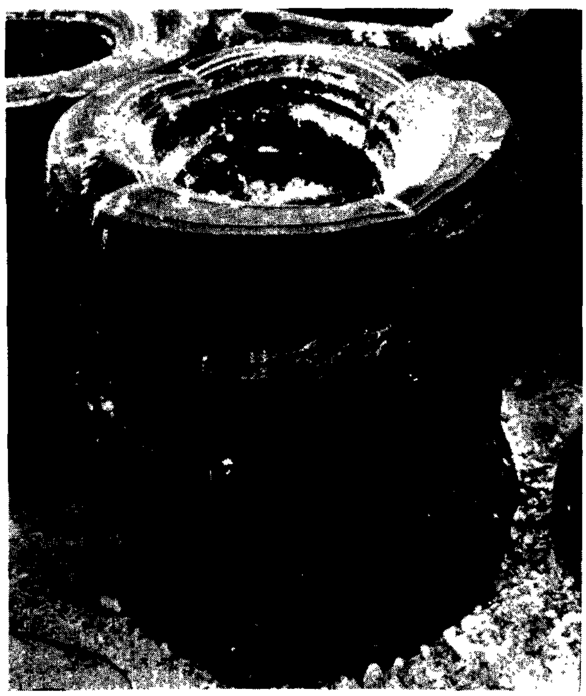

FIGURE 13. Banding is used to hold band 8-tire unit together. The unit is ballasted by pouring concrete in the core of the unit.

Rod 8-Tire Unit. The rod 8-tire unit is constructed with eight tires, held together by reinforcing rods and weighted with a concrete filled base tire. The original unit we used on our research reefs is described in detail by Stone and Buchanan.[12] However, State Fish and Game Departments have modified this unit and made it easier to build. The unit is now constructed by inserting three reinforcing rods into a base tire and tying the rods together at the top to make a tripod configuration. The base tire is then filled with concrete and six or seven tires with air holes are stacked over the tripod. The rods are then bent over the top tire. This unit should be used in deep or protected waters to minimize the possibility of the reinforcing rods breaking through the action of wave surge. A safety line or band of noncorrosive material, e.g., nylon, should be used to secure the ventilated tires to the concrete filled base tire.

Single-Tire Unit. The single-tire unit consists of a single tire with a No. 10-size can filled with concrete or a concrete test cylinder weighing approximately 15 pounds for the ballast.[12] The ballast is forced between the sidewalls of the tire (Figure 14). One or more holes, drilled or punched in the tire opposite the ballast, allow trapped air to escape and the unit to sink rapidly when thrown overboard. The single-tire unit costs about $0.26 per tire for materials and labor and is easy to handle from any size boat. This unit should not be used on soft or unstable bottoms, since it can be easily covered by mud or shifting sand.

Band 4-Tire Unit. The band 4-tire unit is made of four single-tire units banded together at a common point with stainless steel or plastic banding (Figure 15). Although more difficult to handle than the single-tire unit, this design offers the advantage of higher profile and more surface area.

Rod 3-Tire Unit. The rod 3-tire unit design has been used by many private groups along the east and Gulf coasts. It consists of three tires, standing upright, that are held together with a piece of reinforcing rod inserted through the sidewalls (Figure 16). The unit is weighted with concrete poured around the rod.[13] Air vents are drilled in the tire face opposite the concrete.

FIGURE 14. The single-tire unit, the most economical and easiest to build, is simply a single tire with a 15 pound concrete weight forced between the sides and an air vent opposite the weight. This unit can be carried in small boats to the reef site.

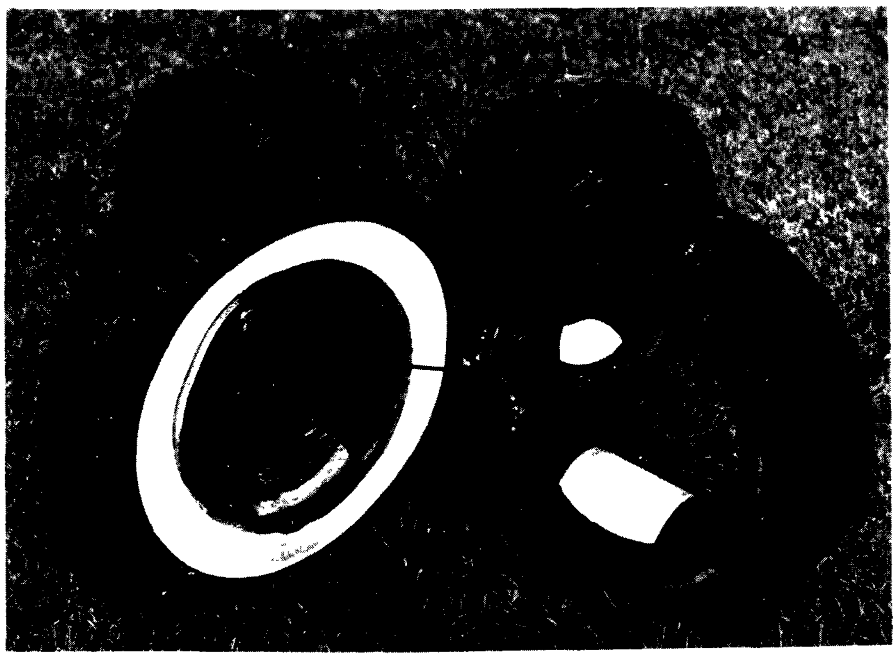

FIGURE 15. The band 4-tire unit is simply four single-tire units banded together at a common point. This unit is an effective habitat for reef fishes but is difficult to handle.

This is easily built and provides about 2 feet of elevation to the reef. Moving it around is, however, a two-man job. Once on the bottom, this unit has proved to be stable in strong currents and wave surge.

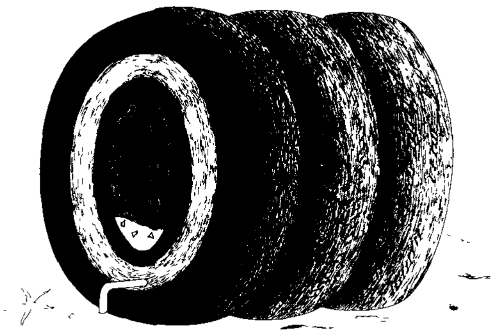

FIGURE 16. The rod 3-tire unit consists of three tires held together by a reinforcing rod and ballasted by concrete. The main disadvantage of this unit is that it is too heavy for one man to move, but once on the bottom it has proved to be stable.

Concrete-Base 3-Tire Unit. The concrete-base 3-tire unit is a modification of the rod 3-tire unit and simpler to build, but much more difficult to handle. It consists of three tires standing side by side in a concrete base (Figure 10). It is the most costly of the eight units to build, because of the amount of concrete required and the need for heavy equipment to load and unload. This unit is probably the most stable of the eight and should not move once on the bottom.

Cost Variations. A number of States are continuing to experiment with tire units, so the price will vary from year to year. For the latest information on costs and more detailed information on construction techniques contact the authors.

The least variable figure for judging tire unit costs is that for materials. Artificial reef-building groups may use volunteer labor but normally must pay for most materials, except tires.

Several reef committees along the east coast have had much of the material as well as the labor donated, particularly if the project is a community effort. In these cases, a tire reef can be built for minimal cost. The cost of transporting materials to the reef may also be minimal, depending on the interest of participants.

ANGLER SUCCESS

Artificial reefs have been built in the New York Bight since 1937. Their effect on the local sport fishery is relatively unknown, although it is generally believed that anglers catch a greater variety of fish and at a greater rate over artificial reefs than over natural habitats. During 1970, we conducted a survey to assess the fishing effort and success of sportsmen over artificial reefs, wrecks and natural habitat in the northwest section of the New York Bight (Figure 9).* Due to the inherent difficulties of collecting sport fishery statistics, we were not able to segregate the data by individual reefs.

Natural habitat within the survey area is composed of sand and mud, with scattered areas of rock (Table 2). There are four artificial reefs and approximately 180 wrecks, which are still sufficiently intact to attract fish, within the survey area. These manmade habitats encompass less than .1 percent of the survey area.

There are three types of boats used by sportsmen: headboats, private, and charter.† The headboat fleet is most active in the spring, summer, and fall with only a few boats sailing during the winter. The majority of these vessels fish only during daylight hours, while a few vessels, during the summer, fish at night. Private boats are most active during the summer, while very few, if any, are active during the winter.

Catch Rates and Species Composition

We estimated catch rates (number of fish caught per angler-hour) and catch composition (number of each species caught of private boat anglers) through mail questionnaires and that of headboat anglers through logbooks maintained by the vessels' captains. Refer to the 1972 report by Buchanan for more

* Preliminary report of the first year's data from a 2-year study.

† Charter boat data were not presented in this report.

information on survey methods.[14] We received returns from nearly 1,700 (57%) of our 3,000 inquiries made to private boat owners and nearly 3,000 logbook pages from headboat captains. We considered only gamefish in our analyses, since many non-gamefishes were not reported during the survey. Three dozen different kinds of fishes were caught during the survey (Table 3). We omitted all night-fishing data.

TABLE 2
APPROXIMATE AMOUNTS OF MANMADE AND NATURAL HABITATS IN THE NORTHWEST SECTION OF THE NEW YORK BIGHT

Habitat	Square miles		% of Total	
Manmade	0.11		<0.1	
Artificial Reefs (4)*		0.02		<0.1
Wrecks (Approx. 180)†		0.09		<0.1
Natural habitats	755.00		99.9	
Sand and/or mud ‡		583.00		77.0
Clam beds (commercially fished)†		132.00		17.7
Gravel (cobblestone and smaller)† ‡		23.00		3.1
Rock (larger than cobblestone)†		7.00		0.9
Mussel beds †		4.00		0.5
Polluted §		6.00		0.8

* Includes the open area between individual pieces of reef material.

† Acquired through personal communication with several headboat captains who fish in the survey area.

‡ Compiled from C&GS Charts 1215 and 1216.

§ Greater than 20% organic matter. From report "The Effects of Waste Disposal in the New York Bight" for the Coastal Engineering Research Center, U.S. Army Corps of Engineers by the Sandy Hook Sport Fisheries Marine Laboratory, 9 July 71.

TABLE 3

COMMON AND SCIENTIFIC NAMES OF FISHES REPORTED CAUGHT DURING 1970 MARINE SPORT FISHING SURVEY AND HABITAT CAUGHT

Local name	Scientific name	Type of habitat		
		Artificial reef	Natural bottom	Wreck
American eel	*Anguilla rostrata*		X	
Atlantic bonito	*Sarda sarda*	X	X	
Atlantic cod	*Gadus morhua*	X	X	X
Atlantic herring	*Clupea harengus*	X	X	
Atlantic mackerel	*Scomber scombrus*	X	X	
Atlantic menhaden	*Brevoortia tyrannus*		X	
Black sea bass	*Centropristis striata*	X	X	X
Bluefin tuna	*Thunnus thynnus*	X	X	
Bluefish	*Pomatomus saltatrix*	X	X	X
Cunner	*Tautogolabrus adspersus*	X	X	X
Dolphin	*Coryphaena hippurus*		X	
Goosefish	*Lophius americanus*		X	X
Hake	*Urophycis* sp.	X	X	X
Jacks	Carangidae		X	
Little tunny	*Euthynnus alletteratus*	X	X	
Northern kingfish	*Menticirrhus saxatilis*	X	X	
Northern puffer	*Sphoeroides maculatus*	X	X	
Northern searobin	*Prionotus carolinus*	X	X	
Northern stargazer	*Astroscopus guttatus*		X	X
Ocean tout	*Macrozoarces americanus*		X	
Oyster toad	*Opsanus tau*		X	
Pollock	*Pollachius virens*	X	X	X
Sculpins	Cottidae	X	X	X
Scup	*Stenotomus chrysops*	X	X	X
Shad	*Alosa* sp.		X	
Sharks	Squaliformes	X	X	X
Silver hake	*Merluccius bilinearis*	X	X	X
Skates and rays	Rajiformes	X	X	X
Skipjack tuna	*Euthynnus pelamis*		X	
Striped bass	*Morone saxatilis*	X	X	X
Summer flounder	*Paralichthys dentatus*	X	X	
Tautog	*Tautoga onitis*	X	X	X
Weakfish	*Cynoscion regalis*		X	
Windowpane	*Scophthalmus aquosus*		X	
Winter flounder	*Pseudopleuronectes americanus*	X	X	X
Yellowtail flounder	*Limanda ferruginea*		X	

Bottom Fishing. Headboat anglers had about the same degree of success over artificial reefs as over wrecks (Table 4). They caught only 0.42 fish per angler-hour less from reefs as from wrecks. Hake, black sea bass, tautog, and scup, species normally found over rocky areas, constituted over 90 percent of each catch (Table 5). The most marked difference was that scup represented over 25 percent of the reef catch and less than 1 percent of the wreck catch.

TABLE 4

BOTTOM FISHING STATISTICS OF PRIVATE BOAT AND HEADBOAT ANGLERS

Habitat types	Angler hours	Catch	Catch per angler-hour
	Private Boats		
Artificial Reefs	252	187	.74
Natural	3,344	3,148	.94
Artificial Reefs	179	106	.60
Wrecks	144	263	1.83
Natural	2,585	2,801	1.08
Wrecks	144	263	1.83
	Headboats		
Artificial Reefs	2,726	7,660	2.81
Natural	48,972	85,360	1.74
Artificial Reefs	2,679	7,541	2.81
Wrecks	7,934	25,629	3.23
Natural	72,405	108,400	1.50
Wrecks	8,234	25,838	3.14

Differences in the number of different fish caught from artificial reefs and wrecks may be due to physical variations between the habitats. Profile and depth of water over the material will influence the species which occupy a habitat. The age of a manmade habitat and depth of water will affect the number and kinds of food organisms present. Most of the artificial reefs in the survey area are located in shallow water, have low to medium profile (1 to 10 feet) and have been in place only a few years, whereas the approximately 180 wrecks encompass an array of profiles and depths. Most of these wrecks have been on the bottom much longer than the reef material. Therefore, it was expected that we should find some differences in the species composition between the two types of manmade habitats.

TABLE 5

THE RELATIVE ABUNDANCE OF EACH SPECIES CAUGHT BY HEADBOAT AND PRIVATE BOAT ANGLERS BOTTOM FISHING ON ARTIFICIAL REEFS, WRECKS AND NATURAL HABITATS

Species	Private			Headboat		
	Artificial reefs	Wrecks	Natural habitats	Artificial reefs	Wrecks	Natural habitats
Atlantic cod	8.55		.36		.94	4.39
Atlantic herring						.02
Atlantic mackerel			.84			.79
Black sea bass	14.43		.63	8.03	8.60	2.18
Bluefish			.84	.15	.16	.07
Hake	52.40	5.32	18.87	51.56	83.83	60.81
Northern kingfish			2.9			.07
Pollock				.01	.29	.04
Scup	14.43		15.21	25.86	.71	1.78
Silver hake			9.86	.14	.36	11.36
Striped bass			4.39		Tr.	.76
Summer flounder	8.02		21.57	.44		6.46
Tautog	1.60	94.67	12.66	12.50	5.00	10.72
Weakfish			.33			Tr.
Windowpane			.48			.02
Winter flounder	.53		11.00		.07	.42
Yellowtail flounder						.04

Headboat anglers bottom fishing over reefs caught 1.07 more fish per angler-hour than over natural habitats (Table 4). Their catches differed in the relative abundance of species primarily associated with one type of bottom (Table 5). Silver hake and summer flounder, which are associated with flat, sandy bottom, made up a larger portion of the catch from natural habitats (18%) than from artificial reefs (less than .5%), whereas scup, tautog, and black sea bass composed a larger portion of the catch from artificial reefs (46%) than from natural habitats (19%). Hake accounted for over 50% of each catch.

Headboat captains choose the type of natural habitat they fish over, depending on the species desired by their patrons. We cannot, therefore, fully evaluate the effect of artificial reefs on species composition without first segregating fishing over natural habitat by bottom type. This is beyond the scope of this paper and will be done at a later time.

Headboat anglers bottom fishing over wrecks caught 1.64 fish per angler-hour more than over natural habitats (Table 4). The differences in their catch composition were similar to those between reefs and natural habitats (Table 5).

Private boat anglers caught 1.23 and .75 fish per angler-hour more from wrecks than from artificial reefs or natural habitats respectively (Table 4). Their catch rates while over natural habitats and artificial reefs differed by only .20 fish per angler-hour. The number of species caught and the relative abundance of each differed considerably among the habitat types (Table 5). Natural habitats yielded 14 game fish species and artificial reefs only 7 game fish species, while wrecks, which received very little fishing pressure, only produced 2 game fish species. Natural habitats yielded mostly hake, scup, tautog, and summer flounder; artificial reefs mostly hake, black sea bass, and scup; and wrecks nearly all tautog.

The differences in the private boat angler's success between the different habitat types is probably due to the physical variations between the habitats and selective fishing.

Headboat and private boat anglers differed as to their average bottom fishing catch rates and species composition from wrecks and artificial reefs. These differences may partly be due to the private boat angler's inability to locate the exact position of the reef material. Even though the artificial reef sites in the survey area are buoyed and easy to find, most materials on the sites are scattered over a large area. From our experience, we found that in order to achieve a high catch rate on an artificial reef, you must fish on or directly next to material. We believe that as more materials are added to the sites, they will become easier to locate, resulting in higher catch rates for private boat anglers.

Surface Fishing. Manmade habitats did not affect the catch per angler-hour and species composition of headboat and private boat anglers seeking pelagic species, although Tables 6 and 7 falsely show marked differences. The differences in angling success are due to disproportional distribution of monthly fishing pressure and selective fishing for certain species on the different habitat types. This caused different months and species to receive undue emphasis in the analysis. For example, during May, headboat anglers surface fishing over wrecks spent most of their angler-hours selectively fishing for bluefish. But, while surface fishing over natural habitats during the same month, they spent the majority of their efforts for Atlantic mackerel. This resulted in different catch rates and catch composition.

ANGLING EFFORT

Only angler-hours reported through the questionnaires and logbooks are presented since it was not possible to estimate total fishing effort during the 1970 survey.

Manmade habitats did not receive a large portion of the total fishing effort (Table 8) since the combined area of reef habitat covers less than 0.1 percent of the survey area. However, the rate of fishing pressure (angler-hours per square mile of habitat) on manmade habitats was several hundred times greater than on natural habitat (Table 9).

Artificial reefs and wrecks did not receive the same relative amounts of bottom fishing time from the two groups of anglers (Table 8). Headboat anglers bottom fished nearly 3 times as many angler-hours on wrecks as they did on artificial reefs, whereas private boat anglers bottom fished twice as much on artificial reefs as on wrecks.

TABLE 6

SURFACE FISHING STATISTICS FOR PRIVATE BOAT AND HEADBOAT ANGLERS

Habitat types	Angler hours	Catch	Catch per Angler-hour
	Private Boats		
Artificial Reefs	1,234	2,441	1.98
Natural	13,498	17,053	1.26
Artificial Reefs	210	1,107	5.27
Wrecks	8	6	.75
Natural	1,930	6,992	3.62
Wrecks	8	6	.75
	Headboats		
Artificial Reefs	1,527	3,749	2.45
Natural	60,953	196,674	3.23
Artificial Reefs	42	3	.07
Wrecks	46	15	.33
Natural	50,252	611,864	12.18
Wrecks	100	76	.76

Several factors may have contributed to the differences in fishing intensity by the two angler groups on wrecks and artificial reefs. Private boat anglers may have been influenced to fish over the reefs because of the publicity in the local newspapers and the fact the reefs sites are easy to locate. However, the average private boat angler has difficulty in locating most wrecks because he does not know the required land ranges or does not have the necessary electronic sounding and positioning equipment. Most headboat captains know land ranges for many wrecks or have equipped their boats with sophisticated sounding and locating devices. Headboat anglers probably fished as intensely on artificial reefs as on wrecks because of the similarity of their angler success on each manmade habitat type. But they may have fished more angler-hours over wrecks than artificial reefs simply because of the greater number of wrecks available. The number of wrecks available to any one headboat captain is limited by the distance he can travel during a normal fishing trip. Most headboats have about 50 wrecks and one or two artificial reefs within their normal fishing areas.

TABLE 7

THE RELATIVE ABUNDANCE OF EACH SPECIES CAUGHT BY HEADBOAT AND PRIVATE BOAT ANGLERS SURFACE FISHING ON ARTIFICIAL REEFS, WRECKS, AND NATURAL HABITATS

Species	Private			Headboat		
	Artificial reefs	Wrecks	Natural habitats	Artificial reefs	Wrecks	Natural habitats
Atlantic bonito	.12		1.28			Tr.
Atlantic cod						Tr.
Atlantic herring	.12		.06			.01
Atlantic mackerel	67.06		45.80	46.54	2.63	83.11
Black sea bass	.04		.03			Tr.
Bluefin tuna	.04		.84			.02
Bluefish	30.72	100.00	42.90	53.24	93.42	16.51
Dolphin			.14			Tr.
Hake			.68			.03
Little tuna	.49		1.73			.01
Northern kingfish	.81		.06			
Scup			.21			Tr.
Shad			.01			Tr.
Silver hake	.24		1.07	.05		.23
Skipjack tuna			.40			
Striped bass	.20		4.25		3.94	Tr.
Summer flounder	.08		.36	.16		.01
Tautog			.03			
Weakfish			.02			Tr.
Windowpane			.05			
Winter flounder	.04					Tr.

TABLE 8

ANGLER-HOURS SAMPLED SPENT BY HEADBOAT AND PRIVATE BOAT ANGLERS FISHING IN THE NEW YORK BIGHT DURING 1970

Vessel type	Fishing method	Artificial reefs	Natural habitats	Wrecks
Headboat	Surface	1,521.3	142,636.7	100
	% of total	1.05	98.87	.06
	Bottom	2,746.6	77,639.9	8,233.6
	% of total	3.09	87.60	9.29
Private	Surface	1,233.8	13,951.3	8
	% of total	8.12	91.82	.05
	Bottom	251.9	3,374.4	143.6
	% of total	6.68	89.50	3.80

TABLE 9

FISHING INTENSITY RATES * (ANGLER-HOURS PER MILE) OF SAMPLED HEADBOAT AND PRIVATE BOAT ANGLERS SURFACE AND BOTTOM FISHING ON EACH TYPE OF HABITAT

Fishing method	Artificial reefs	Natural habitats	Wrecks
	Open Boat Anglers		
Surface	76,350	117	1,111
Bottom	136,300	103	91,489
	Private Boat Anglers		
Surface	61,700	18	88
Bottom	12,600	4	1,600

* It should be noted that the fishing intensity rates in Table 9 are only relative estimates and are valid for comparisons only within an angler group, not between groups. This limitation was caused by disproportional sampling of the groups.

EXISTING TIRE REEFS AND PROJECTED ESTIMATES

By January 1, 1973, there were 114 approved artificial reef sites along the east coast of the United States. A total of about 400,000 scrap tires have been used on 43 of these sites (Table 10). None of the 114 reefs have been constructed as large as originally planned. Actually, only a small portion of the total surface area the sites encompass (approximately 36 nautical sq mi) contains reef material.

Most of these reefs are not large enough to maintain angler success at a high level with the increasing fishing effort. To meet immediate demands, existing reef sites should be enlarged. If scrap tires are used to complete these reefs to an average height of 3 feet, a total of about 600 million tires would be required. We also anticipate a need for more reefs to meet future demands. If tires are only a portion of the material used to build these reefs, several hundred million more tires would be needed. Based on these projections, nearly one billion tires could be used on artificial reefs in marine waters off the east coast of the United States.

DISCUSSION AND CONCLUSIONS

In studying the use of scrap tires as artificial reef material, we found that scrap tires can be readily obtained at no cost from many tire dealers, easily assembled into units, and transported to reef sites at moderate cost. Once on the bottom they provide additional habitats for many fishes and invertebrates.

During 1970, we questioned a number of service station operators, tire dealers, and retreaders in the New York–New Jersey area to determine methods and costs of scrap tire disposal. Service stations and low volume tire dealers had three common methods of tire disposal, as follows: (1) place two or three tires in the garbage each night before a scheduled pickup and hope that the city sanitation department would remove them. This method helped only dealers who handled few tires. (2) Contract for removal of scrap tires. This could cost as much as $150 per 1,500 tires. (3) Take the tires directly to the city dump. In New York City this was an expensive choice. Dealers paid either $2.00 per cubic yard or $80.00 per 1,500 tires to use the dump, exclusive of labor and transportation costs. It cost up to $5 per pickup truck load to dispose of tires in the municipal dump for a suburban area within commuting distance of New York City.

Large volume tire dealers or recappers were able to sell some scrap tires to recapping companies in other areas. Most of the time, however, dealers paid for disposal of their tires. Some engaged a contractor at $35 to $100 per 1,500 tires to haul tires to a reprocessing mill. A mill could handle only a small percentage of the scrap tires available in a metropolitan area. Some dealers or recappers had a contract enabling them to take tires directly to the mill on a pre-set schedule. They received $6 per ton (about 200 tires) which, in many cases, did not cover the cost of labor and transportation. A few dealers would freight scrap tires to a mill that paid $10 per ton for them. This return did not equal the costs of shipping and handling. Use of the city dump was another choice for larger volume dealers, but many city dumps would not accept scrap tires unless directed to do so by the police.

With this tire disposal problem, we were able to obtain an ample supply of tires from local tire dealers at no cost to build our study reefs. In addition to the dealers who actually supplied tires, other dealers offered tires, not only in New Jersey and New York but also in many of the surrounding States. One company in Brooklyn, New York, offered to deliver 1,400 tires a day at their expense. This would have involved a round trip of about 120 miles for each delivery. The same type of cooperation is presumably available from tire dealers in most cities along the coast. At present, however, there might be some problem in obtaining large numbers of tires at no cost in rural areas.

TABLE 10

LOCATION OF EAST COAST ARTIFICIAL REEFS CONSTRUCTED PARTIALLY OR COMPLETELY OF SCRAP TIRE UNITS (JAN. 1, 1973)

Location	Number of tires
Ipswich Bay, Mass.	1,000
Shinnecock Bay, N.Y.	1,000
Ocean off Shinnecock, N.Y.	6,000
Ocean off Moriches, N.Y.	600
Great South Bay, N.Y.	3,500
Ocean off Fire Island, N.Y.	1,500
Ocean off Atlantic Beach, N.Y.	30,420
Ocean off Rockaway, N.Y.	6,500
Ocean off Monmouth Beach, N.J.	1,500
Ocean off Sea Girt, N.J.	70,000
Ocean off Indian River Inlet, Del.	2,000
Ocean off Ocean City, Md.	1,000
Bay near Millers I., Md.	660
Bay near Love Pt., Md.	660
Bay near Cedarhurst, Md.	660
Bay near Eastern Bay, Md.	660
Bay near Holland Pt., Md.	660
Bay near Patuxent, Md.	660
Tangier Sound, Md.	660
Ocean off Parramore I., Va.	2,500
Bay near Onancock, Va.	1,000
Ocean near Chesapeake Light Tower, Va.	300
Ocean off Morehead City, N.C.	1,000
Ocean off Wrightsville Beach, N.C.	500
Ocean off Lockwood Folly, N.C.	3,800
Ocean off Murrells Inlet, S.C.	6,000
Ocean off Murrells Inlet, S.C.	36,000
Ocean near Charleston, S.C.	20,000
Ocean off Beaufort, S.C.	8,000
Ocean off Beaufort, S.C.	20,000
Ocean off Beaufort, S.C.	20,000
Ocean off Warsaw I., Ga.	16,000
Ocean off St. Simons, Ga.	24,768
Ocean off Brunswick, Ga.	768
Ocean off Cumberland I., Ga.	14,320
Ocean off Jacksonville, Fla.	7,000
Ocean off St. Augustine, Fla.	2,000
Ocean off Ponce de Leon Inlet, Fla.	1,500
Ocean near Cape Canaveral, Fla.	1,200
Ocean off Singer Island, Fla.	2,000
Ocean off Ft. Lauderdale, Fla.	65,000
Ocean off Hallandale, Fla.	1,000
Ocean off Elliott Key, Fla.	560
Total	384,856

The cost of building tire units was extremely variable, but the total cost per tire for the single-tire unit, including labor and materials, was only a few cents higher than some tire dealers have to pay to dispose of their tires. By incorporating some assembly and staging refinements, the cost per tire to build tire units could probably be reduced below their disposal costs. We conferred with major tire companies, the National Tire Dealers and Retreaders Association, and the Rubber Manufacturers Association about ways to mechanize the processing of large numbers of scrapped tires for artificial reef sites. If this process proves feasible, as now seems likely, then building reefs with large numbers of scrap tires could be much less expensive than present disposal costs. In addition, the tires would be used beneficially for habitat improvement programs rather than buried at city dumps or left stockpiled to harbor rats or to collect water in which mosquitoes may breed.

Once tires are in place on the reef site, they provide an excellent surface for the attachment of encrusting organisms. Tires are durable; we found no evidence of toxic substances leaching from the tires,[15] they do not decompose like metal, and there is no evidence of structural breakdown caused by boring organisms, such as occurs with wood, although some bacteria can attack them. They have a high ratio of surface area to volume, and the configuration of the tire provides protective niches for motile species as well as the useful substrate.

Just like any reef material, tires must be used properly to assure that a reef will not conflict with other uses of the marine environment such as navigation and commercial fishing. If the units are constructed correctly, there should be no movement of materials once they are on the bottom. To construct a reef, Federal, and in most cases State, permits are required. These permits allow regulation of where and how reefs can be constructed and eliminate conflicting uses of an area of ocean bottom. For more details on constructing artificial reefs and the problems involved, contact the authors.

The need for marine habitat improvement exists because of the limited amount of reef habitat now available and the increasing demand placed on reef-related or associated marine fishes by sport and commercial fishermen. During the 10-year period from 1960 to 1970 the number of salt water anglers increased from 6.2 million to 9.4 million (51.6%). It is necessary to manage the marine environment if this ever-increasing demand on its resources is to be provided for. The carrying capacity (the ability of the ocean to support fish) can be increased especially for bottom species by enlarging existing artificial reefs and constructing additional reefs along the coast.

Our preliminary findings indicate that manmade habitats in the New York Bight area improved angler success for game species normally associated with rocky habitats, but not for pelagic species or species typical of open bottom. Only anglers on commercial sport fishing boats were able to take advantage of the improved bottom fishing. The inability of private boat anglers to reap this new success was probably due to their inability to locate the reef material and not due to limitations of the manmade habitats.

Artificial reefs have proven to be an effective tool for increasing the amount of good bottom fishing sites in the New York Bight, although, the average angler fished only a small percent of his time over artificial reefs. This may be due to the small portion of the survey area covered by artificial reefs, limiting the number of anglers which could fish a reef at one time. We are confident that as artificial reefs are increased in numbers and size, they will be more effectively and habitually used by a much larger portion of the marine sportfishing population.

Another use for tire reefs could be rehabilitation of areas, both ocean and estuarine, that have been damaged either by pollution or by dredge-and-fill operations. The sludge-dumping area off New York City, for example, which contains many square miles of oxygen-depleted sediment and an impoverished fish fauna, could possibly be rehabilitated more quickly, once the sludge dumping has stopped, if tire reefs were constructed in that area. These could provide a substrate that would protrude above the oxygen-depleted sediments and enable the encrusting organisms to settle and have enough oxygen to survive. A recolonization of the area by other invertebrates and fish may then occur. An example of this is a reef in Biscayne Bay, Miami, Fla. The reef was constructed in an area that had been dredged to a depth of approximately 30 feet from a normal depth of 8 to 10 feet. The natural bottom (coral and limestone) had been destroyed, leaving an unstable, soupy mixture of particulate matter that could support very few organisms. When high-profile reef material was placed on the bottom, it protruded above this soft bottom and provided a substrate that quickly was covered with encrusting organisms. A variety of fish returned to the area, and anglers reported making good catches within 6 months after the reef was constructed.[16]

Most of the successful reefs built along the Atlantic coast have been cooperative efforts. Cooperation between Federal and State Governments, industry, and local groups can reduce both the time required to build a large reef and the cost of building it. A number of reef committees are receiving technical assistance from State conservation departments and the National Marine Fisheries Service. In many cases, they also receive financial support from the State.

The future for habitat improvement with use of artificial reefs seems bright. These reefs offer a potential for increasing coastal gamefish resources, the possibility for improved catches in local commercial and sport fisheries, and a functional use for certain non-toxic waste materials.

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