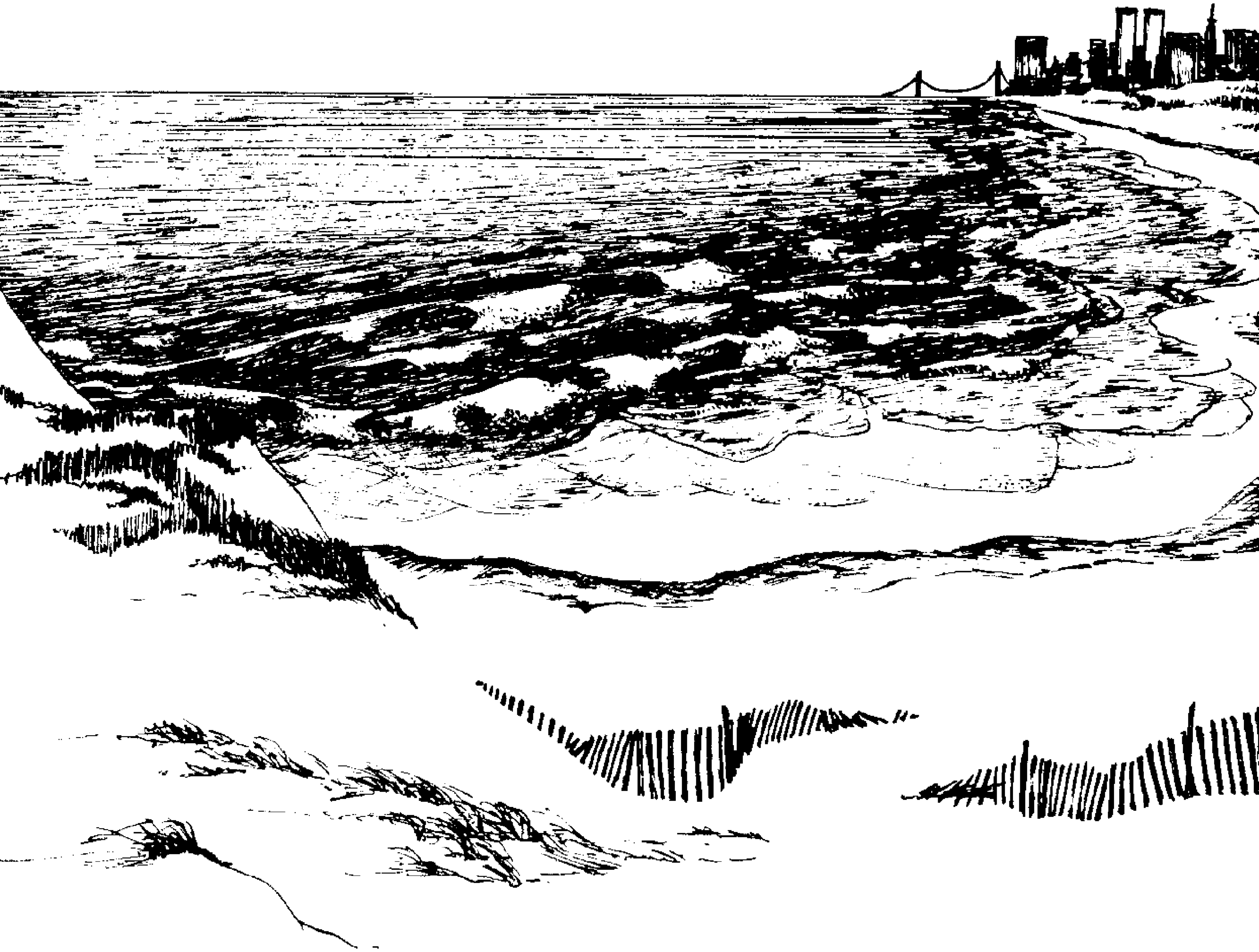
Artificial Fishing Reefs

Albert C. Jensen



MESA NEW YORK BIGHT ATLAS MONOGRAPH 18

The offshore water in the bend of the Atlantic coastline from Long Island on one side to New Jersey on the other is known as New York Bight. This 15,000 square miles of the Atlantic coastal ocean reaches seaward to the edge of the continental shelf, 80 to 120 miles offshore. It's the front doorstep of New York City, one of the world's most intensively used coastal areas – for recreation, shipping, fishing and shellfishing, and for dumping sewage sludge, construction rubble, and industrial wastes. Its potential is being closely eyed for resources like sand and gravel – and oil and gas.

This is one of a series of technical monographs on the Bight, summarizing what is known and identifying what is unknown. Those making critical management decisions affecting the Bight region are acutely aware that they need more data than are now available on the complex interplay among processes in the Bight, and about the human impact on those processes. The monographs provide a jumping-off place for further research.

The series is a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the New York Sea Grant Institute. NOAA's Marine EcoSystems Analysis (MESA) program is responsible for identifying and measuring the impact of man on the marine environment and its resources. The Sea Grant Institute (of State University of New York and Cornell University, and an affiliate of NOAA's Sea Grant program) conducts a variety of research and educational activities on the sea and Great Lakes. Together, Sea Grant and MESA are preparing an atlas of New York Bight that will supply urgently needed environmental information to policy-makers, industries, educational institutions, and to interested people. The monographs, listed inside the back cover, are being integrated into this *Environmental Atlas of New York Bight.*

ATLAS MONOGRAPH 18 details the best kinds of materials and profiles for an artificial reef, from studies of the Bight's dozen or so planned reefs and hundreds of "accidental reefs"–sunken ships. On the shelf's relatively flat, sandy bottom, reefs attract many kinds of fish and the organisms they feed on, making things better for sport fishing. Constructing reefs in this region has almost stopped in recent years, says Jensen, because costs run high despite donated materials. When saltwater sportsmen are willing to pay a fee for their recreation, programs to improve their fishing–including reefs–can be put into effect.

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Artificial Fishing Reefs

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New York Sea Grant Institute
Albany, New York
December 1975

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Acknowledgments

Many people from private, state, and federal agencies provided me with advice, guidance, and materials. I am especially grateful to my colleague, Chester S. Zawacki, for detailed information gleaned from his years of research experience on artificial fishing reefs. Richard B. Stone, Chester C. Buchanan, and Frank W. Steimle, Jr., National Marine Fisheries Service, generously supplied reports, including unpublished data, describing federal research. Mr. Stone also supplied the underwater photographs.

Mrs. Barbara Durciansky typed the manuscript through its several revisions, and Ms. Susan Marchese typed additional material.

Finally, a note of thanks to the many anglers who have taken the time to let us know of their fishing success over artificial fishing reefs. It is because of their efforts that we know the reefs work.

Manuscript accepted February 1975.

Abstract

Artificial fishing reefs are underwater structures designed to attract and concentrate fishes, making them more available to anglers. In contrast to natural fishing reefs, such as rock ledges or coral formations—rare in New York Bight—artificial reefs consist of both natural and man-made materials. Some artificial reefs have originated from sunken ships, but most artificial fishing reefs are of solid materials deliberately sunk as part of fisheries management plans under the direction of governmental agencies. Research has shown that discarded automobile tires are among the best materials for the reefs. Tires are easily obtained, inexpensive, attract a variety of organisms, and are long-lasting in the destructive environment of seawater.

Seven planned artifical fishing reefs, constructed beyond the barrier beaches in New York Bight, have been studied intensively. They are offshore of Shinnecock Inlet, Moriches Inlet, Fire Island Inlet, Atlantic Beach, Rockaway Beach, Monmouth Beach, and Sea Girt. The reefs attract sport fishes like tautog, scup, black sea bass, red hake, Atlantic cod, winter flounder, summer flounder, striped bass, bluefin tuna, Atlantic mackerel, and bluefish.

Artificial fishing reefs are not simply junkyards in the sea; the reef builder must obtain permits and comply with governmental regulations. In addition to being part of good fisheries management, a well-designed reef building program could help solve some of the solid waste problems plaguing most communities.

Introduction

This monograph discusses artificial fishing reefs outside barrier beach areas in New York Bight. I describe materials, locations, and success of these reefs in enhancing the marine environment to improve angling opportunities for sport fishermen. I have not included the numerous reefs in bays and inlets, although many are well-built, productive structures, designed and placed there by anglers' clubs and civic groups as well as by state and local agencies.

Artificial reefs depend on the readiness of certain marine plants and animals to colonize submerged surfaces of wood, metal, concrete, rubber, and other materials. These fouling or encrusting organisms serve as food for other invertebrates and forage fishes, which in turn attract larger *piscivorous* (fish-eating) species. Whenever a ship accidently sinks or when concrete, rocks, discarded boats, barges, and like materials are deliberately sunk to encourage fouling, an artificial reef is created.

The concept of artificial reefs is not new; for centuries the Japanese dumped rocks into local waters to increase fishing productivity (Zawacki 1969). The relationship between a fish species and bottom topography is not direct but is linked to the food and shelter offered by the substrate. A well-known example is the tautog (*Tautoga onitis*); its occurrence over rocky bottom no doubt results from its appetite for the crustaceans and mollusks found there.

Reef Materials and Locations

Almost any solid, nontoxic material can serve as an artificial fishing reef. The reef should cover a bottom area of at least 2 to 3 acres (0.8 to 1.2 hectares). The material must be bulky enough to project off the ocean bottom and massive enough to remain in place during severe storms. It should resist rapid corrosion, furnish nooks and crannies for the fishes, and provide a suitable substrate for hydroids, mussels, barnacles, and other fouling organisms. Materials that have been used for fishing reefs include surplus warships, excavated rock, building rubble, scrap concrete pipes, old refrigerators and other household appliances, old streetcars, junked automobiles, and discarded automobile tires.

The *reef profile*—that is, how high it projects above the bottom—is also a factor in the reef's success in attracting fishes and other marine organisms. There are no precise definitions of profiles except two given by Myatt (1974). After reviewing the available literature, I was able to add two other profile definitions by extrapolation. Thus, for this monograph the following definitions of reef profiles are used:

low	< 1 ft (< 0.3 m)	from Myatt (1974)
medium	1 to 6 ft (0.3 to 2 m)	from Myatt (1974)
high	6 to 15 ft (2 to 5 m)	from extrapolation
very high	> 15 ft (> 5 m)	from extrapolation

Two kinds of artificial fishing reefs exist in the Bight: accidental and planned. The accidental reefs result, for example, where shipwrecks or solid waste dumped on the ocean bottom have become popular fishing spots, not by design but because fishermen have discovered that fish are attracted to such areas. Planned reefs, as the term implies, are deliberately built to attract bottom fishes and thus provide clearly marked sport fishing locations.

Shipwrecks

A few enterprising fishermen, especially the operators of charter vessels and headboats*, learned early that concentrations of bottom-dwelling fishes could be found over sunken ships. Catches made over these wrecks include Atlantic cod (*Gadus morhua*), pollock (*Pollachius virens*), red hake (*Urophycis chuss*), white hake (*Urophycis tenuis*), tautog, and black sea bass (*Centropristis striata*). Some wrecks are more than a century old; *Black Warrior*, for example, sank in 30 ft (9.2 m) of water off the Rockaways (Long Island) in 1858 (Map 1) and has provided fine fishing for many years, particularly to the nearby Sheepshead Bay sport fishing fleet.

Wreck fishing is the specialty of many Long Island and New Jersey headboat captains who have equipped their vessels with sonar scanners and other electronic devices—for example, precision-recording fathometers and loran equipment—to detect and locate wrecks that might offer good fishing. Cod weighing more than 50 lb (22.7 kg), large pollock, and white hake are caught in large numbers over such wrecks.

Wartime and Accidental Sinkings. The number of shipwrecks greatly increased during World Wars I and II when allied and enemy vessels were sunk in the Bight. One of the most famous was the cruiser *USS San Diego*, torpedoed and sunk in 90 ft (27.7 m) of water off Fire Island in 1918 (Map 2). This hulk is a source of excellent fishing even today.

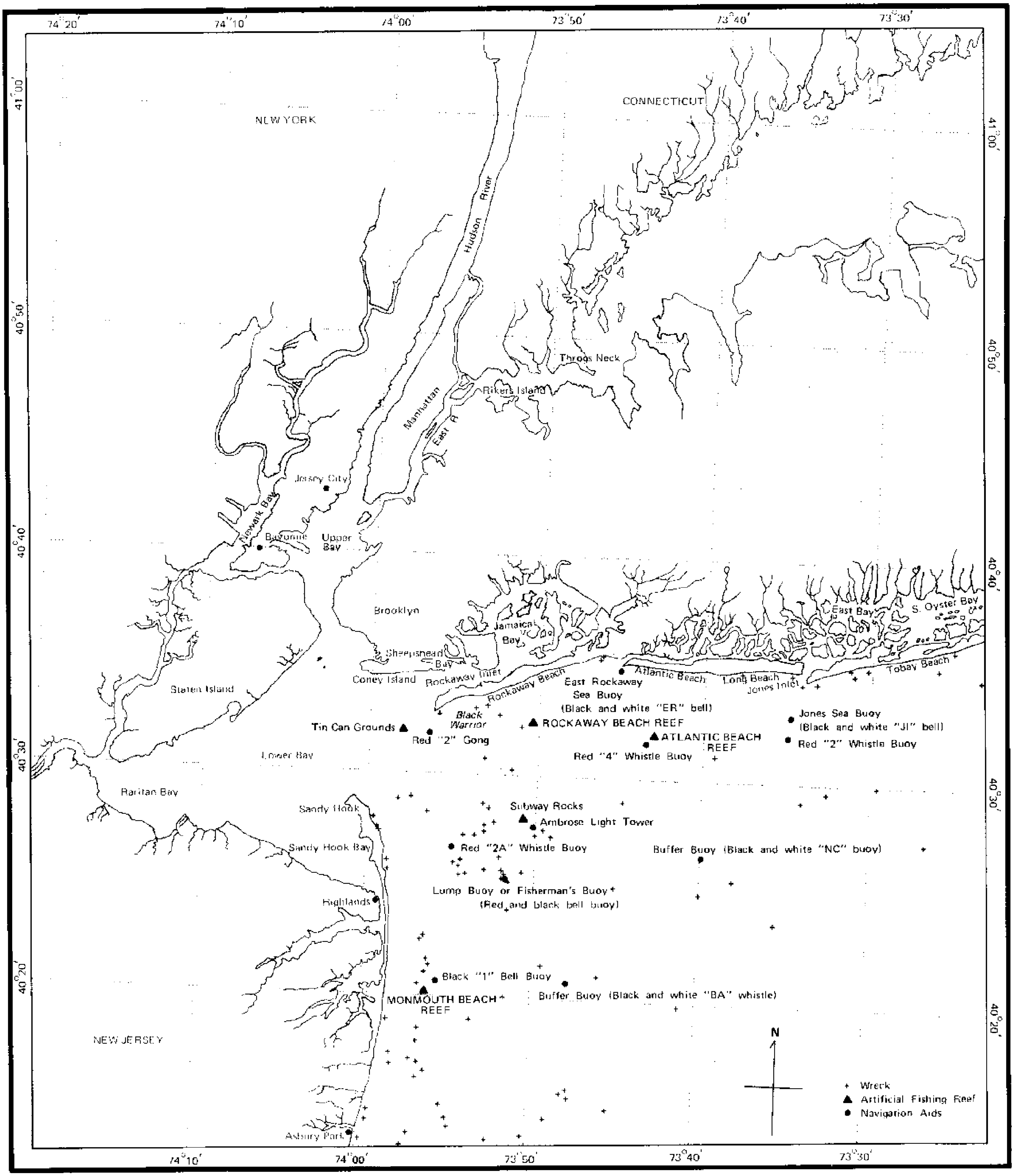
Deliberately Sunk Vessels. Surplus warships and other vessels have been purposely sunk in prescribed places for artificial fishing reefs. Stone (1974) reports that "old ships and barges make excellent reefs because their high profiles induce upwellings and eddy currents that attract bait fishes and large predators." Very high profiles appeal to Atlantic mackerel (*Scomber scombrus*) and bluefish (*Pomatomus saltatrix*), which rarely venture near the bottom (Zawacki 1969).

Before being sunk, the ships usually are stripped of valuable nonferrous metals, engines, and usable parts; oils, fuels and other liquids, wooden parts and other floatables are removed. Hatches and doors are taken off to eliminate hazards to divers who later may investigate the ships. Large holes are cut in bulkheads and overheads to insure good water circulation that will promote biological activity of fouling organisms and fishes.

Approval for the sinking must be secured from governmental agencies, including the US Army Corps of Engineers and the US Coast Guard. Reef materials

*Vessels operated by licensed captains who take fishermen to fishing grounds daily for a fee per person on a first-come-first-served basis.

Map 1. Bight apex



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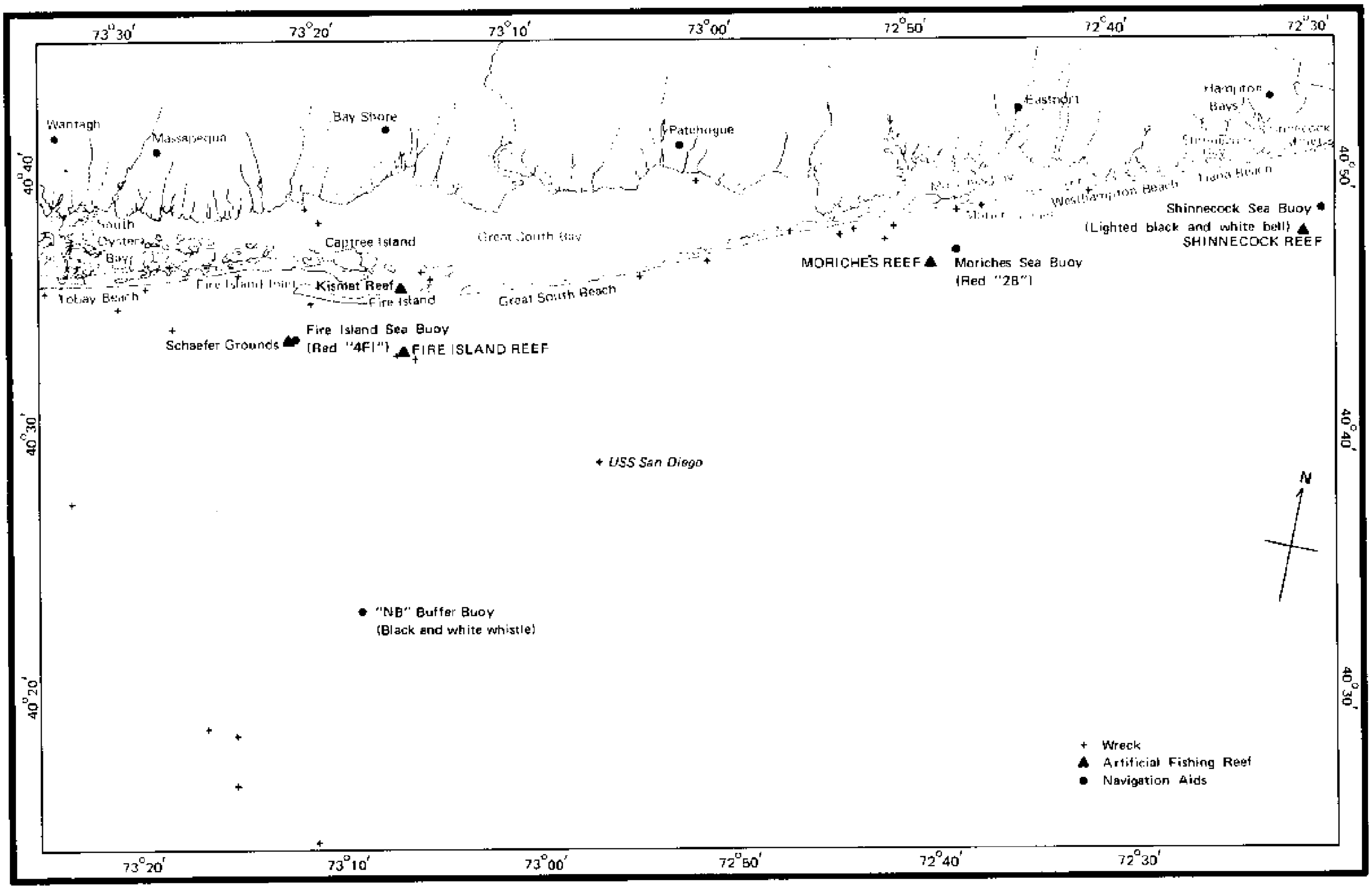
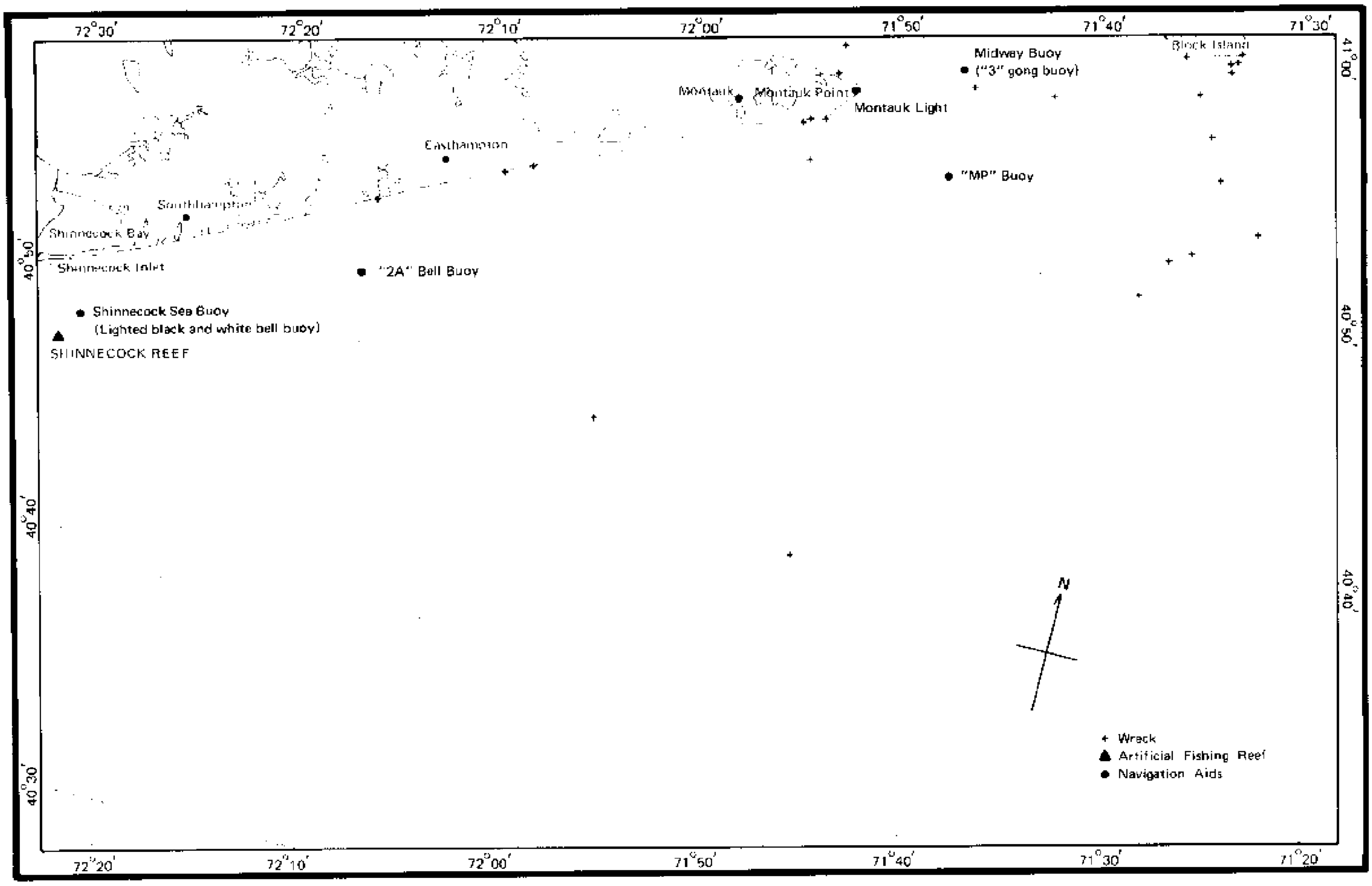
Lambert Conformal Conic Projection

5 0 5 10 Statute miles
5 0 5 10 Kilometers
5 0 5 10 Nautical miles

Adapted from *Anglers' Guide* 1974

Map 2. Long Island





Lambert Conformal Conic Projection

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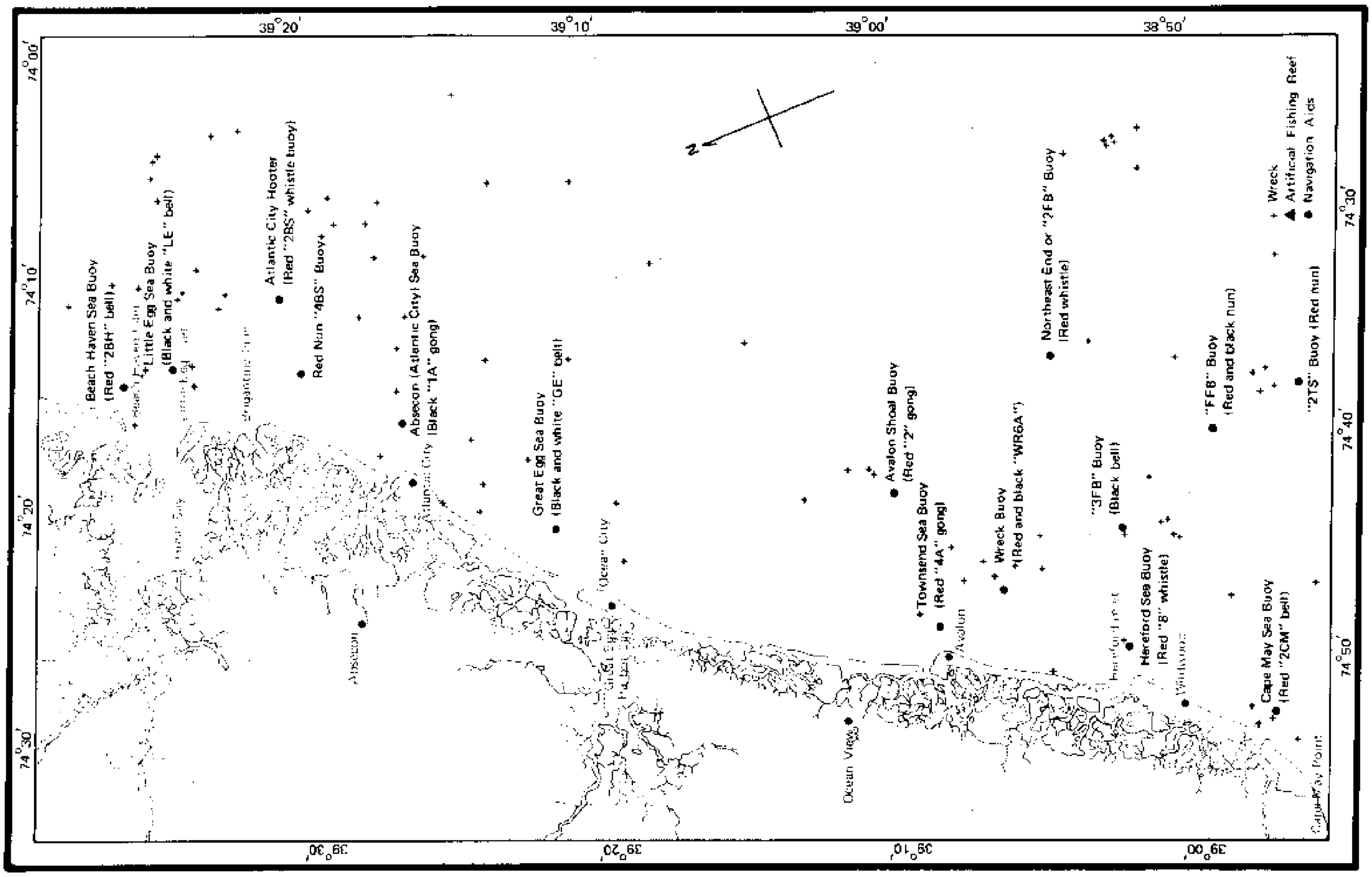
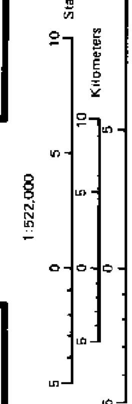
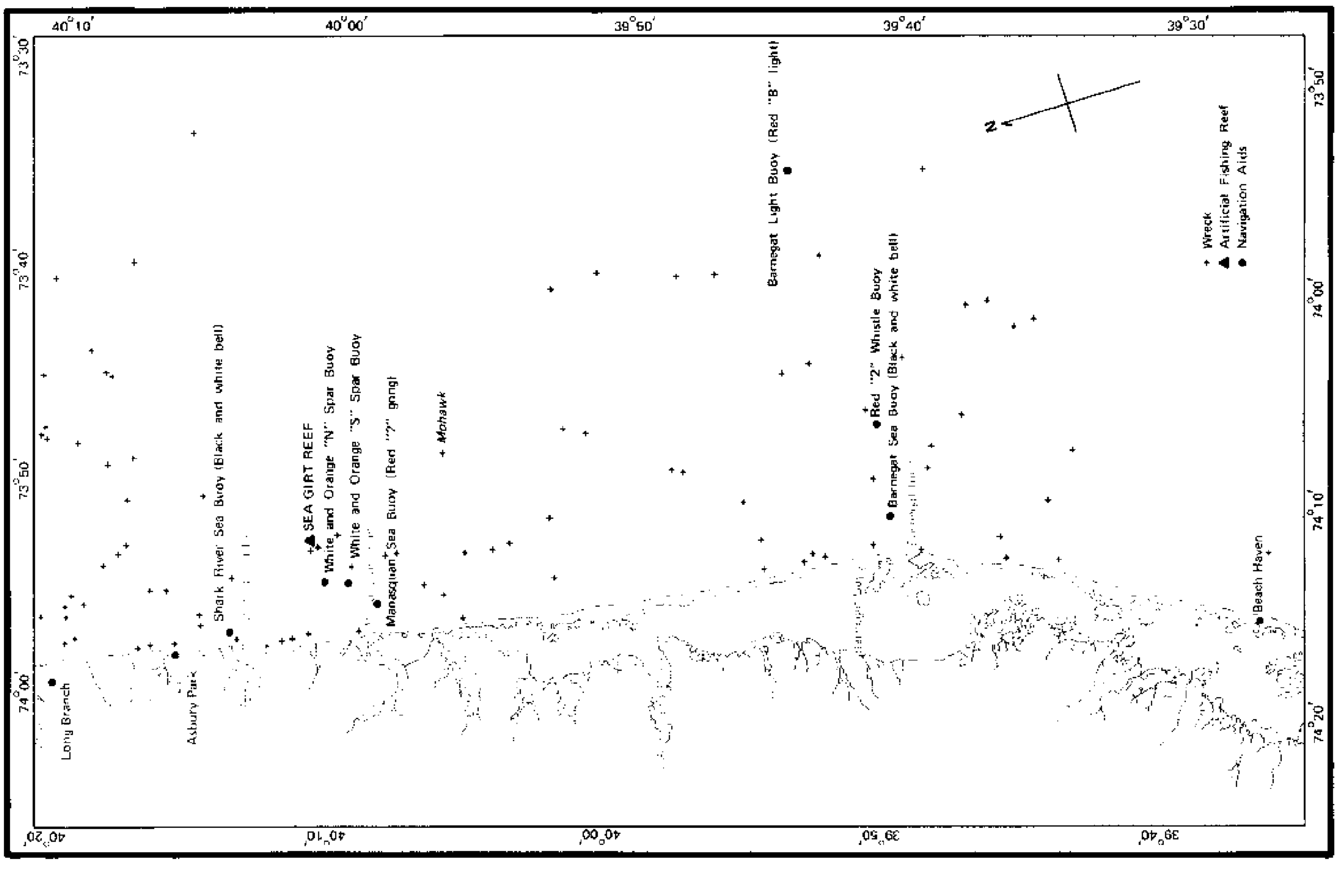
Statute miles · Kilometers · Nautical miles

Adapted from *Anglers' Guide* 1974

Map 3. New Jersey







Adapted from *Anglers' Guide* 1974

Lambert Conformal Conic Projection

must meet the water quality standards of the Environmental Protection Agency (Amson 1974). Criteria assuring federal approval of artificial reefs were established in 1961 during a meeting between representatives of the 15 East Coast states in the Atlantic States Marine Fisheries Commission (ASMFC) and federal agencies (Atlantic States Marine Fisheries Commission 1962). As a result, the exact location of the sinking must be clearly indicated; the ships must be sunk in water deep enough to provide a minimum of 50 ft (15.4 m) between the top of the ship (or any artificial reef) and the surface. Buoys must be properly maintained to mark obstructions on the bottom and to locate the ships for anglers.

Vessels used in artificial reefs vary from the large 440 ft (135.4 m) Liberty ships to a wooden pirate ship used as a stage prop in a 1967 Jones Beach Marine Theatre production (Zawacki 1969). Wooden and steel barges slated for deepwater disposal are ballasted with discarded concrete culvert pipe or surplus ready-mix concrete donated by contractors, and scuttled on the reef site.

In 1972 the federal government made available surplus World War II Liberty ships for artificial fishing reef programs. A number of coastal states took advantage of the offer but New York and New Jersey could not afford the expense of towing the ships from where they were tied up in mothball fleets nor the cost of preparing and sinking them; in New York, towing and sinking charges were estimated at $25,000 per vessel. Virginia, on the other hand, had minimal towing fees because a fleet of Liberty ships was tied up at the US Naval base in Newport News, and recovered some preparation costs by selling scrap and other salvage rights to parts of the ships not needed for reefs (James Douglas, personal communication). North Carolina passed a law in 1973 authorizing one-eighth of 1% of the net returns on motor fuel taxes to the Department of Natural and Economic Resources "for the exclusive purpose of establishing, maintaining and marking artificial reefs" (Stroud 1973).

Rock and Rubble

One of the best sources of material for artificial fishing reefs is rock and rubble—the so-called *cellar dirt* from excavations for building foundations and similar projects. Rock and rubble not only satisfies the criteria for good reef material but also is natural and environmentally compatible. The supply of cellar dirt is good in an active construction area like metropolitan New York, but it sometimes is valuable as landfill and so not always available for reefs. When available, the cost of transporting it and placing it at the reef site is often high, about $500 per trip (Unger 1966).

A typical rock and rubble reef is located off Rockaway Beach, Long Island. It is known to anglers as the Subway Rocks (Map 1) because it is composed of bedrock excavated during subway construction in Manhattan. Renewed subway excavation in 1973 provided additional material for existing reefs in New York waters; the rock was transported at no cost by the Moran Towing Company. When it can be obtained, rock and rubble make a nearly ideal reef material.

Solid Waste

Zawacki (1969) suggested that artificial fishing reefs may help solve some of the solid waste disposal problems of metropolitan areas. In New York State alone, for example, the 50,000 automobile tires discarded each year could be used to enlarge old reefs or to build new ones.

Wooden butter tubs half-filled with concrete were used in the mid-1920s in the first venture to build a fishing reef in New York. The tubs were sunk in the vicinity of Kismet Reef (Map 2) in Great South Bay and still provide good fishing as the Butter Tub Grounds (Unger 1966). Wooden boxes, also half-filled with concrete, were sunk in the bay in 1946 and 1947 in a project carried out by the Bay Shore Tuna Club. Wooden beer crates with concrete ballast make up the Schaefer Grounds (named after the brewery that donated the crates) off Fire Island in 1953 (Map 2). Incinerator wastes from New York City were dumped off Coney Island to form the Tin Can Grounds (Map 1), "one of New York's finest porgy (scup) [*Stenotomus chrysops*] fishing hotspots" (Zawacki 1969). Sealed bales of compressed solid waste, including food wastes, have been used experimentally to create reefs while helping to solve the disposal problem (Loder, Rowe, and Clifford 1974). When properly prepared, the bales were found not to be an ecological hazard; the authors suggested, however, that the bales be monitored to assess any environmental impact.

Massiveness and weight are particularly important for a stable reef, as illustrated by the following New Jersey experience (Unger 1966). In 1961 the New Jersey Department of Conservation and Economic Development provided advice and supervision to the Cape May County Party Boat Association for building a reef off Cape May. Seven wooden boats 35 to 90 ft (10.8 to 27.7 m) long and several thousand ballasted automobile tires were sunk on Five Fathom Bank (38°57'N, 74°34'W). During an unusually severe spring coastal storm in 1962, the reef was swept away, prompting the comment by Paul E. Hamer, a New Jersey fisheries biologist, that "quarry rock is the only feasible material to use" (in Unger 1966).

Automobiles. Junked automobile bodies have been used for years to build fishing reefs (Figure 1). At first this seemed to be an ideal way to dispose of the millions of automobiles abandoned each year (80,000 annually in New York City) but there are a number of drawbacks. The autos must be drained completely of fuel, lubricating oil, and other fluids. Upholstery and other floatable materials must be removed by hand. In the past, car bodies were burned to destroy the upholstery, headlining, and any wooden parts, but local air pollution laws now ban such burning. The labor of preparing the cars for sinking raises the per unit cost. The auto bodies should be cabled in fours or fives to keep them together in stormy winter seas; unfortunately, this makes them bulky and heavy to move when they are sunk. Probably the major drawback to car bodies for reefs is their relatively short life in the water. Stone (1974) states that the bodies last only about three to six years; according to Unger (1966) they may have to be replenished every two to four years.

For years the US Navy opposed the use of automobile bodies for reefs because the metallic mass gave a false sonar reading and because foreign

Figure 1. Junked automobiles being unloaded on Atlantic Beach Reef, NY. (Courtesy of R.B. Stone, NMFS)

submarines could hide behind the reef to avoid detection. Unger (1966) reports that "the U.S. Navy appears to have relaxed its old restriction against use of metallic objects for artificial reefs along the Atlantic coast, though this is as yet, unofficial."

Automobile Tires. Discarded automobile tires have proven to be one of the best materials of all those tested for artificial fishing reefs. The supply is nearly limitless; more than 200 million worn-out tires are discarded each year in the United States (Stone, Buchanan, and Steimle 1974). Tires are well-suited for building reefs because they do not corrode like metal, do not undergo organic decomposition, add no toxic leachates, provide excellent substrate for invertebrate organisms, and offer shelter for fishes (Figure 2). Quantities can usually be obtained from local sources at little or no cost; occasionally dealers and trade organizations have offered modest money incentives to agencies willing to take the tires (C.S. Zawacki, personal communication). Old tires are a problem to service stations because there is almost no market for them; less than 10% of scrap rubber is reused (Stone 1974).

Stone et al (1975) experimented with the effect of tire leachates on fishes. A simulated tire reef was constructed in a 528 gallon (2,000 liter) tank containing pinfish (*Lagodon rhomboides*) and black sea bass. The tissues of these experimental fishes were compared with the tissues of control fishes of the same species for concentrations of zinc, organochlorine insecticides, and polychlorinated biphenyls. Analyses showed that the experimental fish did not have increased concentrations of these substances. Stone and his associates unfortunately do not specify whether the tires used were natural or synthetic rubber.

The disadvantages of automobile tires can be overcome with proper planning and design of the reef components (Edmund 1967). For example, air trapped in the tires can make them buoyant, but holes drilled beforehand prevent air pockets. Individual tires are light and may shift in strong currents and storm waves, but sufficient ballast and unit grouping will keep them on the bottom. The few tires that have washed up on beaches are suspected to be either discarded fenders from foreign trawlers fishing offshore or sections from improperly constructed artificial reefs.

Figure 2. Sea bass in auto tire on Sea Girt Reef. (Courtesy of R.B. Stone, NMFS)

Tires have been used in eight different combinations, varying quantity, connectors, and ballast. The number of tires in each unit has varied from one to twelve (Stone et al 1974). In the 12-tire unit the tires are bolted in a triangle with 100 lb (44.5 kg) of concrete ballast distributed among the individual tires. The unit has a large surface area, a 5 to 6 ft (1.5 to 1.8 m) profile, and many crevices to shelter the fishes. However, it is very heavy, awkward to handle, takes time to build, and costs about $15 per unit for labor and materials. The single tire unit is the simplest: it consists of one tire with air vent holes drilled or punched in the tread opposite the ballast—a No. 10 can filled with concrete and forced between the sidewalls. The unit can be handled by one man from any size boat and costs about 26 cents for labor and material. The single tire unit does not have the stability of the multitire unit.

Construction details of various tire units for artificial reefs, with photographs and drawings of each unit, can be found in Edmund (1967), Parker et al (1974), and Stone et al (1974). Unger (1966) describes some procedures for obtaining the necessary state and federal licenses and permits for building artificial reefs.

Seven Planned Reefs

Stone at al (1974) identify seven planned artificial fishing reefs in New York Bight: five off Long Island—Shinnecock, Moriches, Hempstead or Fire Island, Atlantic Beach, and Rockaway—and two off New Jersey—Monmouth Beach and Sea Girt. The reefs are built of assorted materials at a variety of depths.

Shinnecock Reef. Located 2.6 mi (4.2 km) off Shinnecock Inlet at a depth of 80 ft (24.4 m), Shinnecock Reef consists of 6,000 automobile tires in three-to-eight tire units and a wooden barge (Map 2, Table 1). The reef was privately funded and built by the Long Island Fishing Reef Foundation. During spring, summer, and fall, it supports populations of tautog, scup, and black sea bass and in winter, Atlantic cod.

Moriches Reef. Built with two wooden boats and 600 tires in units of three and six, Moriches Reef is 2.4 mi (3.9 km) off Moriches Inlet in 72 ft (21.9 m) of water (Map 2, Table 1). This reef was privately funded and constructed by the Moriches Anglers Club under the supervision of biologists of the New York State Department of Environmental Conservation (DEC). The fish species here are the same as on Shinnecock Reef.

Fire Island Reef. Called Hempstead Reef by Stone et al (1974), Fire Island Reef is in water 68.6 to 70.6 ft (20.9 to 21.5 m) deep approximately 5 mi (8 km) southeast of Fire Island Inlet. It was begun by Captree Boatman's Association and taken over by DEC. Materials include 28,885 yd^3 (26,500 m^3) of rock and building rubble, 1,500 tires in three-tire units, 7 wooden barges, 1 steel barge, and a wooden boat hull 65.6 ft (20 m) long. In addition to the same fish species found on Shinnecock Reef, this reef seasonally attracts red hake, silver hake (*Merluccius bilinearis*), Atlantic mackerel, and summer flounder (*Paralichthys dentatus*). The summer flounder generally are found around the edges of the reef rather than on or over the reef. The Atlantic mackerel probably are attracted to food organisms swept up

Table 1. Major planned artificial fishing reefs

Name	Areal Extent	Size	Year Started
Shinnecock Reef	14 acres (5.7 hectares)	Length: 450 yd (411.5 m) Width: 150 yd (137.2 m) Profile: high	1968
Moriches Reef	14 acres (5.7 hectares)	Length: 450 yd (411.5 m) Width: 150 yd (137.2 m) Profile: high	1968
Fire Island Reef	64 acres (25.9 hectares)	Length: 1,760 yd (1,609.3 m) Width: 176 yd (160.9 m) Profile: very high	1962
Atlantic Beach Reef	414 acres (167.2 hectares)	Length: 2,000 yd (1,828.8 m) Width: 1,000 yd (914.4 m) Profile: very high	1968
Rockaway Beach Reef	414 acres (167.2 hectares)	Length: 2,000 yd (1,828.8 m) Width: 1,000 yd (914.4 m) Profile: high	1968
Monmouth Beach Reef	550 yd^2 (460 m^2) [estimated]	Length and width unknown because reef is now scattered and there is no record of what its size was supposed to be.	1966
Sea Girt Reef	993.6 acres (401.3 hectares)	Length: 6,000 yd (5,486.4 m) Width: 800 yd (731.5 m) Profile: low to medium	1969

into the water column by the upwelling induced by the reef profile. A lobster population was studied by Briggs and Zawacki (1974), who caught 0.67 lobsters per pot haul; 20% of these were legal size. They report that the reef is heavily fished by commercial lobstermen from mid-May through early July.

Atlantic Beach Reef. Located approximately 4 mi (6.4 km) south of Atlantic Beach in water 58 to 65 ft (17.7 to 19.8 m) deep, Atlantic Beach Reef includes 404 automobile bodies, 40 concrete culvert pipes and boxes, 30,420 tires in various unit sizes, 10 truck bodies, 5 wooden barges, and 4 steel barges (Map 1, Table 1). The fish species it attracts are the same as for Fire Island Reef, excluding summer flounder.

Rockaway Beach Reef. About 5 mi (8.1 km) east-southeast of Rockaway Inlet is Rockaway Beach Reef in water 35 to 38 ft (11.0 to 11.6 m) deep (Map 1, Table 1). The reef consists of 16 auto bodies, more than 1,000 tires "strung on lengths of chain and ballasted with several pails of concrete. One tire and concrete unit of 15 tires is in pyramid form" (R.B. Stone, personal communication). The reef attracts cunner (*Tautogolabrus adspersus*), tautog, black sea bass, and red hake.

Monmouth Beach Reef. About 1.8 mi (2.9 km) east of Monmouth Beach is Monmouth Beach Reef, begun in 1966 with old tires and a few automobile bodies. The reef has since scattered and there was never a record of its exact size. It attracts tautog, black sea bass, cunner, and red hake.

Sea Girt Reef. Sea Girt Reef is in water 65 ft (19.8 m) deep, approximately 4.7 mi (7.6 km) east-northeast of Manasquan Inlet (Map 3, Table 1). It was built with "700 multitire units (6 or 7 tires each), 50,000 to 65,000 single tire units, (approximately 70,000 tires total), miscellaneous junk" (R.B. Stone, personal communication). Common fish species on the reef include back sea bass, red hake, winter flounder (*Pseudopleuronectes americanus*) tautog, and cunner. Striped bass (*Morone saxatilis*), bluefish, and bluefin tuna (*Thunnus thynnus*) are taken occasionally.

Research

The casual observations of anglers, boat captains, and biologists leave no doubt that artificial fishing reefs do attract and hold a variety of marine fishes. The reefs obviously improve angler success in areas that heretofore offered little good fishing. The sizes and shapes of the different reefs as well as materials used have raised questions about what constituted a good reef. The biologists' wish to quantify their observations has led to a number of research projects by federal, state, and university groups, most of which have employed scuba divers.

Federal Agencies

Most federal research on artificial fishing reefs in the Bight has been carried out by the National Marine Fisheries Service (NMFS) from the Middle Atlantic Coastal Fisheries Center, Highlands, NJ. In 1966 a team of diver-biologists headed by Richard B. Stone systematically surveyed potential reef sites, supervised reef construction, and made follow-up studies of biota on the reefs and of the experience of fishermen. In 1972 the team and its headquarters moved to the NMFS Atlantic Estuarine Fisheries Center, Beaufort, NC, and is conducting research on reefs south of the Bight (Buchanan 1973).

Buchanan (1972) and Stone and his colleagues (1974) have summarized federal research results for the northwest section of the Bight (Jones Beach Inlet, NY, to Manasquan Inlet, NJ). More than 36 species of fishes were reported taken, according to studies comparing catches over planned artificial reefs, natural bottom, and shipwrecks. Table 2 indicates that in

Table 2. Surface fishing by anglers in northwest section of the Bight, 1970

Habitat Type	Angler Hours	Number of Fish Caught	Catch/Hour
		Private Boats	
Natural bottom	14,103	17,823	1.3
Artificial reefs	1,245	2,491	2.0
Wrecks	8	6	0.7
		Headboats	
Natural bottom	162,018	936,646	5.8
Artificial reefs	1,521	3,751	2.5
Wrecks	396	701	•1.8

Source: After Buchanan 1972

surface fishing, anglers in private boats had the most success over the planned artificial reefs, moderate success over natural bottom, and least success over wrecks. Data for the wrecks should not be considered significant, however, because of the very limited fishing effort (8 hours) expended by the private boats studied by Buchanan. Anglers aboard headboats had the most success over natural bottom, and less success over artificial reefs and wrecks (Table 2).

Table 3 shows that the catches made in surface fishing by anglers on both private boats and headboats were mostly schooling, pelagic fishes that swim at or near the surface. These fishes derive little direct benefit from the food and shelter provided by planned artificial reefs and wrecks. They may be attracted to food organisms brought near the surface by upwelling over the reefs and wrecks but this is only speculation. Unfortunately, there has been little or no research to describe details of upwelling over these man-made structures on the bottom.

Table 4 indicates that in bottom fishing, anglers in private boats had the most success over wrecks and slightly less success over natural bottom and reefs. Anglers aboard headboats had least success over natural bottom, although at the same rate as anglers aboard private boats. Best fishing was over wrecks and reefs.

Table 4. Bottom fishing by anglers in northwest section of the Bight, 1970

Habitat Type	Angler Hours	Number of Fish Caught	Catch/Hour
		Private Boats	
Natural bottom	3,386	4,916	1.5
Artificial reefs	252	357	1.4
Wrecks	144	333	2.3
		Headboats	
Natural bottom	87,026	128,631	1.5
Artificial reefs	2,751	8,249	3.0
Wrecks	10,516	32,368	3.1

Source: After Buchanan 1972

Table 3. Percent of species caught by anglers surface fishing in northwest section of the Bight, 1970

Species	Private Boat			Headboat		
	Artificial Reefs	Wrecks	Natural Habitats	Artificial Reefs	Wrecks	Natural Habitats
Atlantic bonito	0.12		1.28			Tr
Atlantic cod						Tr
Atlantic herring	0.12		0.06			0.01
Atlantic mackerel	67.06		45.80	46.54	2.63	83.11
Black sea bass	0.04		0.03			Tr
Bluefin tuna	0.04		0.84			0.02
Bluefish	30.72	100.00	42.90	53.24	93.42	16.51
Dolphin			0.14			Tr
Hakes (red and white)			0.68			0.03
Little tuna	0.49		1.73			0.01
Northern kingfish	0.81		0.06			
Scup			0.21			Tr
Shad			0.01			Tr
Silver hake	0.24		1.07	0.05		0.23
Skipjack tuna			0.40			
Striped bass	0.20		4.25		3.94	Tr
Summer flounder	0.08		0.36	0.16		0.01
Tautog			0.03			
Weakfish			0.02			Tr
Windowpane			0.05			
Winter flounder	0.04					Tr

Tr—less than 0.01%

Source: From Stone et al 1974

Table 5. Percent of species caught by anglers bottom fishing in northwest section of the Bight, 1970

Species	Private Boat			Headboat		
	Artificial Reefs	Wrecks	Natural Habitats	Artificial Reefs	Wrecks	Natural Habitats
Atlantic cod	8.55		0.36		0.94	4.39
Atlantic herring						0.02
Atlantic mackerel			0.84			0.79
Black sea bass	14.43		0.63	8.03	8.60	2.18
Bluefish			0.84	0.15	0.16	0.07
Hakes (red and white)	52.40	5.32	18.87	51.56	83.83	60.81
Northern kingfish			0.29			0.07
Pollock				0.01	0.29	0.04
Scup	14.43		15.21	25.86	0.71	1.78
Silver hake			9.86	0.14	0.36	11.36
Striped bass			4.39		Tr	0.76
Summer flounder	8.02		21.57	0.44		6.46
Tautog	1.60	94.67	12.66	12.50	5.00	10.72
Weakfish			0.33			Tr
Windowpane			0.48			0.02
Winter flounder	0.53		11.00		0.07	0.42
Yellowtail flounder						0.04

Tr—less than 0.01%

Source: From Stone et al 1974

The number of fishes caught in bottom fishing varied according to species (Table 5). Some differences can be attributed to life history dissimilarities among the species, but some are the result of the anglers' fishing habits. A good example of the former is the Atlantic cod catch (Jensen 1972, 1974). The data in Table 5 show that fishermen in private boats caught more cod over planned artificial reefs than over natural habitats; this reflects the wintertime occurrence of the species on the reefs (Zawacki 1972). Fishermen in headboats caught more cod over natural habitats than over wrecks, reflecting the nearly year-round occurrence of the species on offshore banks, such as Cox Ledge (41°03'N, 71°02'W), regularly fished by headboats but too far offshore for most private boats.

The data in Tables 2 through 5 do not lend themselves to sophisticated analysis because of the tremendous number of variables (season, anglers' habits, bait, gear, species sought, fishes' habits) inherent in the research. However, it appears that if suitable natural bottom, with rock ledges and other cover, is not present—as on the smooth, sandy ocean floor off Long Island and New Jersey—planned artificial reefs can supplement any available shipwrecks to provide anglers with good fishing.

Other federal research looked at reef materials rather than at fishes caught. Pearce and Chess made two systematic studies (1968, 1969) to determine the suitability of different kinds of substrates in attracting fouling organisms. They sank a multiple disc sampling apparatus in 59 ft (18 m) of water off New Jersey, near Monmouth Beach Reef. The apparatus consisted of an array of discs of rubber, concrete, steel, wood, glass, and aluminum. In the 1968 report the authors concluded that during the first 10 months rubber was the best substrate because it was densely colonized by a variety of species. The authors also found that automobile bodies were heavily covered with mussels (*Mytilus edulis*), important to the diets of cunner, tautog, black sea bass, and other fishes in the area. In the later report (1969) Pearce and Chess said that although rubber appeared to be the best substrate at first, after 18 months concrete was better. They speculated that some substance(s) repellent to invertebrates may have leached out of the concrete during the first year and a half in the sea, resulting in an attractive fouling surface. The steel discs were poorly colonized by epibenthic invertebrates, corroded rapidly, and prevented the formation of well-developed, ecologically balanced communities.

State Agencies

Both New York's DEC and the New Jersey Department of Environmental Protection have cooperated with NMFS in artificial reef studies. New York State research has mostly described the abundance and species diversity of the reef fauna. For example, Briggs and Zawacki (1974) recorded the lobster catch in pots on reefs in New York waters. Unfortunately, their research did not include pots on control areas away from the reefs for comparison purposes. Briggs (1975) studied fishes caught in pots on the reefs. He found 25 species of fishes on Fire Island Reef. Cunner was the most abundant fish, followed by black sea bass, ocean pout (*Macrozoarces americanus*), tautog, scup, red hake, and sea raven (*Hemitripterus americanus*). Anglers caught Atlantic mackererel, Atlantic cod, bluefish, scup, and such subtropical species as barrelfish (*Hyperoglyphe perciformis*) and banded rudderfish (*Seriola zonata*). In late October and November, fishing pressure increased when fishermen went after Atlantic cod. Briggs' data also show that the reef was well-colonized by a variety of sessile and moving invertebrates.

New Jersey research (Hamer 1960, 1963) was designed to determine the optimum materials and their manner of deployment for artificial reefs. The research revealed that reefs should be built with heavy materials, particularly concrete pipe and rocks, to prevent displacement in heavy seas and that ballasted wooden ships and weighted automobile tires should not be used for reefs in shallow ocean waters. Strong wave action breaks up the boats, washing timbers and tires onto nearby beaches.

Private Agencies

The most active private studies on artificial reefs in the Bight have been done by members of the American Littoral Society (ALS), some of whom are scuba divers. Their studies are not research in the strict sense of the word but are somewhat like the observations made by bird-watchers. Not affiliated with institutions or agencies, they have helped with placing reef materials and later made systematic dives to observe the development of reef populations. They perform a valuable service in supplementing the observations of professional biologists. Some of their data have been incorporated into technical reports prepared by research and regulatory agencies; some have been published separately in popular and semitechnical journals, including the society's own publication, *Underwater Naturalist* (De Camp 1963; Unger 1964; Brewer 1965).

The reports are frequently detailed. Brewer (1965) described a dive by a team of ALS members on Fire Island Reef. He reported that the reef—then three years old—had attracted numerous black sea bass, red hake, winter flounder, cunner, ocean pout, and a few goosefish (*Lophius americanus*), conger eel (*Conger oceanicus*), tautog, and lobsters. The algae, invertebrates (including squid eggs), and fishes on this reef are illustrated with color photographs by Dow (1974).

In an earlier study, De Camp (1963) described a dive to the sunken vessel *Mohawk* off the coast of New Jersey (Map 3). The wreck supported a population of tautog and cunners, which seldom strayed more than 14.8 ft (4.5 m) above or away from the sides of the ship's hull. American lobsters were seen in holes and crevices (Figure 3). The most common fouling organism was a species of sea anemone. The author pointed out that the fish were never seen to browse on the fouling organisms on the *Mohawk*, in contrast to fish that feed directly on the organic matter attached to steel-hulled wrecks in tropical waters. He suggests that if this observation is generally true, it might indicate that wrecks in northern waters serve as gathering points rather than as direct food sources.

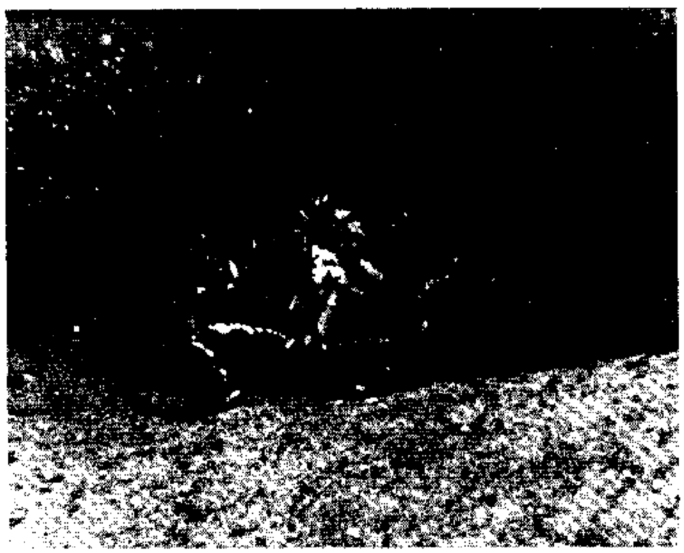


Figure 3. Lobster hiding under auto tires. (Courtesy of R.B. Stone, NMFS)

Summary

There is no question that artificial fishing reefs work. Within the institutional and economic restraints placed upon their construction in marine waters, reefs can be a valuable fisheries management tool. They offer one way of attracting and congregating fish in a given area by supplying shelter and food. Wallace (1971) points out that "most biologists working on these projects believe that artificial reefs do not themselves increase fish abundance. Their major accomplishment is to concentrate species at fixed locations, where they are more readily available to anglers." Holt (1969) suggests that fisheries managers turn this to their advantage by using the reefs as "productivity traps" that "trap biological production originating in a wider area, and by such a biological route . . . [embody] more of the production . . . in organisms of direct interest to man."

In 1974 a three-day meeting on artificial fishing reefs was held in Houston (Colunga and Stone 1974). The conference was sponsored by Texas A&M University Center for Marine Resources (Sea Grant), the Texas Coastal and Marine Council, and NMFS. It drew 280 people from the United States (including Hawaii, Puerto Rico, and the Virgin Islands), France, and Japan. Sessions dealt with "Artificial Reefs Around the World," "The Scientific View," "Building Artificial Reefs," and "The Legal and Economic Views."

With the body of literature so far assembled, the question becomes merely what materials to use and where to place them for maximum effectiveness. A basic question that disturbs some environmentalists and ecologists was raised by Walford (1962)—and later discussed by Wallace (1971)—who asked: "Does an artificial fishing reef merely redistribute the fish or does it increase their numbers?" Is the population built up on the reef at the expense of nearby areas and does the close aggregation increase the risk of disease and predation? Does the increased availability and vulnerability of fish to anglers reduce the fish population in a given region? To date, there has been no research to answer these questions.

Artificial fishing reefs can be used in sport fisheries management and to a limited extent in commercial fisheries management to enhance the marine habitat for sport fishes and to improve angler success. Many sport fishermen equate the enjoyment of their sport with the number of fish they catch.

The Ideal Reef

Research conducted up to now on artificial fishing reefs, including shipwrecks, has provided fisheries managers with some guidelines for materials and their placement in building productive reefs. The ideal reef has a high profile to create the upwelling needed to bring nutrients into the water column and thus increase the food supply. It also offers to fishes and other reef inhabitants protection from strong currents and adverse sea conditions. A high profile—as from large ships, for example—resists being covered with sand moved by bottom currents. The ideal reef also affords numerous openings and surfaces to attract a wide range of marine organisms, each individual seeking its own special niche. Thus the steel surface of a sunken ship surrounded with rock, rubble, concrete pipes, and automobile tires would provide the variety of openings and surfaces reef dwellers seek.

The ideal reef is similar to the composite reef that Unger (1966) suggests as having the widest applicability. Her concept, however, includes automobile bodies. Since the bodies have a reef life of five years or less, they are of doubtful value. Tire units substituted for the auto bodies would provide a long-lasting reef.

I am assuming here that the reef builder will have complied with all the legal requirements of the federal, state, and local governments, that the reef will be clearly marked with buoys, and that it will be within easy boating distance—about 3 to 5 mi (5.1 to 8.5 km) offshore.

Funding

For New York Bight, funding is the weak spot. The cost of building one reef is estimated at about $100,000; the most expense comes from labor and from hiring cranes, barges, and other equipment to move the materials and place them on the reef site (C.S. Zawacki, personal communication). The materials themselves are usually donated. Despite the improved sport fishing value of the reefs and the public relations value for the agency constructing the reefs, state agencies have consistently deleted reef monies from annual budget requests.

A few east coast states are moving ahead with funds for building artificial reefs. Florida, for example, is planning to spend approximately $200,000 and North Carolina, between $250,000 and $275,000 (Stroud 1973).

The federal government, through NMFS, has downgraded its artificial reef program to an advisory service. The rationale is that the prime effort for reef construction should come from the states (Robert Schoning, personal communication).

The problem of adequate funding for artificial reef building is becoming more acute. There is increasing taxpayer resistance to spending public funds—particularly for a privately enjoyed recreation like sport fishing—despite concomitant needs for more law enforcement, environmental preservation, additional research and for more management biologists. Many resource managers now agree with Wallace (1971), who said, "The big leap forward in marine conservation will take place when our saltwater sportsmen are ready and willing to pay a fee for their recreation to finance programs designed to improve fishing." In New York State alone, with an estimated 1.7 million saltwater anglers annually fishing in the marine district, a license fee of, say, $2.00 per year would yield more than twice the total 1974-75 budget for DEC's Division of Marine and Coastal Resources.

The waters of New York Bight are subject to heavy sport fishing, mainly for pelagic species because the Bight floor is a relatively featureless, sandy plain with small populations of bottom species. Habitat improvement to create reefs and other outcroppings would attract and hold bottom species and enhance fishing opportunities. Shipwrecks have become artificial reefs but they are sometimes too far offshore for most fishermen. The answer, then, is to build artificial reefs of long-lasting materials, providing the uneven bottom many fishes seek. An additional benefit to the public was pointed out by Zawacki (1969): "The use of waste materials . . . to construct artificial reefs may help solve some of the disposal problems of large cities while providing excellent fishing for the ever-increasing angling public." We must exercise great caution, however, that in our zeal to build artificial fishing reefs we do not merely move our junkyards and town dumps from the land to the sea. A systematic approach to reef building should include not only compliance with the requirements of the agencies issuing permits but also with accepted environmental safeguards. A dump is a dump, whether it is on land or in the sea. Properly planned, a well-designed deposit of solid wastes, such as discarded tires, scrap cement pipe, and excavation rock, can become a productive artificial fishing reef.

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