Enhancement of Florida Marine Fisheries Using Artificial Reefs: A Review[1]

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Abstract: Florida coastal waters contain more permitted artificial fishing reef sites (ca. 150) than any other state. Initiative stems primarily from local interests, including over 60 different private and public organizations. Florida's earliest reef was authorized in 1936 although 87% were proposed after 1962. Prevalent reef materials include some combination of concrete rubble, tires, automobiles and/or vessels in 40% of Florida reefs, followed by vessels (25%), and automobile bodies and tires (13% each). Statewide resource agencies and educational organizations have fostered local reef building through financial assistance with construction, streamlined permitting procedures, information transfer via advisory services for siting and publications, and coordination of research, which has yet to address the economic impact of recreational reef fisheries.

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Fish-attracting structures seem to be the principal means of physically modifying marine habitat to increase fish harvest. Artificial reefs in the United States primarily are built to enhance recreational fisheries, while the main commercial application is in the development of oyster reefs. Other salt water habitat improvement depends mainly on non-structural approaches, i.e., pollution control and related regulatory measures dealing with quality and quantity of water and its contents.

Scientific understanding and physical deployment of marine artificial reefs have not proceeded as rapidly as habitat improvements in freshwater. The number of freshwater ponds in the U.S., for example, increased from 35,000 in 1960 to over 2,000,000 in 1975 (Everhart et al. 1975). Data on marine reef abundance are less accurate and complete, but only a few hundred exist along the U.S. coast. Yet where reefs are found, they constitute an important fishery resource whose popularity is reflected in a wealth of popular articles.

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Perhaps the most vigorous program of reef construction in the nation has evolved in Florida, where over 150 reefs have been permitted. Conducted along a coastline nearly as long as that of all other Atlantic Seaboard states combined, Florida's program has been far flung not only geographically, but also in terms of the organizations that implement it. Effort is decentralized and highly dependent on local initiative and private volunteers, in contrast to many other states.

By documenting principal strategies for reef development, this paper offers guidance to and makes some comparison with other states and fishery interest groups. In recent years a working coalition of state and federal agency, university, Sea Grant, local government, and private interests in Florida has established a framework for technology transfer of reef design, siting, permitting, construction and administration. Analysis of this foundation includes discussion of criteria for successful reef programs, and elements of future research and policy needs.

Florida Reef Construction

National Setting

Although reef-building has been conducted in other nations in previous centuries, only in the last generation has effort in the United States accelerated. As noted by Futch (1981), recognition of improved fishing success in coastal waters over World War II shipwrecks, coupled with improved boats and engines and more accurate electronic radiolocation gear, has heightened efforts to increase sea-bottom relief.

In a brief review of early national efforts, Johnston (1974) identified a New Jersey reef privately built in the mid-1930's as the first, although it lasted only 10 years. She also described initial research, in California in the late 1950's, and one of the first major efforts in the Gulf of Mexico, initiated by party-boat interests in 1953, and later supplemented by the Alabama Conservation Department.

Initially, deployment of reefs proceeded faster than research. Fishing clubs scattered nationwide accumulated and placed available free materials such as junked automobiles, surplus vessels, scrap, and building debris in nearshore waters. The initial involvement by state-level governmental agencies was with construction. Research by state fishery agencies followed, but at a less uniform degree; perhaps California's program has been most comprehensive (Turner et al. 1969). At the federal level, the National Marine Fisheries Service (NMFS) initiated a decade of research on artificial reefs in 1966, with work at its New Jersey, North Carolina, and Florida laboratories (Stone 1979).

A large body of research literature, particularly on site-specific performance of individual reefs, now exists (Benton 1973). Siting, engineering, and biological studies established guidelines for dumping materials on the sea floor (e.g., Parker et al. 1974). In the 1980's a new dimension is being added through experimentation with prefabricated structures. In Hawaii, for example, 26 fish aggregating devices are anchored in 900 to 1,800 m of water to attract pelagic species such as tuna, dolphin, and scad for commercial and recreational purposes (Suiso 1982). The State of Washington is responsible for all reef-building along its coast, and is conducting research on the configuration of reefs to suit selected species, as well as design and placement of reefs near fishing piers (R. Buckley, pers. commun.). In the Southeast, experimental deployment of structures developed by Japanese technology is underway off Ft. Lauderdale, Panama City and Jacksonville, Florida, under contract to NMFS.

Southeastern States

The establishment of artificial fishing reefs in the region is difficult to summarize numerically, although an informal survey identified, per state, about a dozen or fewer approved reefs specifically to enhance habitat. To determine the need for reef development in a particular area, data on existing reefs must be supplemented by statistics concerning both natural reefs (Moe 1963) and already-existing structures that can contribute to fisheries. For example, in Louisiana and Texas there are, respectively, 3,000 and 350 petroleum platforms (Ditton and Falk 1981). Also, demand for reefs varies.

Futch (1981) summarized limited available information, and noted the earliest efforts were in Texas 30 years ago, with the latest starts made in the early 1970's in Georgia, Louisiana, and South Carolina. The Atlantic states south of Maryland have implemented modest activities using traditional bottom materials; Virginia's program is the oldest. South Carolina also has utilized mid-water attractors to create trolling lanes for pelagic species fisheries. Liberty ships have been emphasized in the northern Gulf.

Leadership by state agencies is seen in North and South Carolina; Georgia is no longer active. Private efforts predominate in Mississippi, focused by a non-profit corporation (Daniel and Seward 1975). Combined public and private activity occurs in Virginia and Alabama. No active programs exist in Texas and Louisiana (Futch 1981).

History of Florida Reefs

In Florida, artificial reefs are mostly near the State's major population centers (Fig. 1). These reefs are used principally by recreational fishermen and divers. In places, they alleviate pressure on commercial fishing areas.

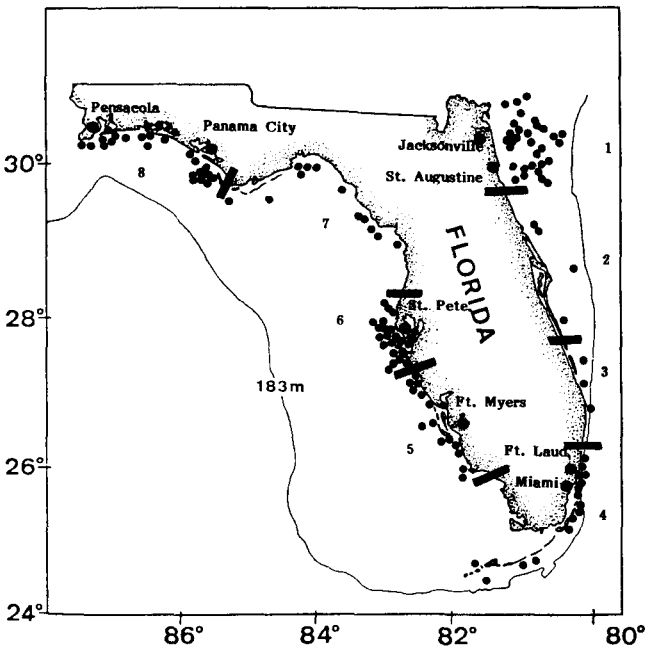

Figure 1. Geographic distribution of Florida marine artificial fishing reef sites, as authorized by permit. Areas 1–8 conform to format of 1979 Florida Sea Grant atlas, and are depicted for use with Figures 3 and 4.

Elsewhere, they create new recreation areas close to shore and accessible to small boats. They may provide an alternative to landfill disposal of certain materials.

The earliest permit for a Florida reef was issued in 1936, for Federal waters off Miami Beach by the U.S. Corps of Engineers. Prior to 1960, when the State started to require construction permits, perhaps a dozen coastal reefs were known. The exact number of early reefs is unclear, since record-keeping was not standardized. However, a Department of Natural Resources letter dated 1962 identifies 4 reefs on the Gulf coast and 1 in Southeast Florida, built in the 1950's. The Corps of Engineers issued 6 permits between 1936 and 1958, all in Southeast Florida except for 1 in Tampa.

Data analyzed below formed the basis for an atlas of reef sites (Florida Sea Grant College 1979), and represent the latest comprehensive statewide statistics available. Although the 146 permitted sites described in the Florida atlas reflect both Federal and State records, some of the discussion is based only on State permit data, since Corps of Engineers statistics do not identify

materials used and are not as detailed concerning placement. (In some cases reef permits were issued but construction was not initiated. Hence, the count of 146 reef sites may be too high, but in the last 5 years a number of new reefs have been built. Non-permitted reefs have been constructed by individuals for private use over the years.)

Historically, initiative to develop reefs in Florida has come largely from the local level, mostly within the last 20 years (Fig. 2). Of the 146 state-permitted reefs authorized between 1960 and 1977, nearly one-third were requested by 11 of Florida's 35 coastal county governments through either boards of county commissioners or parks and recreation departments (Table 1). Of all applicants, local civic groups made the greatest number of individual requests for permit approval (i.e., 25). Without volunteer effort to secure materials, enlist free labor, and solicit donations of equipment and money, Florida's efforts would not have been as widespread or successful. The most reefs built by 1 angling club is 22, in the vicinity of Jacksonville.

Private efforts have been complemented by local governments, which initially may assist with permit applications, and provide shore staging areas and coordination. Follow-up may include annual appropriations for salary and equipment. Although many localities have made large efforts to develop reefs, perhaps the largest amalgamation of organizations has been in Pinellas County. There, the cities of Clearwater, Madeira Beach, St. Petersburg, St. Petersburg Beach, and Treasure Island, and the County Board of Commissioners and its Parks and Public Works Departments received State and Federal authorization to build 20 reefs, all but 1 within 16 km of shore. The County now administers 10 reefs. Its annual budget supports a small crew, barge purchase and operation, operating expenses and equipment such as tire splitters, and publicity.

Other relatively large reef programs exist near Panama City and St. Augustine. Fewer reefs are found on the Northeast coast of the Gulf of Mexico and along the central Atlantic coast. Newer programs in populous South Florida are adding reefs not tabulated in the State permit data. The latter

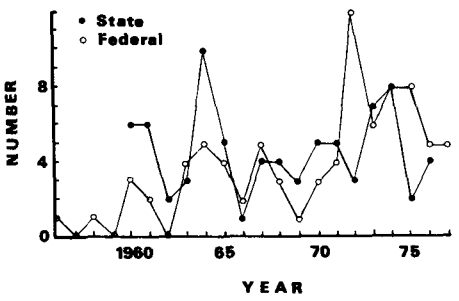

Figure 2. Issuance of regulatory permits for reef construction in Florida. Prior to 1956 only 5 Federal permits were issued. Some individual sites received 2 permits, and some permits authorized multiple reefs at 1 site.

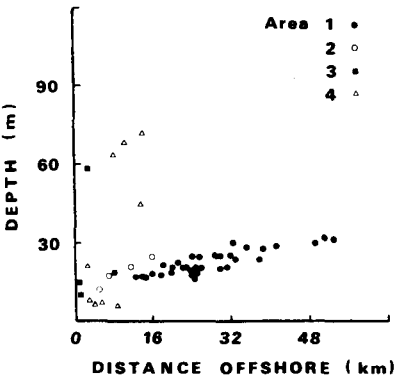

Figure 3. Placement of artificial reef sites in Atlantic Ocean offshore Florida, including keys. Geographic extent of Areas 1–4 shown in Figure 1.

Table 1. Applicants for State Permits to Build Reefs in Florida, 1960–1977

Type of Organization	Number Submitting Applications	Number of Applications	Number of Reefs
County Government	11	24	47
City Government	10	11	30
Chamber of Commerce	10	12	22
Educational	3	3	4
Civic Group	23	25	37
Business	3	3	6
Total	60	78	146

area also supports more natural reefs in its tropical waters, and shipwrecks supplement the reef fishery (D. Pybas, pers. commun.). The steep and narrow lower East coast shelf does not offer as many desirable reef construction sites as the broad, gently sloping West coast (Fig. 1). With the exception of the upper Atlantic coast, all other areas of Florida have built reefs within 16 km of shore. The average distance offshore for all reefs in 12 km; mean depth is 50 m (Figs. 3 and 4, Table 2).

Construction and Materials

Virtually all reefs built to date are of traditional composition and arrangement, i.e., suitable and readily available material is dumped on an approved site to add relief to flat ocean floor. Reefs in Florida are of 4 basic constitutents (i.e., ships, automobiles, tires, concrete), placed either individually or with other materials. Combined construction rubble, junk, tires and/or other automobile parts comprise 40% of the reefs (Table 3). Ships,

Table 2. Number, Depth, and Distance Offshore of Permitted Florida Marine Reef Sites

Area[a]	Number	Mean Depth (m)	Mean Distance (km)
1	34	23.2	27.2
2	4	19.1	9.9
3	7	30.1	2.9
4	12	31.1	7.5
5	11	7.9	6.1
6	30	9.4	6.4
7	14	5.3	10.1
8	34	12.5	5.9

[a] Areas depicted in Figure 1.

barges, and other craft, either alone or as the nucleus of a reef, constitute 25% of the reefs; tires and automobile bodies each account for 13%. Concrete may be either pre-cast or debris. Miscellaneous materials, namely polypropylene plastic straps, metal junk, and the boom of a crane were selected for 4 reefs.

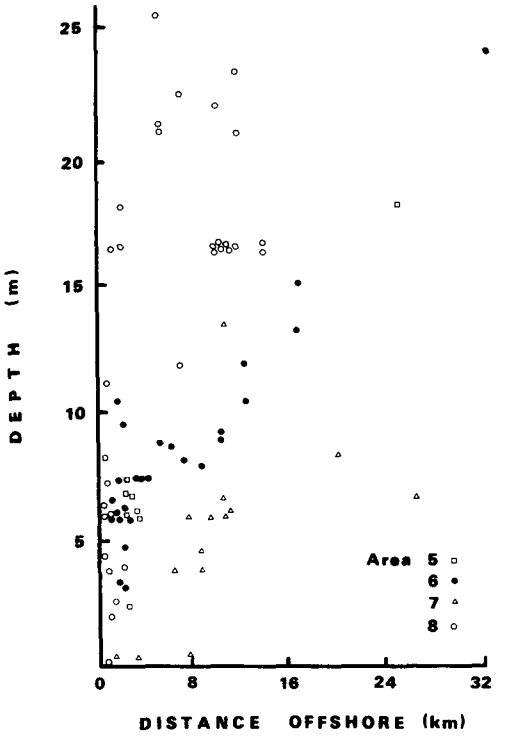

Figure 4. Placement of artificial reef sites in Gulf of Mexico offshore Florida. Geographic extent of Areas 5–8 shown in Figure 1.

Table 3. Types of Materials Used in Florida Reef Construction, As Proposed in State Permit Applications

Area[a]	Material						
	Autos Possibly with Other Metal	Ships	Ships Plus Other Material	Concrete	Tires	Combinations of Rubble, Tires, Junk, Autos, Etc.	Misc. Single Items
1	0	5	14	0	8	7	0
2	0	0	0	2	0	2	0
3	0	0	2	0	4	1	0
4	2	1	4	2	1	1	1
5	1	0	1	0	3	5	1
6	2	1	3	1	1	22	0
7	4	1	0	0	3	6	0
8	10	4	2	2	0	14	2
Total	19	12	26	7	20	58	4

[a] Areas depicted in Figure 1.

The most discernible trend in what is generally a random statewide pattern of distribution of materials is seen on the upper Atlantic coast, where over half the reefs are made of various vessels, either alone or with other materials dumped around them (Table 3). The focus of the State's efforts to acquire Liberty ships was the Northern Gulf of Mexico, which also is the site of the first surplus oil drilling template placed as a fishing reef in Florida. The Panhandle also has the highest percentage (30%) of automobile reefs.

Organizational Support

State government natural resource agencies have aided reef development in a variety of ways, although only since the late 1970's has the Department of Natural Resources (DNR) designated an individual with prime responsibility for coordinating reef effort. A Federal grant and recent legislative appropriations provided over $500,000 in the last 3 years for local construction. Early efforts by DNR facilitated acquisition of Liberty ships in Northwest Florida, while some research was conducted at its St. Petersburg Bayboro Harbor laboratory. Guidance to local groups to conform to siting restrictions was provided by DNR and then the Department of Environmental Regulation (DER).

All reef construction must meet regulatory requirements at the federal and state levels. The principal agencies are the U.S. Army Corps of Engineers and the Florida DER. At the first statewide reef conference in 1977, complaints of delays in permit application processing and excessive paperwork were voiced (Aska 1978). Subsequently, a common permit application form was adopted by both agencies.

While conducting some research (on natural reefs), the academic community mainly has provided advisory services through the Florida Sea Grant College. After a conference in 1977, a 5-member team of faculty and county employees was established to assist local interests with reef design, siting, and administration. To date, over 20 sites have been visited, with biological site evaluations conducted in accord with DER requirements. Work of the team is enhanced on-site by Marine Advisory Program (MAP) field personnel operating under joint Sea Grant/Florida Cooperative Extension Service support. MAP agents are often the initial point of contact for local interests. They may evaluate a group's plan, arrange an advisory team visit and site survey, or identify agency contacts.

Sea Grant also developed 3 advisory bulletins, produced an atlas, and organized a Southeast regional conference (Aska 1981). Two pilot programs developed training for recreational divers interested in assisting the acquisition of field data for evaluation of reef performance. This year Sea Grant convened a statewide technical meeting to coordinate research, extension, and education efforts of seven universities and 2 agencies.

Current and Future Trends

Data on permits in the last few years are not yet available, but it is obvious empirically that current reef development is continuing at a pace equal to or greater than previous years. Sea Grant advised 25 different groups in the last 4 years; DNR expects to allocate its current annual construction assistance budget among 20 different applicants. Through cooperative division of labor both organizations will continue to facilitate reef planning and construction.

Present reef efforts largely continue not only the momentum but also the opportunistic patterns of the last 20 years. Adding to the diversity of materials are items such as salvaged apartment house plumbing fixtures, the scuttled Coast Guard cutter *Blackthorn,* and the proposed deployment of the accidentally demolished Skyway Bridge span (the latter 2 in the Pinellas County area). But this pattern is being augmented by recent experiments with various Japanese and other prefabricated structures specifically constructed as oceanic fish habitat (Sheehy 1982). In coastal waters, studies of the configuration of materials such as concrete blocks to create spiny lobster habitat are in progress.

With general acceptance of the premise that materials placed on the sea floor to increase relief do improve fishing, the national marine research community is beginning to address specific issues such as optimal spacing, configuration, and relief of bottom structures, and suspension of attracting devices in the water column. Benton (1973) annotated 396 publications dealing with

reefs, including technical articles that address both sides of the issue of how artificial reefs attract/produce fish biomass.

In Florida, reef biological research has focused primarily on natural communities such as coral reefs, limestone outcrops, and "live" bottom (Smith 1976, Huntsman et al. 1982). Artificial reefs are not as well studied, although some work is now available (Smith et al. 1979). DNR, NMFS, and university scientists were convened recently by Sea Grant to identify research priorities.

Local governments are seeking added accountability concerning reefs before investing tax revenues for construction. Generally, reefs have been accepted at face value as a profitable investment to expand angling and associated expenditures. However, benefit/cost data are now being demanded. It is important to document the economic stimulus of increased resident and tourist expenditures connected with recreational use of reefs. Because of lack of publications dealing with Florida, it is necessary to look to research conducted at places such as Texas A&M University, and in South Carolina where Buchanan (1973) observed almost a 10% increase in gross economic impact of marine angling due to the fishery afforded by an artificial reef.

Technical and legal issues of placing increasingly available obsolete petroleum production equipment are emerging. At a policy level, there is the question of whether more reefs are required to satisfy recreational needs. The carrying capacity of coastal waters for additional reefs is an issue.

In a generation, the art of reef construction in Florida has been fostered by (1) streamlined permitting, (2) effective transfer of information and application of established reef design guidelines, (3) coordinated statewide agency-academic assistance with planning and siting, and (4) widespread local initiative to build reefs, in acceptance of the premise that they improve fishing. Future efforts must further quantify the scientific basis for biological and economic evaluation of reefs. With more reefs than any other state, Florida has made a sizable collective investment of human resources, time, and funds. Future artificial reef development must draw upon knowledge of natural reefs and national and worldwide experiences if this fundamental method of saltwater habitat improvement is to mature as a branch of fishery science.

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