SOUTH ATLANTIC FISHERY MANAGEMENT COUNCIL
4055 Faber Place Drive, Suite 201, North Charleston SC 29405
Call: (843) 571-4366 | Toll-Free: (866) SAFMC-10 | Fax: (843) 769-4520 | Connect: www.safmc.net

Dr. Michelle Duval, Chair | Charlie Phillips, Vice Chair
Gregg T. Waugh, Executive Director

Fishery Ecosystem Plan II - Artificial Reefs
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Artificial Reefs

Artificial reefs, sometimes called "artificial reefs", " fish havens", or "constructed reefs", are broadly defined as any structure placed on the seabed, either deliberately or accidentally (e.g., shipwrecks), that acts similar to natural hard-bottom reefs and enhances fish habitat (Seaman 2000; Seaman and Sprague 1991). Artificial reefs may be composed of a wide variety of materials ranging from natural rock or discarded materials, such as concrete rubble, to entirely manufactured materials. Natural reefs artificially enhanced or rehabilitated by transporting and attaching living corals are usually not considered artificial reefs.

Properly sited artificial reefs can provide habitat for a wide variety of invertebrates and finfish, improve survival for species that are hard-bottom limited (Broughton 2012), serve as memorials, or stabilize coastlines. They can also enhance existing ecosystems or create new ones to fill in gaps where EFH has been damaged or lost (Ambrose 1994; Koenig 2001; Dupont 2008). The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Seaman 2000; Baine 2001). Artificial reefs may provide essential habitat while simultaneously acting to deflect pressure from surrounding natural hard bottom (e.g., Streich et al., 2017), including specially managed areas (e.g., Harmelin 2000); however, increased productivity may be offset by increased fishing pressure (Seaman 2000, Powers et al. 2003). For these reasons, permitted artificial reef sites are considered EFH by the SAFMC.

Here we focus on the use of artificial reefs in an ecosystem approach to fisheries. This focus is on fish and invertebrate fisheries, with the recognition that other biota are important ecological factors that influence fisheries as sources of food, habitat, and mortality for exploited species. Artificial reefs can be considered fishery management tools.

Artificial reef programs in the southeastern U.S. are overseen by individual states (Florida, Georgia, South Carolina, and North Carolina) and require construction permits by the Army Corp of Engineers with review and approval by the U.S. Coast Guard and the Environmental

Protection Agency. Some individual states and counties also require review or approval by other state agencies, particularly if reef construction is to take place inside state waters. While artificial reefs have been in use along the U.S. South Atlantic since the 1800s, their development in this region was somewhat limited through the mid-1960s. From the late 1960s to the present, reef development off the South Atlantic states (as measured by the number of permitted construction sites) has increased dramatically, with over 300 reef sites now permitted in the coastal and offshore waters of these four states. Roughly half of these sites are in waters off the east coast of Florida alone. Artificial reef locations are considered live/hard bottom habitat and are available on the Council's Internet Mapping System accessible at www.safmc.net.

The total area of South Atlantic states ocean and estuarine bottoms permitted for artificial reef development at present is approximately 210,000 acres (or 250 nm^2). This small percent area of shelf and natural hard bottom is managed by the SAFMC. Due to the practical limitations of all artificial reef programs, it is likely that only a very small percentage of permitted reef sites have actually been developed through the addition of suitable hard substrate. However, since in most cases construction activities may continue indefinitely on these sites, the percentage of hard bottom habitat developed will continue to rise as new materials are added.

Recreational anglers are the chief users of artificial reefs in this region. Financial resources made available directly or indirectly through many saltwater sportfishing interests have been a prominent factor in most reef development projects. Due to favorable environmental conditions throughout most of the year along South Atlantic states, recreational divers have also been a driving force in establishing artificial reefs in recent years. This relatively new user group will likely continue to grow as diving becomes more popular. Finally, commercial fishing interests use some artificial reefs, but are less common users compared to recreational fishing and diving users.

Marine resource management agencies in all four South Atlantic states are actively involved in various aspects of artificial reef planning, development and management in their own waters as well as contiguous federal waters. All four states have, or are in the process of developing, their own state artificial reef management plans. North Carolina, South Carolina and Georgia control all artificial reef development through programs within their respective natural resource management agencies, and hold all active permits for reef development. Florida's reef development efforts are carried out by individual county or municipal programs with a limited degree of oversight conducted by the Florida Fish and Wildlife Conservation Commission. Reef construction permits in Florida are held by state, county and municipal government agencies or programs.

North Carolina

North Carolina has a rich history in recreational fishing, with long standing support for artificial reef development. Prior to the 1970s, reefs were mostly constructed by fishing clubs and local

residents. By the mid-70s, North Carolina Division of Commercial and Sports Fisheries, began to take responsibility for artificial reefs and subsequently absorbed many privately owned reefs into its network. In 1985, the North Carolina Division of Marine Fisheries (NCDMF) Artificial Reef Program gained financial support through Federal Sportfish Restoration funds, allowing the state to administer a more organized enhancement effort. Today, the NCDMF Artificial Reef Program exists to develop, maintain, and administer a successful system of artificial reefs to enhance fishing, diving, biological, and ecological opportunities for North Carolinians and visitors. In trusted stewardship of public funds, it is the responsibility of the Artificial Reef Program to coordinate reef planning and construction, secure permits and maintain compliance, encourage research, and clearly communicate with the public.

At present, the NCDMF maintains forty-two artificial reefs in marine waters, designed to serve as recreational opportunities for fishermen and SCUBA divers. In the ocean, reefs are located one to thirty-eight miles from shore and are strategically located near popular ocean inlets. These reefs incorporate 7,300 acres total and have been enhanced to approximately 20% completion, on average. In addition to ocean reefs, NCDMF has established twenty reefs in estuarine waters which are intended to function as EFH, nursery habitat, and in some cases, oyster sanctuaries. Estuarine artificial reefs cover 517 acres and have been enhanced to about 71% completion. Approximately two reefs are enhanced annually with state and federal funding and typically, two to three additional reefs are enhanced through private funding and support (fishing clubs and artificial reef associations). A variety of materials may be used in enhancement projects, including vessels, concrete pipe of various sizes, prefabricated reef structures (e.g. Reef Balls™), bridge spans and pilings, limestone marl, concrete rubble, train boxcars, aircraft, basalt, granite, and other experimental concrete reefs structures. Concrete pipe is often most cost effective, as it is usually donated at no cost, except for transport. In most cases, small-scale reef construction (less than 1,000 tons) is completed using NCDMF staff and vessels, while large scale enhancements are contracted. Reef construction at all artificial reef sites is allowed under a general permit issued by the U.S. Army Corps of Engineers (USACE). In state waters, a Coastal Area Management Act (CAMA) permit is also required and issued by the North Carolina Division of Coastal Management. In addition to USACE and CAMA construction permits, aids to navigation permits, issued by the U.S. Coast Guard, are maintained for reefs which require markings. No artificial reefs in North Carolina have been designated as special Management Zones.

Since 1990, the Artificial Reef Program has expanded its enhancement effort to include both development and monitoring. Recent work, funded by the Federal Aid in Sportfish Restoration Program, has focused on evaluating the benefits of various materials used in reef construction. Several sampling programs have been developed to study the physical and biological characteristics of North Carolina reefs and experimental materials. Until 2019, biological evaluation will be limited to estuarine reefs, as a way to focus effort. The estuarine reef

biological study seeks to identify materials which maximize ecological services (oyster habitat, EFH, etc.) while offering a minimum cost to the state. Information from this study will not only help managers maximize biological benefits of each enhancement project, but will also provide site-by-site material rankings to assist in budgetary decision-making. Physical studies will occur simultaneously. These studies seek to expand on previous work conducted on material stability and durability metrics for various materials. Equally important as biological activity, material movement and longevity are factors which must be considered when designing reef development projects. An extensive side-scanning effort has been completed to establish baseline data for evaluating material behavior over time. Continued side scanning of new materials, paired with SCUBA surveys, will help determine lateral movement, subsidence, decay, and sedimentation characteristics of different materials in various locations. A reef enhancement database will summarize physical attributes and help guide future planning. Finally, the Artificial Reef Program has designed a 10-year sampling plan to characterize reefs by abiotic factors, such as trends in salinity and dissolved oxygen. Continuous water quality data loggers will record metrics for one year at each estuarine reef in NC. These data will help managers relate biological activity to environmental conditions.

Public outreach and user support are also a pivotal component of the NC Artificial Reef Program. In addition to maintaining constant contact with public interests through presentations and public meetings, the Artificial Reef program actively maintains an artificial reef guide for public consumption. The guide, which will be published in 2016, will exist in printed form and as an interactive web-based map. The reef program recently completed high resolution side-scan surveys of all sixty-two reefs and "digitized" material for easy identification. In the new guide, both printed and online, Artificial Reef users will be able to select certain materials at a given reef site, in patches, and review specific information such as type, GPS location, vertical relief, acreage, tonnage, and vessel specifications.

South Carolina

The use of artificial structures to enhance fishing activities in South Carolina's coastal waters was first documented during the mid-1800s when anglers began placing wooden crib-like structures in estuarine waters to attract sheepshead and other popular inshore species. During the mid-1960s the construction of offshore and coastal artificial reefs for the benefit of saltwater recreational anglers was carried out by numerous private organizations. In 1967 the state provided funding for its first artificial reef construction project, and in 1973 an on-going state-sponsored marine artificial reef program was established. This program is currently maintained by the Marine Resources Division of the South Carolina Department of Natural Resources (SCDNR) within the Division's Office of Fisheries Management. Funding for the program consists of state support through the South Carolina Marine Recreational Fisheries License, federal support through grants from the U.S. Fish and Wildlife Service's Sport Fish Restoration Program and donations from private fishing and diving clubs and other civic organizations.

The primary focus of the South Carolina Marine Artificial Reef Program (SCMARP) is the coordination and oversight of all activities within the state of South Carolina concerning the management of a viable system of marine artificial reefs in both state and contiguous federal waters. The primary goal of these artificial reefs is the enhancement of hard bottom marine habitats, associated fish stocks and resulting recreational fishing activities that take place on and around them. The SCMARP's responsibilities include reef planning, design, permitting, construction, monitoring, evaluation, research and marking. The program also plays a key role in interfacing with the public in areas related to general fisheries management issues as well as in providing specific reef-related information to user groups.

All artificial reef development and management in South Carolina is guided by the South Carolina Marine Artificial Reef Management Plan, adopted in 1991. As of December 2015, the state's system of marine artificial reefs consisted of 48 permitted sites (13 inside state waters) along approximately 160 miles of coastline. These sites range in location from estuarine creeks to as far as 50 miles offshore. Each artificial reef site consists of a permitted area ranging from several thousand square yards to as much as 24 square miles. Approximately 40 square miles of coastal and open ocean bottom has been permitted, of which less than 2 percent has actually been developed through the addition of artificial reef substrate.

Saltwater recreational anglers are the primary group associated with marine artificial reef utilization in South Carolina. Their annual fishing activities on artificial reef sites alone account for greater than 200,000 angler-days, which result in an estimated total economic benefit to the state of over 83 million dollars each year (Rhodes and Pan 2007). While some use of permitted artificial reefs by commercial fishing interests has been reported over past decades, this activity has been difficult to quantify since these practices do not have popular support with the majority of the fishing public, or may in some cases be illegal. Recreational divers comprise the second most common user group relying on the presence of marine artificial reefs. While sport divers have traditionally not been as large a user group as the saltwater recreational fishing community, significant expansion of the recreational diving industry in the state has resulted in a noticeable increase in this type of usage over the past two decades.

In an attempt to better manage the use of permitted artificial reefs in offshore waters and to ensure their long-term viability, the SCDNR has, through the South Atlantic Fishery Management Council, obtained Special Management Zone (SMZ) status for 29 of the 35 permitted reef sites located in federal waters. Fishing on those reef sites granted SMZ status is restricted to hand-held hook and line gear and spearfishing (without powerheads) and take is limited to the current recreational bag limits. In 2014 the program began construction of a first-of-its-kind deep-water (>300 ft) artificial reef Marine Protected Area (MPA) with the goal of creating spawning habitat for deep-water snapper and grouper species and protecting spawning

stocks. In addition, the SCDNR has established two experimental artificial reefs in order to examine the feasibility and possible benefits of establishing no-take artificial reefs in nearshore and offshore waters solely for the purpose of stock and habitat enhancement. These sites have also recently been given MPA status by the SAFMC. For additional information visit: www.dnr.sc.gov/marine/pub/seascience/artreef.html.

Georgia

The continental shelf off Georgia slopes gradually eastward for over 80 miles before reaching the Gulf Stream and the continental slope. This broad, shallow shelf consists largely of dynamic sand/shell expanses that do not provide the firm foundation or structure needed for the development of reef communities, which include popular gamefish such as groupers, snappers, sea bass, and amberjack. It is estimated that only about 5% of the adjacent shelf features natural reefs or live bottoms anchored to rock outcrops, with most of these found well offshore. Large areas of Georgia's estuaries similarly feature broad mud and sand flats lacking the firm substrate needed for the growth of oyster reefs, which provide prey and shelter for seatrout, sheepshead, drum, and other popular sportfish in an otherwise highly energetic environment. Ditching, pollution, and coastal development have also impacted water quality and further restricted use of inshore areas by not only fish, but also fishermen, resulting in even greater demands on the remaining estuarine habitat.

Sporadic attempts to develop artificial or artificial reefs in Georgia began in earnest in the late 1950s by sport fishermen, who knew that good angling opportunities existed on scattered shipwrecks and other artificial structures found in estuarine and offshore waters. Only short-term benefits were realized through these limited initiatives when deployed materials rapidly silted in, deteriorated, or were lost. Working with coastal sport fishing clubs, the Georgia State Game and Fish Commission began experimenting with artificial reef construction in the 1960s, focusing initially on estuarine areas and expanding later to offshore waters in the 1970s.Today, the program is housed within the Georgia Department of Natural Resources (GADNR), Coastal Resources Division, Habitat Restoration and Enhancement Unit, and is funded through State fishing license revenues, the Federal Aid in Sport Fish Restoration (SFR) program, and private donations, including the support of fishing and conservation organizations, tournaments, businesses, individuals, military services, and other branches of State and federal government.

Goals of Georgia's artificial reef program are to 1) create and enhance fisheries habitat and associated marine communities; 2) develop increased, more accessible recreational fishing opportunities; 3) facilitate and support fisheries management; and 4) generate economic benefits for coastal communities and the State. To date, GADNR has permitted 30 artificial reef areas located 2½ to 70 nautical miles (nm) offshore and reef construction has been initiated at 21 of those sites. The majority of the artificial reefs off Georgia are located in adjacent EEZ waters 6 to 23 nm in 30 to 70 feet of water east of coastal trawling grounds. Development of two

experimental deep-water reefs in 120 to 160 feet of water 50 to 70 nm offshore has also been initiated to address a growing recreational component targeting tunas, wahoo, and other bluewater gamefish. The GADNR 30 permitted artificial reefs cover a 116 square mile area and consists of 20 offshore reefs, two 400-yard diameter beach reefs sited in the State's territorial sea, and eight Department of Defense Tactical Aircrew Training System Towers.

Georgia's 90-mile coast also contains 15 permitted estuarine reefs constructed within inter-tidal areas in order to promote oyster reef development and to provide fish habitat enhancement. All artificial reefs constructed in inshore waters within Georgia's 3 nm territorial sea require U.S. Army Corps of Engineers (USACE) (Programmatic General Permit No. 37) and State (Coastal Marshland Project Act Permit No. 682) permits. In the adjacent EEZ, the State conducts artificial reef development under the authority of a USACE Regional Permit No. 36 that encompasses 30 offshore reef locations. While the permitted estuarine and coastal beach reef sites are limited in size, the offshore EEZ sites typically average 4 nm^2. These larger areas allow for the development of multiple patch reefs, a design that improves material performance and helps disperse fishing pressure.

Artificial reef development in Georgia has largely relied on stable and durable secondary use materials or materials of opportunity to create fisheries habitat. Material complexity and surface area are other important factors. Similar to other early U.S. artificial reef development efforts, the Georgia program also initially utilized tires, which were bound into compressed 8-tire units using rebar and anchored with concrete. While many tire units remain intact at Georgia's offshore reefs, several have also deteriorated; however, due to early concerns expressed by the trawler fleet in coastal waters, most units were placed well offshore and many have sunken into the soft sand bottoms at the reef sites closest to shore.

Perhaps the best known and most popular materials of opportunity used for artificial reef development are metal vessels, which have been employed as materials off Georgia for over fifty years. Prior to sinking, all vessels are cleaned, cut down to satisfy required water depth clearances, and modified to promote sunlight and water flow. As vessels age and collapse, they often become more complex, improving the overall growth and development of associated reef communities. Ranging from 29 to 447 feet in length, approximately 86 vessels are found on Georgia's offshore reefs, including tugs, barges, landing craft, sailboats, steel trawlers, a dredge, a USCG buoy tender, a former Japanese research vessel, and two Liberty ships -- the *Edwin S. Nettleton* and the *Addie Bagley Daniels*.

Emulating the rock outcroppings underlying temperate natural reef communities, marine grade concrete is another preferred material of opportunity used for reef development in Georgia's estuarine and adjacent offshore waters. To date, almost 200,000 tons of concrete pipe, pilings, and bridge/wharf rubble generated through coastal construction projects have been deployed on

Georgia's artificial reefs. Other notable materials of opportunity also utilized for offshore artificial reef development in Georgia include approximately 800 metal poultry transport cages, 55 U.S. Army battle tanks, and 200 New York City Transit Authority subway cars. Designed for stability, complexity, and long-term service, several thousand concrete fisheries enhancement units have been deployed by the program since the mid-1990s on Georgia's inshore and offshore artificial reefs. Commercially available, the final unit design selected is dictated by project goals, site characteristics, cost per-unit-deployed, and the availability of comparable reef materials.

Normally occurring during the warmer months, SCUBA diving at Georgia's artificial reefs primarily takes place on the reef sites 15 nm and further offshore due to poor water visibilities and strong tidal influences found closer to shore. The larger wrecks popular with divers are also found on the artificial reefs located further offshore in deeper water depths. However, Georgia's artificial reefs are constructed to first provide enhanced fisheries habitat and recreational angling opportunities and are not specifically designed for diving. Entanglement and entrapment are diving hazards unavoidably associated with artificial reef structures, especially as the materials age, deteriorate, and collapse.

Nineteen of the 30 artificial reefs located in Georgia's adjacent EEZ waters have been established as Special Management Zones (SMZs) under the SAFMC's Snapper-Grouper Fishery Management Plan. SMZs assist in increasing numbers of fish in an area and or create fishing opportunities that would not otherwise exist. In conjunction with this designation, allowable gears on the reefs are restricted to handheld hook-and-line and spearfishing gear, including powerheads or bangsticks. Powerheads may only be used to harvest a recreational bag limit and any powerheaded catches in excess of the bag limits aboard a vessel at a SMZ is considered *prima facie* evidence of a violation. Further information on Georgia's marine artificial reefs may be obtained through the Coastal Resources Division, Habitat Restoration and Enhancement Unit, One Conservation Way, Brunswick, GA 31520; phone (912) 264-7218, or by going to http://coastalgadnr.org/ArtificialReef.

Florida (East Coast)

Encompassing 34 of 35 different coastal counties spread along 2,184 kilometers (1,357 miles) of ocean fronting coastline (1,362 kilometers fronting the Gulf of Mexico and 822 kilometers fronting the Atlantic Ocean), Florida manages one of the most diverse, and most active artificial reef programs in the United States. Florida leads the nation in the number of public artificial fishing reefs developed. The first permitted artificial reef off Florida was constructed in 1918. Artificial reefs are found in waters ranging from eight feet to over 400 feet with an average depth of 65 feet. As of March 2016, no fewer than 1,029 deployments of artificial reef materials off the Florida East Coast are on record with the Florida Fish and Wildlife Conservation Commission (FWC). Over the last 50 years the state artificial reef program has experienced a gradual

transition in construction materials use, funding sources, and recognition of the importance of measuring effectiveness.

The State's involvement in funding artificial reef construction began in the mid-1960s when the Florida Board of Conservation awarded a limited number of grants to local governments to fund reef development projects. In 1971 a Florida Recreational Development Assistance Program grant was awarded to a local government by the DNR Division of Recreation and Parks for reef construction. Between 1976 and 1980 the DNR Division of Marine Resources received, and oversaw the preparation and placement of five Liberty ships, secured as a result of passage of the Liberty Ship Act, which facilitated the release of obsolete troop and cargo ships for use as artificial reefs.

In 1978 a systematic state artificial reef program was begun. The Division of Marine Resources received a large grant from the Coastal Plains Regional Commission for artificial reef development. Rules for disbursing these funds were developed, defining a grants-in-aid program with projects selected through a competitive evaluation of local government proposals. In 1979 the State Legislature appropriated general revenue funds for reef construction which continued on an annual basis, with the exception of one year, through 1990. In 1982, in addition to receiving general revenue funds, the program was officially established as a grants-in-aid program by law (s. 370.25, Florida Statutes). One staff position was assigned responsibility for program administration.

The rapid proliferation of publicly funded artificial reefs in Florida beginning in the mid-1980s is the result of increased levels of federal, state and local government funding for artificial reef development. Prior to that, other state funding sources intermittently provided reef development assistance. In 1966 there were seven permitted artificial reef sites off Florida in the Atlantic Ocean. By 1987, this number had grown to 112. Consistent federal funding for Florida's reef program became available in 1986 as a result of the Wallop-Breaux amendment to the 1950 Federal Aid in Sport Fish Restoration Act (Dingle-Johnson). During the decade of reef-building activity from 1986 to 1996, Sport Fish Restoration Funds provided almost three million dollars to complete 164 Florida reef projects.

In January 1990, Florida instituted a saltwater fishing license program. About 5% of the revenue from the sale of over 850,000 fishing licenses annually became available for additional artificial reef projects. Additional personnel were hired into the state artificial reef program to assist with coordination, information sharing, grant monitoring/compliance and diving assessment of artificial reefs. Funding in Florida remained steady during the following years, with funds from the Federal Aid to Sport Fish Restoration Program matched with state saltwater license funds.

Florida is the only southeastern Atlantic coastal state active in artificial reef development which does not have a direct state-managed artificial reef program. For the last 30 years, Florida's artificial reef program has been a cooperative local and state government effort, with additional input provided by non-governmental fishing and diving interests. The state program's primary objective has been to provide grants-in-aid to local coastal governments for the purpose of developing artificial fishing reefs in state and adjacent federal waters off both coasts in order to locally increase sport fishing resources and enhance sport fishing opportunities. As of 2016, all active permitted reef sites are held by coastal counties or cities.

Reef management expertise at the local government level is variable. Reef programs are found in solid waste management, public works, natural resources, recreation and parks, administrative, and planning departments. Local government reef coordinators range from biologists and marine engineers to city clerks, grants coordinators, planners, and even unpaid volunteers. Reef management and coordination are generally collateral duties for most local government reef coordinators.

In response to long-range planning initiatives, in 2003 the FWC completed a long-range Artificial Reef Strategic Plan (Florida Fish and Wildlife Commission, 2003) to serve as a blueprint for both the FWC and the local coastal government reef programs. Representing the broad range of public interests in artificial reefs throughout Florida, the plan is comprised of guiding principles, goals, and objectives that optimize biological and economic benefits, provide policy guidance, support research and data collection, pursue additional funding opportunities, provide a framework for public education and outreach, and provide guidance for operational planning at the state, regional, and local levels of artificial reef construction and monitoring. The Strategic Plan is available at http://myfwc.com/marine/ar/FLARStrategicPlan2.pdf.
In 2011 the FWC and Florida Sea Grant published a guidelines document for Southeast Florida titled "Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida" which is available at: http://edis.ifas.ufl.edu/sg101.

Due to its long coastline, ideal conditions, and large number of academic and research-oriented institutions, a significant quantity of the existing body of field research dealing with artificial reefs has been conducted in waters off Florida. Artificial reef research projects undertaken with over $4.5 million dollars in state funding since 1990 have included studies on reef spacing and design, material stability and storm impact studies, long term studies of reef community succession, residency of gag grouper on patch reefs through tagging and radio telemetry, juvenile recruitment to reefs, impacts of directed fishing, remote biological monitoring techniques, and the effects of unpublished artificial reefs.

As with most other artificial reef programs in the U.S., there has been a shift in the types of materials used in the construction of artificial reefs in Florida waters over the past 50 years.

Through experience, reef builders have learned which materials work best in providing effective long-lived artificial reefs. Modern construction practices have evolved to a point where reef programs are much more selective in the types of materials they use.

Concrete materials, chiefly culverts and other prefabricated steel reinforced secondary-use concrete, were the primary reef material in nearly 43% of the 3,098 public reef deployments in waters off Florida as of March 2016. Engineered artificial reef units have been a growing component of the state's artificial reef development efforts since the early 1990s and now represent 25% of the artificial reefs off Florida. Most, but not all, units designed specifically for use as artificial reefs have proven to be durable and stable in major storm events. Prefabricated units designed specifically for use as artificial reefs have focused on improving habitat complexity, stability and durability, as well as providing a standard design for research and monitoring projects.

Secondary use materials such as obsolete oil platforms and steel vessels have also been used off Florida in the development of artificial reefs. Twenty-six percent of Florida's artificial reef structures are metal structures, including 515 sunken vessels and barges. These vessel reefs have catered to fishermen fishing for pelagic species, and a rapidly expanding resident and tourist diving population. The majority of vessels sunk as artificial reefs are concentrated off Miami-Dade, Palm Beach, and Broward Counties. On May 18, 2006, in partnership with the U.S. Navy, Florida's artificial reef program and Escambia County successfully deployed the *Oriskany*, an 888 foot-long aircraft carrier, 23 miles southeast of Pensacola, FL. The *Oriskany* is presently the largest vessel in the world intentionally deployed as an artificial reef.

Ecological Role and Function

Artificial reefs have the effect of changing habitats from a soft substrate to a hard substrate system or of adding higher relief to low relief (< 1m) hard substrate systems. Historically, fishermen created artificial reefs as fish attractants (Lindberg and Seaman 2011). An ongoing debate within the scientific community exists as to whether artificial reefs simply aggregate current individuals or actually enhance production (e.g., Bohnsack 1989, Pickering and Whitmarsh 1997; Lindberg 1997, Osenberg et al. 2002; Powers et al. 2003; Brickhill et al. 2005). The answer to that question can only be determined by viewing individual artificial reefs in a broader ecological context. For example, are fisheries habitat-limited (production) or recruitment-limited (aggregation) (Lindberg and Seaman 2001)? When well sited, the augmentation of species composition and local abundance of important species in a specific area are often seen as the primary benefits of reef deployment activities.

Although artificial reefs are not identical to naturally occurring hard-bottom areas or coral reefs, demersal reef-dwelling finfish, pelagic planktivores, and pelagic predators can use natural and

artificial hard substrates in similar ways and often interchangeably (Arena et al 2007). In addition to location, temporal variation exists: elevated fish densities occur quickly after deployment (Bohnsack 1989), but substantial uncertainty remains about estimating overall fish production long-term (Powers et al. 2003, Lindberg et al. 2006). Finally, artificial reefs may affect species and life history stages differently: many reef-associated species occur on both natural and artificial reef habitats, with significant differences in the fish communities (Patterson et al. 2014; Streich et al. 2017).

Newly placed or exposed hard substrate is colonized when marine algae and larvae of epibenthic animals successfully settle and thrive. Species composition and abundance of individuals increase quickly until all suitable primary space is used by the epibenthos. At some point, a dynamic equilibrium may be reached with the number of species and number of new recruits leveling off, although recent studies indicate that this may take decades to achieve (Burgess 2008; Nicoletti et al 2007). Competition for space and grazing pressure become significant ecological processes in determining which epibenthic species may persist (Kirby-Smith and Ustach 1986; Paine 1974; Sutherland and Karlson 1977). The reef community itself should remain intact as long as the supporting hard substrate remains and is not buried under too great an overburden of sediment.

Concurrent with the development of the epibenthic assemblage, demersal reef-dwelling finfish recruit to the new hard-bottom habitat. Juvenile life stages will use this habitat for protection from predators, orientation in the water column or on the reef itself and as a feeding area. Adult life stages of demersal reef-dwelling finfish can use the habitat for protection from predation, feeding opportunities, orientation in the water column and on the reef and as spawning sites.

Pelagic planktivores can occur on hard-bottom habitats in high densities and use these habitats for orientation in the water column and feeding opportunities. These species provide important food resources to demersal reef-dwelling and pelagic piscivores. The pelagic piscivores use the hard-bottom habitats for feeding opportunistically. Most of these species do not take up residence on individual hard-bottom outcrops, but will transit through hard-bottom areas and feed for varying periods of time (Sedberry and Van Dolah 1984).

As long noted by researchers, the physical characteristics of artificial reef habitat may result in differences in the observed behavior of fish species on or around such structures in contrast to behavior observed on equivalent areas of natural hard-bottoms (Bohnsack 1989; Lindberg et al 2006). Some reef structures, particularly those of higher relief, seem to yield generally higher densities of managed and non-managed pelagic and demersal species than a more widely spread lower relief, natural hard-bottom or reef (Rountree 1989; Collins et al 2016, Streich et al. 2017). However, many fishes in Gulf of Mexico studies have been documented as older and more fecund on natural reefs (Glenn et al. 2017; Karnauskas et al. 2017). The fishery management implications of these differences must be recognized and taken into consideration when

planning, developing, and managing artificial reefs as EFH (Lindberg and Seaman 2011).

Other artificial hard substrates in marine and estuarine systems provide habitat of varying value to fisheries resources. Coastal engineering structures such as bridges, jetties, breakwaters and shipwrecks provide significant hard substrate for epibenthic colonization and development of an associated finfish assemblage (Van Dolah 1987). Some of these structures also provide habitat in the water column and intertidal zone which differs significantly from typical benthic reefs. The result of the different ecotones provided by these coastal structures is often higher species diversity than was present before the structure was placed on site. These structures also may provide refuge from predation as well as feeding opportunities and orientation points for juvenile and adult life stages of important finfish species in the South Atlantic region. They differ from artificial reefs as defined above, in that there is generally no direct intention in their design or placement to achieve specific fishery management objectives. However, their impacts should be considered just as any other activity which modifies habitats in the marine environment.

Fisheries Enhancement

The proper placement of artificial materials in the marine environment can provide for the development of a healthy reef ecosystem, including intensive invertebrate communities and fish assemblages of value to both recreational and commercial fishermen. The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Strelcheck et al. 2007). Artificial reefs have developed an impressive track record of providing beneficial results, as estimated in recent models and measured by fishing success for a wide range of finfish species (e.g., Pitcher et al. 2002, Gallaway et al. 2009). To date, artificial reefs have been chiefly employed to create specific, reliable, and more accessible opportunities for recreational anglers. They have been used to a lesser extent to enhance commercial fishing probably because artificial reef total area is small compared to much larger, traditionally relied-upon, natural commercial fishing grounds.

In their present scale and typical design, most artificial reefs, while well-suited for use by recreational anglers, would be unable to withstand intensive commercial fishing pressure, especially for many of the popularly sought-after demersal finfish species, for more than a short period of time. Currently, most artificial reef programs receive the majority of their funding through sources tied directly to recreational fishing interests.

Special Management Zones

Conceptualized by the South Atlantic Fishery Management Council within the Snapper/Grouper Management Plan, several Special Management Zones or SMZs have been established in the South Atlantic off South Carolina, Georgia, and Florida to provide gear and harvest regulations

for defined locations including many artificial reef sites. The basic premise of this concept is to reduce user conflicts through gear and landings regulations at locations that feature limited resources, managed for specific user groups. Generally, artificial reefs have been developed for recreational use utilizing recreational resources. The ability to regulate gear types utilized over the relatively limited area of a artificial reef enables fisheries managers to prevent rapid depletion of these sites and promote a more even allocation of reef resources and opportunities.
Present SMZ regulations apply to about 50 artificial reef sites off South Atlantic States, with several more proposed. Since regulations concerning the management of SMZs are tied to specific gear restrictions and bag limits, it is possible that the use of SMZs in the future could be expanded to a point where any possible type of fishing gear could be restricted for a set period of time or indefinitely. This could provide fishery managers with the ability to turn individual artificial reef sites on or off as the specific needs of the fishery in question dictate. The ability to have some degree of control over fishing activities on these sites would give managers more power to use artificial reefs as a true fishery management tool.

Hard-bottom Habitat Enhancement

Habitat enhancement through the construction of artificial reefs can be achieved by converting some other type of bottom habitat into a hard-bottom community. Mud, sand, shell or other relatively soft bottom habitat can be altered by the addition of hard structure with low to high profile to add to the total amount of hard-bottom reef environment in a given area. While it would be difficult and particularly costly to construct artificial reefs with an equivalent area of most typical hard-bottom found off the southeastern U.S., substantial areas of ocean bottom can be effectively converted to hard-bottom over time given sufficient planning, proper design and adequate resources.

In areas where existing hard-bottom habitat is limited spatially, temporally, or structurally, artificial structures may be used to augment what is already in place. Hard-bottom with or without a thin veneer of sediment constitutes a preferred substrate for this type of artificial reef development, as opposed to sand and mud bottoms; however, deployment of structures in already productive areas carries a certain degree of risk. Existing hard-bottom may be directly damaged or impacted by modified current regimes, movement of materials and potentially increased user pressure. Although sparse, the hard-bottom may constitute valuable juvenile habitat and refugia that may be severely compromised by creating additional habitat conducive to predators. On the other hand, a properly planned artificial reef could be constructed without impact to existing resources by utilizing stable materials that are designed to enhance juvenile habitat and survival.

In cases where critical hard-bottom habitat is damaged or lost due to ship groundings or natural forces such as severe storms or burial, the addition of artificial reef material could be used to compensate for this loss on site or in adjacent areas. Artificial reef structures can also be used to

repair damaged habitat or mitigate for its loss in cases where stable, hard substrate placed on the bottom would provide the closest in-kind replacement, or at least provide the long-term base for the eventual re-establishment of the hard-bottom reef community that was originally impacted.

Artificial Marine Reserves

Marine reserves, marine protected areas (MPA's), and marine sanctuaries are a proven management technique that has been implemented successfully worldwide to protect essential fisheries habitat and sustain fisheries stocks and genetic variability. Although the concept of protected areas is gaining support in the southeastern United States, the actual application of this management measure has generated resistance among user groups who feel that the establishment of such reserves will adversely impact fishing opportunities by limiting access to existing habitat. For areas with little fisheries habitat, these impacts are viewed as significant.

The potential role that artificial reefs could play as marine reserves has only recently begun to be explored. As part of its efforts to protect deep water snapper and grouper species, the South Atlantic Fisheries Management Council in 2007 created a series of Type II Marine Protected Areas in offshore waters from North Carolina to Florida. A Type II MPA prohibits bottom fishing while allowing surface trolling for pelagic species such as billfish or tuna. One of these newly regulated protected areas encompasses an old shipwreck known locally as "The Snowy Grouper Wreck". Although not a deliberately created artificial reef, this artificial structure is known to hold spawning aggregations of snowy grouper, an overfished species in serious need of protection.

Another of these newly established MPA's is, in fact, the first deliberately created artificial reef marine protected area on the east coast. The Charleston Deep Reef, off South Carolina, was permitted by the South Carolina Department of Natural Resources specifically with the intention of creating protected habitat for deep-water species. The permitted area includes no known hard-bottom habitat so that the created habitat can be studied and compared to other, natural bottom MPAs to determine the effectiveness of artificial reserves in stock enhancement.

If created habitat such as these areas can be shown to enhance fisheries stocks, additional marine reserves consisting of artificial structures could be developed in habitat-limited areas to assist specifically in such roles as habitat and stock enhancement without impacting existing fisheries practices or asking local anglers to give up traditional fishing grounds.

Enhancement of Eco-Tourism Activities

Along with other ecotourism activities, recreational diving is one of the fastest growing sports in the United States. Properly planned, artificial reefs can be designed to encourage diving and to reduce spatial conflicts with other user groups, including fishermen. Specific SMZ or other regulations established for a artificial reef could conceivably allow non-extractive uses only,

including diving, underwater photography, snorkeling, and other ecotourism activities. Materials selected could be designed and deployed to create specific fisheries habitat for tropical, cryptic, and other species valued by tourists, conservationists, naturalists, photographers and other non-extractive users.

The establishment of additional hard-bottom reef communities in areas with thriving dive-related industries could be used to reduce diving-related pressures on existing natural reefs, especially in the case of sensitive coral reefs in the Florida Keys (Leeworthy et al. 2006). Finally, a non-extractive, conservation reef would essentially constitute a sanctuary, providing fisheries and the associated habitat with *de facto* protection.

Artificial Reef Construction Practices

Artificial reefs have been built from a wide variety of materials over the years. Throughout the present century, most construction materials relied upon in the South Atlantic states have been forms of scrap or surplus; some more suitable for this purpose than others. In an effort to decrease dependency of successful reef development on the availability of scrap or surplus materials, and to improve the overall effectiveness and safety of artificial reefs, most artificial reef programs have, in recent years, designed, manufactured and/or evaluated a number of specifically engineered reef habitat structures which may become a more viable option for future reef development projects. Due primarily to improved financial support for most artificial reef programs in the South Atlantic states and a willingness within private industry to develop new and affordable designed reef structures, the use of such reef construction material is now much more feasible.

Whether specifically designed or secondary-use materials are utilized to construct artificial reefs, individual state resource management agencies should be able to define particular materials that are deemed acceptable for use as reef structures in their coastal and adjacent offshore waters. Some states and individual counties have specific stability requirements that materials must meet regarding horizontal and/or vertical movement. The decision to allow or disallow the use of certain materials should be based on existing state and federal regulations and guidelines, as well as any soundly based policies established by a particular state. Materials should only be considered for use if they possess characteristics which allow them to safely meet the established objectives for the artificial reef project under consideration, and present no real risk to the environment in which they are being placed. The document entitled *Guidelines for Marine Artificial Reef Materials* (Gulf States Marine Fisheries Commission, 2004) provides detailed information of the experiences, benefits, and drawbacks of past uses of a variety of materials by state resource management agencies. This, as well as other related documents (e.g. National Artificial Reef Plan, EPA Ship Preparation Guidelines), and the collective experiences of individual artificial reef programs, may be relied upon as the best available data in making decisions regarding the use of certain types of materials in artificial reef development.

Secondary Use Materials

Although past artificial reef development in most states has been directly tied to the availability of surplus or secondary use materials due to budgetary constraints, this has not been the most desirable situation for long-term planning and development of reef construction efforts. While a total dependency on scrap and surplus materials is not the most effective means of managing reef development activities, some secondary use materials, when available in the proper condition, are very desirable in carrying out artificial reef construction projects and should continue to be utilized to enhance fisheries habitat.

In some cases naturally occurring materials such as quarry rock, limestone, or even shell have been utilized to construct artificial reefs. While these are not by definition scrap materials, their availability is sometimes dictated by a desire to move them from an existing site where for some reason they may no longer be desired. In these cases, they could be classified as a material of opportunity. In other cases, as in the intent to build a reef to provide a rocky bottom substrate, material such as quarry rock or limestone may be the most suitable material available to create the intended habitat, and may be specifically sought after.

In the South Atlantic states individual state artificial reef programs, resource management agencies, or other approved reef programs serve as the central contact and coordination point for evaluating, approving, distributing and deploying secondary use materials on a given state's system of artificial reefs. Before approving any materials for use in reef construction, the managing or oversight agency must carefully inspect the items and ensure that they are environmentally safe, structurally and physically stable, needed, practical, and can be deployed in a cost-effective and safe manner. A detailed discussion of the benefits, limitations and problems encountered in using the almost limitless list of secondary use materials that have been employed over the years in the construction of artificial reefs is well beyond the scope of this document. However, the Atlantic and Gulf State Marine Fisheries Commission's, as well as other individual artificial reef programs have produced publications which cover in great detail, many of the strengths and weaknesses of secondary use materials which have been employed in reef development.

Designed Habitat Structures

If an artificial reef program is to function in a manner that is conducive to effective long-term planning and the pursuit of realistic (fishery management driven) reef development goals, it cannot continue to base reef construction solely on the unpredictable availability and diminished quantity of acceptable scrap or surplus materials. The only practical solution is to consider the incorporation of manufactured reef structures into planned reef development activities.

Manufactured artificial reef structures can be developed which possess the characteristics desired of a reef substrate for a specific environment, application, or end result. Although the initial costs in procuring these reef materials may be higher than those involved in obtaining many secondary use materials, the transportation, handling and deployment costs are typically about the same, and the lack of expense in having to clean or otherwise prepare these structures can often balance out this difference. Being able to engineer into a reef material design specific qualities of stability, durability, structural integrity, transportability and biological effectiveness also gives manufactured reef structures a great advantage over most secondary use materials which are often severely limited in how they can be modified or deployed.

Manufactured reef units can be deployed in any quantity, profile and pattern required, allowing them to provide for maximum efficiency of the materials used in achieving the desired results. Secondary use materials such as ships must be deployed in a single unit, often with a great deal of the total material volume being taken up in vertical profile. The same volume of designed reef materials that would be found in a vessel can be spread over a much larger area of ocean bottom with much less relief, allowing for better access to a larger number of reef users and a more natural appearance in the layout of the reef.

One of the most significant advantages offered by the use of designed reef structures is the ability to procure them in any quantity whenever they are needed. This allows reef managers to plan ahead and make the best possible use of available funding, as well as predict exact costs needed to accomplish specific reef construction objectives from month to month or year to year. When depending on secondary use materials for reef development, this type of short and long-term planning is rarely available.

Standards for Artificial Reef Construction

The National Fishing Enhancement Act of 1984 (Title II of P.L.98-623) provides broad standards for the development of artificial reefs in the United States. The purpose of the Act was to promote and facilitate responsible and effective efforts to establish artificial reefs in the navigable waters of the US and waters superjacent to the outer continental shelf (as defined in 43 USC, Section 1331) to the extent such waters exist in or are adjacent to any State. In Section 203, the Act establishes the following standards for artificial reef development. Based on the best scientific information available, artificial reefs in waters covered under the Act...shall be sited and constructed, and subsequently monitored and managed in a manner which will:

(1) enhance fishery resources to the maximum extent practicable;

(2) facilitate access and utilization by U.S. recreational and commercial fishermen;

(3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters;

(4) minimize environmental risks and risks to personal health and property; and

(5) be consistent with generally accepted principles of international law (e.g. MARPOL) and shall not create any unreasonable obstruction to navigation.

Section 204 of the Act also calls for the development of a National Artificial Reef Plan consistent with these standards. This plan was first published by the National Marine Fisheries Service in 1985 and includes discussions of criteria for siting and constructing artificial reefs, as well as mechanisms and methodologies for monitoring and managing such reefs. While the Plan itself lacked any degree of regulatory authority, adopted regulations subsequently developed by the U.S. Army Corps of Engineers for dealing with the issuance of artificial reef construction permits were based on the standards set forth in the Act as well as wording taken from the Plan. The National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs (NOAA, 2007) was approved in 2007 and is available at
http://www.nmfs.noaa.gov/sfa/management/recreational/documents/narp_cover_3.pdf

Each state artificial reef program has its own set of standards for the development and management of artificial reefs. In most cases these state standards were developed with the federal standards from the National Fisheries Enhancement Act and the National Artificial Reef Plan in mind. While specific state programs may differ in matters involving technical operation or specific management issues, they are all very similar in their adoption of the national standards that exist.

Artificial Reefs as Essential Fish Habitat

Earlier sections have discussed the ways in which artificial reefs are specifically used by both invertebrate and finfish species. Since artificial reefs are established by marine resource managers throughout the entire South Atlantic Bight, the diversity of species present on and around such structures is extremely wide. Artificial reefs are used in almost every possible marine environment, from shallow-water estuarine creeks to offshore sites up to several hundred feet in depth. Due to the broad distribution of reef sites along the South Atlantic states, many different species may interact with artificial reefs at different life-stages and at different times. For species which may be to some degree habitat-limited, the establishment of additional suitable habitat targeted to specific life-history stages may improve survival (Herrnkind et al., 1997). Additional artificial habitat designed specifically to promote survival of targeted species in protected areas could potentially enhance existing ecosystems or create new ones to fill in gaps where essential fish habitat had been damaged, lost, or severely overfished. Artificial structures also may provide essential habitat while simultaneously acting as a deterrent to illegal fishing practices in specially managed areas (e.g. Oculina HAPC).

Since the majority of the artificial reefs constructed along the southeastern U.S. are in coastal and offshore waters, the species most often present on these sites are predominantly the adult

and/or sub-adult stages of virtually all species within the South Atlantic Snapper Grouper Complex, as well as all species managed within the Coastal Migratory Pelagics Fishery Management Plan. Depending on environmental conditions on a specific reef site, and the behavior patterns of certain fish, species within the Snapper Grouper Complex tend to be long to short-term reef residents, while those among the Coastal Pelagics tend to be more transient visitors to the reefs as they migrate up and down the coast. Red drum and spiny lobster, as well as some of the managed shrimp species, may be found on and around specific reef sites at different times of the year, depending on the exact location and design of the reef. While some species of managed corals may occur on reef structures as far north as the Carolinas, the waters off South Florida are the predominant site where such species are found attached to artificial substrate.

In conclusion, artificial reefs are constructed from a wide range of materials, and are used for a variety of purposes. They function by enhancing natural habitat and are especially popular sites for fishing and diving. Socioeconomic studies clearly indicate positive returns from artificial reef construction (Johns et al. 2001; Rhodes and Pan 2007). Considerable evidence also exists that artificial reefs both attract and produce a variety of marine finfish species, in some cases exhibiting greater reproductive productivity than natural areas (Danson 2009). While the creation of successful and productive artificial reefs requires careful preparation and planning, they constitute a habitat-based tool with considerable potential that, ideally, should be incorporated into an integrated holistic approach to fishery management.

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