Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida

Updated: June 2011

Southeast Florida Coral Reef Initiative
Maritime Industry and Coastal Construction Impacts (MICCI)
Local Action Strategy Project 18 & 19

Southeast Florida Coral Reef Initiative

Acting above to protect what's below.

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Southeast Florida Coral Reef Initiative
Maritime Industry and Coastal Construction Impacts (MICCI)
Local Action Strategy Project 18 & 19

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Miami-Dade County Department of Environmental Resource Management

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Preface

This document is one means of putting into action concerns for the conservation and health of the important, valued and numerous coral reefs of southeast Florida. It addresses a specific type of undersea construction that has impacted coral ecosystems but also offers a tool for repair of damage to them. That tool is the deployment of structures on the sea floor to serve as artificial reefs. In fact, artificial habitat materials such as limestone boulders and concrete are already in use to "mimic" to varying degrees the natural structure and ecological function of coral habitats, and thereby hasten recovery and repair damage from accidental vessel groundings, as well as intentional disturbances such as occur with the laying of submarine cables.

To the degree possible, state-of-the-art practices concerning artificial reef science and technology are presented in this document. In some cases, so-called "best practices" are based on solid research; in others it is a matter of relying on tried-and-true practical experiences that have evolved over time. As a first document of its kind in Florida, it offers a benchmark for developing future science-based guidance for the placement of artificial reefs in waters where coral reefs are found. At this stage of the technology, it is realistic to defer "teasing out" best management practices into distinct pages until the next edition of this document.

The history of planning and developing artificial reefs in southeast Florida, as well as across the state generally, features strong involvement and leadership of volunteers. In many cases, private citizens laid the foundations for more recently organized artificial reef programs in county governmental departments. Meanwhile, this document came to exist because a group of public servants, employed in various federal, state, and mostly local agencies concerned with natural resources and coastal environments devoted time outside of their normal employment responsibilities to draft its various chapters. It has been a privilege to work with these dedicated colleagues in editing the present version.

William J. Lindberg
William Seaman, Jr.
June 2011

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Chapter 1. Introduction

Coral reefs are one of southeast Florida's most highly valued ocean resources, and their conservation is a high priority for numerous private and public interests. Despite their significant economic and ecological importance (Figure 1.1), they continue to face damage and destruction from human activity. Among the tools increasingly available for restoration of damaged coral reefs, or mitigation for their loss, are so-called "artificial reefs," which much more commonly are placed on the sea floor for fishing and diving purposes. Literally hundreds of deployments of natural and man-made structures have been made in southeast Florida coastal waters over the last 30 years (Figure 1.2). However, construction practices, design features and use patterns associated with reef-building all have the potential to affect coral ecosystems.

This document describes artificial reef technology and some of the science behind it, as a means of assisting practitioners with varied backgrounds, skills and experience in achieving responsible and sustainable reef development. Its goal is to present best and acceptable guidelines and management practices for artificial reef planning, siting, construction, anchoring and monitoring in southeast Florida, and thus provide essential information and guidance to resource users, managers and planners on the most effective methods for protecting natural reefs and other natural resources, such as "soft-bottom" (e.g., seagrass beds) habitats, during the establishment of artificial reefs and reef ecosystems. This information directly applies to use of artificial reefs for mitigation and restoration of coral habitat.

Figure 1.1. The southeast Florida coral reef ecosystem is the northern extension of the Florida Reef Tract. It is generally comprised of three reefs running parallel to shore and separated by sand flats. The reefs are colonized by a variety of organisms including stony corals, octocorals, sponges and algae, which provide habitat, food and shelter for many species of fishes, invertebrates, sea turtles and marine mammals. Fishing, diving and other boating-related activities on Florida's coral reefs generate approximately $6 billion in sales and income for Florida's citizens and sustain more than 60,000 jobs annually (Johns et al. 2001 & 2004) (Photograph courtesy of Dave Gilliam, National Coral Reef Institute).

This first chapter briefly introduces the subject of artificial reefs in the marine ecosystem of southeast Florida and beyond, offers a context for the practices described in the other chapters, and indicates how they contribute to the aim of this document. An overview of artificial reef project organization is in Figure 1.3.

Finally, we encourage reef practitioners to use a "question-driven" approach to designing their artificial reefs and seeking the best practices to develop them. As a reef project or program evolves, questions to ask and the reasons for asking them include:

- ***Is the concept of the reef realistic?*** The significance of this question is that here we decide if the idea for an artificial reef or habitat is even valid in particular ocean waters of southeast Florida, before making a commitment to further planning and development.
- ***How will the new reef and natural ecosystem interact?*** It is essential that the influences of an artificial structure upon the sea floor be understood before construction, in terms of how natural habitat such as coral reefs may be modified or eliminated, and also how ecological processes of microbes, plants and animals (e.g., reproduction, colonization, feeding, movement) may be affected.
- ***What are the rational—and measurable—purposes of the reef?*** Unless the broad goal and specific aims of the artificial reef are defined, it will not be possible to assess performance of the structure rigorously nor to calculate returns on investment from environmental and financial perspectives.
- ***Who and how skilled is the reef architect?*** Here we evaluate the approach for turning the concept of the reef into a reality. It is important to evaluate how theory can be transformed into practice.

Figure 1.2. The most common application of artificial reef technology in southeast Florida is enhancement of recreational fishing, such as through the use of (A) large steel objects such as ships (Palm Beach County) and (B) concrete items such as culvert (Martin County). Newer aims include (C) restoration of coastal habitat and enhancing biodiversity, using fabricated structures such as limestone boulders embedded in concrete bases (Miami-Dade County). The numerous deployments of artificial reefs such as these contribute significantly to the distinction of Florida's coastal waters being home to more marine artificial habitats than all other states combined [Photographs courtesy of Florida Fish and Wildlife Conservation Commission (A, B) and Miami-Dade County Department of Environmental Resource Management (C)].

- ***What is an ecologically valid design for the reef?*** It is essential to have technically valid specifications of the artificial reef as dictated by its purposes and its environmental setting. Note: The practices of medicine to "do no harm" most certainly apply here.
- ***How will a productive and stable reef be built?*** The significance of the question is that it is vital that the best engineering and construction practices be used, to ensure that the structure is built as designed, and will withstand the physical forces of the local and regional environments of the inshore and offshore marine waters of southeast Florida.
- ***How is the reef to be managed and used sustainably?*** Asking this question is meant to optimize the benefits to all interests who will use the underwater structure and the habitat that it creates, and to reduce conflict among them; it is essential that appropriate "coastal zone management" practices be instituted to the degree appropriate.
- ***How are stakeholders engaged and informed in the process?*** If all interested parties concerned with artificial reef sites and permit areas (and ocean environments in general) in the coastal waters of southeast Florida are kept informed of the status and activities about their construction, management and use, then they are more likely to offer guidance and perhaps assistance for this and similar efforts.
- ***What are the measures of reef performance?*** To determine the effectiveness of the undersea construction effort, a scientifically valid monitoring and assessment campaign must be conducted. "Success criteria" must be established for artificial habitats deployed, similar to those established and routinely used worldwide. Monitoring will enable the project sponsors to gain evidence concerning the ecological performance of the structure toward meeting planned objectives, and ultimately providing a return on the financial investment.

A much more detailed set of questions is presented in Table 1.1, and discussed in section 1.3 below. At this point, readers are encouraged to build their own list of questions that must be answered in the reef development process. It is in response to such questions that "best" practices should be sought and developed.

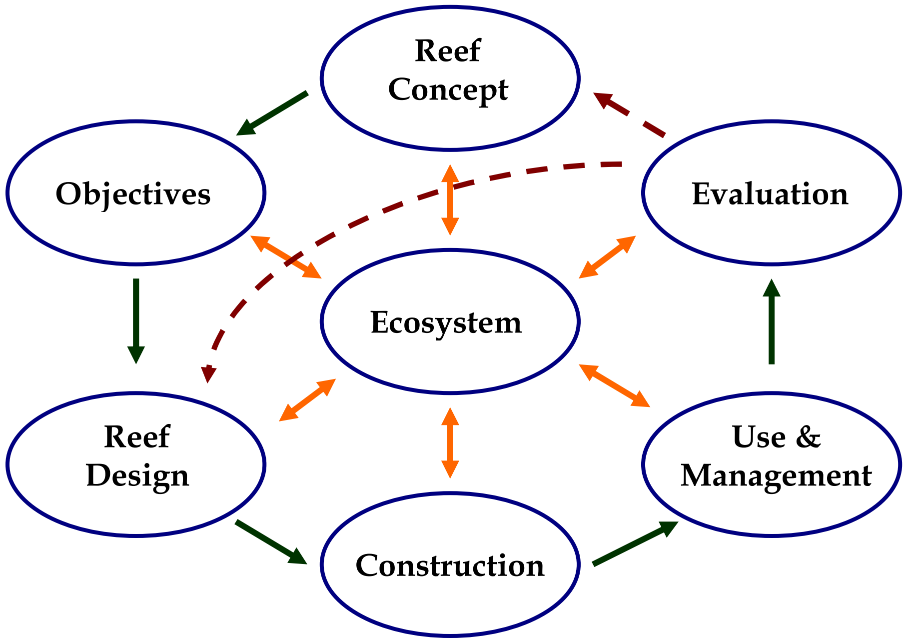

Figure 1.3. A flow chart of major steps, elements and considerations in development of artificial reef project plans, implementation and evaluation.

1.1 Rationale, Purpose and Readership of the Document

Carefully planned artificial reefs are placed to achieve one or more clearly defined and measurable objectives, do no harm to other marine resources and not interfere with other accepted uses of the coastal ecosystem. In 2004, the Southeast Florida Coral Reef Initiative (SEFCRI) began a series of Best Management Practice documents to improve the performance of marine construction activities in Miami-Dade, Broward, Palm Beach and Martin counties (i.e., from the northern boundary of Biscayne National Park north to the St. Lucie Inlet), in order to enhance protection of natural coral reefs (e.g., PBS&J 2008). This area is an important focus because its reefs are close to an intensely developed coastal region, with a large and diverse human population. No coordinated management existed for the natural reefs north of the Florida Keys and Biscayne National Park. (See Section 1.5 for contact information.) The SEFCRI actions are in response to a variety of broad threats to coral and other marine resources, such as land-based pollution and overfishing, and are ultimately working with local stakeholders towards developing a coordinated management plan for the southeast Florida coral reef and hardbottom resources.

Various species of coral in southeast Florida constitute a "keystone" of the marine environment, whereby many fishes and invertebrates—including snapper, grouper, and spiny lobster—depend on them as habitat for growth and reproduction (Figure 1.4). And, natural reef-related expenditures by anglers, divers and others during June 2000-May 2001 generated $357 million in sales in Palm Beach County, $1.1 billion in sales in

Broward County, and $878 million in sales in Miami-Dade County (Johns et al. 2001). These sales resulted in $142 million in income to Palm Beach County residents, $547 million in income to Broward County residents, and $419 million in income to Miami-Dade County residents. In turn, the expenditures supported 4,500 jobs in Palm Beach County, 19,000 jobs in Broward County, and 13,000 jobs in Miami-Dade County. (Note that Johns et al. (2001) also report data for artificial reefs, which add another significant economic contribution.) Meanwhile, recent damage to coral reefs stems from vessel groundings, pollutants, and other marine construction efforts such as sand dredging. Beyond the region, according to the Florida Department of Environmental Protection (FDEP), *"Coral cover on many Caribbean reefs has declined up to 80% over the past three decades… Monitoring data from 105 stations in the Florida Keys… revealed a 44% decline in coral cover from 1996-2005."*

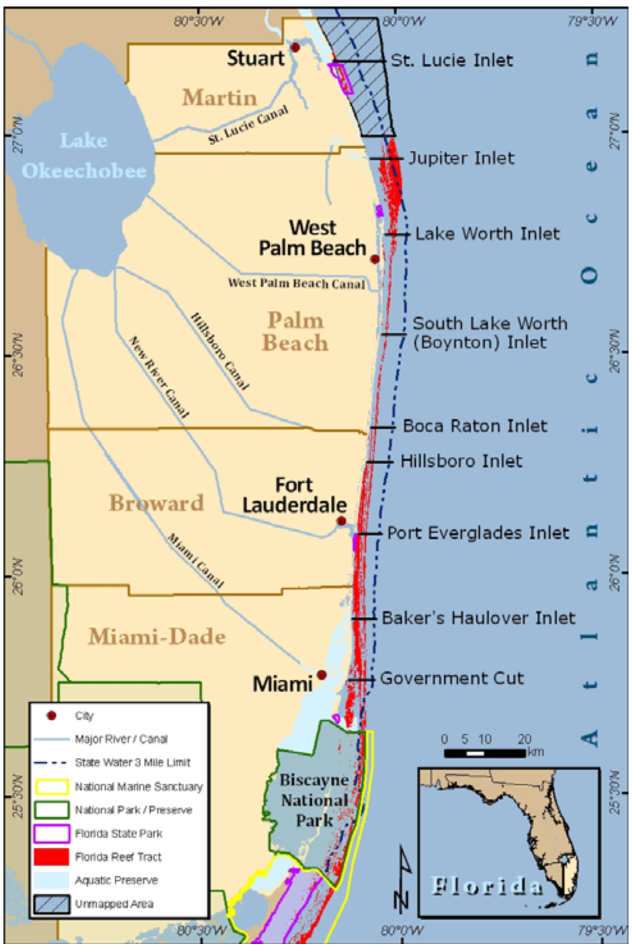

Figure 1.4. Extensive tracts of coral reef run along the nearshore waters of southeast Florida, and are a valuable ecological resource that supports diverse populations of fishes and invertebrates (Map courtesy of FDEP CRCP).

In a narrow sense, this document is a response to impacts to southeast Florida's coral reef ecosystems associated with coastal construction and maritime industry, such as navigation, beach renourishment, telecommunication cables and artificial reefs.

These activities can result in intentional and unintentional impacts that change marine populations and/or reef-community structure. Appropriate mitigation and restoration is needed to repair the adverse effects of permitted or non-permitted activities on coral resources. Therefore, there is a need to evaluate and promote stable, durable, and environmentally appropriate artificial reef construction without adversely affecting natural marine habitats.

More broadly, this document responds to the expressed need of artificial reef program managers for a compilation of technical information as a single source and handy reference for artificial reef development. Additionally, there are many practical aspects of artificial reef development that local county reef coordinators have learned from experience that until now have not been compiled. This document organizes existing references together with local knowledge to develop a practical guide for artificial reef development in southeast Florida, and beyond. However, it should not be considered a definitive handbook as practices may be refined over time and full coverage of some topics (e.g., reef ecology and monitoring) is beyond the scope of one document.

The participants in artificial reef development in southeast Florida represent a remarkably broad "who's who" among coastal interests. Stakeholders include recreational anglers and associated businesses, federal, state, and local governments, tourism and economic development interests, recreational and commercial scuba divers, commercial hook-and-line and trawl fishermen, academia, volunteer reef research and monitoring groups, artificial reef module manufacturers, marine contractors, environmental organizations, and the media. Strong linkages and partnerships leverage their resources.

Figure 1.5 depicts three broad categories of stakeholders: Sponsors are those involved in artificial reef planning, building, and monitoring. They vary from individuals, to organizations, to research institutions, but primarily involve local coastal governments as the driving force behind artificial reef planning, construction and monitoring. Regulatory organizations include federal, state, and local agencies involved with issuing permits and responsible for final inspections of artificial reef materials to ensure compliance with the law. Support for project sponsors and regulatory agencies comes from agencies that provide comment and technical guidance during the planning and permitting phase (non-regulatory entities), organizations that provide monitoring support, volunteers, and entities that provide funding and/or materials for artificial reef construction.

The primary audience for this document is expected to have a basic understanding of artificial reefs (and hopefully at least the basics of marine ecology), general environmental permitting, and marine contracting. Published references, website links and contact information are provided throughout the chapters for readers seeking more background or additional technical information.

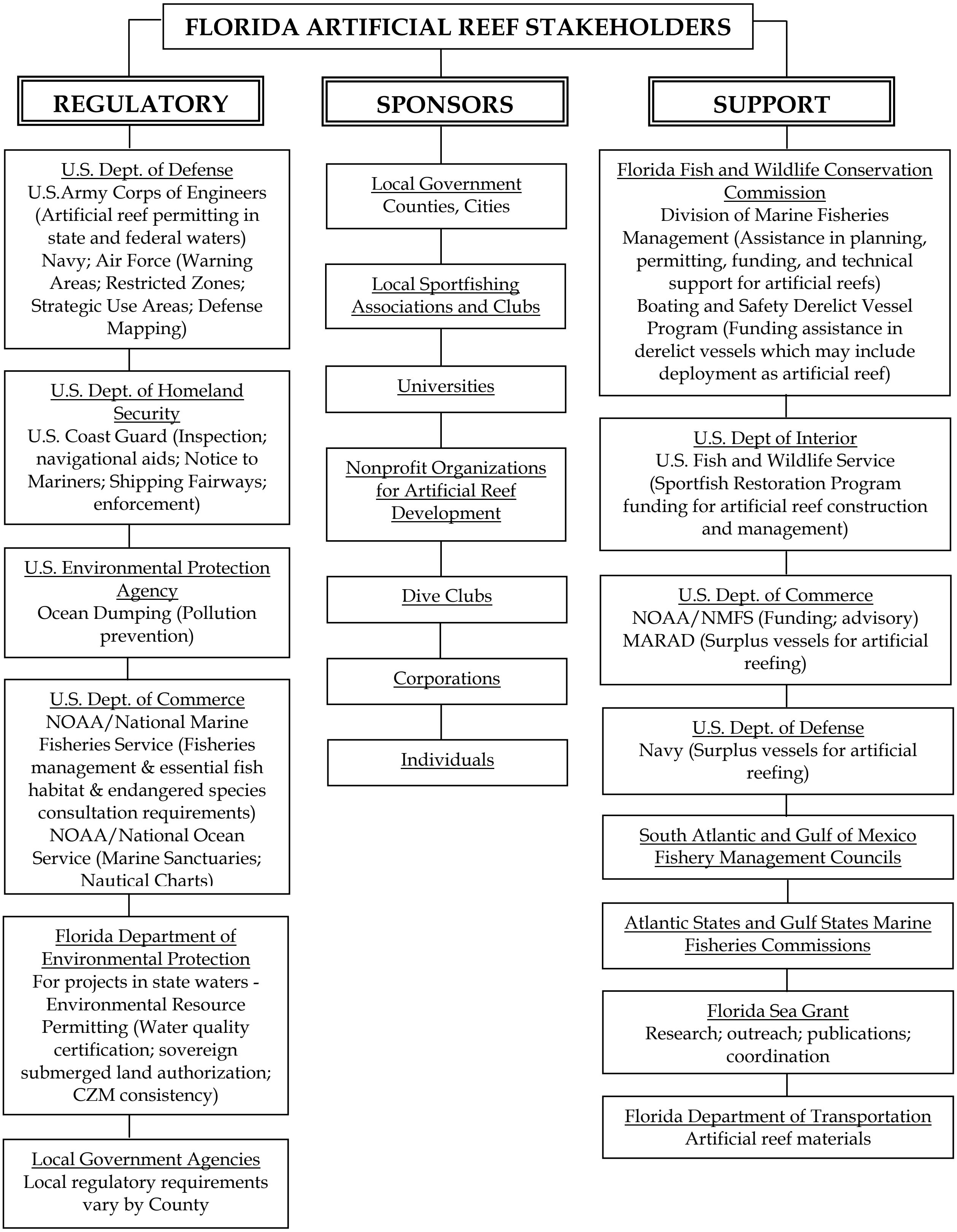

Figure 1.5. Florida artificial reef stakeholders (Courtesy of Florida Fish and Wildlife Conservation Commission).

1.2 Artificial Reefs in an Environmental Context

An artificial reef is a structure intentionally placed on the ocean bottom to achieve biological but also socio-economic or engineering purposes of one or more stakeholders. The structure may be of natural or manmade materials, deployed at one time or over a long period, and ideally will serve as habitat that functions as part of the natural ecosystem, while doing "no harm." In southeast Florida, artificial reefs exist offshore in Miami-Dade, Broward, Palm Beach and Martin counties.

Worldwide, artificial reefs are used in over 50 nations. While the traditional aim in Florida and the United States has been to boost recreational fishing success, newer applications in this country and especially overseas are meeting with success. For example, artificial reefs in Korea are deployed as part of a marine ranching system wherein juvenile fish reared in hatcheries are released at reefs constructed to accommodate behavioral preferences of fish species for varying closed and open spaces. The pilot studies to restore kelp forests off California using granite boulders are now being scaled up as the largest such project in America. In Hong Kong, reef modules are being deployed as part of an ecosystem recovery program. A different form of environmental management is practiced in European countries bordering the Mediterranean Sea, such as Spain, where large structures are placed on the seafloor to protect seagrass meadows from illegal trawling. Japan is well known for its long-term investment of billions of dollars in a national artificial reef program to sustain production of seafood species such as abalone and fish, for which the engineering and precise placement of large offshore structures has been important. Deployment of obsolete naval vessels in western Canada has created a major sport diving industry. Finally, in Italy and Portugal research lasting as long as three decades has led to sustained artisanal fishing at artificial reefs that contribute to local economies at the community level.

Research by biologists, engineers and economists, among others, has in the last 30 years helped to guide a technology that has been evolving for centuries. Description of at least some aspects of the ecological structure and function of artificial reefs has been developed by numerous observational programs worldwide, while more recent experimental efforts are starting to explain some of the dynamics of how these objects can function much like natural reefs such as coral and rocky outcrops. (See Chapter 2 for additional information. Further reading is given in the References section at the end of this document.) The economic activity generated by the artificial reefs in Florida was summarized by Adams et al. (2006), who reported that non-residents and visitors in four southeastern counties annually spent $1.7 billion on fishing and diving activities associated with artificial reefs. Of the total expenditures, Broward, Miami-Dade and Palm Beach counties contributed 53%, 25% and 11% of the total, respectively.

Artificial reefs are included to varying degrees in the natural resource, ecosystem and fisheries management efforts of governmental agencies; sometimes as a mainstream effort, sometimes as almost an afterthought. Guidance for artificial reef development in the United States can be traced back to the National Fishing Enhancement Act of 1984, which resulted in the 1985 National Artificial Reef Plan (NOAA Technical Memorandum, NMFS OF-6, 1985; updated in 2007). The plan set national standards and guidelines for permitting procedures, siting, constructing, monitoring and managing artificial reefs in U.S. coastal waters. Since then there have been a variety of regional, state and site-specific artificial reef plans produced, including the Atlantic and Gulf States Marine Fisheries Commissions' "Coastal Artificial Reef Planning Guide" (1998) and the "Guidelines for Marine Artificial Reef Materials" (1997, updated in 2004). State of Florida milestones include three documents: the "Florida Artificial Reef Development Plan" (1992), "Environmental and Fishery Performance of Florida Artificial Reef Habitats: Guidelines for Technical Evaluation of Sites Developed with State Construction Assistance" (1992), and the "Florida Strategic Artificial Reef Plan" (2003).

1.3 Artificial Reefs in a Resource Planning Context

Table 1.1 lists 52 questions that should be part of any reef planning process. While at first glance this may seem a daunting set of issues, consideration of them ahead of the long and expensive process of actual reef construction, maintenance and monitoring actually will make for a more economical and efficient process over time.

Briefly, reef planning (Figure 1.3) will begin with formulation of a reef concept, such as enhancing recreational fishing or diving or environmental conservation. Concurrently, the stakeholders must consider the ecosystem where they would like to deploy an artificial reef and how that environment will be affected by the introduction of new structure(s). Only after these considerations are resolved should formal, specific and measurable objectives for the new reef be defined, such as generating certain levels of fishery harvest or economic returns. The reef planners will then formulate a design for the structure, first by taking into account the life-history and ecology (e.g., shelter, reproduction, feeding, movement) of species in the ecosystem; then adapting for example, fabricated modules of concrete or natural materials such as limestone boulders; and then applying for appropriate regulatory agency permits in which a myriad of construction, liability, maintenance, and monitoring requirements are specified. Actual reef construction will be accompanied and followed by monitoring for compliance with permits and also longer-term performance toward meeting project objectives. Finally, reef project managers must continually provide information about the reef to stakeholders, and be on top of management of the reefs in the larger land and seascape of social, economic, and environmental factors in their geographic area.

Table 1.1. Checklist of key questions and essential information for planning and implementing artificial reef development best practices.

Planning Component and Primary Question	Key Questions to Consider
Concept: The initial idea for a reef, and the brainstorming to judge its soundness. Is the concept of the reef valid and realistic?	Is a legitimate interest expressing the concept? What is the motivation for reef-building? What in the ecosystem will be enhanced? Who will benefit from the reef?
Ecosystems: The interaction of a new structure and the natural environment, at all scales of landscape. How will the artificial reef and the existing ecosystem interact?	How will the ecosystem "respond" to the reef? What ecological processes will be modified by the reef? What applicable scientific studies exist for the area and species of concern?
Objectives: The reason(s) for building the reef, in very specific "who, why, what" terms. What are the rational and measurable purposes of the reef?	What is the specific objective of the reef? Who is going to use the reef, and how? What are the expected biological, physical, economic, social and political outcomes of the reef? Can the expected outcomes be measured?
Planning: The approach for turning the concept into reality; design prerequisites. Who, and how skilled, is the reef architect?	Who is the overall planner (and permit holder) of the reef? What is the overall plan for the reef? What are the qualifications of the architect? What is the timetable for the overall project?
Design: The technical specifications of the reef as dictated by its purposes and its environmental setting. What is an ecologically valid reef design?	What is the broader "landscape" context into which the reef is introduced? What is the existing social, economic and cultural setting into which the reef will be placed, and how compatible will it be? What will the reef look like? What is the biological and technical basis for the physical shape, size, orientation, complexity and material of the reef? How does the reef design meet the reef's objective(s)? How does the reef meet life-history requirements of reef species? How will the reef interact with and influence the ecosystem and its natural structure and ecological processes? What is the site plan for the reef? What pilot studies or other information are available to guide reef design?

Table 1.1, continued.

Planning Component and Primary Question	**Key Questions to Consider**
Construction: The "nuts-and-bolts" aspects of deployment of the reef. What are the best practices for building a stable and productive reef?	What past experience with this type of reef is available for guidance? Who will sponsor the project? Who will fund the project? How will construction and deployment affect the environment? What site selection and preparation is planned? What are the composition, size, design, engineering basis and construction methods for the reef? Where are reef materials obtained? What are the on-site deployment practices for reef materials? How durable and stable are the reef materials? What kind of staging area is to be used? What are the qualifications of the contractor or construction group? What will the project cost? What regulatory, legal and permitting requirements must be satisfied in order to build the reef? What kind of inspections of reef stability and integrity will be made of the reef? What maintenance of the reef is planned? What is the expected lifetime of the reef?
Use and Management: Sustainable allocation of resources. How is the reef to be managed sustainably, and all stakeholders/users engaged in that process?	Who are the audiences that will use the reef? Is there a plan to manage the levels of reef use? Is active management of reef use needed? Are any research and education projects planned for the reef site?
Evaluation: Measuring the "pay-off" from the reef as it meets the original objectives. How is reef performance determined?	What is the overall plan for evaluating reef performance? What are the methods for ecological evaluation? What are the methods for physical/engineering evaluation? What are the methods for social and economic evaluation? What is the plan for managing, analyzing and reporting technical data from reef performance studies?
Information Management and Communications: Providing high quality information about the reef. How will all stakeholders be kept informed of the reef status and descriptions of it?	What scientific data processing and management protocols will be followed? Is there a central point of contact for communications? How will the reef be publicized?

1.4 Best Management Practices and Acceptable or Customary Management Practices Concerning Artificial Reefs

To the degree possible this report aims to provide the most reliable and current practices for reef development, based principally on the knowledge and experience of the contributors as they have worked in southeast Florida. However, because the technology and science is relatively young and still evolving, some of the information presented in the following chapters is more based on traditional practices in widespread use. We make this distinction to indicate the dynamic nature of the subject, and also to indicate the room for improvement of techniques. This document represents the first attempt, as far as can be determined by the sponsors and authors, to provide a comprehensive set of technically valid methods for artificial reef development.

Best Management Practices attempt to give structure to common sense, practical experience and accumulated wisdom through written presentation of guidelines and techniques that have a solid basis in fact. Examples in the wider scientific/ environmental world include longstanding applications to water pollution control and forest management, and newer applications in wetlands restoration and aquaculture production systems. An existing best practices document related to artificial reefs focuses on preparation of vessels for sinking (USEPA 2006).

For purposes of this report, a "Best Management Practice," or BMP, is defined as a specific method or a more general course of action intended to guide objective and responsible development of artificial reefs on the sea floor, whether near or far away from coral reefs, based on validated scientific knowledge and appropriately tempered by professional experience and judgment. When applied to reef planning, design, siting, construction, use, management and related aspects, BMPs will foster positive ecological, physical and socio-economic performance of artificial reefs. Thus, the intent of a reef-related BMP is to prevent or minimize adverse impacts of artificial reefs on southeast Florida coral ecosystems, while enhancing their conservation and restoration when possible.

In the following chapters, guidelines may be as concise as a sentence, or longer, depending on the situation addressed. Following the guidance, and drawing upon appropriate sources of background information as necessary, an applicant should be able to develop a permit that reflects sound technical procedures concerning all phases of artificial reef development (Figure 1.3). Information needs of the stakeholders recognized in Figure 1.5 (and addressed in the chapters indicated) include:

- Asking the right questions before starting an artificial reef (Chapter 1)
- Historical background, trends and applications (Chapter 2)
- Ecological function of artificial reefs (Chapter 2)
- Administrative aspects (Chapter 3)

- Planning (Chapter 4)
- Design (Chapter 5)
- Permitting (Chapter 6)
- Pre- and post-deployment (Chapter 7)
- Buoys and marking (Chapter 8)
- Maintenance and monitoring (Chapter 9)
- Compensatory mitigation (Chapter 10)
- Vessels (Chapter 11)
- Communications (Chapter 12)

Complete information for publications cited in this document is given in the References section.

1.5 Contact Information

For additional information about the Southeast Florida Coral Reef Initiative (SEFCRI), its mission and local action strategies, please visit the website: http://www.southeastfloridareefs.net/

For additional information about FDEP's Coral Reef Conservation Program (CRCP), which also contains information about SEFCRI, please visit the website: http://www.dep.state.fl.us/coastal/programs/coral/

Chapter 2. Environmental and Management Context for Artificial Reefs in Southeast Florida

Artificial reefs in southeast Florida are an established part of the undersea landscape, especially due to their use in fishery situations dating from the 1940s (Pybas 1997). This chapter provides an overview of the regional history and a summary of broadly applicable management and ecological considerations in artificial reef program planning and execution. The intent is to give the reader an appreciation for the level of detail and care necessary for artificial reef development, as emphasized throughout this document, particularly as related to coral reef ecosystems.

2.1 What Constitutes an Artificial Reef?

It is essential to have a clear understanding of what an artificial reef is and how it functions. A first step is to have consistent terminology to describe the different tiers of artificial reef development. A succinct definition of an artificial reef can be found in Seaman and Jensen (2000, p.5): *"An artificial reef may be described as one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological or socioeconomic processes related to living marine organisms."* The different tiers describing artificial reefs range in scope and complexity from a single individual artificial reef unit or materials deployed together, to a cluster of multiple individual artificial reef units or materials, to an area or region composed of a complex of multiple artificial reef clusters.

Different terms can be used when describing artificial reefs which lead to problems in data tracking and communication. For example, the state of Alabama purports to track (Cowan et al. 2010) every individual piece of material, regardless of its proximity to other materials, resulting in a very large listing of artificial reefs within a limited area. In Florida, artificial reefs are tracked at three different levels by the Florida Fish and Wildlife Conservation Commission (FWC) (Figure 2.1). The lowest and most detailed level is termed an artificial reef "*deployment.*" This level of detail generally describes materials that are deployed as a single pile, whether on the same or on different days. The next level describing artificial reefs is termed the "*reef.*" The *reef* is a *deployment* or a cluster of *deployments* within 150 ft of each other. The *reef* may contain multiple *deployments* placed during the same or different days. While artificial reef managers are interested in tracking each individual artificial reef deployment, the public is generally only interested in tracking a single centermost feature of a cluster of materials. The third, and broadest term used in artificial reef management is "*permit area.*" The *permit area* is the area of seafloor, generally rectangular or square, authorized for artificial reef construction by the regulatory agencies [i.e., U.S. Army Corps of Engineers (USACE) and/or FDEP]. The *permit area* is typically illustrated on the National Oceanographic and Atmospheric Administration (NOAA) nautical charts as a "blued-out" shape, often labeled as 'Fish Haven.' While other terms are commonly used to designate artificial reefs, it is nevertheless important to clearly communicate an artificial reef's scope in terms of location and proximity of materials.

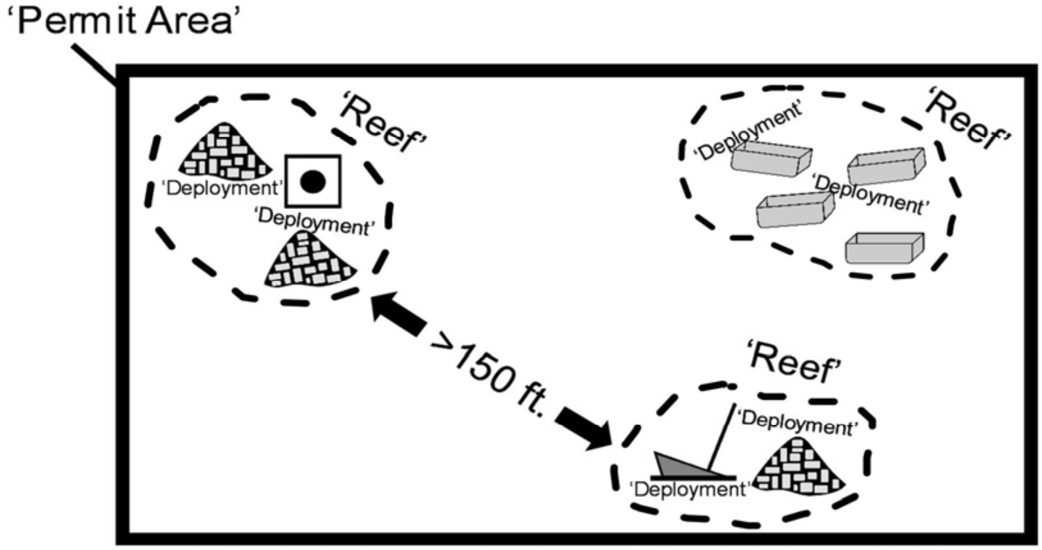

Figure 2.1. Three terms used to describe the different levels of artificial reefs by the FWC, from largest to most specific: "Permit area," "reef" and "deployment" (Figure modified from Grove and Sonu 1985).

2.2 Fisheries and Artificial Reefs in Southeast Florida: Status, Trends, Historical Issues

Artificial reef technology had its beginnings centuries ago, when fishermen sank assorted objects in lakes and seas to attract fish for easier harvesting. They had learned through experience that fishing efforts were more productive near floating debris or above bottom structures such as submerged logs, rocky ledges or shipwrecks. Although we still have much to learn, today's reef technology is based on a better understanding of the roles artificial reefs play in the marine environment. This section provides a brief overview of southeast Florida's natural reef and hardbottom fisheries, and also trends for artificial reefs, followed by discussion of the concepts of artificial reefs as both components of the marine ecosystem and as management tools to enhance fisheries.

2.2.1 Artificial Reefs in Florida

In accordance with Chapter 379.249(5) Florida Statutes (F.S.), the FWC tracks all artificial reef deployments off Florida, in both state and federal waters. In 2006, Delaney and Mille reported 448 permit areas statewide, with an average size of 1.48 square nautical miles (nm^2), ranging from 48.44 square feet (ft^2) to 98.09 nm^2. As of April 2010, the FWC listed 2,598 artificial reef deployments statewide (FWC Artificial Reef Program Website). Of the material types deployed statewide, concrete secondary-use materials dominate (43%), followed by concrete modules (24%), steel materials such as steel towers and military equipment (17%), steel vessels and barges (11%), natural rock (primarily limestone boulders) (3%), and other miscellaneous materials (including historic materials such as tires, wooden boats, or other materials which are no longer used or permitted) (2%). Florida waters hold more artificial reefs than any other state.

2.2.2 Artificial Reef Trends in Southeast Florida

As of April 2010 within the southeast Florida region (Miami-Dade, Broward, Palm Beach, and Martin counties), FWC records show a total of 445 artificial reef deployments reported since 1947. Material types deployed within the region include steel vessels and barges (49%), secondary-use concrete (19%), concrete modules (14%), natural rock (8%), miscellaneous steel (7%), and other miscellaneous materials (3%) (Figure 2.2.A). The average depth of artificial reefs is 101 feet (ft) with a minimum depth of 7 ft (concrete culvert estuarine artificial reef deployed in Miami-Dade County), and a maximum depth of 414 ft (steel barge artificial reef deployed in Broward County) (Figure 2.2.B).

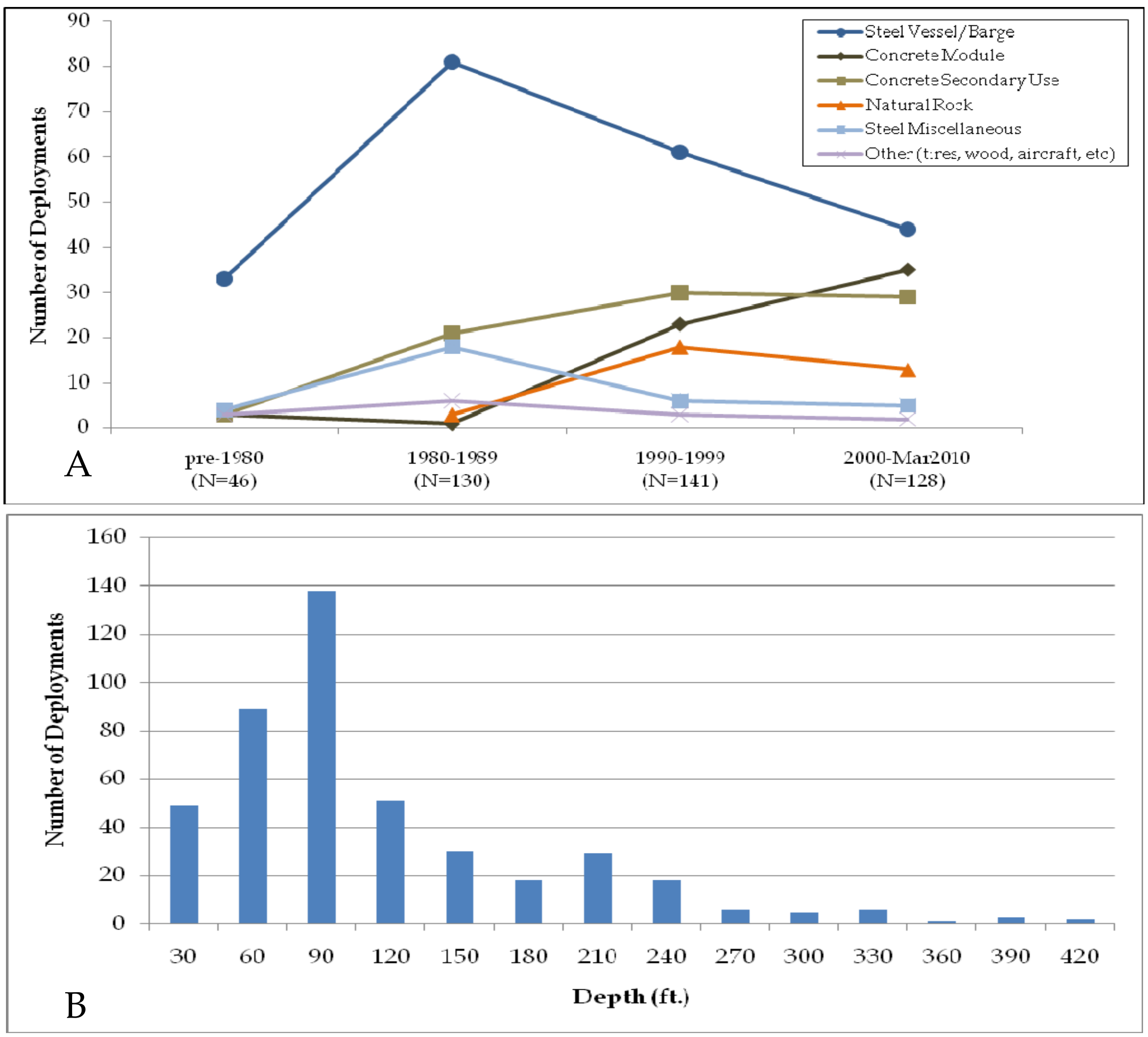

Figure 2.2. Trends over time for artificial reef materials used in southeast Florida (A), and depth distribution of artificial reefs in the region (B) (Charts courtesy of FWC).

Since 1985, the rate of deployment within the southeast Florida region is about 12.8 per year; the fewest was in 1979 with two deployments, and the most in 1991 with 24. A dramatic increase in artificial reef deployments beginning in the early to mid-1980s coincided with the inception of state and federal financial assistance for reef development, including State of Florida General Revenue funding (1980-1990), Federal Sportfish Restoration Program funding (1986 - present), and State of Florida Saltwater Fishing License funding (1989 - present). The gradual decline in the average number of deployments since 1985 can generally be attributed to the funding sources not keeping pace with the increased cost for offshore marine construction. For example, the cost to prepare, tow, and deploy a steel vessel during the 1980s in southeast Florida generally cost around $4,000-$10,000, but during 2010 the cost is averaging around $10,000-$80,000.

In southeast Florida steel vessel and barge deployments continue to represent the greatest number of artificial reef deployments. Since the 1980s there has been a decline in the number of steel vessels and barges deployed as artificial reefs as a result of increased costs to clean and prepare vessels as well as increased value of scrap steel.

Secondary-use concrete has historically been the second most common artificial reef material in southeast Florida. This includes concrete culverts, concrete bridge material, concrete pilings, concrete railroad ties, and other concrete materials. Commonly referred to as "materials of opportunity," secondary-use concrete generally represents selected materials generated at construction demolition sites or at concrete manufacturing plants that are damaged in some way and/or no longer meet minimum load-bearing specifications for their primary purpose of terrestrial construction, be it stormwater lines, power poles, or bridge spans, etc. Historically, such materials would have had no value as construction material and been shipped to a landfill. During the 1990s and 2000s, concrete recycling became more prominent and today, large, portable concrete crushers are readily available for use directly at construction sites, reducing the cost-savings incentive for donations of secondary-use concrete for artificial reef construction. As a result, the use of secondary concrete for artificial reef construction has reached a plateau in southeast Florida. Reduced use may be expected in future years.

Concrete modules have seen a dramatic increase in southeast Florida since the 1980s. While there generally is a higher cost per ton associated with designed modules, the ability to manipulate design parameters affords numerous benefits for fisheries research as well as practical construction and deployment considerations. They are easier to transport and deploy. Palm Beach, Broward, and Miami-Dade counties have used designed mitigation modules to offset impacts to natural reef habitat caused by activities such as telecommunications cables, vessel groundings, and dredging.

Natural rock, primarily limestone boulders, has increased in use for artificial reef construction in southeast Florida, especially in construction of numerous nearshore mitigation reefs to offset the impacts of natural nearshore hardbottom buried by beach nourishment activities. The natural surface rugosity of limestone continues to be a preferred material type, especially in the context of coral settlement.

Miscellaneous steel has declined in use. With minimal complexity, it does not provide much benthic habitat. Its primary use has been in the form of steel towers for creating fishing opportunities for pelagic fish species. The increased recycle value of scrap steel has also resulted in its reduced use.

2.2.3 Historical Lessons Learned

Lessons learned in southeast Florida include the recognition that lightweight materials, such as tires, are inappropriate for artificial reefs in the region because of their propensity to be displaced and impact natural habitats, as well as their nominal biological value for reef development. The physical forces on sunken vessels during storm events have been documented to displace, break up or dislodge vessels or pieces of vessels to the detriment of adjacent reef resources. In some cases even high density materials deployed on softbottom without adequate foundation have been known to subsequently scour and become completely buried, especially in areas of strong current. Therefore, it is important for the artificial reef manager to realize that even projects completed with the best of intentions may result in long-term negative performance that was not expected. An excellent document on lessons learned for a variety of different material types is the “Guidelines for Marine Artificial Reef Materials” compiled by the Artificial Reef Joint Subcommittee of the Atlantic and Gulf States Marine Fisheries Commissions (Lukens and Selberg 2004).

Especially because of the sensitivity of the adjacent coral reef communities, it is critically important for artificial reef managers in southeast Florida to be aware of lessons learned, and maintain a high level of diligence and care when developing artificial reefs.

2.2.4 Socioeconomic Aspects of Artificial Reefs

The socioeconomic aspects of artificial reefs have been well studied in southeast Florida, and the anticipated regional economic benefits are often included among the primary objectives for artificial reef development. Artificial reef development creates recreational opportunities that attract fishing and diving enthusiasts, generating tourism, local spending, and job creation, and stimulating the economy, both locally and beyond.

From the national perspective, "The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation," produced about every five years by the U.S. Fish and Wildlife Service (USFWS) Wildlife and Sport Fish Restoration Program, provides a broad overview of the status and trends of fishing in the United States, and highlights the national significance of recreational angling in Florida. Anglers in Florida represent 27% of the total trips, 27% of resident trips, and 28% of nonresident trips in the United States (USFWS 2007). Florida accommodates the greatest number of angler trips in the nation, which is 52% greater than Texas, the second-most abundant state for anglers in the United States (Figure 2.3).

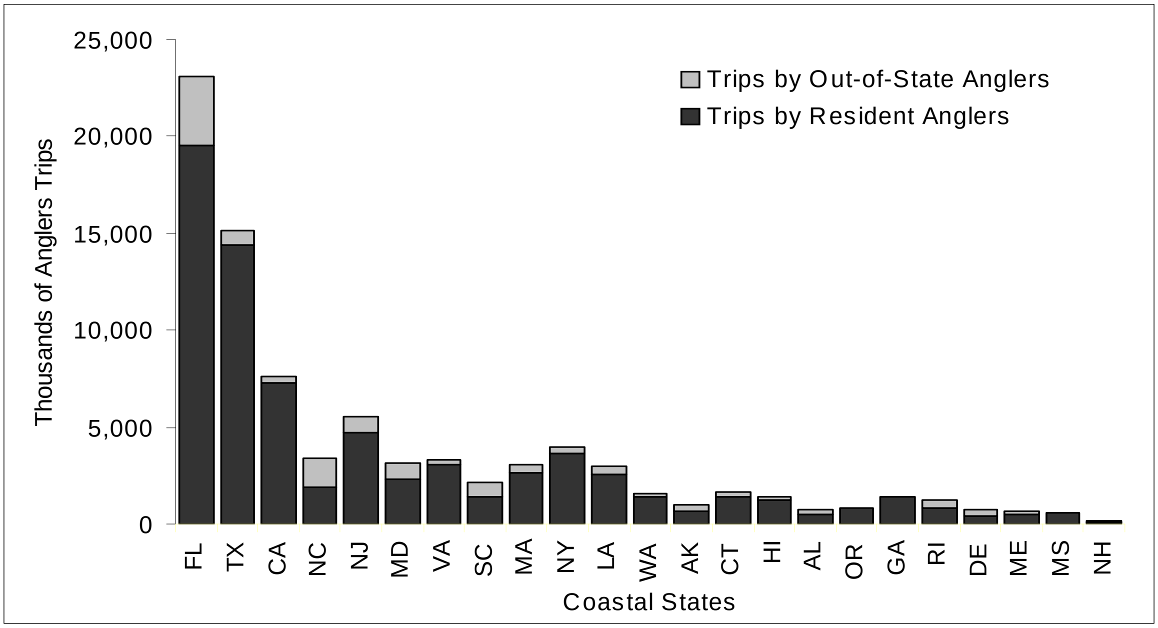

Figure 2.3 Number of saltwater fishing trips by coastal state in 2006 (USFWS 2007).

In 2008, to focus long-range planning for the future of Florida's wildlife and fisheries in response to projected human population growth and climate change, the FWC completed a report titled "Wildlife 2060: What's at Stake for Florida?" (Cerulean 2008), which provides a broad overview of trends in population growth and fishing pressure in Florida (Figure 2.4). While there is uncertainty associated with such long-range predictions, simply being aware of historical trends, contemplating future needs and limitations, and characterizing user groups are all important items for resource managers to consider as components of long-range strategic artificial reef planning. Information that artificial reef managers and stakeholders should be aware of includes the number of registered vessels, available from the Florida Department of Highway Safety and Motor Vehicles (http://www.flhsmv.gov/dmv/vslfacts.html), and the number of licensed saltwater fishermen, available from the FWC Office of Licensing and Permitting (http://myfwc.com/License/Index.htm).

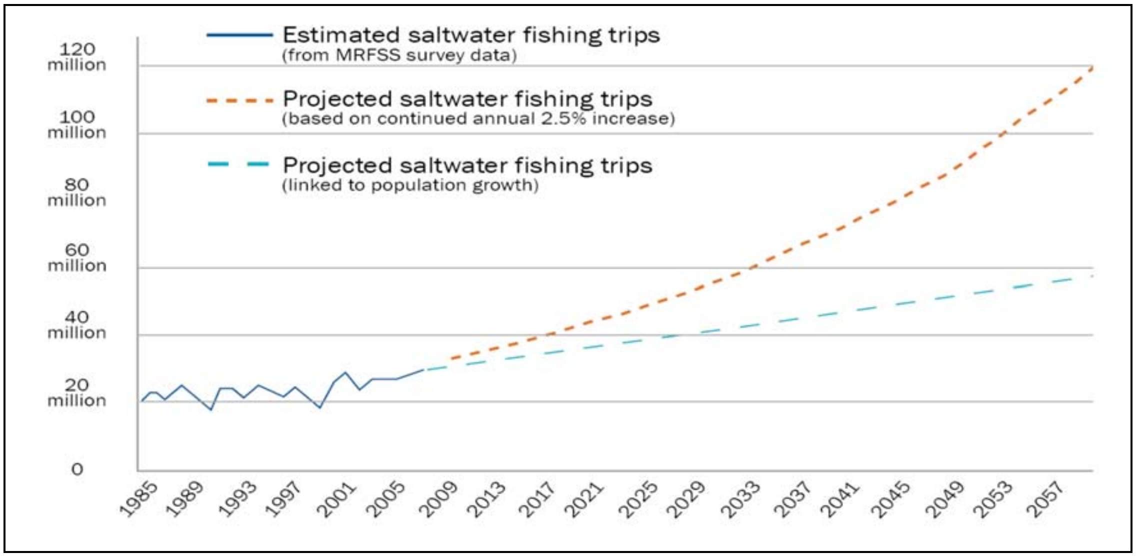

Figure 2.4. Projected saltwater fishing effort in Florida to 2060 (Cerulean 2008).

Artificial reefs also offer opportunities in southeast Florida for scuba diving, snorkeling, and glass-bottom boat excursions. These offer socioeconomic benefits from non-consumptive uses of the resource, sometimes referred to as ecotourism. In southeast Florida, with its warm waters and good underwater visibility, these uses of natural and artificial reefs are very important. More information about scuba diving and snorkeling interests can be found with the Diving Equipment and Marketing Association, a nonprofit organization created to help businesses in the scuba diving and action water sports industries.

In southeast Florida recreational activity (as quantified by "party-days" on natural and artificial reefs) is comprised of 53% fishing, 24% snorkeling, and 23% scuba diving, and these percentages are much the same for both natural and artificial reefs (Johns et al. 2001). Adams et al. (2006) provide an excellent overview of the different types of reef-related economic studies that have been completed throughout Florida. For southeast Florida a detailed regional socioeconomic study was completed by Johns et al. (2001) for Palm Beach, Broward, Miami-Dade, and Monroe counties, and a subsequent study of the socioeconomic aspects of reefs in Martin County was completed in 2004 (Johns et al. 2004). The Johns 2001 report is an important reference in requests for the necessary funding to support artificial reef development in southeast Florida.

Artificial reefs can be a successful means to help manage the human dimension associated with adjacent natural marine resources. For example, the "*Spiegel Grove*" is a 510-ft steel vessel deployed in 2002 as an artificial reef near Key Largo. Leeworthy et al. (2006) documented within the first 10 months following deployment successful reduction of diving pressure on adjacent natural reefs, with simultaneous increased visitation in the area.

Artificial reef managers should be aware of the artificial reef user groups in their region and the benefits each of the user groups brings to the community. Managers should also be able to effectively communicate and describe those benefits and uses to the associated industries, tourism development councils, environmental groups, stakeholders, and others who will either directly or indirectly benefit from the proper development of artificial reefs within their region. (See Chapter 12)

2.2.5 Overview of Southeast Florida Offshore Reef Habitats and Fisheries

Natural Reef Hardbottom Habitat

With the advent of new mapping technologies over the last 10 years, such as high-resolution laser and multibeam hydrographic survey methods, and side scan sonar, the locations and extents of natural coral reef and hardbottom habitat in southeast Florida--especially down to the 130-ft depth contour limit of surveys--are well known (Figure 2.5). Responsible artificial reef development includes the integration of artificial reefs in the region without impacting the natural coral reef and hardbottom system.

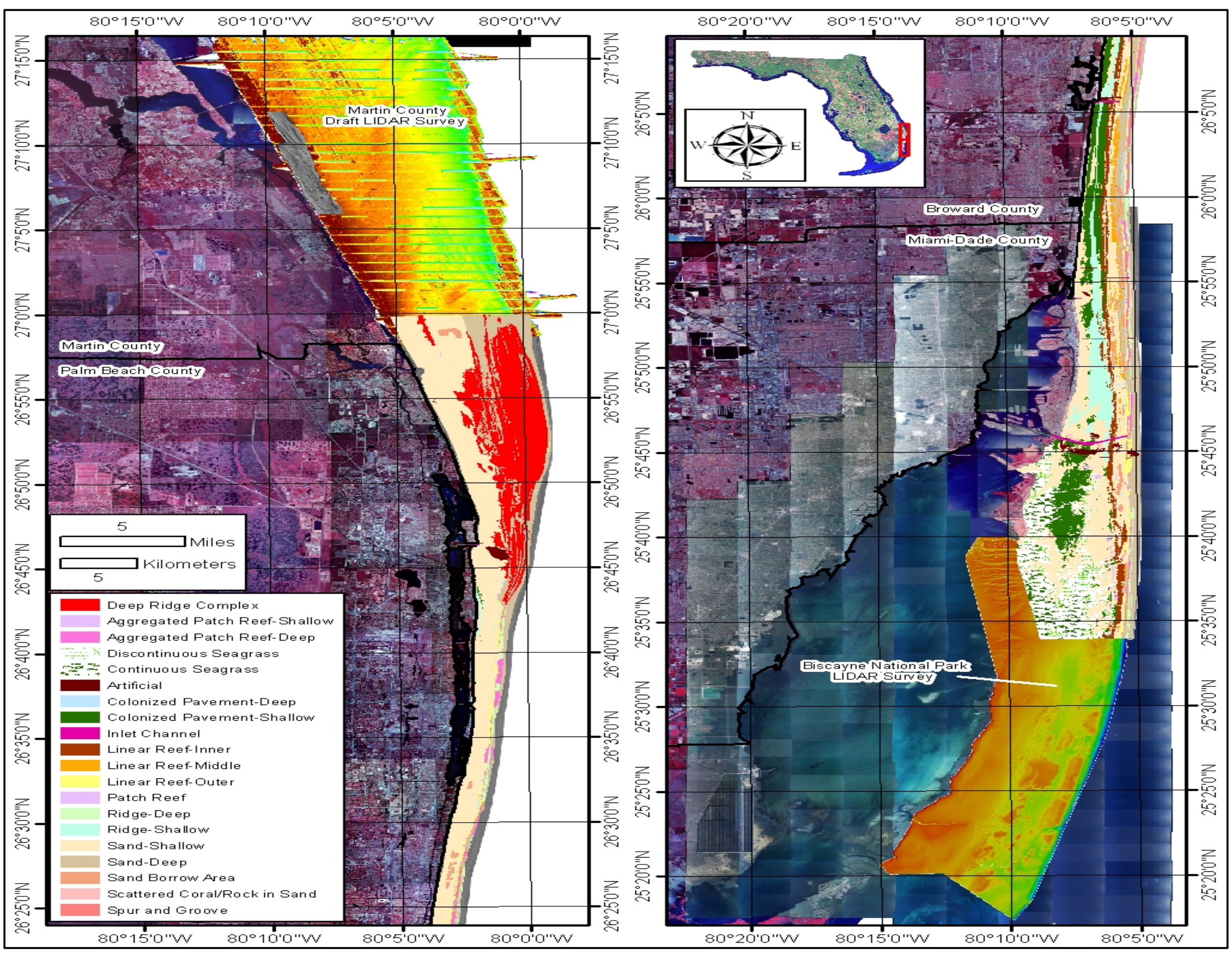

Figure 2.5. LIDAR maps showing the habitat distribution of coral reef resources in southeast Florida (Maps courtesy of FDEP CRCP).

Fishery Landings

A detailed discussion of reef and other fishery landings in southeast Florida (Martin through Miami-Dade counties) is provided by Johnson et al. (2007), who profiled all commercial and recreational marine fisheries data for 1990 through 2000. They found that mean total annual landings for all fisheries (reef fish, coastal, offshore pelagic, and invertebrates) was 21.4 million lbs/yr (range 17.7 - 26.9) and consisted of 66% recreational, 31% commercial, and 3% headboat landings. Total finfish landings significantly declined 22% (23.2 to 18.1 million lbs) over the study period. (Editors' note: Cause of decline not indicated.)

For reef fishes alone, Johnson et al. (2007, p.1) found that *"total annual landings over the 11-year study period from all sectors averaged 4.8 million pounds and were composed of 68% recreational, 5% headboat, and 27% commercial landings. No significant trend was detected in total annual reef fish landings for the recreational fishery (mean = 3.3 million lbs/yr), between 1990 and 2000. Significant declines were detected for both headboat (-65%; 0.3 to 0.1 million lbs) and commercial sectors (-56%; 1.74 to 0.8 million lbs). Total annual headboat reef fish landings declined in response to a 48% reduction in the number of angler days between 1990 and 2000 and a 60% decline in catch per unit effort (CPUE) (lbs/angler/day) since 1993."*

It is clear that recreational fishing may have a strong influence on reef fish populations. Artificial reefs are well publicized, generally easy-to-find locations that are especially popular among new boaters and fishermen. The artificial reef manager should consider the fisheries management implications of artificial reef construction in consultation with the South Atlantic Fishery Management Council (SAFMC) and FWC, especially as it relates to the exploitation of overfished reef fish stocks. While there may be strong economic benefits to the ease of access and increased catchability of reef fishes at certain artificial reef types and locations, artificial reef managers should consider the fisheries management trade-offs that may be associated with artificial reef development in their long-term artificial reef and fisheries management decisions. Understanding the status of marine fish populations is critical to this evaluation. In the absence of artificial reefs constructed in closed areas (or lack of enforcement in those areas), traditional fisheries management rules (e.g., size and bag limits, closed seasons) will continue to be necessary to properly manage the regional fishery. Table 2.1 provides a number of excellent online resources concerning the status of reef fish fisheries.

Table 2.1. Online information sources for reef fish fisheries.

South Atlantic Fishery Management Council, Fishery Management Plans http://www.safmc.net/Library/FisheryManagementPlansAmendments/tabid/395/Default.aspx
NOAA Southeast Fisheries Science Center, Southeast Data, Assessment, and Review (SEDAR) Process http://www.sefsc.noaa.gov/sedar/
FWC-Fish and Wildlife Research Institute (FWRI) Finfish Stock Assessments http://research.myfwc.com/features/category_sub.asp?id=4587
FWC-FWRI Species Accounts http://research.myfwc.com/features/category_sub.asp?id=2394
NOAA Fish Watch http://www.nmfs.noaa.gov/fishwatch/

2.3 Ecological Functions of Artificial Reefs in the Fishery

The purpose of this section is to consider how artificial reefs function ecologically, particularly how reef-dwelling organisms use the habitat provided. A good way to begin is to think of artificial reefs in the absence of directed fishing pressure. What is it about the habitat that benefits the reef organisms? These organisms include microbes, plants, invertebrates, and fishes, which collectively contribute to the biodiversity of an area. With a better understanding of the habitat effects, one can better weigh artificial reefs' function as habitat versus their function as fishing gear. Note that in overfished populations, as is the case with many of the reef fish species in southeast Florida, habitat effects are often swamped by the fishing effects. Fundamentally, reef-associated organisms including reef fishes may use habitat with respect to reproductive resources, food resources, and shelter resources.

2.3.1 Reproductive and Life-History Functions

Observationally and anecdotally a broad range of fish species including sheepshead, Goliath grouper, common snook, and lemon sharks (*Archosargus probatocephalus, Epinephelus itajara, Centropomus undecimalis*, *Negaprion brevirostris*, respectively), may use prominent reef structures—including artificial reefs—as locations for seasonally concentrated mating activity. These species are repeatedly observed at reef structures in significant numbers during times in their reproductive cycle when they should be mating, and those aggregations are not prominently observed during non-breeding periods.

It is likely that reproduction occurs in association with artificial reefs for a wide variety of fishes, just not as prominently as for natural reef habitats. Ecologically, while the reproductive function is undoubtedly important, it is not often a function specifically targeted by the design and placement of artificial reefs. An exception reported at the (2010) 9th International Conference on Artificial Reefs and Related Aquatic Habitats for Korea described a reef design to provide spawning substrate for egg attachment by mimicking the vegetation on which valued fish species spawn, so as to provide attachment sites to increase the reproductive output of a fisheries species (Chang Gil Kim, pers. comm.) Possible offshore spawning aggregations of the common snook on artificial reefs of St. Lucie County, Florida were indicated by a passive acoustic monitoring system recording sounds of snook spawning activity (Gilmore 2006).

In terms of the total life history, the use of habitat for mating contributes to the reproductive output. But how to "close the loop" in life cycles requires understanding connectivity in spatially staged-structured life histories (i.e., life stages occur at different locations). Even in coral reef systems, not all reef fishes demonstrate a simple bipartite life-history (i.e.., larvae strictly up in the water column and down on to the reef); therefore, it is important to understand the horizontal component across the marine landscape that may be temporally important in the life-history of a reef fish species (Mumby 2006, Habeeb et al. 2007). Understanding spatially staged life-history connections, horizontal connectivity, and proximity issues are all important considerations in artificial reef site planning and selection. Selection of artificial reef permit areas that will enhance the connectivity between coral reefs, seagrass beds, mangrove habitat, and the assemblage of reef fishes on coral reef patches is an important consideration in artificial reef design from the perspective of life history. Examples of species with spatially staged-structured life histories include spiny lobster (*Panulirus argus*), gag grouper (*Mycteroperca microlepis*), Goliath grouper, common snook, and a variety of coral reef fishes (e.g., Mumby and Hastings 2008).

2.3.2 Trophic Functions: Who Eats Whom

Benthic reef communities provide diverse food resources and accommodate feeding mechanisms for numerous species at multiple trophic levels in the food web (McClanahan and Branch 2008). Trophic relationships associated with artificial reefs are complex, and not every species found on an artificial reef is necessarily consuming food sources directly from the reef structure itself. Primary producers, which require ambient sunlight for photosynthesis, constitute the lowest level of a reef's food chain (e.g., Miller and Falace 2000). This group includes encrusting algae, nearby seagrasses, and free-floating phytoplankton. These plants serve as food for herbivorous consumers, which either graze directly on seagrasses or algae (e.g., sea urchins, crabs, lobsters, blennies, parrotfish) or filter-feed phytoplankton from the water column (e.g., zooplankton, oysters, corals, menhaden). These lower-level consumers serve as food for carnivores, with predators becoming prey to successively larger animals. One of the top predators - the fisherman - ultimately takes his share.

How the artificial reef functions with respect to food resources, tropho-dynamics, and bio-energetics depends on the adaptations of particular taxa. Sessile animals are dependent on localized conditions for their food resources and capture prey flowing through, to, or past the reef. Flow dynamics influenced by the reef structure will directly affect the food dynamics and contribute to the growth and performance of those sessile organisms. Similarly, the highly site-attached cryptic and small fishes, crustaceans, and motile invertebrates associated primarily with the turf community on the reef structure will forage primarily within that turf community and on the associated prey resources. Generally they will not expose themselves to the risk of foraging away from the structural complexity of the reef itself and the turf community growing on it. Ambush predators that associate with the reef and use the reef as part of their camouflage or concealment (e.g., toadfish) will opportunistically prey on organisms that come within their range. The more active foragers include the grouper/snapper complex - the primary reef-associated fisheries species of interest in southeast Florida. They will forage opportunistically at the reef, but primarily forage adjacent to and around the reef in a home range in which the reef itself functions as a focal point for shelter (discussed below) (e.g., Lindberg et al. 2006).

The prey resources that sustain the fisheries' important species are drawn from a much broader area than the reef structure itself (e.g. Parrish 1989, Graf 1992). The reef fishes while in residence may exhibit a home range in which they move in search of, or pursuit of prey. Therefore, given what is known particularly of the fishes that comprise the targeted fishery for an artificial reef, it would be inappropriate to consider the artificial reef structure simply as the foundation for the entire food web supplying all of the food resources for the fishes associated with that reef. Thinking of the artificial reef in the broader context of energy flow with respect to the actual food web recognizes that a substantial portion of the metabolic demand associated with artificial reefs is derived from non-reef sources.

2.3.3 Refuge Functions

For many, if not all, of the reef fish of recreational or economic importance, one of the ecological functions accomplished by reef development is to bring predator and potential prey into proximity with each other. This occurs by virtue of their adaptations to seek shelter and take up residence in areas of structural complexity so as to avoid either detection or direct predation. Thus, the balance of access to shelter and access to prey is manipulated. For those fishes occupying a central shelter or nodes of shelter within the landscape and then moving to forage, artificial reefs are affecting those movement dynamics in the short term and longer term and are affecting the trade-off between the use of the structural complexity and the access to prey.

It is important to emphasize that the physical structural complexity of the artificial reefs needs to be scaled to the body sizes of the organisms naturally occurring in the region, or the organisms desired to be occupants on the reefs. It is also important to note that with growth, as body size increases, the availability of suitable size cavities is typically diminished (Caddy 2007). When organisms are small there is an abundance of tiny spaces available, but as body size increases there is less available habitat for shelter. This is demonstrated in experiments with spiny lobsters, where their settlement habitat in the architecturally complex red algae (*Laurencia* spp.) in the inshore, or bay areas is extremely abundant and they can occur at low densities. Then they transition into the live-bottom communities at the base of sponges, and with time and growth have to undergo an ontogenetic shift out to the reef tract where there is a greater abundance of larger cavity spaces available for their daylight, or diurnal shelter requirements. The same process is essentially true for virtually all motile reef organisms, with the use of structure occurring during a time of day when predator avoidance is most evolutionarily important. For some species occupying structurally complex space will occur at periods during daylight;, other species might use shelter at night, or nocturnally. For some species the use of shelter will occur only when disturbed (episodic use). Red grouper will quickly dive into shelter when disturbed, and gag grouper will not really start moving into the cavity space at high densities unless they are imminently threatened (Loren Kellogg, pers. comm.).

The escape response of many reef-associated fishes is to move into the structural complexity upon the initial disturbance and then emerge as the threat passes, or with the passage of time so as to assess the threat. This is where the physical complexity of the reef structure (void space, cavity space, diversity of cavity space) determines the use by reef fishes seeking shelter. This is also why early Japanese work identified reef profiles above 1.5 m as wasted construction for demersal reef fishes, since there are diminishing returns in terms of benthic structure for their shelter function.

Meanwhile, pelagic fishes (e.g., jacks, mackerel, barracuda, amberjack) are transients that will use higher profile and more open structure. Transients are frequently and predictably associated with reef structure, but not necessarily utilizing the reef structure itself as their means of managing mortality risk. The transient species are likely visiting a number of structures, and not establishing residency associated with any one structure. The visitation of transient species is generally associated with their prey-seeking behavior.

There have been a number of excellent experiments studying the physical habitat complexity of artificial reefs (Hixon and Beets 1993, Eklund 1996, Sherman et al. 2002). Figure 2.6 illustrates just one of several experiments done by various authors establishing the importance of shelter in the selection of reef habitat by fishes. John Caddy's book titled "Marine Habitat and Cover: Their Importance for Productive Coastal Fishery Resources" elaborates how structural habitat functions and includes an extensive reference list (through about 2005) (Caddy 2007).

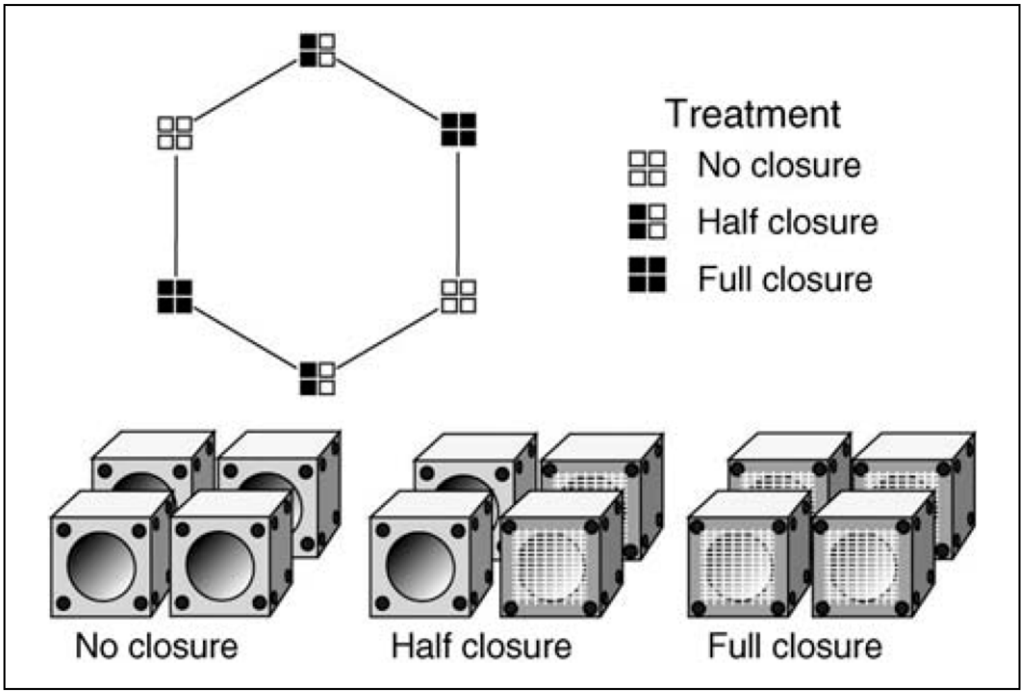

Figure 2.6. One of several experiments done by various authors establishing the importance of shelter in the selection of reef habitat by fishes (Lindberg et al. 2006). Spacing between clusters of reef sets varied from 25 to 225 meters.

2.3.4 Interaction and Tradeoffs between Habitat Functions of Food and Shelter

While it is easier for us to focus attention on one function at a time in order to understand how the reef functions, the reef organisms are adapted to integrate these functions and balance the need to obtain food and access shelter when necessary. These functions are not separate and independent, but involve trade-offs in the behavior of the reef fishes to manage risk, to avoid being prey themselves while seeking the prey they require. The structural complexity provided by the reef structure influences the trade-offs and interactions of those two fundamental functions. Werner and Gilliam (1984) explained ontogenetic habitat shifts (specifically when is it advantageous for a fish to move from nursery to juvenile to adult habitat), and Walters and Juanes (1993) provided "arena foraging theory" to explain differential mortality with size and habitat use. Those variations of general habitat selection theory have been developed and applied specifically to fishes and are just part of the overall understanding of what is accomplished by modifying habitat with artificial reef structure.

In artificial reef development we are essentially taking the physical complexity provided by the reef structure and (1) allowing for some of the bottom-up processes for that portion of the food web that is dependent on the fouling turf community, and/or (2) providing access to prey in close proximity to shelter. The ecological functions are a balance between food and shelter influenced by spatial and temporal dynamics. The intentional design and placement of artificial reefs essentially manipulates those dynamics. Context matters - reef placement, size and the spacing of the reef, and proximity to natural hardbottom or isolation in an otherwise open sand plane - all affect the spatial dynamics of shelter and prey-seeking. As for pelagic baitfishes that associate with reefs, they will compact around the artificial reef structure when threatened by pelagic predators. Synergistic predation has been documented between pelagic predator and site-attached reef fish, showing that predator avoidance response to pelagic predators subsequently makes prey fishes available to demersal reef fish (Hixon and Carr, 1997).

2.3.5 Behavioral Stimuli

Reef structures serve as behavioral stimuli in ways that have been observed but are not fully understood. These stimuli, called taxes, include phototaxis (response to light); thigmotaxis (response to touch); and geotaxis (response to gravity) (Dethier and Stellar 1961).

A Japanese study revealed that nearly 150 species exhibit distinct responses to reefs (Nakamura 1985). This study classified reef-responsive species into three types:

- Type A fish, which prefer physical contact with a reef;
- Type B fish, which associate with a reef through vision and sound;
- Type C fish, which hover above a reef.

In southeast Florida, Type A fish include most groupers and snappers, Type B fish include jacks, mackerels, bluefish, sailfish, and dolphin, and Type C fish include creole-fish, yellowtail and vermilion snappers.

While these descriptions are useful, they provide no understanding of how the artificial reef functions ecologically to enhance the ecosystem. Understanding behavioral stimuli is useful and provides necessary insight, but is sufficient only if the objective is simply to build reefs to improve the propensity to catch certain types of fish. Understanding behavioral stimuli alone is not sufficient if the purpose is to build reefs to enhance biological performance for sustainable management objectives.

2.3.6 Hydrodynamic Effects

Bottom-lying structures, whether natural or manmade, can have beneficial impacts on the surrounding environment because of their hydrodynamic effects. For example, in tropical seas, coral reefs and atolls change wave patterns and speed, protecting shorelines from erosion and storm damage. Altered current patterns also create a protective wake on the reef's leeward side, providing an area where fish can escape from strong currents, resulting in improved energetics. Oyster reefs in estuaries may promote sedimentation by trapping sand and mud to create substrate for vegetation, such as marsh grasses. In other areas, they funnel water into faster channels, preventing soil buildup. Manmade jetties and breakwaters are often built to produce hydrodynamic effects similar to those of natural barrier reefs (Pandolfi et al. 1998).

In dynamic nearshore areas, structures can cause dramatic changes in sediment transport. Depending upon reef design and placement relative to current flow, structures can cause accretion of sand in some areas, with concurrent erosion or scouring in others. These impacts may be beneficial in some cases but not in others, thus they should be considered in the artificial reef planning and design process. For example, some Japanese reefs are designed and placed in a manner that intentionally creates scour holes for flounder habitat and to trap detritus (Nakamura 1985). Placed along the 30-to-60-foot contour, the modules intercept long-shore migration of the fishes, while also intercepting on- and offshore movement of detritus.

Reef structures alter currents differently in deeper water. As water flows into vertical reef surfaces, it veers upward, creating upwellings and eddies. This upward flow mixes nutrient-rich bottom water with less rich but more biologically active surface layers (Sverdrup et al. 1961). The exchange of surface and bottom water takes a fresh food supply down to filter-feeders and other reef inhabitants. It also takes highly oxygenated surface water to the bottom.

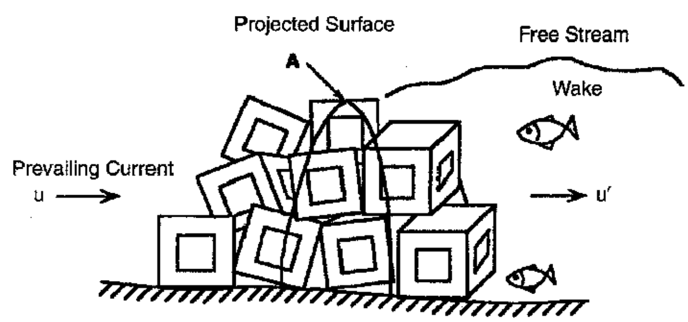

Figure 2.7. Wakes in the lee of reef rocks, where U and U′ are flow velocities (U >U′) and A is the total projected area of the reef in the direction of flow (Sheng 2000).

2.4 Fisheries Management Issues and Considerations

Given our understanding of how fishes use reefs from an ecological perspective (section 2.3), and how humans use artificial reefs from a socioeconomic perspective (section 2.2), the purpose of this section is to discuss how fishermen use the reefs and describe how the ecological functions are altered when fishing is layered as an ecological, as well as an economic factor in the reef system. Just as in section 2.3 where we discussed the ecological trade-offs between reproduction, shelter, and food, in this section we discuss the trade-offs between the economic and ecological impacts of fishing.

Essentially, fisheries management issues and considerations are the interaction between the fishing effects and the habitat effects. A good way to look at fishing pressure, from an ecological perspective, is to think as if you are adding a higher-order predator. Often with artificial reef development, we have introduced to the system not only an artificial reef habitat, but also targeted fishing pressure. While we may be creating an optimum habitat for reef fish in artificial reef development, the fish have not yet evolved defenses to avoid fishing mortality. Artificial reefs may influence the ecological and economic management objectives for an area or systems, depending on such factors as the fish species, the life-history stage, the length of time spent on the reef, the level of exposure to directed fishing harvest, level of protection from predators, and the reef location.

2.4.1 Production Considerations: Ecological and Economic

When analyzing an artificial reef program, whether existing or proposed, it is important to understand which species, fisheries and stakeholders will be affected by the program, based on scientific information about the systems. In considering establishment of new areas to deploy artificial reefs, for example, it is important to evaluate and understand potential benefits and impacts to the fishery resources, as well as to the ecosystem (including humans).

Terminology can be used quite differently when considering artificial reef development, especially for ecological versus economic “production,” which can be understood quite differently by different people. One could look at production or yield from the fish population level or the production at a specific reef as observed by anglers. Production could be defined as an increase in fish size (length and weight gain and/or increase in the ability to produce more eggs) or a true increase in the numbers of fish, not just a re-distribution of an existing population. There is some consensus that biomass production of grouper/snapper stocks (e.g., providing a location for growth and reduced natural mortality) can be neutralized or negated by the level of directed fishing harvest and bycatch mortality. Fish biomass can be harvested (or discarded dead) faster than the fish residing at the reef site can grow (Lindberg 1997, Shipp 1999, Cowan et al. 1999). The attraction versus production considerations are not a simplistic dichotomy (see discussion in Bohnsack 1989). There are attraction-production considerations in the purely ecological sense, which is how an ecologist might approach the subject, and then there is attraction-production in terms of fisheries, in which production may be taken to mean harvest or yield or as biomass in fish population models. Even though the different terminologies are not unrelated, they still result in opposing parties talking past one another (e.g., Shipp and Bortone 2009 versus Cowan et al. 2010). Recognizing the semantic differences and considering all facets (ecological, economic, management) is in the best interest for both the resources and stakeholders to ensure the economic viability of fisheries resources into the future.

Another aspect of production is habitat limitation. In other words, artificial reefs regionally increase numbers of fish because the species is limited by the amount of available hardbottom habitat, or at least quality habitat. One option is that greater numbers of artificial reefs could translate to greater numbers of fish, as opposed to a mere redistribution and movement of part of an existing population from other existing natural or artificial structure to additional reefs (Bohnsack 1989). For example, a common assumption among many southeast Florida recreational fishers is that more reefs mean more fish. On the other hand, if a fisheries population is not habitat-limited but rather recruitment-limited (i.e., population increase is limited by the reproduction and recruitment back into the fishery), then it is unlikely that artificial reefs undergoing directed fishing harvest contribute sufficient production to offset the harvest. In a worst case situation, if there was a high enough percentage of hardbottom contributed by artificial reefs, they could measurably contribute to the ongoing overexploitation of a fishery resource. This could occur through directed fishing on concentrated fish resources on artificial reefs in locations that are geographically accessible and can be easily and routinely located (Bohnsack 1989). The perspectives provided by Bohnsack in 1989 represent the beginning of the attraction-production debate. Since 1989 there have been many excellent studies, reports and papers on the subject. For example, in 1997 an issue of *Fisheries* (American Fisheries Society) was dedicated to attraction-production discussions, and the debate continues (Shipp and Bortone 2009 and Cowan et al. 2010).

The real question is, can artificial reefs be used to simultaneously maximize economic benefit and ecological benefit? Or do these two ways of using and valuing reefs run into conflict, or involve trade-offs? Probably the most important take-home message from more than 20 years of debate is that maximizing economic benefit will come at the expense of ecological benefit, or, maximizing ecological benefit will come at the expense of economic benefit. To think of the message in ecological terms (from the perspective discussed in section 2.3 above), it is impossible for a reef fish to simultaneously minimize mortality risk and maximize growth. The only way to absolutely eliminate mortality risk is to never leave shelter, resulting in starvation!. Similarly, if the fish seeks to absolutely maximize growth it will incur risk that will result in greater mortality.

What we are really faced with is an optimization problem, which gets back to the importance of specifying and thinking deeply about the objectives for the reef program and each of the individual reef projects at the level of the county and regional artificial reef programs. This includes recognizing the economic drivers for the fisheries effort and reef planning, such as site selection to decrease trip length and reduced costs so as to maintain the economic value of the fishing activity. Hypothetically one could ask fisheries managers: Is there an artificial reef placement strategy that could reduce boat run times and redistribute fishing effort from distant locations to closer locations, providing a trade-off, without incurring a greater fishing mortality, or imposing an increase in natural mortality?

2.4.2 Spatial Considerations

When reviewing the literature and considering different scenarios, it is important for the artificial reef manager to keep geographic setting in mind. For example, southeast Florida, where the coastal shelf is very narrow, is a very different setting compared to the broad coastal shelf of the northern Gulf of Mexico. As a result of significant differences, such as access distance, fish density, fishermen density, or hardbottom density, the outcome of artificial reef placement strategies may be very different. On a narrow shelf such as southeast Florida, the effective distance accessible to fishing reduces the economic costs, but exacerbates the ecological costs and reduces the economic costs. Furthermore, because of the narrow area available for economically targeted reef fish, it is reasonable to assume that the overall abundance of the regional standing stock is lower. Thus, potential total fisheries resources available would be fewer than on a broader shelf area. All of these features combined exacerbate the situation in southeast Florida, where consequences may be more pronounced. What are the density and standing stocks of the economically important fishes? How does human population relate to abundance of reef fish (Stallings 2009)?

Even with development of the best possible artificial reef habitat, "prime real estate", if you are placing artificial reefs in a system that is severely overfished, it will be unrealistic to expect that each site will be colonized by economically targeted species. For example, despite construction of artificial reef habitats that would be ideal for economically important species in southeast Florida, in many cases the most abundant and greatest fish species biomass was represented by grunts (Spieler 1998, Walker et al. 2002, Thanner et al. 2006).

2.4.3 Fishery Dynamics Considerations

Under conditions of regional overexploitation of existing fisheries stocks, as determined by fisheries stock assessments, an artificial reef manager would be wise to make the judgment that the enhancement of fish habitat for the benefit of the fishery stock is not going to provide much of a return on that ecological investment until such time as those stocks are rebuilding. A reef manager might have to decide to invest in the infrastructure now for a future date when the population as a whole is at a higher level, due to the stock rebuilding, or large year classes moving through, providing periods of high density. Or, if the prospects for a rebuilt stock are too far in the future, an artificial reef manager might want to shift from fish and fishing enhancement to other economic benefits such as ecotourism activities like diving, snorkeling, and glass-bottom boat tours. Consider adjusting to the scale of artificial reef construction that is attractive and favored by divers.

When considering the development of artificial reefs in the context of fisheries management, a significant consideration of artificial reef managers should be the status of the stocks. Are they at a sustainable level, or is there a rebuilding plan where one can reasonably expect the enhancement benefits? What are the implications of affecting fishing mortality?

Another consideration is that if you are going to enhance habitat so as to benefit the fish population, the earlier in the life-history you can intervene, the greater the consequence. Designing reefs for fish that are harvested may not provide the same bang for your buck as attempting to enhance the survivorship and growth of juvenile life-history stages. Improved survivorship and growth rates of juveniles may improve reproductive stocks. The design considerations in artificial reefs should weigh fishing mortality and natural mortality to improve the likelihood that the design meets the planned objective. For example, in the scenario of the planned enhancement for juvenile habitat, the design should not introduce unintended species or other life-history stages which may increase fishing pressure or natural mortality of the species targeted for enhancement. Artificial reef developers should coordinate with fisheries managers to be aware of all aspects of the proposed construction, and realize that even with good intentions, the design being proposed may not match the stated goal, resulting in unintended consequences.

For further reading about applications of artificial reefs in fisheries management, see Bortone et al. (2011).

2.5 Artificial Reef Research Questions

One of the most important aspects of planning research and monitoring is to clearly identify monitoring and research objectives. Research projects that provide the greatest contribution for future artificial reef management are those that address unresolved scientific issues and/or provide data relevant to artificial reef management. This involves staying up to date on current research, and maintaining a list of unresolved scientific issues still to be addressed.

Goal B of the 2003 "Florida Artificial Reef Strategic Plan" provides guidance to "*utilize artificial reefs in scientific research to obtain a mechanistic and predictive understanding of how artificial reefs function ecologically and physically across spatial and temporal scales*" (FWC 2003). One of the recommended actions in the plan to help achieve that goal is to "*identify, establish, update, and maintain a list of researchable problems/questions whose resolution would substantially improve our understanding of artificial reefs*."

Historically artificial reef research has been conducted on a localized, case-by-case basis, with little long-term planning to achieve a bigger picture objective. Artificial reef managers are strongly encouraged to establish long-range goals and objectives for research and monitoring. To that end, and in accordance with the "Florida Artificial

Reef Strategic Plan," research questions should be established and maintained to help guide future projects.

The table below provides some starting points for artificial reef (AR) managers to think about pending issues and to prioritize research questions.

Table 2.2. Research questions from the Florida Fish and Wildlife Conservation Commission (Note: This information is repeated verbatim from that source. For explanation of terms, contact FWC).

BIOLOGICAL ISSUES	
Attraction vs. Production Issues	Can properly designed and placed artificial reefs enhance local survival of juvenile fish? Can artificial reefs alleviate population bottlenecks on their own or with an absence of fishing? When do artificial reefs act more like "Fish Attraction Devices" (FADs) than habitat?
Fishing Mortality Issues	If artificial reefs are a fishery tool then at what point are deployment efforts canceling out what fishery management is trying to accomplish? Do ships receive higher fishing pressure than large artificial reefs composed of other materials (e.g., concrete rubble, railroad ties, high tonnage)? We know ARs contribute to Fishing Effort ("F"), but to what extent for select species (e.g., red snapper, gag, gray triggerfish)? If fishing effort remains constant, how will any manipulation of the number of artificial reefs change "F"? How much do artificial reefs increase catchability? Can artificial reefs reduce fishing pressure on adjacent natural reefs? Can simulation modeling evaluate changes in bag and size limits, with and without artificial reefs?
Ecosystem Management Issues	What is the importance of artificial reefs in the life-history of pelagic species? Could placement of artificial reefs near known/unknown spawning aggregation sites disrupt this activity? Would it make sense to place ARs favorable to a particular species in the path of that species' migratory pattern? What is the impact of potentially inflating prey abundance by adding artificial reefs? (tomtate/grunt factories)?

Table 2.2, continued.

	What role do artificial reefs have in spawning for select species (e.g., red snapper, gag, gray triggerfish)? What role do artificial reefs play in the life-history and the recovery of goliath grouper? Are they spawning there? What role do artificial reefs play in the life-history of snook, especially off the Ft. Pierce area? How are community structures over artificial reefs different than over natural structure in various regions? How can artificial reefs be used to supplement or augment natural habitat? How wide is the prey field for typical artificial reef deployments in various regions and species? More nearest-neighbor studies including artificial reefs to natural reefs would be helpful. Develop artificial reefs as juvenile habitat and do research projects on the effectiveness of these reefs as juvenile habitat. What is needed in order to reach the level of predictive ability to determine how artificial reefs will function before they are even deployed? Is the percent bottom coverage by artificial reefs off Florida so insignificant that ARs neither help nor adversely impact regional snapper/grouper stocks or open sand bottom communities on a regional level? How are reef communities modified ecologically by the consistent removal of targeted reef fishes? Are there any trophic cascade effects? How are fish abundance and reef fish assemblages affected by changes in distribution of demersal and pelagic prey and at varying artificial reef densities? Compare non-fish diversity of organisms associated with artificial reefs vs. natural reefs. What role can artificial reefs play in oyster reef recovery? What role do artificial reefs play in expansion of invasive species? (e.g., Asian green mussel, orange cup coral, lionfish) Can artificial reefs be designed for a specific reef fish life-history stage? Can artificial reefs be designed for a specific reef fish species?

Table 2.2, continued.

Marine Protected Area Issues	Are there nursery hot spots around the state that could be identified and possibly protected? Can the AR program play a role in reef restoration (e.g., Oculina Reef)? Is it possible to place all new ARs in temporary no-take zones for a predetermined period of time with the hope that the reduction in fishing pressure will result in a more sustainable local fish population when the no-take rule is lifted? What role can artificial reefs play in MPA's?
PROGRAMMATIC ISSUES	
Physical/ Structural Issues	What is the average (or range of) life expectancy of typical concrete reef deployments in the varying regions of the state? What is the percentage of artificial reef bottom footprint compared to natural hardbottom for select species in various regions (e.g., red snapper, gag). What are the impacts of marine debris fields created around sunken vessels as the vessels deteriorate? How do such fields function, what organisms use them? Are debris fields stable? Can we build better artificial reefs? e.g., Have different materials and designs been monitored for efficacy? What is the ideal size and spacing of artificial reef deployments? What role can unpublished reef deployments play? Is natural rock/limestone better than concrete; better than steel for reef fish? How many artificial reefs are too many? Is there a maximum capacity? How reliable are existing artificial reef stability analysis software? Have the results been ground-truthed? Are the stability analysis software products too conservative?
Sociocultural and Economic Issues	What are the factors that increase angler visitation (fishing pressure) on an artificial reef? How important are artificial reefs for collection of baitfish by charter boats, and other anglers? What characteristics are important about artificial reefs and baitfish densities? What reef material provides a greater economic/ecological value: A $4 million military ship or $4 million in other reef materials?

Table 2.2, continued.

	What is the value of artificial reefs, and at what point does the construction expense outweigh the expected economic benefits? How do short-term economic benefits (perceived) compare to long-term impacts (positive or negative) of artificial reefs?
Regulatory Issues	How can the FWC generate a strong enough case to allow for legally unpublished and secret reefs? What is the extent of illegal dumping within permitted/ outside permitted areas? What is the level of compliancy of deployments within permitted area?
Assessment Method Issues	Should we require side scan of areas prior to any artificial reef deployments? How can visual census and monitoring data be incorporated into management decisions (e.g., used in stock assessments)? Need a common FWC database to compile artificial reef data including monitoring data collected by volunteer groups. Can some of these data be accessed by the public? Are there any closed water bodies where experimentation could take place? i.e., military closed areas? How are volunteer visual census surveys being used? Compiled? Comparable? Need more rigor to improve accuracy.
Outreach Issues	Need to educate Sea Grant agents after FWC determines goals and objectives and get them to help us educate the public. We need to get the message out to the public about what artificial reef can and cannot do. Need to establish protocol for volunteer/dive monitoring groups. Could get community involvement by doing artificial reef debris clean-ups. Do we know the general public's overall understanding of ARs? Should develop an AR outreach initiative: kiosks, boater education tools, etc. Could we produce a display for getting the AR message out to the public at outreach events? Could we produce an AR PowerPoint presentation for boating/angling/diving clubs? What will garner more public support: more reefs now or better fishing later?

Chapter 3. Administrative Responsibilities, Risk Management Concerns and Funding

Unlike most states, where artificial reefs are managed solely at the state level, in Florida artificial reef management relies heavily on county oversight. Here, a wide array of interests may assist in developing artificial reefs as long as the project meets all local, state, and federal permit requirements. The permit holder may be an individual, local government (county or municipality), club, educational institution, corporation or nonprofit entity. However, since virtually all artificial reefs represent permanent changes to the marine environment, it is vitally important for managers of artificial reefs to assure continuing reef stewardship through their planning and management efforts. There are numerous administrative duties associated with each phase of artificial reef development, from permitting to liability and from finding funding to filling out forms. This chapter provides an overview of some administrative functions. In a sense, it lays a foundation for the actual planning of reefs discussed in Chapter 4.

3.1 Elements of Program Success and Viability

It is the responsibility of a permittee to create and foster a support group(s) of stakeholders to ensure the long-term success and viability of the artificial reef program. Examples would include dive and fishing clubs, artificial reef committees and even an organized stewardship group to monitor the success of the reef projects.

3.1.1 Artificial Reef Committee

This would be a community-based group under the auspices of the Board of County Commissioners consisting of various user groups including both commercial and recreational fishing and diving, municipal governments, marine industries, and environmental organizations. Recommendations made by this group would carry significant weight with the local government and generate support both politically as well as financially. Only Palm Beach County currently has such a committee.

3.1.2 Reef Research Team

This usually is a volunteer group of trained divers for monitoring and collecting data on the artificial reefs. The team mission would be to observe, collect, document and record scientific data for use in project evaluation. The team would map, conduct fish counts and monitor invertebrate status on many of a county's man-made and natural reefs. Further, the team would inform government officials and the general public of the results and of the need for protecting all reefs. A group such as this would provide good public relations and thus interest that could translate into potential future funding to cover more projects. Volunteer teams currently exist in Palm Beach County and are developing elsewhere.

3.1.3 Staff and Resources

At a minimum, there needs to be qualified staff, vessel(s) and equipment to provide the necessary oversight for the purposes of planning, constructing, and monitoring the reef projects at the local governmental level. Historically (1960s - 1980s), county and municipal staff involved with artificial reefs were generally associated with a solid waste department, and placement of scrap materials for building artificial reefs was considered an alternative to land-filling. Since then, programs have become much more accountable for planning, placements and long-term sustainability. Therefore the budget for staff and resources committed to this work has increased over time. Historically, staff had little background in the marine and estuarine sciences but was more related to sanitary engineering [See Seaman (2004) for reef evaluating capabilities in Florida counties]. The tides have changed in that regard with many artificial reef program coordinators having advanced degrees in marine biology, oceanography and coastal engineering, and many years of experience in environmental regulation and/or management. Additionally, artificial reef program coordinators should be familiar with county, state, and federal purchasing guidelines and contract management to oversee marine contracts. At a minimum, local government artificial reef program staff should have a 4-year college degree with 3-5 years of experience. Salaries should be at a senior-level grade. Programs require a dedicated boat and equipment to construct and manage the daily operations of the artificial reef program. As an alternative to hiring full-time dedicated staff to manage these programs, smaller local governments could hire on a case-by-case basis a consultant to oversee the permitting and construction of an artificial reef.

3.1.4 Project Documentation

Reef program or project activities need to be well documented for four major reasons: (1) to satisfy legal requirements, such as permit conditions; (2) accountability to sponsors; (3) development of construction budgets; and (4) reef program continuity, regardless of sponsorship or program personnel changes. Artificial reef managers should maintain detailed files for each artificial reef deployment to satisfy each of these criteria. In addition to maintaining project documentation in the form of correspondences, contracts, dive assessment surveys and reports, and other paperwork, project managers are strongly encouraged to maintain multi-media files associated with the artificial reef deployments, including historical photographs and videos of deployments.

3.2 Permitting

Artificial reef developers are responsible for obtaining all appropriate permits before developing a new reef site and for timely renewal of existing permits if additional construction is planned at an established site. There are also times when permit amendments may be needed, possibly to correct incorrect data, to expand the size of a permitted area, or to secure approval to place a new type of material. See Chapter 6 for detailed guidance on permits.

3.3 Liability and Risks

Liability is an ongoing concern with the construction of artificial reefs. Relative to liability of the federal Government, nothing in the Fishery Enhancement Act of 1984 (P.L.98-623) created any liability on the part of the United States. However, it mandated a stringent permitting process for the U.S. Army Corps of Engineers (USACE) and enforcement mechanisms for various other agencies, including the Environmental Protection Agency (EPA) and U.S. Coast Guard (USCG). The USACE must make sure not only that a permittee can financially assume the liability associated with a reef, but also that the permittee's plans for reef design, location, types and quantities of materials, construction, operation, maintenance, monitoring, and managing reef use meet all applicable federal laws and regulations. For this reason, artificial reef permits today are only issued to governmental entities. See Chapter 6 for more information on permitting.

Florida Statute 768.28 (supplement 1985) waives the sovereign immunity of the state and its political subdivisions in circumstances in which a private person would be liable. The statute places monetary limits on the damages that are recoverable in an action against the state or its political subdivisions. The immunity provided to state and municipal governments does not apply to others who may be involved in reef construction, including material donors (before title transfer), private permittees, or volunteer transporters.

Liability risks can be categorized into three areas of concern: pre-construction, construction, and post-construction.

3.3.1 Pre-Construction Risks

This category includes the handling and preparations involved in construction and transportation to a staging site. Issues that could arise include injury to personnel handling materials, possible exposure to toxic and dangerous materials including asbestos in the preparation of a ship, liabilities in using a staging location during times when materials are being stored, and damage to vessels transporting reef materials. This is a good time to review the following risks (Stone 1985) and ensure that all insurance-related paperwork is in order:

- Injuries to personnel handling artificial reef materials;
- Damage to vessels transporting artificial reef materials;
- Improper location (reef initially sunk off site or moving off site later) causing damage to fishing gear;
- Damage to vessels in transit over the reef;
- Injury to recreational divers;

- Decomposition or movement of artificial reef material to an unauthorized location (including buoys, if applicable);
- Environmental hazards caused by incomplete cleaning of hulls or holds containing toxic residues.

There is also potential exposure to liability for environmental damage if material is placed on sensitive habitat outside the permitted site or if such habitat is damaged on a site that was not adequately surveyed prior to permit application and approval.

The Florida Coral Reef Protection Act (403.93345 F.S.) was enacted in July 2009 and specifically prohibits damage to coral reef and hardbottom resources from vessel-related impacts like grounding and anchor damage. Any permits associated with deployments, or subsequent monitoring visits, should include specific language regarding any anticipated impacts to reef resources from vessels associated with the permit. Anchoring plans should be developed to ensure that there are minimal coral reef or hardbottom resource impacts (i.e. vessels must anchor in the sand). If an inadvertent impact to resources occurs, it is required to be reported to FDEP within 24 hours. FDEP's Reef Injury Prevention and Response Coordinator can be contacted at 786-385-3054. For more information, see the website:
http://www.dep.state.fl.us/coastal/programs/coral/ripr.htm

The artificial reef developer may be liable and have to pay compensation costs for damage to coral reef or hardbottom resources that are not specifically authorized in a permit. See Chapter 10 for more information on compensatory mitigation.

3.3.2 Construction Phase Risks

Most of the potential liability exists at this stage, generally associated with improper placement of materials. Concerns include impedance to navigation if the artificial reef materials are lost within an inlet or channel, damage to existing bottom resources including seagrasses and natural reefs, injury to personnel, collision with other vessels during transportation to the reef site, and navigation clearance improperly calculated [e.g., the *Red Sea* off Panama City, Florida (J. Dodrill, FWC, pers. comm.)]

Governmental reef programs are typically self-insured. Meanwhile, the contractor selected would have, at minimum, insurance coverage for all marine activities with policies to include: General Marine Liability, Jones Act, and Longshoremen coverages. These policies will provide some level of protection during the "overwater" portion of the project. A minimum of $2 million dollars in General Marine Liability is a typical requirement of contractors performing services for these types of projects. However, this amount will not cover the potentially high costs of a catastrophic event such as a collision with a vessel, sinking a vessel within an inlet or placing a ship onto a natural reef.

The agency holding the reef permit has limited liability for damages if the reef has been properly constructed, using approved methods and materials meeting the terms and conditions of the permit (Fishery Enhancement Act of 1984, Public Law 98-623). The permittee is liable, however, for damages not related to the terms and conditions of the permit. According to the Act, any person who has transferred title to artificial reef materials to a permittee *"shall not be liable for damages arising from the use of such materials in an artificial reef, if such materials meet applicable requirements"* of the National Artificial Reef Plan, and are not otherwise defective when the title is transferred.

3.3.3 Post-Construction Phase Risks

This phase includes the long-term final disposition of the project over time. Issues can include damage to fishing gear, injuries to recreational divers, decomposed materials or movement of materials off-site and environmental hazards caused by toxic residue on materials. Damage to fishing gear can be avoided as long as the reef location is on the NOAA Chart with a "notice to mariners." Artificial reef managers should verify the current NOAA nautical chart, and if the permitted area is not charted, notice should be provided to NOAA National Ocean Survey (NOS). Environmental hazards can be avoided during the preparation phase of the work. In some instances, a ship or other materials must be rejected.

Injury to recreational divers visiting one of the reef sites is a harder issue, and at a minimum requires that the agency constructing the reef provide diver safety guidelines or instructions concerning inherent risk. An example would be the web page set up by the FWC on precautions when diving the *USS Oriskany*, a naval aircraft carrier placed off of Pensacola. Another hold-harmless effort was published on the 2010 Palm Beach County website. *"WARNING: Many artificial fishing reefs lie in water depths that exceed the recommended sport diving limitations. Any swimmer, diver, or snorkeler shall approach or visit each artificial reef at his or her own risk. The Palm Beach County Artificial Reef Program and Committee, the Board of County Commissioners of Palm Beach County, and the County of Palm Beach are not responsible for any hazards which may exist or arise on, about, or near the artificial reefs, or for any injuries or fatalities which may occur as a result of any person's presence on, about, or near the artificial reefs."*

The potential movement of the artificial reef on the sea bottom after placement is an issue that requires close scrutiny and additional planning. Artificial reef managers are encouraged to review the performance of existing materials and run stability analysis using computer software programs such as the Paul Lin or the Miami-Dade County Department of Environmental Resource Management (DERM) stability software programs (Paul Lin and Associates 2000, and Miami-Dade County DERM 2001). A buffer may be incorporated into the planned reef location to account for possible movement of the reef during storm events, most notably hurricanes. Ships especially need to be placed where the potential for movement and damage to nearby reefs has been minimized. More detail about ships as artificial reefs is discussed in Chapter 11.

3.4 Funding Concerns, Issues and Opportunities

In upholding the terms of the National Fishery Enhancement Act (P.L. 98-623, Title II) the USACE will not grant permits for building artificial reefs unless the applicant can demonstrate financial responsibility for the proposed project. Artificial reef development usually requires substantial funding, and it is the responsibility of the developer to ensure financial needs will be met. Budgetary items include:

- Pre-permitting and preconstruction surveys
- Permit processing fees
- Material acquisitions
- Material cleaning/preparation
- Transportation and towing
- Potential for buoys and buoy maintenance
- Liability insurance
- Compliance monitoring and maintenance
- Personnel
- General operating expenses
- Data management
- Publicity
- Performance monitoring

The first and most important funding requirement is a dependable and consistent local source of monetary support for the ongoing program activities. If salaried staff manage the program (even if only on a part-time basis), a steady revenue source must be available to meet payroll obligations. Insurance premiums, telephone bills, secretarial services, utility bills, bookkeeping costs and other basic support services must be funded from a dependable source. Local government-run programs usually absorb these costs as part of their general overhead, which is usually covered by taxes. Clubs and other organizations could dedicate a percentage of membership fees and dues, if levied, to artificial reef development.

Before local government programs or organizations agree to accept the terms and conditions of a reef permit, they need to be aware of what those commitments may entail and to determine if reliable funding can be assured for upholding those commitments. Conditions of a permit might include maintenance of aids to navigation, annual monitoring inspections and other continuing responsibilities. Generally speaking, the bigger the ongoing commitments, the greater the funding needs to be.

Funding requirements can be kept to a minimum by carefully avoiding situations that require perpetual funding. However, long-term costs can never be completely avoided, particularly because of maintenance and monitoring responsibilities for reef programs. An important benefit of local government committing to long-term funding of a formal reef program is that it lends credibility to program efforts. These funds could also be used as matching funds or in-kind collateral for leveraging other financial support.

If a substantial, steady source of funding is dedicated to a reef program budget, it could allow implementation of planned long-term development operations that could elevate the program above an opportunistic, short-term effort. This often results in the assignment of specific equipment and personnel to the program and the focus of activities on operations and materials specially designed to achieve program goals.

Various state and federal grants work very well for funding specific projects where the scope of work and work schedule can be clearly defined. This is beneficial because the parties involved must clearly define what is to be received and what is to be delivered. The biggest drawback with grants, in general, is that they are not flexible enough to serve the unpredictable aspects of artificial reef program activities that rely heavily on materials of opportunity, donated services and the mercy of the weather. The grant approach to funding also calls for repeatedly investing program resources into preparing project proposals that may or may not be funded. Since grant awards are rarely guaranteed, it is very difficult to implement a comprehensive reef development plan if grants are the primary funding source. Reef program managers who heavily depend on grants often encounter dilemmas in which, for example, funds are available but materials are not; or materials are available but there are no readily available funds for processing and deploying them; or when funds are available for only a limited time but are lost when activities are delayed beyond the grant period because of equipment problems or foul weather.

3.4.1 Federal Grants

Wallop-Breaux Funds -- The "Federal Aid in Sport Fish Restoration Act of 1952" Sport Fishing and Boating Enhancement Fund (or, the Wallop-Breaux Trust Fund) is derived from fees, taxes and duties imposed on recreational fishing equipment, non-commercial motorboat fuel, imported watercraft and fishing tackle. The revenues are allocated to the states, on a formula basis according to recreational fishing licenses and are used to protect natural resources and enhance recreational fishing and boating opportunities. In Florida, these federal monies are appropriated by the FWC. Some revenues are used to maintain the program at the state level, but the main thrust of Florida's program is directed toward aiding local artificial reef construction and monitoring efforts through an annual grant process. For details, contact Environmental Administrator – Artificial Reef Program, Division of Marine Fisheries Management, Fish and Wildlife Conservation Commission, 620 South Meridian Street, Box 4B2, Tallahassee, FL 3399-1600, Telephone: (850) 487-0554, or 487-0580 x209, Fax: (850) 487-4847.

3.4.2 State Grants

FDEP Solid Waste Management Grant -- The Solid Waste Management Trust Fund provides grants for research and demonstration projects related to solving solid waste problems. It provides incentives for counties and municipalities to form interlocal agreements to implement solid waste recycling and education grants. For details, contact Florida Department of Environmental Protection, Division of Waste Management, Bureau of Solid and Hazardous Waste, 2600 Blair Stone Rd., Tallahassee, FL 32399-2400, (904) 922-6104.

State Fishing License Proceeds – The FWC manages the proceeds collected from the fishing licenses with a portion used for the planning, construction and monitoring of artificial reef projects. For details, contact Environmental Administrator – Artificial Reef Program, Division of Marine Fisheries Management, Fish and Wildlife Conservation Commission, 620 South Meridian Street, Box 4B2, Tallahassee, FL 3399-1600, Telephone: (850) 487-0554, or 487-0580 x209, Fax: (850) 487-4847.

State Vessel Registration Funds -- The state-collected vessel registration fees managed through the Florida Boating Improvement Program were historically used for acquiring land for boating-related activities, marine enforcement, boating facilities including public docks and ramps, aids to navigation, and activities as related to the maintenance and the construction of artificial reefs. A bill was passed in 2007 that redefined and narrowed the focus of these funds to include only uniform waterway markers, public launching facilities, and removal of vessels and floating structures deemed a hazard to public safety and health. These funds no longer are provided for construction of reefs.

State Line-Item Appropriation -- State appropriations for projects typically managed by FWC have included the 2002 Panhandle Reef Refugia Project, the 2006 Indian River County Artificial Reef *Didson* Evaluation, and the 2009 *Hoyt Vandenberg* Project. Certain protected water bodies in southeast Florida can qualify for additional artificial reef funding through a line-item appropriation that is approved by the state legislature on a yearly basis, including Indian River Lagoon, Lake Worth Lagoon and Biscayne Bay.

Governor's Office of Tourism, Trade and Economic Development – Created in 1996 by the Legislature, the Office of Tourism, Trade and Economic Development (OTTED), within the Executive Office of the Governor, provides executive direction and staff support to develop policies and advocate for economic diversification and improvements in Florida's business climate and infrastructure. In the case of the *Hoyt Vandenberg* Artificial Reef project for example, the tourism value of the project resulted in financial support from OTTED.

3.4.3 Local Funding and Donations

Federal and state funding usually comes with stipulations and conditions that often frustrate reef managers because of lengthy bidding requirements or the inability to use these funds according to their own discretion. Local funding from ad valorem or vessel registration fees, or private donations can usually be much more responsive to the immediate needs of a program. Funds from sportsmen's clubs, fishing tournaments, recreationally oriented businesses or even wealthy individuals are often the catalysts needed to bring major projects to fruition when timely action is critical.

County Vessel Registration Fees -- Florida Statutes 328.66 authorizes each county to collect an annual vessel registration fee of up to 50% of the state registration fee for vessels registered, operated or stored in its jurisdiction. A portion may be used for enhancement and maintenance of the county's lakes, rivers, and ocean. This ordinance authorizes the county to use funds for the acquisition, transportation and placement of artificial reef materials, and for enhancing inland fisheries and estuarine habitats that will improve water quality and breeding grounds for fish and shellfish. For details, contact your local county manager or the Board of County Commissioners.

Mitigation Funds -- These are funds generated through the environmental impact process from applicants whose marine construction projects would impact natural habitat. To offset impacts the applicant could be required to build mitigation reef(s). Examples of coastal projects that would typically require mitigation include beach nourishment and pipeline and cable crossings. It should be noted that these funds do not cover the costs of additional fish habitat but simply replace the habitat lost, in effect, a "break even" venture. (A detailed review of compensatory mitigation is given in Chapter 10.)

Pollution Recovery Trust Funds -- These funds would be available through fines collected from past enforcement settlements and earmarked specially for artificial reef projects. Similar in nature to the mitigation funds, this would be a "breakeven" effort.

Sold Waste Tipping Fee Program – Here, a local solid waste management agency could designate a temporary staging area for collecting concrete materials that meet general criteria. The client bringing the materials to the site would pay a reduced fee per ton but be responsible for ensuring the quality of the materials. Waste management personnel would collect tipping fees and place them in an account to cover the costs to truck the materials to a staging area for an artificial reef project. Benefits include reuse of concrete and saving landfill space.

Establishment of a 501(c)(3) Account to Collect Donations -- This would be a fund set up by the local fishing and diving organizations, or economic councils that would provide a tax break for those interested in donating funds to enhance the local fisheries. The FWC has a close working relationship with the Wildlife Foundation of Florida.

With low overhead costs, the Foundation can set up a 501(c)(3) account and manage funds earmarked to support the mission of FWC, such as artificial reef development.

Other Types of Donations -- Other valuable assets could include suitable reef material such as concrete, limestone boulders or ships, towing and cleaning services as they relate to preparing a ship, the use of a waterfront staging site at no cost, use of volunteers to monitor reefs post-construction and free dockage. Artificial reef managers are encouraged to secure trucking receipts, log volunteers hours, and track donated materials and services as these donations could potentially be used as match for federal grants. Also, when dealing with donated services, managers should be aware of the associated risks, and establish written memoranda of agreement, or in the case of vessel donations, title transfer agreements may be appropriate (see Chapter 11).

Before a project can proceed to the implementation and construction stages, resources need to be evaluated and allocated to the tasks at hand. Potential artificial reef developers need to put together a plan to assess levels of physical involvement required for reef building activities, along with organizational capabilities for handling the tasks. Small, privately or individually sponsored artificial reef projects may be best served by donated contractual services and volunteers to keep operating costs to a minimum. In the case of small, publicly funded artificial reef operations with intermittent, opportunistic construction projects, it would be difficult to justify the hiring of staff and investing in heavy equipment unless there is collateral work to do between artificial reef jobs.

3.5 Contract Administration and Coordination

Sooner or later every artificial reef program will probably need to contract for goods and services. Privately funded and managed programs may elect to forgo a competitive bidding process and negotiate terms and conditions of contracts directly with vendors, thus saving time. Before signing a contract or making a purchase, however, it is advisable to shop around to determine fair costs and to investigate qualifications of potential vendors. Since many vendors are reluctant to provide quotes without a commitment from the prospective customer or client, competitive bidding may actually provide the best course of action to get the best price for goods or services. FWC invites consultation on these matters.

Competitive bidding procedures are normally required when public funds or public agencies are involved in buying goods or contracting services associated with artificial reefs. Local governments have standard purchasing procedures designed to comply with all laws, regulations and policies associated with public expenditures. If state funds are to be used for contractual services, the state has its own set of requirements vendors must meet.

The simplest means for awarding contracts is to hire the lowest bidder. If a contract award is to be based on factors other than cost, however, it will be necessary to explain (in the bid request announcement) any no-cost evaluation criteria (e.g., past experience, references, level of subcontracting, subcontractor qualifications, availability of equipment or other resources). A numerical scoring system, whereby points are awarded on the basis of desirable qualifications (or other clearly defined procedure for vendor selection) helps vendors understand the decision-making process and can help prevent possible disputes regarding contract awards.

Once a contract is executed, someone from the program must track the contractor's activities to ensure contract compliance. This usually requires overseeing the work until material is finally deployed on a reef. If the contract contains provisions for progress payments, each deliverable stage needs to be verified. Final payment for the work typically depends on verifying that the placement complies with contract terms and submittal of a certification of completion report.

3.6 Technical Information Exchange

Technical information exchange can be as simple as one-on-one networking to discuss mutual reef work and develop a sense of camaraderie with fellow reef developers. Organizing and participating in local or regional workshops is another valuable way to share informal progress reports, techniques, and words of wisdom. State-level summits, held on an average of every four years in Florida, promote a broader purview of state reef activities, along with updates on major changes affecting reef development strategies. There are also interstate and international conferences, providing opportunities to obtain updated information and discuss specific reef issues with other reef developers. Both the Atlantic States and Gulf States Marine Fisheries Commissions have artificial reef advisory committees, comprised of state reef coordinators, which meet once a year.

Literature on artificial reefs includes published proceedings, professional journals, bibliographies, abstracts, special publications, periodicals, newsletters, so-called gray literature (internal reports and publications), and a number of commercial publications. Published proceedings for state and international artificial reef conferences are prime references. Literature citations and annotated bibliographies are excellent means for finding out about other artificial reef publications. Holistic reef development requires multidisciplinary knowledge, so be sure to check these fields: fisheries management and biology, oceanography, hydrology, meteorology, hydrodynamics, ocean engineering, structural engineering, statistics and socioeconomics. The FWC Artificial Reef Program maintains an extensive library of artificial reef references (Mata et al. 2010).

Chapter 4. Artificial Reef Program Planning Framework

Preceding chapters of this report provide a context for artificial reef programs in southeast Florida, while the subsequent chapters address the many details of running a successful program. In this chapter we emphasize the vital role of planning at the programmatic level. Without an overarching plan, a program will drift from one reef project to the next without cohesiveness and direction, and thus never fully realize its full potential.

4.1 Rationale and Benefits of a "Business Plan" for Reefs

Documented project plans, goals and objectives, and project justifications should be the foundation for development of an overall local or regional artificial reef management plan. In 2003 Florida completed the "Florida Strategic Artificial Reef Plan" (FWC 2003). The state strategic plan is intended to provide a general framework within which local entities can develop their own more comprehensive local or regional plans, based on local needs and management strategies.

Ideally, a written plan--which has been vetted thoroughly--should be in place at the onset of a reef program, so established programs without formal plans are advised to make plan development a priority item. A written plan can be viewed as the cornerstone of a reef program, much like the bylaws of a civic organization or the business plan of a private enterprise. The benefits of a plan are listed in Table 4.1. (Please also see Table 1.1, Chapter 1, for a set of questions that address some of these issues.)

Table 4.1. A well-developed plan can be a forceful tool with many benefits.

1. Provide consistency and continuity to the program, regardless of personnel or sponsorship changes;
2. Lend credence to the program and provide additional leverage when competing for funds;
3. Establish short-term and long-term goals and objectives;
4. Establish sound strategies for reaching goals;
5. Establish material and construction standards to promote reliability and integrity;
6. Address fiscal responsibilities and liability concerns;
7. Show ample justification for an ongoing reef program based on local socioeconomic and biological factors;
8. Establish program's primary regard for environmental concerns;
9. Demonstrate program's consideration for traditional commercial fisheries and other natural resource users;
10. Show program's administrative capabilities;
11. Demonstrate program's responsiveness to public concerns;
12. Establish constraints for protecting natural resources;
13. Provide monitoring methods for ensuring compliance with state, federal, and local regulations and restrictions;

Table 4.1, continued.

14. Establish mechanisms for networking with other artificial reef programs (particularly in neighboring counties);
15. Show program's commitment to the general public welfare rather than special interest groups;
16. Establish methods for mediating gear conflicts arising on a reef site within legal jurisdiction of the county;
17. Document existing official policies governing the program and see where new ones might be appropriate;
18. Establish official lines of communication between the program and other interest groups;
19. Provide better mechanisms for obtaining donated materials and services;
20. Support and simplify decision-making processes;
21. Provide program education and orientation for new personnel;
22. Elicit more respect for the program from upper-echelon agency administrators;
23. Provide a basis for experimental projects;
24. Provide avenues for interagency coordination;
25. Serve as a handbook for the overall program.

A plan that also contains such ancillary information such as biological profiles of target species, historic environmental data, reef construction data, monitoring and maintenance data, reef permit application forms and instructions, and a list of important contacts can be used as a complete working handbook for all program activities.

The development of artificial reef management plans takes time and personnel, neither of which may be readily available. In this regard, members of the Atlantic States Marine Fisheries Commission Artificial Reef Advisory Committee recommended that agency administrators should encourage reef managers to produce a plan and to provide extra staff or hire consultants to assist the manager in writing it (Murray 1989). Potential funding sources for plan development include county or local government appropriations, FWC grants, and possibly other sources that fund reef development activities.

4.2 Establishing Program Goals and Objectives

Goals and objectives (i.e., the purpose) are the driving forces behind artificial reef development. These elements steer the selection of specific techniques and strategies and also provide standards for measuring progress. As part of the goal-setting process, the prospective reef sponsor needs to carefully weigh the potential benefits of artificial reefs against their limitations, liabilities, and costs in the context of specific objectives. Table 4.2 contrasts goals and objectives. As of 2010, 13 of 35 counties involved in artificial reef development in Florida have artificial reef management plans. Artificial reef managers are encouraged to read other plans in their region for guidance locally.

Table 4.2. Artificial reef program goals, in general terms, and objectives in more specific wording, so as to measure success in achieving them for a given artificial reef project (adapted from Lindberg and Relini 2000).

Examples of Goals	Corresponding Objective(s)
Protect valued or sensitive habitat	Eliminate trawling in seagrass or anchoring on corals
Enhance recreational fishing	Achieve a certain catch per unit of effort; achieve a certain level of "angler satisfaction"
Conserve fisheries stocks	Reduce natural mortality on juveniles; increase juvenile growth rates; increase connectivity between nursery grounds and adult habitat
Restore biodiversity	At specific sites, recreate the density and size distribution of cavities typically occupied by motile invertebrates and fishes that characterized the impacted habitat
Create economic infrastructure	Establish high densities of charismatic species (e.g., Goliath grouper) readily accessible to dive charter operations

4.2.1 Fishing Enhancement

Recreational fishing opportunity enhancement has historically been the primary reason why the majority of Florida artificial reefs are constructed. Further, most "Sport Fish Restoration" for reef-building in Florida counties has been to increase angling opportunities. Faced with increased fuel costs, many recreational fishermen look toward artificial reefs as readily accessible locations to fish or reliable locations to catch baitfish. Additionally, with a steady rise in the number of boaters across Florida, recreational fishermen look toward artificial reef development and the creation of new places to fish as a means to disperse fishing pressure across a broader area and reduce user conflicts.

4.2.2 Fisheries Management

Fisheries management is receiving increased attention as a primary objective for artificial reef development. Historically, artificial reefs were deployed with the intent of increasing catchability of reef fish. Artificial reef and fisheries managers are now working more closely together towards identifying the different roles that artificial reefs might play in achieving future regional fisheries management objectives. While fishing pressure is still identified as a driving factor in reef fish community structure, efforts such as artificial reef development in areas with restricted or closed fishing, unpublished deployments, and designs specifically to increase juvenile fish survival or reduce fishing pressure are being considered.

Chapter 2 provides a more detailed discussion of fisheries management objectives for artificial reefs. These include:

- Establishing reef fish in areas naturally lacking reefs where lack of such habitat can be clearly identified as a factor limiting fish production;
- Restoring habitat where destruction by unanticipated human or natural causes (such as ship groundings or hurricanes) has contributed to a decline in the habitat;
- Creating or improving habitat in refuges established to benefit over-exploited, threatened or endangered fish stocks, affording appropriate habitat and protection from fishing;
- Creating habitats to relieve life-history bottleneck, such as by increasing survival of juvenile fishes.

4.2.3 Socioeconomic Benefits

The economic values of artificial reefs in Florida are well known. Adams et al. (2006) is the most recent economic benefits summary.

4.2.4 Dive Attractions

Artificial reefs are important dive attractions throughout Florida, especially in the clear, subtropical waters of southeast Florida. This is discussed throughout this document, with emphasis in Chapters 2 and 11. Depending on geographic location of a new artificial reef, the structure can actually serve to reduce diver pressure on natural reefs nearby.

4.2.5 Repair Structural Damage to Natural Reefs

Artificial reef technologies play an important role in reef restoration following non-permitted damage events such as ship groundings. While some reef restoration experts consider their work as natural reef repair, as opposed to artificial reef construction, the end result of their work is a man-made reef structure. This often requires many of the same natural materials and techniques used in traditional artificial reef construction, such as concrete modules, and limestone boulders. There is much that artificial reef managers can learn by reviewing the methods and materials used to repair structural damage to natural reefs. Good examples include coral reef restoration completed within the Florida Keys Marine Sanctuary.

4.2.6 Mitigation

Artificial reefs constructed as compensatory mitigation are intended to offset impacts to natural reefs or hardbottom damaged by human activities, such as beach dredge and fill (or nourishment), installation of telecommunication cables or pipelines on the seafloor, or ship groundings. Chapter 10 discusses different types of artificial reefs that have been constructed for compensatory mitigation in southeast Florida. This document identifies how to construct artificial reefs once the decision has been made that mitigation construction is appropriate; it does not address the decision to do so.

4.2.7 Secondary Reefs: Hard Structures and Other Types of Artificial Habitats and Special Considerations

Florida's shorelines and coastal waterways include a variety of submerged hard structures constructed for purposes other than artificial reef-related objectives. They commonly are known as "secondary reefs." These include shoreline stabilization structures (e.g., offshore breakwaters, jetties and groins), bridges and piers, offshore navigational towers, pipelines or other structures that were created for some other functional purpose. Other artificial reef objectives are sometimes offered for artificial reef construction, including memorial artificial reefs, electric reefs and artwork.

While these "hard structures" or "other artificial reefs" may have hard substrate for the colonization of coral colonies or other particular characteristics similar to natural reefs, they may not have other attributes representative of natural reefs, such as appropriate relief based on water depth or general design to mimic natural reef communities found in similar depths. In general, these structures may exhibit some, but not all of the characteristics that comprise a traditional artificial reef. Therefore, they are not in the scope of this document. However, they are recognized as an important emerging issue (e.g., foundations for offshore energy farms) with potential to create habitats and to damage habitats used by reef species.

Some of the BMPs developed throughout this document may apply to these types of structures, but some new BMPs may also be needed. For the artificial reef-like structures, BMPs still apply regarding the needs to place the structures in previously designated artificial reef areas, to develop hypothesis-based monitoring, and to provide financial assurance if monitoring shows that the project is not meeting the habitat objectives or is causing harm to coral reefs or associated resources.

4.3 Measuring Success of an Artificial Reef Program

It is crucial that a guiding question, "Is the artificial reef or reef system satisfying the purposes for which it was built?" be integrated into all reef program planning. The book "Artificial Reef Evaluation" devotes 246 pages in seven chapters to the subject of measuring performance of artificial reefs. Major topics include physical, socio-economic and biological assessment practices, with statistical guidance, addressed by 16 experienced scientists from seven nations (Seaman 2000). The reader is referred to this source document for extensive guidance.

In this document, see Chapters 1 and 9 in particular for information on monitoring and assessment of reef performance.

4.4 Unintended Consequences

The unintended consequences of artificial reef construction and siting should be considered in the program development and planning phase to the greatest extent possible. Unintended consequences can include, but may not be limited to, providing habitat for invasive exotic species and displacing other natural species and/or habitats.

4.4.1 An Example of an Invasive Exotic Species

The orange cup coral, *Tubastraea coccinea*, is a non-native stony coral in the South Atlantic region (Cairns 2000, Fenner and Banks 2004). It is easily recognized by the orange cups. In natural conditions, *Tubastraea* sp. is often found upside down at the entrance to caves. However, it can also be occasionally found in the open reef, under overhangs or in areas of high nutrients. The concern is that it competes with native benthic invertebrates for space on the substrate. It was first observed in southeast Florida in 2001. As of 2010, the hull of the *Duane* artificial reef in Key Largo is 100% covered with the orange cup coral (Shearer 2010).

The orange cup coral was introduced in Brazil in the late 1980s and has since invaded 900 kilometers of rocky coastline, threatening the local coastal biodiversity. The "Projecto Coral-Sol," initiated in 2007, proposes to control the spread of this species with the intent of eradicating it in 20 years while adding value to its extraction and contributing to the sustainable development of coastal communities (See: http://www.biodiversidademarinha.org.br/index.php?option=com_content&task=view&id=23&Itemid=35).

In Florida, artificial structures appear to be the preferred habitat. It is not known to exist on natural reefs (Fenner and Banks 2004). Sammarco et al. (2004) examined the expansion of coral communities in the northern Gulf of Mexico via oil and gas platforms. The authors found a relationship between *T. coccinea* abundance and platform age in shallow water, where its abundance decreased with increasing platform age. This indicates that *T. coccinea* may be an opportunistic pioneer species. Given that orange cup coral is a species that should potentially be eradicated, the creation of artificial reefs may be providing additional habitat for this potentially dangerous species.

4.4.2 Artificial Reefs Displacing Other Habitats

Artificial reefs have the potential to displace other important habitats. In general, artificial reefs are placed in sand or softbottom habitats, which are occupied by a wide variety of ecologically (but not economically) important species that are integral to the food web and overall ecosystem. Species of economic importance associated with these habitats include adult and subadult brown shrimp (*Farfantepenaeus aztecus*); adult, subadult, and juvenile pink shrimp (*Farfantepenaeus duorarum*) and Spanish mackerel

(*Scomberomorus maculatus*); adult and juvenile black seabass (*Centropristus ocyurus*) and gag grouper (*Mycteroperca microlepis*); juvenile cobia (*Rachycentron canadum*) and lane snapper (*Lutjanus synagris*). Additional species associated with muddy sand and sand/shell habitats include adult, subadult and juvenile yellowtail snapper (*Ocyurus chrysurus*), white grunt (*Haemulon plumieri*), hogfish (*Lachnolaimus maximus*) and mutton snapper (*Lutjanus analis*) (SAFMC 1998). Notably, many of these species are considered reef fish species, yet rely on surrounding (non-reef) foraging areas.

The SAFMC designates soft bottoms as "Essential Fish Habitat" (EFH) because they play an important role in the ecological function of coastal ecosystems by controlling fluxes of nutrients between the sediment and the water column. Tidal bottoms also provide EFH by serving as nursery grounds for early life stages of benthic-oriented, estuarine-dependent species; refuges and feeding grounds for forage species and juvenile fishes; and feeding grounds for specialized predators (SAFMC 1998), including adult white grunts, which are an important food source for commercially valuable snapper-grouper complex species, and feed mainly on benthic invertebrates (Potts and Manooch 2001).

In particular, the construction of hard structures or artificial reef-like structures in nearshore waters in proximity to nearshore hardbottom reefs is an emerging issue. In recent years resource management agencies have not given favorable reviews for projects that aim to create a higher relief structure in areas that contain lower relief natural hardbottom communities. Placing emergent structures immediately offshore of an important nesting beach could also block access to the beach for marine turtles. For example, breakwaters may deter nesting by interfering with behavior like shore-parallel swimming associated with nest site selection (Bustard and Greenham 1969, Meylan 1978).

From a fisheries perspective, low-relief nearshore hardbottom communities are highly represented by early life stages (Lindeman and Snyder 1999). The nearshore species assemblage shows similarities with the offshore reef fish assemblage, many of which are absent from offshore areas in the early life-history stage (CSA 1999). The placement of higher relief structures can displace the functions that lower relief reef habitats provide, thereby disrupting the ecological balance.

4.5 Inappropriate Goals for Reef Development

Artificial reef construction creates a long-lasting and possibly permanent change to the marine environment. It is the responsibility of the artificial reef manager to exercise due diligence and use the best scientific information available so there will be no adverse results from reef construction. All artificial reef materials, locations and goals need to be evaluated during the planning phase on a case-by-case basis, especially when considering using secondary use materials.

Following is a list of inappropriate objectives for artificial reef construction:

- The disposal of waste products as a sole or principal objective of reef construction.
- Deliberately increasing fishing pressure or efficiency directed at species for which management objectives require a decreased harvest.
- Attempting to increase production of certain fish species when there is no direct evidence that the absence or scarcity of reef habitat is a primary factor limiting abundance.
- Placement that would place persons or property in danger (e.g., creation of a navigation hazard, attraction of anglers to offshore areas remote from access points, or concentration of anglers near commercial shipping lanes or dangerous currents).
- Placement that would result in the significant destruction of fish or wildlife or critical natural habitat.
- Mitigating dissimilar habitat types (e.g., attempting to compensate the destruction of a wetland by constructing a reef), unless there is a clear and overriding benefit to fishery or broader ecological purposes.
- Fish aggregation without proper protection from overharvest.

Chapter 5. Considerations for the Selection and Establishment of Permitted Artificial Reef Areas

This chapter discusses some management, environmental, and socio-economic considerations for selecting and establishing a permitted artificial reef area. A permitted artificial reef area is a specified area of sovereign submerged lands authorized for artificial reef deployments through local, state, and federal permits. Selecting one is more than determining the physical outline of the artificial reef. The permit area can be large and accommodate multiple deployments, or it can be an area permitted for a specific project.

The necessary regulatory steps to establish a permit area are described in Chapter 6. Additional information concerning planning and conducting individual project deployments within a permitted area is outlined in Chapter 7. Ecological functions of reef habitat, including artificial reefs, are described in Chapter 2, which also reviews the terms used to define permit areas and deployment. (See Figure 2.1.)

Regardless of the size of a permitted artificial reef area, the structures placed within it will become part of the broader ecological landscape. So it is essential to consider the selection of the permit area in that broader context. In southeast Florida coral reefs are important parts of that context.

Figure 5.1. The landscape proportions of artificial reefs are depicted in this project off Palm Beach County (Photograph courtesy of Palm Beach County Environmental Resources Management).

5.1 Management and Siting Considerations

The development and design of a new or reauthorized permitted artificial reef area must meet the goals outlined in the program management plan (Chapter 4). Program managers must also evaluate the appropriate size of the permit area and ensure that the size meets the stated objectives. Managers ought to address two questions: 1) How do you know when the area is full? and 2) What is the saturation point where no more artificial reefs are needed? Although the answers will depend on the specific objectives for the artificial reef development, consideration should also be given to unintended consequences affecting non-target taxa or other resource values. Projection planning is needed to ensure that a permitted artificial reef area will meet the size and space needs of the program. This type of planning can be done through Geographic Information System (GIS) software (ArcView/ArcGIS).

Prior to the establishment of a new permitted artificial reef area, managers should do a thorough review of historical (charted) and existing artificial reef areas. Artificial reef program managers will know and have on hand information on the location and characteristics of artificial reef areas that have currently valid permits, and possibly previously permitted (yet expired) areas. Previous managers can often provide historical knowledge not captured in paper or electronic files. Authorized artificial reef areas are noted as “Fish Havens” on NOAA nautical charts, viewable online at: http://www.charts.noaa.gov/OnLineViewer/AtlanticCoastViewerTable.shtml

Once the historical and current permit areas are known, the program manager should evaluate each area based on location, environmental characteristics including depth and proximity to natural resources, and available room for future deployments. It may be possible that existing sites will serve the program management goals or old permitted sites might be reauthorized to fit the program needs, eliminating the need to permit a new area.

5.2 Stakeholder Considerations

Conflicting uses should be evaluated when establishing a permitted artificial reef area. Possible conflicts over sea bottom use could include telecommunication cables, oil, gas or sewer pipelines, alternative energy projects, U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) (formerly the Minerals Management Service) lease areas, sand borrow areas, and restricted areas for military activities. Historical trawling areas and known shipping lanes should also be considered.

Proximity to inlets and the distance of travel to use the permitted artificial reef area must be taken into consideration when establishing new artificial reef areas. If the purpose of a permit area is to provide recreational fishing opportunities, the area might not be used to its fullest potential if fishers have to travel a long way to get there. On the other hand, if a permit area was not established with recreational use as part of the goals, the distance from the inlet may not be as important. The distance to the permit area will also be a factor to consider with respect to the costs of each deployment within the site. The cost of a project is likely to increase with distance from major inlets.

Prior to establishing a permitted artificial reef area, conducting user surveys is recommended. Stakeholders could then provide input as to where permit areas should be established, where possible conflicts may exist, and what types of permit areas would benefit them. Commercial and recreational fishers, boaters, and divers should be included in the survey effort.

5.3 Environmental Considerations

5.3.1 Existing Natural Resources and Buffer Zones

The most recent bathymetry (i.e., Laser Airborne Depth Sounding surveys, or LADS) and benthic habitat maps should be used to identify existing natural resources in the vicinity of any proposed artificial reef permit area. For the SEFCRI region, benthic habitat maps by county can be obtained from the FDEP CRCP.

When natural resources including coral reef habitats and seagrass beds exist in the vicinity of a construction site, appropriate buffers may be necessary between the permit area and the resource to ensure it is protected from materials placement. The size of the buffer required will be dependent on the material being placed, the method and equipment used for placement, and the proximity of resources in the area of the deployment. Examples from existing permits in southeast Florida have required in-water depths greater than 30 ft, and a buffer distance of 250 ft for all materials except maritime vessels. However, appropriate studies are needed to determine suitable buffers to protect adjacent resources during deployment, and secondarily, from unforeseen storm-induced movements. For vessels, because of the increased chances for placement error and the threat of post-deployment migration due to storms, the boundary should be increased. In shallow water less than 30 ft, and based on the equipment used and method of deployment, a lesser boundary could be used. This would require proper agency approval. For example, deployments from a spudded barge are often limited by the reach of the crane. If the crane can only reach out 50 ft to deploy material, a buffer zone of less than 250 ft could be achieved while still affording protection to natural resources. In regions of strong current, the buffer zones may need to be increased in the direction of the prevailing current to offer more protection to natural resources in the event the current carries the artificial reef material away from the target deployment coordinates.

In general, permitted artificial reef areas should not include hardbottom habitat or other benthic resources. Exceptions can be made on a case-by-case basis by the permitting agencies. For example, a vessel grounding site might benefit from the use of artificial reef material to restore the structural complexity and relief of a damaged area, in which case permitting agencies must be involved.

5.3.2 Substrate Characteristics

The characteristics of the bottom sediments must be known and evaluated prior to deployment of materials. Substrate conditions must be appropriate to prevent reef material from sinking beneath the sediment surface. Inappropriate placement can cause significant or total loss of exposed material and greatly reduce the potential habitat and functionality of the artificial reef. Although some settling of deployed material is expected to occur in unconsolidated sediments and can actually assist in the stability of the material, conditions of the sea floor must support deployed materials sufficiently to allow long-term colonization and ecological function of the material placed.

In general, areas with soft sediments such as clay, fine silts or loosely packed sand should be avoided, as they increase the likelihood of artificial reef material sinking or subsiding. On the other hand, deployment on a hard substrate or a hard substrate with a thin sand veneer may increase the material's susceptibility to slide (horizontal movement) during storm events. The possibility of sliding must be addressed ahead of construction. The desired bottom habitat for artificial reef placement would be soft sediment with an underburden of rock.

Artificial reef managers should also be aware that bottom sediments shift and may change significantly during storms, hurricanes and strong currents. Scouring is a potential at strong current locations.

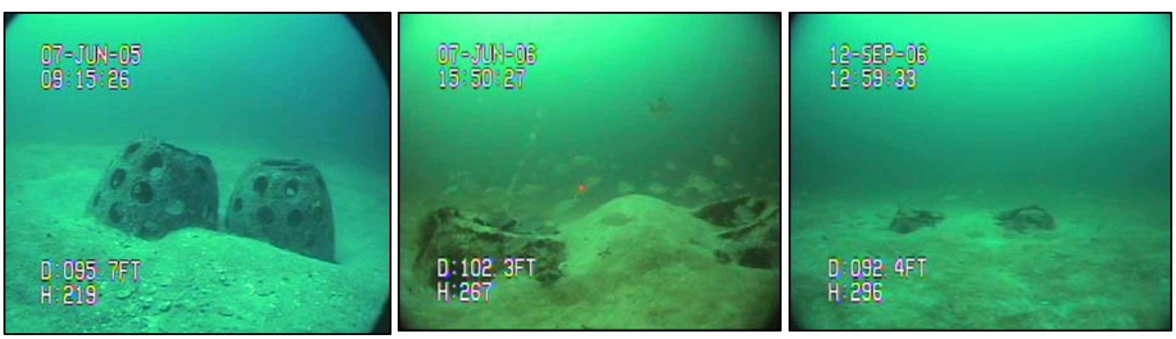

Figure 5.2. Example of subsidence of artificial reef material into soft sediments (Photographs courtesy of FWC).

5.3.3 Water Depth

Safe Navigation -- The water depth of the permitted artificial reef area must be sufficient to allow for safe navigation over the reef material. The USCG will make a determination as to the required clearance (i.e., minimal water depth above the material) based on the location and anticipated kinds of marine traffic that would traverse the area. This will be incorporated into state and federal permit conditions. The USCG may, on a case-by-case basis, require specific buoys or other markers be placed to designate the artificial reef area or material to aid in safe navigation (see Chapter 8). In general, the depth clearance of a permitted artificial reef must not exceed the shallowest depth of surrounding natural features. For example, for an artificial reef area in 40 ft of water near a natural reef that crests at a depth of 25 ft, the relief of the material (i.e., height above seafloor) cannot be greater than 15 ft. The depth clearance may also be altered due to proximity to navigation channels.

Material Durability and Stability -- Assurance of long-tem stability is likely one of the single most critical aspects of pre-deployment planning to ensure no harm occurs to coral reefs within the region. The shallower the water on a high-energy shoreline the more severe the physical conditions the artificial reef will experience. This may lessen the durability of the artificial reef material. The depth of the permit area can also affect the stability of individual deployments. Some material may be more stable at deeper depths and less stable at a shallower depth. For more information on stability requirements for individual deployments within a permitted artificial reef site, please refer to Chapter 7.

Artificial Reef Site Goals -- The depth of the reef must also be considered based on the goal of the permitted artificial reef area. For example, if the goal is to create recreational dive opportunities, the permit area should be within recreational dive limits (<130 ft). If the goal of the permit area has a biological component such as providing habitat for a given species, the preferred depth range of that species should be known and factored into where the permitted artificial reef area is placed.

5.3.4 Hydrodynamic Processes

Wave Energy -- Areas of consistently high wave energy may not be suitable as artificial reef areas. High wave energy will decrease the durability and stability of artificial reef material due to constant exposure to wave surge. The wave-energy may also limit the settlement potential of sessile organisms if water is too turbulent. High wave energy zones are often close to shore. Placing material in these areas might affect longshore sand transport and alter the wave energy. These might or might not be desirable effects and should be evaluated thoroughly. Prior to permitting a high wave energy zone as an artificial reef area it is recommended to have an engineer familiar with artificial reef stability and durability evaluate the area to determine overall suitability for artificial reef material placement.

Currents -- When planning for a permitted artificial reef area, the program manager must be aware of local currents (e.g., Gulf Stream and longshore currents) as well as tidal currents associated with inlets and how they factor into the overall program goals. While strong currents are generally not desirable for a variety of reasons, some level of water circulation is necessary to distribute planktonic larvae for settlement potential on artificial reef material and to provide nutrients to the biotic community. If the program goals are to provide recreational diving opportunities, then placing an artificial reef in an area with consistently strong currents might not be desirable. However, if the plan is to increase substrate available for benthic growth, an area with stagnant water void of currents and water circulation also would not be desirable. Strong currents often make individual artificial reef deployments more difficult and costly. They can also make deployments less accurate, potentially putting existing resources at risk especially if the material is not anchored properly. Currents can cause scouring of the substrate around the artificial reef, causing sand depletion on one side and accumulation on the other, which may affect the overall stability of the material. Outgoing tidal currents can bring some undesired characteristics such as increased turbidity and pollution from land-based sources. However, for bay or inshore artificial reef areas, tidal currents may be a useful source of water circulation.

5.4 Contact Information

Contact information for accessing documentation associated with charted artificial reefs/ fish havens:

NOAA—Office of Coast Survey
Nautical Data Branch
1315 East-West Highway
Silver Spring, MD 20910
(301) 713-2737
http://www.nauticalcharts.noaa.gov/

Contact information for accessing county-level habitat maps:

FDEP CRCP
Biscayne Bay Environmental Center
1277 NE 79th St. Causeway
Miami FL 33138
coral@dep.state.fl.us
http://www.dep.state.fl.us/coastal/programs/coral/

Chapter 6. Artificial Reef Permitting and Regulations

The permitting process for artificial reef development in southeast Florida begins with submittal of the "Joint Application for Environmental Resource Permit" form. This single form is used by both the FDEP and the USACE to process permits for work on or over surface waters in state and federal waters, and includes such activities as dredge and fill, marina redevelopment, horizontal directional drills (e.g., gas, electrical, water and sewer lines), single family wetland construction, dredging projects, single family docks and seawalls, boat lifts, gas pipeline installation, and artificial reefs. Since the application form is not specifically for artificial reefs, most of the questions pertain to wetland fill and boat docks and are not applicable to artificial reef construction. Most of the artificial reef project information should be listed in the project description area, and it is the responsibility of the applicant to attach information to the form that is specifically relevant to artificial reef construction.

For a complete application all agencies require: the appropriate complete application form; permit fee; location of project including latitude and longitude of all corners; purpose and need for the project; description of type, quantity, and composition of material to be placed in the water; legible plan and elevation/ cross-section drawings on 8 ½" by 11" paper "signed and sealed" (e.g., by an experienced environmental engineer) showing dimensions of all proposed structures and depth of water; copy or permit number of all previous permits issued at this location; provisions for siting, construction, monitoring, and managing the artificial reef; and a list of other certifications/approvals/application numbers from other local, state or federal agencies for the work. The permit review process is illustrated in Figure 6.1.

Pre-application meetings with agencies, especially for larger, complex artificial reef projects are strongly encouraged. Separate permits or authorizations may be necessary from other agencies, depending on the work proposed.

Two completed original copies of the "Joint Application for Environmental Resource Permit" form should be submitted to the FDEP Southeast District Office (Figure 6.1) located in West Palm Beach, which serves St. Lucie through Miami-Dade counties. The FDEP will process one original, and will forward the second original to the appropriate field office of the USACE Jacksonville District, either the USACE Palm Beach Gardens Field Office (serving Martin, Palm Beach and Broward counties), or the USACE Miami Field Office (serving Miami-Dade County). It is important to submit two originals with all supporting documentation and attachments to ensure that a complete copy of the application is forwarded by FDEP to the USACE. The permit application form is available online at: http://www.dep.state.fl.us/water/wetlands/erp/forms.htm, or at: http://www.saj.usace.army.mil/regulatory/forms/forms.htm under the link "For Florida."

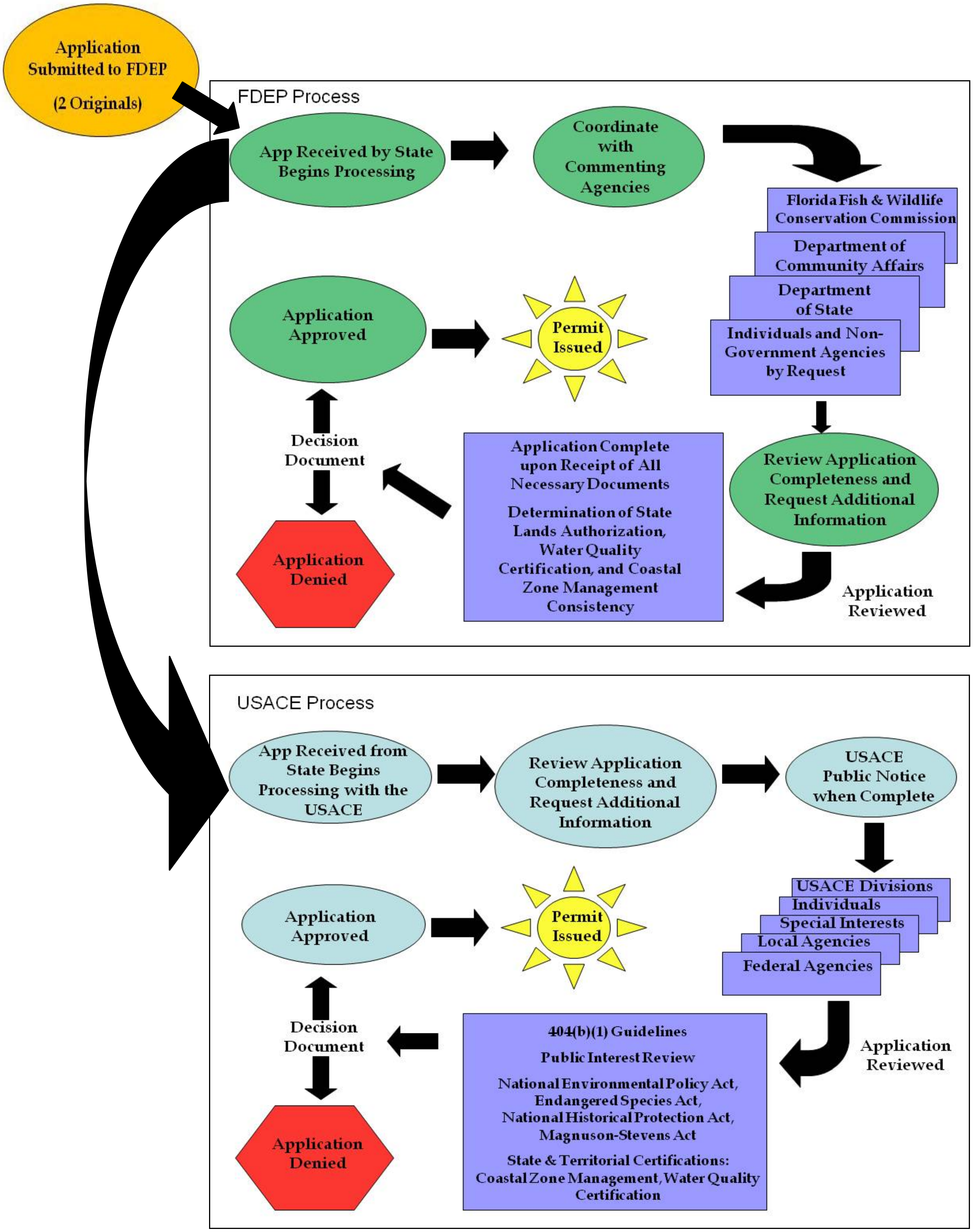

Figure 6.1. Steps in the Florida Department of Environmental Protection and U.S. Army Corps of Engineers Joint Application for Environmental Resource Permit review process (modified from USACE "Overview 2008" slideshow).

It is important to begin the permitting process well ahead of any planned reef construction. In general, permitting takes longer than in the past. Historically, the state and federal process combined would be no longer than 3-6 months for general permits and one year for larger sites. The best available science has shown that more detailed information needs to be provided by applicants in order to ensure that artificial reefs are meeting appropriate objectives, avoiding impacts to natural resources and are not conflicting with other uses of the sea floor.

The time it takes to issue a permit is dependent on the agency receiving a complete application from the applicant. For this reason, it is strongly recommended that applicants coordinate with the FWC Artificial Reef Program prior to submittal to ensure that the application is complete to the greatest extent possible. Once an application is determined complete and all necessary and requested supporting documentation is received by the agency, an FDEP permit is required by statute to be issued in 60 days for the Noticed General Permit and 90 days for an Environmental Resource Permit (ERP). The USACE has a goal of 120 days to issue any individual permit. The agency timeclocks do not begin until the application is determined to be complete.

As a practical matter it may be in the best interest of the reef program to apply for multiple sites at the same time through one individual permit process. The application fee to the state for this is increased, but savings in staff time to process sites independently would be reduced considerably. Individual permits typically are issued for 5 to 10 years, as opposed to 3 years for the general permit, and can be extended for additional time with little extra effort.

6.1 Federal Permits

6.1.1 United States Army Corps of Engineers

A USACE permit is needed for all artificial reef projects. Pre-application meetings are recommended to begin the process.

The USACE holds authority under Section 10 of the Rivers and Harbors Act and under Section 404 of the Clean Water Act to regulate structures and placement of materials into the waters of the U.S. (the EPA has delegated the "404 process" to the USACE.) The USACE jurisdictional authority extends from the high tide line to the seaward limits of the outer edge of the continental shelf.

The USACE determines a level of permit for which the proposed work will qualify. Projects which qualify for the category of Nationwide Permits are usually smaller projects with a scientific or restoration aspect. Projects which qualify for the Individual Permit category are usually larger projects such as recreational reef deployments, ships, and larger concrete structures. The level of review is determined by the assigned USACE project manager. For general questions, contact the Palm Beach Gardens office at 561-472-3528 and the Miami office at 305-526-7484.

The USACE may coordinate plans with other federal agencies, including, but not limited to NOAA, EPA, USCG, USFWS, and BOEMRE through the public notice process. For example, endangered species surveys may be requested from the reviewing agencies in order to note the presence and prevent damage or destruction to hardbottom, coral reefs or endangered species. Surveys may also be requested to identify historical artifacts that should be avoided. Applicable authorities include the National Environmental Policy Act which provides a mandate and framework for federal agencies to consider all reasonably foreseeable environmental effects of proposed actions and to involve and inform the public in the decision-making process by considering environmental impacts and reasonable alternatives. It requires federal agencies to conduct an Environmental Assessment or Environmental Impact Statement for each project. The National Historic Preservation Act provides for evaluation of direct and indirect impacts of the project on historic resources in the area. The Endangered Species Act provides a consultation requirement for any federal actions (e.g., USACE issuing an artificial reef permit) that may affect a listed species to minimize the effects of the action.

A consistency determination with the federal Coastal Zone Management Act (CZMA) of 1972 (Public Law 92-583, 16 U.S.C. 1451-1456) is needed for all artificial reefs. The CZMA Program in Florida is delegated to the FDEP. In state waters CZMA approval is accomplished through issuance of an environmental resource permit by the FDEP Environmental Resource Program. In federal waters, since no state environmental resource permit is issued, the USACE must secure a separate letter from the Florida State Clearinghouse operated by the FDEP Florida Coastal Management Program.

If mooring buoys are required, they may be issued as a Nationwide Permit. A "Joint Application for Environmental Resource Permit" must be submitted for the authorization to use sovereign submerged state lands and to obtain a federal dredge and fill permit. This application requires but is not limited to providing a general project summary, buoy or marker coordinates, summary of construction methodology and maintenance plan for the buoys or markers.

6.1.2 United States Coast Guard

The USCG routinely reviews all artificial reef permit applications submitted to FDEP/USACE. If, based on this review, the USCG decides the reef would be a hazard to navigation, the applicant will be advised of this finding and be required to submit a separate buoy permit application to the appropriate USCG District Commander.

The USCG Seventh District Commander in Miami is responsible for Florida's East coast and decides on a case-by-case basis if a buoy is required on a reef. The decision is usually based on whether or not the top of the reef will be at least 55 ft below the water surface at mean low water. Variance depends on navigational circumstances at the site. Contact Commander (DPW) USCG Seventh District at 305-415-6800. Artificial reef managers should plan to site the reef at a depth and location where buoys are not required by the USCG to ensure maximum navigational safety, and to avoid the high cost of long term buoy maintenance and oversight (see Chapter 8).

Mooring buoys do not require USCG approval for installation, while markers or special purpose buoys do require USCG approval. A *Private Aids to Navigation Application* (see http://www.uscg.mil/forms/cg/CG_2554.pdf) must be submitted to the Aids to Navigation and Waterways Management Branch of the USCG District 7. This application requires coordinates and general information on the location of each buoy or marker.

The USCG should receive notification of an artificial reef deployment at least 30 days prior to the planned sinking of a vessel. It will inspect the vessel to ensure the doors and windows are removed and the vessel is free from oil, hazardous material, and debris. The vessel tow plan with sinking location should be submitted to the USCG at least 10 days prior to the planned sinking, using USCG Artificial Reef Towing Plan and Notification Forms. Contact USCG Sector Miami, Waterways Management Division, at 305-535-4307 or 4317. The website is http://www.uscg.mil/.

6.1.3 Bureau of Ocean Energy Management, Regulation and Enforcement

The USACE will coordinate (by posting of public notice) with the U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) (formerly the Minerals Management Service) in order to verify that placement of the artificial reef will not conflict with potential oil, gas, gravel or sand fields. BOEMRE will review the permit application to see if the proposed project will affect the National Baseline and therefore the position of the Submerged Lands Act Boundary and the Limit of the "8(g) Zone" boundary.

Please contact (703) 787-1297 for questions concerning USACE permits in conjunction with BOEMRE. The Bureau of Ocean Energy Management, Regulation and Enforcement website is located at: http://www.boemre.gov/.

6.1.4 Environmental Protection Agency

The USACE will coordinate (by posting of public notice) with the EPA. Ships must be cleaned to the standards described in EPA 842-B-06-002 ("National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs," USEPA 2006). Project managers may also confer with the EPA outside of the USACE public notice process if a separate disposal permit needs to be issued for the project. See http://www.epa.gov/owow/oceans/habitat/artificialreefs/index.html.

6.1.5 National Oceanic and Atmospheric Administration National Marine Fisheries Service

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) (in the U.S. Department of Commerce) is responsible for reviewing and commenting on each permit application submitted to the USACE as it relates to impacts to the marine environment, fisheries and endangered species. The NMFS Habitat Conservation Division has an Essential Fish Habitat (EFH) consultation requirement under the provisions of the Magnuson-Stevens Fishery Conservation and Management Act. Federal action agencies which fund, permit, or carry out activities that may adversely affect EFH are required to consult with NMFS regarding potential adverse impacts of their actions on EFH, and respond in writing to NMFS recommendations. The NMFS Protected Resources Division consults on federal actions that may affect a species listed under the Endangered Species Act (as threatened or endangered) to minimize the effects of the action.

6.2 State Permits

6.2.1 Florida Department of Environmental Protection – Environmental Resource Permits

For an artificial reef to be built inside state waters (i.e., within three nautical miles of the Atlantic shore), it will require state permits in addition to the federal permits discussed above. The application is the same for both the USACE submittal and the FDEP submittal; an applicant now just prepares two original copies of the same application. As of June 2008, FDEP forwards one of those applications to the appropriate USACE office. FDEP does not routinely forward additional information received after the initial application. FDEP also does not routinely forward applications to the county permitting departments. The FDEP evaluates the application and issues a state permit if a proposed reef satisfactorily meets established criteria similar to that of the USACE. (See Figure 6.1, Table 6.1 and Table 6.2).

Table 6.1. Essential information to be submitted with application to FDEP for an artificial reef permit. (Information courtesy of Jennifer Smith, FDEP Submerged Lands & Environmental Resource Permitting Program.)

- Pre-application meeting
- Results of detailed habitat assessments (e.g., from scuba, fish counts, or side scan sonar)
- Location maps and drawings
- Threatened and Endangered Species protection measures
- Detailed description of materials
- Stability analysis (past performance of similar materials)
- Tow, anchoring and sink plan
- Reasonable assurance that project will not cause water quality violations and not adversely impact adjacent natural habitat or threatened/endangered species.

Issuance of the state permit also certifies that the project is in compliance with the Coastal Zone Management Act and includes authorization to use sovereign submerged lands before reef-building in state waters.

If a proposed reef is outside of state waters (beyond three nautical miles on the Atlantic Coast) state permits will not be required. In this case, FDEP will advise the applicant of the non-regulated status. However, pertinent state agencies will nonetheless have application review privileges, along with the opportunity to object to proposed construction that does not appear to be in the best interest of the state, through the Florida State Clearinghouse program.

Table 6.2. A checklist for siting and materials specifications for artificial reefs, according to FDEP (Chapter 62-341.600, F.A.C) and terms of the Noticed General Permit for the Construction of Artificial Reefs (Information courtesy of Jennifer Smith, FDEP Submerged Lands and Environmental Resource Permitting Program).

General Criteria

- Clean concrete, rock, steel boat hulls, other heavy gauge steel, or a mixture of clean concrete and steel;
- Material free of pollutants and debris;
- Firmly anchored to the bottom;
- Not indiscriminately dumped; and
- Top of reef shall not exceed ½ distance from the bottom to the surface of the water

Specific Criteria

- Site shall not be located on grasses, corals or other hardbottom communities
- Water depths shall not be less than 12 ft deep
- No “white goods,” asphalt, or tires
- Site marked with buoys during deployment
- Not located within shipping lanes
- Notify state and federal agencies of location

Most Limiting Criteria

- Size of the boundaries of the reef shall not exceed ¼ mile on any side.

6.2.2 Florida Department of Environmental Protection – Joint Coastal Permits

Under certain circumstances, where an artificial reef is proposed at a location that might influence littoral transport of sand or potentially affect the shoreline, a different type of ERP application, called a Joint Coastal Permit (JCP) application, might need to be sent to the FDEP Bureau of Beaches and Coastal Systems (BBCS). For projects in the nearshore beach area, an applicant should contact the FDEP BBCS directly for the JCP information and application forms, at 850-414-7728.

6.2.3 Florida Fish and Wildlife Conservation Commission – Special Activity License

If the artificial reef project includes the transplantation of corals or other organisms, then a separate permit called a Marine Special Activity License will be required by the FWC (see http://myfwc.com/license/Saltwater_Licenses_SAL.htm).

6.2.4 Florida Fish and Wildlife Conservation Commission – Florida Uniform Waterway Marker Application

For marker or buoy installation, a "Florida Uniform Waterway Marker Application" must also be completed and submitted to the Office of Boating Safety and Waterway Management under the Division of Law Enforcement (an artificial reef marker buoy is a "special purpose buoy"). If the application is satisfactory, temporary authorization will be granted to begin installing the buoys or markers and final approval will be granted after successful installation. This application requires coordinates and general information on the location of each buoy or marker (see http://myfwc.com/RECREATION/boat_waterways_index.htm).

6.2.5 Florida Department of State – Historical Resources

The Division of Historical Resources within the Department of State is the agency responsible for promoting the historical, archaeological and folk culture resources in Florida. Its director serves as Florida's State Historic Preservation Officer, providing a liaison with the national historic preservation program conducted by the National Park Service. The locations of all new artificial reef areas are reviewed by the Department of State to ensure that no impacts will occur to any submerged archeological resource.

6.3 Local Government Permits

Activities conducted within, on, over and under surface waters of local counties out to three nautical miles from the shoreline are subject to review by the appropriate county environmental department. Reef construction also might require local permits if it will take place within the jurisdiction of a county or municipal agency. Inshore bay and estuarine reefs are the most likely candidates for this requirement. It is the responsibility of the reef developer to investigate local laws and regulations and obtain appropriate permits. If mooring buoys are installed, permits may also be required from the local county environmental agencies. Local artificial reef plans should be a source of information on local permitting procedures. In southeast Florida local permits are required by Broward and Miami-Dade counties.

6.3.1 Miami-Dade County Department of Environmental Resource Management

The Coastal Resource Section (CRS) of Miami-Dade County DERM issues two Class 1 Coastal Construction permits for artificial reefs to the Miami-Dade County Board of Commissioners. One is for the inshore (bay) artificial reef sites, and one is for the offshore artificial reef sites within the county's jurisdiction. Such permits are valid for two years and can be renewed for an additional two years with approval of an extension application. Creation of new artificial reef sites will require additional Class 1 Permit approval. This may occur through the modification of the existing permit or through a new application. Contact CRS at 305-372-6575. For applications and general information see http://www.miamidade.gov/derm/permit_applications.asp.

The Restoration and Enhancement Section (R&E) of Miami-Dade County DERM is the county's designee to manage its artificial reef program and the permitted artificial reef sites. Individual artificial reef deployments are coordinated through the R&E Section, which also provides the management and oversight for all reef deployments and ensures compliance with conditions in the Class 1 permit as well as the FDEP and USACE permits. Contact R&E at 305-372-6864 or reefs@miamidade.gov.

6.3.2 Broward County

Applications for artificial reefs within Broward County limits are reviewed in accordance with Chapter 27, Pollution Control, Code of Ordinances of Broward County, Article XI, Aquatic and Wetland Resource Protection. An artificial reef project requires an Environmental Resource License, issued by the Aquatic and Wetlands Resources Section. The license would be approved up to five years and extensions may be granted if requested prior to the original expiration date. They may be contacted at 954-519-1230. The application and fee schedule can be found online at:
http://www.broward.org/environment/licenses_apps.htm.

6.3.3 Palm Beach County

Palm Beach County does not have any permitting program; however, the Environmental Resource Management Department will review the public notice posted by the USACE for offshore impact applications, including artificial reefs, treasure salvers, pipelines, etc. Applicants that will be conducting work offshore at night or maintaining vessels offshore at night must apply for and comply with the Sea Turtle Protection and Sand Preservation Ordinance. Palm Beach County requires an approved Sea Turtle Lighting Plan prior to commencement of any projects within the Sea Turtle Protection Zone, which extends three miles offshore of the Atlantic Ocean and along inlet shorelines to a line 600 ft landward of the mean high water line. Contact 561-233-2400.

6.3.4 Martin County

Martin County does not have an offshore permitting program, however the County will review the public notice posted by the USACE.

Chapter 7. Construction of Artificial Reefs

Responsibilities related to artificial reef construction are not limited to deployment day activities. Project managers must determine the purpose of the reef, select an appropriate site, identify suitable materials, notify permitting agencies, coordinate with marine law enforcement and other interested parties, prepare the site, generate publicity and conduct post-deployment evaluations. This chapter addresses such considerations and tasks.

As explained in Chapters 1 and 2, artificial reefs influence physical, biological or socioeconomic processes. There are many types of artificial reefs that can potentially achieve those purposes. In general, the constructed reefs can be low, medium or high-relief structures, usually built of rock, concrete or steel. These options can be combined in various locations for fisheries management, fishing enhancement, dive destinations, mitigation, research or other special purposes, such as surfing and shore protection.

7.1 Reef Materials Selection

Materials used for marine habitat in Florida waters must be environmentally safe and comply with water quality standards established by the EPA and/or the FDEP. Reef programs are offered a wide assortment of "materials of opportunity," but such items should be rejected if they do not meet all the criteria for acceptability.

The State of Florida requires that all material placed on an artificial reef site funded by the FWC Artificial Reef Program be stable in a "20-year storm" (i.e., wind, wave, and current conditions that would have a 5% chance of occurring in any given year) [Ch. 68E-g.004(4) Florida Administrative Code (F.A.C)]. Miami-Dade County DERM follows a rule of thumb that requires all materials be stable in a 50-year storm event.

The design process for each individual deployment site must incorporate physical characteristics that best assure maximum longevity in the ocean environment and optimal habitat for marine species. This goal may be achieved in several ways. Engineered prefabricated reef units can be designed such that an individual unit is a fully functioning, free-standing reef. In contrast, natural rock, concrete rubble, or other similar material must be stacked and interlocked to achieve the same purpose. Managers should select, design, construct, and deploy reef material to create stable and durable marine habitat. (See Lukens and Selberg 2004.) To this extent, and consistent with accepted management practices, material should:

- Have sufficient density as determined by the Lin (or equivalent) model (mass-to-volume ratio) to remain stable in the ocean environment at depths and currents in which it will be deployed;

- Be extremely durable in seawater and non-subsiding in sediments characteristic at the construction site;
- Have suitable substrate characteristics and ample surface area for fouling organisms;
- Create vertical profile and structural complexity to encourage species diversity;
- Ensure adequate water circulation;
- Provide refuge for animals;
- Minimize exposed rebar or other protruding steel components which may entangle fishing gear or line, which may in turn result in entrapment of marine life;
- Abide by all permit and grant conditions; and
- Maximize the benefit-to-cost ratio.

Additionally all materials used in construction must be free of:

- Asphalt, petroleum, other hydrocarbons, and toxic substances that may be harmful to humans, animals or other aquatic life;
- Substances attributed to municipal, industrial, or other discharges producing color, odor or other conditions in such degrees as to create a nuisance;
- Loose free-floating materials; and,
- Material producing turbidity should be minimized, whether or not it leads (or might lead) to permit violations.

7.1.1 Materials Types

The following list of potential artificial reef materials (Figure 7.1) is supplemented by Table 7.1, which indicates advantages and disadvantages. Note that density of material is an essential consideration, in the sense that an item weighing 500 pounds (lbs) and say, 3 ft across, will be more stable than an item of similar weight but 6 ft across. The ratio of weight to surface area is important.

- Engineered modules, which can be composed of ferrous and/or aluminum-alloy metals, concrete, rock or a combination of these materials that weigh more than 500 lbs (subject to density consideration);
- Natural rock, such as limestone and granite;
- Cleaned concrete materials, including bridge sections, pilings, culverts, stormwater junction boxes, power poles, railroad ties, jersey barriers, or other similar concrete material that weighs more than 500 lbs (subject to density consideration);
- Heavy gauge ferrous and aluminum alloy metal material components or structures ¼ inch or more in thickness, such as utility poles or antenna towers that weigh more than 500 lbs (subject to density consideration);
- Heavy gauge ferrous and aluminum alloy metal hulled vessels (at least ¼ inch thick) with a minimum of 60 ft hull length (subject to density consideration).

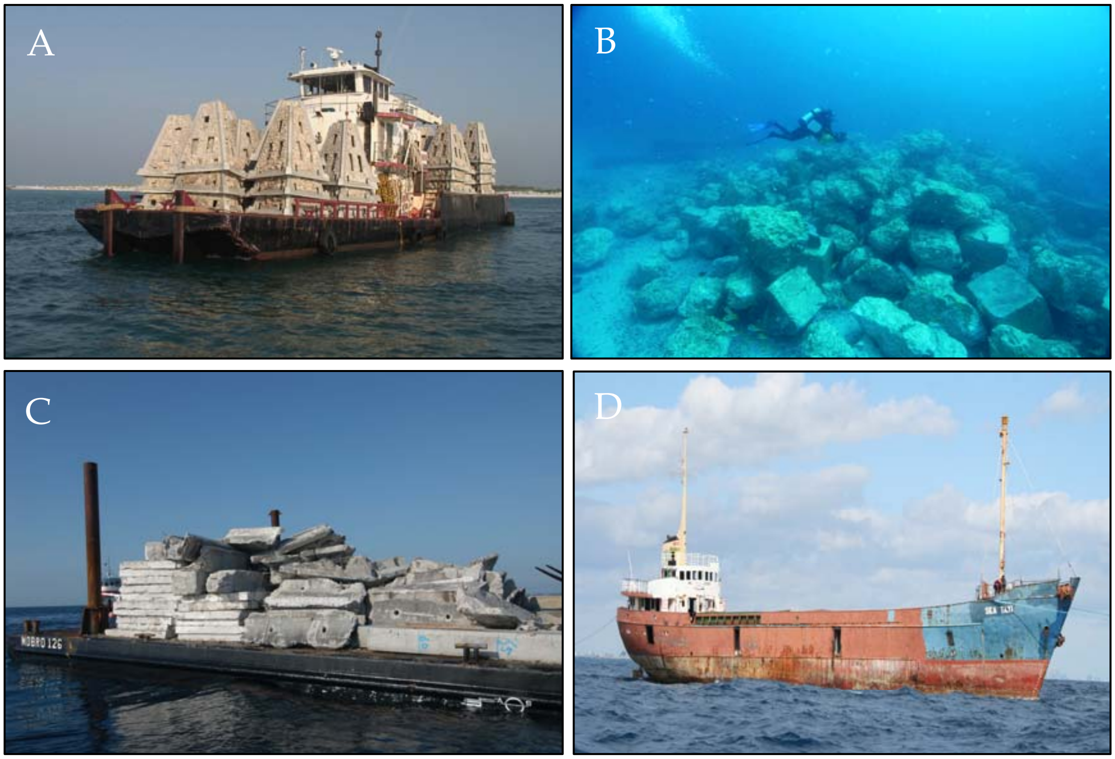

Figure 7.1. Typical materials and structures used in artificial reefs in Florida coastal waters. A, Concrete modules, with open space customized to enhance biodiversity; B, limestone rock, arranged to increase physical complexity of the substrate; C, surplus concrete rubble, arranged for profile and complexity of spaces; D, a vessel cleaned to meet pollution and safety requirements (Photographs courtesy of FWC).

Table 7.1. Characteristics of materials commonly used in southeast Florida artificial reefs.

Material	Some Advantages	Some Disadvantages
Prefabricated Artificial Reef Modules	• Can combine all design elements of an artificial reef into a single structure (not dependent on deployment methods to achieve this goal) • Can be designed specifically for an intended use and can combine construction materials • Concrete mixes can be pH-balanced to allow for rapid recruitment of benthic organisms	• Not readily available "off the shelf" • Must be constructed either on-site or by a contractor • Relatively expensive • May require extra care and equipment during deployment
Natural Rock	• Surfaces of "natural" rock are irregular and rough, making them attractive to attaching organisms • Size and density can be specified (Lower density rock will be more attractive for drilling and attaching organisms; higher density rock will provide greater stability) • Height and complexity of proposed reef can be controlled by construction methods • Stability can be maximized by combining various sized rock • Can be deployed to result in high profile, complex structures as desired	• Dependent on construction methods to produce a good, functioning reef • May need to be transported from distant sources
Clean Secondary Use Concrete Material	• Inexpensive, often free • Readily available • Can be deployed to result in high profile, complex structures as desired	• Newly constructed concrete materials may take some time after exposure to marine environment to neutralize pH levels and allow growth of attaching organisms (typically 1-3 months) • Contractors "donating" material may need to be supervised to ensure that concrete meets cleaning specifications • Long-term access to staging areas, ideally waterfront property with barge access, is necessary to maximize the accumulation of donated material
Heavy Gauge Ferrous and Aluminum Alloy Metal Material, Components or Structures	• Often function well as FADs (fish attracting devices) if deployed and anchored vertically in the water column • Can be deployed to result in high profile, complex structures as desired	• Handling for effective deployment can be difficult • Sections or pieces of debris may disassociate with the vessel as normal corrosion and storm events take their toll on the structure over time • Risk of failure if too thin

Table 7.1, continued.

Heavy Gauge Ferrous and Aluminum Alloy Metal Hulled Vessels (at least ¼″ thick) with a Minimum 60 ft. Hull Length	• When prepared properly can function much like a prefabricated artificial reef, providing stability, complexity and refuge • Often provide very popular fishing and diving destinations • Larger vessels especially can be an economic engine for a community	• Can be very expensive as a result of preparation and deployment requirements • Often a very long lead time required to complete extensive environmental preparation required by all agencies • Requires extensive coordination with all agencies for inspections and approvals • Deployment of large vessels is complex and dangerous and should only be undertaken by highly qualified contractors

7.2 Reef Material Siting Considerations

With a clear goal for the proposed artificial reef, and selection of appropriate construction materials, the next step is to identify an appropriate construction site. The selection process for the best deployment site will depend on several factors. Areas of natural hardbottom communities should be eliminated from consideration. Additional information on siting is in Chapter 5.

Analysis of the weight and dimensions of material to be used for construction will identify a minimum depth at which the material will remain stable. The size of the material may also dictate a minimum water depth, due to navigational clearance requirements. An additional consideration is the intended use of the material; a mitigation reef may have a preordained location; a reef dedicated to fisheries enhancement may be placed in an area less likely to feel heavy fishing pressure and possibly proximal to existing hardbottom to facilitate recruitment; reefs constructed for a diving experience may require a certain depth and travel distance from an inlet; and an artificial reef designed as a fishing destination will have specific requirements based on the target species.

Bathymetry must be analyzed to ensure that water depths are sufficient to allow for safe navigation over the reef material as per USCG directions. Generally, the requirement in southeast Florida is for clearances of at least 6 ft in 7 to 12-foot depths, 50% of the water depth between 13 and 100 ft and at least 50 ft in depths greater than 100 ft.

Bottom types should be analyzed to ensure that known areas of existing hardbottom are excluded from consideration, and to ensure that the substrate is firm enough - or has a supportive basement layer - to support the material being deployed. Reef material can settle into and disappear below areas of loose sand and mud. Buffers of sufficient size should be placed around any known hardbottom habitat to protect the existing resources in the event of slight unintentional deviations from the planned deployment. Buffer size will depend on the water depth, prevailing currents, and the material to be deployed. Increased buffer sizes should be considered in the down-current direction. Even with minimal currents, material will tend to scatter over greater areas of the bottom as depth increases, which should be accounted for in the planned reef footprint shape and buffer design. GIS coverages based on the databases available (e.g., offshore side-scan sonar traces of reef areas, bathymetry of the offshore area, bottom types, existing artificial reefs) can be layered to obtain a more complete view of the potential areas available for deployment.

Information regarding navigational channels, utility cables, pipelines or other rights-of-way, disposal sites or sand source sites, and shrimp trawl or other commercial fishing routes should be solicited from all possible sources and included as additional areas to be avoided. GIS mapping will allow the artificial reef coordinator and the public to get a comprehensive view of the reef, its surroundings, its accessibility, and an assessment of prevailing sea conditions. Coordinates (corners) for the selected location are recorded and provided to field personnel to conduct an inspection.

7.2.1 Pre-Deployment Site Inspections

Artificial reefs are generally deployed on sediment-covered substrate. Pre-deployment site inspections should be carried out before each deployment to determine the size and boundaries of the soft substrate, sediment type and grain size characteristics and thickness, site water depth and location; depth of all adjacent hardbottom; water current velocity; and the magnitude and direction of the largest typical waves. Documentation provided by remote sensing technologies such as towed side-scan sonar, transom-mounted side-scan sonar. RoxAnn sonar, towed video, and/or ROV video are encouraged to be used when available. This information should be used to update the GIS map created during the planning stage and to refine the reef site selection, and in stability analysis calculations. Specifications from Miami-Dade County DERM are included in Box 7.1 as an example.

Box 7.1 Method for inspection of the proposed reef site, dependent on its depth, visibility and currents (Methods courtesy of Miami-Dade DERM).

A. *For proposed sites in less than 120 ft*, a dive team with biologists experienced and trained in evaluation and assessment of marine benthic habitats and coral reef communities should conduct a visual assessment of the site and surrounding areas. Any existing habitat and cultural materials or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property should be recorded for evaluation, and should be added to the GIS map for the project.
   1. If no hardbottom or reef areas, cultural materials, or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property exist, the center point of the site should be determined by floating a 'taut-line' buoy to the surface, and recording the location of the position with a Differential Global Positioning System (D-GPS).
   2. Should any hardbottom or reef habitats, cultural materials, or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property be found within the placement zone (inclusive of the buffer zone), the adjacent areas should be surveyed to determine if a suitable area exists to modify the position and placement of the material. If a suitable adjacent area is located, the center point of that location will be determined by floating a 'taut-line' buoy to the surface, and recording the D-GPS coordinator.

B. *For proposed sites in greater than 150 ft*, personnel with experience in interpretation of bathymetric fathometer output will conduct a grid of fathometer tracings over the proposed area. The number of transects to be conducted will depend on the size of the material in consideration. The fathometer will have a "zoom" function that will allow for displaying only the last 20 ft above the bottom. With this resolution, areas of hardbottom with benthic growth or significant materials that may be representative of cultural materials or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property are discernable from flat sand bottom, and will be detected and noted by the operators.
   1. If no hardbottom or reef areas, cultural materials, or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property exist, the center point of the site will be determined by recording the location of the center point of the surveyed position with a D-GPS.
   2. Should any hardbottom or reef habitats, cultural materials or artifacts that would indicate the presence of a potentially significant shipwreck or other historic property be found within the placement zone (inclusive of the buffer zone), the adjacent areas will be surveyed to determine if a suitable area exists to modify the position, and place the material. If a suitable adjacent area is located, the center point of that location will be determined by recording the center point of the position with a D-GPS.

7.3 Pre-Construction Notifications

A number of agencies require notification at specific points in the pre-deployment timeline. Pre-deployment site inspections are typically conditions in both permits and grants. Finally, to maintain public support and awareness of an artificial reef program, it is good business to keep the media and material donors informed of the project's status (see Chapter 12).

7.3.1 Notifications to Applicable Permitting and Other Regulatory Agencies

Construction of artificial reefs is regulated through permits issued by the FDEP and the USACE. In some cases county environmental agencies may permit reef construction (see Chapter 6). Permit conditions generally include pre- and post-project reporting requirements. The following are items that may be required by permits (subject to change):

FDEP:
- Reef site survey notice
- Pre-deployment notification form USACE, Regulatory Division, Enforcement Section
- Signed USCG inspection form, as applicable
- Cargo manifest
- Verbal notification 14 and 5 days before deployment
- Specific FDEP Notice of Commencement Form (#62-343.900(3)) 48 hours before deployment

FWC:
- Notification 30 days before deployment for EPA sample collection – vessels only
- Cargo manifest
- Pre-deployment notification form

USCG Sector Miami (and local, as applicable), Waterways Management Division:
- Ocean disposal/artificial reef notification form
- Ocean disposal/artificial reef towing plan form
- Ocean disposal/artificial reef inspection form

USACE:
- Pre-deployment notification form USACE, Regulatory Division, Enforcement Section

Other notifications may be required depending on the conditions included in the permits issued for construction.

The USACE will notify the NOAA Office of Coast Survey when artificial reef permits are issued in order to update navigation charts. It is the responsibility of the local artificial reef program manager to verify the latest navigational charts to ensure that updates have been incorporated. Artificial reef managers are encouraged to refer to the most recent nautical charts, available online at http://www.nauticalcharts.nos.gov. If any errors are noted it is necessary to notify the NOAA Office of Coast Survey (1315 East-West Highway, Silver Spring, Maryland 20910-3282).

7.3.2 Notifications to Outside Parties

If the planned reef construction involves donated material and/or warrants news media attention, contact the donors and send out press releases (see Chapter 12) announcing the scheduled activities well in advance, but advise recipients to make last-minute inquires in case of unforeseen delays. It may also be necessary to arrange marine transportation for donors and reporters. Bear in mind that increased publicity about a deployment will result in increased vessel traffic at the deployment site, and may require additional logistical coordination and possibly support from law enforcement agencies to help manage boater safety and security. Media relations could be assigned to an experienced spokesperson for the project, but the project coordinator should still be available for interviews or press conferences. The media prefer to hear directly from the person in charge.

7.4 Liability and Insurance

Due to the variability among local, state, and federal concerns about liability, it is always important to check with your appropriate agency contact (typically agency contracting office or office of general counsel). See section 7.5.2, below, and also section 3.3 in Chapter 3 for more information.

7.5 Pre-Deployment Construction Guidelines and Standards

7.5.1 Transportation, Equipment and Staging Areas

Staging areas are sites where reefing materials can be stockpiled in anticipation of a construction effort. Ideally, they should be close to a navigation inlet, have easy access from land and water, and have sufficient area to store large quantities of material. Materials delivered to a staging area should be ready for "reefing," stacked and inventoried in an organized manner and require no cleaning or alteration prior to being loaded onto the barge for deployment.

Every artificial reef construction is different, requiring various types of transportation and equipment. Land transportation of materials is usually done by truck. Quantities of trucked materials can be determined by sending the loaded trucks to a weigh station. When materials are transported by tugboat and barge, the most accurate quantity measurements can be obtained by measuring displacement of a loaded barge and then displacement of the unloaded barge, as soon as possible after deployment and prior to removal of any equipment or debris from the barge. This sequencing protects the project from paying for water that may leak into the barge. Barges carrying materials beyond inland rules demarcation lines must be ABS load line certified and inspected by the USCG. The usual equipment used to move and deploy materials includes front-end loaders, cranes, excavators, and/or forklifts. (See Box 7.2 for formula to calculate tonnage of barge.)

Box 7.2. Formula for calculating tonnage using before and after barge draft measurements. For grant-funded reefs, the following data will be recorded at the staging area prior to and after the deployment. This formula represents an average, single rake barge and may not represent the exact tonnage of materials placed (Source: FWC).*Note: Using this formula for payment of transportation costs should be agreed upon in advance with a contractor.*

Barge Length:___ feet Barge Width:___ feet Loaded Draft:___ feet Unloaded Draft:___ feet

(Length X Width X Loaded Draft X 0.93 X 65) / 2,000 = ___(Loaded barge weight in tons)

SUBTRACT

(Length X Width X Unloaded Draft X 0.93 X 65) / 2,000 = ___(Unloaded barge weight in tons)

TOTAL TONNAGE FOR THIS DEPLOYMENT = ___________

7.5.2 Safety and Legal Concerns

In the final step prior to actual placement, reef material is moved to the construction site, typically by barge. It should be noted that tow vessels are restricted in their ability to maneuver so pose some potential hazard to navigation. Therefore, it is prudent to notify USCG Sector at origination of tow, local law enforcement marine units, and other vessels through “security” announcements on VHF Channel 16. (See section 7.3.)

The artificial reef project manager in coordination with the USCG and local marine law enforcement must decide if there is need for a safety perimeter around the deployment site to ensure that no private vessels, scuba divers, contractor or county personnel are at risk during construction. Depending on the perceived need, local law enforcement may need to be supplemented by private security enforcement.

If the donor requests to be clearly and legally relieved of responsibility and liability at some time during the operation, legal title to material should remain in the donor’s name as long as the donor has control over it and preferably not transferred to the reef program until after the material has been placed on the seafloor in accordance with project specifications. At that point the reef sponsor, program or permittee should assume liability for the materials. If the reef sponsor contracts services for preparation, delivery, and/or deployment of material, the contractors should be required to assume full legal responsibility for the material under their control until after the material is sunk according to specifications, or until they are specifically relieved of responsibility. Contractors working for government entities may be required to furnish a performance bond in the form of a certified or cashier's check or surety bond, and must also provide proof of public liability insurance and workmen's compensation insurance before commencing work on a project. After the contractor is specifically relieved of responsibility, the responsibility for the material would be assumed by the next authorized party involved in the operation. Agreements should be executed in advance of material deployment to guarantee unambiguous title to the material and clarify the burden of responsibility associated with it.

For some donated materials, donors may expect to receive income tax credits for donated materials. It should be made clear before any transactions occur that the donor should consult with income tax professionals to determine the value of the donation for tax credit purposes. As in all donations, the recipient of the donation (in this case the artificial reef program) can provide a letter acknowledging receipt, but it is the responsibility of the donor to determine the value of the donation.

7.5.3 Site Marking and Mooring During Construction

In southeast Florida, it is critical to deploy all artificial reef materials precisely in pre-planned locations to avoid impacts to the extensive hardbottom resources in the region. Preparation for deployment involves the placement of temporary marker buoys and possibly temporary anchors or moorings (if permitted) for work vessels or vessel(s) to be sunk. A support boat is usually required for guiding tow vessels to the deployment site, ensuring proper location, and clarifying significance of all marker buoys.

Temporary marker buoys are valuable during deployments to mark adjacent resources, deployment locations, and deployed objects. It is advisable to use different types and/or colors of buoys for resource buoys and site buoys to avoid confusion. For example, red buoys are used to mark resources and white to mark the deployment location. If a buffer is used around natural resources, then the resource buoys should mark the buffer. Buoy positions should be periodically checked during the course of deployment. Spare buoys should be available since barges and support vessels often move previously placed buoys. These buoys and their associated lines and weights should be removed after deployment. In strong currents it is advisable to add 6-10 ft of polypropylene line with a terminal buoy to the primary buoy, i.e., a tag line and additional buoy sufficient to avoid being dragged under by the current. Adequate anchor weight is needed to maintain the position of the buoys in such conditions. (See Chapter 8)

If there is any concern over locating artificial reef materials after deployment it is advised to tie a buoy to the material with sufficient line for the current conditions and water depth. Make sure that the buoy line will float free as the material sinks in order to mark the site. This line should be removed from the artificial reef after the position of the material is precisely recorded.

To maintain precise and constant position it is usually necessary to anchor artificial reef vessels and deployment barges. There are four commonly used alternatives for deployment anchoring: anchors placed at the time of deployment; temporary anchors placed before deployment; mooring to existing structures; or, in the case of construction barges in very shallow water, spud poles.

Since currents can be strong and highly variable in southeast Florida, anchoring is usually done on the day of deployment. Two to four anchors are needed to hold position if wind or current change, and support vessels are used to set anchors to achieve most efficient holding. However, if there is a need to save time on deployment day and facilitate vessel placement, anchors can be pre-set. Support vessels will be needed to place these anchors and secure to them.

Sometimes it is feasible to use existing artificial reefs as a primary mooring. However, it is critical to correctly assess the structural integrity of the existing artificial reef as well as its stability under additional loading. This technique can serve a secondary purpose if the mooring line is left in place by providing a guideline for divers from one reef to the other. Mooring line length should be at least five times the water depth.

In recent years horizontally expansive artificial reefs have been constructed for mitigation or habitat enhancement. If placed on or near existing natural hardbottom, precise placement of artificial reef material, as well as avoidance of other construction-related impacts, is critical. To achieve precise placement of material over large areas it is necessary to have an anchoring scheme that allows frequent movement of deployment barges with minimal time loss during relocation. One strategy that has worked well for this in shallow water deployment is a series of steel piles driven into sand bottom around the deployment area. The barge can secure to these piles with floating lines and easily shift from one set of piles to the next. The advantages are that it requires very little anchor scope (normal anchors require five to seven times water depth); there is no risk of anchor drag or misplacement of anchors; and mooring piles can be left in place for the attachment of small boat moorings to facilitate recreational use of the artificial reef. The disadvantage to mooring piles is the additional upfront cost of planning and installation. For large projects, however, or when considering the risk and cost of environmental damage, mooring piles become cost-effective.

In deep water, anchoring may be extremely difficult for deployment vessels, and live-boating may be necessary. This technique requires the vessel operator to maintain location using the vessel's own power. If possible, site buoys are used as reference points and the vessel captain starts and stops deployment according to his position relative to the site buoys. Live-boating deployment operations should not be used where precision placement is a necessity, or in shallow water, or when currents are very strong.

In extreme current conditions it may not be possible to set site buoys. When this situation occurs, a separate small boat equipped with a precision D-GPS can be used to hold location on the deployment site, in effect becoming a site buoy. The deployment vessel then maintains position relative to the small boat. The small boat captain/project manager should then direct barge positioning and construction activity. Live-boating with or without buoys should not be the preferred method of deployment, and contractors should be encouraged to work under conditions where more secure anchoring techniques can be used. In other words, live-boating should only be used when all other options have been exhausted, and then only if adequately determined buffers and safeguards are in place to ensure accurate material placement.

7.5.4 Weather and Sea State

Weather and sea conditions are controlling factors in construction work, from both safety and efficiency perspectives. It is desirable to schedule deployments during seasons with relatively predictable periods of calm weather and to incorporate weather delay days in the project timeline. For example, wind data from the National Climatic Data Center (www.ncdc.noaa.gov) indicate that average wind speed at West Palm Beach and Miami is lowest (8 mph) in June through August. Sea state, of course, is a function of wind speed, direction and duration.

It is important to establish a maximum workable sea state for each deployment. This should take into account the type of vessels to be used; whether or not a crane will be used, which requires calmer seas;, vessel-to-vessel transfer of equipment and personnel; and positioning strategy for vessels. Accepted practice in southeast Florida considers 3 - 5 ft waves as generally a maximum weather condition for working offshore. It is useful to establish the source of the sea state information to avoid misunderstandings among parties involved in deployment. Above all, never allow arbitrary deadlines, collateral interests (such as ceremonies, media coverage or end of a grant period) or bravado to jeopardize safety.

7.5.5 Deployment Supervision

The project manager or designated representative should be present during construction to coordinate the operation, direct deployment, and perform post-deployment inspections to verify that materials have been placed according to permit and contract specifications. The primary purpose of the inspection is to close the books on a particular project's operational phases and authorize final payments, if applicable. However, this inspection also provides a good opportunity to gather baseline data for program archives and for comparison with future compliance and performance monitoring.

The operational procedure after materials reach the reef site depends upon the desired configuration of materials on the ocean floor. When high-profile or tightly clustered reefs are desired, the barge position should be precisely controlled. The full load is then dropped, rolled, pushed, dumped, or lowered overboard into a single heap or several closely spaced heaps. The deployment supervisor should frequently check positions of temporary markers during construction to ensure they are on station.

7.6 Post-Construction Activities

When practical, post-deployment material inspections should be made by divers. When placements are too deep or widely dispersed for divers, or other factors prevent direct observations, sample transects and indirect inspections can be done by such means as a calibrated fathometer, side-scan sonar, and remote photo or video camera. The intent of this survey is to determine if the material is in the proper configuration and location and meets relief criteria in permits and design. It offers a baseline for future measurement of performance. Beyond immediate post-deployment inspections, long-term monitoring of the physical and biological performance is absolutely necessary (See Chapter 9)

7.6.1 Notifications to Applicable Permitting and Other Regulatory Agencies

NOAA Charting Office:
- Post-deployment location notification

USACE:
- Post-deployment notification form USACE, Regulatory Division, Enforcement Section

FDEP:
- Post-deployment notification form USACE, Regulatory Division, Enforcement Section

FWC:
- Post-deployment notification form
- Material placement report

Chapter 8. Buoys and Other Reef Identification Markers

Buoys, markers and other navigational aids are useful for a variety of purposes in artificial reef management. Buoys indicate the boundary of a permitted reef deployment area, mark an individual reef deployment site, or identify resources to avoid during construction. Buoys can be placed for navigational safety reasons or to serve as moorings for recreational boaters to avoid anchor damage to the reef structure, which is a special concern owing to the extensive yet fragile coral reefs of our region.

Ultimately the use of buoys or markers is at the discretion of the program manager unless they are explicitly required through the permitting process. The permit requirements of local, state, and federal agencies are described in Chapter 6.

8.1 Feasibility and Costs

Before buoys are placed managers should evaluate the feasibility and costs. Expenses include not only buoys, anchors, and mooring systems, but also vessel time, crew time, maintenance, and possible subsequent liabilities if a stray buoy creates navigational problems or is washed upon a beach where personnel and equipment are required to remove and dispose of it. In Miami-Dade County, for example, the average installation cost per mooring buoy was approximately $1,300 in 2009 (Miami-Dade County DERM, pers. comm.). The price for mooring buoys will vary depending on different anchoring systems, site depth, and quantity of buoys installed. So-called special purpose buoys are, in general, more expensive to install than mooring buoys. Special purpose buoys (yellow, lighted can buoy) at the Neptune Memorial Reef in Miami-Dade County cost approximately $1,600 per buoy to install in 2008 (Miami-Dade County DERM, pers. comm.). Cost for special purpose buoys will often go up from there depending on size and lighting requirements.

In addition to installation costs, routine maintenance will be approximately another $1,000 per buoy per year according to Miami-Dade County cost estimates in 2009 (Miami-Dade County DERM, pers. comm.). Maintenance costs will increase due to improper mooring buoy uses and storm activity.

Buoys may not be feasible or practical in certain conditions such as strong currents and deep water. In these situations, difficulty in installing and maintaining may make them cost-prohibitive. Early in the determination of project feasibility the aspect of regulatory agency permit requirements must be resolved.

Considering the environmental and safety factors involved, cost-effectiveness does not mean scrimping on initial costs of the floating portion of a buoy system. If this part fails, everything else is lost, along with the reef program's most visible representative. Money invested in good buoys, sound moorings, and regular preventive maintenance is well spent in the long run because of reduced overall costs and the goodwill created among the reef constituency.

8.2 Buoy Types and Criteria

Buoys are divided into two main categories: special purpose buoys and mooring buoys (Figure 8.1). Regardless of the type of buoy used, it is advisable to include the permittee's name and address on each buoy to increase the likelihood of it being returned if lost.

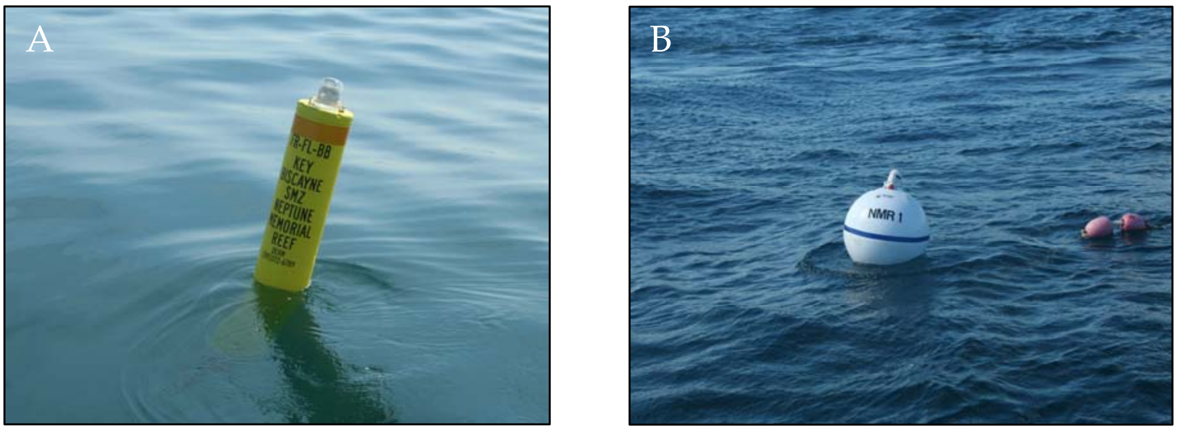

Figure 8.1 Representative special purpose (A) and mooring (B) buoys from southeast Florida. (Photographs courtesy of Miami-Dade County DERM).

8.2.1 Special Purpose Buoys

"Special purpose" buoys, as categorized by the USCG, can be used to mark artificial reef site boundaries and/or placed to protect shipping or indicate navigational hazards. The USCG will advise the permitting agencies if special purpose buoys are required. Independent of permit conditions, a program manager can also elect to install special purpose buoys if warranted to meet the program goals and if approved by the applicable regulatory agencies.

If buoys are being used to aid in the construction of an artificial reef and will be in place for an extended time period, the USCG should be contacted. These buoys should follow special purpose buoy requirements.

Special purpose buoys or special aids to navigation must follow the United States Aids to Navigation System (Title 33 Part 62) adopted by the USCG, specifically Part 62.31. If the buoy will specifically mark an individual artificial reef, the rules governing the marking of structures, sunken vessels, and other obstructions (Title 33 Part 64) must also be followed. Before purchasing buoys, check with the appropriate USCG district Aids to Navigation Officer to obtain current buoy information. (Addresses are provided in Section 8.5 of this chapter.)

Special purpose buoys or special aids to navigation must be yellow. Buoys that are colored plastic all the way through are recommended as opposed to painted buoys because the paint will eventually scrape off. Reflective materials used on the buoy also must be yellow. Radar-reflective elements also are advisable.

The buoy shape is optional, but it should be different from buoys with navigational significance unless intended to be interpreted that way. For example, if you want ships to pass offshore of the reef, use nun-shaped buoys on the outer edge. Letters or messages may be exhibited on special aids to navigation, but numerals are prohibited.

Lights -- If required by the USCG, the lights on a special purpose buoy must also be yellow (amber). Solar-powered lights are recommended. They are generally more expensive, but last longer. The flash pattern will be determined by the USCG. Coordinate light installation on the buoy with the USCG as they may want to install it themselves to make sure it is operational to their satisfaction.

Tackle or Downline -- The tackle should be at least ½ inch stainless steel cable. Smaller cables are more susceptible to vandalism. Installing a subsurface buoy to keep the tackle vertical about a third of the way up off the bottom is also recommended. The subsurface buoy helps make maintenance and buoy replacement easier.

Anchoring -- The anchoring plan will depend on the substrate or structure to which the buoy will be affixed and the purpose of the buoy. If the buoy is near a common dive site, anchoring the buoy in the substrate sufficiently away from the structure might be best to ensure that boaters do not use the special purpose buoy for mooring. The increased distance from the site will also help keep the buoy and tackle free from fishing gear entanglement.

8.2.2 Mooring Buoys

Mooring buoys are installed to facilitate use of the artificial reef site without needing to anchor and possibly cause damage to the reef or benthic organisms. Mooring buoys are optional unless required by a federal, state or local permit. They must follow the United States Aids to Navigation System (Title 33 Part 62) adopted by the USCG specifically Part 62.35. Before purchasing buoys, check with the appropriate USCG district Aids to Navigation Officer to obtain current buoy information. (Contact information and web addresses are provided in Section 8.5 of this chapter.)

Mooring buoys are ready-made, commercially available spherical (18 inch diameter) structures of polyethylene plastic filled with polyurethane foam and treated with UV inhibitors, recommended for flexibility and ability to endure strain after continual exposure to sunlight. A 1 inch PVC pipe is embedded in the buoy for a through-line. To meet Coast Guard requirements, the buoy must be white with a horizontal blue stripe (Figure 8.1.B).

A unique reef buoy system devised by biologist John Halas for the Key Largo National Marine Sanctuary should be of primary consideration to Florida artificial reef managers because of similar benefits to artificial reefs and their users. The Halas Mooring Buoy System, illustrated in Figure 8.2, is fully described in the "PADI Project Aware Mooring Buoy Guide" (see Section 8.5, below).

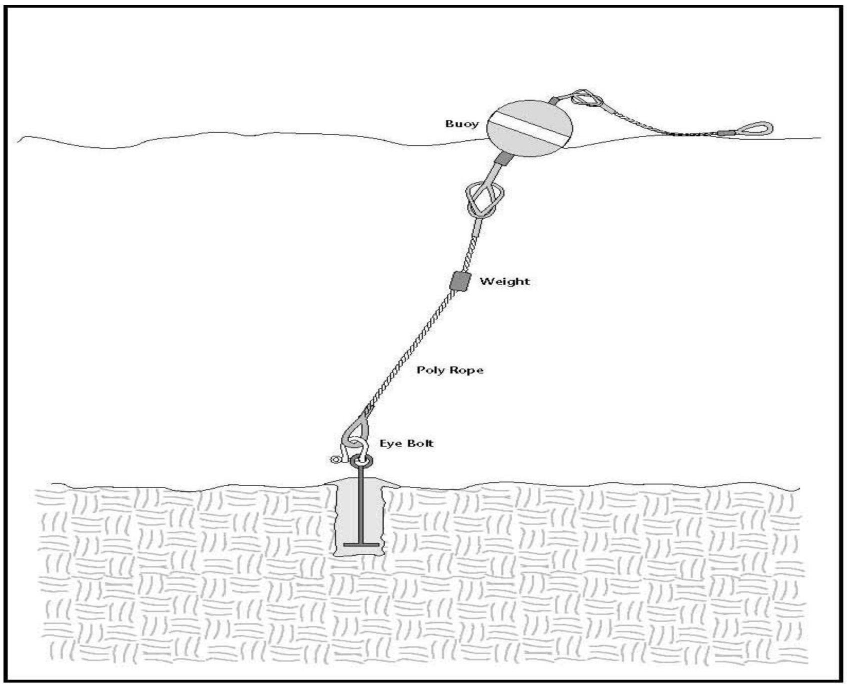

Figure 8.2. Halas Reef Mooring Buoy System (Source: PADI Project Aware Mooring Buoy Guide).

Tackle or Lines -- The general Halas mooring buoy design uses a three-part line (tackle) system with spliced eyes at each end. The three sections are comprised of the pick-up line, buoy through-line, and the down-line. The three-part system allows for easier maintenance as well since individual sections can be replaced when wear is evident. UV-treated polypropylene rope is recommended for the three-part rope system: 3/4 inch rope for the down-line and pickup-line, and 7/8 inch rope for the buoy through-line. The line is durable, lightweight and strong when protected from chafing.

Anchors and Shackles -- Several different anchors and associated shackles can be used with the standard Halas system depending on substrate conditions, including standard concrete core anchors (using an eye or U-shaped bolt), manta anchors, or helical anchors. Concrete core anchors are used in solid substrate while the manta and helical anchors are used in soft substrate.

8.2.3 Buoy Maintenance

Routine maintenance is required for mooring buoys to remove biofouling and replace worn lines and shackles. It is important to select high-quality buoys and mooring systems that can withstand the rigors of a marine environment. Regardless of high standards, though, monitoring will be required to ensure the buoys remain properly anchored in the permitted locations, have not been damaged or destroyed and are still displaying the correct characteristics according to permit specifications. Many programs plan buoy checks as part of their annual preseason task list and make supplemental inspections as soon as possible after severe storms. Other programs make arrangements with dependable individuals or user groups to report on buoy conditions after reef visits. A representative inspection and maintenance schedule used in the Florida Keys is given in Box 8.1.

Box 8.1. A suggested maintenance routine for the Halas Mooring System (van Breda and Gjerde 1992).

(1) Monthly Maintenance:
   a. Inspect all buoys and pick-up lines for condition.
   b. Clean pick-up line of growth; replace if needed.
   c. Clean buoy and check for cracks; replace if needed.
   d. Inspect and clean exposed portions of the buoy through-line; replace if needed.

(2) Every 3 Months (In-water Inspections):
   a. Inspect down-line and protective hosing for wear and damage; replace if needed.
   b. Inspect shackle for wear or damage; replace if needed.
   c. Inspect anchor. Examine contact area between anchor and shackle for signs of wear.
   d. Inspect anchor mount site and surrounding area. Look for signs of movement between anchor and cement core or between the cement core and the surrounding substrate.

(3) Every 6 Months:
   a. Replace buoy through-line and pick-up line after six months of use if the system is used on a regular basis.

(4) Every 12 Months:
   a. Replace pin in down-line shackle.

(5) Every 24 Months:
   a. Replace down-line if needed.

Buoy monitoring and maintenance programs should be oriented toward preventing failures in the field, regardless of whether the buoys are required for navigation or simply to aid fishermen or divers. Missing buoys can ruin someone's fishing trip, and the drifting aids become potential hazards to boaters. It is far more cost-effective to perform scheduled monitoring and preventive maintenance than to be constantly responding to discrepancy notices. With the preventive maintenance approach, buoys are replaced at scheduled intervals based on known service life of the system. In the event the buoys break free, or if the public calls in to report that the buoy is missing, the buoys will need to be reinstalled within 30 days.

Inspections consist of checking exposed characteristics of buoys and also determining the condition of mooring systems. If repairs are required, the procedure consists of retrieving buoys and their lines from their respective stations and replacing them with new or refurbished buoys and lines. Buoys are not usually found at local hardware stores, and suppliers often need considerable lead time to meet orders. Having a new or refurbished buoy on standby provides a safety cushion for the inevitable times when an unscheduled buoy replacement is needed.

If scuba divers do the work, the procedure entails securing a tagline from the boat or temporary marker to the buoy anchor, disconnecting the old chain or line, and attaching the replacement buoy to the old anchor. The old buoys are taken ashore, cleaned, inspected for serviceability, reconditioned (or replaced, if necessary) and put on standby for the following season. Old chain and hardware are usually not good candidates for reuse. They can be discarded, sold as scrap, or added to wet concrete cast for new sinkers to increase density.

When depths are too great for diving, either the entire buoy system needs to be recovered with lifting equipment, or, lacking heavy lifting capacity, the buoy alone could be recovered and if appropriate authorizations have been obtained, the remaining system (line and sinker) could remain in place.

8.3 Other Navigational Aids for Facilitating Reef Use

8.3.1 Daymarkers

Daymarkers are nautical signposts that conform with the lateral buoy system. When reefs are in shallow water, a piling can be sunk into the bottom and adorned with an appropriate placard. This method can be more cost-effective than attempting to mark the site with a buoy. Another advantage of using daymarkers is that they don't move because there is no slack in their moorings. This can be important in inshore waters, because passable depths and shallows may be very close to one another. Fixed pilings can be unforgiving to small boats that may hit them. Spar buoys can be used instead, with very short mooring or none. This buoy type has most of the benefits of fixed daymarkers, and will give a little if accidentally hit.

Daymarkers for reefs should be yellow, and if non-angling traffic needs to steer clear of the reef, the shape should comply with the navigational aids that indicate the correct side for passing (e.g., a square means pass to your right leaving port, while a triangle means pass to your right returning; a rectangle denotes an informational marker). When in doubt about appropriate characteristics, consult the local USCG Aids to Navigation Officer.

8.3.2 Signs

Signs can be placed on buoys or daymarkers, with USCG approval, to provide information to reef users. Large, permanent signs can also be erected at key land-to-water access points, such as boat ramps and public marinas. These signs can give potential reef users key information about how to find local reef sites, the coordinates of important artificial reef structures, rules and regulations for the site and where to get additional information. Signs provide an ideal opportunity to promote a local reef program or acknowledge contributors, which may play a role in ensuring continued support. If using public money for a reef project, show the public its money has gone to a worthy cause.

8.4 Contact Information

U.S. Coast Guard District 7
Aids to Navigation and Waterways Management Branch
909 SE First Avenue, Suite 406
Miami, FL 33131
(305) 415-6748

United States Aids to Navigation System: Title 33 Part 62
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=141da879cbe6a1d7bee85eb7847ac25a&rgn=div5&view=text&node=33:1.0.1.3.26&idno=33

Project Aware Mooring Buoy Guide:
http://www.projectaware.org/assets/library/135_mooringbuoyguide.pdf

Chapter 9. Artificial Reef Monitoring, Maintenance, Research, and Mapping

Artificial reef permits contain general and special conditions related to location, material, and stability for construction. To determine compliance with these conditions (see Chapter 6) it is necessary to monitor reefs following deployment. Permits may also specify structural integrity or safety features. Maintenance requirements of the artificial reef to meet the permit conditions will be determined by compliance monitoring.

Artificial reefs do not exist in ecological isolation on the sea floor (see Chapter 2). There are direct, negative impacts to softbottom communities under the footprint of the structure. There are indirect impacts to adjacent softbottom and hardbottom communities after deployment. Examples of these indirect impacts include alteration in trophic structure and the water current flow field, which can impact recruitment of organisms. Thus, there is a need to determine impacts to adjacent habitats and biological development of the artificial reef, respectively. Goals for reef construction are usually related to biological development so biological (performance) monitoring will determine whether or not goals have been met.

This chapter reviews permit compliance monitoring, performance monitoring, research, and maintenance issues for artificial reefs.

9.1 Permit Compliance

Permit conditions cover three time steps in the artificial reef construction process, namely pre-construction, during construction, and post-construction. Pre-construction conditions require submittals related to deployment site conditions, vessel cleanup, reef stability, notifications and towing plans. During construction, compliance relates to marking buoys, safety perimeters, and deployment methodology. Issues related to these two time steps are discussed in Chapter 7. Post-construction conditions are usually related to the physical condition of the artificial reef. Performance monitoring may be a permit condition, but this is rarely the case, except in mitigation reefs, because of funding constraints. (Such monitoring that takes place is usually done voluntarily by the permittee.)

9.1.1 Compliance Monitoring

Compliance monitoring, as defined by the original National Artificial Reef Plan (Stone 1985), is monitoring "*to assure compliance with the conditions defined in any authorizing permits, or other applicable laws or regulations.*" According to the same document, specific monitoring strategies will depend on the degree of compliance required and the objectives and resources of the reef builder. The USACE and FDEP general permits require Florida reef developers to maintain their reefs after initial construction. This is also a requirement of projects receiving state grants.

In southeast Florida, hurricanes or long-duration tropical storms can significantly damage or move an artificial reef. Movement can result in substantial damage to adjacent natural reef or hardbottom resources. Regular or event-based monitoring is therefore used to determine if corrective maintenance is needed for buoys or the reef structure.

Observations that should be made at each compliance monitoring event are:

- Location of the artificial reef
- Height of material above the bottom (relief)
- Minimum vertical clearance to sea surface (include time of measurement for tide correction)
- General structural condition, i.e., intact, partly deteriorated, severely deteriorated, unrecognizable, collapsed, or absent
- Settling condition
- General fouling conditions on various materials, i.e., no fouling, some fouling, complete fouling
- Presence or absence of selected species on different structures
- Reef user information at sites
- Significant weather events since last monitoring period

Reef sponsors without adequate capabilities may need to tap outside resources for help with monitoring tasks. Contractors can be hired, or simple compliance monitoring tasks could be handled by volunteers from community organizations, such as sport fishing and diving clubs, environmental groups, and student groups from schools, colleges, and universities. Some areas also have dive research teams specifically trained in reef monitoring techniques. Community involvement in a reef program can result in valuable feedback and enable local residents, especially youth, to gain a greater appreciation for the program.

9.1.2 Guidelines for Volunteers

One significant hurdle in the use of volunteers is the availability of personnel to provide training and oversight of activities. Since volunteers are generally only available on weekends the reef manager or co-worker must donate their personal time to manage the volunteers. This type of management is time-intensive and the volunteer manager must consider the full scope of the task before committing to this activity. The volunteer manager must train the volunteer divers, secure boat time, plan and organize the dives, maintain data quality, and perform data analysis. Most volunteers are well intentioned but they have other demands on their time and may not be reliable over the long term, so diver turnover is another challenge.

If volunteers are used, a formal agreement, clearly detailing required information, monitoring frequencies and report deadline, if applicable, will help ensure maximum benefits. It is imperative that volunteers receive training in scientific dive planning, safety, data collection procedures, quality assurance, and data management. Each diver should be qualified by an interobserver comparison with trained scientists. The role of the volunteer diver is to collect data, not interpret them. This should be left to the trained scientist. Halusky (1991) is a good reference for volunteer science divers. Training should be carried out by the reef permittees or their qualified scientist designees in order to maintain data quality.

A simple field data form will help keep monitoring reports consistent. The project manager should review completed forms as they are submitted, and do an overall assessment at least once a year to see if particular trends or problems appear to be developing. Forms should be maintained in a permanent central file for easy reference and to reduce the chance of loss. Photocopies or scanned data sheets can be stored separately in case of loss of original forms. Data are usually maintained in a data management system consisting of spreadsheet or database files for subsequent analysis.

Using volunteers by no means relieves the permit holder of the legal responsibility to monitor and maintain a reef's condition. A reef manager should therefore not depend completely on volunteer monitoring help but should also schedule "official" monitoring to verify site conditions. If corrective maintenance is needed, that should be carried out in an official capacity and not left to volunteers.

9.1.3 Maintenance and Cleanup

The USACE general permit specifies that, except for maintenance dredging, works constructed under a federal permit must be maintained in good condition, with maintenance defined as the upkeep of existing structures by repairing and restoring deteriorated components to original design specifications. For reef project maintenance it is impractical (if not impossible) to strictly comply with USACE terms which were mainly intended for dredging, filling, dock construction, and other similar projects. Common sense suggests that reef maintenance should be approached on a site-wide rather than placement-specific basis. For instance, if a high-profile structure deteriorates and collapses in place but still offers low-profile habitat, it might be best to leave it that way rather that heap materials on top simply because of the original design.

If, however, monitoring reveals that structural deterioration has created a hazard to divers, or materials have moved offsite and are jeopardizing shipping interests, trawling activities, or natural hardbottom communities, remedial measures may indeed be needed. Monitoring could also reveal that material has settled or disintegrated to the extent it has lost effectiveness as habitat. In this case, extensive restoration would probably be needed.

9.1.4 Derelict Fishing Gear

Since artificial reefs are popular recreational sites, derelict fishing gear is often present. This takes the form of monofilament entanglements, including lead weights and hooks; fishing rods; gaffs; bait packaging; lost spears; catch bags; and trash. Commercial fishing gear, such as lobster traps, may drift into a reef or become entangled during retrieval. In addition to the unsightly nature of this debris, it can be an entanglement hazard to marine life or divers.

One successful way to deal with fishing-related gear has been to organize "reef haircuts" using volunteer divers. Diving clubs or charter operators can adopt an artificial reef and plan regular trips to remove monofilament entanglements and other debris. This activity can be expanded into regional "reef sweeps" for cleanup of natural reef. This requires a significant time commitment for organizers but yields positive environmental benefits as well as public awareness of the impacts of littering. The annual International Coastal Cleanup, organized by the Ocean Conservancy, is one good platform for reef cleanups.

9.2 Performance Monitoring and Research

Every artificial reef project should begin with a goal and objectives. Many projects have been constructed with the vague goal of enhancing fisheries with no specific knowledge of how this would be achieved or how to monitor for success. Objectives should be specific. One way to ensure this is to determine if a feasible monitoring program to test attainment of the objective can be designed. In other words, what are the criteria to be used in evaluating the objectives and can they realistically be measured? Recent interests in socioeconomics of natural and artificial reefs have legitimized the concept of creating reefs for economic gain so reefs with socioeconomic objectives are acceptable.

This section presents the basic premise of study design but is not intended to be a summary of all study design considerations or methods, nor is it a discussion of reefs constructed specifically for testing hypotheses. The reader is referred to Seaman (2000) for a comprehensive review of the concepts of study design, implementation and analysis.

Performance monitoring of artificial reefs should rely on the same basic scientific principles as any other type of environmental study. It should be mindful of two basic questions: Does the artificial reef meet its specific objectives and, does it positively or negatively affect adjacent natural habitats, such as hardbottom and sand? The first question requires the measurement of those parameters that define success (based on goal and objective) over time, until some stability in the data is achieved, if ever. To address the second question, data must be collected from suitable sites on adjacent natural habitat, as well as control sites on distant natural habitat, before and after deployment. This becomes a more complex sampling design, yet this question has been neglected to a great degree. Artificial reef construction in most of the U.S. occurs on vast sediment plains. However, the coastal shelf off southeast Florida is dominated by hardbottom, so artificial reefs may have an effect on these communities.

It is important not to overlook the measurement of environmental parameters (physical and chemical) when designing a performance study. All too often interpretations of biological data are complicated by a lack of knowledge of the environmental factors that often influence biological communities. A preferred method of monitoring environmental parameters is to install data loggers. These devices can measure a variety of abiotic parameters at high frequency and store a large amount of data for extended periods of time. Temperature loggers with large memory capacity, long battery life, and high sampling rate can cost in the $100s. Low-cost salinity loggers don't perform well at this time. Water quality sampling data sondes and water current profilers (ADCPs) are considerably more expensive. Region-wide coastal water quality sampling is on the horizon for southeast Florida. It may be possible to coordinate the needs of the artificial reef manager with other planned or existing programs to obtain environmental parameters.

Despite the stated desirability of setting goals and explicit objectives for artificial reefs, and using performance monitoring to determine their success, the reality of artificial reef construction in southeast Florida is a somewhat different picture. With the exception of specially funded artificial reef projects, such as mitigation reefs, reef materials generally are opportunistic with an overriding goal of providing fishing and diving opportunities. Funding for artificial reefs is limited and generally comes from diving or fishing groups, or taxes and fees related to those groups. The goal in providing this funding is to enhance their recreational activity. No provisions are made for monitoring.

Presently, Palm Beach County has the most extensive performance monitoring program in southeast Florida. A volunteer team has been organized to census fishes on artificial reefs, using the methods described by Bohnsack and Bannerot (1986) and roving diver techniques. Analysis of epibenthos was added to the protocol, but methods are still under development. The intent of this monitoring is to examine trends in fish community structure. Miami-Dade County performs an annual census on the relative abundance of both benthic and fish species on its more recent artificial reef deployments. Miami-Dade County has also completed several "snap-shot" comparison studies on several carbonate-based artificial reefs with reports available at: http://www.miamidade.gov/derm/reefs_monitoring.asp. In Broward County, many artificial reef monitoring projects have been completed by Nova Southeastern University Oceanographic Center. Martin County has posted the results of monitoring reports online at http://www.martinreefs.com/.

9.3 Mapping and Habitat Characterization

Mapping and habitat characterization studies are useful to the artificial reef builder in selecting appropriate areas for artificial reef construction, establishing buffers to natural habitat, and predicting impacts to natural hardbottom/reef. Remote sensing techniques improve the feasibility of studying large areas of the sea floor.

9.3.1 Bathymetric Data Collection

Bathymetry data can be collected using a wide variety of sensors including single-beam and multi-beam acoustic depth sounders, and airborne laser sensors. The utility of bathymetric data depends on the resolution at which they are collected. Table 9.1 presents currently available methods (and comparative features) for collecting bathymetric data.

Table 9.1. Comparison of currently available bathymetric data collection methods.

Bathymetric data collection method	Relative horizontal resolution	Advantages	Disadvantages	Relative cost for large area survey of uniform resolution
Single-beam echosounder	Low	Low-cost fathometers can be used	High resolution along survey track, low resolution across track; sensitive to sea state; time-consuming to survey large areas	Very high
Multi-beam echosounder	Very high	Very high resolution	Sensitive to sea state; time-consuming to survey large areas	High
Aerial laser hydrographic survey	High	High resolution; cover large areas quickly; less sensitive to sea state; cost-effective for large areas	Need very clear water; limited to depths <20 meters	Moderate

9.3.2 Mapping

"Mapping," as discussed herein, is defined as the projection of artificial and natural reef boundaries onto a two-dimensional, horizontal plane. Mapping natural reefs and hardbottom is important in site selection for artificial reef placement to avoid physical disturbance of natural habitats. Ideally, base maps are created from georeferenced aerial photography for clear water settings, or hillside shaded images from bathymetric data for deep clear or turbid water settings.

For small-scale mapping, scuba divers can use dive scooters or swim along reef edges towing a GPS antenna or a small float. A vessel equipped with DGPS and position recording software, commonly used by hydrographic surveyors, tracks the float and records the position of the vessel at pre-determined distance or time intervals. The track-line plot can be exported into GIS or mapping software for display or analysis. Diver limitations restrict this to small areas in shallow water. Underwater diver GPS systems are beginning to be marketed and might offer a technological improvement for this type of mapping. Towing a float can be difficult in deeper water or high currents. An additional constraint is vessel speed. Many boats cannot maintain steerage at the slow speeds of divers on scooters.

For regional-scale mapping in the variable turbidity conditions of southeast Florida, acoustic techniques, such as side-scan sonar (e.g., Figure 9.1) and acoustic backscatter analysis, have proven useful for two-dimensional mapping of reefs. Some of the acoustic backscatter methods provide useful information on bottom type and biological community structure. Riegl and Purkis (2005) and Moyer et al. (2005) provide more detail and applications to southeast Florida.

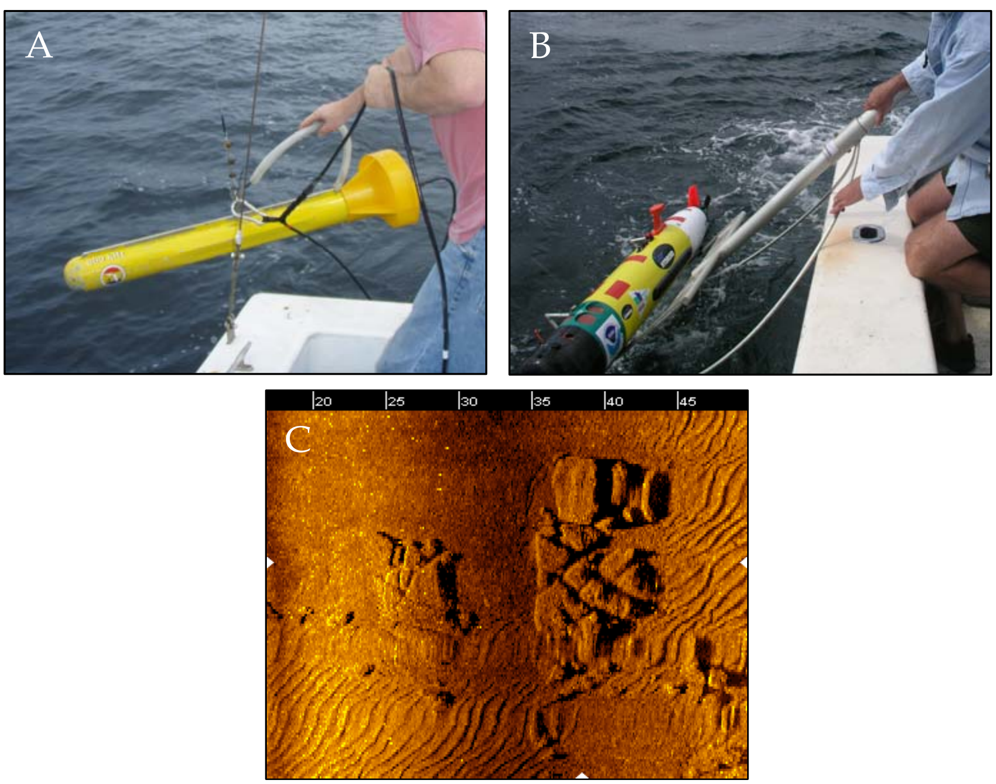

Figure 9.1. A 600 kHz side-scan sonar towed from a surface vessel (A) or deployed in an autonomous underwater vehicle (B) generates high-resolution imagery of the seafloor (C) [Photographs courtesy of FWC (A) and University of Florida (B, C)].

Chapter 10. Compensatory Mitigation

This chapter addresses the use of artificial reefs in compensatory mitigation projects in southeast Florida. It summarizes state and federal requirements and approaches to the subject, highlights three case studies, and discusses different approaches to designing, constructing, and monitoring compensatory mitigation projects. The high ecological and socio-economical value of natural reefs or artificial reefs is documented in Chapters 1 and 2; see Johns et al. (2004) and Adams et al. (2006).

Artificial reefs have been deployed for fishery management and habitat enhancement for many years (Seaman 2000), however their construction as a compensatory action is more recent (Ambrose 1994, Thanner et al. 2006). For purposes of this document "mitigation reefs" refer to the replacement of lost functions of natural reefs due to a planned (permitted) or unplanned (grounding) impact.

10.1 Overview of Compensatory Mitigation in Southeast Florida

Southeast Florida coral reefs are close to a highly urbanized coast. This results in many physical stresses from marine construction and the maritime industry. Impacts result from activities including the installation of telecommunication cables, beach dredge-and-fill (or nourishment) projects, navigation channel expansions and major vessel groundings (Figure 10.1). Anecdotal reports by divers offer perspective, about the loss of reefs and hardbottom over time, for which mitigation was never attempted. Thus, coastal and marine construction activities require authorization from local, state, and federal regulatory agencies (see Chapter 6).

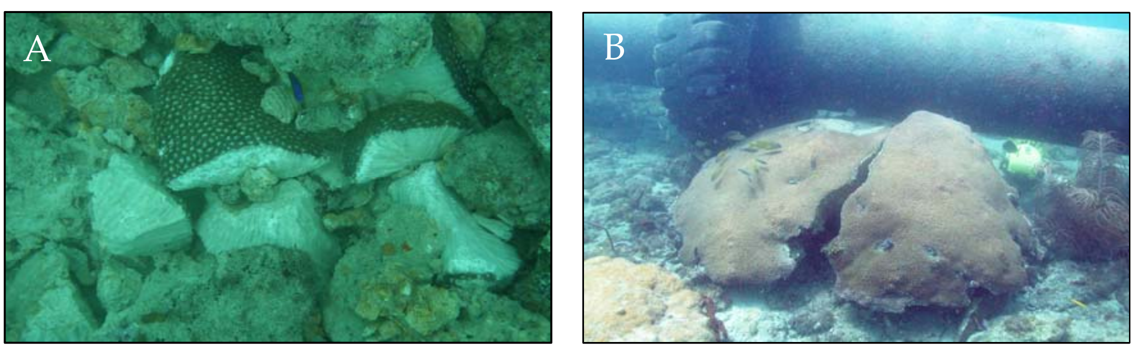

Figure 10.1. Damaged coral reefs from a ship grounding (A) and a permitted beach renourishment pipeline (B) (Photographs courtesy of Miami-Dade County DERM).

When direct or indirect impacts to coral reefs or nearshore hardbottom habitats are proposed as part of a permit application, the project goes through an environmental review (or permitting process) which may result in a requirement to perform a compensatory action, called "compensatory mitigation," designed to offset any unavoidable impacts. Compensatory mitigation is only one part of the mitigation process, and is only generally considered after a comprehensive evaluation of project alternatives, including least damaging project alternatives. It is assumed that sequential mitigation (first, avoid impacts; second, minimize impacts; third, determine compensatory action) has been thoroughly considered. It is important to note that coral relocation is generally required as a minimization effort, versus a mitigation effort.

In southeast Florida, the primary approach for reef compensatory mitigation projects has been through the construction of limestone boulder reefs in locations near or adjacent to the impacted reef site (Figure 10.2). This is considered "on-site" compensatory mitigation. If correctly planned, designed, and sited, a compensatory mitigation reef can provide the necessary framework for the colonization of corals, sponges, algae and other reef-associated species.

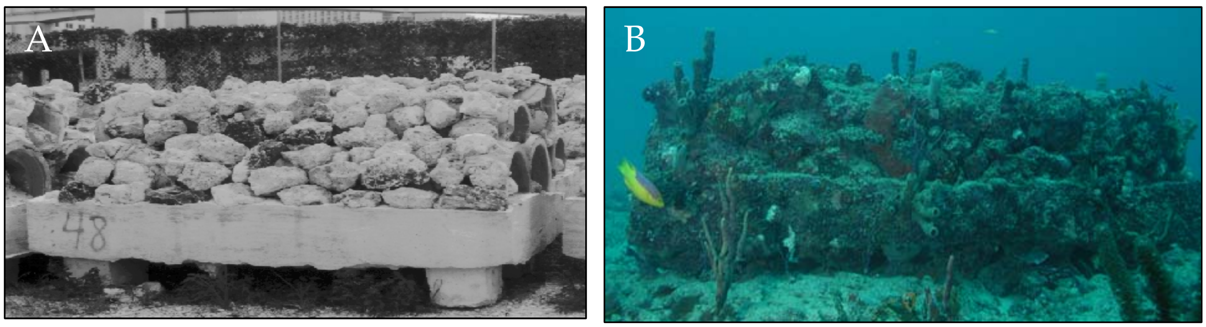

Figure 10.2. Representative artificial reef of limestone boulders used in compensatory mitigation. A, at time of deployment; B, after years with colonization by microbes, plants, invertebrates and fishes (Photographs courtesy of Miami-Dade County DERM).

In the last several years, a heightened awareness of system-wide reef enhancement and restoration needs has been identified in southeast Florida, in part through the Local Action Strategy process. In 2002 the United States Coral Reef Task Force implemented development of Local Action Strategies, which are short-term, locally-driven roadmaps for cooperative action among federal, state, territory and non-governmental partners, to reduce key threats to valuable coral reef resources. In Florida, the SEFCRI Team identified four focus areas. A transition from single-species or single-habitat management approach to an ecosystem approach is evident.

Therefore, as an alternative to continuing to require limestone boulders to compensate for the loss of coral reef and hardbottom habitat, other non-traditional approaches are surfacing that address more immediate needs of the reef ecosystem. This approach does not preclude replacement of reef structure if a coastal construction project eliminates a large area of reef. However, reef structure replacement through the construction of an artificial reef may be just one component of the overall compensatory mitigation plan. Agencies are currently exploring suitable compensatory mitigation alternatives that would address the needs of the southeast Florida system as a whole, including the critical factors affecting the reef system that are unrelated to hard substrate availability. Non-traditional approaches include (1) reductions in point-source and non-point source pollutants into southeast Florida waters to help abate degraded water quality conditions, and (2) restoration of grounding sites.

Determining how these non-traditional mitigation approaches meet the state and federal requirements to offset functional losses of impacted habitats is complicated. Coral reef recovery studies are needed in the SEFCRI area. However research in other areas has concluded that coral reefs can take several decades (Pearson 1984) up to 150 years (Cook et al. 1996) to recover from major disturbances. To provide southeast Florida-specific information on this topic and inform mitigation discussions in the SEFCRI area, the Maritime Industry and Coastal Construction Impacts (MICCI) Project 14, 15, 16: "*A Study to Evaluate Reef Recovery Following Injury and Mitigation Structures Offshore Near Southeast Florida*" is currently underway. For more information see the website: http://www.dep.state.fl.us/coastal/programs/coral/sefcri.htm.

Most of the information contained in this document applies to all artificial reef projects, but the following sections are additional necessary considerations when dealing with compensatory mitigation projects involving coral reefs.

10.2 State and Federal Compensatory Mitigation Regulatory Requirements

The following is an overview of state and federal approaches to, and requirements of, compensatory mitigation projects in 2010. The intent is to highlight the essential minimum amount of information needed by the agencies to review a compensatory mitigation reef project proposed as part of a permit application. This is not intended to facilitate additional projects requiring compensatory mitigation reefs, but rather to encourage more thoroughly designed projects to be submitted as part of an application.

10.2.1 Florida Department of Environmental Protection and Florida Fish and Wildlife Conservation Commission

State agencies follow a Basis of Review, which identifies the permit review criteria and information used by State of Florida staff when reviewing permit applications. According to the South Florida Water Management District's Basis of Review (2000), to receive FDEP's Regulatory District will approve mitigation only after the applicant has complied with the requirements regarding practicable modifications to eliminate or reduce adverse impacts.

FDEP guidance states that impacts to corals must be avoided. The FWC and South Atlantic Fishery Management Council manage corals as fishery resources. The FWC Marine Life Rule (62B-42.009) states that *"no person shall take, attempt to take or otherwise destroy or sell, or attempt to sell any sea fan of the species Gorgonia flabellum or of the species Gorgonia ventalina, or any hard or stony coral (Order Scleractinia) or any fire coral (Genus Millepora)."*

10.2.2 U.S. Army Corps of Engineers

The Compensatory Mitigation for Losses of Aquatic Resources; Final Rule (USACE CFR Parts 325 and 332; and EPA 40 CFR Part 230), provides some guidance on mitigation related to reef communities. Section 332.3(b)(1) [§ 230.93(b)(1)] discusses general principles for determining the appropriate type and location for compensatory mitigation projects. This provision states that to replace lost functions and services, compensatory mitigation project sites for marine resources should be located in the same marine ecological system as the impact site, citing reef complexes and littoral drift cells as examples of marine ecological systems.

The rule also states that a watershed approach is not appropriate in areas where watershed boundaries do not exist, such as marine areas. In such cases, an appropriate spatial scale should be used to replace lost functions and services within the same ecological system (e.g., reef complex, littoral drift cell).

Effective June 9, 2008, the USACE published a mitigation rule; however, the application of the rule in the southeast Florida region has not yet been well tested. The rule not only affected § 332 but also made changes to § 325.1, which now states:

- *§ 325.1 Applications for permits. (d) (7) For activities involving discharges of dredged or fill material into waters of the United States, the application must include a statement describing how impacts to waters of the United States are to be avoided and minimized. The application must also include either a statement describing how impacts to waters of the United States are to be compensated for or a statement explaining why compensatory mitigation should not be required for the proposed impacts.*

Based on what will now be § 325.1(d)(10) (the old § 325.1(d)(9), this means that the application must include receipt of a statement of avoidance and minimization, and either a compensatory mitigation plan or rationale as to why one is not necessary for the application to be considered complete.

10.3 Methodologies Used in Florida to Determine Compensatory Mitigation Amounts

There are two methodologies that are applied in the review of southeast Florida coastal construction projects to determine the amount of compensatory mitigation required to offset the lost resource (e.g., coral reef) functions: the Habitat Equivalency Analysis (HEA) and the Florida Unified Mitigation Assessment Method (UMAM). Generally, HEA is an analytical tool and UMAM is a functional assessment. Neither method is intended to affect other aspects of natural resource impact regulation or sequential mitigation requirements; these may include ascertaining that the direct and secondary impacts have been reduced or eliminated, that the project does not result in unacceptable cumulative impacts, or that the mitigation is appropriate. Importantly, it must be recognized that the results of an HEA or UMAM are only as good as the inputs and the assumptions used in the calculations.

10.3.1 Habitat Equivalency Analysis

The HEA is a methodology developed by NOAA. The principal concept underlying HEA is that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type.

Natural resource trustees have employed HEA for vessel groundings, spills, and hazardous waste sites. Habitats involved in these analyses include seagrass, coral reef and hardbottom resources, tidal wetlands and estuarine softbottom sediments (NOAA 1996). The HEA is the required evaluation tool in some injury assessments. For example, the 1996 final rule of the Oil Pollution Act of 1990 states that, *"when injured resources and/or services are primarily of indirect human use, the appropriate basis for evaluating and scaling the restoration is HEA"* (King 1997).

More recently, HEA has been authorized for use as a tool in southeast Florida to determine how much artificial reef would need to be constructed to offset un-permitted impacts to natural reef from vessel anchoring and grounding incidents. Although HEA is not currently authorized for use in the regulatory permitting process, state agency staff are working to draft statutory language changes that will allow it to be used for both JCP (Joint Coastal Permit) and ERP (Environmental Resource Permit) permits. Until then, the State of Florida is required to use UMAM.

In situations where sufficient knowledge exists (Box 10.1) about the injured and restored systems, the HEA model can provide a useful framework for estimating lost services and determining compensatory mitigation requirements. Necessary conditions for the applicability of HEA include that (1) a common metric (or indicator) can be defined for natural resource services that captures the level of services provided by the habitats and captures any significant differences in the quantities and qualities of services provided by injury and replacement habitats; and (2) the changes in resources and services (due to the injury and the replacement project) are sufficiently small that the value per unit of service is independent of the changes in service levels (NOAA 1995).

Box 10.1. The parameters necessary to complete a simple HEA (NOAA 1995).

Injured Area Parameters:
- Baseline level of services at the injury site
- Nature of the injury: Spatial extent of injury (e.g., in acres), and initial reduction in service level from baseline at the injured site (characterized as a percent of the baseline level of services)
- Injury recovery function (with primary restoration or natural recovery): Rate of (incremental) service recovery, and maximum level of services to be achieved (characterized as a percent of the baseline level of services)
- Recovery period for injured resources: Dates when recovery starts and when maximum level of services will be achieved

Replacement Area Parameters:
- Initial level of services at the replacement project site, measured as a percent of baseline services at injury site
- Replacement project maturity function: Rate of (incremental) service growth, and maximum level of services at the replacement project site (as a percent of the baseline level of services at injury site)
- Maturity period for replacement resources: Dates when services begin to increase, and when maximum level of services will be achieved
- Replacement/creation project duration: Lifetime of increased services

Discount Rate:
- Annual real discount rate

10.3.2 Florida Unified Mitigation Assessment Method

The UMAM rule (Chapter 62-345, F.A.C.) went into effect February 2, 2004. Although only the FDEP was required to adopt the method by rule, it is now the sole means for all State of Florida entities to determine the amount of mitigation needed to offset adverse impacts to wetlands and other surface waters, and to determine mitigation bank credits awarded and debited.

Assessments are completed in two parts: Part I, Qualitative Description, and Part II, Quantification of Assessment Areas. The forms for Parts I and II can be accessed at: http://www.dep.state.fl.us/water/wetlands/erp/forms.htm.

Part I is a narrative that includes general information about the project area, including (but not limited to) size of the area, identification of special classifications, an assessment area description, and anticipated use by listed species. Part II provides the score parameters: (1) Location and Landscape Support; (2) Water Environment; and (3) Community Structure. The Community Structure score parameter provides for two scoring indicators, Vegetation and Benthic Community. For submerged habitat injuries (e.g., coral reef, hardbottom, seagrass) the Benthic Community indicator is scored. This indicator is intended to be used in marine or freshwater systems that are not characterized by an emergent plant community, and is not intended to be used in wetlands that are characterized by a plant community.

Part II provides scoring guidance on a ten (10) through zero (0) scale. A score of 10 means that the benthic communities are indicative of conditions that provide optimal support for all of the functions typical of the assessment area and provide optimal benefit to fish and wildlife. A score of 7 means that, relative to ideal habitat, the benthic communities of the assessment area provide functions at 70% of the optimal level. A score of 4 means that, relative to ideal habitat, the benthic communities of the assessment area provide functions to 40% of the optimal level. A score of 0 means that the benthic communities do not support the functions identified and do not provide benefits to fish and wildlife.

The scores should be based on reasonable scientific judgment and characterized by a predominance of factors provided in:
http://www.dep.state.fl.us/legal/Rules/surfacewater/62-345/62-345.pdf

10.3.3 Comparison of UMAM to HEA to Determine Mitigation Amounts for Activities That Require Artificial Reefs as the Compensatory Mitigation Approach

In general UMAM could be considered more user-friendly than HEA, because all that is required to complete the UMAM are the Part I and Part II worksheets, knowledge about the resources affected, and an understanding of the UMAM rule. HEA tends to be more of an academic exercise and requires an interdisciplinary knowledge base (resource economics coupled with reef science). However, the National Coral Reef Institute developed a computer program, "Visual_HEA," which facilitates input of HEA assumptions and parameters, and calculates the compensatory action required for a given set of assumptions about injury and compensation (Dodge and Kohler 2004). The program is available free to interested researchers affiliated with scientific institutions and is for non-commercial use. For more information, visit: http://www.nova.edu/ocean/visual_hea

State of Florida agencies are required by statute to use UMAM. Federal agencies see value in using the same methodology as the State of Florida. HEA is the required assessment method for some federal activities (oil spill response). However in some cases federal agencies may rely on HEA more than UMAM because HEA has been vetted through the scientific peer review process, (e.g., Milon and Dodge 2001, Dunford et al. 2004, Thur 2007). Considering that both methods can be subjective, the application of both HEA and UMAM to a reef injury/mitigation project can be used to help calibrate the results of the compensatory mitigation requirement. However, in many complex projects in southeast Florida, both methods are used. It should be emphasized that results of an HEA or UMAM are only as good as the inputs and the assumptions used in the calculations.

10.4 Special Considerations Specific to Compensatory Mitigation Projects

While many of the concepts described in preceding chapters apply to mitigation reefs, special considerations also are required. One of the foremost is the overall goal of the mitigation reef, which should be to replicate the functional attributes of an unimpacted reef, such as coral cover and species richness. The goal is not to create something that would not naturally exist in the particular environment. A representative reef is shown in Figure 10.3.

Figure 10.3. A compensatory mitigation artificial reef in southern Florida (Photograph courtesy of Miami-Dade County DERM.).

10.4.1 Design and Siting of Compensatory Mitigation Reefs

When designing a project, one size does not fit all. It is important to note that both substrate foundations and hydrodynamics can differ significantly by location. The general approach that has been used in the southeast Florida region to offset the loss of reef habitat has been to construct mitigation reefs near or adjacent to the impacted site. Many invertebrates, including corals, will colonize appropriately designed and sited hard substrates through larval recruitment. Fishes will also colonize the hard substrate through migration or the settlement of larvae.

Maintaining the Trophic Structure -- Mitigation reef design usually has particular considerations that relate to fish life-history stage, but the potential predation risk to newly settled organisms is a common concern with respect to design and siting. Some field studies, such as Hixon and Beets (1993), documented that the presence of only a few small predators can exert considerable influence on the existing community.

Nearshore Considerations -- Projects that require mitigation very near shore can be problematic from engineering, design, and siting considerations. From an engineering perspective, the design must consider the high-energy wave and dynamic sand environments. Reefs and associated organisms at these depths may experience the highest wave energy that occurs when hurricanes and other storm events affect the area. The mitigation reef design must also consider the sediment thickness and select an appropriate overburden to avoid subsidence. Deployment in the nearshore environment (specifically the surf zone) can also be especially challenging due to access issues for both vessels and vehicles, as well as the high-energy waves that make reef deployment difficult.

10.4.2 Timing of Mitigation with Respect to Impact

It is generally standard practice that mitigation reefs are created as soon as possible after the resources are impacted. Historically, deployments have been delayed due to a variety of reasons, including complications in the permitting process and deployment weather windows. Presumably, this increases both the window of lost ecological services, as well as the lost socioeconomic value since the loss of coral habitat directly and indirectly affects user groups that depend on them for their recreation and livelihood.

Pre-Impact Mitigation Projects -- From a project planning and temporal perspective, there are advantages to deployment of mitigation reefs prior to the activity that will adversely impact the natural reef. This allows for the mitigation reef to provide some biological functions like habitat, shelter, and recruitment during and after construction. However, it is important to note that mitigation reefs can only resolve the impacts from loss of structural habitat. Other effects of coastal construction or other activities that impact reefs, such as sediment and turbidity, are not mitigated through the construction of artificial reefs.

10.4.3 Monitoring Issues Specific to Mitigation Reefs

Monitoring of mitigation reefs is critical to determine if they are providing ecological services and functions equivalent to those lost from natural reefs. However, in southeast Florida there are insufficient long-term data to show that mitigation reefs are replicating lost services from the natural reefs that have been impacted. As mentioned above, reef managers and scientists are currently exploring alternative reef mitigation options.

Peer-reviewed monitoring protocols exist that describe the minimum monitoring design criteria necessary for general artificial reef monitoring projects (see Chapter 9, and also Rogers et al. 1994). The following are specific considerations for successful compensatory mitigation monitoring projects.

Pre-Project Planning -- Successful mitigation monitoring design begins before there are any impacts to the resources. Due to the multitude of sensitive marine and terrestrial resources in Florida, the state's regulatory programs emphasize the benefits of pre-application, multi-agency consultations, and project site visits to ensure that both applicants and permit reviewers understand the full spectrum of fish and wildlife resources that may be impacted by a project (USFWS 2004). Although this is beneficial for all projects, it is especially important for mitigation projects whose goal is to replicate the existing habitat. These visits also lead to better project designs, which minimize impacts, as well as more useful mitigation recommendations. Overall, this leads to improved compliance with special permit conditions.

Temporal Monitoring -- Pre-project site visits allow for a good qualitative description of the resources, but only pre-project monitoring can accurately quantify what is actually present prior to construction. Without this baseline information, it is impossible to successfully recreate the existing habitat accurately. This applies to both the original project site and the mitigation reef site. Additionally, monitoring during both construction and post-construction are equally important for their ability to show how the resources were actually impacted as well as how they have recovered.

Success Criteria -- A USFWS review of mitigation projects in southeast Florida states that the majority of the projects reviewed did not include performance standards to determine if the project was successful (USFWS 2004). Success criteria are based on the objectives of the project as well as what is being measured. For compensatory mitigation the objective is to recreate the same habitat that was impacted.

Accurate and Timely Reporting -- It is extremely important to accurately report the results of monitoring associated with the mitigation reef, and submit those reports to the agencies for review in a timely manner (as stipulated in the special permit conditions). These reports are the only way permitters are able to determine if the project has been successful.

Adaptive Management Including a Back-up Plan -- Adaptive management allows for the flexibility to change portions of a project in response to particular events (MICCI 6, 2008; http://www.dep.state.fl.us/coastal/programs/coral/reports/). The USFWS (2004) report found that the majority of mitigation conditions did not include any back-up plans in the event that the monitoring results and/or success criteria showed that the mitigation project had failed. A back-up plan to compensate in the event of failure can save valuable time in restoring (some level of) lost ecological services.

10.5 Overview of Mitigation Review Documents

Only recently have there been any documents that review the historical compensatory mitigation projects in southeast Florida to determine if they were successful based on the goals of the project, or to recommend improvements to the design of mitigation projects. Two such documents are summarized below.

10.5.1 Summary of the U.S. Fish and Wildlife Service Review

In 2004, the USFWS reviewed permit applications from southeast Florida (Indian River to Miami-Dade counties) for projects where compensatory, ocean ecosystem mitigation was recommended or required to offset impacts to hardbottom habitats. Twenty-six USACE regulatory division permits and planning division civil works projects were reviewed; 217 acres of hardbottom were expected to be impacted and approximately 113 acres of artificial or natural materials were to be deployed as replacement habitat. This total included 43 acres completed and 70 acres for projects not yet completed (USFWS 2004). The impacts in these examples were caused by filling, sedimentation, dredging for beach nourishment, and port expansion.

For each project, the following information was reviewed: *"1) Whether or not impact avoidance and minimization measures were developed and implemented; 2) the extent of direct and indirect impacts; and 3) whether or not compensation for impacts to coral habitat was required and implemented."* The following are excerpts from the review (USFWS 2004), which can be found in detail at www.southeast.fws.gov/es:

- *The information in this report suggests that compensatory mitigation recommendations, requirements, and compliance have improved over time. However, the expected impacts planned for the 10 pending projects in South Florida exceed the known impacts from the 16 completed projects of the last 20 years, with mitigation requirements still being evaluated.* (See Table 10.1, this report.)
- *The report recommends the establishment of a technical advisory team and/or regional interagency teams to provide consistent evaluation of project impacts, analysis of more effective coral reef mitigation techniques, and the development of appropriate protocols for mitigating unavoidable impacts, monitoring project construction, and complying with mitigation conditions.*
- *Increased intra- and inter-agency collaboration, particularly sharing monitoring and report results, would improve mitigation efforts for all agencies concerned with coral reef impacts.*

Table 10.1 provides an updated summary, based on the USFWS (2004) review, of compensatory mitigation anticipated for proposed projects in southeast Florida.

Table 10.1 Summary of compensatory mitigation anticipated for proposed projects in southeast Florida, based on U.S. Fish and Wildlife Service review (USFWS 2004).

Project Name (USACE Permit Number)	County	Avoided & Minimized	Reduced Impacts (Acres)	Recommended Acres	Required or Proposed Acres	Constructed Acres	Location	Type (In / Out-of- Kind)	Coral Colonies Trans-planted (number)	Material & Acreage	Monitoring Reports Required
Phipps Park Shore Protection (200000380)	Palm Beach	Yes	N/A	3.1	N/A	N/A	Onsite	In-kind	N/A	Limestone	Yes
Central Boca Raton Shore Protection (200200200)	Palm Beach	No	N/A	0.32	0.32	N/A	Onsite	In-kind	N/A	Limestone	N/A
Broward County Shore Protection (199905545)	Broward	Yes	22	13.5	13.5	10.1	Onsite	In-kind	TBD	Limestone	Yes
Alternate Test Beach 63rd St. BEC&HP (Federal Project)	Miami-Dade	Yes	N/A	0.08	0.08	0	Onsite	In-kind	N/A	Limestone	Yes
Port Everglades Expansion (Federal Project)	Broward	Yes	N/A	49.58	49.58	Project pending	Onsite	In- & Out-of-kind	TBD	Limestone & Tire Removal	Yes
Port of Miami Expansion (Federal Project)	Miami-Dade	Yes	N/A	15.94	6.2	Project pending	Onsite	In-kind	TBD	Limestone	Yes
Key West Harbor (20030203)	Monroe	Yes	N/A	N/A	N/A	TBD	Onsite	N/A	TBD	N/A	Yes
Seafarer, Inc. Gas Pipeline	Palm Beach	Yes	TBD	N/A	N/A	Project pending	Onsite	In- & Out-of-kind	TBD	N/A	Yes
Ocean Express Gas Pipeline (2001065555)	Broward	Yes	TBD	N/A	N/A	Project pending	Onsite	In- & Out-of-kind	TBD	Tire Removal	Yes
Tractebel/ Calypso Gas Pipeline (200102775)	Broward	Yes	TBD	N/A	N/A	Project pending	Onsite	In- & Out-of-kind	TBD	Tire Removal	Yes

10.5.2 Combined Project: Southeast Florida Coastal Project Monitoring and Evaluation

The goal of the MICCI – Fishing, Diving and Other Uses (FDOU) Combined Project 27, 47, 48 was to develop guidance for regulatory staff and others. The purpose was to ensure effectiveness of permit monitoring requirements, which include pre-, during, and post- construction evaluations of permitted coastal construction, and mitigation project surveys and monitoring, including artificial reefs. Objectives included: 1) Completion of a literature review and synthesis of information of relevant peer-reviewed, white and grey literature pertaining to monitoring (i.e., monitoring design, statistical power to detect change) in the four-county southeast Florida region (Miami-Dade, Broward, Palm Beach, and Martin counties), nationally, and internationally, for both permitted coastal construction projects and non-permit-related independent monitoring protocols; 2) review of all available past and present local, state, and federal coastal construction and mitigation project survey and monitoring programs in southeast Florida; and 3) interviews with regulatory agency personnel.

The data gathered were assessed for strengths, gaps, sufficiency, statistical validity and scientific rigor to create criteria, guidance, and recommendations for future nearshore and offshore surveying and monitoring programs, methods, and techniques. The draft report contains recommendations for benthic, fish, and water quality/ turbidity and sedimentation monitoring. Additional monitoring criteria were recommended as needed based on project type. The final report will be available in fall 2011.

10.6 Case Studies

This section reviews two permitted construction projects for laying of cable and beach nourishment, and a third in response to a vessel grounding. Table 10.2 offers highlights.

10.6.1 Permitted Coastal Construction Impacts

Two construction projects in southeast Florida that required deployment of artificial reefs as compensatory mitigation are the CFX-Emergia Fiberoptic cable project (also known as Telefonica or Emergia) and the Broward Beach Segment III Shore Protection Project (SPP), located in Palm Beach County and Broward County, respectively. As evidenced in other MICCI projects, there is not a good permit tracking system in the southeast Florida region, and monitoring reports from past projects are often difficult to obtain. While the information provided below is from an incomplete data set, it provides an example of how mitigation reefs have been executed. It was easier to track down information for the Broward project, probably because the project was more recent.

Table 10.2 Summary of three case studies of mitigation for damage to coral reefs in southeast Florida (two permitted and one un-permitted).

	CFX-Emergia	**Broward SPP Segment III**	***Eastwind* Cargo Vessel**
Type of impact	Permitted	Permitted	Un-permitted
Area of natural reef impacted	1 ft wide by 800 linear ft of reef [800 ft^2 or 0.018 acres (ac)]	7.6 ac of nearshore hardbottom, including 1.1 acre of worm reef (authorized by permit) *Evaluation of actual impact underway	2.72 ac [10,995 square meter (m^2)] of nearshore hardbottom Scarified Area = 1.37 ac (5,546 m^2)
Date of impact	Cable installed, December 2000	Beach renourished, 2005-2006	Grounding, March 26, 2004
Depth	55 to 104 ft	0-15 ft	28 ft
Location	Between FDEP monuments R-205 and R-207; North of the Boca Inlet and offshore Spanish River Road	Between Port Everglades and the Broward/Miami-Dade County Line (FDEP monuments R-86 to R-92 and R-99 to R-128)	1.8 nautical miles north-northeast of the Port Everglades Inlet. 0.25 miles east of Las Olas Boulevard, Fort Lauderdale
Artificial reef required size	1,852 ft^2 (0.043 ac) required by the FDEP permit; 2,646 ft^2 (0.061 ac) artificial reef actually constructed	8.9 ac	0.038 ac (154.22 m^2)
Method to determine amount of mitigation artificial reef	Ratios and best professional judgment	HEA	HEA
Date of artificial reef construction	January 7-8, 2001	August to September 2003 (20 months prior to impact)	Fall 2005 (Approximately 1.5 years after impact)
Artificial reef permit specifications	400 tons of limestone boulders, each boulder 3-4 tons and placed with 6-8 ft vertical relief	One layer of 4-6 ft diameter limestone placed	N/A

Table 10.2, continued.

	CFX-Emergia	**Broward SPP Segment III**	***Eastwind* Cargo Vessel**
Location of artificial reef	Palm Beach County ERM's Boca Raton Artificial Reef Site #1	6 discrete areas between R-101 to R-125	Original injury site
Depth of artificial reef	70 ft	12-18 ft	28 ft
Coral relocation required?	No, but dislodged corals from the impact site re-attached with cement	654 corals relocated from the impact site and transplanted to 0.27 ac of mitigation reef August 24, 2004-January 11, 2005	Approximately 583 corals reattached within grounding site. Many corals reattached to large stabilized rubble boulders. Reattachment sites collectively cover of 263 m^2
Artificial reef monitoring duration	2 years (immediately post-construction, 6 months post-construction, 1 yr, 2 yr)	Semi-annually during first two post-construction years, and annually during the third and fourth post-construction years	Biological surveys conducted pre-and post-primary restoration, April 2004 and June 2006, respectively. Funding included in settlement agreement for monitoring of reattachment of viable corals, if and when there is a ten percent or greater loss of reattached corals.
FDEP permit No.	50-164707-001	0163435-001-JC	N/A
USACE permit No.	SAJ-2000-0159 (IP-BP)	Reef impacts permitted in SAJ-1999-5545 (IP-SLN). Construction permitted under SAJ-2002-2344 (IP-SLN)	N/A

Project Descriptions

CFX-Emergia - Fiberoptic Cables H and I were placed over the outer reef offshore of Boca Raton, Florida in December 2000. The cable lay was between FDEP monuments R-205 and R-207, an area located offshore Spanish River Road (north of the Boca Inlet).

Broward Segment III SPP - Segment III of the Broward County SPP is located between Port Everglades and the Broward/Miami-Dade County line. The project fill area in Segment III is approximately 6.8 miles long. The project was designed to provide beach renourishment for the majority of the Segment III shoreline including John U. Lloyd State Park, Dania Beach, and Hollywood/Hallandale shorelines. Beach fill was placed from FDEP monuments R-86 (Port Everglades) to R-92 within John U. Lloyd State Park, and from R-99 (Dania Beach Pier) to R-128 (Miami-Dade County line). The permitted sand fill volume for Segment III was approximately 1.54 million cubic yards of sand. However, the actual amount of material added to the beach was greater.

Reef Impacts Associated with Each Project

CFX-Emergia - Cable H was measured to cross approximately 450 ft [137 meters (m)] of hardbottom habitat, and Cable I was laid over approximately 350 ft (107 m) of hardbottom habitat. Each cable is approximately two-inches in diameter; however, resource management agencies required a 12 inch wide swath for the impact calculations. Therefore the impacts associated with this project were determined to be 800 ft^2 (0.018 acres).

Broward Segment III SPP - Placement of sand during nourishment activities and subsequent equilibration of beach fill (over several years) will result in the burial of approximately 7.6 acres of nearshore hardbottom in Segment III, including direct burial of 0.9 acres in John U. Lloyd State Park and 1.1 acres of worm reef habitat in Hollywood.

Artificial Reef Mitigation Requirements for Each Project

CFX-Emergia - Impacts to the stony corals and associated hardbottom communities were offset by the construction of a 2,646 ft^2 artificial reef (0.046 acres). Monitoring of the stony corals along Cables H and I and juvenile coral recruitment at the artificial reef was conducted.

Broward Segment III SPP - Due to the projected burial of natural hardbottom areas, FDEP required the placement of 8.9 acres of artificial reef. The artificial reef was constructed as one layer of limestone boulders 4 - 6 ft in maximum diameter placed in the nearshore zone in approximately 12 - 18 ft water depths. The mitigation reef was constructed in six discrete areas between FDEP monuments R-101 and R-125, each with different geometries. The singular “mitigation reef” refers collectively to all of these. The project provided additional mitigation for impacts by transplanting stony corals greater than 10 cm diameter from impact areas to the mitigation reef between R-101 and R-102.

Comparison of the Projects

Timing of reef construction with respect to impact to natural reef - The CFX-Emergia artificial reef was constructed approximately one month (January 7-8, 2001) after the natural reef was impacted by cable laying activities. The Broward Segment III SPP reef was constructed 20 months (August – September 2003) before the anticipated construction of the beach nourishment project. Deploying it prior to the beach fill was desired by resource management agencies to allow for additional fisheries habitat in the region prior to the loss of the natural habitat. A reduced temporal lag can reduce mitigation requirements.

Coral relocation - Resource management agencies required pre-impact coral relocation for the Broward Segment III SPP project. Specifically, 654 coral colonies were relocated to 0.27 acres of artificial reef. The CFX-Emergia project was not required to relocate corals; however, it was required to re-attach corals that became dislodged after the cable was laid.

Method to determine the mitigation amounts - The evaluation of the CFX-Emergia artificial reef pre-dates UMAM and in general pre-dates state and federal agency adoption of functional assessments. Generally, ratios were the primary method for determining mitigation amounts before 2001. The Broward Beach Segment III applied an HEA for the determination of the mitigation amounts and used ratios to gauge the HEA results.

Duration of monitoring - Resource management agencies required two years of monitoring for the CFX-Emergia artificial reef (four total monitoring events), whereas Broward Segment III SPP artificial reef required four years of monitoring (six total monitoring events).

10.6.2 Non-Regulatory (Un-Permitted) Vessel Grounding Impacts

In the case of vessel grounding incidents, *"compensatory mitigation is assessed after primary restoration [of the grounding site] has been completed, and is designed to provide for the interim loss of ecological services from the time of the injury until natural recovery returns the resources to their baseline condition"* (Collier et al. 2007).

One vessel grounding in southeast Florida that required the construction of artificial reefs as compensatory mitigation is reviewed here: A 166 m cargo vessel, the *M/V Eastwind,* grounded in approximately 28 ft of water on March 26, 2004, 1.8 nautical miles north-northeast of the Port Everglades Inlet offshore of Fort Lauderdale in Broward County (See Table 10.2.).

Reef Impacts Associated with Grounding

The total vessel grounding injury area was 10,995 m^2 of nearshore hardbottom, with 5,546 m^2 of that being a completely scarified area. Injury categories included

Rubble, Crushed Reef/Scattered Rubble, Sand with Scattered Rubble, Sand Overburden, and Exposed Bedrock.

Artificial Reef Mitigation Requirements

Timing of reef construction with respect to impact to natural reef - The restoration of the *Eastwind* grounding site (and placement of artificial reef boulders) was approximately one year (April 2005) after the natural reef was impacted by the vessel.

Coral Relocation - Approximately 583 corals were reattached within the grounding site. Many corals were reattached to large stabilized rubble boulders. Reattachment sites collectively covered an area of 263 m^2.

Method to determine the mitigation amounts - HEA.

Duration of monitoring - Biological surveys were conducted pre- and post-primary restoration in April 2004 and June 2006, respectively. Funding was included in the settlement agreement to continue monitoring if and when there is a 10% or greater loss of reattached corals.

These three case studies illustrate circumstances in which the use of artificial reefs as part of a mitigation plan might be warranted.

Chapter 11. Vessel Deployment

The deployment of maritime vessels as artificial reefs - when deemed appropriate for a given situation - allows reef builders to produce a relatively large reef footprint, with significant relief, in a short time and often at less cost than more common rock or concrete construction. Use of vessels requires some additional consideration in preparation, siting and different deployment techniques. This chapter outlines the methodologies that have proven most successful for the particular conditions encountered along the Palm Beach County coast. These practices are not Best Management Practices per se; they are only what have proven most efficient for a particular area of the Florida coast (i.e., "Accepted Practices").

Having a chapter devoted to vessels reflects the reality of reef-building in southeast Florida, where 192 vessels (barges, tugs, boats, ships) represent 47% of all deployments of all materials in the past 30 years. "Reefing" is a term commonly used for this practice. In Miami-Dade County 215 reefs include 85 ships and 27 barges (S. Thanner, Miami-Dade County DERM, pers. comm.).

The principal purposes for using ships as reefs have been to enhance sportfishing (catch and accessibility) and recreational diving. It is important to analyze if a ship is the right choice for a given location, in terms of environmental and other effects.

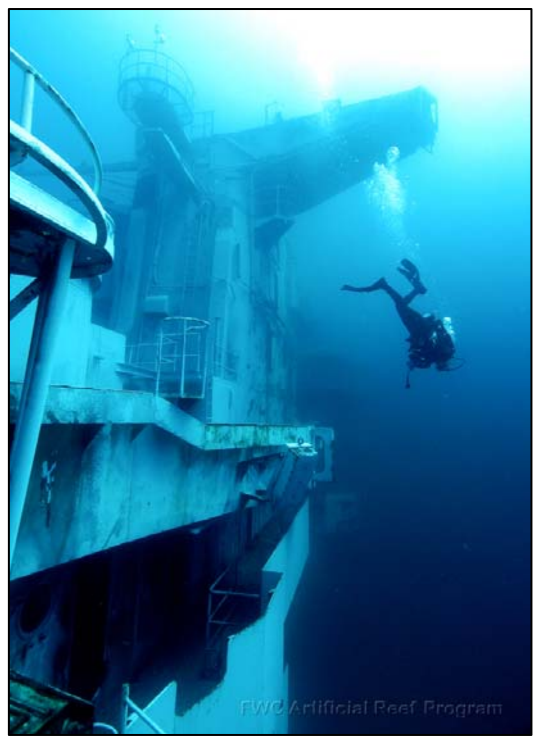

Figure 11.1. The largest vessel sunk in Florida waters is the *U.S. Oriskany* aircraft carrier off Pensacola. Recreational diving is a principal objective of this reef (Photographs courtesy of FWC).

11.1 Vessel Procurement

Vessels can be acquired from a variety of sources including the U.S. Customs Service, U.S. Navy, U.S. Maritime Administration, and marine contractors. Costs for vessels can range from "turnkey" donations, to U.S. Naval vessels that might cost millions of dollars to prepare and deploy. It is intuitive that any vessel used for reefing should be within the program budget to purchase, prepare, and transport to the deployment location. Costs for reefing ships are escalating due, in part, to fuel costs, scrap metal prices, environmental regulations, and liability concerns.

Whatever the source, the purchase of vessels for reefing usually requires fast action on the part of the project manager. Quite often, vessels become available on the spur of the moment as materials of opportunity. Money is usually the limiting factor for obtaining the vessels; both the amount required and the ability for rapid payment. If consistent with program plans, it is advisable to establish an account dedicated to the purchase of vessels and containing sufficient funds, to provide for fast purchase and/or preparation and deployment of a vessel when one becomes available.

It is essential in budgeting to estimate costs of cleanup and preparation. Vessel dockage charges should be a basic consideration during the purchase of any vessel because there might be considerable time between purchase and sinking, which might require dockage charges. This could be further complicated if the vessel must be kept during hurricane season. If that is the case, contingency plans should be in place for securing the vessel should storm conditions arrive.

Vessel donors may want to transfer title to the permit holder. If so, the permit holder should maximize liability protection through a third-party agreement. This agreement should clearly identify responsibilities and assign liability to another party until the vessel is cleaned to the satisfaction of the permit holder and the vessel properly reaches the sea bottom within the permitted area. The purpose for this is to reduce potential liability to the permit holder should there be a mishap before, during transport or sinking of the vessel. For the longer term, the title could conceivably remain with someone other than the reef site permit holder as a precaution against post-deployment liability (e.g., diving and navigational accidents and storm-generated issues). More information about liability is given in Chapter 3, section 3.3.

11.2 Vessel Selection and Composition

Vessels to be used as artificial reefs should be constructed of materials durable enough to persist and withstand the marine environment, and their constituent materials should not significantly degrade or deteriorate as a result of their immersion in water. Heavy gauge steels should be the preferred hull material. Any vessel for reefing should be seaworthy enough to be safely towed and maneuvered to the reef site location without fear of sinking or capsizing, even if the weather deteriorates during transit. Lighter gauge metal, fiberglass and many ferro-cement hulls do not tend to hold up well. Wood is not allowed by permit. Naval ships are usually larger, heavier vessels and have greater stability on the bottom and much thicker hulls that will last longer in the marine environment than the average commercial ship or yacht. Derelict vessels as defined by state statutes are typically too small, constructed of unsuitable materials or in such poor shape that they do not make suitable candidates for reef projects.

Vessels with large open holds, even if very heavily constructed, may tend to twist or break during sinking, and/or after being sunk when the forces of waves and currents act upon them for a time. Welding heavy steel covers or I-beams across the hold opening(s) provides additional strength to the vessel's overall structure and increases the durability and life expectancy, once sunk.

Ships must be stable enough to resist migration during severe weather. This stability is greatly enhanced by selecting vessels for reefing with the greatest possible weight for their amount of surface area. Regardless of weight, however, if the greatest surface area of a vessel is presented perpendicular to prevailing currents and waves, the likelihood of that vessel moving or breaking increases. If a vessel is sunk while at anchor, and the conditions at the time of sinking are normal for the site, then the vessel should at least be oriented with the prevailing current. Unfortunately, for Palm Beach County this N-S current orientation is more or less perpendicular to prevailing wave conditions.

Variations in size, shape, internal and external complexity, and utility in providing habitat and recreational resources have made steel vessels publicly popular artificial reefs. Size of the vessels can range from small (50-60 ft) barges and tugs, to decommissioned aircraft carriers (>900 ft long). Vessels often provide significant relief (from 15 - 20 ft to greater than 80 ft) which is favored by some fish species. These structures are commonly very popular sport diving and fishing sites. In general, marine vessels used for reefing should be at least 150 ft in length to withstand the rigors of the ocean environment and yield a significant life span. During the early planning stages of a ship reefing project, the vessel's physical characteristics should be subjected to mathematical stability analysis according to the specific conditions of the intended site to determine if it is appropriate for that site. Adding ballast to ships' holds in the form of limestone, concrete or heavy gauge metal pieces can increase the overall stability of the vessel and decrease the likelihood of migration during heavy sea conditions. The ballast that is added can also significantly increase the attractiveness of the reef to marine life by providing additional habitat complexity.

Additionally, to be attractive to marine life, the external shape of the vessel should be relatively complex. That is, a barge is a less complex structure than a ship with multiple deck levels and would presumably be less attractive to marine biota. It is also true, however, that once epibiota begin to colonize an underwater structure, even one as relatively simple as a barge, it can become attractive to fish and invertebrates (e.g., Arena et al. 2007).

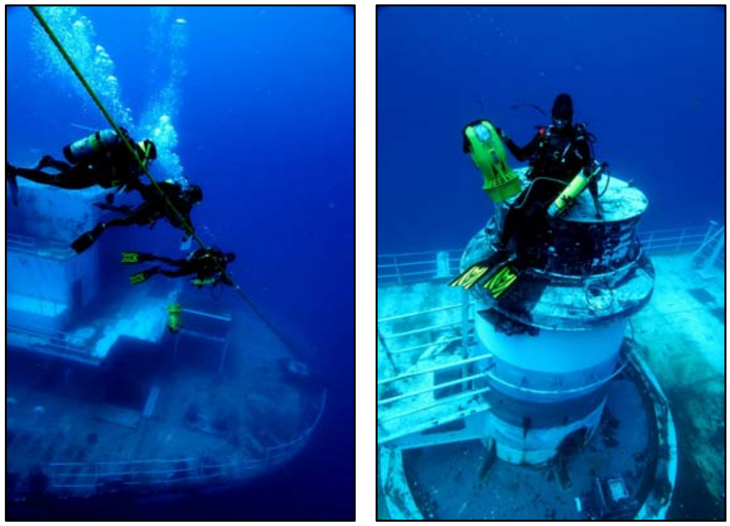

Figure 11.2. Vessels deployed as artificial reefs are intended to enhance recreational fishing, provide new recreational scuba diving sites and boost eco-tourism opportunities along the coast (Photographs courtesy of FWC).

11.3 Vessel Preparation and Cleaning

The most basic preparation of vessels for reefing involves removal of potential hazards to divers. A ship sunk within recreational diving depths will be visited by divers. Accordingly, hazards to divers such as cables and sharp metal objects should be removed. Access to physically restrictive areas should be blocked by welding heavy gauge metal bars across entrances to deny entry. However, over time the corrosion of steel results in the eventual creation of new access points, and the most curious and persistent divers have been known to use crow bars and other means to access areas previously sealed. Therefore, the best approach is to prepare the vessel in a way that assumes divers will eventually access all locations. Where entry is not restrictive, access should be made easier and safer by enlarging entrances, and removing hatches and portholes.

All materials aboard a vessel, including the hull, superstructure and all other attached materials that will remain onboard after sinking must comply with FDEP and USACE artificial reef permit conditions, or be removed. These materials must be non-polluting and non-toxic, complying with all applicable water quality standards for class III (ocean) waters. Prior to being sunk, vessels must be inspected for pollutants, debris, and floatables and be cleared for use by the USCG Marine Safety Office.

Ships must be sampled, tested, cleaned and prepared for reefing according to the standards and protocols described in EPA 842-B-06-002 ("National Guidance: Best

Management Practices for Preparing Vessels Intended to Create Artificial Reefs"), http://www.epa.gov/owow/oceans/habitat/artificialreefs/index.html.

Beyond this, it is worth stressing that every artificial reef deployment, especially maritime vessels, is unique; what is appropriate for one vessel deployment may not be adequate for another. Project managers should confer with the FWC and the EPA on a per ship basis prior to starting any sampling, testing or cleanup, since ship specifics vary significantly. The age, history and physical characteristics of each ship must be considered in producing a sampling protocol to adequately test and clean a ship. For instance, military ships and non-military ships built after 1979 are much less likely to contain Polychlorinated Biphenyl (PCB) pollutants. All ships to be used as reef material, no matter how unlikely to contain PCBs and asbestos, must still be sampled and tested for these pollutants. Although there has been one PCB disposal permit issued to date, for the *Oriskany*, which was requested by the Navy due to limitations on their reefing budget, it will be unlikely that the EPA will grant a future PCB disposal permit for an artificial reef.

All maritime vessels approved for reefing must be cleaned of any polluting, toxic, color-causing or turbidity-causing substances and all floatables in accordance with all applicable federal and state regulations. All tanks, hoses, pipes and engines should be opened and drained of hydrocarbons or other polluting fluids. Any ropes, cables, wires or cordage that might potentially result in entanglement by marine life or divers should be removed.

11.4 Staging Areas and Towing

Vessels are usually stored at a dock or mooring prior to their purchase or donation. Ideally, if at all possible, preparing the vessel for reefing should be done at its home dock or mooring. But cleaning and pre-deployment preparation areas could be different since very few artificial reef staging sites have the capacity or the facilities to properly prepare a large vessel for reefing. Once ready for sinking, vessels are usually towed to the reef location at the intended time of reefing, with no need to ever dock or moor the vessel again. Towing should be accomplished using an ocean-going tug of sufficient size and power to control the towed vessel if the weather turns bad, or if the vessel requires positioning on site. The size and power of the tug should be determined by a qualified marine towing contractor. A towing plan must be submitted to and approved by the USCG prior to moving the vessel from the staging area. Transit to the reefing site should only be attempted during weather windows that are forecast to be suitable for an extended period of time (longer than what is required for normal transit and reefing operations).

11.5 Vessel Placement Considerations

All reef construction, regardless of type, requires not only appropriate permitting but also advance notification to a variety of agencies and authorities. Notifications typically are listed and explained in the permit(s). Additionally, new USCG notification and inspection forms recently have been completed that directly pertain to ships. These forms must be submitted prior to sinking a ship: CG-MIA-02 (Rev 08-06) "Ocean Disposal/Artificial Reef Notification, Ocean Disposal Artificial Reef Inspection Form," and CG-MIA-03 (Rev 08-06) "Ocean Disposal/Artificial Reef Towing Plan." See website www.uscg.mi/d7/.

Ships should be used for reef building only in deeper waters. In general, and remembering that each deployment has its own set of unique conditions, water depths for reefing a maritime vessel should be a minimum of 90 ft. The shallower the water, the more severe the environmental conditions the vessel will experience, especially in open, unprotected waters. Chances for navigational problems also increase with decreasing depth due to the relief created by large vessels. Water depth must be sufficient to allow for safe navigation over the sunken vessel as per USCG directions. Navigational clearance requirements are detailed in artificial reef permits and should be strictly followed. These requirements may vary according to USCG region. A typical requirement found in 2008 Palm Beach County reef permits is to maintain a clearance of 50% of the water depth between 13 and 100 ft with at least 50 ft of clearance in depths greater than 100 ft.

Sites for all types of artificial reefs should be selected so that they do not contain active utility cables, pipelines or other rights-of-way, disposal sites or sand-source sites. Nor should they present a hazard to navigation because of their location or due to the bottom relief of the reef construction material. A stability analysis including the ship dimensions and reef site description should be run prior to finalizing the site selection.

Ships should be placed on bottoms with a thick sediment layer. This allows current scour around the vessel to produce a bowl in the sand which will contain the vessel. This reduces the chance of the vessel migrating across the bottom during severe weather. Additionally, thick sediment overburdens minimize the effects to the vessel's hull of working against a hard substrate which will stress and may eventually break the hull.

Construction sites for artificial reefs should be (1) selected that have no live/hardbottom resources, and (2) surveyed and buoyed immediately prior to reef deployment to ensure that no resource will be impacted. When live/hardbottom exists in the vicinity of a construction site, appropriate exclusionary boundaries should be placed around the resource to ensure it is protected during materials placement. In general, buffer zones to protect resources should be greater as water depth increases due to decreasing precision in materials placement in deeper water. Generally, depths greater than 30 ft should have expanded boundary requirements sufficient to protect any resources present. In the case of Palm Beach County, a minimum 200-foot buffer zone around all types of resources is a permit requirement. For vessels, because of the increased chances for placement error and the secondary threat of post-deployment migration during storms, the resource buffer zone should be increased. There have been incidences when ships were inadvertently sunk in the wrong place, requiring refloating the ship and moving it to the proper location or demolishing the hull to accommodate marine traffic. In other cases, the ship has remained where sunk (Box 11.1), in some cases permanently buoyed as a navigational hazard.

Box 11.1 An example of the importance of proper planning and communication: the tugboat "Tuff-E-Nuff" sunk off Martin County as "Kyle Conrad Memorial Reef".

On January 17, 2011 the 70-ft, steel harbor tug "Tuff-E-Nuff" was sunk off Martin County as the "Kyle Conrad Memorial Reef" by a local non-profit organization. Unfortunately, the location was 2.4 nm outside of the planned and permitted Martin County Sirotkin Artificial Reef Site. The FWC, NOAA and the USACE were notified via post-deployment reports on January 24, 2011 and the county submitted a request to the U.S. Army Corps of Engineers to amend their reef permit to include that unintended artificial reef site. The permit modification was issued on April 26, 2011. Nevertheless, this vessel sinking gone awry provides invaluable lessons learned.

Poor weather conditions, 3-5 ft seas and a ½ knot current contributed to a series of compounding errors. However, an FWC review concluded that the inability of the contractors to deploy the vessel within the permitted reef site was a result of numerous planning and coordination problems. The most critical included failure to submit a complete tow, anchoring and sink plan; failure to have any VHF or other hand-held radio communications among the contractors on board the "Tuff-E-Nuff" prior to it sinking; use of inadequate anchoring; failure to confirm that the anchors were holding prior to initiating flooding of the "Tuff-E-Nuff" and failure to adjust the deployment schedule according to weather conditions.

As a result of this incident, the Martin County Artificial Reef Program developed the following vessel scuttling operations plan, which FWC supports:

1. No third party deployments will be allowed on Martin County reefs.
2. The County will continue to require that the Coast Guard approved sink plans be provided to the County for review and approval.
3. When the contractor brings the reef vessel into the area, the contractor's project manager will be required to sign the sink plan, acknowledging all the requirements therein.
4. Immediately prior to the deployment day, an "all hands" meeting will be held to review the sink plan. All tug crew, contractor's crew, and other persons involved in the sinking will be in attendance and sign a roster attesting to their understanding of the plan. At that time, a county representative will:
    a. Document the size and weight of anchors onboard the reef vessel;
    b. Document the length of anchor rope/chain attached to each anchor, and ensure that the anchors are attached properly.

Box 11.1, continued.

5. On deployment day when the reef vessel is in position, the anchors will be deployed and allowed to catch. GPS instruments will be used to verify that the vessel is secured and that no movement or anchor drag is detected.
6. The onsite County representative will use the GPS information to determine if/when the reef vessel is secured. The representative will then give the contractor the go-ahead to begin flooding the vessel.
7. The tow vessel will be equipped with a line of sufficient strength to hold the reef vessel in place. The length of this line will be, at a minimum, equal to twice the depth of water at the deployment site.
8. The tow vessel will remain onsite and connected to the reef vessel using the line described in #7 above. This will ensure that the reef vessel will be held in place as it sinks should the anchors prove inadequate to hold the reef vessel.
9. GPS will be used to continually monitor the vessel's position. If movement (anchor drag) is detected, and safety permits, flooding will be stopped and the vessel will be moved back into position.
10. The contractor will have a rapid release methodology to disconnect the reef vessel from the tug when final sinking is imminent, but in any case the length of line required will safeguard the tug if this rapid release mechanism does not function.

Fortuitously, this vessel sank 8.5 nm northeast of the St Lucie Inlet at a depth of 150 ft, not within navigation or safety fairways, nor within areas known for commercial shrimping. Diver surveys confirmed that the vessel does not impact or threaten hard-bottom habitat. NOAA-NOS confirmed the location does not pose a navigational hazard. Consequently, post-hoc permitting without substantial penalties and liabilities was possible in this particular case. But, that is not always so. Thorough planning and careful communication is necessary for all artificial reef construction, especially when vessels are involved because of how quickly things can go bad.

Typically, deployment of a vessel should be scheduled during a period when weather forecasts indicate extended light wind and low wave heights. Long-range weather forecasts should be watched carefully. Transit times to a reef site are usually not excessive in southeast Florida, but in the event of some unforeseen delay, the tow vessel and ship to be reefed could be forced to anchor in the open water or to remain under tow until reefing occurs. This might require an extended period of time, during which suitable wind and sea conditions would be preferred, if not required.

The intended artificial reef placement site must be buoyed prior to sinking a vessel. Depending upon the precision needed for a reef deployment, a specific site, construction site boundaries, or both should be buoyed. Additionally, it may be helpful to buoy the sites where the vessel's anchors should be placed. On reefing sites swept by current, attention should be paid to buoy location versus bottom location (a buoy will not be directly over its dedicated anchor). (See Chapter 8)

Vessels used for reefing should be carefully positioned on the intended site and anchored with at least a two-point, bow anchoring system. Anchor chain and ship anchors are preferred over steel cable and large metal or concrete pieces, especially for larger vessels. The length of the anchor chain on each bow anchor should be no less than three times the water depth. The scope of the anchor chains must be considered during anchor placement and anchors deployed an appropriate distance up-current of the intended bottom location for the scuttled vessel. Anchors and chains used should be appropriate for anchoring the size of vessel being reefed. Each individual set of anchor and chain should be of sufficient size and strength to secure the vessel without the second anchor set being used.

As a ship fills with water during sinking, the pull on the anchors from the current increases as more of the vessel sinks into the water. In areas with significant currents it may be prudent to increase the length of each anchor chain (for more holding power) and to increase the boundary zone around down-current resources in the event that the anchors holding the vessel begin to drag.

Anchoring can be used as an additional assurance that a sunken vessel doesn't move during storm events; however, vessels still need to be stable at their planned depth. Stern anchor(s) will help to secure the vessel at its intended location and decrease the likelihood of post-deployment migration during storm conditions. The anchor chain for stern anchors may be less than three times the depth of the water. They should be long enough to secure the vessel once on the bottom, but less than the resource buffer distance. The scope for stern anchors can be calculated using the height of the chain attachment to the ship above the sea floor. The scope for an anchor chain is much less for a ship sitting on the bottom of the ocean, than floating at the surface of the ocean.

11.6 Sinking

Flooding is the safest way to sink a vessel. A vessel may be flooded using fire hoses and/or dedicated pumps that pump seawater into it, either from another vessel or from pumps placed aboard the vessel to be sunk. However, this might take a relatively long time depending upon the size and configuration of the ship, and greatly increases the risk of anchor drag and personnel injury while attending to pumps.

Flooding ports cut in the vessel prior to transport to the reefing location can be a very efficient way to sink a vessel. While at its home dock, or at the workplace of the marine contractor doing the preparatory work, the vessel is lightened to its maximum extent. A series of holes (12-18 inch diameter) are then cut through the hull, just above the waterline, as decided by a marine contractor with experience in sinking vessels for reefs. Temporary water-tight patches, hatches or valves that can be quickly removed or opened are fabricated over the holes. These patches must be able to withstand the rigors of towing, even if sea conditions are less than optimal. The vessel is then ballasted for towing to the site so that the patches are below the waterline. Once the vessel is positioned and anchored at the reef site, the patches are removed or opened, allowing the hull to flood. Depending upon the number and size of the holes and their position along the hull, the vessel will very rapidly fill and sink. In the case of the 265-foot coastal freighter, *Celtic Crusader,* which was sunk off Palm Beach County during 2007, eight flooding ports were cut in the hull. The ports were opened as rapidly as possible by one person and the ship was on bottom in about 12 minutes.

The use of flooding ports is easiest on vessels with a large cargo hold(s) which permit easy, rapid access to the ports. Vessels without holds can present access problems in getting to the individual ports to release them in a sequential, timely manner. It may also be helpful to provide air escape holes when many small compartments or cabins must be flooded for the vessel to sink. Air holes can be provided most easily by removing doors, hatches and port covers, and by cutting holes in the deck, as part of the preparatory work before the vessel ever leaves the dock. This also reduces the chances of diver entrapment once the vessel is on the bottom.

In general, the use of explosives to sink a maritime vessel should be avoided, except in the case of very large vessels where the interior would complicate the use of flooding ports. Explosives require expert knowledge to determine the necessary size, number and placement of focused shape charges to accomplish sinking the vessel. Errors in any of these elements can cause significant problems. Explosives also pose a threat to public safety and to wildlife and necessitate additional levels of preparation. Prior warning of explosive use must be posted giving the exact time and location of the planned sinking in order to assure a level of public awareness regarding the potential danger involved with explosive use. Blast sites must be patrolled by FWC Law Enforcement, or the USCG to ensure that people and listed or protected marine life such as whales, manatees, and turtles are not within the area affected by the blast concussion or possible shrapnel zone. The size of this zone must be determined by qualified marine biologists (e.g., NOAA NMFS) and personnel experienced in the use of explosives. Explosives may be necessary for sinking very large vessels, such as large military ships, because their size and complex interior spaces make them slow to flood and sink. The use of explosives must be justified as an engineering requirement, minimized to the extent possible, and used only as a last resort. The use of pyrotechnics (as was used for some high media profile ship sinkings through the 1980s) is strictly prohibited.

No matter how well a vessel is cleaned and prepared for sinking, once it goes down there are usually some small amounts of floating debris that surface. It is advantageous to have a boat on site with the capability (e.g., maneuverability and gear) of collecting floatables. Usually the amount of material is minimal, but it is a sound conservation practice to retrieve the material, especially since there probably will be an audience at the sinking.

Chapter 12. Promotion and Communication

Publicly sponsored and funded artificial reefs essentially belong to the public, so a public reef builder often falls into the multiple roles of public relations specialist, information disseminator, educator, and sounding board. The public support and ultimately financial support of a local program can greatly depend on the finesse and expertise with which these communications tasks are handled. This chapter gives an overview of how to proactively interact with the media, and how to use technology (e.g., websites) and other forms of communication to disseminate information as well as the importance of good stewardship of the marine environment.

12.1 Why Communicate?

The importance of communication to anglers is stated by Moore (1984): "*In terms of user information....the more he is made aware of the environment, the fish, his role as a sport fisherman, etc., the greater appreciation he can have of the fishing experience and the greater his input into the concept of optimum sustained yield.*" While the value of information and the role of communicating with the public may have largely either been ignored or underestimated by most fisheries managers in the past, today there is broad understanding that conserving species and ecosystems depends on involving communities with a stake in conservation of the resources (Berkes et al. 2009).

To promote increased public support of your artificial reef program, resource users need access to objective and comprehensive information about the economic and ecological importance of artificial reefs. A detailed website or reef user guide, for example, can provide information on where and how to fish and basic fisheries, including:

- Sources for finding laws and regulations for each fishery;
- Access points and available facilities;
- Fishing and harvesting techniques;
- Proper use and preparation of catches;
- Techniques for preventing mortality in fish caught and released;
- Basic life-history information and other interesting facts about target species.

Providing life histories of target species might not seem important, but this information can convey the dangers in overharvesting certain species. For example, a species might not have prolific reproduction capacities for any number of reasons, including slow maturity, low fecundity or a high natural mortality rate. A fisherman educated in the life histories of target species may be far less likely to overfish, thus helping prevent serious problems and possibly helping to aid in the recovery of stressed stocks through cooperation. Perhaps the most valuable aspect of communication is the incentive that once anglers understand how their actions fit into the management and conservation of the resource, they can visualize and understand the role they play, take ownership of the resource, and then be more likely to exhibit stewardship and participate in conservation and management of the resource (Berkes, 2004; Berkes et al. 2009; Pinkerton 2009).

12.2 Media Publicity and Promotion

Publicity and promotions are an essential part of artificial reef work, whether simply to apprise the public of ongoing reef development or to spur interest in special events, such as fund-raisers or ship sinkings. Closely coordinate your publicity campaign with your respective agency's press office to determine if it's necessary to include specific content or formats. The following pointers are based on the advice of a public relations and marketing experts with comprehensive knowledge of tools and skills to help get the message out (Walker 1987[1], Feinglass 2005, ClickZ 2011).

Planning starts early. As soon as the date is set for an event, it's time to begin publicizing and promoting it. This is a big job for one person, so get help if possible. Several important aspects to consider are advance publicity, on-site activities, the decision to use websites or social technology, follow-up publicity and creating a turn-over file. It is advisable to include a release of liability statement in all printed and electronic communication media (Box 12.1).

Box 12.1 Example of liability statement, from Palm Beach County. (Source: http://www.pbcgov.com/erm/coastal/reef/)

"WARNING: Many artificial fishing reefs lie in water depths that exceed the recommended sport diving limitations. Any swimmer, diver, or snorkeler shall approach or visit each artificial reef at his or her own risk. The Palm Beach County Artificial Reef Program and Committee, the Board of County Commissioners of Palm Beach County, and the County of Palm Beach are not responsible for any hazards which may exist or arise on, about, or near the artificial reefs, or for any injuries or fatalities which may occur as a result of any person's presence on, about, or near the artificial reefs."

12.2.1 Advance Publicity

Advance publicity requires developing a contact list of media persons, a social media strategy and possibly a media kit. Develop a list of names, affiliations, email addresses and phone numbers of known local outdoor writers. Keep track of this information with spreadsheet software such as Excel. For more widespread publicity at local, state or national levels, compose a list of other contacts who may provide good exposure, including appropriate staff members or supporting members of:

- Daily and weekly newspapers;

[1] Original publication out of print, but content can be accessed at http://procs.gcfi.org/pdf/gcfi_40-22.pdf.

- Syndicated news services (e.g., Associated Press);
- Radio and television station sportscasters (including cable stations);
- National television networks (e.g., CBS, NBC, ABC, CNN, Fox);
- Local fishing and diving clubs;
- Professional writers associations (e.g., Florida Outdoor Writers Association) and popular fishing blogs;
- Chambers of commerce;
- Visit Florida;
- Florida Department of Tourism;
- FDEP & FWC;
- Outdoor recreational magazines, both online and in print (e.g., *Florida Sportsman, Florida Scuba News*).

Once your contacts are organized, it's much easier to prepare mailing labels and email lists for regular correspondence.

12.2.2 Press Releases

A tool that will be used repeatedly in your publicity effort is the press release. Not only does it act as a "silent salesman" for your program, it can provide new content for your program's website, blogs, Facebook and Twitter streams, giving users access to instant information. Work with your respective agency communications office to develop and distribute your press release to increase chances of getting good, accurate coverage in the media. Make sure all your releases contain:

- Contact Information (Name, address, cell number and daytime number of key person to contact in case of questions, and event website typed at either top or bottom, but in a place easily seen);
- Date of Release (To show it's current) followed by the words "For Immediate Release."
- Short Headline (All capital letters, bold and/or underlined, centered at top, to quickly show what the release is about). It is helpful to add a subheadline, in italics, that elaborates on the headline.

Learn to be succinct when preparing your news release or news pitch. Briefly state the most pertinent details (who, what, when, where, and why) in the first paragraph. Less important information should follow in subsequent paragraphs (e.g., funding acknowledgments, listing any specific purpose for the reef, noting if a vessel was confiscated by the state), with each covering a single subject. Keep the length to one page, if possible, ending with the journalistic style convention of the centered pound symbols (###). If two pages are essential, the first page should end with "-MORE-" and the second with pound symbols. Repeat the contact's name, address, and telephone number on the second and all succeeding pages. Double-check and get someone else to check again, especially for errors in the text, addresses, or telephone numbers.

Press releases today are most often sent as email attachments, or in the body of the message. Photographs are optional, but if used, send high-resolution color color digital .jpgs as attachments with the news release. If underwater video (on DVD) is available, include that information in the press release with the contact information. It is very important that the video is clear, steady, and that the subject is obvious. Include an identification of the subjects in the images and a caption for each photo used. If the recipients do not acknowledge receipt of the content within one or two days, be sure to follow up the release with a subsequent phone call.

Press releases and photos are often re-posted on your organization's website, and adapted to a blog or Facebook page. Video can easily be uploaded to YouTube, and linked through the event's website.

12.2.3 Media Kits

Media kits are advisable when a single press release is not sufficient, and greater detail is preferred or required in additional release. Such a kit would include press releases with general information on the local artificial reef program, plus any project background materials. It is preferable, but not necessary, to put these materials in a folder with your program/agency logo and contact information. The content of the kit can be modified to fit multiple situations. For instance, if you are sinking a former military vessel, include a fact sheet with various statistics (length, beam, and height). Another sheet could provide the ship's service record of commissioning and decommissioning dates, battles fought, honors received, or local persons who may have served aboard the ship. Still other pages might provide a schedule of events; celebrities who might be present; and information about sponsors, particularly those making financial donations. You might also want to include invitations and press passes to various related functions, but this will probably require numerous follow-up telephone calls to verify who and how many will be attending. Be sure to repost this information to your website and social media outlets.

Timing can be crucial in getting out the word. Morning is typically the best time to send material for newspapers, late morning or early afternoon for television stations. These are some additional guidelines for delivering content to the media, but do your own checking, because each outlet has different needs. If possible, try getting an announcement in an "upcoming events" column so that people can plan ahead for the occasion.

- Weekly papers--Usually 2 -3 days before publication date;

- Sunday papers--Early Thursday for insert sections; otherwise, Saturday afternoon;
- Magazines--Up to three months before publication date;
- Television--Contact assignment editor early in the week of event;
- Radio--As appropriate for spot news. Otherwise, 10 days for calendar listing;
- State publications -- Up to four months before publication date.

Walker (1987) also offered this advice: "*Consider the lead time required, and work accordingly. Daily papers probably won't use your material more than two weeks in advance, and the same for weeklies. Broadcast media can't be expected to provide your publicity earlier than a week before, except for the outdoor-oriented shows. Even so, expect your publicity closer to the actual event. Some taped shows operate as far as five weeks in advance, so make certain you know your local deadlines.*"

12.2.4 Contingencies, On-Site Activities and Follow-Up Publicity

It is important to plan on contingencies with regard to the press. Bad weather or other unforeseen delays can change a long-scheduled event. If this happens, inform media contacts immediately of the revised schedule. They will appreciate the courtesy.

Also, be sure to thoroughly think through where and when you want the media to be present on the day of reef deployment. For example, should media meet at the dock before or after the deployment for staff interviews? Will the media have boat access to view the deployment? Program staff will have their hands full with completing the deployment, so make sure to dedicate one staff person to handling the media and any questions they have. This dedicated staff person should be sure to get contact information for all media present, and also be tasked with providing the media with any follow-up information that you may want to provide, such as underwater images or footage of the new deployment.

12.2.5 Tips for Media Relations

Good press relations and media coverage can help gain public support for reef projects. Both FWC and FDEP have Media Guides that are available through their respective communications offices. These guides offer a wealth of information on how to effectively handle various situations that might arise. Major topics are:

- Basic guidelines for positive media relations;
- Being prepared to go public;
- The release of information;
- The interview;
- Tips for TV;
- How to respond to a reporter's mistake;

- The press conference;
- Crisis management.

A close review and integration of the information from both agencies can help put both the reef developer and the project on sound footing with the media.

12.2.6 Creating a Turn-Over File

Developing a strong relationship with the media takes time. Turn-over is inevitable with both program staff and media staff. Therefore, it is very important that a media turn-over file is created and kept as up-to-date as possible and which contains, but is not limited to:

- Media contact information, including type/name of media, mailing address, as well as mobile and daytime phone numbers, and email address for each individual reporter/videographer;
- Dates and projects for which each media contact was invited to attend, or attended, an event;
- Preferred information type (e.g., text articles, videos) and what already has been sent by your program.

By having the turn-over file available, it easily can be transferred between staff tasked with handling the media. It also ensures that any relationships your program has built with the media are not lost due to any staff turn-over.

12.3 Information and Social Media Technologies

Evolving information technologies can easily become another great tool to increase local and regional awareness and education. Search engines (e.g., Google) can work for you by bringing users to your website, but once visitors are there, finding quality content is what will bring them back. Stakeholder engagement possibilities are limitless with this form of communication.

12.3.1 Using GIS Tools

The advancement of remote sensing and its incorporation into Geographic Information Systems (GIS) technology has given managers the ability to create accurate images of actual siting locations in relation to other points of interest (e.g., locations of other artificial reefs, natural reefs, fishing piers, mooring buoys). This information is essential in providing artificial reef users with the most accurate and up-to-date information possible. GIS, digital video and other information content can readily enhance your program's online presence.

12.3.2 Websites

Reef permit holders have an ongoing responsibility to furnish reliable, current information on artificial reef locations and status. How you present your program to the online community will speak volumes. Websites are usually low-cost, and are an increasingly popular, fast and accurate way to transmit information regarding artificial reefs. (See Figures 12.1, 12.2, 12.3, 12.4.) Some artificial reef programs have still to realize the full potential of this kind of information sharing.

If possible, work with your agency's communications program and piggyback on its resources to develop your website and social media outlets. The decision to create a website, open a Facebook page, or delve into other types of social media should be carefully considered within your agency's more comprehensive social technology plan (ClickZ.com). A program without a current and complete website, for example, could negatively affect the success of an artificial reef program. Moreover, while they provide remarkable opportunities to connect with your constituents, websites, Facebook pages, blogs, Twitter accounts, YouTube channels and the like require constant streams of fresh content, so a commitment to ongoing maintenance is a prerequisite. If visitors to your online presence see interesting content, they will likely spend more time at the site and recommend it to acquaintances.

In addition to the information adapted from the media kit and ongoing press releases, some things to consider including on your website are:

- A current (preferably interactive) list/map of all artificial reef descriptions including name, type of material, year placed, or depth and GPS locations;
- If possible, include GPS locations in a format that can easily be downloaded directly to GPS receivers;
- Daily/weekly weather and tide forecasts;
- Volunteer opportunities and recognition;
- Calendar of upcoming events;
- Quick links to other local or regional artificial reef programs, laws and regulations for the area (e.g., the Florida Coral Reef Protection Act);
- Frequently asked questions;
- Related research, monitoring, or technical reports;
- Most recent deployments;
- Ways to donate money or materials to the program (if applicable);
- Stakeholder feedback;
- Any special management zones that exist in the area;
- Photography contests;
- Permit information;
- A kid-friendly educational page (see Figure 12.4);
- A photo gallery full of color photos and videos!

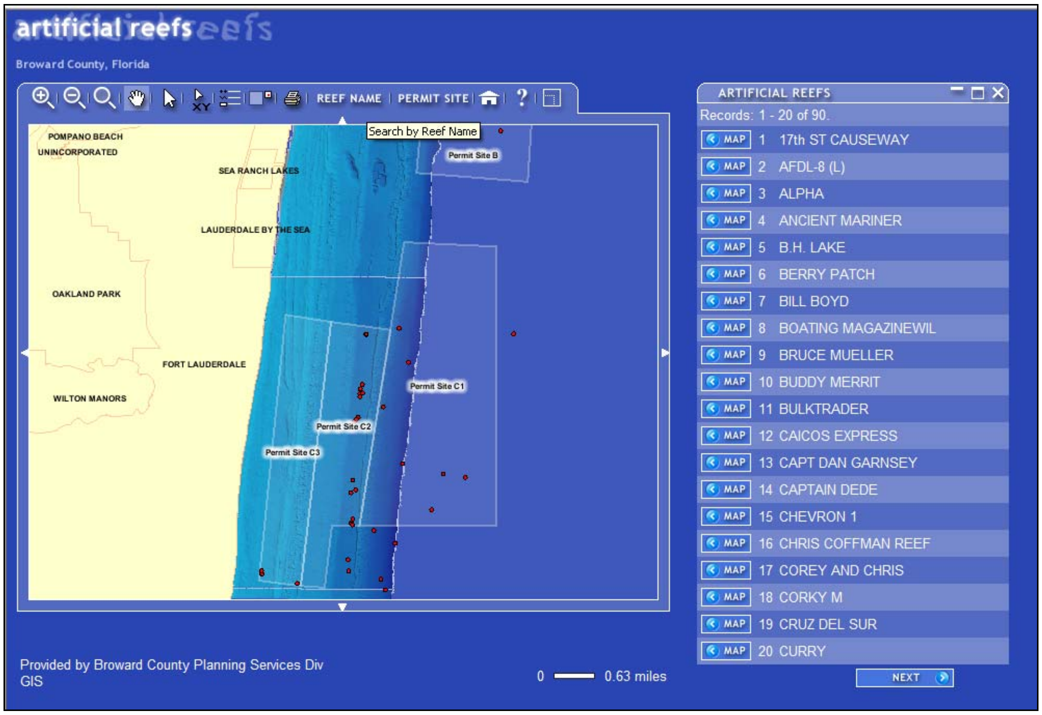

Figure 12.1. Broward County's Artificial Reef Finder Map uses GIS technology to create an interactive map of artificial reef sites in relation to other points of interest
(Source: www.broward.org/bio/reefs.htm).

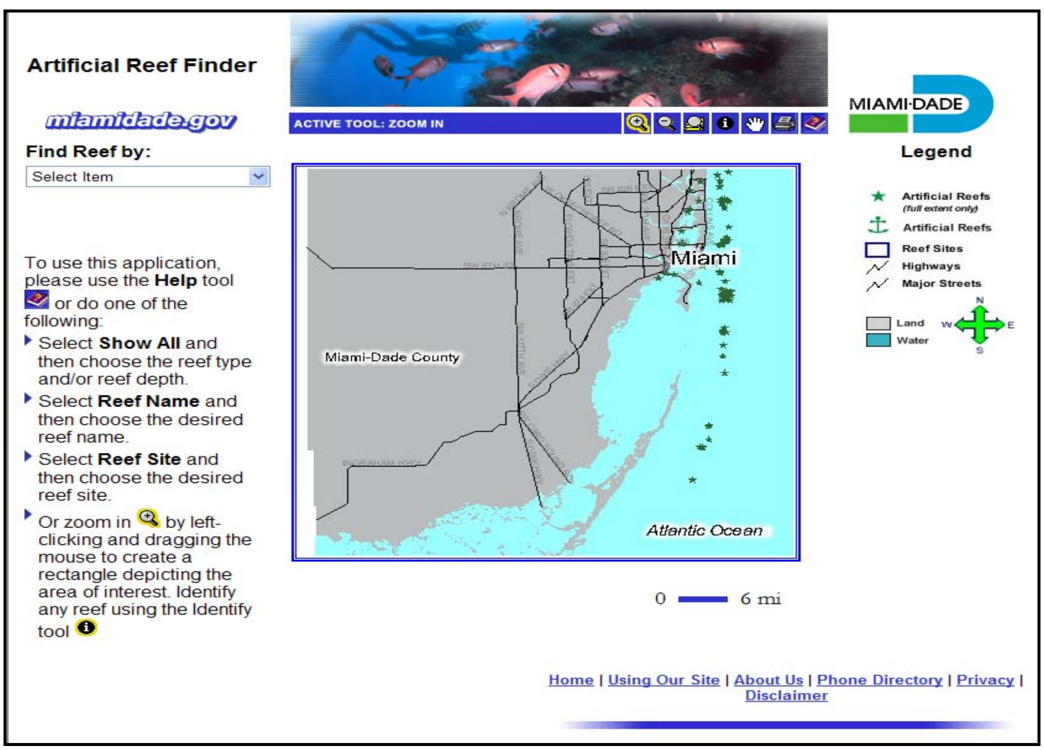

Figure 12.2. Miami-Dade County DERM's Artificial Reef Finder Interactive Map
(Source: http://gisims2.miamidade.gov/ArtyReef/Reefmap.asp?Cmd=INIT&Choice=1).

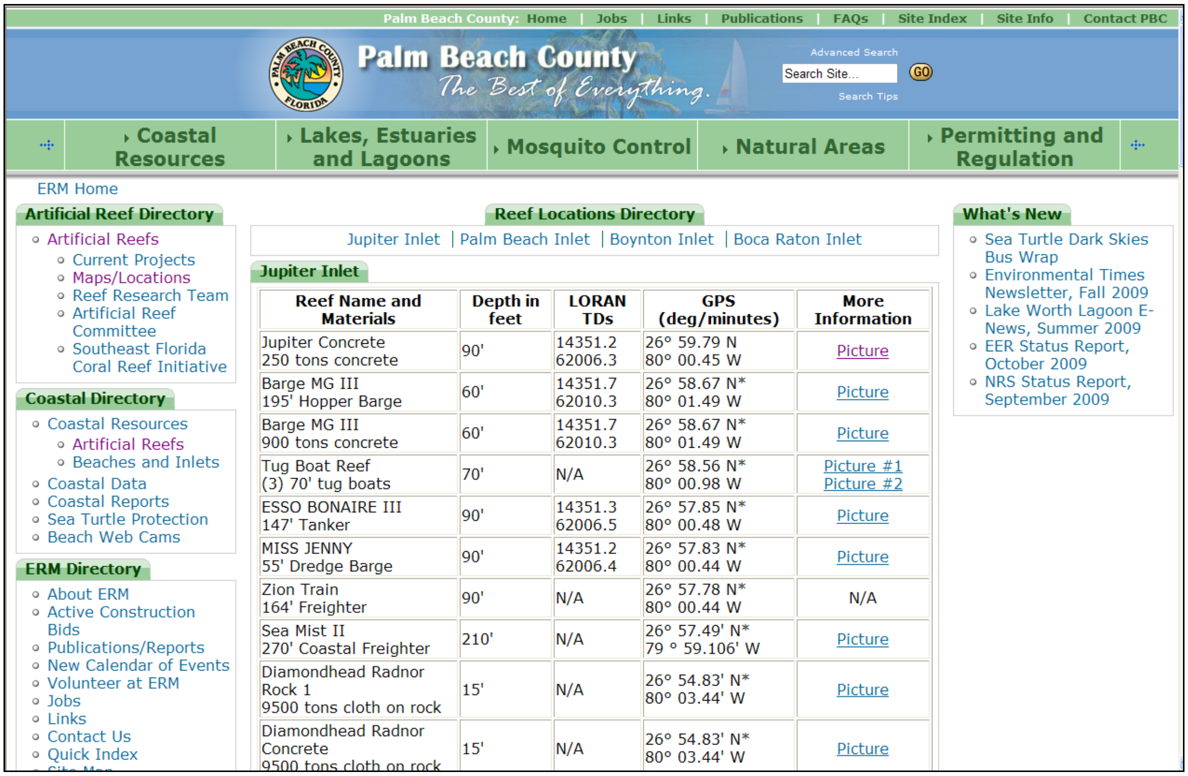

Figure 12.3. Palm Beach County's Artificial Reef Directory
(Source: http://www.pbcgov.com/erm/coastal/reef/locations/).

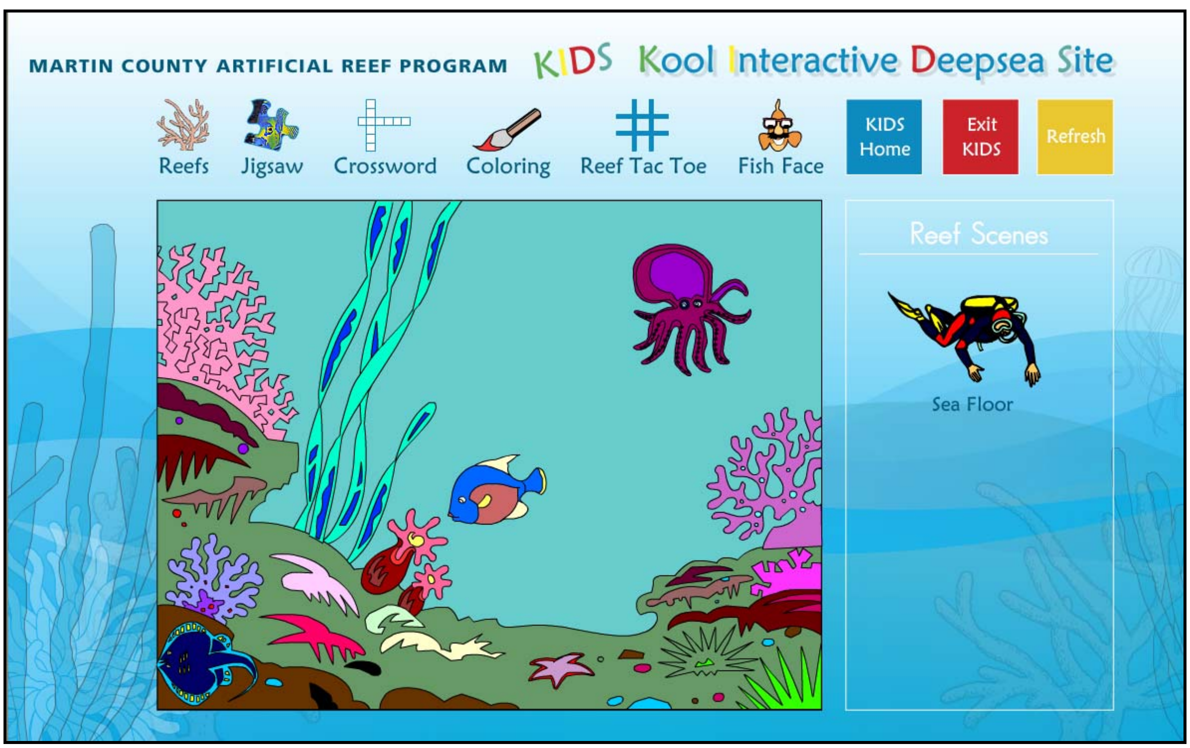

Figure 12.4. Martin County's "Kids Kool Interactive Deepsea Site"
(Source: http://www.martinreefs.com/pages/kids.html).

The following are examples of artificial reef program websites:

- Miami-Dade County: http://www.miamidade.gov/derm/reefs.asp
- Broward County: http://gis.broward.org/artificialreefs/
- Palm Beach County: http://www.co.palm-beach.fl.us/erm/coastal/reef/
- Martin County: http://www.martinreefs.com/
- FWC Artificial Reef Program: http://myfwc.com/Conservation/Conserv_Progs_Habitat_Saltwater_AR.htm

12.4 Brochures, Charts and User Guides

Budgets and available resources generally dictate how elaborate printed information can be. A simple brochure can be created using any current word processing software and reproduced on the office copier. In fact, this avenue may be preferable to an expensive, quickly out-of-date, full-color brochure. Plain or fancy, the main objective is to satisfy the public need for basic data on artificial reefs. Reef users mainly want to know: (1) nearest ocean access point; (2) reef site location; and (3) individual placement locations within a site.

A list of coordinates will do, but a brochure can be greatly enhanced with a chart showing site parameters, locations, latitude/longitude, and navigational bearings. A basic chart can show local access points and put a user in the general vicinity of a reef, but more explicit directions are needed to find individual placements. Budget permitting, a guide could provide fishing, diving, anchoring, safety tips and species identification guides. It is essential to include a disclaimer on charts stating, "This chart is not intended for navigational purposes," and to refer users to the appropriate nautical chart.

Public reef sponsors generally furnish simple reef guides at no cost to the reef user, but another approach is to develop an additional comprehensive marine recreational fishing and diving guide to sell, with proceeds going into a reef development fund or into a fund to defray printing costs. However, before investing in such an enterprise, it might be wise to do an informal market survey to determine local interest and to make sure the market does not already have access to other sportfishing maps and guides containing similar information. Besides being a potential moneymaker, a comprehensive publication can serve triple-duty as user guide, educational tool and method to assist fisheries management and conservation efforts

12.5 Newsletters and Blogs

Newsletters and their online equivalents, blogs, can be extremely effective in updating reef users on program activities and for staying attuned to reef user attitudes and needs relative to a program. This is a good interim method (between brochure revisions) for providing such information as new reef site or material drop locations or tips on diving or fishing on new reefs. It's also a good way to publicly recognize contributions to the project, such as volunteer help or donated materials. An email or hard copy mailing list can be compiled from rosters of local fishing and diving clubs, and those of outdoor writers' organizations. Instead of expending large amounts of valuable resources on expensive hard copy mail-outs, consider distributing newsletters in strategic locations such as checkout counters of fishing tackle shops, dive shops, marinas and other places the target audience is likely to patronize.

The local newspaper's editorial page still provides a lively forum for audience participation and feedback, so make sure to submit the occasional "Letter to the Editor." In your letters, solicit reef fishing and diving news from readers, because enthusiasm for a reef project can be highly contagious. Reader responses provide valuable insight into the success of a reef or possibly into problems that need resolving. Be sure to invite readers to visit your website, or submit inquiries about the reef program and requests to be put on a permanent emailing list for future newsletter editions. This list can be used for a variety of communications purposes.

12.6 Other Communications Methods

Reef coordinators can educate the public by speaking at meetings of local civic groups, schools, fishing and diving clubs, and environmental groups. Get in touch with a speakers bureau if there is a problem breaking into the speaking circuit. Participating in local television and radio talk shows is another good way to get free publicity while educating the public. A presentation augmented with clear underwater movies, videos or images of fishes and reef structures will leave a lasting impression with the audience.

Exhibits can also be effective educational tools and methods for getting audience feedback. Portable exhibits can be set up at fairs, fishing tournaments, boat shows, wildlife exhibitions or any function likely to draw a crowd. Again, underwater photography attracts attention. Handouts, in the form of newsletters, brochures, or special publications, such as reef species identification pamphlets, will also help take the message home. Manning a static display will provide the opportunity to answer questions about artificial reefs and be a sounding board for public opinion. This give-and-take exchange also can be made through more formal processes, such as through hearings and workshops or by means of formal reef advisory committees.

12.7 The Importance of Stewardship

Stewardship is defined as "*the conducting, supervising, or managing of something; especially: the careful and responsible management of something entrusted to one's care* <*stewardship of our natural resources*>" (Merriam-Webster 2010). While all of the previously discussed information deals with informing stakeholders how best to use artificial reef resources, teaching them about the importance of stewardship will provide them with a sense of ownership for the resource and encourage them to use the resources responsibly.

12.7.1 Code of Ethics

NOAA NMFS adopted an Angler's Code of Ethics, which encourages anglers to:

- Promote, through education and practice, ethical behavior in the use of aquatic resources;
- Value and respect the aquatic environment and all living things in it;
- Avoid spilling and never dump any pollutants, such as gasoline and oil, into the aquatic environment;
- Dispose of all trash, including worn lines, leaders and hooks, in appropriate containers, and help keep fishing sites litter-free;
- Take all precautionary measures necessary to prevent the spread of exotic plants and animals, including live baitfish, into non-native habitats;
- Learn and obey angling and boating regulations, and treat other anglers, boaters and property owners with courtesy and respect;
- Respect property rights, and never trespass on private lands or waters;
- Keep no more fish than needed for consumption, and never wastefully discard fish that are retained;
- Practice conservation by carefully handling and releasing alive all fish that are unwanted or prohibited by regulation, as well as other animals that may become hooked or entangled accidentally;
- Use tackle and techniques that minimize harm to fish when engaging in "catch and release" angling.

This code of ethics could easily be modified for each different type of user group. Information of this type should be included in as much of your program’s education and outreach as possible.

12.7.2 Promote Environmentally Sound Artificial Reef Construction

Another way of promoting good stewardship is to inform the artificial reef users and stakeholders of ways that your program is helping to promote environmentally responsible artificial reef construction. Southeast Florida natural reef resources are especially sensitive, and by following the guidelines and practices in this document your program is directly helping to protect and sustain them. Additional materials are identified in the other chapters of this publication.

12.7.3 Diving Guidelines and Use Standards

The following are links to various websites that provide general information regarding diving guidelines and standards that can be integrated or modified for use in your program's education and outreach materials:

- **PADI Project Aware – Tips for Divers**
  http://www.projectaware.org/content/index.php?pid=76
- **FWC - Oriskany Reef Dive Safety Considerations**
  http://myfwc.com/CONSERVATION/Conserv_Progs_Habitat_Saltwater_AR_OR.htm
- **Florida Sea Grant – Catch-and-Release: Things you can do to help saltwater fish survive**
  http://catchandrelease.org/

References

Adams, C., W. Lindberg and J. Stevely. 2006. The economic benefits associated with Florida's artificial reefs. EDIS Document FE649, Food and Resource Economics Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 6 pp. Available on the website: http://edis.ifas.ufl.edu.

Ambrose, R.F. 1994. Mitigating the effects of a coastal power plant on a kelp forest community: Rationale and requirements for an artificial reef. Bulletin of Marine Science 55: 694-708.

American Fisheries Society. 1997. Fisheries: Special issue on artificial reef management. Volume 22. Bethesda, Maryland. 62 pp.

Arena, P.T., L.K.B. Jordan and R.E. Spieler. 2007. Fish assemblages on sunken vessels and natural reefs in southeast Florida, USA. Hydrobiologia 580: 157-171.

Berkes, Fikret. 2004. Rethinking Community-Based Conservation. Conservation Biology 18(3): 621-630.

Berkes, F. G. Kofinas, and F.S. Chapin. 2009. Conservation, community, and livelihoods: Sustaining renewing, and adapting cultural connections to the land. In: F.S. Chapin, G. Kofinas, and C. Folke, eds. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer Science + Business Media, New York. 129-147 pp.

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? Bulletin of Marine Science 44(2): 631-645.

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report NMFS 41: 1-15.

Bortone, S.A., F.P. Brandini, G. Fabi and S. Otake (eds.). 2011. Artificial Reefs in Fisheries Management. CRC Press, Boca Raton, Florida. 350 pp.

Bustard, H.R. and G. Greenham. 1969. Nesting behavior of the green sea turtle on a Great Barrier Reef Island. Herpetologica 25: 93-102.

Caddy, J. 2007. Marine Habitat and Cover: Their importance for productive coastal fishery resources. UNESCO Publishing, Paris, France. 253 pp.

Cairns, S. 2000. A revision of the shallow-water azooxanthellate Scleractinia of the Western Atlantic. Studies of the Natural History of the Caribbean 75: 1–240.

Cerulean, S. 2008. Wildlife 2060: What's at stake for Florida? Report by the Florida Fish and Wildlife Conservation Commission. Tallahassee. 28 pp.
Available on the website: http://myfwc.com/Conservation/FWC2060_index.htm

ClickZ: Marketing News & Expert Advice. 2011. Incisive Interactive Marketing LLC. New York, New York. http://www.clickz.com/

Collier, C., R. Dodge, D. Gilliam, K. Gracie, L. Gregg, W. Jaap, M. Mastry and N. Poulos. 2007. Rapid response and restoration for coral reef injuries in southeast Florida: Guidelines and recommendations. Southeast Florida Coral Reef Initiative. 57 pp. Available on the website:
http://www.dep.state.fl.us/coastal/programs/coral/reports/MICCI/MICCI_Project2_Guidelines.pdf

Cook, C.B., R.E. Dodge and S.R. Smith. 1996. Fifty years of impacts on coral reefs in Bermuda. Biological Conservation 76(2): 214-215.

Cowan Jr., J.H., W. Ingram, J. McCawley, B. Sauls, A. Strelcheck and M. Woods. 1999. The attraction vs. production debate: Does it really matter from the management perspective? A response to the commentary by Shipp. Gulf of Mexico Science 17: 137–138.

Cowan Jr., J.H., C.B. Grimes, W.F. Patterson III, C.J. Walters, A.C. Jones, W.J. Lindberg, D.J. Sheehy, W.E. Pine III, J.E. Powers, M.D. Campbell, K.C. Lindeman, S.L. Diamond, R. Hillborn, H.T. Gibson and K.A. Rose. 2010. Red snapper management in the Gulf of Mexico: Science- or faith-based? Reviews in Fish Biology and Fisheries (online). 18 pp. Available on the website:
http://www.springerlink.com/content/8838622k166g7g43

CSA International, Inc. 2009. Ecological functions of nearshore hardbottom habitat in east Florida: A literature synthesis. Prepared for the Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, Tallahassee, FL. 186 pp + apps.

Delaney, J.P. and K. Mille. 2006. Analysis of Florida's permitted artificial reef areas, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 14 pp.

Dethier, V.G. and E. Stellar. 1961. Animal Behavior: Its evolutionary and neurological basis. Prentice–Hall, Inc., Englewood Cliffs, NJ. 118 pp.

Dodge, R.E. and K. Kohler. 2004. Visual HEA: Habitat equivalency software to facilitate calculation of compensatory restoration following natural resource injuries. National Coral Reef Institute, Nova Southeastern University Oceanographic Center. 7 pp.

Dunford, R.W., T.C. Ginn and W.H. Desvousges. 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics 48: 49-70.

Eklund, A.M. 1996. Habitat complexity and recruitment to artificial reefs off southeast Florida. Miami Laboratory Contribution No. MIA-93/94-25, National Marine Fisheries Service, Miami, Florida. 6 pp.

Fenner, D. and K. Banks. 2004. Orange cup coral *Tubastraea coccinea* invades Florida and the Flower Garden Banks, Northwestern Gulf of Mexico. Coral Reefs 23: 505–507.

FWC. 2003. State of Florida artificial reef strategic plan. Florida Fish and Wildlife Conservation Commission. 16 pp. Available on the website: http://myfwc.com/media/131588/FLARStrategicPlan2.pdf

Gilmore Jr., G.R. 2006. Automated Monitoring: Artificial reef project. Grant No. 04031, Florida Fish and Wildlife Conservation Commission. 68 pp.

Graf, G. 1992. Benthic-pelagic coupling: A benthic view. Oceanography and Marine Biology Annual Review 30: 149-190.

Habeeb, R.L., C.R. Johnson, S. Wotherspoon and P.J. Mumby. 2007. Optimal scales to observe habitat dynamics: A coral reef example. Ecological Applications 17: 641-647.

Halusky, J. 1991. Artificial reef research diver's handbook. Florida Sea Grant Technical Paper TP-63. Gainesville, Florida. 198 pp.

Hixon, M.A. and J.P. Beets. 1993. Predation, prey refuges, and the structure of coral-reef fish assemblages. Ecological Monographs 63(1): 77-101.

Hixon, M.A. and M.H. Carr. 1997. Synergistic predation, density dependence, and population regulation in marine fish. Science 277: 946-949.

Johns, G.M., J.W. Milon and D. Sayers. 2004. Socioeconomic study of reefs in Martin County, Florida. Final Report, Prepared by Hazen and Sawyer for Martin County, Florida. 120 pp.

Johns, G.M., V.R. Leeworthy, F.W. Bell and M.A. Bonn 2001. Socioeconomic study of reefs in southeast Florida: Final report. Hazen and Sawyer, Florida State University and National Oceanographic and Atmospheric Administration. Available on the website: http://broward.org/bio/socioeconomic.htm

Johnson, D.R., D.E Harper, T.G. Kellison and J.A. Bohnsack. 2007. Description and discussion of southeast Florida fishery landings, 1990-2000. NOAA Technical Memorandum NMFS-SEFSC-550. 64 pp.

King, D.M. 1997. Comparing ecosystem services and values: With illustrations for performing habitat equivalency analysis. Paper #1 prepared for the NOAA Damage Assessment and Restoration Program, Silver Spring, MD. 34 pp.

Leeworthy, V.R., T. Maher and E.A. Stone. 2006. Can artificial reefs alter user pressure on adjacent natural reefs? Bulletin of Marine Science 78(1): 29-37.

Lin, Paul and Associates. 2000. Artificial reef stability analysis software for the Florida Fish and Wildlife Conservation Commission and Lee County Department of Environmental Services Natural Resources Division. 14 pp.

Lindberg, W.J. 1997. Can science resolve the attraction-production issue? Fisheries 22: 10–13.

Lindberg, W.J. and G. Relini. 2000. Integrating evaluation into reef project planning. In: W. Seaman, Jr., editor. Artificial Reef Evaluation: With application to natural marine habitats. CRC Press, Boca Raton, Florida, USA. Pp. 195–235.

Lindberg, W.J., T.K. Frazer, K.M. Portier, F. Vose, J. Loftin, D.J. Murie, D.M. Mason, B. Nagy and M.K. Hart. 2006. Density-dependent habitat selection and performance by a large mobile reef fish. Ecological Applications 16(2): 731-746.

Lindeman, K. and D. Snyder. 1999. Nearshore hardbottom fishes of southeast Florida and the effects of habitat burial caused by dredging. Fishery Bulletin 97: 508-525.

Lukens, R.R. and Selberg, C. 2004. Guidelines for marine artificial reef materials, second edition: A joint publication of the Gulf and Atlantic States Marine Fisheries Commissions. Report Number 121, Gulf and Atlantic States Marine Fisheries Commissions, Ocean Springs, Miss. and Washington, D.C. 198 pp. Available on the website: http://www.gsmfc.org/pubs/SFRP/Guidelines_for_Marine_Artificial_Reef_Materials_January_2004.pdf

McClanahan, T.R. and G.M. Branch (editors). 2008. Food webs and the dynamics of marine reefs. Oxford University Press, New York. 238 pp.

Mata, C., K. Mille and C. Scott. 2010. Digitizing the Florida Artificial Reef Program reference library using EndNote X2. 2010 Florida Artificial Reef Summit Abstracts and Program. January 21-23, 2010. Cocoa Beach, FL. 38 pp.

Merriam-Webster Online Dictionary. 2010. Merriam-Webster Online. Available on the website: http://www.merriam-webster.com/dictionary

Meylan, A. 1978. The behavioral ecology of the West Caribbean green turtle (*Chelonia mydas*) in the internesting habitat. M.S. Thesis, University of Florida. 132 pp.

Miami-Dade DERM. 2001. Artificial Reef Stability Program, Version 1.0 Documentation. July 2001. Miami-Dade County Department of Environmental Resources Management. Miami, FL. 9 pp.

Miller, M.W. and A. Falace. 2000. Evaluation methods for trophic resource factors – nutrients, primary production, and associated assemblages. In: W. Seaman, ed. Artificial Reef Evaluation. CRC Press, New York. Pp. 95-126.

Milon, J.W. and R.E. Dodge 2001. Applying habitat equivalency analysis for coral reef damage assessment and restoration. Bulletin of Marine Science 69: 975-988.

Moore, C.J. 1984. User information needs and the role of information in fisheries development and management. In: R.H. Stroud (ed.), Proceedings, 9th Ann. Mar. Rec. Fish. Symp. Mar. Rec. Fish. 9: 85 -104.

Moyer, R.P., B. Riegl, K. Banks and R.E. Dodge. 2005. Assessing the accuracy of acoustic seabed classification for mapping coral reef environments in South Florida (Broward County, USA). Revista de Biología Tropical / International Journal of Tropical Biology and Conservation. 53 (Suppl. 1): 175-184.

Mumby, P.J. 2006. Connectivity of reef fish between mangroves and coral reefs: Algorithms for the design of marine reserves at seascape scales. Biological Conservation 128: 215–222.

Mumby, P.J. and A. Hastings. 2008. The impact of ecosystem connectivity on coral reef resilience. Journal of Applied Ecology 45: 854-862.

Murray, J.D. 1989. A policy and management assessment of southeast and mid-Atlantic artificial reef programs. UNC Sea Grant College Program, North Carolina State University, Raleigh, North Carolina. 40 pp.

Nakamura, M. 1985. Evaluation of artificial fishing reefs in Japan. Bulletin of Marine Science 37: 271-278.

National Oceanic and Atmospheric Administration (NOAA). 1995. Habitat equivalency analysis: An overview. Internal document of the Damage Assessment and Restoration Program, NOAA, Department of Commerce (Revised October 4, 2000 and May 23, 2006). 24 pp.

NOAA. 2007. National Artificial Reef Plan (as Amended): Guidelines for siting, construction, development, and assessment of artificial reefs. United States Department of Commerce, Silver Spring, Maryland. 54 pp. Available on the website: http://www.nmfs.noaa.gov/sfa/PartnershipsCommunications/NARPwCover3.pdf

Palm Beach County Artificial Reefs 2010. Available on the website: http://www.pbcgov.com/erm/coastal/reef/

PBS&J. 2008. Best management practices (BMPs) for construction, dredge and fill and other activities adjacent to coral reefs. Southeast Florida Coral Reef Initiative, Maritime Industry and Coastal Construction Impacts Focus Team, Local Action Strategy Project # 6. 120 pp. Available on the website: http://www.dep.state.fl.us/coastal/programs/coral/reports/

Pandolfi, J., D. Robertson and D. Kirtley. 1998. Roles for worms in reef-building. Coral Reefs 17: 120.

Parrish, J.D. 1989. Fish communities of interacting shallow-water habitats in tropical oceanographic regions. Marine Ecology Progress Series 58: 143-160.

Pearson, R.G. 1984. Recovery and recolonization of coral reefs. Marine Ecology Progress Series 4: 105-122.

Pinkerton, E. 2009. Coastal marine systems: Conserving fish and sustaining community livelihoods with co-management. In: F.S. Chapin, G. Kofinas, and C. Folke, eds. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer Science + Business Media, New York. Pp. 241-257.

Potts, J.C. and C.S. Manooch II. 2001. Differences in the age and growth of the white grunt (*Haemulon plumieri*) from North Carolina and South Carolina compared with southeast Florida. Bulletin of Marine Science 68: 1-12.

The Public Relations Handbook for Nonprofits: A Comprehensive and Practical Guide. Art Feinglass. 2005. Jossey-Bass: San Francisco, CA

Pybas, D.W. 1997. Atlas of artificial reefs in Florida. Florida Sea Grant College Program, University of Florida, Gainesville, FL. SG-1. 59 pp.

Riegl, B. and S.J. Purkis. 2005. Detection of shallow subtidal corals from IKONOS satellite and QTC View (50, 200 kHz) single-beam sonar data (Arabian Gulf; Dubai, UAE). Remote Sensing of Environment 95: 96-114.

Rogers, C.S., G. Garrison, R. Grober, Z. Hillis and M.A. Franke. 1994 (English) and 2001 (Spanish). Manual for coral reef monitoring in the Caribbean and Western Atlantic. U.S. National Park Service, Southeast Region. 114 pp.
Available on the website: http://fl.biology.usgs.gov/Monitoring_Manual.pdf

Sammarco, P.W., A.D. Atchison and G.S. Boland. 2004. Expansion of coral communities within the Northern Gulf of Mexico via offshore oil and gas platforms. Marine Ecology Progress Series 280: 129–143.

Seaman, W. 2004. Artificial reef monitoring in Florida coastal counties. Florida Sea Grant, SGEB-58. 16 pp.

Seaman, W. (editor). 2000. Artificial Reef Evaluation: With application to natural marine habitats. CRC Press, Boca Raton, Florida. 246 pp.

Seaman, W. and A.C. Jensen. 2000. Purposes and practices of artificial reef evaluation. In W. Seaman, Jr., editor. Artificial Reef Evaluation: With application to natural marine habitats. CRC Press, Boca Raton, Florida. Pp. 1–19.

Shearer, T. 2010. Distribution of *Tubastraea coccinea* in Florida and Flower Garden Banks: Progress Report. Georgia Institute of Technology, Atlanta, GA. 14 pp.

Sherman, R.L., D.S. Gilliam and R.E. Spieler. 2002. Artificial reef design: Void space, complexity, and attractants. ICES Journal of Marine Science 59: 1-5.

Shipp, R.L. 1999. The artificial reef debate. Gulf of Mexico Science 1999(1): 51-55.

Shipp, R.L. and S.A. Bortone. 2009. A perspective of the importance of artificial habitat on the management of red snapper in the Gulf of Mexico. Reviews in Fisheries Science 17(1): 41-47.

South Atlantic Fishery Management Council (SAFMC). 1998. Final Habitat Plan for the South Atlantic Region: Essential fish habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. Charleston, SC. 408 pp.

Spieler, R.E. 1998. Recruitment of juvenile reef fish to inshore and offshore artificial reefs: Final report. Oceanographic Center, Nova Southeastern University, Dania, Florida. 94 pp.

Stallings, C.D. 2009. Fishery-independent data reveal negative effect of human population density on Caribbean predatory fish communities. PloS ONE 4(5): e5333. Available on the website:
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0005333

Stone, R.B. 1985. National Artificial Reef Plan. NOAA Technical Memorandum NMFS OF-6. National Marine Fisheries Service, Washington, D.C. 83 pp.

Sverdrup, H.U., M.W. Johnson and R.H. Fleming. 1961. The Oceans, Their Physics, Chemistry, and General Biology. Prentice–Hall, Inc., Englewood Cliffs, NJ. 1060 pp.

Thanner, S.E., T.L. McIntosh and S.M. Blair. 2006. Development of benthic and fish assemblages on artificial reef materials compared to adjacent natural reef assemblages in Miami-Dade County, Florida. Bulletin of Marine Science 78(1): 57-70.

Thur, S.M. 2007. Refining the use of habitat equivalency analysis. Environmental Management 40: 161-170.

U.S. Environmental Protection Agency (USEPA) and U.S. Maritime Administration. 2006. National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs. Washington, D.C. 76 pp.
Available on the website:
http://www.epa.gov/owow/oceans/habitat/artificialreefs/finalguidance.html

U.S. Fish and Wildlife Service (USFWS). 2004. Investigations of Mitigation for Coral Reef Impacts in the U.S. Atlantic: South Florida and the Caribbean. 97 pp. Available on the website: www.southeast.fws.gov/es

USFWS. 2007. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. 164 pp.

Walker, M. 1987**.** How to promote a fishing tournament from Yamaha Outboards. Walker Agency, Scottsdale, AZ. 14pp.

Walker, B.K., B. Henderson and R. Spieler. 2002. Fish assemblages associated with artificial reefs of concrete aggregates or quarry stone offshore Miami Beach, Florida, USA. Aquatic Living Resources 15: 95-105.

Walter, C.J. and Juanes, F. 1993. Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taking by juvenile fishes. Canadian Journal of Fisheries and Aquatic Sciences 50: 2058–2070.

Werner, E.E. and J.F. Gilliam. 1984, The ontogenetic niche and species interactions in size-structured populations. Annual Review of Ecology and Systematics 15: 393-425.