Oyster Reef Restoration in North Carolina: Recommendations for Improvements in Techniques and Monitoring

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Abstract

The Eastern oyster (*Crassostrea virginica*) is important to the North Carolina economy, ecology, and way of life. Oysters provide many direct and indirect services that benefit coastal fisheries and North Carolina's economy. In the past 10 to 15 years oyster reef restoration efforts have increased in the state. Many stakeholders such as the North Carolina Coastal Federation, North Carolina Division of Marine Fisheries, and state universities have collaborated to create and enhance oyster reefs throughout the state. These stakeholders each have their own methods for monitoring restoration sites that they constructed. In the past decade there were metrics of success created by the Oyster Restoration Workgroup to monitor newly restored reefs. There have also been many different types of alternative substrates developed for oyster recruitment in an effort to make up for a decrease oyster shell supply.

It is recommended that stakeholders involved with oyster reef restoration in North Carolina continue to collaborate. Recommendations are presented to these stakeholders focused on long-term monitoring goals and standardized monitoring metrics, agreement on priorities for new projects, alternative substrates, and increased use of volunteers. These recommendations serve to improve methods for creating or enhancing future oyster restoration projects in North Carolina.

Introduction

The Eastern oyster (*Crassostrea virginica*) is important to the North Carolina economy, ecology, and way of life. Oysters provide many direct and indirect services that benefit coastal fisheries and North Carolina's economy. The reefs formed by the oysters serve as vital habitat, providing food, refuge, and nursery areas for many recreational and commercial fish and shellfish. The combined revenue generated every year by both commercial and recreational fisheries targeting fish using oyster reefs in the state is about $1.67 billion (NCDMF 2010). The filtering capacity and reef structure of oysters help improve water quality, increase the productivity of estuaries, and stabilize estuarine shorelines.

The main issue with the population of oysters in North Carolina and throughout the country is that they have declined since the late 1800's (NCDMF 2001). In the past, oyster reefs in Pamlico Sound were so extensive that they were described as navigation hazards. Historical harvest pressure, oyster diseases and toxic algal blooms and water quality impairments have led to the decline of oysters (NCDMF 2001).

In the past 15 years there has been an increased effort to restore and create oyster reefs throughout the state. An ambitious restoration strategy to rebuild oyster stocks to self-sustaining levels is being carried out as a collaborative effort between federal and state government agencies, non-profit organizations, universities, fishermen, and citizens.

The objective of this paper is to summarize the recent efforts to restore oyster reefs in North Carolina. Considerations for the use of alternative materials for substrate and new monitoring techniques are analyzed. Based upon the analysis recommendations are made for the improvement of in-the-water oyster reef restoration and creation in the state.

Ecological Importance

The first major ecosystem service that oysters provide is a water quality improvement. Oysters have a high filtering capacity. An individual oyster can filter between 40 and 50 gallons of water every day (NCCF 2011). By removing phytoplankton, sediments, and other particulates in the water, oysters improve water quality. The improved clarity benefits submerged aquatic vegetation growing nearby by increasing light availability to the plants (Wilgis 2011).

The second ecosystem service oysters provide is increased habitat for several species of fish and invertebrates. Oyster reefs aid in providing habitat for both young and adult fish that are both commercially and recreationally important. They are a vital part of the life cycle of many types of fish and shellfish. Some of these species associated with oyster reefs are transient and others are residents. Transient species include red drum, bluefish, striped bass, sting rays, and black sea bass. Resident species include several types of crabs including the blue crab, oyster toadfish, shrimp, and several types of mussels. Oyster reefs also provide habitat for several juvenile fish and invertebrate species. Species such as oyster toadfish, gobies, and blennies attach their eggs to oyster reefs and need the reef structure to aid them in their reproductive success (Coen et. al 2004).

A third service that oysters provide is shoreline stabilization. Oyster reefs absorb wave energy from either wind or boat wakes, preventing the erosion of shorelines. Stabilization allows for the colonization of and persistence of salt marsh habitat surrounding the reef (Coen et. al 2004).

Economic Importance

Oyster reefs aid in providing habitat for both young and adult fish that are both commercially and recreationally important. They are a necessary part of the life cycle of many species of fish and shellfish. The commercial fishery in North Carolina for oysters was worth about $2 million in 2008. The commercial fishery for all species using oyster reefs at any stage in their life history was worth $70.7 million in 2010 with about 65.3 million pounds of seafood caught (NCDMF 2010).

Recreational marine fisheries are a large part of North Carolina's economy, contributing even more to the state than commercial fisheries. In 2009 there were 6.8 million pounds of fish caught recreationally that use reefs for habitat. There were 482,000 pounds of fish caught with recreational/commercial licenses as well. The NCDMF estimates that recreational fishing was worth $1.6 billion in 2008 (NCDMF 2010).

The Problem

The main problem, as stated previously, related to oysters in North Carolina has been a decimation of their population in the last 100 to 150 years. Harvest rates in bushels of oysters per year have decreased by 90% of what they were historically. The Eastern oyster is listed as a species of concern by the North Carolina Division of Marine Fisheries (NCDMF 2001).

Recovery from the large decline in populations is hindered by the life history traits of oysters. Oysters are bivalve shellfish that are sessile for most of their lives. One of the most important aspects of their biology is the fact that they live in clusters to form reefs. They spawn from late spring to early fall. The larvae are planktonic and after approximately 3 weeks they settle and attach to hard surfaces. They prefer to attach to existing oyster reefs because of chemical cues from oysters. Oysters take about three years to attain the minimum harvest size of 3 inches. They can live up to 40 years, but most of them never live this long due to predators, diseases, and the many anthropogenic pressures on them. Oyster reefs can either be intertidal along tidal creeks in shallow water or subtidal in deep water (Kennedy et. al 1996).

Oysters are easily harvested for commercial and recreational purposes. Overharvesting occurred in North Carolina until 1997 when more stringent regulations were established to conserve the resource from the North Carolina Fisheries Reform Act (NCDMF 2001). The oyster fishery in North Carolina is a classic case of the "tragedy of the commons". A tragedy of the commons is when people act independently for their own self-interest to deplete a shared and limited resource. Oysters, like most fisheries, are a common pool resource making it difficult to control individuals using the resource. In addition, oysters are highly subtractable, meaning that the use of them decreases the future use by other fishers (Ostrom 2005).

Diseases such as DERMO and MSX, which are parasites, also led to the huge decline in oysters in North Carolina. DERMO outbreaks happen during droughts when the parasites thrive due to high temperatures and high salinities. MSX infections began in the Eastern oyster when the Japanese oyster (*Crassostrea gigas*) was introduced in the east coast of the United States as an experiment to boost the oyster fishery in the 1950s (NCDMF 2001).

Predators such as oyster drills and boring sponges have also become more prevalent because they prefer higher salinity areas. Reefs made with marl (limestone rock from quarries), which are put in these high salinity areas further attract these predators. The oyster populations on these restored reefs constructed with marl that are in high salinity areas have therefore seen a decrease in the past 5 to 10 years (Hardy 2011).

Another factor that has further damaged the Eastern oyster population in the state has been the impacts of stormwater runoff and coastal development. The fact that oysters are sessile puts them at a disadvantage. Stormwater runoff causes erosion, sedimentation, eutrophication, and increased freshwater flows. All of these combine to kill oyster reefs by depleting oxygen and increasing sediment on top of reefs (Wilgis 2011).

Current Oyster Restoration Materials Used in North Carolina

There are many different types of oyster restoration methods that have been implemented in North Carolina. There is a set of specific criteria for the selection of sites to be restored. The criteria include suitable sediment, presence of a current for larval dispersal, salinity patterns, historical productivity in the area, and existing oyster concentrations in the area. Project sites are identified through the regional workgroups with input from the public. Researchers and managers from local universities, non-profit organizations, and the North Carolina Division of Marine Fisheries (NCDMF) provide design, management and monitoring strategies for the reef restoration projects. The materials that are used in restoration in North Carolina include marl, purchased from regional quarries and dead oyster shell purchased from commercial shucking houses. These materials have been found to be the best for the larval oysters, or spat, to attach to, grow, and form new reefs (Wilgis 2011).

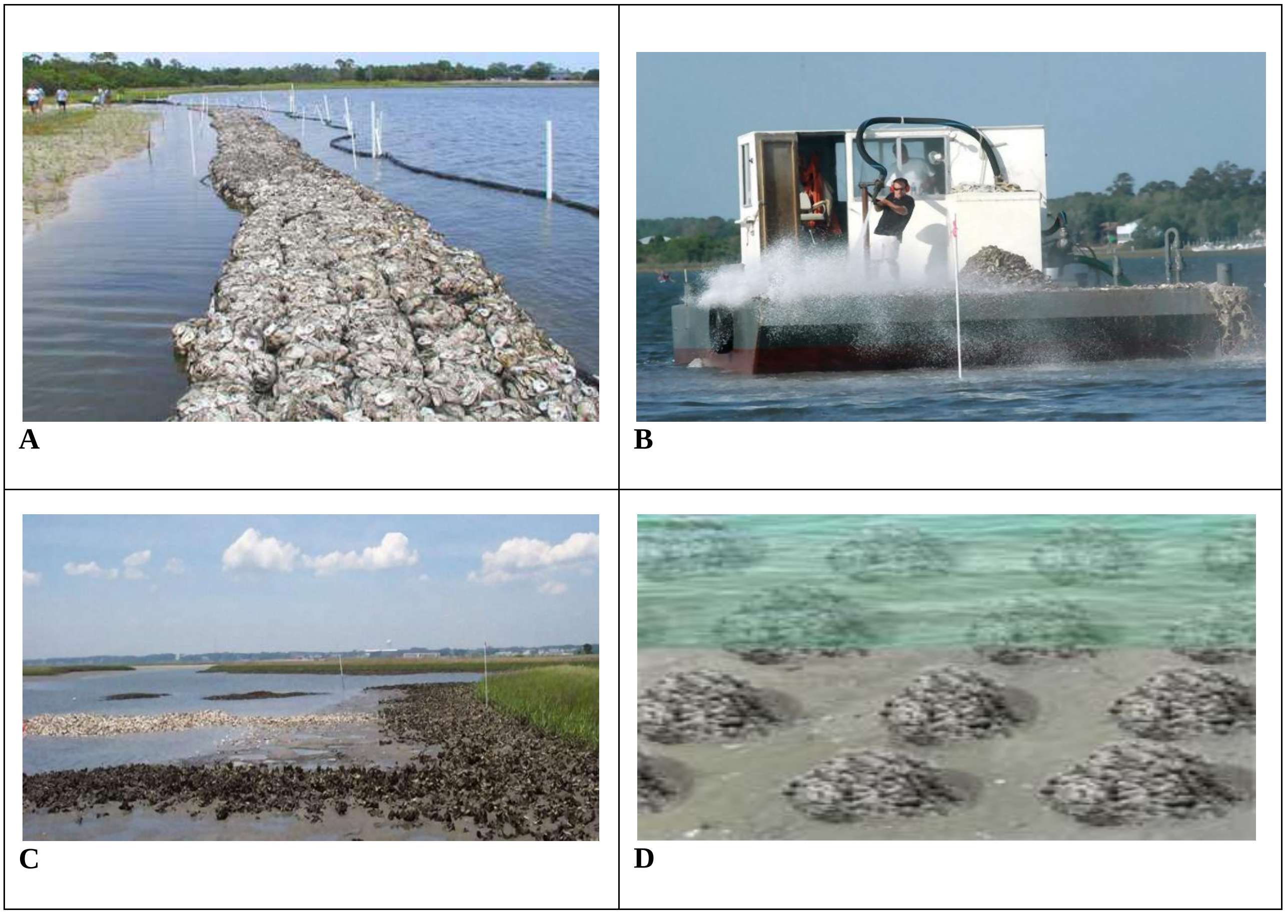

Figure 1 A. Shoreline stabilization restoration project. B. Barge aiding in restoration, spraying dead oyster shell (cultch) to shoreline or subtidally. C. Intertidal reef restoration project. D. Subtidal marl mounds. *Images A,B,C are courtesy of the North Carolina Coastal Federation (NCCF 2010) and D is courtesy of the North Carolina Division of Marine Fisheries (NCDMF 2011).*

In intertidal or shallow areas, the reef materials are deployed into patches and mounds in the estuarine waters and along shorelines. As part of a living shoreline project, the reef materials are bagged and stacked to form a protective reef along the shoreline. In addition, the shell and marl can be deployed with shallow draft barges into mounds and interconnected patch reefs. In deeper subtidal waters the marl or shell (Figure 1) is transported by large barges and vessels and is placed by heavy equipment into 6 foot high mounds (Wilgis 2011).

Methods

The goal of this project is to make recommendations about monitoring and restoration techniques for oyster reef restoration project in North Carolina. The data and information reported here were obtained by literature searches using the resources of the North Carolina Division of Marine Fisheries, Oyster Restoration Workgroup, and the North Carolina Coastal Federation. Researchers and managers involved in oyster restoration and management from the North Carolina Division of Marine Fisheries (NCDMF), N.C. State University (NCSU), University of North Carolina – Chapel Hill (UNC), North Carolina Coastal Federation (NCCF), and the South Carolina Department of Natural Resources were consulted. This information was analyzed and used to make recommendations for improving oyster restoration techniques and monitoring for North Carolina.

Regional Differences of Oyster Reefs and Restoration in North Carolina

In North Carolina, oyster restoration sites are different in both the northern and southern regions due to the shape of the shoreline. This region is characterized by large areas of open water in the Pamlico Sound, the lower Neuse River, and lower Pamlico River. The region was once dominated by extensive oyster reefs. Currently, the NCDMF has 10 oyster sanctuary sites totaling 100 acres. All of these sites were constructed using marl mounds. Oyster sanctuary sites are sites that prevent harvesting of oysters. The first five sites that were constructed around 1995 include Croatan Sound, Deep Bay, West Bay, Bogue Sound, and Clam Shoal. The Bogue Sound and Clam Shoal sites were buried in sedimentation after Hurricane Floyd in 1999. In 2002 through 2005 five other sanctuary sites were constructed which include Middle Bay, West Bluff, Ocracoke, Crab Hole, and Neuse River. Clam Shoal was enhanced during this time period (Holmlund 2011). In 2009 Gibbs Shoal was constructed and is the tenth active sanctuary site. This site will be completed in 2014 (Hardy 2011).

The southern region of the state spans the coast between Cedar Island on the southern tip of Pamlico Sound to the border of North Carolina and South Carolina. This region has many more intertidal sites because the estuaries are much smaller shallower than the northern region. The region contains a significant amount of oyster habitat and has strong oyster reproduction. All of the restoration sites in this region are shellfish management areas. These areas can be harvested for oysters when they are opened by the director of the NCDMF or closed due to water quality issues or stock enhancement. Twenty acres of restored or created reefs in the southern region have been constructed in the last decade by the NCDMF, NCCF, and The Nature Conservancy with the help of researchers at the University of North Carolina at Wilmington (UNCW) (Wilgis 2011).

Monitoring Methods of Oyster Reefs in North Carolina

Oyster Sanctuary Monitoring

Over the past 15 years there have been 10 oyster sanctuaries built in Pamlico Sound in North Carolina. The NCDMF has been monitoring these sanctuaries with a formalized protocol since 2007. In 2010 this protocol was revised. Below is a list of the physical and biological criteria observed for the protocol (Table 1).

Physical	**Biological**
Location	Oyster Recruitment
Size	Oyster Size
Material Type	Oyster Density
Deployment Configuration	Presence of Predators
Structure Dimensions	

Table 1 Physical and biological criteria measured by the NCDMF for oyster reef sanctuary sites.

There are several steps to the monitoring protocol. These sanctuaries are sampled once every year by divers from the NCDMF. Divers first select 3 to 4 mounds randomly at each sanctuary. Environmental parameters are measured including temperature, salinity, dissolved oxygen, and turbidity. These parameters are measured with a hand-held YSI water quality instrument and Secchi disk. The height of the mound is recorded and then 2 to 3 rocks from three strata are collected. The first stratum is near the bottom where rocks should be as close to the substratum as possible, but not touching it. The middle stratum is sampled at the midpoint of the mound as measured from the top to the bottom. The top stratum is sampled at the top of the mound. These rocks are placed in a basket and brought onto the boat (Holmlund 2011). The boat crew then places the rocks into a bag labeled with the correct mound and stratum. If rocks can't be brought to the surface then a 25x25 cm frame is used to extract samples. On deck the degree of sedimentation is assessed visually as thin, average, or heavy. The rocks or samples are then rinsed with sea water to remove sediment and data is collected that includes the number of dead and live oysters, height of each alive and dead oyster, organisms attached to sample, and the presence of predators.

The NCDMF has 3 main categories in its evaluation of live and dead oyster densities over time and depth. These include spat (0-3 cm), sub-legal (3-8 cm), and legal (greater than 8 cm) oysters. Abundance of these sizes gives the NCDMF an idea of the status of reef development and the oyster population inhabiting it. Distribution of predators shows how many predators are competing with oysters for resources and preying upon the oyster population (Holmlund 2011).

Monitoring of Cultch Planting and Harvestable Populations

The NCDMF also monitors their cultch planting sites to determine if they are able to recruit oysters for harvest. The method for this is to take a random sample of 30 pieces of shell or marl depending on the site. The average number of oysters per piece of cultch is calculated. This average is on a 0 to 1 scale. The average number of spat is also calculated. The data is collected for 3 years after each site is planted. The data allows NCDMF to evaluate recruitment and whether they should continue planting at that site (Caroon 2011).

North Carolina Coastal Federation Monitoring

The North Carolina Coastal Federation performs most of their oyster reef restoration projects with funding from grants. Some of these grants are federally funded and most have a two to three year monitoring period. After this period, some sites continue to be monitored depending on resources. The two to three year time frame allows researchers to measure recruitment for and growth of oysters for one to two years each. The main goals of restoration projects carried out by the NCCF are to increase the oyster populations, to provide habitat for fish and invertebrates, and to improve water quality in the surrounding area (Wilgis 2011).

The parameters that the NCCF uses are similar to what was discussed under the Oyster Restoration Workgroup which was started in 2004 to evaluate metrics for oyster reef restoration success on a national scale. The parameters used by the Oyster Restoration Workgroup will be discussed in a later section. There are four categories of parameters measured by the NCCF with the first three being the most important. The first category is reef success which NCCF evaluates reefs by using 1 m^2 quadrats to measure density, size, living oysters, and associated organisms using the reef. Recruitment is measured by using tiles to collect spat. The second category is reef architecture in which rugosity and reef footprint are measured. The third category is water quality in which turbidity is measured using a Secchi disk, temperature is measured with a thermometer, salinity is measured with a refractometer, and dissolved oxygen is measured with a test kit. Other parameters included in a fourth category are sedimentation, current flow velocity, and substrate observations (Wilgis 2011).

Shell-bag reefs are sampled by picking up 5 bags from a certain section of the reef and emptying them into buckets. Mussels, crabs, and other organisms are identified and counted. Oyster spat are also counted and measured. Currently the NCCF is working on creating better measures of success for their reefs as well as increasing the number of years that their reefs are monitored (Wilgis 2011).

UNC-Wilmington Monitoring

The University of North Carolina at Wilmington (UNCW) has created a new program in 2010 named Spat-tered. In this program volunteers go out and collect data on oyster spat settlement and other organisms using the reef space using “spat racks”. These racks are made with 6 tile pieces that are tied to a PVC pipe. These racks are then either hung from a dock or placed at mean high-tide on a mudflat or sandflat and then secured with rebar. Each rack is put into the water for 6 weeks and then removed. The second rack is placed in the water 4 weeks after the first rack is deployed. Data are collected and the tiles are then cleaned. This rack rotation is continued throughout the year (UNCW 2011).

The data that are collected include air temperature, water temperature, and salinity twice a week. When the rack tiles are removed each tile is sampled for live oysters or spat, oyster scars, barnacles, mussels, oyster drills, and other fauna. The presence of worm tubes, hydrozoans, bryozoans, sea squirts, and sponges are also noted. Rainfall is also recorded if the volunteer has a rain gauge in place at the site. The data obtained from the volunteers is placed on a website where it can be used to show spat recruitment in different areas of the North Carolina coastline. This is an example of one of the new ways of monitoring oyster recruitment throughout North Carolina (UNCW 2011).

Site Selection Parameters

There are several site selection parameters for restoration of oyster reefs that were agreed on at a national level by the Nature Conservancy and the National Oceanic Atmospheric Administration. The first is identifying where oyster populations existed historically. Then stressors in the area such as poor water quality, harmful algal blooms, sedimentation, erosion, and disease should be evaluated. Some areas where reefs weren't living historically may still be good because conditions may have changed. Historical information can be found from historical mapping of reefs and from fishing records. Spat collectors such as tiles or plates should be deployed at sites to find if that area will recruit oysters (Brumbaugh et. al 2006). The second parameter to consider is the bottom condition. This evaluation is necessary to make sure that that type of substrate can be used for an oyster reef. Preferable bottom conditions include a mixture of sand and mud. The third parameter is water movement. Currents and flow should be evaluated since oyster growth is better in areas with greater flow which brings more nutrients. The fourth parameter would be to consider creating reefs in poor water quality areas and closed areas which would create de-facto sanctuaries (Brumbaugh et. al 2006). These national parameters are often used by researchers and managers in North Carolina.

Methods for Monitoring Oyster Reef Restoration Success from the Oyster Restoration Workgroup

The Oyster Restoration Workgroup was started in 2004 by a group of researchers from academia, non-profit groups, and stakeholders involved in oyster reef restoration in the United States. The purpose of the group is to find metrics for success for the monitoring of oyster reefs in multiple states and to specify the goals of any restoration project.

The goals that were established by the workgroup include habitat creation, shoreline stabilization, water quality improvement, harvesting enrichment, brood stock enhancement, and educational outreach. The workgroup also created metrics to describe restoration success. These include: reef density, size frequency of oysters, associated fauna, reef size, reef architecture, fragmentation, salinity, dissolved oxygen, turbidity, temperature, and chlorophyll A concentrations.

Density is the number of live oysters per area. The method that the workgroup suggests for this is by using quadrats that equal a meter-squared unit of area. There are four measurements made with the quadrats at mean sea-level along a transit line parallel to the shoreline. These samples should be spaced along a 20 meter distance and be taken about 10-15 cm deep. Each live oyster is measured with calipers for shell height from the umbo to the outermost edge. The suggested season for sampling is in the fall when the oysters have finished spawning. Oyster size frequency is then calculated from these (Coen et. al 2004).

Under the workgroup's suggestions, resident fauna are sampled in intertidal and subtidal areas by using small lift nets, trays, or baskets embedded where quadrat samples were taken. Samples from these methods should be washed through a 1.0 mm or 0.5 mm mesh sieve after a specified amount of time in the water determined by the researcher. The organisms are then identified to species or lowest taxonomic level. Transient species are sampled with either lift nets as described above, breder traps, drop nets, seines, gill nets, and small trawls near the reef. In the intertidal zone the most efficient method is the lift net. It is impossible to use these nets in subtidal reefs because it is too deep.

At the intertidal sites, reef size should be measured in square meters by surveying the perimeter. Subtidal reef size can be found using side-scan sonar and evaluated using GIS software. Reef architecture should be measured with similar equipment. The descriptors of architecture include surface rugosity, relief or absolute reef height, shell depth, reef size, and total area. Measurements of fragmentation are still under discussion. Fragmentation, or the spacing of reefs, should be noted as far as the configuration of the reefs. Turbidity can be measured with a Secchi disk. Dissolved oxygen and salinity can be measured with a hand-held meter.

Other parameters that the workgroup suggested measuring are as follows: (1) The areas and types of vegetation surrounding or on the reef using quadrats; (2) Sediment size from core samples; (3) Diseases can be assessed by collecting oysters from reefs and testing the oyster tissue for these diseases in a laboratory; (4) Recruitment to sites can be assessed by using tiles or bins of dead shell to collect spat over time. These methods of measurements of parameters for monitoring are the main methods that the Oyster Restoration Workgroup suggests using to be able to define restoration success for projects nationally (Coen et. al 2004).

New and Alternative Materials for Reef Restoration

Oyster shell is the best material for reef restoration but its availability is limited. In the past 20 years shell has become scarce due to many reasons. These include poor water quality, oyster diseases, less shell left from dredging, and competition from buyers of other industries from shucking houses. Oyster shell is still considered to be the best substrate for the recruitment of oysters for created or restored reefs. However, there are new studies that are ongoing that are comparing shell with other types of alternative substrates in North Carolina waters. These new materials include marl, reef balls, concrete, castles, and pyramids.

Marl has been used throughout North Carolina. Marl is either class B rip-rap, that is the size of basketballs or footballs, or can be smaller and bagged. The larger marl has been used in the sanctuary program in North Carolina. Recruitment of oysters in some sanctuary sites using marl mounds has been increasing, while the boring sponge has been invading marl used in high salinity areas in some of the other sanctuary sites. Marl is still a useful alternative to planting shell in some intertidal sites in the southern region of North Carolina and in the sanctuary sites in the northern region of the state (Hardy 2011).

A **B**

Figure 2 A. Reef ball before oyster recruitment (Reef Ball Foundation 2011). B. Reef ball after oyster recruitment (Allied Concrete 2011).

Reef balls can be made out of either concrete or a combination of concrete and oyster shell (Figure 2). They have been used in small-scale oyster restoration projects in North Carolina and in offshore artificial reef projects. They are better used in subtidal areas where the depth is at least 10 feet above them to avoid damage from waves and currents (Hardy 2011).

Pre-casted concrete pipes and crushed concrete rubble from various building projects is being used in North Carolina for oyster reef restoration. In North Carolina concrete has been found to work well for oyster recruitment. In the future there will be increased use of concrete in restoration projects (Hardy 2011).

Figure 3 An example of an oyster castle used in experimental and small-scale restoration projects since 2007 (Allied Concrete 2011).

Castles have been used in small-scale projects since 2007 in South Carolina and Massachusetts. They are made out of concrete and oyster shell and have been used mainly as a research tool (Figure 3). They are used to measure recruitment of oysters in certain areas and demonstrate spatial variation of oysters in relation to substrate height. Castles could be used in larger-scale projects in the future (Kingsley-Smith 2011).

Pyramids are made out of concrete and similar to reef balls in structure. They have been used for reef restoration throughout the country. They are easier to transport than marl and have more interstitial space for habitat. Pyramids are being considered for new projects by the NCDMF (Hardy 2011).

New Research on Reef Restoration in North Carolina

In North Carolina there are several research projects involving oyster reef restoration. One that has been performed recently from 2006 to 2008 was done by PhD student Brandon Puckett and his advisor Dave Eggleston of NCSU. Using monitoring data they have simulated larval dispersal in the oyster sanctuaries in Pamlico Sound. A program called ADCIRC that calculates the speed and direction of currents was used to model how larvae could be dispersing between the sanctuaries. Data was collected from 2006 to 2008 from sanctuaries. Recruitment, density, and growth of oysters at the sites were added to the model. It was found that the network of sanctuaries as currently established is not self-sustaining and that sanctuaries are receiving and recruiting juveniles from other sites (Puckett 2011). Additional oyster reef sites, including known cultch planting sites, were added to the model and it was found that the sanctuaries could be sustainable. A question of using several large sanctuary sites or several small sites was asked. These sites were added to the model and it was shown that depending on the time period in the model, both several large and several small sites in the sanctuary system would create a self-sustaining system for recruitment. This model indicated the best 10 to 30 sites to be added to the network to create better connectivity. Research on this subject is ongoing (Puckett 2011).

There also has been a "critical depth" hypothesis developed from a study performed in 2010 by researchers at the University of North Carolina: Institute of Marine Science. They have found from recent studies that oyster reefs in intertidal sites in Middle Marsh near Beaufort, NC have grown larger and recruited more juveniles on mudflats. The study was compared to studies of the same area in 1997 of restored oyster reefs. They have also been using laser scanning surveying equipment to determine the depths of these reefs. Through this research, they have initially found that oyster reefs in intertidal areas at Middle Marsh built between -40 cm to -60 cm relative to the mean water level have grown larger and have less fouling by predators than the sites built at a depth below -60 cm. In 2011 these researchers plan to build experimental sites in the same area to test this hypothesis. These researchers at UNC also will be conducting an experiment using derelict crab pots in 2011 to test how well they could potentially be used as suitable substrate for oyster recruitment and habitat for fish and invertebrates (Fodrie 2011). These are some of the most recent studies aimed at improving oyster reef restoration in North Carolina.

Current Reef Restoration Strategies in North Carolina

Shellfish Rehabilitation Program and Oyster Shell Recycling

The Shellfish Rehabilitation Program in North Carolina was started officially in 1997, but the NCDMF has been planting cultch material before it was officially named. The focus of the program in North Carolina is to place cultch material out to enhance habitat for oysters so that they can eventually be available for harvest. In 2010, 153,480 bushels of oyster shell were planted throughout North Carolina (NCDENR 2011). This material is bought from 3 shucking houses in North Carolina. Most of these houses receive their oysters from sources outside of North Carolina, most from states along the Gulf of Mexico. There are 7 stockpile sites that are used by the NCDMF to store oyster shell for deployment throughout North Carolina (Caroon 2011).

Over the years there has been an increase in price of cultch material due to several factors. One factor is that other companies are outbidding the NCDMF for shell. The shell is used for feed and fertilizer by these competing companies. In response to this bidding war, the

NCDMF had a budget approved that increased prices from $1.00 per bushel to $1.50. Another problem with oyster shell supply is a result of the Deepwater Horizon oil spill in the Gulf of Mexico in April of 2010. This spill has led to a decrease in the amount of oyster shell available to North Carolina and other states. Recently the NCDMF has been buying an increasing amount of marl for cultch planting sites to offset the effect of the limited supply of shell. In 2011 there will be about 130,000 bushels of marl used as cultch material in addition to the 70,000 bushels of shell (NCDENR 2010). The Shellfish Rehabilitation Program has many cultch planting sites that act as a seed source to other oyster reefs and restoration projects. The program is an important part of oyster restoration in the state.

In 2003 the NCDMF started the Oyster Shell Recycling Program. The program's goal is to collect and make use of shucked oyster shell to create new oyster reefs and add to the Shellfish Rehabilitation Program cultch planting sites. Bushels of shell are contributed by restaurants, the public, festivals, and sometimes shucking houses. There are recycling locations that have either bins or trailers to collect shell set up throughout North Carolina (Varnam 2011). In 2010 19,736 bushels of shell were recycled. Most of the recycled shells are deployed in cultch planting sites in the southern region of North Carolina (NCDENR 2010). These state programs have been very beneficial in efforts to restore oyster reefs.

Oyster Restoration and Protection Plan

In 2003 the NCCF convened a group of about 50 people to discuss what could be done to speed up oyster restoration efforts in the state. This first meeting called together all the key stakeholders who were already working directly and indirectly to revive oysters. These stakeholders were from a wide range of disciplines including the industry, academia, government, and non-profit organizations. Oyster restoration needs had been identified, and some funding was already going towards enhancing oyster harvest areas and oyster sanctuaries. Participants agreed that better coordination between stakeholders would help to speed up the pace and enhance the scale of restoration that was occurring. The goals that were agreed upon for future restoration efforts in the state were to focus public attention on restoration needs, increase funding for research and actual restoration activities, build support for a sustainable fishery, and align the interests of federal and state agencies to protect and restore the oysters by protecting water quality as well as rebuilding reefs (Wilgis 2011).

This first forum resulted in the formation of a coordinating group called the "Oyster Steering Committee" as well as three regional workgroups that began working on restoration targets and priorities. The Oyster Restoration Protection Plan was created. This plan provides a road map for both small and large scale oyster restoration projects that are linked to regional water quality, research, education, and fishery initiatives and priorities. Stakeholders in the Oyster Restoration Protection Plan have since collaborated to fund and implement a series of oyster restoration and fishery enhancement projects throughout the state totaling close to 100 acres. One of the most notable projects was a federally funded project through the American Recovery and Reinvestment Act to enhance the existing oyster sanctuary system in Pamlico Sound with an additional 50 acres of marl mounds. This project was completed in the fall of 2010 (Wilgis 2011).

Partnerships under the Oyster Restoration and Protection Plan

Stakeholders convened by the North Carolina Coastal Federation include federal and state government agencies, non-profit agencies, fishermen and other private citizens, and academics (NCCF ORPP 2008). Institutions involved include:

- Federal – U.S. Army Corps of Engineers, Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, and Natural Resources Conservation Service.
- State – North Carolina Sea Grant, NCDMF, N.C. Department of Environment and Natural Resources, N.C. Department of Coastal Management, N.C. Clean Water Mgmt. Trust, N.C. Division of Water Quality, N.C. Shellfish Sanitation, Albemarle-Pamlico Estuary Program, Hammocks Beach State Park, and Jockey's Ridge State Park.
- Non-Profit – NCCF, The Nature Conservancy, Friends of Jockey's Ridge State Park, and PenderWatch and Conservancy.
- Academia – UNC, UNCW, NCSU, and Duke University
- Private – J&B Aquafoods, Stevens Towing Company of North Carolina, Mill Point Aquaculture, and volunteers from the public.

Goals of Oyster Restoration and Protection Plan

▪ Create sustainable oyster habitats that grow more fish and provide for more work for fishermen.

▪ Restore functional and productive oyster reefs that provide for a healthy estuarine system that produces vibrant fisheries.

▪ Provide enough oyster habitat to support a sustainable and economically viable fishery.

▪ Create public awareness and support for restoration, conservation, and fisheries.

▪ Create and retain jobs through restoration and by enhancing recreational and commercial fishing to help stimulate the coastal economy (NCCF ORPP 2008).

Feasibility and Recommendations for Using New Methods of Monitoring and Restoration in North Carolina

Feasibility of Using New Methods of Monitoring for Restoration

The methods that are used currently by the stakeholders involved with oyster restoration in North Carolina are very diverse. The NCCF uses many monitoring parameters from the Oyster Restoration Workgroup for monitoring their restoration projects. The NCDMF has their own monitoring protocol for oyster sanctuaries and shellfish management areas. This creates a potential problem in determining the success of restoration projects. To be able to compare sites and studies in the same region within North Carolina there should be a standardized monitoring system and list of indicators of success. These indicators should include most of the parameters described from the oyster restoration workgroup since these monitoring parameters provide a comprehensive system for monitoring of restoration projects.

The parameters include measures of reef density, size frequency of oysters, spat density, associated fauna, reef size, reef architecture, fragmentation, salinity, dissolved oxygen, turbidity, and temperature (Coen et. al 2004). Because it is time consuming and expensive to sample associated fauna for each reef, a solution to the problem would be to pick one or two methods to sample fauna and identify organisms to an agreed taxonomic level. According to the Oyster Restoration Workgroup the most important indicators for ecosystem services are the associated transient and resident fauna and oyster juvenile recruitment (Coen et. al 2004).

Another problem in regards to oyster reef restoration is a recent cut in the budget of the NCDMF. This budget cut could slow monitoring efforts and the progress of new oyster reef creation. The availability of funding has to be considered when implementing monitoring and restoration efforts. The NCCF and other non-profit stakeholders receive funding from grants and donations. However, NCDMF receives their funding directly from the state legislature and thus an effort at maintaining or increasing funding requires the active support of the citizens of the state.

New Goals for Restoration

In North Carolina significant progress has been in oyster reef restoration in the past decade, but there remains a need for improvements in methods of restoration. Such improvements may involve a revision of the Oyster Restoration Protection Plan. One avenue for improvements would be to hold a new meeting for stakeholders that would establish new goals to improve what has already been accomplished in the state in the past decade. Currently there is no agreement on long-term monitoring and no specific goals for restoration projects themselves. The NCCF stated that they want to build 500 acres of oyster reefs by 2020 (Wilgis 2011). There is no formal agreement with all stakeholders on this goal. The feasibility of building reefs in certain areas need to be determined. As has been noted, the boring sponge and oyster drills have caused a significant decrease in the population of oysters in the oyster sanctuary in high salinity areas including the Ocracoke Inlet sanctuary. This problem is cyclical and happens about every three years (Hardy 2011). This problem and other environmental and anthropogenic factors need to be considered in future projects. Alternative substrates other than marl and shell need to be tested to see if they would be successful in other regions of the state both at subtidal and intertidal sites.

There are several goals that each restoration project include. These are:

1. Ecological Benefits
    a. Water Quality
    b. Habitat
2. Fishing Benefits
    a. Recreational
    b. Commercial
3. Shoreline Stabilization
4. Oyster Harvest
5. Educational Outreach
6. Oyster Broodstock as a Seed Source

These benefits should be prioritized by the stakeholders involved with the resource. At the present time in North Carolina there are many different projects each with different goals. A consensus is needed on how many acres of reefs should be either restored or created when compared to historical numbers. The NCCF is also considering building reefs in closed waters to act as de-facto sanctuaries. This plan is not a goal of the NCDMF or any other stakeholder. The NCCF plan needs to be discussed with all stakeholders in a meeting such as the one that developed the Oyster Restoration Protection Plan. Monitoring for longer periods of time for each new restoration site needs to be discussed aimed at determining how well these sites are functioning and whether predators or disease are effecting them. One to three years of monitoring for each site is the usual time allotted by grants for the monitoring of restoration sites. This only allows for minimal comparison and such time limited study does not account for environmental variability or other effects on these reefs that occur over a longer time period. The framework for monitoring has been created and thus there needs to be a decision on what aspects of these reefs are most important to stakeholders in North Carolina.

Increased Use of Volunteers

North Carolina could benefit from expanding its volunteer-based oyster restoration program. The South Carolina Department of Natural Resources SCORE program was developed to involve volunteers with state oyster restoration projects (SCDNR 2011). In North Carolina the NCCF includes volunteers to help in their oyster projects. The NCDMF should join the NCCF in having volunteers help them with their projects. The two organizations have already joined efforts in several other projects and it appears that NCDMF could support its restoration program with the help of such volunteers.

Conclusion

In North Carolina there have been many improvements on oyster reef restoration in the past 15 years. The Oyster Restoration Protection Plan as well as the Oyster Shell recycling Program and new research being performed from universities has all been important in shaping where and how restoration projects have been done. I propose that a new summit on oyster restoration monitoring methods and techniques be held to unite the interests of the stakeholders involved. A summit will establish a process for better integration of monitoring at restoration sites throughout North Carolina. The improvements in monitoring will give the stakeholders better information on what regions and areas are best suited for new projects. Experimenting with the use of alternative substrates for oyster recruitment will give stakeholders more options for the use of shell in future projects. With revisions in monitoring techniques and agreed upon priorities for new restoration projects with the stakeholders involved in North Carolina, there will be improvements in future constructed and enhanced oyster reefs.

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