AN INTEGRATED ANALYSIS OF OYSTER FISHERIES MANAGEMENT IN PAMLICO SOUND, NORTH CAROLINA

by

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ABSTRACT

Conservative estimates for population levels of the Eastern Oyster, *Crassostrea virginica*, in North Carolina are around 10% of the levels estimated at the turn of the 20th century. Oyster reefs perform many functions including providing habitat for fish and other species, stabilizing sediment, and helping to improve water quality. The important, intertwined, and valuable functions that oysters perform are lost when their populations decline; therefore there is a growing movement in eastern North Carolina to restore native oyster populations.

My master's project evaluates different stakeholders' beliefs about oyster stock status, factors affecting oyster population decline, restoration strategies, and current management strategies. My goal was to gain a broad understanding of the present and future needs for managing oyster stocks in the Pamlico Sound of North Carolina, and make recommendations regarding management and recovery efforts. I am interested in a multi-sector perspective, because understanding different stakeholders' beliefs is important for designing and implementing successful management strategies. In order to do this, I conducted 16 interviews with key informants involved in the oyster fishery in Pamlico Sound. The participants were involved in state management, academic research, commercial fishing, aquaculture, and the non-profit sector.

My results indicate that there is a range of opinions and beliefs regarding stock status, factors affecting oyster decline, restoration, and management strategies. Opinions on stock status and management strategies varied widely across and within sectors, as did opinions on the need for more accurate stock assessment. Restoration efforts were widely supported, and opinions on the need for more restoration varied depending on factors such as the type of restoration and the time frame for recovery. Based on my findings I recommend that the state of North Carolina map all oyster beds in the Pamlico Sound by use type. This will allow for more efficient allocation of resources, and will aid in the design of future sanctuary locations as larval sources for wild oyster populations and restoration projects.

INTRODUCTION

The North Carolina Division of Marine Fisheries (DMF) has landings data for oysters that dates back to the late 1800s. Their landings data, based on their trip ticket program, shows a dramatic decline in the amount of oysters harvested in the state over the last 130 years (DMF (North Carolina Division of Marine Fisheries) 2008). It is generally accepted among researchers and managers that current oyster population levels are a reflection of the declining trend seen in this landings data, which puts population levels at about 10% of the peak landings recorded around the turn of the 20th century. This declining trend is a concern for fishers, managers, and citizens because oysters are a crucial part of coastal ecosystems and fisheries in North Carolina.

Mechanical dredging has commonly been cited as the main cause for low oyster populations (Jackson *et al*. 2001). However, it is also possible that landings have declined due to, or in conjunction with other factors such as declining market demand and increased sedimentation (Mackenzie 2007). The many factors affecting oysters appear to be integrated and continually changing, which makes it impractical to attempt to identify one major one factor that caused the decline in oyster landings over the last century.

It is widely accepted that oysters provide a suite of ecosystems services including commercial harvest, habitat for fish, crustaceans and other species, sediment stabilization, shoreline buffering, and water filtration. The variety of ecosystem services and values that oysters provide make management decisions difficult and complicated. Competing use values, varying levels of support for oyster restoration efforts, and uncertain estimates of oyster populations are a few of the issues that managers attempt to balance.

Due to “widespread public concern about the status of oysters in the state” (North Carolina Blue Ribbon Advisory Council on Oysters 1995), *The North Carolina Blue Ribbon Advisory Council on Oysters* was assembled in 1995 to assess the condition of North Carolina’s oyster stocks and make recommendations for their management. The recommendations of this council laid the foundation for the first North Carolina Oyster Fishery Management Plan. Since this panel, North Carolina has enhanced its restoration programs and has been recognized as a national leader in oyster restoration (North Carolina Coastal Federation 2010). However, despite the creation of oyster sanctuaries and other conservation measures oyster landings remain low and the long-term goals for restoration needs remain unclear.

PURPOSE

The purpose of my research is to gain a broad understanding of the issues associated with oyster fisheries management in the Pamlico Sound of North Carolina, and incorporate this into recommendations for improving oyster management. I am focusing on the Pamlico Sound as a case study, and looking at the opinions and beliefs of stakeholders in this area. I am hoping to identify key areas of contention and agreement across different sectors involved in oyster fisheries. I think that understanding different stakeholders' perspectives is important for designing and implementing widely accepted management strategies. I am also hoping that my research will serve as a preliminary study in the social issues that are largely unstudied in the Pamlico Sound oyster fishery, and will identify interesting themes and research opportunities.

BACKGROUND INFORMATION

Oyster Biology and Ecology

The most common oyster in the Pamlico Sound is the Eastern Oyster, *Crassostrea Virginica*, this species of oyster is also the primary target of commercial and recreational fisheries. The Eastern Oyster is naturally established from the Gulf of St. Lawrence in Canada to the Caribbean Sea (Bahr 1981). When I refer to oysters throughout the rest of this paper I am referring to the Eastern Oyster. Oysters have two major life stages, a sessile adult stage that forms a hardened bivalve shell, and a planktonic larval stage. The larval stage is carried through the water column, by currents, until it finds suitable substrate to attach to and develop into a shelled adult form. There are many factors that may affect the recruitment location and timing of the planktonic larval stage. Some of the most widely studied factors include light, rugosity, current velocity, temperature, and chemical cues released into the water column (Kennedy 1996). Larval oysters are attracted to settle on or near established oysters (Crisp 1967), which results in oysters growing on top of each other creating large hardened structures, commonly referred to as reefs, rocks, or clumps. This aggregation is advantageous for external fertilization, because a high density of sexually mature oysters increases the chance of reproductive success (DMF 2008). Also, the vertical structure of an oyster reefs is important to the survival of individual oysters because low oxygen levels along the bottom of oyster reefs, associated with hypoxic and anoxic events, can cause oyster mortality (Lenihan and Peterson 1998).

Oysters are filter feeding organisms with adaptations to remove suspended particles from the water column including microorganisms, detritus, and inorganic matter (Kennedy

1996). After oysters assimilate nutrients and sediment from the water column, they excrete them as waste, which accumulates in the benthos surrounding a reef. This deposition of nutrients makes them more readily available for uptake by plants and is an example of how oysters play a crucial role in estuarine ecosystems.

Oyster Ecosystem Services

The many functions that oysters perform are considered ecosystem services, because they can directly or indirectly affect humans. For example, oyster ecosystem services include improved water quality, habitat for commercially valuable species, and buffering the effects of sea level rise (Grabowski 2007). Shell bottoms have a direct relationship with sediment stabilization, decreased erosion, and decreased wave energy which buffers the coastline during storm events (DMF (North Carolina Division of Marine Fisheries) 2008). Stabilized sediment also provides better conditions for submerged aquatic vegetation (SAV) and salt marshes(Grabowski 2007), which contribute to primary production. Oysters filter water while feeding and this decreases turbidity, suspended solids, microbial production, and phytoplankton in the water column (Grabowski 2007). Decreased turbidity allows light to penetrate deeper through the water column and increases the light available for photosynthesis by plants living on estuarine floor. Increased nutrients and light penetration in the benthos of the estuary are important functions for increasing primary production. In addition, the nutrients and phytoplankton that oysters remove from the water column contributes to the control of eutrophication events, which can lead to anoxic or hypoxic

conditions. Nutrient influxes into coastal systems in North Carolina have led to large-scale fish kills (Glasgow Jr. 2000), so the functions that oysters provide should not be undervalued.

The vertical structure of oyster reefs provides habitat for many commercially and recreationally valuable species, such as blue crabs (DMF 2008).

Most recently, the carbon sequestration value of oyster reefs has been explored (Grabowski 2007). Oysters assimilate carbon from the water column as they build their shells and as the carbon market develops this function may become more valuable.

Stock Status

Current populations of *Crassostrea Virginica* are predicted to be about 2 and 3% of historical population levels (North Carolina Blue Ribbon Advisory Council on Oysters 1995; Jackson, Kirby et al. 2001) along the eastern coast of the United States. Recent estimates for the oyster population in Pamlico Sound are about 10% of the historical levels seen in the early 20th century (North Carolina Division of Marine Fisheries 2010). These recent estimates are primarily based on landings data from the DMF trip ticket program that dates back to 1880.

The North Carolina Division of Marine Fisheries identifies oysters as a "species of concern". The DMF qualifies this status with the statement: *"concern status due to long-term decline caused by over harvesting disturbances. Sampling data shows DERMO has declined in recent years and commercial landings have shown some improvement. Recreational landings are unknown"* (DMF (North Carolina Division of Marine Fisheries) 2009).

Historical Decline

People in North Carolina have harvested oysters for hundreds of years. Major changes were seen in the methods used to collect oysters in North Carolina in the late 1800s (DMF 2008). This is believed to be the result of harvest pressure from the Chesapeake Bay and Connecticut where fishers were using mechanical oyster dredges to harvest oyster at unsustainable levels. As stocks in these areas became depleted fishers moved further south to find new harvest areas to sustain the demand for oysters in their home states (DMF 2008).

The primary fishing method used by these Northern fishers was the mechanical dredge, and it was introduced into NC systems as the northern fishers moved south. Many of the stocks that were harvested in the early mechanical dredge fishery in North Carolina are believed to have been "virgin" stocks, which meant they had never been harvested (DMF 2008). The dredging technique can destroy the vertical structure of an oyster reef, therefore reducing the amount of suitable habitat available for oyster recruitment and development (Lenihan and Peterson 1998). In 1887 the state of NC created a law that prohibited oyster fishing in state waters during certain times of the year. The writing of this law made it applicable only to NC residents; which meant that non-resident fishermen were allowed to continue harvesting year-round with mechanical dredges. Non-resident fishermen were eventually excluded from the fishery, but the mechanical dredge remained in NC waters. Throughout the early 1900s fishers in North Carolina landed millions of bushels of oysters a year, and oysters became a lucrative fishery for many people. In 1902 fishers landed 1,833,000 bushels of oysters, which remains the largest landing on record in NC (DMF (North Carolina Division of Marine Fisheries) 2008). Over time it became apparent to managers that oyster populations were not recovering at a level sufficient to withstand harvest pressure.

Mechanical dredging has been banned in most areas of the state, and rehabilitation projects have been completed. However, populations are believed to remain low and the interaction of numerous stresses on oysters has prevented recovery. These stresses include harvest pressure, disease, increased fresh water input, sediment deposition, eutrophication as a result of stormwater runoff, decreases in available habitat due to unsustainable harvest, and impacts from other fisheries such as shrimp trawls, crab trawls, and clam kickers (DMF 2008).

Additional Factors Affecting Oysters in Pamlico Sound

Low dissolved oxygen conditions (hypoxia and anoxia) in estuarine waters stresses oysters, and can lead to death. This is directly related to nutrient loading in coastal waters due to an increase in storm water runoff, which is a direct result of increased impervious surface cover from development (North Carolina Coastal Federation 2008). Storm water run-off carries fertilizers, sediments, nutrient rich animal waste, and other pollutants to coastal waters with little opportunity for it to be filtered by natural systems, such as wetlands. The pollution that is carried to the coast via storm water is not new pollution; the change has been increased levels of transportation due to increases in impervious surface cover (Kirby-Smith 2006). Increased levels of nutrients can lead to algal blooms and eutrophication. Bacterial contamination is another problem associated with polluted storm water. Humans can become sick by ingesting raw oysters that contain pathogenic bacteria such as *Escherichia coli*, or *E. coli*, that was carried to coastal waters via storm water run-off (DMF 2008).

Sedimentation has also been a huge problem for oysters because sediments cover oysters, inhibiting filter feeding and larval recruitment (Mackenzie 2007).

Oyster diseases have contributed to the decline of native oyster stocks. There are two diseases that have affected oysters in the North Carolina, Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) (DMF (North Carolina Division of Marine Fisheries) 2008). Dermo was introduced from neighboring oyster populations, such as those in the Chesapeake Bay, and caused heavy mortality of oysters in the Pamlico Sound from 1990 through 1992 (DMF 2008). Since 1993, mortality from Dermo disease has not been a major problem in Pamlico Sound (DMF (North Carolina Division of Marine Fisheries) 2008). However, the parasite remains present in natural populations, and it is possible that increases in salinity and temperature could cause another breakout of the disease (DMF 2008).

All of the factors affecting oysters are synergistic. For example, work by Lenihan and Peterson (1998) has shown that stress on oysters in Pamlico Sound from reduced reef structure, due to mechanical dredging, is compounded by low dissolved oxygen levels and increased predation rates associated with oysters near the bottom of reef structures. Naturally, the most viable oysters are found on the upper levels of the reef structure, so altering this distribution interferes with oyster's ability to recover from fishing pressure. We are trying to understand all of the pressures and interactions on oysters, and simultaneously we are focusing restoration efforts primarily on reversing the effects of dredging. As the factors affecting oysters become better understood, hopefully so will recovery efforts.

Overfishing of oysters with destructive fishing gear is commonly cited as the primary reason for the decline in oyster abundance (Jackson, Kirby et al. 2001; Lotze, Lenihan et al. 2006). However, recent work by Mackenzie (2007) states that over harvest is not the main reason for the decline. Instead, consumer fears of human pathogens, economic depressions,

and biological and physical damage from fishing and sedimentation are the three factors, combined, that caused the decline. MacKezie (2007) concluded that restoration alone will not restore the oyster fishery. It must be coupled with enhancing consumer demand. The idea that there is not one, but many contributing factors that caused the decline of oyster populations along the eastern coast of the U.S. are becoming more widely accepted (Lenihan and Peterson 1998; Lenihan, Peterson et al. 2001; Grabowski 2007; Mackenzie 2007). I agree with this idea, and I think that it helps to explain slow recovery of oysters.

Commercial Oyster Fishing

The current regulations for legal oyster harvest allow harvest to begin on October 15th and continue until May 15th, unless otherwise proclaimed by the Director of the Division of Marine Fisheries. The oyster season was extended in 1996 from March 31st to May 15th to allow six additional weeks for the harvest of Dermo infested oysters (DMF 2008). However, because of the difficulty of identifying infested oysters the six-week addition has never been used. The DMF allows oysters longer than three inches to be harvest during the open season.

Commercial hand harvesters are allowed five bushels per person per day, not to exceed ten bushels per boat per day, and commercial mechanical harvesters are allowed 15 bushels per fishing operation per day.

Commercial oyster harvest accounted for only 2.5 percent of the total value of landed species in the North Carolina (DMF 2008). The majority of commercial oyster fishers are part-time fishers, who harvest oysters during the winter months in North Carolina (DMF (North Carolina Division of Marine Fisheries) 2008). The income generated from oyster harvest is only

a portion of most commercial fishers' annual income. However, it is important because it supplements fishers' incomes during a crucial time of year when there are a limited number of species available to fish (DMF 2008). Recently, the DMF has seen a continued increase in the amount of oysters harvested annually (Hardy 2010).

Recreational Oyster Fishing

Recreational oyster fishing is an important tradition for many families and/or coastal communities. All North Carolina residents are allowed to harvest one bushel of oysters a day, not to exceed two bushels per boat, from waters open to shellfish harvest, during the open season for oysters. There is no accountability for the amount of oysters that recreational fishers are taking throughout the year. Recreational fishers are not required to obtain permits or licenses for fishing, so there are no efficient methods available to estimate the number and frequency of people harvesting oysters recreationally. During the 2004 to 2005 season the DMF estimated that recreational harvest could increase the total oyster landings by 4.3% in New Hanover County and 9.8% in Pender County (DMF 2008).

Government Structure

The agency that is responsible for managing the natural resources in North Carolina is the Department of Environment and Natural Resources. Within this agency are divisions responsible for managing and enforcing environmental regulations. Associated with the divisions are commissions, and these are the rule making bodies.

The Division of Marine Fisheries (DMF) is "responsible for the stewardship of the state's marine and estuarine resources" (DMF (North Carolina Division of Marine Fisheries) 2010). The DMF is responsible for creating a fishery management plan for oysters as required by the Fisheries Reform Act of 1997. The fisheries management plan assesses the status of oyster stocks and forms the basis for future regulations. The first oyster fishery management plan was approved in 2001 and included recommendations from the Blue Ribbon Advisory Council on Oysters (North Carolina Blue Ribbon Advisory Council on Oysters 1995). The DMF houses the office of marine patrol, which is the enforcement body for fisheries regulations. The Marine Fisheries Commission is the rule maker that receives the DMF's recommendation. Since 1966, the Director of the DMF has had proclamation authority over the opening and closing of the harvest season and the harvestable legal size for oysters.

Additional divisions that are involved in oyster management are the Division of Coastal Management (DCM) and the Division of Environmental Health. The DCM is responsible for carrying out the Coastal Zone Management Act of 1972 and the Coastal Area Management Act. The DCM writes the Coastal Habitat Protection Plan (CHPP) which includes recommendations for managing shellfish beds (primarily oyster shell) as habitat (Street 2005). The role of the Division of Environmental Health (DEH) in oyster fisheries is strictly related to human consumption. The DEH is responsible for monitoring bacterial contamination in oysters, and reporting their findings and closure recommendations to the Director of DMF.

METHODS

I conducted sixteen interviews with key informants across different sectors involved in oyster fisheries from March 8, 2010 to March 23, 2010. The interview participants included members of state government, academic research, commercial fishing, and the non-profit sector (Table 1). The interviews were semi-structured and lasted from ten minutes to an hour. The length of each interview depended on the availability of the interviewee and the circumstances surrounding the interview. For example, some participants were intercepted on an unloading dock and were anxious to move away from the dock and clear the area for other fishers. I used a question guide to focus my interviews (Appendix).

Table 1. List of key informants and their associated sectors.

ID	Profession	Sector
1	Research Professor	Academia
2	Research Professor	Academia
3	State Manager	Government
4	Research Professor	Academia
5	Commercial Fisherman	Commercial Fishing
6	Fish House Manager	Commercial Fishing
7	Commercial Fisherman/Researcher	Commercial Fishing
8	Fish House Owner	Commercial Fishing
9	Commercial Fisherman	Commercial Fishing
10	Commercial Fisherman	Commercial Fishing
11	Non-Profit Director	Non-profit
12	State Biologist	Government
13	Commercial Fisherman	Commercial Fishing
14	Non-Oyster Commercial Fisherman	Recreational/Former Aquaculture
15	Distributor	Commercial Fishing
16	Commercial Fisherman	Commercial Fishing

I used a snowball sampling method based on participant's recommendations, and initially a review of management documents, to identify key informants. Some of the

participants in the commercial fishing sector were identified by fish house owners, and I was given access to fishermen at a commercial unloading dock. All of the participants I interviewed were involved with oyster fisheries in the Pamlico Sound in North Carolina, or were knowledgeable about this area. The area defined as Pamlico Sound for the purpose of this study is roughly outlined in Figure 1. The interviews were recorded and transcribed with permission from participants. NVivo was used to code my interviews and notes for data analysis.

I also completed a literature and document review of oyster policy in North Carolina. This was specifically focused on reviewing management documents such as the NC Oyster Fishery Management Plans (DMF 2008, (DMF (Division of Marine Fisheries) 2001), the North Carolina Coastal Federation's Oyster Restoration and Protection Plan for NC (North Carolina Coastal Federation 2007), the North Carolina Coastal Habitat Protection Plan (Street 2005), and the 1995 report by the North Carolina Blue Ribbon Advisory Council on Oysters (North Carolina Blue Ribbon Advisory Council on Oysters 1995).

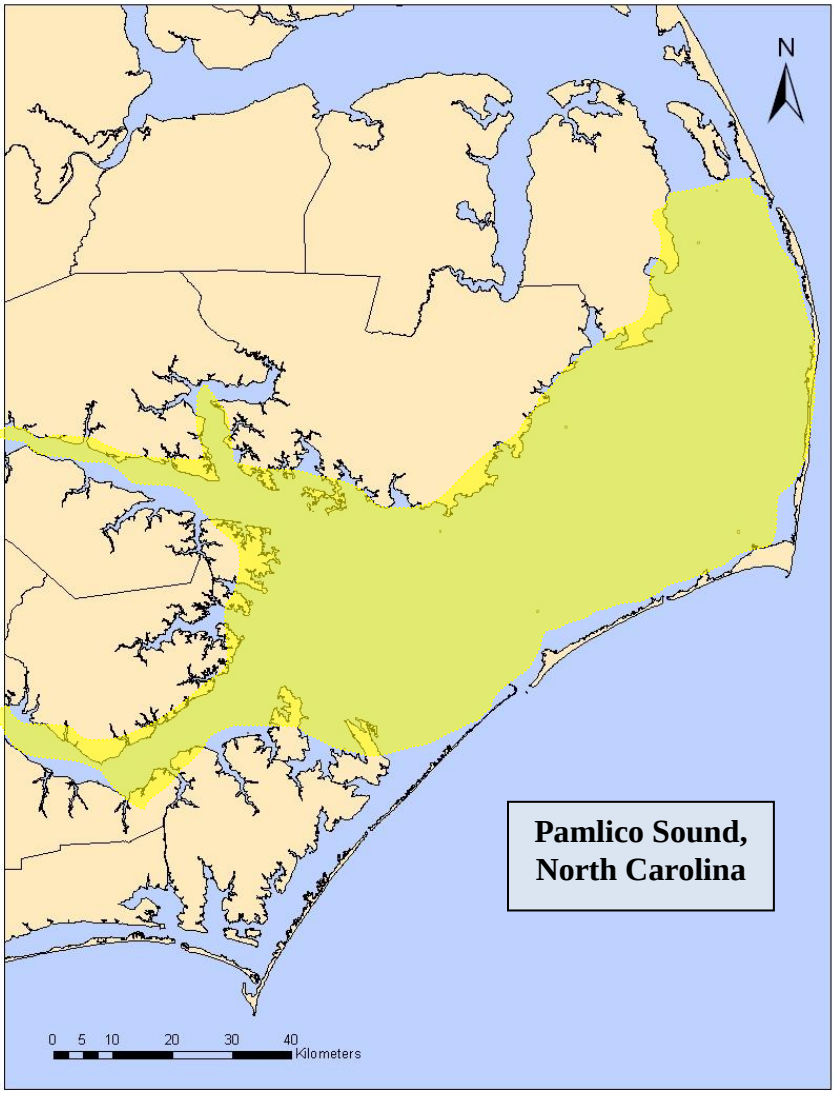

Figure 1. Map of Eastern North Carolina, Pamlico Sound highlighted in yellow.

RESULTS

Oyster Stock Level

I was interested in this topic because during my document review it was not obvious to me that the state had a rigorous method for assessing oyster stocks. I wanted to see what people from different sectors thought about the oyster population levels in Pamlico Sound.

When I asked participants about current stock status and what they thought about oyster population levels, compared to historical populations (late 1800s early 1900s), I received varying opinions. There were a few themes that emerged from my discussions with participants, and many talked about short-term stock status or long-term stock status, not both.

Some of the participants in the commercial fishing sector were reluctant to make assumptions about historical landings and population levels that they had not experienced first-hand. For example, when I asked one fish house manager how he thought current oyster populations compared to historical levels seen around the turn of the twentieth century, he responded, “How old do you think I am?” Many of the participants stated that the population levels have been up recently, and others replied that they are down historically (Box 1). The varying opinions on stock status seem to be related to the experience level and knowledge of historical oyster populations that participants had.

It was commonly believed across all sectors that the stocks in Pamlico Sound have been increasing for the past 2 to 6 years, and this was frequently supported by the short duration of trips that fishers were taking to acquire their daily limits.

The reasons for this increase varied from a phase in a natural cycle to the result of restoration projects by the DMF.

Some of the researchers only seemed to think of stock levels in terms of historical comparisons and stated that this year the stocks were still drastically reduced, as they have been historically. Two participants mentioned that populations are at ten percent of historical levels (Box 1) and this may be based on the trip ticket data from the DMF that tracks oyster landings. Some of the researchers quoted a 2 to 3% level compared to historical populations. This is most likely a reference to the Jackson *et al.* paper from 2001 or the Blue Ribbon Council's findings (North Carolina Blue Ribbon Advisory Council on Oysters 1995), that make this conclusion about oyster populations along the eastern coast of the U.S. It was common for participants to reference the Winslow surveys (Box 1) that were conducted in the 1880s to survey North Carolina's estuaries for suitable oyster habitat (DMF 2008). There were also a few participants who stated that they just didn't know.

Box 1

"This has been our best year in a long time."
~ Commercial fisher

"The last two to three years oysters have been growing real fast, faster than anybody has known them to grow before… that's why there has been so many oysters."
~ Commercial fisher

"This year is normal comparatively to lifetime experiences, [oysters] not as thick as they were 20 years ago…"
~ Commercial fisher

"Regardless of the pressure that's out there, the amount of oysters that are being harvested are steadily increasing, so I think that shows that the fishery is making a recovery…"
~ State biologist

"In the places that are not polluted there is less… if it's a polluted area they'll still be there…"
~ Commercial fisher and researcher

"Probably 10%, I know its way down from the Winslow surveys."
~ Non-profit

"Obviously, they're way down, we've got records on that. We're harvesting a tenth, or something like that of what they were harvesting around the turn of the century."
~ State manager

Stock Assessment

The state of North Carolina does not perform a stock assessment for oysters; instead relative oyster population levels are inferred from landings data and effort per trip information (DMF 2008). I asked all of the participants if they were familiar with the type of stock assessment methods used by the state to manage oyster fisheries. If so, I asked them if they thought this was an effective technique for management, and if there was a need for better stock assessment methods. Many of the participants responded that inferring stock assessment, based on landings data was an ineffective technique (Box 2). Some of the researchers pointed out that there are many variables that affect fishing effort, so landings data is not truly reflective of oyster populations. However, it was also commonly acknowledged that the current method for stock assessment might be the most practical and cost-efficient method available to the state. Both the state manager and the state biologist saw the need for better stock assessment of oysters. One of the researchers did not see the need for more stock assessment, because in his opinion oyster populations are too low to bother with stock assessment (Box 3).

Box 2

"Its effective at knowing how many oysters are being harvested, they've got a pretty good handle on that… that doesn't sound like management, that sounds like reporting on stock"
~ Researcher

"Without an assessment we have to be precautionary in our management, [stock assessment] would be a big improvement. If we had an assessment, we could have an idea of what legal harvestable oysters are out there, and we could set a limit."
~ State manager

Box 3

"We've got so damn few oysters… what we need to do is just do it, instead of someone running around counting them."
~ Researcher

Management

The strong and diverse range of opinions expressed by participants about management strategies made it clear that oyster fisheries managers are faced with complicated, challenging decisions. There was a common theme throughout my interviews that oysters have historically been mismanaged (Box 4).

Box 4

"There's a tendency to just find places where there are lots of oysters and then open them. It's managed for the fishermen, and not in a sustainable way"
~ Researcher

"Unintentional mismanagement for the biology and ecology of the oyster"
~ Researcher

"I don't agree with anything the DMF does"
~ Fish house manager

The issues that participants raised and their suggestions for improving management strategies varied widely and were usually directly related to the participant's interests. Table 2 summarizes the issues raised by participants.

Table 2. List of issues raised by interview participants about oyster fisheries management in Pamlico Sound.

Participant	**Management Issue**
Researcher	There is a tendency to allow over harvest of oysters
Commercial fisher	Commercial mechanical harvest limit too small
Non-profit	Lack of money available to rebuild substrate
State biologist	Lack of resources available for managers and enforcement
Former aquaculturist	Not proactive enough in leasing program
Researcher	Mismanagement of dredge fishery, allows too much substrate damage
State manager	"1950s style management"
Researcher	Mismanaging as a fishery, need to manage as habitat
Commercial fisher	Season too short, commercial mechanical harvest limit too small
Fish house manager	Don't have harvest closure triggers, when FMP says they should. Need more adaptive management
Fisher/researcher	Mechanical dredging is damaging to substrate, lack of evaluation of restoration projects
Commercial fisher	Size limit and mechanical harvest limit need to be more adaptive to allow year-to-year changes.

There were a few unexpected responses to my questions regarding suggestions for management. I expected support for larger harvest limits and a longer open season for oyster fishing to be widespread among participants from the commercial fishing sector. However, in two of the interviews participants from the commercial fishing sector pointed out the need for more adaptive management (Box 5). They both suggested making management more flexible and more clearly based on real-time data. This would allow managers to change restrictions when necessary to prevent over harvest or harvest of immature oysters. Table 3 summarizes participant's suggestions for better oyster fishery management.

Box 5

"*I would just like to see them put the triggers in place where they can do it either way, because I have seen years where 15 bushels were too many*"
~ Commercial fisher

"The way these [oysters] are growing this year, the size limit should have been bigger than three inches. Their lips are so long, it makes a little oyster pass inspection when it is really too small for harvest."
~ Commercial fisher

Table 3. List of suggestions made by interview participants for oyster fisheries management in Pamlico Sound.

Participant	**Suggestion for better management**
Researcher	Manage oysters based on location and most important function for that location.
Commercial Fisher	Raise commercial harvest limit to 20 or 30 bushels per person
Non-profit	Balance sanctuary program and cultch planting, secure more funding for restoration
Former aquaculturist	Support small-scale aquaculture
Oyster buyer	Rotate harvest areas
Researcher	Follow recommendation of Blue Ribbon Advisory Council (1995), emphasize aquaculture.
State manager	Get more funding and resources
Researcher	Manage as habitat, only allow diver harvest
Commercial fisher	Leave season open all year, increase commercial harvest limit
Fish house manager	Identify triggers, relay information to fishers, close fishery when needed based on triggers
Fisher/researcher	Phase out dredging, and do more research
Commercial fisher	Adjust size limit and harvest limit based on yearly oyster conditions.

Restoration

The DMF Oyster Rehabilitation Program was started in 1947, and the state has been planting cultch since 1915 (DMF 2008). Previously, the rehabilitation program was focused specifically on enhancing the oyster fishery, cultch planting was not strategic, and material supplies were not constant (North Carolina Division of Marine Fisheries 2010). In response to the recommendations made by the Blue Ribbon Advisory Council on Oysters, the DMF enhanced their rehabilitation program to incorporate restoration for habitat and the non-harvest ecosystem services provided by oyster (DMF 2008). Recently, the DMF partnered with the North Carolina Coastal Federation and received a federal grant through the American Recovery and Reinvestment Act (ARRA). Together they received $5 million to build a new oyster sanctuary, finish work on existing sanctuaries, and pay fishermen $2/bushel to distribute 48, 000 bushels of oyster shell to designated cultch planting sites (North Carolina Coastal Federation 2010). According to one of the state's biologists, the recent allocation of federal funding to their rehabilitation program has moved the DMF's sanctuary program ahead seven to ten years on their estimated timeline for building sanctuaries. This sanctuaries program was the first step taken by North Carolina to manage the oyster populations as both a fishery resource and as an important habitat. As the program progresses the ARRA money will expire and the sanctuaries program will need to acquire additional funding in order to manage their sanctuaries and cultch planting sites.

My research questions were intended to investigate awareness of the state's restoration programs, gather perspectives on the state's restoration efforts, and determine if participants thought there was a need for more restoration projects. Through these interviews I identified a potential area of disjoint between state programs and fishers.

Twelve out of the thirteen participants who responded on this issue expressed positive statements about the program, and the other participant stated that they were not familiar with the state's restoration efforts (Table 2). However, when I asked this person if they knew where any of the sanctuaries were located, the participant responded that they were familiar with a project in Rose Bay. In three interviews this question was not answered due to time constraints.

Table 2. Participant's views on state restoration projects and future needs.

Profession	Sector	View on sanctuaries	More restoration needed?
Commercial fisher	Comm. Fishing	It helps	More for harvest
Commercial fisher	Comm. Fishing	N/a	N/a
Commercial fisher	Comm. Fishing	Not familiar	No
Commercial fisher	Comm. Fishing	Supports	More oyster beds (cultch)
Commercial fisher	Comm. Fishing	Supports	More marle
Commercial fisher/researcher	Comm. Fishing	Seems good	Review stimulus sanctuaries first
Distributor	Comm. Fishing	N/a	N/a
Fish house owner	Comm. Fishing	N/a	N/a
Fish house manager	Comm. Fishing	Supports	No
Non-oyster commercial fisher	Recreational/former aquaculture	Great	More evaluation
Non-profit director	Non-profit	Good	Yes
Research Professor	Academia	Excellent	Yes
Research Professor	Academia	Good	Yes
Research Professor	Academia	Supports	Yes
State biologist	Government	Good	Yes
State manager	Government	Good	Yes

Participants supported restoration for different reasons across sectors. Four commercial fishermen responded on this topic and all four indicated that they would like to see more cultch planting sites, and they did not see the need for more oyster sanctuaries (Box 6). These fishermen also did not attribute the recent rise in

Box 6

"The more beds they put down, the more people have… scatter them around so we have more beds to get oysters off of. I don't think they need to be putting out those big rocks, I think they need to be oyster shells".
~ Commercial fisher

"The two or three years they hadn't planted anything for oysters, they only planted for the fish, the fishing reefs. They took all of our oyster, all our money for replanting oysters and put it in making fish sanctuaries, instead of oysters."
~ Commercial fisher

oyster populations to any of the restoration projects completed by the state (Box 7). Opposite statements were made by state employees, researchers, fishers/researchers, and the member of the non-profit sector, who attributed some or the entire recent increase in oyster populations to the restoration work done by the state (Box 7). The state biologist also stated that much of the commercial harvest of oysters is done on cultch planting sites created by the state. Many of the participants from the commercial fishing sector did not recognize cultch planting sites as popular fishing areas; instead they said natural areas were the best harvest sites. Two of the older commercial fishers noted that they harvested on cultch planting sites, but still did not attribute any changes in population levels to these projects.

Box 7

"From what I've seen most of the oysters that have come back are naturally reoccurring, they are not stuff the state has actually done to help oysters recover."
~ Commercial fisher

"If they actually have to have them, I don't know. From what I've seen most of the oysters that have come back are naturally reoccurring, they are not stuff the state has done to help oysters recover… Yes, oysters have recovered in the last several years, but they have recovered on natural sites that have always been where oysters grew. Where we've really had extreme growth is places where the sanctuaries aren't supplying or near."
~ Fish house manager

"I think sure there needs to be more restoration projects… this last 5 to 6 year period harvest levels have been up, the oyster sanctuary program has really taken off, and I attribute that to all of the work we're doing."
~ State biologist

Two of the commercial fishers who had both participated in research projects indicated that they would like to see more review of the restoration projects before new projects are built (Box 8).

Box 8

I would like to see a little research done on that (relay program). The whole program, they get involved in things, and there doesn't seem to be a lot of review.
~Recreational fisher, former oyster grower

We'll see after the stimulus, how they go… ~commercial fisher/researcher

Other relevant points that were brought up throughout the interviews were the need to plan future sanctuaries using biological and ecological data, and the differences between the cultch materials. Several researchers, the non-profit participant, and two fishers mentioned the need for incorporating larval distributions when planning sanctuary

locations. Many of the research and fishing participants noted that the different types of cultch promote different styles of oyster growth. The marl, which is a type of limestone rock, is generally believed to grow single oysters, while shell promotes the growth of clumped oysters.

Oyster Culture

In my interviews I used the terms aquaculture and oyster culture to mean growing oysters on leased submerged bottomlands. Oyster culture requires a lease for submerged aquatic bottom and may also require a water column lease depending on the techniques used. Oyster culture requires using a public trust resource to harvest a privately owned product. Because oyster culture requires leasing public bottom, in some areas of the state, such as Core Sound, there has been extreme public backlash to aquaculture. However, oyster culture has many positive environmental impacts. It introduces spat into the environment, it reduces harvest pressure on wild stock populations, and it provides the same water filtration services as wild populations (DMF 2008).

My interviews revealed that while none of the fishers in Pamlico Sound were interested in participating in oyster culture themselves, none were opposed to others undertaking this activity. Fishers mentioned that as long as leases did not interfere with the areas they harvested, then they wouldn't care if people leased the bottom and created their own oyster "clumps". This is contradictory to what I expected to find, based on my experiences in Core Sound.

Other participants felt that there is a need for the state to strongly support aquaculture in North Carolina (Box 9). Otherwise, increased pressure on wild stocks will drive the

populations down further and make the recovery of oysters in Pamlico Sound less likely. Two of the participants thought that managing the bottom should remain in the hands of the state because it is their job to manage it as a public resource.

Box 9

"The potential for growing oysters is immense, I don't think you could say that about potential continuing to wild stock harvest oysters."
~ Former oyster culturist

Recommendations… emphasize, oyster aquaculture, because that's sustainable."
~ Researcher

Some of the issues that participants brought up in regard to oyster culture are important issues that the state needs to address in order to support this activity. First, many participants mentioned the lack of protection that leasers have for their final product. This has been an issue for over 100 years and is a matter of enforcement. Oyster growers invest large amounts of resources including time and money into growing their product, and if their oysters harvested by someone else they are not able to recuperate those sunk costs.

In the 2008 Oyster Fishery Management Plan the DMF states that one of the biggest obstacles to establishing a viable oyster culture industry in North Carolina is a lack of markets willing to pay the higher prices associated with the higher cost of oyster culture. They also mention that there has been a lack of in-state seed available for North Carolina growers. However, recent changes in both of these areas may ameliorate these issues. First, the NC Sea Grant program is in the process of building an aquaculture facility at the University of North Carolina in Wilmington that will produce native oyster seed (Wilgis 2010). This has the potential to make native oyster seed an affordable option for interested growers. Second, proposed restrictions on the Gulf of Mexico's oyster fishery will require increased post-harvest treatments during the summer months in an attempt to reduce illnesses associated with Gulf

Coast oysters (FDA). This additional treatment cost would raise the price of Gulf oysters, and potentially create openings for new markets in areas that do not require this treatment, such as North Carolina.

Value

In a 2003 paper Charles H. Peterson (Peterson, H. et al. 2003), he proposed that oysters are more valuable for the habitat they provide then they are as a harvestable resource. I was interested in the opinions of participants on this topic, because I wondered if there were similar thoughts among other researchers, fishers, or other sectors. My small sample size is not reflective of broad views, but it does highlight the complexity of this issues. I expected that commercial fishers would generally agree that oysters were more valuable for their fishery value, than for the other ecosystem services they provide as habitat, because they depend directly on this resource. However, two fishers said these services were equal, one did not know what to answer, one said it depend so what you want, the non-oyster fisher said as habitat, and two were not asked this question (Table 3). Two of the researchers stated habitat, but the third said that it depends on the oyster's location and role within the estuary. The opinions on what is the most valuable function of oysters are varied across and within sectors.

Table 3. Participant list and their opinions on the value of oysters as a fishery or for other ecosystem services.

Profession	Sector	Value
Research Professor	Academia	Depends on location in estuary
Commercial Fisherman/Researcher	Commercial Fishing	Depends on what you want
Commercial Fisherman	Commercial Fishing	Don't know
Commercial Fisherman	Commercial Fishing	Equal
Commercial Fisherman	Commercial Fishing	Equal
Fish house manager	Commercial Fishing	Fishery
State biologist	Government	Fishery (oyster & fish habitat)
Non-profit Director	Non-profit	Habitat
Research Professor	Academia	Habitat
Research Professor	Academia	Habitat
State manager	Government	Habitat
Non-oyster Commercial Fisherman	Recreational/Former Aquaculture	Habitat
Fish house owner	Commercial Fishing	N/a
Commercial Fisherman	Commercial Fishing	N/a
Distributor	Commercial Fishing	N/a
Commercial Fisherman	Commercial Fishing	N/a

DISCUSSION

It was interesting to find that some concepts, which appeared to be generally accepted in scientific literature, had various levels of understanding across my interviews. For example, participant's views on the stock status of oysters in Pamlico Sound in comparison to historical levels were varied, and at times contradictory to what is generally accepted in scientific literature.

There were a few issues that stood out as having divergent perspectives. This included perceptions on the effectiveness of oyster rehabilitation programs, the sustainability of the mechanical dredge, and whether or not populations of oysters in Pamlico Sound are currently being over-harvested.

In the following sections I will address the information I gathered during my interviews and make recommendations with the intent of taking the needs of different sectors into consideration.

Restoration

My results indicated that there is a lack of awareness and perceived benefit of restoration projects among the commercial fishing sector. This is an area of concern for the DMF rehabilitation program, because the fishers I interviewed did not make connections between the DMF's projects and benefits to their livelihood. This indicates that fishers are not invested in the long-term success of projects that could potentially benefit them through an increase in harvest. I recommend that the DMF investigate this issue further to see if commercial fishers place value on their restoration projects. Having fishers invested in the

state's restoration efforts seems like it would also be important for compliance in no-take zones that the state sets up. It is important that the goals and impacts of the projects are clearly stated and widely disseminated to fishers and other citizens. The upcoming cultch planting project that is funded by the ARRA grant will hopefully increase awareness and investment of fishers in rehabilitation programs.

It is important that the DMF begin to show the social value of their restoration projects as grants such as the ARRA expire, because this information could be used to garner more funding for their projects. Increased funding will be needed in order to maintain the current pace of the restoration program, and quantifying the values created by restoration projects will increase the perceived value of this program.

Use Planning for the Pamlico Sound

The DMF needs to develop a strategic plan for the management of oysters in the Pamlico Sound. My results indicate a disjoint between where cultch planting sites are located, and fisher's knowledge of these sites. From my interview results it appears that some of the areas fishers consider natural sites may actually be old cultch sites. I think it is important that the DMF pursue this issue by creating a use map for oysters in the Pamlico Sound.

In order to do this the DMF would need to use social science methodologies to gather fishers' knowledge and identify commercial harvest sites. This information could then be used to create a map that would benefit management, and allow the DMF to concentrate their fishery and restoration resources in specific areas. This information will also allow managers to determine if commercial fishers are harvesting on cultch planting sites.

One example of how use mapping would aid in more efficient allocation of resources is the use of cultch material for restoration. My results indicated that there is a distinction between the ways oysters grow on different cultch materials in the Pamlico Sound. As the DMF plans their sanctuaries and cultch sites, they can allocate materials based on the intended use at each location. Those sites intended for harvest would benefit from marl, because this promotes single oyster growth and is more desirable for fishers. The sites intended for sanctuaries would be built with shell material, because it promotes clumping and is more reflective of habitat needs.

Use mapping will also aid in the citing of new sanctuaries. Larval transport models have been developed at NC State University (Puckett 2010), and combining these models with the known locations of harvest sites will allow development of a larval source/sink system. These models can by used to place sanctuaries in source areas that utilize currents to feed larvae into commercial harvest and cultch planting sites.

More information on where fishers are harvesting oysters would be beneficial to managers. It would allow managers to target fishing areas for enforcement and stock assessment. The use mapping of the Pamlico Sound is an important step in taking oysters from being managed as a fishery to being managed separately as a fishery and as a habitat.

Stock Assessment

The DMF does not do stock assessment for oysters anywhere in the state. In my interview with one of the state managers he referred to the current method for oyster fishery management as a “1950s management philosophy”. It is important that the DMF begin

performing stock assessment for oysters in NC. This will provide a better understanding of how to develop seasonal indicators of over harvest. It will also provide reference information that can be used to gauge restoration and fishing impacts on the population. If the DMF creates a use map for Pamlico Sound, it will be a valuable tool that can be used to prioritize areas of Pamlico Sound for stock assessment based on harvest pressure.

Aquaculture

As early as 1907, accounts were made of the need for oyster culture in North Carolina, and of the many suitable areas available for private oyster culture (Coker 1907). In 1995 one of the primary recommendations of the Blue Ribbon Advisory Panel on Oysters was to enhance aquaculture within the state (North Carolina Blue Ribbon Advisory Council on Oysters 1995). Coker (1907) noted that there were two major factors that contributed to the early failed attempts at oyster culture were 1) lack of experience on the part of the planters and 2) the lack of legislative conditions that allocated the proper needs to oyster planters. Coker also mentions that because oyster growers were not given exclusive rights to their product they were often stolen before the planter was able to harvest, which resulted in sunk costs that were not regained. Unfortunately, this second issue is still a concern based on my interviews, but the problem is now lack of enforcement.

My research results do not indicate that there is much conflict surrounding oyster culture in the Pamlico Sound. The main issues that arose were based on fears that oyster culture would not be a lucrative investment because of past experiences or the many external variables that can affect the outcome, such as poaching and oyster disease. Therefore, I think

that the state needs to encourage and support oyster culture in the Pamlico Sound by increasing education for interested growers and subsidizing grower's initial investment in the necessary aquaculture equipment.

CONCLUSION

It was clear throughout this research that there needs to be two main focuses for managing oysters. One needs to be oysters as a fishery for harvest, and the other needs to be oysters as habitat. In order to best address these two needs my primary recommendation is that the DMF develop a strategic management plan based on regional uses. I am also recommending that the state encourage oyster culture in the Pamlico Sound by offering educational and financial support to interested growers.

The most important next step that the state should take for oyster fisheries management is to create the use map for oysters in the Pamlico Sound. This will allow the DMF to allocate resources more efficiently. Some of the benefits of this will be stock assessments in areas with heavy harvest pressure, efficient distribution of cultch material based on intended use, and development of a source/sink system for sanctuaries, cultch sites, and wild stock populations.

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APPENDIX

Interview topics and sample questions

- Current status of oyster stock
  - Do you think that oyster stocks are over harvested in NC? Pamlico Sound? Core Sound?
  - If so, do you think oyster populations will recover to historical levels?
  - What is a reasonable goal/measure for recovery?
  - What is needed to aid in their recovery?
  - How do current oyster populations compare to historical populations of oysters?
  - What are the biggest factors affecting oyster populations in Pamlico Sound? In Core Sound? In NC in general?
  - Is using landings data for stock assessment an effective technique? Are better stock assessment methods needed?

- Oyster Management
  - What do you think about current management strategies?
  - What is needed for better management of oyster populations?
  - Do you think that mechanical dredging is a sustainable fishing practice?
  - Are oysters more valuable as a fisheries resource or for their other ecosystem services?

- Oyster Restoration
  - What do you think about oyster sanctuaries?
  - Are more oyster restoration projects needed to recover native oyster populations?
  - Have you seen any changes in oyster populations as a result of restoration efforts?

- Aquaculture
  - What role, if any, should aquaculture play in the future of oyster fisheries?
  - Is there public support for oyster aquaculture in NC? Why or Why not?

- Oyster market
  - Has the market for oysters changed over the past 20 years? How? Why?

Any recommendations for other people I should contact, or papers I should read?

Anything else you would like to add?