Cooperative Research In South Carolina

Final Report

By

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Table of Contents

Grant Projects

Executive Summary

In 2004 the South Carolina Department of Natural Resources was awarded a grant to conduct cooperative research grant to provide information on existing and potential fisheries in South Carolina. This research was prompted by requests from fishing industry representatives who wished to see the commercial and recreation fishermen have a greater stake in the study and management of living marine resources. The project was undertaken in basically two phases. Phase 1 involved a Needs assessment Phase 2 took recommendations from the assessment and implemented cooperative research projects with the recreational and commercial fishing community members. Additionally, new research needs were uncovered over the course of the project and research projects were developed as opportunities arose.

The research projects are grouped as Contractual projects and Grants. The Contractual Projects were largely specific programs that came directly out of the Needs Assessment. DNR Cooperative Research personnel developed project outlines and then contracted with private parties, primarily commercial and recreational fishermen, to complete the tasks. For projects that were anticipated to exceed a cost minimum established by state law, a bidding process had to be utilized. We also solicited ideas for research needs and projects from the public. Because DNR does not have the authority under state law to issue grants, The SC Sea Grant Consortium was contracted as a subrecipient to administer a grant program for cooperative research projects. This proved to be a successful collaboration; utilizing Sea Grant's grant review and evaluation process and their Marine Extension agents who brought valuable experience that greatly facilitated dealing with the fishing public.

Needs Assessment

The potential applied-fisheries, management-based research topics included those related to resource assessment, fishery biology, socio-economics, resource management, and sustainable harvesting technology. These research needs were to address potential projects for both commercial and recreational fisheries. The assessment took place during year one of the grant period with a report being competed in September 2005. Criteria used to evaluate potential research projects included the degree in which the proposed project:

1) positively impacts participants in SC commercial or recreational fisheries.
2) provides useful information for management purposes and/or environmentally-friendly fisheries management.
3) has a good likelihood of success
4) incorporates broad a cross section of the various fisheries of the State
5) is not likely to be funded through other sources
6) provides potentially useful information for state managers and researchers throughout the region.

CRP personnel met with other DNR staff, South Atlantic Fishery Management Council Staff, Atlantic States Marine Fisheries Commission representatives, and others included commercial and recreational fishermen to develop the needs assessment. The needs assessment yielded research needs in the following areas: Sustaining an economically viable shrimp fishery, Shrimp bycatch, Shrimp disease, Collection of fishery-dependent blue crab data and characterization of the fishery, Socioeconomic impact of a limited entry blue crab fishery, Diamondback terrapin bycatch, Horseshoe crab fishery, Utilization of discarded crab traps as oyster substrate, Pond culture of oysters, Oyster/clam depuration facility, Field grow out of single oysters, Relay of single oysters, Examination of Alternative Oyster Cultch materials, Development of "synthetic"

cultch material, Hard clam depuration facilities, New mesh bag for clam mariculture, Octopus Fishery potential, Evaluations of inshore and offshore artificial reefs, Establish a logbook survey for recreational anglers, Fish tagging study for Sciaenids and Flounder, Utilization of recreational divers to assess fish species diversity and abundance, Characterization of the Flounder Fishery, At-sea evaluations of the health of released hook-and-line caught fish, Shad fishery evaluation, Compare age and size of selected offshore reef fishes caught by fishery-dependent and fishery-independent methods, Evaluation of mortality of regulatory discards in the snapper-grouper fishery, Movement of adult cobia in Port Royal Sound, Migration of dolphin, Temperature stratification in nearshore waters of the Grand Strand, Development of baseline data for proposed marine protected areas, Compilation of fishery-related historical changes and local knowledge. Of the 31 specific research needs identified in the needs assessment, 22 were addressed with research projects, including 10 that were addressed by multiple projects.

We believe this program was a success on several levels. A main goal was to get fishermen and other citizens involved in the research and management of marine resources. To that end, 46 separate projects were undertaken – 24 as contracted projects and 22 as grant projects with assistance from Sea Grant. An estimated total of 500 participants, not including professional biological staff participated in this program. Of this number, 391 were recreational fishermen (including 303 pier fishermen) who participated in 11 separate projects. A total of 109 commercial fishermen participated in 23 projects. About 23 recreational divers participated in two offshore diving projects. An estimated 55 college students participated in three projects. 31 professional, ranging from DNR staff to college professors from three institutions participated in a wide range of studies. Including all participants, about 586 people participated in the overall program.

30 of the projects were related directly to commercial fisheries and fifteen projects were related to recreational fisheries. Four projects were considered environment in nature. (Due to some projects being both commercial and recreation, the sum does not equal 46). Fisheries for or biology of the following species or species groups were addressed: shrimp, blue crab, stone crab, octopus, sea birds, oysters, clams, and several finfish species including toad fish, cobia, dolphin, flounder, spot, weakfish, red drum, black sea bass, various sharks, offshore snapper/grouper species and others.

We found that all participants were pleased to participate in the program and most were highly energized to provide a good product. Many commented that it is a good idea to involve fishermen more in fisheries monitoring and research. It was clear that this work fostered improved communication and developed relationships with will endure long after the program has ended.

This being the first comprehensive program of its kind in South Carolina, it provided a number of conclusions about how future cooperative programs should be operated. We determined early on that it was important for biologists or technicians to conduct on-site visits with cooperators. These visits help DNR personnel better understand methods being used and staff often had advice to give the cooperator. We underestimated from the beginning the amount of time that would be required for professional staff to conduct on-site visits. In hindsight, it probably would have been better to have a couple more staff in order to be in the field more frequently. We also learned that it is often useful for the professional staff to manage the data sets, including quality control, data entry, proofing and analysis. Although a number of DNR staff volunteered to help mentor cooperators, providing some salary support for these people would have been helpful. It was also clear, that it should be mandatory that a

professional biologist or scientists should work closely with each cooperator to develop data forms and data recording techniques. A professional should also be involved in data analysis and report preparation. Otherwise, funds should not be disbursed. Although one of the mandates was to put as much money into grants as possible and minimize DNR personnel costs, going too far in this respect can jeopardize the quality of the work. Fishermen, particularly commercial fishermen, are by their nature independent and being so, they prefer to adjust methods as they encounter problems, just as they might during normal fishing operations. Sometimes this can jeopardize scientific methods. Having fishermen understand exactly what questions are being addressed, the need for consistent sampling and good record keeping would help make cooperative projects more valuable. Additionally, we believe that relatively frequent onboard visits by professional staff are valuable in keeping lines of communication open, adjusting procedures in a valid manner, and providing needed metadata for eventual data analysis and interpretation. Also, fishermen are typically not open to periodic progress-reporting meetings because they prefer to be working, but quarterly or at minimum semi-annual review meetings should be conducted.

This project was different from regional cooperative research programs, in that many relatively small projects were run instead of a few very expensive projects. This program also had a much higher diversity of types of projects and involved many more fishermen. South Carolina was particularly well suited for a project of this nature, given its diversity of fisheries and a relatively large contingent of scientists and biologists engaged in research and management who were available to assist.

We recommend that either state and/or federal funds be set aside annually to run various cooperative research projects. Not only do these projects improve communication between the fishing public and the managers, but they help the stakeholders feel more engaged in the process and the fishermen are more likely to “trust the data” and understand resultant management actions. Additionally, cooperative research projects can provide comprehensive data at a fraction of the cost that it would cost for state or federal scientist to take research vessels to sea to collect the same information.

Introduction

In 2004 the South Carolina Department of Natural Resources was awarded a grant to conduct cooperative research grant to provide information on existing and potential fisheries in South Carolina. This research was prompted by requests from fishing industry representatives who wished to see the commercial and recreation fishermen have a greater stake in the study and management of living marine resources. The project was undertaken in basically two phases. Phase 1 involved a Needs Assessment and Phase 2 took recommendations from the assessment and implemented cooperative research projects with the recreational and commercial fishing community members. Additionally, new research needs were uncovered over the course of the project and research projects were developed as opportunities arose.

This report provides an overview of the needs assessment and summaries of the projects that were undertaken. The research projects are grouped as Contractual projects and Grants. The Contractual Projects were largely specific programs that came out directly out of the Needs Assessment. DNR Cooperative Research personnel developed project outlines and then contracted with private parties, primarily commercial and recreational fishermen, to complete the tasks. For projects that were anticipated to exceed a cost minimum established by state law, a bidding process had to be utilized. We also solicited ideas for research needs and projects from the public. Because DNR does not have the authority under state law to issue grants, The SC Sea Grant Consortium was contracted as a subrecipient to administer a grant program for cooperative research projects. This proved to be a successful collaboration, utilizing Sea Grant's grant review and evaluation process and their Marine Extension agents brought valuable experience that greatly facilitated dealing with the fishing public.

Reports provided in this document are largely condensed versions of the full reports. More extensive information in the form of PDFs may be obtained through the authors at SC DNR.

Needs Assessment

The potential applied-fisheries, management-based research topics included those related to resource assessment, fishery biology, socio-economics, resource management, and sustainable harvesting technology. These research needs were to address potential projects for both commercial and recreational fisheries. The assessment took place during year one of the grant period with a report being competed in September 2005. Criteria used to evaluate potential research projects included the degree in which the proposed project:

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Methods

1. A committee of DNR marine fisheries management staff met internally several times and developed an initial list of research needs for state-managed commercial and recreational fisheries, as well as federally managed species in the EEZ.
2. DNR marine research scientists in the Marine resource Research Institute were polled for ideas and comments on the initially generated list of suggested research projects.
3. Staff met with the Executive Director of the South Atlantic Fisheries Management Council (SAFMC) and discussed research needs that could assist the Council.
4. The SAFMC provide a list of research needs developed by staff, the Science and Statistical Committee and the advisory committees.
5. DNR staff searched the various regional fishery management plans, technical committee reports and other documents of the Atlantic States Marine Fisheries Commission to glean needs and potential research projects.
6. Project staff evaluated the list of possible research ideas for practicality, relative importance of the related fishery, usefulness of the data to managers, likelihood for success, relative cost, and interest among fishermen (i.e., likelihood that fishermen would endorse the project and participate).

Results

The following were identified as general data needs that could potentially be obtained through cooperative research projects:

2. Shrimp Fishery
    a. **Sustaining an economically viable shrimp fishery** – Profitability in the traditional commercial shrimp trawler based fishery in the U.S. Atlantic coast has declined substantially since 2001. Economic factors contributing to this situation at the vessel (harvester) level include a major downturn in ex-vessel shrimp prices, rising operation costs (especially fuel), and increasing costs to repair ageing vessels. Consequently, aggregate fishing effort in the Atlantic shrimp trawler fishery has steadily decreased. *Therefore, there is a need for to develop sustainable harvesting techniques that include less fuel intensive ("passive") technologies (e.g. shrimp traps).*
    b. **Bycatch issues** – Several state and regional projects have examined species composition and magnitude of shrimp trawl bycatch, but questions remain about the representativeness of the data. Although a large number of samples have been taken, the diversity of variables make it difficult to adequately characterize bycatch for the entire fleet (vessel size, time of day, day vs. night, season, depth, net type, net size, latitude, distance from river mouths, experience of the captain, etc.) Short of a massive program, it is unlikely that additional studies of bycatch will add significantly to what is currently known and additional research on bycatch reduction devices is not a high priority for the industry. Also, with the decline in aggregate fishing effort, total bycatch mortality of finfish bycatch has probably declined substantially. However, an emerging concern is that declining finfish bycatch discard by shrimp trawlers may be negatively affecting coastal avian species that may depend upon bycatch discard for food. *Consequently, the DNR and other agencies are interested in knowing if a decline in the trawl fishery*

bycatch discard availability could have negative impacts upon sea bird populations.

c. **Shrimp disease** -- A condition known as black gill or brown gill syndrome (BGS) has become an annual issue of concern for white shrimp. Relatively large percentages of white shrimp (and some brown shrimp) have been observed with black gill condition during late summer and fall. Although biologists suspect this condition impairs oxygen/ carbon dioxide exchange, no obvious mass mortalities have been observed. In contrast, some commercial fishermen claim to have seen mortalities of shrimp (and reduced quality) and blame BGS. Many are convinced that this disease has affected abundance. Given the concerns about the effects of BGS, *DNR is interested in learning more about the geographic distribution of the disease, relative abundance, onset, duration, and impacts upon shrimp market quality.*

3. Blue Crab Fishery
   a. **Collection of Fishery Dependent Data and Characterization of the fishery --** South Carolina's commercial blue crab fishery has not been intensively studied through fishery-dependent field observations since the 1970's. Over time, the fishery has moved from one largely supplying local picking houses to being almost exclusively dependent on the live crab market (e.g., shipping to Virginia, Maryland) and associated price instabilities. *A new study is needed of the current harvesting and marketing methods employed in the crabbing industry.*
   b. **Socioeconomic Impact of a Limited Entry System --** DNR has been working with SC crab producers on a potential limited entry system for the blue crab fishery. *Socio-economic data could be used in analyzing the potential socioeconomic impacts of a limited entry (**LE**) system on participants in this fishery.*

   c. **Diamondback Terrapin Catches** – Diamondback terrapin are occasionally caught as bycatch in blue crab pots with some associated mortality. There are concerns about the terrapin populations. Experiments with turtle excluder devices (TEDs) that prevent turtles from entering traps show that catch rates can be decreased significantly. However, commercial crabbers have not been employed in testing TEDs. *A study of this nature using fishermen could dispel fears that that TEDs would reduce blue crab catches, and hopefully encourage fishermen to use TEDs voluntarily*.

4. Horseshoe Crab Fishery
   a. **Tagging studies** -- Horseshoe crabs are harvested by the thousands in South Carolina for the production of pharmaceuticals through controlled bleeding of crabs and subsequent return of the live crabs to the water. We are not aware of any serious problems with this fishery, *but more data on the survival and behavior of these crabs after bleeding would be very useful in judging the impacts on the population and the frequency at which crabs are recaptured for second or third bleedings.*

5. <u>Oyster Fishery</u>
    a. **Utilization of discarded crab traps as oyster substrate** -- Abandoned or lost blue crab pots are a persistent concern of the DNR. Pots may be brought to shore and discarded, but many are simply crushed and thrown back into the water or left on the bank. Others are lost because of cut buoy lines or displacement by storms or spring tides. DNR has observed that lost pots that end up in intertidal areas typically become covered with oysters and may form mini oyster reefs. *A study to examine the usefulness of using old pots as dedicated oyster settlement substrate could provide a use for old traps and help restore the oyster resource*.
    b. **Pond culture of oysters** -- Experiments in SC indicated that grow-out of oysters in brackish water ponds may be very productive. This approach has potential to provide large, marketable single oysters from local waters if SC Department of Health and Environmental Control (DHEC) would allow shore-side depuration of these oysters. *A feasibility study could provide valuable biological and economic data to determine the applicability of this method.*
    c. **Oyster/clam depuration facility** -- Currently, there is no approved land-based (shore-side) depuration facility in South Carolina. Such a facility could allow shellfish to be taken from restricted waters and cleansed of potentially harmful bacteria, thus making them acceptable and marketable for interstate shipment and human consumption. Associated with this is the potential for farming oysters and clams in high-ground brackish water ponds. *Creation of a DHEC-certified depuration facility could result in greater shellfish production and reduce imports.*
    d. **Field grow out of single oysters** – Some oystermen have had success in efforts to grow-out large, high-value single oysters in South Carolina through use of alternative attachment substrates. Others have expressed an interest in obtaining oyster seed from hatcheries and testing various techniques for intertidal and subtidal grow out of single oysters. *If disease and predation problems can be solved, grow out of large oysters in state waters could help reduce harvest pressures on natural, intertidal populations, could help reduce importation of oysters*.
    e. **Relay of single oysters** -- Large single oysters that do well in restricted (closed) areas could be transferred to clean water areas and depurated in cages or trays. *If this can be shown to be logistically and economically viable, this would allow the use of a valuable, existing oyster resource.*
    f. **Examination of Alternative Oyster Cultch materials** -- With the closing of oyster canneries in South Carolina, the production of high-quality cultch material was been reduced drastically. Biologists believe that lack of good cultch is an important limiting factor for continued propagation of the State's oyster resource. *Field testing of alternative cultch materials such as mined fossilized shell, marl, and other materials could provide sources of cultch.*
    g. **Development of "synthetic" cultch material** – *Manufactured materials that could be produced inexpensively to create oyster spat cultch could be important in helping sustain natural oyster populations.*

5. Hard Clam Fishery

a) **Depuration facilities** -- As noted above for oysters, creating depuration facilities for the utilization of clams from closed areas could be a boon to the shellfish industry. Some of the more productive clam beds are in areas closed to harvesting. *Reliable and certified depuration facilities may provide a means to use these underutilized renewable clam resources*.

b) **New type of mesh bag for clam mariculture** – The successful culture of clams in natural waters is largely due to the use of "Florida" mesh bags for grow-out. clams. While very successful, these bags are occasionally raided by blue crabs (and probably other crab species). *Development of a new bag material that is resistant to blue crabs, and possibly reusable, would be a significant contribution to the fishery.*

6. Octopus Fishery

a. Field testing of octopus fishing techniques – In the 1980's DNR successfully tested various octopus-fishing techniques. Economic hardships related to the shrimp fishery and other fisheries now make the octopus fishery more attractive and demand for octopus has gradually increased. *A new study to explore the potential for a small-scale fishery is recommended*.

7. Finfish Fisheries

a. **Evaluations of inshore and offshore artificial reefs** – The DNR spends considerable amounts of money on development and maintenance of artificial reefs. *Use of fishermen or fishing clubs in the evaluation of these estuarine reefs in terms of production of desirable fish catches is recommended.*

b. Establish a logbook survey for recreational anglers -- Estimates of recreational finfish catch is notoriously poor. Problems include recall error and the lack of details regarding harvesting sites and time fished. *Development of a recreational logbook program employing a cross-section of representative recreational fishermen could help address these problems.*

c. **Fish tagging study for Sciaenids and Flounder --** There is growing interests in the DNR and ASMFC with regard to flounder, spot, weakfish and croaker. *A cooperative study with recreational fishermen who target these species should be explored.*

d. **Utilization of recreational divers to assess fish species diversity and abundance** -- When collected in a routine and standardized manner, data collected by recreational divers can be used in stock assessments, frequency of invasive species, and could provide agencies (e.g. SAFMC) with insights into the usefulness of Marine Protected Areas and other regulatory approaches. *The use of volunteer recreational divers should be explored with local divers and clubs*.

e. **Characterization of the Flounder Fishery** – Questions have been raised about the health of the state's flounder stocks. Better information, particularly from the nighttime gigging fishery is needed to evaluate this resource. Data are also needed on flounder spawning and larval fish recruitment mechanisms. *Cooperative research should be explored with fishermen to evaluate the flounder resource.*

f. **At-sea evaluations of the health of released hook-and-line caught fish** -- A major concern for the SAFMC is mortality of released of hook-and-line caught fish. Relatively few data exist to address this issue. *A study involving fishermen in the "bandit fishery" could provide DNR with qualitative evaluations of released fish.*

g. **Shad fishery evaluation** – The department is dependent upon shad gill net fishermen to provide catch records of shad as well as bycatch such as Atlantic sturgeon or striped bass. The gill net fishing mortality on sturgeon and striped bass is largely unknown but is needed to properly evaluate stock condition and recovery needs. *Selected shad fishermen could be contracted to provide daily catch/effort data on shad and associated bycatch information.*

h. **Compare age and size of selected offshore reef fishes caught by Fishery-Dependent and Fishery-Independent Methods** -- Preliminary analysis of age and size of fishes caught by commercial hook-and-line fishermen and DNR traps indicates that the hook and line caught fish are often larger than trapped fish even though otoliths suggest they are the same age. *Discerning the differences between the two gears is critical in estimating growth and size-at-age for managed fish species and important to NMFS and SAFMC.*

i. **Evaluation of Mortality of Regulatory Discards in the Snapper-Grouper Fishery** -- A major issue in the management of offshore finfish in the snapper-grouper complex is the fate of discarded sublegal fish. *Computation of realistic fishing mortality rates is very important in development of accurate stock assessments.*

j. **Movement of Adult Cobia in Port Royal Sound** – Port Royal Sound is known for its high catch rates of large cobia during spring and early summer. However, little is known about the life history of this species in SC waters. *Satellite tags could be used to determine local and long-distance movements.*

k. **Migration of Dolphin** – Dolphin fish (mahi) are known to migrate extensively with tagged fish from South Florida being recovered off North Carolina and farther north. Some biologists believe there are two (or maybe three) stocks, with one being in the Gulf and western Caribbean and another in the northwestern Atlantic and eastern Caribbean. The use of satellite tags has not been used to examine movements of this species. Satellite tags could be employed to determine their practicality with this species and to learn about migratory patterns.

l. **Temperature stratification in nearshore waters of the Grand Strand** – In July 2004 a hypoxia event occurred in Long Bay, SC. As a result, flounder moved nearshore and were caught in unusually high quantities -- some being taken by hand in the surf. Other fish species apparently evacuated the area. Additionally, there is concern about the fate of nearshore live bottom communities that probably provide important marine habitat. *Efforts should be made to monitor water temperatures and dissolved oxygen in the Long Bay area.*

m. **Develop Baseline data for proposed Marine Protected Areas** —The SAFMC is likely to designate areas off the Southeastern coast as Marine Protected Areas (MPAs). These areas have tentatively been selected, but relative little baseline data exist on fishery resources in those areas. *Data are needed to assess the status of the fishery resources in these areas.*

n. **Compilation of Fishery-Related Historical Changes and Local Knowledge** — There is a need to collect historical information as metadata in order to facilitate the analysis and documentation of post-WWII fishery trends (e.g. changes in fishing capacity due to adoption of new technology) and fishery history. *Personal interviews to collect historical and local knowledge can be used to secure the history of commercial and recreational fishing in South Carolina.*

Cooperative Research Projects

Cooperative research project accomplished in this grant can be roughly divided into two types – contracted projects and grant-funded projects. Contracted projects largely represent those that arose from the needs assessment. Project personnel developed conceptual ideas and then talked to fishermen, divers, and others to determine the practicality of conducting the various research projects. When grants were deemed appropriate, project scopes were developed and contracts were developed. State procurement guidelines were followed in advertising and awarding contracts. Projects were reviewed by National Marine Fisheries Service staff to assure NEPA compliance.

In an effort to allow private commercial and recreational fishermen to develop their own ideas about cooperative research projects, grants were awarded to selected individuals. South Carolina DNR does not have legal authority to provide grants, but the SC Sea Grant Consortium (SC SGC) does. As such, DNR developed a sub-recipient agreement with the Sea Grant Consortium to administer cooperative research grants. This involved joint-development of grant guidelines and recommended research areas. DNR and SC SGC staff worked together to develop a request for proposals. Brief pre-proposals were first solicited and reviewed by DNR experts and SC SGC staff. Over a two-year period, a total of 78 pre-proposals was submitted. A subset of 34 pre-proposals was approved for full proposal development. Full proposals were reviewed by DNR and SC SGC staff based upon predetermined criteria. A total of 23 full proposals was accepted for funding. Investigators were strongly encouraged to partner with a scientist of marine biologist to assure that methods were scientifically acceptable.

Contracted Projects

1. Characterization of the Offshore Spear Fishery for Flounder and Collection of Biological Data on Southern Flounder

By Brad Floyd (SCDNR)

Project Period: Sept 2007 to March 2009

Project Justification and Goal

In South Carolina, the primary flounder species targeted by recreational and commercial fishermen is the southern flounder, *Paralichthys lethostigma*, and to a lesser extent the gulf flounder (*P. albigutta*) and the summer flounder (*P. dentatus*). The flounder fishery in South Carolina is predominantly recreational, conducted primarily in estuarine and near shore waters. While gigging and hook and line activities dominate this fishery, spear fishing by divers may play a role in some areas along the coast. Information on flounder age and growth of adult stages and maturity is adequately available and some information exists on early life history and

environmental aspects of flounder ecology. However, there is a lack of knowledge about flounder reproduction, in particular spawning locations. Based on the occurrence and age of larvae, the age of juveniles collected in nursery areas, the migration of adults, and natural spawning in captivity, it is known that the spawning period of the southern flounder in this region is from December through March. Adult flounder migrate from estuaries and near shore areas, where they reside from late spring through the fall, to offshore areas during the winter spawning period. Once spawning grounds are known it will be possible to assess the potential effect fishing may have on the spawning flounder population and subsequently on spawning potential. In addition, information on spawning locations is important in the understanding of transport of eggs, larvae, and juveniles to nursery areas, and the subsequent survival to adulthood and recruitment to the fisheries. The project objectives were 1) to characterize the offshore flounder spear fishery, including species composition, seasonality, size distributions, and catch per effort data; 2) to collect biological data on flounder harvested in the offshore fishery, including gender and reproductive stage; and 3) to locate spawning locations for Paralichthid flounder off of the SC coast.

Methods

Flyers were placed in four dive shops along the SC coast to recruit offshore spear fishermen who target flounder. Volunteer divers were selected and contracted to provide dive trip observations and flounder racks. Divers were asked to fish the areas they typically dive. However, most activity in this fishery occurs in the northern portion of the state, so sampling was concentrated in this area. Dive trips were reported in person, via email and phone calls. When flounder racks were collected, they were frozen in plastic bags with tags documenting the date, location, and diver. Divers were compensated monetarily per dive trip and were paid whether or not they encountered flounder. All biological samples were brought back to the lab for processing. Each rack was thawed and identified to species. Total length (TL) was measured and otoliths were removed. Sex was determined by observing the gonads and a sample of gonadal tissue was taken for histological processing.

Results and Conclusions

Eight cooperating spear fishermen provided 108 dive reports and 183 flounder samples from Sept 2007 to March 2009. Additionally, 41 dive trips were conducted by SCDNR resulting in 87 flounder and two fish were provided by recreational hook and line anglers. The range of dive depths was 5 to 58m. Sampling was conducted every month with the majority of trips occurring in October, March, and May. The majority of samples was collected within 35 miles of the coast and primarily off the northern part of the state. Of the 270 collected flounder, 167 were Gulf flounder (61.8%), 83 were southern (30.7%), and 6 were summer (2.22%). 14 were recorded as unidentified flounder (5.19%). This differs from the inshore gig fishery where approximately 99% of the fishery is southern flounder. Southern flounder were found all along the coast and in all months of the year except December, February, and March. Since it is known that southern flounder migrate to offshore waters in winter to spawn, it is hypothesized that they are migrating to depths greater than those sampled here. The largest numbers were observed during October and May which corresponds with emigration from the estuaries. However, these elevated numbers may be misleading because of increased sampling efforts during these months. Gulf flounder were also found widespread along the coast with samples collected every month except April. Summer flounder was found only in Long Bay and in

January, June, July, and October. Lengths ranged from 251-778mm (mean = 456±4.5). Mean length of southern flounder was largest (482±6.0mm) followed by Gulf flounder (446±5.9mm) and summer flounder (378±27.1mm). Monthly size differences were not detected in any species. Only the dives conducted specifically by SCDNR staff could be confidently used to estimate catch-per-unit- effort, but the sample size was too small to be useful.

By species, 81% of Gulf flounder, 98% of southern and 100% of summer flounder were female. 62% of all flounder histological samples were classified as "developing," meaning that they were not close to spawning. Only 8 individuals (all *albigutta*) were identified as running ripe (within 24 hours of spawning). These specimens were collected in the months of December, January and February at depths ranging from 20 to 30 meters with a bottom temperature of around 13°C. Large spawning aggregations were not found by DNR divers, although one cooperative spear fisherman described a large aggregation of flounder exhibiting what could potentially be spawning behavior in November. Three samples were processed from this location. Two were male and the one female was identified as running ripe. No southern or summer flounder with ripe gonads were collected. The majority of southern flounder with developing gonads were collected during October and November by recreational anglers.

Results from this study indicate that southern flounder may be present in offshore waters year round – albeit not as abundant as Gulf flounder. Studies in NC have documented the presence of southern flounder in offshore waters during all 12 months. It is generally assumed that the majority of southern flounder moves to estuarine waters in spring and remain there until the fall when migrations to offshore spawning grounds begins. The harvest of southern flounder in SC waters occurs primarily in inshore waters.

Spawning habitat or locations for southern flounder were not identified. It is hypothesized that southern flounder may potentially be migrating further offshore to greater depths than were sampled in this study. Reproductive activity of summer flounder was also inconclusive; however, none of the collected summer flounder was in spawning condition. The eight gulf flounder identified as "running ripe" were collected in winter at depths ranging from 20-30m with a bottom temperature of 13°C. Anecdotal information from cooperating spear fishermen suggests that possible spawning aggregations of flounder may be associated with sandy bottom habitat located in close proximity to artificial reefs and ledges. Artificial reefs may provide a source of food or cover between spawning events. Cooperating anglers have also described flounder feeding beneath schools of sardines and/or anchovies in offshore waters. Learning more about the behavior and locations of schooling sardines and anchovies may lead to understanding more about flounder spawning grounds.

2. Feasibility/Pilot Study for Under Dock Oyster and Clam Culture

by Nancy Hadley (SC DNR)

Project Period: December 2007 – November 2008

Project Justification and Goal

Homeowners with dock in coastal waters have expressed interest in growing their own oysters and clams. Personal oyster gardens are awkward under state law because shellfish on the bottom are considered a public resource (unless that bottom is a Culture or Mariculture Permit area under control of a permitted fisherman). Any area open to harvesting is available to licensed citizen. An under dock program where oysters are contained in enclosures would allow personal ownership thus providing a method for a riparian landowner to grow his or her own

shellfish. Not only does this provide shellfish for the land owner, but it helps reduce fishing effort on wild stocks and gives the land owner a more personal stake in seeing that the water quality is maintained in good condition. The goal of this project was to initiate a pilot project to evaluate the feasibility of a recreational shellfish aquaculture program in South Carolina and to determine if it could be used as a tool for increasing responsible stewardship of coastal waterways. The objectives of the pilot project were:

- to determine if there is public interest in such a program;
- to evaluate if methods used in Virginia for oyster gardening work in South Carolina;
- to evaluate how much time participants need to devote to an oyster garden;
- to evaluate what growth and survival rates might be expected;
- to determine potential problems and develop recommendations for circumventing those;
- to determine whether citizens with a minimal amount of training could successfully grow shellfish in low-tech culture systems;
- to develop an application and permit process; and
- to develop a training program and manual.

Methods

The program was limited to 12 participants (although we ended up with 14 locations, one participant being an organization which had 3 locations available). Participants were selected based on location and interest. We wanted to represent a range of conditions and as much of the geographical range of the SC coast as possible. Participants were required to have a dock in Approved Shellfish Harvesting waters. Participating sites ranged from Awendaw to southern Beaufort County.

Participants agreed to attend a workshop and to collect data and maintain records during the 1- year study. A manual was prepared for distribution at the workshop and participants were given basic information on oyster biology, water quality, and human health concerns. They constructed their own culture cages and developed their own methods for deploying them. All cages were constructed of stiff plastic mesh and were basically shallow boxes. Participants were provided with all materials for cage construction and deployment (ropes, anchors, etc.).
One participant grew hard clams but all others grew oysters. The data reported here are from the oyster growers. Oyster spat were procured from Island Fresh Seafood and averaged 30-35mm shell height (SH) at the start of the study. The seed was received in two shipments in December 2007. One shipment was deployed in Beaufort County and one in Charleston County. The oysters deployed in Beaufort were larger but had thinner shells than those deployed in Charleston. Deployment methods were quite varied and included: suspending the cages from one or more lines at varying tidal heights, floating the cages, tying cages to floating docks, and placing cages directly on the bottom. Fouling was controlled by air-drying daily at low tide, air-drying weekly or bi-weekly by removing cages from the water, pressure washing as needed, flipping floating cages so one side would dry.

Results and Conclusions

The initial December 2007 shipment of seed had survival rates of 30-50% while the second shipment had survival rates >70%. Growth rates were variable and are not strongly related either to batch of oyster seed or to any environmental parameters or site characteristics that we measured. Growers reported varying degrees of success with the various deployment methods.

A blog was created for sharing experiences but the growers did not make much use of it. Growers submitted water quality data fairly regularly but were less conscientious as the project progressed. Growers did not measure their oysters as often as requested and many did not follow sampling guidelines or did not supply raw data. For comparing sites all growth data has been expressed in mm/month but this is not a perfect solution since growth rates vary seasonally. Growers were offered an online spreadsheet for entering growth data but it was a clumsy solution to sharing data and was abandoned by all after a month or so of frustration. Participants were asked to complete an "exit survey" in November 2008. Only 50% of participants completed the survey. Of those who completed the survey, 67% were satisfied with growth, 100% were satisfied with survival. When asked to rate the experience on a scale of 1 to 5 (1 being low), most participants rated it '3' with one rating it '5'. All participants said the experience was educational and 67% indicated they would apply for a permit to continue doing it. Only one participant had consumed their product at the time of the survey which was administered in November 2008. Most were waiting until January or February to consume their oysters. Most indicated their oysters were still a little small for consumption. Participants spent between one and six hours per month on the project, much of that in measuring water quality. The most common problems reported by participants were overspat and fouling. No problems with predation were reported. Growth rates were lower than we had anticipated but this may be largely due to the fact that oysters were obtained in the winter. Ideally oysters would be stocked in the early fall. Growth rates ranged from <1 to 5.5 mm/mo. This means that oysters obtained at an average size of 30mm will require about 12 months to reach eating size. Survival of one batch of oysters was very high (in some cases 100%) while the other batch, which looked stressed when received and had thin shells, had much poorer survival (<50%). Two participants lost culture containers during the study and it is not clear whether this was poaching or a failure to secure the container adequately. We anticipated problems with fouling organisms, predators, and overspat. There were no reported predator problems. Fouling organisms were a problem for some growers who apparently made no effort to clean cages or to dry them regularly. Those who dried the cages and/or cleaned them did not have problems. The overspat was the biggest problem and those methods which were tried to circumvent it did not work. Many participants had difficulty with their deployment systems and would likely change their methods if given a permit. Most participants found the project more time consuming and more labor intensive than expected. Most confessed to spending more time on it in the beginning than towards the end. Cages were considered a little flimsy but this is probably due to failure of the growers to thin the oysters as they grew. One participant modified the cages to a more cylindrical shape which increased strength and made them easier to hang.

A manual which includes information learned during the pilot study was developed which will be available online or distributed at training workshops. After reviewing the manual or taking the workshop, potential participants will take a test. Successful completion of this test is a pre-requisite to getting a permit for recreational shellfish aquaculture.

3. **Pilot Study Using Pop-Off Satellite Tags to Monitor Dolphin (Corypheana hippurus)**

By Donald L. Hammond, SCDNR

Project period: 1 January 2005 To: 31 March 2006

Justification and Goal

Although reasonable numbers of East Coast dolphin have been tagged with traditional fish tags and relative abundance studies have suggested apparent migratory behavior, there remains much to be learned about the migratory behavior of dolphin. Additionally, little is known about daily behavior related to vertical movement, depth or temperature preferences. The goal of this study is to use explore the usefulness of pop-off satellite tags for learning about dolphin behavior.

Methods

Private recreational fishermen who were experienced in the application of conventional streamer tags on dolphin were solicited to implant satellite pop-off archival tags in large dolphin. Large fish were targeted because dolphin are relatively fragile and the relatively large size of the tag required a large fish. Tags were provided to two anglers fishing in the Florida Straits, three in South Carolina, and one in North Carolina. Another tag was provided to a biologist with the North Carolina Division of Marine Fisheries for deployment off Cape Hatteras. The Microwave Telemetry model PTT 100 HR archival tag with geo-location capabilities was utilized. This tag is 34 cm long and weighs 68 g. The sensing device records time specific temperature, pressure and light intensity every 3 to 4 min. It was programmed to release itself from the fish after a 30-day period. Volunteers were asked to tag fish of 13 kg or larger. Subsequently, only one tag was deployed during the 2005 fishing season. This tag was deployed off Charleston on June 4 by the charter boat *Tag Team* captained by Howard Mosley. The male fish was released approximately 157 km due east of Savannah, GA in waters 136 m deep. After the tag releases from the fish and rises to the surface, it transmits to an Argos satellite which relays recorded information to a receiving station until the tag's battery dies. Data are subsequently forwarded electronically to the researcher.

Results and Conclusions.

The tag surfaced prematurely 10 days after being attached to the dolphin, June 13th, roughly 167 km due east of Isle of Palms, SC in 274 m of water. Pressure data indicated that the fish was at 26.9 m when the tag separated from the fish. Upon first contacting the satellite, the instrument was located 146.9km ENE of the release site in 274 m. It is unknown why or how the tag separated from the fish, but similar problems have been encountered by other projects using this type tag. The tag initiated downloading data to the Argos Satellite system on June 17, 2005 at 19:44 EDST and continued transmitting until July 22, 2005.

Temperature and depth data were recorded for 213 hours after tag deployment. 2,482 time-specific readings documented temperature and depth for 64 % of the tracking period. Gaps in data records were generally less than 30 minutes each. Depth, light intensity and temperature were recorded from 43.6 to 78.1 % of each day.

The fish made dives as deep as 74 m and moved through waters that ranged from 19.6ºC to 27.1ºC. The fish exhibited both extensive and rapid vertical movement in the water column. Such was the case on June 5th when it traveled from the surface to 56.5 m in 3 minutes.

The fish used a wide range of depths and the portion of time spent at a particular depth varied day to day. Overall, however, the majority of time was spent at or near the surface. The

proportion of time at the surface ranged from 16.2% on the day it was tagged to 94.3% on June 12. The single longest period spent in the surface waters was 15.1 hours on June 10th. Overall, the fish spent an average of 63.1 % of its time within 10m of the surface, however, on an individual day it may have spend up to 84% of its time below 10 m.. Considering each day individually, the dolphin spent substantially more time in shallow water than deep on 7 of 10 days. On only one day did the fish spend more time below 30 m than above. Considering diurnal differences, the fish spent 61% of its time less than 10 m during daylight, but only 44% during darkness. Interestingly, however, the deepest dive (to 74 m) occurred during daylight. The dolphin did repeat one movement every morning. At first light, the fish would always rise to the surface layer. This initial visit to the surface ranged from 4 minutes to 16 hours before making a sustained descent. The fish remained in the surface layer for an average of 2.3 hours each morning during this initial rise.

Temperatures utilized by the dolphin ranged from 19.6 to 27.1ºC during the monitored period. The largest variation for a single day was 19.6 to 26.2 ºC, on June 6th. The average daily temperatures used by the fish ranged from 22.1 to 26.5ºC with an overall average of 24.9ºC. Over 87% of all temperature observations were between 23.0 and 26.7oC. The lower temperature recordings were usually associated with the deeper depths while the highest temperatures were normally observed at the surface.

Data acquired from this short-term monitoring of a male dolphin reaffirm it as an epipelagic species, spending the majority of its time at the surface. This study provides the first insights into the daily water column usage by the species. It has shown that this specimen spent almost a third of its time below 20m and visited waters as deep as 74 m. There was no evidence that the fish descended all the way to the bottom since the release as well as the recovery sites were more than 60m deeper than the deepest recorded dive. Temperature observations support the dolphin as a warm-water subtropical species.

These data provide the record track of one fish for a short period off South Carolina made during June 2005. It cannot be assumed that data collected from this fish are representative for the species as a whole. However, it does provide the first information on vertical water column movements and temperature selection by a dolphin over a multi-day period off the South Carolina coast.

Additional tagging studies should be conducted to fully evaluate dolphin behavior. The tag attachment system needs to be adjusted to be more compatible to the species and to aid in preventing premature separation from the fish due to anchoring failure.

4. Pilot Study Using Pop-Off Satellite Tags to Monitor Cobia (*Rachycentron canadum)* Captured in Port Royal Sound

by Donald L. Hammond, SCDNR

Project period: June – August 2005

Justification and Goal

Cobia (*Rachycentron canadum,* is a highly prized game fish that is targeted heavily by recreational fishermen during spring and early summer in Port Royal Sound, SC, St. Helena Sound, SC and offshore along the entire length of the South Carolina Coast. Fishing pressure on this resource has been increasing recently, particularly in Port Royal Sound. This high density fishery, primarily in Broad River, attracts numerous private anglers as well as charter boats. Several fishing tournaments are also held annually in Port Royal Sound. This rising rate of

fishing mortality in Port Royal Sound has raised concerns among local anglers as well as fishery managers. Preliminary research suggests that at least some portion of these large fish is spawning in the Sound (eggs and larvae have been collected). There is also evidence that hatchery spawned and released fish are returning to Port Royal after a year at sea. Adult fish apparently arrive in the Sound in April and emigrate into the ocean in June or early July. This migratory behavior has been surmised largely by the lack of fishing success after June. The goal of this study was to determine migratory behavior of Port Royal Sound cobia in the weeks after leaving the sound through the use of pop-off satellite tags.

Methods

Personnel carried out the worked in cooperation with the Port Royal Sound Conservancy and the Hilton Head Sportfishing Club. The latter organization provided financial support to this study purchasing two of the six satellite tags. Mr. David Harter organized and coordinated a two-day fishing effort, June 6 and 7, 2005, using volunteers to capture cobia in the Broad River of Port Royal Sound to implant satellite pop-off archival tags. This coordinated fishing effort resulted in 10 private vessels participating the first day and about five vessels the second day. A volunteer boat also provided transportation for DNR biologists to the vessels capturing cobia for implantation of the tags. A minimum size of 110 cm fork length or a weight of 16 kg were set as the minimum size for a fish to be considered for tagging.

The one cobia tagged was captured using standard recreational fishing gear. It was caught using natural bait fished on the bottom utilizing a circle hook which resulted in the fish being hooked in the corner of its mouth. A hose dispensing saltwater pumped from surface waters was placed in the captured fish's mouth during the tagging procedure. This was done to provide water flow over the gills in an attempt to provide oxygen to the fish while out of the water. A Microwave Telemetry, Inc. model PTT-100 HR archival pop-off satellite tag was attached to the fish. The tag was attached by making a 1-cm incision in the skin covering the dorsal musculature and then inserting the tag anchor through this opening to reduce trauma to the tissue. The tag was placed approximately 1/3 of the body length behind the head. The Microwave Telemetry, Inc. model PTT-100 HR archival pop-off satellite tag was programmed to monitor environmental parameters for 30 days from time of deployment. These instruments are set to record ambient light level, water temperature, and pressure every 1 to 6 minutes. The manufacturer reports that the instrument has an accuracy level of +or - 0.2º C for temperature and + or – 0.5 m for depth. After the tag releases from the fish and rises to the surface, it transmits to an Argos satellite which relays recorded information to a receiving station until the tag's battery dies. Data are subsequently forwarded to the researcher.

Results and Conclusions.

Although other attempts were made to tag additional fish, only one fish was successfully tagged in this inaugural effort to satellite-tag adult cobia. The tagged fish had a 136-cm fork length which indicates that it was probably a female since males have not been reported to reach that length. It was estimated to weigh 28 to 30 kg. Capture and subsequent release occurred in the Broad River approximately 300 to 400 m east of the highway 170 bridge (N32º 23.150', W80º 46.607'). Water depth was about 13 m at time of release at 10:00. When returned to the water, the fish swam off slowly in a normal manner.

The PTT-100 HR archival tag comes pre-programmed to automatically release from the fish if the tag remains at a constant depth for 4 days. This feature was intended to allow tags to

release early from fish that had died. However, the manufacturer defined constant pressure as being within a 20 meter depth range. During the 5.5 day period that the tag was attached, the fish remained in shallow water with its deepest dive of 21.5 m occurring in the last few days. This resulted in the premature release of the tag from the fish due to activation of the early release software in the tag.

Water temperature, water pressure, and daylight intensity were recorded every 3 to 4 minutes for 132 hours. Pressure data indicated that the cobia remained near the surface (within 4 m) for the first 25 minutes post release, before sounding to 8.1 m and began a series of vertical ascents/descents that increased in amplitude, but remained at least 2.7 m below the surface for 29 minutes. The fish then began irregular movements between 10.8 m up to 1.3 m for the next 90 minutes. However, the fish did not rise fully to the surface until 2 hours and 40 minutes following its release. From this time until sunset the fish rose to the surface on 29 occasions with intermediate dives to as deep as 12.1m. At sunset on June 6, the fish sounded and remained between 12 m to 4 m until midnight. The fish did not visit the surface again until 12:42 AM and then made four additional ascents to the surface before sunrise.

Data indicated that the cobia made regular visits (above 2 m) to the surface only during the first two days following tagging. The fish rose to the surface on 93 different occasions during June 6 and 7 with 88 percent of these occurring during daylight hours. On June 8, the fish did not move to the surface-rising no closer than 4m. After sunset on June 9, the fish rose to the surface on four occasions before midnight and six times between midnight and sunrise on June 10. The fish continued this behavior in to the daylight hours, rising to the surface four times before 8:00 AM.

Roughly 40 minutes after sunset on June 9 the fish rose to within 1.3m of the surface. This was the first of 14 vertical movements of 10m+ that the fish would make before midnight. This pattern of rapid vertical movement continued into the morning hours (June 10) with 24 ascents before daylight and 10 additional ascents from sunrise to 8:00 AM. After 8:00 AM the fish dove to 17.5m and remained there (within 2m) until just after 8:00 AM on June 11. After this extended period at depth, the cobia began a series of vertical movements that continued until sunset. Following sunset, the cobia dove to 18.8m remaining between this depth and 15 meters when the tag released itself at 9:56 PM. The tag made first contact with the satellite approximately 5 hours later at a position of N31.963 latitude and W80.512 longitude.

During the first 29.5 hours following its release on June 6th, the cobia stayed in waters of 26.1 to 26.9ºC. Just after 4:00 PM on June 7th, the fish began making progressively deeper dives encountering temperatures of 24 to 25ºC. Continuing its gradual descent, it reached depths of 16 to 17.5m at 10:00 PM entering waters of 23.0 to 23.7ºC. A dive to 15 – 19 m coincided with the lowest temperatures recorded at 22.7 to 22.9 ºC.

Although these data are from a single fish for less than a week, they provide the first accurate data of daily activity of a live cobia from Port Royal Sound. During the first 29.5 hours when the fish remained in >26ºC, it is likely that the fish was either in Port Royal Sound or in the Sound's water mass as it ebbed from the bay. During this period, the cobia seldom went deeper than 12m with a maximum 16.1m. The maximum depth for Port Royal Sound proper as indicated by NOAA charts is 16.5m with a hole at the entrance to the sound reported to be 20.1m

On the evening of June 7th the fish either moved out of the sound or cooler water entered the sound because observed temperatures declined to as low as 23.1ºC. However, water temperatures recorded at the Waddell Mariculture Center on the Colleton River, a tributary of Port Royal Sound, were 27.7ºC on June 6th and 28.5ºC on June 15th, indicating there was no

obvious decline in the Sound's temperature. Data from the Cara-Coops weather buoy located 6.5 km offshore of Fripp Inlet indicated that temperatures at 11.1 m depth ranged from 23.5ºC to 24.5ºC , thus supporting the notion that the fish had moved into the ocean.

The heightened vertical movements noted on the night of June 9/10 could have been associated with spawning activity since a similar behavior has been reported from cobia spawned in holding tanks (Al Stokes, personal communication, 2006). He reported that cobia were more active in their swimming during spawning activity - spending most of the time at the surface and then settling to the bottom of the tank following spawning.

While the information presented here is very interesting, no hard conclusions can be made from this brief look into cobia behavior. The one solid piece of information this study does provide is that there is real potential to use archival satellite pop-off tags for gathering never-before-available information on the life history of cobia. Additional tagging studies should be conducted to fully evaluate cobia behavior.

5. Characterization of Recreationally-Caught Adult Red Drum Stocks in Port Royal Sound SC

By David Harter and Glenn Ulrich, Hilton Head Reef Foundation

Project Period: August 2007- March 2009

Project Justification and Goal

Stock assessments for the recreationally important red drum (*Sciaenops ocellatus*) rely primarily upon recreational fisheries data (MRFSS) and to a lesser degree on fisheries independent data. While relatively large data bases exist on juveniles, adults sampling has been limited to some studies conducted off Charleston. The ASMFC and state biologists have noted the critical need to have better data on adults including spawning stock size, recruitment rates to the spawning population and migratory behavior. The goal of this study is to augment existing SCDNR studies of adult red drum to examine adult red drum population characteristics (relative abundance, size composition, movements and stock mixing) in the Hilton Head/Port Royal Sound area through cooperative sampling with area charter boat captains. Objectives included: a) develop a network of cooperating charter boat captain to assist, b) maintain effective levels of sampling through direct participation by the co-PI in tagging activities, and frequent contact with captains and the local fishing community, c) develop a fishery-dependent index of abundance for red drum, d) to measure and tag adult red drum, e) collect fin clip samples for DNA analysis, and f) provide reports to the HHRF and DNR.

Methods

Sampling was accomplished with the use of Hilton Head Island charter and private recreational boats that target adult red drum, primarily during the fall run of post spawning adults as they initiate offshore migration. A core group of cooperators was trained in tagging procedures. The co-PI accompanied the volunteers to insure uniformity and to provide additional training. Frequent contact was be maintained with captains to check progress and to review data sheets. It soon became apparent that most charters did not carry a mate, thus making tagging very difficult. As a result, most tagging work was limited to trips in which a PI could be present. Partial payment for directed trips was provided to offset expenses to the captain. Data collected included number of anglers, rods fished and time fished; fishing location; fishing mode (anchor, drift or troll); and physical environmental condition. All fish were measured (FL and TL) and

drumming was noted to indicate males. Running ripe males were noted. Adult red drum (>70 cmTL) were tagged with two types of tag: an external dart tag (Hallprint 15-cm nylon) and a PIT (passive integrated transponder/ microchip tag). A small piece of fin tissue from the tip of the anal fin was taken for DNA analysis by SCDNR. If a fish had difficulty submerging, it was retrieved with a dip net and a hypodermic needle was inserted into the swim bladder to release gas buildup.

Fishing was generally done while at anchor with 4 to 6 rods being used. A 3-5 foot leader of 50-100 pound test and a 10/0-14/0 circle hook was employed. GPS was used to locate anchoring sites. Most captains preferred to use live menhaden or thread herring as bait. The most effective fishing time was 1-1.5 hours on either side of low tide. Spring tides were relatively unproductive times for fishing. "Bird fishing" was found to be highly effective. This including finding diving birds and dropping baits quickly in that area. All fishing was done in Port Royal Sound and Caliboque Sound.

Results and Conclusions

A total of 53 sampling trips occurred with 23 in Oct-Jan 08 and 30 in Sept-Jan 09. 156 adult red drum were captured, 77 and 79 in 2007 and 2008, respectively. Of the 156 fish, nylon dart tags were placed in 146 and PIT tags were placed in 111. The average length of was 988 cm TL (range = 726 to 1155 cm). The modal length was 1050 to 1099 cm. In incidence of drumming was 21.1% with 78.8 making no sounds (not all males will drum). Although circle hooks were used, the incidence of deep hooking was 14.7%. Most deep hooking seemed to take place at slack tide or when the wind and tide were in opposition making it difficult to fish with a taut line. Catch per unit effort (CPUE) was 3.35 fish/trip in 2007, 2.63 in 2008, and 2.94 overall. The change in CPUE was attributed to differences in water temperature. In this study, 23 of 156 fish (14.7%) were deep hooked. This was a higher rate than expected. This seemed to occur most frequently at slack tide when it was difficult to keep the lines taunt. Shorter leaders should help address this problem.

Starting in 2005, DNR began tagging adult red drum in the area. 316 adults were tagged through 2008 and the current study tagged 146. The total tagged red drim in the area is currently 462. To date, only one fish has been recaptured representing a 0.2% recapture rate. Charleston Harbors recapture rate is currently 4-6%. Given the high rate of fishing effort, the results may be indicative of a large adult population.

Because of the variety of fishing trip types (charter vs. noncharter, directed vs. non-directed, anchored vs. "birding," assessing overall catch rates can be challenging. The highest single trip was when "birding" and 20 fish were collected (more could have been caught but get fishing tagged slowed operations). Bottom fishing trips ranged from 0 to 12 fish. Catch per unit effort (cpue) in 2007 (October - January) was 3.35 fisher per trip. In 2008, cpue was 2.63 and both years combined was 2.94. Removing the bird fishing trip in 2008 yields a 1.97 cpue and a 2.57 cpue for both years combined. The decline in 2008 is most likely related to an earlier drop in water temperature, causing fish to emigrate from the sounds. In 2007, water temperature remained at 58 F as late as December 18, whereas temperature in 2008 dropped to 54° F by December 3.

This study is a good example of a cooperative effort utilizing the charter industry and private boat partners to collect fishery dependent data on an important recreational species. Utilizing the expertise of charter captains and local anglers and their vessels provides a cost effective means to expand the data base for adult red drum in the Hilton Head/Port Royal Sound

area. Additionally, conducting the study in the Hilton Head/ Port Royal Sound expands our knowledge of an area that is important but has historically not been studied as much as other South Carolina coastal areas.

6. **The Flow of South Carolina Harvested Seafood Products through South Carolina Markets** By Mark S. Henry(Clemson University), Raymond J. Rhodes (College of Charleston) and Daniel Eades (Clemson University)

Project Period: 2008

Project Justification and Goal

The South Carolina (SC) seafood market place has changed markedly over the last 30 years. Technological changes (e.g. expansion of modern mariculture technology in China and Vietnam, use of brine freezers on SC trawlers, etc.), shifts in consumer demand (e.g. increased seafood consumption away from home), and retail consolidation have reshaped the traditional market relationships between producers, processors, wholesalers, retailers, and food service outlets. The most recent research on South Carolina seafood market channels was conducted in 1972. Consequently, only fragmented and sometimes questionable anecdotal information exist regarding SC seafood market channels and the effects market place and regulatory changes. The goal of this report is to provide a current view of SC harvested seafood product flows.

Methods

To characterize and quantify the flow of major South Carolina marine harvested seafood products through market channels, the report summarizes research that: 1. Defines and describes major South Carolina market channel members and their role in the flow of major marine South Carolina seafood products and applicable substitutes imported into the state. 2. Estimates the flows (i.e. quantities and market level value) of South Carolina's major harvested seafood products and related substitutes. 3. Summarizes seafood market knowledge from key South Carolina market channel members on product flows.

The research proceeded in the several phases. First, a SC seafood industry focus group and other sources were used to document the role of SC major market channel members. Second, a sample survey collected product flow data and other information from SC retail and restaurant market channels. Data sources for identifying the population of market channel groups to be surveyed included the South Carolina Department of Natural Resources (SCDNR) license records, telephone directories, the Harris *Infosource* database, and Internet based seafood supplier lists. SCDNR aggregated data regarding annual seafood landings were also reviewed.

Results and Conclusions

In South Carolina a person or business that buys or handles saltwater species landed in South Carolina must purchase a "wholesale seafood dealer license." Using the SC trip ticket system, these licensed seafood dealers are also required to routinely report on seafood sold to them by SC harvesters. Landings value (Inflation adjusted ex-vessel values in constant 2007 prices) was cyclical around $40 million throughout the 1980s and 1990s. A few years were about $10 million above this benchmark (1980, 1982, 1983 and 1995), and a few years were about $10 million below (1984, 1985 and 1995). In sharp contrast to this cyclical pattern, a steady downward trend in the real value of landings took hold in 2000 with landings declining from about $37 million to about $15 million in 2007. This decline is, in part, a result of the

lower profitability of owning and operating fishing vessels related to substantial increases in the cost of diesel fuel and declining prices for many seafood products.

In 2007, annual seafood landings in South Carolina were comprised of a wide variety of finfish and shellfish. The total nominal ex-vessel value was $15.574 million with shrimp comprising about 29% of the total and various "offshore" finfish accounting for 26%. The 4.1 million pounds of Blue Crab landings made up 44.1% of the 9.1 million pounds of total landings and ranked second of all species in value. The top ten species ranked by value in 2007, were: 1. Shrimp, 2. Blue Crab, 3. Eastern Oysters, 4. Grouper, 5. Scamp, 6. Snapper group, 7. Clams, Northern Quahog, 8. Hind, 9. American Shad, 10. Leatherjackets

The most recent Census of Aquaculture in 2005 found the total number of aquaculture farms expanding from 27 in 1998 to 85 in 2005. Estimates from Clemson Univ. aquaculture specialists suggest that the value of aquaculture including non-food market aquatic products was about $11.250 million in 2007.

In sum, the total value of seafood landings at South Carolina dealers in 2007 was about $15.574 million while aquaculture value was estimated at about $11.250 million. Since about $2 million of farmed seafood is used for stocking or bait purposes, a reasonable estimate is that about $25 million in seafood products in South Carolina enters the market channels.

Shrimp. Shrimp have minimal processing (perhaps headed and frozen Individuallyquick frozen (IQF) or on ice). Shrimp is fresh with heads off or whole and the size varies from very small (100 count per pound) to very large (10 to 15 count per pound). Buyers sell shrimp to processors (primarily out-of-state with the exception of one), the local retail market, or to other distributors of seafood products. The suppliers of the fresh shrimp are located in the states of SC, NC, GA and FL. These primary suppliers are shrimp dealers or seafood wholesalers that are selling domestic East Coast wild shrimp, or in the case of IQF shrimp, from the Gulf of Mexico.

Mollusks. Both wild and farmed oysters are purchased to supply retail and restaurant needs in SC. The leading sources in 2007 for SC markets were dispersed among producers and wholesalers in LA, MS, AL, SC, NC. It is also common for Oysters harvested in the Gulf states to be shucked in NC with the shell being sold locally for paving and architectural purposes. The second ranking source of supply is imported oysters from Canada, the Mid-Atlantic and New England states. Fresh hard clams come from South Carolina, North Carolina and Mid-Atlantic state producers while most mussels originate from Prince Edward Island.

Crabs. There are three major forms of crab: domestic live Crabs, domestic processed, and imported processed crabmeat derived from Asia. Imported pasteurized crabmeat products are the number one seller. Snow Crab products come from Alaska, Canada and Russia. Domestically produced Blue Crab meat products come from the Gulf and Mid-Atlantic states. In the domestic processed category, Snow and King crab are predominant species. Domestic products have seen a slight increase in retail sales through niche marketing / "buy local" programs. South Carolina hard and soft shell blue crab products are important to the supply, but much of the live Blue Crab harvest is sold to buyers in the Mid-Atlantic States.

Finfish. The four leading species in the fresh fish market segment in SC are not available (e.g. Atlantic salmon) or not commonly sourced in SC: Atlantic salmon, Tilapia, Yellowfin tuna, and Grouper. Atlantic salmon mainly comes from Canada and Chile while Tilapia is primarily from farms in Latin America. Yellowfin tuna is mostly imported with the exception of some supply from Gulf States. Grouper is a bit different with South Carolina being an important source along with imports. Frozen sales are lead by flounder, whiting and catfish.

It is readily apparent that the historical market channel structure for SC landed shrimp and hard blue crabs has shifted away from seafood processors being the first-level major buyer of SC harvested product. For shrimp, this shift was probably accelerated by the substantial decline in shrimp prices since 2001 as well as long-term reductions in shore-side infrastructure. For crab harvesters, it appears that more hard blue crabs than ever are being shipped to out-of-state wholesalers including the remaining domestic blue crab processors. This shift is consistent with the exit of the SC domestic blue crab processing sector during previous decades, an exit

7. Evaluation of the Ability of Camera Surveillance to Detect Landings at a Recreational Fishing Pier By C. Christian Johnson (Coastal Carolina University)

Project Period: 2008 - June 2009

Justification and Goal

Monitoring marine fisheries catch and effort data from Oceanside, commercial fishing piers is a challenging problem. Fishing piers such as those in the Myrtle Beach area attract 300 or more fishermen per day, and total finfish catch for piers can be relatively large. South Carolina has 9 commercial fishing piers with most being in the Myrtle Beach area and others location farther north in North Carolina. Collectively, these piers account for thousands of hours of fishing effort and relatively large quantities of landed finfish. Natural resource agencies have traditionally estimated daily or monthly finfish catch on piers by conducting random interview with fishermen or episodic monitoring of fishing activity. For some species this type of sampling may be adequate, provided enough samples are collected. For other species that move along the coast as migrating schools, sampling infrequently can miss "runs" of these fish, and result in significant underestimations of total catch. Unfortunately, meager funds for sampling by creel clerks greatly limits the frequency of observations on piers, and correspondingly inadequate data may be collected on fishery harvest rates and total harvest.

This study explores the potential for using a video surveillance system to monitor recreational fish landings on Apache Pier, Myrtle Beach, SC. The goal of this study was to determine if video monitoring could be used in a cost-effective manner to estimate fishing effort, total catch, species composition and numbers of fish retained vs. released.

Methods

Cameras were placed at locations along Apache Pier at N. Myrtle Beach that captured fields of view of varying distances and angles, and particular objects of interest. Some fields of view were divided into zones to further evaluate spatial variability of landings and camera detection ability within these zones. While cameras recorded fishing, an on-site observer simultaneously watched the camera angle of interest. The observer recorded the number, species, time and location of each fish caught within the field of view during the study period. The numbers of fishermen, and fishing rods were recorded. At the end of each study day, the recorded video was transferred from hard drive to digital video disc for later analysis on a digital video disc-player-equipped computer. The same parameters were recorded using the same methods as on-site surveys to the best of the analyzer's ability while watching the video. The data from the on-site surveys were compared to the data from the video for differences.

Wired cameras, though more difficult to install were chosen over comparably priced wireless cameras which offered lower picture quality. On a pricing scale of surveillance units, the package was low to moderately priced. More expensive packages could potentially offer

high definition, motorized mount cameras, and remote operation capability. Further study may find that is worth the extra cost to obtain higher quality images.

A long-range camera was used to determine effective distance for determining catch rates and species. No distance resulted in 100% confirmation accuracy and accuracy dropped below 60% at seventy five feet. No observations were confirmed past one-hundred and fifty feet. Species like bluefish and Spanish Mackerel were more readily discernable because of shimmer and a longer time held in view by the fishermen.

A rail-mounted camera was compared to a deck camera (mounted above the deck and inboard of the rail). Compared to an on-site observer's live records, the rail camera was slightly better (63.7% than the deck camera (53.9%). The rail camera had less chance of its view being obscured by fishermen or bystanders.

A nighttime camera was used and compared to daytime cameras. The nighttime camera was ineffective in seeing or identifying fish. This may have been in part related to the loss of shimmer during nighttime. Only white rods were observable and a pier light in the distance interfered with the camera's infrared LEDs.

Twenty-two species were observed during the on-site live landing surveys. 78% of landings were either, bluefish (35% total), Spanish mackerel (19% total), or whiting (25% total), while 19 other species each made up 0-4% of the total. Two percent of landings were not identified because the subjects were too far away from the observer, they were thrown back too quickly, or the view of the fish was blocked by the handler. Relatively few fish were identified successfully by the camera (<1%).

It was determined the short range camera (20 ft or less) could be used successfully to determine d species identification. The cleaning table camera was very effective in species identification and estimation of size. Its usefulness is limited however, because it provides data only on retained, legal-size fish.

The camera was effective in counting numbers of fishermen, accounting for about 75% (compared to on-site live observations). Estimating the number of rods was less effective with only about 30% being observed. This was because many rods contrasted poorly with the water and background.

Cost computations, using a number of assumptions, estimated that the cost of an observer over six years would be about $11,844 compared to $6,802 for a camera system. Other applications of video cameras include observing schools of bait fish in the water, numbers and species of birds, boat traffic, and illegal activity.

This study showed that technology has application on fishing piers – providing numbers of fishermen, fishing activity, numbers of fish caught (within a practical distance from the camera), fish species and size at cleaning stations. With more cameras and perhaps higher quality cameras, these methods hold even more promise in providing managers with a better index of fishing activity on commercial pier.

8. New Shrimp Net and Rigging Design by Anthony Lettich (Commercial Fishing Net Builder)

Project Period: June 2006 - November 2006

Project Justification and Goal

The commercial shrimp fleet in South Carolina has utilized the otter trawl for most of its duration. A small fishery exists for "channel nets" in Winyah and North Santee Bays, but the bulk of commercial landings have come as trawl-caught shrimp. Over the last two decades

profitability of the shrimp trawling feet has steadily declined. This has been largely the result of large increases in imported shrimp, particularly from aquaculture farms in Asia and South America. Imports are approaching 90% of all shrimp consumed in the United States. The rise in availability of shrimp has caused prices paid for domestic product to decline substantially. Meanwhile rising Diesel fuel prices and other escalating costs have brought severe economic hardships on domestic shrimp harvesters. Devising new harvesting technologies for commercial shrimp fishermen that reduces fuel consumption would be important in maintaining profits for commercial fishermen. The goal of this study is to develop a new shrimp harvesting gear that could be used profitably by fishermen.

Methods

The basic concept is to develop a gear that will fish passively from a shrimp trawler in an ebb tide. Shrimp are known to emigrate from estuaries during ebb tides. To accomplish this, nets were built that could be deployed from the outriggers of an anchored shrimp trawler. The net was constructed on smaller size thread than normally used for shrimp trawling in order to reduce friction. The body of the 60-ft. wide net had 1 7/8-in. stretch mesh with 1 ¾-in. stretch mesh in the tailbag. Each net was attached a "bullet" device to hold the net to the bottom. The bullet was essentially a 6-ft pipe filled with concrete to serve as a weight to hold the net down on the bottom. Lines were extended from the bullet to the net wings. The bullet was designed to keep the net close to the bottom and to help prevent the boat from dragging anchore. A bullet was suspended from each outrigger. Floats were used to open the nets vertically and chain on the footrope kept the net on the bottom. A chartered 55-ft double-rigged shrimp trawler was anchored for fishing operations with two 150-lb Danforth anchors. Fishing was largely conducted at night. As the ebb tide began to gain velocity the bullets and net were deployed and fished through the tide. The gear was pulled back up to the outrigger and redeployed with the change of tide. Shrimp catch and bycatch was monitored.

Results and Conclusions

Installing and dismantling the gear took about 4 hours. The first set was on October 5 and 6, 2006 near Fort Fremont in Beaufort River in Beaufort County. At the onset, water depth was about 24 ft and by low tide had dropped to 16 ft. This sampling took place during a full moon when tides were above average. The first two hours of sampling produced no catch, shrimp or bycatch. Subsequently a second attempt was made on flood tide the same night. Inspection indicated that the net was well off the bottom, so more cable was deployed. This set caught about a basket of shrimp but because the nets had a twist only about half the catch was recovered. The investigators continued to have problems during the next ebb tide when the net continued to clog and not let shrimp into the bag. This yielded another basket of shrimp, but about ¼ of that was lost overboard as the net was pulled in. The following flood tide produced another basket of shrimp and again 5-10 pounds were lost overboard. The last ebb tide was hampered by a large catch of marsh grass (wrack) yielding no shrimp. Bycatch during this experiment consisted of a basket of menhaden, some small flatfish (probably bay whiffs or hogchokers), 3 small sharks (probably sharpnose), two blue crab, and one 10-lb. stingray.

The second fishing trip occurred on Oct 23, 24, and 25, 2006. This set was made in Beaufort River near the end of Parris Island. The first set lasted 3.5 hours during ebb tide and produced very little, 1 shrimp and one southern flounder. That evening, the wind picked up to 15-35 mph and made it impossible to fish because the boat was being held at an angle to the tidal

flow. The next night the boat was move to Chechessee River. A daylight ebb tide set was made for 4 hours and produced only about 1 lb. of shrimp. A subsequent set was terminated when the still-strong winds pushed the boat sideways again. The boat was moved to Fort Fremont in the Beaufort River for a nighttime ebb set. This gear worked properly here but no shrimp and a handful of fish were caught. The captain believed that the weather may have been affecting the shrimp. For the entire trip, only two pounds of shrimp were recovered along with bycatch consisting of 20 star drum, 3 brief squid, 1 horse shoe crab, ~50 lookdowns, one striped burrfish, and about 30 menhaden.

On October 29, 30, and 31, the boat was taken to Caliboque Sound in southern Beaufort County. A set was made between Cooper River and Middle Marsh Island in 24 ft. of water. Again, the strong tide and 15 mph winds prevented the gear from working properly. The boat's anchors dragged several times making it impossible to fish the gear properly. In 7 hours of fishing effort, about 1 pound of medium size shrimp was caught. The boat then proceeded back to Beaufort River and worked ebb and flood tides for 6 hours in 30 feet of water. This produced about 1 lb of shrimp. This was followed by a 2-hour ebb tide set at Fort Fremont in Beaufort River. This was unsuccessful also.

On November 2 and 3, 2006, the boat set the gear at Fort Fremont in Beaufort River. After making several attempts to set the anchor and have it hold, it finally held in 28 feet of water. 2 ½ hours of fishing produced about ½ lb. of shrimp. Heavy winds, 25-30 mph hampered fishing, causing the boat to be at an angle to the gear.

The next sampling trip was on November 5, 6, and 7, starting in Calibogue Sound. Again the wind was fairly strong out of the northeast (20-25 mph). The gear was set in 25 ft for 5 hours and produced 1 pound of shrimp. During the ebb tide, the anchor dragged making the gear unfishable. The boat returned to Beaufort River just east of the end of Parris Island. Again the anchor dragged and the gear was ineffective. Later, at the dock, it was discovered that a fluke of the anchor was bent and that probably caused the anchor to drag.

Thus far, this gear as used in this study, has proven to be relatively nonproductive. Initial catches of shrimp were encouraging although not of commercially viable quantities. Unfortunately, the following efforts were seriously hampered by strong winds and tides, and perhaps be gear damage. It is apparent that using this type of gear has potential but will require relatively good fishing conditions. The investigator is confident that a passive gear could be successful if properly designed. Shrimpers while at anchor have dropped try nets and caught impressive quantities of shrimp and channel nets, which are simply shrimp trawls anchored to the bottom during ebb, are known to be highly effective at times. Future experimentation should employ lighter thread netting, perhaps monofilament, to reduce net friction, and possibly scaled-down trawl doors rather than the bullets used in this study.

9. Real-time Water Quality and Weather Monitoring Station at Apache Oceanfront Pier and Family Campground in Myrtle Beach, South Carolina By Susan Libes (Coastal Carolina University), David Whitaker (SC DNR), and Jason Powers, (SC DNR)

Project Period: August 2007- September 2009

Project Justification and Goal

In July 2004, an hypoxia event took place very near the shore in the Myrtle Beach area of Long Bay, also known locally as the Grand Strand. This area encompasses the northern portion of South Carolina's coast from just north of Georgetown to the North Carolina border. This

hypoxia event began with several reports of abnormally high catch rates of flounder at ocean fishing piers and along the beaches. Beachgoers reported flounder in the surf and washing ashore. Pier operators also noted that hundreds of flounder were being landed daily by hook and line fishermen, when total catches are typically one or two dozen per day. Luckily, Dr. Susan Libes of Coastal Carolina University was on site at Apache pier recording water quality information for a project dealing with beach contamination by fecal coliform bacteria. Dr. Libes took dissolved oxygen readings of the water at the surface and bottom near the end of the pier and found hypoxic water. She reported this information to DNR and other agencies, and this stimulated an investigation of water quality in the entire Long Bay area. Subsequently, we learned that the hypoxia extended up to two miles offshore and at least 20 linear miles of beach. The 2004 event lasted about two weeks.

Conversations with local long-time residents suggested that hypoxic events may have been occurring periodically for years. Scientists immediately began asking questions as to the cause(s) of the hypoxia. Was this caused by movement of an offshore water mass onto the beach or was it the result of nutrient-loaded local rainfall runoff? A major question was, "What are the ambient conditions and what are the dynamics of dissolved oxygen in the near-beach waters?" The goal of this study was to determine the ambient water quality conditions of nearshore waters of Long Bay through collection of daily water quality and weather data through a monitoring station at a public fishing pier.

Methods

Several public fishing piers were contacted to determine if they would be agreeable to erection of a permanent water quality monitoring station at their pier. Apache Pier responded that they would be happy to host a water quality station, and arrangements were made through state procurement procedures. This worked out well since Apache Pier was where Dr. Libes found low DOs in 2004 and this is the longest pier on the grand strand at 1,206 feet. Subsequently, Cooperative Research staff of DNR contracted with AMJ, Inc and YSI Econet in spring 2006 to install vertical pipes at the end of the pier in which bottom and surface datasondes were installed. These datasondes were connected via cable to recording station on the pier. Data were transferred by telephone to WSI Econet where they were maintained for web-based delivery of the raw data in near real time. Econet automatically sends email messages to selected researchers every time DO falls below 4 mg/L.

The sondes are housed in two 4" ID PVC standpipes that extend from sea floor to the pier decking which is about 25 ft above sea level. The standpipes are fastened to pier pilings. They are painted with antifouling paint and perforated with 1" diameter holes to promote water exchange.

The sondes became fully operational on 6/20/06. One sonde is deployed approximately 1 m from the bottom and the other is positioned near the surface via attachment to a float. The sondes collect and transmit real time dissolved oxygen, salinity and temperature measurements every fifteen minutes to YSI's data server which uploads the information to a public website: http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=131. A meteorological station was installed in December 2006 and became operational on 1/4/07. These data (wind direction and speed, air temperature, barometric pressure, humidity, and rainfall) are also reported at YSI Econet's Apache pier website. Because of recurrent damage by thunder storms, two pom-pom diffusers that are each independently grounded to the ocean beneath the

pier were added. Once enhanced lightening protection was installed at this site in December 2006, no further lightening damage has been sustained (except for a brief event in 2008).

The datasondes are YSI model 600Rs outfitted with conductivity, temperature and Clark cell DO sensors. The DO sensors are salinity, pressure and temperature compensated, enabling onboard computation of %DO. Temperature is measured with a thermistor. Salinity values are reported in units of ppt although they are measured conductimetrically and should theoretically be reported as psu (practical salinity unit based on the PSS-1978). Dissolved oxygen is reported in units of mg/L DO. Temperature is reported in ºF for the benefit of pier fishermen who use these data. Maintenance and calibration procedures for the salinity and DO sensors are documented in a laboratory SOP. The meteorological station and temperature sensors are checked when the units are returned to YSI.

From October to March, post-calibration checks are performed at least once every other week. The sondes are redeployed if their post-calibration checks are in control for salinity and DO. After two weeks of deployment, or failure of a post-calibration check, the sondes are exchanged with ones that have been freshly calibrated in the lab. The retrieved sondes that are returned to the lab are thoroughly cleaned and new DO membranes installed. The DO sensors are periodically reconditioned. During the winter 2008-2009, all four sondes were sent to YSI for their winterization special which involved cleaning, checking, and repair of any problems.

The standpipes are painted with antifouling paint. They are periodically cleaned by scraping internally with a specially configured weight set and the PVC surfaces have been coated with antifouling paint. Over the years, additional measures have been taken to reduce biofouling. In 2008, we began covering exposed surfaces with adhesive-backed copper tape that is periodically replaced. In 2009, we began covering the sonde guard vents with wide mesh copper gauze.

YSI installed the sondes, power and telemetry connections as a unified package. The data are fed directly to the YSI Econet server and are displayed at their web pages. The public website features a SC DNR logo and is located at: http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=131. YSI Econet also provides a password protected website to facilitate data downloads at: http://www.ysieconet.com/, establishment of alarm settings, reports for the public website. Web links to the YSI Econet site include:

- Apache Family Campgrounds and Pier at http://bearwebservices.biz/apache/index.php.
- Long Bay Near-shore Water Quality Management website (http://www.caro-coops.org/longbay/realtime.php) which is maintained by the Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS), the Southeast Atlantic Coastal Ocean Observing System (SEACOOS), and the Southeast Coastal Ocean Observing Regional Association (SECOORA).
- SECOORA also hosts a link at http://secoora.org/maps/inventory/ .
- The site is also available through SC DNR at: http://www.dnr.sc.gov/marine/coopresearch/apache.html

Through contractual agreement, funded largely through DNR, and in part by the SC Dept. of Health and Environment Control's Office of Ocean and Coastal Resources, Coastal Carolina University has maintained the monitoring station and datasondes. Dr. Libes has headed up this work and has provided data reports and alerts. Data has been available to other CCU researchers and University of South Carolina researchers. Efforts are underway to examine DO trends with regard to temperature, winds, currents, weather, tidal stages and other factors. Preliminary

models have been developed, based to a large degree upon data provided by this project. This work is ongoing.

Results and Conclusions

The results herein represent the first continuous record of DO levels in the nearshore of Long Bay. The only other DO data are those collected via grab sampling at a number of sites during the July 2004 hypoxic event and a continuous deployment of a Hydrolab datasonde from Jan 2006 to Sept 2007 at Springmaid Pier (located at the southern end of Myrtle Beach, SC). DO variability has been observed to occur over multiple temporal and spatial scales. An evaluation of horizontal spatial variability is possible via comparison of the Apache Pier sondes to the one deployed concurrently at Springmaid Pier in approximately 6 to 7 m water depth. Vertical spatial variability can be evaluated via comparison of the surface and bottom water sondes at Apache Pier.

At Apache Pier, the sondes were deployed in June 2006, providing a 3-year record although the first year was marked by significant data loss during June and July because of an electrical storm. Other data losses were caused by Tropical Storm Hannah in 2008 and loss of the standpipes in January 2009. The latter were replaced in April 2009 and the sondes redeployed.

DO concentrations have been observed to vary over time scales of days, seasons, and inter-annually. The nature and causes of these degrees of variability are unique and distinct. The period of lowest DO is broadly May through October, with July and August tending to be the peak times of lowest concentrations. In 2008, the period of very low DO extended through October. Seasonal variations of the monthly mean DO are on the order of 4 mg/L. They are caused by temperature-driven changes in gas solubility, with the atmosphere providing a buffering reservoir of O_2. A second influence of temperature is due to an increase in respiration rates with increasing temperature. This provides a faster DO sink during warm weather. The surface monthly mean at Apache Pier has generally been equal to or greater than that of the bottom mean.

The threshold for hypoxia is 2 mg/L, but several sources report significant impacts to fisheries at DO concentrations less than 3 to 5 mg/L. At Apache Pier, DO concentrations less than 4 mg/L were observed seasonally during all years, starting in Apr/May and ending in Sept/Oct.

Similar observations were made at Springmaid Pier where during July – August 2006, during which 30% of the observations of DO were less than 4 mg/L. The lowest DO observed was 1.8 mg/L. At Apache Pier, DO's less than 2 mg/L were observed during August 2006 for 1 hr collectively (4 records) and during August and Sept 2008 for a total of 30 hrs. The lowest observed DO at Apache Pier has been 1.2 mg/L (bottom water on 8/31/08 at 10:30 AM). The lowest surface water DO observed has been 2.2 mg/L (9/10/08 at 11:00 AM). In summary, hypoxic conditions have been observed at Springmaid and Apache Piers in 2006 and 2008 but do not appear to have been sustained for a period as long as the event which caused the flounder Jubilee in July 2004.

Beginning on August 17, 2009, dissolved oxygen values at Apache Pier dropped below 30% saturation. Hypoxic conditions continued until August 26 when conditions began improving. In addition on August 19, an anoxic situation occurred -- meaning all oxygen at both surface and bottom was zero. During this time, flounder were forced into the surf zone where wave mixing improved the oxygen levels. Flounder catches were good but most other fish

species disappeared during this time. In response to this event, Dr. Libes and other staff at Coastal Carolina stepped up water quality monitoring from the piers as well as testing ground water flow into the ocean. DNR sent boats and divers to take water samples, set out remote water sampling equipment and observe effects of bottom life. DNR also examined water samples for unusual numbers and types of phytoplankton as well as documented fish catches on the piers and flew over the area to look for discolored water. University of South Carolina staff assisted with supplying water sampling equipment and information, and laboratory testing of water samples. SC Sea Grant Consortium staff coordinated the overall effort.

This hypoxia event was worse than the July 2004 event, with waters actually becoming anoxic (no oxygen). Water that was hypoxic appeared to also be significantly cooler than other nearby waters and hypoxia appeared to be most acute at high tide. Persistent southwest winds seemed to set up this event by causing "upwelling" of cold deep water to the nearshore and stratification of the water column. Concurrently, unusually high tides during the summer -- perhaps related to dynamics of the Gulf Stream. These high tides may have flushed excessive nutrients into the nearshore area which in turn could have fueled increased bacterial activity and caused phytoplankton blooms, both of which could have driven down dissolved oxygen. Put simply, a suggested hypothesis is that cold, upwelled offshore water may have moved towards the coast and "compressed" the nutrient-laden coastal runoff and ground water against the coast, forming a narrow band of sub-optimal water along the coast, thus leading to a decline in oxygen.

From a management perspective, Long Bay appears to have low assimilative capacity for O_2-demanding substances and is likely at a tipping point where hypoxia could become more frequent if hydrographic conditions promote enhanced vertical density stratification and/or terrestrial loading of nutrients and organic matter increases. The former is likely given current trends in global climate change. Another related impact could derive from ocean acidification which is likely to alter microbial community structure and function.

Low DO is a concern to local recreational and commercial fisheries. A much higher abundance of king mackerel were present along the Grand Strand's fishing piers in 2007 as compared to 2006. This was been attributed to lower DO concentrations in 2006 and a poorer water clarity. Local fisheries are already stressed as documented by sharp declines in the fish catch at the fishing piers since the 1970s (C. Johnson, pers. comm. based on Grand Strand Fishing rodeo fishing logbooks. Low DO also has the potential to alter microbial community structures and hence select for undesirable ecosystem outcomes, such as Harmful Algal Blooms.

In Long Bay, increasing coastal development is likely to result in increased nutrient and organic matter loading in the form of polluted stormwater runoff and surficial ground water seeps. The stormwater treatment practices in current use focus on directing stormwater flows out into the ocean. Some efforts have been made at treatment prior to discharge, but the performance of these best management measures (BMPs) is of unknown effect. Plans are underway to tie together the discharges from hundreds of stormwater pipes that now discharge terrestrial runoff onto the beach face thereby merging their flows. These discharges will be emitted into a few stormwater outfalls located approximately 1000 ft offshore. This is the location where low DO has been most commonly observed. It is unclear as to whether any additional treatment devices will be installed as part of these outfall pipes.

The current trajectory of climate change will result in warmer coastal waters, thereby lowering DO solubility and enhancing respiration rates. The higher surface water temperatures could lead to increased vertical density stratification. As noted above, concurrent acidification from dissolution of atmospheric CO2 coupled with lower DO will likely later microbial structure

and function regardless of the impacts from increased terrestrial loading of nutrients and organic matter.

Since no routine monitoring of dissolved oxygen had been conducted in the nearshore region of Long Bay prior to this work, all data collected herein represent wholly new insights. Periods of DO with concentrations less than 4 mg/L have been frequently observed seasonally during the months of May through October with the most significant oxygen deficiencies occurring during July through September. Hypoxia was briefly observed during 2006 in June and in 2008 during August and September. The occurrence of the anoxia event in August 2009 indicates that this problem continues. The monitoring station provided by this project was instrumental in alerting researchers to an imminent event in 2009, thus setting in motion a number of ad hoc initiatives to capture as much data as possible. Thanks to the early warning from Apache pier, several CCU, USC and DNR crews were mobilized to collect data. These data are continuing to be analyzed, but there is no doubt that the data provide invaluable insights into the DO dynamics in Long Bay. We are now in agreement that both terrestrial influences (runoff and subterranean flow) and coastal upwelling are working together to caused hypoxia in Long Bay. However, more research is needed to fully understand how this phenomenon works and if practical mitigation measures are possible.

10. Estimating the Size and Age Composition of the B-2 Fish (caught and released alive) in the Recreational Fishery for Red Drum in South Carolina

By Christopher McDonough and Charlie Wenner, SCDNR

Project Period: August 2007- December 2008

Project Justification and Goal

When examining a stock or population of fish, the ability to determine its relative condition is dependent on the amount and quality of the data available for that population. Fish populations, like all natural systems, undergo constant changes in rates of increase (reproduction) and decline (mortality). In a balanced system these two rates cancel each other out and the population reaches a steady state. In an unexploited fish population, rate changes are driven by natural variations in the environment (e.g. temperature, food and predation levels), but when fishing pressure is added the fish stock has to contend with both natural and fishing mortality. An indication of fishing mortality can be determined from reported and estimated harvest levels. However, a proportion of fish that are caught and released alive die soon afterwards, and so information on these fish is also required to assess total fishing mortality. Previous stock assessments have assumed a 0% mortality on adult red drum because they were considered outside the fishery. However, hooking mortality studies have since shown that anglers do have an effect on released adult fish with estimated mortality rates ranging from 2% to 15% depending on hook type and hook placement. Without more specific information on what types of hooks are used, the best estimate for hooking mortality in South Carolina in adult red drum was the 2.0%.

The MRFSS (Marine Recreational Fisheries Statistical Survey) conducted by the National Marine Fisheries Service and the SC's recreational survey both provide data on the number and sizes of harvested fish, but there are few data on the size of the B-2 (caught and released alive) fish. There are methods available to assign fishes of a given length to a specific age group or cohort. The size composition can be used to estimate the age structure. If one has an estimate of the catch and release mortality by size (age) of the fish, then the B-2 losses due to fishing can be assigned into year-classes.

There is very little information on the sizes or ages of red drum and spotted seatrout that are captured and released (B-2 fish). This was a noted data deficiency for red drum in the last stock assessment for this species. To estimate the condition of the population through present day techniques, the size and age composition of the B-2 fish is required. The goal of this study was to establish the size structure of B-2 red drum in South Carolina using log book data from recreational angling guides. Additional information is also presented for spotted seatrout, southern flounder, and black drum, for which incidental data were also collected.

Methods

South Carolina Department of Natural Resources biologists worked in cooperation with selected fishing guides and the DNR inshore fisheries tagging Program. Log books were provided to fishing guides monthly. The information recorded by the guides was date, location, number caught, number retained, number released alive, and individual lengths of the released and retained fish. Individual lengths were recorded as total length in inches. Logbooks were collected per month. The primary species of interest was red drum, but length data were also collected on spotted seatrout, southern flounder and black drum. Length data for red drum and spotted seatrout were analyzed for frequency of occurrence within different size classes and then applied to existing age-length keys. Combined age/length keys from South Carolina's fishery independent surveys (trammel net, electroshock boat, long line surveys) covering the same time period were applied to the annual size frequency distributions of B-2 red drum and spotted seatrout to derive age distributions. Southern flounder and black drum were analyzed for length frequencies only because of limited age data on both of these species.

Results and Conclusions

There were 855 logged trips by seven guides between August 2007 and December 2008. The majority of the trips (84.6%) occurred in the Winyah Bay and Cape Romain systems. The next greatest number of trips occurred in Charleston Harbor (12.4%) followed by Port Royal Sound and St. Helena Sound (3%). There were 12,226 specimens caught, representing 28 species of fish. The most numerous species in the study were spotted seatrout (48.8% of the total), red drum (40.8%), southern flounder (3.8%), and black drum (2.3%).

Red Drum

5,003 red drum were captured and almost all were released (4,992; 99.8%). Specimens ranged in size from 191 to 1,295 mm total length with a mean size of 577 ± 2.7 mm (SE). The overall length frequency distribution was bi-modal with major peaks occurring within the legally harvestable slot limit (382 – 585 mm) and just above the slot limit (675-725 mm). Red drum were captured every month of the year with highest catches occurring from August through December. Specimens caught within the slot limit range represented 48.6% of the catch, with fish smaller than the slot (< 382 mm) making up 9.1% of the total, and fish greater than the slot (> 585 mm) representing 42.3%. Adult fish (approximately ≥ 5 years in age and > 900 mm) made up 7.05% of the total catch. The results indicate that South Carolina's red drum recreational fishery is based almost entirely on sexually immature juveniles. Red drum first recruit to the recreational fishery in September-October when they are slightly smaller than the legal size slot and at an age of approximately 12 months old. These same months are also when the greatest number of large adults are caught, although adult fish can be caught from May through October. While the majority of fishing effort occurs inshore, targeting juveniles and sub-adults, the current data illustrate that some fishing pressure is also directed at mature adult fish.

In order to estimate an age distribution for the red drum in this study, an age-length key (ALK) was applied to a cross-tabulated data matrix of numbers of B-2 red drum in 25-mm size

categories. The ALK was derived for the latest red drum stock assessment (SEDAR 18) and is based on age estimates from scales and otoliths collected SCDNR. Ages in the ALK ranged from 1-38 with the majority of specimens (93.9%) being age 9 or younger across the entire size distribution. The remaining specimens occurred in age classes 10 or greater, which was almost equal to the percentage of adult fish (7.05%) from the size distribution data.

The catch per unit effort (CPUE) of red drum was estimated by dividing the mean monthly number of fish caught by the number of trips per month by estuarine system and as a combined total across all the estuaries. The guides were successful at locating red drum on most trips with red drum occurring in 753 out of 855 logged trips (88.1%). Winyah Bay was the only system that had logged trips every month and represented the only collections made in January and February. Cape Romain was the next most sampled area by month (March through December), followed by Charleston Harbor (May through December) and both Port Royal Sound and St. Helena Sound were sampled from August through December. Comparisons of CPUE between estuarine systems was only possible during the months when all of the estuaries were sampled (Aug. to Nov.). During these months, the two southern systems (Port Royal and St. Helena Sounds) had higher catch levels in all months except October. Catch levels in St. Helena sound remained the most consistent throughout the entire time period. Winyah Bay catch levels increased noticeably in October but were lower than any of the other systems in September and November. Winyah Bay and Cape Romain were both fished by the same participating guides who fish year round and accounted for 85.8% of all trips logged in the study. The warmer months of the year (May through November) accounted for 74.7% of all logged trips. The CPUE values for January and February only represented Winyah Bay and the value for January was significantly higher ($p = 0.05$) than all the other months, representing 144 red drum caught over 8 trips that month, while the lower value in February came from 45 fish caught over 9 trips. Given the schooling behavior of red drum during winter, a fishing guide's enhanced ability to locate large schools in January and February would have a significant effect on how many fish they catch. Also, the fewest number of days sampled occurred in January and February, so greater effort over the entire month might have resulted in CPUE values closer to that seen in other months

Spotted Seatrout

There were 5,987 spotted seatrout captured by all the guides on 495 out of 855 reported trips (57.9%). Specimen lengths ranged from 165 to 660 mm, with a mean size of 386 ± 0.69 mm. The majority of the trout reported (85.7%) were legal size (355 mm or 14 inches) or larger. The overall length frequency was uni-modal with a single peak at 375-400 mm. Spotted seatrout were captured every month of the year with the highest catches occurring from September to December. Monthly size frequency distributions indicated spotted seatrout began to show up in catches (i.e. recruiting to the fishery) at approximately 250-305 mm which is when they are approaching one year in age. Spotted seatrout were captured every month of the year with the highest catches occurring from September to December. Trout reach sexual maturity at one year of age at approximately 300 mm and spawn from April through August.

In order to estimate age using the B-2 length frequency distribution, an age length key (ALK) was developed using otolith and length data from SCDRN surveys. The ALK was applied to the size frequency distribution of spotted seatrout in the same manner used on red drum. Ages in the key ranged from 0 to 8 years with 1 and 2 year olds accounting for 87.1% of all the fish. Less than 1% of the all trout in the ALK were greater than 4 years of age.

Overall mean catch levels were relatively consistent in Port Royal, St. Helena, and Charleston Harbor estuaries, with CPUE ranging from 3.1 to 3.8 fish per trip. Catch levels for Cape Romain and Winyah Bay were significantly higher, particularly during fall. As with red drum, CPUE values for January and February were representative of only Winyah Bay and Cape Romain.

There was a slight increase seen from March through May, after which catches declined from June through August. This decrease coincided with the main part of the spawning season for spotted seatrout. For the time period where all the estuaries were sampled (Aug. to Nov.), Cape Romain showed a consistent month to month increase in catch levels not seen in any of the other systems. This increase continued into December as well, which had the highest CPUE value for any month from any system. There was a similar increase in catch from August to September for Winyah Bay, but catch levels decreased in October and November. St. Helena Sound showed an increase in October as well, but was the only system that had a decrease in catch going from October to November. This reflected decreasing effort levels in this system more than any reduction in abundance.

Southern Flounder

There were 464 southern flounder caught in 193 out of the 855 logged trips. Fish were reported every month of the year except February, with 74.3% of specimens caught from June through September. Only 9 flounder were caught during the winter months (Dec. – Feb.). Sizes ranged from 178 to 610 mm with a mean size of 401 ± 3.2 mm. The legal minimum total length for southern flounder in South Carolina is 14 inches (356 mm). 36.7% of the specimens caught were below the legal limit. The size frequency distribution was uni-modal with the peak occurring at the 326-350 mm L_T size class, which was just below the legal size (356 mm).

Black Drum

There were 278 black drum caught in 84 logged trips. The majority of black drum (85.6%) was caught from October through February with the highest catches occurring in January and February. Fish ranged in size from 197 to 584 mm with a mean size of 390 ± 4.1 mm. The size frequency distribution was uni-modal with the peak centered around the 351-375 mm size class which included the minimum legal size (356 mm) (Fig10).

Summary

This study provides the most detailed information to date on the size and age-frequency distributions of caught and released-alive (B-2) red drum, spotted seatrout, southern flounder, and black drum in South Carolina. This study presents data on the full range of sizes and ages that are susceptible to the recreational fishery. While the major portion of the red drum fishery occurs inshore and targets juveniles and sub-adults, this study also demonstrates that adult fish are targeted by the fishery. This information coupled with the size and age distributions from this study will enable better estimates of mortality rates for both sub-adult and adult B-2 red drum.

11. Rearing Cultured Single Oysters (Crassostrea virginica) in Experiment Trays in Intertidal Areas in South Carolina

by Joseph Morris (Commercial Fisherman)

Project Period: 2008

Project Justification and Goal

South Carolina's oyster production is primarily restricted to intertidal clustered oysters that are naturally recruited as spat. These are not preferred oysters in the restaurant trade; restaurants preferred the large single, subtidal oysters from the Gulf of Mexico. However, a large single oyster from South Carolina would be superior to Gulf oysters because of higher salt content. Mariculturists in the northeastern United States and on the West Coast have had success growing

shellfish in stacked cages. With the recent availability of single oyster seed in South Carolina, this research proposed to test stackable trays as a method for growing large single oysters on an intertidal flat in South Carolina.

Methods

Experimental trays were constructed of 1x1-in. coated wire mesh. Single trays were 1xel 3ft x 3ft. x4 inches. Trays were tied together and attached to PVC pipes that were driven into the bottom. Bottom trays had 6-in. legs to elevate them off the bottom. Ten bottom trays were placed in a row. Oyster seed was added to the bottom tray and then another tray was placed atop the bottom tray, this was followed in a like manner with a third tray atop the second tray. The initial stocking involved oyster seed that measured about 1.5 inches. A second stocking was done with ½ bar mesh liners being placed in the trays. 30,000 oysters measuring 1.25 to 1.50 inches were added to the trays with liners.

Results and Conclusions

The initial set of 1.5-inch oyster seed was unsuccessful. Strong currents (probably 3-4 knots) that swept across the intertidal flat forced oyster seed to one side of the trays and many of the oyster became wedged in the wire mesh. The smaller mesh liners were installed to prevent the oysters from becoming lodged in the meshes. Strong northeast winds and waves damaged the liners and resulted in most of the 30,000 1.25- to 1.5-inch oysters being forced out of the cage and lost. Despite the problems, so oysters survived showed relative good growth rates. Use of the bags after losing oysters through the tray meshes appeared to help with retention. Settlement of spat on the oysters was also a problem, however oysters close to the bottom in the lower tray did not have as much of problem with overset. One problem with cages is that they tended to sink into the bottom over time. This was probably a result of the water currents. Overall success has been limited, but some oysters are expected to be sold by fall 2009. The methods evolved to using only a single layer of trays and periodically turning and separating oyster as they grow.

12. Assessment of Surf Zone and Near-shore Nekton Community in Horry County

by Jeremy Mull (Coastal Carolina University)

Project Period: Jan 2007- June 2009

Project Justification and Goal

There have been very few studies of the surf zone in the southeastern United States, and South Carolina only has studies by DeLancey (1989) and Anderson et al. (1977). Horry County has no published surveys of the surf zone nekton community. The surf zone is of ecological importance because it may serve as a refuge and or a foraging area for larval and juvenile organisms. In turn, many authors have described the surf zone as a nursery area because of the presences of many juvenile individuals and in some areas of the world the surf zone rivals that of estuaries as a nursery ground for teleosts. Larval fishes move either by active swimming or passive drift from the area of spawning to the nursery area of the surf zone. Before arriving in the nursery area the larvae must go through metamorphosis to a juvenile stage to stay in the nursery habitat. In the nursery area of the surf zone the juveniles are sheltered and have plenty of food from the rich zooplankton populations, and the shallow turbulent zone gives protection from predators. Most predators in this environment hunt by visual clues and the turbidity in the

surf zone makes capturing prey difficult, and the predators usually being large may have problems maneuvering in the shallow waters of the surf zone.

The main objectives of this study were (1) to gather year-round, baseline data on the surf zone nekton community in Horry County and compare the abundance and diversity of the surf zone nekton between open beach and swash sites, and (2) to correlate the abundance and diversity of the surf zone assemblage with that of two adjacent habitats: the infauna macro-invertebrate community of the sandy beach swash zone, and the near-shore nekton community extending out from the beach to approximately 150-200 meters offshore. This is the first study to systematically sample this near-shore nekton community in South Carolina, which includes many recreationally and commercially important species. In addition to the primary objectives for this project, we will compare the surf zone nekton community in Horry County with that of Charleston County by comparing data with a concurrent study by College of Charleston graduate student Jacquelyn Wilkie at the Folly Beach site previously studied by DeLancey and Anderson et al.

Methods

The fish surveys were conducted along the sandy beaches of Horry County in northern South Carolina. The "Grand Strand" is a nearly 50 mile stretch of continuous beach. The coast is considered microtidal with a tidal range from 1.4 to 1.6 meters. There were a total of six sites, three swash habitats and three open beach habitats within the study area. The swash habitats were Singleton Swash, Wither's Swash and White Point Swash. The open beach habitats were approximately 900 m north of Apache Pier, 7th Avenue North in Myrtle Beach and 27th Avenue South in Atlantic Beach. The open beach habitats were all at least 1 km or more from a swash or freshwater inflow. All samples were collected within two hours of dawn and low tide, thus limiting sampling to a cluster of three consecutive days (two sites per day) that recurred approximately every two weeks. Two sampling dates were missed at Wither's Swash due to beach renourishment activities, and once at 27th avenue where there was high turbidity due to active renourishment less than a kilometer from the site. The sampling time was selected to be consistent with previous South Carolina studies for comparison and to limit interactions with crowds of beachgoers.

Communities were sampled using a beach seine for the surf zone nekton community, a boat-set haul seine for the near-shore nekton community, and various methods for the sandy beach benthic community. Samples were collected from May 2007 through November 2008 for the beach seine and benthic surveys and from November 2007 to November 2008 for the haul seine. No haul seine surveys were conducted from August 2008 to November 2008 due to boat failure.

The surf zone was sampled using a 19.8-m long by 1.8-m deep nylon beach seine with a 9-mm stretch-mesh and a 1.8-m long bag with a 1.8-m diameter opening. At each site, the seine was towed 100 m with the longshore current. At swash sites, the tow encompassed the mouth of the swash and approximately 50 m on either side of the center of the swash.

All of the organisms captured, except for decapods, were preserved on ice immediately following each tow and frozen at the laboratory. The decapods were identified, sexed, measured (carapace width), and released. Once in the laboratory, the organisms were counted and identified to the lowest possible taxonomic group. Then the standard, fork and total lengths and wet weights (to the nearest tenth g) were taken for each fish, except when there were more than thirty of a species. With thirty or more, the largest and smallest fish and thirty randomly selected

individuals were measured, and a total weight was recorded for all individuals of each species. Water quality data, including salinity, temperature, and dissolved oxygen, were recorded with a hand held meter before each tow at three locations within the sample area at 1 meter depth. Turbidity was measured with a Secchi disk. Three measurements were taken along the width of the beach seine.

Three infauna samples each were collected with a yabby pump and a shovel just prior to the beach seining at each site. Both shovel and yabby samples were processed using a 2 mm^2 mesh box sieve to filter the sediment, and then the organisms were preserved on ice.

The near-shore nekton community was sampled with a 200-m long by 3-m deep haul seine with a 6.35-cm square mesh of No. 12 monofilament. Only a single site was sampled with the haul seine, since this was a pilot study for a new and labor-intensive sampling technique. One end of the net was anchored on the beach and the haul seine was deployed perpendicular to the beach using a Sea Doo Explorer watercraft. During the final 50 m of the set, the seine was angled into the longshore current in a "J" shape. The total approximate area swept was ~13000 m^2. Once enclosed, the area of the seine was approximately 6,366 m^2. The haul seine's catch was processed immediately after the seine was retrieved. The organisms that could be easily identified were measured on the beach. The same three length measurements (standard, fork and total lengthens) were taken for these fish just as the fish were measured in the lab for the beach seine, but only a total wet weight (to nearest tenth of a kg) was taken for each species and then the organisms were returned to the ocean alive, if possible.

Results and Conclusions

Surf Zone

The surf zone was sampled by 197 beach seine pulls between May, 2007, and November, 2008, yielding 6,426 specimens from 45 families. The open beach was sampled 101 times, yielding 3,246 specimens (average 32.1/pull) from 37 species, with 10 species exclusive to the open beach locations. The tops species in order were anchovy, silversides, pompano, another anchovy, bluefish, mullet, speckled crab, and whiting. The pompano provided the greatest biomass. The swashes were sampled 96 times, yielding 3,180 specimens (average 33.1/pull) from 35 species, with 8 species exclusive to the swashes. Mullet mad up the greatest biomass in the swashes. Both the open beach and swash had the same top eight species in abundance. These species made up 95% of the catch for the open beach and 91% for the swash.

The total biomass of open beach samples was 18,037 g (average 5.56 g/specimen), while swash samples had a total biomass of 20,878 g (average 6.57 g/specimen). The higher average biomass for swash locations is due primarily to the capture of two larger bodied species: *Mugil curema* and *Mugil cephalus*. The open beach habitats had eight species that made up 95 % of the total biomass. The swash habitats also had eight species that made up 91 % of the total biomass, but only 6 of these were among the top 8 for the open beach.

A nested ANOVA was used to test for differences in abundance and biomass between the swash and open beach. In the design, the sites (for example, Apache pier) are nested within the location (either swash or open beach). The ANOVA of the abundance data after a log+1 transformation was performed to correct for normality. An ANOVA showed no difference in abundance between the swash and open beach. The biomass data also yielded no significant difference between the open beach and swash. The Shannon's diversity index provided H values of 1.95 and a E_H of 0.54 for the open beach. The swash location had an H value of 2.06 and a E_H of 0.58. The H value shows that the swashes have a slightly higher diversity, and the E_H shows that

the swashes' species are distributed more evenly. Although no overall differences were found between the fish assemblages in each habitat, two species (*Fundulus majalis,*and *M. curema)* were more abundant in swash habitats. *F. majalis* only occurred at the swash habitats, and *M. curema* was significantly more abundant at swashes.

Infaunal Sampling

Benthic organisms in the sandy beach were sampled on 197 days resulting in 1,182 samples. These samples resulted in the capture of 18 *C. islagrande* and 34 *E. talpoida*. These low numbers of occurrence give *C. islagrande* a capture rate of 1% and *E. talpoida* a capture rate of 2%. *T. carolinus* and *M. littoralis* abundances were used because DeLancey found *E. talpoida* to be a large part of the diet of the two fish.

Nearshore Nekton

The nearshore nekton community was sampled by 18 haul seine sets from November 2007 to November 2008. A total of 880 specimens was collected representing 34 species and 17 families. Three families, Sciaenidae, Clupeidae and Carangidae, made up 75% of the catch.

Comparing Horry County to Charleston County:

To compare Horry and Charleston counties, surf zone nekton data were shared between this project and Jacquelyn Wilkie's project at Folly Beach, SC. Wilkie collected data at two sites on the same day every two weeks. One of her sites is the original site from Anderson et al. and DeLancey. The Charleston sites were sampled a total of 83 times resulting in the capture of 1,568 organisms encompassing 40 species in 19 families. For comparison some samples at the beginning and end of the sampling period were removed.

The water temperature and dissolved oxygen (DO) were significant variables affecting the fish communities. The DO is slightly less significant than water temperature and is directly related to the temperature, cold water high dissolved oxygen. When analyzing DO data for the surf, nearshore and apache pier there are patterns of the surf zone having higher DO values; however there are some questionable data points probably from instrument failure. The apache pier recorded a DO below 2 mg/L on August 6, 2008, but the surf zone at 27th avenue sampled on that date was 8 mg/L. The lowest DO record 5 mg/L in the surf zone was at 7th avenue and apache pier recorded a DO of 4.5 mg/L on August 7, 2008.

The Charleston County study found 40 species in the surf zone communities similar to Horry County at 45 species. The abundance for the top 8 species shows relatively similar numbers.

In conclusion, there was no difference between the swash and open beach fish communities in terms of abundance, diversity, and species richness, though two species were more abundant at the swashes. Water temperature was an important variable associated with the seasonality of the fish communities. This study piloted a new haul seine method which effectively sampled an understudied habitat and demonstrated the ability to sample larger size classes not captured by other net-based methods.

13. A characterization of the South Carolina flounder gigging fishery and collection of biological data on South Flounder (*Paralichthys lethostigma*)

by J. Powers, D. Whitaker, B. Gooch and N. West

Project Period: May 2006 to May 2009

Project Justification and Goal

The flounder gigging fishery is believed to be relatively large in South Carolina, with potentially thousands of fishing trips made annually. However, because this fishery is

prosecuted only during night-time hours, DNR and Marine Recreational Finfish Statistical Survey (MRFSS) observers, who make observations at boat landings during daylight hours only, rarely intercept flounder giggers. There are also observational data from DNR law enforcement officers that flounder gig harvest rates can be relatively high (approaching or meeting the 20-fish/person/day limit). This is contrary to the relatively low average catch rates of hook and line anglers (less than three fish per trip).

Because creel intercepts are rarely made of gigged fish, very little information exist on fish size which is critical for developing a stock assessment. Furthermore, it is presumed that most gigged flounder are southern flounder (*Paralichthys lethostigma),* but it is possible the summer (*P. dentatus*) and gulf flounder (*P. abigutta)* may be part of the catch. This work will also provide information of other species that may be gigged.

There is a perception among some anglers that flounder abundance has declined and they attribute the decline to the gigging fishery. Catch-per-effort trends in fishery independent surveys (trammel net and trawl) do not suggest a significant decline in flounder stocks, but DNR biologists believe the stock cannot be adequately assessed until the magnitude of the gigging fishery can be determined. During July 2004, a significant and unusual event occurred in the Myrtle Beach, SC area. Thousands of flounder were caught by anglers fishing from the beach and commercial fishing piers. These anomalously high catch rates were attributed to unusual hydrographical conditions (low dissolved oxygen) that appeared to herd fish toward the beach. This event casts some doubt on our perceptions and understanding of flounder abundance and life history. This goal of this project was to provide new information that should be useful in examining the health of the flounder resource through a better understanding of the recreational gigging fishery.

Methods

In March of 2006, the CRP began soliciting recreational flounder giggers for participation in a three-year research study. The study was designed to include a maximum of six giggers, two from each of the Northern (Georgetown/Horry County), Central (Charleston County) and Southern (Beaufort County) regions. During the course of the study, five giggers were contracted: one from the North and two from each of the Central and Southern regions. Fishermen were compensated per gigging trip with no more than one trip per week allowed and no more than 20 trips per year. Giggers were required to fill out a logbook that recorded the name, date, location, trip start and end times, number of giggers, the size (TL) of all flounder and any bycatch species. The giggers were given detailed drawings of the three potentially encountered flounder species (summer, Southern and Gulf) to increase the accuracy of their identification.

Results and Conclusions

From May 2006 to May 2009 five cooperating giggers completed 135 fishing trips. During that time period 1,417 flounder were gigged along with 6 different bycatch species totaling 148 fish. Of the 135 trips, 20 were conducted in the Northern region of the state, 23 in the Central and 92 in the Southern. The majority (53%) of the trips were conducted with 2 active giggers in the boat, with 45% of the trips having one gigger fishing alone. Only 3 of the 135 trips (2%) had more than 2 active giggers. The gigged flounder ranged in size from 279mm (11 in.) to 673mm (26.5 in.). Their average size ranged from 410 mm (16.1 in.) in the South to 396 mm (15.6 in.) in the Central with the overall average being 406 mm (16.0 in.). The giggers

reported 70% of the flounder to be *P. dentatus* and 30% *P. lethostigma.* (Although many *P. Dentatus* were reported, DNR biologists are skeptical that these identifications were correct. It is likely most, if not all of these fish were *P. lethostigma).* No *P. abigutta* were recored on any of the sampling trips. The most trips occurred in the 3rd quarter (45%); while the fewest happened in the first quarter (7%). The CPUE by quarter showed the highest catch rates in the 3rd quarter with an average of 3.86 flounder gigged per hour and the fewest flounder caught per trip in the first quarter with an average of 0.86 gigged per hour. An analysis of gigging effort showed the average trip length to be 3 hours 49 minutes with the shortest trip lasting 50 minutes and the longest trip lasting 7 hours 45 minutes. Additionally, a significant number of giggers (77%) started their trip before low tide and ended their trip after low tide.

The six gigging bycatch species (in order of abundance) were: Red Drum, Mullet, Sheepshead, Speckled Trout, Black Drum and Tripletail. Red Drum was by far the most common gigged bycatch species comprising 70% of the bycatch. The majority of the bycatch was gigged in the 3rd quarter corresponding with increased effort over that same time period. Although a few sublegal fish were reported, the average size of all species was well within legal limits.

Flounder gigging is generally regarded as a recreational fishery. Because this fishery occurs almost exclusively after sunset very little information exists on the behavior of the fishermen; couple that with large flounder bag limits (20 per person or 40 per boat) and there is potential for overfishing. The purpose of this cooperative study was to collect detailed information from avid flounder giggers regarding the duration of their fishing trips, the number and size of flounder and other bycatch species gigged. With this information we determined the catch of avid fishermen which can be compared with catch rates of other flounder research being conducted concurrent to this project. Unlike the occasional gigger who averages 0.5 -1.5 flounder per trip (based upon another SC study of all giggers) our giggers averaged 10.5 flounder per trip. On one occasion two giggers in the central region gigged 32 flounder during a 3.5 hour trip. The majority of our cooperative trips (55%) had more than one gigger. Having more giggers did not necessarily equate to more fish gigged.

Coincidently this study occurred during a change in size and bag limits for flounder. Before July of 2007 the minimum size limit was 12” (305mm) and the bag limit was 20 per person per day. The current regulations increased the minimum size limit to 14” (356mm) and although the bag limit remained at 20 per person, a cap was set at 40 per boat. During this study no trips with multiple giggers caught over 40 flounder but there was a change in the average size of flounder caught before and after the law change. The 60 trips recorded before July 2007 had an average flounder size of 15.34in. (393.2 mm) with a standard deviation of 1.89 in. (48.6 mm). The 75 trips made after 7/07 had an average flounder size of 16.15 in. (414.2 mm) with a SD of 1.475 in. (37.6 mm).

In conclusion, the data collected by this 3-year cooperative study sheds some light on the habits and precision of a few avid giggers, but in order to get a complete picture of the fishery as a whole the data collected in this study should be combined with the creel and aerial studies conducted around the same time period. Only then will we know the true size, scope and effect of the South Carolina flounder gigging fishery.

14. Examination of the frequency of black gill disease in white shrimp in South Carolina Using Samples Collected by Commercial Shrimp Fishermen By J. Powers, D. Whitaker, B. Gooch and N. West (SC DNR)

Project Period: August 2006- October 2007

Project Justification and Goal

The condition known locally as black gill (brown gill, brown lung) has been persistent in white shrimp in South Carolina since at least 1999. This condition is caused by an apostome (Protozoan) that attaches to the shrimp's gills and causes melanization (a darkening of the chitin). This melanization results in the brown or black color that is easily observed through the exoskeleton of the carapace. Based upon reports from shrimp fishermen and observations by DNR staff, the "disease" has typically appeared in August and manifested itself in mid to late September before becoming scarce in late October or November as water temperatures decline below 22°C. The impact of this condition remains largely unknown. Shrimpers report that buyers, both retail and wholesale, complain about the appearance of black gill shrimp. Some shrimpers have reported that the exoskeletons are soft and tow duration must be reduced to prevent damage to the shrimp. Some believe that shrimp die quickly in the nets and come aboard the boat in a state of decomposition, although DNR personnel have not observed this directly. Anecdotal reports from shrimpers suggest that the disease "moves" up and down the coast, seemingly starting near the Charleston area each year. During one year, the disease appeared to "spread" from central South Carolina through the Georgia coast in about 6-8 weeks.

Although no mortalities have been directly attributed to black gill, it is hypothesized that the condition may inhibit respiration which could reduce endurance and possibly growth. Laboratory tests at the College of Charleston by Dr. Lou Burnett have shown that black gill shrimp tire much quicker with physical exertion than do non-infected shrimp. It is conceivable that black gill shrimp are less capable of escaping predators, thus raising their natural mortality value rates.

The overall abundance of the shrimp population has not seemed to decline although some shrimpers will debate that point. Quality of shrimp, however, does appear to be a real concern in terms of taste and marketability of the tails. The main goal of this study is to determine when and where the disease first shows up in commercial catches, when it peaks and when it declines. Additionally, much better information on spatial occurrence and insights into the "spread" or geographical occurrence of the disease will be provided. The perceived spread of disease might not be a movement along the coast *per se*, but the staggered emigration of shrimp from the estuaries.

Methods

In June of 2006 a letter was sent to all South Carolina's commercial shrimp trawler captains and owners soliciting participation in the two-year cooperative study. Shrimpers working in the southern, central and northern areas of the coast were utilized. The field research began in August and continued through October 2006 and then repeated again in 2007 through November. Efforts were made to have at least three boats in each region. Shrimpers were trained in field identification of black gill disease. Beginning in August, on each day that shrimpers were working, they recorded the percent occurrence of black gill from a sample of approximately 100 randomly-selected shrimp. These data were recorded and provided to DNR on a weekly basis. Samples of about 50 randomly selected shrimp from the consolidated daily catch were frozen during three pre-selected days during the week and provided to DNR (picked

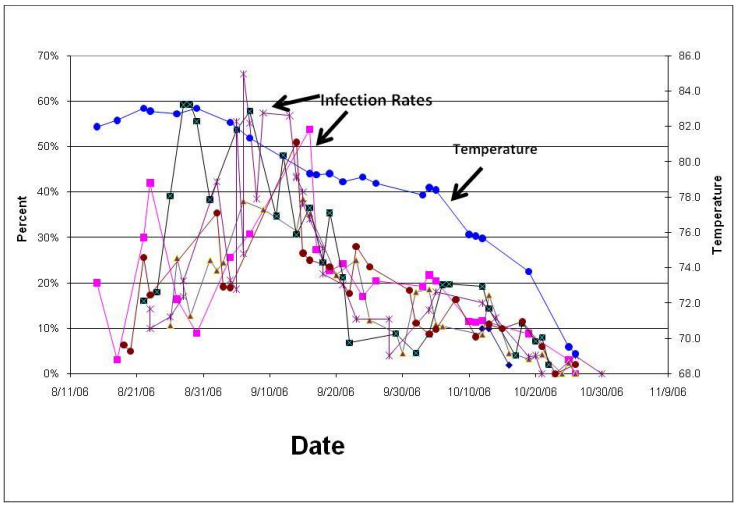
up weekly). These samples were used to validate results provided by the shrimpers and to establish shrimp size and species composition. Samples were taken until the incidence of black gill fell below 5 percent. Fresh samples were returned to the lab for examination of the Black Gill parasite using microscopes and magnifier loops. Laboratory data were compared to field data provided by shrimpers.

Results and Conclusions

In 2006, six commercial trawlers collected data on black gill disease. Samples were taken from Capers Island, north of Charleston. to Fripp Island in the southern part of the state. Sampling began on August 15 and concluded on October 30 with tow duration averaging 162 min. (range = 20 to 180 min). A total of 145 samples was taken from 145 separate trawl tows. Water temperature peaked at 28.4º C on August 28 and declined steadily to 20.5º C on October 30. Heads-off counts (tails per pound) were 52.1 in August, 48.8 in September and 54.0 in October. Daily heads-off counts ranged from 72 on August 15 off Kiawah Island to 26 on October 22 off St. Helena Sound.

Infection rates as determined by shrimpers (as percent of total) for white shrimp in the northern portion of the study zone (Capers I. to Isle of Palms) started at about 6 to 26% and increased relatively quickly to peak around September 10-12 at about 30 to 50% infection. Thereafter, infections rates declined in a linear fashion through the end of October when they approached zero. The observations represented by different boats were remarkably similar, generally all falling within 10% of each other. Trends for the central area (Morris I., Folly Beach, and Kiawah) do not mimic each other because of unequal effort, but generally show the same trend as the northern area with infection peaking in the second week of September and trending downward in a linear fashion until the end of October. The southern sampling area included Edisto I., Otter I., St. Helena Sound, and Hunting I. Sampling began on August 20-22 with infection rates being about 10 to 18%, but rising quickly to 38 to 66% by the first week in September. Rates at all four islands declined linearly from that point on, approaching zero by October 20. These declines in all three regions appear to follow closely the steady decline in water temperature. All three regions and data from all six participating shrimpers followed similar trends, with black gill already being present in mid-August, peaking on about September 10-12 and declining linearly until approaching zero by the last week in October as water temperature reached 22-23ºC.

Observations on infection rates made in the field by four of the six participating shrimpers were very close to those confirmed by DNR staff in the laboratory using magnification. The fifth shrimper submitted only three samples and the sixth deviated by 20-30% of laboratory observations until the beginning of October when his estimates fell in line with DNR lab estimates.



Black gill occurrence rates from six shrimp boats in 2006, shown as percent of total for white shrimp. Blue Line represents water temperature.

In 2007, 349 samples were collected from 349 trawling tows by nine participating trawlers. Sampling covered much more of the coast in 2007 than 2006, ranging from Little River Inlet at the North Carolina border to the southern end of Hilton Head near Georgia. Water temperature during the study period ranged from 29.6ºC (85.2ºF) on September 10 to 15.2ºC (59.4ºF) on November 15. Samples were taken into November in 2007 to be certain that all black gill had disappeared and to document that it did not recur. The average catch per daily trip was 244 pounds (heads on) with a range of 1 to 680 pounds. Sampling began on August 23, 2007 and ended on November 24. Sampling was conducted on 84 days during this period. For 265 samples for which heads off count (tails per pound) was determined, the average count for the entire study was 45.1 (std dev = 16.0). Monthly mean counts were 45.7 in August, 46.9 in September, 45.5 in October, and 40.7 in November. Count ranged from 24 to 99 tails per pound (both occurring in November).

Examination of black gill infection rates in 2007 was more geographically complete than that of 2006. Working from north to south, samples were taken in the Little River area. Infection rates for Little River were generally below those found farther south, remaining below 40% during August and September. However, black gill rates inexplicably peaked in October, reaching 70% and 100% on two separate dates. Thereafter infection rates fell sharply to near 10% in early November.

Date were collected in the Bull's Bay area from late August until November 19. Unlike observations from other areas, infection rates as recorded by the shrimper, never exceeded 50%. Three peaks in infection were found, one in early September at 48%, one on October 8 and 9 at 44%, and then for a single day on October 25 at 47%. Otherwise, most samples collected had relatively low infection rates with the overall average for the area being 17%. In fact, on November 3rd, the rate was only 2% and remained below 5% through the end of sampling.

Sampling just north of Charleston Harbor began on August 31 and continued until November 11. This relatively continuous data set indicated that infection rates hovered around 50% through September, with one single brief peak to 83% on September 23 at Dewee's Island. Beginning in early October, rates fell in nearly a linear fashion falling below 5% on November 5.

Sampling immediately offshore of Charleston Harbor began on September 1 and continued until November 24. Infection rates started near 30% and increased to a maximum of

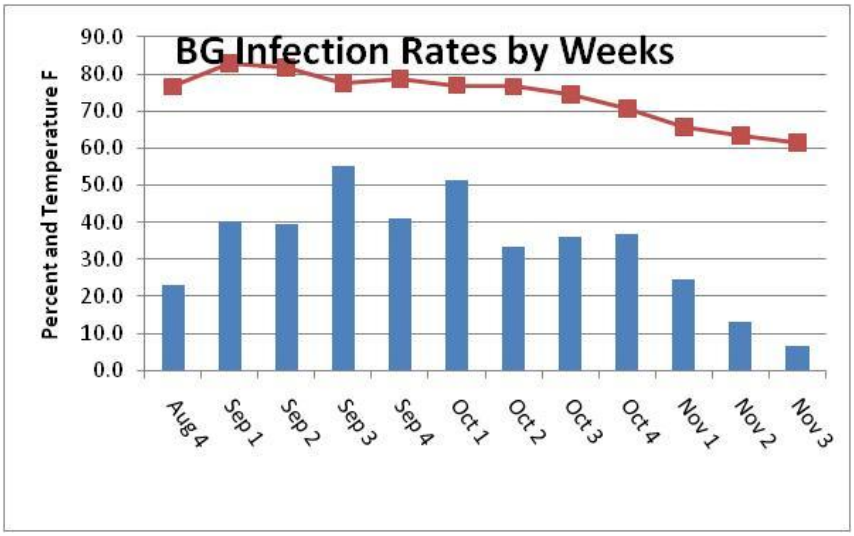
50% on September 15. From that time on, rates decline in a near linear fashion until reaching zero on November 18. However, rates increased again slightly, reaching 24% on November 19, although the day before was 0% and the day after was 6%.

Farther south at Edisto Beach, sampling began on September 4, starting at 50% and remained steady until rising quickly to 80% on October 3 and thereafter declining in a linear manner until approaching 20 % on the last sampling day, November 19.

Just south of Edisto Beach is St. Helena Sound where sampling began on August 24. Sampling suggested that infection rates rose steadily until peaking around September 14. (DNR conducted intensive sampling about this vessel at this time. Those data are presented in the "tow duration" cooperative research study). During the 3rd week in September, rates fell to 30% briefly and then climbed to 71% on October 1. Beginning on October 3, rates hovered at about 40% through November 8. After this date, rates fell to near 5% on November 16.

Sampling just south of St. Helena, around Hunting and Fripp Islands, rates began at 10% on September 6, but quickly rose to 60% by September 10. Rates fluctuated wildly between 30 and 60% until October 11 when rates began declining in a linear manner, going below 5% on November 9.

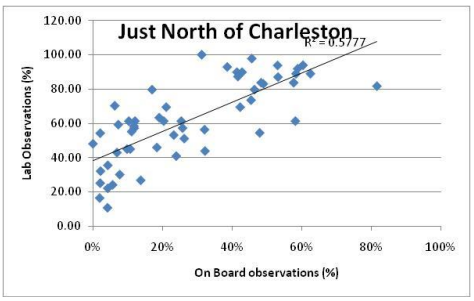
Data from Hilton Head, the most southerly site sampled began on August 30, but terminated on October 3. Rates started out at 16% on September 3, but rose to 40% on the 9th, and continued to rise peaking at 94% on September 23. From that point until October 3, rates fluctuated, being as low as 20% on Sept 24 and as high as 89% a few days later. They then fell to 4% on September 30 before jumping again to 92% on October 2.

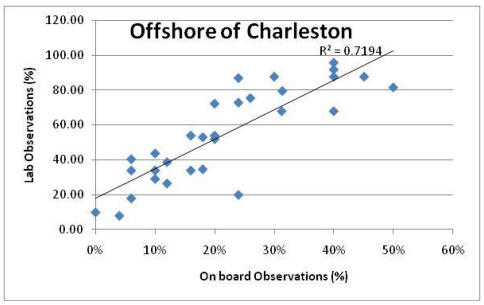


2007 average Black Gill infection rates for the entire state shown as weekly averages. The temperature line (in red) represents weekly averages.

A comparison of infection rates recorded in the field by the shrimpers with those recorded in the laboratory using frozen shrimp from the same date and location provided by the shrimpers generally show a relatively good correlation (overall $r^2 = 0.21$). Shrimpers examined freshly caught shrimp and used only the naked eye, whereas laboratory observations were done with the aid of a microscope and/or a magnifying loop. Therefore, one would expect slightly higher values for infection rates from the laboratory analysis. Indeed, the overall infection rate for 244 samples that were examined both on the boat and in the lab yields means of 32.2% (std.dev = 22.4) for the onboard observations by shrimpers and 57.8% (std. dev. = 21.4%) for the

laboratory observations by biologists. Nevertheless, some fishermern were clearly better at determining black gill infection or perhaps all the shrimp in their areas had more intenes infections. Two Charleston area shrimpers had r^2 values of 0.57 and 0.72. Their data are shown graphically below.





Comparisons of black gill infection rates recorded onboard shrimp trawlers by cooperating commercial fishermen vs. rates recorded in the laboratory by biologists.

Summary

Data collected over two years by commercial shrimpers indicated that black gill disease in white shrimp first becomes noticeable in August. This has generally been the pattern observed by DNR for the last ten years. In both years of this study, the infections rates appeared to peak at about 80% during the second and third weeks of September. These peaks came about two to three weeks after water temperatures were at their maximum in late August. As water temperature cooled in the latter half of September and October, infection rates fell, typically in a linear manner until approaching less than 5% in late October or early November. A comparison of years suggests that infection rates declined more rapidly in 2006 than 2007, perhaps related to slightly warmer temperatures in 2007. Some relatively high, isolated samples in November 2007 suggested the disease was still present in some localized areas. However, samples were not taken in November 2006, so it is impossible to be certain that all black gill disappeared in October 2006. Because infection rates appeared to be consistent for all size classes, we concluded that infection rates were related to temperature. There is no indication from our observations that this disease is abating.

Timing of the disease did not appear to differ along coast. The peak infection period was uniformly in mid September. Based upon data from shrimpers in this study, infection rates north of Charleston were less than those recorded south of Charleston. However laboratory analysis of the same samples indicated that the northern samples were just as high as those south of Charleston, if not higher. This may indicate that infection intensity is less north of Charleston and cannot be as easily seen without magnification. A more systematic study would be required to answer this question.

This study also demonstrated that fishermen can reliably track the presence and magnitude of black gill infection. Although they may overlook the very early traces of the disease that are not apparent to the naked eye, the shrimpers were relatively accurate. Some were clearly better than others suggesting that proper training and quality control may help improve observations. We also found that the shrimpers were very willing to do this work and appreciated the DNR's efforts to learn more about the disease. No obvious mass mortalities attributable to the disease were observed, but shrimpers continue to complain that the quality of black gill shrimp is less than that of non-infected shrimp.

15. An Examination of Migratory Behavior of Selected Finfish Species through a Cooperative Fish Tagging Program with Commercial Ocean Fishing Piers in Long Bay South Carolina

By J. Powers, D. Whitaker, B. Gooch and N. West (SC DNR)

Project Period: October 2007- May 2008

Project Justification and Goal

Sciaenid species such as Croaker (*Micropogonias undulatus*), Whiting (*Menticirrhus americanus*), Spot (*Leiostomus xanthurus*) and Weakfish (*Cynoscion regalis*) are abundant along the US East Coast. These species typically grow larger north of Cape Hatteras than they do south of that point. Additionally, they also mature at a much smaller size in the southern part of the range. Larger sciaenids from Chesapeake Bay have been observed to migrate south during late fall or early winter to offshore of Cape Hatteras. These fish are thought to migrate northward during spring, probably to spawn in the Middle Atlantic. A recurring issue with these species is stock identification. Mitochondrial DNA has suggested there is enough gene flow between the regions to indicate a single stock. More recent genetic studies question that finding, proposing that two stocks exist. Studies of variations in anatomy also suggest two stocks, and recent examination of endemic parasites indicates two separate stocks (for croaker). Some suggest that sciaenids from the South Atlantic Bight migrate to the Middle Atlantic Bight and contribute to spawning stocks in that region. This was the presumption used in requiring the use of by catch reduction devices in the South Atlantic shrimp fishery in the ASMFC weakfish management plan. Although studies have been done tagging sciaenids, they have been relatively small in scale and inconclusive. With this study, we attempted to tag and release several hundred, possibly thousand, fish through cooperative tagging with recreational fishermen on commercial piers. This fishery has historically been a fishery in which most of the catch is retained for consumption, therefore incentives were required to encourage fishermen to give up their catch. Information gained in this study will be useful in helping determine if fish do indeed migrate into the Middle Atlantic from the South Atlantic Bight.

The secondary goal of this project is to use the tagging events as a forum to engage and educate the public on fisheries research. Horry County is an area of limited DNR presence, therefore a cooperative research event utilizing members of the general fishing public will provide DNR biologists an opportunity to interact with South Carolinians who typically only see DNR as Law Enforcement Officers and to help educate local fishermen.

A tertiary goal was to determine if pier tagging is a viable and effective way to tag large numbers of migratory fish.

Methods

Apache Pier and Springmaid Pier, located in Long Bay between Georgetown and the North Carolina border, were contracted to host a series of "Cooperative Tagging Events" in fall 2007 and spring 2008. The first tagging event was conducted in October at both piers on the same day. Twenty-two volunteers from SCDNR and Coastal Carolina University helped with the tagging and the recording of data. Subsequent events in November and April were conducted on one pier per day.

Cooperating fishermen were signed up for the event as they entered the pier and given a unique numbered bracelet for identification. The fishermen were instructed to bring all eligible fish to one of the three "tagging stations" on each pier. Initially, only four species (Spot, Croaker, Whiting and Weakfish) were accepted for tagging, but that number was quickly

expanded because of low catch rates and a desire to encourage more anglers to participate. For each fish tagged, the fishermen received $1 toward the respective pier's restaurant and/or tackle shop. Additionally, the top 5 anglers received gift cards to Dick's Sporting Goods® and Bass Pro Shop®.

Two tagging stations, manned by trained DNR biologists, were setup – one at the middle of the pier and the other near the end of the pier. Eventually a mobile tagging station (water filled coolers pulled in a wagon) was developed to accommodate fishermen who did not want to leave their favorite fishing spot. Biologists were instructed to not tag any fish less than 5" in total length in an attempt to reduce post-tagging mortality. Fish that were brought to the tagging station were deposited in the "drop-off" tank and allowed a few minutes to recover from handling. Fish were then removed from the tank and information on condition, total length and species were recorded. Fish deemed to be in fair or good condition were tagged with a T-bar style streamer tag (provided by Hallprint® tags). If fish were deemed to be in poor condition they were released without being tagged. Tags were labeled with serial numbers, the DNR name, and a toll free telephone number for reporting recaptures. After tagging, fish were placed in an aerated recovery tank for a few minutes and then lowered back into the ocean by net.

Results and Conclusions

In October, 130 fish were tagged at Springmaid and 103 at Apache. In November, 811 were tagged at Springmaid and 214 at Apache. The April event was only held at Apache and 286 fish were tagged there. The total for the three events was 1,544 fish tagged by 303 cooperating anglers. Table 1 lists all the species tagged for the three tagging events.

Table 1: Species composition of tagged fish for all events combined

Species	Number Tagged	% of Total	Average Size (mm)	Max	Min	SD
Atlantic Croaker	30	1.94%	205	316	160	30
Black Drum	27	1.75%	260	447	210	47
Black Sea Bass	6	0.39%	185	228	161	26
Bluefish	93	6.02%	314	763	181	88
Oyster Toadfish	1	0.06%	165	165	165	N/A
Pigfish	1	0.06%	205	205	205	N/A
Pinfish	5	0.32%	203	216	190	9
Pompano, Florida	89	5.76%	215	373	131	45
Red Drum	6	0.39%	367	439	341	36
Rock Sea Bass	10	0.65%	215	311	150	60
Silver Perch	2	0.13%	197	206	188	13
Southern Flounder	4	0.26%	326	403	267	58
Southern Kingfish	265	17.16%	222	352	119	45
Spanish Mackerel	111	7.19%	380	471	285	27
Spot	729	47.22%	207	310	124	18
Summer Flounder	11	0.71%	302	341	246	33
Unknown	11	0.71%	226	309	189	44
Weakfish	143	9.26%	275	364	136	36
Total	*1544*	*100.00%*	*248*	*763*	*119*	*64*

Table 2: Species composition of fish tagged at Springmaid Pier

Species	Number Tagged	% of Total	Average Size (mm)	Max	Min	SD
Atlantic Croaker	22	2.34%	212	316	161	32
Black Drum	3	0.32%	255	260	250	5
Black Sea Bass	0	0.00%	N/A	N/A	N/A	N/A
Bluefish	8	0.85%	271	342	195	43
Oyster Toadfish	1	0.11%	165	165	165	0
Pigfish	1	0.11%	205	205	205	0
Pinfish	1	0.11%	190	190	190	0
Pompano, Florida	41	4.36%	197	295	139	35
Red Drum	1	0.11%	357	357	357	357
Rock Sea Bass	10	1.06%	215	311	150	60
Silver Perch	2	0.21%	197	206	188	13
Southern Flounder	1	0.11%	403	403	403	403
Southern Kingfish	125	13.30%	210	342	119	119
Spanish Mackerel	0	0.00%	N/A	N/A	N/A	N/A
Spot	572	60.85%	207	310	130	18
Summer Flounder	3	0.32%	327	341	315	13
Unknown	9	0.96%	213	293	189	36
Weakfish	140	14.89%	274	364	136	35
Total	*940*	*100.00%*	*244*	*403*	*119*	*67*

Table 3: Species composition of fish tagged at Apache Pier.

Species	Number Tagged	% of Total	Average Size (mm)	Max	Min	SD
Atlantic Croaker	8	1.32%	186	200	160	13
Black Drum	24	3.97%	261	447	210	50
Black Sea Bass	6	0.99%	185	228	161	26
Bluefish	85	14.07%	318	763	181	90
Oyster Toadfish	0	0.00%	N/A	N/A	N/A	N/A
Pigfish	0	0.00%	N/A	N/A	N/A	N/A
Pinfish	4	0.66%	206	216	200	7
Pompano, Florida	48	7.95%	231	373	131	48
Red Drum	5	0.83%	369	439	341	40
Rock Sea Bass	0	0.00%	N/A	N/A	N/A	N/A
Silver Perch	0	0.00%	N/A	N/A	N/A	N/A
Southern Flounder	3	0.50%	301	335	267	34
Southern Kingfish	140	23.18%	231	335	137	47
Spanish Mackerel	111	18.38%	380	471	285	27
Spot	157	25.99%	207	260	124	18
Summer Flounder	8	1.32%	293	335	246	33
Unknown	2	0.33%	274	309	239	49
Weakfish	3	0.50%	315	331	290	22
Total	*604*	*100.00%*	*268*	*763*	*124*	*64*

Tables 2 and 3 list the species tagged at Springmaid and Apache Piers respectively; with 940 fish tagged at Springmaid over 2 events and 640 fish tagged over 3 events at Apache Pier the average number of fish tagged per event are 470 and 201 respectively. Figure 1 shows the number of each species tagged for each location.

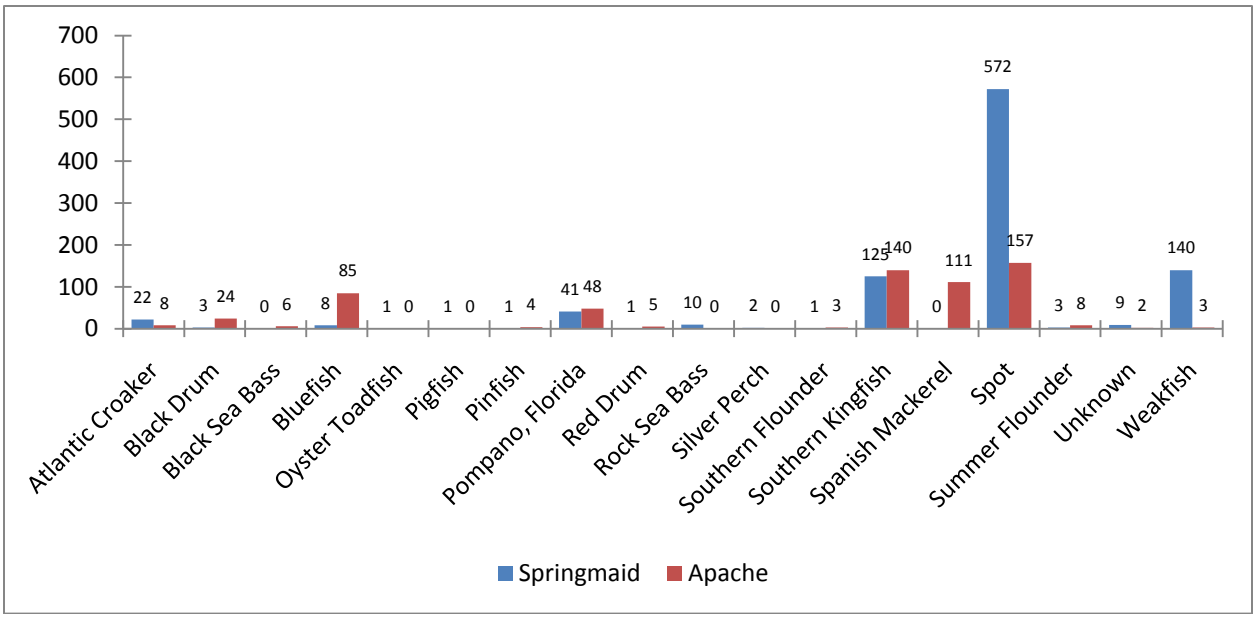


Figure 1: Number of Species Tagged by Location

The most commonly tagged species was Spot with 729 individuals tagged amounting to 47% of the total. On November 18th, at Springmaid Pier, 560 Spot were tagged making this the most Spot tagged in one day in South Carolina. Only 13 of the 1,544 fish tagged or 0.8% were recaptured. Only 2 of the 13 were recaptured at a different location than where they were tagged. The furthest distance traveled from tag location to recapture location was 11 miles. The greatest time at large was 32 days by a Summer Flounder tagged on November 18th.

Although, to date, the main goal of this study, to better understand migration behavior of sciaenids, was not fully realized; the secondary goal of public outreach was an overwhelming success. In all, 303 fishermen participated in the cooperative events and 170 of them helped to tag at least one fish. A non-scientific exit survey conducted after each event showed the majority of participating fishermen enjoyed the event and hoped there would be more in the future. The most common comment from the fishermen was that they were unaware that SCDNR had biologists. Their previous interactions with DNR employees were only with Law Enforcement Officers. In addition to receiving information on the value of Mark-Recapture studies the fishermen were offered a variety of other educational publications and promotional materials.

Overall, it is our opinion that these types of events go a long way to foster positive relationships between SCDNR, the pier owners and the general fishing public. If outside sponsors like Dick's Sporting Goods® and Bass Pro Shop® provided the prize money, future tagging events could be held with the only costs to the department being the fish tags and travel funds for the volunteers.

We also feel that this method of tagging can be employed in the future, particularly to tag spot. However, this fishery probably requires monetary or prize incentives to have good participation. A team of 6 biologists could tag several hundred tagged species in one day, provided that species is being caught. The 111 Spanish Mackerel tagged may well represent the most ever tagged for the species. This species is rather fragile, but we believe a sizable proportion of those survived the tagging, based upon the speed at which they swam away from the pier.

16. A Study of the effectiveness of Turtle Excluder Devices in Crab Traps

J. Powers, D. Whitaker, B. Gooch and N. West
Project Period: 5/2006 – 12/2008
Project Justification and Goal

Diamondback terrapin are known to become trapped and killed in blue crab traps. Bishop (Estuaries, 1983) noted captures of turtles in crab traps in South Carolina with an average mortality rate of 10%. Hoyles and Gibbons (Chelonian Conservation and Biology, 2000) observed terrapin in crab pots near Kiawah Island, SC and stated that recreational pots are likely to cause more mortalities than commercial pots. They noted that recreational crabbers are often in small creeks where turtles are more abundant. Commercial crabbers have volunteered information suggesting that the only time they see terrapin are during spring at about the time of "peeler season" which is typically late April and May in South Carolina. Crabbers insist that mortalities are minor because of the relatively cool water temperatures during that time of year.

Terrapin Excluder Devices or TEDs for crab traps are made of 6 X 2-inch (or 6 X 2) rectangles made of stiff wire or plastic. These rectangles are secured in the throat of the funnels of a crab pot. Due to the greater depth of body of terrapins than blue crabs; most terrapins are excluded from traps while the thinner crabs can still enter the trap. A recommendation for use of a turtle excluder was apparently first made by R. C. Wood in 1992 (Guillory and Prejean, Mar. Fish. Rev. 1998). Guillory and Prejean tested TEDs in 1986 in Louisiana and Belcher and Sheirling (UGA Mar. Extension, 2004) later tested them in Georgia. In both studies, TEDS were judged to be effective in reducing or eliminating terrapins while maintaining normal or improved catch rates of blue crab.

Commercial crabbers do not believe their fishing is causing any long-term negative impacts on the diamondback terrapin population because they only see incidental capture during a brief period during spring. They also note that they tend to fish in more open waters where turtles are less common. However, Tucker, Gibbons and Greene (Can. J. Zool, 2001) documented local extirpation in a "metapopulation" in South Carolina. They concluded that blue crab pots were an important cause in reducing turtle abundance.

Commercial crabbers have an understandable reluctance to use TEDs because they believe anything restricting the entrance of a crab trap would reduce catch rates of blue crab. However, two studies suggest this is not the case. In fact, Guillory and Prejean (1998) found that catch rates of blue crab actually increased (6.32 crabs per catch day in traps with TEDs vs. 5.52 in standard crab traps). Belcher and Sheirling (2004) working in Georgia also found that blue crab catch was not statistically less in experimental traps vs. standard traps.

We believe that fishermen will accept TEDs, at least seasonally, if they are convinced that catch rates of blue crab would not be jeopardized. Compensating crabbers to utilize TEDs should encourage participation and should provide the crabber with first hand evidence that

turtles can be protected while blue crab catch rates are maintained. If fishermen perceive that catch rates of blue crab are actually enhanced, they may voluntarily begin using TEDs or not complain if mandatory regulations are imposed.

Methods

In spring 2006, letters were mailed to all commercial crabbers soliciting bids to participate in a three year cooperative TED study. Three commercial blue crab fishermen were selected for the study; one from each of the Northern, Central and Southern regions. Twenty crab traps were purchased for each of the cooperative fisherman. Ten of the traps were fitted with 2x6 TEDs, while the other 10 had no TEDs and acted as the control. Under the cooperative agreement, crabbers were paid a certain amount to record catch effort and socioeconomic data for the 20 traps for one day each week for three years. The amount paid to the crabbers was slightly more than the similar logbook study due to the perceived potential loss in income from the utilization of TEDs. Additionally, once a month SCDNR observers accompanied the crabber for the duration of the fishing trip. In addition the data collected weekly by the crabbers, observers collected more detailed data; specifically carapace width (CW) for all crabs, sex and shell measurements of any terrapins caught, bycatch data, GPS locations and water quality measurements. Crabbers will be encouraged to fish as they would during normal operations. Field activities will be most intensive during early spring when incidental catch rates of turtles are believed to be most intensive (pers. comm., Mr. F. Dockery, Mr. P. Davis).

Results

Blue crab were sampled from May 2006 until December 2008 utilizing three commercial fishermen. Samples were taken throughout the coastal zone of South Carolina, Table 1 lists the estuary systems sampled for this study. The three commercial crabbers participating in this project, collecting data on 207 fishing days. During the course of this study the contracted fishermen caught 28,026 legal crabs in 4149 pots.

Region	Estuarine System
Central	Ashley River
Central	Folly Creek
Northern	Little River Inlet
Northern	Waccamaw
Southern	Battery Creek
Southern	Harbor River

Table 1: List of Sampling Locations

This program produced an enormous amount of data that will take much more time to fully analyze. However, some data collect in 2006 and 2007 has been analyzed and should give the reader an idea of the potential outcomes for this study once all the data can be reviewed, edited and analyzed. Figures 1 and 2 show the catch per unit effort (CPUE) for data collected in the weekly fishermen logbooks and the data collected by DNR observer technicians for the TED and nonTED traps. Preliminary data from figure 1 show that TED traps catch fewer crabs than nonTED traps. The difference in CPUE ranges from 0.29 crabs in the first quarter to 4.25 crabs in the fourth quarter. The technician data in figure 2 tells a slightly different story. The fourth quarter results show a difference in CPUE of 3.58 but the third quarter data shows TED traps caught better by 1.1 crabs per trap. Once the 2008 data is added to this data set a more refined conclusion on the value of TEDs in commercial crab pots can be generated.

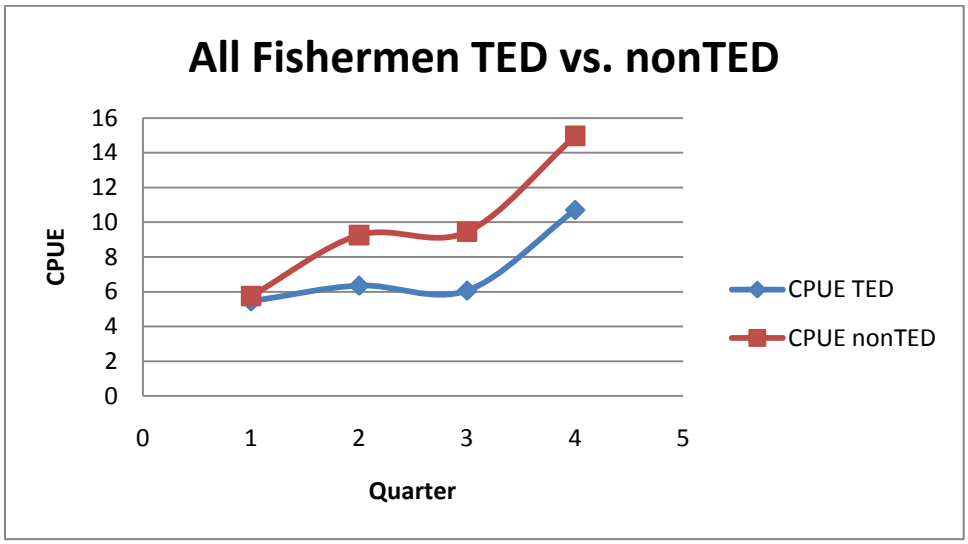


Figure 4: CPUE of data collected by fishermen for 2006 and 2007 for TED and non-TED traps. N Days = 142; N Traps = 2685; N Crabs = 11,472

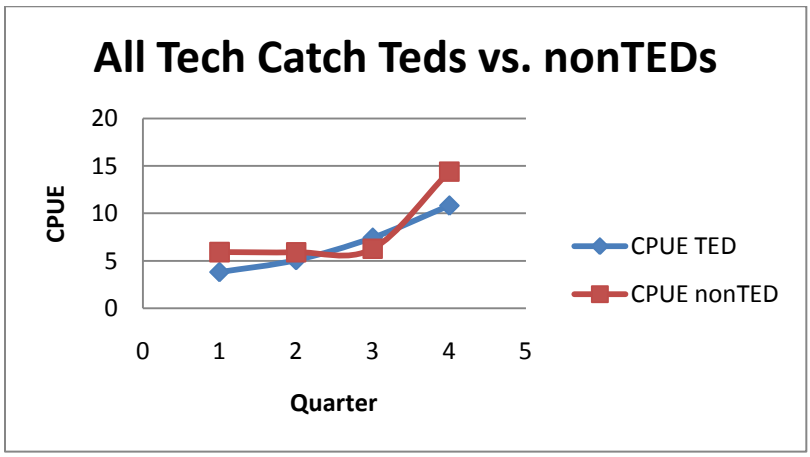


Figure 5: CPUE of DNR technician data for TED and nonTED traps for 2006 and 2007. N Days = 19; N Traps = 375; N Crabs = 1879

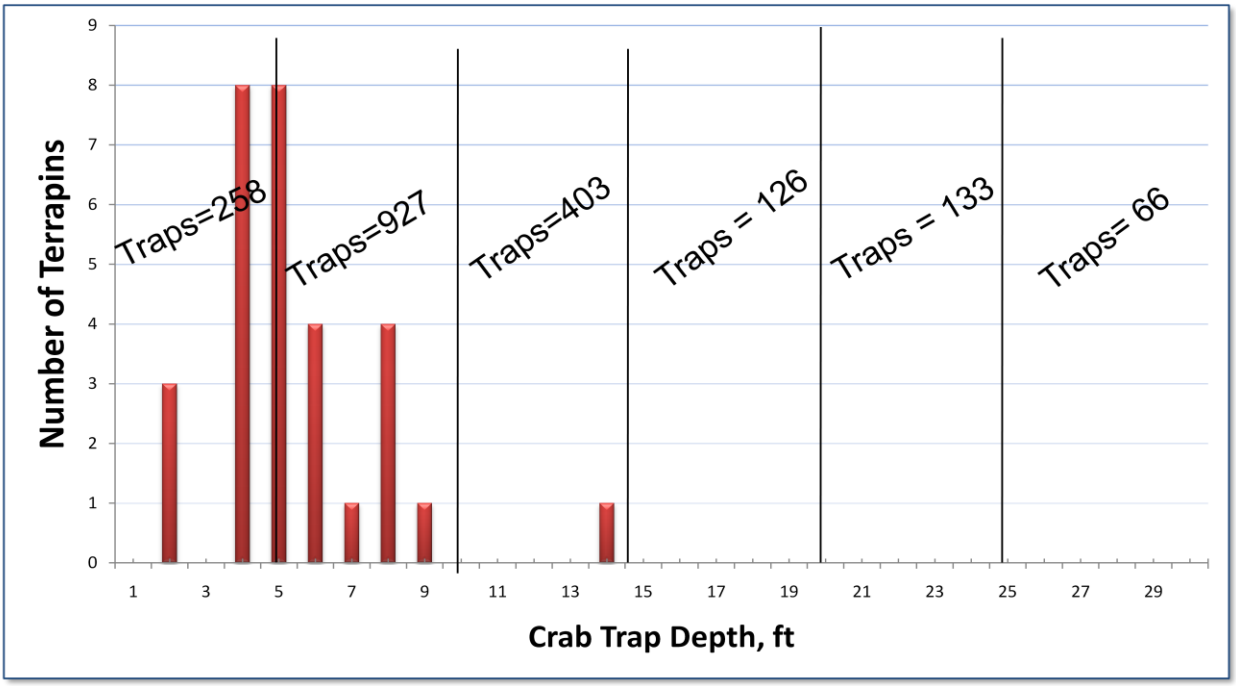


Table 3: Number of terrapins caught in 2006 and 2007 by trap depth

There were 30 terrapin caught in 2006 and 2007 and 97% were caught in less than 10 feet of water (figure 4). Figure 4 also shows that the majority of commercial crab pots are placed in the 5 to 10 foot depth where they are most likely to encounter terrapins. This is more compelling evidence on the need for TEDs in traps placed in shallow water.

This project served its purpose as a pilot study to see if crabbers could be contracted to collect fishery dependent data with TED. Preliminary results suggest the TEDs did not catch as well as was expected but once the finalized analysis from this report is combined with the supplemental study conducted in Abbapoola creek and tertiary study may be needed to compare the 2x6 TED to the toothed TED to see which works best in our coastal waters. The anecdotal response from the contracted crabbers was that in times of the year when crabs are plentiful the TEDs did not seem to have an effect on over all catch but if crabs were scarce they preferred to pot in traps without TEDs. It would also be interesting to test the effectiveness TEDs in peeler pot. These pots are typically fished the same time of year that terrapins are most prevalent. In theory, peelers are smaller crabs and should not be inhibited by the TEDs.

17. Pilot Study to Establish a Logbook Survey for Commercial Blue Crab (Callinectes sapidus)

By J. Powers, D. Whitaker, B. Gooch and N. West (SC DNR)
Project Period: May 2006 – December 2008

Project Justification and Goal

The blue crab fishery has been an important to South Carolina fishery since the early part of the last century. Historically landings (by weight) have exceeded all other fisheries and total value has been exceeded only by the shrimp fishery. However, in recent years, the fishery has appeared to be in decline with reported landings falling well below the long-term mean. Correspondingly, both commercial and recreational crab fishermen have complained about poor catches. This downward trend started in about 2001 with the onset of a severe drought. Below normal rainfall years have continued (until fall 2009) and have generally been blamed for the poor crab harvests.

While landings and periodic fishery-independent surveys have suggested declining stocks, no comprehensive sampling as been done engaging the fishermen. Landings can suffer from inaccurate reporting, particularly when crabbers retail their own product, and fishery independent sampling cannot sample as frequently and thoroughly enough to assess daily and geographic variability in catch rates. Because crab fishermen are on the water five to seven days per week, and because they sample a large number of pots, they provide potential means to collect relatively comprehensive temporal and spatial data. The goal of this project was to evaluate the practicality, cost and success of utilizing crab fishermen in an intensive survey through the use of log books.

Methods

In spring 2006 letters were mailed to all commercial crabbers soliciting bids to participate in a three-year cooperative logbook study. Five of crabbers' bids were selected; one from the northern and three from the central and one southern regions. Under the cooperative agreement, crabbers were paid a certain amount to record catch effort and socioeconomic data for ten traps for one day each week for three years. Additionally, once per month, SCDNR observers accompanied crabber for an entire fishing trip. In addition to the data collected weekly by the crabbers, observers collected more detailed data; specifically carapace width (CW) for all crabs, bycatch data, GPS locations for traps, and water quality measurements. The observer trips were incorporated for quality control and assurance with regard to data filled out in logbooks by crabbers.

Results and Conclusions

Blue crab were sample from May 2006 to December 2008 utilizing five fishermen. Samples were taken throughout the coastal zone of South Carolina, Table 1 lists the estuarine systems sampled. The commercial crabbers collected data on 298 fishing days. DNR staff accompanied these fishermen on 67 days additional days, thus yielding data for a total of 365 fishing days. The total number of crabs caught over the entire course of the study was 31,481 from 3,409 pot pulls (Table 2). The overall average catch per trap (CPUE) was 9.68 legal crabs (4.69 males and 4099 females). Among the crabbers, the range of average CPUE for a year ranged from 4.68 to 17.34. Data are available for more intensive analysis – including daily, monthly, yearly, and regional trends. These data can also be compared to historical catch rates, fishery-independent sampling by DNR, and landings data.

Estuarine Systems Sampled		
Northern	**Central**	**Southern**
Little River	Five Fathom Creek	Ashepoo River
Cape Romaine	Bulls Bay	Battery Creek
Romaine River	Abbapoola Creek	Beaufort River
Waccamaw River	Ashley River	Combahee River
North Santee River	Charleston Harbor	Coosaw River
South Santee River	Cooper River	Fripp Inlet
Guerin Creek	Folly Creek	Harbor River
Wards Creek	Kiawah River	South Edisto River
	Leadenwah Creek	Whale Branch
	Lighthouse Inlet	
	Nowell Creek	
	Old House Creek	
	Stono River	
	Wando River	

Table 1: List of sample locations by region.

Fisherman by Region	Year	N Traps	N Legal Males	N Legal Females	N Legal Crabs	CPUE Legal Males	CPUE Legal Females	CPUE Legal Total
Central Crabber 1	2006	280	1009	546	1555	3.60	1.95	5.55
Central Crabber 1	2007	280	1465	1109	2574	5.23	3.96	9.19
Central Crabber 1	2008	380	1111	668	1779	2.92	1.76	4.68
Central Crabber 2	2007	130	649	478	1127	4.99	3.68	8.67
Central Crabber 2	2008	49	264	103	367	5.39	2.10	7.49
Central Crabber 3	2006	180	1119	2002	3121	6.22	11.12	17.34
Central Crabber 3	2007	289	1496	2001	3497	5.18	6.92	12.10
Central Crabber 3	2008	261	863	1895	2758	3.31	7.26	10.57
Southern Crabber	2006	230	2903	968	3871	12.62	4.21	16.83
Southern Crabber	2007	406	2290	1970	4260	5.64	4.85	10.49
Southern Crabber	2008	309	784	1342	2126	2.54	4.34	6.88
Northern Crabber	2006	94	350	1011	1361	3.73	10.76	14.48
Northern Crabber	2007	431	787	1837	2624	1.83	4.26	6.09
Northern Crabber	2008	90	218	244	462	2.42	2.71	5.13
	Total	**3409**	**15,307**	**16,174**	**31,481**	**4.69**	**4.99**	**9.68**

Table 2: Catch Effort data for 5 crabbers by year

This program produced an enormous amount of data that will take much more time to fully analyze. However, the greatest value of a log book program is its use as a long-term data set for trend evaluation. Or, at minimum, logbook data sets provide a snapshot of catch/effort data that can be used to compare against future or past comparable data sets. Additionally, such data sets can be extremely useful in correlative analysis with landings data and fishery-independent data.

This project required a considerable amount of staff time and funding to ride with crabbers for quality assurance of data and in data entry, proofing and analysis. Additionally crabbers had to be monetarily compensated for their time. Although many crabbers will profess the willingness to provide logbook data, previous efforts without compensation have been short-lived. Despite the cost to conduct this work, it would have been much more expensive for DNR personnel to collect the same data. Should the DNR determine it needs more comprehensive blue crab fishery data in the future, implementation of a logbook program is worthy option.

18. Effects of Shrimp Trawl Tow Duration on the Quality of White Shrimp with Black Gill Disease

By D. Whitaker (DNR), R. Baldwin (commercial shrimper), B. Gooch (DNR), and J. Powers.

Project Period: Sept 2006 to Sept 2007

Project Justification and Goal

The condition known locally as black gill (brown gill, brown lung) has been persistent in white shrimp in South Carolina since at least 1999. This condition is caused by an apostome (Protozoan) that attaches to the shrimp's gills and causes melanization (a darkening of the chitin). This melanization results in the brown or black color that is easily observed through the exoskeleton of the carapace. Based upon reports from shrimp fishermen and observations by DNR staff, the "disease" has typically appeared in August and manifested itself in mid to late September before becoming scarce in late October or November as water temperatures decline below 22°C. The impact of this condition remains largely unknown. Shrimpers report that buyers, both retail and wholesale, complain about the appearance of black gill shrimp. Some shrimpers have reported that the exoskeletons are soft and tow duration must be reduced to prevent damage to the shrimp. Some believe that shrimp die quickly in the nets and come aboard the boat in a state of decomposition, although DNR personnel have not observed this directly. Anecdotal reports from shrimpers suggest that the disease "moves" up and down the coast, seemingly starting near the Charleston area each year. During one year, the disease appeared to "spread" from central South Carolina through the Georgia coast in about 6-8 weeks.

Although no mortalities have been directly attributed to black gill, it is hypothesized that the condition may inhibit respiration which could reduce endurance and possibly growth. Laboratory tests at the College of Charleston by Dr. Lou Burnett have shown that black gill shrimp tire much quicker than do non-infected shrimp. It is conceivable that black gill shrimp are less capable of escaping predators, thus raising their natural mortality value rates.

The overall abundance of the shrimp population has not seemed to decline although some shrimpers will debate that point. Quality of shrimp, however, does appear to be a real concern in terms of taste and marketability of the tails. The primary goal of this study was to determine if tow duration is related to declining quality of the shrimp.

Methods

A single commercial shrimp boat was required to conduct this research. In accordance with south Carolina's procurement code, all shrimpers were invited to submit bids for this work. The boat submitting the lowest bid but also judged to be acceptable for the work (adequate space for biologist, sea worthy, etc.) was selected for this study. The boat that was selected was the FV Billie B, a 78-ft St. Augustine Trawlers based out of Bennett's Point, South Carolina. Sampling gear was four 48-foot tongue trawls (two on each side of the vessel) with 1 7/8-in. stretch mesh. The boat was paid a daily fee and the captain was allowed to keep and sell shrimp in excess of needed scientific samples.

In both 2006 and 2007, the boat was chartered for four days each year. Work began on Monday morning and continued through Thursday afternoon (25-28 Sept. 2006, and 10-13 Sept. 2007). Each day the boat made four tows of each of the following durations: 0.5 hour, 1.0 hour, 2.0 hours, and 3.0 hours. Tow duration was considered from the time the net was set (winch dogs locked down) until haul back first began. By Thursday afternoon, four tows of each duration had been accomplished. The sequence of tows was chosen randomly on the first day and rotated each day through Thursday. This allowed each tow duration to start one day, thus controlling to a degree for any effects time of day may have on the results.

After each tow, a five-pound sample of white shrimp was immediately picked up by two DNR biologists. The vessels crew collected all other shrimp and provided them to the scientific party to determine a total weight. From the five-pound sample, 100 shrimp were randomly selected for individual measurements (total length), body condition, shell hardness, and degree of black gill infection. Body condition was ranked on a scale of 1 to 10 with 1 equaling shrimp that appeared to be dead and possibly in some state of early decomposition when first observed on deck. 10 was given to shrimp that were vigorous with no lesions or other physical problem. Black gill condition was also ranked from 0 to 10, with 0 being totally free of the disease and 10 being heavily infected in both gills. Shell hardness was judged on a scale of 1 to 10 with 1 being extremely soft (recently molted) and 10 being very hard. Heads-on and heads-off counts (tails per pound) were also determined. A sample of heads-on shrimp was retained and frozen for later laboratory examination. Water temperature and weather conditions were recorded for each tow. Sampling was conducted on the north side of the mouth of St. Helena Sound just seaward of the mouth of the Ashepoo River and near Otter Island. Sampling was generally in 25 to 35 feet of water.

Results and Conclusions

2006

In 2006, each days trawling began between 6:19 and 6:36 am. Tow sequences are shown int the following table . Tows are shown in minutes.

Day	Monday	Tuesday	Wednesday	Thursday
1st Tow	30	60	120	180
2nd Tow	60	120	180	30
3rd Tow	120	180	30	60
4th Tow	180	30	60	120

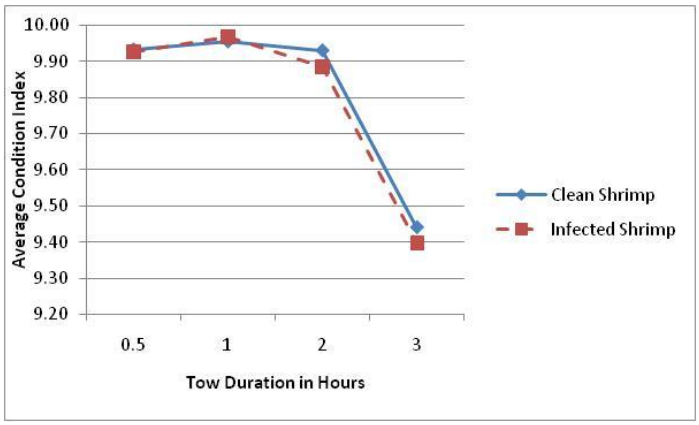
Water temperature for the week was consistent, averaging 26.8ºC. Over the course of the four days, the boat caught a total of 3,922 pounds for an average of 150.8 pounds (heads on) per hour. The total estimated number of shrimp caught was 87,554. Overall heads off count was 39. Overall,

61.54% of the shrimp were uninfected with black gill disease and 38.46% were judged to be infected. Overall size of uninfected shrimp was 137 mm and 140 mm for infected shrimp. Hardness for infected shrimp averaged 9.26 whereas uninfected shrimp, overall, were somewhat softer at 8.99. Average condition was almost identical at 9.81 for uninfected shrimp and 9.79 for infected shrimp. Cotton disease was relatively rare at 0.00023% of the total.

Interestingly, when catches are examined as pounds per hour, cpues were 236 lbs/hr for the 0.5-hr tow, 158 lbs/hr for the 1-hr, 122 lbs/hr for the 2-hr, and 153lbs/hr for the 3-hr. This could be fortuitous, but could suggest the gear becomes less effective as tow time increases. Examination of CPUE with regard to sequence found that the first tow each day was the highest (mean = 196 lbs/hr), followed by tow 2 (mean = 194 lbs/hr) , tow 4 (mean = 161 lbs/hr) and tow 3 (mean = 118lbs/hr). Shrimp catch rates are said to usually be highest at dawn and just after because shrimp have moved seaward overnight while no trawling was occurring and because shrimp that may have been inactive at night become active at dawn. This may explain the higher catch rates for the first to tows of the day. Additionally, tidal stage may have been important with the first tow of the day occurring near low tide.

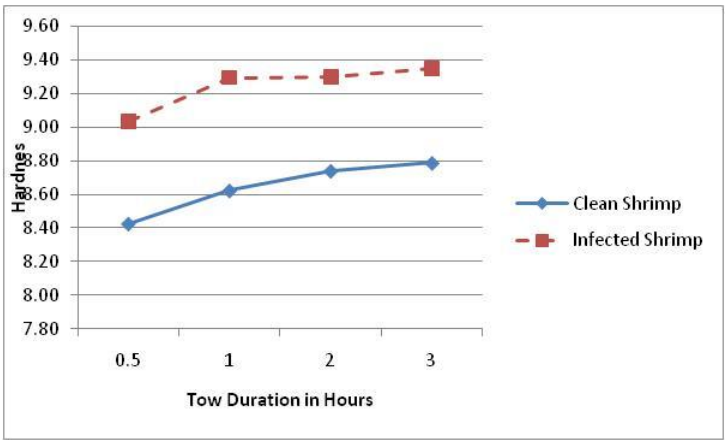
Average heads off counts by gear were relatively constant, ranging from 38 to 42 tails per pound. Daily counts were more variable: Monday = 41, Tuesday = 36, Wednesday = 37 and Thursday = 42.

Comparison of shrimp condition for clean shrimp (un-infected as judged by unaided eye) and infected shrimp found no difference as shown below. In both cases, it was apparent that condition decline dramatically as tows exceeded two hours. This may be caused mortality of a portion of the shrimp early in the tow, resulting in early stages of decomposition after two hours.



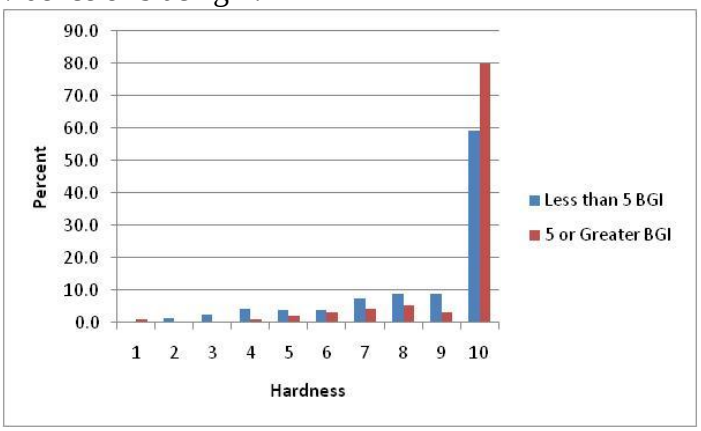
Average condition index for infected and non-infected shrimp by tow duration.

A comparison of uninfected shrimp and infected shrimp and hardness (shown below) interestingly shows a trend of greater hardness with increasing tow duration, although these data may not be statistically significant (further evaluation is planned). It is clear, however, that infected shrimp are harder than uninfected shrimp. Since the parasite for Black Gill must re-infect the shrimp after molting, it takes time for the melanization to occur. Therefore, harder shrimp have had more time develop the black gill condition.



Average hardness for Infected and non-infected shrimp by tow duration.

A histogram examining heavily vs. lightly infected shrimp (see below) and exoskeleton hardness, indicates that the majority of shrimp had relatively hard shells (=10), but the frequency was much less for lightly infected shrimp. As indicated above, this further illustrates that black gill is not as common in recently molted shrimp. However, one curious observation was made of a single soft shrimp (=1) that had evidence of black gill.



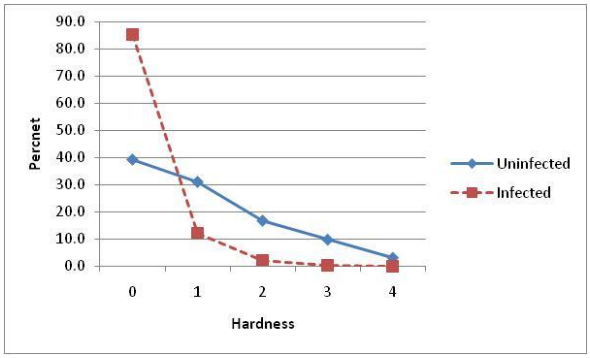
Comparison of shell hardness for non-infected or lightly infected Shrimp (< 5BGI and heavily infected shrimp (> 5BGI).(BGI= Black Gill Index)

<u>2007</u>

Sampling methods in September 2007 were very similar to those of 2006, except the initial tow on the first morning was a two-hour tow and hardness was judged on a scale of 0 to 4 instead of 1 to 10. In addition, "white body" counts were recorded and condition was not recorded in 2007. These white-body shrimp had obviously been dead for some time in the net, thus causing the musculature to appear chalky white and not translucent as recently-dead shrimp appear. The initial 2-hour tow was followed by a 0.5-hr tow, 1-hr tow and finally a 3-hour tow. On succeeding days the second tow of the day before became the first tow and this continued to rotate through the fourth day.

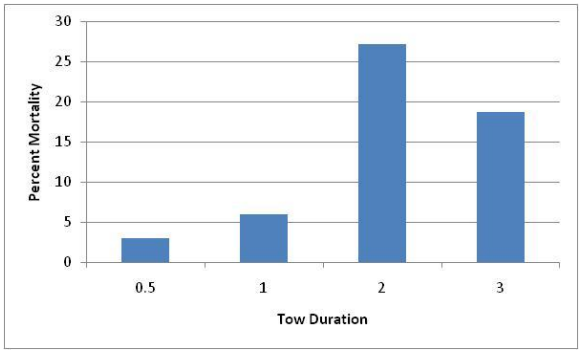
Water temperature for the four days ranged from 28.2 to 28.9ºC. A total of 3,825 lbs (heads on) of shrimp was collected in 26 hours of sampling. Total catch was only 97 lbs or 2.5% less than the previous year's effort in which the same boat, gear, and location were used. Average catch rate was 147.1 lbs/hr. Overall average length of non-infected shrimp was 131.5 mm TL compared to 131.7 mm TL for infected shrimp, slightly smaller than the previous year (137-140 mm in 2006). The overall incidence of black gill infection was 79.5% , which was 18% higher than that observed in the 2006. Of the 1600 shrimp examined for black gill disease, 76.7% of them in the 0 to 5 category (less severely infected) had an average shell hardness of 0.44 and the remaining 23.7% (more intensely infected) had an average shell hardness of 0.08 meaning that infected shrimp were less hard than the uninfected shrimp.

The average hardness value (on a 0-4 scale, 0 = hard shell, and 4= soft shell) for infected shrimp (those with any discernable infection) was 1.06 compared to 0.17 for non-infected shrimp. Overall, most infected shrimp (85.4%) hand a hardness rating of 0, (maximum hardness) (See below) . Uninfected shrimp were more likely to have softer shells. This is similar to the finding from 2006.



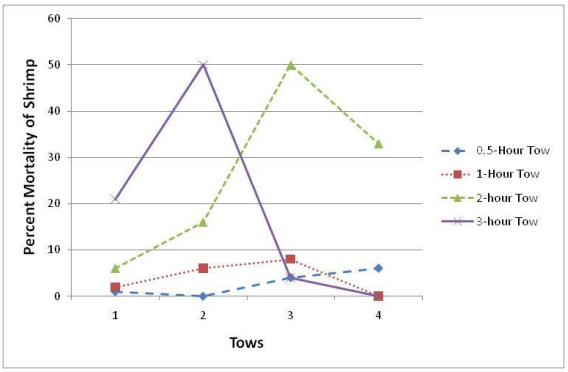
Exoskeleton hardness for uninfected and infected white shrimp shown as percent of total. 0=hard shrimp and 4=soft shrimp.

In 2007, rather than doing a condition index on each measured shrimp as was done in 2006, we instead chose to record those shrimp in our random sample of 100 measured shrimp per tow, that were obviously dead, having a white color or the head becoming loose from the abdomen. Overall, with data from all tows combined, 220 of 1600 shrimp (13.8%) were considered dead on arrival to the deck. Based upon our subsamples, we estimate that 528 pounds of the total 3825 collected were dead on arrival. The histogram below shows the total mortality associated with tow duration. It is clear that mortality increased with the two- and three-hour tows.

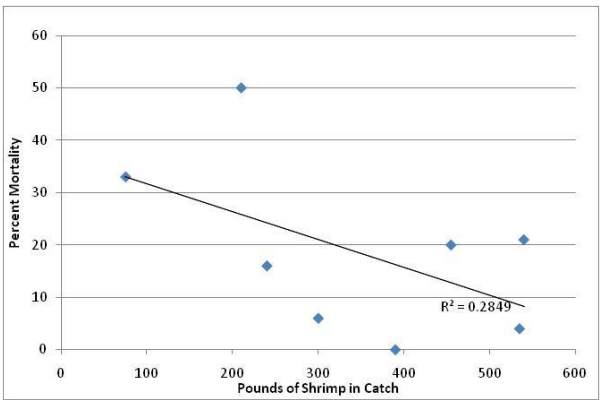


Percent mortality (shrimp immediately dead upon being released from the net) as related to tow length (All four tows combined.)

Examination of the same data but shown by individual tow (see below) show the same overall trend, but two of the 3-hour tows and one of the 2-hour tows had mortalities of less than 10 percent. This indicates there can be extreme variability in mortality rates for longer tow time. It is also clear that long tows can result in up to 50% of the shrimp being in of poor quality upon arriving on deck. There appears to be a relationship between total pounds harvested and percent of dead shrimp. The increased mass in the net could result in crushing and greater mortality. Additionally, this may be related to unusually high mass of bycatch such as jellyfish, crabs or finfish. Bycatch species composition or mass was not recorded, but we did not notice any anomalously high or low bycatch levels. Nevertheless, if a shrimp wishes to improve the quality of his catch, he could reduce his tow to one hour or perhaps one and one half hours, particularly if he believes his total catch may be relatively high based upon try net samples.



Percent mortality of white shrimp by individual tows.



Relationship between total catch of shrimp and shrimp mortality.

In 2007, sampling was conducted about two weeks earlier in September. Based upon other black gill sampling aboard volunteer trawlers throughout the fall season , black gill infection rates were found to peak at about the same time that the 2007 tow duration study was conducted (around the second week in September). The shrimp being smaller in 2007 than 2006 may have been related to sampling earlier in the season (shrimp were about two week younger in 2007, assuming

comparable spawning times). Since infection rates in late September 2006 were less than those observed in 2007, this could suggest that smaller shrimp are more vulnerable or likely to acquire the disease. However, because we saw no obvious trend in individual size and infection rates, we do not believe that size in an important factor in causing black gill disease, rather warmer water temperatures in late August and early September appear to be causative.

19. Cooperative Research Project to Collect and Analyze Three Species of Snapper/Grouper Fishery from the Deepwater Complex

By Steve Shelley (Commercial Fisherman), Byron White & Marcel Reichert (SCDNR)

Project Period: April 2008 – June 2009

Project Justification and Goal

Life history information for the deepwater species of the Snapper Grouper complex of the Atlantic coast of the Southeastern U.S. is difficult to obtain. In addition to living at great depths (200-400 m), these fish are typically long-lived and difficult to age. Four deepwater species of fish in the Snapper Grouper complex include snowy grouper (*Epinephilus niveatus*), tilefish (*Lopholatilus chamaeleonticeps*), blackbelly rosefish (*Helicolenus dactylopterus*), and yellowedge grouper (*Epinephilus flavolimbatus*). These fish are primarily landed by the commercial fishery. Tilefish is a large (1.2 m max TL) gonochoristic, long-lived (54 max age), deep water species that is found mostly over muddy bottoms. In spite of the longevity, most females mature at a relatively young age of less than 2 years (MARMAP data). Male tilefish create burrows that they supposedly defend against other males. Blackbelly rosefish is a small (< 50cm maximum TL), gonchoristic species that bears live offspring. They have a life span of at least 30 years, and they do not mature until they reach 10 years of age, which makes them vulnerable to heavy fishing pressure. Snowy grouper is a deep water grouper that can reach a total length of more than 1 m and live up to 29 years. It is a protogynous species – females reach maturity at 3+ years and transition into males between 8-13 years and a size of 77 and 100 cm TL. Yellowedge are protogynous species, very long-lived (85 years) growing to 1,170 mm TL (SEDAR4-SAR1, 2004).

SEDAR4-SAR1 estimated that the snowy grouper stock was quite low in 2002, the final year of the last assessment period. The 2002 average weights and lengths from the commercial fisheries suggest the population is at very low levels. The length composition data from the most recent years (2000-2002) also suggests a depleted population of snowy grouper. Tilefish stock was experiencing overfishing during 2002. The median estimate of the degree of overfishing was E2002/EMSY = 1.55, which suggests that fishing pressure should be reduced by about 35% to meet SFA requirements. SEDAR4-SAR1 reported that overfishing of tilefish began in the early 1980's and has since continued in most years. The assessment suggests that, despite overfishing, the tilefish stock has remained near SSB msy since the mid-1980s due to a few strong recruitment events.

A SEDAR stock assessment update has been scheduled for snowy grouper for 2010 and for tilefish in 2012. The primary goal this study is to provide life history information for snowy grouper, and tilefish and blackbelly rosefish for the upcoming SEDAR assessment. Both snowy grouper and tilefish are managed using a quota system. These samples collected during the introductory period of the quota system will provide critical data that can be compared to pre-quota ddata, and used to document the impacts of the quota system in the future. In addition, this project will provide blackbelly rosefish information. This species was included in the sample

collection as it is under no management at all, but occurs as part of the same deepwater complex, and is a species targeted by some commercial fishermen.

Methods

The MARMAP program worked with Capt. Shelly to collect a minimum of 1000 specimens of each targeted species from April of 2008 through June of 2009. Capt. Steve Shelley collected the fish using standard commercial bottom long line gear during trips specifically dedicated to sample collection. Collected fish were kept on ice and landed whole. Captain Shelly recorded capture date, time, depth, and location (for each gear deployment). Bottom temperature data were collected on selected gear deployments using EMCO® Mini-logger data recorders provided by DNR. After fish were returned to port , DNR personnel determined individual lengths (total, fork, and standard, mm), weights (whole & gutted, Kg), for each specimen. The left sagittal otolith was removed cleaned and stored for later examination to determine the age of the fish. The gonads were removed from each specimen, weighed, and preserved for later analysis of sex, and reproductive state.

Since snowy grouper, tilefish, and yellowedge grouper are landed in gutted condition, a conversion factor was calculated to convert the landed (gutted) weight to its equivalent value in whole weight. Using a linear regression (Y= a+b*X) on the gutted and whole weight measurements for snowy grouper, tilefish, and yellowedge grouper a conversion factor was calculated.

The posterior portion of the gonad was be fixed in 10% seawater-formalin for 7–14 days and transferred to 50% Isopropanol for 7–14 days. Gonad samples were processed and vacuum infiltrated in a Modular Vacuum Tissue Processor, and blocked in paraffin. Three transverse sections (6–8 ìm) will cut from each sample with a rotary microtome, mounted on glass slides, stained with double-strength Gill hematoxylin, and counterstained with eosin-y. Sex and reproductive stage will be determined microscopically by two readers independently using histological criteria. If their assessments differ, both readers examine the section by viewing the image on a video monitor. If no agreement can be reached, the section is be omitted in the analyses.

.Results and Conclusion

Between April 2008 and June 2009, 18 trips were made by Capt. Shelly to provide specimens of the three targeted species. All of the trips occurred off South Carolina in depths 73-299 meters. 3,593 specimens caught and examined, including snowy grouper (N=1,014), tilefish (N=1,025), and blackbelly rosefish (N=1,447). In addition, the principal investigator also landed yellowedge grouper (*Epinephilus flavolimbatus*) (N=107). We collected this species opportunistically, since it was caught with the other species and provided an opportunity to add to the sparse information. We collected bottom temperature data for 55 gear deployments.

Table 1. Total length and weight averages and standard errors of species caught by longline off South Carolina (N=number, s.e.=standard error).

	Total Length (mm)				Total Weight (g)			
Species	N	Min.	Max.	Mean ± s.e.	N	Min.	Max.	Mean ± s.e.
E. niveatus	1014	208	1113	611.2 ± 4.18	1011	168	19080	3862.2 ± 78.89
L. chamaeleonticeps	1025	395	1064	693.2 ± 4.10	1022	640	15110	4268 ± 88.33

H. dactylopterus	1444	108	380	250.7 ± 0.93	1444	18	927	274.9 ± 3.55
E. flavolimbatus	106	294	1115	595.8 ± 12.79	105	360	14920	3135.3 ± 211.47

Snowy grouper

Specimens ranged in length from 208-1113 mm (Fig 1) and captured in a depth range of 98-260 m, with the largest catches (>20 individuals) from 98-200 m. Snowy grouper were captured in a temperature range of 9-27ºC, with the largest catches (>20 individuals) from 12-22ºC. The result of the whole wet weight to gutted wet weight analysis indicated a relationship for snowy grouper of whole wet weight = -6.98 + 1.077 *(Gutted wet weight). (R^2 = 0.998, N=1,014).

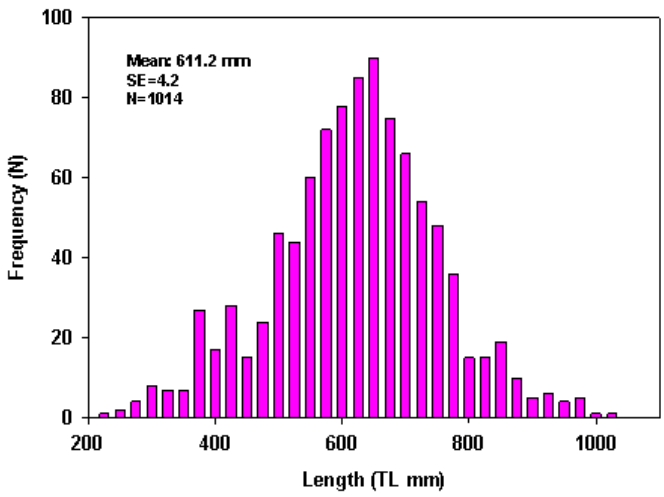


Figure 1. Snowy grouper length frequency.

Tilefish

Specimens ranged in length from 395-1064 mm and were captured in a depth range of 73-282 m, with the largest catches (>20 individuals) from 145-282 m. Tilefish were captured in a temperature range of 6-23ºC, with the largest catches (>20 individuals) from 8-13ºC. The gutted to whole weight analysis indicated a whole weight to gutted weight relationship for tilefish of : Fish whole wet weight =56.128 + 1.0486*Gutted wet weight (R^2 = 0.999, N=1025).

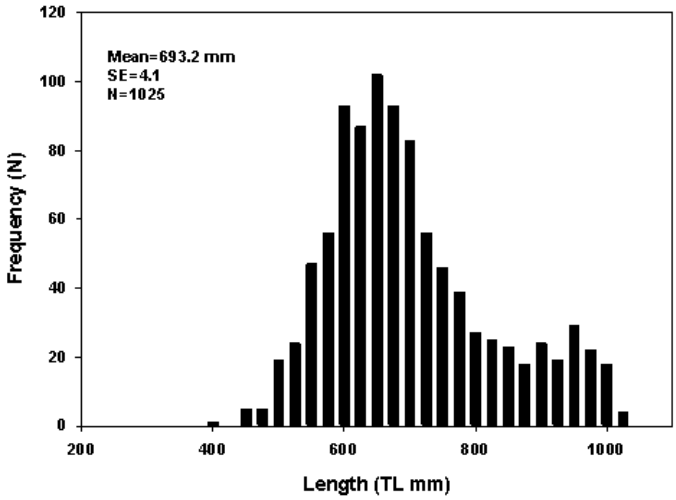


Figure 2. Tilefish length frequency.

Blackbelly rosefish

Specimens ranged in length from108-380 mm (Figure 3) and were captured in a depth range of 132-266 m. Blackbelly rosefish were captured in a temperature range of 8-19ºC, with the largest catches (>100 individuals) from 8-12ºC. No gutted weight data were collected.

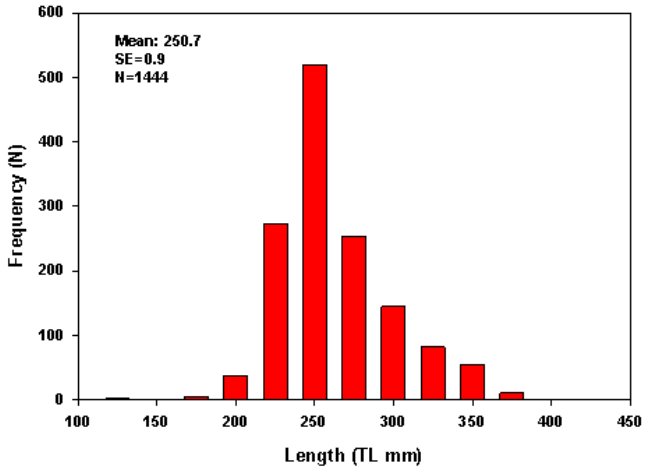


Figure 3. Blackbelly rosefish length frequency.

Yellowedge grouper

Specimens ranged in length from 294–1115 mm (Figure 4) and were captured in a depth range of 132-210 m, with the largest catches (>5 individuals) from 160-210 m. Yellowedge grouper were captured in a temperature range of 12-27 Celsius, with the largest catches (>5 individuals) from

14-17 C. The result of the whole weight vs. gutted weight analysis indicated: Fish whole wet weight = 34.349 + 1.0556*Gutted weight (R^2 = 0.999, N=106

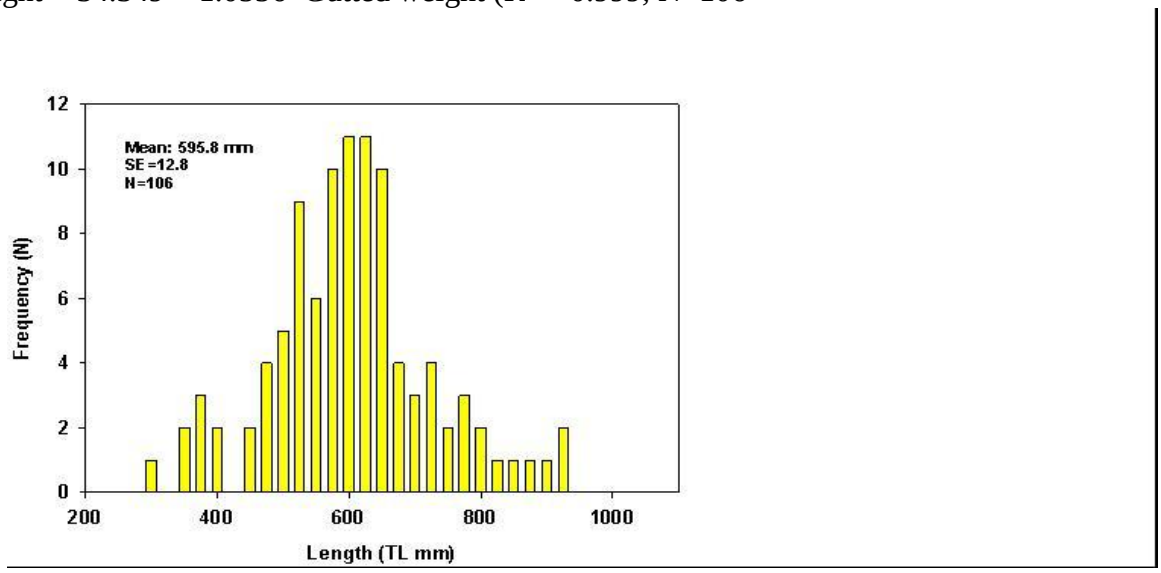


Figure 5. Yellowedge grouper length frequency.

The data collected in this study, including age data to be determined will be organized and provided to the upcoming SEDAR workshops.

20. Alternative Oyster Cultch Study

By *Eric Skaar (Clemson University)*

Project Period:

Project Justification and Goal

Oyster cultch, material that oyster larval settle on, is a critical need for sustaining healthy wild oyster populations. Natural cultch is normally comprised largely of living or deal oyster shell that serves as a settlement site for young oysters. However, other materials, particularly those that contain calcium carbonate, are known to be relatively effective in attracting oyster spat. With the demise of the oyster canneries in South Carolina (the last being in 1986), readily available, inexpensive sources of oyster shell for replanting disappeared. Culture permit holders are required to plant 50 bushels per acre to remain in compliance with their permit. The DNR also plants recreational shellfish beds each year, as well as conducting various efforts to reestablish oysters as part of habitat enhancement. Some shell are currently recycled through a state program but the volume is inadequate for demand. Most shell used by DNR is purchase from a North Carolina shucking house. Development of an alternative substrate that could be "manufactured" could be important in helping sustain and restore oyster beds. The goal of this study was to develop and test creative alternatives that could be used in place of or in addition to natural materials.

Methods

This study was carried out over two years utilizing students in ceramic engineering classes at Clemson University. Exercise 1 began working during fall semester 2006 and was to an effort characterize the chemical and physical properties of oyster shells including density, porosity, grain structure and chemical composition. Density was chosen because it is important that faux shell not sink in the marsh mud or that it not be vulnerable to being washed ashore by boat wakes and wind wave. Optical imaging of the oyster shells was performed to determine if there were unusual grain structures in oysters that could lead to the spat's preference. The chemical composition of oyster was determined in case the spat required a certain chemical compound for attachment or as a source of sustenance. Tests included density and porosity measurements using optical microscopy, x-ray diffraction (XRD), x-ray fluorescence (XRF) and thermal gravimetric analysis (TGA)/Fourier transform infrared spectrometry (FTIR).

To measure the density, shells were first weighed after being dried and then allowed to soak for about a day under vacuum, and weighed suspended in water, and then weighed in air while still completely saturated. These three weights allowed for the calculations of the apparent density, the bulk density, and the porosity of the material. To gain our target density, tests were performed on oyster shells that would be used for cultch. Also, shells known as "washed shell" that had been washed ashore were examined for density. Shells were examined for porosity by cutting with a diamond saw, set into a resin, and polished. They were then etched with hydrochloric acid to help dissolve the grain boundaries, and to make the grains more visible. The samples were observed under an optical microscope.

X-ray florescence was used to determine elemental constituents. Another technique used was thermal gravimetric analysis (TGA) to measure the weight change of the material as it is heated. As gases volatilize, they are analyzed by the FTIR, which uses infrared light to determine the gas composition which also provides elemental composition. X-ray diffraction was used to determine crystal structure of the shell.

Exercise 2 involved experimental development of several manufactured clutches. Materials developed were flat limestone slabs, concrete slabs, building bricks, and wire mesh. Over the course of the semester, students crushed about 1.5 tons of bricks, and created 64 slabs of concrete. Limestone was cut into "stakes" or left as tiles. 40 3-ft wooden stakes were cut to hold mesh wire in place.

Exercise 3 was an project to coat washed natural oyster shells with calcium carbonate to make them more attractive to oyster spat. The first experiment involved coating shell with Portland cement and placing these along the shore of Lake Hartwell to determine if they would be moved around by wave action. The second experiment involved making the shells heavier. For this trial the shells would be designed as an agglomerated mass. This included three groups: single-coated, double-coated, and a single coat with sand as an aggregate.

Exercise 4 in spring 2008 was to create a method in which wash shells could be reincorporated into the coastal environment as effective cultch. The goal was to do this in a cost-effective manner that fishermen could do easily, while also being aesthetically acceptable. The final design involved creating mats which could be laid along the bottom and banks of the inter-tidal region. Burlap was chosen as the bottom layer material due to its biodegradability characteristics, aesthetics, low cost, and availability. The design was to attach vertical structure with wires.

Results and Conclusions

Exercise 1 found that bulk density measurements of the shells varied from as little as 1.86 g/cm^3 to 2.23 g/cm3. The average South Carolina shell had a density of 2.01 g/cm3. The white wash shell's bulk density was 1.73 g/cm3. Keeping these numbers in mind, the target density for cultches was set ranging from 1.9-2.1 g/cm3. The optical microscopy showed that there were pores throughout the material, and not just on the surface. The porosity was in the range of 7-15% with the average South Carolina shells being about 12%, meaning that this amount of the sample was air contained within the pores. It was concluded that the material was predominately calcium carbonate (95%). The x-ray diffraction test showed the only crystal detectable was calcite; a polymorphism of calcium carbonate.

Exercise 2 involved placement of material in a intertidal area of Folly Creek in Charleston County. These items remain in place for approximately a year when they were evaluated. The vertical limestone stakes appeared to be the most effective structure although most had fallen over. Those remaining upright had proportionally more attached oysters. Flat slabs were relatively unproductive with only edges having attached oysters. Interestingly, toadfish had burrowed under these flat slabs and left numerous egg cases. Also, flat oysters were relatively common on the underside of the slabs. Wire was not tested because DNR had previously used this material. A conclusion was that limestone is a good substrate but it should be off the bottom and ideally should have maximum surface area and edges.

Exercise 3 with clusters of shell proved to be much more durable and capable of withstanding wave action. However, quicker and more efficient methods need to be developed to form clusters. Methods used here were too slow and labor intensive.

In Exercise 4, four mats were created, each with increasing complexity of design. The simplest design involved wiring terracotta pots to the burlap mat, followed by the same design coated with concrete, concrete and additional wash shell, and finally entire pillars made of concrete and wash shell. As the mats increased in complexity, the ease of creating and "rolling" the mats diminished. These mats were deemed to be potentially useful for collecting oyster spat but too bulky and complicated for large-scale use. Smaller structures covered with cement that could be "glued" to the mats may be a viable option.

21. Life History Parameters of Kept Versus Discarded Fish Captured by Commercial Fishermen off the Southeastern United States

Jessica A. Stephen and Patrick J. Harris, SC Dept. of Natural Resources

Project Period:

Project Justification and Goal

Recreational and/or commercial fisheries target many species of the snapper/grouper complex off the Atlantic coast of the southeastern United States. The management of these fisheries, which occur predominantly in U.S. federal waters, is the responsibility of the South Atlantic Fisheries Management Council (SAFMC). As more species-specific data have become available since the first management plan was published, size limits (supplemented by seasonal closures for some species) have remained the control measure of choice for the SAFMC. Frequently, the only acknowledged disadvantage of size limits is the mortality of released undersized specimens, and an estimate of this is typically included in stock assessment models as an additional source of mortality.

Several recent field and empirical studies have clearly demonstrated that size limits may have an effect on exploited populations that is contrary to the goals of management by

exacerbating the effects of size selective mortality on the population being managed. Size-selective fishing pressure can result in the mortality of faster-growing phenotypes and therefore the size limits may not only protect young small fish, but protect all small fish, regardless of age. Over time and with heavy exploitation, small fish may come to dominate the population, as they have more opportunities to reproduce prior to removal from the population through fishing. Previous studies found that mean size and mean size at age of red porgy and vermillion snapper collected through fishery-independent sampling decreased dramatically between 1979 and 1994. Similar results were reported for vermilion snapper over the same time period.

The degree to which size limits are then protecting a heavily exploited population is uncertain, as small fish of all ages could begin to dominate the population. If this has occurred, then the status of the population (experiencing overfishing or being overfished) may well be exacerbated by the continued implementation of the size limits. Increasing the size limit would only provide temporary relief from the problem, until the new maximum size of the small fish reached the new size limit. The effects on management of this phenomenon (if it is occurring within a managed population) are twofold: 1) Any life history parameters derived from the landed portion of the population would be based on an unknown percentage of the population that is fast growing, and could result in incorrect parameters being incorporated into stock assessments (Goodyear, 1996), and 2) continued decreases in landings may not reflect a decrease in abundance of the exploited population, but rather a reduction in fish larger than the size limit.

The only way to test if the size limits are exacerbating a potentially deleterious effect as suggested by fishery-independent data is to compare the life history parameters of landed (legal length) fish to those of the regulatory (sublegal length) discards. If there is a shift in the population towards small, slow growing fish, then the portion of the catch that is subjected to regulatory discard should show a similar age range to landed fish, but smaller sizes at maturity, smaller size at ages, and smaller size at transition than landed fish. On the other hand, if there are no changes in life history parameters within the population, then the regulatory discards should consist almost exclusively of young, immature, specimens (maturity stage would vary depending on the size limit and species being investigated).

This study investigates if size limits are causing these unintended consequences for three species of the snapper-grouper complex under different levels of exploitation as of 2004 – (Vermilion snapper - not considered overfished and a size limit of 12” TL; Red porgy - considered overfished and a size limit of 14” TL; and Scamp - not experiencing overfishing and a size limit of 20” TL. The results of this study should aid managers to re-assess the techniques, in particular size limits, currently being used to manage these species.

Methods

Sampling took place on-board a South Carolina commercial snapper-grouper fishing vessel from June 2005 through September 2007. The captain participating in project dedicated the last few days of each trip to sample collection, when he would keep whole legal and sublegal specimens of red porgy, vermilion snapper and scamp. Fishing operations during sampling were identical to a normal trip. All locations fished were selected by the captain as part of his normal fishing. Specimens kept for life history workup were marked using a numbered t-bar tag, and the captain kept a record of the location of capture for each tag number. Up to 1000 legal and 1000 sublegal specimens per year of each species were to be kept by the fisherman. Mapping of the fisherman’s locations showed that he predominately fished along the shelf-break, from 30° 16.558’ N to 33° 36.795’ N in depths between 20 and 128 m (average 51 m ± 15.12 SD)

Specimens sampled by the fishery-independent Marine Resources Monitoring Assessment and Prediction (MARMAP) program were used to allow comparisons of life history parameters between legal, sublegal and fishery-independent specimens. These specimens were collected in randomly deployed traps at depths between 16 and 91 m.

For this study, individual weight and lengths were measured for each fish sampled. Both sagittal otoliths were removed and stored dry. A posterior section of each gonad was removed and stored in 10% seawater formalin for 1-2 weeks, after which samples are transferred to 50% isopropanol for 1-2 weeks.

Age and growth

All fishery-independent otoliths were read independently by two readers and final age or increment count determined according to the established criteria. Ages were used in all fishery-dependent analyses, but for comparison to fishery-independent samples increment counts were used for red porgy and scamp, since edge type had not been recorded for the fishery-independent specimens. Mean age and FLs at age were compared between the sublegal and legal datasets using a general linear model with Tukey's pairwise comparison. Nonlinear regression analysis with Marquardt's algorithm (NLIN procedure) was used to fit the Von Bertalanffy growth model ($L_t = L_\infty \left[1 - e^{(-K(t-t_0))}\right]$) to individual observed lengths at age with combined sexes.

Reproduction

Reproductive tissues were vacuum-infiltrated in a tissue processor, blocked in paraffin and then sectioned at 7 µm on a rotary microtome. Stained and counterstained tissue sections were viewed under a compound microscope to determine sex and reproductive state via criteria. Correct assignment of reproductive stage was confirmed through length histograms by reproductive state (immature and mature), in which there was little overlap in the tails. To estimate length and age at 50% maturity and sexual transition the SAS PROBIT procedure (SAS Institute, Inc., 2002) was used to fit the logistic, normal or Gompertz model to maturity or sexual transition data in 20-mm length intervals or one year increments.

Results and Conclusions

Rhomboplites aurorubens, vermilion snapper

There were 1,739 vermilion snapper collected from the commercial fisherman, with 1,638 (94%) successfully aged. Legal sized (LFD) vermilion snapper (n = 844) were 1 to 10 years old (mean 4.5 yrs) with fork lengths (FL) from 247 to 477 mm (mean 327 mm FL). Sublegal sized (SFD; <273.86 mm TL) vermilion snapper (n= 894, 99-273 mm FL, mean = 254 mm FL) had a similar age range from 0 to 12 years (mean = 3.47 yrs). Despite overlapping age ranges, LFD vermilion snapper were significantly older (ANOVA, $p < 0.0001$). While SFD vermilion snapper dominated (>62%) the young age classes (0-3 yrs) and comprised 31-46 % of the 4-6 year olds, SFD fish were still present in all older age classes (7-12 yrs). In fact, the two oldest age classes (10 and 12 yrs) were predominately SFD, albeit with low sample sizes (n = 3 and 1, respectively) (Figure 3A). Size (FL) at age analysis revealed LFD vermilion snapper were significantly larger across all age classes (ANOVA, p values from <0.0001 to 0.0181). Von Bertalanffy growth parameters showed differences between the two subsets, with the asymptotic length, L_∞, higher and growth rate, k, lower for LFD vermilion snapper (Table 2).

Of the 1,708 (98%) fish assigned sex and maturity values, males were more abundant than females overall (males = 916; females = 792) and within both subsets. The LFD female:male sex ratio (1:1.08) did not differ significantly from a 1:1 ratio. While the SFD sex ratio (1:1.23) had significantly higher percentage of males than a 1:1 ratio, it did not significantly

differ from the LFD sex ratio. Furthermore, comparisons of sex ratios by age class did not differ significantly among datasets, except for age class 3 sex ratio favored males (1:1.82) and the LFD sex ratio favored females (1:0.91).

All males were mature and only 3.9% of females were immature. Mature females were as young as age 0 and as short as 183 mm FL. Fifty percent of females were mature at 212 mm FL and 100% at 261-280 mm FL. Age at fifty percent maturity for females was less than one year and 100% maturity occurred by age 3.

Comparison to Fishery Independent catches

Both the legal-size (LFD) and all fishery-dependent (FD) vermilion snapper were compared to the fishery-independent (FI) vermilion snapper during a similar time frame (2004-2006). FI vermilion snapper had a mean fork length of 259.00 mm (range: 168-412 mm) and mean age of 4.07 years (range: 0-13 yrs). Most (68%) FI vermilion snapper were sublegal in length. FI vermilion snapper were significantly shorter in length than either LFD or FD vermilion snapper. FI mean age was significantly younger than LFD mean age (4.5 yrs), but not significantly different from FD mean age (3.97 yrs). For ages 1-7, FI size at age was significantly smaller than either LFD or FD size at age, but from ages 8-10 there were no significant differences. Von Bertalanffy growth curves were fitted for the FI, LFD, and FD datasets . Asymptotic length, L_∞, was similar between the FI and LFD dataset (FI= 345 mm FL; LFD = 348 mm FL), but FD's L_∞ was lower (FD = 326 mm FL). FI growth rate (0.18) was lower than both LFD's (0.35) and FD's (0.37) growth rates.

There were 1,094 FI sex and maturity readings, consisting of 779 females and 315 males. For the majority of age classes (2-8 yrs) FI sex ratio was significantly different from LFD or FD sex ratios. Similar to the overall sex ratio analysis, FD vermilion snapper always had higher male percentages per age class than FI.

Sublegal sized (SFD) and legal sized (LFD) fishery-dependent vermilion snapper catches had similar age ranges and distributions. While sublegal mean age was significantly younger than legal mean age, the difference was only one year. The differences between sublegal and legal age distributions were apparent in size at age comparisons, where sublegals consistently had smaller sizes at age than legal-size vermilion snapper. Together the age distributions and size at age comparisons are strong indicators that smaller old fish are present in population. There was a notable deficiency of immature vermilion snapper (male and female) in the entire catch. Mature males in our study were younger and smaller than those found in other studies, and mature females were younger, but of comparable length. Therefore, it is likely that our study reflects a more accurate estimate of LM_{50} .than other studies. The low number of immature vermilion snapper as well as the young age and small length of mature males and females indicates that vermilion snapper are maturing at a very young age and small length.

While FI caught vermilion snapper's lengths, ages, and size at age were significantly different from LFD caught vermilion snapper, the differences decreased when compared to FD caught vermilion snapper. While FI and FD caught vermilion snapper had broad length distributions, FI mean lengths were significantly shorter than FD mean lengths. While FI size at age was smaller than both LFD and FD catches, the difference decreased when compared to FD sizes at age.

FD catches had a male biased sex ratio across all variables, which was in direct contradiction to FI catches which were always female biased. While FI catches employ traps rather than baited hooks, previous studies found no differences in sex ratios between traps and commercial hook and line. In those studies, sex ratios favored females for all gears. Since the

FD catches have more males, an important unexplored variable to explain the difference is fish behavior. Traps fish on the bottom and commercial hook and line gears fish off the bottom. One possibility is that vermilion snapper schools segregate by sex in the water column, with males being higher in the water column perhaps making them more vulnerable to baited hooks. An alternative is that males are more aggressive, and therefore attack the bait first. This aggressive behavior might not be captured in trap catches since males may feed and then exit the trap before the trap is retrieved. The difference in sex ratios is of utmost concern as it will have significant impact in fishery stock models. Future studies that look at gear bias due to fish behavior are needed to determine the cause of this difference and which sex ratio is more indicative of the population.

Pagrus pagrus, red porgy

Of the 2,019 red porgy collected from the commercial fisherman, 2,010 (96%) were successfully aged. Legal sized red porgy catch (LFD were 0 to 14 years old (mean = 4.5 yrs) and ranged from 208 to 503 mm FL (mean = 346 mm FL). Sublegal sized red porgy catch (SFD; <307.14 mm TL) were 0 to 12 years old (mean = 3.23 yrs) and ranged from 150 to 307 mm FL (mean = 280 mm FL). Despite overlapping age ranges between the subsets, LFD mean age was significantly older than SFD mean age. The majority (>80%) of all red porgy collected was age 4 and younger. For ages 0-3, 70.5% of the catch was of sublegal length, but for older fish (4+) only 32% were of sublegal length. Von Bertalanffy growth parameters differed between the subsets, with asymptotic length higher and growth rate lower for LFD red porgy. Growth parameters for the entire dataset had an asymptotic length similar to LFD and a growth rate between the subsets.

Males were slightly more abundant in the LFD subset (56.33 %), while SFD catches favored females (58.82%). Both sex ratios significantly differed from 1:1 and from each other. While LFD sex ratios by age class favored males from age 4 and older, SFD age-specific sex ratios favored females until age 6. Despite these differences, age-specific sex ratios did not significantly differ except for age 5.

There were only 23 (1.1%) immature specimens collected, all female and only two were legal size. The majority (46%) were one year old. Lengths of immature red porgies ranged from 150 to 346 mm, with the bulk (65%) occurring between 221 to 280 mm FL. All red porgy were mature by 361-380 mm FL.

Comparison to Fishery Independent Catches

Both the legal-sized fishery-dependent (LFD) and all fishery-dependent (FD) red porgy data were compared to the 1,794 fishery-independent (FI) red porgy from MARMAP's 2000-2002 sampling years. FI red porgy were 1-16 years old and lengths ranged from 174-439 mm FL, with a large percentage of sublegal length (74%). FI mean length (280 mm FL) was significantly smaller than either LFD or FD mean length (346 mm and 313 mm, respectively). While mean increment counts significantly differed, FI mean increment count (4.07 yrs) was between LFD and FD mean increment count (4.26 and 3.62 years, respectively. FI sizes at age (based on counts) were significantly younger than LFD or FD sizes at age for increment counts 1-10. Von Bertalanffy growth parameters were consistent with these results, with FI asymptotic length (320 mm FL) lower and growth rate (0.37) higher than LFD or FD parameters (L_∞ = 425 and 419 mm FL and K = 0.11 and 0.14, respectively).

Histological examination of the 1,443 FI red porgy yielded a 1:0.98 F:M sex ratio that was not significantly different from 1:1 ($\chi^2 = 0.12$). While FI and FD sex ratios were equal, LFD's sex ratio, which favored males (1:1.29), was significantly different.

FI's immature red porgy (n=258, 17%) had a similar increment count and length range as FD immature red porgy. Although the increment count range of FI immature red porgy was from 1 to 4 years, the majority of immature fish were one year old. The FI immature lengths ranged from 174-293 mm FL, with the majority (68%) being between 201-240 mm FL. Despite these similarities, FI's LM_{50} (241.98 mm FL, 95% CI = 239.64-244.24 mm FL) was significantly longer than FD's LM_{50} (Wald's χ^2, $p < 0.0001$; 207.76 mm FL, 95% CI = 177.63 -224.03 mm FL).

Similar to vermilion snapper, both sublegal and legal red porgy catches had similar age ranges and distributions, with a one year difference in mean age. Again, the slight differences between sublegal and legal age distributions was apparent in size at age comparisons, where sublegals consistently had smaller sizes at age than legal caught red porgy. Most notable about the age distributions was that a high proportion of the catch was younger than 5 years old, many of which were sublegal in length. There is a definitive lack of older red porgy, which means the many older fish have already been removed from the population. For a species that is known to live up to 18 years, this truncation can have serious implications. While maturation occurred over a wide age range, the majority of immature specimens were sublegal in length and 1 year old.

Fishery independent catches were more similar to fishery dependent than legal fishery dependent catches. Fishery Independent's modal length and increment count values, sex ratios, immature fish length and age ranges, and sexually transitioning fish length ranges were similar to FD's values. Despite similarities between Fishery Independent and Fishery Dependent immature red porgy increment count and length ranges, fishery independent catches had a higher percentage of immature fish which contributed to a larger LM_{50} value. However, the Fishery Dependent LM_{50} value was calculated on very few fish (n=23) which increases the uncertainty in the estimate.

Mycteroperca phenax, scamp

Of the 952 scamp specimens collected from the commercial fisherman, 927 (97%) were successfully aged. Legal-sized scamp catches (LFD) were 3 to 17 years old (mean = 7.4 yrs) with lengths between 472 and 789 mm FL. The sublegal sized scamp catches (SFD; <471.15 mm TL) were 2 to 8 years old (mean = 4.5 yrs), and ranged in length from 307 to 471 mm FL. LFD scamp were significantly older than SFD scamp ($p < 0.0001$), with SFD scamp dominating the younger portion of the catch (ages 2-5). Von Bertalanffy growth curves were fitted for both LFD and SFD scamp, with LFD scamp having a higher asymptotic length and lower K values (Table 2).

Of the 943 (99%) scamp assigned sex and maturity states, 821 were females and 122 males. Both LFD and SFD sex ratios (1:0.01 and 1:0.42, respectively) favored females and were significantly different from 1:1. SFD scamp consisted almost entirely of females (male n = 4), and was significantly different than LFD's sex ratio. There were 32 (3.4%) immature specimens collected, with only 2 of legal size. Fifty percent of the scamps were mature by 2 years and 330.76 mm FL. Immature females averaged 3.7 years (range = 2-6 years) and 412 mm FL (range = 307-473 mm FL). All fish were mature by age 7 and 500-519 mm FL.

Comparison to Fishery Independent Catches

The 450 fishery-independent (FI) scamp collected between 1995 and 1997 were compared to the legal-size fishery dependent (LFD) and all fishery-dependent (FD) scamps. FI scamp were 1-21 years old and lengths ranged from 305-790 mm FL, with slightly more than half of sublegal length (51%). The majority of scamp (93%) were between 2 to 6 years old, which is similar to the bulk of increment counts for LFD and FD scamp. FI mean increment count (4.1 yrs) was significantly younger than either LFD (mean =7.3 yrs) or FD mean increment counts (mean = 5.6). FI mean length (484.7 mm FL) was also significantly smaller than LFD mean length (mean = 567.7 mm FL), but not different from FD mean length (mean = 489.5 mm FL). FI lengths were significantly smaller than LFD lengths for increment counts 3 and 4, but similar thereafter. FI lengths were similar to FD lengths for all increment counts except 4-7, where FI lengths were greater. Von Bertalanffy growth parameters for FI scamp indicate a lower asymptotic length (856 mm FL) and a higher k value (0.11) than the LFD or FD datasets (L_∞ = 1000 and 1115 mm FL, respectively; K = 0.06 and 0.05, respectively).

Of the 417 FI scamp with sex and reproduction information, 364 were females and 53 males. The FI sex ratio, 1:0.15, was significantly different from 1:1. While FI sex ratio was significantly different from LFD sex ratio, it was not different from FD sex ratio. In general, sex ratios in all datasets favored the females except in larger and older fish.

There was very little evidence to suggest a shift in the scamp population towards small, slow growing fish. Age ranges between legal and sublegal showed very little overlap, with SFD scamp composing over 77% of two through five year olds. Furthermore, sublegal mean age and size at age were always smaller than legal values. As expected, the sublegal subset contained nearly all immature fish and was composed mainly of female scamp. While legal catches also consisted mainly of female scamp, this may result from the fisherman's allocation of specimens towards the study or a lack of males in the population. During the last year of collection, the fisherman provided few legal-sized scamp. Lengths taken by the MARMAP fishery-independent survey for 2000-2008 also had comparable lengths. Therefore, the values derived from the fisherman's catch are reasonable approximations of the fisherman's catch and the lack of males is representative of the population. The small proportion of males in Fishery Dependent catches is of real concern as it could indicate a future scenario of a sperm- limited population. It has been suggested that sexual transition in scamp is socially mediated and occurs only in post-spawning aggregations. The small male proportion may be due to the removal of males and large females at a faster rate than sexual transition is occurring, especially as sexual transition could be confined in time.

This study supplies some strong indications that heavily exploited fisheries that also impose size limits can create a shift in the population to a high proportion of small yet old fish through the removal of the young but larger sized fish. When populations of long-lived species have the majority of its population maturing at very young ages, the decrease in growth rate due to early maturation may have a profound effect. Early maturing fish spawn fewer times, produce fewer offspring per spawning, and these offspring have higher mortalities rates, thereby compounding fishing effects on population size and biomass. Fishery-independent life-history parameters were comparable to the entire fishery-dependent catches for all three species, regardless of the exploitation level. The argument that fishery-independent catches select for smaller fish than fishery-dependent catches is only valid if the catch is compared to just the landed portion of fishery-dependent catches. The most significant difference that remained when comparing fishery independent to fishery dependent catches was in size at age. In all species, fishery-independent catches had smaller mean sizes at age, although these differences were not

always significant. Yet, these differences are most likely attributed to the high frequency within a narrow length range for fishery-dependent caught fish.

23. **Foraging Ecology of Seabirds in Relation to Commercial shrimp Trawler Activity**
by Lisa Claire Wickliffe and Dr. Patrick G. R. Jodice, Clemson University.
Project Period: May 2006 –August 2007
Project Justification and Goal

Commercial fisheries are globally abundant in both nearshore and pelagic marine zones and affect both target and non-target species. Increasing evidence suggests that the increased levels of anthropogenic influence brought about by commercial fisheries create a range of changes at the marine ecosystem-level and can influence overall trophic structure including top marine predators such as seabirds and marine mammals. For these reasons, current fisheries policies not only focus on sustainability of the target species but also the structure and functioning of the overall ecosystem.

One aspect of fisheries operations that is receiving increasing attention for its potential ecosystem level effect is the interaction of commercial fisheries with both nearshore and pelagic seabirds. Much of the research that has been conducted in the realm of seabird-fisheries interactions has focused on issues pertaining to the monitoring and reduction of seabird mortality due to bycatch and to the assessment of the potential impact of competition between seabirds and commercial fisheries for forage fish. Less attention has been given to the potential effect that discarded bycatch can have on ship-following seabirds, i.e. the role of discarded bycatch in seabird diets. For example, it is estimated that ca. 25% of the 110 million tons of marine catch is discarded from fisheries each year, although this figure varies considerably among fisheries and regions. Top marine predators, such as seabirds, can consume a significant proportion of this discarded bycatch and it appears that the availability of this discarded bycatch may affect population dynamics, species composition, diet composition, and spatial distribution of seabirds in some regions. In the North Sea, for example, it has been estimated that energy available in bycatch from commercial fishery operations (3.4 x 1012 kJ) could support ca. 5.9 million seabirds. These North Sea studies indicate that the dynamics of inshore fisheries, such as shrimp fleets, may play a crucial role in the foraging ecology and the distribution of seabirds in a given geographic area.

To date little to no similar research has been conducted on the potential importance of discarded bycatch to seabirds in the United States. Few estimates are available that examine either the abundance of seabirds foraging at commercial fishing vessels or the success with which they scavenge prey from these vessels despite the often close proximity of seabird breeding sites and commercial fishing operations. For example, the central South Carolina coast supports a substantial commercial shrimping industry that operates primarily in inshore waters which also provide the primary foraging habitat for brown pelicans (*Pelecanus occidentalis)*, sandwich terns (*Sterna sandvicensis*), royal terns (*Sterna maxima*), and laughing gulls (*Larus atricilla*).. Given that food availability can affect reproductive success in temperate seabirds, it is necessary to investigate the extent to which the four aforementioned seabird species utilize fisheries bycatch as a food source.

The goal of this research was to examine the relationship between seabirds and commercial shrimp trawlers operating adjacent to seabird colony sites. The objectives were to (1) determine the relative abundance and distribution of ship-following seabirds

at shrimp trawlers during the seabird breeding season, (2) determine the species composition of bycatch from commercial shrimp operations, particularly items that are appropriately sized for capture by seabirds, and (3) for each of the most common species collected as bycatch, determine which items were most likely consumed by each of the four focal seabird species observed foraging at trawlers. Seabirds were counted every 40 mins for the entire duration of each cruise (n =39 cruises, n = 434 surveys). At the start of each survey the observer scanned a 270o arc around the ship (minus the area obstructed by the wheel-house was excluded), counting all of one species present at that time, and then counting the next species, until all birds within a 50-m radius were counted. Seabird count data were mapped with graduated proportional symbols used to represent the relative number of seabirds counted at each geographical coordinate.

Methods

Abundance and distribution of seabirds in relation to shrimp trawling in nearshore waters of South Carolina was examined by observing seabirds during 39 cruises on commercial shrimp trawlers operating from the Cape Romain and Charleston Harbor ports during May – August, 2006 and 2007.

Seabird use of discards from a shrimp fishery was examined to determine species composition of bycatch discarded by shrimp trawlers and the extent to which these items are consumed by scavenging seabirds (i.e., laughing gulls, brown pelicans, royal terns, sandwich terns). Fieldwork was conducted on commercial shrimp trawlers operating in the Charleston Harbor and Cape Romain regions of South Carolina during the 2006 and 2007 seabird breeding seasons. Samples of bycatch were collected each time the net was pulled in from a tow (i.e., haulback phase) and emptied onto the boat deck. A representative sample (ca. 4l) was collected from the left (bag 1), right (bag 2) and middle (bag 3) of the bycatch pile.
Each collected item was identified (species) and its length measured (±5 mm) before discarding the item overboard. A representative sample (n = 6-10 items) of species that appeared to be relatively abundant in the bycatch on each trawl was collected following the first tow of the day. Items were between 50 – 600 mm as these were the sizes most likely to be consumed by the most common seabirds in the area. All items to be used in discard experiments were either discarded within 30 minutes of appearing on deck or stored on ice to preserve the freshness of the sample until discarded. Items were identified to the species level, measured to ± 5 mm, and then discarded individually by hand (ca. 5 fish min-1). Each discarded item was observed until its final fate could be determined as (1) consumed (if so, by the seabird species) or (2) not consumed, which resulted in sinking or consumption by other marine organisms (e.g., dolphins, porpoises, or sharks). All discard experiments were conducted during the operational discarding and sorting of bycatch to ensure that an artificial feeding environment was not created by our single item discards. Two discard experiments were conducted per cruise, although discard experiments were not conducted if the catch from the haul was small (i.e., discard time < 10mins). A foraging success index (SI) was calculated for each species of seabird for each discard experiment. The SI measured the relative efficiency of each of the four most common seabird species at capturing discarded items.

Results and Conclusions

The species of seabirds observed during surveys from commercial trawlers

included laughing (*Larus atricilla*) and herring gull (*Larus argentatus*); royal, sandwich (*Sterna sandvicensis*) and common tern (*Sterna hirundo*); brown pelican (*Pelecanus occidentals)*; greater shearwater (*Puffinus gravis*); and magnificent frigatebird (*Fregata magnificens*). Laughing gulls, royal terns, brown pelicans, and sandwich terns comprised > 99% of the total counts in each region each year. Laughing gulls were the most abundant species present at trawlers comprising ca. 65 - 70% of the total seabirds counted each year. Royal terns comprised ca. 17 – 20 % of the seabirds present at trawlers each year while brown pelicans comprised ca. 8 - 14% of the seabirds present at trawlers each year. There was a significant relationship between activity and abundance for each species except sandwich terns. Few other variables or interaction terms were consistently significant across species. Abundance of brown pelicans was most strongly affected by trawler activity. Brown pelicans, laughing gulls, and royal terns were most abundant during the discarding phase and least abundant during towing. Laughing gulls were the most abundant and royal terns the next most abundant species during each of the three activities. Sandwich terns were the least abundant species during discarding and together with brown pelicans were least abundant during dragging and hauling.

5,428 items from 37species of fish and invertebrates were identified from samples collected during 92 hauls. Atlantic croaker (*Micropogonias undulatus*), Atlantic cutlassfish (*Trichiurus lepturus*), star drum (*Stellifer lanceolatus*), and spot (*Leiostomus xanthurus*) were the most abundant bycatch items. In Cape Romain in 2006, Atlantic menhaden (*Brevoortia tyrannus*) comprised 5% of the bycatch, but this same species comprised <2% of the bycatch in Cape Romain in 2007 and in Charleston Harbor in 2006 and 2007. Silver seatrout (*Cynoscion nothus*) comprised ca. 8-9% of the bycatch in Charleston Harbor in both years, but <3.5% in Cape Romain in both sampling years. The diversity of the bycatch, as measured by Shannon's diversity index (H′), was nearly identical among the four location-years, ranging only from 2.3 to 2.7. The evenness index (EH) also was nearly identical among the four location-years, ranging only from 0.69 to 0.76. Highest values for both H′ and EH were measured in Charleston Harbor in 2007. Croaker, drum, and menhaden all comprised a significantly greater proportion of the bycatch in Cape Romain compared to Charleston Harbor ($\chi 2 > 6.9$, $P < 0.008$ for each). In contrast, spot and silver seatrout comprised a greater proportion of the bycatch in Charleston Harbor ($\chi 2 > 14.2$, $P < 0.0002$ for each). Spot and 56 menhaden comprised a greater proportion of the bycatch in 2007 ($\chi 2 > 4.9$, $P < 0.03$ for each) while croaker were more common in 2006 ($\chi 2 = 13.22$, $P = 0.0003$). There were substantial shifts in the rank of the abundance of the five most frequently occurring items of bycatch. Spot was the highest or second highest ranked item in all location-years except Cape Romain in 2007 when it was the fourth ranked item. Croaker also was the highest or second highest ranked item in all location-years except Charleston Harbor in 2006 when it was the fifth ranked item. Menhaden was the fifth ranked item in Cape Romain each year but was not among the top five items in the Charleston Harbor region in either year. Of the 1,706 items discarded during experiments in 2006 and 2007, 1,313 (77%) were perch-like fish (i.e., perciformes), 192 (11.3%) were herring-like fish (i.e., clupeiformes), 105 (6.2%) were flatfishes (i.e., pleuronectiformes), and the remaining 95 were from a variety of orders each comprising <2% of the total items discarded during experiments. Laughing gulls consumed 32.7% of the discarded items, brown pelicans consumed 21.2%, royal terns consumed 12.6%, and sandwich terns consumed 2.6% of discarded bycatch. The remaining 30.9% of the discarded items sank or were consumed by other organisms (e.g., sharks, marine mammals). The odds of consumption for small items were 1.7 to 4.8x more likely compared to the odds of consumption of all other sizes. The odds of consumption of Clupeiformes were 1.3 to 14.5x more likely

compared to the odds of consumption of perciformes, pleuronectiformes, and all other items. The odds of perciformes, the most frequently occurring group of fish in the bycatch, being consumed were ca. 6x more likely compared to the odds of pleuronectiformes and all other items.

This study clearly showed that shrimp trawlers appeared to be a strong, local attractor for seabirds. All of the four locally breeding species attended trawlers regularly, and the most generalist of these (i.e., the laughing gull) was the most abundant and frequently observed. Based on the abundance and frequency of presence of each species during surveys it appears that if policies change for the shrimp fishery or if the shrimping industry continues to decline (i.e. local fleet reduction) then changes in the distribution and abundances of locally breeding seabirds also may occur.

This research also demonstrates that breeding seabirds in South Carolina are successfully foraging upon discarded bycatch provided by regional shrimp trawlers despite the fact that many of the discarded items were benthic species that typically would be unavailable to seabirds in their natural diets. Approximately 70% of the bycatch discarded in experiments was consumed by seabirds, suggesting that bycatch possibly makes up a large part of their diet at certain times of year (i.e., breeding months). Laughing gulls, the most abundant species following trawlers in South Carolina, consumed the greatest number of items discarded during experiments (ca. 33% of items). The potential benefit of discarded bycatch from shrimp trawlers on seabirds still requires further investigation of proximate composition of bycatch species, bioenergetic modeling, total mass of discards available and diet composition at nesting colonies. These findings should be viewed as a foundation for understanding the effects that inshore shrimp fisheries may have on local breeding seabirds. With further investigation, a more comprehensive management plan can be formulated for ship following seabirds in South Carolina.

24. **Characterization of the Surf Zone Macrofauna at Folly Beach, South Carolina**

By Jacquelyn Wilkie, Grice Marine Laboratory, College of Charleston

Project Period: June 2007 March 2009

Project Justification and Goal

Surf zones are physically dynamic environments that have low habitat complexity, yet the fish composition within this habitat is widely variable. In many locations the surf zone ichthyofauna consists of a large number of individuals representing a small number of species. The large abundance of fishes in this physically challenging habitat has been attributed to the high availability of food in the form of zooplankton. Fishes also use this habitat as a refuge, by utilizing the characteristic shallowness, high turbulence, and turbidity to avoid predation. Most fish species in the surf zone are represented by early life history stages which use this environment as a nursery. Some surf zones that are not directly associated with estuaries contain the same faunal composition and same percent of estuarine-dependent species as estuaries. As estuaries and associated habitats (e.g., salt marshes) continue to decline, the surf zone may become increasingly important for some species. In addition to juveniles that use the surf zone as well as estuaries, there are species such as *Trachinotus carolinus*, Florida Pompano, and *Menticirrhus littoralis*, Gulf Kingfish, for which the surf zone appears to be the only nursery habitat.

Species composition and diversity vary spatially and temporally in a surf zone, making long-term sampling necessary for adequately characterizing the community and providing background

information for assessment of this habitat. Despite the importance of surf zones as nurseries, most studies conducted are temporally limited and lack the long-term data essential for understanding processes and effects.

Although the surf zone is of recreational, economic, and environmental importance, much of its ecology is poorly known. Attention has been given to surf zones along the Gulf of Mexico, but fewer studies have been conducted in the South Atlantic Bight.

Some studies that have sampled surf zones in the South Atlantic Bight have focused on tidal and daily trends in fish communities. Seasonal changes in surf zone fauna have been studied in Virginia, South Carolina, and Florida. Wilber et al. surveyed the surf zone in New Jersey immediately before, during, and after beach renourishment.

This study was conducted as part of the South Carolina Department of Natural Resources Cooperative Fisheries Research program and focused on nekton, consisting of both fish and macroinvertebrates, in the surf zone off Folly Beach, South Carolina. It occurred in conjunction with a study of the surf zone in Horry County, South Carolina, contributing a spatial aspect to the research.

Hypotheses:

H_1: Species diversity and abundance of individuals do not differ appreciably from those of 1969 to 1971 by Anderson et al. (1977).

H_2: Community abundance and diversity does not differ spatially between Horry County and Folly Beach.

H_3: The ichthyofauna and macroinvertebrate species composition and abundance will vary with season.

Methods

Folly Island is a barrier island which lies approximately 14 km south of the Charleston peninsula. The surf zone at this beach has high wave impact, and the substrate is consists mainly of sand. Two locations along Folly Beach were chosen for study. The first site at the southwestern end of the island was chosen in order to make a direct comparison with a previous study in the 1970s at the same location. Collections were made within an hour of low tide when the water was seaward of the nearby wooden groins.

The second site, located 0.5 km southwest of the southernmost groin, was used as a replicate and was sampled on the same days and during the same tidal cycles as the first site. There was adequate distance separating the two sampling locations to ensure that the first seine haul would not disturb the second. The sites were sampled in a random order, determined by a random number generator

A 19.8 m by 1.8 m, 9 mm stretch mesh nylon bag seine was pulled through the surf zone parallel to the shore for 100 m. The net was deployed so that the end closest to shore was in approximately 0.2 m of water. Samples were taken biweekly within one hour of low tide in the early morning (shortly after sunrise to avoid interaction with swimmers) from June 2007 to March 2009.

After the seine was beached, organisms were deposited into full strength formalin to which seawater was added in order to obtain a 10% formalin concentration. In the laboratory each specimen was identified and measured to the nearest tenth of a millimeter, then blotted dry and weighed to the nearest hundredth of a gram. Before each seine haul, Dissolved Oxygen, Conductivity, Salinity, and Temperature was measured.

Data collected included the number of species, the number of individuals for each species, and body size and mass of each specimen. These data was compared between seasons,

and sites. The two sites at Folly Beach, were evaluated by using the Wilcoxon Signed Rank test (the non-parametric equivalent to the paired t-test). Variation in species richness and abundance between seasons was analyzed using Kruskal-Wallace tests. The data were used in additional statistical analyses to examine correlations between abundance, species richness and biomass with any of the physical parameters such as salinity, temperature, and dissolved oxygen.

Results and Conclusions

Collections

From July 2007 to March 2009, 83 hauls were pulled thereby sampling approximately 164,340 m^3 of the surf zone. 1,757 specimens were collected consisting of 109 swimming invertebrates and 1,648 fishes. These organisms represented 40 species (10 invertebrate, 30 fishes), 30 genre (7 invertebrate, 23 fish) and 19 families (3 invertebrate, 16 fish). There were four hauls in which nothing was caught. The number of fish specimens caught in each haul ranged from 0 to 202. The number of invertebrate specimens caught in each haul ranged from 0 to 9. The number of species in each haul ranged from 0 to 10. The total biomass was 18,490.55 grams with 17,813.19 grams of that being fish and 677.36 grams invertebrates.

The most abundant species was *Trachinotus carolinus* (Florida pompano) with 392 individuals making up 22.3% of the total catch. *Anchoa mitchilli* (bay anchovy) and *Menidia menidia* (Atlantic silverside) followed closely comprising 19.3% and 17.6% of the total catch.

Although *Mugil cephalus* (striped mullet) comprised 9.9% of the study's abundance, they made up 67.9% of the total biomass caught. *Trachinotus carolinus* ranked second in the biomass at 5.2%, followed by *Menidia menidia* at 4.5%. Two of these top ten species, *Dasyatis sayi* and *Sphoeroides* sp., were only caught once.

Comparison of Sites

Not only were the number of species collected per haul not significantly different between sites, but when analyzing the fish and invertebrate species separately, there were also no differences between sites. There were no significant difference s between sites in total abundance, as well as the fish and invertebrate abundances. The sites were pooled for all further analysis.

Comparison of Seasonal and Yearly Collections

From November through the end of May, no more than four species were collected in any one haul. Species richness increased included the summer months (July, August, and September) and one month on each side. Species richness reached a high of 10 for two collections in July of 2007. Ignoring the influence of 3 fish schools, the data show an increase in specimen abundance in the summer months and slight decrease in specimen abundance in late fall and winter months.

Of the seven seasons sampled, summer of 2007 had by far the highest abundance and species richness. From July through September of 2007, 20 species of fish and 4 species of invertebrates were captured totaling 565 specimens (559 fish, 6 invertebrates). The most common species found was *Anchoa mitchilli* which made up 48.0% of the season's abundance, however only 7.7% of the biomass caught during that season. *Anchoa hepsetus* and *Trachinotus carolinus* were second and third most abundant at 14.7% and 9.6%, respectively. *Mugil curema* (white mullet) caught made up the greatest proportion of biomass at 21.3%.

During fall 2007, 127 fishes and 8 invertebrate specimens were collected comprising 15 species. The organisms collected during fall of 2007 weighed a total of 3,862.25g (3,822.17g of fishes and 40.08 g of invertebrates). The most abundant species was *Menidia menidia* which

comprised 51.1% of the catch, followed by *Mugil cephalus (*14.1% in abundance and 85.4% in biomass. *Menidia beryllina* was the third most abundant species at 11.1%.

During winter of 2008 there was a heavy predominance of *Mugil cephalus* both in abundance as well as biomass. This was primarily due to a very large school of 118 striped mullet being caught in one seine haul. The second most abundance species was *Menidia menidia* (20.7% in number and 1.51% of biomass), followed by *Menticirrhus littoralis* at 5.5% (number).

A single large school also dominated the spring 20008 catch. In May, 202 *Trachinotus carolinus* were caught in one haul, making it the largest catch in abundance for one seine pull. Total abundance for the season was 356, with 330 fishes representing 15 species and 26 invertebrates representing 5 species. *T. carolinus* rank first (69.1% by number); *Anchoa mitchilli* and *Menidia menidia* ranked second and third with relative abundances of 11.0% and 6.7%, respectively.

218 organisms were captured during summer 2008, representing 4 invertebrate species and 8 fish species. This season's invertebrate numbers were the highest at 47, primarily of *Arenaeus cribrarius* (speckled crab,78.7%). Total biomass during summer 2008 was 896.28 g, 212.65 g of which was invertebrate. The most abundant fish was *Chloroscombrus chrysurus* (Atlantic bumper) which comprised 31.7% of the total abundance followed by *Trachinotus carolinus* (29.4%) which made up the highest biomass at 285 (258.28%). 23.7% of the total biomass was from invertebrates, the highest in any season.

The smallest seasonal catches were recorded in fall 2008 (79 fish caught in 6 species and 2 invertebrates in 2 species. Total biomass was 164.57 g, 11.50 g of which were from the two invertebrate species. *Menidia menidia* had the highest abundance at 35 specimens (43.2. *Trachinotus carolinus* ranked second in both abundance and biomass at 23.5% and 25.5%, respectively. *Anchoa mitchilli* also made up 23.5% (number)

Menidia menidia made up the vast majority of the organisms collected during winter 2009, totaling 136 (73.5%). There were 13 species collected (10 fishes, 3 invertebrates) which were comprised of 185 species (174 fishes, 11 invertebrates). *Mugil cephalus* ranked second 7.0% and there were 10 specimens of *Menticirrhus americanus* making the species the third most abundant for the season (5.4%).

Nine species made up at least 5% of the season's catch in at least one of the seven seasons sampled. These were *Trachinotus carolinus, Anchoa mitchilli, Menidia menidia, Mugil cephalus, Chloroscombrus chrysurus, Anchoa hepsetus, Menticirrhus littoralus, Arenaeus cribrarius,* and *Menidia beryllina*. Figure 9 depicts the seasonal percent composition of these most abundant species. The seasonal abundance of these most prominent species is illustrated in Figure 10.

Relationships between Environmental variables and Collections

The seasonal variations were most likely linked to temperature which ranged from 7.8 to 30.0^{o}C. Apart from one outlier, there is a clear shift at 24°C resulting in low catch rates. Catch rates were higher with higher temperatures. Salinity range was small (27.7 to 34.3 psu) over the course of this study with no relationships with catch rates or species composition. Dissolved oxygen was measured both in concentration as well as in percent. The Secchi depth ranged from 17 to 113 cm, but the number of species and number of animals caught did not correlate with the Secchi depth.

Eight species dominated more than 90% of the catch: *Trachinotus carolinus, Anchoa mitchilli, Menidia menidia, Mugil cephalus, Chloroscombrus chrysurus, Anchoa hepsetus,*

Menticirrhus littoralis, and *Arenaeus cribrarius* (in order of total abundance). These were the same species found in previous studies conducted in previous decades.

There are remarkable differences in both specimen abundance as well as species composition not only between different seasons but between the same seasons which were sampled for two consecutive years. There was not a species whose presence dominated more than one of the seven seasons season.

Summer 2007 had a significantly higher number of species and specimens collected than summer 2008. Five of the twenty species of fish caught were only caught in this season and two of those (*Stongylura marina*, and *Dasyatis sayi*) were only caught once in this study indicating that they may not normally be within this habitat. Biomass was also significantly higher in the summer of 2007 than that in 2008. Yet the summer of 2007 had a significantly lower number of invertebrate species and specimens than the summer of 2008. This annual disparity may be linked to events that occurred just prior to the start of the study. In spring 2007, a 3 km stretch of beach was renourished adjacent and downstream to the study sites. The sediment which was pumped onto the beach may have brought with it excess nutrients and organic matter, increasing the food resources within this habitat. The invertebrates, especially *Areneaus cribrarius* were drastically diminished in summer 2007 compared to those sampled in the summer 2008 and in Anderson *et al*. (1977). The renourishment of the beach during the spring may have buried these speckled crabs. Winter samples were dominated by two species (Striped mullet and Atlantic silverside), in 2008 and 2009, respectively.

25. Purchase of Whole Cobia from Recreational and Commercial Anglers for the Purpose of Characterizing a Coast Wide Population Structure

By J. Yost and M. Denson (SC DNR)

Project Period: Jan – Dec 2007

Project Justification and Goal

Cobia is a migratory coastal pelagic species found in most tropical to sub-tropical waters throughout the world. While it is known that cobia concentrate in the southern estuaries of South Carolina during spring, knowledge of their population size, growth rate, and migration patterns is limited. Few fish from the northern portion of the coast have been examined. In order to properly manage the species it is important to collect data throughout the species' range. The goal of this study was to enhance the cobia data base by collecting cobia from the northern portion of South Carolina.

Methods

In 2007, SC DNR made an effort to collect cobia from offshore commercial fishing boats in Murrell's Inlet. DNR creel clerks working the Murrell's Inlet area purchased six fish in the round from April-June at $3.00/lbs. and transported them to the Marine Research Resource Institute in Charleston, SC. From each of these fish, otoliths were examined to determine age, gonads were examined to determine stage of development and fecundity, stomachs were examined to determine diet, and DNA was analyzed to evaluate hatchery contribution and help define population structure.

Results and Conclusions

Due to the small sample size, limited conclusions can be made about life history and population structure; however, these samples can be combined with samples collected by recreational anglers offshore of Hilton Head and Edisto to form a combined South Carolina offshore group. We are currently evaluating the genetic difference between these offshore groups and cobia caught in South Carolina's inshore estuaries. . All fish collected from Murrells Inlet were sexually mature and females were either in early or late stages of development. The age ranged from 3 to 6 years with the majority (4) being 3 years old. This range is similar to the samples collected in the Broad River (Port Royal Sound, Beaufort County) and the surrounding estuary in 2007 (~90%). Fish size ranged from 936 to 1180 mm (TL).

Because cobia do not school but travel in pods of two to three individuals, they are primarily caught commercially as bi-catch. Therefore, collecting samples from commercial fishing boats will always be limited and a more directed effort should focus on the cottage industry of recreational guides and charters that target this species. Currently, recreational anglers and guides in the Beaufort and Port Royal area are being solicited to help collect additional samples.

Table 1: Cobia sampled from offshore Murrell's Inlet during April-June 2007

Collection #	Date Caught	TL (mm)	FL (mm)	Weight (kg)	Sex	Age
MI0001	4/6/2007	1126	1004	12.1	Male	3
MI0002A	4/9/2007	1180	1028	12.6	Female	6
MI0002B	4/9/2007	1004	889	7.4	Female	3
MI0003	5/22/2007	1174		9.98	Male	4
MI0004	6/7/2007	1044	922	9	Female	3
MI0005	6/14/2007	936	822	6.17	Male	3

Cooperative Research Grants

The programs covered in this section were developed through a subrecipient agreement with SC Sea Grant Consortium.

1. Study of the Commercial Long-line Fishery of Coastal Sharks Occurring in State Waters

by Terry Annibale, Commercial Fisherman

Project Period: June 2007 – December 2007

Project Justification and Goal

Sharks populations along the South Carolina coast are routinely sampled by DNR staff, primarily in estuarine waters and in limited locations. Relatively intensive sampling in nearshore

ocean waters has not been conducted. The primary objectives of this work included taking samples along much of the South Carolina coast and using that information to examine life history and reproductive habits of coastal sharks. A secondary objective was to determine if fishing for sharks in this manner could be commercial feasible and if a local market could be developed.

Methods

Fishing gear included a 0.080-in. diameter mainline that was 0.25 mi. long. The line was weighted with 5-pound weights. International orange buoys were attached to the longline. Leaders were made of 0.080-in. monofilament with 12/0 long line snaps. Hooks were 14/0 circle hooks. The longline was typically deployed around 7 am as hooks were baited as the line was paid out. Hooks were located in 30-ft intervals. Gear was typically allowed to fish for a period of 30 minutes. Captured fish were identified and recorded before the next set was made. Two or three sets were made each day. All sharks were identified, examined for sex and measured for FL and TL. Locations fished included Charleston Harbor entrance (one off the north jetty and one off the south jetty), North Edisto area (one at a 10-15ft. deep slough between Botany Island and Deveaux Bank and a second at a 12-20 ft deep slough between Seabrook Island and shoals just south of this location). Little River area (one location just off the Little River Jetty in 15-20 ft. and another just southwest of the first location in 8-12 ft of water), Murrell's Inlet (one location just off the jetty in 15-20 ft of water), Trenchard's Inlet in Beaufort County (one location within the inlet at a depth of 20 ft. and a second just off the inlet in a live bottom area), and Winyah Bay in Georgetown County (one location in lower Winyah Bay near the lighthouse in about 15-30 ft and a second location just offshore of the Winyah Bay jetty entrance).

Results and Conclusions

Samples in all locations were made in June, July, August, September and November 2007. Fishing was conducted on 24 days, usually with two sets per day, and occasionally three. 54 sets were made. A Total of 361 sharks were recorded. The most abundant were sharpnose and Bonnetthead and Blacknose, in that order.

Atlantic sharpnose (*Rhizoprionodon terraenovae)* were relatively common in all locations sampled. 140 sharpnose were collected, with 114 (81%) considered adults. The adults averaged 894 mm TL (SD= 96 mm). Among the juveniles that were measured, they were about 300 mm TL. Catch rates were relatively high in June although mostly limited to the central and northern part of the state's coast. Catch rates declined during July and only five sharks were collected in August and five in September. Catch rates then increased greatly in November with good catch rates in both the northern and southern locations. A non-grant related fishing trip in January 2008 found relatively large numbers of sharpnose at 90 ft off the central coast of South Carolina.

Blacknose sharks (*Carcharhinus acronotus)* were found in all three regions of the coast on 16 days from June through September. For the 16 days with blacknose present, the average catch was 4.1 per day. None were encountered in November. 65 blacknose were collected with the largest one-day catch being 10 (7 males and 3 females) on August 18 at Murrell's Inlet. Overall, 60% of the sharks were males. Overall average length was 1216 mm (SD=93mm).

At total of 21 Blacktip sharks (*Carcharhinus limbatus)* was collected and most were young adults and juveniles. The average length of these sharks was 1077 mm TL (SD=391mm) with a range of 600 to 2290 mm. Blacktips were relatively uncommon being caught on 13 of 24 days,

but on 7 fishing days, only one was taken each day. Catches of 3 fish per day were made on June 22 and June 26, at Murrell's Inlet and Trenchard's Inlet, respectively.

Finetooth sharks (*Carcharhinus isodon)* were relatively uncommon throughout the study area with only 19 adult sharks being. A few sharks were taken in late June but the multiple captures all occurred in Mid August to Mid September being found in all three regions of the coast. The average length of the 19 sharks collected for the entire study was 1326 mm TL, although the larger sharks (about 1500 mm) were more common in late August and September. No finetooth sharks were observed in November. Bonnethead sharks (*Sphyrna tiburo)* were the second-most commonly caught shark species. A total of 92 bonnetheads was collected – all being collected on 14 of the 24 days sampled. None were collected in November. Overall catch per day was 3.8, although on June 26 at Trenchards Inlet, 24 were collected and on August 6 at Charleston, 18 were collected. The sex ratio on June 26 was 12:12 but, interestingly, all 18 caught on August 6 were female. Overall sex ratio of all samples combined was 33 males to 59 females. Overall average size was 1018 mm TL (SD=121mm). Size ranged between 850 and 1300 mm TL. Sandbar sharks (*Squalus plumbeus)* were not common. Only 16 sharks were collected over the entire period and 11 of those were taken on one date in one set (June 28 off Winyah Bay). Of these 12 sharks, 9 were females ranging in size from 1100 to 1600 mm. The two males were 2140 and 2290 mm. For the entire study, the average length was 1443 mm TL (SD=486 mm). Sharks were caught on only 6 of 24 sampling dates being collected on June 28, July 12,15, and 25, August 6, and November 13.

Scalloped hammerhead sharks (*Sphyrna lewini)* were relatively rare, with only 8 being caught during the study. Of these 4 were caught on June 28 at Winyah Bay and were relatively small (380,380,380, and 610 mm TL). The remaining hammerheads averaged 850 mm. Of the three sharks for which sex was determined all wee females.

2. To Determine Ideal Placement & Methodology to Grow-out Single Farmed Oysters in a Wild Environment.

by Roddy Beasley

Project Period: 2008- August 2009

Project Justification and Goal

A ready market awaits production of locally grown single oysters in South Carolina. Single oysters are preferred by restaurants but most single oysters come from out-of-state suppliers and locals generally prefer the native, saltier oysters. With production of relatively low cost local seed oysters in a hatchery, it may now be possible to culture single oysters for market. The goal of this study was to grow out hatchery produced seed oysters in local waters to determine the optimal conditions and locations for successful propagation.

Methods

Approximately 38,000 seed oysters ranging in size from 1 to 1.5 inches were obtained from Island Fresh Seafood, Yonges Island, SC. Five intertidal pens were used to raise the seed oysters to marketable size (~3"). Each pen was 14 by 24 feet and covered with plastic mesh to discourage predators. ¼ inch bar mesh was used initially but was replaced with ½ by ¾ inch mesh because the ¼" mesh was trapping too much sediment. Mesh was held in place with hooked metal rods pushed into the bottom. Each pen was marked with a 10ft. vertical bamboo pole. Pens locations are described as follows:

Pen (A) was sited on a shell-sand bottom surrounded by semi-sandy mud. On the east half of the pen 4,670 ½ to 1-inch oyster seed were placed in 5 green bags and on the western half, 5,328 1-inch seed were placed in 2 purple bags.
Pen (B) utilized a shell-sand bottom surrounded by semi-sandy mud. 7,472 ½ to 1- inch oyster seed were contained in 8 green bags.
Pen (C) also utilized a sandy-shell bottom surrounded by semi-sandy mud. 2,802, ½ to 1-inch seed oysters (3 green bags) were placed on the east half of the pen. 5,328 one inch seed were placed in two bags on the western side.
Pen (D) was sited on a sandy-shell filled bottom on the upper intertidal half of the pen (north) and a semi-sandy muddy bottom on the bottom half (south). Investigators placed 4,670 ½ to 1-inch seed oysters on the east half of the pen (5 green bags) and 6,993 ½ to 1-inch on the western end of the pen (9 green bags ,777 per bag).
At site (E), west of pen (D), the investigators placed 1,868 ½ to 1-inch seed clams in 2 green bags around the base of a shell-filled circular shell rake No mesh cover was used.

Results and Conclusions

Initial plans were to deploy 160,000 oysters, but the Island Fresh Seafood hatchery was able to provide only 38,000. The experiment was terminated on June 26, 2008.
Pen A. The west-end of the pen's seed was not as successful as the east-end probably because the initial seed size was smaller. Survival was estimated at 25%. Also, in May 2008, sharks became entangled in the mesh covering and totally destroyed the pen.
Pen B. This pen was silted over with mud more than the three other pens, but the oyster survival rate appeared to be higher than the others. Silting may have given the oysters some protection from predators and possibly environmental extremes. Silt covering very likely protected the seed oysters from oversetting by oyster spat since none were observed.
Pen C. This pen performed similarly to Pen A, with east-end seed growing better than the west-end seed. The pen cover was also destroyed by sharks.
Pen D. The large seed placed on the northwest end of the pen grew well and the northeast portion performed almost as well. The bottom half (south-east and north-east) had no survival because the seed oysters were covered with approximately one inch of mud.
Site E. This site was not covered with mesh had no survival. The investigators suspect that stingrays consumed the seed oysters almost immediately after they were planted.

Larger seed oysters had higher survival rates. In future plantings, larger seed (>1/½") is recommended. It became obvious that some degree of light silting was beneficial to survival and prevented oversetting by spat. Light silt covering oyster seed should not be removed in future endeavors to grow single oysters. Seed placed in higher intertidal areas (Pen D) did better than seed observed in the lower pens. Therefore, special attention should be paid to planting on higher intertidal areas. The investigators concluded that protective covering in the form of plastic mesh is important to improve survival, although plantings should be monitored for sharks or other marine life that may damage the protective mesh.

3. Evaluations of Icelandic Cambered Trawl Doors by Scott Cook (Commercial Fisherman)
Project Period: July 2007- June 2008
Project Justification and Goal

Fuel costs currently account for the highest expense in the shrimp trawl fishery.

There does not appear to be any relief in the future for reduction of fuel prices on the world market and in order for the shrimp fishery to remain a viable business, measures are necessary to increase fuel efficiency. This project is directed toward evaluating new gear to reduce vessel fuel consumption during trawling operations.

Recent work performed by Texas Sea Grant has revealed that non-traditional trawl doors can be utilized in the shrimp fishery to significantly reduce fuel consumption. Gary Graham, Texas Sea Grant Fisheries Specialist, reports that he has documented 20-28% fuel reduction through use of Icelandic, cambered trawl doors on a number of Texas boats. In fact, fourteen Texas shrimp vessels have now adopted these new style doors and are fishing them successfully. Five vessels currently are being rigged with the cambered doors throughout the Gulf of Mexico for additional evaluations. Although this work is ongoing in the Gulf of Mexico, a number of unanswered questions still exist. There are significant differences in fishing practices in the Gulf as compared to the South Atlantic fishery and these doors had not been tried in South Carolina. The goal of this study is to evaluate the Icelandic, cambered door in the South Carolina shrimp fishery to determine if fuel efficiency and improved shrimp production per unit of fuel consumed could be achieved. The following evaluations were performed:

1. Determine if cambered doors can be adapted to South Carolina style trawls.
2. Document potential fuel savings from cambered doors (experimental) and compare this to traditional doors (control).
3. Obtain shrimp production comparisons between cambered doors and traditional doors.

Methods

Methodology was designed in this project to perform scientific comparison of Icelandic, cambered doors to traditional doors currently being used in South Carolina. A fuel flow meter was purchased and installed aboard the vessel, FV Capt. Dennis. A standardized towing speed of 2.6-2.7 knots was established for fuel efficiency tests. The vessel was rigged with wooden doors and baseline fuel consumption was measured. Comparative tows were made with simultaneously towed cambered doors and traditional wooden doors for catch comparisons. Finally, fuel utilization through use of the cambered doors was documented. Tides, currents and sea conditions were noted so that these variables could be taken into account when performing analysis. The cambered doors were installed on one side of the vessel and traditional doors on the other. For catch comparison, these two doors types were towed simultaneously and fished in areas where shrimp seemed to be uniformly distributed on both sides of the boat. Production of the try net, which can impact catch from the trawl on the side of the boat in which it is installed, was recorded. Comparisons of shrimp production between the cambered doors and the traditional doors were recorded and used to determine if catch is impacted utilizing the experimental cambered doors. Upon completion of this work, data were given to South Carolina Department of Natural Resources where statistical analyses were performed for final report preparation.

Results and Conclusions

Fuel Efficiency Comparisons - Concern exists that data from these evaluations do not effectively represent the potential fuel saving capacity of the new, experimental cambered doors. Data were acquired with the new doors at the end of the shrimp season after data had been collected data with the wooden doors. Rough sea conditions with 20-knot winds out of the southwest existed during this time, especially during the last four tows that the cambered doors

were deployed. This may have resulted in higher than expected fuel consumption. In order to effectively conduct fishing operations, stabilizers were utilized which created additional drag on the vessel. This phenomenon and the fact that rough seas placed heavier demands on the engine to achieve a 2.6 knot speed may have contributed to higher fuel rates. Usually, when fishing the cambered doors, fuel consumption ranged from approximately 10.0 to 10.5 gal/hr. The fuel consumption recorded during the official portion of the study averaged 11.78 gallons per hour with the cambered doors and 12.16 gal/hr with the traditional wooden doors. Although the cambered door mean was less than the traditional door mean, there was no statistically significant difference. If the last four tows are eliminated from the data set and the remaining tows averaged, fuel consumption rates would have averaged 11.0 gal/hr with the cambered doors. The captain noted that fuel consumption observations during numerous non-study drags utilizing the cambered doors in better than those observed during the experimental trials.

Catch Comparisons - A minimum of 30 tows was performed utilizing the two different doors simultaneously. All 30 tows were drags where trawls were not impacted from clogged TEDs, or other gear malfunctions. No statistical differences in catch rates were noted between the two gears.

Fishing Behavior of the New Doors - During the initial phase of learning to fish the new cambered doors, they were subjected to different substrate types (hard sandy bottom and soft mud bottom). Because of bogging into muddy bottom, some weight had to be removed from the cambered doors. This was found to be a simple process. The Captain believes the experimental doors performed well in the different substrate types. There has been an occasional problem with doors lying down during turns. A modification has been suggested to Texas shrimpers who tried it and found that it solved the problem.

4. **Establishment of a Toadfish Fishery in South Carolina** by Fred Dockery (Commercial Fisherman)

Project Period: August –September 2007

Project Justification and Goal

Toadfish have never been a targeted fishery species in South Carolina. They have generally been regarded as a nuisance to both recreational and commercial fishermen. They are often taken during hook and line fish and in crab traps. Recently, seafood dealers and fishermen in South Carolina have been approached by brokers who are looking from product to export to China. Prices paid for toadfish harvested in New Jersey range from $1 to $3 per pound depending upon the time of year. The goal of this study is to determine if toadfish can be caught in profitable numbers for establishment of a new fishery for this non-utilized resource. The three main objectives of this project are: 1.) Can toadfish be caught in marketable quantities in South Carolina using methods currently used in New Jersey? 2.) Can toadfish be stored in water for a moderate amount of time to allow for the accumulation of shipping quantities? and 3.) Will the market actually buy toadfish, and if so at what price?

Methods

Toadfish are reportedly taken in traps in New Jersey using putrid bait. This study will investigate a variety of trap types using old bait (fish). Given that distributions of this species are largely unknown, multiple sites will be fished to determine where the best catch rates will occur. 80 traps were purchased and deployed. The initial plan was to work these traps between August

1, 2006 and December 1, 2006. Traps were to be pulled once every five days. All catch would be recorded. Catches were to be marketed to determine potential prices and handling costs.

Results and Conclusions

Initial efforts indicated that toadfish do not trap as well in South Carolina as they do elsewhere, and they do not appear to be as prevalent. In 164 trap samples, only 12 toadfish were caught. A variety of baits, locations, and trap types was tested, all with no significant results. Some locations tested included a near a commercial seafood dock in Folly Creek, Kiawah River, and the Charleston Jetties. Crab traps tested included tried yellow hex mesh, black hex mesh, yellow square mesh, and black square mesh, all in both new and worn condition. Peeler traps (1-inch hex mesh) were also tried. Soak times were increased substantially but this was not helpful. Baits tested included rotten menhaden, fresh menhaden, chicken, shrimp heads, oysters, dead crabs, live crabs, and combinations of all the above. Crabs showed the most potential, catching 5 of the 7 toadfish collected (caught at the Jetties). This work was terminated early.

Given that fishing efforts were unsuccessful, no attempts were made to explore marketing.

Toadfish are known to be relatively common in South Carolina, but they do not appear to be abundant enough to support a fishery. Or, they are not susceptible to the gears used in this study. More research is needed on the habits of toadfish in South Carolina, and perhaps this could lead to a more productive method for harvesting.

5. Crab Tagging in Stono Inlet by Fred Dockery (Commercial Fisherman)

Project Period: September 2007 – April 2009

Project Justification and Goal

Relatively little tagging of blue crabs has occurred in South Carolina. Studies, to date, have be small scale and mostly limited to Charleston Harbor. Recent concerns about declining numbers of blue crab spawners (based upon DNR trawl and trap monitoring surveys) have highlighted the need to understand more about behavior of female blue crabs. The goal of this study was to learn the behavior of female blue crabs tagged in the Stono River, Charleston County. Specific objectives include: 1. Test the practicality of tagging crabs as a means for monitoring local population dynamics and crab behavior 2. Examine the migratory pattern of female crabs in a typical, high salinity estuary, and 3. Determine if most females in an area are caught before they develop sponge masses or do they move seaward first.

Methods

Plastic tags were purchased from Floy Tags Company. Tags, with serial numbers and contact information, were affixed with either aluminum or galvanized wire inserted through holes on each end of the tag and wrapped around the crabs lateral spines. Wire was 18 and 20 gauge. Stainless wire was also tried, but it was too stiff to use effectively. 1,500 mature female blue crabs were tagged over 9 days between September 2007 and March 2009. Lots of between 100 and 400 crabs were released per location per day. Locations were throughout the Stono River, except for 100 crabs that were releases in Capt Sam's Inlet. Latitude and longitude were

recorded for release locations. Signs were posted prominently at nearby landings alerting fishermen of the tagged crabs, and all local commercial crabbers were informed of the project. A raffle was established to award $500 to the winning entry to be drawn from all returned crab tags.

Results and Conclusions

Most of the crabs were recaptured in the same water body in which they were tagged, moving up or down the river, perhaps in response to environmental factors. Of 1,500 crabs tagged and released, 447 (to date) were recaptured for a recapture rate of 29.8%. One location, the upper Stono had a 66% recapture rate. Stono Inlet crabs had recapture rates of 18.5 to 36%. Capt Sam's inlet had the lowest recapture rate of 4%. Within the Stono River, the greatest one day travel was 8 miles, and typical movement was much more gradual (a mile or two or less, over days or weeks). Some of the long distance travelers went as far as 40 or 50 miles, mostly southward along the coast and then inland. Three of those long distance entries were reported although tags and tag numbers were never submitted. As there was no benefit to the reporter to make up these reports, there is no reason to doubt them. No tagged crabs were recaptured after the sponging season ended in April 2008. The closer crabs were tagged to this period, the shorter the apparent recapture window, which might suggest that most of these crabs die after sponging or move out of the area. The best time to tag crabs for seeing maximum recaptures appeared to be October, when the water temperature started to drop below 70. Crabs appeared to leave the estuary as water temperature dropped, but in the spring as temperatures warmed, it appeared that no crabs left and the migration moved back up the river. At least two tagged crabs were recaptured after sponging. There was no indication that recaptures stopped because of tag degradation. Almost all recaptured crabs had their tags still well attached.

Recapture rates could probably be used to assess crab density. In the spring, as the winter female harvest tapered off, the recapture rate for tagged crabs seemed to go up, suggesting tagged crabs were becoming a greater percentage of the overall population. In the fall, early recapture rates were very high as well, even though total crab catch rates were also high. This may suggest a low population, or possibility aggregated and feeding aggressively. The market was weak at that time of year as well, so commercial fishermen weren't removing as many crabs. It would be good to do a second study in a closed environment (pond) to come up with a correlation between recapture percentage and crabs per acre at different water temperatures and seasons.

Including a monetary reward associated with a raffle was important in getting crabbers to participate in the program.

It appeared that recapture rates were useful in judging relative population size, although a more thorough study is needed to determine this with certainty. The study showed that females migrate seaward more readily during fall and move upriver during spring. This study demonstrated that commercial fishermen can be used to provide useful information of blue crab population via tagging studies.

6. Weakfish Tagging Project

by John Dunphy (Recreational Fisherman)

Project Period: July 2007- June 2008

Project Justification and Goal

Weakfish (*Cynoscion regalis*), also known locally as the summer trout or grey trout, has a distribution along most of the east coast of the United State, being most common north of Cape Hatteras. The east coast population has had large fluctuations in its abundance. Currently the population in the mid Atlantic region is very low according to stock assessments. The Atlantic States Marine Fisheries Commission is likely to put severe harvest restrictions on the species throughout its range, including South Carolina. While not among the most popular recreational species, weakfish are seasonally important to a modest number of recreational fishermen in South Carolina. While the entire stock is managed as a single population, there is some question about the relationship between subpopulations north and south of Cape Hatteras. It has been speculated that weakfish from the south may migrate northward and contribute to the spawning population. Others doubt this assertion. Weakfish are difficult to tag because they are rather fragile, thus their common name. The research projects goal is to tag significant numbers of weakfish in hopes of learning more about potential migratory behavior.

Methods

Fish were caught using traditional hook and line techniqes and all tagged fish were released immendiately. Barbless circle hooks, sized 2/0 and 5/0, were used as well as size 1 and 2 barbless J-hooks The investigator tagged fish using both traditional dart tags and the new T-bar tags/gun provide by the SCDNR Marine Game FishTagging Program. The data collected for the dart and T-bar tags were recorded on field data sheets and included fish species, tag number, total length, weight and date/location of capture. The areas fished during this study were located in nearshore waters in northern Beaufort County (Fripp Island area) including the SCDNR artificial reefs/wrecks commonly known as The Savannah, Dry Dock and Tire Reef. The bait type used for circle hooks was live and dead bait (i.e., cut fish). The bait type use for J-hooks was artificial jigs and floats/corks.

Results and Conclusions

Fish were tagged from from July 1 2007 through June 30, 2008. During the period, the investigator tagged a total of 624 fish with 185 being weakfish. Other species caught and tagged during this study were: Red Drum (190), Black Drum (65), Blacktip shark (21), Lemon Shark (17), Black Sea Bass (16), Flounder (9), Spiny Dogfish Shark (8), Cobia (7), Sheepshead (6), Red Snapper (6), and lesser quantities of six othr species.

The total length (inches) of weakfish ranged from 12 to 28 inches with many of the fish consistently in the 20 to 26-inch range. Among 100 fish tagged with the T-bar tag, 52% were 13-15 in., 17% were 15.1-17 in., 17% were 17.1- 19 in. , 7% were 19.1-21in., 5% were 21.1-23 in., 1% were 23.12-25 in., and 1% were 25.1-27 in. Of the 31 fish greater than 17 in., 16 (51%) wre caught in may, 5 (16%) were caught in October, and 10 (32%) were caught in November. However, among the 14 fish greater than 19 in., 10 or 71% were caught in May, and all 7 fish greater than 23 in. were caught in May. Seventy-three percent of the fish greater than 15 in. were caught on dead natuaral bait, compared to live and artificial.

The investigator found the T-bar tagging gun to be highly efficient and easy to use. This device is much faster to use than the standard dart tagging device and the smaller tag used with

the T-bar gun appeared to be less harmful to the weakfish. The T-bar tagging gun could be used very effectively to tag any soft-skinned fish, such as spanish mackerel, grouper, snappers, bluefish, etc., but was more difficult to use on fish with harder, larger scales, such as red drum, black drum, and tarpon The investigator also caught and released without tags almost 400 other fish including spotted seatrout and spanish mackerel. Circle hooks were used to catch 400 fish or 40% of all fish caught and released (with and without tags) during the study period. J-hooks caught approximately 600 fish or 60% of all fish caught and released (with and without tags). Based on the percent of fish caught using each type of hook, it appears that either type of hook effectively catches fish. Observations made of the fish condition indicate those fish hooked in the lip with the circle hook, typically swam away when released. Personal observations have shown that circle hooks do hook fish in the jaw more often when using live/dead bait. However, at a slack tide with no water current/tidal flow an angler has to be sure to keep a tight line when reeling in the fish or sometimes a fish will swallow the bait even with a circle hook deployed.

7. Alternative Bait for Crab Traps By Arthur Ford (Commercial Fisherman)

Project Period: November 2007

Project Justification and Goal

Commercial blue crab trap fishermen almost universally use menhaden as their preferred crab bait. This bait is effective and usually of high quality. However, during some times of the year menhaden are in limited supply and prices can quickly escalate. The availability of bait may also is vulnerable to menhaden stock fluctuations, as well as management restrictions or closures for that fishery. An alternative to menhaden could carry crabbers through periods when menhaden are in short supply or the price is exorbitantly high. The goal of this study is to determine if various readily available substitute materials could be suitable as replacements for menhaden.

Methods

In November 2007 crab pots with various experimental baits were fished on a line running at approximately 32.5185°; 080.5639°, or near the confluence of Bull River and St. Helena Sound. Traps were alternately baited with 'alternative bait' and menhaden. The traps were standard commercial pots and were spaced approximately 50 yards apart, placed at depths ranging from 10 – 15 feet. Four types of baits were tested against menhaden. The experimental baits were chicken thighs, shrimp heads, catfish and lobster pucks. There were five replicate traps for each experimental treatment. Catch of blue crabs and stone crabs was recorded for each trap including the total number of legal (> 5 inches) and sublegal crabs.

Results and Conclusion

Chicken thighs proved to be the best of the four tested baits. They are very easy to obtain with processors having no problems getting usable quantities. The catch rates were often equal to or better than menhaden, but menhaden appeared to be more consistent. Also, chicken had an objectionably strong odor after being in the water for 24 hours and is undesirable for that reason. The environmental impacts to throwing old chicken parts into the water, as is done with menhaden, should probably be evaluated. Dolphin are known to frequently follow crab boats, consuming old menhaden bait that is discarded by the fisherman. It is unknown if dolphin would be attracted to discarded chicken parts and if consumption of these could pose a health risk to the dolphin.

Catch rates of blue crab with freshwater catfish were about 50-60% of those of menhaden. At times catfish were not readily available at a reasonable price. Also the size of catfish varied with some being too large and some being too small. Large catfish slowed fishing operations because fish had to be cut in order for them to fit into the bait box. Some catfish were often so small that they were judged to be unaffordable for fishing large numbers of numbers of traps.

Shrimp heads, while readily available, provided a poor catch rate, 20-to 25 % of that of menhaden or chicken. During the warm season, shrimp heads did not hold up well thus reducing catching efficiency. Like chicken, shrimp heads also had a strong odor.

The lobster puck is a commercial developed bait substitute for lobsters. It is made from a herring base. Catch rates with the lobster puck were poor, scarcely catching any crabs at all. The manufacturing company recommended adding one menhaden fish to the bait box with the lobster puck. This was tried and did not help. The company also suggested breaking the puck before putting it into the bait box, but this was also unsuccessful.

None of the alternative baits proved to be as effective in catch crabs or as economical as the traditional menhaden bait. Despite this, the project was very helpful to commercial crabbers as it provided an opportunity to try alterative baits that had been suggested in the past or used in other fisheries. Although chicken parts, shrimp heads, and catfish were not as good as traditional menhaden bait, they did prove to be viable options in the event menhaden are unavailable.

8. Feasibility Study to Assess a Seasonal Blue Crab Fishery in Historically Closed South Carolina Waters

by Robert J. Gault (Commercial Fisherman)

Project Period: May 2007- September 2007

Project Justification and Goal

Observations made during recent prolonged droughts have indicated that blue crab abundance may increase substantially in the upper portions of estuaries and decline in the lower seaward portions. Mechanisms for this dispersal pattern are not fully understood, but it appears clear that blue crab are more abundant farther inland during severe droughts. These droughts result in increases in water salinity thus allowing the euryhaline blue crab to range farther up rivers where salinities would normally be too low to accommodate them. Current state law allows commercial blue crab fishermen to fish only seaward of a legally specified saltwater/freshwater line. During a sustained drought, when crabs are most abundant farther inland, crab fishermen find that they are legally prevented from fishing above the saltwater/ freshwater line where crabs are most abundant. The goal of this study was to learn more about the distribution, abundance and migration of blue crabs above the legal fishing line so that considerations could be made to allow fishing access during drought conditions.

Methods

Sampling was conducted aboard a 26-foot commercial crab boat. Traps were fished from May 15, 2007 to September 30, 2007 in brackish (freshwater) areas of the Combahee and Ashepoo Rivers. 18 traps were set in each river. All traps were fished four times each month. In the Combahee, 249 traps were fished and in the Ashepoo, 269 traps were fished. Trap placement was random with the fisherman using his judgment as to where traps would be most productive. Traps were then moved as needed to improve the catch. The fishing areas are

above the legal saltwater/freshwater line and a permit from DNR was required to fish in this location. All crabs that were collected in this study were subsequently released. Data recorded included catch per trap, crab size, and location of crabs. A monetary reward was as an incentive to encourage other crabbers to report recaptures. $1,000 was set aside for rewards, with the reward per crab being $1,000/ the number of tags recovered. A total of 800 crabs was tagged.

Results and Conclusions

This study found a high catch rate of legal male crabs in both rivers. In the Combahee, 3,598 legal males (98.9%, ≥ 5 inches width) and 40 females (1.1%, ≥ 5 inches width) were collected for catch rates of 14.4 legal males per trap and 0.2 legal females per. There were 244 sublegal crabs (<5 inches width) or 0.98 per trap. 48 peeler crabs (crabs showing sign of approaching molting). No ovigerous females were found.

In the Ashepoo River, 4,315 legal males were collected in 269 traps for a catch rate of 16.0 crabs per trap. Only 31 legal females were collected (0.11 per trap). Sublegal crabs were more numerous in this river with a total of 382 being taken (1.4 per trap). Likewise more peelers were taken here also (108 or 0.40 per trap). No ovigerous females were observed.

There was virtually no bycatch in the Ashepoo River, above the traditional saltwater/ freshwater line. Bycatch consisted of 0 softshell turtles, 17 catfish, 3 flounder, and 1 croaker.

In the Combahee River, 13 softshell turtles were caught at the uppermost section fished near where the water was fresh (all were caught in 2 ppt or less salinity). 200 catfish and 1 garfish were collected.

In initial operations, 10 mature females and 390 large males were tagged. In November, SCDNR requested that another 400 crabs be tagged and this was done. Out of 800 crabs tagged, 69 tagged crabs were recovered, a recovery rate of 7.5 percent. A total of 69 tagged crabs was recovered with 4 being taken in the immediate area of release. One crab was found in another estuary, St Helena Sound in Morgan River, 47 days after release. Fifty crabs were recovered downriver of their release point, within 3 to 6 miles. Fourteen crab tags were recovered with no recovery information provided. Thirty-eight (38) crabs or 55% were recovered within 20 days of release and 21 (30%) were recovered within 10 days of release. Among other recovered crabs, 4 were recovered 21-30 days post release, 3 were 31-40 days, 1 was 41-50 days, 1 was 51-60 days, and 8 were 61+ days. All of the crabs out 61+ days were released in the Combahee River and were recaptured within 3-6 miles of the release site.

The principal investigator has been a commercial fisherman/wholesaler for 30 years. Results showed that four days of fishing each trap were not enough time to establish the crabs' movements. Contrary to popular belief, it is not possible to just throw the trap out and catch crabs. A fisherman has to learn their patterns and movements. Still, the principal investigator was impressed with the catch rates. The fisherman concluded that that if these waters were to be opened to commercial crabbing, he could fish profitably in them. Crabs in this area proved to be of the highest quality and value.

9. Study the Viability of a Commercial Octopus Fishery off South Carolina's Coast

by Robert J. Gault II (Commercial Fisherman)

Project Period: June 2007 – March 2008

Project Justification and Goal

Potential for a cephalopod fishery off the southeastern coast has been speculated on for some time. Work conducted in the 1980s by SCDNR staff suggested that octopus could be successfully potted just offshore with relatively inexpensive fishing gear. Octopus is basically an annual resource that would likely support a limited sustainable fishery. Additionally, octopus is being more widely accepted in the United States as a seafood choice. The goal of this study was to perform large-scale sampling of octopus off the coast of South Carolina between Port Royal and Charleston Harbor, to gather data related to distribution, abundance, general biology and potential for a commercial fishery.

Methods

Using a 26-foot boat, the project conducted sampling with 400 SDP (Sewer Drain Pipes) pots — 300 four-inch and 100 six-inch inside diameter. The project manager and crew set three, half mile long each line, with approximately 150 habitat-type traps in each line. Each half-mile of line included 150 "quicksnaps" to hold traps (for line attachment), two anchors, and four buoys. The longline was pulled with a longline reel, but it proved less effective being replaced by a traditional crab pot hauler after the first few sampling trips. A longline reel was installed on the boat, and traps were prepared to begin sampling. Sampling and data collection began in August 2006. Data collected included date, location, and catch rate.

Results and Conclusions

During sampling, the four-inch trap proved to be more efficient on handling and caught the same size octopus as the six-inch trap. The six-inch trap brought up more bottom and shell making it heavier and more cumbersome. The octopus would cover themselves with sand and shell with the six-inch traps, burying themselves more completely, and with the four-inch trap, they would use a shell as a door over the entrance. Preliminary data suggested type of bottom was crucial to catch rate. Overall catch rates by month in 2007 were 52% in June, 47% in July, 60% in August, 81% in Sept, 60% in October, 43% in November, and 14% in March the following year. Average size for all octopus collected was 328g in June, 541g in July, 721g in August, 724 g in September, 750g in November, 900g in December and 1,217g in March 2008. Like the DNR study, octopus size increased through the summer and fall, reaching a maximum in early winter. This continues to support the hypothesis that this is an annual crop. Typical of many annually harvested resources, one year's catch and population abundance may not be related to that of succeeding years. More work is needed to determine inter-annual variability in octopus populations and total reproductive potential.

Final results confirmed octopus fishing was more profitable in the fall and winter months when the octopus were larger and catch rates were greater. These findings were consistent with the Whitaker study and with data compiled in a Sea Grant study in Alaska in the 1980s ("Fishing for octopus, a guide for commercial fishermen" by Brian C. Paust, published by the University of Alaska), which noted a similar trend and suggested that reproductive activities might be responsible.

This project could not determine the effect of the lunar cycle because of the infrequency of fishing trips. Soak times proved to be important. If they extended beyond a week, catch rates increased considerably.

Catch rate, size of the octopus and commercial value are the determining factors for a commercial fisherman. This project showed commercial octopus fishing can be profitable, and indeed, the principal investigator was approached by a number of local commercial fishermen

who wished to learn more. The project also demonstrated that there is a domestic market for octopus and, potentially, export markets as well. However, a prolonged and consistent effort to establish such markets will be necessary. During the short duration of this study, the investigator was able to establish markets with wholesalers in Florida and New York.

10. Cherry Point Oyster by Tony Geisman (Commercial Fisherman)

Project Period: June 2006 – May 2008

Project Justification and Goal

Large single oysters are the preferred oyster by restaurants in South Carolina, yet almost all are imported from Gulf Coast states. Development of a ready source of locally-produced single oysters has significant economic potential for South Carolina, as well has helping to reduce harvesting pressure on the native wild stock. There have been limited attempts to grow single oysters in South Carolina; however a new source of locally-produced single oyster seed has opened the door to state-wide experimentation. The goal of this project is to obtain large local hatchery seed oysters (>½") and grow commercially marketable single oysters in South Carolina waters using off- bottom oyster cages and racks.

Methods

One hundred thousand single seed oysters were obtained from Island Fresh Seafood's oyster hatchery in Yonges Island, SC. Oysters ranged in size from ½ inch to just under 1 inch. A custom-made barge was constructed to suspend trays and cages containing oyster seed. The barge was anchored on both ends and marked with lights. Oysters were deployed November 2007 in Range Marker Creek, a tributary of the North Edisto River. A system of pulleys and winches was devised to raise and lower the caged seed oysters for cleaning and inspection. Various designs of enclosed trays and cages were utilized. Oysters were raised from the water for cleaning every few weeks initially, but later every 2 to 2½ months. As it became clear that overset of naturally recruited spat had become a problem, experiments were undertaken to " brine treat" and "heat shock" the oysters in hot water.

Results and Conclusions

After almost 24 months, about 30,000 oysters remain. Those that were sold were good quality single oysters with prices as high as 45-48 cents each. Unfortunately, after about 17 months, boring sponge (*Cliona spp.*) suddenly became a problem, ruining the aesthetic appeal of the oysters as well as causing mortalities. An estimated 90% of the oysters were infected with boring sponge.

A portion of the overall oyster mortality can be attributed to the various experimental treatments that were attempted to control spat overset. A first attempt involved dipping baskets of oysters into a hyper-saline solution. This proved ineffective and led to experiments using hot water dips. Seed oysters were found to be highly vulnerable to excessive soaks in hot water. Ultimately, however, the principle investigator determined that certain temporal heat treatments were relatively successful in killing spat. During warm weather a quick dip of about 10 seconds in 140 degree water was adequate to kill spat while not harming the oysters. A slightly longer soak could be used in cold weather without any mortality of seed oysters. This dipping procedure requires gear that can quickly immerse and remove a heavy basket of oysters.

The research was initially successful with growth rates of oysters being much faster compared to their wild stock counterparts.. After the first 6 or 7 months, most oysters had grown larger than two inches, many exceeding three inches. However, boring sponge damage that occurred after 16-18 months during the second summer persuaded the principle investigator that the experimental methods used were unsuccessful. He is currently considering deploying baskets of seed oyster in the intertidal zone where growth rates would be reduced but mortality from boring sponge should be minimized. It is speculated that more frequent removal of the oysters from the water and allowing them to dry out periodically might prevent or reduce sponge damage. This has not been tried. Additionally, another approach may be to grow the oysters subtidally as was done in this study for the initial year and then plant them intertidally for final grow out. The researcher also observed that oysters held near the bow of the barge seemed to grow better than those "downstream." This observation may be explained by depletion of plankton consumed by the oysters as the water flows past the barge's bow or a deflection of water or currents. Further study is needed to examine this question.

11. Use of Microwave Telemetry X-PSAT Tags to Monitor Behavior of Cobia and Dolphin

by Don Hammond Cooperative Science Services, and David Harter Hilton Head Reef Foundation

Project Period: June 1, 2007 to November 1, 2007

Project Justification and Goal

Cobia, *Rachycentron canadum*, and dolphin, *Corypheana hippurus*, are important species in the marine recreational fisheries of South Carolina as well as the South Atlantic Bight and Gulf of Mexico. In South Carolina, the cobia fishery is centered in the inshore and nearshore waters of Beaufort County. Both fish are highly esteemed for their food quality. Dolphin is the most frequently harvested fish by recreational anglers trolling in Federal waters off South Carolina. Little data are available on the movements and migrations of these economically important species – especially for their South Carolina occurrence. While dolphin are considered little more than nomads passing by the state, many fishermen have a different view of cobia, questioning if there is a unique group of fish that use Port Royal Sound (PRS), spawning in nearshore or inshore waters. The Marine Gamefish Tagging Program of SC DNR has shown that cobia tagged in PRS show a strong site fidelity returning to the sound after two and three years of liberty with few fish being recovered off other states. Where cobia migrate once they leave the Beaufort County's inshore and coastal waters remains a mystery. Information on movements of this species could be very useful in determining if the PRS population is unique and isolated from offshore cobia. While dolphin are known to be seasonally abundant off South Carolina and general occurrence patterns are known, little specific information on migratory habits is known. The goal of this project is to use pop-up satellite tags to learn more about migration and temperature preferences for cobia and dolphin.

Methods

Seven Microwave Telemetry, Inc. model X and one model PTT-100 pop-off satellite archival tag (PSAT) were used for this study. These instruments were preprogrammed to remain with the fish for 30 or 180 days, recording time-specific water temperature, pressure and light intensity at regular intervals. At the end of the monitoring period, the device is preprogrammed to release itself from the tether connecting it to the fish. Once released, the device floats to the

surface, contacts an Argos system satellite and begins transmitting data. Once the unit had stopped transmitting for seven days, Microwave Telemetry, Inc. processes the stored data. The manufacturer also calculates daily geo-position uses time of sunrise to calculate longitude and water temperature for an estimation of latitude. This positioning system is reported by MTI to have accuracy ±2 degrees of latitude and ±1 degree of longitude. The older model measures 338 mm in length with a 206-mm long antenna and weighs 65- 68 g. The new model X tag is 303mm in length with a 185-mm antenna and weighs approximately 45 g. A 254mm long section of 1.6 mm monofilament was used to tether the tag to the fish. The monofilament was secured in the dorsal musculature of the fish.

Two PSATs used for dolphin along with two attached to cobia were programmed to record data for 30 days in a high-resolution format. Three additional PSAT instruments attached to cobia and one attached to a dolphin were programmed to record for 180 days.

This study enlisted the aid of private anglers and charter boat captains to secure cobia for tagging. Captains and anglers were instructed to use a specific VHF radio frequency to contact the tagging boat which carried the biologist who would decide whether a fish was qualified for use as a satellite tag subject. For a fish to qualify as a candidate for a satellite tag, it had to be hooked in the outer part of the mouth y and it had to measure a minimum of 100 cm (FL). The project was able to deploy five satellite tags in three days of field work in Port Royal Sound. Private recreational vessels were utilized to capture dolphin for satellite tag deployment. 11 different offshore vessels were involved in field trips. These vessels fished out of Beaufort Inlet, NC, Charleston SC, Cape Canaveral, FL and High Borne Cay, Bahamas. Project staff participated in each of 10 offshore trips. Normal recreational offshore trolling tackle and techniques were employed. Fish were required to be a minimum of 110 cm FL to qualify for tagging and to be hooked in a fashion so as not to cause serious injury. The tag was inserted through the dorsal musculature about one-third of the fish's length behind the head and half way between the spine and top of the dorsal muscle.

Results and Conclusions

Cobia

Five satellite tags were deployed on cobia captured in Port Royal Sound. Specimens ranged in length from 102 to 124 cm FL and were estimated to weigh 13 to 23 kg. Following the tag attachment, each fish swam quickly away when returned to the water. All but one cobia (46483) used in this study were captured by charter boats (Table 4). Two instruments never made contact with an Argos satellite. Such failure could be related to faulty units or damage to the unit while on the fish or that it had washed ashore and was resting on its side where it could not transmit. A third PSAT was recovered May 31, 2008 on the beach at Hilton Head Island, SC. It was clearly that this tag had been pulled out of the fish with marks on the instrument's body suggesting that a fish had grabbed and pulled. A fourth instrument, detached prematurely after only 12 days. The remaining cobia carried its instrument for the full programmed period of 30 days and providing information. The tags reported on 12, 20 and 30 days of activity.
Over 13,500 time-specific pressure and temperature observations were received from the three instruments during their collective 62 fish-days of monitoring. These records show that during May, the fish utilized waters from the surface down to depths of 27m. The average monthly water depths utilized by fish similarly tagged in 2008 ranged from 6.1 to 9.2m. This bay and its main estuary, the Broad River, has a main channel with depths of 6.7m to 13.4m up to the SC highway 170 bridge with holes as deep as 18.3m. In May, the three fish occupied water

averaging 7.4 m. Depth records for two units suggested that both fish were moving to deeper water following May 25th , likely outside of the PRS. Combined records indicated that the fish utilized waters ranging from 20.03 to 25.66°C with 84% of the readings falling between 23.0°C and 24.99°C. The thermal track of one fish suggests that at least some cobia may leave and return to PRS during May. After being at liberty for 31 days one fish was located 32.5km east (81° magnetic) off the mouth of PRS. When the temperature track, depth track, and surfacing/recovery location of the tags are combined, the evidence suggests that these cobia remained in the sound for most of May with periodic, short-term excursions to nearby offshore waters.

Dolphin

Three PSAT instruments were attached to dolphin during the study. One PSAT was deployed off Charleston and two units were deployed off Cape Canaveral. All PSAT deployed in 2008 ultimately contacted an Argos satellite and transmitted their data. The tags made first contact with a satellite from locations that were 452km to 605km from their deployment position. The two fish tagged off Cape Canaveral were males (114 cm and 119 cm FL) and weighed 15.0 to 17.2 kg, respectively. The first female tagged was released off Charleston (109cm FL and 11.3kg).

Data show that dolphin actually utilize depths at least as deep as 120 m, regularly moving up and down through the water column. A wide variation was observed in the deepest waters utilized each day ranging from 40 to 120 m. The Florida fish were shown to utilize waters as deep as 75.3 and 102.2 m. The daily average depth off South Carolina was 20 m on less most days. The fish made only one dive to a depth below 100 m during a daylight period but made many such dives during darkness reaching its maximum-observed depth of 119.7 m. The limited data show dolphin using the surface waters more frequently during the day, 39% as opposed to 15% for the nocturnal reading. Dolphin utilized waters with temperatures ranging from 20.05 to 26.37°C (overall average = 24.56°C). Average water temperatures used by the off South Carolina was 24.59°C while the Florida fish were in 23.85 and 24.40°C, respectively.

12. Use of pop-off archival satellite tags to study cobia in Port Royal Sound, South Carolina and dolphinfish present off the East Coast

by Donald L. Hammond, Cooperative Science Services; David Harter, Hilton Head Reef Foundation

Project period July I, 2006 to May 24, 2007

Justification and Goal

Cobia and dolphin are two important species supporting major recreational fisheries not only in South Carolina but in all coastal states from Texas to Massachusetts. Science has little information about the movements, migrations and essential habitat for these species. The South Atlantic Fisheries Management Council, which is responsible for managing both species, has identified collection of fish movement information as a priority for research. The use of pop-off archival satellite tags (PAST) on bluefin tuna, marlins and sailfish has shown that the instrument can be effective in collecting long term information on water temperatures, vertical movement, and temporal/spatial movements. However, these instruments have never been used to study dolphin anywhere and only four cobias in the Gulf of Mexico have been monitored with these devices. The goal of this project was to use satellite tags to monitor the movements and behavior of several dolphin and cobia.

Methods

The Microwave Telemetry, Inc. PTT-100 instrument (satellite tag) utilized in this study weighs 68 g with a module measuring 13.3 cm by 4.1 cm. A fork length of 112 cm was set as the minimum size for tagging which translated to an 18 kg cobia and a 14 kg dolphin. After using an attachment system comprised of large metal dart heads roughly 2cm by 5cm, the method was determined to cause excessive trauma for the sizes of animals tagged in this study. A new anchoring system was adopted in 2007 to reduce the tissue damage. The system involves passing a heavy monofilament line from the instrument laterally through the dorsal musculature below the dorsal fin and secured it on the opposite by a stainless steel plate that is held in place by a double barrel crimp placed on the monofilament. Because this system requires the fish to be removed from the water, a special mouthpiece was developed to facilitate ventilation of the gills with saltwater using a pump and hose system while the fish was out of water. This anchoring system should remove the potential for the tether to be dislodged from the fish. All cobia used in this study were captured by charter boats. Each charter captain was paid $300 for providing a fish that was acceptable for tagging based on meeting size and health qualifications.

The plan was to tag six cobia. The first cobia was tagged in 2006 but the instrument never contacted a satellite. Other studies have noted a 25 % failure rate in these tags to transmit data. Such failures could be due to any number of reasons from damage to the device by a predator to instrument malfunction. The other three telemetry platforms were attached to cobia and deployed May 12, 2007. All cobia tagged were provided by different charter boats operating in Port Royal Sound. The first of these tags was set to begin transmitting data around the middle of June 2007 with the other two devices were to initiate data transfer in mid-August 2007.

This study proposed to deploy six tags on dolphin. Three instruments were deployed in 2006. Two were deployed in the Florida Straits, one off Islamorada and the other off the western side of Bimini. The third tag was deployed off South Carolina. All fish were provided by private recreational fishermen. All of the instruments reported data via satellite, however, none remained with a fish for the full 30 days. All instruments reported being released due to constant pressure. This could have been due to the death of the fish, the tag attachment to the fish being dislodged, or the monofilament tether being severed.

The 30-day high resolution tags used on dolphin were set to record time sensitive temperature, pressure and light intensity every 3 to 4 minutes.

Results and Conclusions.

Dolphin

Over 12,000 time observations on temperature and depth were received from the three tags. One fish tagged off Florida in May used waters ranging from 22° to 29°C) than the June fish which used waters from 24 to 30°C. The fish tagged off South Carolina on July 1 had a temperature range of 16.1 to 29 C, but most readings were above 25°C. 92% of the temperature observations for the two fish off south Florida and 63% of the observations for the South Carolina fish were at or above 26°C.

While dolphin have historically been considered reside at the surface, data from the three monitoring devices clearly show that they will occasionally dive to depths of at least 123 m. Results indicate that dolphin spend more of their time, both day and night in the surface layer than in any other depth. One unexpected behavior found to be common to all fish was that they would to rise to the surface just before or at first light each day. Fish off south Florida spent

roughly 50% more time in the surface layer than did the South Carolina dolphin. The South Carolina dolphin utilized the lower water layers, especially waters below 30 m, 10 times more frequently during the daylight and 60% more often at night than the fish off Florida. However, fish in both areas clearly showed higher usage of the deeper waters during the night than in daylight. The fact that dolphin off South Carolina spent 35 % of the daylight period below the surface layer could suggest that they may be less vulnerable to harvesting by recreational anglers who traditionally fish their baits at the surface than in Florida where the fish left the surface layer only during 3% of the daylight hours.

All fish utilized deeper water more frequently at night but not uniformly from one day to the next. However, the South Carolina fish appeared to dive more readily during day and night than did the Florida fish. Interestingly, the fish seemed to return to about the same depth on consecutive dives. This diving behavior may be related to preying upon animals such as squid that are known to show diurnal vertical migration in the water column.

Cobia

Four satellite tags were successfully deployed on cobia captured in Port Royal sound or adjacent waters during this study. Cobia selected for monitoring ranged in length from 102cm to 132cm FL and were estimated to range in weight from 15 to 30kg. The fish carrying tag 55504 was suspected to be a female because males seldom exceed 120cm FL. One of the four fish was suspected as being a female because of the relatively large size. Caught fish required 12 to 35 minutes to bring to the boat for netting. Upon release each tagged fish swam quickly away.

Upon detaching and surfacing, all tags were less than 161km from their release site when they made first contact with the satellite. A 30-day tag tagged in Port Royal Sound surfaced 47 ikm east of its release site near an artificial reef on June 9, 2007. Three other fish tagged on May 12, 2007 had tags that remained with the fish for 30, 90, and 90 days. One tag made first contact 17.9 km south southeast of the Navy R8 tower off Savannah, Georgia which is 129.3km from the release site. Another made its initial contact from a location 35.6km north northeast of the Navy R8 tower which was 115.3 km from the original release point. Both 90-day tags surfaced in waters approximately 45 m deep.

More than 14,000 time-specific pressure observations were received from the three instruments during their collective 214 fish-days of monitoring. These records show that during the three months monitored, the study-fish utilized waters from the surface down to depths of 70m. The average monthly water depths indicated that the fish gradually utilized deeper waters with time. Depths observed in May were relatively shallow, suggesting that the fish remain in the inshore waters, probably Port Royal Sound.

Average daily depth tracks varied among the fish but all followed a general trend of increasing depth. In May, the three fish occupied the shallowest waters of the study, averaging 10.5 m. The two 90-day tags showed an average depth for June of 17.4 m, and in July the average depth occupied increase to 32.4 m. The greatest depth recorded for the two fish in July were 59 and 70 m.

Cobia are well known for their close association with the ocean floor and the bottoms of bays and sound. Fishermen also know that cobia will visit the surface waters especially in spring. Frequency of surface visits and duration of vertical movements have never been examined. One cobia showed both the largest vertical movement (53 m), and the longest period of deep water fidelity, 11 days of 5.4 m or less depth variation. The overall amplitude for daily movement for the three fish was similar in May and June at 12.1m and 11.4m respectively. As

the fish began to use deeper waters in July and August the amplitude of the overall daily vertical movements increased to 19.4m and 26.9m, respectively. All fish visited the surface more frequently in May,(63%), than any other month . In June, overall surface-visit days declined 75% to 15% of the days. The overall surface-visit frequency declined further in July to only 10% of the days. However, in August 27% of the days had surface visits. Most surface-visits lasted just a few minutes. One fish remained at the surface for at least 62 minutes.

More than 14,500 time-specific water temperature observations were reported for the three fish. Combined records indicated that the fish utilized waters ranging from 20.7^{o}C to 29.3^{o}C, and that slightly more than 86% of the observed water temperature readings fell between 22°C to 27°C. Daily variations in water temperature for a fish rarely exceeded 2°C. The largest daily temperature variation was 7.06^{o}C and was noted in July for a fish moving between 37.7m and the surface. A comparison of the average monthly temperatures for the monitored period showed the lowest average temperatures were utilized during May and the highest during June. The lowest water temperature recorded, 20.7^{o}C, was in August for a fish at 53.8m. Water temperatures of 28.0^{o}C and higher were recorded starting in late June with the highest temperature, 29.3^{o}C recorded in August for a fish at the surface.

Temperature records show that the temperatures encountered by cobia steadily increased into late June and early July where they peaked around 26°C. Over the next week, the average daily water temperature declined roughly 2°C and then oscillated around 24°C for the remainder of the monitoring period. This temperature decline is suspected to be the product of the movement of fish into deeper waters, presumably offshore. Comparing the tag-provided temperatures to the bottom water temperature recorded at an inshore buoy indicated tag temperatures were comparable to those recorded in the Sound. However, by early July, the observed temperatures for the fish dropped well below those recorded in the shallow nearshore waters off Port Royal Sound, suggesting the fish had moved offshore.

All of the cobia satellite tags were located southeast of Port Royal Sound when they first contacted an Argos satellite. After being at liberty for 29 days, one tag located 32.5kl offshore of the mouth of the sound at a position north of the Betsy Ross Artificial Reef. Using the speed and direction at which this tag drifted over the next 11 hours after first contacting the satellite, it appears that the tag may have surfaced 15.4km southwest of its first contact position. This would place it closer to shore northeast of the White Water Artificial Reef off Hilton Head Island. Back calculating the surfacing position for the two tags out for 92 days indicates these tags surfaced at a point 4km east northeast of its first contact location and just 0.7km southeast of its first contact point. These back-calculated positions for where the tags probably surfaced, still place the fish in areas offshore of Beaufort County.

13. Slotted Trawl Door Study by Steve Kerchner (Commercial Fisherman)

Project period: June 2006 – June 2007

Justification and Goal

The shrimp commercial shrimp trawling industry in the United States has fallen on hard economic times. Imported product is now making up 90% or more of the shrimp consumed in the United States. This imported product is available at low prices and in large quantities. This has resulted in a softening of the wild shrimp market causing prices paid to the harvest to drop to low levels. Accounting for the effects of inflation, prices paid for shrimp are less than that received in the 1960s. Additionally, Diesel fuel prices have risen significantly as a result of

increasing worldwide demand, effects of Hurricanes and dwindling US domestic production. Concurrently operating cost including repair parts, hull maintenance, ice, and insurance have negatively impacted the economic well being of commercial shrimpers. Shrimpers must now explore every possible solution to remain economically viable. Among the alternatives is reducing fuel consumption, such as finding more hydrodynamic fishing gear. The goal of this study was to develop and test a newly designed, slotted trawl door that would be more efficient in the water.

Methods

Experimental trawl doors were designed and built in fall 2006. The doors were designed by extrapolating features from several different steel fish trawl doors. Some of these doors had two vertical slots, some had one; most were V-type doors. The curved steel section on the back of the door is what makes this type of door more efficient than the conventional flat door. This curved section creates spread in the same way an airplane wing creates lift. As the water travels over the curved section there is less pressure on that side and so the door spreads the trawl net more easily.

Construction of the doors took longer than anticipated – the curved steel sections being difficult to fabricate. The local welding shop in wasn't able to bend the steel because their press was out of order. A fabrication shop in Savannah was contracted to do the work. Their first attempt was not correct, and the plates had to be returned and re-done. During the construction phase, the principal investigator was working during the shrimping season, thus not allowing additional time to complete the doors. The first pair of doors were rigged and towed at the end of November. The boat pulls four 50' mongoose (tongue) type nets. A test door was rigged to each outside net so that if the doors turned out to be totally unstable they would be as far from the boat as possible and would minimize any webbing/propeller interactions. Fuel flow meters were acquired to test fuel consumption while towing the control and experimental gears.

The first test day, November 30th, had a SE wind and swell, conditions that are not generally desirable for shrimping. The next partial test day was Dec.2nd, at Egg Bank, an area at the mouth of St. Helena Sound that consistently produces shrimp. If the doors could not work at this location due to the stronger running tides and softer bottom, they could not be considered feasible. On Dec. 4th, a full test day was made off Fripp Island. The door chains had been adjusted to reduce net spread in order to eliminate the “shuffling” problem. On Dec. 7th, a partial test day was made off Hunting Island. December 10 was a partial test day, again at Egg Bank. Dec. 11th was a partial test day in which a large red buoy float was added to the doors. On Dec. 30th, the boat was rigged with all four test doors. During construction of the second set of doors, a two-part foam was poured into a cavity between the curved steel section and the wood in an attempt to add floatation and so improve stability. Jan. 4th was the first trial day with all four test doors. In April, the two-part foam was used to fill the spaces between the wood and the curved steel section. This was done by mixing two different liquids and then pouring the mixture into the space to be filled, adding a bit at a time. Doors were tested on May 11, 12, 14, and 15.

Results and Conclusions

The fuel flow meters showed 8 to 9.0 gallons per hour (gph) while towing with four conventional doors at 1525 rpm. The average speed over bottom in calm winds with no tide was 1.9 to 2.0 knots.

On the first test day, Nov. 30, two short tows were made and the doors seemed to spread well, however, they wanted to shuffle and jerk at 1525 rpm. This shuffling indicated the doors were over-spreading. Because of rough seas and high winds, fuel usage and towing speeds were not likely to be accurate, so this day was not considered a good test day.

One of the uncertainties with the new doors was their stability in turns. When the boat turns, the set of rigs on the inside of the turn move slower than normal dragging speed. If the boat turns too sharply the forward motion will not be sufficient to keep the doors upright, especially the outboard door. With the extra steel in these doors, particularly with the curved steel back, it seemed likely these doors would be more susceptible to this problem. On the first test day a few turns were made and the doors did quite well. In hindsight, this was likely due to the wood being dry, and more buoyant than they would be in later testing, when door stability became a problem.

The next partial test day was Dec.2. The towing cables were shortened to keep the rigs lighter on the bottom and to allow for better turning. The port outboard net, with a test door, produced the most shrimp of all four nets. All turns were successful until the last turn, when a sharper-than-normal turn was attempted. The test door fell over and the net closed, but with extra throttle the net re-opened. Towing speeds in this area vary with the tides, and rpm settings vary when going with or against the tide.

On Dec. 4 off Fripp Island, the door chains had been adjusted for a bit less spread to do away with the shuffling problem. In 20 ft of water at 1520 rpm, fuel usage was 8.6-8.7 gph, speed over bottom was 2.1 to 2.2 knots. This was at slack tide with very little wind. Engine rpm was decreased to 1510, with 8.4 to 8.5 gph and the same towing speed of 2.1 to 2.2 knots. Again, this was with two test doors and two conventional doors. One of the nets with the test door produced better than the other three which each produced about the same numbe of shrimp.

On Dec. 7, test day was made off Hunting Island. This was when the stability problems while turning started to become persistent. When making a right turn, the starboard outboard door would fall over and it became more and more difficult to stand it back up using extra rpms. Some small floats were attached to the top of the doors in an attempt to keep the door upright while turning. Fuel usage at 1505 to 1520 rpm was 8.6 to 8.7 gph, at 2.5 -2.6 knots towing with the tide and wind.

On Dec.8 a strong cold front moved thru the area, and temperatures fell into the low 20's on the morning of Dec. 9. This sort of weather usually causes shrimp to move down the rivers and sounds to the ocean. Because the investigator needed to take advantage of these good harvest days, this was not used as a test day. However, one long tow was made at Egg Bank and the doors worked well catching about 1600 lb. of shrimp. The test door nets produced at least as well as the conventional door rigs.

On Dec. 10, testing was again at Egg Bank. The outboard port door fell over while turning, and more net floats were added to try to correct this problem.

During testing on Dec. 11, a large red buoy float was added to the doors. Several turns were made with no problems, but one hard turn did cause a door to fall and the nets to close up. The nets had to be hauled back and re-set. At 1510 rpm fuel usage was 8.4 to 8.6 gph, and towing speed was 2.1 to 2.2 knots.

On Dec. 30, the boat was rigged with all four test doors. During construction of the second set of doors, a two-part foam was poured into a cavity between the curved steel section and the wood in an attempt to add floatation and so improve stability. Jan. 2 was the first day with all four test doors. Again, in a turn, a door fell over and would not come back upright.

This was on a turn in a fairly hard tide, and into the wind, thus slowing the boat speed. Fuel usage was 8.8 gph at 1520 rpm dragging into the wind, boat speed was 2.0 to 2.1 knots. Dragging with the wind at 1520 rpm fuel usage was 8.7 gph at 2.3 knots.

When the doors were taken off the boat at the end of the season it was discovered that some of the open space between the curved steel section and the wood had partially filled with sand. This most likely occurred when the doors fell over in a turn and extra engine rpms were used to try to stand the door back upright. During this process the door would be lying flat on the wood face; this was apparent because the door chains were shining from bottom contact. This accumulation of sand inside the door made it more unstable, more likely to fall over, and more likely to scoop up more sand. This would explain the increasing tendency of the doors to fall over.

The doors were kept inside the fish house during the winter and the sand was cleaned from the cavity. Calculations showed that if all of the empty space between the curved steel section and the wood face was filled with the two part foam to add buoyancy, the doors would be within 60 lbs of the weight of the conventional 7.5 x 3' doors when underwater. It was hoped that filling the cavity with foam would solve the instability problem and prevent an accumulation of sand inside the doors.

In April, the two part foam was used to fill the spaces between the wood and the curved steel section. This is done by mixing two different liquids and then pouring the mixture into the space to be filled.

The first test day during spring was May 11, after the NE winds had subsided. The boat worked offshore of the St. Helena sea buoy. The doors were still unstable in turns in 25' of water. By increasing engine rpm prior to turning made it possible to turn without the door falling over, but the hoped for improvement in stability from the added foam did not occur. At 1500 to 1515 rpm, fuel usage was 8.4 to 8.6 gph at about 2.1 knots. The door chains on the outside doors were adjusted to increase spread, and another test day was made on May12th. The doors still fell over in a turn unless engine rpms were increased. Fuel usage and speed were about the same.
The door chains on the outside doors were adjusted again to increase spread and a partial test day was made on May 14. The doors were again unstable in turns, and fuel usage and speed were about the same.

On May 15, one drag was made on the low tide. More adjustments were made to the nets and doors to try to alleviate the instability in turns. On this day the doors did better, turns could be made with less increase in engine rpms. Fuel usage was up a bit, 8.6 to 8.9 gph at 1515 to 1525 rpm. This may have been due to the extra bridle in the door chains. This adjustment controls the spread, and at this point the doors may have been overspreading. This was done to keep the doors open while turning. It was also noted that the foam was contracting, likely due to water pressure at 15 to 25'.

In conclusion, the first year of testing these new doors was largely a learning experience. While there were some indications of improved speed and production with the new doors, the instability problem remains. More experimentation is needed.

14. Assessing Slotted Trawl Door Efficiency by Steve Kerchner (Commercial Fisherman)

Project period : July 2007 – June 2008

Justification and Goal

This project is a continuation of work done the previous year under a similar grant in which a new design of shrimp trawl doors was created and tested. The concept is to develop a more hydrodynamic door that will have less resistance in the water but still function well in spreading the trawl net. This new design could help the shrimper become more profitable in a time when low prices of shrimp and increasing prices for fuel are major disadvantages for the shrimping industry. The goal of this year's study was to utilize divers who could physically ride the doors while they were being towed so that the investigator could make immediate adjustments rather than having to make several tows to determine the effectiveness of gear adjustments.

Methods

The original plan was to utilize SCUBA divers using who would use self-propelled underwater scooters or sleds to follow the trawl doors while under water and being towed. This would facilitate direct observation of the doors to examine angles and position of the door on the bottom. Testing was to take place in October and Novembers during slack water of neap tides when water clarity should be best. Divers would deploy from an outboard boat following the trawler and the dives would be conducted off Fripp and Hunting Islands in 12 to 20 feet of water. Unfortunately, due to circumstances beyond the Investigator's control, the divers were not able to participate in the project. When this became known, the grant was modified to use net monitoring gear from the University of Georgia's Marine Extension office in Brunswick. While not as effective as direct visual observation, the acoustic gear from UGA can provide immediate data on distance of net spread.

The doors were again modified during summer 2007 to increase buoyancy by adding wood between the curved steel back section and the wooden front side. Previously, a two-part foam had been used it was subject to shrinking in response to depth pressure. The steel for the curved section was originally 3/16" plate, but it was replaced with 1/16" to lighten the doors. The aim was to allow the doors to be used without the inflated buoy balls that had been added to keep the doors upright in turns. The doors did well at first. However, after the new wood soaked up water and lost buoyancy, the buoy balls had to be attached to allow for hard turns that are necessary when working in the sound with the strong tide. Without the buoy balls the doors were unstable in the harder turns.

Results and Conclusions.

On 4 December 2007, a tow using traditional flat trawl doors was made at the mouth of St. Helena Sound with the net monitoring gear installed. This tow was made just before during and just after low tide. Readings were taken at particular points during the tow to use for comparison with the slotted doors. The boat returned to the dock, the flat doors removed, and the slotted doors were rigged. The next day, the same tow was made at the same stage of the tide, and readings were taken at the same points during the tow.

Reading Number	Door type	Depth (Ft)	Speed (knots)	RPMs	Fuel Use (gph)	Net spread (Feet)
1	Flat	22-23	3.4	1530	9.2	67.1
	Slotted	22-23	3.4	1520	8.9-9.2	72.7-75
2	Flat	21	1.7	1525	8.9-9.0	61
	Slotted	21	1.8-1.9	1530	1.8-1.9	62.7-63.6
3	Flat	12	1.9	1550	9.1;9.6	63

	Slotted	12	1.8-1.9	1550	9.0-9.5	66
4	Flat	25	3.0	1525	9.0-9.2	67
	Slotted	25	3.0	1520	8.8-9.0	70-71.2
5	Flat	37	--	--	--	60
	Slotted	37	--	--	--	66-67
6	Flat	42	--	--	--	54
	Slotted	42	--	--	--	55-58

The new slotted doors have 20% less surface area that the traditional doors) 18 sq ft vs. 22.5 sq ft. Despite this difference, the new doors generally result in less fuel consumption, greater speed across the bottom and several feet of greater spreading of the nets. Although more work is needed to perfect the doors, it is clear that there are economic advantages with use of the new doors. Catch rates should increase while fuel use should decrease.

Fuel usage when dragging the slotted doors during the first grant testing was lower than during this grant. This could be due to growth on the propellers, loss of propeller efficiency due to electrolysis robbing metal from the props, or loss of engine efficiency due to fuel pumps and injectors needing service. Also, most of the testing for the second grant was conducted at the mouth of St. Helena Sound, where it is not advisable to experiment with speed over bottom. The bottom composition is generally softer mud, and varying speeds leads to mudding down the rigs. Slightly higher engine rpms are generally used in this area to insure the rigs keep moving. The boat turns more often in this area, and higher rpm's are used during turns to keep the rigs spread.

The slotted doors have been used throughout the spring season until this report was written, using the buoy balls for extra floatation, and have been stable in turns. Some towing has been done in areas with relatively soft bottom (muddy), but the new doors have not been a problem.

15. Recording Catch Composition and Rates of Undersized/Legal Black Sea Bass

by Donald Lombardi (Charter boat fisherman, Recreational fisherman)

Project period: June 1, 2007 to June 6, 2008

Justification and Goal

The size limit for Black Sea Bass (*Centropristis striata*) in Federal Waters is to be increased from 11 to 12 inches in 2007. In May 2006, the minimum limit was 10 inches. During the June to November period many people anchor over reefs and fish for black sea bass while they also fish for king mackerel and cobia. Others target only black sea bass year-round. The goal of this research was examine the catch and release rate of black sea bass to get an estimate of the frequency of sublegal fish caught and released. Some contend that catch and release mortality is substantial, thus making size limits somewhat ineffective and possibly an unwise management option. This research should shed some light on this issue.

Methods

This investigation took place over a 12-month period beginning June 2007. The investigator made 30 offshore fishing trips to five area artificial reefs located off Beaufort County, South Carolina. Each reef was fished six times and all four seasons were represented in the sampling. Fishing was limited to artificial reefs only and not natural "live bottom." The

names of these reefs are: (1) PA-4 Hunting Island, (2) PA-44 Betsy Ross, (3) PA-48 Eagles Nest, (4) PA-49 Hilton Head, and (5) PA-42 Beaufort 45. The water depth ranged from 45 to 90 feet. Fishing methods included either anchoring or drifting, depending upon current and wind conditions, over suitable bottom as determined with a depth finder. Two fishermen used identical rods and reels with bait on double-hook bottom rigs, one with a #2 circle hook and one with a #2 "J" hook. Daily results were recorded on waterproof paper. This included the number of 12-inch or longer fish and the number of undersized fish that were released. Undersized fish were measure for length. Also the numbers of gill/gut-hooked fish for each hook type were recorded. Condition of released fish was recorded.

Results and Conclusions.

1,308 Black Sea Bass were caught. The catch per reef, in order, was 446 at Hilton Head, 306 at Beaufort 45, 245 at Eagle's Nest, 196 at Hunting Island, and 115 at the Betsy Ross.

Reef	Total Number of Fish	No. Legal	% Legal	Sublegal	% Legal
Hilton Head	446	34	7.6	412	92.4
Beaufort	306	14	4.5	292	95.5
Eagles Nest	245	21	8.5	224	91.5
Hunting Island	196	17	8.6	179	91.4
Betsy Ross	115	10	8.7	105	91.3
Total	1308	96	7.3	1212	92.7

The ratio of legal to sublegal ranged from 11.5: 1 to 21.8:1 and averaged 13.6: overall. Splitting the sublegal fish into 2-inch size classes showed that 7.3% (96) were 4-6 inches, 23.5% (307) were 6-8 inches, 35.6% (466) were 8-10 inches, and 26.3% (343) were 10-12 inches. The number of gut/gill-hooked fish on the J hook was 38 and 6 for the circle hook. When released all 44 of these fish were visibly injured and probably did not survive.

Among the 1,212 released sublegal fish, 8(0.7%) drifted away, 36 (3.0%) floated and then swam away, and 1,168 (96.4%) swam away immediately.

This study demonstrated that an overwhelming majority of fish caught at this time following the new size limits were sublegal. Perhaps with time, a larger percentage will be legal, provided they have reasonably good survival if caught and released. This study indicated that most 96.4% of the fish seemed to swim away okay. It is impossible to determine what eventual mortality rates may have occurred. Also, gut and gill-hooked fish were relatively rare, but the circle hook seemed to be much less damaging.

16. Development of new gear for the commercial harvest of stone Crab Claws

by Dan Morey (Commercial Fisherman)

Project Period: August 2006 to June 2007

Project Justification and Goal

The stone crab fishery constitutes the third largest crustacean fishery in the southeast, but its commercial utilization is confined primarily to Florida. Only the claw of a stone crab is harvested, and captured crabs are then returned to the water to regenerate their missing claw. There is little habitat damage and no by-catch associated with this fishery. A legal size claw has a propodus base measurement of more than 70 mm (2.75 inches). In South Carolina, only the larger of the two claws may be taken and crabs must be returned to the water immediately upon their capture. There is currently no directed fishery in South Carolina. Stone crab claws sold commercially are primarily from incidental catch from crab pots fished for blue crabs. This is often an inferior product since stone claw must be handled differently than live blue crabs. It is necessary to immediately blanch a claw (within -4 hours of being caught) and put them on ice to provide a high quality seafood product. Typical blue crab traps are not ideal for capturing stone crabs. Although stone crab populations are thought to be relatively large in South Carolina, the species has never been widely exploited. The goal of this research is to develop and test a gear that could be successful in developing a stone crab fishery.

Methods

The traps designed for this study has a PVC pipe bait well, over-sized entrances, is made of extra heavy larger mesh wire (which reduces by-catch) and has four entrances. Collections of stone crabs were made near Charleston, SC from August 2006 to June 2007. The new design of stone crab trap uses a long line bottom rig to help reduce the associated fishing costs while targeting the stone crab specifically. Many of the limitations of this trap design have been resolved with a long line bottom rig with an anchor and buoy at each end. It is not necessary to haul out all traps twice per month. Long-line traps are weighted less making them less cumbersome to work and less prone to damage. Buoys make it easier for boaters to see than crab pot floats; regular crab pot floats get run over all the time. Sampling was conducted from an 18-foot outboard boat. Sampling sites were chosen in nearshore and inshore waters. Approximately 20 crab traps were used in the field sampling. Five vinyl-coated wire mesh blue crab traps, each with four entrance holes, and 15 vinyl coated wire mesh stone crab traps of an original design with four entrance holes were baited with menhaden and fished near each other for comparative testing. Stone crab traps were deployed with a long line bottom rig and blue crab traps fished by the traditional methods were fished nearby to serve as controls. The paired anchors of the long line system were 20-lb Danforth anchors each with 8' of 3/8" galvanized chain; floats at each end of the line were 21-in. diameter inflatable vinyl mooring buoys. An experimental permit was obtained from SCDNR. In addition to collecting harvest data on the stone crab claws and by-catch, notes were kept on general location, depth, bottom type, and weather conditions at the study sites. Latitude and Longitude were determined with a handheld Global Positioning System (GPS) receiver. Water surface temperature was measured and monthly salinity checks performed. A YSI model 85 handheld dissolved oxygen and conductivity instrument (YSI Inc., Yellow Springs, OH) was used for measuring dissolved oxygen, salinity and water surface temperature. The total weight of claws for test and control pots and number of pots fished were recorded by gear. For each trap pulled during a set, the total catch of *M. mercenaria* and C. *sapidus* was recorded. The carapace width and claw length (propodus length of the major

cheliped measured with a micrometer as the distance along the lower margin from the tip of the fixed finger to the proximal end of the palm) for a portion of catch (up to 30 individuals for control and test pots each month), including sublegal crabs, which were then released, was recorded. Claws were also weighed. SAS version 9.1.3 (SAS Institute Inc., Cary, NC) was the statistical packaged used to analyze data.

Results and Conclusions

Data represent information collected on 46 separate occasions from from Aug 2006 -July 2007. The depth range was 17- 69 ft; dissolved oxygen levels ranged from 4.70 to 8.42 mg/l; surface water temperature range was 54.5-84°F; and salinity was 25 -35ppt. Average total weight of stone crab claws harvested per trip was 11.1 ± 9.58 lbs. with a range of 3-45 lbs. The average number of stone crabs landed was 123 ± 88 with a range of 6 to 372. The overall catch per unit of effort (CPUE) was 6.7 ± 3.6 crabs per trap; for test and control traps. The CPUE for the test traps was 7.4 ±4.5 and 5.3 ±4.8 for the control traps. A Student's t-test showed that the test traps caught significantly more stone crabs than the control traps; however, using the Shapiro-Wilkes test, it was determined that the data were not normally distributed and variances not equal, so the t-test was not valid for comparing trap types for catch rates. The data did fit a Poisson Distribution and using the generalized linear model procedure (GENMOD), the results of the t-test were confirmed with the test traps catching significantly more than the control traps ($p < 0.0001$). Data were also collected for blue crab catches. These data were normally distributed with equal variances, and data did fit a Poisson Distribution. Using GENMOD shows that the control traps caught significantly more blue crabs than the test traps ($p < 0.0001$). The Wilcoxon-Mann-Whitney test of ranked data confirmed the results of the Student's t-test and the GENMOD procedure with the Poisson distribution using raw data. When gear was compared by year/month and by year/season, in general there were more stone crab landings with test traps and more blue crabs using control gear. While there is definitely a difference in catch between the two gear types, there is no clear statistical trend with regard to depth, salinity, temperature, or season. Fewer stone crabs were taken at salinities below 27 ppt. A total of 553 crabs of legal and sublegal size was evaluated on six occasions throughout the study. Of these, 118 stone crabs (21%) presented with only one claw, and 21 (4%) had no claws. There were 330 female crabs measured, and 128 were male (1 female: 0.39males). The average carapace width for all stone crabs was 99 ± 17mm (n =553), with a range of 65 -182mm. Crabs with legal size claws had carapace widths ranging from 70 -182 (n =371), and crabs with undersized claws had carapace widths ranging from 65 -114mm. Females measured had an average width of 100 ± 18mm (n =330); males were an average of 101 ± 16mm (n =128). The average claw length of landed crabs was 78 ± 17mm (n =532), with a range of 28 -165mm. Harvested claws ranged from 70.0-165mm (n = 350). Females measured had a claw length range of 28 -165mm (n = 321); males had claw lengths from 48 -148 (n = 117). The average mass of harvested claw was 92 ± 33g (n =137). The average mass for harvested claws from females was 84 ± 24 (n = 91); males had an average larger mass of 115 ± 41 (n =36).

This study confirmed that the experimental trap exceeded the traditional blue crab trap for catch stone crabs. This gear may be suitable to establishing a dependable stone crab fishery.

17. Evaluation of the Viability of a Stone Crab Fishery in South Carolina Using GIS

by Dan Morey (Commercial Fisherman)

Project Period: June 2007-June2008

Project Justification and Goal

South Carolina's stone crab fishery has traditionally been primarily a by-catch of the blue crab fishery. No recent surveys of the stone crab population exist. Presuming a reasonable fishery could be developed, it is important to understand the relative abundance of the population and its natural fluctuations. I would also be useful to map crab density for purposes of repeated monitoring and for understanding the species' required habitats.

Methods

Crab traps were fished in long line fashion meaning that traps were snapped to a long line at regular intervals. Given that soak times for stone crabs are longer than blue crab traps and that the investigator wanted to minimize theft of crabs or traps, the long line system was thought to be the optimal method. DNR law enforcement was notified weekly by email as to general location of the long line. Traps were fished via an 18-ft custom built Privateer outboard boat with a 115 HP Yamaha engine. Long lines were set in the North Edisto River, Stono River, Lighthouse Inlet, or near the Charleston Harbor from June 2007 to June 2008. Fishing depth ranged from 12 to 88 feet; the average depth was 36.6. 12 identical vinyl-coated wire stone crab traps of an original design having four entrance holes were used in the field sampling. The traps were baited with menhaden or artificial bait and deployed with a long line bottom rig or individually fished approximately twice weekly (weather permitting). At each end of the long line system was a 20-lb Danforth anchor, with 8 ft of 3/8-inch galvanized chain and buoys. For each trap pulled during a set, the total number of stone crabs, blue crabs and other bycatch was recorded along with the Global Positioning System (GPS) coordinates, site parameters, and date. The GPS was a eTrex Legend® (Garmin International, Inc., Olathe, KS). In addition, general location, depth, bottom type, weather conditions, water surface temperature and salinity at the study sites were noted. Records were kept on the total weight of claws, number of traps, how the product was marketed, and the price at which it was sold.

At three of the sampling locations, the Stono River, the Lighthouse Inlet, and the North Edisto River, a total of 106 crabs was tagged and released using uniquely numbered T-bar carapace anchor type tags manufactured by Floy Tag Inc. (Seattle, WA). Tagging was accomplished in October, November and June. Tags were inserted into the posterior suture of the carapace so that the T-anchor of the tag resided in the middle of the muscle group associated with the left walking leg. The needle was immersed in 70% isopropyl alcohol between each tag application to minimize the chance of infection. DNR biologist Larry Delancey was consulted on tagging techniques. DNR technicians, Barry Gooch and Nathan West, assisted in parts of the tagging survey. Date, time, location, carapace width, and claw length were recorded at ageing and are measured again at any recapture time. The carapace width and claw length were measured using a Westward FB3071 digital micrometer (Westward Tools, Edmonton Canada).

Results and Conclusions

Water surface temperature over the course of the study ranged from 51-89°F. During June -December 2007, a total of 6,894 crabs was landed: 2,573 crabs were landed in January - June 2008 for a total of 9,467 crabs in 1,245 traps for a catch rate of 7.6 crabs per trap. This includes crabs landed regardless of whether the claw was harvested. A total of 775 pounds of

stone claws was harvested. Only legal size claws (with a propodus base measurement of more than 70 mm) were taken from crabs with two claws, and only the larger of the two claws was removed. Upon their capture, crabs were declawed and immediately returned to the water. Catch per unit of effort (CPUE) for the project was estimated at 7.72 ± 6.02 crabs per trap. This compares well with the CPUE of 6.7 ± 3.6 recorded in the previous year's Cooperative Research project, implying that for at least the two years, the stock appears to be relatively static in terms of relative abundance.

For data collected during eight trips when DNR biologists were aboard the vessel (Nov 2006 thru November 2007), the percentages of crabs missing one or more claws ranged from 5 to 33%. Crabs having legal claws ranged from 57 to 100% for the various dates sampled. The range of crabs with only sublegal claws ranged from 0 to 43%. Of the 691 crabs observed during this period, 262 were male and 429 were female (sex ratio 1M:1.63F). Interestingly, however, on one date (23 May 2007) the catch was largely males (125M:44F). Overall catch rates were highest from spring through summer. Carapace width ranged from 66 to 180mm but the vast majority of the crabs were between 80 and 110 mm.

To date, only two tagged crabs have been recaptured. One crab was recovered the following day, and the other more than 8 months later and less than two nautical miles inland up the Stono River. Its carapace width had increased by 3.6 mm, and both claws were intact. Since SCDNR contact information is on each tag, in addition to my continued reporting on recaptures, other fishermen can report the capture of a tagged crab. Thus, data collection on the movements and growth of the crabs can continue.

The catch and location data have been entered, analyzed, and evaluated using a geographic information system. Collected data were converted to the dBaselV file format (*.dbf) and used as an attribute table in a feature class in the GIS project. ESRl's (Redlands, CA) ArcView 9 was used to prepare views to help visualize the dynamics of the stone crab fishery. Using a Digital Orthophoto Quarter Quadrangle image of the study area as a background, an overlay of stone crab spatial distribution densities with points of graduated size (to represent number of crabs per trap linked to landed location) allows one to easily see where landings of crabs are concentrated. It becomes apparent that the catches of stone crabs are occurring in the deeper areas of the rivers. As more tagged crabs are recaptured, more will be gleaned on localized movements.

18 Assessment of Fish Communities Associated with South Carolina Permitted Artificial Reef Sites with Comparable Natural Hard Bottom Sites by South Carolina Aquarium Divers

By Arnold Postell, Raymond J. Rhodes, Dale Swing and Brian Kennedy, South Carolina Aquarium

Project Period: June 2007- July 2008

Project Justification and Goal

The South Carolina Department of Natural Resources developed and currently manages a system of 45 permitted marine artificial reef (PAR) areas or sites off the South Carolina coast and within SC estuarine waters. Given the environmental and economic importance of this system, MRD like other marine resource management agencies is often faced with formulating policies and/or regulatory decisions regarding natural systems and related habitats like their PAR system despite limited information on these systems. Additionally, MRD is interested in

evaluating the utility of cooperative fishery research approaches involving fishery stakeholders working in conjunction with professional scientists.

The South Carolina Aquarium (SCA) started in 2007 to implement and conduct field research to assist MRD in improving the understanding of fish assemblages associated with selected PAR sites and comparable hard bottom areas off of South Carolina using a core of volunteer divers trained by the SCA. Specifically, this research examined the importance of variables such as: depth, location, construction materials, age, or productivity on an artificial reef versus comparable natural hard bottom areas. The natural hard bottom (HB) areas off South Carolina's coast are characterized as broad expanses of smooth sand bottom interspersed with areas of low relief hard ground and rocky outcrops. These habitats provide hard substrate for a diverse assemblage of sessile invertebrates which, in turn, attract a variety of motile species including many demersal fishes.

The goal of this study was to implement a project involving volunteer divers trained by the SCA with these divers routinely collecting field observations on fish species associated with selected man-made structures within PAR areas and a comparable HB area starting in 2007.

Methods

The sites selected for observational dives during this project were limited to areas generally considered accessible by private boat recreational anglers and divers or the greater Charleston area and within about two hours or less of traveling time. Three different sites were selected for surveying per dive trip: one offshore man-made structure, (Y-73) within a PAR area, one comparable offshore natural HB site, (locally called "The Gardens"), and one nearshore PAR site,(the Charleston 60'). The "Y-73" is approximately 30 miles offshore and is comprised of a 180-foot steel hull tanker ship sitting straight up in sand at 100 feet. "The Gardens,", the project's selected HB area, is a limestone out-cropping about 28 miles offshore that has a maximum depth of approximately 90 feet with a 12-ft ledge. The "Charleston 60", a PAR site, is a 240- foot broken up barge with concrete tubes on top in about 60 feet of water about 18 miles offshore. It was hypothesized that "The Gardens" HB site was generally comparable with the "Y-73" PAR site based on comparable depth and a proximity of two miles from each other. No comparable HB was chosen to compare with "Charleston 60'" due to limitations of three dives per day and the desire for consistency during each trip to aid with the seasonality component.

Survey Protocols

A "survey" is defined as one dive completed by one diver on a given date and site using the Roving Diver Technique. For each survey site selected, two (2) fish assessment trips per month were attempted at each of the three selected sites per trip (i.e. a total of three assessment dives per trip) from June 2007 through July 2008. During each fish assessment survey, divers used the Roving Diver Technique (**RDT**). RDT is considered a viable fish assessment technique and has been effectively used with trained volunteer divers to collect scientific observations on marine fish communities and assemblages. This methodology has been utilized by NOAA. The RDT is a non-stationary *in situ* survey technique used by individual divers to record fish species observed while freely swimming or "roving" throughout a designed dive site such as an artificial reef. Besides the simplicity, it was also selected because of the SC offshore diving environment (safety issues associated with strong currents and potential poor visibility).

During and immediately following each survey dive, divers recorded species observed during the dive as well as other biotic and selected abiotic information. Information also

included assigning observed species to relative abundance categories (i.e. four $\log_{10}$ categories), survey depth ranges, temperatures, and estimated overall visibility. After each survey trip, a SCA Survey Coordinator was responsible for the timely (e.g. within five days) review of observations recorded on each diver's survey form and subsequent entry into a database. The relative abundance category data recorded by surveyor divers as described above was used to calculate a relative index, DEN, for ranking the overall abundance of a given species observed during a specified time period and site(s). Specifically,

$$DEN= [(S * 1) + (F * 2) + (M * 3) + (A * 4)]/n$$

Where n is the number of surveys in which species was observed at a specified site(s) and time period, and S, F, M and A are the number times that a diver assigned an observed species to an abundance category such that S+F+M+A=n. (The weights are Single=1, Few=2, Many=3, and Abundant=4.) All divers participating in field survey activities were required to receive training on identification of fish species that might be observed during a survey dive.

Only divers with AAUS or equivalent certification were selected for training. Advanced fish identification training included testing and then evaluation under field (open-water) conditions before being allowed to participate in an assessment survey. Candidate divers also had the opportunity to hone their fish identification skills while diving in a 385,000 gallon display tank that holds about 45 different marine fish species.

This project started with a group of eight (8) SCA divers with a tested advanced quality of fish identification and grew during 13 months to 25 qualified divers.

Results and Conclusions

Because of poor conditions, six trips were canceled with short notice and one trip had to return to port due to unpredicted seas. Also, after October 2007, the number of available qualified volunteer divers was decreased due to some volunteers lacking access to wetsuits or dry suits. Other mechanical and equipment problems resulted in no surveys completed during January to April 2008.

From June 2008 to July 2008, 153 survey dives were completed using the RDT field protocol. For each site, 48, 55, and 50 survey dives were completed. Slightly more than half of the surveys, 57.5% (88), were completed by divers assigned an "Advanced" fish identification skill level. The total (aggregate) bottom times (hours:min) by all survey divers for the Charleston 60', the Gardens and Y-73 were 37:52, 35:06 and 28:35, respectively.

The lowest (64^0F) and highest (84^0F) bottom temperatures reported by survey divers occurred on December 8, 2007 and August 31, 2007, respectively. This temperature range was indicative of seasonal seawater temperatures of the shallow continental shelf area. In contrast, the two offshore sites reached a high of 82^0F on September 27, 2007 and a low of 66^0F on December 8 , 2007. Mean underwater visibilities were 21 ft, 37 ft and 42 ft for the Charleston 60', the Gardens and Y-73 s, respectively.

The overall mean number of different fish species reported (per site per day) was 37, 44 and 40, respectively for the Charleston 60', the Gardens and Y-73 sites. The total number of different fish species sightings at a given survey site ranged from a low of 26 species on May 23, 2008 at the Charleston 60' to a high of 56 species at the Gardens site on June 25, 2007. 143 different fish species were observed at the three survey sites. In ascending order of frequency the top five species were Tomtate (89%), Bank Sea Bass (88%), Belted Sandfish (84%), Slippery Dick (84%) and Blue Angelfish (80%). Tomtate (3.78) and Slippery Dick (3.03) also had the highest density scores among the top ten species based on frequency of sighting. For

economically important species, Greater Amberjack (77%) and Black Sea Bass (66%) were the among the top ten species while Scamp, Gag, Atlantic Spadefish and Sheepshead were ranked 12th, 15th, 17th and 18th. Greater Amberjack had the highest density score, 2.95, of all economically important species in the top 20 species.

The numbers of different species recorded by site were 91, 112 and 103 for the Charleston 60' (Table 7), the Gardens (Table 8) and Y-73 (Table 9) sites, respectively. The top five species based on sighting frequency for the Charleston 60' site were Bank Sea Bass (96%), Slippery Dick (94%), Tomtate (92%), Belted Sandfish (92%) and Black Sea Bass (90%) with Tomtate having the highest density score among the top ten species. Along with Black Sea Bass, other economically important species, Atlantic Spadefish, Greater Amberjack and Gag were among the top 20 species for Charleston 60 ft. Scamp were conspicuously missing from the top 20 species listing at this site; they were only ranked 36th (23%). Although not commonly observed at PAR sites, aggregating behavior of adult Red Drum was observed at the Charleston 60 during fall of 2007.

At the Gardens site, the top five species were Black Sea Bass (93%), Scamp (93%), Bank Sea Bass (89%), Two spot Cardinalfish (89%) and Blue Angelfish (87%). The Queen Angelfish (86%) was also among the top ten species for the Gardens site. Among economically important species, Gray Triggerfish (82%), Gag (73%) and Greater Amberjack (73%) were among the top 20 species. Tomtate (84%) had the highest density score, 3.74, of the top 20 species.

Greater Amberjack had the highest sighting frequency (94%) (DEN=3.30) at the Y-73 site followed by Tomtate (92%), Whites potted Soapfish (88%), Blue Angelfish (86%) and Cocoa Damselfish (82%). Economically important species among the top 20 species included Atlantic Spadefish (78%), Scamp (70%), Vermillion Snapper (66%) and Gag (48%). Black Sea Bass were not commonly observed (12%) at this site even though Bank Sea Bass was among the top ten species observed (80%) at Y-73.

The rarely seen Goliath Grouper (*Epinephelus itajara*) was observed in summer 2007 at the Y-73, and red Lionfish (*Pterois volitans*) were seen at both deep water sites multiple times and had a sighting frequency of 44% and 28% at the Gardens and Y-73 sites, respectively. A fish thought to be a Palefin Batfish (*Ogcocephalus rostellum*) was seen during fall 2007 at the Y-73 site. This will be confirmed later.

The mean number of different species at the Charleston 60' was statistically different than means for the other two sites ($F=3.820$, $p=.031$). Moreover, the results of a multivariate linear regression analysis with mean number of sightings as the dependent variable resulted in approximately 43% (Adjusted $R^2=0.437$; $F=16.106$, $p<0.000$) being "explained" by visibility and water temperature variables. These preliminary statistical analysis results suggest that the relatively lower visibility at the Charleston 60' may have negatively influenced the number of different fish species observed by survey divers at that site while the higher temperature at the deepwater PAR sites may have generally increased the diversity of species observed.

Loggerhead sea turtles (*Caretta caretta*) were observed at all three survey sites during 2007 for a total sighting frequency of 8.5% with most (8 of 13) of these sightings at the Y-73 on July 16, September 27 and October 14. These turtles were seen resting on the bottom tucked under a ledge or they were seen swimming on the surface taking a breath. These animals were probably adults with estimated curved carapace length of 1 meter or greater.

19. Atlantic Sturgeon Sampling in Winyah Bay and Edisto River, SC by Dr.. Anna Toline (ENTRIX, Inc), William Post (SCDNR), Leo D. Lentsch (ENTRIX, Inc), Mark Collins(SCDNR), Ronnie Campbell (Commercial Fisherman), and Ivy Perry (Commercial Fisherman)

Project Period: July 2006 to January 2008

Project Justification and Goal

Atlantic sturgeon (Acipenser oxyrhynchus) is anadromous, occurring in the ocean, estuaries, and large rivers of the Atlantic coast. This species has been reduced by overfishing, pollution, and dam construction. In South Carolina the fishery for sturgeon was closed in 1985 following drastic declines in landings in 1983 and 1984. Juvenile and sub-adults are still captured incidentally by commercial shad fishermen in rivers and nearshore ocean waters. Management needs for this species include information on: 1) specific spawning locations, early life history, and migratory patterns 2) broodstock availability and genetics, methods to induce reproductive activity for both males and females, and needs for nursery systems. In addition to the state closing the fishery, the Atlantic States Marine Fisheries Commission has placed a moratorium on the fishery for the entire eastern seaboard until stocks have recovered.

Research efforts in South Carolina include tagging and measuring of sturgeon caught as bycatch in the shad fishery of the Edisto River. The goal of this present study was to expand on existing work and incorporate commercial fishermen from Winyah Bay. Objectives include: collect location and catch rate information on sturgeon in SC, compare information collected to historic information, and collect preliminary population demographic data.

Methods

Winyah Bay Study

Sampling occurred from fall 2006 through winter 2008. Sampling dates varied based on availability of the fishermen. Dates also varied based on timing of the tide. Various times were attempted at the start of the project, such as late at night and from high to low tide. Each sampling trip required the presence of one biologist (Dr. Toline) and two fishermen. All fishing was performed from a 19 ft. open shrimp boat. Sampling methodology and training was provided to Dr. Toline by SCDNR staff (Mr. Bill Post). Total length, fork length, weight, and water temperature were measured for each sampling date. Fin spines were sampled for age analysis. Samples were placed in 95% ethanol for DNA analysis. General condition of each fish was noted.

A passive integrated transponder (PIT) tag and a spaghetti-type Floy tag (provided by SCDNR) were inserted into each fish. Tags were placed on the left side of each fish as requested by SCDNR. Spines were sampled from the left side unless this side was damaged such that it prevented a spine sample. If more than one fish was captured, the remaining fish were tied by their caudal fin to the side of the boat where they could remain in the water while the other fish were processed. Each fish was in the boat for approximately five minutes.

Two 100-yd nets were set in the Waccamaw River at upstream and downstream locals of Butler Island. These locations were chosen based upon past levels of success by the sturgeon fishermen during their commercial sturgeon fishing operations. They believed that the location, particularly that of the downstream net, was likely to capture sturgeon based upon the presence of a river channel that directed fish through this particular area.

Sampling in October 2006 consisted of setting drift nets. These were followed with the boat. However, this method was unsuccessful and all other sampling occurred with anchored nets.

Nets were set at low tide and left to fish until the peak of high tide. Nets were considered capable of capturing fish anytime while the tide was incoming. The commercial fishermen believed that the greatest chance of capture sturgeon would occur as the fish moved upstream with the incoming tide. Nets were checked every hour while they were in the water. The boat was anchored with one of the two nets at all times to monitor for fish. Nets were removed at the end of the sampling period.

Edisto River Study

In the Edisto River, the cooperating fisherman is Mr. Ivy Perry of Jacksonboro, Sc. During fall 2006, the sampling effort was initially 7 days per week with DNR biologists assigned to weekend duty on a rotating basis. However, this level of effort proved too much of a burden for everyone involved, especially Mr. Perry, so effort was reduced to 5 days per week, weekdays only. Genetic and ageing specimens were archived for future processing. Nets were fished in the Edisto River September 6th-November 30th 2006, April 2nd-June 29th 2007, and August 4th-November 1st 2007. Nets were fished at two different locations (upriver and down river) during these times.

Results and Conclusions.

Winyah Bay Study

Between October 19, 2006 and December 19, 2007, twenty-five sturgeon were captured. Two of the twenty-five fish were recaptures. One of the recaptures was from the Winyah Bay sampling, while the other was from elsewhere. The majority of these fish were captured between mid May and mid-June. Twenty-three of the twenty-five fish were captured at the Butler Island downstream site. The greatest number of fish captured on any date was six. Fish were typically captured during the last two hours of sampling. No fish were killed during this study.

All data, including sampling dates, tag numbers, lengths, weights, DNA number, and water temperatures are provided below. The largest fish was estimated to weigh approximately 130 lbs and was identified by the fishermen as a female. Average fork length was 60.2 inches (153 cm). Average total length was 67.0 inches (170.2 cm). Average weight was 84.4 lbs (38.2 kg).

Collection data for Atlantic sturgeon. Dates with no captured sturgeon were 10 October 2006, 24 October 2006, 27 March 2007, 20 April 2007, 24 October 2007, and 30 November 2007. The 52.5-cm sturgeon captured on 4 May and the 54–cm on 28 Sept were recaptured after being tagged elsewhere.

Date	Fork Length (inches)	Total Length (inches)	Weight (lbs)	Water Temperature (ºC)	Sex
1 Nov 2006	54.5	62.5	~60	--	Unk
1 Nov 2006	52.75	62	~60	18.1	Unk
2 Nov 2006	60.5	67	85	18.5	Unk
2 Nov 2006	52.5	58.5	62	18.5	Unk
30 March 2007	45	51	42	18.9	Unk

6 April 2007	52	59	63	19.0	Unk
6 April 2007	60	67	92	19.0	Likely Female
12 April 2007	81	91	~130	16.8	Female
4 May 2007	52.5	58.5	80	23.5	Unk
4 May 2007	53	57	60	23.5	Unk
4 May 2007	59	65	85	23.5	Unk
4 May 2007	55	61	70	23.5	Unk
4 May 2007	62	67	95	23.5	Likely Male
7 June 2007	58	65	72	27.2	Unk
7 June 2007	72	79	105	27.2	Likely Female
2 July 2007	61	68	85	29.6	Unk
2 July 2007	57	65	85	29.6	Unk
2 July 2007	72	65	92	29.6	Unk
2 July 2007	74	67	105	29.6	Unk
2 July 2007	64	59	90	29.6	Unk
2 July 2007	72	79	107	29.6	Unk
17 July 2007	59	68	85	29.5	Unk
17 Aug 2007	71	80	108	30.7	Unk
28 Sept 2007	58	64	80	26.8	Unk
28 Sept 2007	54	61	78	26.8	Unk

Edisto River Study

In the Edisto River, the cooperating fisherman was Mr. Ivy Perry of Jacksonboro, SC. During fall 2006, the sampling effort was initially 7 days per week with DNR biologists assigned to weekend duty on a rotating basis. However, this level of effort proved too much of a burden for everyone involved, especially Mr. Perry, so effort was reduced to 5 days per week, weekdays only. During fall, 34 adult Atlantic sturgeon were captured upriver of Highway 17. All fish were processed by biologists, and all were released in good condition. None of these fish were recaptured, but four tagged fish from a previous project were encountered. Tissues for genetic and ageing analysis were archived for future processing. During spring 2007, Mr. Perry began fishing in late March as water temperatures began increasing and his efforts continued until the end of June 2007. Subsequently, he resumed fishing in August until November to cover the potential fall spawn. There were no sturgeon caught in spring 2007 and only one caught in fall 2007. Mr. Perry's theory, and one that has been proposed by biologists in the past, is that conditions were not right for the spawning run during spring and the fish did not move upriver. Water levels and flow were extremely and unusually low during spring due to a drought. It is hypothesized that these abnormal conditions did not ""cue" the fish to initiate the spawning

migration. If this is the case, the result would be a "missing year class", which has been described in the general literature for other sturgeons.

Data Collected from Sturgeon Captured in the Edisto River. l

Date	Fork Length (inches)	Total Length (inches)	Weight (lbs)	Sex
6 Sept 2006	59.2	61.8	75	Unk
7 Sept 2006	67.9	78.1	119	Unk
8 Sept 2006	54.4	58.3	61	Unk
8 Sept 2006	57.7	64.0	65	Unk
9 Sept 2006	55.4	62.6	56	Unk
9 Sept 2006	60.0	67.6	78	M
10 Sept 2006	72.2	77.8	140	Unk
15 Sept 2006	51.6	58.1	58	Unk
15 Sept 2006	65.1	73.1	102	Unk
15 Sept 2006	53.5	60.0	60	Unk
15 Sept 2006	62.6	70.5	95	Unk
15 Sept 2006	62.2	71.1	82	Unk
17 Sept 2006	54.7	62.2	51	M
18 Sept 2006	57.9	65.2	64	Unk
19 Sept 2006	60.6	66.1	75	Unk
22 Sept 2006	65.7	73.6	110	Unk
25 Sept 2006	57.1	61.9	64	M
29 Sept 2006	58.5	65.7	69	Unk
12 Oct 2006	60.4	67.5	82	Unk
27 Sept 2007	64.0	71.0	110	Unk
27 Sept 2007	68.0	76.0	134	Unk
2 Oct 2007	64.0	71.9	100	Unk
2 Oct 2007	64.5	71.0	99	Unk
16 Oct 2007	65.7	72.5	91	Unk

Overall, 35 Adult Atlantic sturgeon were caught between September 6th and October 12th. Of those, 20 were worked up . The other 15 were captured when SCDNR personnel were unavailable. In these cases, approximate lengths and weights only were recorded by the fishermen. Also, three of the 35 sturgeon were recaptured fish from a previous day. In these

cases, fish were released without workup. The mean fork length was 59.8 inches (1519 mm) and the mean weight was 79.26 lbs (35.95 kg) for the 19 fish measured by SCDNR biologists. Biologist noted seeing three running ripe males, and one possible gravid female. Four sturgeon were recaptured from past projects, with one having been tagged in 1997. The upper net CPUE was 0.00107, and the lower net CPUE was 0.00066 (CPUE is number of sturgeon per 100 yards of net per hour fished.

This study, conducted in two parts, showed that working cooperatively with fishermen can be successful in providing biological data relatively inexpensively. Working in close coordination with biologist meshed the fisherman's expertise in using fishing gear with the biologists' expertise in collecting the needed data. Longer-term data will be needed to establish if sturgeon stocks are recovering, but this study indicated that young sturgeon are relatively common in these two rivers.

20. Enhancement of Commercial Oyster Production by Dr. Anna Toline

Project Period: July 2006 – June 2008

Project Justification and Goal

Substrate available for attracting oyster spat is lacking in many locations of South Carolina because of a paucity of shucked oyster shells that have traditionally been used as cultch. With the decline of shucking houses and canneries, shell is difficult to find and obtain. This project was designed to assess a variety of enhancement techniques with the purpose of identifying a material that optimizes oyster production per unit of effort in South Carolina. The study site is within a private oyster culture permit (C-370) in Murrell's Inlet, SC managed by William Chandler.

Methods.

Cement- coated manila twine was coated with cement and hung from an upright wooden frame. Conceptually, the oysters would attach to the twine and, over time, the twine would degrade and the clumps of oysters would fall off the frame.

Coated and uncoated shell was splayed across snow fencing in a tidal creek to mimic the concept of spraying shell onto intertidal shellfish habitat. French collectors-- long rubber tubes 1 inch in diameter rough on the outside are designed to collect spat but are flexible so that single adult oysters can be removed easily by bending the collector. Collectors were mounted in wooden frames in between another material (Chinese hats). Chinese hats are small, slightly flexible disks (6 inches in diameter) that attach to a pole. Because the hats are flexible, it is proposed that single oysters may be obtained by bending the hat. Similar to the French collectors, these are reusable. An attempt was made to coat the Chinese hats with a light layer of cement to improve their attraction potential for spat; however the coating did not stick well to the hats. Cement coated bamboo stakes were placed vertically in the mud bottom. Stakes were placed in metal fencing in a zig-zag manner on the mud flats. This design provided a large surface area that spat can potentially adhere. Upright cylinders of snow fencing were tested and presumed to work similarly to wooden stakes, but increase chances of entrapment of plankton and spat. Aluminum screening was placed inside wire fencing material along with bricks so they would not move. "Lobster-trap type" collectors provided potential for trapping spat while allowing for plankton movement throughout the material. Bamboo was put into wire fencing and shaped into a tube (Figure 10). This design provided a high level of surface area that spat can

attach. Cement-coated and uncoated bamboo stakes were placed on mud flats. Aluminum screening panels (2' x 4') were placed upright in the mudflats. These were expected to allow spat to adhere while allowing for plankton to flow readily through the screening material. Cut brush placed in a circular wire fence was tried as an inexpensive source of material for spat attachment and oyster growth. Dry brush was placed inside a tube of metal fencing and placed on the mudflat.

Results and Conclusions.

Cement coated twine did not work well. Very few spat attached to the twine and the twine seemed to disintegrate within a short period of time. Shell placed on snow fencing remained in place but became covered with sediment with no evidence of barnacle or spat attachment. This approach does not appear to work particularly well. Although it is relatively simple to put out the shell, it does not appear to attract spat perhaps because the shell is sitting low on the reef. High sediment load was probably due to high boat traffic in the area. Success may increase if shell is "piled up" to some extent; however, this would require a much larger amount of shell and a much greater effort for the commercial shellfisherman. After several months, the French collectors were collecting barnacles and spat. However, they did not appear to collect spat better than the more traditional coated stakes. French collectors, however, are reusable. More time for spat collection and oyster growth is needed to fully evaluate these collectors relative to wooden stakes. The Chinese hats collected oysters and they accumulated more on the bottom of the hats than the top. The investigators assume this was due to the ability of the bottom of the hats to capture plankton and spat as they create a small eddy. Cement coated pine stakes work well. Mr. Chandler observes that they do better when placed more closely together (i.e., about 6 inches apart). Reduced spacing between stakes likely traps more plankton and spat. The bamboo, snow fencing, aluminum screening, and lobster trap bamboo, were not deployed long enough to work before the final report was due, but appeared to hold promise. Some spat attached to bamboo or wooden the stakes. If this method proves successful, particularly the uncoated stakes, Mr. Chandler feels it will be the simplest and most cost-efficient approach. Dried cut brush did not appear to attract spat. Although a number of these methods show some immediate potential, most require testing over two or three years to provide definitive answers.

21. Determining Profitable Ways to Grow Premium Select Single Oysters

by Edgar T. Van Buren

Project Period: November 2007 – June 2008

Project Justification and Goal

Commercially available local oysters in South Carolina are typically intertidal oysters that grow in clusters. These oysters, while popular, for oyster roasts, are not the high quality, premium oysters that restaurants prefer. Recently, a South Carolina hatchery has been successful in producing single oyster seed that is available for experimentation in grow-out of large single oysters. The goal of this study is to determine if single seed oysters can be grown and survive in intertidal areas where cluster oysters are known to grow well.

Methods

Oysters were obtained from Island Fresh Seafood, Yonges Island, SC. 58,803 oysters were deployed on November 13, 2007 and 41,197 on November 24th. The first group of seed

was planted in small tributaries and marsh drains by hand scattering. No covering mesh was used. All of the selected sites were intertidal and in beds already producing wild stock singles and cluster oysters.

The second group was planted under mesh netting on established fringe oyster banks in larger rivers. Tenax 3/8" mesh netting was fastened by 60D pole barn nails with plastic washers fabricated from used milk and juice jugs approx one inch square. On larger plots, nailings were fastened in 4' rows to prevent the seed from washing to one edge under the netting by waves, tidal currents, or boat wakes.

Results and Conclusions

This project proved to be unsuccessful. Both uncovered and covered oyster seed suffered from high mortality, most likely by blue crabs. There were a few oysters remaining in the covered plots, but only a small quantity. It was clear that boat wakes and other waves moved oysters around under the mesh and probably affected survival. Future work should be limited to using fine mesh bags that have been successful with hard seed clams or in cages that keep out crab predators. It would also be wise to begin experiments at smaller scales and to try a greater diversity of techniques.

23. A History of the South Carolina Shrimping Industry By Ford Walpole (James Island Charter High School) and Dr. Victor Burrell (SCDNR, Retired)

Project Period: June 2007 – August 2009

Project Justification and Goal

The "modern" commercial shrimping industry has existed in South Carolina since the 1920s, beginning with single net, steam-powered vessels and evolving to steel-hulled vessels with two diesel engines and four nets. Along the way, noteworthy independent, colorful shrimp fishermen, many of them descendents of the earliest shrimpers, led the modernization of the industry as new technologies, political issues, and regulations were encountered. As techniques and conditions changed, numerous dramas were played out. In addition, the industry has had to deal with effects of severe winters, hurricanes, floods, diseases, and other natural issues.

Although some written accounts exist of the history of the shrimp industry, no well-researched, inclusive history has been written. The goal of this project is to provide a thorough and complete history of the shrimping industry of South Carolina.

Methods

This completed history will include information gathered through researching written reports, reading and organizing previously published materials, and gleaning information through numerous oral interviews through the use of tape recorders. All information will be collated and used to develop a written history to be published by DNR.

Results and Conclusions

The PIs researched the infancy of the industry, beginning with the African American and Native American influences. They traced the changes in technology, technique, and changes in growth of the industry. In addition, they have examined collateral impacts of the industry and the benefit of related industries. Documents examined included DNR documents, such as reports of landings/harvests and numbers of commercial licenses, as well as laws pertaining to

the fishery and the impact of such laws and the benefits to the natural resources and the industry itself. In many ways, some of the richest results have come from the oral interviews with members of the industry, including their stories, memories, perspectives, motivations, and personalities. Results will be compiled in the final product--the publication itself, which will be published subsequently by DNR. This book will be made available either free of charge or at a nominal fee to cover printing, binding, publication, and distribution costs.

Supplemental Study

(This supplemental study was carried out as a short-term experiment to quickly address questions that has arisen through the course of a cooperative research study. This work was critical in helping plan the larger study being conducted by commercial fishermen. Commercial fishermen were unwilling to spend the time to collect the needed data taken in this project. However, commercial fishermen provided consultation.)

1. Supplemental Examination of the Effectiveness of Modified Turtle Excluder Devices in Crab Pots Placed in Abbapoola Creek, South Carolina

By J. Powers, D. Whitaker, B. Gooch and N. West (SC DNR)

Project Period: April 2008- May 2009

Project Justification and Goal

Diamondback terrapin, *Malaclemys terrapin centrata*, are known to become trapped and killed in blue crab pots. Bishop (Estuaries, 1983) noted captures of turtles in crab pots in South Carolina with an average mortality rate of 10%. Commercial crabbers have volunteered information suggesting that the only time they see terrapin are during spring at about the time of "peeler season" which is typically late April and May in South Carolina. It is generally inferred that his time of year is when the terrapins emerge from hibernation and immediately begin foraging for their first meal. Crabbers insist that mortalities are minor because of the relatively cool water temperatures during that time of year.

The purpose of this project was to provide supplemental data to the commercial TED (Turtle Excluder Device) logbook study by testing the effectiveness of modified TEDs in Abbapoola Creek, a tributary of the Stono River in Charleston County. This project unlike other CRPs does not involve the contracting of commercial or recreational fishermen, although commercial crabbers were consulted during the project design phase. Instead, DNR biologists, boats and pots were exclusively used for this two year study. In the commercial TED logbook study standard 2"x6" TEDs were used in a portion of the crabber's pots throughout the entire season. In this study we utilized the small TED (1.75"x4.75") and a modified or "toothed" TED. Figure 1 shows the three different styles of TED utilized by the CRP. Small TEDs are currently required by law on recreational pots in Maryland and Delaware whereas standard 2x6 TEDs are required by law in New Jersey on commercial pots fished in bodies of water less than 150' across. The toothed TED was developed internally by DNR technicians and is a standard 2x6 TED with two bolts and four nuts placed on the top side of the TED. These two bolts reduce the height of the TED down to 1.75" but still leave the width at 6". Based on the preliminary results of the commercial TED logbook study, 36% more terrapins would be excluded using the small TED vs. the standard TED. Our hypothesis was that the toothed TED would be as effective at keeping out terrapins as the small TED but be able to catch crabs as well as the standard TED and hopefully as well as no TED at all.

Methods

Abbapoola Creek was selected as the study site because of its proximity (approximately 10 miles) to MRD headquarters at Ft. Johnson, the high number terrapins found there in the Spring and it is an area where blue crabs are found in sufficient numbers. Fifteen commercial crab pots were purchased for this study; 5 were given the small TEDs, 5 had the toothed TEDs

Figure 2: Three types of experimental TEDs. From top to bottom: Toothed, Small and Standard

inserted and the remaining 5 acted as the control with no TEDs. Five stations in the creek were selected and one of each type of pot was placed at each station. The pots were pulled every week day and left unbaited over the weekend. Pots were all baited with Atlantic menhaden, *Brevoortia tyrannus*, a typical bait used by commercial crabbers. The data recorded for each pot hauled were water temperature, water depth, TED type, number of legal crabs (by sex), number of subleagal crabs (by sex); number of terrapins, their sex, shell depth, plastron length, carapace length, carapace depth and any other bycatch species caught. After speaking with the veterinary staff at the South Carolina Aquarium a protocol was developed to try and resuscitate comatose terrapins that had been trapped under water for an extended period of time. According to the veterinary staff, terrapins that look as though they have drowned can be revived by draining the lungs, administering CPR and a shot of adrenaline. During the course of this study, this technique was tested on a few comatose terrapins, but none were successfully revived.

Results and Conclusions

Year 1 of the study ran from April 12th until June 4th, 2008. Year 2 from March 24th until May 8th, 2009. In 2008 twenty-four terrapins were caught, all in the non-TED pots. Fourteen of the captured terrapins were male, 9 female and one was unidentified. The mortality rate for the 24 terrapins was 46%. Figure 3 shows the shell depth frequency for all the terrapins caught in 2008. All terrapins to the right of the red line would have been excluded by the small and toothed excluders. All terrapins to the left of the red line would have been trapped regardless of if the pot had a TED or not.

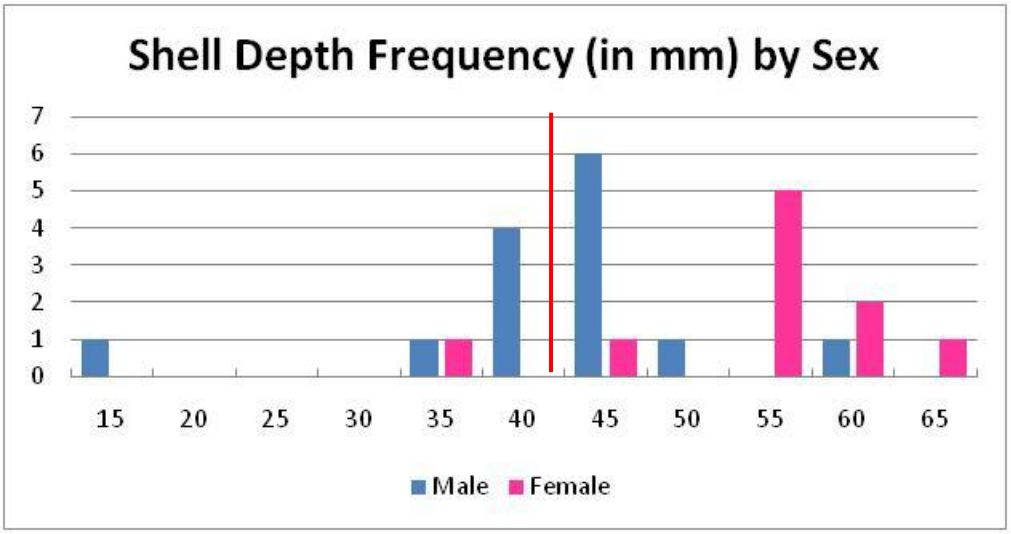


Figure 3: Shell Depth Frequency (in mm) by Sex in 2008. Red line indicates Small and Toothed TED height.

In 2009 sixty-two terrapin were captured, 51 in the control pots (Figure 4). The mortality rate in 2009 was 31%. Figure 5 shows the shell depth frequency by sex and Figure 6 by pot type. If we look at all 85 terrapins caught in Years 1 &2; 68% of the total (94% of the females and 53% of the males) would have been excluded by the 1.75" (45mm) TED height.

TED Type	Number Caught	%
No TED	51	82.26%
Toothed	8	12.90%
Small	3	4.84%

Figure 4: Number of Terrapins caught by pot type, 2009.

The research clearly indicates that the TEDs do accomplish their desired task of keeping terrapins out of crab pots, but what impact do they have on the overall crab catch? After all, if TEDs reduce the number of crabs per pot (CPUE) then it will be nearly impossible to get the commercial fisherman to voluntarily use the TEDs.

A recommendation for use of a turtle excluder was apparently first made by R. C. Wood in 1992 (Guillory and Prejean, Mar. Fish. Rev. 1998). Guillory and Prejean tested TEDs in 1986 in Louisiana and Belcher and Sheirling (UGA Mar. Extension, 2004) later tested them in Georgia. In both studies, TEDS were judged to be effective in reducing or eliminating terrapins while maintaining normal or improved catch rates of blue crab. The data collected for this study

reveals that small and toothed TEDs do catch less legal crabs (Figure 6 & 7) but, at least in the case of the toothed TED, the number lost was small. In 2008 and 2009, the number average of legal crabs excluded per pot are 0.24 and 0.23 respectively. Small TEDs caught slightly less legal crabs averaging 0.59 and 0.91 in 2008 and 2009 respectively.

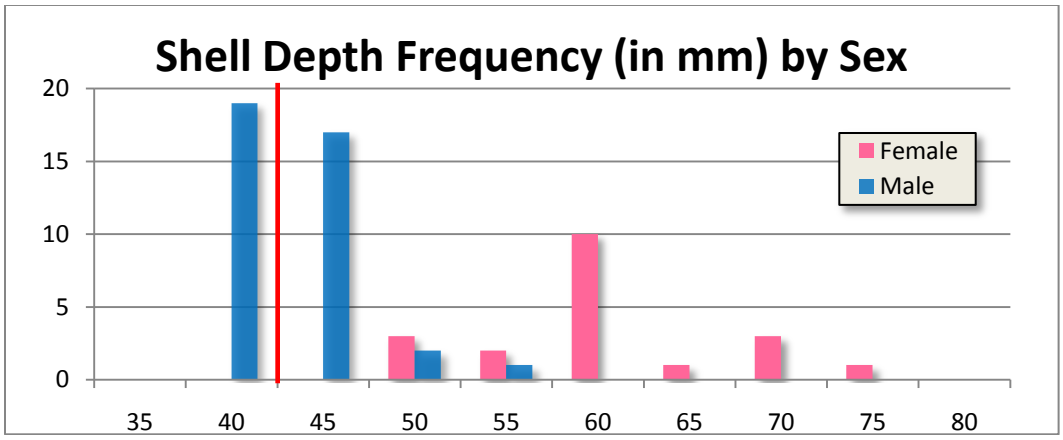


Figure 5: Shell Depth Frequency by Sex in 2009. Red line indicates Small and Toothed TED height.

Pot Type	total Crabs	total legal	total sublegal	CPUE per pot	CPUE Legal	CPUE Sublegal
N	600	380	220	4.84	3.07	1.77
S	486	323	163	3.89	2.48	1.30
T	507	348	159	4.12	2.83	1.29
Grand Total	***1593***	***1051***	***542***	***4.28***	***2.79***	***1.46***

Figure 6: CPUE table for Crabs caught by pot in 2008

Pot Type	total Crabs	total legal	total sublegal	CPUE per pot	sum CPUE Legal	CPUE Sublegal
N	737	441	296	6.14	3.68	2.47
S	620	329	291	5.23	2.77	2.46
T	654	404	250	5.57	3.45	2.12
Grand Total	***2011***	***1174***	***837***	***5.65***	***3.30***	***2.35***

Figure 7: CPUE table for Crabs caught by pot type in 2009

The goal of this study was to test alternate TED types in commercial crab pots. Based on the data presented the toothed TED has an advantage over the small TED, with regards to crab catch, and deserves further study. Future studies should involve collaboration with commercial crabbers similar to the cooperative TED logbook study also outlined in this final report. It would be interesting to see the CPUE of toothed TEDs verses standard 2x6 TEDs. TEDs should also be tested in peeler pots (pots with no escape vents and baited only with a large male). Working with the industry will also provide valuable socioeconomic data on whether 0.24 crabs per pot loss would be insignificant enough to get crabbers to voluntarily use TEDs at least during the spring peeler season when terrapins are most prevalent.

Program Evaluation and Recommendations

This program was initiated with a comprehensive needs assessment that ultimately produced 31 specific research needs and 22 were addressed in the cooperative research program, including 10 that were addressed by multiple studies.

We believe this program was a success on several levels. A main goal was to get fishermen and other citizens involved in the research and management of marine resources. To that end, 46 separate projects were undertaken – 24 as contracted projects and 22 as grant projects with assistance from Sea Grant. An estimated total of 500 participants, not including professional biological staff participated in this program. Of this number, 391 were recreational fishermen (including 303 pier fishermen) who participated in 11 separate projects. A total of 109 commercial fishermen participated in 23 projects. About 23 recreational divers participated in two offshore diving projects. An estimated 55 college students participated in three projects. 31 professional, ranging from DNR staff to college professors from three institutions participated in a wide range of studies. Including all participants, about 586 people participated in the overall program.

30 of the projects were related directly to commercial fisheries and fifteen projects were related to recreational fisheries. Four projects were considered environment in nature. (Due to some projects being both commercial and recreation, the sum does not equal 46). Fisheries for or biology of the following species or species groups were addressed: shrimp, blue crab, stone crab, octopus, sea birds, oysters, clams, and several finfish species including toad fish, cobia, dolphin, flounder, spot, weakfish, red drum, black sea bass, various sharks, offshore snapper/grouper species and others.

We found that all participants were pleased to participate in the program and most were highly energized to provide a good product. Many commented that it is a good idea to involve fishermen more in fisheries monitoring and research. It was clear that this work fostered improved communication and developed relationships with will endure long after the program has ended.

This being the first comprehensive program of its kind in South Carolina, it provided a number of conclusions about how future cooperative programs should be operated. We determined early on that it was important for biologists or technicians to conduct on-site visits with cooperators. These visits help DNR personnel better understand methods being used and staff often had advice to give the cooperator. We underestimated from the beginning the amount of time that would be required for professional staff to conduct on-site visits. In hindsight, it probably would have been better to have a couple more staff in order to be in the field more frequently. We also learned that it is often useful for the professional staff to manage the data sets, including quality control, data entry, proofing and analysis. Although a number of DNR staff volunteered to help mentor cooperators, providing some salary support for these people would have been helpful. It was also clear, that it should be mandatory that a professional biologist or scientists should work closely with each cooperator to develop data forms and data recording techniques. A professional should also be involved in data analysis and report preparation. Otherwise, funds should not be disbursed. Although one of the mandates was to put as much money into grants as possible and minimize DNR personnel costs, going too far in this respect can jeopardize the quality of the work. Fishermen, particularly commercial fishermen, are by their nature independent and being so, they prefer to adjust methods as they encounter problems, just as they might during normal fishing operations. Sometimes this can jeopardize scientific methods. Having fishermen understand exactly what questions are being

addressed, the need for consistent sampling and good record keeping would help make cooperative projects more valuable. Additionally, we believe that relatively frequent onboard visits by professional staff are valuable in keeping lines of communication open, adjusting procedures in a valid manner, and providing needed metadata for eventual data analysis and interpretation. Also, fishermen are typically not open to periodic progress-reporting meetings because they prefer to be working, but quarterly or at minimum semi-annual review meetings should be conducted.

This project was different from regional cooperative research programs, in that many relatively small projects were run instead of a few very expensive projects. This program also had a much higher diversity of types of projects and involved many more fishermen. South Carolina was particularly well suited for a project of this nature, given its diversity of fisheries and a relatively large contingent of scientists and biologists engaged in research and management who were available to assist.

We recommend that either state and/or federal funds be set aside annually to run various cooperative research projects. Not only do these projects improve communication between the fishing public and the managers, but they help the stakeholders feel more engaged in the process and the fishermen are more likely to "trust the data" and understand resultant management actions. Additionally, cooperative research projects can provide comprehensive data at a fraction of the cost that it would cost for state or federal scientist to take research vessels to sea to collect the same information.

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