SAVING THE SHALLOW WATER GAG GROUPER
IN THE SOUTH ATLANTIC:
AN INVESTIGATION OF FISHERY MANAGMENT

by

KerriLynn Miller

Date:________________

Approved:

____
Dr. Lisa Campbell, Advisor

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment and Earth Sciences of
Duke University

2007

ABSTRACT

With the continued depletion of the nation's fish stocks, this paper investigates fisheries management through the case study of the gag grouper in the South Atlantic. In accordance with the Magnuson Stevens Fishery Management Act, the South Atlantic Fishery Management Council has the responsibility to design regulations to prevent the gag grouper stock from becoming overfished. The 2006 summer Southeast Data, Assessment, and Review (SEDAR) analysis suggested the SAFMC wasn't adhering to their responsibility, allowing the gag to become potentially overfished. Given the management challenges of a data poor environment, complicated species biology, and a multispecies complex, the gag grouper case illustrates the problems associated with fishery management. A list of potential management options was compiled from a literature review of fishery management practices focusing on case studies of successful multispecies fisheries in similar situations. An analysis of the fishery highlighted three themes necessary for the sustainability of the gag grouper stock: better information on the status of the stock, a reduction in fishing mortality and bycatch, and protection of the spawning aggregations. Based on the literature review, personal communications, and the logistics of the gag grouper fishery, recommendations were devised and presented to the South Atlantic Fishery Management Council. The reauthorization of the Magnuson Act in January 2007 will hopefully provide the necessary impetus for the SAFMC to take actions to save the shallow water gag grouper in the South Atlantic.

ACKNOWLEDGMENTS

I would like to thank Elizabeth Fetherston for providing me with the opportunity to work with the Ocean Conservancy and for all her guidance on the project. Special gratitude is extended to Dr. Lisa Campbell for her advice throughout the various steps of the project. I would like to thank Louis Daniel, Vicki Cornish, and Kim Iverson for taking the time to talk with me to provide information on the gag grouper stock and bycatch strategies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Fishery management began in the United States in 1976 with the enactment of the Magnuson Fishery Conservation and Management Act. While it created a system of governance for management at both the national and regional scales, the pattern of regulation that developed has proven to be problematic. Management measures designed to reduce catch were based on the ease of implementation and not necessarily the degree of efficiency (Kalo, et al., 2002). Additionally, managers were faced with the dilemma of basing regulations on uncertain science vs. the economic and political will of the fishing communities. The longstanding perception that oceans represent the last frontier and fishing is an unalienable right presents a difficult hurdle for managers to overcome when determining regulations that limit a fisherman's harvest (Kalo, et al., 2002). Unfortunately, in the past 30 years fish stocks have declined and the management system has experienced little change lacking mechanisms to adjust.

This paper explores the fisheries management system in the United States through the case study of the gag grouper in a multispecies complex within the South Atlantic of the United States. The policy framing the gag grouper management is described along with various fishery management practices and examples of their uses. Specifics of the particular fishery in the South Atlantic are presented including the biology of the species, the management practices under the South Atlantic Fishery Management Council, and a characterization of the situation. Current problems in the fishery are pointed out and analyzed with comparisons to other multispecies fisheries around the world. Recommendations for current measures and steps for future consideration are presented to provide an approach for the gag grouper management in the South Atlantic.

METHODS

This project investigates various fishery management options and applies them to the gag grouper fishery in the South Atlantic, highlighting recommendations to alter the current fate of the stock. With the mismanagement of many of the nation's fish stocks, I chose to tackle a project with the Ocean Conservancy, a nonprofit organization who advocates wild, healthy oceans. In May 2006, I attended the Southeast Bycatch Workshop in St. Petersburg, FL. During this weeklong NOAA sponsored event, I gained background knowledge on bycatch, the problems with managing bycatch, and potential solutions. In addition to obtaining knowledge, I witnessed the difficulty of combining various stakeholder interests in managing fisheries. The gag grouper stock assessment took place during the 2006 summer in a series of workshops called the Southeast Data, Assessment, and Review (SEDAR). These assessment results caused alarm, and were the basis for this project. Using information from the SEDAR assessment, the South Atlantic Fishery Management Council, and research studies, a case study was developed that includes the biology, management, characterization of the fishery, and the current situation. From this information the gag grouper fishery was analyzed to determine areas that required focus for further action. A literature review of general fishery management practices was conducted to compile a range of potential options for future implementation. Specific case studies of multispecies management in New Zealand, Australia, British Columbia, and the Pacific Coast were then applied to the gag grouper case. In addition to the literature, ideas and the feasibility of the management practices were determined based on discussions with various stakeholders, including members of the SAFMC and NOAA. Based on the logistics of the fishery and the information gathered from the literature and personal accounts, recommendations for implementation were identified for the South Atlantic Fishery Management Council.

Chapter 1

BACKGROUND INFORMATION

1.1 Policy Framework

The establishment of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976 marked the beginning of the fishery management era in the United States. The MFCMA delineated a domestic boundary of control out to 200 nautical miles, delegated national standards for managing fisheries, and developed a complex system of management consisting of two tiers of decision making (Cicin-Sain and Knecht, 2000). Eight regional councils were designated to establish fishery management plans (FMPs) and regulations for the stocks in their jurisdiction. Within the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the National Marine Fisheries Service (NMFS) was created to oversee the regional councils. While the Secretary of Commerce possesses the overall legal authority for implementing the MFMCA, NMFS and its regional offices control the approval of the regional councils' fishery management actions that are undertaken in the Exclusive Economic Zone (EEZ) (Cicin-Sain and Knecht, 2000; Kalo, et al., 2002). Through the enactment of the MFCMA, a vertical structure of management for the fisheries sector was established starting at the national level and narrowing to the states.

Despite this new regional framework, continued depletion of fish stocks caught environmental groups' attentions leading to the amendment of the MFCMA in 1996 to the Sustainable Fisheries Act (Cicin-Sain and Knecht, 2000). The amendment focused on preventing overfishing, rebuilding depleted stocks, reducing bycatch, minimizing the mortality of unavoidable bycatch, and conserving essential fish habitat (Cicin-Sain and Knecht, 2000). The management rules, designated through the National Standards, declared the MFCMA a sustainable use act emphasizing the desire to benefit the nation.

According to National Standard One, FMPs are designed to attain the optimum yield (OY), providing the greatest benefit to the nation, economically and recreationally (NS1). By specifying the average catch that can be taken, overfishing must be prevented, while also balancing the nation's welfare (NS1). A clear and measurable definition of overfishing is required in each FMP, along with how it was determined and the relationship with the stock's reproductive potential (FAO Fisheries Dept.; Restrepo, et al., 1998). To assist the councils in managing the stocks, thresholds were designed so that the maximum sustainable yield is not exceeded, keeping the stock at safe levels (Southeast Fisheries Science Center, 1999; Restrepo, et al., 1998). The Maximum Fishing Mortality Threshold (MFMT) is a single number or function of spawning biomass which defines overfishing; exceeding this value for over a year constitutes overfishing (Restrepo, et al., 1998). The Minimum Stock Size Threshold (MSST), also in terms of spawning stock biomass, is defined as which ever value is greater, ½ the MSY stock size or the minimum stock size at which rebuilding to the MSY level would be expected (Restrepo, et al., 1998). The stock is considered overfished when it falls below MSST. A stock approaches an overfished condition when the Secretary of Commerce estimates the stock will be overfished within 2 years based on current trends (Kalo, et al., 2002). National Standard One provides clear definitions for the boundaries the councils must use in their management decisions.

National Standard Nine introduced the need to minimize bycatch and bycatch related mortality, but this increased the difficulty in assessing and managing the stocks (NS 9). As stated in National Standard Nine, bycatch is defined as "fish that are harvested in a fishery, but are not sold or kept for personal use, and includes economic discards and regulatory discards." The definition of bycatch was expanded in 2004 by NMFS to include "discarded catch of any living marine resource due to a direct encounter with fishing gear" (Benaka and Dobrzynski, 2004, 7). Both National Standards One and Nine remain central to the regional council's duty to sustainably manage their fish stocks.

Each council, under the authority of NMFS, has the responsibility to create a FMP for every stock under their jurisdiction in accordance with the National Standards. The FMP must contain: an assessment of the stock, social and economic implications, impacts on the habitat, occurrences of bycatch, allocations between different resource users, and regulations for conservation of the stock (Witherell, 2003). Once the initial FMP has been approved, each council amends the plans, as necessary, according to the status of the stocks regulated under that management plan (Kalo et al., 2002). If a stock is considered overfished, the responsible council must submit a FMP amendment that details the regulations for ending overfishing and rebuilding the stock to MSY (Kalo, et al., 2002). The council has one year to submit the amendment and approximately ten years to rebuild the stock (depending on the biology of the fish), but if the council exceeds that timeframe, the Secretary of Commerce must then develop regulations within nine months (Kalo, et al., 2002). The federal district courts have exclusive jurisdiction over any controversy that may arise from the provisions under the MFMCA (Kalo, et al., 2002). The integration of the political sectors, federal and local, frames the management through the designation of FMPs.

The structure of each council reflects the expertise of the states concerning conservation and management, integrating the policy across disciplines (Okey, 2003). Members of the council must be knowledgeable regarding the fishery resource and geographic area as a result of their occupation, scientific expertise, or other experience (Kalo, et al., 2002). Appointments to the council are made by the state governors and are to be fair and balanced (Okey, 2003). Voting members include: fishery state officials, the regional director of NMFS, and members of the public representing the fishing industry (Cicin-Sain and Knecht, 2000). Federal agency representatives from the Fish and Wildlife, the Coast Guard, and the Department of the State constitute the non-voting members of the council (Cicin-Sain and Knecht, 2000). The council design includes a balance from the fisheries sector across states under the premise that participation of the fishing industries in management is crucial for successful allocation, conservation, and compliance (Okey, 2003). In addition to the members of the council, each council has their own staff and advisory panels. Meetings are held throughout the geographic jurisdiction of the Council, allowing interested people to attend and make comments regarding the current fishery management plans and amendments (Kalo, et al., 2002). By incorporating stakeholder interests into the management process, the fishery goals are better achieved.

Science and policy are not equivalent interfaces; management requires the integration of both disciplines. Accordingly, the Magnuson Act designated scientific advisory panels to receive and analyze the best available science to provide the council with recommendations for further regulations (Kalo, et al., 2002). The absence of adequate scientific information is no excuse for postponing management; actions must utilize the best scientific information available and use caution when faced with uncertainty (Restrepo, et al., 1998). Initiating the precautionary approach requires that the management target be defined below the overfishing/overfished limit, allowing uncertainty and other management objectives to be taken into consideration (Restrepo, et al., 1998). The greater the uncertainty surrounding the status of the stock, the more caution should be used when deciding on target catch levels (Restrepo, et al., 1998). Science and statistical committees are responsible for providing their fishery management councils with advice on levels of mortality – or allowable biological catch – that a stock can sustain, while still conforming to the goals and mandates in the Sustainable Fisheries Act.

2.2 An Overview of Fishery Management Strategies

Data Collection

In order to accurately manage and monitor fish stocks, comprehensive data that is representative of the entire stock must be taken – preferably both fishery-independent and fishery-dependent in nature. Fishery-dependent data are collected from the fishermen themselves which include logbooks, landing reports, and interviews. Logbooks are a mandatory form of self-reporting that provide information on type of gear used, date, time of day, position of fishing activity, weather conditions, fishing characteristics of the deployment of gear, and catch data (NOAA, 2004). Fishermen tend to have incentive to underreport fishing effort, access, or bycatch resulting in inaccuracies of the logbook's reporting (NOAA, 2004). Recreational fishing data is collected via the Marine Recreational Fisheries Statistics Survey (MRFSS). With the emphasis on recreational catch and effort, MRFSS conducts two independent surveys: a telephone survey of coastal households and an intercept survey of anglers at fishing access sites (NOAA, 2004). The telephone survey provides recreational fishing effort, while the intercept survey supplies information regarding species identity, number, weights, and lengths (NOAA, 2004). Since the interviewer fails to witness catches, discard information is less reliable than landings. Fishery-independent research surveys aid in the characterization of species, particularly those of concern. Fishery-independent data are collected using standardized sampling gear, with multiple samples taken, and distributed over the range of the stock (NOAA, 2004). The data include information on the distribution, abundance, and biology of the species being assessed (NOAA, 2004). Fishery-independent data have the following limitations: smaller gear than commercial vessels, predetermined sampling areas, shorter time durations, and seasonal limitations (NOAA, 2004). Both forms of data collection provide necessary information for fisheries management with the combination ensuring a more informed decision making process.

Observer Coverage

To improve the reliability of fishery-dependent data, trained biologists board fishing vessels to collect data on the activities regarding catch and discards. Observers additionally collect information on gear used, vessel type and power, fishing techniques, effort, gear characteristics, environmental conditions, and economic information (NOAA, 2004). Observers provide a reliable source of information, but funding limitations, safety considerations, and logistical constraints make monitoring all fishing effort impossible (NOAA, 2004). To combat some of these limitations, Babcock et al. (2003) recommended that only 20% of the fishery receive observer coverage. Since smaller vessels can not safely accommodate an observer, the sample size of monitored vessels becomes limited. Additionally, the presence of an observer on board has the potential to alter the fishing behavior, which results in a bias known as the observer effect (NOAA, 2004). Training, salaries, travel costs, gear, and insurance make the cost of observer coverage very high ($350-$2,000/day), which reduces the amount of observer coverage (NOAA, 2004). Even though the benefits of observer coverage prove substantial, logistical constraints limit the mandatory implementation of full coverage on all fishing vessels.

Alternative methods have been designed to combat the logistical constraints of using human observers on board fishing vessels. When vessel size makes the use of an observer impossible, an alternative platform can be used. The alternative platforms of the smaller vessels allow observers to monitor the fishing activity from a better view slightly in front of the fishing vessel (NOAA, 2004). While providing an opportunity to monitor smaller fishing vessels, alternative platforms do entail a higher cost of gaining access to a boat and captain (NOAA, 2004). Tork (2004) argued that the benefits received from an alternative platform actually make its use cheaper than regular observers. Alternative platforms result in less time looking for active fishing vessels, less time arranging trips, and less dependency on fishing captains (Tork, 2004). Alternative platforms also allow observers to monitor more than one fishing vessel in one day (NOAA, 2004). Vessels can no longer refuse coverage due to safety concerns of smaller vessels, thus providing a larger sample size for observation (Tork, 2004). Alternative platforms, therefore, provide a more efficient characterization of the fishery by supplying a clearer picture in a shorter amount of time (Tork, 2004).

The use of observer coverage, as a fishery management tool, is expanding with the growing acceptance of its success rate. In Western Alaska observers supply an independent source of quota accountability through the monitoring of all catch/ discards (Bibb, 2002). Since all activity must be witnessed, the vessels require two observers at all times (Bibb, 2002). Monetary constraints tend to dictate the amount of coverage available, leading most programs to support less that 100% coverage (Babcock, et al., 2003). In limited coverage situations, observers tend to be placed on vessels that volunteer, but they may result in an unrepresentative sample of the fishery (Babcock, et al., 2003). Potential biases can be avoided through the continued monitoring of observed and unobserved vessel catches (Babcock, et al., 2003). The Northern Shrimp Fishery off Atlantic Canada illustrates the impracticality of 100% observer coverage, but the usefulness of the realistic coverage of 10% (Kulka, et al., 2004). Although limited, this coverage verifies logbook catch data, catch-at-age compositions, and monitors bycatch (Kulka, et al., 2004). A comparison between the monitored and unmonitored vessel logbooks shows the observed fishing vessels are representative of the whole fishery, spatially and temporally, and that the discarding behavior remains consistent (Kulka, et al., 2004). The observer data further assists future management by providing a standard for which the rest of the fleet can be monitored against, in essence a "conservation enforcement tool" (Kulka, et al., 2004). Thus, observer coverage, even as small as 10%, provides a tool for verifying catch and the fishery standards as a whole, thereby improving the quality of the data and future management.

Electronic Monitoring Systems provide observational capabilities of human observers but remove the human component. The tamper-proof video cameras collect information on the time and area of fishing, compliance with requirements, and the species caught and/or discarded (NOAA, 2004). Costs include equipment, cameras and computer with a removable hard drive, installation, and analysis of video (NOAA, 2004). While initial implementation proves costly, EM is seen as a lower cost option with the ability to monitor a larger proportion of the fleet (McElderry, et al., 2003). The premise for EM was to create automated monitoring equipment that provides "accurate, timely, and verifiable fisheries data comparable to at-sea observer monitoring" (McElderry, et al., 2003, 6). Fishermen believe camera use is intrusive, displaying opposition to the implementation of EM (McElderry, et al., 2003). In the British Columbia longline halibut fishery, EM catch estimates agreed within 2% of the observers' data (McElderry, et al., 2003). Additionally, EM was shown to reliably distinguish catch species making it a promising tool for monitoring (McElderry, et al., 2003). EM provides another alternative method for observing fishing activity when vessels are too small to permit an observer on board.

Cooperative research and Self-monitoring

Cooperative research enhances communication and relationships among stakeholders, thereby improving the overarching fisheries management process. Previous failures to communicate have left the various sectors in tense relationships, creating a low morale that ultimately impedes the management process (Kaplan and McCay, 2004). Cooperative research involves the use of active fishing vessels and crew by onboard researchers or side-by- side trials from government research vessels (Kaplan and McCay, 2004). These partnerships unite and engage fishermen and scientists to actively address information needs for fishery management (Conway and Pomeroy, 2006). Not only are these efforts a cost effective form of collecting data, but they combine the expertise of the fishermen, scientist, and government, which can foster understanding and trust among the stakeholders (Conway and Pomeroy, 2006). The research process undergoes greater scrutiny and provides an increased transparency helping to ensure the results are the “best available science” (Kaplan and McCay, 2004).

Cooperative research between the fisheries management agencies and the commercial fisher organizations indirectly became an outcome of the New Zealand right-based fisheries management framework (Harte, 2001). Cooperation occurred for two reasons: incentives were created for commercial fishermen to take responsibility for the research and governance structures ensured the transparency and integrity of industry-led research (Harte, 2001). Harte (2001) emphasized that the knowledge held by fishermen and the way in which they apply their knowledge are key components of sustainable fisheries management. Collaborative research is essentially about “creating opportunities to gain knowledge, articulate values, express culture, and establish communities based on a shared understanding of fisheries” (Harte, 2001, 167). Ultimately, fishery problems will only find a solution from the collective actions of fishermen on the water who are willing to "listen, learn, and change", working together with the scientist and government towards the goal of fishery management (Harte, 2001, 167).

If limited funding prevents the use of observers or researchers, self-monitoring, a form of cooperative research, can be established to supply the desired data. Self-monitoring involves the skipper or crew monitoring the catch by taking small units of effort across a broad range (Starr). Self-monitoring takes advantage of fishermen actively on the water to aid in the collection of biological sampling. Since many small samples are taken, they occur at a more frequent rate allowing the accumulation of a larger subset of information, thereby enhancing the confidence in the reliability of the information. Self-monitoring proves to be the most cost effective method of data collection. By enlisting vessels already on the water who are most familiar with the fishery, self-monitoring is more efficient and effective than 100% observer coverage (Harte, 2001).

The New Zealand Chatham River hoki fishery illustrates an example of self-monitoring and industry-led research. The sampling program was designed to improve the characterization of the catch, verifying that the resource is undergoing proper assessment and management (Harte, 2001). All of the vessels currently in the fishery partake in the research to measure and sex the fish. Vessel crew training is gained through a one day certification course by SeaFIC which meets the New Zealand Qualification Authority standards (Starr; Harte, 2001). Through the crew's sampling, a large subset of information has been gathered which is magnitudes larger than any previous study (Harte, 2001). Upon reaching the shore, the data undergo careful scrutiny to ensure quality requirements are being met. The larger more robust data increases the confidence in the results, leading to better management (Harte, 2001). Potential downsides of the program have been a lack of motivation from the fishermen, bias of the data, and a real cost to fishermen through time spent collecting samples (Starr). With increased participation in self-monitoring, the methodology can be enhanced supplying a greater quality and quantity of knowledge to the fisheries management process.

Indirect measures

Indirect measures regulate the input controls of a fishery which display benefits but fail to adequately maintain the sustainability of the fishery on their own. Included within the category of input controls are gear restrictions, size limitations, and bag limits. Gear restrictions prevent the use of undesirable gear types, whether for habitat considerations or species bycatch. Size limitations establish a minimum size that can be harvested with the goal of allowing fish to reach maturity prior to being harvested. Slot limits provide an additional size limitation by constraining the upper boundary of fish that can be caught. Recreational harvest regulations tend to implement bag limits, or a specified daily harvest. While input controls present an affordable management option to implement, the reliance solely on input controls has failed to ensure biological sustainability of commercial stocks (Gibbs, 2007). Without a measuring stick, these methods fail to illustrate the response of a stock, requiring large adjustments when a change is necessary (Southeast Fisheries Science Center, 1999). Apostolaki, et al. (2006) further demonstrated a need for additional management through their modeling of various strategies. They discovered that for slow-growing, late maturing species, size limits were less effective than catch quotas in achieving stock recovery. While useful management options, input controls (indirect measures) fail to provide sufficient outcomes, requiring the addition of other management practices.

Quotas

Quotas, used as an output control, regulate fisheries by setting a limit on the amount of harvest in a fishery. Once the quota has been reached, that particular fishery is shut down. The fishing season becomes shortened as more fishermen enter and technology advances, so that each fisherman attempts to catch as much of the quota as quickly as possible (Kalo, et al., 2002; Meister). This “race for fish” results in potential overages along with a high economic cost and fishing hazards. Additionally, there exists the problem of discards that may not be included in the assessment (Punt, et al., 2006). Discarding of target species primarily occurs as (a) size-based discarding of small, unmarketable fish (high-grading) and (b) quota-related discarding where landings are constrained by the available quota or market (Punt, et al., 2006). In addition to discarding target species, bycatch also occurs due to the temporal and spatial overlap of species (Diamond, 2004). Quotas, while beneficial in capping the harvest, also jeopardize the sustainability of the fishery (Grafton, et al., 2006).

Limited entry

Individual Transferable Quotas (ITQs) combine quota management with a limited entry system by dividing up the right to harvest and allocating the quota to certain user groups. While permits and licenses change the property structure of a fishery from open access to common property by limiting the number of vessels allowed to participate in a fishery, ITQs further alter the property rights of the fishery dividing the common property into individual shares (Meister). Hilborn et al. (2004) notes that inappropriate incentives have been one of the major causes of unsustainable harvests. ITQs have been shown to provide the necessary incentive through a secure harvest and territorial rights to fish (Grafton, et al., 2006). By removing the race to fish, ITQs allow fishermen to refocus their efforts to maximize revenues while minimizing harvest costs (Fina, 2005). With an extended season, fishermen have the ability to choose when and where to fish, allowing them to avoid treacherous weather and areas of high bycatch potential (Branch, et al., 2006). By granting security of access to the fisheries resource, ITQs in New

Zealand have given fishermen the ability to improve the quality of their product making them more competitive in the overseas market (Bess, 2005). Other ITQ benefits include: increased profit, increased economic rent, reduced gear loss, and greater economic stability (Branch, et al., 2006; Kearney, 2001). By providing a sense of entitlement to fishermen, ITQs supply the potential benefit of incentives for fishermen to protect their resource, leading to sustainable fishing practices.

Even though the use of ITQs is becoming more prevalent, problems still persist which require each fishery to determine their own approach to management. Social concerns regarding the assignment of the quota, the change in balance of power, and loss of employment represent potential contention from the stakeholders (Branch, et al., 2006). The largest issue surrounding ITQ implementation revolves around the problem of discarding. High grading is of particular concern when there are low costs of discarding and a large price differential between classes of fish (Branch, et al., 2006). Multispecies fisheries present an additional constraint since a fisherman's catch will inevitably fail to match the quota catch rights (Sanchirico, et al., 2006). Through discarding, fishermen can continue to fish for species in which the quota has yet to be filled (Branch, et al., 2006). The ability to transfer, lease, or sell quota provides an incentive for fishermen to retain their catch. Additional mechanisms include: rollover provisions, carrying the quota forward; deemed value payments, a fee for going over the quota; and allowable discards (Sanchirico, et al., 2006). In the British Columbia groundfish trawl fishery, observers record all discards and count the fish against the fishermen's quota. Fishermen have an incentive to catch less fish and communicate areas to avoid, thereby ensuring their harvest is profitable (Grafton, et al., 2006). The New Zealand fisheries use the deemed value method, charging a fee that is lower than the ex-vessel prices, for any quota overage (Holland and Herrera, 2006). Due to the catch-balancing flexibility design, fishermen gain an incentive to land the bycatch, but at the same time avoid catching fish for which they lack sufficient quota (Holland and Herrera, 2006). The Alaska groundfish fishery establishes bycatch quotas that close the fishery when those quotas are filled (Diamond, 2004). Through the application of various forms of ITQs, multispecies fisheries around the world are determining their own unique form of combating potential problems.

Closures

Marine protected areas provide a management tool that when faced with uncertainty may provide a range of benefits. By enclosing a particular area, the habitat is protected from fishing gear, bycatch of non-targeted species is prevented, and a refuge for a broad range of species is provided (Stefansson and Rosenber, 2005). MPAs not only provide a range of benefits for the overall biodiversity of the area, but they present many benefits for fisheries themselves. Through the preservation of a designated area, MPAs are capable of protecting specific life stages and critical functions that will assist in stock management (Australian Government). MPAs also contribute a supply of larvae to surrounding areas and are responsible for the spillover of exploited species beyond the boundaries of the MPA designation (Australian Government). The increased yield can be obtained by fish exiting the reserve and larger fish producing more eggs which have the potential to spill over, but this increase can only be seen in fisheries where heavy fishing mortality has substantially reduced recruitment (Hilborn, et al., 2004). Fish with an intermediate rate of movement are suggested to experience the largest gains from MPA implementation (Hillborn, et al., 2006). MPAs have the potential to provide a buffer when faced with management uncertainty, but the lack of biological knowledge can still lead to uncertainty. Seasonal closures have been shown to be as, if not more, effective in the protection of juveniles when faced with uncertainty (Hilborn, et al., 2004). MPAs provide a cost effective form of management for multispecies fisheries by supplying protection to the entire complex, not just one particular species (Hilborn, et al., 2004). By supplying fishery stability, MPAs provide an opportunity to better understand the impacts and options for further management along with gaining greater knowledge on the ecological systems (Hilborn, et al., 2004).

While MPAs have the potential to provide benefits to the fishery, their use must be done on a case-by-case basis taking the spatial structure of impacted fisheries, ecosystem, and human communities into consideration (Hilborn, et al. 2004). Problems associated with fisheries management stem from the initial management design and tools resulting in improper incentives and institutional structures (Hilborn, et al. 2004). MPAs present a tool to specify the location of fishing; they can not provide a fix for incentives or institutional related problems (Hilborn, et al. 2004). Without the proper incentive to limit their catch, fishermen fail to realize the full impact of their harvesting practices leading to unsustainable conditions (Grafton, et al., 2006). If designed improperly, MPAs could even be detrimental to the fishery. Other problems include a spatial shift in fishing, hardships on the community through the creation of a larger cost and increased risk, and other options may be available (Hillborn, et al., 2004). In addition, MPAs pose higher costs to fishermen and can not guarantee the proper amount of fish are being harvested (Kalo, et al., 2002). As a result, MPAs should be evaluated as an alternative fisheries management tool and used where appropriate, but should be considered an element in a larger package of management tools (Hillborn, et al., 2004).

Chapter 2

THE GAG GROUPER CASE STUDY

2.1 Biology of Gag Grouper

Gag reside in the shallow water of the South Atlantic ranging from North Carolina to the Yucatan Peninsula and the Gulf of Mexico (SAFMC, 2003). Habitat preferences include: inshore reefs, shelf-breaks, and vertical structures such as seagrass beds, oyster reefs, wrecks, pilings, and dredged canals (SAFMC, 2003; Sedberry). Gag share the reef habitat with a number of other fish species that compose the multispecies snapper grouper complex.

Habitat selection corresponds with the gag life stages, ranging from larvae to adult (Fig. 1). Gag transition from the initial offshore residence to the higher salinity waters of estuaries as larvae (MARMAP sampling; Heppell, et al., 2006). The spawning process releases eggs into the plankton where they remain for approximately 43 days (MARMAP sampling; Heppell, et al., 2006). With the assistance of flood tides, the postlarvae recruits settle in the oyster beds and shells within high salinity waters that encompass the nursery habitat (MARMAP sampling). These estuarine-dependent juveniles remain in the nursery until the cooler temperatures of September and October signal a shift in habitat from the seagrass beds to the nearshore reefs (SAFMC, 2003; Heppell, et al., 2006). With increasing age gag move further offshore to deeper waters (SAFMC, 2003; Heppell, et al., 2006).

The gag grouper life history characteristics present a number of challenges to management and each aspect must be fully understood to adequately manage the species. Gag are slow-growing, late maturing, and long-lived (26 years) (Sedberry, SAFMC, 2003). In addition to their long lifespan, gag can reach sizes of 58 in. and 81 lbs. (SAFMC, 2003).While sexual maturity begins at the size of 20.2 in., it takes six years for the entire year-class to reach maturity (SAFMC, 2003; Sedberry). Only 50% of the age class is mature at the size of 24.7 in. (SAFMC, 2003), but by 30 in. the entire age class has reached maturity (McGovern, et al., 1998). Due to their life history characteristics, gag have a low resistance to overfishing with a minimum population doubling time ranging from 4.5-14 years (SAFMC, 2003).

Gag grouper are protogynous hermaphrodites, which presents an additional management dilemma relating to sex ratios. Initially, all gag are female (up to at least 34.7 in.) but by the size of 48 in., gag have transitioned into male (SAFMC, 2003). Even though females are capable of transitioning as early as age 6, the presence of large females in the population suggests transitioning is dependent on both biological and social cues (McGovern, et al., 1998; Heppell, et al., 2006). The hermaphroditic feature results in a naturally skewed sex ratio of more females-to-males in the population, with a natural population ratio of 5:1 (Koenig, et al.). Due to their large size and aggressive feeding behavior, males are caught more frequently, which further skews the sex ratio (Sedberry). In recent decades female-to-male sex ratios have responded to increased fishing pressure by changing from 8:1 to 30:1, leading to less genetic diversity in the stock (Chapman, et al., 1999).

The spawning period for gag not only results in increases in stock abundance, but is thought to provide important social cues for females to transition into males, improving the sex ratio. Gag grouper spawning occurs from the months of December to May, with a peak in March and April (SAFMC, 2003). The spawning season consists of 114 days with roughly 1 spawn every 2.5 days (38 spawns per season) (SEDAR DW, 2006). The gag grouper form pre-spawning aggregations in shallower water (66ft), moving to the shelf-edge reefs to spawn (164-328 ft) (Sedberry). These aggregations may include fish from great distances, since gag migrate to spawning locations (Koenig, et al.). Males tend to spend the entire year along the shelf edge while females migrate to the location only during spawning periods (Heppell, et al., 2006). Normally solitary creatures, the aggregations provide a mechanism for females to evaluate the current sex ratio and note whether a sex change would be advantageous (Koenig, et al.). Catch ratios show an increase in males and transitionals caught following the spawning season, suggesting the transition occurs after spawning (Koenig, et al.). A thorough understanding of the biology and life history of gag provides a conceptual framework for designing protective management that will ensure the reproductive success of the species (Chapman, et al., 1999).

2.2 Management in the South Atlantic

With a jurisdiction ranging from North Carolina to the eastern coast of Florida, the South Atlantic Fishery Management Council applies its motto, "to conserve and manage," to 98 species (SAFMC, snapper grouper complex) (Fig. 2). Of these 98 species, 73 are managed as one multispecies unit under the Snapper Grouper Fishery Management Plan. The snapper grouper complex poses the greatest challenge to management due to the nature of mixed species, the species' life histories, and the lack of scientific information (SAFMC, snapper grouper complex). The initial regulations established for this complex included the input controls of size, bag, and gear restrictions. As indirect measures, these regulations generally fail to keep within some scientifically-set limit, and set no hard and fast 'backstop' when limits have been exceeded. Additionally, indirect management measures make yearly adjustments to fishing mortality all but impossible (Southeast Fisheries Science Center). Unlike so-called "hard" quotas and other direct measures, the fishery is allowed to continue even when management targets, limits, and thresholds have been crossed. Through the FMP amendment process, the Council adopted further management mechanisms, but none have sufficiently limited harvest to prevent overfishing and stock depletion.

To obtain information on stock status and health, the SAFMC began periodic assessments for each fish stock in a series of workshops called the Southeast Data, Assessment, and Review (SEDAR). Combining the South Atlantic, Gulf of Mexico, and the Caribbean councils, SEDAR provides steps towards integrating science into management along with integration across regions where species co-occur (Daniel, 2005). Each of the Councils contribute their own Advisory Panel composed of scientists from their scientific and statistical committee, individuals from their advisory panels, and individuals from the environmental community in the SEDAR workshops (Daniel, 2005).

The first step in the stock assessment process occurs when participants at the data workshop gather all the available science regarding fishery data and life history information, which is then analyzed in models during the subsequent assessment workshop. Contracted scientists from the Center for Independent Experts conduct an independent peer review of the stock assessment during the review workshop – the final stage of the SEDAR process (Daniel, 2005). The final assessment is presented to the Council by the Scientific and Statistical Committee after they have ensured the relevance and scientific credibility of the report (Daniel, 2005).

Having completed a SEDAR assessment in the summer of 2006, gag grouper management has gained attention. Current management has been inadequate to prevent unsustainable fishing levels and stock depletion (Table 1). According to the Fishery Management Plan, landed groupers must have their head and fins intact and the gag must be at least 24 inches in length (SAFMC, Gag regulations). Vertical hook-and-line gear, both handheld and bandit, are permitted gear choices along with spearfishing, without rebreathers, and powerheads (SAFMC, Gag regulations). Information on gag grouper landings, areas fished, and gear used, are gathered from commercial logbooks and recreational surveys completed by the fishermen, so data can be obtained on the status of the stock (SEDAR, 2006).

Gag grouper regulations are further specified according to the fishing sector. A bag limit of 5 snapper/groupers per day, only 2 of which can be gag, regulates the recreational sector (SAFMC, Gag regulations). A permit is required to commercially fish in the South Atlantic. Amendment 8 established the permitting system granting transferable permits to those vessels that landed 1,000 lbs of gag in the previous years. Vessels failing to qualify for a transferable permit received a nontransferable permit with a 225lb trip limit. Vessels wishing to enter the fishery must obtain two snapper grouper transferable permits and exchange them for one (2 for 1), thus, reducing the number of vessels. Amendment 9 designated a fishing closure for gag during the peak spawning period of March and April. No sale or purchase of gag is permitted and commercial fishermen are restricted to the recreational bag limits during this period. The SAFMC established indirect measures to manage gag suggesting a need for further action.

2.3 Characterization of the Fishery

The characterization of the gag grouper fishery proves difficult to specify due to the intertwining nature of the snapper grouper complex. While management continues to be imposed under one FMP, in recent amendments the species have been distributed into more manageable sectors. As a shallow water species, the gag grouper belongs to the shallow water grouper subunit. Within this subunit, the most information is known regarding the status of the gag stock making it a potential indicator for the status of the other lesser known stocks. The red grouper, scamp, and black grouper are among the most frequently landed fish with the gag grouper composing 95% of the shallow water grouper subunit landings (SAFMC, 2005). While specifics for the gag grouper stock characterization are uncertain, the available information illustrates the nature of a multispecies fishery and the difficulties in managing a single species within the larger context.

The combination of nonselective gear and a multispecies complex has led to gag being caught even when not targeted. Amendment 13C (2006) focuses on vermillion snapper, golden tilefish, black sea bass, and snowy grouper, but catch compositions show gag is actually one of the most commonly landed species during these trips. Specifically, gag represented 13, 16, and 22 % of the trips where vermillion snapper, red porgy, and black sea bass were harvested, respectively (SAFMC, 2006) (Figs.3-5). As seen from these figures, gag actually dominated the catches of black sea bass and to a lesser extent red porgy. The catch characterization demonstrates that even if regulations restrict the harvest of gag, shifting the target, gag will still be caught (SAFMC, 2006).

The nonselective nature of the hook-and-line snapper grouper gear leads to an inability to determine the number of the gag grouper fishermen. Even though the commercial sector requires transferable permits, an exact count of gag fishermen is impossible to achieve. The transferable permits only provide an estimate of the number of fishermen, since they are a broad snapper grouper permit. According to the SAFMC, a total of 637 snapper grouper permits existed in 2006 (Table 2, Fig. 6). Of these 637 permit holders, only 56 were strictly fishing snapper grouper, the remaining 581 permit holders also held permits for other species (Table 3, Fig. 7). With a general snapper grouper permit and multiple other permits, fishermen are able to switch targets to obtain the greatest catch from their nonselective hook-and-line gear. Gag grouper trips are defined as: “handline trips where four or fewer lines were fished, with three or fewer hooks per line, the days at sea was eight or less, and the number of crew members was four or less” (SEDAR, 2006, II-41). Boats using the hook-and-line gear tend to be the shortest vessels, with less powerful engines, small fuel capabilities, and a small holding box for fish and ice (SAFMC, 2006). Boats typically have 2-4 bandit reels attached and average 30-50 feet (SAFMC, 2006) (Table 4). The timing of the catch continues to be dependent on the personal preferences of the fishermen themselves who fish day/night and year round (SAFMC, 2006). The only variation in their routine is during the seasonal gag closure and periods of inclement weather (SAFMC, 2006). The majority of commercial fishermen who possess a snapper grouper permit are found within the waters of Florida and North Carolina (Table 2-3).

With no required licensing system for recreational fishing of the snapper grouper complex, there fails to be a mechanism for obtaining an exact number of recreational fishermen. According to MRFSS, in recent years 4.5 million anglers participated in recreational saltwater fishing in the Southeastern U.S. (SAFMC, 2006). Even though exact numbers of fishermen can’t be determined, personal accounts suggest recreational snapper grouper fishermen are increasing with the hook and line gear as the most popular choice (SAFMC, 2006). While there has been an increase in recreational fishing for the entire snapper grouper complex, the shallow water grouper has experienced a large proportion of this increased effort due to the ease of the catch. The location of shallow water reduces the travel for fishermen offshore and the hook-and-line gear limits the skill needed to obtain the catch (SAFMC, 2006). As a result, the increase in recreational fishermen places a larger fishing effort on the shallow water grouper with the inability to adequately monitor and control the effect on the fishery. The catch data depicts this situation with an increase in recreational catch beyond the commercial landings and an astronomical increase in recreational discards (Figure 8). The recreational sector poses a threat to the management of the gag grouper with no limit on catch or numbers.

The shallow water grouper unit has emerged as one of the dominant economic groups in the snapper grouper fishery. Most vessels in the South Atlantic depend on the shallow water grouper for primary and secondary sources of income (SAFMC, 2006). Shallow water snappers and groupers dominate the trips in the snapper grouper fishery (SAFMC, 2006). Specifically, shallow water groupers are shown to contribute a high proportion of revenue to North Carolina, South Carolina, and Georgia (SAFMC, 2006) (Table 5). May, June, and July, directly following the gag grouper closure, are the peak harvest months for shallow water grouper in the South Atlantic (SAFMC, 2006) (Table 6). Target, catch, and harvest effort data reveal gag are of particular interest to recreational anglers in the South Atlantic (SAFMC, 2006). Of all the species within the snapper grouper complex, only black sea bass and vermilion snapper landings exceeded that of gag (Reichert and Wyanski, 2005). Even though the gag experience higher landings, a significant decrease has been exhibited in the mean length of the landed fish, the proportion of males in the population, and the size of female maturity (McGovern, et al., 1998). The effects of increased fishing pressure are beginning to be seen through the response of the stock.

2.4 Current Situation

The gag grouper situation, like most fishery management issues, results from a stream of problems. Due to a chronic lack of funding, the SAFMC is forced to rely on limited data to manage its stocks. The difficulty of managing 73 species under one FMP is combined with uncertainty as the lack of adequate scientific information has led to numerous species classified as “status unknown” and potentially overfished species. While information about gag exists, the data are mainly collected through self-reporting from commercial logbooks and recreational interviews. Total numbers of fish caught, the size of the fish, discards, and conditions of discards (dead/alive/ not known, etc.) are not part of the required reporting (Rudershausen, et al., 2005). Self-reporting fails to provide an adequate overall picture of the total gag grouper removals from South Atlantic waters.

The inability to characterize the snapper grouper catch results in management measures based on insufficient information. Most hook-and-line gear fails to discriminate between targeted fish and other landed fish. Thus, gag are being caught even when not targeted and discarded as bycatch. The Council relies heavily on landings to manage fishing mortality; yet bycatch presents one of the greatest challenges to managing the gag grouper and improving the status of the stock. There is currently no reliable mechanism to accurately count this bycatch and the resulting dead discards, which the SEDAR models estimate to be quite high. In addition, the landings data that are available fail to be accurate since each state uses a different conversion for whole weight to gutted weight (SEDAR, 2006). By not explicitly counting both the landings and the dead discards against some science-based limit, the Council is ignoring the fishing mortality that gag is experiencing from the target of other reef fish (Sedberry; Rudershausen, et al., 2005).

The depth gag are caught and consequently returned determines their survivorship rate. Depth studies have shown that gag in greater depths experience mortality after being released due to the increased pressure on their swim bladders (SEDAR, 2006). At depths less than 37 m, gag illustrate high survival upon release, while at depths greater than 73m, gag experience high mortality (SEDAR, 2006). Since gag reside deeper with age, the mid to outer shelf depth range between 37 and 73m represents habitat for a broad range of size and age classes. This suggests undersized gag will be exposed to a high risk of mortality upon release (SEDAR, 2006). Therefore, this depth range of 37 and 73 m presents the greatest concern for released mortality with the chance of survival decreasing with increased depth (SEDAR, 2006).

The gag grouper spawning aggregations, while important for maintaining the population biologically, are prime targets for fishermen. Over the years, fishermen have gained increased knowledge of the patterns of gag grouper spawning and the locations of these events. As a result, fishermen, both commercial and recreational, target the gag spawning aggregations (Koenig, et al.). Since the spawning period, especially the peak, bring all of the larger fish to one narrow location, the catch per effort increases (Koenig, et al.). Not only does the heavy fishing pressure make gag prone to overfishing but the focus on the aggregations can lead to detrimental effects on the spawning process itself, further impacting the survival of the stock (Louis Daniel, personal communication). In addition, data have shown gag grouper spawning aggregations can actually be fished to extinction (Koenig, et al.). The continued targeting of spawning aggregations proves detrimental to the survival of the gag grouper stock.

Tagging data provides insight into the movement patterns of gag and the differences in catch rates by state. The recapture rate of tagged gag was found to be higher in Florida with a shorter time frame between tagged release and recapture compared to the Carolinas (McGovern, et al., 2005). These results suggest a higher mortality exhibited by the greater fishing pressure from commercial and recreational fishermen and sport divers in Florida. The narrow continental shelf off the eastern coast of Florida allows gag, especially when aggregated, to become more accessible to fishermen and may increase fishing mortality by “funneling” them close to shore (McGovern, et al., 2005). In addition to the higher fishing mortality potential off the Florida coast, 25% of gag tagged in the Carolinas were recaptured in Florida illustrating a southern migration (McGovern, et al., 2005). The results from the tagging studies suggest gag migrate to Florida, where they experience a higher rate of fishing mortality; yet the regulations do not reflect this imbalance.

Catch data illustrate that the expanded recreational sector combined with the insufficient information on bycatch highlights an area where the Council needs to focus. Reports in 2003 show the commercial sector landed 250-275 metric tons, while the recreational sector landed 300 metric tons of gag grouper (Reichert and Wyanski, 2005). The increase in recreational landings is not of as much concern as the even larger recreational discards. Figure 8 depicts the large discrepancies between the recreational catch and discards compared to the commercial sector. The recreational regulations are difficult to enforce presenting a challenge to management, as seen by the increase in recreational landings. The inability to limit and monitor the recreational sector leads to an even greater inconsistency in the data vs. actual stock size, which affects all future management.

The gag grouper case, through the most recent assessment process and consequent Council responses, demonstrates the problems associated with fisheries management. The available science, while limited, identified the gag stock as undergoing overfishing according to current definitions. Models predicted that the stock will reach an overfished condition by 2007 under all uncertainty (Fig. 9). Once notified of this assessment, the SAFMC has the responsibility to develop regulations within one year that will end overfishing (SEDAR, 2006). The SEDAR panel, however, argued that the current definition of MSST was too conservative and suggested lowering the level to 5,000 million lbs. According to this new definition, the gag grouper stock will no longer become overfished by 2007, tabling any further discussion of restrictions. The insufficient amount of data and the potential bias of the self-reporting should lead the council to be more conservative with their management actions and enact a precautionary approach, but their actions suggest otherwise. Prior to any decisions, the assessment was reevaluated revealing the numbers were incorrect; the recreational releases had been double counted (Louis Daniel, personal communication). Unfortunately, the Council lacked the political will to act on this discovery, pushing implementation of more restrictive measures until June 2007. Given the biology of gag and projections under the current fishing mortality, the Council should proceed with precaution with the belief that the stock will become overfished in 2007 and take necessary actions to rebuild the stock.

Chapter 3

ANALYSIS

The gag grouper stock presents a case similar to other fishery management situations around the world. Difficulties stem from the biology of a long-lived, slow-growing, late maturing species that is a protogynous hermaphrodite and part of a multispecies complex. The management system itself only worsens the situation through a lack of funding, lack of political will, insufficient data, and discrepancies in stakeholder interests. Additional complexities revolve around the small vessel size and the increase in recreational harvests. From these problems, three main themes have become apparent as necessitates for the gag grouper stock to survive in the South Atlantic: better information on the status of the stock, a reduction in fishing mortality and bycatch, and protection of the spawning aggregations.

Better information on the status of the stock

Mismanagement of the gag grouper results from the lack of adequate data regarding the entire snapper grouper multispecies complex. As seen from the 2006 summer SEDAR assessment, the existing data provide uncertainties leading to various opinions on how to proceed in the situation. Even with a high proportion of knowledge related to the gag grouper stock, uncertainty still persists. As a result, the management of the other reef species is called into question with most stocks possessing the title of "status unknown." This lack in reliable data will continue to present problems in management as regulations are implemented without a measurable response from the stock. The gag grouper stock requires an increase in data, both fishery-dependent and fishery-independent, for proper management. The dearth in fishery-independent data forces all management to be based on the limited reports fishermen supply. By conducting research in the South Atlantic, a greater understanding of the fishery will be achieved. In addition to acquiring this fishery-independent data, the methods of collecting fishery-dependent data need to be improved. The snapper grouper fishery requires a system of monitoring to prevent any discrepancies in the already limited data.

Observer coverage, even in limited form, remains the best type of monitoring for fishing vessel activity. Monetary constraints have been shown to dictate the amount of coverage that can be instituted. In British Columbia the cost of observers on board vessels and dockside monitoring is covered by the industry itself (Sanchirico, et al., 2006). In the British Columbia Pacific halibut fishery, fishermen have been given the option to pay for an observer and harvest more fish or to have limited observer coverage with a more restricted harvest (Diamond, 2004). Even though other fisheries have devised methods to combat monetary constraints, vessel size must be considered before observer coverage can actually become a realistic option. The addition of a human to an already space limited vessel presents concerns about safety. The monitoring of catch fails to be worth jeopardizing a human life, leading to the use of alternative monitoring methods. The majority of the gag grouper vessels are less than 50 ft., too small to safely hold an observer (Table 4). This prevents even limited observer coverage of 10% from being implemented in the fishery. The other methods of monitoring, alternative platforms and electronic monitoring systems, provide potential options, but the logistics of the fishery make these alternatives unlikely. The South Atlantic already lacks the funding necessary for monitoring and research, which makes additional implementation unlikely. The South Atlantic does possess an adequate monitoring protocol, but with even more funds being cut, they are unable to implement the data collection necessary for management of the multispecies complex (Elizabeth Fetherston, personal communication). While the lack of funding prevents the use of alternative forms of observer coverage, it doesn't provide an excuse for ignoring the need for better data.

Methods of cooperative research and self-monitoring by fishermen present a cost effective measure of gathering data to better inform the management of the fishery. By training fishermen in data collection, a greater number of samples can be obtained with increased support from the stakeholders. The uncertainties surrounding the gag grouper status have led to contention and mistrust of the management system. By combining researchers and fishermen in the data collection process, trust can be regained in the science through the increased knowledge of the stock. The reduction of uncertainty will result in less changes in future management, providing the fishermen incentive to cooperate. The ability to work with the fishing industry to find solutions along with cooperative research have shown to be critical components of bycatch management (Steele, 2003). As seen in the New Zealand fisheries, fishermen have an incentive to participate in the research increasing transparency and integrity in the information (Harte, 2001). Taking advantage of fishermen's knowledge to achieve a better standard for data collection improves the support from the fishermen and the reliability of the data. While cooperative research was an indirect result of rights-based fisheries, New Zealand is attempting to restructure the process to go beyond the science to build institutions and processes for better management (Harte, 2001). Faced with limited funds and data, cooperative research and self-monitoring, as seen in other fisheries, provide the best approach for reducing the uncertainty in the gag grouper fishery. Through the achievement of better data collection and knowledge of the fishery, gag and the other reef species can be better understood receiving the best forms of management from the best available science.

Reduction in fishing mortality and bycatch

Given the uncertainty surrounding the stock status in the data poor environment of the multispecies fishery, gag grouper require limits to the incurred fishing mortality. The current management measures of gear restrictions, size limits, and bag limits fail to portray the stock's response to fishing pressure. Without an annual response from the stock, minor adjustments to the measures can't be made, resulting in drastic adjustments when implemented. Altering the current management through a reduction in the bag limit or an increase in the size limit would reduce the harvest of gag, especially in the recreational sector. A drastic reduction in the bag limit from 5 snapper grouper to 1 would provide an estimated 6.5% decrease in recreational harvest (NOAA, 2005, 95). The benefits gained from this decrease in harvest, however, would only be countered by increases in discards. The same discard problem would occur with increasing the size limit. The size of landed gag has decreased (McGovern, et al., 1998), so by raising the size limit for retainable fish, more gag are going to be discarded. While designed to protect the larger females and males, slot limits would ultimately lead to an increase in bycatch mortality. By forcing fishermen to discard the larger fish, slot limits would lead to the death of the very fish that they are designed to protect due to the effect of depth on gag swim bladders (Rudershausen, et al., 2005). Input controls, therefore, fail to provide the necessary protection for the gag grouper stock requiring the implementation of better regulations.

Without a direct limit on fishing effort, the catch of gag continues to increase along with the discards, thus requiring the implementation of a quota management system. Perpetual uncertainty continues to surround the status of the stock as managers attempt to decide whether gag is actually overfished. The recreational sector, through the increase in numbers, landings, and discards, presents concern without a clear form of monitoring and enforcement of the sector.

The current measures also fail to account for bycatch mortality from the nonselective gear. As a result, direct measures of output controls need to be implemented to adequately reduce the fishing mortality and bycatch of gag to a sustainable level.

Quota systems provide the basic management framework necessary for limiting catch, but they are shown to be less effective when compared to incentive programs of Individual Transferable Quotas (ITQs). With the use of any fishing mortality limit, fishermen will have an incentive to discard, whether for regulatory purposes or high-grading, especially in multispecies fisheries. Even though discarding presents a substantial problem in quota systems, discarding as a result of minimum length requirements is actually higher (McGarvey, 2003). Discarding becomes problematic through a loss in income and inaccuracies in stock assessments, which lead to overly optimistic or pessimistic management based on biased accounts (Branch, et al., 2006). Total mortality, landings and discards, needs to be incorporated in stock assessments to provide the full picture on the status of the stock (Branch, et al., 2006). While ending the race to fish exhibited in regular quota systems, ITQs require accurate and timely quantitative stock assessments, difficult in poor data environments (Baelde, 2005), leading to a need for greater monitoring and enforcement (McGarvey, 2006). As a result many ITQ systems incorporate observer coverage and other systems of monitoring to prevent discarding.

While all ITQs provide incentives for fishermen to enhance stock abundance for future conservation (McGarvey, 2006), differences in individual incentives from the ITQ system may account for discards (Branch, et al., 2006). Branch, et al.(2006) found the use of individual incentives of ITQ management in the British Columbia fishery helped avoid discards when compared to the fleet-wide incentives of the West Coast fishery. The British Columbia fishery restricted vessels to midwater trawling once their individual quota was achieved. The West

Coast fishery, on the other hand, permitted fishing for other species when a specific quota was reached, which led to the discarding of any species harvested that exceeded the quota. The West Coast fishery incurred a larger fishing mortality due to bycatch compared to the British Columbia fishery under ITQs, further emphasizing the importance of individual incentives.

Multispecies Case Studies

Globally, management of multispecies fisheries tends to include a form of ITQs which can be applied to the gag grouper in the South Atlantic. The specific cases that were investigated include: New Zealand, Australia, British Columbia, Iceland, and the Pacific coast. All of the systems exhibit similar features of allocation, differing in the mechanisms of monitoring and dealing with discards. From their successful practices and lessons learned, a process for gag grouper management can be achieved.

The first stage requires setting a limit on the amount of fish that can be harvested; thus the gag grouper fishery requires the implementation of a quota system. In the British Columbia groundfish fishery, TACs are based on assessments with a precautionary buffer that is based on the life history characteristics of the stock (Sanchirico, et al., 2006). As discussed earlier, gag grouper management needs to include the biology of the species and it is their life history that makes them prone to overfishing. Since the stock is currently in a state of uncertainty, defining the correct TAC will take time and monitoring. Once a balance has been achieved, the quota can be divided into individual shares. Most ITQ systems base allocations on catch histories with some including vessel characteristics and social considerations into the division (Sanchirico, et al., 2006). For example, each licensed vessel in the British Columbia halibut fishery received a share of the TAC based on historical landings (70%) and vessel characteristics (30%) (Dewees, 1998). New Zealand takes a step further in ITQ allocation by dividing the EEZ into fishery management areas (Dewees, 1998; Sanchirico, et al., 2006). Each species within the management area receives a TAC, which is divided into commercial and recreational shares (Kearney, 2001). The commercial share is allocated as ITQs, whereas the recreational allotment is loosely defined based on previous catch history (Kearney, 2001). While ITQs in New Zealand are a well-defined property right that are registered, secure, and can be used for collateral, (Dewees, 1998), in British Columbia possession of an ITQ is a privilege of 1-9 years that can be revoked (Sanchirico, et al., 2006). The limited entry permitting system, already in effect, provides the first step in an adaptive management system of reducing fishing mortality and bycatch for gag. Based on previous experiences, the gag grouper fishery needs to establish a TAC and then determine the best method of allocation into individual shares.

The British Columbia halibut fishery provides a framework for gradually establishing ITQs in the gag grouper fishery. The first two years under the system were non-transferable, there was a period of limited transferability, and then finally full transferability was granted (Dewees, 1998). By gradually transitioning into transferability, fishing participants were able to adjust to the new system and make decisions regarding their participation (Dewees, 1998). The gag grouper fishery can base its transition from input controls to an ITQ system over a gradual period as seen in other multispecies examples.

While the quota allotment may present challenges, the biggest obstacle in the implementation of an ITQ system in the gag grouper fishery will be the issue of discards. In all multispecies fisheries, the quota allocation will not match the actual catch leading to overages and incentives for fishermen to discard the excess catch. To combat the potential for bycatch, each multispecies fishery has established its own methods of catch-quota balancing. All of the systems include a rollover allowance permitting fishermen to carry forward unused quota for the next year (10-30% TAC) and most allow fishermen to carry back a percentage that will be deducted the following year (5-20%) (Sanchirico, et al., 2006). The fishermen have been shown to carry forward quotas more than carrying back, especially in instances such as Australia where there is a penalty of 2:1 weight for excess catch (Sanchirico, et al., 2006). Multispecies fisheries with ITQs demonstrate flexibility in handling catch-quota balancing proves to be a necessary feature for successful management design.

In addition to the use of observers and monitoring, most systems require full retention of catch with penalties enacted in situations of overages. New Zealand charges a deemed value for landing a fish without sufficient annual quota. The deemed value is usually set below the ex vessel price to discourage discarding at sea, but at the same time prevent targeting of fish for which fishermen don't have quota (Sanchirico, et al., 2006). To further discourage fishermen from exceeding the quota limits, the deemed value payments increase with owner's use (Sanchirico, et al., 2006). Iceland operates under a similar system, but the overage is supplied to an auction where the proceeds are split 80% to the Minister of Fisheries and 20% to the vessel owner to cover costs (Sanchirico, et al., 2006). The British Columbia overages are deducted from the annual catch and revenues go to a non-profit that conducts fisheries research (Sanchirico, et al., 2006). Species quota exchanges performed in ratios of catch had been used in a number of fisheries, but each method failed to adequately limit bycatch making the method "biologically unsound" (Sanchirico, et al., 2006, 779). Additional methods include retrospective balancing and quota aggregations. Retrospective balancing provides a limited window in which fishermen can balance their catch through transfers and other methods before that particular fishery's penalty kicks in. Aggregations occur in New Zealand where a group of multispecies fish form an aggregate for which a single quota is issued. The catch of each species is allowed to vary within the aggregate but the quota for the aggregation limits the total catch of all species (Sanchirico, et al., 2006). Sanchirico, et al. (2006,781) found that there is no one optimal design for multispecies ITQ systems and that participants are responding to changing information and conditions.

In addition to a regular ITQ system, multispecies fisheries can also implement a bycatch quota. Within the ITQ system, the TAC is reduced so that allocations can be given to other fisheries that catch the targeted species as bycatch (Siegfried, 2006). In this case, bycatch is no longer an overage but is instead included in the limit (Siegfried, 2006). By assigning a portion of the ITQ to bycatch, the proportion of catch that will be harvested as bycatch by other fisheries will be taken into account. Bycatch quotas give fishermen an additional incentive to participate in data collection programs to ensure an accurate assessment of the proportion of TAC that will be dedicated to bycatch (Siegfried, 2006). The Alaska groundfish fishery closes when the fleet has reached a bycatch quota for any species, illustrating the need for fishermen to shift their mindset and fishing practices to a more long-term approach (Diamond, 2004). Bycatch quotas provide a further application of the ITQ system to multispecies management that can be investigated for gag grouper in the future.

ITQ implementation will only be successful in the gag grouper fishery if successful catch-balancing methods are put into effect. Transferability of quotas is crucial to cover overages due to the inability to predict the catch composition (Branch, et al., 2006). As shown by all fisheries, a rollover provision needs to be established allowing fishermen to carry forward a percentage of the quota, and to a lesser extent subtract a percentage from the following year. Without the 100% observer coverage of the British Columbia fishery, total mortality will be hard to assess, but by requiring the retention of all fish, a more accurate assessment can be obtained.

The ownership granted through ITQs provides fishermen an incentive to protect their property leading to a system of self-policing (Meister). Instituting a penalty, whether deemed value or auction, helps reduce discards at sea and provides a source of revenue to cycle back into the fishery management system. With the limited data and uncertainty of the stock status, aggregation quotas should be considered, especially as a form of transition into ITQs. Each system has their own method of accounting for discards but the key feature from all the multispecies fisheries is flexibility in the catch-balancing methods and the gag grouper fishery proves no different.

As in the New Zealand fishery, an allotment from the TAC should be established for the recreational sector before it becomes out of control. Australia recognizes the need to control recreational catch and has implemented a license system (Kearney, 2001). Even though the Australian license is designed to produce revenue, not regulate entry, establishing a recreational license in the gag grouper fishery will take a step towards capping the catch. By placing a limit on the number of licenses, the recreational sector can be regulated. The revenue will aid in data collection while the licenses will provide a list of gag fishermen to survey, thus further enhancing the knowledge in the fishery. Through the introduction of a licensing system to the recreational sector and an ITQ system to the commercial sector, the fishing mortality and bycatch will both be reduced leading to the protection of the stock.

Protection of the spawning aggregations

Due to the life history characteristics and hermaphroditic nature of gag, the stock is very prone to overfishing, requiring the incorporation of the biology into the management practices. Currently, the gag fishery is closed during the peak spawning period from March and April. However, this closure only reduces the commercial catch to the recreational bag limit of 2 gag a day. Therefore, gag are still being caught and experiencing mortality due to discards. In addition, the fishermen know the location of the spawning aggregations, so they can target the fish. Hermaphrodites that don't form spawning aggregations are shown to not experience the same skewed sex ratios from fishing pressure, further emphasizing the need to protect the spawning aggregations (Libby Fetherston, personal communication). The peak revenue months in which gag are harvested the most are from May-July, directly following the gag closure (SAFMC, 2006). These months represent a vulnerable period with spawning still occurring during the month of May and females transitioning following the spawning period. The peak spawning closure currently in effect fails to protect the gag during their most vulnerable period requiring additional measures to be evoked, either temporally or spatially.

Marine protected areas (MPAs) would spatially protect a portion of the spawning aggregation, but this may not be sufficient for gag. Fishing has been shown to affect the spawning behavior, health, and viability of the population (Lesher; Sedberry). By removing this disruption, prespawners and larger females will be protected increasing recruitment, and therefore improving the overall spawning stock biomass (Lesher). With the increase in transitionals being caught following the spawning period, a spawning closure would be unable to protect the newly acquired males (Koenig, et al.) In addition, males have been shown not to migrate, remaining along the shelf edge reef year-round, further emphasizing the need for MPAs to protect the sex ratio (Koenig, et al.). By establishing MPAs in shelf-edge habitats where gag are most vulnerable, the population age structure and genetic diversity can be protected along with producing a supply of recruits to exploited areas (McGovern, et al., 2005).

Tagging data illustrates two important features about the gag grouper stock that impact the justifications for MPAs. Gag were shown to migrate to FL where they were caught more quickly off the eastern coast, signifying a larger fishing effort in FL (McGovern, et al., 2005). In addition, the shelf edge reef is narrower, funneling fish, providing easier access for fishermen (McGovern, et al., 2005). From this information, the best location for an MPA would be along the shelf edge reef off the eastern coast of FL to protect the greater proportion of the stock from this larger fishing effort (McGovern, et al., 2005). Lack of adequate data on the movement of males suggests a few larger MPAs would be preferable to many small ones off the shelf-edge reef (Koenig, et al.). Due to the sensitivity of the gag grouper stock to fishing pressures, the establishment of MPAs would invoke the precautionary principle ensuring some of the larger fish, mainly the males, would be protected (Alonzo and Mangel, 2004). The establishment of MPAs would not only provide protection for the gag grouper stock, which is already in need but would provide insurance for the other economically important reef species and the ecosystem that supports them (Koenig, et al.).

While providing potential benefits, the development of a MPA off the coast of FL will be met with strong opposition. The majority of commercial fishermen holding snapper grouper permits reside in FL. A large component of Florida revenue is gained through fishing, both commercially and recreationally, leading to a lack of political will for implementation due to the potential loss of access to fishing grounds (Baelde, 2005). Even if stakeholders would agree on areas to designate for closure, there is no guarantee a MPA would protect gag. Studies have shown gag migrate to form aggregations (Koenig, et al.). Under normal circumstances they are solitary creatures, implying there is no guarantee they will remain within the MPA boundaries. To adequately protect the stock, a sizeable MPA would have to be designated requiring enforcement in addition to lost fishing wages from the closure to other species. A MPA was designated in the Gulf of Mexico to protect the gag grouper, but thus far the impacts remain inconclusive. A successful MPA takes time to implement and monitor the impacts, making it an impractical solution for the already troubled gag grouper stock.

Due to the vulnerability of the entire stock during the spawning period, a temporal closure provides the greatest benefit to the biology of gag. The current closure does limit fishing effort helping to protect the spawning period, but it isn't enough. Spawning occurs from the months of December to May allowing fishermen to increase their concentrated efforts on the remainder of the spawning period (McGovern, et al., 2005). Additionally, the closure doesn't prevent fishing for gag, it only reduces the level to the recreational limit, allowing the continued harvest of gag. Gag will also be exposed to greater bycatch due to high grading under the imposed bag limit and the target of other reef fish (McGovern, et al., 2005). In addition to the mortality from depth, discarded gag will have difficulty spawning and transitioning following release. An extension of the March and April seasonal closure to include all shallow water grouper species would reduce the recreational harvest by 15.7% (NOAA, 2005, 95). Declines in abundance, changing sex ratios, and evidence of spawning migration led Chapman et al. (1999) to suggest a proposed spawning season closure might be necessary. Through the protection of the final spawning month of May, more males and transitionals will gain protection along with allowing females a chance to migrate away from the shelf edge reef. While an extension of the seasonal closure will reduce revenue, the closure would provide less economic hardship as a year round spatial closure. Furthermore, since the closure has already been implemented, an extension of the seasonal closure may face less resistance than a spatial closure. The extension of the seasonal spawning closure will provide biological protection while gaining enough political will to ensure implementation.

A combination of both spatial and temporal closures should be considered for future endeavors to fully protect gag biology during the spawning period. As stated previously, both spatial and temporal closures provide benefits to gag biology, but political will and uncertainty of success make a seasonal closure a more viable option at this time. Once further monitoring has occurred both of the South Atlantic and the Gulf of Mexico gag grouper stocks to determine the responses to the different closures, additional measures can be implemented. According to Lesher, the gag grouper fishery would gain the greatest benefits from a combination of temporal and spatial closures ensuring the protection during the spawning period. The rockfish of the Pacific groundfish fishery provides an example of the closure combination. Fishing is eliminated in "areas where and times when those overfished species are likely to co-occur with more healthy stocks" (NMFS NW Regional office). Vessel monitoring systems, a satellite tracking system, are placed on vessels to monitor compliance with the conservation areas. The Pacific rockfish closure combination demonstrates a potential next step for gag grouper management.

Chapter 4

RECOMMENDATIONS

Through the analysis of the gag grouper case study and the application of other multispecies fishery practices, management options are recommended to restore the health of the gag grouper. Under the condition of uncertainty, these recommendations are presented as a form of adaptive management, acknowledging that the options will require monitoring and alterations before they become effective, but if done properly will lead to a successful fishery management system. As Mesister mentioned, "Fisheries are vulnerable to Murphy's Law: 'If anything can go wrong with a new fisheries management scheme…it will' (12)." In addition, these management measures take into consideration that gag grouper are managed as a unit within a multispecies complex, not as a single species. Each recommendation is provided in response to the three themes identified in the analysis: better information on the status of the stock, a reduction in fishing mortality and bycatch, and protection of the spawning aggregations.

According to Meister, successful fishery management requires: total catch be controlled, access to fishery be controlled, decision making be participatory (bottom- up), research and monitoring, and development of a management system take place in an integrated fashion considering all factors associated with or affected by the system (17). Each of these components is addressed within the recommendations for the gag grouper in the South Atlantic.

Cooperative research and self-monitoring provide a cost effective form of obtaining data while building a strong relationship between fishermen, scientists, and managers. Even though the gag grouper fishery can not support observers or other alternative methods, the need for research and monitoring is still essential. As a result it is recommended to implement a system of cooperative research with fishermen who volunteer first. From cooperative research, fishermen on the water can be trained in self-monitoring. The data collection systems can then be expanded to include the entire snapper grouper fishery, thereby improving the fishery management system for the whole complex. Not only will data be improved but the management will be participatory from the bottom-up as fishermen gain incentive to verify the data collection and participate in the management system.

To reduce fishing mortality and bycatch, a progression into ITQ management will provide incentives for fishermen to limit their catch, protecting the gag grouper stock. The commercial sector already operates under a limited entry permit system, but the increase in the recreational sector demonstrates a need to limit access through licenses. Recreational licenses will limit the number of fishermen controlling the sector's harvest and providing a concentrated number to sample. A TAC should be established for the gag grouper fishery. Once it reaches a constant level, individual quotas should be implemented that gain the property of transferability over time. As seen in other fisheries, rollover provisions along with a form of penalty have been shown to be successful management tools when faced with catch-quota balancing. Based on previous experiences, a series of potential penalties along with the method of allocation should be discussed with the fishermen themselves in a series of workshops to ensure stakeholder support. In addition, a portion of the TAC should be saved for the recreational sector to allocate through the licensing system. The penalties and licenses will provide revenue that will be explicitly used each year in the snapper grouper fishery for monitoring and research. Further actions, such as a bycatch quota, need to be evaluated once the ITQ system has been implemented.

The protection of the spawning period has been shown to be crucial to the survival of the gag grouper stock. While a spatial closure may demonstrate long term potential benefits, the urgency of the response and the lack of political will make the option less desirable at this time. An extension of the existing spawning closure proves to be a more viable option, providing protection and feasibility. A spawning closure for all fishing should be extended to all shallow water grouper during the months of March-May to aid in the protection of the vulnerable spawning aggregations, while ensuring enough political will to implement the temporal closure. All fishing for gag during these months will be prevented and the fishing of other shallow water grouper within the shelf edge reef off the eastern coast of Florida will also not be permitted. Fishing for other shallow water grouper outside of the shelf edge reefs and in other states will be allowed during these months. Through the combination of a seasonal and spatial closure, the gag grouper spawning will be completely protected from any fishing pressure while reducing the economic hardships related to a full closure. Once the progress has been monitored, a combination of temporal and spatial closures, as seen in the Pacific rockfish fishery, can be further implemented to provide the best protection for the gag grouper fishery.

Paul MacGregor of Mundt MacGregor stated at the Policy Perspectives on Bycatch panel, "The key elements to successful management of bycatch are first reliable monitoring; second, reliable accounting for the bycatch mortality; third, providing incentives to fishermen to make sure that they can fish in a responsible way and keep bycatch at the lowest rate possible; and lastly, you've got to give them the tools with which to accomplish those goals." (Witherell, 2003, 201). The gag grouper stock in the South Atlantic is no different, requiring each of these items for successful management as seen in the proposed recommendations.

CONCLUSION

With the reauthorization of the Magnuson Act in January 2007, the SAFMC will be forced to implement some, if not all, of the proposed recommendations for the gag grouper stock. With the firm deadline of ending overfishing by 2011, the SAFMC will be required to set annual quotas. The act also encourages the increase in limited-access privilege programs, which supports the use of ITQs in the gag grouper stock. Furthermore, the act focuses on improving enforcement and information gathering, key elements to improving the gag grouper stock status. The analysis of this study demonstrates areas of focus and highlights recommendations to achieve a healthier gag grouper stock. The reauthorization of the Magnuson Act provides the the impetus for the SAFMC to save the gag grouper in the South Atlantic.

REFERENCES

Alonzo, Suzanne H. and Mangel, Marc. (2004). The effects of size-selective fisheries on the stock dynamics of and sperm limitation in sex-changing fish. Fisheries Bulletin 102:1-13.

Apostolaki, P., Babcock, E. A., and McAllister M. K. (2006). Contrasting deterministic and probabilistic ranking of catch quotas and spatially and size-regulated fisheries management. Can. J. Fish. Aquat. Sci. 63:1777-1792.

Australian Government, Department of Environment and Heritage. The Benefits of Marine Protected Areas. 10 Feb. 2007 <www.environment.gov.au/coasts/mpa/wpc/**benefits**/pubs/**benefits-mpas**.pdf>

Babcock, Elizabeth A., Pikitch, Ellen, K., and Hudson, Charlotte, G. How much observer coverage is enough to adequately estimate bycatch?

Baelde, P. (2005). Interactions between the implementation of marine protected areas and right-based fisheries management in Australia. Fisheries Management and Ecology 12: 9-18.

Benaka, Lee R. and Dobrzynski, Tanya J. (2004). The National Marine Fisheries Service's National Bycatch Strategy. Marine Fisheries Review 66(2). 1-8.

Bess, Randall. (2005). Expanding New Zealand's quota management system. Marine Policy 29: 339-347.

Bibb, Sally. "Observers and technology: A system for monitoring quotas in the western Alaska community development quota fishery." Proceedings from the third International Fisheries Observer Conference. Panel Session 1. New Orleans, LA. 18-21 Nov. 2002.

Branch, Trevor A., Rutherford, Kate, and Hilborn, Ray. (2006). Replacing trip limits with individual transferable quotas: implications for discarding. Marine Policy 30:281-292.

Chapman, Robert W., Sedberry, George R. Sedberry, Koenig, Christopher C., and Elby, Brandon M. (1999). Stock identification of gag, Mycteroperca microlepis, along the southeast coast of the United States. Marine Biotechnology 1:137-146.

Cicin-Sain, Biliana and Knecht, Robert W. The Future of U.S. Ocean Policy: Choices for the New Century. Washington, D. C.: Island Press, 2000.

Conway, Flaxen D. L. and Pomperoy, Carrie. (2006). Evaluating the human – as well as the biological- objectives of cooperative fisheries research. Fisheries 31(9): 447-454.

Daniel, Dr. Louis. Testimony: on the operations of the South Atlantic Fishery Management Council and the reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act before the House Committee on Resources. 27 Oct, 2005.

Description of MARMAP Sampling. "Annual estimation of juvenile gag abundance and development of a pre-recruit index for the Southeast U.S. Atlantic." SEDAR10-DW-05.

Dewees, Christopher M. (1998). Effects of individual quota systems on New Zealand and British Columbia Fisheries. Ecological Applications 8(1): S133-S138.

Diamond, Sandra L. (2004). Bycatch quotas in the Gulf of Mexico shrimp trawl fishery: can they work? Reviews in Fish Biology and Fisheries 14: 207-237.

Fina, Mark. (2005) Effects of a share-based management program on the central Gulf of Alaska rockfish fishery. Presented at "Biology, Assessment, and Management of North Pacific Rockfishes", Lowell Wakefield Fisheries Symposium, Alaska Sea Grant, Anchorage, Alaska, 13-15 Sept. 2005.

Fisheries Department, FAO Corporate Document Repository. "The Development and Diversity of Reference Points." Reference points for fisheries management. 15 Sept. 2006. <http://www.fao.org/docrep/003/v8400e/v8400E02.htm>

Gibbs, Mark T. (2007). Lesser Known Consequences of managing marine fisheries using individual transferable quotas. Marine Policy 31: 112-116.

Grafton, R. Quentin, Arnason, Ragnar, Bjorndal, Trond, Campbell, David, Campbell, Harry F., Clark, Colin W., Connor, Robin, Dupont, Diane P., Hannesson, Rognvaldur, Hilborn, Ray, Kirkley, James E., Kompas, Tom, Lane, Daniel E., Munro, Gordon R., Pascoe, Sean, Squires, Dale, Steinshamn, Stein Ivar, Turris, Bruce R., and Weninger, Quinn. (2006). Incentive-based approaches to sustainable fisheries. Can. J. Fish. Aquat. Sci. 63: 699-710.

Harte, Michael. (2001). Opportunities and barriers for industry-led fisheries research. Marine Policy 25:159-167.

Heppell, Selina S., Heppell, Scott A., Coleman, Felicia C., and Koenig, Christopher C. (2006). Models to compare management options for a protogynous fish. Ecological Applications 16(1): 238-249.

Hilborn, Ray, Micheli, Fiorenza, and De Leo Guilio A. (2006). Integrating marine protected areas with catch regulation. Can. J. Aquat. Sci. 63: 642-649.

Hilborn, Ray, Stokes, Kevin, Maguire, Jean-Jacques, Smith, Tony, Botsford, Louis W., Mangel, Marc, Orensanz, Jose, Parma, Ana, Rice, Jake, Bell, Johann, Cochrane, Kevern L., Garcia, Serge, Hall, Stephen J., Kirkwood, G.P., Sainsbury, Keith, Stefansson, Gunnar, and Walters, Carl. (2004). When can marine reserves improve fisheries management? Ocean and Coastal Management 47: 197-205.

Holland: Daniel S. and Herrera, Guillermo E. (2006). Flexible catch-balancing policies for multi-species individual fishery quotas. Can. J. Aquat. Sci. 63: 1669-1685.

Kalo, Joseph J., Hildreth, Richard G., Rieser, Alison, Christie, Donna R., and Jacobson, Jon L. Coastal and Ocean Law: Cases and Materials. 2nd Ed. St. Paul, MN: West Group, 2002.

Kaplan, Ilene M., and McCay, Bonnie J. (2004). Cooperative research, co-management and the social dimension of fisheries science and management. Marine Policy 28: 257-258.

Kearney, Robert E. (2001). Fisheries property rights and recreational/commercial conflict: implications of policy developments in Australia and New Zealand. Marine Policy 25: 49-59.

Koenig, Christopher C., Chapman, Robert W., Collins, Mark R., Harris, Patrick, McGovern, John, Sedberry, George R., Wyanski, David M., and Johnson, Allyn G. The effects of shelf-edge fishing on the demographics of the gag, *Mycteroperca microlepis*, population of the southeastern United States. 1-22.

Kulka DW, Orr D, and Rogers B. An observer deployment scheme based upon past fisheries performance. Proceedings of the 4th International Fisheries Observers Conference. Sydney, Australia. 8-11 Nov. 2004. Session 8: 128-129.

Lesher, Ammon T. and Sedberry, George R. Analysis of preliminary results for release of satellite-tracked drifters over gag spawning sites. SEDAR 10- DW- 06.

McElderry, H., Schrader, J., and Illingworth, J. (2003). The efficacy of video-based electronic monitoring for the halibut long-line fishery. Canadian Science Advisory Secretariat, Research Document 042.

McGarvey, Richard. (2003). Demand-side fishery management: integrating two forms of input control. Marine Policy 27: 207-218.

McGovern, John C., Sedberry, George R., Meister, H. Scott, Westendorff, T. Mark, Wyanski, David M., and Harris, Patrick J. (2005). A tag and recapture study of the gag, *Mycteroperca microlepis*, off the southeastern U.S. Bulletin of Marine Science 76(1): 47-59.

McGovern, John C., Wyanski, David M., Pashuk, O., Manooch, III, C. S., and Sedberry, George R (1998). Changes in sex ratio and size at maturity of gag, *Mycteroperca microlepis*, from the Atlantic coast of the southeastern U.S. during 1976-1995. Fisheries Bulletin 96:797-807.

Meister, Anton D. The New Zealand Experience with Fishery Management: Lessons Learned. 25 Mar. 2007 <http://www.idcr.ca/en/ev-8324-201-1-DO_TOPIC.html>

NOAA. Stock assessment and fishery evaluation report for the snapper grouper fishery of the South Atlantic. 18 Nov., 2005.

NOAA. "Evaluating bycatch: a national approach to standardized bycatch monitoring programs." NOAA Technical Memorandum NMFS-F/SPO-66 Oct. 2004.

NMFS Northwest Regional Office. Rockfish Conservation Areas. <http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Groundfish-Closed-Areas/Index.cfm>

Okey, Thomas A. (2003). Membership of the eight Regional Fishery Management Councils in the United States; are special interests over-represented? Marine Policy 27: 193-206.

Punt, Andre E., Smith, David C., Tuck, Geoff, N., and Methot, Richard D. (2006). Including discard data in fisheries stock assessments: Two case studies from south-eastern Australia. Fisheries Research 79: 239-250.

Reichert, Marcel J.M. and Wyanski, David M. Analytical report on the age, growth, and reproductive biology of gag, *Mycteroperca microlepis* from the southeastern United States, 1996-2005. South Carolina Department of Natural Resources. December, 2005. SEDAR 10- DW- 15.

Restrepo, V.R., Thompson, G.G., Mace, P.M., Gabriel, W. L., Low,L.L., MacCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P. R., and Wtzig, J.F. Technical guidance on the use of the precautionary approaches to implementing National Standard One of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum. 17 July, 1998.

Rudershausen, Paul J., Ng, Alex, Ng, Anthony, and Buckel, Jeffrey A. By-catch, discard composition, and fate in the snapper/grouper commercial fishery, North Carolina. 16 Feb. 2005. SEDAR 10- RD- 06.

Sanchirico, James N., Holland, Daniel, Quigley, Kathryn, and Fina, Mark. (2006). Catch-quota balancing in multispecies individual fishing quotas. Marine Policy 30: 767-785.

SEDAR. SEDAR 10 Stock Assessment Report: South Atlantic Gag Grouper. Stock Assessment Report 1, 2006.

Sedberry, George R. Gag, *Mycteroperca microlepis*.

Siegfried, Kate. (2006). Fishery Management in data-limited situations: Applications to stock assessment, marine reserve design, and fish bycatch policy. Dissertation, University of California Santa Cruz June, 2006.

South Atlantic Fishery Management Council. Final Amendment 13A to the Fishery Management Plan for the snapper grouper fishery of the South Atlantic region. September, 2003.

South Atlantic Fishery Management Council. Draft Amendment 13B to the Fishery Management Plan for the snapper grouper fishery of the South Atlantic region. Spring, 2005.

South Atlantic Fishery Management Council. Final Amendment 13C to the Fishery Management Plan for the snapper grouper fishery of the South Atlantic region. February, 2006.

South Atlantic Fishery Management Council. Gag grouper regulations. <http://www.safmc.net>

Southeast Fisheries Science Center. Control parameters and alternatives for control rules for selected stocks under the jurisdiction of the South Atlantic Fishery Management Council. September, 1999.

Starr, Paul. Fishery Management Innovations in New Zealand. New Zealand Seafood Industry Council.1-6.

Steele, Lori. “Technology, data, and information in bycatch managment.” Managing Our Nation’s Fisheries: past, present, and future.Ed. David Witherell. Proceedings of a conference on fisheries management in the United States. Washington, D.C. 13-15 Nov., 2003.

Stefansson, Gunnar and Rosenberg, Andrew A. (2005). Combining control measures for more effective management of fisheries under uncertainty: quotas, effort limitation, and protected areas. Philosophical Transactions of the Royal Society B 360: 133-146.

Tagart, Jack. "Policy perspectives on bycatch." Managing Our Nation's Fisheries: past, present, and future.Ed. David Witherell. Proceedings of a conference on fisheries management in the United States. Washington, D.C. 13-15 Nov., 2003.

Tork, M. "Alternative platform observations: Observing small vessels that cannot accommodate an observer." Proceedings of the 4th International Fisheries Observers Conference. Sydney, Australia. 8-11 Nov. 2004. Session 8: 132-133.

Witherell, David. Editor (2003). Managing Our Nation's Fisheries: past, present, and future. Proceedings of a conference on fisheries management in the United States. Washington, D.C. 13-15 Nov., 2003.

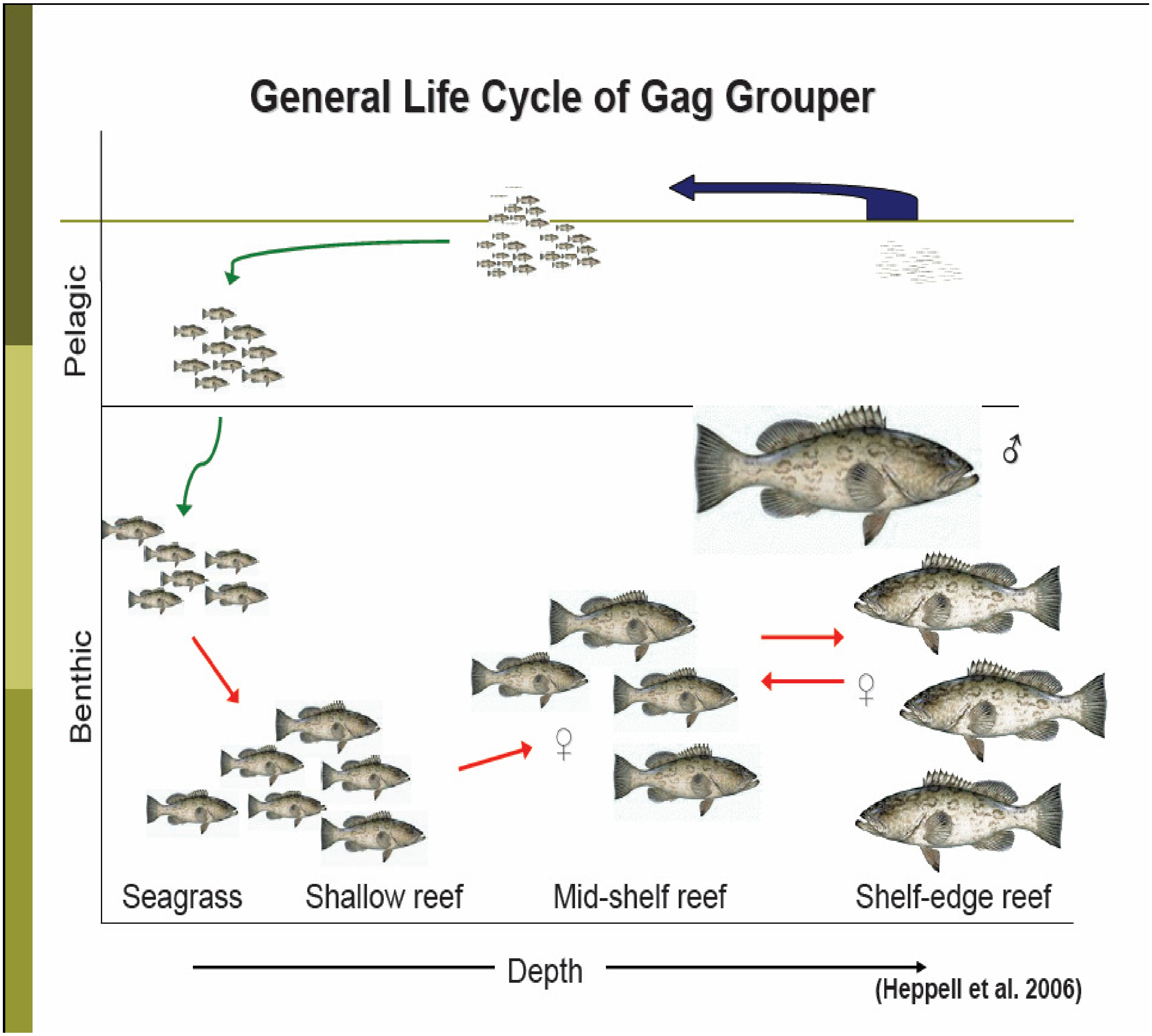
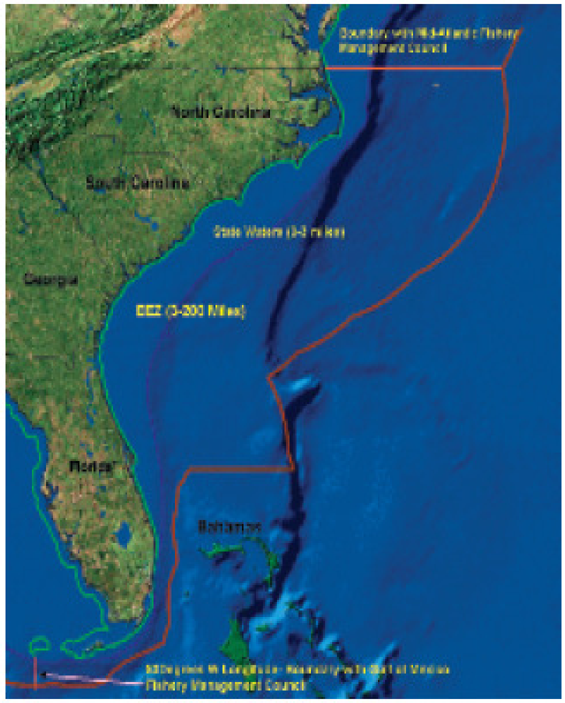


Figure 1 This is a pictorial representation of the general life cycle of gag grouper. The cycle begins with the spawned eggs. As gag age, they move to deeper waters until maturity. Males remain along the shelf edge reef while females migrate there to spawn. Depths range from 2 to 200m throughout the life cycle.



The South Atlantic Exclusive Economic Zone

Figure 2 **An illustration of the South Atlantic Fishery Management Council jurisdiction ranging from North Carolina to the eastern coast of Florida. Source: SAFMC**

Table 1 **A list of all the regulations that pertain to the gag grouper in the South Atlantic including the effective dates and the Amendment that enacted them. Source: SEDAR 2006**

Table 1-1. History of gag regulations.

Regulation	Effective Date	Plan or Amendment
4" trawl mesh size	8/31/83	FMP
Prohibit trawls	1/12/89	Amendment 1
Prohibit fish traps, entanglement nets & longlines within 50 fathoms; 20" size limit and 5 grouper bag limit; rebuilding timeframe	1/1/92	Amendment 4
Oculina Experimental Closed Area	6/27/94	Amendment 6
Limited entry program: transferable permits and 225-pound non-transferable permits	12/98	Amendment 8
24" size limit and within 5 grouper bag limit only 2 may be gag or black. March & April - no harvest above bag limit & no sale. Vessels with longlines may only possess deepwater species	2/24/99	Amendment 9
Oculina Experimental Closed Area extended indefinitely	04/26/04	Amendment 13A

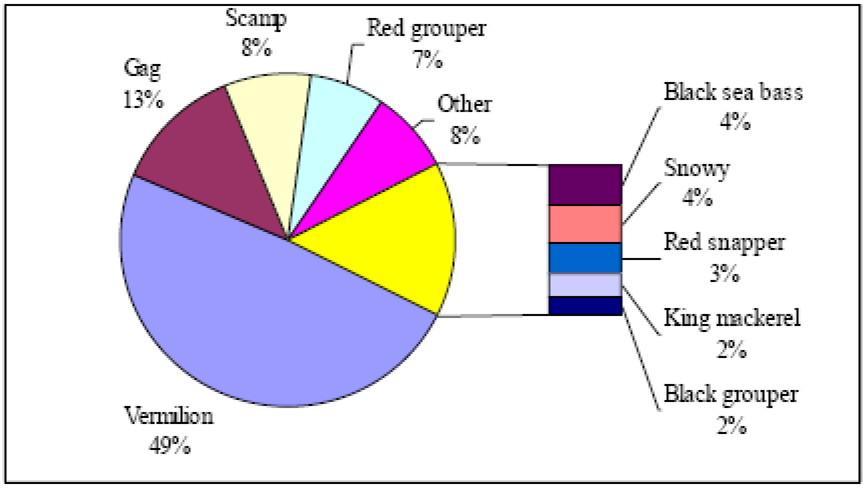


Figure 3 **Proportion of trips where vermilion snapper were harvested, but the respective species was the top revenue earner. Source: NMFS Beaufort Lab, SAFMC, 2006**

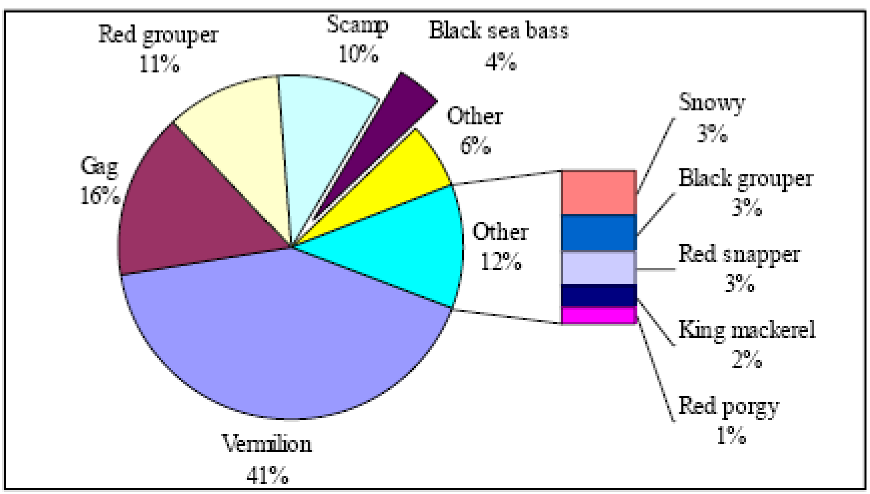


Figure 4 **Proportion of trips where red porgy were harvested, but the respective species was the top revenue earner. Source: NMFS Beaufort Lab, SAFMC, 2006**

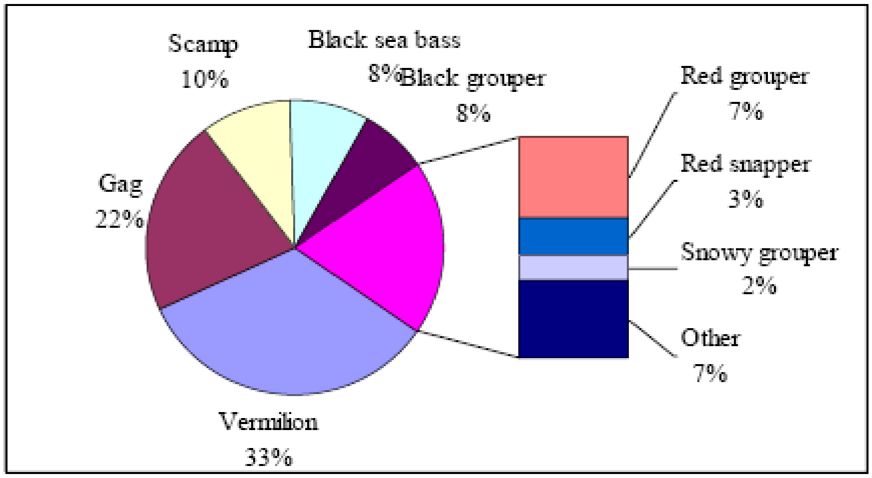


Figure 5 Proportion of trips where black sea bass were harvested, but the respective species was the top revenue earner. Source: NMFS Beaufort Lab, SAFMC, 2006

Table 2 A breakdown by state of the snapper grouper permits held in the South Atlantic in 2006. Each state's percentage of ownership is also provided. Source: SAFMC

State	SG Permits	%
FL	435	68%
GA	8	1%
SC	64	10%
NC	120	19%
Other	10	2%
TOTAL	637	

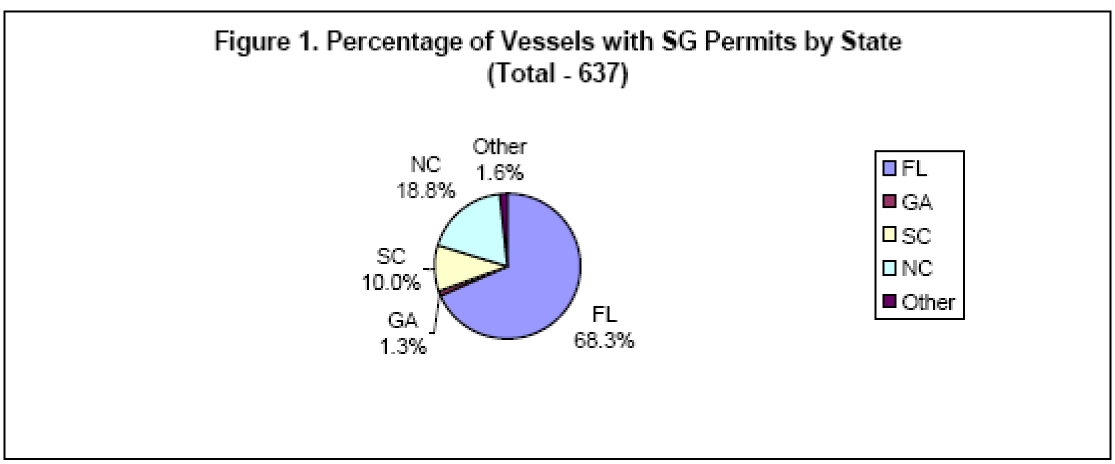


Figure 6 A graphic representation of the distribution of snapper grouper permits by state in 2006. Source: SAFMC

Table 3 **A breakdown by state of snapper grouper permit holders that only possess a snapper grouper permit and no other fishing permit Source: SAFMC**

State	Permit Owners with No Other Permits	%
FL	42	75%
GA	1	2%
SC	6	11%
NC	4	7%
Other	3	5%
TOTAL	56	

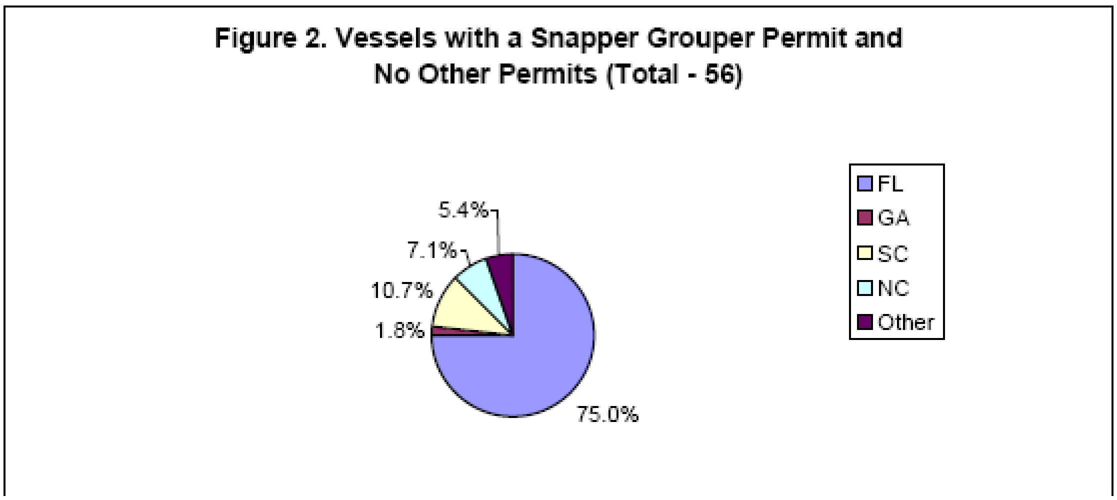


Figure 7 **A graphic representation of the distribution of snapper grouper permits by state that hold no other fishing permit in 2006. Source: SAFMC**

Table 4 **Length of permitted vessels in 2004 by state. Source: Permits Office, NMFS, SAFMC, 2006**

Size Category (feet)	Florida	North Carolina	Georgia	South Carolina
Less than 20	6%	2%	0%	1%
20-29	51%	35%	17%	22%
30-39	31%	46%	42%	44%
40-49	10%	16%	42%	30%
50-59	2%	1%	0%	2%
60-69	1%	1%	0%	1%
70-79	<1%	<1%	<1%	<1%
larger than 80 feet	<1%	<1%	<1%	<1%
	100%	100%	100%	100%

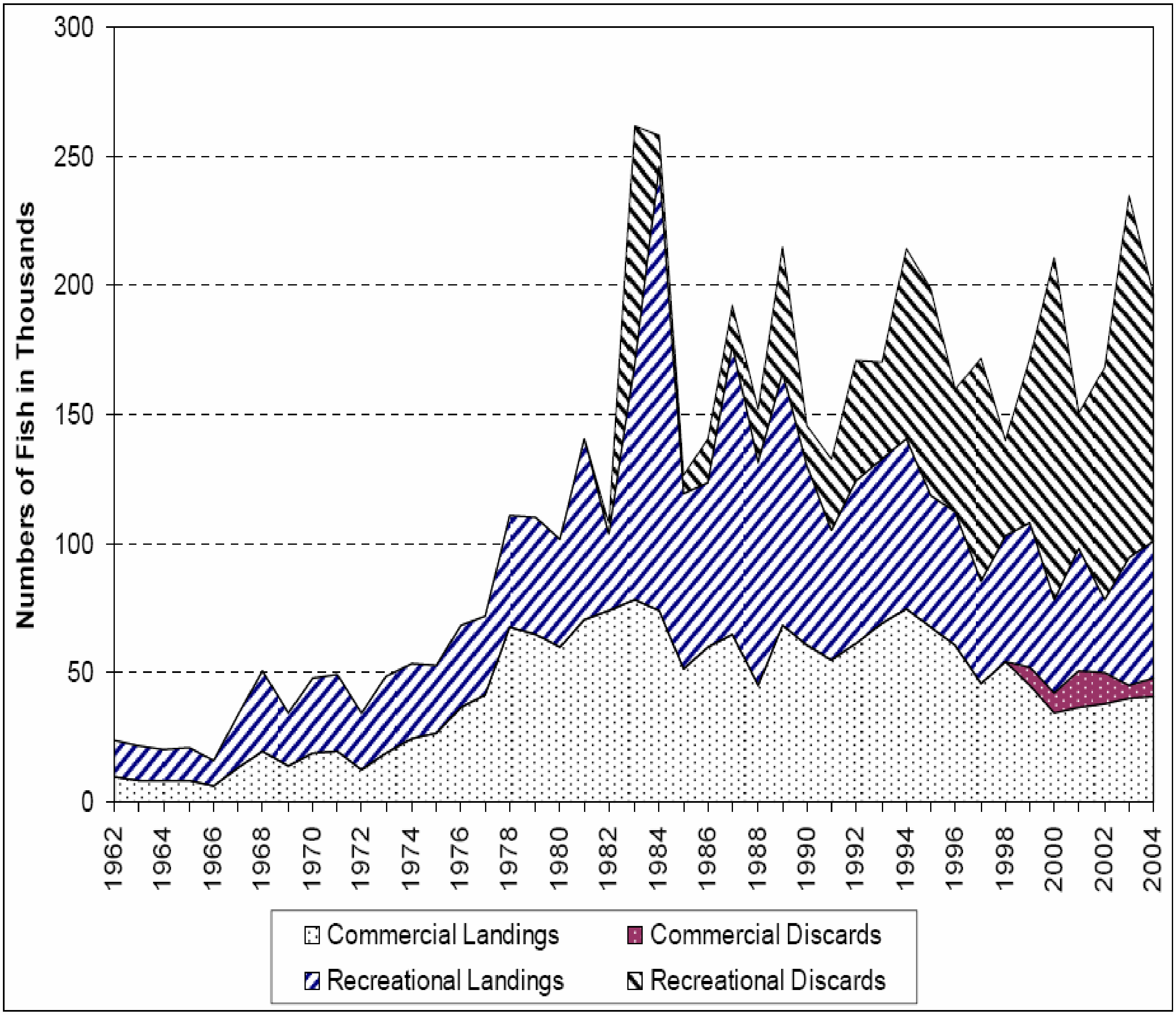


Figure 8 **The total number of catches, both landings and discards, in numbers of fish in thousands for the commercial and recreational sector in the South Atlantic from 1962-2004. Source: SEDAR 2006**

Table 5 **Average ex-vessel value of the snapper grouper subunits by state during 1999-2003. Source: NMFS Beaufort Lab, SAFMC, 2006**

Group	North Carolina	Georgia	South Carolina	Florida	Other
Shallow water groupers	$1,077,252	$217,731	$1,228,433	$962,362	
Deep water groupers	$275,553	$14,044	$228,680	$367,193	$3,505
Tilefishes	$105,115	$5,476	$266,709	$689,805	$13,318
Shallow water snappers	$24,362	$10,111	$41,884	$2,483,091	
Mid-shelf snappers	$1,083,541	$481,999	$1,025,725	$581,215	
Triggerfish / Spadefish	$119,604	$29,671	$72,314	$30,884	
Jacks	$103,690	$51,803	$144,306	$640,809	
Red Porgy	$34,969	$3,854	$24,191	$12,338	
Grunts and other porgies	$77,769	$5,269	$44,746	$32,770	
Sea basses	$771,669	$3,770	$196,278	$6,361	

Table 6 **The percent revenue of snapper grouper subunits by month in the South Atlantic averaged over 1999-2003 with the top revenue months highlighted. Source: NMFS Beaufort Lab, SAFMC, 2006**

Month	Shallow water grouper	Deep water grouper	Tilefish	Shallow water snapper	Mid-shelf snapper	Triggerfish/ spadefish	Jack	Red porgy	Grunt/ porgy	Sea bass
Jan	8.4%	6.06%	4.3%	6.6%	5.3%	6.1%	8.1%	11.2%	6.6%	**21.0%**
Feb	8.6%	9.23%	5.1%	7.3%	5.0%	5.5%	9.1%	4.6%	7.1%	**15.6%**
Mar	3.0%	10.91%	**8.7%**	**10.9%**	7.5%	7.9%	**13.5%**	0.1%	7.1%	8.5%
Apr	4.0%	10.73%	**11.1%**	**11.1%**	9.3%	8.9%	2.9%	0.6%	6.4%	5.4%
May	**12.8%**	**11.95%**	**10.5%**	**10.1%**	8.8%	7.1%	**17.0%**	12.9%	7.9%	5.2%
Jun	**11.5%**	**12.32%**	**9.1%**	**9.8%**	9.2%	7.9%	8.1%	13.9%	8.7%	3.0%
Jul	**10.8%**	9.54%	5.8%	**10.6%**	7.5%	5.7%	7.2%	12.5%	9.8%	3.8%
Aug	9.0%	8.31%	11.3%	7.1%	9.9%	8.2%	6.6%	14.1%	10.2%	4.1%
Sep	6.2%	7.18%	8.7%	5.8%	9.9%	**12.1%**	7.3%	8.1%	9.1%	2.2%
Oct	9.1%	5.39%	9.6%	7.0%	11.4%	**13.2%**	7.3%	7.2%	9.6%	3.9%
Nov	8.8%	4.14%	8.1%	6.4%	9.6%	9.3%	6.4%	8.4%	8.5%	9.3%
Dec	7.9%	4.23%	7.6%	7.4%	6.8%	8.2%	6.7%	6.4%	9.0%	**17.8%**

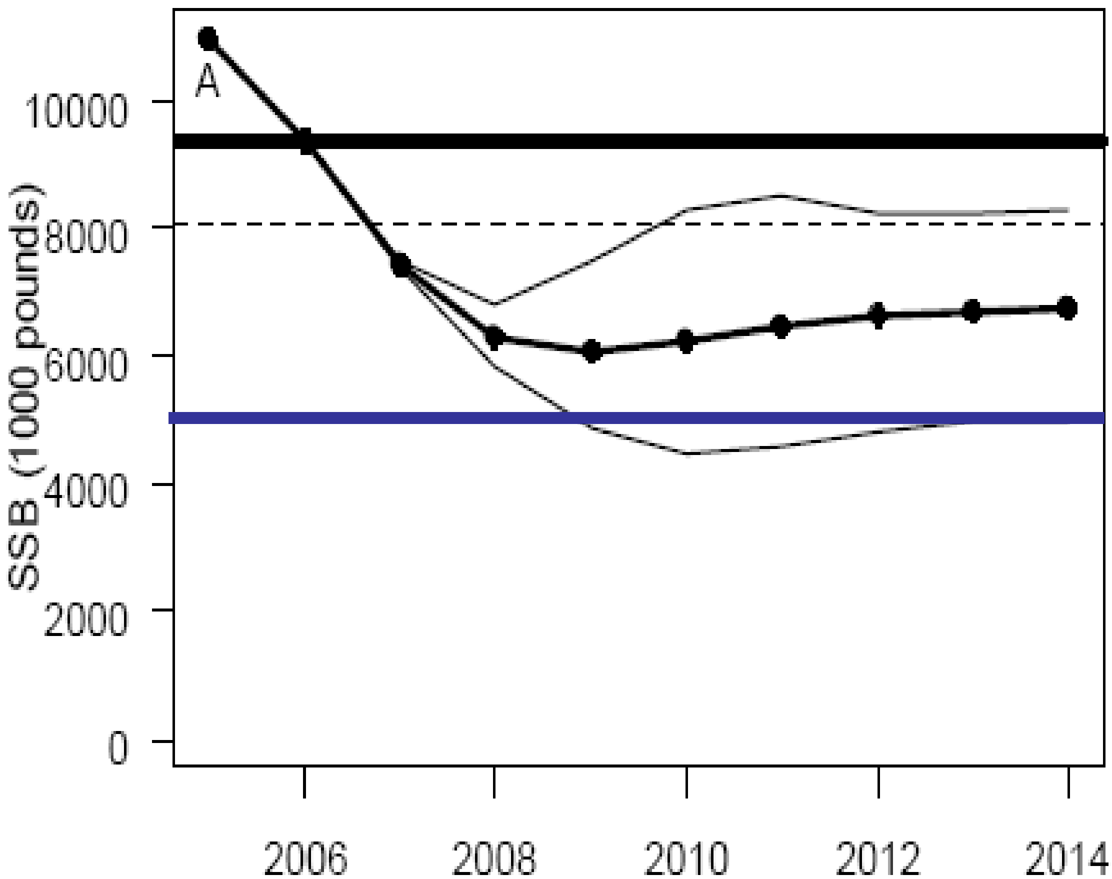


Figure 9 **SEDAR model projections under current fishing mortality for all years. Expected values are shown as the black line with circles and uncertainty is given as the thin lines corresponding to the 10th and 90th percentiles. The solid horizontal black line is Spawning Stock Biomass$_{MSY}$ and the horizontal dashed line is the Minimum Stock Size Threshold, below which a stock is overfished. The solid horizontal blue line represents the proposed change in the definition of MSST. Source: SEDAR 2006**