SEDAR

Southeast Data, Assessment, and Review

Complete Stock Assessment Report
of
SEDAR 5

Atlantic and Gulf of Mexico King Mackerel

SEDAR5
Assessment Reports 1-5

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Stock Assessment Report

South Atlantic and Gulf of Mexico King Mackerel

i. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review), is a process developed by the Southeast Fisheries Science Center and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Council in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean), and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products and provide management advice. The Data and Assessment Workshops are organized and chaired by the SEDAR coordinator. Participants are drawn from the Council SEDAR Advisory Panels, which include representatives of state and federal agencies, non-government organizations, Council members and advisors, and the fishing industry, with a goal of including a broad range of disciplines and perspectives. The Review Workshop is led by a scientist selected by the Center for Independent Experts, an organization that provides independent, expert review of stock assessments and related work. Reivew panels typically include around 12 participants drawn from the Council SEDAR Panels, regional NOAA Fisheries Science Centers, and the CIE.

This assessment, fifth in the SEDAR series, is charged with assessing the Atlantic and Gulf of Mexico migratory groups of king mackerel and is the first SEDAR assessment of king mackerel.

The Data Workshop convened at the SEFSC Laboratory in Miami FL, December 1-5, 2003. Data and analyses prepared for the workshop are documented in the SEDAR Working Papers Series (SEDAR5-DW-XX). Following the SEDAR approach, working groups were convened to address specific data issues: Life History, catch at age (CAA), and Indices. Groups were charged with developing preferred and alternative solutions to each issue, and presenting these solutions to the group for resolution. Groups were also charged with documenting all decisions and preparing report sections according to the SEDAR5 assessment report outline. The Assessment Workshop convened at the SEFSC Laboratory in Miami Florida, February 16-19, 2004. Data and analyses are documented in the SEDAR Working Papers Series (SEDAR5-AW-XX). Workshop participants considered several assessment analyses and completed drafting the assessment report.

ii. Terms of Reference

Terms of Reference for the Data Workshop

1. Evaluate stock structure, develop a unit stock definition, and estimate the rate of Atlantic-Gulf stock mixing over time and area.
2. Evaluate the quality and reliability of life-history information (Age, growth, natural mortality, reproductive characteristics); develop models to describe growth, maturation, and fecundity by age, sex, or length as appropriate.
3. Evaluate the quality and reliability of fishery-independent measures of abundance; develop indices by appropriate strata (e.g., age, size, and fishery) for use in assessment modeling.
4. Evaluate the quality and reliability of fishery-dependent measures of abundance; develop indices for use in assessment modeling.
5. Evaluate the quality and reliability of commercial and recreational fishery-dependent data for determining harvest and discard by species; develop estimates of total annual catch including both landings and discard removals by species
6. Evaluate the quality and reliability of data available for characterizing the size and age distribution of the catch (landings and discard); characterize commercial, recreational, and headboat landings and discard by size and age.
7. Evaluate the quality and reliability of available data for estimating the impacts of management actions.
8. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.
9. Provide recommendations for future research (research, sampling, monitoring, and assessment).
10. Prepare complete documentation of workshop actions and decisions, and generate introductory, descriptive, and research needs sections (1-4, 9) of the stock assessment report.

Terms of Reference for the Assessment Workshop

1. Select appropriate modeling approaches, based on data availability, management requirements, and recommendations of the Data Workshop.
2. Estimate and provide tables of relevant stock parameters (abundance, biomass, fishery selectivity, stock-recruitment relationship etc.).
3. Analyze uncertainty and provide measures of precision for stock estimates.
4. Evaluate current SFA benchmarks, estimate alternative SFA benchmarks if appropriate, and develop stock control rules.
5. Provide declarations of stock status relative to SFA benchmarks.
6. Estimate the Allowable Biological Catch (ABC) for each stock.

7. Provide ABC estimates and SFA criteria based on the following alternative mixing rates between the Gulf and Atlantic migratory groups: a) 100% Gulf; b) 50% Gulf/50% Atlantic; and c) 98% Atlantic.
8. if consensus is not reached on appropriate mixing rates, (1) provide estimates based on assuming an even split of fish in the mixing zone (50% Gulf Migratory Group, 50% Atlantic Migratory Group), and (2) provide a method by which ABC rates may be estimated in the event alternative mixing rates are determined at a later date by the Councils.
9. Estimate probable future stock conditions and develop rebuilding schedules if warranted.
10. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.
11. Provide recommendations for future research and data collection (field and assessment); be as specific as possible in describing sampling design and sampling intensity.
12. Fully document all activities, and draft stock assessment model and results sections of the stock assessment report (sections 5-9).

iii. Workshop Schedule and Attendance

SEDAR5 Data Workshop

Location: December 1-5, 2003. SEFSC, Miami FL

John Carmichael	SEDAR
Rick Leard	GMFMC
Bridgette Vergara	SAFMC
Dave Donaldson	GSMFC
Joey Shepherd	LA DNR
Page Campbell	TX PWD
Bob Muller	FL FWCC
Terry Cody	TX PWD
Steve Brown	FL FWCC
Chris Palmer	NMFS
Bob Palmer	FL FWCC
Arnold Jones	GMFMC/SSC
Doug Gregory	GMFMC/FAP
Steve Turner	NMFS
Gerry Scott	NMFS
Guillermo Diaz	NMFS
Doug DeVries	NMFS
Clay Porch	NMFS
Liz Brooks	NMFS
Nancie Cummings	NMFS
Patty Phares	NMFS
Alex Chester	NMFS
Mauricio Ortiz	NMFS
Larry Massey	NMFS
George Geiger	SAFMC
Myron Fisher	GMFMC
Greg DiDomenico	Monroe Co. Comm. Fishermens Inc.
Joe Powers	NMFS
John Poffenberger	NMFS
Ben Hartig	SAFMC/AP
Joanne Lyczkowski-Shultz	NMFS

SEDAR5 Assessment Workshop

Location: February 16-19, 2004. SEFSC, Miami FL

John Carmichael	SEDAR
Jennifer Frapwell	SEDAR
Panayiota Apostolaki	Univ. Miami
Harry Blanchet	Penn State Cooperative Extension
Steve Branstetter	NMFS
Elizabeth Brooks	SEFSC
Guillermo Diaz	NMFS
Barbara Dorf	TPWD
Myron Fisher	GMFMC
George Geiger	SAFMC
Doug Gregory	FL Seagrant
Randy Gregory	NCDMF
Ben Hartig	SAFMC/AP
David Lavergne	LDW&F
Rick Leard	GMFMC
Bahzad Mahmoudi	FMRI
Mike Nugent	Port Aransas Charterboat Assoc.
Mauricio Ortiz	NMFS/SEFSC
Clay Porch	NMFS/SEFSC
Jerry Scott	SEFSC
Steve Turner	NMFS
Monica Valle	CIMAS Univ. Miami

1. Introduction

1.1. Management Unit

King mackerel in the Southeast United States are managed under the Fishery Management Plan for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and South Atlantic Region. The management unit is defined as King mackerel in the Gulf of Mexico and South Atlantic, specified as a single stock and managed as two independent migratory groups: Gulf Migratory Group and Atlantic Migratory Group. The Atlantic Migratory Group management area extends from New York to Florida, and the Gulf Migratory Group management area extends from Florida to Texas. Management areas are separated along the east coast of Florida by a boundary that moves seasonally, specified as the Volusia\Flagler County border on the east coast in Winter (November 1 – March 31) and the Monroe\Collier County border on the Southwest coast in Summer (April 1 – October 31) (Figure 1). Delineation of stock management units does not impact council regulatory boundaries, thus fish landed off the southeast coast of Florida during winter (Nov. 1 – Mar. 31) are regulated under the South Atlantic Fishery Management Council and counted against the Total Allowable Catch (TAC) for Gulf of Mexico Fishery Management Council's Gulf Migratory Group.

1.2. Regulatory history

King mackerel in the Southeast United States are managed under the Fishery Management Plan for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and South Atlantic Region, approved in 1982. The FMP has been amended 14 times, with the most recent being Amendment 14, approved in 2002, which extended the moratorium on charter and headboat permits (GMFMC, 2003; SAFMC, 2002). King mackerel are managed through TAC's calculated for each migratory group and allocated to various user groups according to FMP requirements. Commercial fisheries are typically managed through quotas, possession and trip limits, size limits, and seasonal closures. Recreational fisheries are typically managed through possession limits and size limits. Limited entry restrictions are in effect for commercial and charter and headboat fisheries. Modifications to TAC's, updated MSY values, and framework adjustments such as trip limits, size limits, and seasonal closures are addressed and documented through regulatory amendments.

1.2.1. Gulf of Mexico Group

The most recent framework adjustment for the Gulf Migratory group of king mackerel was approved in 2003. It maintained the status quo TAC of 10.2 million pounds, allocated 6.94 million pounds to the recreational sector and 3.26 million pounds to the commercial. Recreational fisheries are restricted by a 2 fish possession limit and 24" FL minimum size. The commercial TAC is allocated by zones and gear types, and restricted by trip limits and seasonal closures specific to each zone and gear.

1.2.2. Atlantic Migratory Group

The most recent framework adjustment for the Atlantic Migratory group of king mackerel was approved in 2000. It increased the TAC to 10.0 million pounds, with 3.71

million pounds (37.1%) allocated to the commercial fishery and 6.29 million pounds (62.9%) allocated to the recreational fishery. Commercial fisheries are restricted by a 3,500 pound trip limit from NY to the Brevard\Volusia County, FL, line, 50 fish from that line south to the Dade\Monroe County line, and 1,200 pounds in Monroe County. Recreational fisheries are subject to a 20" TL minimum size and a possession limit of 3 fish from NY to GA and 2 fish off FL.

2. Life History

2.1. Stock Definitions

Current U.S. king mackerel management and stock assessments assume that 100 percent of the king mackerel south of the Volusia County boundary along southeast Florida during November 1 through March 31 (i.e., the mixing zone) are Gulf Migratory Group king mackerel. The group reviewed results of updated tagging analyses, otolith shape analysis, and otolith elemental analysis at the workshops (SEDAR Documents SEDAR-DW-5, 9, and 11. Tagging, otolith shape, and otolith elemental analysis all indicate that some percentage of fish in the mixing zone, from November 1 through March 31, are from the Atlantic migratory group. No consistent stock allocation was evident from the various studies. The group recommended these studies be continued for purposes of providing additional information on mixing rates between the two groups and to evaluate consistency between years in results.

Comparing tagging studies from the 1970's through the 1990's suggests a greater proportion of Gulf migratory fish in the east coast mixing zone in the early years (up to the mid 1980's) than in the more recent years (SEDAR-DW-5, SEDAR-DW-9). This could imply that migration patterns of the two groups have changed or that relative abundances have changed. However, the group felt that tagging data need further evaluation to see if the trend is consistent once short-term tag-recaptures are excluded from analysis (the distribution of releases was quite different between the two time periods and ample time needs to be allowed for the tagged animals to intermix with the population as a whole).

For the upcoming stock assessment workshop the participants concluded that the tagging data probably will be useful for use in modeling movement and mortality rates in population analyses with multiple stocks. It is recommended that the tagging data be used at least for sensitivity analyses, assuming that sufficient numbers of recaptures occurred after three months at liberty.

The group recognized that it is difficult to interpret raw tagging data beyond consideration of simple indicators such as relative fishing effort and recovery rates. The Group recommends using an alternative model, such as the 2-box virtual population analysis (VPA) model designed by Porch (SEDAR DOC DW-10), to estimate possible mixing ratios. Such an approach, including simultaneous examination of catch, indices of abundance and tagging data, may allow estimation of factors that would otherwise confound the analysis. However, it is noted that results may be biased by short-term tag recoveries, particularly since much of the tagging occurred over a relatively small fraction of the stock range. The Group recommends estimating area specific growth curves for estimating age composition for strata (year, quarter, stock) for which age-length keys are not available. The group requests a comparison of length frequency data among the Northern Gulf of Mexico, North Carolina, and the mixing zone during winter (November 1 – March 31), to evaluate whether movements and stock exchange rates are influenced by fish size.

The group emphasized the need to consider management of the Gulf group in relation to mixing between the eastern and western Gulf. The group recommended as a long term research need the collection of required fishery catch statistics and biological samples of length, age, and catch per unit of effort and in addition obtaining similar kinds of data as being current collected to assess mixing of the Atlantic and eastern Gulf of Mexico groups (e.g., otolith shape, elemental chemistry, tagging).

The working group concluded that preponderance of information suggested that the overlap model was perhaps more applicable than the diffusion model.

2.2. Natural Mortality (M)

The life history subgroup discussed the level of natural mortality in relation the values used in previous stock assessments and the supporting information associated with these choices. It was noted that a range of 0.10 to 0.25 was used to determine upper and lower limits of ABC and the value of 0.15 used for the deterministic VPA runs through June 1996. At that time the panel revisited the selection of natural mortality rates for Gulf group king mackerel. The life history parameters versus natural mortality relationships were re-examined on the basis of additional knowledge of maximum age observed from Gulf king ageing studies and examination of other scombroids. While the Panel was not overly confident in the additional information, they agreed that very low natural mortality rates are probably less likely than originally specified. Therefore, the Panel chose the lower limit of the range to be 0.15 per year instead of the previous 0.10 per year. Thus, the instantaneous natural mortality rates used for the June 1996 assessment ranged uniformly between 0.15 and 0.25 per year. The median of this range is 0.2 per year.

During the SEDAR 5 workshop other information considered in establishing reference value for M included observed values of longevity for this species. Current information suggests a maximum age of about 26 for king mackerel (Devries and Grimes 1997) and although early growth studies reported differences for males and females, DeVries and Grimes (1997) did not find differences in longevity between sexes. Estimates of M based on life history parameters and the Hoenig (1983) method were calculated during the workshop to provide additional information on M. This procedure gave values of M ranging from 0.15 - .021 for maximum ages of 20 to 27. These results are consistent the values of M used in the assessments. Empirical estimates of M from the Pauly (1980) were calculated for the Atlantic and Gulf migratory groups separately by sex (Table 1). Those estimates ranged from 0.26 - 0.38 (Atlantic) and 0.27 – 0.45 (Gulf of Mexico). The group noted that these values were higher than those calculated from the Hoenig (1983) method. The group recommended that the range of natural mortality be 0.15-0.25 for both groups with a mean at 0.2.

2.3. Age and Growth

Growth of king mackerel in the Gulf of Mexico and the Atlantic has been documented in several studies. Early studies utilized age determinations from whole otoliths to model growth (Beaumariage 1973, Johnson et al. 1983, Manooch et al. 1987). Subsequent studies documented the underageing of older fish (>80 cm FL males, 90 cm Fl females) from whole otoliths (Collins et al. 1988, Devries and Grimes 1997. The life history group considered a report, SEDAR Doc.-6, which was a literature review of the growth of king mackerel in the southeastern U.S. Information presented in this report included a summary of available formulae for transforming from individual length to weight, length to age and length to length.

The group noted that sexual dimorphism was very significant in the length to age relationship, in the weight to length relationship and also the body size – otolith size relationship, and should be taken into account when modeling growth of king mackerel. In addition DeVries and Grimes (1997) documented spatial differences. The group noted that the information on sex ratio at size currently used in the current assessment included observations available through 1994 (Restrepo 1996). The group recommended the sex ratio at length curves be updated to include data collected subsequent to the Restrepo (1996) study. Currently the assessment assumes that the sex ratio of fish size 50 cm FL and smaller is 1:1 however little data exist to verify this assumption. The group recommended as a long term research object to conduct a histological study to evaluate this assumption.

The group also reviewed a report providing a summary of the updated king mackerel otolith observations through fishing year 2002/2003 (SEDAR 5 Doc-7).

The group reviewed the existing formulae for converting individual length to age and felt that the von Bertalanffy growth equations of DeVries and Grimes (1997) were most current (

Table 2). These growth equations used data available through 1992 and the group felt that as a research recommendation the update the growth curves to incorporate age observations since the DeVries and Grimes (1997) study and further evaluate changes in growth temporally and spatially.

2.4. Reproduction

Very few studies on reproduction of king mackerel in the U.S. have been conducted - one in the Gulf and Atlantic (Finucane et al. 1986) and two in the Atlantic only (Waltz 1986; Noble et al. 1992). Only Finucane et al. (1986) provide fecundity estimates (by length, weight, and age). These estimates were derived from 65 fish 446-1,489 mm FL, 0.681-25.610 kg, and ages 1-13 yrs. The spatial distribution of the fecundity samples was: North Carolina, n=12; Texas, n=12; Louisiana, n=24; and northwest Florida, n=17. One caveat with the Finucane et al. (1986) results is that the fish were all aged with whole otoliths, which have been shown to underage older fish (Collins et al. 1989; DeVries and Grimes 1997).

Recent assessments have used the fecundity – length relationship of Finucane et al. (1986) and the age to length relationships of Collins et al. (1988) for the Atlantic and Manooch (1987) for the Gulf (Table 3). The age specific fecundity values correspond to millions of eggs. The group recommends that the most recent growth curves of DeVries and Grimes (1997) be incorporated in calculating the fecundity at age estimates for both groups. As a long term research recommendation the group suggest field studies be conducted to develop estimates of batch fecundity and spawning frequency.

The relationship between recruitment and spawning stock fecundity is uncertain. In past mackerel assessments there has not been sufficient contrast in the VPA estimates of spawning stock fecundity to allow that relationship to be well-determined. Management advice has therefore been based on a hockey-stick type model where recruitment is constant for spawning fecundity levels greater than some threshold value and declines linearly for levels below the threshold value. In terms of management benchmarks such as MSY, this constant level is similar to prescribing a Beverton and Holt model with a steepness values close to the upper limit of 1.0, which seems unlikely based on the steepness estimates for other species with similar life history strategies (Rose et al, 2003).

3. Fishery Descriptions and Data Sources

A fishery description and analysis of all available data were presented to the group utilizing the document, *Review of the Catch Sizing and Aging of King (Scomberomorus cavalla) from U.S. Gulf of Mexico and South Atlantic Fisheries* by Ortiz, et. al., December 2003, SEDAR 5 DW/8.

3.1. Commercial and Recreational Landings Data

3.1.1. Commercial Landings and Discards

Catch data from commercial fisheries have been collected by NMFS and individual state programs for many years. For this workshop, data from 1981 – 2002 (data from 2002 was preliminary and only covered part of the year) was utilized. For the assessment, landings data will be updated to include all of 2002 data. Table 3.1 shows the catch for king mackerel Atlantic and Gulf stocks. Commercial catch inputs are in weight units (lbs), by month, state, county (FL only) and gear. Table 4, Table 5, and

Table 6 show the distribution of catch by gear for the commercial sector; all landings were recorded in the data files as whole weight.

The group looked at the Terms of Reference item #5 (see Section ii) and discussed the quality and reliability of commercial fishery-dependent harvest. The group concluded that the data are adequate except for the lack of catch data off Mexico and recommended NMFS explore the possibility of acquiring additional mackerel data from Mexico.

The Data Workshop reviewed the data on commercial discards presented in document SEDAR 5-DW-12 (Estimates of king mackerel discards for the Atlantic and Gulf migratory groups). These data are contained in the Southeast Fisheries (SEFSC) coastal fisheries logbook program database. Regulations requiring vessels that have a king mackerel permit to report their catches were implemented in January 1998. Beginning in August 2001 a 20% sample of the vessels with a Gulf of Mexico reef fish, South Atlantic snapper-grouper, king mackerel, Spanish mackerel, or shark permit were selected to also report information on their discards, including king mackerel. Thus, discard information on king mackerel for this fishery is available for two fishing years (August 2001-July 2002 and August 2002-July 2003). Data were stratified for three gear types (handlines, trolling, and gill nets). Estimates were made of total numbers of king mackerel discarded for these two survey years and also for the three preceding survey years, 1998, 1999, and 2000, based on the later two years' reported discard data.

For the two survey years, there were a total of 9,848 trips for which discard forms were submitted. King mackerel discards were reported on 498 trips for the Gulf and Atlantic migratory groups combined. Fishermen also were asked to give their best estimate of the disposition of the fish and their condition, if released. The mean number of king mackerel discarded per trip (for three gear types) ranged from 0 to 6.6 fish per trip for the 503 vessels that reported king mackerel discards. When the other vessels that reported no king mackerel discards are included, the average number of king mackerel discarded ranged from 0 to 0.7 fish per trip. Using these numbers and the reported total number of trips by all vessels with permits, estimates of total king mackerel discards were made for the years 1998 to 2002. These estimates ranged from 4101 to 5285 fish for the Atlantic group and from 5138 to 6571 fish for the Gulf group.

These estimates of king mackerel discards by the commercial fleet are small compared to the total recreational and commercial catches of king mackerel. Total recreational catches of king mackerel in 1998-2002 ranged from 340,000 to 550,000 fish per year (2002 data still incomplete) for the king Atlantic group and from 290,000 to 620,000 fish per year for the king Gulf group. Total commercial catches of king mackerel in 1998-2002 were approximately one-third to one-half that of the recreational catch in weight, and presumably roughly the same ratio in numbers. Condition of the majority of the discards was reported as “all or most” alive and presumably released. Commercial discards should be used in future assessments and be assigned as undersized fish. In addition, the group recommended that shrimp trawl bycatch estimates of the numbers of king mackerel be updated and be part of the available data for the 2004 assessment.

3.1.2. Commercial Sampling Intensity for Developing a Catch-at-Age Matrix

Size frequency sample data for commercial fisheries in the southeast states have been provided since 1983 by the SEFSC Trip Interview Program (TIP). This cooperative program receives data from state sampling programs as well as NMFS samplers in some states. Before 1991, some samples of commercial landings collected under the direction of the NMFS Panama City Laboratory, which were not submitted to TIP were also available. Samples of commercial landings for states north of NC have not been available. The group noted that king mackerel size data is now available from the Fisheries Information Network (FIN) biological sampling activities, beginning in 2002. Table 7 shows the total number of king mackerel size samples by migratory group and sector from 1981 to 2002.

The group identified deficiencies in size samples for various years, particularly in the western Gulf. The group discussed methods for handling deficiencies of size data. They recommended that NMFS look at existing length/frequency data to see which ones would most closely represent the size frequencies of the catch from identified deficiencies. The group also recommended that separate east/west size frequencies be created due to significant differences of growth rate for female in the eastern and western Gulf.

An important component of sizing the catch is the classification of catch by sex. King mackerel shows dimorphic growth patterns, with females attaining larger size compared to same age males, for both the Atlantic and Gulf migratory groups. For assessments after 1994, sex ratios were assumed to be constant at the 1994 value. The group recommends using current sex ratio data rather than assuming the ratio is constant at the 1994 value. And if sex ratio information is not available for a given year, then a separate prediction model should be developed for the eastern and western Gulf.

King mackerel otoliths have mainly been collected from recreational fisheries via various state and federal data collection programs. However, sampling for age has increased for the commercial fisheries in recent years. Review of the available fish-aged observations, from king mackerel otoliths is summarized in Table 8. The group noted a deficiency in otolith sampling in the western Gulf for 1993 to 2001. In the existing assessment, a stochastic ageing method is used to assign an age to a length if age data are insufficient. Also, if an age at length bin contains less than 10 observations, adjacent cells are combined to assign an age to a length. The group recommended that NMFS determine the most robust process for assigning age to length in the event of insufficient data. Possible scenarios include a stochastic method developed with growth equations for eastern and western Gulf, combining years to develop an age/length key for the eastern and western Gulf, or alternative grouping of adjacent length cells.

3.2. Recreational

3.2.1. Recreational Landings and Discards

Recreational catch estimates are provided by the Marine Recreational Fishery Statistics Survey (MRFSS), NMFS Headboat Survey, and the Texas Parks and Wildlife Coastal Creel Survey. Table 4 shows the catch for king mackerel Atlantic and Gulf stocks (data for 2001-02 are partial; “year” is the calendar year). Recreational catch inputs were the numbers of fish by state (i.e. Florida East and West as separate states), mode (i.e. private, shore, charterboat, headboat, or charterboat and headboat combined), month or groups of months. The MRFSS estimates of catch by mode are shown in Table 9, Table 10. Information about discards is routinely collected through the existing MRFSS methodology; however, the estimates of discards that are thrown back alive are not used in the current assessment. The group concluded that the recreational catch data for king mackerel are adequate. It was also recommended that fish thrown back alive be utilized in the future assessments by assuming 0% or 100% mortality. The recreational discards should assume that all sizes are released.

3.2.2. Recreational Sampling Intensity for Developing a Catch-at-Age Matrix

Size frequency sample data for recreational fisheries were collected by the MRFSS (southeast and northeast states), NMFS Headboat Survey (southeast states), NMFS Charterboat Survey (1983?-1990). Alabama Charterboat Survey (1991-1995) and Texas Parks and Wildlife coastal creel survey, which also provided the recreational catch estimates. Table 11 shows the distribution of annual samples (number of fish size-sampled) from recreational fisheries for both the Atlantic and the Gulf migratory groups. The group concluded that the recreational size data for king mackerel are adequate.

Sampling of king mackerel from the recreational fisheries has historically (through 2002) been conducted opportunistically from charter boats, head boats and tournaments. Sampling for sex and age in the MRFSS survey has been sparse until recent years. The group concluded sex/age sampling for the recreational fisheries is inadequate. Collection of these data should be made on a routine basis via a supplemental sampling program (independent from the existing MRFSS). Sampling should be Gulf-wide and collected through a cooperative and standardized program. Estimation of catch at age of the recreational catch should be conducted using the same procedures as utilized in the commercial fisheries.

4. Measures of Abundance
4.1. Commercial Fishery Catch Rates
4.1.1. Gulf Commercial Catch Rates

Ortiz et al. (2002) used the two indices of commercial catch rates from the Florida Fish and Wildlife Conservation Commission's Marine Resources Information System (FWC trip tickets) in the 2002 stock assessment of Gulf king mackerel based on the MSAP's recommendations in 1996. The trip ticket program began in late 1984 and continues so the index used data from 1985-86 through 2000-01 fishing years. The first index used trip tickets from Florida's Panhandle (Escambia county east through Taylor county) from the months of July through October. The index was applied to ages three through six. The second index included trips with 3500 pounds or less from Southwest Florida (Collier and Monroe counties) during November and December only and was applied to ages three through eight. The indices provided by FWC were based on successful trips only and were the mean pounds per trip by fishing year adjusted by general linear models for month, and county.

The trip ticket data includes both gillnet and hook-and-line effort but gillnets were banned in state waters in July 1995. Gear on individual trips became available in late 1991 so the working group recommended investigating development of an index using just hook-and-line data beginning in 1992 or perhaps 1995.

The Indices Working Group had concerns regarding the utility of the commercial catch rates as indices of the population because of trip limits. While the data were subset to minimize impacts from season closures, individual trips were limited and, hence, the indices do not reflect the full range of trip landings. A possibility of using the catch per time was discussed but catch per hour was considered to be inaccurate because often fish house employees fill out the trip tickets not the fishers and catch per day reflects the current situation because most trips are one-day trips.

A sub-group of the Indices Working Group will obtain the specific dates when trip limits were adjusted and quotas filled and, within those time frames, examine the distribution of trips to see what adjustments would be necessary to account for the regulatory effects. As a first approximation, landings will be converted to numbers caught using average lengths by time and location from TIP data. If most of the trips are taking the trip limit, then the working group recommends using an index in catch per hour developed from the NMFS logbook. Another possible improvement to the index might be to include trips that landed associated species but not king mackerel as is done with the MRFSS indices.

Because of short time series currently available, the group did not recommend using either NMFS's logbooks or the trip ticket programs of Louisiana and Alabama as additional indices of commercial catch rates at this time but thought that they should be investigated in the future.

4.1.2. Atlantic Commercial Catch rates

SEFSC (2003) used two sources of commercial catch rates in the 2003 stock assessment of Atlantic king mackerel: Florida's trip tickets and fishers' logbooks from North Carolina . The Florida index used data from 1985-86 through 2001-02 fishing years and the North Carolina logbook data was from 1981-82 through 1996-97 fishing years. The MSAP (2003) recommended that an additional index from North Carolina's trip ticket program that began in 1994 (Ortiz and Sabo 2003) not be included "until the properties of the new index could be evaluated more rigorously." The Florida index used successful trips from April through October from the Florida's Atlantic coast (Nassau through Monroe counties). The index provided by FWC was applied to ages 2 through 11+ and was the mean pounds per trip by fishing year adjusted by a general linear model for month, and county. The North Carolina logbook index was the mean number of pounds per trip by fishing year.

As noted earlier with the Gulf commercial catch rates, the group had concerns regarding the effect of trip limits on the ability of the index to capture changes in the underlying population abundance and thought that these data also should be examined relative the dates when trip limits changed. Another concern had to do with the possibility of different-sized king mackerels in different areas along the coast. This could be addressed by splitting data into a northern section and a southern section possibly at Brevard County. As with the Gulf indices, including associated species may improve the resolution of the index.

4.2. Recreational Fishery Catch Rates

4.2.1. Gulf Recreational Catch Rates

Ortiz et al. (2002) used four sources of recreational catch rates in the 2002 stock assessment for Gulf king mackerel: the Marine Recreational Fisheries Statistics Survey (MRFSS), Texas Parks and Wildlife Department's Recreational Angler Creel Survey (TPWD), NMFS's Beaufort Headboat Survey (Headboat), and the NMFS charterboat survey. The recreational indices were updated for the 2003 MSAP meeting (Ortiz 2003).

The MRFSS catch rate analysis included only intercepts from July through December, private/rental boat and charterboat modes, and hook-and-line gear if a king mackerel was caught, targeted, or if an associated species was caught (Ortiz and Phares 2002). The associated species were included in an attempt to refine the actual effort expended for king mackerel. Although MRFSS began earlier, the index only used data from 1986-87 through 2001-02 fishing years because of more consistent regulations and increased data availability in the Gulf. The index was the total number (Types A+B1+B2) of king mackerel per thousand angler-hours fished standardized with a delta-lognormal model for two-month wave, state-county of interview, and fishing mode. The index was applied to ages two through eight. The Indices Working Group had concerns about including intercepts from inshore but the workshop decided to retain those intercepts because the question in MRFSS asked where did you fish most of the time. Another issue was whether the index should be restricted to July-October instead of July-December based on the stock identification work. At this time, the working group recommends using the existing indices for comparability with previous assessments; however, other analytical models may require adjustments to the indices. This caveat applies to all the indices.

The TPWD index included interviews from May through September, private and charterboat modes, Gulf areas off major bay systems in nearshore and offshore waters only. The index used data from 1983 through 2001. This index was applied to ages two through eight. The index was the annual number of fish per thousand fishing hours standardized with a delta-lognormal model for month, major bay, and area. The Indices Working Group questioned why the Galveston region was excluded and the after reviewing the landings, a new index was developed including data taken off the coast of Galveston (Figure 2).

Although the headboat survey conducted by NMFS's Beaufort Laboratory began in 1974 off North Carolina, the Gulf was not included until 1981. The headboat data used in the analyses included all trips of one day or less from the 1981-82 through 2001-02 fishing years for 100 vessels (out of 284) that caught 91% of the catch and caught king mackerel in seven or more years. The index was the standardized mean number of fish per trip adjusted with a delta-lognormal model for area, month, and vessel and applied to ages two through six.

The Indices Working Group was concerned about the use of all months and all areas in the index. The MSAP in 1996 recommended excluding the western Gulf data because headboats in that area usually bottom-fished for reef fish. However, discussion by the workshop thought that the catch rates in the peripheral areas may reflect the condition of the stock better than focusing on more core areas.

Two additional recreational indices from NMFS's charterboat survey in the Gulf were included in Ortiz et al. (2002) stock assessment on Gulf king mackerel. The survey was divided into Northwest Florida from 1988 through 1995 and Southwest Florida from 1988 through 1994. The Indices Working Group recommended that these indices be continue to be included.

4.2.2. Atlantic Recreational Catch Rates

SEFSC (2003) used two recreational indices in the 2003 stock assessment for Atlantic king mackerel: MRFSS and headboat. Ortiz (2003) describes the standardization process for these indices. Contrary to the MRFSS Gulf index, the Atlantic index uses information from the 1981-82 through 2001-02 fishing years. The MRFSS catch rate analysis included only intercepts from April through December, private/rental boat and charterboat modes, and hook-and-line gear if a king mackerel was caught, targeted, or if an associated species was caught. The index was the total number of king mackerel per thousand angler-hours fished adjusted with a delta-lognormal model for two-month wave, state-county of interview, and fishing mode. The index was applied to ages two through eleven.

The Indices Working Group was concerned about using a single index when the area included expands in November-December to include Florida's southeast counties. Also, the index included the inshore area and most king mackerel are caught in the nearshore and offshore areas. However, the feeling of the workshop was that these data may improve the index by capturing the dynamics in peripheral areas.

The headboat index included all trips of one day or less from 1981-82 through 2001-02 fishing years for 69 vessels (out of 216) that caught 89% of the catch and caught king mackerel in seven or more years. The index was the standardized mean number of fish per trip adjusted with a delta-lognormal model for area, month, and vessel and applied to ages two through eleven.

The Indices Working Group had the same concerns regarding using a single index that could encompass different sized fish along the Atlantic index. The recommendation is to investigate the size of king mackerel along the Atlantic coast. If there are different sizes by area, then possible regions could be the Keys to Palm Beach County, Palm Beach to the Georgia border, and Georgia through North Carolina depending on the size data.

4.3. Fishery-Independent Survey Data

4.3.1. SEAMAP Larval Index Gulf of Mexico

This fishery-independent survey index is the percent occurrence of mackerel larvae caught in bongo nets during two SEAMAP resource surveys per year since 1986: the Summer Shrimp/Groundfish survey conducted during the months of June and July from Brownsville, Texas to Mobile Bay, Alabama; and the Fall Plankton survey during late August to mid October from Brownsville, Texas to south Florida (Gledhill and Lyczkowski-Shultz 2000, Lyczkowski-Shultz and Hanisko 2003). Approximately 155 samples are conducted each year. This index is applied to ages one through eleven with the partial selectivities by age being based on the maturity schedule.

The Indices Working Group questioned whether to include the summer surveys since this survey only covers the shelf area west of Mobile Bay, unlike the fall survey, that covers the entire Gulf continental shelf. The working group recommended retaining the summer data in the index and including terms for survey type and/or time such as month or season in developing the index. Another issue concerned the difficulties posed by weather and/or ship related failures that have caused geographic differences in sampling coverage during surveys. Since 1986 areas off northwest and southwest Florida and central Texas have been under-sampled (relative to the standard SEAMAP survey grid) for those reasons. In 1998 sampling effort was reduced by one-quarter and one-third during the summer and fall surveys, respectively. The group recommended that analysts consider not using the 1998 survey results due to the greatly reduced geographic coverage that year. The group recommended standardizing the index with the delta method. Statistical standardization procedures will also adjust for the extra sampling that has occurred in some years.

4.3.2. Bycatch Shrimp Fishery Index:

This index is based on the estimated bycatch of king mackerel from the U.S. Gulf of Mexico Shrimp trawl fishery. The current stratification scheme for bycatch estimation includes: three data set types, research, commercial and BRD; three seasons, Jan-Apr, May-Aug, and Sep-Dec; four areas, Florida West coast and the Florida Keys, Mississippi-Alabama, Louisiana and Texas coasts; two depth zones, less or equal to 10 fathoms, and more than 10 fathoms; and 21 years, from 1981 to 2002. Nominal bycatch rates (numbers of king mackerel per one-hour tow time) were standardized with a GLM adjusted for data type, season, area and depth zone (Ortiz 2002).

The working group inquired into the current status and future of bycatch data collection for the index and analyses relative to the use of BRD's in the U.S. shrimp fishery.

4.3.3. SEAMAP South Atlantic Trawl Survey

The Southeast Area Monitoring and Assessment Program - South Atlantic Shallow Water Trawl Survey is funded by NMFS and conducted by South Carolina Department of Natural Resources beginning in 1986 (SEAMAP-SA 2002). After initial development work by SEAMAP the survey stabilized and the index uses data from 1990-91 and later fishing years. The survey extends from Cape Hatteras to Cape Canaveral and is divided into six regions and 4 m depth contours inshore and 10 m depth contours offshore. Trawl sites randomly selected from a pool of trawlable stations within a stratum with the number of stations in each stratum determined by optimal allocation. Data from the paired tows were pooled. Fork lengths of king mackerel ranged from 4 to 51 cm (mean = 14.9 cm) and represented two year classes. Originally, the index was applied to age 0 fish. However due to model instability, the MSAP (2003) asked that the VPA be re-run without the age 0 fish with the trawl index offset one year and assigned to age-1.

The Indices Working Group recommended keeping this index.

5. Stock Assessment Methods

5.1. Model

5.1.1. Overview

The Gulf of Mexico Fishery Management Council's Mackerel Stock Assessment Panel (MSAP) has assessed the status of Gulf of Mexico and Atlantic king mackerel since 1985. In the early 1980's Gulf of Mexico king mackerel were considered overfished and were subjected to a rebuilding plan. Recent assessments have indicated that the stock is no longer overfished but not yet rebuilt to B_{msy}. The MSAP has attempted to maintain consistent assessment methods during the rebuilding period so that changes in estimated status would reflect changes in the observed information rather than changes in assessment methods. When new methods have been proposed the MSAP has carefully reviewed them to ensure that they clearly provide improvements in methodology.

Most recently the MSAP reviewed the status of Gulf of Mexico king mackerel in 2000 and 2002 analyzing assessments by Legault et al (2000) and Ortiz et al. (2002) The MSAP also reviewed the status of Atlantic king mackerel in 2003 based on an assessment by Ortiz et al. (2003).

For the current assessment the SEDAR5 working groups were asked to consider possible impacts of mixing between the Atlantic and Gulf of Mexico stocks on stock status estimates and potential yield. At the SEDAR5 Data Workshop basic assessment information and inputs were reviewed and some conclusions and recommendations for further investigation were made. There was insufficient time in the brief intervening period between the Data and Assessment Workshops to complete all recommended analyses, but significant investigations were conducted into estimated growth rates of king mackerel in the Atlantic and the Gulf of Mexico (Brooks and Ortiz 2004), assignment of age to length (Ortiz 2004a) and the impact of mixing on resource status (Ortiz 2004b, Porch and Diaz 2004). Additionally the assessment working group reviewed the Gulf of Mexico single stock assessment updated through fishing year 2001/2002 (Ortiz 2004b) and a revision to the boot strap results and benchmark estimates for the most recent Atlantic king mackerel assessment (Sustainable Fisheries Division 2004).

Several additional investigations recommended by the Data Workshop could not be fully completed in the available time, though progress was made on some of the topics. The Data Workshop recommended further study of the sex ratio at size needed to convert catch at size to catch at size by gender for subsequent ageing by gender. Ortiz (personal communication) reviewed some of the available information on sex ratio at size and noted that patterns in sex ratio at size did not appear to be markedly different from the last investigation (using data through 1994). Recreational discard mortality effects have not been investigated. Multiple recommendations were made concerning indices of abundance including revision of the fishery independent SEAMAP index and review of commercial fisheries and some recreational fishery indices. The SEAMAP index was updated using the original proportion position methods; further research is needed on alternative estimation approaches. Commercial fishery indices from Florida were reviewed with special attention paid to trip limit effects on index utility; it was concluded that only a small fraction of trips caught their limits (Muller personal communication). Additional progress and/or documentation was needed on the Florida hand line and Atlantic recreational indices. During the SEDAR5 Data Workshop, the index subgroup approved the North Carolina Commercial trip ticket index for use in the assessment.

To provide advice concerning the mixing effects on stock status and allowable biological catch (ABC) estimates, the Assessment Workshop reviewed the Data Workshop conclusions with respect to mixing, a review of stock structure analyses by DeVries (2003 SEDAR5-DW5), and an additional draft report by Patterson et al. (2003 SEDAR5-DW11). Several methods have been used to attempt to discriminate Gulf and Atlantic stocks of king mackerel. Available information comes from studies with various goals, methods, and study durations. The Assessment Workshop concurred with the Data Workshop that no consistent stock allocation was evident from the various studies. The Assessment Workshop Panel also concurred with the Data Workshop that studies should be continued to provide additional information on stock mixing rates, and to evaluate consistency in results between years. The Assessment Workshop did conclude that some mixing occurs, particularly during the November-March period when catches from the mixing area (Collier/Monroe County to Volusia County) have historically all been assigned to the Gulf stock. The assessment working group therefore decided it was likely that (1) less than 100% of the mixing area fish in November-March were from the Gulf stock and (2) less than 100% (and less than 98%) of those fish were Atlantic stock.

The Assessment Workshop reviewed and discussed two types of analyses to address the mixing effects. The primary set alternately assigned catches within the mixing zone to Gulf or Atlantic stocks. The secondary set of analyses used simultaneous virtual population analyses linked with tagging data; this set of analyses was considered a sensitivity case.

5.1.2. Data Sources for Assessments

5.1.2.1. Growth

Otolith data from 1986-2002 were analyzed to estimate stock- and sex-specific von Bertalanffy growth curves. Brooks and Ortiz (2004) estimated growth curves for the Atlantic (12,159 otoliths) & Gulf of Mexico (17,813 otoliths) and compared them to previous work by Collins et al. (1988; 683 otoliths in the Atlantic) and Manooch et al. (1987; 210 otoliths in the Gulf of Mexico). Growth curves were used to assign ages to harvest in the absence of an age-length key for the harvest stratum.

For both Atlantic and the Gulf of Mexico, sex-specific growth curves predicted larger sizes at the youngest ages compared to earlier studies. There are many methodological and sampling differences between the early studies and the present study. Both of the early studies fit the growth model to average weighted back calculated length at age, whereas this study fit the growth model to the recorded integer age and fork length. For this study and Collins et al. (1988), age was determined from reading otolith sections, while Manooch et al. (1987) determined age from whole otoliths, which has been shown to underestimate the age of older fish (Devries and Grimes 1997). The distribution of sample ages was very different between the early studies and the present study. The maximum ages sampled from the Gulf of Mexico (Manooch *et al*. (1987) were 14 and 11 for females and males, respectively, compared to 24 and 23 for females and males, respectively, in this study). Sample maximum ages for the Atlantic (Collins et al. (1988) were 21 and 16 for females and males, respectively, compared to ages 26 and 24 for females and males, respectively, in this study). These data and methodology differences could influence the estimated growth curves.

5.1.2.2. Gulf of Mexico Model Inputs

Inputs for the new Base04 Gulf assessment were primarily based on those used in the 2002 assessment (Ortiz *et al.* 2002). The following adjustments were made:

1. U.S. commercial landings, recreational catches, and size-frequency data for calendar years 1997, 1998, 1999, 2000, 2001, and 2002 were updated.
2. Age-length keys for fishing year 2000/2001 and 2001/02 were added. Those keys were derived using procedures described in Ortiz (2004a) with restrictions on minimum sample size per bin but without the minimum overall sample size used by Ortiz for that simulation study.
3. The age-length data base for 1997/98-1999/2001 was modified based on corrections made to the age data base. These keys were also derived using procedures described in Ortiz (2004a) with restrictions on minimum sample size per bin but without the minimum overall sample size used by Ortiz for that simulation study.
4. Indices of abundance were updated and components of the partial catch-at-age were modified based on corrections made to the age data base.

Catches since 1981/82 range from a high of 12.3 million pounds in 1982/83 to a low of 3.0 million pounds in 1987/88 Table 12 and Figure 3). Landings generally increased after 1986/87 and exceeded TAC until recent years

Catch ages used for the single stock analyses included ages 0 through 11+. Both catches from the directed fisheries and shrimp bycatch (age 0) were included.

For the Gulf of Mexico stock the natural mortality rate was assumed to be 0.2. The ten standardized indices listed below were used to tune the analyses:

<u>Fishery Independent Indices</u>

- NMFS's bycatch estimates as index of age 0 fish
- Southeast Area Monitoring and Assessment Program's (SEAMAP) ichthyoplankton catch rates as an indirect measure of spawning stock biomass

Fishery Dependent Indices

- Southeast Florida headboat catch rates (ages 2-6)
- 2 Texas Parks and Wildlife catch rates (ages 2-8, one for 1983-1985 and one for 1986-2001)
- Marine Recreational Fishery Statistics Survey (MRFSS, Florida) total catch rates (ages 2-8)
- Northwest Florida charterboat catch rates (ages 2-6)
- Southwest Florida charterboats (ages 3-8)
- Northwest Florida commercial (ages 3-6)
- Southwest Florida commercial catch rates (ages 3-8)

5.1.2.3. Atlantic Model Inputs

Basic inputs to the Atlantic stock assessment used for these analyses were as described in Ortiz *et al.* (2003) and modified by the MSAP (2003).

Catches since 1981/82 range from a high of 9.6 million pounds in 1985/86 to a low of 5.7 million pounds in 1999/00 (Table 13 and Figure 4). In recent years, TAC has been set at 10.0 million pounds, but landings have only been between 50 and 74% of TAC since the 1999/00 fishing year.

Consistent with the conclusions of the MSAP in 2003, the catch at age included ages 1-11+; small and variable catches of age 0 king mackerel from the directed fisheries were excluded. Consistent with recent MSAP analyses the highly variable estimates of age 0 bycatch from the Atlantic shrimp fishery were not included.

For the Atlantic stock the natural mortality rate was assumed to be 0.15.

The five standardized relative abundance indices listed below were computed from catch per unit effort (CPUE) data obtained from multiple sources and used as tuning analyses in the base VPA model.

- One fishery independent index
    - A standardized index was developed from the Southeast Area Monitoring and Assessment Program's (SEAMAP) shallow trawl survey catch rates as a fishery-independent index of age 0 fish. Since age 0 fish were excluded, this index was modified and used as an index of age 1 abundance.
- Four fishery-dependent standardized indices
    - Florida Fish and Wildlife Conservation Commission Marine Fisheries Trip Ticket Program (ages 1-11)
    - Marine Recreational Fishery Statistics Survey (MRFSS) (ages 1-11)
    - NMFS Beaufort Laboratory Headboat Survey (ages 1-11)
    - NC Commercial CPUE 1981-1996

5.1.3. Single Stock Model Configuration

The Assessment Workshop adopted configurations for the Gulf of Mexico and Atlantic king mackerel VPAs used in recent years.

For the Gulf King VPA tuning analyses, an 'equal' weighting option with normal error assumption for all indices of abundance available, with the same age(s) coverage and time of year application as presented in the indices section was adopted. The VPA model estimated nine fishing mortality rates in the last year, corresponding to ages 2 through 10, with fixed F ratios for ages 0, 1 and 11+. F ratios were defined as: F_0/F_2 =1.7, F_1/F_2 =0.33 and F_{11}/F_{10} =1.0.

For this Gulf king 2004 stock assessment, updated commercial and recreational catch data were available for calendar years 1997, 1998, 1999, 2000, 2001, and 2002 that were unavailable for the year 2000 stock assessment. Thus, the catch at age (CAA) was updated for fishing years 1997-98 through 2001-02. For fishing years 1981-82 to 1996-97 the CAA was the same as in the 2000 stock assessment. The corresponding Partial CAA (1997-98 to 2001-02) was also updated for the following indices of abundance: the FL-FWC_NW, FL-FWC_SW, Headboat, MRFSS, and TX-PWD. The proportion of directed catch by age for the commercial and recreational sectors was also estimated from the average of CAA by sector for fishing years 1997-2001.

For Atlantic king mackerel VPA tuning analyses, the 2003 MSAP adopted the model with maximum likelihood (ML) estimates option and normal error assumption for all five indices of abundance available, not including bycatch estimates, and for ages 1 through 11+. The 2003 VPA model estimated eight fishing mortality rates in the last year, corresponding to the age classes 2 through 9, with fixed F ratios for F_1, F_{10} and F_{11+}. F ratios were defined as: F_1 = 0.4716 of F_2, F_{10}=1.0 of F_9 and F_{11+} = 1.0 of F_9. F ratio for age 1 was estimated using separable VPA algorithm (SVPA), with the 1997-2001 catch at age as input.

5.1.4. Uncertainty and Measures of Precision

As in the past, the stock status estimates were sources of uncertainty. Management benchmarks were derived using a mixed Monte Carlo-Bootstrap approach that accounted for variability in natural mortality, tuning indices, and numbers of fish-at-age. For the Gulf of Mexico stock the model used a uniform probability distribution for natural mortality rates from 0.15 to 0.25 per year, centering on 0.2 per year while for the Atlantic stock the model used a uniform probability distribution for natural mortality rates from 0.10 to 0.20 per year, centering on 0.15 per year.

6. Stock Assessment Results

6.1. Estimated Growth Curves

6.1.1. Atlantic Migratory Group

The approximate 95% confidence interval for predicted length at age encompassed the growth curve of Collins et al. (1988) for both female and combined sex growth curves. The male Collins et al. (1988) growth curve fell below the predicted 95% confidence interval for ages 0-5, with the difference ranging from 3 - 29 mm FL.

The male Collins et al. (1988) growth curve fell below the predicted 95% confidence interval for ages 0-5, with the difference ranging from 3 - 29 mm FL below the lower CI. The new male growth curve estimates that a 600 mm fish retained in the fishery would average just over 1 year of age, while Collins' growth model would estimate that fish at about 3 years of age.

The female Collins et al. (1988) growth curve was contained within the 95% CI of the new growth function. However, the new estimates of age at length also varied remarkably from those of Collins et al (1988).

6.1.2. Gulf of Mexico Migratory Group

The approximate 95% confidence interval for predicted length at age contained the combined sex growth curve of Manooch et al. (1987). However, the predicted length at age 0 for the Manooch et al. (1987) female growth curve was 10 mm below the lower 95% confidence interval. For males, the predicted length at age 0 was 100 mm less, and at age 1 was 40 mm less than the predicted lower 95% confidence interval.

The new female growth curve estimates that a 600 mm fish retained in the fishery would average less than 1 year of age, while Manooch's growth model would estimate that fish at about 2 years of age. A similar difference (about 1 year) is also estimated for the 1000 mm fish.

6.1.3. Comparison of Growth Between Migratory Groups

When the respective sex-specific growth curves from the Atlantic and Gulf of Mexico were overlaid, the curves overlapped at the younger ages but diverged for the older, larger individuals. Fish in the Gulf obtained larger maximum size. The 95% confidence intervals for predicted size at age from each stock contained the mean predicted size at age of the other stock. These confidence intervals contain the uncertainty in the estimated growth parameters as well as the variance of the error. In assigning otolith samples to stocks, the current seasonal/spatial rules were retained. Future research could be aimed at examining what fraction of the sampled otoliths came from the mixing area, and whether the stock assignment could be blurring distinctions between the two stock's growth curves.

6.1.4. Further Evaluation of Alternative Growth Models

After the presentation of SEDAR5 AW-1 (Brooks and Ortiz 2004), the panel made the following requests:

1. In trying to explain why the growth curves of Manooch et al. (1987) and Collins et al. (1988) predict a smaller size for the younger ages, it was suggested that perhaps the change in minimum size was responsible. A minimum size of 20 inches fork length was enacted in December 1992. Prior to that, a 12 inch minimum size was

in effect. The panel requested that the data be split into periods before and after the change in minimum size, and the resulting growth curves be compared.

2. To follow through on recommendations from the SEDAR5 Data Workshop, it was recommended that a comparison of the new growth model be made to the growth models estimated by DeVries and Grimes (1997).

The resulting plot of predicted length at age between the two time periods used to analyze the effect of minimum size change showed that slightly smaller sizes were predicted for the youngest ages using the time period before the 20 inch minimum size (approximately 50 cm fork length) (Figure 5 and Figure 6). However, even the new growth models for the time period prior to the change in minimum size predict a greater size at age for the youngest age classes when compared to the earlier growth models of Manooch et al. (1987) and Collins et al. (1988). It does not appear that the change in minimum size explains why there are differences in predicted size at the youngest ages. As noted in the discussion, both of the early studies fit the growth curve to back calculated length at age. Thus, there is a methodological difference in how the curves were calculated. As shown in Figure 7 and Figure 8 (Figures 6 and 8 in Brooks and Ortiz 2004), the age composition of the data sets was different. It is not known what the year distribution of samples is for the earlier studies and whether fractional ages were assigned based on marginal increments. The current study used integer ages. The use of fractional ages could be expected to shift the predicted size at age downward, but further study is required to determine the most appropriate way of incorporating fractional ages.

The impact of applying the updated growth models on estimated catch at age was also examined. The result was a shift towards greater numbers of the youngest age classes (ages 0 – 2), and a decrease of about one year in the full selectivity age. In years and cells where age-length keys were not applied, the use of the new growth equation increased the estimate of fish harvested in the first couple years of life (SEDAR5-AW1 Figure 12, SEDAR5-AW3 Figures 1 and 2 show this most clearly for the years 1981-82 through 1985-86). However, the overall effect is to reduce total numbers of fish < age 4 harvested, and increase the proportion of fish assigned older ages (Figure 8).

In response to the second request, the growth models estimated from the years 1986-1992 were plotted against the growth models of DeVries and Grimes (1997). The early time period was selected because the data used by DeVries and Grimes (1997) spanned the years 1986-1992. The DeVries and Grimes (1997) curves show a slightly smaller predicted size at the youngest ages but otherwise the curves largely overlap (Figure 11). The slight differences between the curves can probably be ascribed to differences in the way age was treated—DeVries and Grimes (1997) used quarterly ages whereas this study used integer age. There may be other differences between the two studies, but a detailed discussion with the authors would be needed to determine this. Further research is suggested to determine the most appropriate way to treat the otolith data with regard to fractional age.

6.1.5. Examination of Catch at Age (CAA) from Age Length Keys and Growth Curves

The panel also made the following request:

For years where an age length key (ALK) was predominately applied, the predicted CAA should be compared with the SAR method using the new growth model.

In response, predicted CAA between the ALK approach and the SAR approach were compared with the new growth model using data from the years 1995-2000 in the Gulf of Mexico. During this time period, the ALK was applied exclusively in years 1996-1999, and in the years 1995 and 2000 a mixture of the ALK and the SAR (using Manooch et al. growth parameters) was applied (Figure 9). When the SAR with the new growth model was applied, the estimated age distribution included a higher fraction of age 0 and age 1 fish compared to the CAA using existing methods. Although this result shows the difference between the ALK and the SAR methods, it does not reflect the difference between the growth models Figure 10 (Figure 11 in Brooks and Ortiz 2004).

6.2. Model Results (Estimates and Measures of Precision)

6.2.1. Base 2004 Gulf of Mexico Assessment

6.2.1.1. Comparison Between the 2002 and 2004 Assessments

The 2004 CAA input is listed in Table 14 (also Table 3 in Ortiz, 2004a) and the relative proportion of CAA by year is depicted in Figure 12 (Figure 3 in Ortiz 2004a). The 2004 CAA show a catch distribution at age analogous to the 2000 CAA rather than the 2002 CAA distribution. The changes in proportion at age between the 2002 CAA and the 2004 CAA matrices are listed in Table 15.

6.2.1.2. Base 2004 Gulf of Mexico Estimated Abundance

The estimated historical abundances for ages 0-2, 3-6 and 7-11+ from Ortiz (2004a) are shown in Figure 36.

6.2.1.3. Base 2004 Gulf of Mexico Estimated Selectivity

The selectivity patterns estimated from the 2000, 2002 and 2004 assessments as shown in Ortiz (2004a) are compared in Figure 14.

6.2.1.4. Base 2004 Gulf of Mexico Estimated Fishing Mortality Rates

The estimated historical fishing mortality rates from Ortiz (2004a) are shown in Figure 37.

6.2.1.5. Base 2004 Gulf of Mexico Estimated Spawning Stock Biomass

The estimated historical spawning stock biomass estimates from Ortiz (2004a) are shown in Figure 28.

6.2.1.6. Comparison of the 2002 and 2004 Estimates of Status in the Gulf of Mexico

The above adjustments in the Base04 Gulf assessment resulted in an overall lower F and higher spawning stock biomass when compared to the 2002 Gulf assessment (Figure 13 (Figure 8 and Table 10 in the 2002 assessment). Changes in the bench marks resulted from the above adjustments (Figure 15; Figure 18 in Ortiz 2004a).

6.2.1.7. Sensitivity of Gulf Assessment to Changes in Catch at Age Matrix

When 286 fish (less than 1%) were added to the age-length keys during the 2002 stock assessment, the overall estimated age distribution changed because the size of these "new" fish corresponded to the tails of the distribution. This change indicated that the procedure for estimating the CAA matrix was sensitive to how the inputs were constructed.

Additional evidence of CAA matrix input sensitivity was revealed during the present assessment when other CAA construction criteria were used to develop an automated approach to matching the ALK to catches. Application of those alternative criteria resulted in even more changes to estimates of fishing mortality and spawning stock biomass trends (SEDAR5-02).

The major changes explored in the alternative construction of the CAA matrix in the 2004 stock assessment were 1) fish of both sexes were combined when determining whether there were sufficient samples to develop sex specific age-length keys (since sex is an unknown at time of sampling), 2) minimum number of age samples for use with the ALK was set at 400 (both sexes combined; this resulted in all western Gulf fish in 1981-1985 being aged with the stochastic algorithm), and 3) minimum bin size for including an age sample in a sex specific ALK was increased from 10 fish to 15 fish for smaller sized fish (bins of the oldest fish were not combined to due to greater inherent error created by combining fish of a greater age range).

Clearly the impact of criteria (e.g., minimum sample number and minimum fish number for each size bin, etc.) chosen for construction of a CAA matrix need to be further evaluated through sensitivity analyses using simulated data of known characteristics to determine robustness of alternative CAA matrices on stock status estimates.

6.2.2. Base 2004 Atlantic Assessment

During revision and update of the 2003 Atlantic mackerel stock assessment it was found that some bootstrap runs provided unreasonable solutions, as indicated by extremely high fishing mortality estimates. Modifications were implemented in the FADAPT bisection algorithm to ensure that diverging solutions (divergence from an initial estimate toward unreasonably high F values at an upper limit boundary) were not accepted. Results indicated that changes were marginal (not significantly different from the existing benchmarks) and were located primarily in the upper tail of estimated ABC and MSY distributions (Table 16 and Table 17 (or in SFD 2004--Tables 16, 16A, 17, and 17A respectively).

6.2.2.1. Base 2004 Atlantic Estimated Abundance

The estimated historical abundances of Atlantic king mackerel are shown in Figure 38. These were created from the revised base Atlantic assessment results presented in SEDAR5-AW5.

6.2.2.2. Base 2004 Atlantic Estimated Fishing Mortality Rates

The estimated historical fishing mortality rates of Atlantic king mackerel are shown in Figure 39. These were created from the revised base Atlantic assessment results presented in SEDAR5-AW5.

6.2.2.3. Base 2004 Atlantic Estimated Abundance

The historical estimates of biomass of Atlantic king mackerel are shown in Figure 40. These were created from the revised base Atlantic assessment results presented in SEDAR5-AW5.

6.2.3. Gulf and Atlantic Assessments Using Alternative Assumptions about Catch Composition in the Mixing Area

The terms of reference for the Assessment Workshop required that the implications of mixing on estimated resource status and management benchmarks should be examined. One approach discussed by the panel suggested investigating the effects of alternative assumptions about the catch proportion assigned to each stock in the mixing area during November-March. Currently 100% of that catch is assigned to the Gulf of Mexico stock.

The geographic and monthly distributions of landings from the mixing area as recorded in log books during November-March in 1998-2002 was reviewed (Figure 41). The workshop noted that similar levels of catches were taken from most strata, and that there appeared to be some indication of king mackerel moving in and out of the area.

Effects were examined assuming that 75%, 50%, 25% and 2% of fish in the mixing area during November-March in 1998-2002 were Atlantic stock rather than Gulf of Mexico stock. Historical abundance patterns and fishing mortality rates were not examined for each treatment for each stock. Results with respect to management benchmarks were examined and are presented below (Section 7).

6.2.4. Simultaneous Assessments with Mixing

The Assessment Workshop was requested to provide ABC estimates based on alternative mixing rates between Gulf and Atlantic migratory groups. Several different analyses were presented and discussed, with a variety of mixing rate estimates. Available information includes a review of stock structure analyses by DeVries (2003 – SEDAR5-DW5), and an additional draft report by Patterson et al. (SEDAR5-DW11).

Several methods have been used to attempt to discriminate Gulf and Atlantic king mackerel stocks. These studies have varied in goals, methods, and study duration. The Assessment Workshop reviewed available information, and concurs with the Data Workshop that no consistent stock allocation is evident from the various studies. The Assessment Workshop also concurs with the Data Workshop that studies, especially otolith microchemistry and shape analysis, should be continued to provide additional information on stock mixing rates and to evaluate consistency in results between years.

Diaz (2003, SEDAR5-DW9) described the results of a long-term tag-recapture project based on data recorded in the SEFSC Cooperative Tagging Center database (Figure 16-Figure 19). Porch and Diaz (2004, SEDAR5-AW4) further used the tag-recapture data and a two-area VPA (VPA-2Box, Porch 2003b: Porch 2003a SEDAR5-DW10) to estimate mixing magnitude, along with the effect of changes in mixing proportions on Gulf and Atlantic management unit estimates. Based on Data Workshop recommendations, Porch and Diaz (2004, SEDAR5-AW4) utilized the overlap rather than diffusion model, only used tag recoveries where anchor tags were used, and only used tags from mackerel that were at liberty over 90 days. Some of these decisions could have influenced VPA outcome, but the magnitude and direction of those potential influences is unknown.

The two-area VPA was first run applying various overlaps to each stock using only catch and abundance index data, without applying tag-recapture data. The best fits were obtained when zero stock overlap was assumed (Figure 20 (Figure 3 in Porch and Diaz 2004, SEDAR5-AW4)). Moreover, estimated overlap rates were not significantly different from zero when tagging data were not considered. However, indices of abundance alone did not generally provide much discriminatory power in regards to the magnitude of overlap, particularly when the two stocks are similar in abundance, as in this case.

Tagging data suggested some degree of intermixing or problem in boundary line placement, since fish tagged from one stock (Atlantic stock, for example) were often recaptured in the other stock (Gulf stock) (See Figure 16-Figure 19). Many of the recaptured fish that moved from one stock to the other were originally tagged in the mixing zone (not distributed across the stock range).

The two-area VPA was also run with tagging data in addition to catch and abundance indices. When overlap was set to zero, the model provided a poor fit to the tag-recapture data (Figure 21; Figure 4 in Porch and Diaz 2004). When overlap was estimated, the model predicted that about 12% of the 1-4 year old Gulf stock overlapped into the Atlantic, and about 5% of the 1-4 year old Atlantic stock overlapped into the Gulf. Approximately 5% of the 5-11 year old (spawning age) Gulf stock overlapped into the Atlantic and 14 % of the 5-11 year old (spawning age) Atlantic stock overlapped into the Gulf. It is possible that larger, older, northern Gulf of Mexico fish (> age 4) may be less prone to seasonal movement between stocks, since a relatively large proportion are found in the northern Gulf of Mexico during winter compared to summer.

The last four years of the two-area VPA (1998-2001) data were the most poorly estimated. Excluding those years, the Assessment Panel agreed that the inclusion of tagging data and estimates of degree of overlap has a relatively minor impact on the assessment results. Nevertheless, it was pointed out that the estimates of overlap from this analysis are not consistent with the hypothesis that 100% of the fish in the mixing area belong to the Gulf migratory group. Given the similar estimates of abundance for the two migratory groups, they are rather more consistent with the hypothesis that the Gulf group fraction in the mixing area is between 25% and 75%.

It was recognized that the two-area model is a simple simulation that assumes mixing occurs throughout the range of both stocks. Assessment Workshop participants concurred that a more realistic approach would be a three-area model, in which the mixing zone is modeled separately and mixing only occurs within its boundaries. This might best be accomplished by developing a forward projecting statistical model.

7. Biological Reference Points

7.1. Existing Definitions and Standards

7.1.1. Overfished

Compatible with the Technical Guidelines, minimum stock size threshold (MSST) recommended by the MSAP for mackerels is (1-M)*B_{MSY} (i.e., spawning stock biomass that can support MSY but reduced by the natural mortality rate [M]). Both the SAFMC and GMFMC have accepted this definition of MSST for Atlantic and Gulf king and

Spanish mackerels. Thus, MSSTs for Gulf and Atlantic king mackerel migratory groups are specified as 80% and 85%, respectively, of spawning stock biomass that will support MSY. The determination of whether or not spawning stock size has fallen below MSST (i.e., whether or not the stock is overfished) depends on the acceptable level of risk chosen by the respective Council. The GMFMC has adopted a 50% (median) probability that a given stock's biomass is less than MSST as an acceptable risk level and that risk level is used here to evaluate stock status relative to MSST for Gulf mackerel migratory groups. The SAFMC has not specified an acceptable risk level, but a 50% probability was also used to evaluate stock status relative to MSST for Atlantic mackerel migratory groups.

7.1.2. Overfishing

The GMFMC and SAFMC specified $F_{30\%SPR}$ as a proxy for F_{MSY}. Therefore, the maximum fishing mortality threshold (MFMT) for both king mackerel migratory groups is defined as $F_{30\%SPR}$. When a stock or migratory group is not overfished, the act of overfishing is defined as harvesting at a rate that exceeds MFMT; however, the determination of whether or not overfishing is occurring depends on the acceptable level of risk chosen by the respective Council. The GMFMC has adopted a 50% (median) probability that a fishing mortality for a given stock is greater than MFMT as an acceptable risk level, and that risk level is used here to determine whether MFMT was exceeded (i.e., overfishing occurred) for Gulf mackerel migratory groups. The SAFMC has not specified an acceptable risk level, but a 50% probability was also used to evaluate whether overfishing occurred for Atlantic mackerel migratory groups.

7.1.3. Target Optimum Yield (OY)

The SAFMC and GMFMC have established OY for Atlantic and Gulf king mackerel as the long-term yield associated with $F_{40\%SPR}$ when a stock is at equilibrium. The Assessment Workshop Panel recommended ABC for each of these stocks based on the median probability of achieving this target level. For the Gulf mackerel migratory group, the Assessment Workshop Panel also provided the GMFMC with an estimate of the yield that would result in a 50% probability of not exceeding the yield at $F_{30\%SPR}$.

7.1.4. Rebuilding Program

When a stock or migratory group is overfished, a rebuilding program that makes consistent progress toward restoring stock condition must be implemented and continued until the stock is rebuilt to a biomass level that supports MSY. The rebuilding program must be designed to achieve recovery within an acceptable time frame specified by the Councils. The Councils will continue to rebuild the stock until the stock biomass is restored to greater than B_{MSY} within an unspecified time frame (Amendment 8).

7.2. Estimation Methods, Uncertainty, Risk and Probability

Virtual population analysis (VPA) (FADAPT 3.0; Restrepo 1996) was performed for Atlantic and Gulf king mackerel migratory groups to evaluate stock status relative to SFA benchmarks (Ortiz 2004a, b, SEDAR5-AW3; SEDAR5-AW5). As in past stock status evaluations for these stocks, uncertainty was incorporated into assessment estimates with a mixed Monte Carlo-Bootstrap approach that accounted for variability in natural mortality, tuning indices, and numbers of fish-at-age in the catch. For the current assessment of Gulf of Mexico king mackerel, the particular inputs and model assumptions used (following prior recommendations of the MSAP) are described in Ortiz 2004a (SEDAR5-AW3). For Atlantic king mackerel, a revised assessment was conducted using the same inputs and assumptions as applied by MSAP 2003 (Sustainable Fisheries Division 2003), but with a correction made to an algorithm used in the search method designed to avoid estimation of highly unlikely outcomes. The estimate changes resulting from the bootstrap procedures applied to the 2003 Atlantic king mackerel assessment were described in SEDAR5-AW5 (Sustainable Fisheries Division 2004). Outcomes from model runs (bootstraps) were used to construct probability distributions of fishing mortality rate (F) and spawning stock size (B) estimates for the most recent year in the assessments. Estimates of F and B from each model run were expressed as ratios with F_{MSY} and B_{MSY}, and stock condition was evaluated based on the percentage of ratios that were greater that MFMT and/or less than MSST. The Technical Guidelines (Restrepo *et al*. 1998) recommended that managers (*i.e.,* the Councils) choose low levels of risk as a precautionary approach, such as allowing only 20-30% of outcomes to exceed MFMT or fall below MSST. Following this logic, the MSAP recommended to the GMFMC in March 2001 that the probability of B measuring less than MSST or F measuring greater than MFMT should not exceed 30%. However, the GMFMC has adopted the 50% probability level as acceptable risk and stock status is evaluated in this document based on that risk level.

The Assessment Workshop Panel, following the MSAP practice, recommended ABC for each mackerel migratory group based on the probability a given yield will achieve a reference target (F_{OY}) or exceed a reference threshold (F_{MSY}) in a subsequent fishing year. The inclusion of probability statements, although conditional to the particular data-model set, is intended to portray the risk associated with a given conclusion or action, reduce reliance on point estimates, and better represent the imprecision and uncertainty of parameter estimates. The approach followed by the Assessment Workshop Panel, which is consistent with Standard 1 of the SFA and the Technical Guidelines (Restrepo *et al.,* 1998), is to recommend an ABC for each stock that has a median probability of achieving F_{OY}.

The Assessment Workshop Panel noted that methods applied for estimation and characterization of uncertainty do not capture total uncertainty in the assessment. Notably, methods for incorporating uncertainty in estimates of catch at age, especially for the historical part of the time-series, are not fully considered in stock status evaluations. Work conducted by the Assessment Workshop Panel indicates that this source of uncertainty could have additional measurable impact on projected ABC levels for these stocks. Research is needed to further evaluate and more fully incorporate this uncertainty into analytical methods for assessment and projections.

7.3. Results

7.3.1. Atlantic Migratory Group

Bootstrap based estimates of stock status and productivity measures of interest for the Atlantic stock of king mackerel are shown in Table 18.

7.3.1.1. Estimated $F_{2002/03}/F_{MSY}$

The revised median estimate of F/F_{MSY} for Atlantic king mackerel was 0.52 for fishing year 2002/03 and the percentage of estimated $F_{2002/03}/F_{MSY}$ greater than 1.0 was 1% (3 of 500 boots) (Figure 22, Panel A). Based on the estimated low likelihood that current F exceeds MFMT, the Assessment Workshop Panel's estimation is that overfishing did not occur in 2002/03 for Atlantic king mackerel.

7.3.1.2. Estimated B_{2003}/B_{MSY}

The revised median estimate of B_{2003}/B_{MSY} for Atlantic king mackerel was 1.22 and the estimated percentage of B_{2003} less than MSST was 2% (12 of 500 boots) (Figure 22, Panel B). Based on the estimated low likelihood that current B is less than MSST, the Assessment Workshop Panel estimates Atlantic king mackerel were not overfished in 2002/03.

7.3.1.3. Discussion of Stock Status

Landings of Atlantic king mackerel have been lower than TAC in every year but two since the 1986/87 fishing year (Table 13; Figure 4). In recent years, TAC has been set at 10.0 million pounds, but landings have only been between 50 and 74% of TAC since the 1999/00 fishing year. Estimated Atlantic king mackerel stock size has increased since the mid 1990s but not to the higher levels seen in the early 1980s. Recently, recruitment has trended downward (Figure 23).

Current estimates indicate the fishing mortality rate of Atlantic king mackerel in fishing year 2002/03 was below MFMT and the spawning biomass is above MSST at the beginning of fishing year 2003 (*i.e.*, less than 50% of B_{2003} estimates are less than MSST) (Figure 24). Therefore, the Assessment Workshop Panel considers Atlantic kings were not overfished and overfishing was not occurring in fishing year 2002/03.

7.3.1.4. Allowable Biological Catch (ABC*)*

The SAMFC's stated objective is to select a TAC for Atlantic king mackerel that has a median probability of achieving its management target, OY, defined as the yield associated with a fishing mortality rate of $F_{40\%SPR}$. Therefore, the MSAP recommends ABC for 2005/06 as the median estimate of catch at $F_{40\%SPR}$, which is 5.8 million pounds

(20^{th} - 80^{th} percentile range = 4.5 – 7.7 million pounds) (Figure 25). Yields above 5.8 million pounds would exceed 50% probability of future F> $F_{40\%SPR,}$ conditional on projection assumptions.

7.3.2. Gulf Migratory Group

7.3.2.1. Estimates of $F_{2002/03}/F_{MSY}$

The median estimate of F/F_{MSY} for Gulf king mackerel was 0.82 in 2002/03 (Figure 26) and the percentage of estimated $F_{2002/03}/F_{MSY}$ greater than 1.0 was 17% (86 of 500 boots). Based on the acceptable risk level chosen by the GMFMC, that there should be no greater than a 50% probability that current F exceeds MFMT, the Assessment Workshop Panel's estimation is that overfishing did not occur in 2002/03 for Gulf king mackerel.

7.3.2.2. Projections of B_{2003}/B_{MSY}

The median estimate of B_{2003}/B_{MSY} for Gulf king mackerel was 0.95 and the estimated percentage of B_{2003} less than MSST was 18% (88 of 500 boots) (Figure 27). Based on the acceptable risk level chosen by the GMFMC, which states that there should be no greater than a 50% probability that current B is less than MSST, the Assessment Workshop Panel estimates Gulf kings were not overfished at the start of the fishing year 2003. Although the stock is not estimated to be overfished, since 18% of B_{2003} estimates are below MSST, it has yet to fully rebuild to B_{MSY} after being overfished. Currently, 61% of the bootstrapped outcomes indicate $B<B_{MSY}$. (Note: According to the criteria recommended by the GMFMC, the stock would not be considered rebuilt to B_{MSY} until there is at least a 50% probability of B > B_{MSY}.)

7.3.2.3. Discussion of Stock Status

Landings of Gulf king mackerel have been lower than TAC since 1997 (

Table 12). This is due in part to the fact that the GMFMC increased TAC in 1997 from 7.8 to 10.6 million pounds; however, recent landings have declined regardless of the TAC limit. Lower landings resulted in lower fishing mortality projections, hence spawning biomass projections increased (Figure 28 (Taken from Figure 13 of Ortiz 2004a)). Increasing spawning stock biomass also reflects year classes with somewhat higher than average recruitment moving through the fishery; however, as noted in the MSAP's 2002 Report, year classes with somewhat lower recruitment may now be entering the fishery and subsequent spawning stock biomass may decline. The potential for this to occur will increase if landings are approximately equal to current TAC. Current estimates indicate the fishing mortality rate on Gulf king mackerel in fishing year 2002/03 was below MFMT and the spawning biomass is above MSST at the beginning of fishing year 2003 (*i.e.,* less than 50% of B_{2003} estimates are less than MSST) (Figure 29). Therefore, the Assessment Workshop Panel considers Gulf kings were not overfished and overfishing did not occur in fishing year 2002/03.

7.3.2.4. Allowable Biological Catch (ABC)

Given the GMFMC's objective not to exceed MFMT ($F_{30\%SPR}$), the Assessment Workshop Panel recommends the Council select a TAC that is consistent with OY, which is defined by the GMFMC as yield associated with a fishing mortality rate of $F_{40\%SPR}$. Therefore, for the 2005/2006 fishing year the Assessment Workshop Panel recommends an ABC of 8.3 million pounds (20^{th} - 80^{th} percentile range = 6.7 – 10.2 million pounds). The rationale behind this recommendation is that an ABC of 8.3 million pounds has a 50% probability of achieving the OY target (yield at $F_{40\%SPR}$), but a low probability (about 12%) that it will exceed MFMT ($F_{30\%SPR}$) (Figure 30). This value is lower than current TAC, but is consistent with recent landings (Table 12). Clearly, the lower TAC is set, the lower the probability of overfishing during the 2005/06 fishing year.

7.3.3. Mixing Zone Alternatives

Available data on mixing combined with available assessment methodology are insufficient to identify specific mixing rates most appropriate for estimating stock abundance and projection of allowable catch levels. Joint analysis of tagging and catch-effort data for the Gulf and Atlantic Migratory Groups (Porch and Diaz 2004, SEDAR5-AW4) indicate that mixing could result in approximately equal catches from either stock within the mixing zone. Considering the uncertainties associated with this form of analysis, the Assessment Workshop Panel considers that the analysis and supporting microconstituent and otolith shape analysis information could be consistent with a relatively broad range of mixing scenarios. For the purpose of advising the Councils on possible mixing scenario impacts on perceived stock productivity, status, and ABC calculations, the Assessment Workshop Panel considered assessments assuming different catch levels of Gulf stock fish from the mixing zone ranging from 100% (status quo) to 2%. However, attention was focused on scenarios for which 25% to 75% of catch within the mixing area during November-March was assumed to be from the Gulf Migratory Group. Methods used for this evaluation are based on VPA methodology used by the MSAP to monitor rebuilding of Gulf king mackerel and to provide advice on Atlantic king mackerel management (see Ortiz 2004, SEDAR5-AW53, Legault 1998, MSAP/98/10). The current application of methods described by Porch and Diaz (2004, SEDAR5-AW-4) was judged to be inappropriate for evaluations of recent stock status and for projecting ABC due to the instability in recent abundance estimates, especially in the unrealistically high recruitment estimates which may have impacted estimates of older age fish for the most recent analysis years.

7.3.3.1. Stock Status and Productivity Implications

Bootstrapped stock status estimates for Gulf and Atlantic king mackerel stocks under the mixing scenarios modeled are shown as phase plots in Figure 31. In general, the results indicate that estimates of Gulf group stock status are more sensitive than the Atlantic group with assumed lower proportions of mixing area catch indicating higher probability of the stock undergoing overfishing and being in an overfished state (Table 19 – P(B<MSST), P(F>MFMT)).

Estimates of SFA-related parameters (proxies for MSY, B_{MSY}, $F_{MSY,}$ OY, B_{OY} and F_{OY}) for the scenarios evaluated are provided in Table 18 and compared in Figure 32. Considering the uncertainty in the estimates, fishing mortality rate benchmarks are insensitive to mixing proportion assumptions. However, estimates of long-term productivity (proxies for MSY, OY) and estimates of spawning abundance which could support these yield levels (proxies for B_{MSY}, B_{OY}) do change with reduction in assumed proportion of Gulf group fish catch from the mixing zone. Considering the uncertainty in the estimates (Figure 32), the sensitivity of these benchmarks for the Gulf group is more apparent than for the Atlantic group. When all other variables are held constant, reduced levels of historical catch for the Gulf group result in lower estimates of MSY, OY, and the associated equilibrium biomasses (Figure 32).

The current king mackerel management regime (and recent recruitment estimates) seems to be allowing Gulf stock biomass to increase, while Atlantic stocks remain approximately stable. This condition may allow additional time to collect more information, and if necessary conduct further studies to develop a more supportable estimation of mixing rates.

7.3.3.2. ABC Implications

Cumulative probability plots for projected yields associated with MFMT ($F_{30\%SPR}$) and F_{OY} ($F_{40\%SPR}$) for fishing year 2003 are shown in Figure 33 for the Atlantic and Gulf groups under each of the mixing scenarios considered. As above, the projected ABC levels for the Gulf group show somewhat greater sensitivity to the assumptions about different assumed mixing levels than do those for the Atlantic group (Figure 34). Should the Councils desire to account more directly for mixing in the TAC setting, these results indicate the allowable catch levels should be more conservatively established for the Gulf group than is implied solely on the basis of the status quo assessment and projection method currently in use.

While the Assessment Workshop Panel was unable to select the most appropriate form of mixing analysis based on available data, the information available to the group indicated that mixing scenarios within the range of 25% to 75% Gulf group catch from the mixing zone appeared more consistent with the tagging data interpretation than either the status quo assumption or the assumption of only 2% of the catch from the Gulf group during the entire assessment time period. The Panel examined a range of ABC estimates based on bootstrap results from the 25%, 50%, and 75% Gulf group catch scenarios, combined. Bootstrap results from these 3 scenarios were combined by assigning the 50% scenario to be twice as likely as either the 75% or 25% scenarios and computing the associated cumulative probabilities over yields associated with $F_{30\%SPR}$ and $F_{40\%SPR}$ for fishing year 2003. Results of this calculation provide some qualitative guidance on the degree of conservatism that might be employed in TAC setting for the Gulf group and are shown in Figure 35. Alternatively, should the Councils later determine that alternatives to the modeled scenarios are more appropriate, Figure 34 can be used to interpolate.

8. Research Recommendations

Currently, it is only possible to model two stocks using tagging data to model mixing rates (Porch 2003). In the long term the Data Workshop and Assessment Panels recommend that assessment models be developed which can model multiple stocks and/or areas and which can use multiple types of data that enable mixing rate estimations (including tagging data and biological tags including elemental and isotopic composition, genetic information and morphological information).

8.1. Assessment Data Needs

- Available growth data needs to be evaluated for improved application to historical catch at age.
- Available sex ratio at size data needs to be evaluated to determine how sex ratios vary by size.
- Methods that allow for including error estimates in the catch at age matrix need to be developed.
- Continued evaluation of tag data, ongoing otolith microchemistry and shape analysis studies, and microsatellite genetic marker data to improve estimation of stock structure and mixing proportions.
- Field studies are needed to develop or improve batch fecundity, spawning frequency, and age specific fecundity estimates, including size and age at maturity.
- Western Gulf king mackerel catches need to be aged for use in age length key analyses.

8.2. Assessment Modeling Needs

Sensitivity of CAA and management benchmarks to changes in the growth model used in the stochastic ageing procedure need to be evaluated.

A three-area age structured model with forward projection formulation may result in better estimation of the impact on stock status of mixing zone dynamics using existing tagging data and most recent recruitment estimates.

Sensitivity runs considered in this assessment indicate two areas where additional research is critically needed to improve stock status evaluation. The Assessment Workshop Panel advises that stock assessment uncertainty will not be reduced until these issues are resolved.

These two areas are:

1) Methods used to allocate catches to age class when samples are inadequate for constructing age-length keys. Sensitivity runs based on alternative growth models suggest that estimates of stock status are sensitive to differences in growth models when they are used to estimate age from size in the absence of an ALK. The raw data used to develop the historical growth models (Manooch *et al.* 1987; Collins *et al*. 1988) are no longer available, and thus it may not be possible to provide the type of identical analyses of current and historic data that are necessary to evaluate whether growth model differences are simply due to analytical technique or whether the differences truly reflect changes in growth over time. The Panel recommends that current growth data (1987 onward) be modeled with increased resolution to refine growth model parameters. Specifically, decimal rather than integer ages should be modeled, and attention should be paid to collection date, birth date, and annulus formation date.

2) Sensitivity analyses of stock mixing impacts on stock status determination. Results suggest that the assumed degree of stock mixing has relatively equivalent impacts on the perceived productivity of each migratory units, but divergent impacts on stock status determination. The estimated status of the Gulf of Mexico Migratory Unit is strongly influenced by mixing assumptions, while status determination of the Atlantic Migratory Unit varies minimally. Both the Data and Assessment Workshop Panels devoted significant discussion and effort toward resolving stock allocation within the mixing zone. Based on Data Workshop recommendations, the SEFSC reconsidered mixing rates through updated analyses of tag data, developed an alternative assessment framework to incorporate tag-based stock mixing estimates into a VPA framework, and developed stock estimates with the base assessment configuration for a variety of mixing rates within the mixing zone. However, none of these efforts have led to a consensus recommendation on the actual level of stock mixing.

The Assessment Workshop Panel believes that analyses of otolith shape and microchemistry, as presented in the progress reports discussed at the Data Workshop, offer a promising approach to resolving stock mixing. The Assessment Workshop Panel strongly recommends that this work be continued for several additional years to increase sample size, continually improve the resolution of the method, and better account for potential annual variation in mixing. The Panel also recommends increased sampling intensity within the mixing zone, with sample allocation that is representative of the fine-scale geographic distribution of the catch within the mixing zone. Also an effective tagging program designed specifically to address the mixing issue could increase the quality and quantity of available data.

9. Literature Cited

Anonymous. 2004. SEDAR5 Atlantic and Gulf of Mexico king mackerel stock assessment report—draft 1, Data workshop – 1/17/04. 26 pages.

Anon. 2003. Stock assessment analyses on Spanish and king mackerel stocks. Sustainable Fisheries Division Contribution No. SFD-2003-008. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA .

Brooks, E. N. and M. Ortiz. 2004. Estimated von Bertalanffy growth curves for king mackerel stocks in the Atlantic and Gulf of Mexico. NMFS, SEFC, Sustainable Fisheries Division Contribution SFD – 2004-05. SEDAR5 AW-01. 24 Pages.

Collins, M.R., D.J. Schmidt, C.W . Waltz, and J.L. Pickney, 1989. Age and growth of king mackerel, Scomberomorous maculates, from the Atlantic coast of the U.S. Fish. Bull. 98(1):49-61.

DeVries, D.A. 2003. A review of the stock structure of king mackerel off the southeastern U.S. Mackerel SEDAR Data Workshop Report SEDAR5-DW5. NMFS, SEFC, Panama City Laboratory, 3500 Delwood Beach Road, Panama City, Florida 32408.

DeVries, D.A, C.B. Grimes, and M.H. Prager. 2002. Using otolith shape analysis to distinguish eastern Gulf of Mexico and Atlantic Ocean stocks of king mackerel. Fisheries Research 57:51-62

DeVries, D.A., and C.B. Grimes. 1997. Spatial and temporal variation in age and growth of king mackerel, Scomberomorus cavalla, 1977–1992. Fishery Bulletin 95:694–708.

Diaz, G. A. 2003. Preliminary analysis of king mackerel tag data from the Cooperative Tagging Center. SEDAR5-DW9. 11 pages. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA

Finucane et al. 1986

GMFMC. 2003. A framework seasonal adjustment of harvest procedures, reference points, and status criteria under the Fishery Management Plan for Coastal Migratory Pelagic Resources in the Gulf of Mexico and South Atlantic Region. GMFMC, Tampa FL.

Gledhill, C.l T. and J. Lyczkowski-Shultz. 2000. Indices of larval king mackerel (Scomberomorus cavalla) abundance in the Gulf of Mexico for use in population assessments. Fishery Bulletin 98: 684-691.

Hoenig, John. 1980. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 1980.898-903.

Johnson, A.G., W.A. Fable Jr., M.L. Williams, and L.E. Barger. 1983. Age, growth, and mortality of king mackerel, Scomberomorus cavalla, from the southeastern United States. Fish. Bull. 81(1):97-106.

Legault, C. M. 1998. What if mixing area fish are assigned the Atlantic migratory group instead of the Gulf of Mexico migratory group? MSAP/98/10. . NMFS SEFSC Miami Sustainable Fisheries Division Contributions MIA-97/98-18. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA

Legault, C.M., M. Ortiz, G.P. Scott, N. Cummings and P. Phares. 2000. Stock assessment analyses on Gulf of Mexico king mackerel. MSAP/00/02. NMFS SEFSC Miami Sustainable Fisheries Division Contributions 99/00-83. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA

Lyczkowski-Shultz, J. and D. S. Hanisko. 2003. A general description of the SEAMAP larval king mackerel dataset with updated indices of larval occurrence and abundance, 1982 to 2000. NOAA/NMFS/SEFSC Mississippi Laboratories. Pascagoula Facility, Pascagoula, MS. SEDAR5-DW-4.

Manooch, C.S., S.P. Naughton, C.G. Grimes, and L. Trent. 1987. Age and growth of king mackerel from the U.S. Gulf of Mexico. Mar. Fish. Rev. 49(2):102-108.

MSAP (Mackerel Stock Assessment Panel) 2002. 2002 Report of the Mackerel Stock Assessment Panel. Prepared at meeting held May 26-28, 2002. Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council.

MSAP. 2003. 2003 Report of the Mackerel Stock Asessment Panel. Prepared by the Mackerel Stock Assessment Panelat the Panel Meeting Held May 19-21, 2003 in Miami, Florida. SEDAR5-DW2 Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council.

Nobel, Elizabeth, B. Linda P. Mercer, and Randall W. Gregory. 1992. Migration, age and growth, and reproductive biology of king mackerel (Scomberomorus cavalla) in North Carolina. Study 1 in Completion Report for Project –F/29. N. C. Dept. Env. Health, and Nat. resc., Div. Mar. Fish. 79 pp.

Ortiz, M. 2002. Estimates of Gulf king mackerel bycatch from the U.U. Gulf of Mexico shrimp Gulf trawl fishery. Southeast Fisheries Science Center, SFD-01/02-162.

Ortiz, M. 2003. Standardized catch rates of king mackerel (Scomberomorus cavalla) and Spanish mackerel (S. maculatus) from U.S. Gulf of Mexico and south Atlantic recreational fisheries. Southeast Fisheries Science Center, SFD-02/03-6, 31p.

Ortiz, M. 2004a. Stock assessment analysis on Gulf of Mexico king mackerel. NMFS, SEFC, Sustainable Fisheries Division Contribution SFD – 2004-04. SEDAR5-03. 43 Pages.

Ortiz, M. 2004b. Sensitivity of stock assessment analysis of Gulf of Mexico king mackerel to alternative methods for estimating the historic catch at age matrix 1981-2002. NMFS, SEFC, Sustainable Fisheries Division Contribution SFD – 2004-0?. SEDAR5-02. 39 Pages. . NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA.

Ortiz, M. and P. Phares. 2002. Standardized catch rates of king mackerel (Scomberomorus cavalla) from U.S. Gulf of Mexico and south Atlantic recreational fisheries. Southeast Fisheries Science Center, SFD-01/02-155, 14p.

Ortiz, M., G. P. Scott, N. Cummings and P. L. Phares. 2002. Stock assessment analyses on Gulf of Mexico king mackerel. MSAP/02/01. Sustainable Fisheries Division Contribution No. SFD-01/02- 161. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA.

Patterson, W. F., III, T. R. Clardy, D. A. DeVries, Z. Chen, and C. Palmer. 2003. Draft: Discrimination between Gulf of Mexico and Atlantic Ocean king mackerel with otolith shape analysis and otolith microchemistry: A progress report. SEDAR5-DW11. University of South Alabama, Department of Marine Sciences, LSCB 25, Mobile, Alabama 36688.

Pauly, Daniel. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. int. Explor. Mer, 39(2):175-192.

Porch, C. E. 2003a. A method for analyzing the abundance and mortality of Atlantic and Gulf King Mackerel when the two stocks are presumed to intermix. Sustainable Fisheries Division Contribution No. SFD-2003-0030. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA.

Porch, C. E. 2003b. VPA-2BOX Version 3.01 User’s guide. Sustainable Fisheries Division Contribution SFD-01/02-151. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA.

Porch, C. E. and G. A. Diaz. 2004. Virtual population analyses of Atlantic and Gulf king mackerel using tag-recapture data and alternative models of migration. NMFS, SEFC, Sustainable Fisheries Division Contribution SFD – 2003-0?. SEDAR5-04. 10 Pages.

Restrepo, V.R. 1996. FADAPT 3.0 A Guide. University of Miami, Cooperative Unit for Fisheries Research and Education (CUFER).

Restrepo, V.R., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade and J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Tech Memorandum NMFS-F/SPO-. 54 pp.

Rose, Kenneth

SAFMC. 2000. South Atlantic Fishery Management Council framework seasonal adjustment of harvest levels and related measures under the Fishery Management Plan for the Coastal Migratory Resources of the Gulf of Mexico and South Atlantic Region. SAFMC, Charleston SC

SEAMAP-SA. 2002. Results of trawling efforts in the coastal habitat of the South Atlantic Bight, 2002. South Carolina Department of Natural Resources. Charleston, SC.

SEFSC. 2003. Stock assessment analyses on Spanish and king mackerel stocks. Southeast Fisheries Science Center, Miami, FL, SFD/2003-8

Sustainable Fisheries Division 2004. Revision and update of the stock assessment analyses on Atlantic king mackerel 2003. NMFS, SEFC, Sustainable Fisheries Division Contribution SFD – 2004-0?. SEDAR5-AW05. 16 Pages. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Dr. Miami, Florida 33149 USA

Sustainable Fisheries Division. 2003. Stock assessment analyses on Spanish and king mackerel stocks. Sustainable Fisheries Division No. SFD 2003-008. National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149. 108 pp.

Waltz, Wayne. 1986. Data report on preliminary attempts to assess and monitor size, age, and reproductive status of king mackerel in the South Atlantic Bight. Rpt. Prepared in partial fulfillment of Contract No. 6-35147, sponsored by NMFS, MARMAP Program Office, and the South Carolina Division Marine Resources, 56 pp.

10. Tables

Table 1: Estimated natural mortality parameters (M) for king mackerel based on the Pauly method, by Migratory Unit and sex, for various temperature values.

Migratory Group			Temperature (°Celsius)		Expected M	
	L infinity	k	20	22	20°C	22°C
Male Atlantic	94	0.19	-0.97257	-0.92841	0.366929	0.383499
	127	0.15	-1.21119	-1.16702	0.289036	0.302088
Male Gulf	111	0.14	-1.21876	-1.1746	0.286855	0.299809
	103	0.25	-0.81852	-0.77435	0.428043	0.447372
Female Atlantic	121	0.13	-1.29132	-1.24715	0.26678	0.278827
Female Gulf	142	0.14	-1.28748	-1.24331	0.267806	0.279899
	138	0.17	-1.15247	-1.10831	0.306516	0.320357

Table 2: Summary of weight to length and weight to weight transformations for king mackerel in the southeastern United States.

Study	Geographic Location	Study Period	Fishery	Sex	n	Size Range Length Weight.	A	B	Notes
Beardsley and Richards (1970) Units : FL (cm), Wt (kgs) Length recorded to 1mm Wt recorded to 0.1 pound	Miami, Florida	1968 and 1969	commercial (troll, gnet, purse seine) and recreational tournament samples	Combined	197	58.5-150 1.47-32.09	$2.701 * 10^{-6}$	3.2300	
Beaumariage (1973) Units: SL (mm), Wt (grams)	So Florida (east and west coast)	1968 and 1969	recreational and commercial (troll, purse seine, gnet	Males Females Combined	237 293 530	465-1,030 Sl 879-9.752 g 390-1,590 SL 454-37,195 g 390-1,590 SL 454-37,195 g	$1.330 * 10^{-5}$ $3.907 * 10^{-6}$	2.9372 3.1256	
Fischer (1980) Units: FL (mm), Wt(pounds) and converted to grams for estimation	SE Louisiana	December 1 1977 to November 30 1978	Recreational	Males Females	38 500	Not provided 11-27 Not provided 8-67	$1.922 * 10^{-7}$ $1.002 * 10^{-6}$	3.533 3.291	Size range (wgt) interpolated from Figure 16 of Fischer
Johnson et al. (1983) Units: FL (mm), Wt (grams)	NC, SC, Tx, La, Fl	June 1977-August 1979	recreational hook and line, few small individuals from shrimp trawls (cape Canaveral)	Males Females Combined	701 202 3 282 1	428-1,355 Not provided 351-1,554 Not provided 351-1,554 Not provided	$0.8064 * 10^{-5}$ $0.8801 * 10^{-5}$ $0.8464 * 10^{-5}$	2.9928 2.9827 2.9881	n=20 (or max if <20) per 50mm length interval used in regression
Campbell et al. (1988). Units: TL(mm),Wt(grams) and Wt converted to grams for estimation Relation fit was: log Wt=log a + b Log TL	Galveston Bay, Matagorda/San Antonio Bay, Aransas/Corpus Christi Bay and lower Laguna Madre Bay	1978-1983	recreational creel surveys	Males Females Combined	231 386 133 1	595-1170 Not Provided 614-1440 Not Provided 573-1675 Not Provided	-5.641 -5.428 -5.495	3.114 3.045 3.070	

Study	Geographic Location	Study Period	Fishery	Sex	n	Size Range Length Weight.	A	B	Notes
Campbell et al. (1988). Units: TL(mm), Wt(grams) and Wt converted to grams for estimation Relation fit was: log Wt=log a + b Log FL	Galveston Bay, Matagorda/San Antonio Bay, Aransas/Corpus Christi Bay and lower Laguna Madre Bay	1978-1983	recreational creel surveys	Males Females Combined	199 308 754	515-1050 Not Provided 500-1323 Not Provided 500-1350 Not Provided	-5.322 -4.910 -4.879	3.059 2.921 2.911	
Waltz (1986) Units: Fork length mm WT : grams Relation fit was: log(WT)=b(log (FL mm) - a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	Males Females Combined	418 174 912	Not Provided	4.69 4.65 4.80	2.85 2.85 2.89	
Waltz (1986) Units: Total length mm WT : grams Relation fit was: log(WT)=b(log (TLL mm) -a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	Males Females Combined	164 393 873	Not Provided	5.05 5.33 5.08	2.93 3.03 2.93	
Waltz (1986) Units: Wt 9grams) Relation fit was: log (whole WT)=b(log(Gutted Wt)) - a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	combined	15	Not Provided	169.21	1.11	1.Relation fit: log(whole WT)= b(log(Gutted Wt)) - a

Table 3: Gulf of Mexico King Mackerel reproductive parameters at age.

AGE	FL mm	% Mature	Female Fecundity	Population Eggs 10^6
0	335	0	47269	0.000
1	472	0.157	185947	0.015
2	592	0.529	457773	0.121
3	697	0.704	874959	0.308
4	789	0.856	1428538	0.612
5	869	0.989	2096139	1.037
6	938	1	2849046	1.425
7	999	1	3657394	1.829
8	1052	1	4493458	2.247
9	1099	1	5333418	2.667
10	1139	1	6158047	3.079
11	1174	1	6952705	3.476
12	1205	1	7706939	3.853
13	1232	1	8413894	4.207
14	1256	1	9069662	4.535
15	1276	1	9672663	4.836
16	1294	1	10223076	5.112
17	1310	1	10722368	5.361
18	1323	1	11172892	5.586

Table 4: King mackerel landings (pounds) by migratory group and sector from 1981 to 2002. (2002 data is provisional, and 2001-02 recreational landings were provided in numbers of fish, but not converted to weight units.)

Sum of LB	STOCK	Sector				
	Atlantic		Atlantic Total	Gulf		Gulf Total
YR	Commercial	Recreational		Commercial	Recreational	
1981	2,399,459	3,813,916	6,213,375	6,714,600	5,581,753	12,296,353
1982	3,938,370	5,853,949	9,792,319	4,566,449	8,403,500	12,969,949
1983	2,386,021	6,231,916	8,617,937	4,751,722	2,440,391	7,192,113
1984	1,968,572	6,152,396	8,120,968	3,383,376	3,028,207	6,411,583
1985	2,456,228	7,034,836	9,491,064	3,072,275	1,910,715	4,982,990
1986	2,801,995	5,895,233	8,697,228	2,969,771	1,707,993	4,677,764
1987	3,392,485	4,036,602	7,429,087	1,822,192	3,951,485	5,773,677
1988	3,166,062	4,786,299	7,952,361	1,390,413	4,685,704	6,076,117
1989	2,480,843	3,336,627	5,817,470	1,190,061	2,677,376	3,867,437
1990	2,537,741	3,905,392	6,443,133	2,320,777	3,994,043	6,314,820
1991	2,567,902	5,338,859	7,906,761	1,654,709	4,773,681	6,428,390
1992	2,244,302	6,670,337	8,914,639	2,754,142	3,965,159	6,719,301
1993	2,141,263	4,284,508	6,425,771	3,606,441	7,045,373	10,651,814
1994	2,069,574	3,882,720	5,952,294	2,149,527	5,536,448	7,685,975
1995	2,011,811	4,142,416	6,154,227	2,616,933	7,424,592	10,041,525
1996	2,228,032	3,740,689	5,968,721	2,887,972	6,689,630	9,577,602
1997	3,045,909	5,281,571	8,327,480	3,212,639	7,798,919	11,011,558
1998	2,470,723	4,473,059	6,943,782	3,346,639	5,959,000	9,305,639
1999	2,345,625	3,413,082	5,758,707	3,724,817	4,654,630	8,379,447
2000	2,220,774	5,297,380	7,518,154	2,923,983	4,509,300	7,433,283
2001	1,934,857	4,095,440	6,030,297	2,991,040		2,991,040
2002	246,620	31,132	277,752	1,962,793		1,962,793

Table 5: King Atlantic commercial catch in weight units (pounds) by gear.

Year	Hook & Line	Gillnet	Trawl	Unknown	Haul seine	Purse seine	Drift gillnet
1981	2022794	328227	46446	1992			
1982	2991221	920379	14460	12310			
1983	2060285	305117	9564	11055			
1984	1899448	58923	7533	2668			
1985	2333475	26326	10239	599			85589
1986	2496660	19145	4469	3532			278189
1987	2610318	39295	15081	4354	250		723187
1988	1951661	300561	1816	15938		117577	778509
1989	1759303	13008	5772	1216		7569	693975
1990	2474517	52623	6987	3614			
1991	2536791	25178	812	4393	728		
1992	2205065	33094	1384	4759			
1993	2104924	25797	10118	355	69		
1994	2001024	62315	3489	2273	473		
1995	1942059	62957	144	6651			
1996	2168792	55928	1311	1889	112		
1997	2638529	402616	1542	1960	237	1025	
1998	2374174	89644	1453	5452			
1999	2273268	68143	224	3905	85		
2000	2081850	132957	826	5061	80		
2001	1850966	73326	521	10044			
2002	245527	592		501			

Table 6: King Gulf commercial catch in weight units (pounds) by gear.

Year	Hook & Lin	Gillnet	Purse sein	Trawl	Unknown	Haul seine	Traps & po	Other	Beach sein
1981	3440404	3274196							
1982	2325897	2240552							
1983	2821326	1928100		2296					
1984	2131263	1251630	200	283					
1985	2013731	1058544							
1986	1425903	1511421	32397	50					
1987	1453271	367877	899	145					
1988	934648	455259	375	131					
1989	1189159		902						
1990	1854028	465647	1102						
1991	1426095	228614							
1992	2754142								
1993	2097317	1417378			91746				
1994	2020016	2599			126912				
1995	2243400	373533							
1996	2395831	492141							
1997	2720502	491836			301				
1998	2683589	654720			6807	1523			
1999	2711403	1009135	166	108	3936	69			
2000	2448619	410097		1026	64158	83			
2001	2466484	455726	22	11	68684		77	21	15
2002	1448876	330849		53462	71430			58016	160

Table 7: Number of fish size sampled for king mackerel by sector

	Atlantic		Atlantic Tota	Gulf				Gulf Total
Num Fish	Commercl	Recreatn		Commercl		Recreatn		
Year				EG	WG	EG	WG	
1981	980	2,141	3,121	15,479	84	386	530	16,479
1982		578	578	7,446	548	457	490	8,941
1983	858	902	1,760	7,199	7,961	710	645	16,515
1984	4,447	1,372	5,819	15,021	16,850	1,429	891	34,191
1985	5,059	2,918	7,977	11,840	5,851	690	3,155	21,536
1986	4,548	3,663	8,211	5,883	653	1,116	2,528	10,180
1987	6,785	6,168	12,953	1,872	2,338	3,202	2,399	9,811
1988	6,434	2,500	8,934	1,149	428	1,076	1,959	4,612
1989	5,917	2,131	8,048	1,680	1,389	1,160	1,784	6,013
1990	6,378	2,055	8,433	2,951		1,359	1,086	5,396
1991	8,334	1,959	10,293	3,018	1,789	2,621	1,710	9,138
1992	6,755	2,631	9,386	5,783	3,090	2,124	2,057	13,054
1993	4,401	1,511	5,912	6,671	849	1,475	1,099	10,094
1994	6,632	1,415	8,047	2,288	1,167	1,470	1,519	6,444
1995	2,405	1,583	3,988	4,003	620	923	1,509	7,055
1996	4,374	954	5,328	7,025	330	1,085	1,641	10,081
1997	1,746	2,662	4,408	4,266	370	2,353	1,510	8,499
1998	5,182	1,930	7,112	4,533	37	2,669	1,177	8,416
1999	6,891	1,463	8,354	7,310		2,504	1,338	11,152
2000	7,800	2,136	9,936	6,434	57	3,189	839	10,519
2001	6,313	1,776	8,089	4,315	6	2,506	823	7,650
2002	3,180	853	4,033	4,176	67	1,436	10	5,689
Grand Total	105,419	45,301	150,720	130,342	44,484	35,940	30,699	241,465

Table 8: Sex distribution of king otolith samples for ALK input

	ATL			Eastern Gulf			Western Gulf			Grand Tota
Year	Fem	Male	Unk	Fem	Male	Unk	Fem	Male	Unk	
1986	203	182	146	155	53	26	50	49	17	881
1987	293	205	2	427	164	7	203	131	2	1434
1988	250	196	7	268	97	2	220	99	7	1146
1989	497	339		319	171	31	245	110	1	1713
1990	576	350	41	298	158	5	148	88		1664
1991	527	279	4	849	374	8	252	125		2418
1992	799	478	5	733	319	6	221	140	2	2703
1993	551	353	1	774	379	9	72	68		2207
1994	483	408	4	657	263	6	49	31		1901
1995	353	295	10	728	298					1684
1996	701	267	1	1371	380	8				2728
1997	283	225	23	856	354					1741
1998	545	270	5	422	221	1				1464
1999	503	372	14	391	196					1476
2000	476	234	3	719	172				1	1605
2001	550	271	2	941	772					2536
2002	15	12	4	627	484					1142
rand Total	7605	4736	272	10535	4855	109	1460	841	30	30443

Table 9: Gulf of Mexico King Mackerel migratory unit recreational catch in numbers of fish by mode and year.

Year	Shore	Private	Charter	Headboat	Prv-Chr	Total
1981	81,084	368,506	-	-	218,060	667,650
1982	23,100	680,164	21,476	3,218	183,768	911,726
1983	32,058	217,848	21,476	3,218	49,675	324,275
1984	828	340,458	3,862	7,558	48,006	400,712
1985	-	116,328	4,074	7,000	68,946	196,348
1986	5,862	155,077	43,365	17,228	-	221,532
1987	42,824	315,498	144,449	44,192	-	546,963
1988	23,838	268,402	171,220	11,642	-	475,102
1989	9,818	240,543	93,620	20,469	-	364,450
1990	124,216	264,791	141,068	32,870	-	562,945
1991	125,524	396,237	175,455	30,571	-	727,787
1992	54,086	244,205	163,978	30,079	-	492,348
1993	63,930	250,735	346,102	34,082	-	694,849
1994	67,512	193,908	356,936	35,836	-	654,192
1995	16,626	225,044	378,229	35,026	-	654,925
1996	7,704	177,114	508,931	39,338	-	733,087
1997	14,222	291,291	393,640	41,796	-	740,949
1998	6,504	197,695	387,682	31,126	-	623,007
1999	25,218	185,970	293,910	28,503	-	533,601
2000	31,034	230,857	240,278	28,503	-	530,672
2001	51,842	184,500	282,005	26,441	-	544,788
2002	33,578	103,737	142,419	10,161	-	289,895

Table 10: Atlantic migratory group king mackerel recreational catch by year and mode.

Year	Shore	Private	Charter	Headboat	Prv-Chr	Total
1981	-	153,400	-	-	263,048	416,448
1982	-	401,126	-	-	208,608	609,734
1983	-	442,928	-	-	226,581	669,509
1984	2,814	403,206	-	-	208,092	614,112
1985	-	269,152	-	-	536,948	806,100
1986	23,232	441,559	189,615	28,183	1,484	684,073
1987	1,570	336,796	199,571	29,424	-	567,361
1988	8,470	307,732	207,668	22,066	304	546,240
1989	5,194	180,949	156,086	24,017	2,492	368,738
1990	17,350	266,131	152,732	27,861	220	464,294
1991	12,600	340,933	195,073	41,292	500	590,398
1992	1,620	400,023	289,246	23,172	1,752	715,813
1993	3,048	194,201	139,130	21,641	-	358,020
1994	10,418	183,700	177,766	25,079	838	397,801
1995	3,426	196,292	245,015	18,703	892	464,328
1996	1,714	166,814	162,999	31,573	1,824	364,924
1997	9,836	230,961	268,948	18,658	1,000	529,403
1998	74,056	187,731	169,136	16,260	1,964	449,147
1999	2,890	216,972	119,432	19,961	370	359,625
2000	2,408	395,354	132,313	19,988	-	550,063
2001	4,866	236,648	85,911	12,485	-	339,910
2002	-	801	1,144	71	-	2,016

Table 11: Number of size samples for king mackerel recreational fisheries by year and mode, Atlantic and Gulf migratory groups

Stock	Year	Other Rec	Headboat	Total
Atlantic	1981	2,141		2,141
	1982	578		578
	1983	902		902
	1984	276	1,096	1,372
	1985	1,382	1,536	2,918
	1986	1,893	1,770	3,663
	1987	5,179	989	6,168
	1988	1,929	571	2,500
	1989	1,606	525	2,131
	1990	1,761	294	2,055
	1991	1,575	384	1,959
	1992	2,246	385	2,631
	1993	1,119	392	1,511
	1994	1,053	362	1,415
	1995	1,249	334	1,583
	1996	882	72	954
	1997	2,164	498	2,662
	1998	1,418	512	1,930
	1999	1,155	308	1,463
	2000	1,739	397	2,136
	2001	1,482	294	1,776
	2002	853		853
Atlantic Total		34,582	10,719	45,301

Stock	Year	Other Rec	Headboat	Total
Gulf	1981	916		916
	1982	947		947
	1983	1,355		1,355
	1984	1,856	464	2,320
	1985	3,451	394	3,845
	1986	2,964	680	3,644
	1987	3,951	1,650	5,601
	1988	2,488	547	3,035
	1989	1,623	1,321	2,944
	1990	1,714	731	2,445
	1991	3,518	813	4,331
	1992	3,213	968	4,181
	1993	1,793	781	2,574
	1994	2,060	929	2,989
	1995	1,475	957	2,432
	1996	1,966	760	2,726
	1997	2,647	1,216	3,863
	1998	3,052	794	3,846
	1999	3,297	545	3,842
	2000	3,642	386	4,028
	2001	2,975	354	3,329
	2002	1,446		1,446
Gulf Total		52,349	14,290	66,639

Table 12: Gulf group king mackerel management regulations and harvest levels. Pounds are in millions.

Fishing Year	ABC RANGE[12] (lbs.)	TAC (lbs.)	Rec. Alloc./Quota[3] (lbs. / numbers)	Rec. Bag Limit[4]	Commercial Allocation	East/West-EC/WC-North-South [5,6]	Annual Harvest Levels		
							Com	Rec	Total
1986/87	1.2-2.9	2.9	1.97	2/3 FL-TX	0.93 :	0.60/0.27 + PS=0.06	1.473	3.269	4.742
1987/88	0.6-2.7	2.2	1.50	2/3 FL-TX	0.70 :	0.48/0.22	0.868	2.145	3.013
1988/89	0.5-4.3	3.4	2.31	2/3 FL-TX	1.09 :	0.75/0.34	1.405	5.276	6.681
1989/90	2.7-5.8	4.25	2.89 / 298,000	2/3 FL-TX	1.36 :	0.94/0.42	1.954	3.360	5.314
1990/91	3.2-5.4	4.25	2.89 / 301,000	2/3 FL-TX	1.36 :	0.94/0.42	1.816	3.951	5.767
1991/92	4.0-7.0	5.75	3.91 / 574,000	2 FL; 2/3 AL-TX	1.84 :	1.27/0.57	2.117	4.773	6.890
1992/93	4.0-10.79	7.80	5.30 / 715,000[8]	2 FL-TX	2.50+0.259 :	1.73+0.259/0.77[7]	3.599	6.258	9.857
1993/94	1.9-8.1[9]	7.80	5.30 / 759,000	2 FL-TX	2.50 :	1.73/0.77	2.572	6.146	8.718
1994/95	1.9-8.1[9]	7.80	5.30 / 768,000	2 FL-TX	2.05+0.300 :	1.73+0.300/0.77[10]	2.901	7.948	10.849
1995/96	1.9-8.1[9]	7.80	5.30 / 629,000	2 FL-TX	2.50 :	1.73/0.77	2.645	6.265	8.910
1996/97	4.7-8.8	7.80	5.30 / 629,000	2 FL-TX	2.50 :	1.73/0.77	2.864	6.933	9.797
1997/98	6.0-13.7	10.6	7.21	2 FL-TX	3.39 :	2.34/1.05	3.445	6.634[1]	10.08
1998/99	7.1-10.8	10.6	7.21	2 FL-TX	3.39	2.34/1.05	3.895	5.235	9.130
1999/00	8.0-12.5	10.6	7.21	2 FL-TX	3.39	2.34/1.05	2.953	4.067	7.020
2000/01	5.5-8.8	10.2	6.94	2 FL-TX	3.26	3.25/1.01-1/04/1.21-0.169/1.04	3.079	5.061	8.140
2001/02	5.3 – 9.6	10.2	6.94	2 FL-TX	3.26	3.25/1.01-1/04/1.21-0.169/1.04	2.932	5.163	8.095
2002/03	5.3 – 9.6	10.2	6.94	2 FL-TX	3.26	3.25/1.01-1/04/1.21-0.169/1.04	3.126	4.764[11]	7.890

KM Gulf footnotes

[1] Fishing year 1979/80 begins on 1 July 1979 and ends on 30 June 1980.
[2] Sums within rows may not appear to equal the total value shown due to rounding of numbers before printing.
[3] Recreational quota in numbers is the allocation divided by an estimate of annual average weight (not used prior to fishing year 1989).
[4] Bag Limit “2/3" means 2 for private boats; for charterboats: 2 with, or 3 without, captain and crew.
[5] E/W com. allocations apply to all legal gears except purse seine in fishing year 1986 and are divided at the FL/AL Border (only H&L and runaround gillnet beginning 1990/91).
[6] East Zone allocations are divided into East Coast FL and West Coast FL, and West Coast FL is divided into North and South subzones.
[7] 0.250 million pounds added to com. allocation for FL east only, opened 2/18/93 - 3/26/93. [8] Bag limit will not be reduced to zero when allocation reached, beginning in fishing year 1992/93.
[9] Panel recommended ABC range changed from 16%-84% to 16%-50% and Gulf Council selected TAC accepting greater than 50% risk level.
[10] 0.300 million pounds added to hook-and-line quota for Florida West Coast subzone.
[11] 2002-03 Recreational landings, in pounds, were estimated from the average of 1999-2001 landings.

Table 13: Atlantic group king mackerel management regulations and harvest. Pounds are in millions.

Fishing Year	ABC RANGE[1] (lbs.)	TAC (lbs.)	Rec. Alloc./Quota[2] (lbs. / numbers)	Rec. Bag Limit	Commercial Allocation	Annual Harvest Levels		
						Com	Rec	Total[3]
1986/87	6.9 -15.4	9.68		3	3.59 (PS=0.40)	2.840	5.980	8.820
1987/88	6.9 -15.4	9.68	6.09	3	3.59 (PS=0.40)	3.453	3.905	7.357
1988/89	5.5 -10.7	7.00	4.40	2 in FL, 3 GA-NC	2.60 (PS=0.40)	3.091	4.881	7.972
1989/90	6.9 -15.4	9.00	5.66 / 666,000	2 in FL, 3 GA-NC	3.34	2.635	3.400	6.036
1990/91	6.5 -15.7	8.30	5.22 / 601,000	2 in FL, 3 GA-NY	3.08	2.676	3.718	6.394
1991/92	9.6 -15.5	10.50	6.60 / 735,000	5 in FL-NY	3.90	2.516	5.822	8.338
1992/93	8.6 -12.0	10.50	6.60 / 834,000[4]	2 in FL, 5 GA-NY	3.90	2.227	6.251	8.477
1993/94	9.9 -14.6	10.50	6.60 / 854,000	2 in FL, 5 GA-NY	3.90	2.018	4.438	6.456
1994/95	7.6 -10.3	10.00	6.29 / 709,000	2 in FL, 5 GA-NY	3.71	2.197	3.728	5.925
1995/96	7.3 -15.5	7.30	4.60 / 454,000	2 in FL, 3[5] GA-NY	2.70	1.870	4.153	6.023
1996/97	4.1 - 6.8	6.80	4.28 / 438,525	2 in FL, 3 GA-NY	2.52	2.702	3.990	6.692
1997/98	4.1 - 6.8	6.80	4.28 / 438,525	2 in FL, 3 GA-NY	2.52	2.684	5.158	7.843
1998/99	8.4 - 11.9	8.40	5.28 / 504,780	2 in FL, 3 GA-NY	3.12	2.549	4.268	6.816
1999/00	8.9 - 13.3	10.0	6.3 / 601,338	2 in FL, 3 GA-NY	3.7	2.238	3.424	5.662
2000/01	8.9 – 13.3	10.0	6.3 / 601,338	2 in FL, 3 GA-NY	3.7	2.073	5.338	7.411
2001/02	8.9 – 13.3	10.0	6.3 / 601388	2 in FL, 3 GA-NY	3.7	2.017	4.037	6.054
2002/03	8.9 – 13.3	10.0	6.3 / 601388	2 in FL, 3 GA-NY	3.7	1.712	4.266[7]	5.978

Table 13 KM Atlantic footnotes

[1] The range has been defined in terms of acceptable risk of achieving the FMP's fishing mortality rate target; the Panel's best estimate of ABC has been intermediate to the end-points of this range.
[2] Recreational quota in numbers is the allocation divided by an estimate of annual average weight
[3] Sums within rows may not appear to equal the total value shown due to rounding of numbers before printing.
[4] Bag limit will not be reduced to zero when allocation reached, beginning fishing year 1992.
[5] Bag limit reduced from 5 to 3 effective 1/1/96.
[6] Estimated catch equal to the recreational allocation of TAC.
[7] 2002-03 Recreational landings, in pounds, were estimated from the average 1999-2001 landings

Table 14: Gulf of Mexico king mackerel commercial catch at age (CAA) matrix directed fisheries.

Fishing Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+
1981-82	65	1446	7242	65376	572111	187534	48128	32219	15491	7458	4108	11624
1982-83	9441	22522	183273	135947	324974	287056	91735	64634	38302	73266	19877	20338
1983-84	82	368	129346	258565	166109	49403	69101	28827	15842	5819	2097	5233
1984-85	38	6669	10386	183855	286885	127509	53807	35385	11628	1915	1946	4027
1985-86	497	10645	41627	39065	190830	150344	80569	17960	8789	6325	4700	9689
1986-87	3577	77665	178847	100524	132548	38378	33590	20219	10150	6203	1307	11567
1987-88	1367	64736	167700	78833	43595	26985	15806	10627	3828	1844	1680	4539
1988-89	771	39373	123181	81653	190716	67345	61996	29372	12207	9957	7529	23230
1989-90	2292	220559	191102	97434	72016	37602	15230	21013	12830	6204	6826	14648
1990-91	7005	78530	199413	223494	78530	39696	34648	14600	12055	14711	2929	13139
1991-92	2218	215542	307759	188532	124847	33281	34331	13481	5645	13850	5807	15702
1992-93	2239	89108	247546	316783	123335	91130	46570	28818	32853	15529	11488	36820
1993-94	5768	168104	212503	190773	162643	78023	30426	28361	25445	15776	4481	29790
1994-95	3389	170473	139494	148795	202540	228711	96235	14868	47589	34305	12395	23399
1995-96	3722	126449	298994	177464	99129	66396	69827	35673	14235	7660	10313	14906
1996-97	649	139544	396921	187029	99113	53908	44443	34766	31014	16136	2421	26210
1997-98	0	64013	268137	322665	170212	97593	43478	43526	40282	27631	10220	22100
1998-99	0	75355	69256	206142	257242	202066	72493	43155	32552	19303	9693	15245
1999-00	0	101883	168150	130783	169522	97896	35710	27065	15657	28828	9467	17407
2000-01	19847	70360	184544	215802	171502	101276	46749	39045	18066	17443	11411	28007
2001-02	0	27175	170035	250317	175475	93506	55949	50200	27313	13846	5774	27485

Table 15: Percent difference of the Catch at age (CAA) 2002 and CAA 2004 matrix distribution by age and fishing year of Gulf king mackerel. Positive values (dark shade) indicate that the numbers at age-year in 2004 CAA matrix were larger than the equivalent values in 2002 CAA. Difference numbers, reflect the update total numbers of catch by fishing year for 1997-98 to 2000-01 compare to values of 2002 CAA matrix.

F Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Diff Numb
1997-98	0.01%	1.25%	8.52%	-0.46%	-2.30%	-1.69%	-1.23%	-1.56%	-1.05%	-0.42%	-0.32%	-0.75%	-2625.12
1998-99	0.00%	-5.52%	0.18%	0.03%	3.96%	5.31%	0.34%	-1.85%	-1.00%	-0.83%	-0.09%	-0.52%	519
1999-00	0.02%	9.15%	1.50%	0.05%	-5.00%	-2.00%	-0.56%	-0.69%	-0.17%	-1.66%	-0.57%	-0.09%	6346.05
2000-01	-2.04%	0.82%	6.06%	3.79%	-1.89%	-2.00%	-0.88%	-0.75%	-0.79%	-0.17%	-0.52%	-1.65%	30235.34

Table 16: (Old values as presented at the MSAP 2003) Maximum sustainable yield (MSY) and optimum yield (OY) related values from the Base model and the Full index model for Atlantic king mackerel 2003 stock evaluation. SS is spawning stock biomass in trillions of yolked eggs, F values are associated with the fully selected age, and yields are given in millions of pounds. 80% confidence intervals generated from 500 bootstrap projections.

Old values as presented at the MSAP 2003

MODEL BASE

	SS MSY	F MSY	MSY	SS OY	F OY	OY
Median	2.681	0.298	5.216	4.190	0.213	5.534
low 80%	0.741	0.257	1.364	3.170	0.182	4.115
upp 80%	4.793	0.359	9.060	9.890	0.256	11.653
Deterministic	2.669	0.271	5.169	3.559	0.193	4.776

MODEL Full Index

	SS MSY	F MSY	MSY	SS OY	F OY	OY
Median	2.573	0.300	5.021	3.901	0.211	5.304
low 80%	0.869	0.262	1.545	3.034	0.186	4.030
upp 80%	3.649	0.353	7.338	6.586	0.254	8.121
Deterministic	2.507	0.269	4.953	3.342	0.189	4.598

Updated values from 2004 assessment

Model Base

	SS MSY	F MSY	MSY	SS OY	F OY	OY
Median	2.937	0.294	5.771	4.122	0.207	5.566
low 80%	1.713	0.253	3.125	3.271	0.178	4.376
upp 80%	4.035	0.344	8.033	5.435	0.243	7.548
deterministic	2.744	0.272	5.398	3.659	0.191	5.004

Model Full Index

	SS MSY	F MSY	MSY	SS OY	F OY	OY
Median	2.584	0.296	5.084	3.704	0.207	5.081
low 80%	1.344	0.262	2.567	3.005	0.183	4.019
upp 80%	3.449	0.343	6.983	4.700	0.237	6.544
deterministic	2.511	0.269	4.957	3.347	0.189	4.601

Table 17: Estimated allowable biological catch (ABC) in millions of pounds for the Atlantic king mackerel 2003/04 fishing year under a projected F of F30%SPR or F40%SPR from the Base and Full index models evaluated. Probability denotes the likelihood of exceeding the desired F mortality rates.

Old values as presented at the MSAP 2003

	Base Model		Full Index Model	
Probability	$F_{30\%SPR}$	$F_{40\%SPR}$	$F_{30\%SPR}$	$F_{40\%SPR}$
50% Median	6.378	4.673	5.750	4.164
10% lower CI	3.872	2.816	3.522	2.581
90% upper CI	16.161	12.151	11.805	8.764

Updated values from 2004 Assessment

	Base Model		Full Index Model	
Probability	$F_{30\%SPR}$	$F_{40\%SPR}$	$F_{30\%SPR}$	$F_{40\%SPR}$
50% Median	6.513	4.778	5.169	3.746
10% lower CI	4.230	3.086	3.262	2.387
90% upper CI	10.693	7.696	7.956	5.728

Table 18: Estimates of SFA-related parameters (proxies for MSY, SSMSY, FMSY, OY, SSOY and FOY) for the mixing scenarios evaluated. Yields (MSY, OY) are in million pounds, Spawning stock (SS) is in trillion eggs.

Model	Glf 100%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	6.39	0.269	11.4	8.524	0.190	10.1
	low 80%	5.56	0.235	9.6	7.436	0.166	8.5
	upp 80%	7.39	0.366	13.6	9.779	0.255	12.1
	deterministic	6.38	0.226	11.3	8.506	0.160	10.0

Model	Atl 0%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	2.92	0.288	5.6	4.354	0.205	5.8
	low 80%	1.50	0.252	2.7	3.396	0.180	4.4
	upp 80%	4.38	0.335	8.5	6.053	0.237	8.2
	deterministic	3.05	0.262	5.9	4.072	0.187	5.4

Model	Glf 75%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	5.86	0.267	10.4	7.852	0.188	9.2
	low 80%	5.11	0.233	8.8	6.826	0.164	7.8
	upp 80%	6.82	0.364	12.2	9.044	0.253	10.8
	deterministic	5.94	0.232	10.5	7.920	0.164	9.3

Model	Atl 25%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	3.34	0.304	6.5	4.670	0.214	6.3
	low 80%	2.26	0.266	4.3	3.721	0.187	4.9
	upp 80%	4.69	0.351	9.4	6.341	0.247	9.0
	deterministic	3.22	0.287	6.3	4.300	0.203	5.8

Model	Glf 50%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	5.36	0.285	9.5	7.147	0.199	8.5
	low 80%	4.74	0.235	8.2	6.356	0.166	7.3
	upp 80%	6.21	0.415	11.4	8.235	0.283	9.9
	deterministic	5.39	0.256	9.5	7.180	0.180	8.4

Model	Atl 50%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	3.77	0.309	7.4	5.113	0.218	6.9
	low 80%	2.71	0.267	4.9	4.135	0.189	5.3
	upp 80%	5.18	0.363	10.5	6.956	0.255	9.7
	deterministic	3.56	0.297	7.0	4.748	0.210	6.4

Model	Glf 25%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	4.97	0.293	8.8	6.635	0.203	7.8
	low 80%	4.36	0.239	7.4	5.831	0.167	6.6
	upp 80%	5.65	0.429	10.3	7.568	0.294	9.0
	deterministic	4.95	0.267	8.7	6.603	0.187	7.7

Model	Atl 75%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	4.18	0.318	8.0	5.751	0.225	7.6
	low 80%	3.10	0.275	5.9	4.541	0.195	5.9
	upp 80%	5.63	0.369	11.1	7.432	0.260	10.3
	deterministic	3.90	0.307	7.6	5.200	0.217	7.0

Model	Glf 2%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	4.58	0.315	8.1	6.107	0.217	7.2
	low 80%	4.03	0.247	7.0	5.371	0.171	6.2
	upp 80%	5.25	0.499	9.6	7.015	0.331	8.5
	deterministic	4.55	0.295	8.1	6.067	0.204	7.1

Model	Atl 98%	SS MSY	F MSY	MSY	SS OY	F OY	OY
	Median	4.16	0.312	8.3	5.609	0.218	7.7
	low 80%	3.34	0.269	6.5	4.601	0.191	6.2
	upp 80%	5.66	0.369	11.5	7.602	0.256	10.5
	deterministic	3.91	0.284	7.9	5.210	0.197	7.3

Table 19: Summary of stock status indicators (relative F and relative Spawning Stocks) for the mixing scenarios considered from 500 bootstraps per scenario.

Stock	Model	Summary of Status Indicator Outcomes		
ATLANTIC	0% MixRun		MODEL 0% Atl fish	
			F/Fmsy	F / Foy
		Deterministic	0.53	0.74
		Percent F2002> F ref	0.2%	7.0%
		N boots F2002 > F ref	1	35
		Percent SS2003< MSST ref	2.0%	
		N boots SS2003 < SS ref	10	
ATLANTIC	25% MixRun		MODEL 25% Atl fish	
			F/Fmsy	F / Foy
		Deterministic	0.51	0.72
		Percent F2002> F ref	0.2%	5.0%
		N boots F2002 > F ref	1	25
		Percent SS2003< MSST ref	3.6%	
		N boots SS2003 < SS ref	18	
ATLANTIC	50% MixRun		MODEL 50% Atl fish	
			F/Fmsy	F / Foy
		Deterministic	0.46	0.65
		Percent F2002> F ref	0.0%	3.0%
		N boots F2002 > F ref	0	15
		Percent SS2003< MSST ref	3.8%	
		N boots SS2003 < SS ref	19	
ATLANTIC	75% MixRun		MODEL 75% Atl fish	
			F/Fmsy	F / Foy
		Deterministic	0.42	0.59
		Percent F2002> F ref	0.0%	0.8%
		N boots F2002 > F ref	0	4
		Percent SS2003< MSST ref	3.0%	
		N boots SS2003 < SS ref	15	
ATLANTIC	98% MixRun		MODEL 98% Atl fish	
			F/Fmsy	F / Foy
		Deterministic	0.45	0.66
		Percent F2002> F ref	0.0%	2.2%
		N boots F2002 > F ref	0	11
		Percent SS2003< MSST ref	9.2%	
		N boots SS2003 < SS ref	46	

Stock	Model	Summary of Status Indicator Outcomes		
GULF	100% MixRun		MODEL 100% Gulf fish	
			F/Fmsy	F / Foy
		Deterministic	0.82	1.16
		Percent F2002> F ref	17.2%	70.4%
		N boots F2002 > F ref	86	352
		Percent SS2003< MSST ref	17.6%	
		N boots SS2003 < SS ref	88	
GULF	75% MixRun		MODEL 75% Gulf fish	
			F/Fmsy	F / Foy
		Deterministic	0.89	1.26
		Percent F2002> F ref	36.4%	87.0%
		N boots F2002 > F ref	182	435
		Percent SS2003< MSST ref	30.2%	
		N boots SS2003 < SS ref	151	
GULF	50% MixRun		MODEL 50% Gulf fish	
			F/Fmsy	F / Foy
		Deterministic	1.04	1.48
		Percent F2002> F ref	56.0%	95.0%
		N boots F2002 > F ref	280	475
		Percent SS2003< MSST ref	43.6%	
		N boots SS2003 < SS ref	218	
GULF	25% MixRun		MODEL 25% Gulf fish	
			F/Fmsy	F / Foy
		Deterministic	1.17	1.68
		Percent F2002> F ref	74.0%	99.0%
		N boots F2002 > F ref	370	495
		Percent SS2003< MSST ref	49.4%	
		N boots SS2003 < SS ref	247	
GULF	2% MixRun		MODEL 2% Gulf fish	
			F/Fmsy	F / Foy
		Deterministic	1.31	1.90
		Percent F2002> F ref	87.6%	100.0%
		N boots F2002 > F ref	438	500
		Percent SS2003< MSST ref	59.8%	
		N boots SS2003 < SS ref	299	

11. Figures

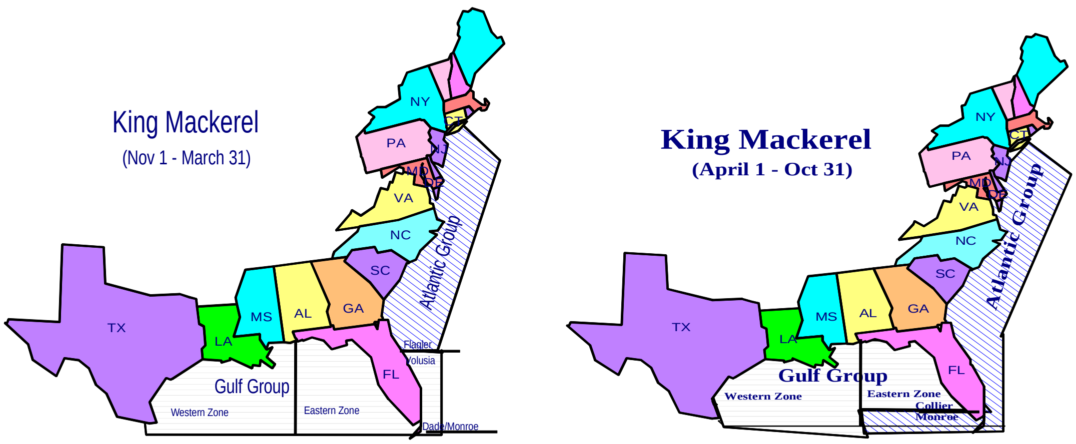


Figure 1: King Mackerel Migratory Groups and seasonal boundaries, and Gulf Migratory Group regional zones

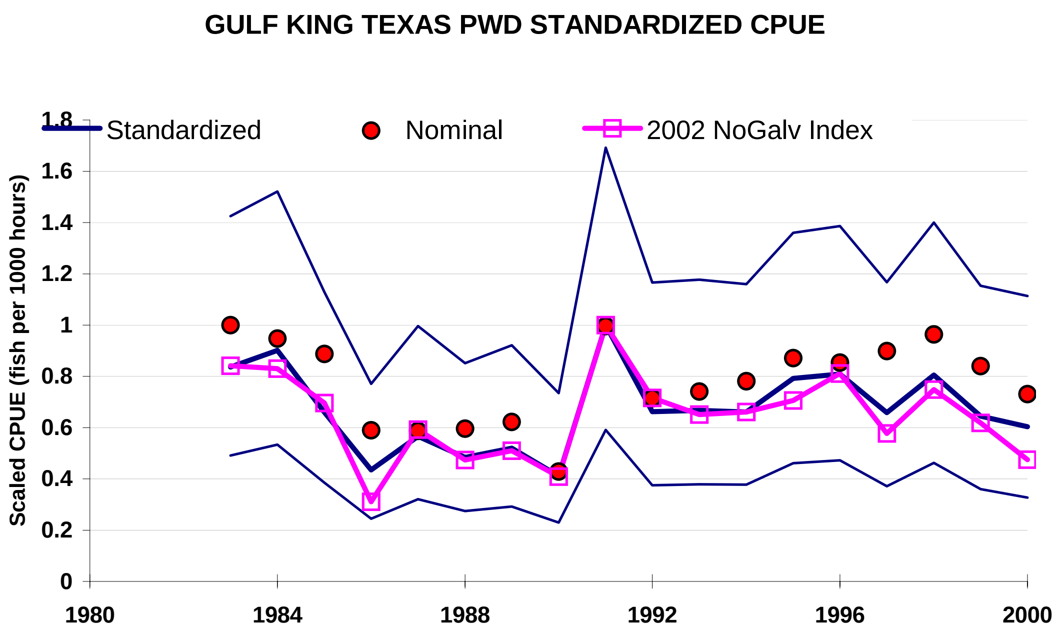


Figure 2: Comparison of indices developed from Texas PWD data with (standardized) and without (2002 NoGalv Index) information from off the Galveston area. 95% confidence intervals about the index including the Galveston area data.

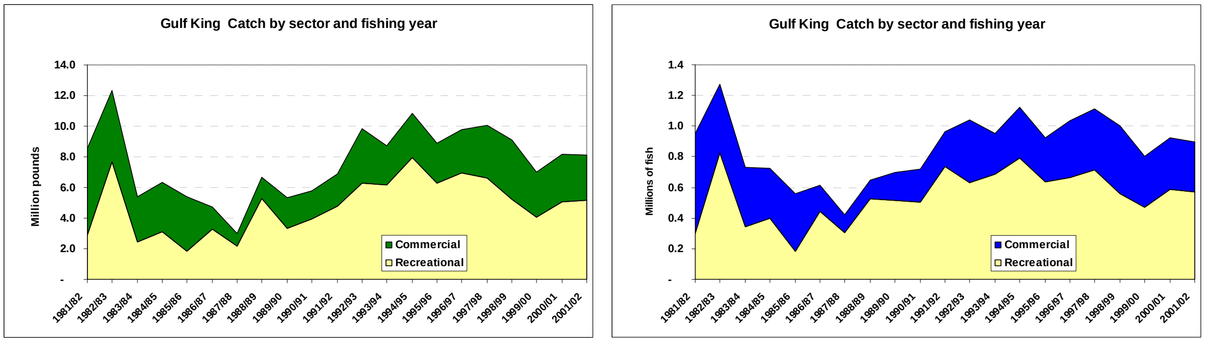


Figure 3: Gulf king mackerel migratory group historical landings by fishing sector in pounds and number of fish

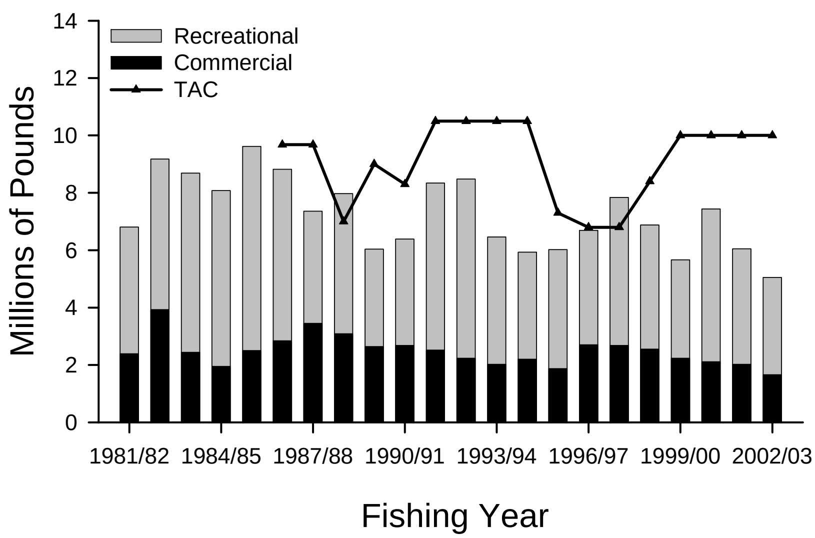


Figure 4: Atlantic king mackerel TAC and commercial and recreational landings

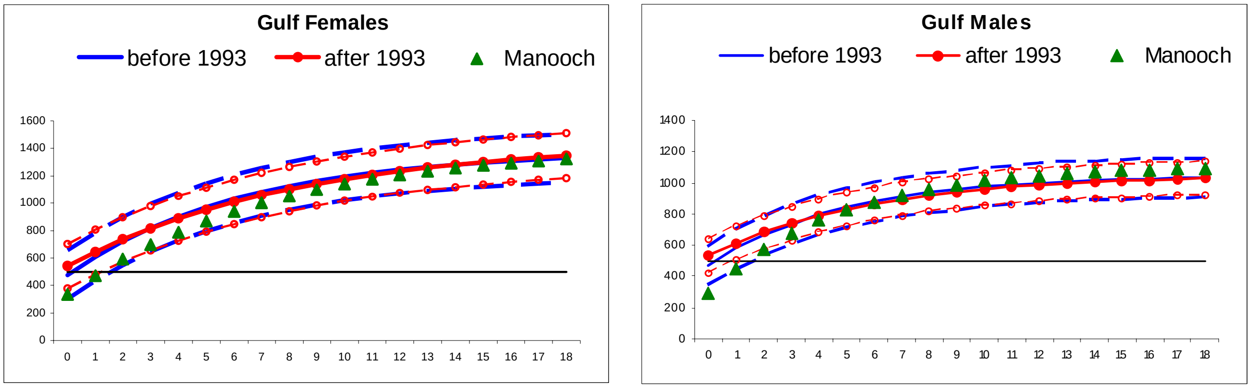


Figure 5: Comparison of predicted length at age before and the change to a minimum size of 20 inches forklength (500 mm forklength, thin horizontal black line) in the Gulf of Mexico

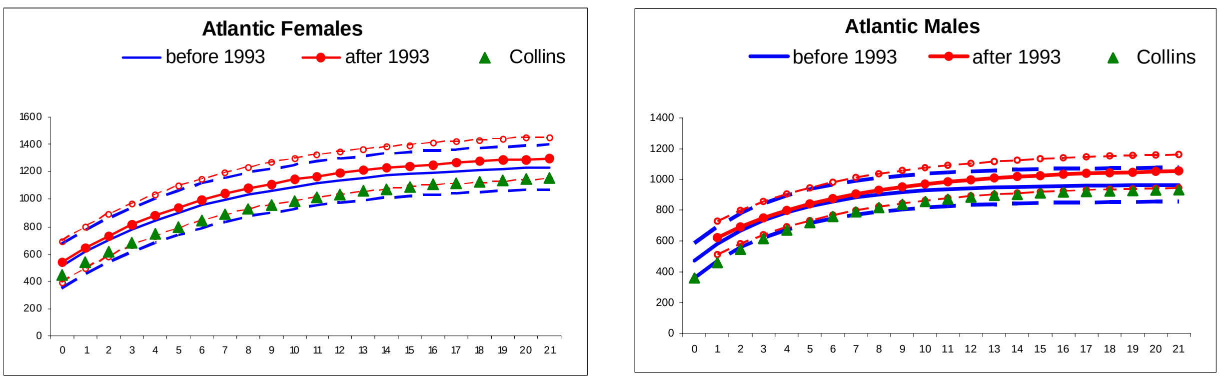


Figure 6: Comparison of predicted length at age before and the change to a minimum size of 20 inches forklength (500 mm forklength, thin horizontal black line) in the Atlantic

Panel A Panel B

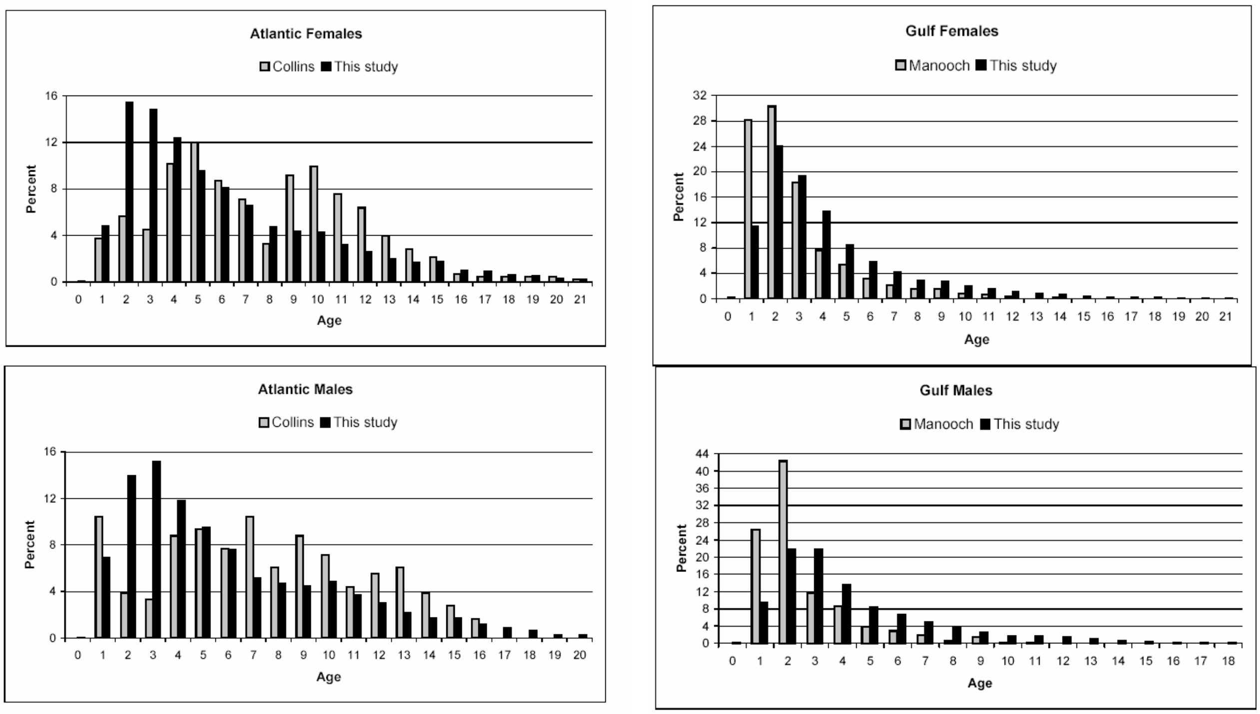


Figure 7: Age distribution of otolith samples from the ALK study versus Collins et al. (1989) for Atlantic fish (Panel A) and versus Manooch et al. (1987) for Gulf fish (Panel B)

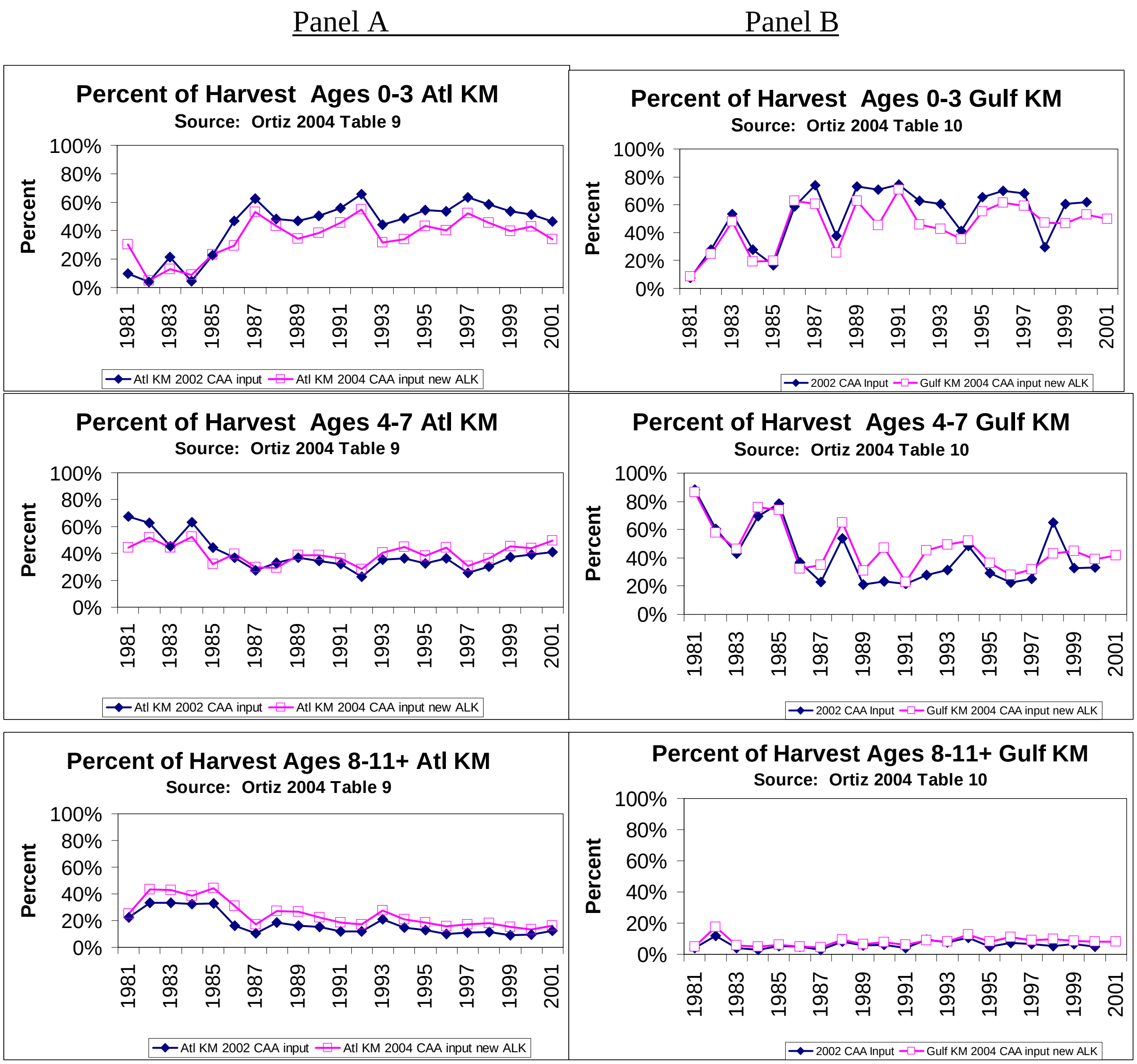
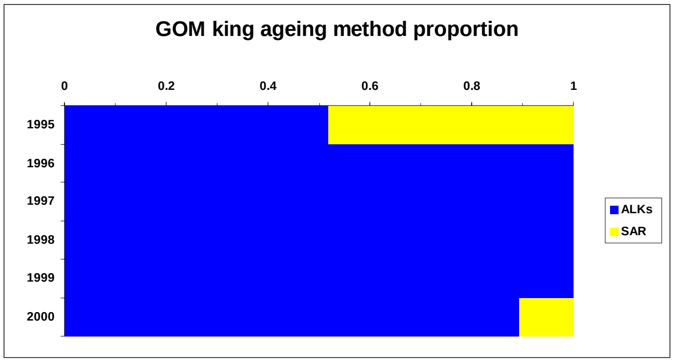
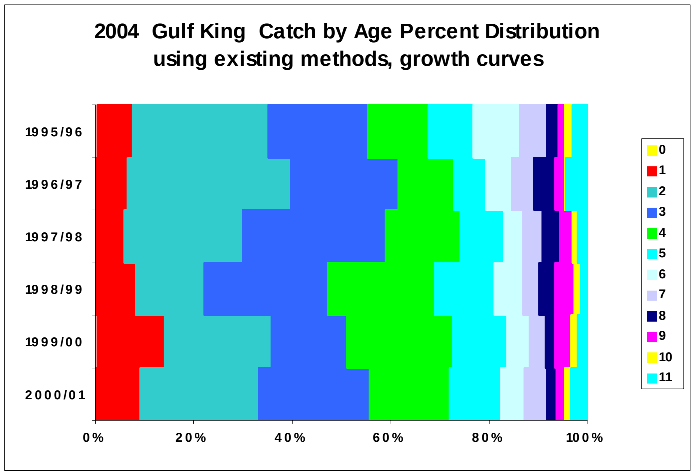


Figure 8: Proportion of Atlantic and Gulf King Mackerel harvested in ages 0-3, 4-7, and 8-11+ for the 2002 CAA estimates (diamonds) and the 2004 CAA estimates with the new growth equation, additional age-length key information, and revised binning criteria (boxes).





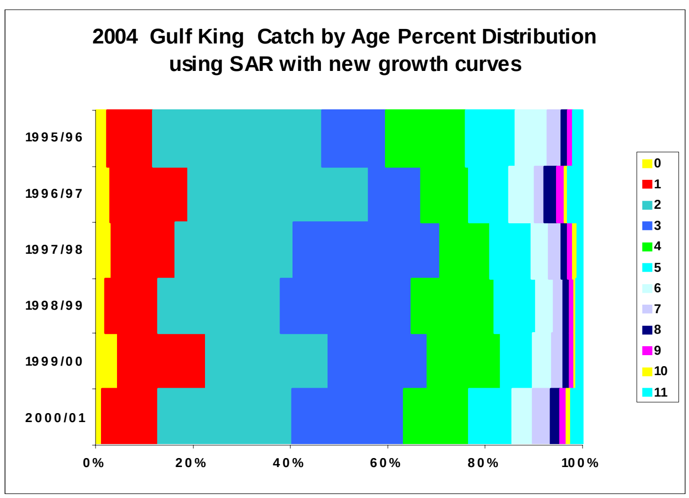


Figure 9: Comparison of age distribution in the estimated CAA (bottom two panels) using existing methods and growth curves or using the stochastic aging routine (SAR) exclusively with the new growth parameters.

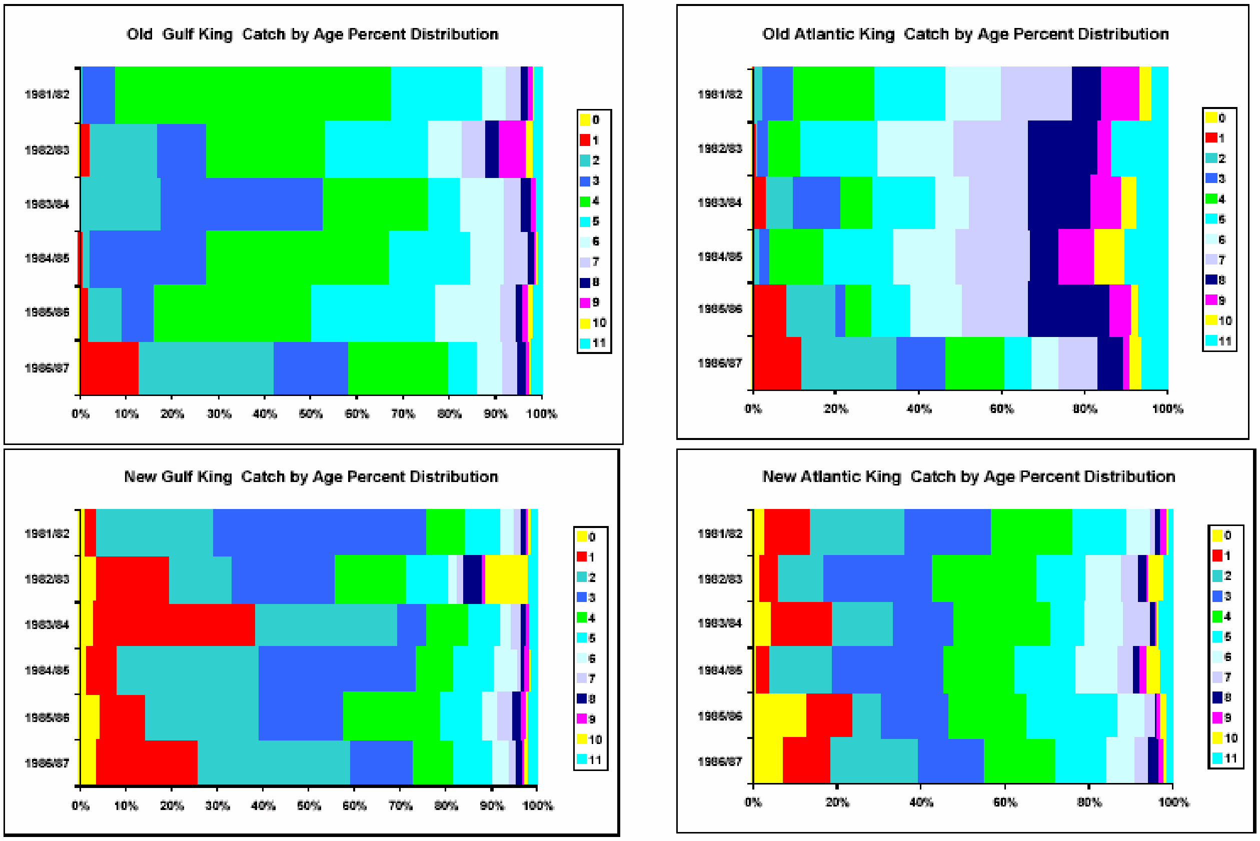


Figure 10: Estimated catch at age using the estimated growth parameters from the ALK data (“NEW”) versus CAA estimated with the previous growth parameters (“OLD”).

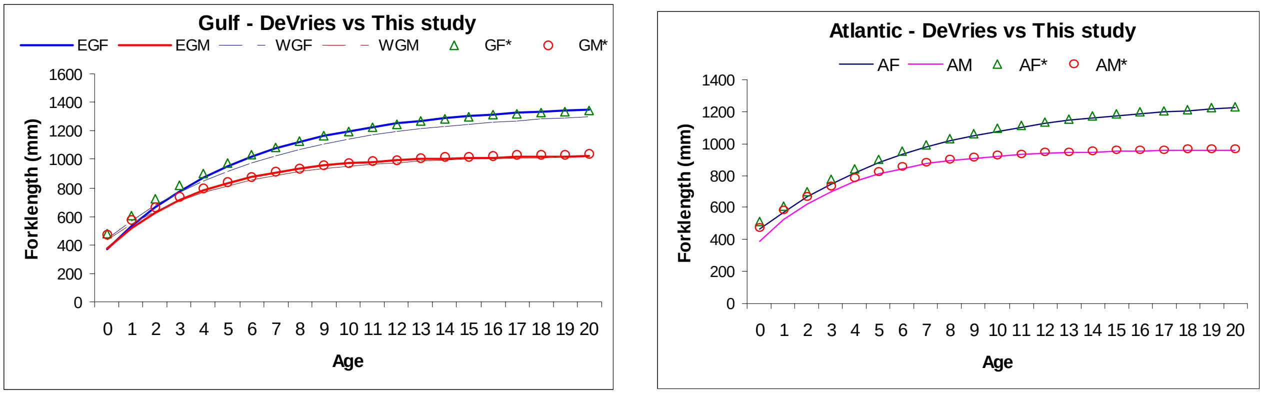
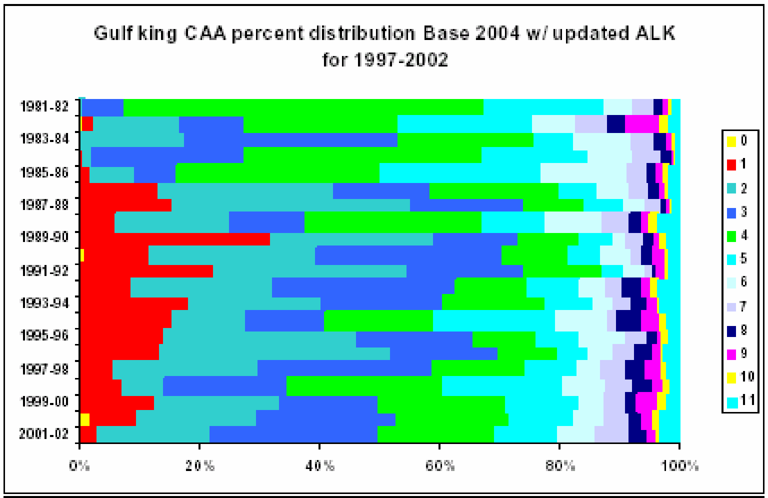


Figure 11: Comparison of predicted size at age between DeVries and Grimes (1997) (solid and broken lines) and this study (open symbols).



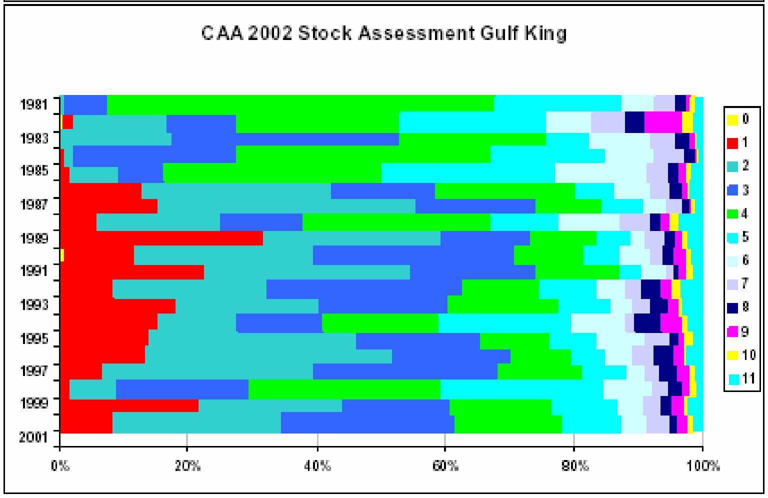


Figure 12: Gulf king catch-at-age (CAA) percent distribution by age and fishing year. Top panel corresponds to the 2004 base 04 model, bottom panel corresponds to the 2002 CAA.

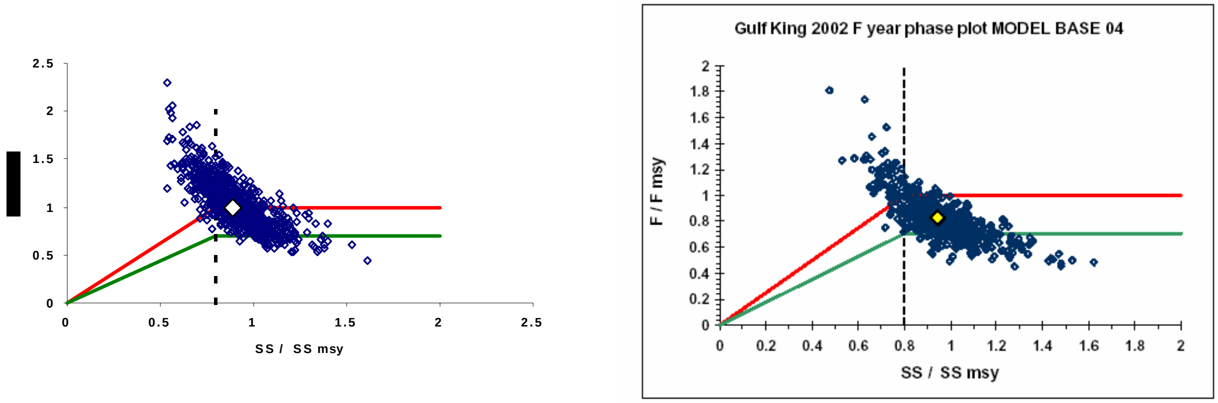


Figure 13: Comparison of 2002 and 2004 phase plots of Gulf king mackerel spawning stock biomass and fishing mortality status relative to SFA benchmarks.

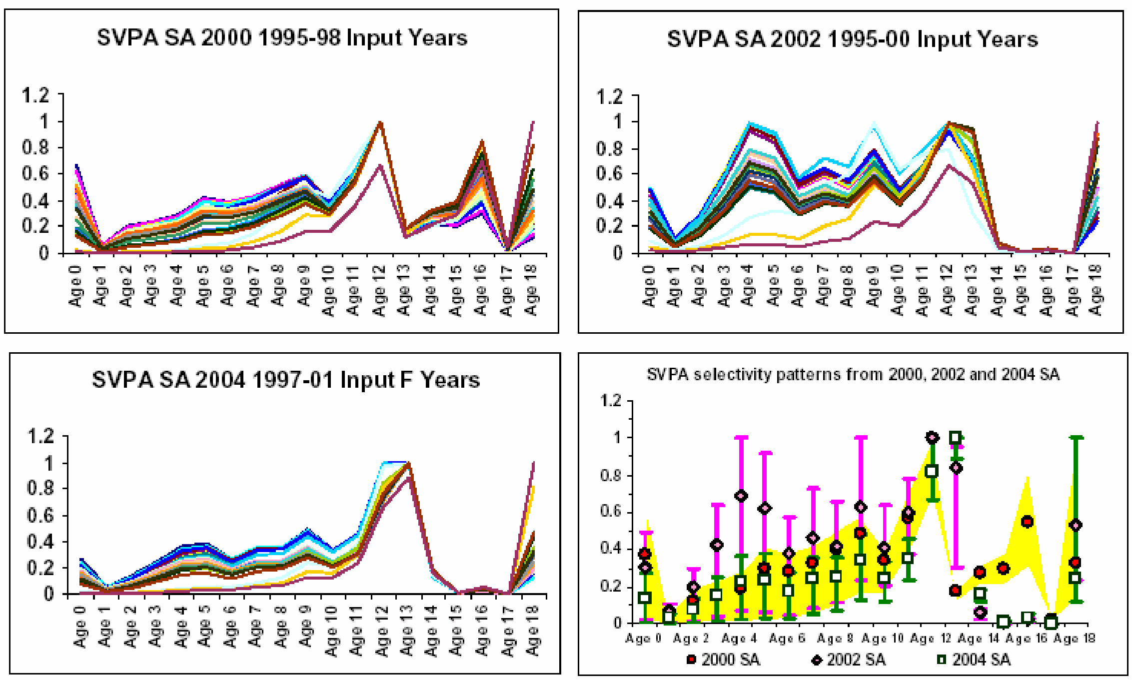


Figure 14: Selectivity pattern results from SVPA models with a range of fixed F ratios for catch at age of Gulf king mackerel. Topleft results of 2000 assessment, top-right results of 2002 assessment, bottom-left results of 2004 assessment. Bottom-right panel compares the results of all three assessments, with markers representing the mean value and the bars the minimum and maximum values per age class; solid circles and shaded area are for 2000 results, solid diamonds and bars, 2002 results and open squares and bars for 2004 results..(Figure 10 in Ortiz 2004).

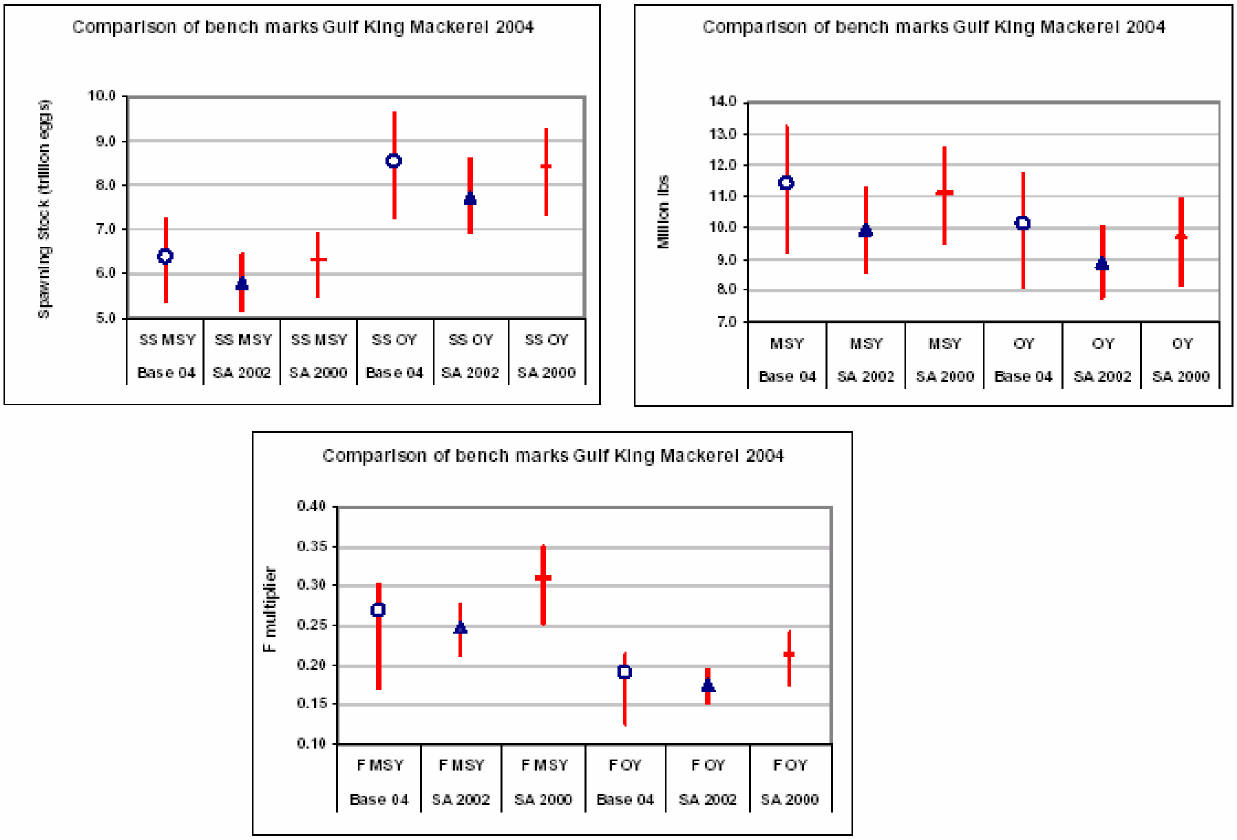


Figure 15: Gulf king mackerel bench marks 2004 assessment. Spawning stock (SS) biomass (trillion eggs), MSY and OY in millions of pounds, and corresponding fishing mortality rates from the base-04 model (open circles). For comparison, equivalent values are plotted from the 2000 (plus marker) and 2002 (solid triangle) assessments. Bars represent 90% range of 500 bootstrap runs.

Figure 16 though Figure 19 correspond to locations of internal anchor tag releases and recaptures from 1981 to 2001. Recaptures only include tags that were at large at least 90 days.

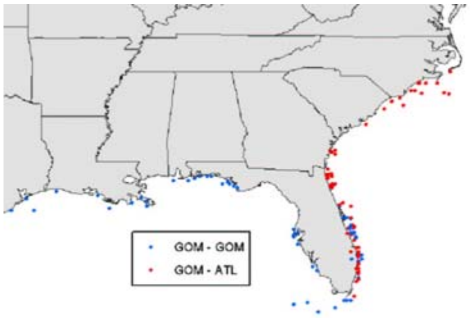


Figure 16: Location of releases in the KNM Atlantic stock (n=2,735).

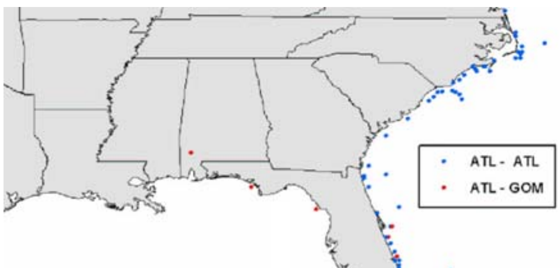


Figure 17: Location of recaptures of tags originally released in the KNM Atlantic stock. Blue circles indicate tags recovered in the same stock where they were released (Atlantic, n=139), red circles indicated tags recovered as part of the other stock (GOM, n=14).

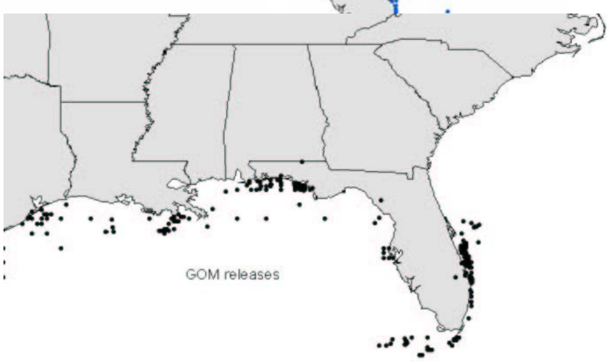


Figure 18: Location of releases in the KNM GOM stock (n=10,381).

Figure 19: Location of recaptures of tags originally released in the KNM GOM stock. Blue circles indicate tags recovered in the same stock where they were released (GOM, n=254), red circles indicate tags recovered as part of the other stock (ATL, n=148).

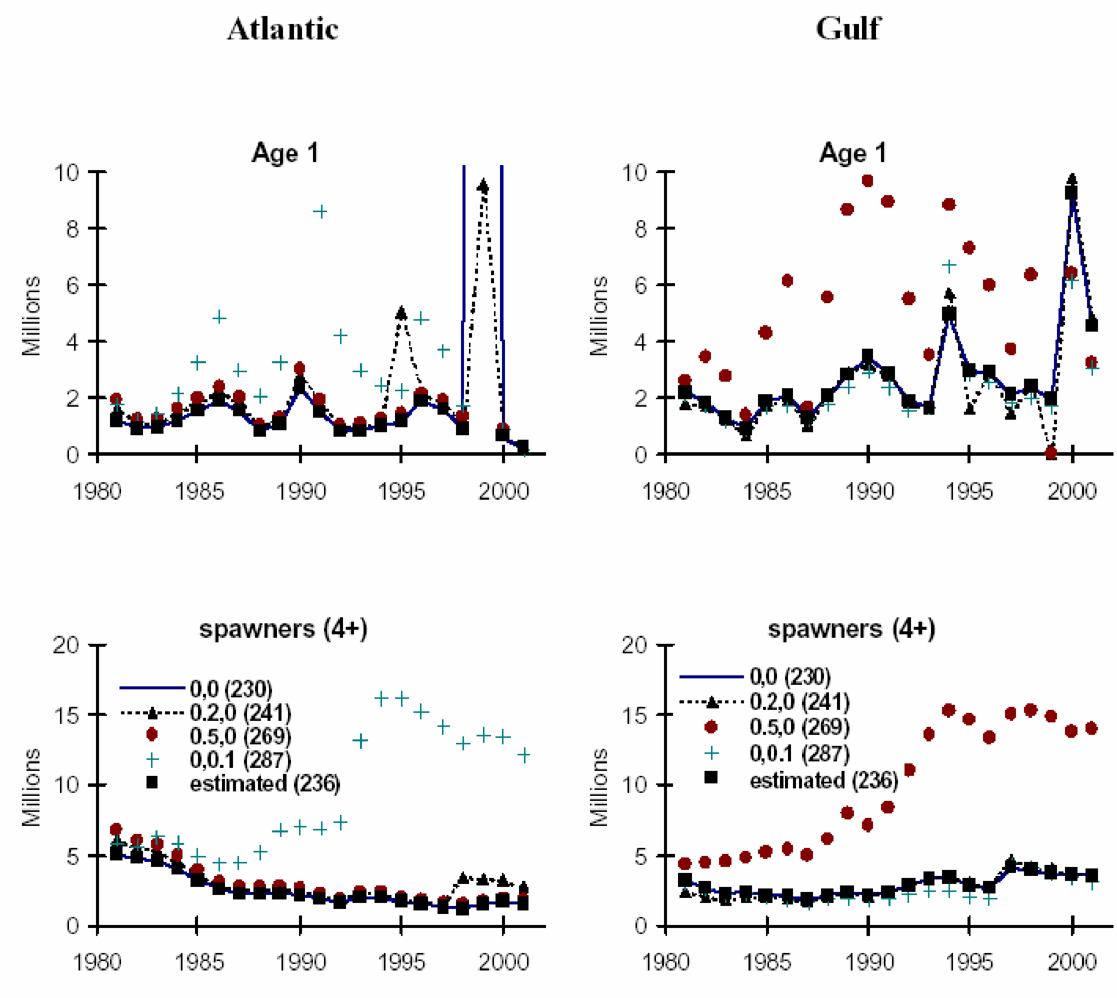


Figure 20: Number of recruits and number of spawners estimated by the VPA without the use of tagging data. The legend labels, e.g., “0.2, 0 (241)" refer to the assumed fraction of the Atlantic stock that resides in Gulf, here 20%, and the fraction of the Gulf stock that resides in the Atlantic, here 0%. The numbers in parentheses are the corresponding AICc values (lower is better). The label “estimated” refers to the fact that these overlap fractions were estimated (in this case they happen to be negligibly different from 0,0, but the AICc value is higher because the overlap parameters are estimated rather than fixed).

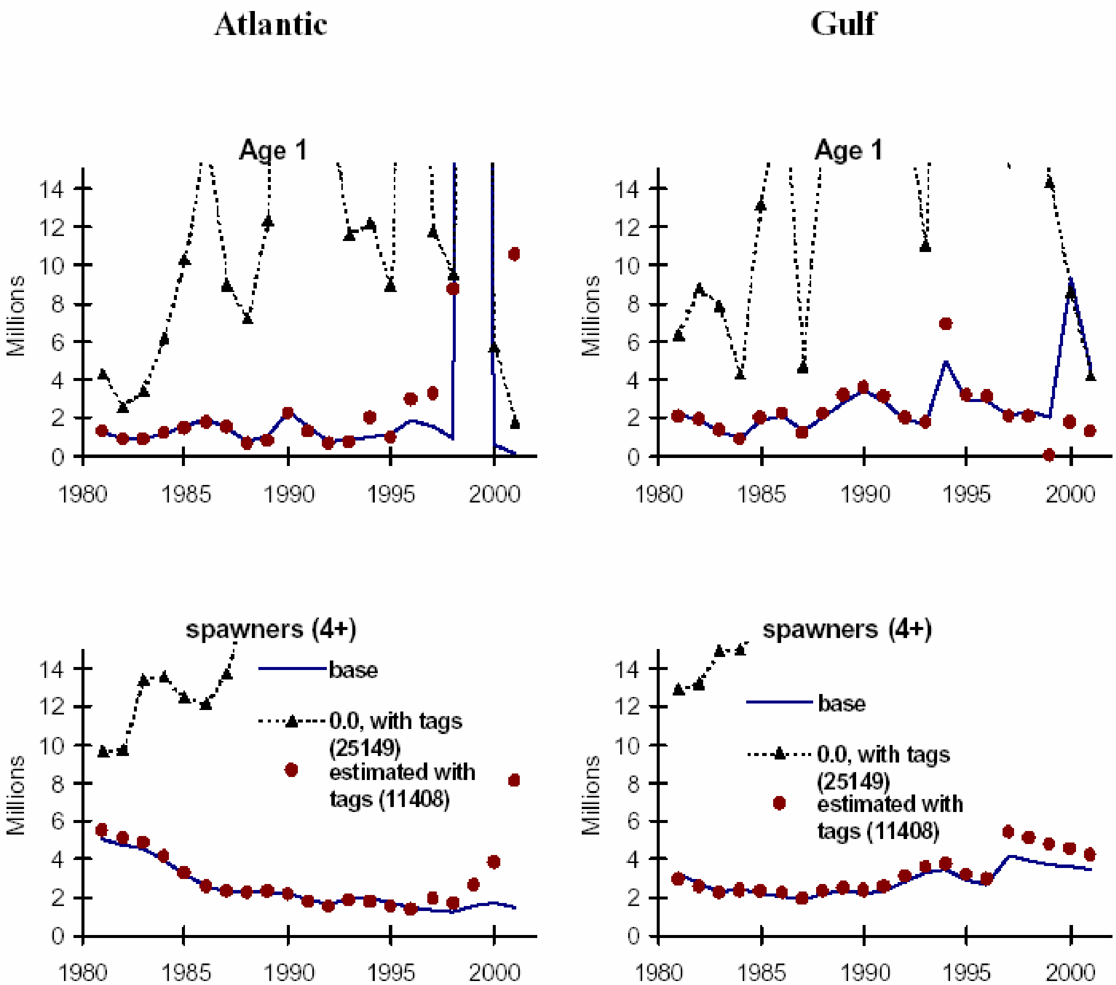
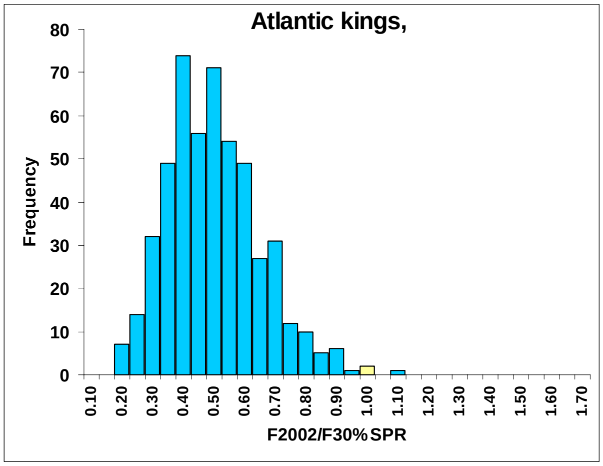


Figure 21: Number of recruits and number of spawners estimated by the VPA using the tagging data. The run labeled "base" refers to the VPA results obtained without tagging data and assuming no overlap. The run labeled "0,0, with tags" refers to the VPA results with tagging data and assuming no overlap. The label "est. with tags" refers to the VPA results with tagging data and estimated overlap rates. The numbers in parentheses are the corresponding AICc values (lower is better).

Panel A Panel B



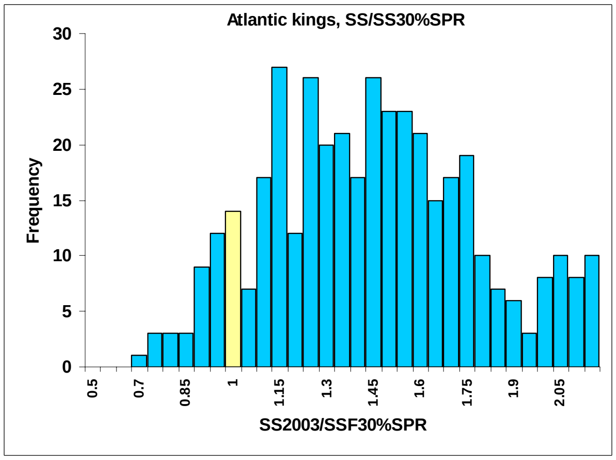
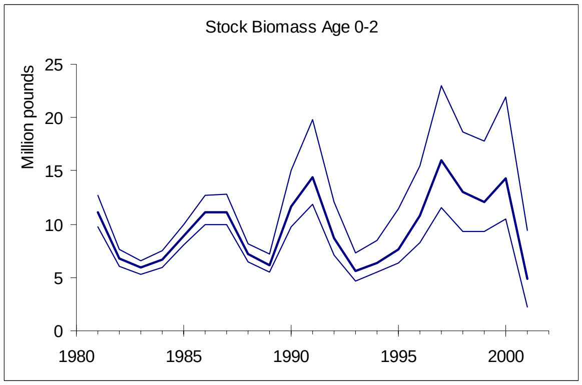
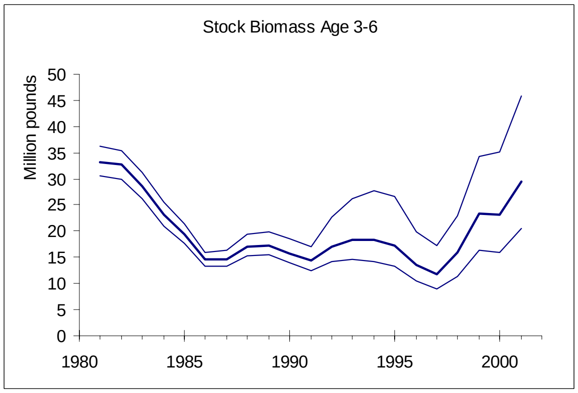


Figure 22: PANEL A -- Bootstrapped distributions of estimated F2002/FMSY proxy (F2002/F30%SPR) for Atlantic king mackerel. PANEL B -- Bootstrapped distributions of estimated B2003/BMSY proxy (SS/SS30%SPR) for Atlantic king mackerel.





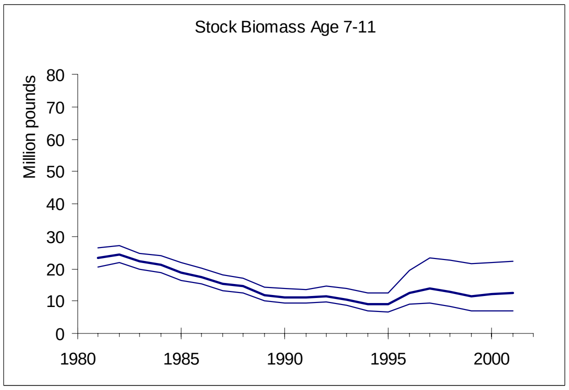


Figure 23: Atlantic king mackerel stock biomass trends with 80% confidence intervals from the base-04 model.

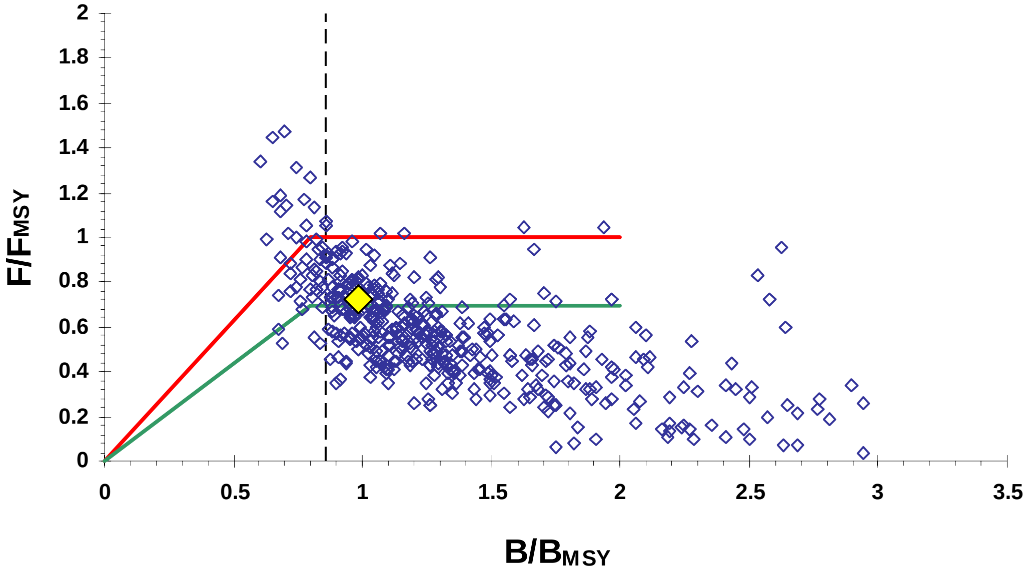
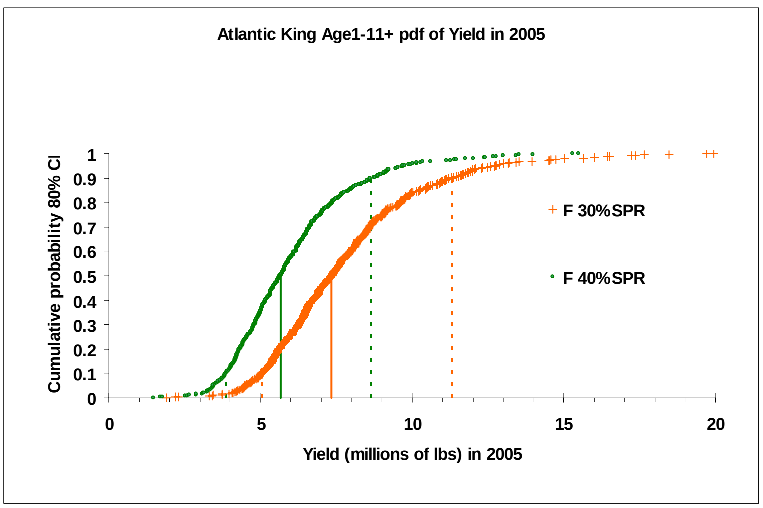


Figure 24: Atlantic king mackerel phase plot from the 2003 base model with the stock-recruit relationship estimated with age-1 recruits.



Atlantic King

		F 30%SPR	F 40%SPR
Median	0.5	7.334	5.662
	0.1	5.033	3.848
	0.9	11.281	8.636
	0.2	5.604	4.311
	0.25	5.923	4.549
	0.75	9.022	6.971
	0.8	9.608	7.378

Figure 25: Atlantic king age 1-11+ cumulative probability with estimated median yield at F30% and F40% with various confidence intervals for the 2005 fishing year.

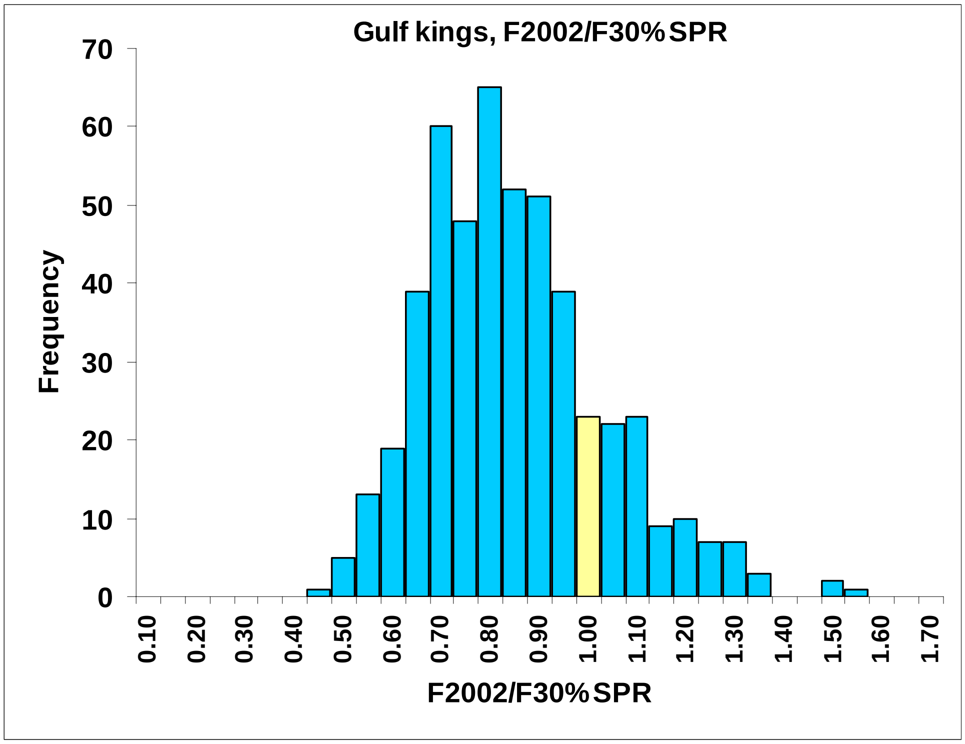


Figure 26: Bootstrapped distributions of estimated F2002/FMSY proxy (F2002/F30%SPR) for Gulf king mackerel.

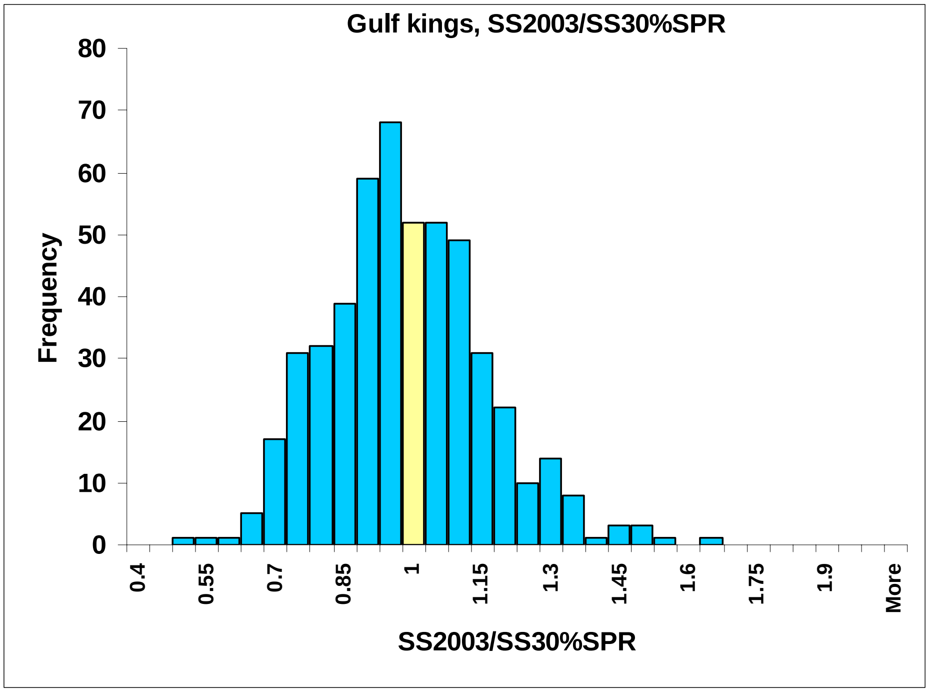


Figure 27: Bootstrapped distributions of estimated B2003/BMSY proxy (SS/SS30%SPR) for Gulf king mackerel.

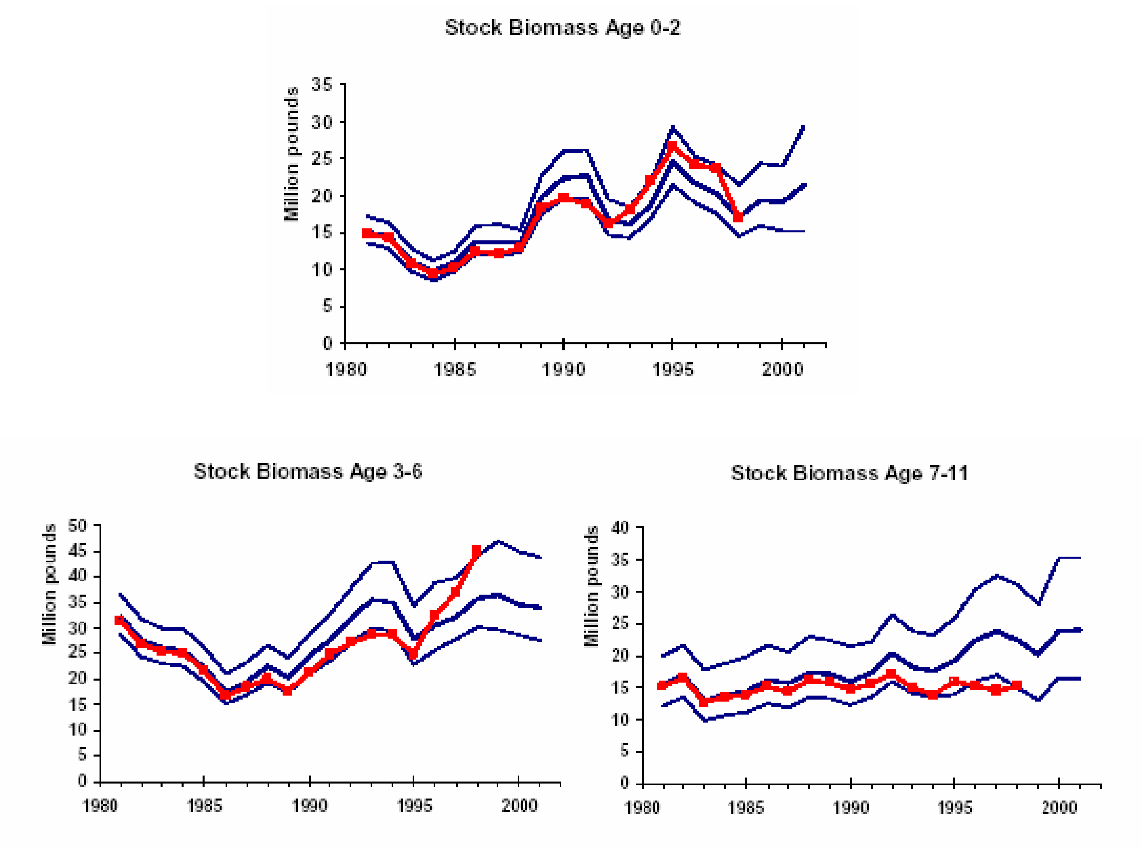


Figure 28: (Taken from Figure 13, Ortiz, 2004); Gulf king mackerel stock biomass trends with 80% confidence intervals from the base-04 model (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).

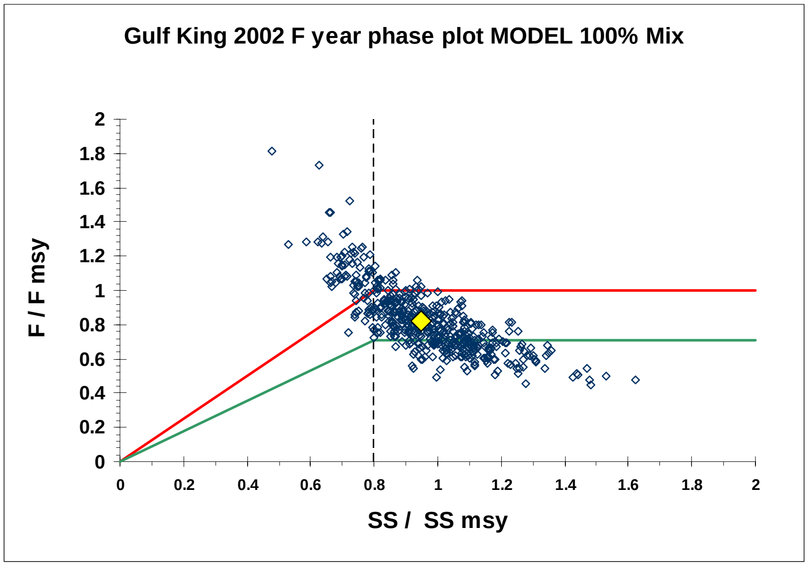
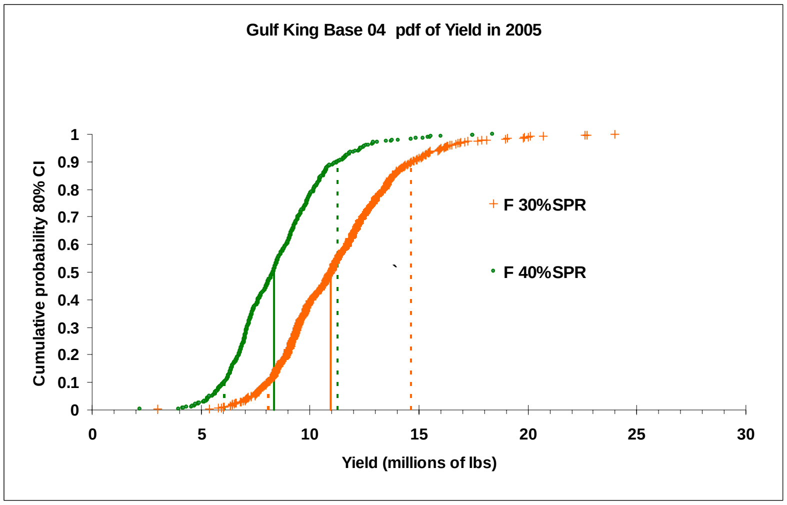


Figure 29: Phase plots of 500 bootstraps for the index scenarios. The red solid line denotes the MFMT, the vertical dashed line denotes MSST, and the lower solid line denotes the OY control rule. The deterministic run corresponds to the larger diamond marker.



		Gulf King F 30%SPR	
Median	**0.5**	11.0	8.3
	0.1	8.1	6.1
	0.9	14.6	11.2
	0.2	8.9	6.7
	0.25	9.2	7.0
	0.75	12.9	9.8
	0.8	13.4	10.2

Figure 30: Frequency distribution of 500 bootstraps range of allowable biological catch (ABC) based on probability of F exceeding F30% SPR and F40%SPR in the 2003/2004 fishing year for Gulf king mackerel from the base-04 model. Vertical solid lines represent 0.5 percentile; broken lines represent 0.1 and 0.9 percentiles of the distributions.

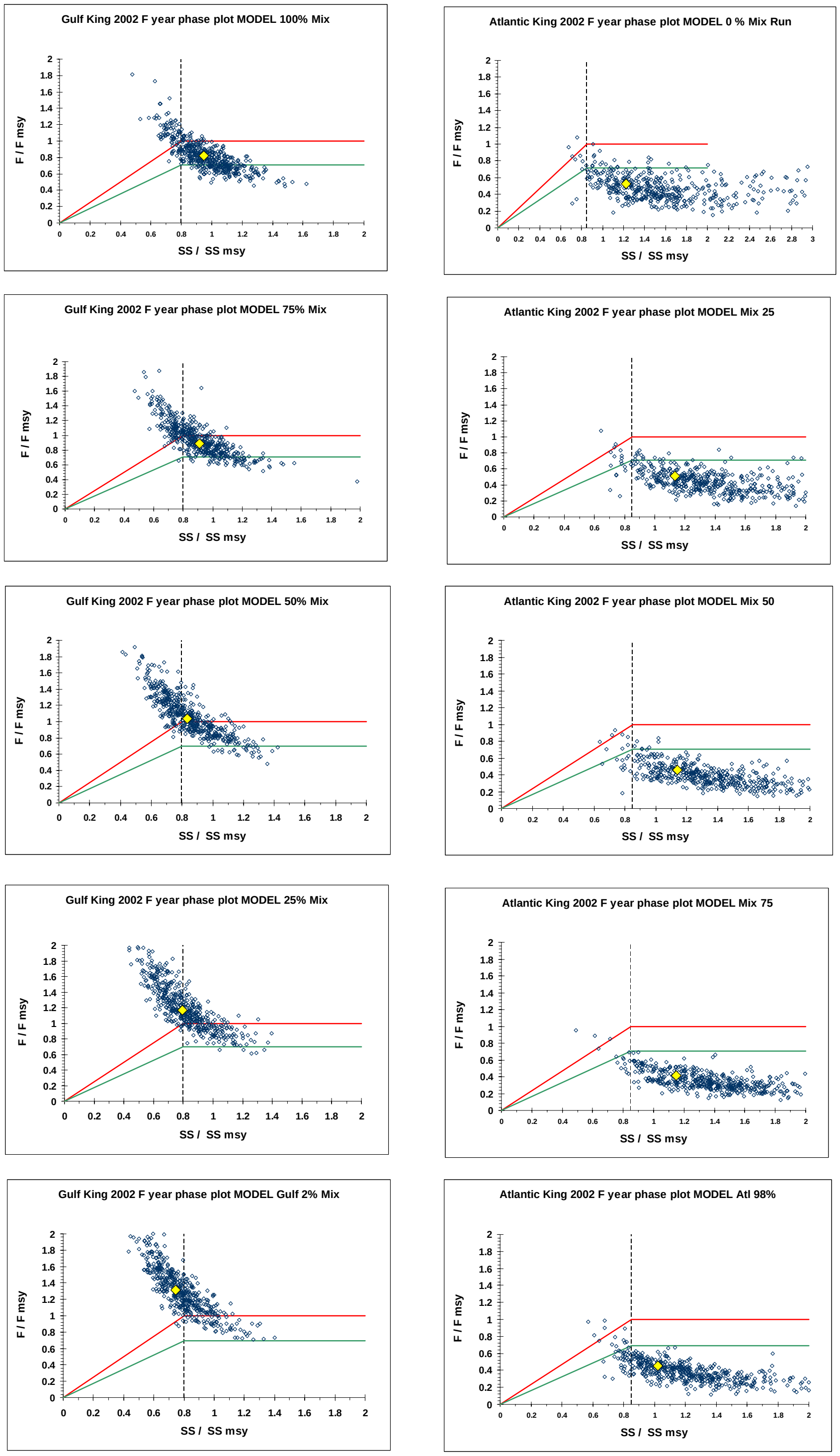


Figure 31: Bootstrapped estimates of stock status for the Gulf (left panels) and Atlantic (right panels) king mackerel stocks under the mixing scenarios modeled (100% , 75%, 50%, 25%, and 2% Gulf Group fish in the mixing area catch, upper to lower panels, respectively) are shown as phase plots. The deterministic solution is indicated as the large diamond in each panel. The dashed vertical line represents MSST and the hockey sticks represent default limit (upper) and target (lower) control rules.

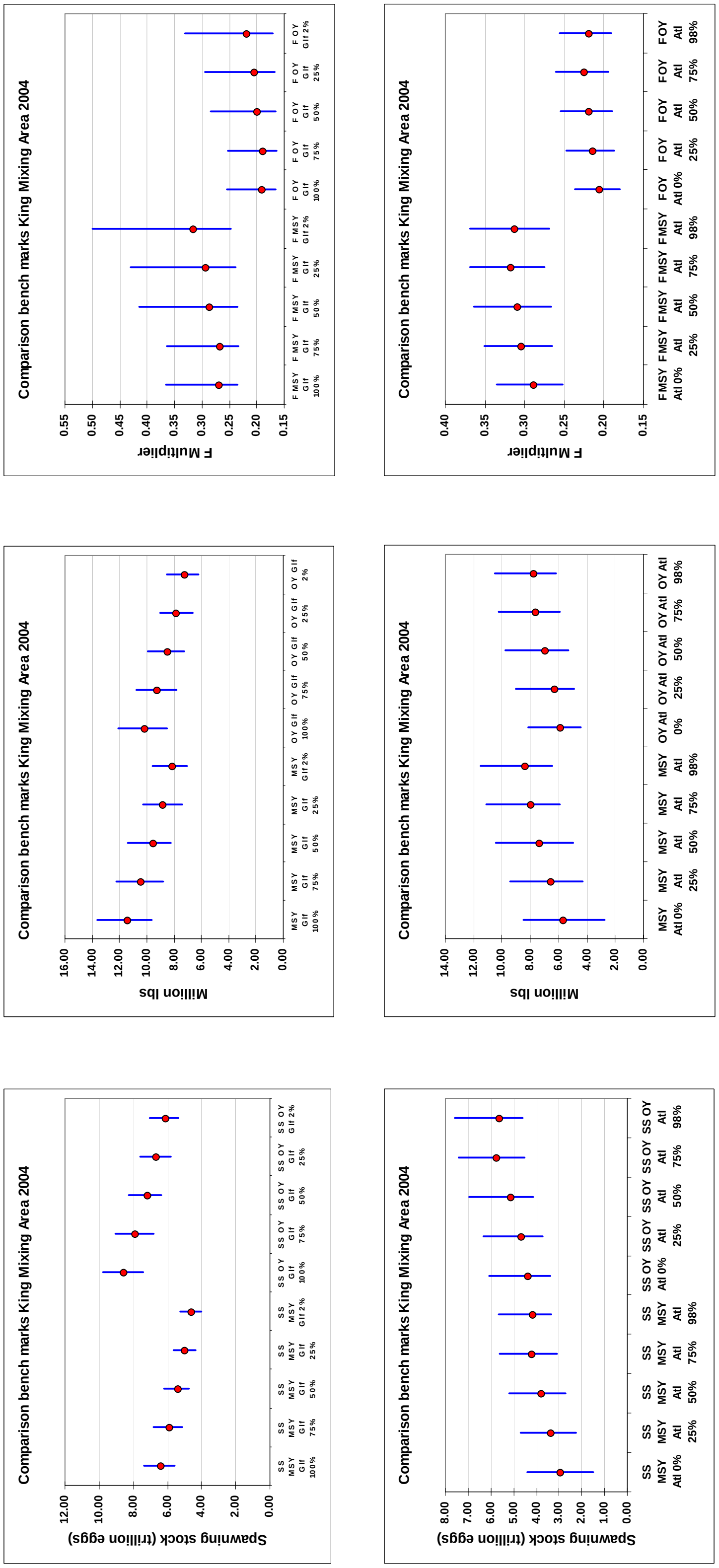


Figure 32: Estimates of SFA-related parameters (proxies for MSY, SS_{MSY}, F_{MSY}, OY, SS_{OY} and F_{OY}) for the mixing scenarios evaluated for each stock as indicated. Central points are medians and error bars are 80% confidence bounds from 500 bootstraps.

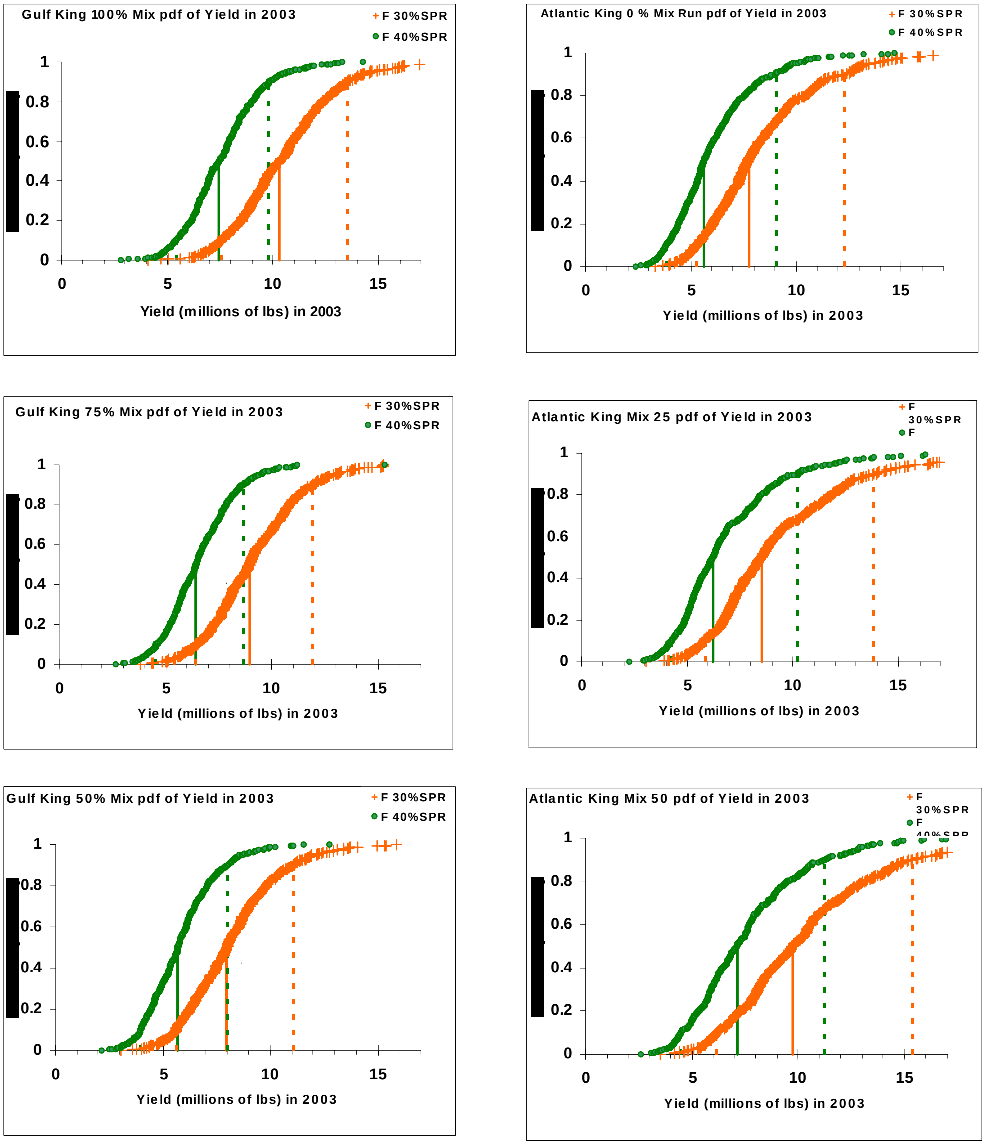


Figure 33: Cumulative probability plots of expected yield under F30%SPR (right-most curved line) and F40%SPR (left-most curved line) fishing mortality rates in fishing year 2003 for the Atlantic (right) and Gulf (left) groups under each of the mixing scenarios considered. Solid vertical lines represent medians while dashed lines represent 80% confidence bounds from the 500 bootstraps. For graphical clarity, the right-most tails of some distributions have been truncated in the display.

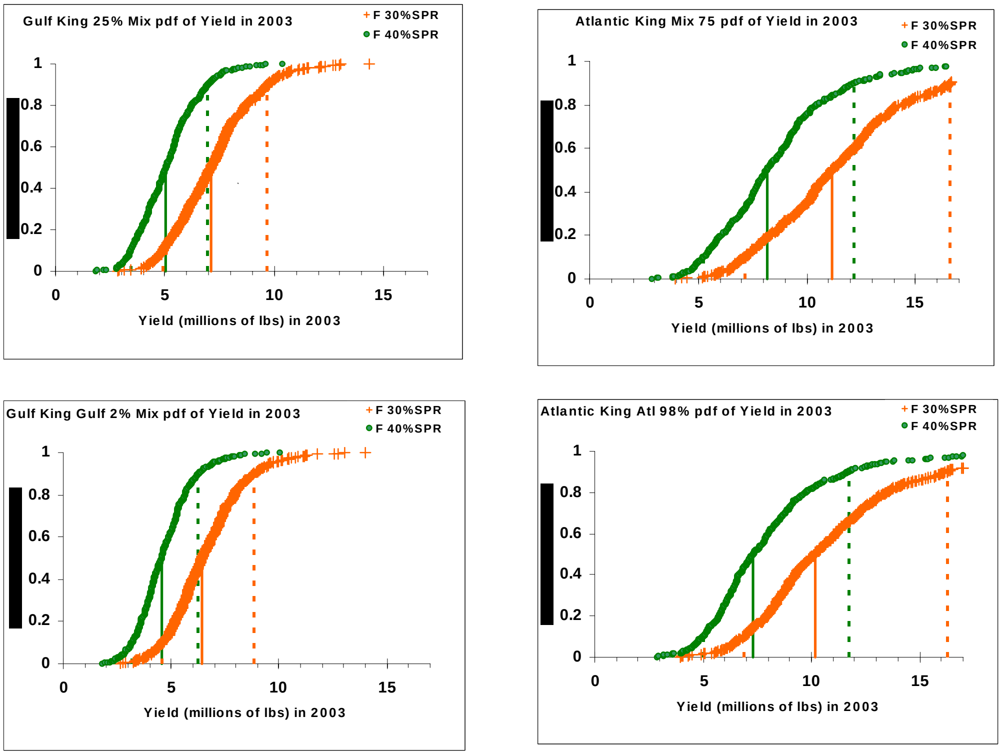


Figure Figure 33 (cont.): Cumulative probability plots of expected yield under F30%SPR (right-most curved line) and F40%SPR (left-most curved line) fishing mortality rates in fishing year 2003 for the Atlantic (right) and Gulf (left) groups under each of the mixing scenarios considered. Solid vertical lines represent medians while dashed lines represent 80% confidence bounds from the 500 bootstraps. For graphical clarity, the right-most tails of some distributions have been truncated in the display.

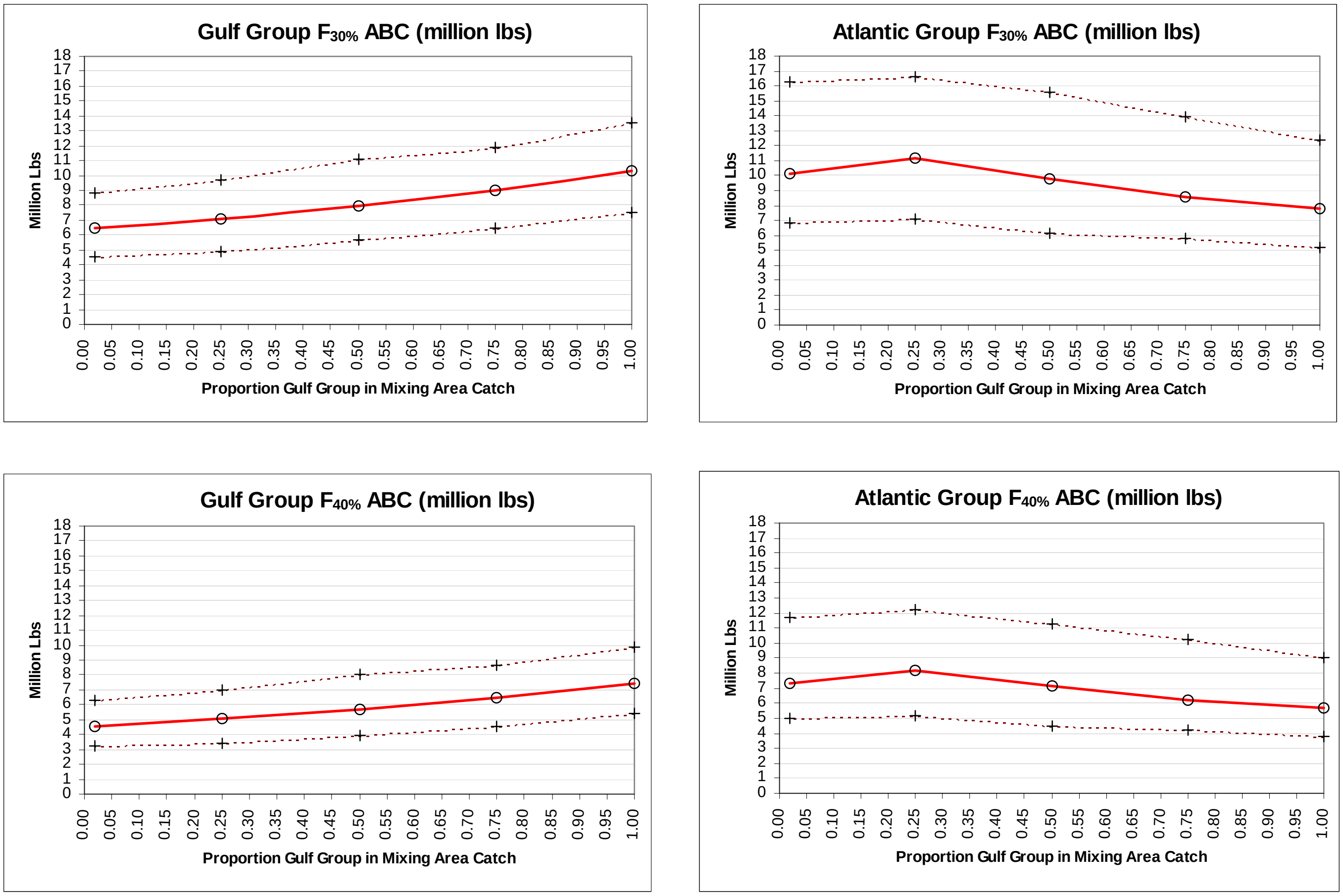
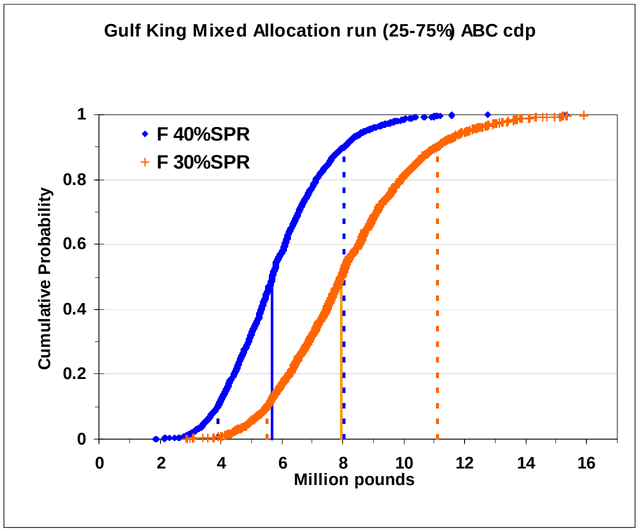
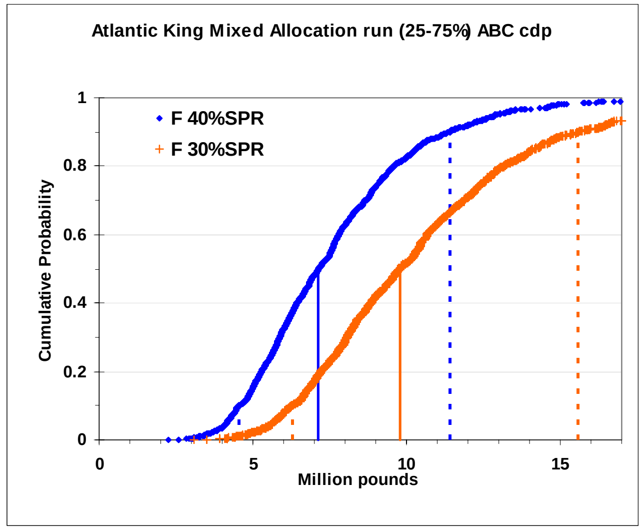


Figure 34: ABC for fishing year 2003 under either an F30%SPR (upper) or F40%SPR Fishing mortality rate for the Gulf Group (left) and Atlantic Group (right) as a function of the presumed proportion of Gulf Group fish in the annual catch taken from the mixing area. Open circles represent bootstrap medians and crosses the upper and lower 80% confidence bounds based on 500 bootstrap results. Solid and dashed lines permit interpolation should the Councils determine at a later date that alternatives to the specific scenarios modeled herein are more appropriate.





percentile	Yield (million lbs) at F 30%SPR	Yield (million lbs) at F 40% SPR
10%	5.5	3.9
20%	6.2	4.4
25%	6.5	4.7
50%	8.0	5.7
75%	9.5	6.8
80%	9.9	7.1
90%	11.1	8.0

percentile	Yield (million lbs) at F 30%SPR	Yield (million lbs) at F 40% SPR
10%	6.3	4.6
20%	7.2	5.3
25%	7.7	5.6
50%	9.8	7.1
75%	12.5	9.1
80%	13.2	9.6
90%	15.6	11.4

Figure 35: Expected yields for Gulf and Atlantic group king mackerel in 2003 under mixing scenarios assuming from 25-75% of the catch in the mixing area was of Gulf group fish. For these calculations, the likelihood of 50% mixing was assumed to be twice that of either 25% or 75% mixing. The right-most curved line represents the cumulative probability distribution for F30%SPR and the left-most curved line, the CPD for F40%SPR fishing mortality. The percentiles of these distributions are based on 1500 bootstraps. The solid verticals represent the medians while the dashed verticals represent the 80% confidence range (10th and 90th percentiles). For reasons of graphical clarity, the right-most tails of some of the distributions were truncated.

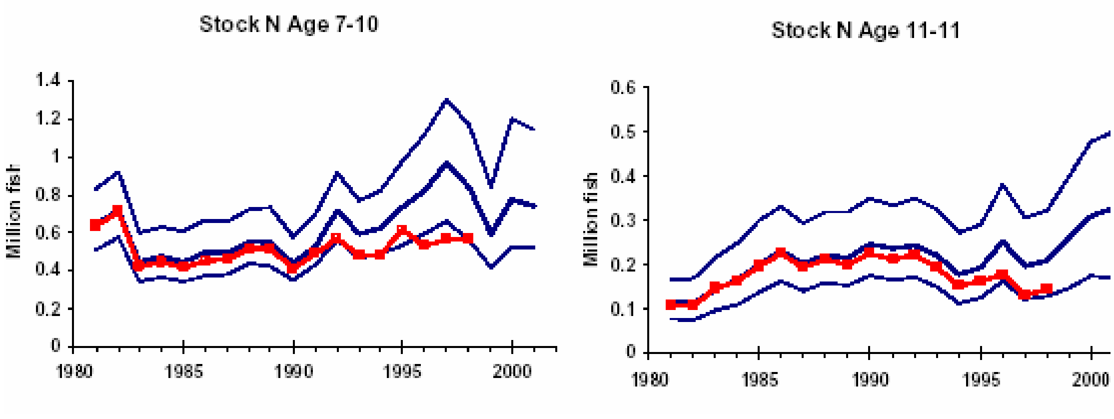


Figure 36: Estimated abundances of Gulf of Mexico king mackerel from the base case 2004 assessment (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).

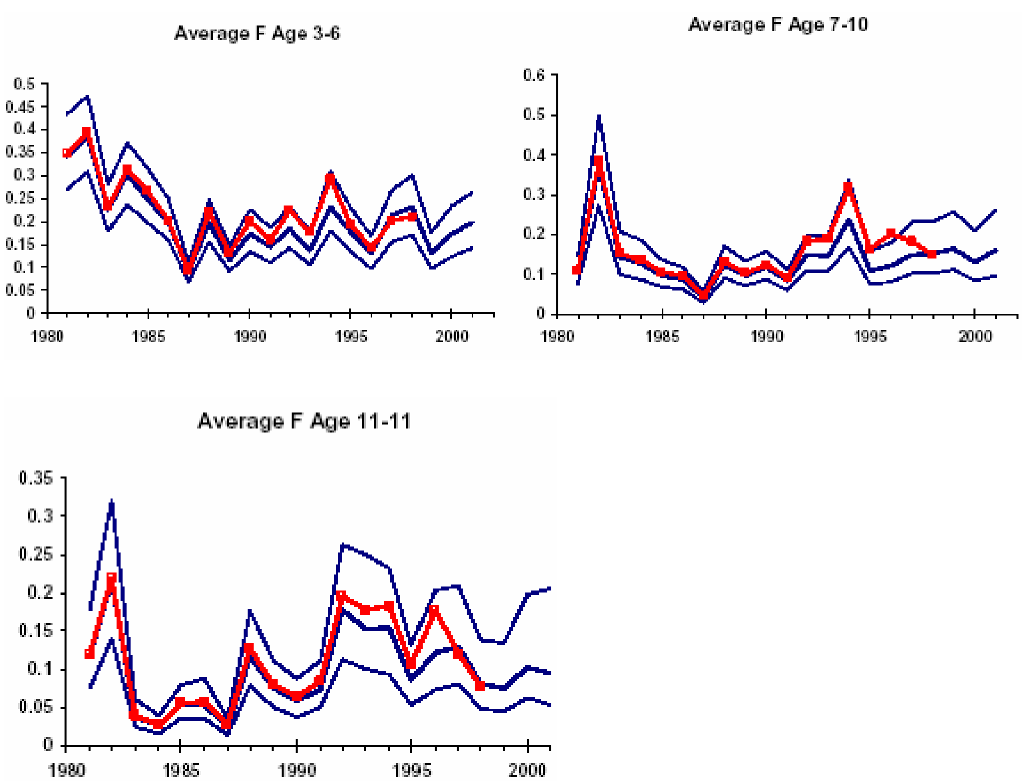


Figure 37: Fishing mortality rates on Gulf of Mexico king mackerel from the base assessment (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).

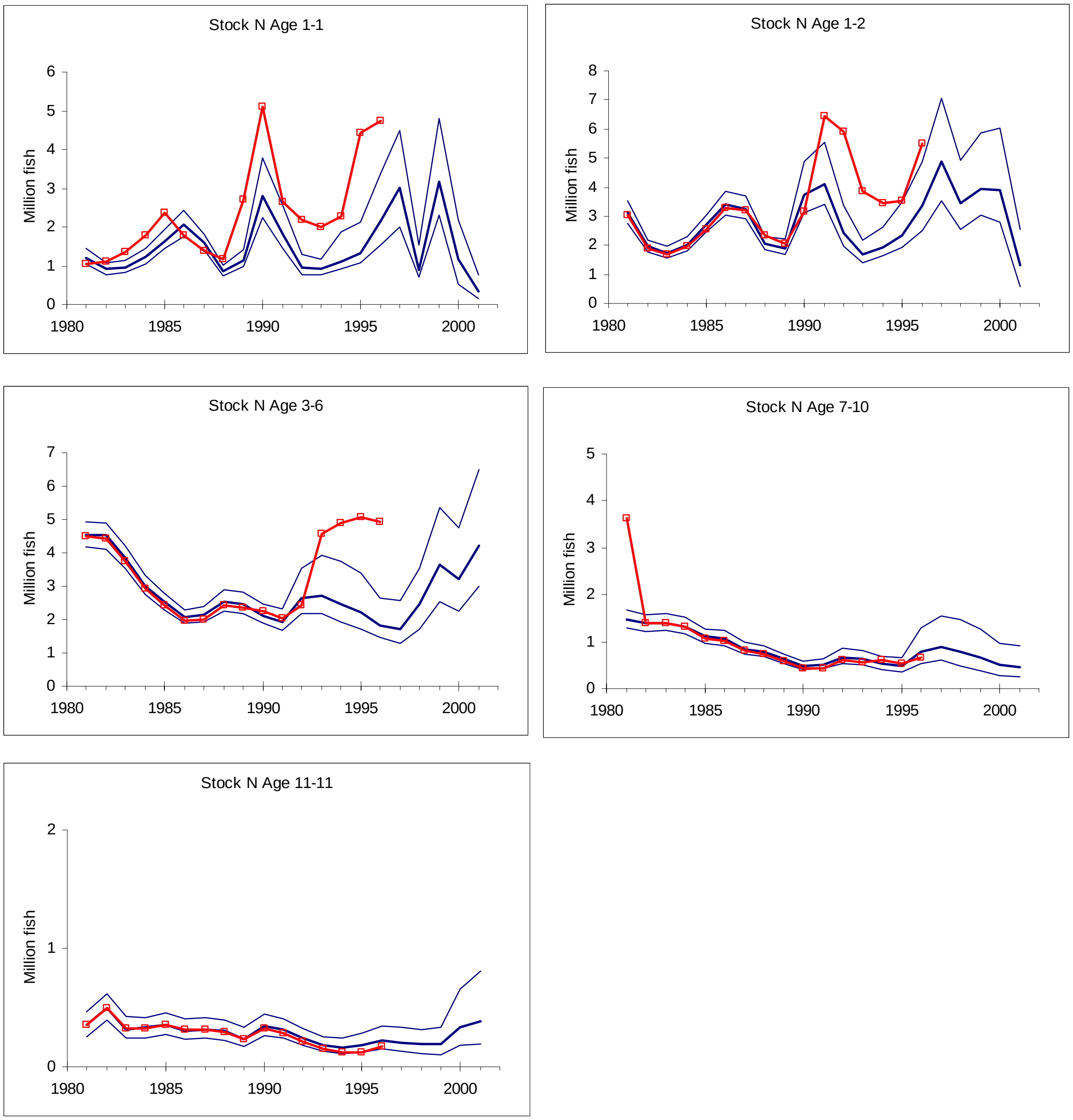


Figure 38: Revised estimates of abundances of Atlantic king mackerel based on the 2003 assessment (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).

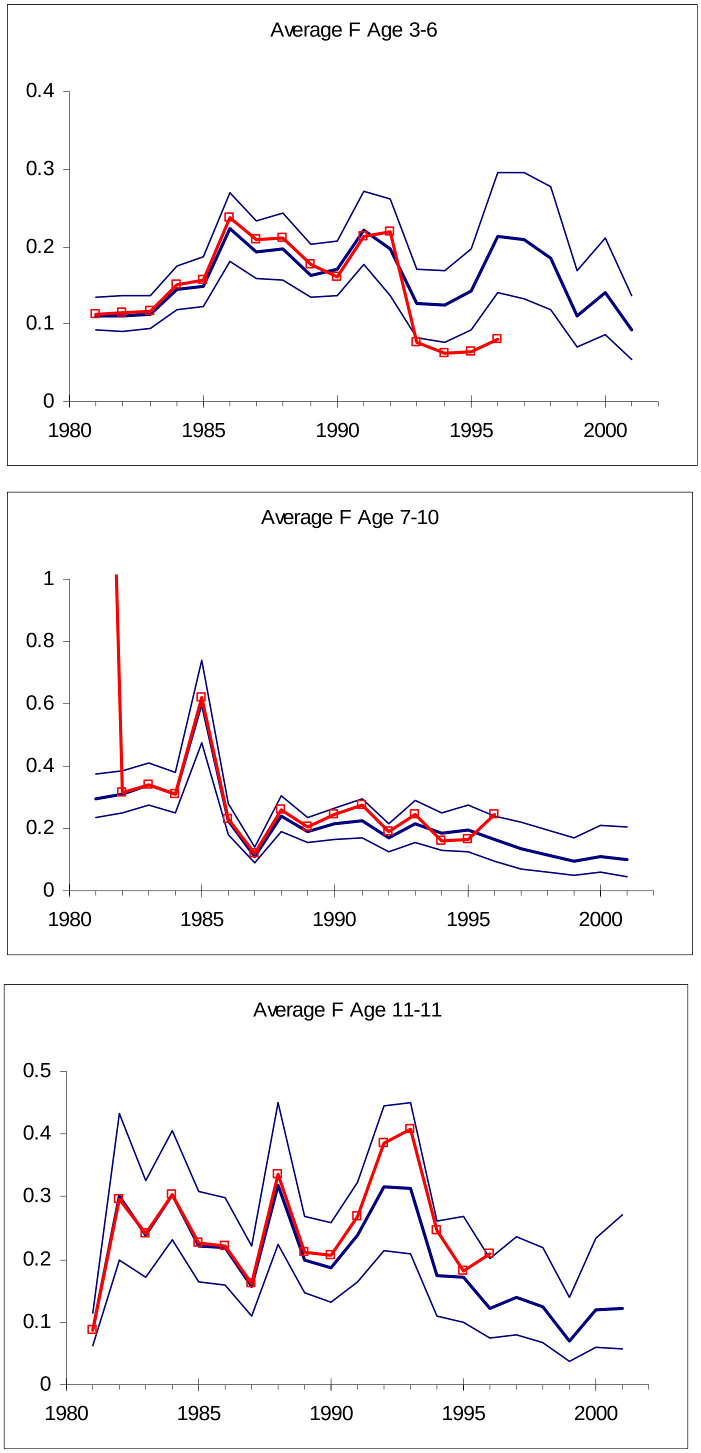


Figure 39: Revised estimates of historical fishing mortality rates of Atlantic king mackerel based on the 2003 assessment (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).

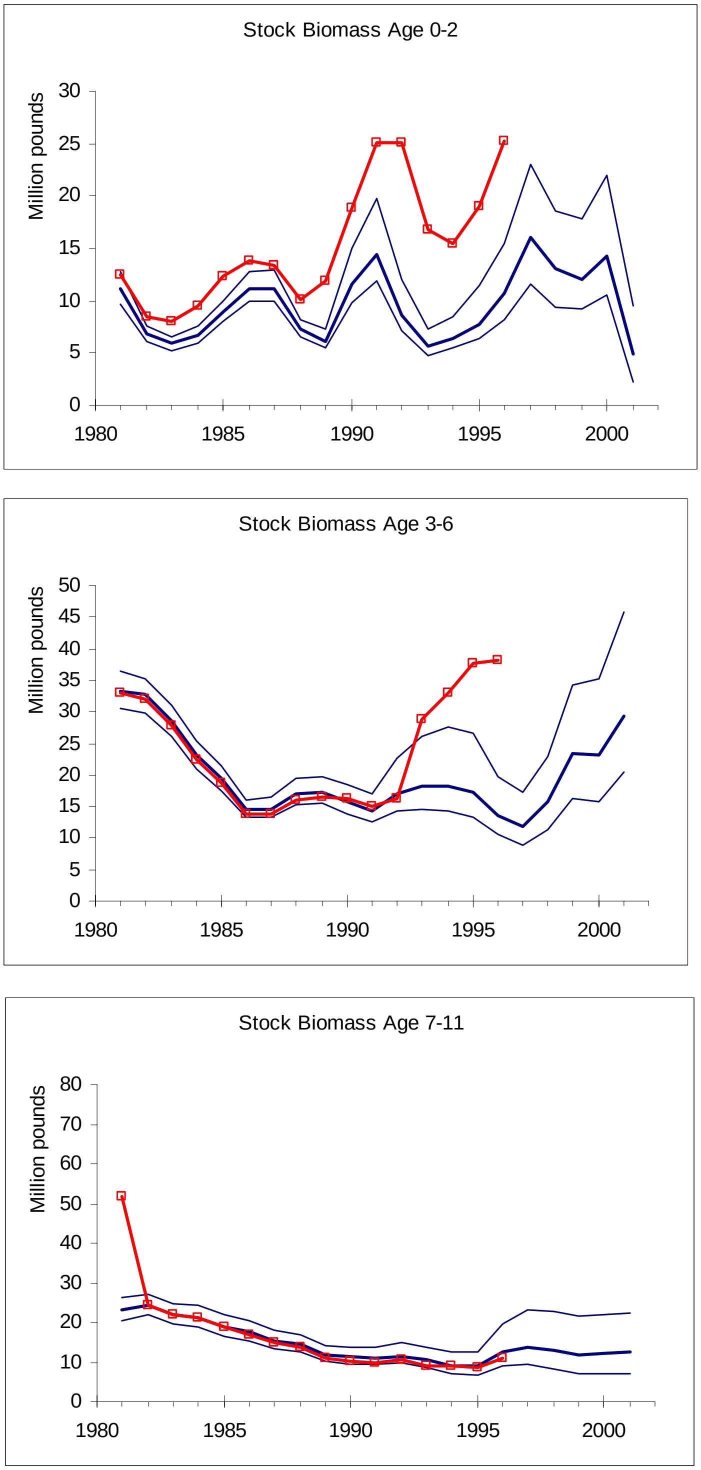
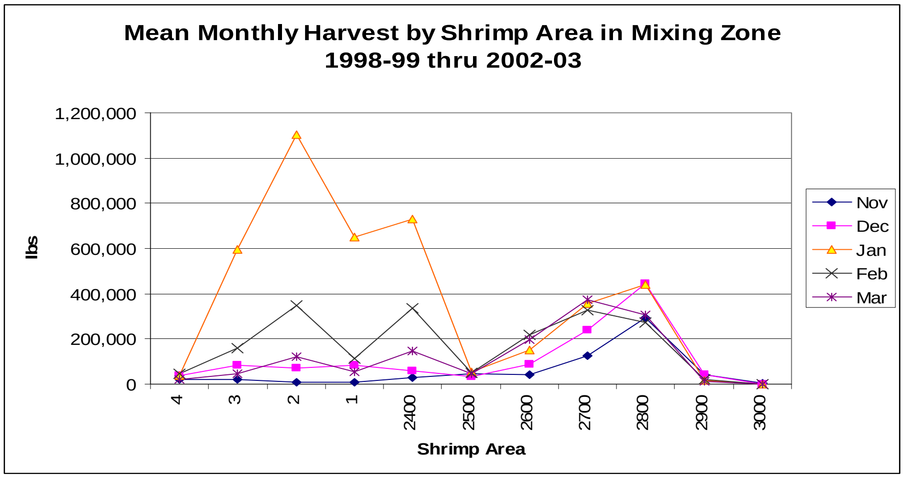
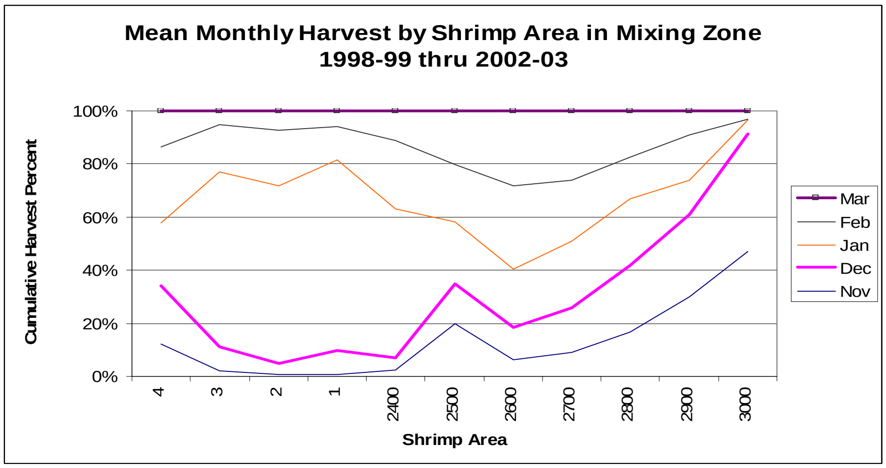


Figure 40: Revised estimates of historical Atlantic king mackerel biomass based on the 2003 assessment (solid lines). For comparison, results from the 2000 assessment are shown (open square marker line).





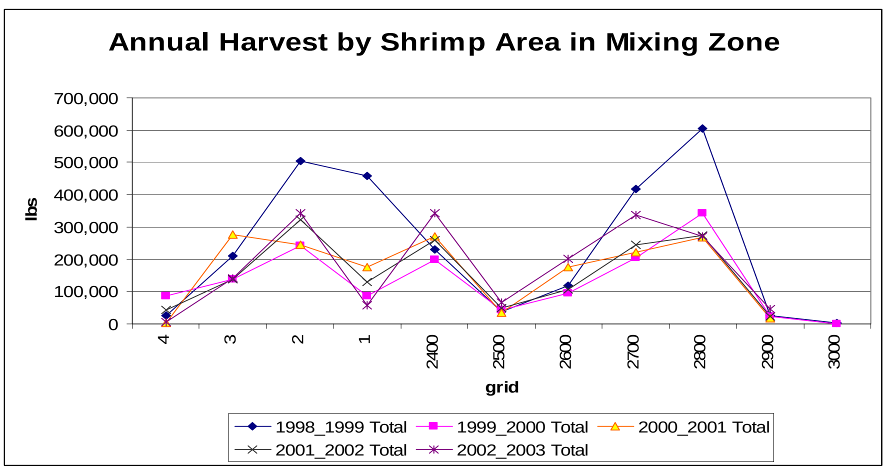


Figure 41: NMFS king mackerel log book harvest statistical area from areas in and near the mixing zone, for the November thru March time period.

Appendix 1: Consensus Summary

Appendix 2: Advisory Report

Appendix 3: Abbreviations and Definitions

List of Acronyms and Abbreviations

B	stock biomass level
$\mathbf{B_{msy}}$	value of B capable of producing MSY on a continuing basis
CPUE	catch per unit of effort
GMFMC	Gulf of Mexico Fishery Management Council
F	(instantaneous) fishing mortality
F_{msy}	fishing mortality to produce MSY under equilibrium conditions
$F_{50\%\ SPR}$	fishing mortality that will result in $B_{50\%\ SPR}$ under equilibrium conditions
F_{max}	fishing mortality that maximises the average weight yield per fish recruited to the fishery
$F_{0.1}$	a fishing mortality close to, but slightly less than, F_{max}
FMRI	(State of) Florida Marine Research Institute
GLM	general linear model
L_{bar}	mean length
M	(instantaneous) natural mortality
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
RVC	Reef Visual Census—a diver-operated survey of reef-fish numbers
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment and Review
SFA	Sustainable Fisheries Act of 1996
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
Z	total mortality, the sum of M and F

GLOSSARY OF ASSESSMENT TERMS

ADAPT. A commonly used form of computer program used to optimally fit a Virtual Population Assessment (VPA, see below) to abundance data.

Availability. Refers to the distribution of fishof different ages or sizes relative to that taken in the fishery.

Biological reference points. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. The reference points may indicate 1) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or 2) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former type of reference points are referred to as "target reference points" and the latter are referred to as "limit reference points" or "thresholds". Some common examples of reference points are $F_{0.1}$, F_{max}, and F_{msy}, which are defined later in this glossary.

B_0. Virgin stock biomass, i.e., the long-term average biomass value expected in the absence of fishing mortality.

B_{MSY}. Long-term average biomass that would be achieved if fishing at a constant fishing mortality rate equal to F_{MSY}.

Biomass Dynamics Model. A simple stock assessment model that tracks changes in stock biomass rather than numbers. Biomass dynamic models employ assumptions about growth (in weight) and can be tuned to abundance data such as commercial catch rates, research survey trends or biomass estimates.

Catchability. Proportion of the stock removed by one unit of effective fishing effort (typically age-specific due to differences in selectivity and availability by age).

Control Rule. Describes a plan for pre-agreed management actions as a function of variables related to the status of the stock. For example, a control rule can specify how F or yield should vary with biomass. In the National Standard Guidelines (NSG), the "MSY control rule" is used to determine the limit fishing mortality, or Maximum Fishing Mortality Threshold (MFMT). Control rules are also known as "decision rules" or "harvest control laws" in some of the scientific literature.

Catch per Unit of Effort (CPUE). Measures the relative success of fishing operations, but also can be used as a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size. The use of CPUE that has not been properly standardized for temporal-spatial changes in catchability should be avoided.

Exploitation pattern: The fishing mortality on each age (or group of adjacent ages) of a stock relative to the highest mortality on any age. The exploitation pattern is expressed as a series of values ranging from 0.0 to 1.0. The pattern is referred to as “flat-topped” when the values for all the oldest ages are about 1.0, and “dome-shaped” when the values for some intermediate ages are about 1.0 and those for the oldest ages are significantly lower. This pattern often varies by type of fishing gear, area, and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear, for example, increasing mesh or hook size, or by changing the proportion of harvest by gear type.

Mortality rates: Populations of animals decline exponentially. This means that the number of animals that die in an "instant" is at all times proportional to the number present. The decline is defined by survival curves such as:
$N_{t+1} = N_t e_{-z}$
where N_t is the number of animals in the population at time t and N_{t+1} is the number present in the next time period; **Z** is the **total instantaneous mortality rate** which can be separated into deaths due to fishing (**fishing mortality or F**) and deaths due to all other causes (**natural mortality or M**) and e is the base of the natural logarithm (2.71828). To better understand the concept of an instantaneous mortality rate, consider the following example. Suppose the instantaneous total mortality rate is 2 (i.e., Z = 2) and we want to know how many animals out of an initial population of 1 million fish will be alive at the end of one year. If the year is apportioned into 365 days (that is, the 'instant' of time is one day), then 2/365 or 0.548% of the population will die each day. On the first day of the year, 5,480 fish will die (1,000,000 x 0.00548), leaving 994,520 alive. On day 2, another 5,450 fish die (994,520 x 0.00548) leaving 989,070 alive. At the end of the year, 134,593 fish [1,000,000 x $(1 - 0.00548)_{365}$] remain alive. If, we had instead selected a smaller 'instant' of time, say an hour, 0.0228% of the population would have died by the end of the first time interval (an hour), leaving 135,304 fish alive at the end of the year [1,000,000 x $(1 - 0.00228)_{8760}$]. As the instant of time becomes shorter and shorter, the exact answer to the number of animals surviving is given by the survival curve mentioned above, or, in this example:
$N_{t+1} = 1{,}000{,}000 e_{-2} = 135{,}335$ fish

Exploitation rate: The proportion of a population alive at the beginning of the year that is caught during the year. That is, if 1 million fish were alive on January 1 and 200,000 were caught during the year, the exploitation rate is 0.20 (200,000 ÷ 1,000,000) or 20%.

F_{MAX}: The rate of fishing mortality that produces the maximum level of yield per recruit. This is the point beyond which growth overfishing begins.

$F_{0.1}$: The fishing mortality rate where the increase in yield per recruit for an increase in a unit of effort is only 10% of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the $F_{0.1}$ rate is only one-tenth the slope of the curve at its origin).

$F_{10\%}$: The fishing mortality rate which reduces the spawning stock biomass per recruit (**SSB/R**) to 10% of the amount present in the absence of fishing. More generally, Fx%, is the fishing mortality rate that reduces the SSB/R to x% of the level that would exist in the absence of fishing.

F_{MSY}: The fishing mortality rate that produces the maximum sustainable yield.

Fishery Management Plan (FMP). Plan containing conservation and management measures for fishery resources, and other provisions required by the MSFCMA, developed by the Fishery Management Councils or the Secretary of Commerce.

Generation Time. In the context of the National Standard Guidelines, generation time is a measure of the time required for a female to produce a reproductively-active female offspring for use in setting maximum allowable rebuilding time periods.

Growth overfishing: The situation existing when the rate of fishing mortality is above F_{MAX} and when the loss in fish weight due to mortality exceeds the gain in fish weight due to growth.

Limit Reference Points. Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g., FAO documents), "thresholds" are used as buffer points that signal when a limit is being approached.

Landings per Unit of Effort (LPUE). Analogous to CPUE and measures the relative success of fishing operations, but is also sometimes used a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size.

MSFCMA. (Magnuson-Stevens Fishery Conservation and Management Act). U.S. Public Law 94-265, as amended through October 11, 1996. Available as NOAA Technical Memorandum NMFS-F/SPO-23, 1996.

Maximum Fishing Mortality Threshold (MFMT, $F_{threshold}$). One of the Status Determination Criteria (SDC) for determining if overfishing is occurring. It will usually be equivalent to the F corresponding to the MSY Control Rule. If current fishing mortality rates are above $F_{threshold}$ overfishing is occurring.

Minimum Stock Size Threshold (MSST, $B_{threshold}$). Another of the Status Determination Criteria. The greater of (a) ½B_{MSY}, or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years of fishing at the MFMT. MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{threshold}$, the stock is overfished.

Maximum Spawning Potential (MSP). This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit

(SSB/ R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e., %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY). The largest average catch that can be taken from a stock under existing environmental conditions. **Overfishing.** According to the National Standard Guidelines, “overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis.” Overfishing is occurring if the MFMT is exceeded for 1 year or more.

Optimum Yield (OY). The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. MSY constitutes a “ceiling” for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for rebuilding to B_{MSY}.

Partial Recruitment. Patterns of relative vulnerability of fish of different sizes or ages due to the combined effects of selectivity and availability.

Rebuilding Plan. A plan that must be designed to recover stocks to the B_{MSY} level within 10 years when they are overfished (i.e. when B < MSST). Normally, the 10 years would refer to an expected time to rebuilding in a probabilistic sense.

Recruitment: This is the number of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Recruitment overfishing: The situation existing when the fishing mortality rate reaches a level that causes a significant reduction in recruitment to the spawning stock. This is caused by a greatly reduced spawning stock and is characterized by a decreasing proportion of older fish in the catch and generally very low recruitment year after year.

Recruitment per spawning stock biomass (R/ SSB): The number of fishery recruits (usually age 1 or 2) produced from a given weight of spawners, usually expressed as numbers of recruits per kilogram of mature fish in the stock. This ratio can be computed for each year class and is often used as an index of pre-recruit survival, since a high R/SSB ratio in one year indicates above-average numbers resulting from a given spawning biomass for a particular year class, and vice versa.

Reference Points. Values of parameters (e.g. B_{MSY}, F_{MSY}, $F_{0.1}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g., MSST) or targets for management (e.g., OY).

Risk. The probability of an event times the cost associated with the event (loss function). Sometimes “risk” is simply used to denote the probability of an undesirable result (e.g. the risk of biomass falling below MSST).

Status Determination Criteria (SDC). Objective and measurable criteria used to determine if a stock is being overfished or is in an overfished state according to the National Standard Guidelines.

Selectivity. Measures the relative vulnerability of different age (size) classes to the fishing gears(s).

Spawning stock biomass. The total weight of all sexually mature fish in a stock.

Spawning stock biomass per recruit (SSB/R): The expected lifetime contribution to the spawning stock biomass for each recruit. SSB/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

S**urvival Ratios.** Ratios of recruits to spawners (or spawning biomass) in a stock-recruitment analysis.

TAC. Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Target Reference Points. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g., OY). Target reference points should not be exceeded on average.

Uncertainty. Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of reference points, and management. Rosenberg and Restrepo (1994) identify 5 types: measurement error (in observed quantities), process error (or natural population variability), model error (mis-specification of assumed values or model structure), estimation error (in population parameters or reference points, due to any of the preceding types of errors), and implementation error (or the inability to achieve targets exactly for whatever reason).

Virtual population analysis (VPA) (or cohort analysis): A retrospective analysis of the catches from a given year class which provides estimates of fishing mortality and stock size at each age over its life in the fishery. This technique is used extensively in fishery assessments.

Year class (or cohort): Fish born in a given year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on.

Yield per recruit (Y/R or YPR): The average expected yield in weight from a single recruit. Y/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are also assumed to be constant.

Sensitivity of Stock Assessment Analysis of Gulf of Mexico King Mackerel to Alternative Growth Parameters

Prepared for the SEDAR5 2004
Assessment Workshop Committee

NOT to be distributed without accompanying Panel Report

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Introduction

During the SEDAR5-AW the committee reviewed and discussed "new" estimated von Bertalanffy growth parameters based on the otolith-aged king mackerel database (Brooks and Ortiz 2004), although serious concern was raised by the Committee regarding the use of integer ages for estimating growth parameters. A request from the working group was to extend the analysis of the alternative growth parameters to the assessment of Gulf king mackerel using the base case VPA model adopted during the meeting (See Report SEDAR5-AW) to investigate sensitivity of stock status evaluations to potentially large change in predictions of size at age implied by these growth parameters. Due to time constraints this recommendation was not completed during the meeting, this report describes the analysis and results of the stock assessment of Gulf king mackerel using the "new" growth parameters.

Methods

Brooks and Ortiz (2004) described the input data and procedures to estimate the von Bertalanffy growth parameters for Gulf and Atlantic king mackerel by sex groups and combined sexes. This document also specified the protocols and results of the ageing of the catch-at-size input matrix for Gulf and Atlantic king, especially when Age-length keys were not available and the ageing is done by the Stochastic Ageing Routine (SAR) method using the asymptotic length, growth rate and size at spawning parameters from the von Bertalanffy equations by sex (Brooks and Ortiz 2004, Ortiz et al 2003).

For Gulf king mackerel, the "new" growth parameters for asymptotic size (L_∞) and growth rate (*k*) were similar to those estimated by Monooch *et al* (1987) which are the one's currently used in the stock assessment VPA and stock projection models (see table 3 Sedar5-AW/1). Overall, asymptotic size (L_∞) and growth rate (*k*) were closer but there were major differences in the estimates of the parameter t_0 compared to the Manooch *et.al* values . Predicted size at age plots showed that with the "new" growth parameters, predicted size of younger age classes increased substantially for males, females and combined sex groups (Table 1, Fig 1). For example for age 0, the Manooch estimated sizes of age 1 class were 45, 47 and 47.5 cm for males, females and combined sex, respectively. With the "new" growth parameters the estimated size of age 1 class were 60, 63, and 62 cm for males, females and combined sex, respectively, roughly a 33% increase. In the case of males, the "new" growth parameters estimated larger size for ages

0 to 5 and smaller size for ages 6 and above, for females all ages the estimated size at age is larger than those estimated by Manooch *et al* (1987).

Applying the logic used in the assessment for computation of reference points, these differences in predicted size at age also extend to other biological parameters such as predicted weight at age, maturity at age and fecundity at age, since these are functions of size. For Gulf king mackerel, size-weight relationship were estimated by Johnson *et al* (1982) and Finucane *et al* (1986), both using samples from the South Atlantic and Gulf of Mexico region. In the current assessment of Gulf king mackerel, the Finucane size-weight relationship is used

$$wgt\ (gr) = 1.5 \cdot 10^{-5} * ForkLength(mm)^{2.89284}$$

The estimated weight at age with the "new" growth parameters show an increase in the mean weight by age class (Fig 2). Weight-at-age is an input in the VPA-FADAPT model needed to predict population biomass from abundance, as some of the tuning indices are in biomass units and as future landings in biomass units are management quantities of concern. The VPA model uses the weight-at-age times the selectivity curve for tuning indices of biomass. Weight at age is also an input in the stock projection model, to estimate biomass related reference point values. Application of the "new" growth parameters increased predicted weight at age especially for younger age classes: 98% for age 1, 56% for age 2 and 35% for age 3. The weight at age for the plus group, in this case age11+, is estimated as the mean weight of ages 11 to 25 taking into account the exponential decline of a non-exploited cohort.

In terms of fecundity at age, for Gulf king mackerel Finucane *et al* (1986) estimated maturity and fecundity of females as a function of their size (fork length). They estimated that fish below 42.5 cm were immature, and fish between 43 cm and 87 cm showed a linear relationship of probability mature as size increased. Fish greater than 87cm were considered all mature (Fig 3) and 50% maturity was estimated about 55-60 cm. However, when translated to maturity proportions by age and fecundity by age, the "new" growth parameters predict that Gulf King mackerel females mature at younger ages and have higher fecundity output. For example, for age 0 the "new" growth parameters predict that 30% of females are mature and at age 1 59% of the females are mature compared to 0% and 16% mature at ages 0 and 1 with the Manooch growth parameters. Figure 4 shows the estimated fecundity and egg production for both growth parameter models. With the "new" growth parameters on average fecundity of Gulf king mackerel females' increased by 62% overall on ages 0 to 18+, while total predicted egg production was approximately doubled (raised by 98%) for a un-exploited cohort.

In addition to changing the growth curves, the analyses presented here used an alternative method of developing the catch at age from the historical approach (Ortiz 2004a). That method used alternative criteria for determining when there were sufficient samples for developing an age length key and used alternative methods for aggregating size bins within each key. The single application of this approach resulted in management benchmarks which were similar to those estimated from the comparable base case. The committee noted that Gulf king mackerel assessments were sensitive to changes in the basic data used for developing the catch at age and recommended that the criteria for developing the CAA be further examined to determine the robustness of the assessment to those criteria.

Application of the "new" growth parameters change the Catch at Age (CAA) matrix for those years where the stochastic method (SAR) of ageing was applied (Brooks and Ortiz 2004). The Partial Catches at age associated with several indices of abundance were consequently modified for consistency in logic. The P-CAAs were estimated from the CAA for the following indices: Florida FWC commercial indices of Northwest and Southwest, the MRFSS index, the HeadBoat index, and the Texas PWD index. Also, in projections of stock status, the program used as an input the average of catch by age for each sector (commercial and recreational) which was also estimated from the CAA input. Table 3 presents a summary of the indices of abundance used, including the ages for which the index was applied based on the review of the estimated P-CAA. Table 3 also show whether the index was estimated in numbers or biomass, and the time of the year to which the index was fit within the VPA model.

Virtual Population Analysis

As in the base case 2004 stock assessment, a tuned VPA (FADAPT) model (Powers and Restrepo 1992, Restrepo 1996) was used to obtain statistical estimates of population parameters. For this analysis each index was given equal weight in the minimization process.

In this analysis, the fishing mortality rates at age in the 2001-02 fishing year (terminal year) were the parameters estimated. As in the base case it was assumed that the fishing mortality rate was the same in the plus group (Age 11+) and the previous age (Age 10) for all years. A Separable VPA (SVPA) indicated that the average of mean selectivity for age 0 relative to age 2 was 1.4 (F_0/F_2 =1.4), while the average of mean selectivity for age 1 relative to age 2 was 0.33 (F_1/F_2 =0.33). The F for the plus group (F_{11+}) in the terminal year was set equal to the F at age 10.

Selectivity at age for each index by year was computed based on the partial catch at age (PCAA) associated with the index during that year. The catch at age for a particular index year was first used to find the proportion of total fishing mortality due to that amount of catch as

$$F_{y,a,i} = F_{y,a} * \text{Catch}_{y,a,i} / \text{Catch}_{y,a}$$

where y, a and I denote year, age and index, respectively. The selectivity at age was then formed by dividing each $F_{y,a,i}$ by the maximum value over age for that year and index.

Characterization of Uncertainty

The uncertainty in the assessment estimation was characterized by mixed Monte Carlo/bootstrap simulations of the tuned VPA. The simulation method repeated the VPA a number of times (500) randomly selecting from 1) a uniform distribution of natural mortality rate for each age and year; 2) a lognormal distribution of directed catch at age assuming the point estimate represented the mean and the variance was characterized by a CV of 25%; 3) a lognormal distribution of bycatch at age assuming the point estimate represented the mean and the variance was characterized by a CV of 25%; and 4) the observed deviations between the indices of abundance and the predicted population model from the original VPA fit. The results were accumulated and sorted to provide probability statements of relevant statistics. Projections were made using each bootstrap iteration such that benchmarks, stock trends and ABC could be evaluated on an absolute or relative scale. Probability distributions from these observations were used to construct 80% pseudo-confidence intervals (removing the 10% lowest and highest observations).

Projections

Population abundances at age in the terminal year of the VPA (2001-02 fishing year) are projected into the 2002/03 fishing year according to the estimated F and M at age values in the terminal year. Recruitment in the projection years came from a stock recruitment model specific within each bootstrap. The point estimate was projected deterministically following this stock recruitment model while the bootstraps used the estimated variability about the model to create a lognormal distribution from which recruitment was randomly chosen. This simulation used the stock recruitment model developed during the 1998 MSAP meeting according to the following rules. Only years in which both the stock and recruitment values have tuning information present were used to create the relationship, excluding the last 2 years as they were highly variable, resulting in a time-series of SR estimates for use from 1987-1999. The maximum recruitment was set at the average recruitment estimated during these years and declines linearly to the origin when the spawning stock size drops below a "break point". The "break point" was determined by the average of the five lowest spawning stock sizes within the years 1987-1999.

The bycatch fishing mortality rate for the projection years was computed as the average of the F at age due to bycatch during the period 1993-1997, modified by the expected bycatch reduction due to full implementation of BRDs as in the base case 2004. The directed fishing mortality rates at age were assumed separable by sector (commercial and recreational) with the selectivity at age pattern for each sector computed as the average over the last five fishing years (1997-98 to 2001-02) and the year multipliers specific to each sector. For the 2002-03 fishing year, the two fishing mortality rate multipliers were estimated simultaneously such that the observed total catch in weight for the commercial sector[1] and the 2002-03 total catch in numbers for the recreational sector[2] were achieved. The total fishing mortality rate at age was computed as the sum of the bycatch F at age, the product of the commercial multiplier and selectivity at age, and the product of the recreational multiplier and selectivity at age. The two multipliers were unique values assuming both catches are smaller than the estimated population.

The population abundances were then projected into the 2003-04 fishing year according to the total fishing mortality rate at age and the natural mortality rate at age. The two fishing mortality rate multipliers (commercial and recreational) for the 2003-04 fishing year were estimated simultaneously such that a desired spawning potential ratio (SPR transitional unweighted) was achieved and the ratio of catches in weight by the two sectors (commercial and recreational) equaled the allocation for the specific migratory group. These F multipliers were again unique assuming the SPR could be achieved in that year. The yield resulting from application of the directed fishing mortality rates on the estimated population abundance generated the ABC value. This approach of treating separately the commercial and recreational sectors was used in previous assessments.

Following the decisions of the Council, the proxy for F_{MSY} is $F_{30\%SPR}$ and the proxy for B_{MSY} was the spawning stock that resulted in equilibrium under the F_{MSY} proxy according to the stock recruitment relationship. The default control rule of Restrepo et al (1998) was recommended by the MSAP; this default sets the minimum stock size threshold (MSST) to (1-M)*B_{MSY} and the maximum fishing mortality threshold (MFMT) to F_{MSY} for SS>MSST and decreasing linearly to the origin for SS<MSST. Risks associated with overfishing, P(F>MFMT), and being overfished, P(SS<MSST), could be calculated from the results of the bootstraps for two year constant catch projections.

Results and Discussion

For the present sensitivity analysis, an 'equal' weighting option with the normal error assumption was assumed for all indices of abundance available, with the same time of year application as in the base case 2004 model. The VPA model failed to converge to a solution when all 10 indices of abundance were included. However the VPA model converged when one index of abundance was removed: the Florida Charter Northwest index (1988-1995). The VPA model estimated nine fishing mortality rates in the last year, corresponding to the ages 2 through 10, with fixed F ratios for ages 0, 1 and 11+. F ratios were defined as: F_0/F_2=1.4, F_1/F_2=0.33, and F_{11+}/F_{10}=1.0. Alternative model structures which could have admitted the full range of tuning data were not examined.

For this sensitivity run, the following input data were modified compared to the base case 2004: Updated CAA matrix for the fishing years 1981/82 through 2001/02, specifically for those years when no Age Length Keys where available. Updated corresponding Partial CAA [1981/82 to 2001/02] for the following indices of abundance: the Florida FWC commercial Northwest and Southwest indices, the Headboat index, the MRFSS, the Texas PWD, and the Charter Florida Southwest index. Note that the age coverage for several indices changed after the revision of the historical Partial CAA derived from the updated CAA matrix. The age distribution of the Florida commercial catch for the northern region [Jul-Oct] indicated that significant proportion of ages 1 and 2 king were consistently caught in this fishery from 1985 to 2001 (the years of available index), in prior assessments, for this particular index only ages 3 to 6

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1 The commercial catch for Gulf king mackerel fishing year 2002-03 was set to 3,125,555 lbs. From the Preliminary Quota Monitoring Report No. 22 on April 28 2003.
2 The recreational catch for Gulf king mackerel fishing year 2002-03 was set to 594,343 fish. From the recreational landings MRFSS FY02/03 with substitutions for HeadBoat and Tx-PWD estimates of 2003.

were included. Therefore the age coverage for the FL-FWC Northwest was extended from age 1 to Age 6. For the Florida commercial southwest fishery [Nov-Dec] from 1985-2001 the updated Partial-CAA indicated that age 2 was consistently present in the catch, thus age coverage for this index was extended from ages 2 to 8. The recreational MRFSS index was also modified in terms of age coverage (previously it included only ages 2 to 8): the age distribution of the updated Partial-CAA indicated that age 1 was also an important component on this fishery. Therefore, for the MRFSS index age coverage was extended to include ages 1 through 8. Partial CAAs for the Charter Florida indices (north and south) were also revised. For the Charter Northwest [May-Oct] age coverage was extended to include ages 1 to 7, and for the Charter Southwest [Nov-Apr] age coverage included ages 1 to 8. The proportion of directed catch by age for the commercial and recreational sectors was also estimated from the average of CAA by sector for the fishing years 1997-2001. Other input data updated for the VPA model was the mean weight at age (Age 0 to Age 11+) as explained in the methods section.

Table 4 presents the results of the deterministic VPA run “new” growth parameters including parameter estimates for Ages 2 through 10, residuals of the indices fit, and estimated selectivity at age for each index (for all purposes this run was labeled New-GP model). Figure 5 shows the distribution pattern of the indices residuals, and Figure 6 shows the plots of observed vs. predicted values for all nine indices from the deterministic run.

Table 5 presents the estimated stock size at age by year, and the fishing mortality at age-year matrix. Figure 7 shows the stock size trends by age and the total stock size estimates. For comparison results of the base case 2004 model are shown (solid diamond lines). Figure 8 shows the corresponding fishing mortality trends by age. Figure 9 shows also estimates of stock size, fishing mortality and stock biomass by groups of ages including 80% pseudo-confidence intervals as estimated from 500 bootstrap runs. For comparison in Figure 9 equivalent results from the base case 2004 model are presented (open squares lines). The estimates of recruits (age 0) from the New-GP and base case 2004 were similar in trend and values, smaller recruitment was predicted by the base case in the 1994-1997 period, and 1981-1982 years. For ages 1 and 2, the New-GP model estimated larger stock size from 1983 to 1991, and again for 1993 to 1999. Similar trends were observed for stock size of ages 3 to 6, but the New-GP model estimated larger stock sizes from 1994 through the last year 2001. These larger stock sizes estimated by the New-GP model translated into a much larger estimated stock biomass also. Stock biomass of ages 0-2 was about twice or greater the biomass estimated in the base case 2004, throughout the whole time series (1981-2001), similarly the biomass of ages 3-6 was consistently greater from the New-GP model. Estimates of stock size for older ages (age7-11+) were comparable between the base case 2004 and the New-GP models. This is a joint effect of the increased predicted weight at age and the increase in estimated stock size in the New-GP model formulation. At the moment, it is assumed that the New-GP model predictions of weight at age represent the underlying population and the harvested population and does not account for potential differences due to fishery selectivity.

The New-GP model estimated larger stock size for age7-10 from 1988 through 2001. Overall, the New-GP estimated larger Gulf king mackerel stocks from 1981 to 2001, following the same trend as the base case 2004 but consistently greater numbers at age, specifically for ages 3 to 6. In terms of fishing mortality F, no consistent trends were observed between the base case 2004 and the New-GP models, total F was similar in early years, with some higher mortality estimates by the New-GP model in the early 1990s and lower F estimates in the latest years (1997-2001) compared to the base case 2004 estimates (Fig 8 and 9).

The estimates of spawning potential ratios (SPR) are shown in Figure 10. The unweighted SPR trend showed an increase from 1983 to a peak in 1993, followed by a decrease until 1995 and an upward trend since 1997. Compared with the base case 2004 model estimates the New-GP unweighted SPR values were higher, the median 2002 unweighted SPR was estimated well above 30% (39.3%). Static SPR also show an overall increasing trend from the New-GP model, with an estimated static SPR value of 51% in the 2001 year. In general, the New-GP estimated SPR ratios being above 30% for most of the time series for Gulf king mackerel (Fig 10).

The proxies for stock status are based upon $F_{30\%SPR}$ and the two-line model of stock recruitment relationship described previously. These proxies were computed by projecting each bootstrap to the year

2070 under constant recruitment and estimated F mortality of $F_{30\%SPR}$ both specific to each bootstrap run. Similarly, proxies for the optimum yield (OY) were computed using $F_{40\%SPR}$. The median and 80% confidence intervals for these MSY and OY related benchmarks are given in Table 6. The base case 2004 model and the New-GP model scenarios estimates of median and the deterministic run were different for most of the benchmarks. Figure 11 shows a comparison of the benchmarks estimates for the 2004 base case 2004 model, and New-GP model. In comparison, the New-GP model estimated higher values for MSY and OY. Estimates of fishing mortality (F) bench marks were higher for the New-GP model but confidence intervals overlap between the base case 2004 and New-GP models.

Using the bootstrap specific estimates of MFMT and MSST, the probability of being classified as undergoing overfishing or being overfished in fishing year 2002/03 were calculated. For the New-GP model, 3 of the 500 bootstraps (1%) estimated F_{2002} > MFMT (Fig 12), while 4 of the 500 bootstraps (1%) estimated a SS_{2003} < MSST (Fig 13). In addition, the New-GP model estimated $F_{2002} > F_{OY}$ for 27 (5%) out of 500 bootstraps. Since currently, the acceptable resource risk of being overfished or undergoing overfishing is not defined, no definite statement about stock status can be made. However, the Technical Guidelines (Restrepo et al 1998) recommend lower risk of exceeding threshold levels, suggesting that a value not be greater than 20-30% and certainly less than 50%. Phase plots for the Gulf king mackerel stock status in fishing year 2002/03 are shown in Figure 14.

The fishing year 2003/2004 acceptable biological catch (ABC) for the New-GP using an $F_{30\%}$ criterion had a median value of 20.3 million pounds, and estimated 80% pseudo confidence interval between 14.8 and 27.2 million pounds (Table 7 and Fig 15). It is noteworthy that historical removals of yields somewhat less than this level led to strict management actions by the Gulf Council, due to concern over stock status, thus limiting removals to much lower levels in the 1980's.

In conclusion using the "new" von Bertalanffy growth parameters of Gulf king, the stock assessment indicated that Gulf king mackerel is not over-exploited. In this sensitivity, estimated stock spawning biomass is above spawning biomass at MSY, and at or above spawning biomass at OY. Fishing mortality is well below F_{MSY} or F_{OY} , and the results imply that, should the assumptions of the formulation prove true, projected allowable biological catch should significantly be raised (perhaps to twice the current quotas). So why such as different stock assessments of Gulf king mackerel when only growth parameters were updated? This is likely a result of magnifying the weights at age, maturity at age, and fecundity at age effects implied by the growth parameters. To the degree these misrepresent the underlying population characteristics, the assessment results would be biased. It should be emphasized that the new growth curves are based on fishery data collected whilst a minimum size limit was in effect. Accordingly, they reflect a selection bias towards larger animals, particularly for the younger age classes. The fitted growth curve will tend to have a more negative t0 (and lower *k*) than the curve for the overall population, with the result that the predicted size of younger fish will be biased in comparison with the overall population. This size-biased curve is appropriate for ageing the size-biased catch, but not for modelling the productivity of the overall stock. If, for example, the size-biased growth curve is used to convert fecundity at length to fecundity at age, the relative fecundity of younger fish will likely be overestimated, making the stock appear more productive than it actually is. It is suggested that future analyses develop separate growth curves for ageing the overall population and ageing the catch, i.e., one that attempts to tease out the effects of selection and one that does not. A review of the implications and effects that the growth parameters have on the stock assessment models follows.

1. The first input of the Gulf king growth parameters was at the conversion of catch-at size to catch-at age data. The stochastic ageing method (SAR) uses growth parameters to assign age by sex for the catch-at size matrix (Ortiz et al 2003). The SAR procedure is used when no Age-length keys are available, in the case of Gulf king primarily this happened for the early years, 1981-1985 when no hard parts were collected. However, there are also some year-quarter-area combinations where no ALK were applied between 1986 and 2001 (Ortiz et al 2003). The effects on the CAA matrix distribution from the "new" growth parameters in the SAR method were described by Brooks and Ortiz (2004). In summary, for years where the SAR is the predominant ageing method, the CAA matrix tends to allocate more catch towards the younger age classes, 0 to 2, reducing the proportion of catch from older ages. Figure 16 shows the age distribution of the CAA input

matrix for the base case 2004 and the New-GP model. The “new” growth parameters estimated a CAA matrix with predominant catch of ages 1 and 2, even age 0 was more common in the directed catch, while ages 4, 5, and 6 were reduced in proportion, and older ages 7+ had much less presence in the directed catch particularly in the early years 1981-1985. This was basically as result that the “new” growth parameters estimate larger average size for male ages 0, 1, 2, and 4, as well for females in all ages (Table 1).

2. Modification of the CAA matrix also implied a change in the Partial CAA. The VPA-FADAPT model used Partial CAA as input for selectivity patterns associated with the indices of abundance from commercial (FL-FWC NW, FL-FWC SW), and recreational (Headboat, MRFSS, Tx-PWD, Charter FL-SW, Charter FL-NW) fisheries. The update Partial CAA indicated in several cases that associated fisheries were catching proportional a higher percent of younger age classes, compared to the base case or prior assessments. Here also the effect of alternative criteria for the use of the SAR or Age-length key can affect the resulted CAA matrix (Ortiz 2004a).

3. In the VPA-model, other modification associated with the growth parameters is the weight-at age relationship. Weight at size relationship has not been updated, thus for this scenario the weight at age increased as expected for combined sex even at higher proportion than the size increases. For example for age 0 mean weight doubles compare to prior assessments or the base case scenario, for ages 1, 2, 3 and 4 on average mean weight increased by 53% ! These changes of mean weight at age were also translated in the stock projection model.

4. Other important effect of growth parameters change was in the estimates of Fecundity at age. Gulf king mackerel assessments had used the estimates of maturity and fecundity from Finucane *et al* (1986) which were in function of female size (fork length). When the functions were translated into age vectors using the “new” growth parameters, the net effect was to increase the maturity and fecundity of the young age classes. With the “new” growth parameters age 0 fish had a 30% probability of maturity, with females age 0 producing about 0.04 million eggs per female annually. 50% maturity was reach before age 2, and full maturity was reach at age 4 while in the prior assessments, full maturity was only reach at age 6. In summary, combining the “new” growth parameters and Finucane’s maturity-fecundity models indicated that Gulf king mackerel mature and spawn a much younger age, and as they weight more at age, potential maximum yield per recruit was consequently pushed toward younger age classes.

In conclusion what was perceived as a minor difference in terms of growth parameter estimates, it had translated into significant differences for the Gulf king input of size at age, weight at age, and maturity-fecundity at age. In addition, the SAR ageing method modified the CAA matrix of directed fisheries by allocating proportionally high catches to the younger ages.

There is no evidence that Gulf king mackerel age 0 reach maturity, or even have a successful spawning capacity. Similarly is unlikely that 50% of the fish reach maturity at age 1. These results could be attributed to two non-mutually exclusive alternatives; A) Incorrect fit of the “new” growth parameters particularly for the younger age classes. Although the number of samples for the “new” growth parameters is sufficiently larger than the number of samples used in the Manooch’s growth estimation, there were still few observations of age 0 fish (less than 1%). As discussed in Brooks and Ortiz (2004) the main differences on growth parameters were for the intercept parameter (t_0) which explained the increase size at age particularly for younger age classes although asymptotic length and growth rate parameters were similar between the Manooch et al (1986) estimates and the “new” growth parameters. This effect could at least be partially moderated by use of more precise information on the fractional age of fish in growth modeling, although larger sample sizes for the youngest fish. And B) The ‘new’ growth parameters reflect the selectivity bias of the aged-samples for king mackerel, particularly related with minimum size implementations. The minimum size regulations could have bias towards selecting fast growing fish, on the younger age classes mainly which were not fully selected to the gears. Thus the ‘new’ growth curves reflect the fishery available stock, but not the population growth which should be used for stock projection assessment.

LITERATURE CITED

Brooks, E.N. and M. Ortiz. 2004. Estimated von Bertalanffy growth curves for King mackerel stocks in the Atlantic and Gulf of Mexico. NMFS-SEFSC Sustainable Fisheries Division Contribution SFD-2004- SEDAR5-AW-1.

Finucane, J.H., L.A. Collins, H.A. Brusher, and C.H. Saloman. 1986. Reproductive biology of king mackerel, *Scomberomorus cavalla*, from the Southeastern United States. Fishery Bulletin. 84(4): 841-850.

Johnson, A.G. W.A. Fable, M.L. Williams and L.E. Barger. 1983. Age, growth and mortality of king mackerel, Scomberomorus cavalla, from the Southeastern United States. Fishery Bulletin 81(1):97-106

Manooch, C.S. III, S.P. Naughton, C.B. Grimes, and L. Trent. 1986. Age and growth of king mackerel, *Scomberomorus cavalla*, from the U.S. Gulf of Mexico. Marine Fisheries Review. 49(2): 102-108.

Ortiz, M P.L. Phares and N.J. Cummings. 2003. Review of the catch sizing and ageing of king mackerel Scomberomorus cavalla from US Gulf of Mexico and South Atlantic fisheries. SEDAR5-DW8 NMFS SEFSC Miami SFD-2003

Ortiz, M. 2004. Stock Assessment Analysis on Gulf of Mexico King Mackerel. SEDAR5- 2004 NMFS SEFSC Miami Lab Sustainable Fisheries Division Contribution 2004-004.

Ortiz, M 2004a. Sensistivity of stock assessment analysis of Gulf of Mexico king mackerel to alternative methods for estimating the historic catch at age matrix 1981-2002. SEDAR5-AW-2. NMFS SEFSC Miami SFD-2003.

Powers, J.E. and V.R. Restrepo. 1992. Additional options for age-sequenced analysis. ICCAT Coll. Vol. Sci. Pap. 39: 540-553.

Restrepo, V.R. 1996. FADAPT 3.0 A Guide. University of Miami, Cooperative Unit for Fisheries Research and Education (CUFER).

Restrepo, V.R., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade and J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-##. 54 pp.

Table 1. Comparison of estimated size at age for Gulf king mackerel by sex group from the Manooch et al (1986) and Brooks and Ortiz (2004) von Bertalanffy growth parameters. Percent increase refers to the size comparison between models; positive values indicated larger size for the Brooks and Ortiz parameters (B&O).

	Males size(mm)			Females size (mm)			Combined Sex (mm)		
Age	Manooch	New GP B&O	% increase	Manooch	New GP B&O	% increase	Manooch	New GP B&O	% increase
0	295	506	71%	334	513	54%	352	517	47%
1	449	598	33%	472	628	33%	475	621	31%
2	573	675	18%	592	728	23%	584	711	22%
3	675	739	10%	697	816	17%	682	790	16%
4	757	792	5%	788	892	13%	769	858	12%
5	824	836	1%	868	959	10%	846	917	8%
6	878	873	-1%	938	1017	8%	915	968	6%
7	922	903	-2%	999	1068	7%	976	1012	4%
8	958	928	-3%	1052	1112	6%	1031	1051	2%
9	987	949	-4%	1098	1151	5%	1080	1084	0%
10	1011	966	-4%	1139	1184	4%	1123	1113	-1%
11	1030	981	-5%	1174	1214	3%	1162	1138	-2%
12	1046	993	-5%	1205	1239	3%	1196	1160	-3%
13	1058	1003	-5%	1232	1262	2%	1227	1179	-4%
14	1069	1011	-5%	1256	1282	2%	1254	1196	-5%
15	1077	1018	-6%	1276	1299	2%	1279	1210	-5%
16	1084	1023	-6%	1294	1314	2%	1300	1222	-6%
17	1089	1028	-6%	1310	1327	1%	1320	1233	-7%
18	1094	1032	-6%	1323	1338	1%	1337	1242	-7%
19	1097	1035	-6%	1335	1348	1%	1352	1250	-8%
20	1100	1038	-6%	1346	1357	1%	1366	1257	-8%

Table 2. Comparison of fecundity at age for Gulf king mackerel females using the Manooch et al (1986) and Brooks and Ortiz (2004) von Bertalanffy growth parameters. Maturity at age relationship, female fecundity and egg production was estimated by Finucane et al (1986) as a function of size (fork length).

Comparison King Gulf Fecundity at Age								
	Female size (Fork) mm		Probability Mature		Fecundity Fem		Eggs Millions	
Age	Manooch	NewGP B&O	Manooch	NewGP B&O	Manooch	NewGP B&O	Manooch	NewGP B&O
0	335	513	0	0.2941	47269	259018	0.000	0.038
1	472	628	0.1572	0.5884	185947	577712	0.015	0.170
2	592	728	0.5288	0.7550	457773	1040375	0.121	0.393
3	697	816	0.7036	0.9011	874959	1632794	0.308	0.736
4	789	892	0.8562	1	1428538	2329878	0.612	1.165
5	869	959	0.9893	1	2096139	3102141	1.037	1.551
6	938	1017	1	1	2849046	3920225	1.425	1.960
7	999	1068	1	1	3657394	4757634	1.829	2.379
8	1052	1112	1	1	4493458	5592090	2.247	2.796
9	1099	1151	1	1	5333418	6405953	2.667	3.203
10	1139	1184	1	1	6158047	7186057	3.079	3.593
11	1174	1214	1	1	6952705	7923232	3.476	3.962
12	1205	1239	1	1	7706939	8611682	3.853	4.306
13	1232	1262	1	1	8413894	9248342	4.207	4.624
14	1256	1282	1	1	9069662	9832272	4.535	4.916
15	1276	1299	1	1	9672663	10364124	4.836	5.182
16	1294	1314	1	1	10223076	10845690	5.112	5.423
17	1310	1327	1	1	10722368	11279537	5.361	5.640
18	1323	1338	1	1	11172892	11668720	5.586	5.834

Table 3. Tuning indices for the New-growth parameters sensitivity run (New-GP) of Gulf of Mexico king mackerel. Time of comparison between observed and predicted values is either mid-year (MID) or at the start of the year (BEG), and the index reflects the stock measurement in units of biomass, numbers or eggs, Age correspond to the coverage of ages by each index.

Fishing Year	Florida FWC NorthWest	Florida FWC SouthWes	MRFSS	Texas PWD	HeadBoat	Charter NorthWest Florida	Charter SouthWest Florida	Bycatch Shrimp Fishery	SEAMAP occurrence
1981/82					1.1929			2.1547	
1982/83					0.8230			2.0945	0.0921
1983/84				0.8489	1.8108			1.9198	0.0169
1984/85				0.8586	0.6202			2.6963	0.1781
1985/86	17.753	36.787		0.6849	0.4126			2.5305	0.0659
1986/87	21.755	35.696	0.2028	0.4854	0.5926			1.6932	0.1031
1987/88	22.838	48.300	0.4842	0.5674	0.4020			3.4250	0.1157
1988/89	18.690	69.571	0.4741	0.5112	0.3407	0.4480	0.4160	2.9394	0.1111
1989/90	19.880	65.726	0.3153	0.5698	0.6599	0.4425	0.5500	6.0170	0.1860
1990/91	26.707	84.943	0.8954	0.4411	0.5241	0.4417	0.4700	4.2740	0.2031
1991/92	29.515	82.456	1.0000	1.0000	0.8671	0.4772	0.3850	4.9805	0.1783
1992/93	38.750	167.154	0.7526	0.6968	1.0862	0.5012	0.4960	2.4888	0.2814
1993/94	32.521	103.767	0.5165	0.6746	1.1565	0.4669	0.5600	5.1361	0.2971
1994/95	39.116	56.904	0.4913	0.7039	1.1859	0.6025	0.8030	4.8192	0.2614
1995/96	34.617	83.851	0.3896	0.8485	1.1611	0.6341		6.3063	0.3268
1996/97	55.880	109.332	0.7036	0.8415	1.4964			3.1842	0.2400
1997/98	75.432	85.442	0.8336	0.6831	1.4625			3.7494	0.3034
1998/99	46.696	104.764	0.4938	0.7668	1.3016			3.9712	0.2667
1999/00	64.776	57.090	0.5651	0.6181	1.4863			3.9894	0.2581
2000/01	57.088	96.376	0.6915	0.5254	1.0371			4.9200	0.1923
2001/02			0.5048	0.5066	1.2314				0.3017
Timing	BEG	MID	BEG	BEG	MID	BEG	MID	BEG	BEG
Units	Biomass	Biomass	Number	Number	Number	Number	Number	Number	Eggs
Ages	1 - 6	2 - 8	1 - 8	2 - 8	2 - 6	1 - 7	1 - 8	0	1 - 11

Table 4. VPA-FADAPT deterministic run results New Growth Parameters sensitivity model.

FADAPT Version 3 (Feb 96) by V. Restrepo

```
Input DATA file: GK1aNewGP.inp
Input CONTROL file: GK2aNewGP.inp
Output Stock Size file: gknGP04.naa
Output Fishing Mortality file: gknGP04.faa
Ouput Fitted Indices file: gknGP04.ind
Output Diagnostics (this) file: gknGP04.par

Run name: Glf_Kng_81-01_NewGP
No. index values: 135  Parameters:  9
Mean Squared Error (rss/df) =  0.14389E+00
Rsquared =  0.0594
Loglikelihood = -0.56039E+02


res from indices   =    195.587947571856
res from curvature =   0.000000000000000E+000


Program termination OK

More details of the run can be found in
fileFADAPT5.RUN
```

Parameter	Estimate	S.E.	% C.V.
F age 2	0.0562	0.01653	29.40
F age 3	0.2875	0.06392	22.24
F age 4	0.1597	0.04009	25.11
F age 5	0.1075	0.03170	29.48
F age 6	0.0757	0.01870	24.71
F age 7	0.1555	0.03422	22.00
F age 8	0.0687	0.04446	64.73
F age 9	0.1247	0.04834	38.77
F age 10	0.0727	0.02319	31.90

Variances of terminal yr F and survivors

Age,	SE(F,101)	CV(F)	SE(N,102)	CV(N)
0	0.23142E-01	29.39932		
1	0.54549E-02	29.39932	0.14906E+07	30.61009
2	0.16530E-01	29.39932	0.38895E+06	29.68199
3	0.63923E-01	22.23617	0.80290E+06	30.26107
4	0.40088E-01	25.10862	0.17359E+06	25.69096
5	0.31698E-01	29.47656	0.24871E+06	27.23288
6	0.18700E-01	24.70907	0.23129E+06	31.14257
7	0.34215E-01	21.99687	0.16492E+06	25.68698
8	0.44459E-01	64.73023	63987.	23.80879
9	0.48340E-01	38.76697	0.23243E+06	67.05259
10	0.23193E-01	31.89737	38830.	41.31453
11	0.23193E-01	31.89737	0.11124E+06	27.95886

Obs. and pred. indices in objective function

0.47184E+00	0.83453E+00
0.57818E+00	0.45906E+00
0.60698E+00	0.57423E+00
0.49673E+00	0.59632E+00
0.52836E+00	0.58017E+00
0.70981E+00	0.96414E+00
0.78444E+00	0.13659E+01
0.10299E+01	0.84511E+00
0.86433E+00	0.12586E+01
0.10396E+01	0.13794E+01
0.92004E+00	0.83606E+00
0.14852E+01	0.12731E+01
0.20048E+01	0.12008E+01
0.12411E+01	0.12823E+01
0.17216E+01	0.10931E+01
0.15172E+01	0.13489E+01
0.45692E+00	0.59870E+00
0.44337E+00	0.48293E+00
0.59993E+00	0.37070E+00
0.86413E+00	0.79948E+00
0.81637E+00	0.47362E+00
0.10551E+01	0.92073E+00
0.10242E+01	0.11257E+01
0.20762E+01	0.10198E+01
0.12889E+01	0.88351E+00
0.70679E+00	0.55253E+00
0.10415E+01	0.11660E+01
0.13580E+01	0.13574E+01
0.10613E+01	0.14903E+01
0.13013E+01	0.13839E+01
0.70911E+00	0.12593E+01
0.11971E+01	0.13000E+01
0.34844E+00	0.70880E+00
0.83177E+00	0.87801E+00
0.81436E+00	0.10609E+01
0.54157E+00	0.75428E+00
0.15380E+01	0.12711E+01
0.17178E+01	0.98699E+00
0.12929E+01	0.52092E+00
0.88729E+00	0.13108E+01
0.84392E+00	0.44360E+00
0.66929E+00	0.11196E+01
0.12087E+01	0.10494E+01
0.14320E+01	0.10338E+01
0.84830E+00	0.94431E+00
0.97068E+00	0.13550E+01
0.11879E+01	0.10727E+01
0.86721E+00	0.81038E+00
0.10645E+01	0.81806E+00
0.10767E+01	0.12236E+01
0.85889E+00	0.88347E+00
0.74391E+00	0.54239E+00
0.86954E+00	0.65204E+00
0.78342E+00	0.49864E+00
0.87329E+00	0.32298E+00
0.67595E+00	0.55424E+00
0.15325E+01	0.11529E+01
0.10679E+01	0.14728E+01
0.10339E+01	0.12280E+01
0.10788E+01	0.45782E+00
0.13004E+01	0.12620E+01
0.12896E+01	0.11652E+01
0.10468E+01	0.12830E+01
0.11751E+01	0.11070E+01
0.94729E+00	0.62742E+00
0.80518E+00	0.88285E+00
0.77637E+00	0.12680E+01
0.12014E+01	0.22447E+00
0.82888E+00	0.71887E+00
0.18238E+01	0.48167E+00
0.62468E+00	0.44022E+00
0.41559E+00	0.61269E+00
0.59687E+00	0.62080E+00
0.40482E+00	0.75003E+00
0.34316E+00	0.73005E+00
0.66465E+00	0.85609E+00
0.52787E+00	0.15094E+01
0.87334E+00	0.12799E+01
0.10939E+01	0.60245E+00
0.11648E+01	0.69214E+00
0.11944E+01	0.88729E+00
0.11694E+01	0.87457E+00
0.15071E+01	0.11549E+01
0.14730E+01	0.14701E+01
0.13109E+01	0.14958E+01
0.14969E+01	0.15101E+01
0.10445E+01	0.84846E+00
0.12402E+01	0.57422E+00
0.79130E+00	0.98327E+00
0.10462E+01	0.12564E+01
0.89402E+00	0.35740E+00
0.73234E+00	0.74353E+00
0.94348E+00	0.47363E+00
0.10652E+01	0.14276E+01
0.15274E+01	0.90176E+00
0.58800E+00	0.63919E+00
0.57158E+00	0.84803E+00
0.52390E+00	0.45860E+00
0.73580E+00	0.72824E+00
0.69056E+00	0.76512E+00
0.46205E+00	0.68999E+00
0.93465E+00	0.85710E+00
0.80214E+00	0.12580E+01
0.16420E+01	0.14969E+01
0.11663E+01	0.11723E+01
0.13591E+01	0.88245E+00
0.67918E+00	0.79481E+00
0.14016E+01	0.13921E+01
0.13151E+01	0.12313E+01
0.17209E+01	0.14629E+01
0.86892E+00	0.11135E+01
0.10232E+01	0.11288E+01
0.10837E+01	0.72249E+00
0.10887E+01	0.13774E+01
0.13426E+01	0.62660E+00
0.46292E+00	0.93196E+00
0.85185E-01	0.72853E+00
0.89503E+00	0.74496E+00
0.33138E+00	0.73191E+00
0.51837E+00	0.74321E+00
0.58171E+00	0.79134E+00
0.55844E+00	0.85982E+00
0.93506E+00	0.85333E+00
0.10209E+01	0.92256E+00
0.89610E+00	0.99621E+00
0.14145E+01	0.10987E+01
0.14934E+01	0.11388E+01
0.13136E+01	0.11482E+01
0.16425E+01	0.11116E+01
0.12062E+01	0.11521E+01
0.15247E+01	0.11947E+01
0.13403E+01	0.12512E+01
0.12970E+01	0.13053E+01
0.96653E+00	0.13836E+01
0.15162E+01	0.14416E+01

INDEX RESULTS

Equal weighting for indices
ML estimate of variance (all indices): 0.1343

Fit results for index = FL_FWC_NW
Index Fitted to Beginning Stock Size in BIOMASS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
85/86	0.4718	0.4718	0.8345	-0.3627	-0.9897
86/87	0.5782	0.5782	0.4591	0.1191	0.3250
87/88	0.6070	0.6070	0.5742	0.0328	0.0894
88/89	0.4967	0.4967	0.5963	-0.0996	-0.2718
89/90	0.5284	0.5284	0.5802	-0.0518	-0.1414
90/91	0.7098	0.7098	0.9641	-0.2543	-0.6940
91/92	0.7844	0.7844	1.3659	-0.5814	-1.5865
92/93	1.0299	1.0299	0.8451	0.1848	0.5041
93/94	0.8643	0.8643	1.2586	-0.3943	-1.0758
94/95	1.0396	1.0396	1.3794	-0.3398	-0.9273
95/96	0.9200	0.9200	0.8361	0.0840	0.2292
96/97	1.4852	1.4852	1.2731	0.2121	0.5787
97/98	2.0048	2.0048	1.2008	0.8040	2.1940
98/99	1.2411	1.2411	1.2823	-0.0413	-0.1126
99/00	1.7216	1.7216	1.0931	0.6285	1.7149
00/01	1.5172	1.5172	1.3489	0.1684	0.4594

ML estimate of catchability: 0.24202E-07
Pearsons (parametric) correlation: 0.637 P= 0.0000
Kendalls (nonparametric) Tau: 0.417 P= 0.0010

Selectivity at age from Partial Catches

year	1	2	3	4	5	6
85/86	0.094	0.979	0.885	1.000	0.335	0.697
86/87	1.000	0.096	0.414	0.152	0.143	0.646
87/88	0.587	1.000	0.228	0.453	0.119	0.114
88/89	0.411	0.687	0.382	0.386	1.000	0.078
89/90	0.562	0.200	1.000	0.070	0.044	0.049
90/91	0.292	1.000	0.575	0.305	0.400	0.487
91/92	0.677	1.000	0.478	0.676	0.921	0.473
92/93	0.425	1.000	0.464	0.149	0.118	0.452
93/94	0.232	0.883	1.000	0.803	0.510	0.565
94/95	0.426	0.641	0.870	1.000	0.838	0.619
95/96	0.045	0.214	0.433	1.000	0.669	0.837
96/97	0.203	1.000	0.793	0.714	0.635	0.627
97/98	0.041	0.552	1.000	0.732	0.861	0.537
98/99	0.336	0.465	1.000	0.736	0.486	0.624
99/00	0.216	0.260	0.443	0.892	1.000	0.448
00/01	0.060	0.783	0.638	1.000	0.986	0.592

Fit results for index = FL_FWC_SW
Index Fitted to Mid-Year Stock Size in BIOMASS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
85/86	0.4569	0.4569	0.5987	-0.1418	-0.3869
86/87	0.4434	0.4434	0.4829	-0.0396	-0.1080
87/88	0.5999	0.5999	0.3707	0.2292	0.6255
88/89	0.8641	0.8641	0.7995	0.0647	0.1764
89/90	0.8164	0.8164	0.4736	0.3428	0.9353
90/91	1.0551	1.0551	0.9207	0.1343	0.3666
91/92	1.0242	1.0242	1.1257	-0.1016	-0.2772
92/93	2.0762	2.0762	1.0198	1.0564	2.8825
93/94	1.2889	1.2889	0.8835	0.4054	1.1061
94/95	0.7068	0.7068	0.5525	0.1543	0.4210
95/96	1.0415	1.0415	1.1660	-0.1245	-0.3398
96/97	1.3580	1.3580	1.3574	0.0006	0.0016
97/98	1.0613	1.0613	1.4903	-0.4291	-1.1708
98/99	1.3013	1.3013	1.3839	-0.0826	-0.2255
99/00	0.7091	0.7091	1.2593	-0.5502	-1.5014
00/01	1.1971	1.1971	1.3000	-0.1030	-0.2810

ML estimate of catchability: 0.33308E-07
Pearsons (parametric) correlation: 0.560 P= 0.0004
Kendalls (nonparametric) Tau: 0.500 P= 0.0001

Selectivity at age from Partial Catches

year	2	3	4	5	6	7	8
85/86	0.074	0.143	1.000	0.659	0.956	0.726	0.111
86/87	0.281	1.000	0.157	0.607	0.196	0.000	0.089
87/88	0.141	1.000	0.139	0.025	0.025	0.195	0.032
88/89	0.225	0.952	1.000	0.761	0.293	0.010	0.025
89/90	0.379	0.366	0.420	0.251	1.000	0.001	0.000
90/91	0.693	1.000	0.302	0.341	0.394	0.069	0.008
91/92	0.547	0.451	0.664	1.000	0.535	0.416	0.339
92/93	0.531	0.614	0.285	0.233	1.000	0.196	0.645
93/94	0.367	0.483	0.487	0.329	0.301	1.000	0.251
94/95	0.224	0.460	0.436	0.241	0.126	0.049	1.000
95/96	0.576	0.762	1.000	0.488	0.424	0.261	0.284
96/97	1.000	0.831	0.632	0.419	0.398	0.248	0.086
97/98	0.743	1.000	0.602	0.596	0.387	0.416	0.274
98/99	0.341	1.000	0.689	0.454	0.511	0.505	0.449
99/00	0.201	0.360	0.806	1.000	0.406	0.678	0.784
00/01	1.000	0.587	0.733	0.487	0.288	0.293	0.308

Fit results for index = MRFSS
Index Fitted to Beginning Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
86/87	0.3484	0.3484	0.7088	-0.3604	-0.9833
87/88	0.8318	0.8318	0.8780	-0.0462	-0.1262
88/89	0.8144	0.8144	1.0609	-0.2465	-0.6727
89/90	0.5416	0.5416	0.7543	-0.2127	-0.5804
90/91	1.5380	1.5380	1.2711	0.2670	0.7285
91/92	1.7178	1.7178	0.9870	0.7308	1.9941
92/93	1.2929	1.2929	0.5209	0.7719	2.1064
93/94	0.8873	0.8873	1.3108	-0.4235	-1.1555
94/95	0.8439	0.8439	0.4436	0.4003	1.0924
95/96	0.6693	0.6693	1.1196	-0.4503	-1.2288
96/97	1.2087	1.2087	1.0494	0.1593	0.4346
97/98	1.4320	1.4320	1.0338	0.3982	1.0866
98/99	0.8483	0.8483	0.9443	-0.0960	-0.2620
99/00	0.9707	0.9707	1.3550	-0.3843	-1.0487
00/01	1.1879	1.1879	1.0727	0.1152	0.3143
01/02	0.8672	0.8672	0.8104	0.0568	0.1551

ML estimate of catchability: 0.19640E-06
Pearsons (parametric) correlation: 0.263 P= 0.0991
Kendalls (nonparametric) Tau: 0.183 P= 0.1140

Selectivity at age from Partial Catches

year	1	2	3	4	5	6	7	8
86/87	0.570	1.000	0.474	0.168	0.364	0.341	0.231	0.158
87/88	0.402	0.837	1.000	0.778	0.623	0.229	0.672	0.837
88/89	1.000	0.594	0.868	0.918	0.996	0.087	0.700	0.294
89/90	0.289	1.000	0.465	0.288	0.330	0.721	0.089	0.240
90/91	0.580	1.000	0.727	0.396	0.259	0.310	0.487	0.028
91/92	0.213	0.740	0.548	0.495	0.354	0.413	0.423	1.000
92/93	0.217	0.276	0.259	0.264	0.313	0.341	0.345	1.000
93/94	0.787	1.000	0.640	0.710	0.630	0.678	0.719	0.773
94/95	0.081	0.280	0.377	0.367	0.165	0.318	0.397	1.000
95/96	0.178	0.621	1.000	0.874	0.590	0.754	0.611	0.834
96/97	0.071	0.733	0.618	1.000	0.787	0.363	0.474	0.644
97/98	0.167	0.330	1.000	0.534	0.977	0.708	0.426	0.524
98/99	0.265	0.311	0.417	1.000	0.537	0.769	0.600	0.456
99/00	0.532	0.875	0.672	0.782	1.000	0.240	0.885	0.344
00/01	0.123	0.840	1.000	0.522	0.369	0.563	0.368	0.706
01/02	0.098	0.212	1.000	0.558	0.461	0.335	0.996	0.611

Fit results for index = TX_PWD_83-85
Index Fitted to Beginning Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
83/84	1.0645	1.0645	0.8181	0.2464	0.6724
84/85	1.0767	1.0767	1.2236	-0.1470	-0.4011
85/86	0.8589	0.8589	0.8835	-0.0246	-0.0671

ML estimate of catchability: 0.38067E-06
Pearsons (parametric) correlation: 0.410 P= 0.2711
Kendalls (nonparametric) Tau: 0.333 P= 0.3254

Selectivity at age from Partial Catches

year	2	3	4	5	6	7	8
83/84	0.326	0.411	0.708	0.085	1.000	0.494	0.218
84/85	0.607	0.483	0.968	0.906	0.472	0.015	1.000
85/86	0.670	0.267	0.709	0.878	0.159	1.000	0.662

Fit results for index = TX_PWD_86-01
Index Fitted to Beginning Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
86/87	0.7439	0.7439	0.5424	0.2015	0.5499
87/88	0.8695	0.8695	0.6520	0.2175	0.5935
88/89	0.7834	0.7834	0.4986	0.2848	0.7771
89/90	0.8733	0.8733	0.3230	0.5503	1.5017
90/91	0.6760	0.6760	0.5542	0.1217	0.3321
91/92	1.5325	1.5325	1.1529	0.3796	1.0358
92/93	1.0679	1.0679	1.4728	-0.4049	-1.1048
93/94	1.0339	1.0339	1.2280	-0.1942	-0.5298
94/95	1.0788	1.0788	0.4578	0.6210	1.6945
95/96	1.3004	1.3004	1.2620	0.0384	0.1047
96/97	1.2896	1.2896	1.1652	0.1244	0.3396
97/98	1.0468	1.0468	1.2830	-0.2362	-0.6446
98/99	1.1751	1.1751	1.1070	0.0682	0.1860
99/00	0.9473	0.9473	0.6274	0.3199	0.8728
00/01	0.8052	0.8052	0.8829	-0.0777	-0.2119
01/02	0.7764	0.7764	1.2680	-0.4916	-1.3415

ML estimate of catchability: 0.29527E-06
Pearsons (parametric) correlation: 0.542 P= 0.0006
Kendalls (nonparametric) Tau: 0.267 P= 0.0294

Selectivity at age from Partial Catches

year	2	3	4	5	6	7	8
86/87	0.304	0.683	0.198	0.651	0.149	1.000	0.456
87/88	0.380	0.706	0.755	0.086	0.382	0.769	1.000
88/89	0.372	0.392	0.138	1.000	0.114	0.236	0.003
89/90	0.230	0.181	0.257	0.141	1.000	0.022	0.074
90/91	0.190	0.332	0.690	0.140	0.497	1.000	0.027
91/92	0.752	0.229	1.000	0.315	0.231	0.135	0.194
92/93	1.000	0.447	0.464	0.828	0.050	0.763	0.786
93/94	1.000	0.671	0.269	0.567	0.647	0.501	0.418
94/95	0.310	0.423	0.147	0.194	0.098	0.045	1.000
95/96	0.405	0.894	1.000	0.871	0.475	0.238	0.615
96/97	0.548	0.397	0.715	1.000	0.650	0.388	0.134
97/98	0.460	0.614	0.431	0.604	1.000	0.735	0.544
98/99	0.512	0.361	0.577	0.306	0.611	1.000	0.659
99/00	0.155	0.377	0.284	0.277	0.134	0.401	1.000
00/01	0.450	0.454	0.495	0.208	0.493	0.141	1.000
01/02	0.361	1.000	0.531	0.454	0.549	0.620	0.224

Fit results for index = HeadBoat
Index Fitted to Mid-Year Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
81/82	1.2014	1.2014	0.2245	0.9769	2.6657
82/83	0.8289	0.8289	0.7189	0.1100	0.3002
83/84	1.8238	1.8238	0.4817	1.3421	3.6622
84/85	0.6247	0.6247	0.4402	0.1845	0.5033
85/86	0.4156	0.4156	0.6127	-0.1971	-0.5378
86/87	0.5969	0.5969	0.6208	-0.0239	-0.0653
87/88	0.4048	0.4048	0.7500	-0.3452	-0.9420
88/89	0.3432	0.3432	0.7300	-0.3869	-1.0557
89/90	0.6647	0.6647	0.8561	-0.1914	-0.5224
90/91	0.5279	0.5279	1.5094	-0.9815	-2.6783
91/92	0.8733	0.8733	1.2799	-0.4066	-1.1095
92/93	1.0939	1.0939	0.6024	0.4915	1.3411
93/94	1.1648	1.1648	0.6921	0.4726	1.2897
94/95	1.1944	1.1944	0.8873	0.3071	0.8380
95/96	1.1694	1.1694	0.8746	0.2948	0.8044
96/97	1.5071	1.5071	1.1549	0.3521	0.9609
97/98	1.4730	1.4730	1.4701	0.0028	0.0078
98/99	1.3109	1.3109	1.4958	-0.1849	-0.5045
99/00	1.4969	1.4969	1.5101	-0.0131	-0.0359
00/01	1.0445	1.0445	0.8485	0.1960	0.5349
01/02	1.2402	1.2402	0.5742	0.6660	1.8172

ML estimate of catchability: 0.23669E-06
Pearsons (parametric) correlation: 0.193 P= 0.1533
Kendalls (nonparametric) Tau: 0.124 P= 0.1887

Selectivity at age from Partial Catches

year	1	2	3	4	5	6
81/82	0.018	0.057	1.000	0.000	0.038	0.062
82/83	0.490	1.000	0.529	0.353	0.075	0.171
83/84	0.018	1.000	0.413	0.361	0.117	0.117
84/85	0.054	0.119	1.000	0.511	0.383	0.734
85/86	0.317	1.000	0.328	0.788	0.657	0.042
86/87	0.399	1.000	0.415	0.147	0.269	0.287
87/88	1.000	0.393	0.611	0.477	0.098	0.136
88/89	0.385	0.511	0.751	1.000	0.792	0.062
89/90	0.446	1.000	0.549	0.206	0.228	0.134
90/91	0.838	0.967	1.000	0.085	0.071	0.376
91/92	0.419	1.000	0.538	0.537	0.484	0.306
92/93	0.371	0.594	0.167	0.032	0.239	1.000
93/94	0.400	1.000	0.316	0.237	0.141	0.074
94/95	0.366	1.000	0.403	0.562	0.182	0.133
95/96	0.174	0.636	1.000	0.589	0.211	0.234
96/97	0.106	1.000	0.725	0.874	0.638	0.468
97/98	0.646	1.000	0.875	0.300	0.282	0.164
98/99	0.740	0.588	0.810	1.000	0.457	0.515
99/00	0.972	1.000	0.662	0.686	0.652	0.195
00/01	0.158	1.000	0.586	0.362	0.238	0.192
01/02	0.042	0.208	1.000	0.458	0.281	0.158

Fit results for index = Charter_FL_SW
Index Fitted to Mid-Year Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
88/89	0.7913	0.7913	0.9833	-0.1920	-0.5238
89/90	1.0462	1.0462	1.2564	-0.2102	-0.5737
90/91	0.8940	0.8940	0.3574	0.5366	1.4643
91/92	0.7323	0.7323	0.7435	-0.0112	-0.0305
92/93	0.9435	0.9435	0.4736	0.4698	1.2821
93/94	1.0652	1.0652	1.4276	-0.3624	-0.9888
94/95	1.5274	1.5274	0.9018	0.6257	1.7073

ML estimate of catchability: 0.37964E-06

Pearsons (parametric) correlation: 0.257 P= 0.2559
Kendalls (nonparametric) Tau: 0.333 P= 0.0969

Selectivity at age from Partial Catches

year	1	2	3	4	5	6	7	8
88/89	0.247	0.278	0.636	1.000	0.952	0.006	0.740	0.160
89/90	0.263	1.000	0.624	0.224	0.403	0.434	0.054	0.238
90/91	0.048	0.104	0.118	0.206	0.056	0.555	1.000	0.011
91/92	0.074	0.256	0.259	0.324	0.218	0.358	0.380	1.000
92/93	0.049	0.149	0.132	0.166	0.117	0.275	0.335	1.000
93/94	0.183	0.555	0.720	0.485	0.674	0.484	1.000	0.247
94/95	0.055	0.199	0.725	0.503	0.177	0.455	1.000	0.883

Fit results for index = Bycatch_GLM
Index Fitted to Beginning Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
81/82	0.5880	0.5880	0.6392	-0.0512	-0.1397
82/83	0.5716	0.5716	0.8480	-0.2765	-0.7544
83/84	0.5239	0.5239	0.4586	0.0653	0.1782
84/85	0.7358	0.7358	0.7282	0.0076	0.0206
85/86	0.6906	0.6906	0.7651	-0.0746	-0.2035
86/87	0.4620	0.4620	0.6900	-0.2279	-0.6220
87/88	0.9346	0.9346	0.8571	0.0775	0.2116
88/89	0.8021	0.8021	1.2580	-0.4558	-1.2439
89/90	1.6420	1.6420	1.4969	0.1451	0.3959
90/91	1.1663	1.1663	1.1723	-0.0060	-0.0164
91/92	1.3591	1.3591	0.8824	0.4767	1.3007
92/93	0.6792	0.6792	0.7948	-0.1156	-0.3155
93/94	1.4016	1.4016	1.3921	0.0095	0.0258
94/95	1.3151	1.3151	1.2313	0.0838	0.2287
95/96	1.7209	1.7209	1.4629	0.2580	0.7040
96/97	0.8689	0.8689	1.1135	-0.2446	-0.6674
97/98	1.0232	1.0232	1.1288	-0.1057	-0.2883
98/99	1.0837	1.0837	0.7225	0.3612	0.9856
99/00	1.0887	1.0887	1.3774	-0.2887	-0.7878
00/01	1.3426	1.3426	0.6266	0.7160	1.9538

ML estimate of catchability: 0.25072E-06
Pearsons (parametric) correlation: 0.686 P= 0.0000
Kendalls (nonparametric) Tau: 0.516 P= 0.0000

Selectivities set to 1.0

year	0
81/82	1.000
82/83	1.000
83/84	1.000
84/85	1.000
85/86	1.000
86/87	1.000
87/88	1.000
88/89	1.000
89/90	1.000
90/91	1.000
91/92	1.000
92/93	1.000
93/94	1.000
94/95	1.000
95/96	1.000
96/97	1.000
97/98	1.000
98/99	1.000
99/00	1.000
00/01	1.000

Fit results for index = SEAMAP
Index Fitted to Beginning Stock Size in NUMBERS

	Scaled	Obj.Function	Predicted	Residual	Scaled resid
82/83	0.4629	0.4629	0.9320	-0.4690	-1.2799
83/84	0.0852	0.0852	0.7285	-0.6433	-1.7555
84/85	0.8950	0.8950	0.7450	0.1501	0.4095
85/86	0.3314	0.3314	0.7319	-0.4005	-1.0930
86/87	0.5184	0.5184	0.7432	-0.2248	-0.6135
87/88	0.5817	0.5817	0.7913	-0.2096	-0.5720
88/89	0.5584	0.5584	0.8598	-0.3014	-0.8224
89/90	0.9351	0.9351	0.8533	0.0817	0.2230
90/91	1.0209	1.0209	0.9226	0.0983	0.2683
91/92	0.8961	0.8961	0.9962	-0.1001	-0.2732
92/93	1.4145	1.4145	1.0987	0.3158	0.8616
93/94	1.4934	1.4934	1.1388	0.3546	0.9677
94/95	1.3136	1.3136	1.1482	0.1654	0.4512
95/96	1.6425	1.6425	1.1116	0.5309	1.4486
96/97	1.2062	1.2062	1.1521	0.0541	0.1476
97/98	1.5247	1.5247	1.1947	0.3300	0.9005
98/99	1.3403	1.3403	1.2512	0.0891	0.2431
99/00	1.2970	1.2970	1.3053	-0.0083	-0.0226
00/01	0.9665	0.9665	1.3836	-0.4171	-1.1380
01/02	1.5162	1.5162	1.4416	0.0747	0.2037

ML estimate of catchability: 0.18382E-06
Pearsons (parametric) correlation: 0.778 P= 0.0000
Kendalls (nonparametric) Tau: 0.558 P= 0.0000

Selectivities input

year	1	2	3	4	5	6	7	8	9	10	11
82/83	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
83/84	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
84/85	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
85/86	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
86/87	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
87/88	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
88/89	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
89/90	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
90/91	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
91/92	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
92/93	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
93/94	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
94/95	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
95/96	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
96/97	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
97/98	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
98/99	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
99/00	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
00/01	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853
01/02	0.015	0.121	0.308	0.612	1.037	1.425	1.829	2.247	2.667	3.079	3.853

Table 5. Gulf king mackerel tuned VPA results from the New-GP model.

Stock at Age at beginning of year.

Age	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92
0	2549397	3382360	1829103	2904589	3051684	2752018	3418538	5017474	5970380	4675890	3519630
1	1975618	1756303	2440817	1192003	1916663	2061378	1906181	2028016	3529142	3710079	3023275
2	1649856	1593767	1403228	1975391	930992	1545055	1630886	1528487	1603686	2786190	2993360
3	882565	1324557	1251155	1126639	1578174	741963	1083351	1264194	1206633	1163430	2175575
4	1433540	700956	890132	753898	881743	1236670	503793	760175	986137	846133	828451
5	808376	819979	382721	552027	359663	570974	953658	363338	494406	736399	500300
6	418395	374389	390608	265729	308118	193081	404912	726335	156384	334045	553050
7	292169	291459	163152	262853	176531	164170	121702	312240	543856	97159	229156
8	125651	191325	195625	110559	164211	111729	113675	90105	198797	423926	61986
9	44389	82788	108208	139712	73543	124702	80774	89386	56393	148462	322546
10	120177	29245	44515	81117	108935	52720	97551	58192	64957	38048	111867
11+	329921	351998	184190	177718	202230	240451	227707	260759	231704	225003	198534

Age	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03
0	3170096	5552502	4911021	5834863	4441133	4502300	2881642	5493709	2499204	6434932	0
1	1896958	2061103	3606063	3164498	3768962	3078405	3019871	1994288	4264731	1630487	4869667
2	2307217	1453670	1589314	2834257	2528707	3024806	2462583	2398053	1546878	3428127	1310390
3	2149876	1714873	1072879	1193643	2091395	1762435	2234699	1889001	1835814	1100162	2653259
4	1637355	1603631	1257758	746265	808757	1509461	1152573	1605315	1422490	1308545	675695
5	596954	1116882	1136039	821908	508282	556032	1082423	746455	1144670	1010079	913255
6	347517	394312	775915	730804	596451	353972	367395	776339	519899	845847	742667
7	416043	207240	273886	548994	519070	440340	250628	247903	596908	383501	642044
8	168483	311912	111700	193067	403507	383560	321277	176639	178726	453480	268754
9	44438	122640	233753	41717	138430	288904	277719	231588	130010	130041	346634
10	242390	17185	90952	157492	24656	96563	211621	193939	165276	90728	93987
11+	230153	337080	249386	234807	282398	208811	220884	329922	405652	431876	397865

F at Age during year.

Age	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92
0	0.1726	0.1262	0.2282	0.2157	0.1923	0.1672	0.3222	0.1519	0.2758	0.2361	0.4181
1	0.0148	0.0244	0.0116	0.0471	0.0155	0.0343	0.0208	0.0348	0.0364	0.0147	0.0703
2	0.0196	0.042	0.0195	0.0245	0.027	0.155	0.0547	0.0364	0.1209	0.0474	0.131
3	0.0304	0.1975	0.3066	0.0451	0.0438	0.1871	0.1543	0.0484	0.1549	0.1396	0.0842
4	0.3586	0.4051	0.2778	0.5401	0.2346	0.0599	0.1268	0.2302	0.092	0.3255	0.1277
5	0.5697	0.5416	0.1648	0.3831	0.4221	0.1437	0.0723	0.643	0.1921	0.0863	0.1644
6	0.1615	0.6306	0.1961	0.209	0.4296	0.2615	0.0599	0.0893	0.276	0.1769	0.0847
7	0.2234	0.1987	0.1891	0.2704	0.2574	0.1676	0.1006	0.2515	0.0491	0.2494	0.1076
8	0.2172	0.3699	0.1366	0.2077	0.0752	0.1244	0.0404	0.2686	0.092	0.0733	0.1328
9	0.2173	0.4205	0.0882	0.0488	0.1329	0.0456	0.1279	0.1192	0.1935	0.083	0.0857
10	0.0458	0.5275	0.0522	0.0468	0.0578	0.0527	0.021	0.1196	0.0765	0.0814	0.0991
11+	0.0458	0.5275	0.0522	0.0468	0.0578	0.0527	0.021	0.1196	0.0765	0.0814	0.0991

Age	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
0	0.2305	0.2316	0.2395	0.2371	0.1665	0.1994	0.1681	0.0532	0.2271	0.0787
1	0.0662	0.0599	0.0408	0.0243	0.02	0.0232	0.0306	0.054	0.0184	0.0186
2	0.0967	0.1037	0.0863	0.1039	0.161	0.1027	0.0652	0.0672	0.1408	0.0562
3	0.0931	0.11	0.163	0.1893	0.1261	0.2247	0.1308	0.0836	0.1386	0.2875
4	0.1825	0.1447	0.2255	0.184	0.1747	0.1326	0.2344	0.1382	0.1424	0.1597
5	0.2147	0.1643	0.2412	0.1206	0.1618	0.2144	0.1324	0.1617	0.1025	0.1075
6	0.3169	0.1644	0.146	0.1421	0.1034	0.1452	0.1934	0.0628	0.1043	0.0757
7	0.0881	0.4181	0.1497	0.1079	0.1025	0.1152	0.1499	0.1272	0.0748	0.1555
8	0.1176	0.0885	0.7849	0.1327	0.1341	0.1229	0.1273	0.1065	0.118	0.0687
9	0.7501	0.0989	0.1949	0.3259	0.1602	0.1113	0.1591	0.1373	0.1597	0.1247
10	0.1378	0.151	0.1712	0.1287	0.1856	0.1239	0.0707	0.0557	0.0791	0.0727
11+	0.1378	0.151	0.1712	0.1287	0.1856	0.1239	0.0707	0.0557	0.0791	0.0727

Table 6. Maximum sustainable yield (MSY) and optimum yield (OY) related bench mark values for the base case 2004 case and the New-GP scenarios. SS is spawning stock biomass in trillions of eggs, F values are associated with the fully selected age, and yields are given in millions of pounds.

Model	**Base case 04**						
		SS MSY	**F MSY**	**MSY**	**SS OY**	**F OY**	**OY**
	Median	6.385	0.269	11.417	8.524	0.190	10.113
	low 80%	5.556	0.235	9.609	7.436	0.166	8.522
	upp 80%	7.387	0.366	13.606	9.779	0.255	12.098
	deterministic	6.380	0.226	11.286	8.506	0.160	9.974

Model	**New-GP**						
		SS MSY	**F MSY**	**MSY**	**SS OY**	**F OY**	**OY**
	Median	9.320	0.326	16.092	12.527	0.222	14.381
	low 80%	7.872	0.291	13.169	10.861	0.199	12.029
	upp 80%	10.908	0.380	19.313	14.609	0.259	17.207
	deterministic	9.368	0.304	16.180	12.490	0.209	14.284

Table 7. Fishing year 2003/04 acceptable biological match (ABC) in millions of pounds for the base case 2004 case and the New-GP scenarios for two levels of F mortality. Probability denotes likelihood of exceeding the desired F mortality rate.

		Base 04		New-GP	
Probability		*$F_{30\%}$SPR*	*$F_{40\%}$SPR*	*$F_{30\%}$SPR*	*$F_{40\%}$SPR*
50%	Median	10.322	7.442	20.281	14.270
10 %	Lower CI	7.544	5.421	14.812	10.403
90%	Upper CI	13.504	9.836	27.217	19.320

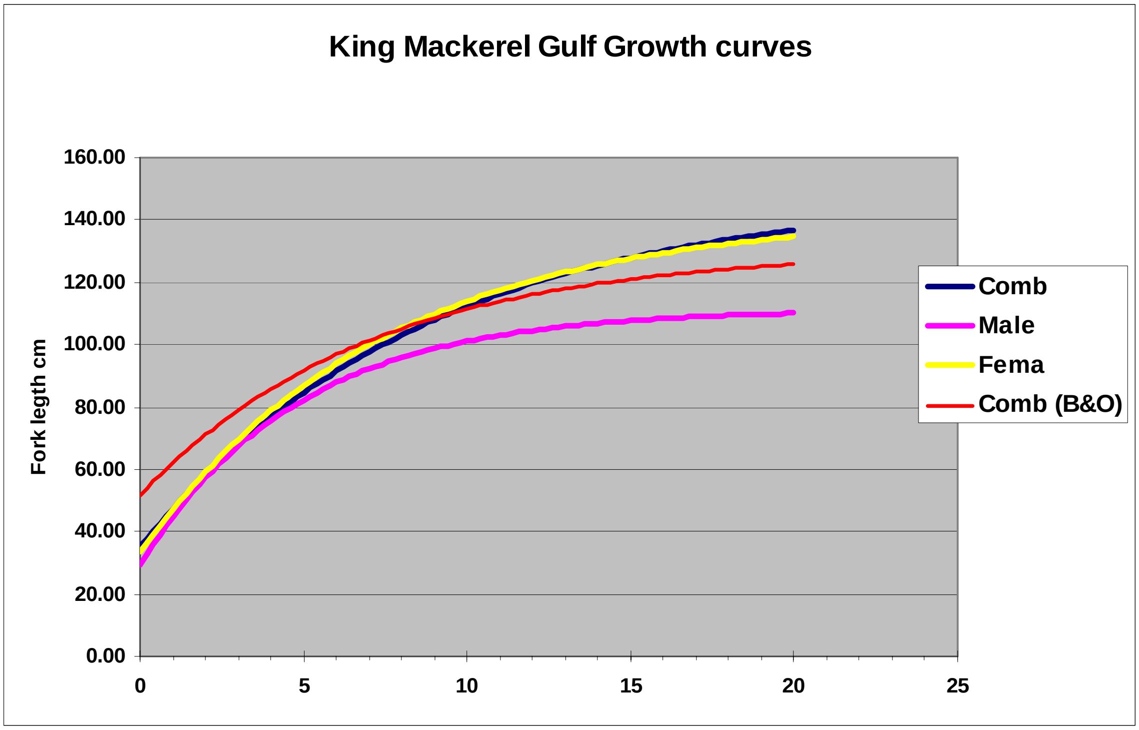


Figure 1. Predicted size (fork length cm) at age for Gulf King mackerel by sex group from Manooch et al (1986) and combined sex from Brooks and Ortiz (2004) growth parameter estimates.

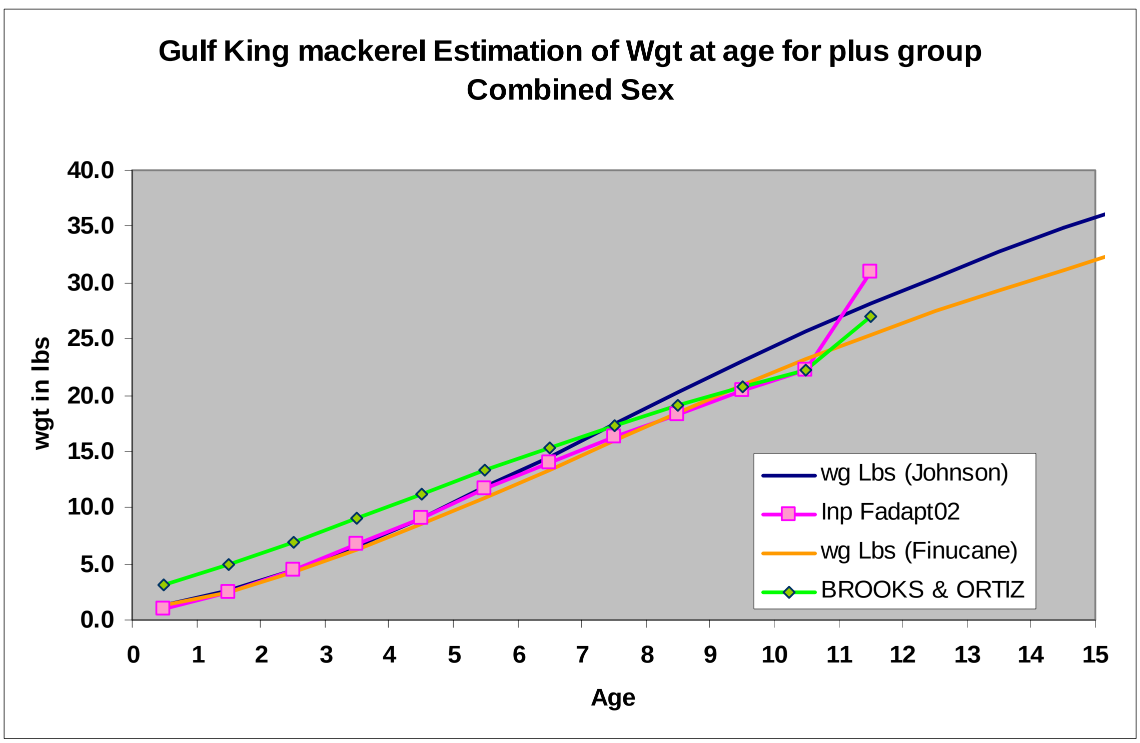


Figure 2. Estimated weight-at-age (mid of the year) from size-weight relationship of Johnson et al (1982) and Finucane et al (1986). Conversion to age used the Manooch et al (1986) (Fadapt02) or Brooks and Ortiz (2004) growth parameters.

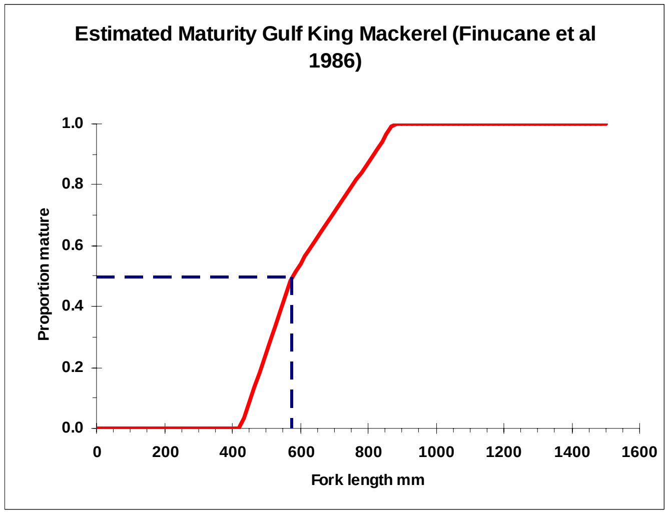


Figure 3. Estimated maturity proportion by size for Gulf king mackerel (Finucane et al 1986)

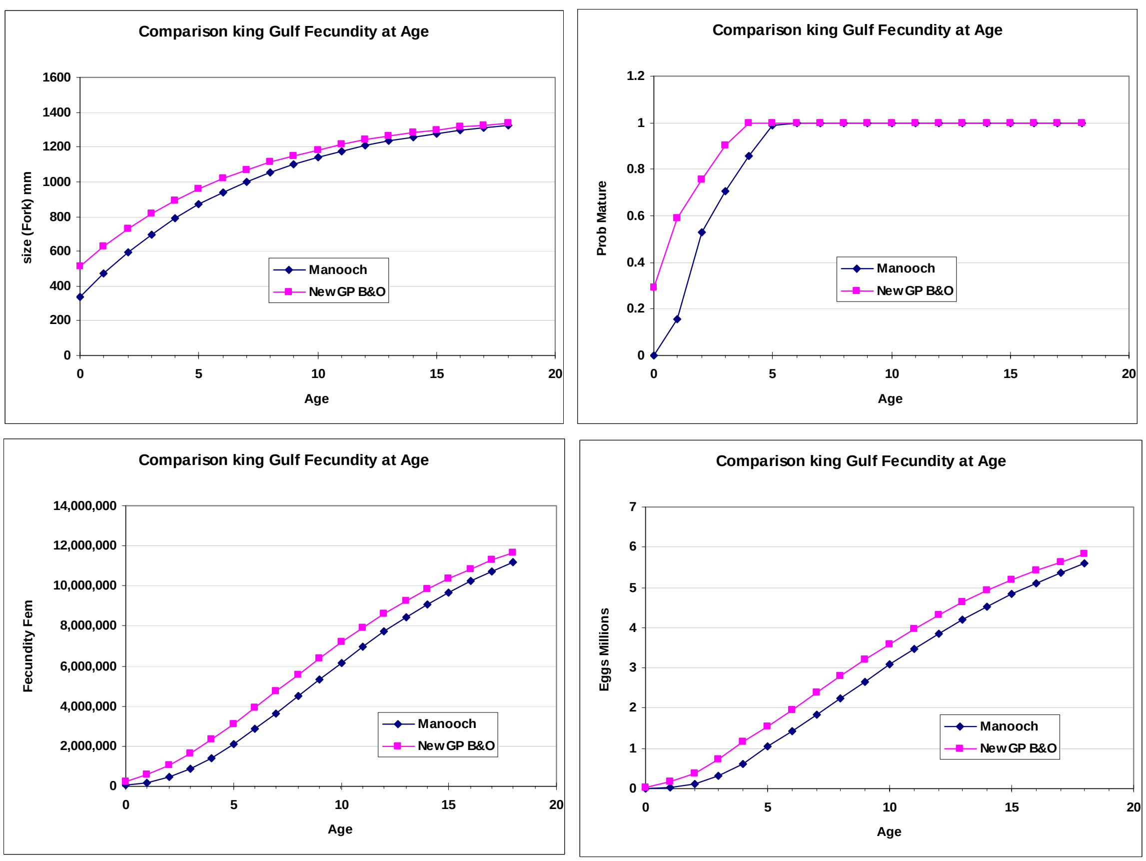


Figure 4. Comparison of maturity and fecundity at age for Gulf king females estimated from the maturity/fecundity size relationship of Finucane et al (1986) and the growth parameters of Manooch et al (1986) or Brooks and Ortiz (2004) (New-GP B&O)

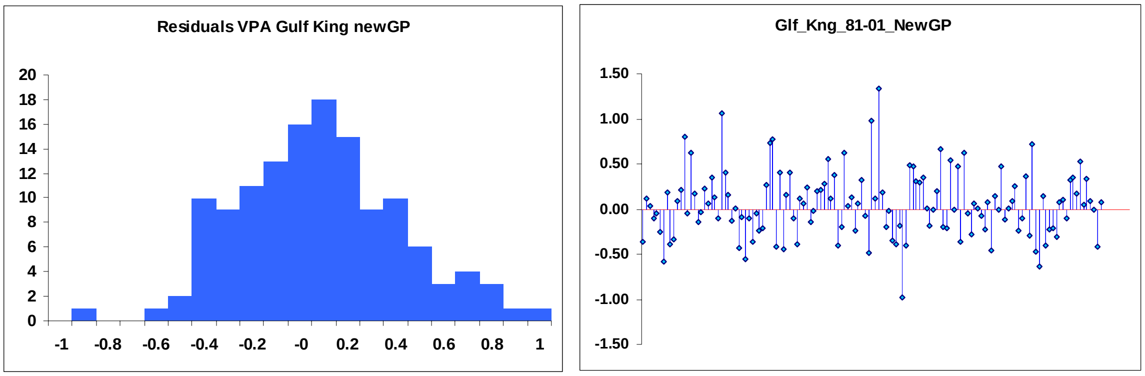


Figure 5. VPA-Fadapt residual distributions from the new growth parameters (New-GP) deterministic run.

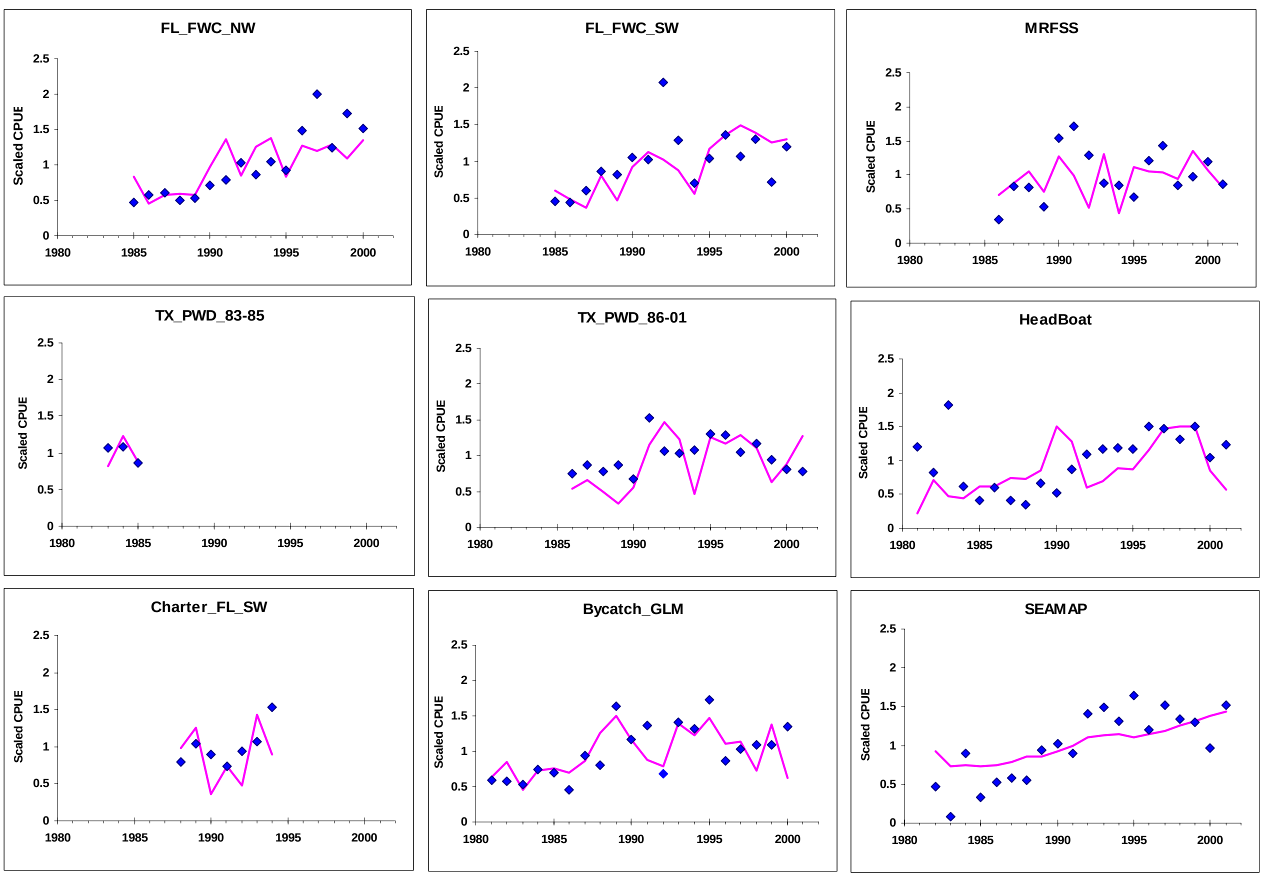


Figure 6. Gulf king mackerel predicted (solid line) and standardized indices of abundance (diamonds) from the tuned VPA New-GP model.

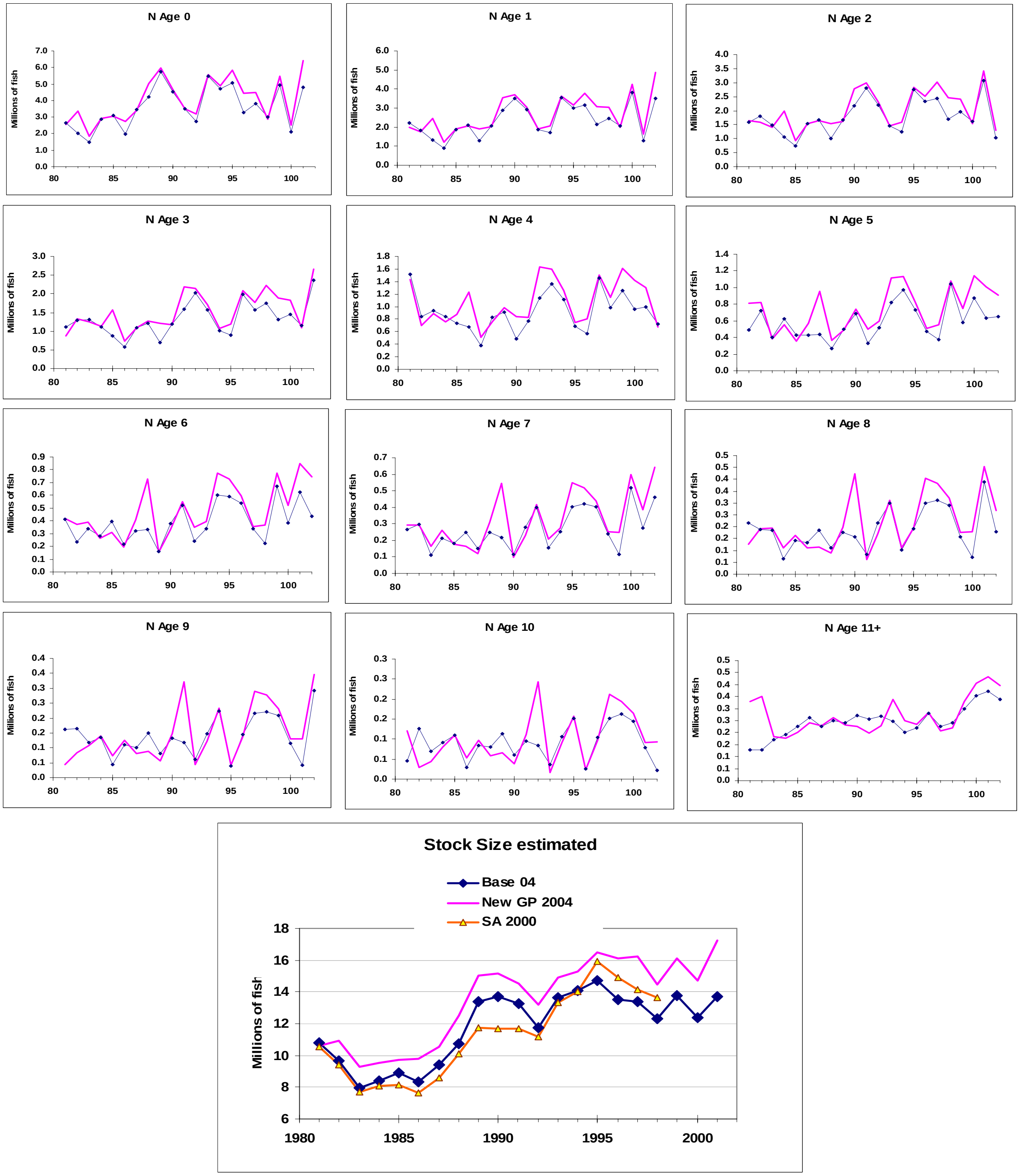


Figure 1. Gulf king mackerel estimated stock size by age trends from the VPA results of the New-GP model (solid line) and corresponding estimates from the base case 2004 model (diamond line).

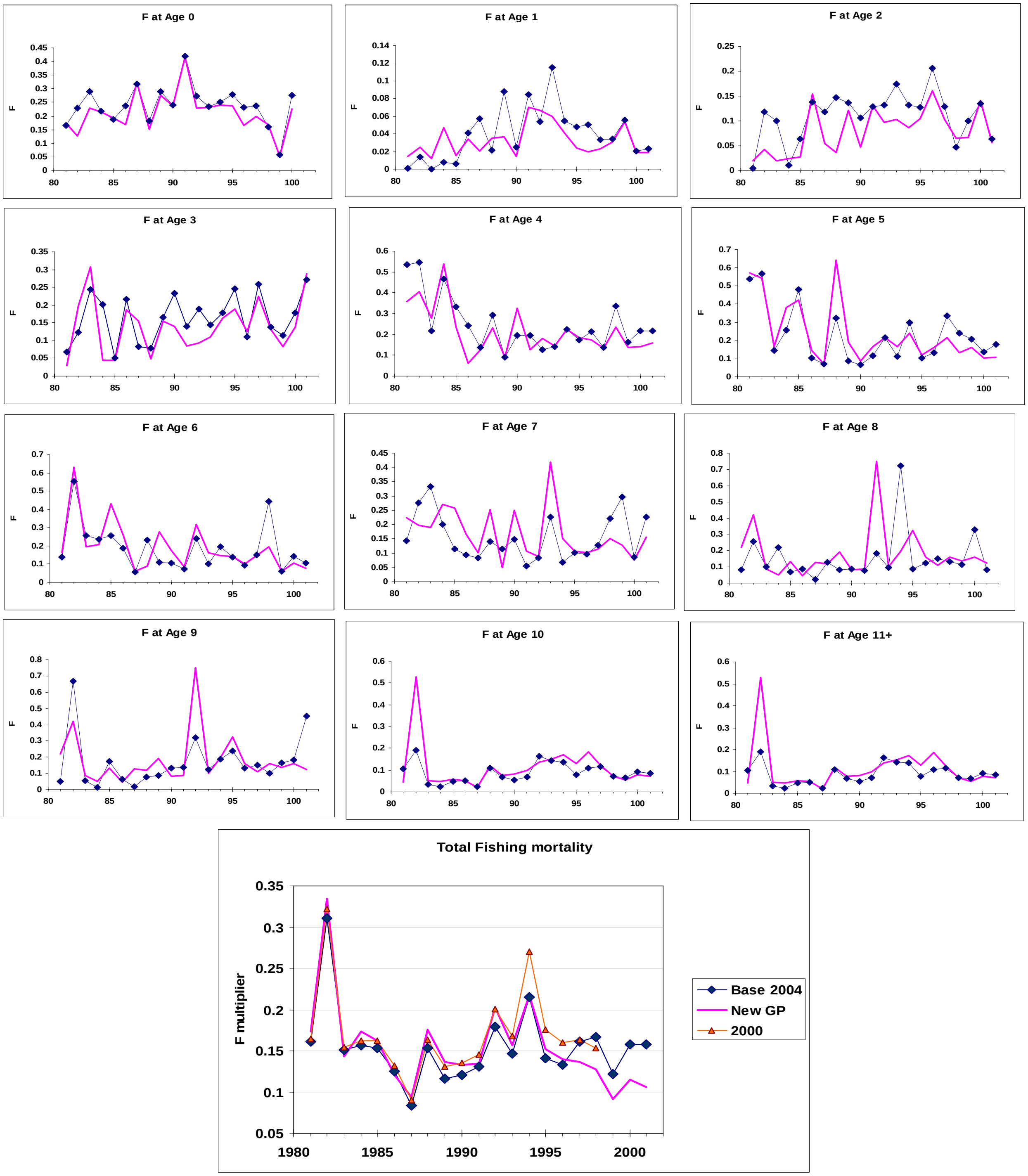


Figure 2. Gulf king mackerel estimated fishing mortality (F) by age trends from the VPA results of the New-GP model (solid line) and corresponding estimates from the base case 2004 model (diamond line).

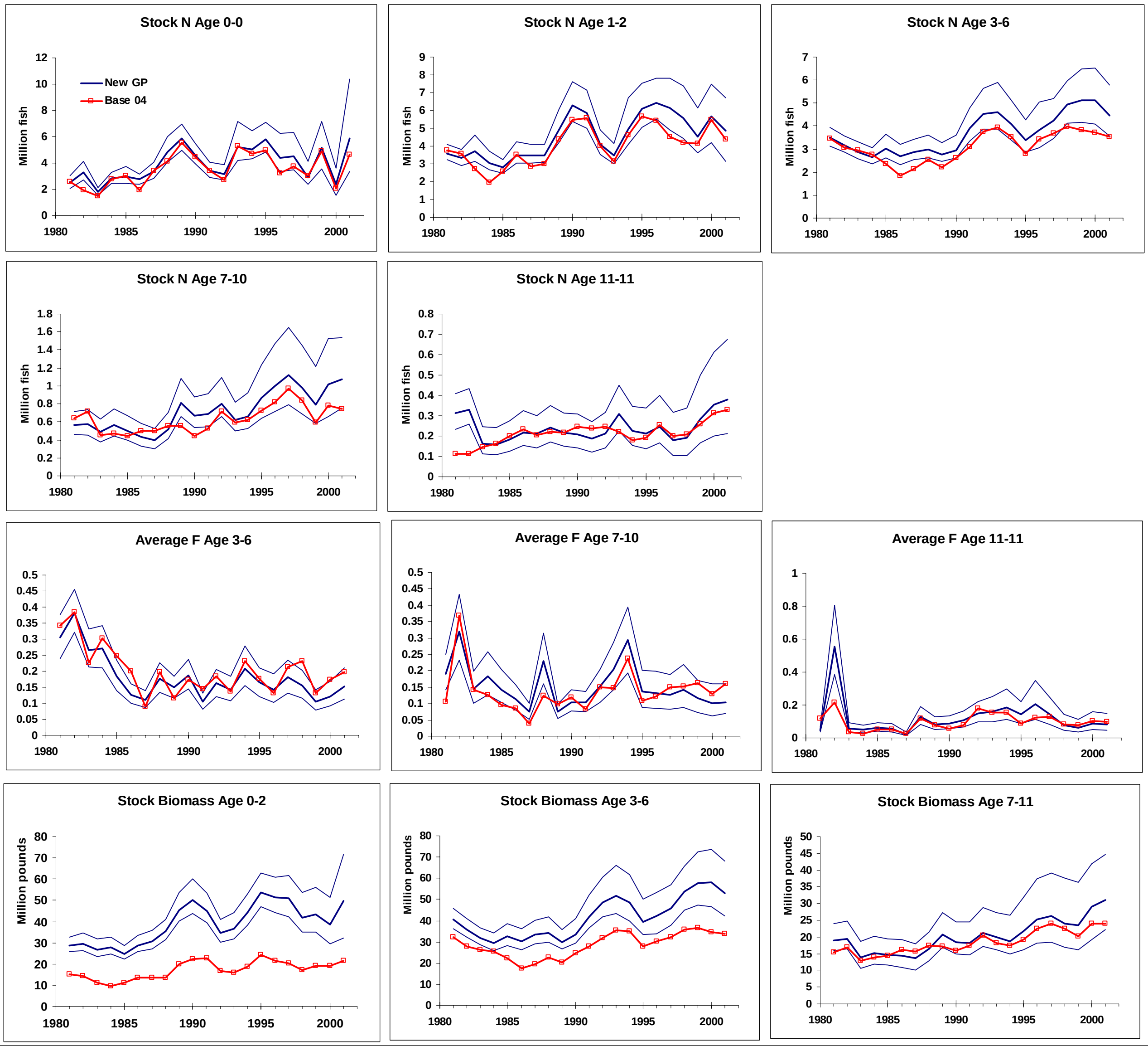


Figure 3. Gulf king mackerel population trends with 80% confidence intervals from the New-GP model (solid lines). For comparison results from the base case 2004 model are shown (open square marker line).

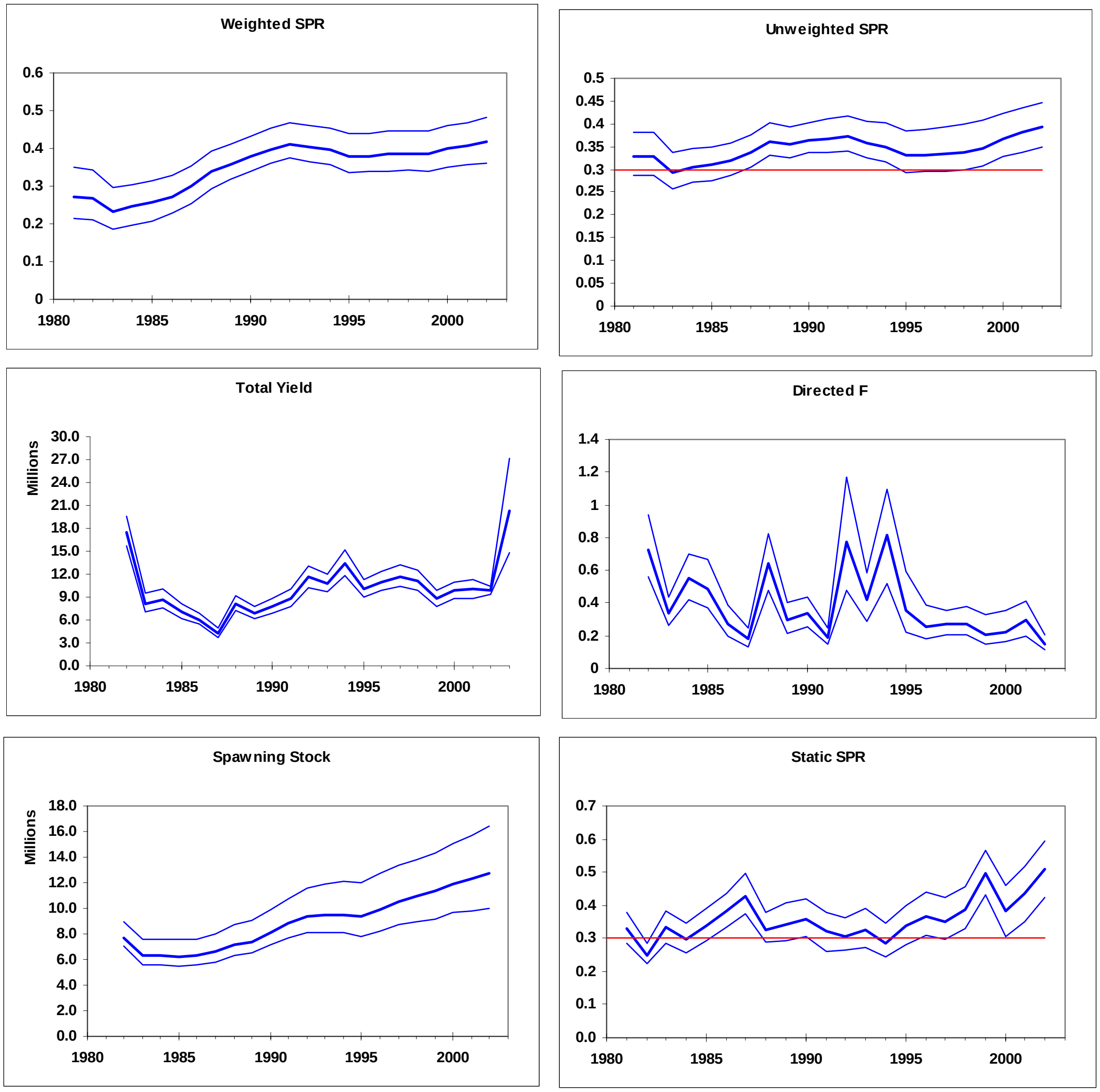


Figure 4. Trends of spawning stock, total yield, directed fishing mortality (F) and spawning potential ratios (weighted, unweighted and static) SPR from the New-GP VPA model. Thin lines represent approximated 80% confidence intervals based on 500 bootstrap runs.

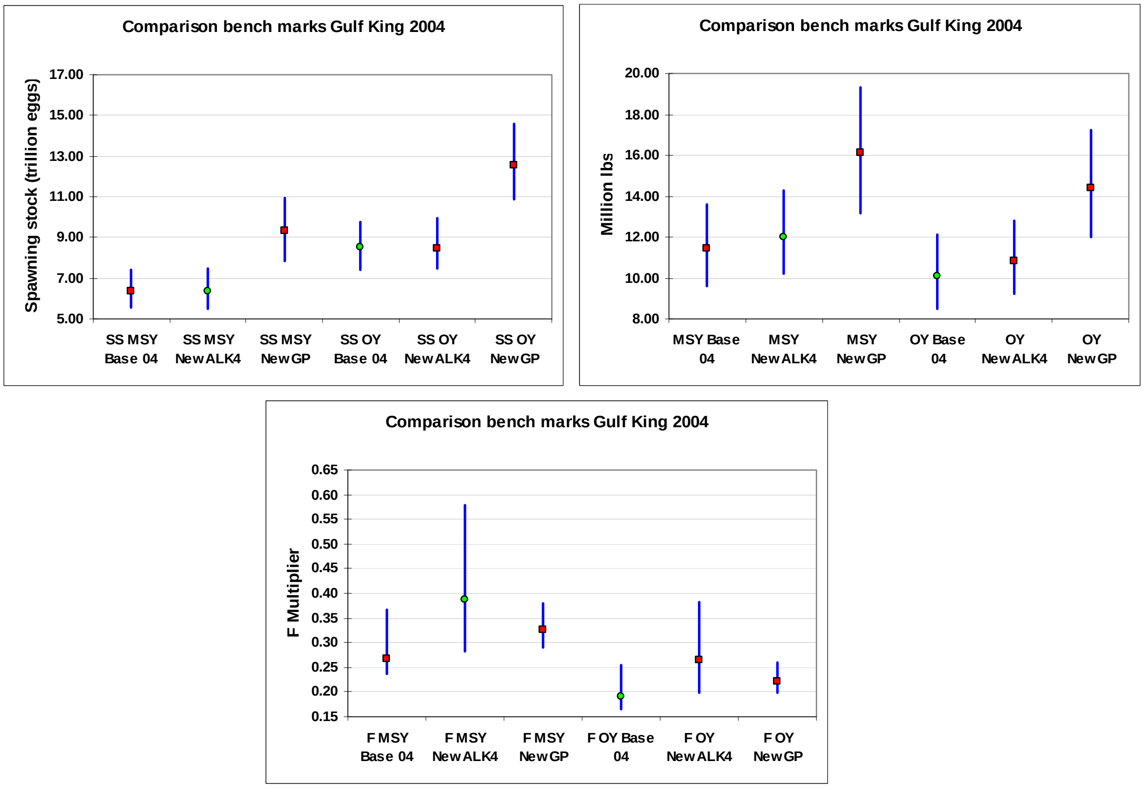


Figure 5. Comparison of Gulf king mackerel benchmarks from the Base model 2004 (Base 04), and two sensitivity runs: the new Age-Length keys (New-ALK4) and the new growth parameters (New-GP). Spawning stock (SS) biomass, MSY, OY (millions of pounds), and corresponding directed fishing (F) mortality rates.

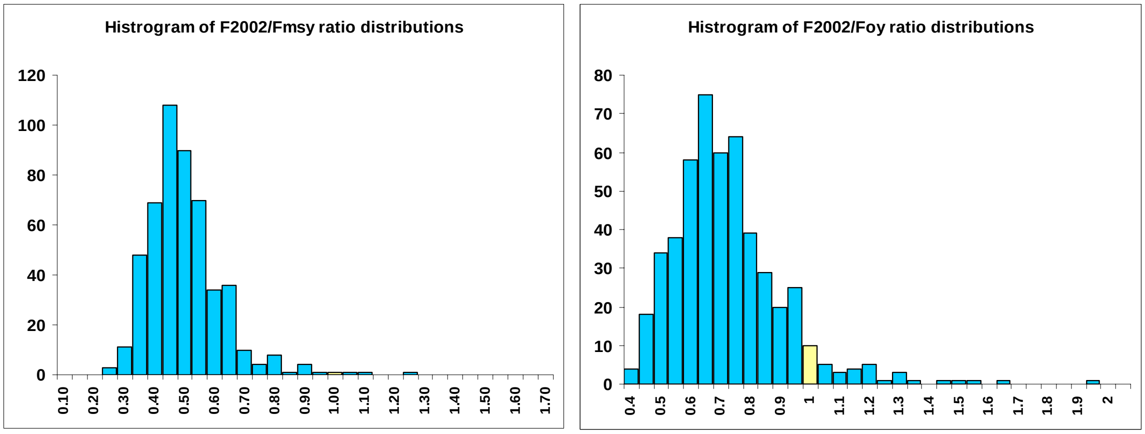


Figure 6. Distribution of Gulf king F_{2002}/F_{MSY} (left) and F_{2002}/F_{OY} (right) ratios from 500 bootstrap runs for the New-GP model.

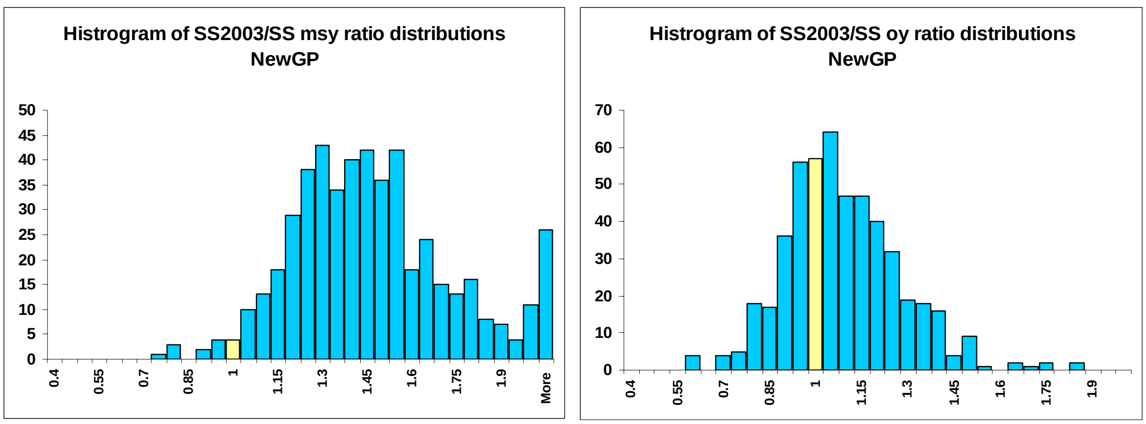


Figure 7. Distribution of Gulf king SS_{2003}/SS_{MSY} (left) and SS_{2003}/SS_{OY} (right) ratios from 500 bootstrap runs for the New-GP model.

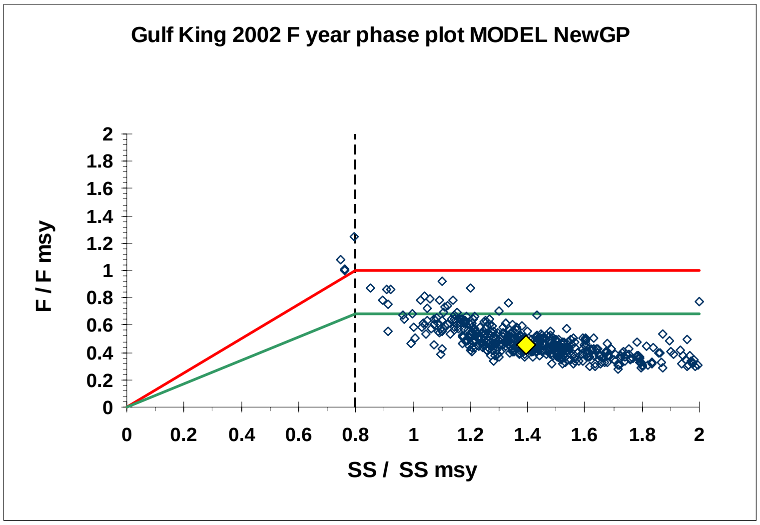


Figure 14. Phase plot of 500 bootstrap runs for the New-GP model. The deterministic run corresponds to the larger diamond marker

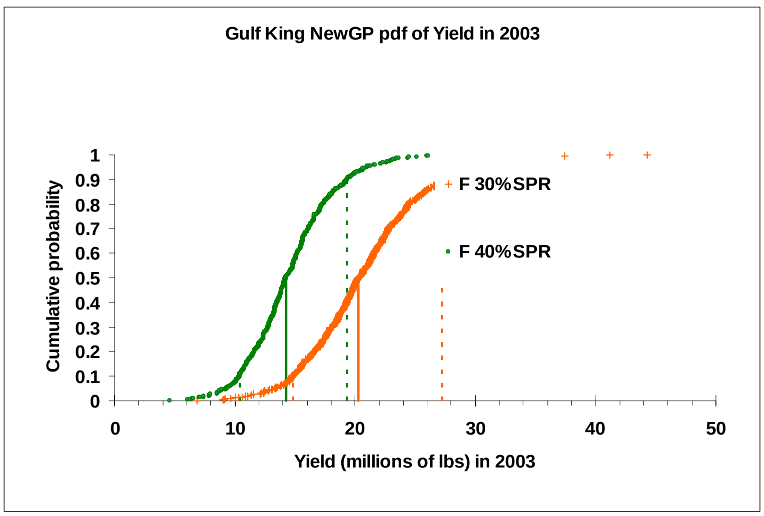
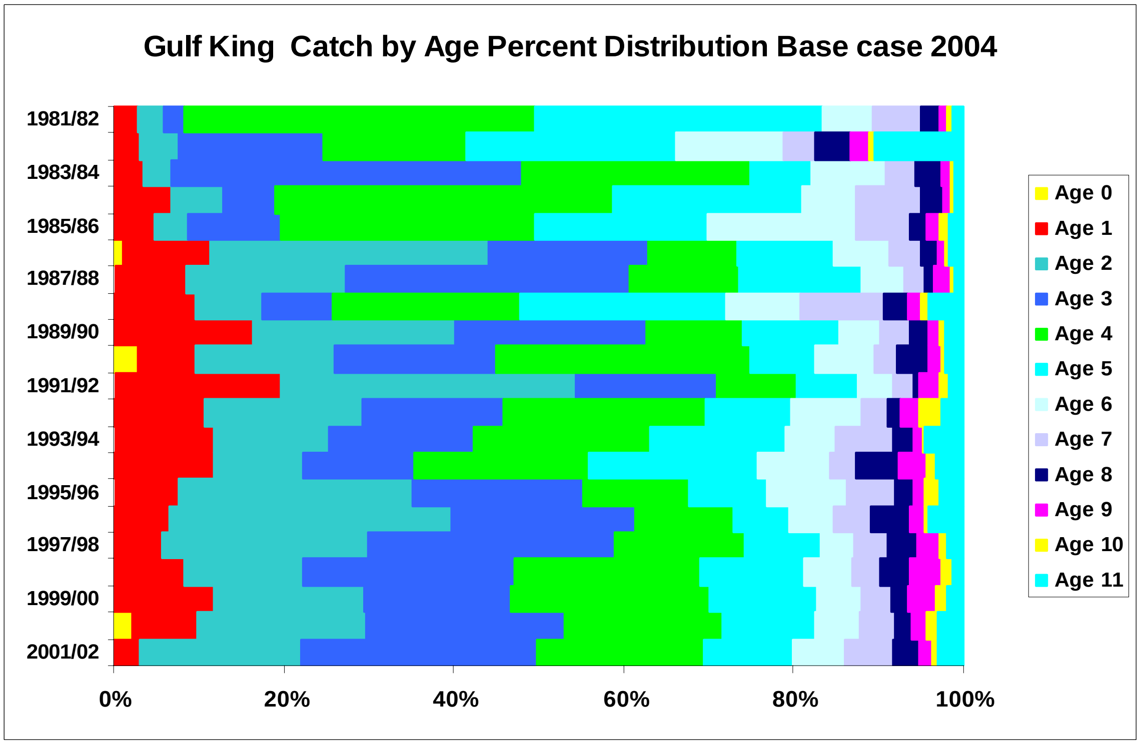


Figure 15. Frequency distribution of 500 bootstrap range of allowable biological catch (ABC) based on probability of F exceeding $F_{30\%SPR}$ and $F_{40\%SPR}$ in the 2003/04 fishing year for Gulf king mackerel estimated by the New-GP model. The vertical solid lines represent 0.5 percentiles; broken lines represent 0.1 and 0.9 percentiles of the cumulative distributions.



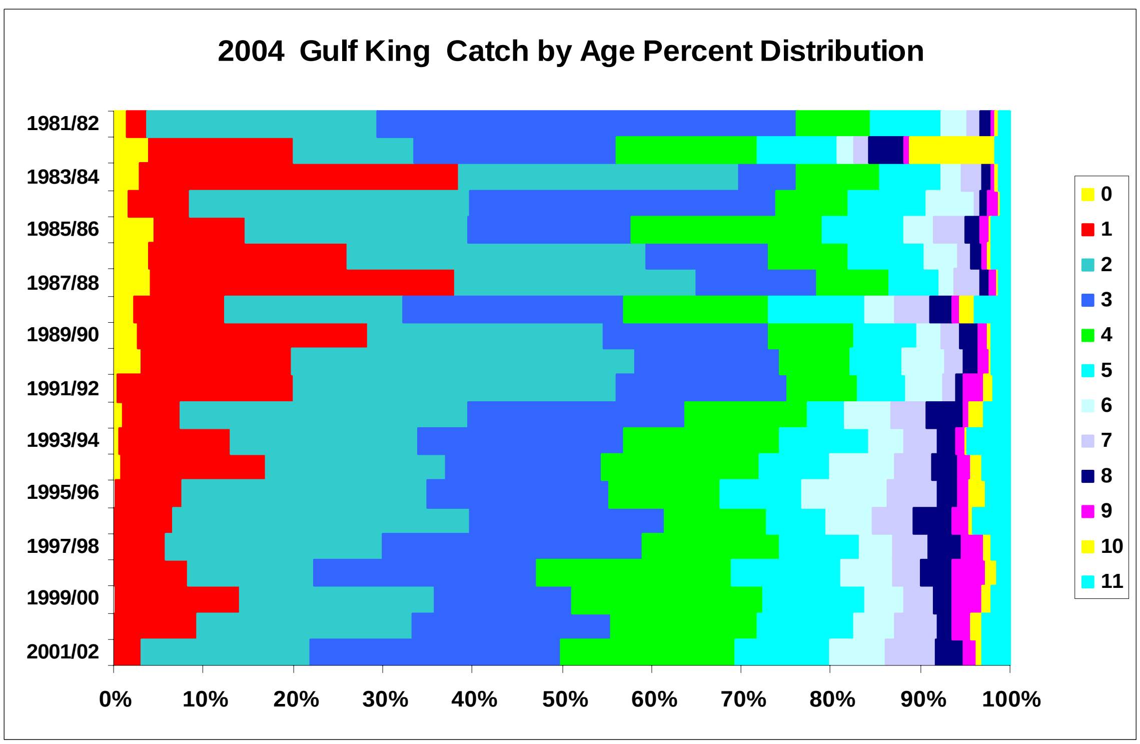


Figure 8. Comparison of the age distribution for Gulf king mackerel directed catch from the base case 2004 input matrix (top) and the New-GP CAA matrix (bottom).

SEDAR

SouthEast Data, Assessment, and Review

Stock Assessment Consensus Summary

SEDAR 5: Atlantic and Gulf of Mexico
King Mackerel

SEDAR Document: SEDAR5-AR3 April 2004

SEDAR
SouthEast Data, Assessment, and Review

SEDAR5 Review Workshop

Consensus Summary

King Mackerel
Atlantic and Gulf of Mexico Migratory Units

April 30, 2004

I. Workshop Information

SEDAR Review Workshops provide an independent peer review of the input data, methods, and results of stock assessments. This Review Workshop Panel (RW Panel) considered an assessment of south Atlantic and Gulf of Mexico (hereafter Gulf) migratory groups of king mackerel developed through the SEDAR process, including both data and assessment workshops. The Southeast Fisheries Science Center, Miami Laboratory, served as the lead assessment agency for this assessment.

The SEDAR 5 Review Workshop was held at the Southeast Fisheries Science Center, Miami Florida, between April 5 and 8, 2004. The Review Panel consisted of regional and international assessment scientists, fisheries researchers, and commercial and recreational fishermen.

SEDAR 5 Review Panel Composition:

Henrik Sparholt	*CIE Chair*
Jon Volstad	*CIE Reviewer*
Rick Hart	*SEFSC Galveston*
Mark Terceiro	*NEFSC Woods Hole*
Will Patterson	*University of West Florida*, *GMFMC SSC*
Andy Strelcheck	*SERO*, *GMFMC FAP*
Albert Jones	*GMFMC SSC*
Joe Grist	*NC DMF, SAFMC SSC*
Bob Zales II	*GMFMC AP*
William Gibson Jr.	*GMFMC AP*
Ben Hartig	*SAFMC AP.*

II. Terms of Reference

1. Evaluate the adequacy and appropriateness of all data used in the assessment. State whether or not the data are scientifically sound and the best available.
2. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population parameters such as abundance, biomass, and exploitation. State whether or not the methods are scientifically sound and the best available, and recommend appropriate values of population parameters.
3. Evaluate the adequacy, appropriateness, and application of the methods used to estimate population benchmarks (MSY, F_{MSY}, B_{MSY}, MSST, MFMT, etc.). State whether or not the methods are scientifically sound and the best available, and recommend appropriate values for benchmark criteria.
4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding. State whether or not the methods are scientifically sound and the best available, and recommend probable values of future population condition and status.
5. Provide a recommended range and best point estimate of the mixing rate of Atlantic and Gulf Migratory Groups in the mixing zone.

6. Develop recommendations for improving data collection and assessment and future research (both field and assessment).
7. Prepare a Consensus Summary addressing the Terms of Reference and documenting the Panel's discussion of the assessment.
8. Prepare an Advisory Report summarizing stock status, future condition, and management benchmarks.
9. Submit final Consensus Summary and Advisory Report documents within 3 weeks of the conclusion of the Review Workshop. Reports should be submitted on or before April 30, 2004.

III Review

The review covered Terms of Reference 1-6.

Term of Reference 1

The Data Workshop Panel (DW Panel) for the SEDAR5: Atlantic and Gulf of Mexico King Mackerel Assessment was provided with documents (SEDAR5-DW1-15) which summarized data and gave overviews on stock structure; growth; catches; discards; catch sizing, sexing and ageing; fishery dependent and fishery independent indices; tagging results; and methods of discriminating between and analyzing mixed stocks.

The DW Panel members evaluated these documents and summarized their conclusions and recommendations concerning use of the data in assessments under three categories (life history, catch-at-age, and indices). In addition to reviewing the data, the DW Panel made recommendations for additional work to be done in preparation for the Assessment Workshop. The stock assessments made at the Assessment Workshop and later reviewed at the Review Workshop took note of and used the results of the Data Workshop and the subsequent work that was carried out.

In the opinion of the RW Panel the data used in the assessments for king mackerel are appropriate and adequate for offering management advice. The RW Panel recognized and discussed the uncertainty and incompleteness of certain data sets. Recognizing that these limitations were considered in the assessments through sensitivity analyses and statistical procedures, the RW Panel determined that the data as used, are scientifically sound and the best available.

In general, catch and landings data are adequate for assessment purposes; life history information on fecundity and natural mortality is limited but not result-restricting; new growth information for the Gulf of Mexico was reanalyzed for the Assessment Workshop and shown to impact analytical results; and tagging, otolith shape, and microchemistry data were shown to impact assessment results with respect to mixing rate and consequent predicted stock status.

<u>Stock Distribution</u>

The Management unit is defined as King Mackerel in the Gulf and south Atlantic specified as a single stock and managed as two independent migratory groups. Current stock assessments for king mackerel assume separate Atlantic and Gulf of Mexico stocks, with a "mixing zone" off south Florida that has boundaries defined by season. The RW Panel recognized that other assumptions on stock distribution have been proposed (separate groups in eastern and western Gulf). Limited data up to this time has not allowed carrying these assumptions into a modeling approach. For example, a need to consider management of the Gulf migratory group in relation to mixing between the eastern and western Gulf has been limited by the paucity of information from the western Gulf (catches are smaller there than in the eastern Gulf) and the lack of information on fisheries in Mexico, which possibly interact with western Gulf fish. Likewise, information on mixing between Atlantic and Gulf migratory groups presented to the RW Panel was considered inconclusive or preliminary. Tagging data from early tagging studies were used to test a new modeling approach. Recent data on otolith shape and microchemistry was presented. These data provided qualitative indications that there are fish from both Atlantic and Gulf groups in the mixing zone, but quantitative estimates of the ratios were imprecise. Microsatellite DNA data indicated mixing in the zone, but at present the information could not be used to quantify mixing rates.

Catch and Landings

King mackerel catch and landings information from 1981-2002 was utilized in the assessments. Commercial landings data are collected by trip tickets and logbook programs, which give a nearly complete census of total landings. Recreational catch data are collected under the Marine Recreational Fishery Statistics Survey (MRFSS), NMFS Headboat Survey, and Texas Parks and Wildlife Coastal Creel Survey, which give sample estimates of recreational catch based on creel and telephone surveys. The Panel noted that the precision of MRFSS estimates has improved over time (figures reported during the meeting indicated percentage standard errors of 21-64% in the years 1981-85 decreased to 6-8% in years 1992-2002 for the GOM king mackerel).

Discards

Discards of king mackerel in the directed commercial fishery were measured by a self-reporting logbook program carried out by a 20% sample of permit holders over a survey period of two years. Results were used to estimate discards in 1998-2002 for both Atlantic and Gulf migratory groups. Results indicated discards represented only a small percentage of total landings. The RW Panel agreed with the decision not to include this estimate in the assessment on the basis that inclusion would not significantly improve the assessment results. The Panel did note that new estimates of discards might be appropriate to include in future analyses.

The RW Panel noted that recreational data (MRFSS) included estimates of live releases and that the declining recreational catches in more recent years probably indicated higher release rates due to management action, mercury concerns, angler ethics and other possibilities. However, because discards are poorly estimated and the underlying age distribution of discards is unknown the RW Panel supported not including recreational discards in the assessment.

Indices of Abundance

Six indices of abundance were used for the Atlantic assessment and nine abundance indices were used for the Gulf assessment. Procedures for deriving indices of abundance were similar to those of previous assessments and took into consideration technical decisions made during former Mackerel Stock Assessment Panel (MSAP) reviews of Gulf and Atlantic king mackerel migratory groups. A general linear model approach was used to standardize CPUE series in order to account for variability in CPUE that is independent of abundance.

The RW Panel agreed that indices of abundance were the best available. Several recommendations were made to potentially improve indices, including: 1) pre-smoothing within indices to reduce variability related to sampling, 2) combining indices where appropriate to reduce the number of indices, and 3) accounting for changes in fishing power ("technical creeping"). The panel recognized that some indices could not be combined because they are applied to different age groups or to different harvest areas (e.g. Florida Charter NW index). It was also discussed that fishing power is not likely to have changed over the time series, at least for commercial fisheries, because the primary gear used in the fishery is hook-and-line. For the recreational fishery, GPS technology may have contributed to increases in fishing power, but it was recognized that the change in fishing power would be difficult to quantify.

The RW Panel discussed the recreational MRFSS index for the Gulf of Mexico, which included only trips targeting or successfully catching king mackerel during July-December. One RW Panel member noted that this index did not account for a substantial recreational fishery in the Panhandle of Florida from April – June. The RW Panel also recommended that recreational indices should consider changes over time in fishing seasons.

<u>Life History Parameters</u>

Natural Mortality

Estimates of natural mortality are 0.15 for the Atlantic migratory group and 0.20 for the Gulf migratory group. The DW Panel recommended a range of 0.15-0.25 be used for both subgroups, with a mean natural mortality of 0.20. The RW Panel did not support this recommendation because there was no evidence to support this change and the change would affect the continuity of results between the current assessment and previous assessments.

Age and Growth

Estimates of growth are used to calculate production parameters and the catch at age and affect stock assessment analyses in several ways (e.g., relation of length, weight, and fecundity to age; recruitment size; differences between sexes, areas). The RW Panel reviewed older growth curves used for the Atlantic (Collins et al. 1989) and for the Gulf (Manooch 1987), based on 683 and 210 fish, respectively. These studies relied on whole otoliths for ageing, which have been determined to underestimate ages of older fish (Collins et al. 1989; Devries and Grimes 1997). As was recommended by the DW Panel Brooks and Ortiz (2004) estimated updated migratory group- and sex-specific growth functions based on 12,159 (Atlantic) and 17,813 (Gulf) sectioned otoliths from currently available samples. The RW Panel examined the impact of applying the updated growth models on catch at age, which resulted in a shift towards greater numbers of the youngest age groups (ages 0-2) and a decrease of about one year in the age of full selectivity. The RW Panel, however, decided to retain the earlier growth curve information for the BASE model. The RW Panel rejected the new growth parameters based on the most recent data because MSY was estimated to be higher than levels that drove down the size of the stock and because of suspect impacts of the updated curves on a fecundity at age relationship. Additionally, the estimate of t_0 was larger for the new growth model when compared to the older growth models. The RW Panel discussed the lack of small fish (< 24 inches) in the new growth model, which likely inflated the estimate of t_0 and increased the size/biomass at age for younger fishes. The new growth information also reduced the age at maturity and indicated that some fish were mature by age 0. The RW Panel recommends independent sampling of sub-legal fish (< 24 inches) to obtain a more accurate fit of t_0 for the growth curve.

Fecundity

Estimates of fecundity at age vectors were the same as used in previous assessments. Age-specific fecundity values were estimated in millions of eggs. Fecundity at age was derived from age-length relationships (Gulf – Manooch et al. 1987; Atlantic - Collins et al. 1989), a linear spline fit of maturity at age (data from Finucane et al. 1986), and an egg-length relationship (Finucane et al. 1986).

The RW Panel agreed that the data used for estimating fecundity were the best available. The RW Panel noted that reproductive biology data are nearly 20 years old and need updating. Several recommendations were made, including: 1) updating fecundity estimates and 2) updating maturity at age estimates. In addition, the egg-length relationship is derived from a small sample size (n = 65) that covered a wide spatial distribution. The RW Panel discussed whether differences existed in fecundity at age between subgroups, as has been demonstrated for growth among subgroups. The RW Panel believed that a direct relationship of fecundity at age, which accounts for spatial variability, needed to be developed for future assessments.

Term of Reference 2.

Assessment Workshop Panel members for the SEDAR5 were provided with documents (SEDAR5-AW1-8, MARFIN NA57-FF-0295, Fisheries Research 57(2002): 51-62, MSAP/98/10), which summarized data and gave overviews on growth curve models, stock assessment analyses, alternative assessment models, sensitivity runs, and mixing proportions. At the Review Workshop, panelists were provided these same documents and one additional document (SEDAR-AR-1), which reviewed decisions and recommendations made during the Data and Assessment Workshops.

The RW Panel considered the FADAPT VPA method employed to be appropriate given the available data, although it is suggested that alternative methods, that potentially are more stable when dealing with VPA type situations like here where F is not much larger than M, should be tested. Discussions of modeling methods and results focused on potential bias and precision in the input parameters and tuning indices, and did not evaluate model fits in great detail. Residual plots of the model fits, for example, were not provided for this review. The RW Panel recommends that such model diagnostics information be provided in future reviews. For instance, inspection of the residuals of the VPA model fits can reveal bias in the catch-at-age data, for example resulting from significant discards not accounted for, or from biased catch sampling. The RW Panel considered the stock-recruitment relationship and the abundance indices used for tuning to be adequate and appropriate.

The possibility of combining survey indices outside the VPA model was discussed. The RW Panel agreed that the use of composite estimators to combine multiple surveys potentially could yield more reliable tuning indices. Instead of the current use of equal weights, indices might be combined using weights that, for example, depend on precision and population coverage. The RW Panel cautioned that the combination of indices across surveys that cover different cohorts is problematic. Concerns were raised that fishery-dependent data may not be reliable for tracking trends in abundance because of factors such as targeted fishing, incomplete spatial coverage, changes in fishing practices, and size selectivity, although it was recognized that the assessment and data analysis took some of these aspects into account. A potential systematic shift in catchability related to technological improvements could introduce bias in estimated abundance trends.

Sensitivity analyses of the VPA model demonstrated that the stock assessments are dependent on the input growth parameter estimates. The RW Panel recognized that population length at age estimates based on fisheries dependent samples are likely to be biased because faster growing fish recruits sooner to the fishery. Such bias in growth models also affects fecundity because of conversion from size to age. The use of a stochastic growth model to estimate catch-at-age for early years (1981-1985) with no length-at-age was questioned. Following a request from the RW Panel, a sensitivity analysis was conducted to assess the effect of excluding these early years from the VPA runs. The results demonstrated that the model output is sensitive to deleting data on catch-at-age for the early years. The VPA model based on 1986/87 to 2001/02 catch at age data resulted in lower estimates of stock size, and in contrast to the Base run indicated that over fishing might occur. Collectively, the sensitivity analyses suggested that the current FADAPT model does not fully capture the variability in input parameters.

An alternative two-area VPA model (SEDAR 5 AW-4) that accounts for mixing between the South Atlantic and Gulf migratory groups was presented to the RW Panel. This model simultaneously examines catch, indices of abundance and tagging data in order to estimate rates of intermixing between king mackerel subgroups in the mixing zone off of southeast Florida. The two-area VPA allowed for two alternative box transfer models to account for the mixing. DW Panel preferred the 'overlap model' to the 'diffusion model' (Porch and Diaz 2004). The overlap model assigns fish to a particular stock or subgroup upon birth and assumes that the two stocks have overlapping ranges, but seldom interact. The overlap model initially was applied to catch and abundance information. Tagging data was incorporated in a second model run. In the absence of reliable tagging data, the best model fit was obtained using an assumption of zero overlap between the two migratory groups. The two-area model was sensitive to levels of overlap, resulting in poor fits to abundance indices and noticeably different abundance trends. Inclusion of tagging data and estimation of the degree of overlap between subgroups appears to have a minor influence on assessment results, except in the last few years in which more optimistic population estimates were observed. These observed differences result from very poor estimation of recruitment during the last four years of the assessment (1998-2001). The RW Panel supported SEFSC staff's attempt to account for mixing using a two-area VPA model, but agreed that the model was not adequate or appropriate for estimating king mackerel population parameters based on the data currently available. The original purpose of the tagging data incorporated into the model was not to evaluate levels of mixing and the RW Panel was concerned that tagging fish in a concentrated area (as done in the tagging studies off southeast Florida) did not lend itself to estimation of mixing rates. Overall, the RW Panel agreed with the authors that a three-area assessment model would be more appropriate. A three-area model would allow examination of the mixing zone as a separate area with intermixing of king mackerel restricted only to that area. Assessment at a finer spatial resolution, however, is constrained by the sample sizes for statistically based catch per unit effort indices and age-length data.

The RW Panel recommended that stock assessment methods that estimate fishing mortality for the oldest age class in each year back in time be evaluated as an alternative to the current VPA model. The current assessment is based on a model which estimates F in the last data year and uses a fixed F-ratio between age 9 and 10 to obtain F at age and year for those cohorts that are not represented in the last data year. Also, methods that do not assume that catch at age is known with 100% precision, like ICA, or AMCI could be tried. These methods have the advantage that they are more stable over time, especially regarding the historical stock number and F estimation for cases like the king mackerel where F is not much higher than M. The current base model is more suitable in situations where F is significantly larger than M, by a factor of say 3-4. One of such alternative models could eventually replace the current base model. Alternative methods could initially be tested and included as part of the sensitivity analysis.

Mixing in the mixing zone during "summer" time, where all king mackerel are assumed to belong to the Atlantic migratory group, was not dealt with. Very little data were presented which could be used to estimate the amount of Gulf king mackerel in the mixing zone in "summer" time. It was, however, clear from tagging experiments off east Florida during the summer period (see e.g. SEDAR5_DW5) that these king mackerel are not 100% of the Atlantic migratory group.

In conclusion, the RW Panel, except two members (a minority statement from the two RW Panel members is included in Appendix 1), agreed that the base model should provide the principal criteria for management advice. It has been the model used in the past (historical consistency). The RW Panel, except two members, decided there was only weak scientific justification to change the model or its input parameters. A majority of RW Panel agreed that to change the model at this point would not add any certainty to the management advice.

The RW Panel discussed the effect of mixing rate estimates on the interpretation of the model. Preliminary data provided on mixing rate indicate that fish in the "winter" mixing zone may include both Atlantic and Gulf group fish. Quantitative estimates of mixing rates were imprecise, subject to bias, and seemingly variable from year to year. A majority of the RW Panel, therefore, judged these mixing rate estimates to be scientifically unacceptable at this point in time. The management strategy presently assigns "winter" mixing zone fish totally to the Gulf group. Assigning some of these fish to the Atlantic group would change the estimates of stock status for each group (e.g., more of a change for the Gulf than for the Atlantic), as previously noted and further explained below under TOR 5.

The RW Panel also discussed the effects of growth and fecundity estimates on the interpretation of the model. The RW Panel decided not to change the growth estimates used in the base model because the lack of growth information for small fish cast doubt on the size-at-age relationship for young fish. The RW Panel noted that fecundity data were from a study done a number of years ago and no new data were available. Furthermore, the FADAPT method vs. more robust alternative methods and the sensitivity of the base model to the above mentioned issues adds an un-quantified level of uncertainty to the results of the model and therefore to the precision of the management advice that can be offered. Some of these uncertainties were potentially able to more than counterbalance the uncertainty in the mixing assumption.

Term of Reference 3

The procedures used to estimated population benchmarks (MSY, F_{MSY}, B_{MSY}, MSST, MFMT) were regarded as scientifically sound and the best available.

It was, however, recommended that the direct methods of estimating MSY using the adopted hockey stick stock-recruitment model combined with a standard yield per recruit analysis should be attempted for comparison with the MSY proxies in terms of $F_{30\%SPR}$ used in the assessment. This analysis was performed for the Gulf migratory group and showed that F_{MSY} calculated in this way was 0.35 and thus not very different from the proxy which for the Gulf migratory group is 0.26.

Although somewhat outside the TOR 3, the RW Panel had a brief discussion on the overall framework for the definitions and standards of the biological reference points. Various United Nations (UN) Agreements (see e.g. UN Fish Stock Agreement Annex II, 1995, FAO Code of Conduct of Responsible Fishing, 1995) state that stock specific limit and target reference points regarding fishing mortality and stock size should be defined and "…management strategies shall ensure that the risk of exceeding limit reference points is very low". It is further stated that MSY "…should be regarded as a minimum standard for limit points". The biological reference points defined for the two king mackerel migratory groups – the threshold MSST and $F_{30\%SPR}$ and the target OY and $F_{40\%SPR}$ are thus in accordance with the request to define a limit and a target reference point for both fishing mortality and biomass. However, the definition of MSST as (1-M)B_{MSY} is in apparent conflict with the guidelines of using B_{MSY} minimum standard for a limit point. It was noted that while some fishery management bodies argues that their limit points live up to this definition (the International Council for the Exploration of the Seas, ICES CM 2003/ACFM:09, and its associated management bodies like the European Union and the International Baltic Sea Fishery Commission), other management councils obviously do not (Both the New England Fishery Management Council [Northeast Multispecies FMP, Amendment 13 (NEFMC Amendment 13) and Mid-Atlantic Fishery Management Council, Summer Flounder, Scup, and Black Sea Bass FMP, Amendment 12 (MAFMC Amendment 12) use 1/2* B_{MSY} as the biomass thresholds below which the stocks are classified as overfished] . Furthermore, the adoption by the GMFMC of using the 50% probability value for not exceeding the threshold/limit values cannot be regarded as a "very low" risk of exceeding a limit values. Other management bodies in the North Atlantic area, for example have used 5%, 10%, and 20% probabilities of exceeding a limit to depict "very low" risk. The 50% probability is fine in relation to achieving a target such as OY, because "… management strategies shall ensure that target reference points are not exceeded on average", according to UN agreements.

Term of Reference 4

The RW Panel supports conclusions in the Assessment Report that results of the current Gulf assessment indicates the Gulf king mackerel migratory group is rebuilding, while the Atlantic migratory stock has rebuilt and remains stable. The RW Panel cautioned, however, that the BASE model for Gulf king mackerel appeared very sensitive to changes in input parameters tested with sensitivity analyses. For example, the BASE model incorporates a simplification of the true mixing between the two stocks which may have significant effects on estimates of population productivity, hence status. Furthermore, other sensitivity analyses detailed above demonstrated a wide range in stock productivity and status estimates depending on the choice of input parameters.

Term of Reference 5

The SEDAR Review Workshop, consistent with both the Data and Assessment Workshops, devoted significant discussion and effort toward resolving stock allocation within the mixing zone. The RW Panel discussions mirrored many of the same concerns voiced by the other workshops.

The tagging studies for South Atlantic and Gulf King mackerel were not designed to answer the stock mixing question and it is difficult to interpret raw tagging data beyond consideration of simple indicators, such as relative fishing effort and recovery rates. The SEFSC, based on Data Workshop recommendations, reconsidered mixing rates through updated analysis of tag data and developed an alternative assessment framework to incorporate tag-based mixing estimates into a VPA framework (Porch and Diaz 2004). The SEFSC also developed stock production and status estimates with the base assessment configuration for a variety of mixing rates between Atlantic and Gulf stocks within the mixing zone. The RW Panel determined that no consistent stock allocation is evident based on tagging data. Other tagging discussion dealt with the question of stock mixing outside the temporal/spatial zone and the impacts that may result if significant movement occurs during this time.

The majority of the RW Panel concurred with both the Data and Assessment Workshops that analysis of otolith shape and microchemistry offer a promising approach to resolving stock mixing. However, the majority felt that it was premature to base mixing zone estimates on otolith analyses. The SEDAR Workshop unanimously recommended that otolith analysis should be monitored on a continuing basis to provide additional information on stock mixing rates and to evaluate consistency in results between years.

The genetic population structure of king mackerel has been investigated by a number of researchers (May 1983, Johnson et al. 1994; Gold et al. 1997, 2002; Broughton et al. 2002). The results of these studies ranged from no genetic differences between eastern Gulf and Atlantic fish to a weak genetic difference between eastern Gulf and Atlantic fish. The microsatellite work, which has shown promise in other fisheries, was not consistent with the current spatial and temporal boundaries used in assessing and managing king mackerel in the US. The SEDAR workshop concluded that the current genetic research could not be used to evaluate king mackerel mixing rates.

The RW Panel concurred with the opinion of the Assessment Workshop Panel that both migratory groups contribute to winter landings in the mixing zone. Mixing scenarios within the range of 25 to 75% Gulf group catch from the mixing zone appeared consistent with tagging data and preliminary results from otolith shape and micro-constituent studies, and were perceived more likely than the 100% used in the base line assessments. However, a majority of the RW Panel felt the alternate mixing scenarios suggested were based on imprecise mixing rates, and not developed and therefore premature to consider in the base model assessment, preferring instead to consider their effects by means of sensitivity analysis.

Term of Reference 6

The RW Panel noted that major concerns remain about the growth curves used to age the catch in some years and areas, the fecundity-length relationship used to estimate spawning stock, and the degree of mixing of the Gulf and Atlantic migratory groups in the winter fishery mixing zone. The RW Panel also expressed concern about the limited number of fishery independent indices of abundance available for VPA calibration.

The following is a more detailed and specific list of research issues, which are judged by the RW Panel to be important for improving the assessment and management advice for the two king mackerel stocks:

- The RW Panel recommends enhancing ongoing research programs and implementing new research programs to collect fishery independent data (e.g., length measurements, age structures, fecundity measurements) to improve the accuracy and precision of current estimates of growth, fecundity, and stock mixing. Spatial variability in size at maturity and fecundity at age should be evaluated among regions/migratory groups.
- The data collection program should also be designed to provide fisheries independent indices of abundance for the full age range in the stock. This consideration should have a strong influence on the design aspects [gear, season] of the recommended research programs. These programs might include research sampling targeting spawning aggregations, research sampling targeting juveniles, tagging studies specifically designed to provide information on mixing rates, and hydro-acoustic sampling. Scientists should seek the advice of members of the commercial and recreational fishing communities in the design of these programs.
- The RW Panel suggested that the MRFSS indices of abundance could be recompiled to address two issues: 1) consider incorporation of the January-June intercept data in addition to the current

July-December data, and 2) consider restriction of the sample data to the age classes most likely to contribute to the respective catch types (i.e., recompile the indices including only Catch Types A, and restrict the corresponding length composition to legally landed fish).

- The RW Panel also recommended the future application of different assessment models to provide alternative perspectives on the status of king mackerel stocks (e.g., those including estimation of the likely degree of error in the fishery catch-at-age, and/or those which employ forward-projecting computation approaches).
- One growth model should be developed for the splitting of catch at length data into catch at age data and another one that can be used for stock related data like weight at age in the stock, maturity at age in the stock and the like.
- Available sex ratio at size data needs to be evaluated to determine how sex ratios vary by size.
- Western Gulf king mackerel catches need to be aged for use in age length key analysis.
- The commercial fishery tuning indices should be further developed and it seems important that this is done in cooperation with fishers with an intimate knowledge of the way the fishery is prosecuted.
- Age composition of commercial and recreational discards is needed.
- Discard mortality rates are needed.
- Tuning indices should be weighted according to their internal variability, the part of the stock covered by the index, correlation with other indices etc. For instance it is realized that using their individual degree of correlation to the VPA stock abundance estimates could be problematic due to the circular logic feature of this approach.
- Data from Mexican catches need to be obtained, probably via initiatives for closer cooperation with Mexico. In this connection there is a need to look into whether the eastern and western Gulf King Mackerel are separate stock components.
- Tagging programs specifically designed to examine the mixing should be developed. Otolith shape and microchemistry and maybe micro-satellite DNA analysis are promising methods that should be pursued.
- Mixing of the stocks in the mixing zone should be investigated also the during summer period.

IV. General Comments

RW Panel Statements. The RW Panel was pleased with the effective support from the NMFS SEFSC scientists, and impressed by the open-minded attitude and willingness to support the RW Panel with additional information and analysis. Also, the computer and net work support was excellent. The small local network established by the SEFSC staff proved very effective for the exchange of data files and sharing of information among the RW Panel members.

Scientists. The scientists of the RW Panel except one (see statement by Joe Grist in Appendix 2) were of the opinion that the review was soundly based on science and not biased because of management and socio-economic considerations. RW Panel scientist, Will Patterson, presents his personal view in Appendix 3.

Constituents or fishers. One RW Panel member, William Gibson Jr., representing the commercial fishers said in his closing remark that he was pleased with the meeting and that it had been a clearly scientific meeting. RW Panel fisher, Bob Zales II, presents his personal view in Appendix 4.

IV. SEDAR Review

The overall SEDAR process worked well.

All the documentation and guidelines to the RW Panel members were received about 2 weeks before the meeting, except to one of the CIE reviewers who got it only 5 days before the start of the meeting.

The amount of documentation and issues to be dealt with are significant. Some of the documentation could have been sent out earlier to the RW Panel, for instance background material and the data workshop material. That would have eased the task of getting deeply into the substance of the material, especially for the external reviewers, who (almost by definition) were not beforehand familiar with the assessment.

V. References.

Document #	Title	Authors
Documents Reviewed at the Data Workshop		
SEDAR5-DW-1	Estimating Catches and Fishing Effort of the Southeast United States Headboat Fleet, 1972-1982.	Dixon, R.L. and G.R. Huntsman
SEDAR5-DW-2	2003 Report of the MSAP	MSAP
SEDAR5-DW-3	Regulatory Overview of South Atlantic and Gulf of Mexico King Mackerel	Carmichael, J.T.
SEDAR5-DW-4	A general description of the SEAMAP larval king mackerel dataset with indices of larval occurrence and abundance, 1982 to 2000	Lyczkowski-Shultz, J. and D. S. Hanisko
SEDAR5-DW-5	A review of the stock structure of king mackerel off the southeastern US.	DeVries, D. and W. Patterson
SEDAR5-DW-6	A literature review of the growth of king mackerel in the Southeastern United States	Cummings, N. J., D. DeVries, and C. Palmer
SEDAR5-DW-7	A summary of king mackerel *Scomberomorus cavalla* age data from the Panama City Laboratory, NOAA Fisheries, 1997 – 2003.	Palmer, C. and D. DeVries
SEDAR5-DW-8	Review of the catch sizing and sexing and ageing of king mackerel *Scomberomorus cavalla* from US Gulf of Mexico and South Atlantic fisheries	Ortiz, M., P. L. Phares, and N. J. Cummings
SEDAR5-DW-9	Preliminary analysis of king mackerel tag data from the cooperative tagging center	Diaz, G. A.
SEDAR5-DW-10	A method for analyzing the abundance and mortality of Atlantic and Gulf king mackerel when the two stocks are presumed to intermix	Porch, C. E.
SEDAR5-DW-11	Discrimination between Gulf of Mexico and Atlantic Ocean king mackerel with otolith shape analysis and otolith microchemistry: A progress report	Patterson, W., T.R. Clardy, D. A. DeVries, Z. Chen, and C. Palmer
SEDAR5-DW-12	Estimates of king mackerel discards for the Atlantic and Gulf Migratory groups	Poffenberger, J.
SEDAR5-DW-13	Standardized Catch rates of king mackerel from US Gulf of Mexico and South Atlantic recreational fisheries	Ortiz, M. and P. L. Phares
SEDAR5-DW-14	Standardized catch rates of king and Spanish mackerels from US Gulf of Mexico and South Atlantic recreational fisheries	Ortiz, M.
SEDAR5-DW-15	Standardized catch rates of Spanish and king mackerel from the North Carolina commercial fisheries	Ortiz, M. and L. Sabo
Documents Reviewed at the Assessment Workshop		
SEDAR5-AW-1	Estimated von Bertalanffy growth curves for king mackerel stocks in the Atlantic and Gulf of Mexico	Brooks, E. N., Ortiz, M.
SEDAR5-AW-2	Sensitivity of stock assessment analysis of Gulf of Mexico king mackerel to alternative methods for estimation the historic catch at age matrix 1981-2002	Ortiz, M.

SEDAR5-AW-3	Stock Assessment Analysis on Gulf of Mexico King Mackerel	Ortiz, M.
SEDAR5-AW-4	Virtual Population Analyses of Atlantic and Gulf King Mackerel Using Tag-Recapture data and Alternative Models of Migration.	Porch, C. E., G. A. Diaz
SEDAR5-AW-5	Revision and Update of the stock assessment analyses on King Mackerel stocks 2003	Ortiz, M.
SEDAR5-AW-6	Release locations of tagged king mackerel	Diaz, G.
SEDAR5-AW-7	Discrimination Amount US South Atlantic and Gulf of Mexico King Mackerel with Otolith Analysis and Otolith Microchemistry. Summary of MARFIN Grant No. NA17FF2013	Shipp, R. L. and W. F. Patterson III.
SEDAR5-AW-8	Stock Assessment analysis on king and Spanish mackerel stocks. Report to the MSAP, 2003. SFD Cont. SFC-2003-008.	anon.
MARFIN NA57-FF-0295	Genetic analysis to determine mixing proportions by season of Western Atlantic and Gulf of Mexico stocks of king mackerel.	Gold, J. R.
Fisheries Research 57(2002):51-62	Using otolith shape analysis to distinguish eastern Gulf of Mexico and Atlantic Ocean stocks of king mackerel	DeVries, D. A., C. B. Grimes, and M. H. Prager.
MSAP/98/10	What if mixing area fish are assigned to the Atlantic Migratory Group instead of the Gulf of Mexico Migratory Group	Legault, C. M.
Documents Provided for the Review Workshop		
SEDAR5-AR-1	Stock Assessment of Atlantic and Gulf King Mackerel	anon.

<u>Documents tabled at the start of the meeting:</u>

Legault, Christoffer, M. (probably 2000 but not stated). Status Review of King Mackerel in the Gulf of Mexico. Feature Article. NMFS Southeeast Fisheries Science Center, Miami, Florida.

Legault, C.M., Powers, J.E. Restrepo, V.R. 2002. Mixed Monte Carlo/Bootstrap Approach to Assessing King and Spanish Mackerel in the Atlantic and Gulf of Mexico: Its Evolution and Impact. American Fisheries Society Symposium, 27:37-44.

Power, J.E. and Restrepo, V.R. 1993. Evaluation of Stock Assessment Research for the Gulf of Mexico King mackerel: Benefits and Costs to Management. North American Journal of Fisheries Management, 13:15-26.

Powers, J.E. 1996. Benchmark Requirements for Recovering Fish Stocks. North American Journal of Fisheries Management, 16:495-504.

SEDAR5-AW-/Appendix. Sensitivity of Stock Assessment Analysis of the Gulf of mexico King Mackerel to Alternative Growth Parameters.

Appendix 1. A minority statement.

Minority Report on Mixing Rates

By Joe Grist and Ben Hartig

The stock of king mackerel south of Volusia County along southeast Florida during November 1 through March 31 (i.e. the mixing zone) is currently allocated to the Gulf Migratory Group. Tagging studies from the 1970's through the 1990's suggested a greater proportion of Gulf migratory fish in the mixing zone, though more recent studies (SEDAR-DW-5, SEDAR-DW-9) suggest relative abundances within the mixing zone has changed. Devries (2003) notes that with the implementation of Amendment One that all king mackerel caught in the mixing zone were from the Gulf group. This implementation was based on a FDEP study that suggested that more than half of the fish along the Florida east coast in the winter were from the Gulf migratory group. The 100% was originally chosen to help shore up the overfished Gulf group in the mid-1980's, a management measure. However, data available during that period suggested a more conservative 40/60 split in the mixing zone for the Atlantic/Gulf stock (Williams, R.O. and M.F. Godcharles 1984). The allocation of 100% fish to the Gulf group has a major impact on stock assessments (Devries 2003). If all fish were assigned to the Atlantic group, the 1998/99 allowable biological catch (ABC), assuming a F30%SPR management strategy, would increase between 400 and 2000 mt, depending on the level of bycatch used (Legualt 1998). Correspondingly, Legualt (1998) notes that the Gulf ABC would decrease by approximately 550 mt and estimates of fishing mortality would remain similar for both groups when all mixing area fish were assigned to the Atlantic group.

The terms of reference for the 2004 king mackerel review panel included recommending a range and best point estimate of the mixing rate of Atlantic and Gulf Migratory groups in the mixing zone, based on the best available scientific information. Three additional studies were provided to the review panel that addressed this issue.

Porch and Diaz (2004, SEDAR5-AW4) used tag recapture data and a two-area VPA (VPA-2 Box, Porch 2003b, Porch 2003a SEDAR5-DW10) to estimate mixing magnitude, along with the effect of changes on mixing proportions on Gulf and Atlantic management unit estimates. While the Assessment Panel agreed that inclusion of tagging data and estimates of degree of overlap has a relatively minor impact on the assessment results, it was evident that estimates of overlap from this analysis are not consistent with the hypothesis that 100% of the fish in the mixing area belong to the Gulf Migratory Group. Given the similar estimates of abundance for the two migratory groups, they are rather more consistent with the hypothesis that the Gulf group fraction in the mixing area is between 25 and 75%.

Results of genetic analysis to determine mixing proportions by season of the western Atlantic and Gulf groups were consistent with results of assignment tests, where the proportion of Atlantic and Gulf fish within most samples was approximately 50:50 (Gold 2000). The genetic data presented showed that king mackerel from the Florida Keys cannot be unequivocally assigned to either genetic stock. This study did suggest that the hypothesis that two, very weakly differentiated genetic subpopulations of king mackerel do exist in the peninsular Florida region, and that extensive mixing does occur between the two groups.

Otolith shape analysis was used to distinguish Gulf and Atlantic group female king mackerel collected from 1986 and 1993. Feasibility results for the study showed it's ability to correctly classify 80% of Atlantic and 86% of east Gulf king mackerel with a model based on otolith shape. Composition of the mixing zone stock from a sample of 463 females resulted in an estimate that 99.8% of fish in the winter landings were from the Atlantic and only 0.2% were from the eastern Gulf.

The majority opinion of the king mackerel panel, in spite of the previously referenced studies, was to continue with the assessment assumption that 100% of king mackerel in the mixing zone are from the

Gulf Migratory Group. The majority of panel members did acknowledge that the 100% representation of Gulf fish within the mixing zone was an incorrect assumption, however, the lack of an exact calculation of Atlantic/Gulf king mackerel in the mixing zone precluded the majority from making an informed estimate of a current mixing rates to correct a recognized assessment flaw.

The minority opinion of the king mackerel panel, in spite of the lack of an exact calculation of Atlantic/Gulf king mackerel in the mixing zone but based on the best available science, was to take the conservative approach and correct the previously noted flawed assumption in the assessment report that 100% of the mixing zone stock are from the Gulf group. Studies (reviews, tagging, genetics, otolith shape) have shown that the mixing zone is more likely to support a mixing range of at least 25-75% between Atlantic and Gulf fish, with Atlantic fish possibly being the most dominant in more recent time period.

With the best scientific data available and taking the conservative approach, a more appropriate mixing distribution to base the best management recommendations on would be 50/50 Atlantic/Gulf, providing analysis with a sensitivity range of 25-75%. This takes into account that the mixing zone is not likely comprised of 100% Atlantic or Gulf group fish, a fact recognized by previous scientific studies and the SEDAR5 review panel.

Appendix 2. General comment by scientist Joe Grist.

Consensus Report op-ed. by Joe Grist
Scientist sub-section.

My initial experience with the SEDAR process was with SEDAR2, where I had the opportunity to participate in the Assessment Workshop phase and attend the Review Panel phase. In the SEDAR2 workshops, we stayed on the message 'it's about the science and the science only'. We were not to be concerned about management or socio-economic implications, because that was not part of our terms of reference and would be handled in later phases of the process. We were to use the best data available, make the best assumptions available, and produce an assessment report that was scientifically sound. The SEDAR5 Review Panel got off that message. It was not only about the science this time. Discussions of management and socio-economic implications found their way into the review process. Discussions were not just about the science and the assumptions used to determine the validity of the assessment report, but also the larger impacts of the review panels report on current and future management.

For the SEDAR process to be successful, this issue needs to be addressed and resolved. Stock assessment results, and the assumptions that pertain to achieving those results, cannot be biased by the management implications they may lead to. Discussions on management and socio-economic issues that assessment results could effect are a vital part of developing any fisheries management plan, but they are discussions that fisheries managers and industry (recreational, commercial, environmental) representatives should discuss and pass judgement on, not the stock assessment scientist and reviewers. Otherwise, the credibility of any stock assessment developed in the SEDAR process is automatically jeopardized.

Appendix 3. General comment by scientist Will Patterson.

Scientist Statement: Will Patterson

I feel the Review Workshop for SEDAR5:South Atlantic and Gulf of Mexico King Mackerel provided a thorough and scientifically rigorous review of the king mackerel assessments and the reports produced by the Data and Assessment Workshop Panels. Prior to the Review Workshop, I looked forward to participating in the SEDAR process and wanted to get a sense of how this new review compares with the old Stock Assessment Panel reviews. I was a member Mackerel Stock Assessment Panel for several years, serving as its chairman since 2000, and was impressed with the level of scientific rigor and objective criticism members of that panel injected into the assessment review process. I was equally impressed with objectiveness and thoroughness with which most SEDAR Review Workshop Panel members addressed the Terms of Reference presented to us. In particular, I feel the addition of Center of Independent Experts scientists added fresh perspective to issues other panel members had reviewed many times, or even conducted research on, over the years. The participation of commercial and charter fisherman also added a unique layer of discussion that has been absent in most assessment reviews in which I have participated. Adding an environmentalist or two to the panel really would have broadened our overall perspective; however, I appreciate none of the invited groups were able to send members.

Despite my overall good impression of the Review Workshop for king mackerel, there are some issues I think should be addressed concerning the SEDAR process. Panel members received an immense amount of material to review only two weeks before our meeting. Many of the documents were available months prior and it would have been beneficial to receive them earlier. But along those same lines, it appeared to me we duplicated much of the review already conducted by Data and Assessment Workshop Panels. In the effort to increase transparency of assessment preparation and review, it seems many tasks are being duplicated by various groups during the SEDAR process. Some may take the position that duplicity increases the probability potential problems with the assessment will be caught and corrected, and that may be true. In cases such as when the Review Workshop Panel again reviewed data inputs to the models, however, it seemed to me our time together could have been better spent. For example, one important task for an assessment review should be examining diagnostics of model performance and that subject was addressed only superficially by the panel. I feel the SEDAR process would be more efficient, and potentially even more scientifically rigorous, if the roles of separate panels were more clearly defined and duplicity among workshops was minimized, especially given the fact the Consensus Report produced by the Review Workshop will itself be reviewed by the Standing Statistical Committees of the two councils.

Appendix 4. General comment by fisher Bob Zales II.

To the group,

I want to say I was pleased with the process and the information available. I was also pleased with the way we were all able to discuss the information provided and able to comment as we did. As this is a very controversial subject, I want to also state it was my understanding that the possible separation of the mixing zone fish may not provide an additional biological benefit to the total stock of Gulf and South Atlantic fish as the current management has worked well to rebuild the stock. I am satisfied with the current recommendations and agree that more information is necessary before a definitive separation can occur. As a fisherman, and one who has been involved with the king mackerel fishery management system since 1986, I feel the sedar process was a definite improvement in being able to have constituent participation in the assessment process.

Bob Zales, II

SEDAR

SouthEast Data, Assessment, and Review

Atlantic King Mackerel Advisory Report

SEDAR 5: Atlantic and Gulf of Mexico
King Mackerel

SEDAR Document: SEDAR5-AR4 April 2004

2004 Atlantic King Mackerel Advisory Report

State of Stock: The Atlantic king mackerel stock was not overfished and overfishing was not occurring in 2002/03. Current estimates indicate the fishing mortality rate of Atlantic king mackerel in fishing year 2002/03 was well below MFMT and spawning biomass was well above MSST at the beginning of fishing year 2003/04. The Base model resulted in only a 2% probability that B_{2003} was less than MSST (Fig. 1), and there was only a 1% probability that $F_{2002/03}$ was greater than MFMT (F_{MSY}) (Fig. 1). Combined mean landings of king mackerel were 7.37 million pounds (mpd) between 1981/1982 and 2001/2002, with a range of 5.66 mpd (1999/00) to 9.62 mpd (1985/86). Estimated Atlantic king mackerel stock size has increased since the mid-1990s but not to the higher levels seen in the early 1980s. Recently, recruitment has been highly variable with a low and highly uncertain value in the most recent data year (2001/2002).

Stock Identification and Distribution: King mackerel in the southeast United States are managed under the Fishery Management Plan for Coastal Migratory Pelagic Resources (FMP CMPR). Under the FMP CMPR, all king mackerel occurring in the US Gulf of Mexico and south Atlantic are specified as a single stock, but are managed as two independent migratory groups: Gulf migratory group and Atlantic migratory group. The Atlantic migratory group management area extends from New York to Florida and the Gulf migratory group management area extends from Florida to Texas. Management areas are separated along the east coast of Florida by a boundary that moves seasonally, specified as the Volusia/Flagler County border on the east coast in Winter (November 1 - March 31) and the Monroe/Collier County border on the Southwest coast in Summer (April 1 - October 31). While fish landed off the southeast coast of Florida during winter (Nov. 1 - Mar. 31) count against the Gulf migratory group's Total Allowable Catch (TAC), winter mixing zone fishery regulations are set by the South Atlantic Fishery Management Council.

Data and Assessment: A Virtual Population Analysis model (VPA) was used with maximum likelihood estimates option and normal error assumption for all indices of abundance used, not including bycatch estimates, and for ages 1 through 11+. The Base model assumes that 0% of the catch in the winter mixing area fishery is from the Atlantic migratory group.

Forecasts: Forecasts are based on stock status projections at F30%SPR and F40%SPR, assuming average long-term recruitment and recent (last 5 years) average selectivity patterns. Stock status was projected forward one year from the terminal year (2001/02) stock sizes estimated by VPA to the 2002/03 fishing year using preliminary median landings estimates for 2002/03, and then forward through 2005/06.

Forecasts Table:
Spawning stock (SS) in trillions of eggs, yield (MSY and OY) in millions of pounds, and Allowable Biological Catch (ABC) in pounds.

	F30%SPR			F40%SPR		
	SS MSY	F MSY	MSY	SS OY	F OY	OY
Median	2.93	0.29	5.68	4.40	0.21	5.77
Lower 80%	1.43	0.26	2.58	3.43	0.18	4.50
Upper 80%	4.21	0.35	8.34	5.86	0.24	7.89
Deterministic	3.05	0.26	5.89	4.07	0.19	5.42

ABC	2002/03	2003/04	2004/05	2005/06
F 30%SPR	3,902,220 1)	7,987,560 2)	7,382,960 2)	6,900,130 2)
F 40%SPR	3,902,220 1)	5,811,650 2)	5,708,560 2)	5,554,600 2)

1) Actual catch value.
2) Projected

Catch and Status Table: South Atlantic King Mackerel

YEAR	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	Mean[6]	Min[6]	Max[6]
Commercial Fishery Landings													
Numbers (10^6)	0.27	0.23	0.23	0.18	0.31	0.29	0.29	0.25	0.22	0.19	0.27	0.18	0.38
Pounds (10^6)	2.23	2.02	2.20	1.87	2.70	2.68	2.55	2.24	2.11	2.02	2.53	1.87	3.94
Recreational Fishery Landings													
Numbers	0.67	0.37	0.38	0.46	0.38	0.52	0.44	0.36	0.55	0.34	0.52	0.34	0.82
Pounds	6.25	4.44	3.73	4.15	3.99	5.15	4.31	3.42	5.34	4.04	4.84	3.40	7.12
TOTAL Landings													
Numbers	0.94	0.60	0.61	0.64	0.70	0.81	0.73	0.61	0.77	0.53	0.78	0.53	1.05
Pounds	8.48	6.46	5.93	6.02	6.69	7.84	6.86	5.66	7.44	6.05	7.37	5.66	9.62
Stock Parameters													
Recruits[1]	0.93	0.92	1.07	1.25	2.07	2.80	0.83	2.99	1.05	0.32	1.44	0.32	2.99
Age 1-11 abundance[2]	5.89	5.11	4.91	4.92	5.71	7.07	6.17	7.64	7.06	5.68	6.47	4.91	9.46
Stock Biomass[3]	36.82	33.88	32.85	32.59	34.45	38.43	37.53	42.28	43.57	40.61	42.57	32.59	67.55
Spawn Stock[4]	3.14	3.01	2.98	3.02	3.13	3.25	3.34	3.60	3.92	3.97	4.00	2.98	10.01
Age 1-11 F[5]	0.21	0.19	0.16	0.18	0.19	0.18	0.17	0.13	0.15	0.13	0.19	0.13	0.29

1. Estimated abundance at age 1 in millions of fish. The recruits of the last dataare always poorly estimated.
2. Millions of fish.
3. Millions of pounds, ages 1-11.
4. Spawning stock abundance, measured in trillions of eggs.
5. Arithmetic mean of F at age.
6. Mean, Minimum, and Maximum statistics based on entire 1981/82-2001/02 fishing year time series.

Catches: South Atlantic landings have been dominated by the recreational fishery with a mean take of 4.84 mpd, ranging from a high of 7.12 mpd in 1985/86 to a low of 3.40 mpd in 1989/90. Commercial landings have ranged from 1.87 mpd (1995/96) to 3.94 mpd (1982/83) with a mean of 2.53 mpd. Combined mean landings of king mackerel were 7.37 mpd with a range of 5.66 mpd (1999/00) to 9.62 mpd (1985/86) (Fig 2).

Fishing Mortality: Trends in fishing mortality rates for South Atlantic king mackerel have declined during the past 20+ years (Fig 3), from a high of 0.29 in 1981/82 to a low of 0.13 in 2001/02. Current F (0.13) is below the forecast table reference points for 30% SPR (F_{MSY}=0.29) and 40% SPR (F_{OY}=0.21).

Recruitment: King mackerel age-1 abundance has been variable over time in the South Atlantic (Fig. 4), ranging from 320,000 fish in 2001/02 to 2,990,000 fish in 1999/00. The low recruitment estimates for the 2001/02 is based on VPA terminal year values that are inherently very uncertain. Static, or equilibrium, SPR calculates the ratio of spawning stock biomass under fishing and non-fishing conditions. Static SPR (calculated for SPR 30% and 40%) initially decreased in the early 1980s, but has increased since the mid-1990s to 0.41 for the 2000/01 fishing year (Fig.5).

Stock Biomass: Stock biomass levels have averaged 42.6 mpd since 1981/82 in the South Atlantic (Fig. 4). Biomass levels were highest in 1981/82 at 67.55 mpd and lowest in 1995/96 at 32.59 mpd.

Stock Status Criteria: The SAFMC has adopted (1-M)*BMSY as the MSST and FMSY as the MFMT for Atlantic king mackerel, but has not adopted an acceptable risk level for exceeding MSST or MFMT. F30%SPR (=0.29) has been specified as a proxy for FMSY, and 30%SPR (=2.93 trillion eggs) as a proxy for BMSY. The MSST for Atlantic king mackerel = 2.50 trillion eggs (M = 0.15). The SAFMC has adopted a target F=F40%SPR (=0.21), where 40%SPR = 4.40 trillion eggs.

Special Comments: The sensitivity runs that considered alternative stock compositions in the mixing zone showed that the status of the Atlantic stock was rather insensitive to the assumed mixing rates, both in terms of associated stock biomass and F values and in terms of status of the stock and the fishery in relation to overfishing.

Sources of Information: SEDAR5. 2004. Stock Assessment Report for South Atlantic and Gulf of Mexico King Mackerel.

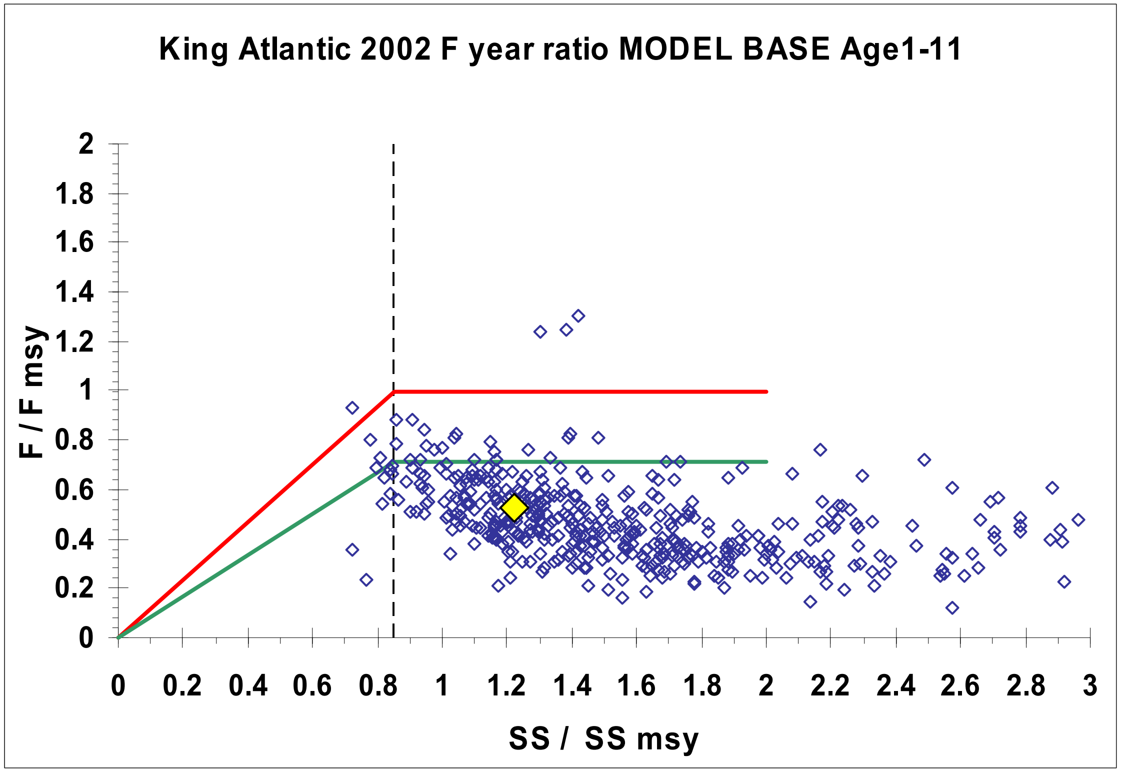


Figure 1: Atlantic king age 1-11+ phase plot stock status for 2002/03 fishing year. Dashed vertical line represents the MSST ratio, the top horizontal line the MFMT and the low horizontal line the OY fishing mortality ratios, respectively. The large diamond marker represent the results of the deterministic run.

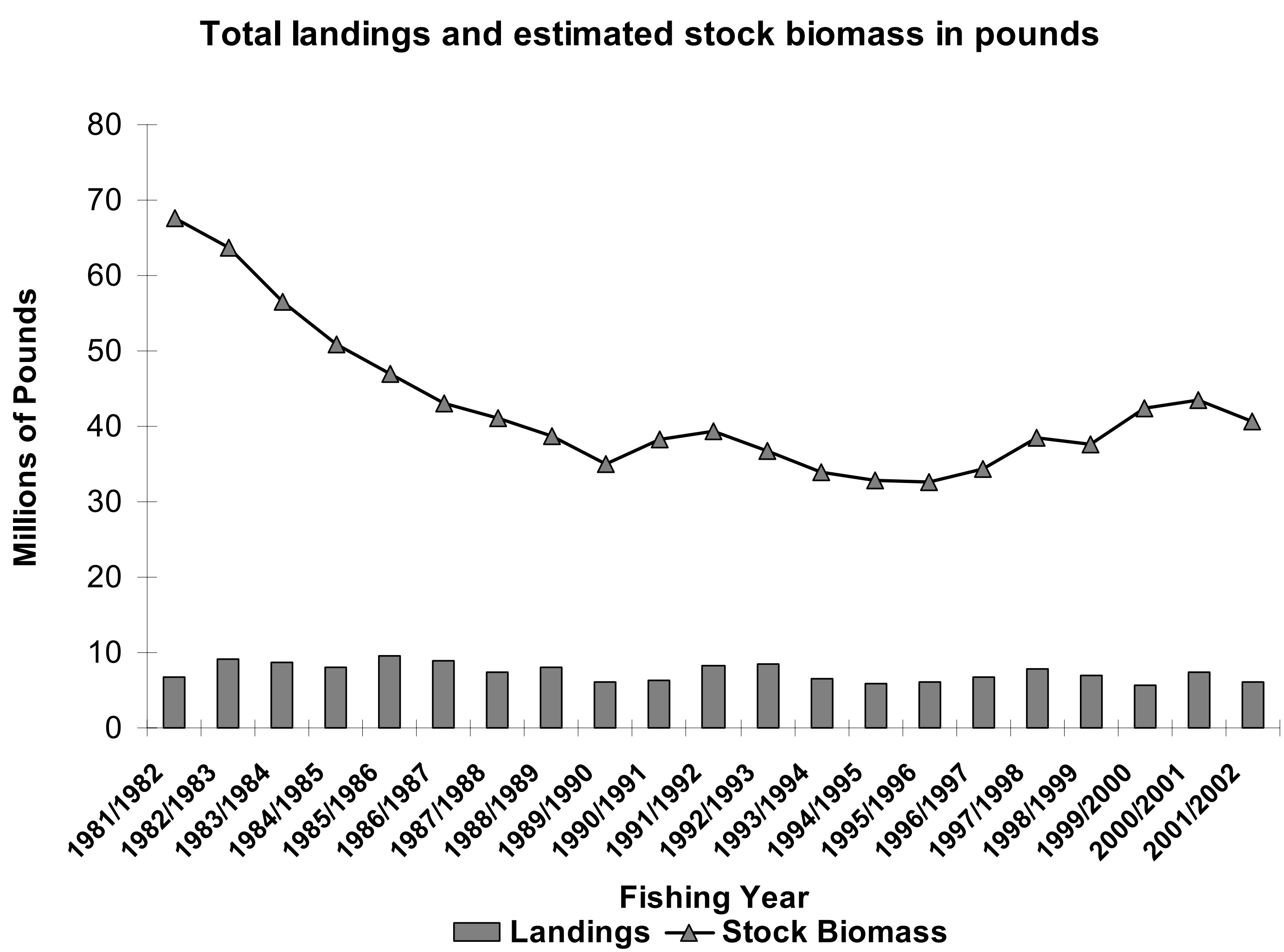


Figure 2: Total landings and estimated stock biomass for Atlantic group king mackerel.

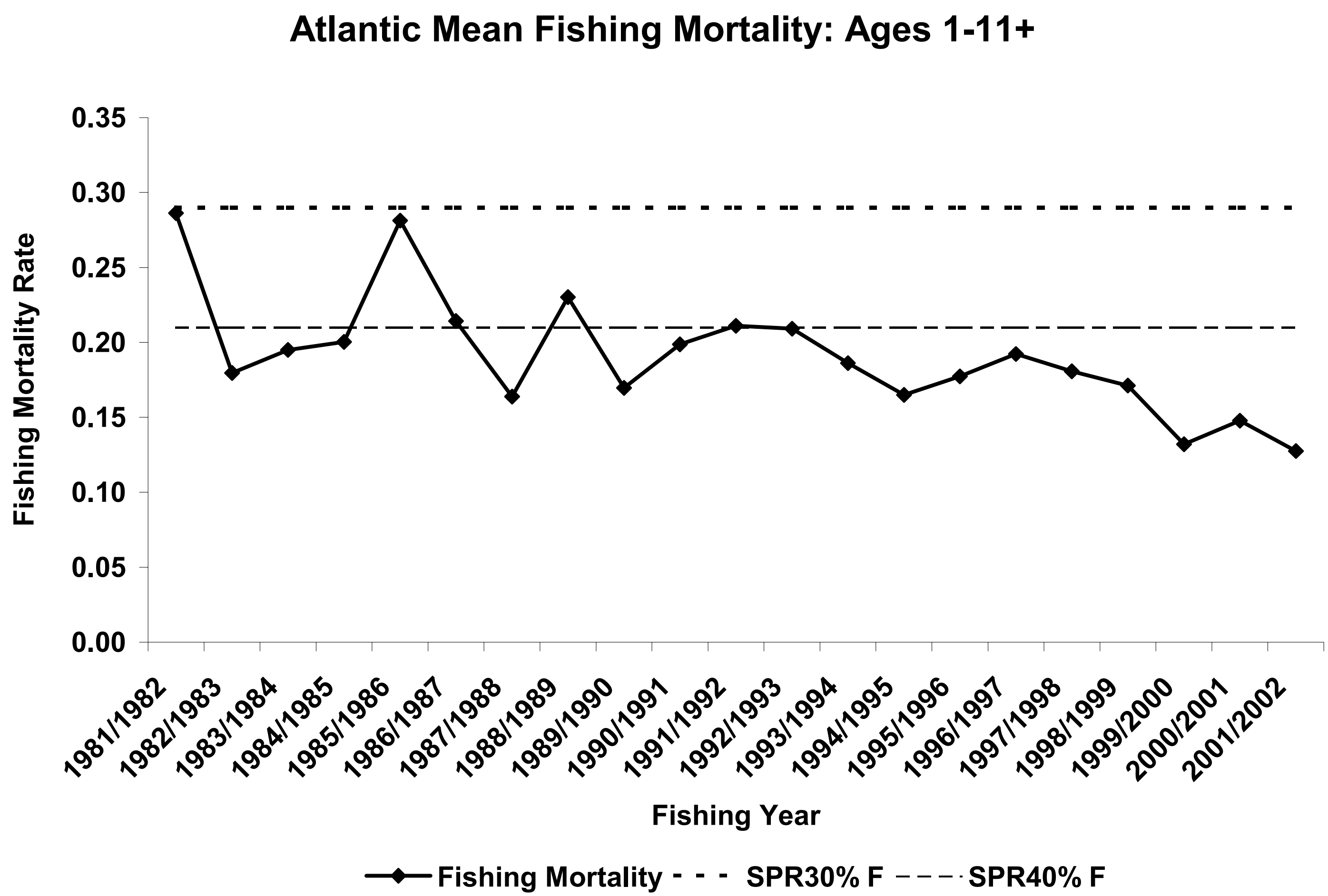


Figure 3: Atlantic group king mackerel fishing mortality (age 1-11+, Y-axis), with current F 30%SPR F 40%SPR40% management reference points.

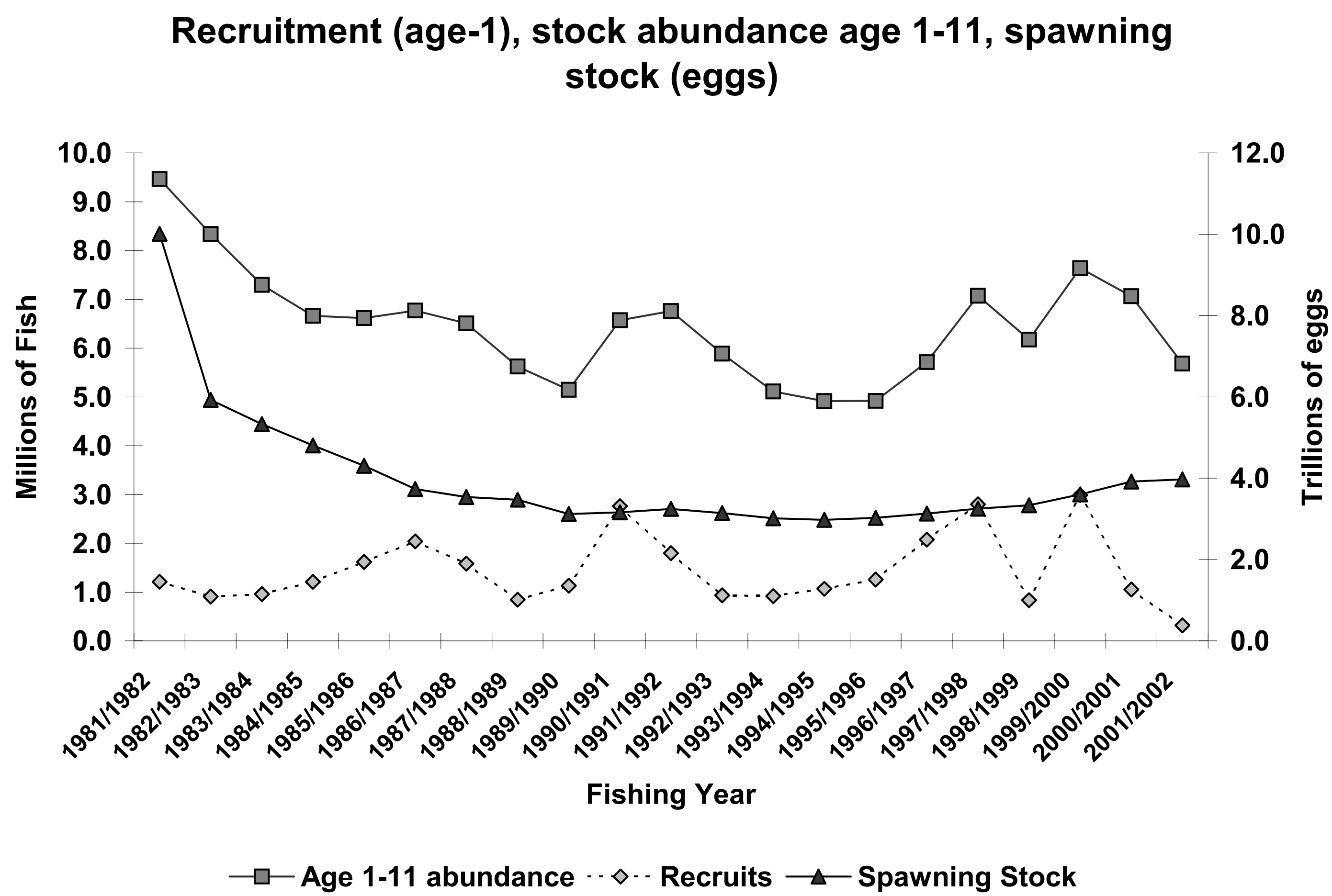


Figure 4: Recruitment, stock abundance (ages 1-11) and spawning stock (eggs) for Atlantic group king mackerel.

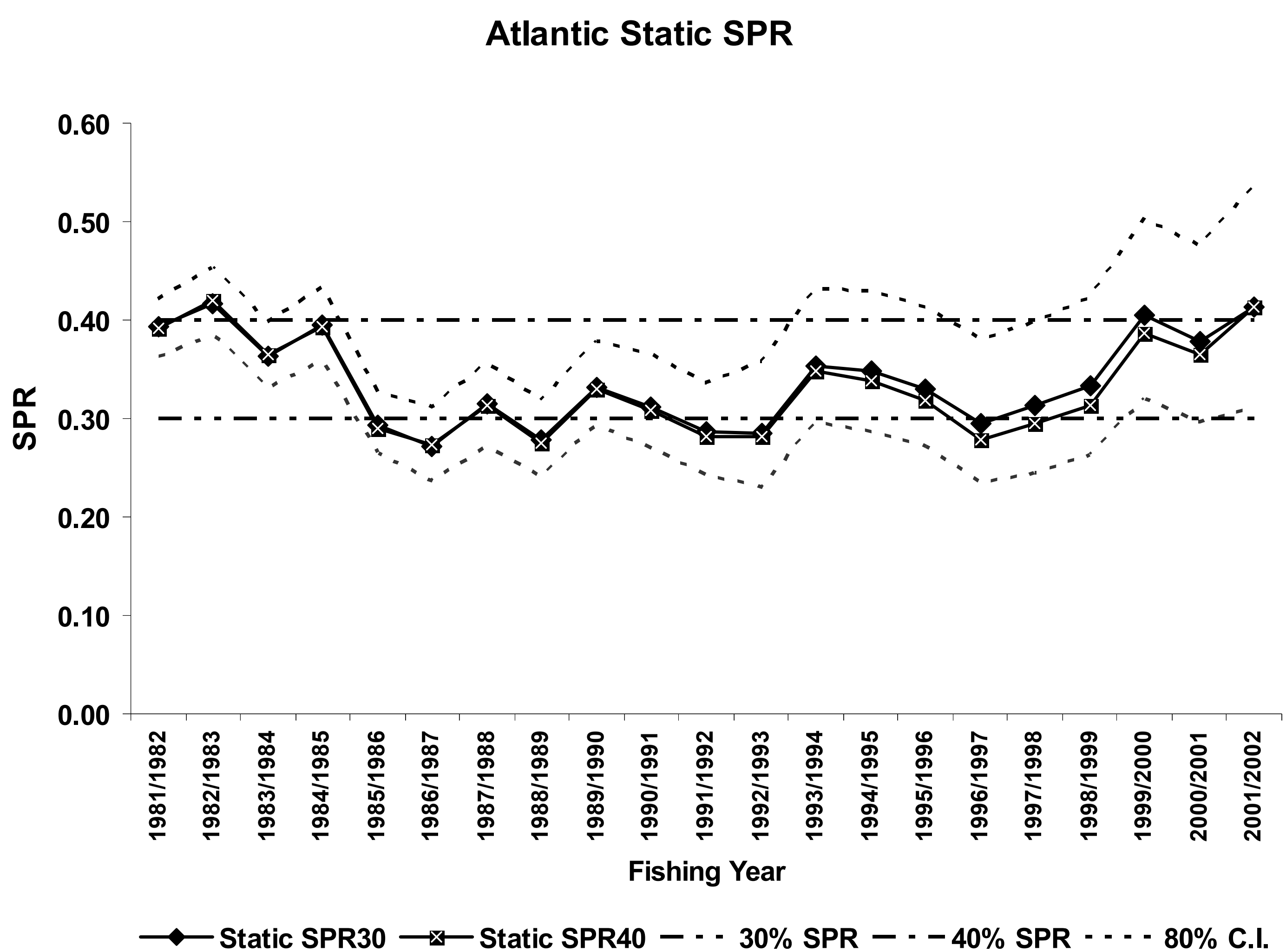
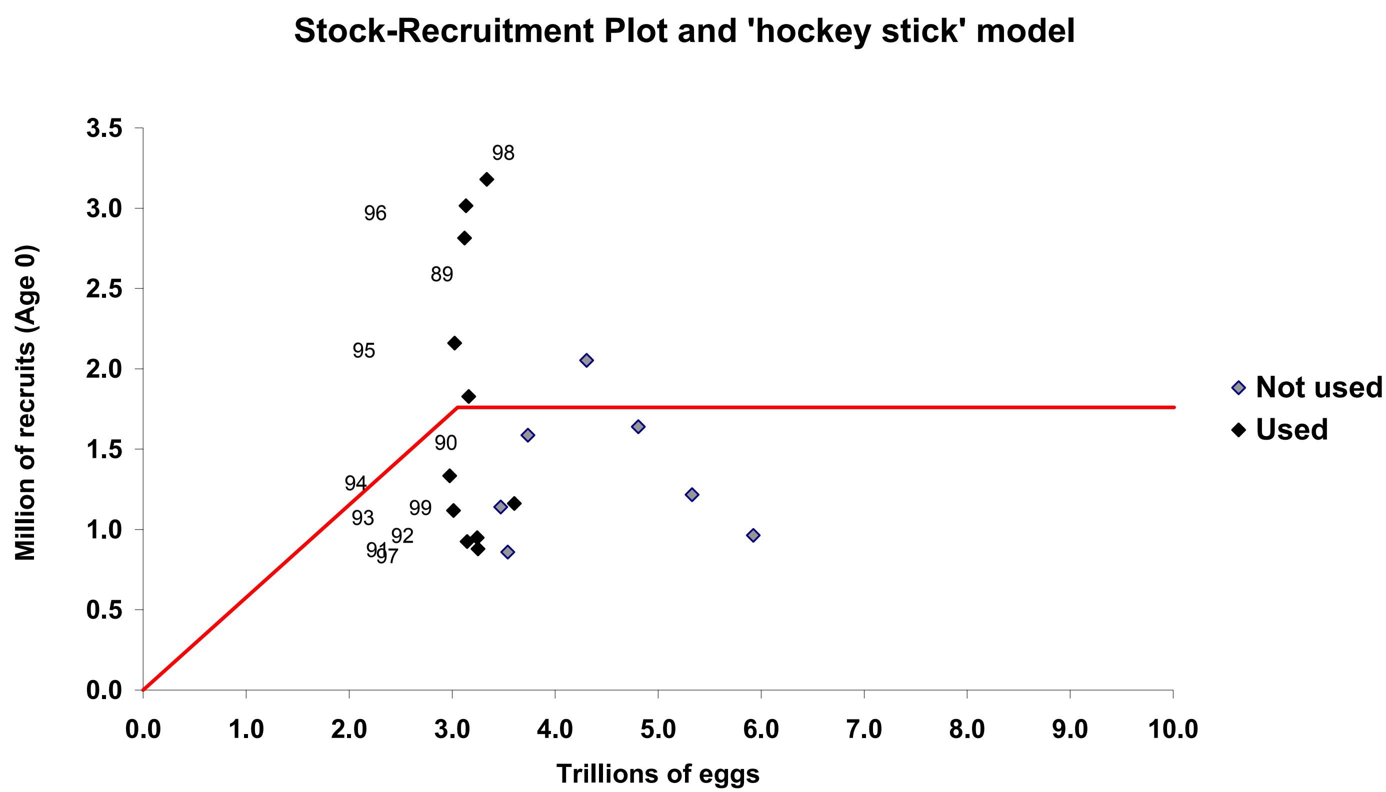


Figure 5: Atlantic group static SPR projections over time.


Stock-Recruitment Plot and 'hockey stick' model
Million of recruits (Age 0)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Trillions of eggs
98
96
89
95
90
94
93
99
92
97
Not used
Used

SEDAR

SouthEast Data, Assessment, and Review

Gulf of Mexico King Mackerel Advisory Report

SEDAR 5: Atlantic and Gulf of Mexico
King Mackerel

SEDAR Document: SEDAR5-AR5 April 2004

Gulf of Mexico 2004 Gulf King Mackerel Advisory Report

State of Stock: The Gulf of Mexico king mackerel stock was not overfished and overfishing was not occurring in 2002/03. There was an 18% probability that B_{2003} was less than MSST and a 17% probability that $F_{2002/03}$ was greater than MFMT. During the time series of the data (1981/82-2002/03), estimated fishing mortality was low during the mid 1980s, high in the early to mid 1990s, and since 1995 almost constant around 0.15. Estimated stock biomass rapidly increased from the mid 1980s through the early 1990s, and has gradually risen since. However, the stock biomass is probably still lower than in the 1970s. The general trend in recruitment was increasing from the early 1980s through the early 1990s, followed by a decline in the mid-1990s. In recent years, recruitment has been level and fluctuated without any clear trend.

Stock Identification and Distribution: King mackerel in the southeast United States are managed under the Fishery Management Plan for Coastal Migratory Pelagic Resources (FMP CMPR). Under the FMP CMPR, all king mackerel occurring in the US Gulf of Mexico and south Atlantic are specified as a single stock but are managed as two independent migratory groups: the Gulf and Atlantic migratory groups, respectively. The Atlantic migratory group management area extends from New York to Florida and the Gulf migratory group management area extends from Florida to Texas. Management areas are separated along the east coast of Florida by a boundary that moves seasonally, specified as the Volusia/Flagler County border on the east coast in winter (November 1 - March 31) and the Monroe/Collier County border on the Southwest coast in summer (April 1 - October 31). Fish landed off the southeast coast of Florida during winter (Nov. 1 - Mar. 31) count against the Gulf migratory group's total allowable catch (TAC); however, winter mixing zone fishery regulations are set by the South Atlantic Fishery Management Council.

Data and Assessment: The status of the Gulf king mackerel migratory group was assessed using the Virtual Population Analysis (VPA) approach, historically employed. Data inputs included commercial and recreational landings estimates through the 2002/03 fishing year (FY), one fishery-independent abundance index, and eight fishery-dependent abundance indices. Model runs included a base model that assumed 100% of winter mixing zone landings was contributed by the Gulf migratory group, as well as several sensitivity analyses. (Note: Sensitivity analyses are described in detail in the accompanying Consensus Summary Report). Stock status evaluations, FY 2005/06, allowable biological catch (ABC) estimates, and estimates of stock Sustainable Fisheries Act (SFA) benchmarks were all derived from the base model.

Forecasts: Stock forecasts were based on forward projections from the terminal year (2001/02) of the VPA to estimate ABC ranges in FY 2003/04, 2004/05, and 2005/06 (Table C1). Preliminary catch figures for 2002/03 (3.13 million lbs. commercial catch and 594,343 fish in the recreational fishery) were used in the calculations. In projection years, recruitment was assumed to equal mean recruitment from the stock-recruitment function (Fig. C6); the selectivity-at-age vector was assumed to be the geometric mean of the last five years' selectivities estimated in the base model.

Long-term projections were computed to estimate SFA benchmarks (Table C2).

It is advised that fishing mortality in 2005/2006 should not be higher than F40%SPR corresponding to a catch of not more than 8.4 million lbs. An ABC of 10.7 million lbs. at FSPR30% for 2005/2006 has a 50% chance of exceeding the MSY limit.

Table C1. Forecasts table containing allowable biological catch (ABC;10^6 lbs.) estimated as the median probability (range = 80% pseudo-confidence intervals) that yield will exceed the management threshold ($F_{30\%SPR}$) or achieving the management target ($F_{40\%SPR}$).

	Allowable Biological Catch		
	2003/04	2004/05	2005/06
$F_{30\%SPR}$	10.3 (7.5 – 13.5)	10.8 (7.9 – 14.2)	10.7 (8.1 – 14.0)
$F_{40\%SPR}$	7.4 (5.4 – 9.8)	8.2 (6.0 – 11.0)	8.4 (6.3 – 11.1)

Table C2. Stock status benchmarks and associated 80% pseudo-confidence intervals estimated for Gulf king mackerel. Spawning stock biomass (SS) is given in trillions of eggs; F values are associated with the fully selected ages; and, yields are given in millions of lbs.

	SS_{MSY}	F_{MSY}	MSY	SS_{OY}	F_{OY}	OY
median	6.385	0.269	11.417	8.524	0.190	10.113
low 80% CI	5.556	0.235	9.609	7.436	0.166	8.522
upp 80% CI	7.387	0.366	13.606	9.779	0.255	12.098
deterministic	6.380	0.226	11.286	8.506	0.160	9.974

Table C3. Catch and Status Table: Gulf King Mackerel.

Fishing Year:	1992/ 1993	1993/ 1994	1994/ 1995	1995/ 1996	1996/ 1997	1997/ 1998	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	Mean[1]	Min[1]	Max[1]
Comm Fishery Landings													
Numbers (10^5)	410	267	330	290	369	396	441	331	339	327	321	119	654
Pounds (10^6)	3.60	2.57	2.90	2.65	2.86	3.42	3.89	2.95	3.08	2.93	3.05	0.87	5.65
Rec Landings													
Numbers (10^5)	632	685	792	634	663	714	561	471	585	570	583	184	792
Pounds (10^6)	6.26	6.15	7.95	6.27	6.93	6.63	5.24	4.07	5.06	5.16	4.78	1.83	7.95
TOTAL Landings													
Numbers (10^5)	1,042	952	1,122	925	1,032	1,110	1,003	802	924	897	862	1,271	422
Pounds (10^6)	9.86	8.72	10.85	8.91	9.80	10.05	9.13	7.02	8.14	8.10	7.67	3.01	12.33
Stock Parameters													
Recruits[2] (10^6)	2.72	5.27	4.70	4.35	3.23	3.75	3.01	4.88	2.08	4.64	3.52	1.47	5.58
Stock Size[3] (10^6)	11.42	13.15	13.68	14.36	13.18	13.13	12.22	13.69	12.36	13.63	11.52	7.69	14.36
Stock Biomass[4]	69.30	69.79	71.40	71.59	74.55	76.32	75.15	75.83	77.62	79.44	64.18	47.44	79.44
Spawning Biomass[5]	4.83	4.88	5.10	4.92	5.17	5.43	5.54	5.47	5.74	5.94	4.58	3.51	5.94
Overall F[6]	0.179	0.147	0.215	0.141	0.134	0.162	0.167	0.122	0.157	0.158	0.154	0.084	0.310

1. Mean, Minimum, and Maximum statistics based on entire 1981/82-2001/02 fishing year time series.
2. Estimated abundance of age 0 individuals.
3. Estimated numbers of individuals, ages 0-11
4. Millions of pounds, ages 0-11.
5. Trillions of eggs.
6. Arithmetic mean of F at age across ages 0-11.

Catches: Gulf king mackerel landings have been dominated by the recreational fishery throughout the time series (Table C3; Fig. C1). Annual recreational landings have averaged 4.78 million lbs. and annual commercial landings have averaged 3.05 million lbs. General landings trends are similar across the time series for each sector. Highest catches were observed in the early 1980s followed by declining catches through the late 1980s. Landings increased from the late 1980s through the 1990s and have been decreasing slightly in the past few years.

Fishing Mortality: Trends in F estimates for Gulf king mackerel show a similar pattern to that observed in landings (Table C3; Fig. C2). The peak in F occurred in the early 1980s but then declined through the late 1980s. Fishing mortality increased from the late 1980s through the mid 1990s. Since the mid 1990s, the trend in F has been relatively flat, centering around 0.15.

Recruitment: Estimated recruitment of age-0 Gulf king mackerel was increasing from the early 1980s through the early 1990s, followed by a decline in the mid 1990s and variable without a trend since then (Table C3; Fig. C4). Recruitment has ranged from a high of 5.57 million fish in 1989 to a low of 1.47 million fish in 1983.

Stock Biomass: Gulf king mackerel stock biomass estimates have averaged 64.18 million lbs. since 1981/82 (Table C3; Fig. C5). Biomass was lowest in the early 1980s and has increased steadily since the mid 1980s. Biomass estimates for the most recent years are the highest in the time series, but probably lower than further back in time.

Stock Status Criteria: The GMFMC has adopted (1-M)*BMSY as the MSST and FMSY as the MFMT for Gulf king mackerel, and has adopted 50% as an acceptable risk level for exceeding MSST or MFMT. F30%SPR (=0.27) has been specified as a proxy for FMSY, and 30%SPR (=6.385 trillion eggs) as a proxy for BMSY. The MSST for Gulf king mackerel = 5.108 trillion eggs (M = 0.20). The GMFMC has adopted a target F=F40%SPR (=0.19), where 40%SPR = 8.524 trillion eggs.

Special Comments: The sensitivity runs that considered alternative stock compositions in the mixing zone showed that the status of the Gulf stock was sensitive to the assumed mixing rates, both in terms of associated stock biomass and F values, and in terms of status of the stock and of the fishery in relation to overfishing. Some runs indicated that the stock was actually overfished in 2002/2003 and that overfishing took place in that fishing year. Other sensitivity runs that considered growth indicated that the stock might be well within safe biological limits.

Sources of Information:

SEDAR5. 2004. Stock Assessment Report for South Atlantic and Gulf of Mexico King Mackerel. 109 p.; Oritz, M. 2004. Stock Assessment Analysis on Gulf of Mexico King Mackerel. Sustainable Fisheries Division Contribution SFD-2004-004. Miami, FL. 43 p.

Figure C1. Recreational and commercial landings of Gulf king mackerel through the 2001/02 fishing year by A. weight and B. numbers of fish.

A.

B.

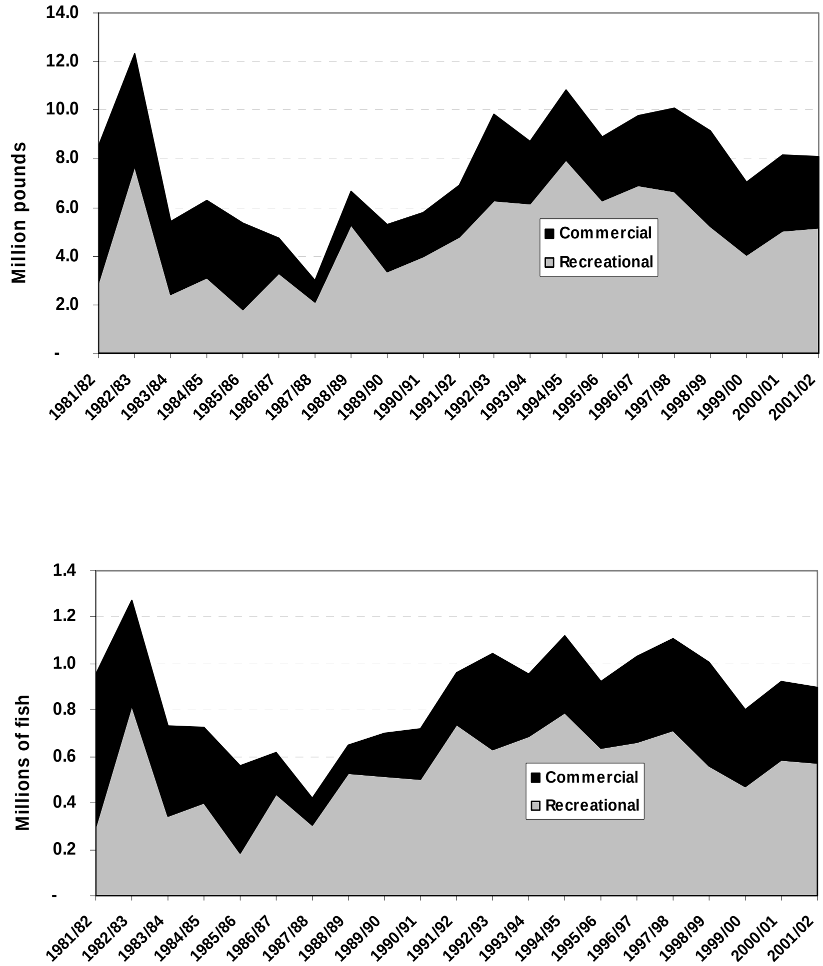


Figure C2. Estimated Gulf king mackerel annual fishing mortality rates.

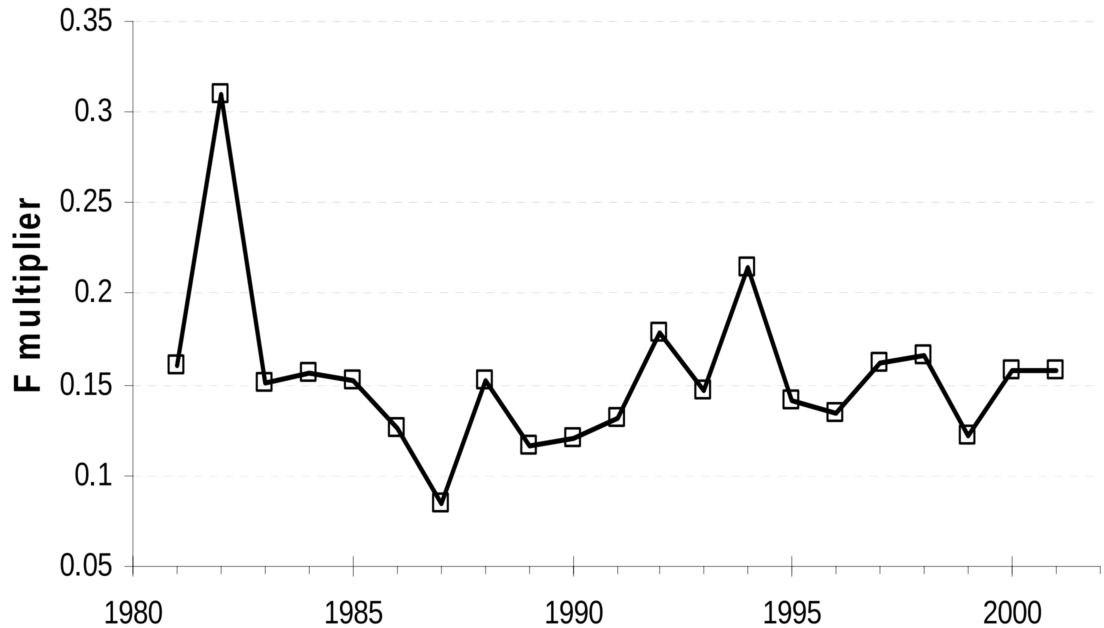


Figure C3. Estimated recruitment of age-0 Gulf king mackerel. Gray lines represent the 80% pseudo-confidence interval about the median recruitment estimates.

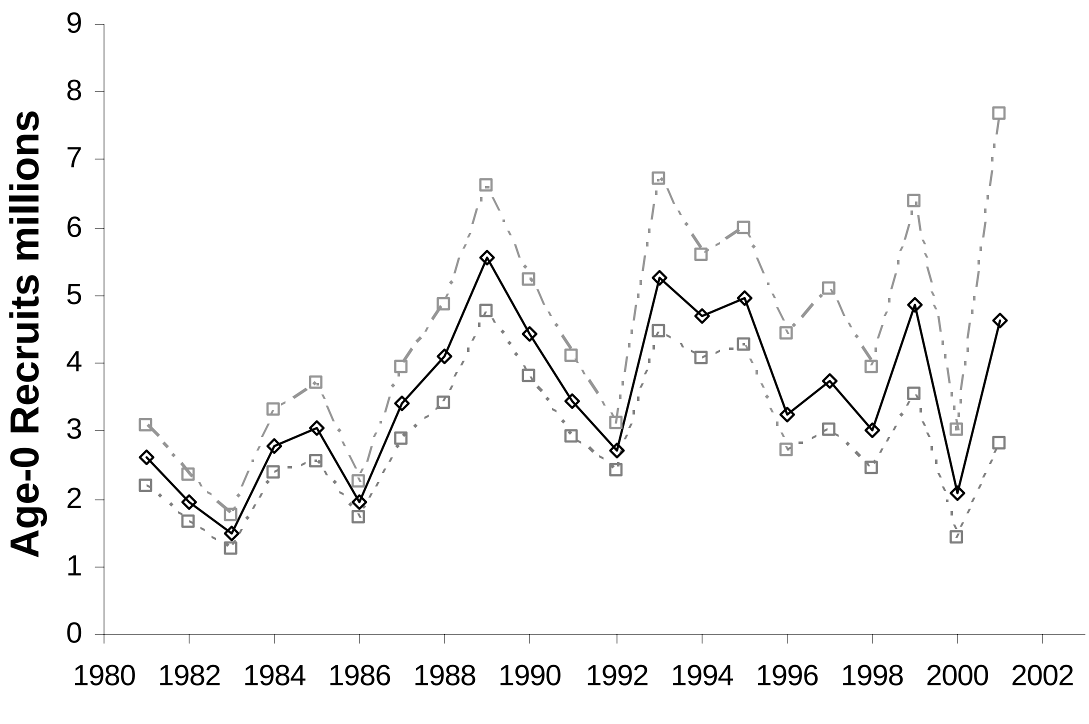


Figure C4. Estimated Gulf king mackerel stock biomass from 1981 through 2001. Gray lines represent the 80% pseudo-confidence interval about the median biomass estimates.

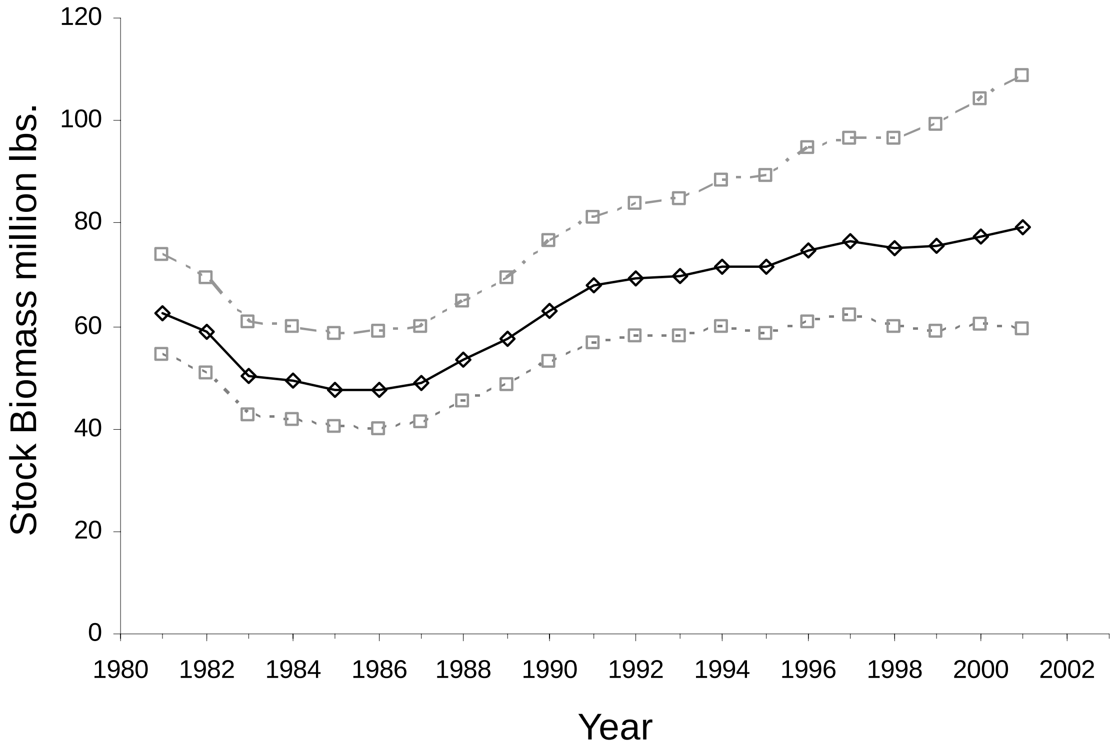


Figure C5. Indices of abundance used to tune the Gulf king mackerel VPA. Diamonds indicate standardized index values and fitted lines indicate predicted values from the base model VPA.

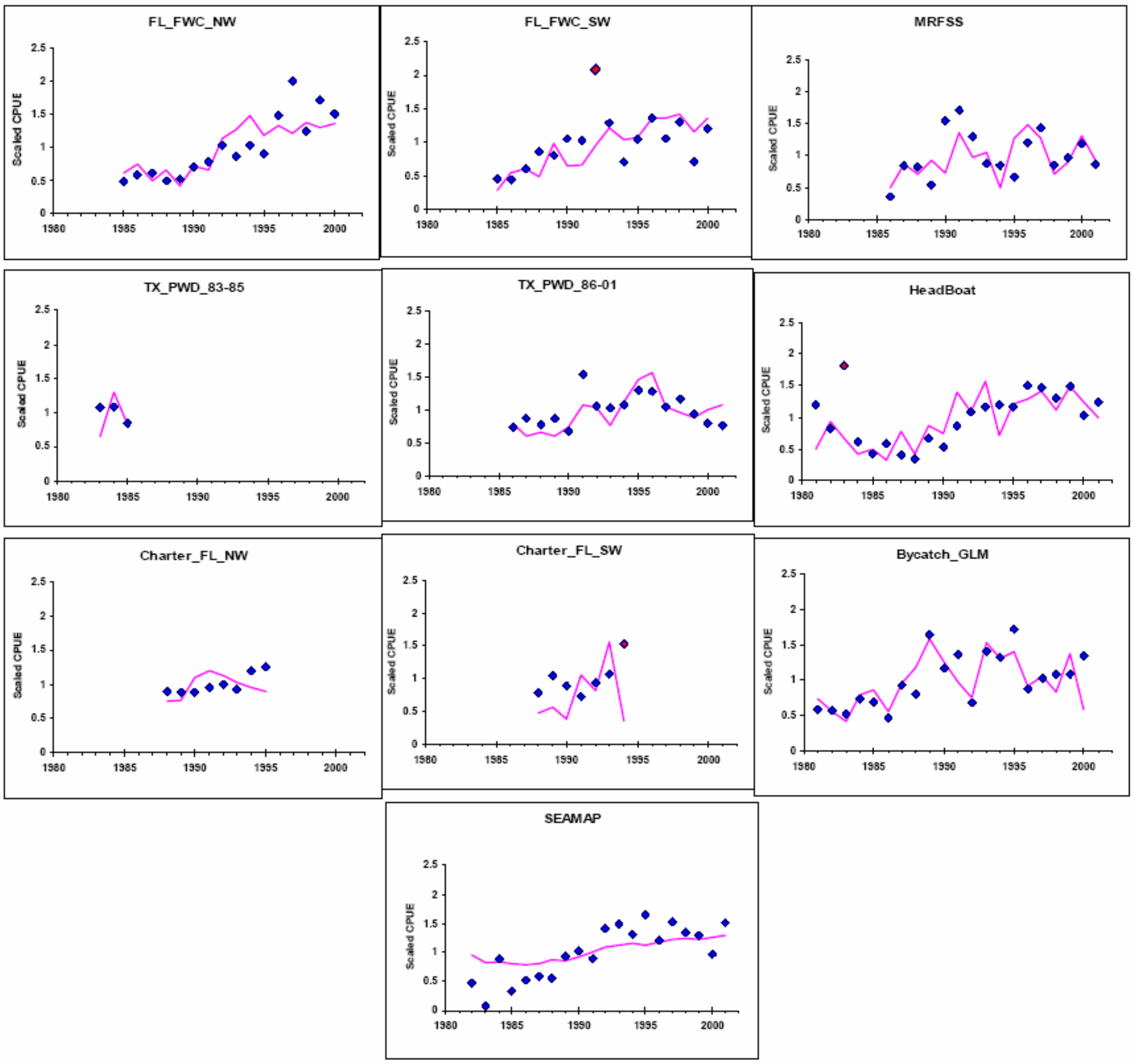


Figure C6. Stock recruitment relationship estimated for Gulf king mackerel.

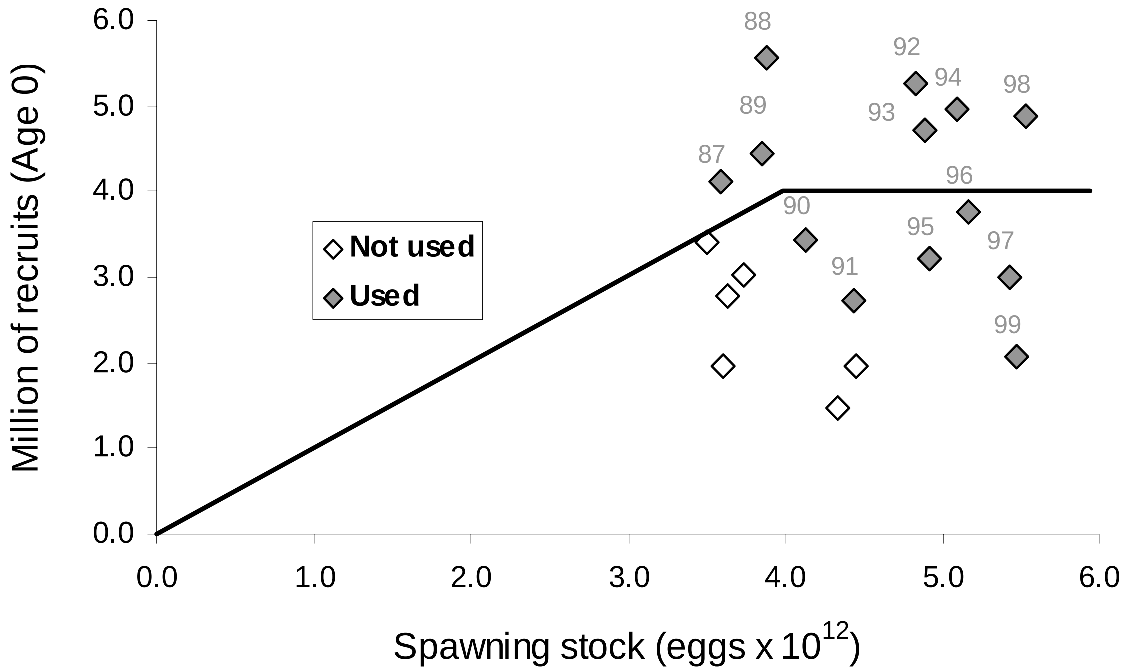
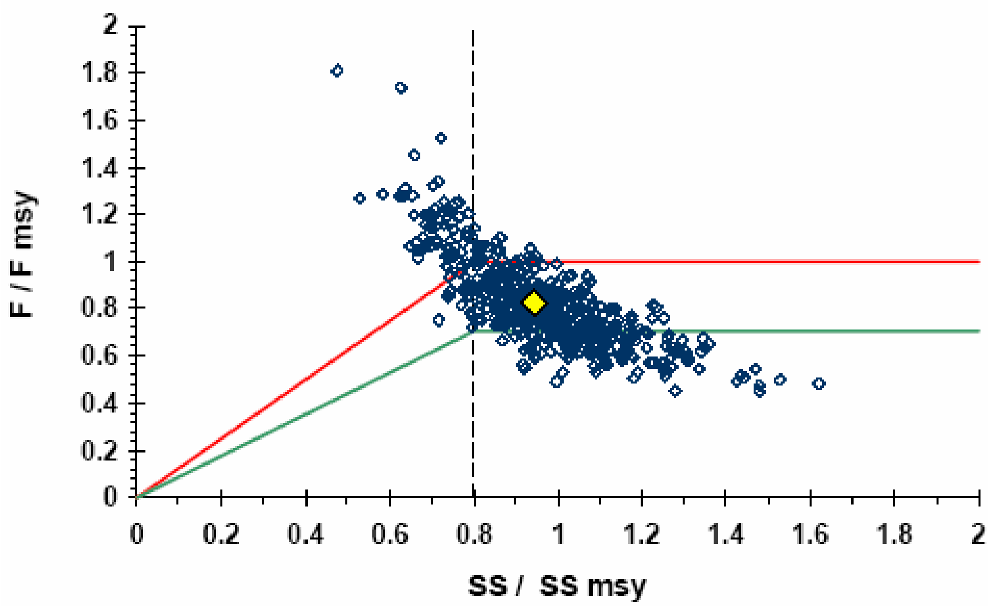


Figure C7. Gulf king mackerel phase plot used to estimate stock status relative to MSST and MFMT. Unfilled diamonds represent results from individual bootstraps of the base model. The filled diamond represents the deterministic model run result.



SECTION VII.

Reports of the CIE Chair and Reviewer

(Exclusive of appended materials duplicating previous report sections)

April 28, 2004

CIE Chair report

SEDAR5 Review Workshop, King Mackerel Atlantic and Gulf of Mexico Migratory Units, Miami, Florida 5-8 April 2004

To:
University of Miami Independent System for Peer Review.

Henrik Sparholt, Dr.Sc.

1. Synopsis/summary of the meeting

Overall, the meeting was well arranged, the participants were dedicated, and the support from SEFSC and the SEDAR Secretariat was effective. The Panel was pleased with the effective support from the NMFS SEFSC scientists, and impressed by the open-minded attitude and willingness to support the Panel with additional information and analysis. Also, the computer and network support was excellent. The small local network established by the SEFSC staff proved very effective for the exchange of data files and sharing of information among the Review Panel members.

Day 1 was spent listening to presentations and taking the first round of discussions of the stock assessment of each of the two stocks and of the mixing issue between the two stocks in the mixing zone southeast to southwest of Florida. The presentations were done by SEFSC staff.

Day 2 was spent with detailed review of the assessments and the mixing issue, and during the evening appointed members of the Panel drafted text for the Consensus Report.

This text was discussed on the morning of Day 3. The main issue discussed was the mixing and whether the Panels agreed that the current assumption about mixing used in the assessment was the best possible. An alternative was suggested. There was an extended discussion about whether this should mean that the alternative mixing assumption should be used in the baseline assessment, and the general opinion was that it was premature, because several other aspects of the assessment (growth, fecundity, FADAPT model vs. more statistically robust methods for stocks where F is not much larger than M as in this case, mixing outside the mixing time, and uncertainties about the actual mixing values), were also in need for revision. Sensitivity analysis showed that these revisions gave quite different results from an assessment with the new mixing rates. It was, therefore, regarded as prudent to wait with changing the baseline assessment method until these other issues were also included. However, two Panel members disagreed and made a minority statement that the new mixing rates should be used already this year.

In the afternoon of Day 3, the advisory reports were discussed and in the evening the first drafts were produced by appointed Panel members.

On the last morning (of Day 4), all three reports were discussed in plenary and appointed Panel members agreed to work further on the reports after the end of the meeting.

The reports were finalised via e-mail correspondence within three weeks after the end of the meeting.

2. Views on the meeting process, including recommendations for improvements

The amount of reports and other material to read before the meeting was extensive. There was only little time to do this, about two weeks. It would be useful if some of the material were sent out as early as possible. It should be possible to send out previous assessment reports, background articles, and the Data Workshop report, several weeks earlier.

A complete description of the assessment with all the input data files and the precise settings of the model would be nice to have in one document. It was a bit difficult to find precisely in which document to look for the various details. The level of details and data files should allow for an exact and easy repeat of the calculations.

Fishers (and nongovernmental organizations (NGOs)) contributed during the meeting some information on CPUE series, the fishery and the management regulations effects on this, and the like. It is, however, important that political issues do not enter the discussions. It might, however, be important for the entire process that fishers participate, or at least get the opportunity to observe what is done, in order to secure transparency and trust in the system. However, extra time would need to be spent on explaining things to non-scientists and in balancing the statements put forward so that fishers and NGOs correctly understand the issues.

My task as Chair for the meeting was a bit difficult because most panel members were more familiar with the process than I was. Maybe a bit more information about the duties of the Chair would be useful. Alternatively, another member of the Panel could be the Chair, and one of the CIE Experts could be appointed as the lead expert and perhaps still be responsible for the reporting.

Maybe the reviewers (and other Panel members) could, to the extent possible, state before the start of the meeting what sensitivity runs they want to see in addition to what has been presented in the documents sent to the Panel. This will allow SEFSC staff more time to prepare the runs, and it will make mistakes less likely.

3. Other observations on the meeting process.

The timing of the whole process from the last data sampled in 2001/02 and until now (start of 2004) with the aim of giving advice for 2005/2006 could be improved. It is a very long time span, and there is a large risk for the things in the fishery and the stock to have changed in between meeting processes. It should be possible to shorten this time span so that the advice for 2005/2006 can be based on data from 2003/2004.

Report on the 2004 South East Data, Assessment, and Review (SEDAR 5) Workshop to Review the Assessments of the Status of the Stocks of King Mackerel Atlantic and Gulf of Mexico Migratory Units

By

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Executive Summary

The SEDAR 5 panel review workshop on King mackerel assessments was competently chaired, and conducted in a spirit of cooperation and teamwork. The assessments were conducted by SEFSC stock assessment biologists, and were subject to a very open peer review process that identified the most likely sources of uncertainty. The Review Panel unanimously agreed that the assessments were based on an appropriate age-structured assessment model and the best available data, with exception for a minority disputing the applied mixing rate between the two migratory groups. A majority of panel members agreed that reliable estimates of mixing proportions could not be established from exiting data, and therefore chose the base-run assumption that Gulf king mackerel represent 100% of the population in the mixing zone. This base-run assumption about mixing rates, used in previous assessments, was disputed by a minority of panel members, who argued that existing data supported an even split between Atlantic and Gulf migratory groups in the mixing zone. After a lively and thorough discussion, no consensus was reached on using estimated mixing rates instead of assuming 100% Gulf mackerel in the mixing zone. A minority report that suggested to use an even split in the mixing zone was thus included as an appendix. I side with the majority opinion on this issue and strongly disagree with the views of one scientist presented in Appendix 2. The base model was chosen by the majority after rejecting the reliability of mixing rate estimates, and not based on management considerations outside the scope of this review. I agree with the majority of the Panel members that the potential effect of using alternative estimates of mixing rates was appropriately evaluated through sensitivity analysis. The Assessment Report states that results of the current Gulf assessment indicate the Gulf king mackerel migratory group is rebuilding, while the Atlantic migratory stock has been rebuilt and remains stable. I support this statement.

Several potential sources of bias and uncertainty in the input data were identified during the review. Uncertainty in the stock assessments results from the extensive dependence

on fisheries-dependent indices of abundance, exaggerated by the limited information about discards. Improved monitoring of the stocks will require fisheries-independent survey indices of abundance and adequate data on discards from all fishery segments.

1. Background

The South East Data, Assessment, and Review (SEDAR) process is part of the NMFS-Southeast Fisheries Science Center’s program for quality control and assurance of stock assessments in the South East region. The SEDAR process is conducted by the South Atlantic Fisheries Management Council (SAFMC) in close coordination with NMFS and the Interstate Commissions to ensure the scientific quality and credibility of stock assessments, and to assure that they continue to support effective fishery management. The SEDAR process comprises a Data Workshop, an Assessment Workshop, and a Stock Assessment Review Workshop conducted in sequence. This is a report on the SEDAR 5 Stock Assessment Review Workshop for King mackerel, held in Miami, FL at the NMFS Southeast Fisheries Science Center (SEFSC) from April 5 to 8, 2004. This report presents my evaluation of the review process, and briefly summarizes the findings and recommendations, with focus on my experience as a reviewer on the panel. This report should be read in conjunction with the two reports prepared by the review panel.

2. Description of review activities

Data and Assessment Workshop reports for the two migratory stocks under consideration, South Atlantic and Gulf King Mackerel, were made available for review before the meeting. I received the voluminous documentation only 5 days before the start of the meeting, and thus only had limited time to review the material beforehand. Apparently, the other panel members received the documentation 2 weeks prior to the meeting.

The SEDAR 5 Stock Assessment Review Workshop for King mackerel was chaired by Dr. Henrik Sparholt (CIE) and coordinated by John Carmichael in an organized and effective manner. The workshop was conducted in a spirit of cooperation and teamwork. During the review meeting, each stock assessment was presented by the responsible assessment expert, and reviewed by the panel. The 11-member review panel represented a broad area of expertise in fisheries, and included participants from the:

- NMFS-Southeast Fisheries Science Center, Galveston, TX
- NMFS-Northeast Fisheries Science Center, Woods Hole, MA
- South Atlantic and Gulf Fisheries Management Councils
- NC Department of Marine Fisheries
- Gulf and South Atlantic fishermen associations
- Center for Independent Experts (chair and reviewer)

Review activities during the workshop involved panel discussions on assessment validity and results, and the development of consensus recommendations and conclusions following the presentation of assessments for each migratory group. Dr. Gerry Scott and his staff of stock assessment scientists from SEFSC did an outstanding job presenting the assessment results, and provided expert knowledge whenever asked. Dr. Liz Brooks from the SEFSC did an excellent job documenting the consensus review comments for inclusion in the reports authored by the panel. The SEFSC assessment scientists and supporting staff were very helpful throughout the review meeting by answering questions related to the panel's interpretation of the available data and results. The effectiveness of the review process was substantially enhanced by the contributions from the Assessment Workshop/Review Panel Support Staff and from the South Atlantic Fisheries Management Council Staff and sub-committee members. In most cases, this diverse group of fisheries experts could clarify issues related to assessment models and the available input-data.

The review panel focused on the evaluation of the adequacy and appropriateness of:

- Fishery-dependent and independent data used in the assessment (i.e. was the best available data used in the assessment);

- Application of models used to assess these species and to estimate population benchmarks (MSY, Fmsy, Bmsy and MSST, i.e. Sustainable Fisheries Act items);

- Models used for rebuilding analyses.

The review panel reviewed the assessments in detail, and had thorough discussions on how to best deal with overlapping distributions of Atlantic and Gulf king mackerel in the respective assessments (“the mixing issue”).

During the week following the review meeting, the entire panel took part in the development of the two summary reports by providing input, and by reviewing comments from fellow panel members. The consensus report covers the terms of reference in detail, and includes all research recommendations that I considered to be of highest priority.

3. Summary of findings

3.1. Input Data

Data evaluated as inputs to the assessments included

- Stock distributions and overlap
    - Historic tagging studies,
    - Recent studies of otolith shape and microchemistry,
    - DNA-microsatellite data
- Catch and harvest by size, age, and sex
    - Trip tickets,
    - Log-book programs,
    - Marine recreational Fishery Statistics Survey (MRFSS),
    - NMFS Headboat survey,
    - Texas Parks and Wildlife Coastal Creel survey
- Discard in directed commercial fishery
    - Self-reporting log-book program
- Life history parameters (growth parameters, fecundity at age)
    - Historic and updated growth curves,
    - Age-length and egg-length from the literature
- Abundance indices
    - Recreational and commercial CPUE,
    - Fisheries-independent surveys (SEAMAP)

The panel focused on the accuracy and reliability of the input-data, and sought information about the availability of additional data that potentially could be used to enhance the stock assessments. I consider the input data applied, including stock-recruitment relationships and the abundance indices used for tuning, to be adequate and appropriate for the stock assessments. Nevertheless, it is of concern that the abundance indices and estimates of population characteristics rely heavily on fisheries-dependent data. It is well known that CPUE from commercial and recreational fisheries often fail to track the true status of the stock for wide variety of fisheries (e.g., Gunderson 1994, and numerous references therein). The VPA method is particularly sensitive to inaccurate information on catches at age, for example related to limited sampling coverage (spatially and temporally) of landings, and unreported discards. Ulltang (1996) shows discrepancy between VPA and fisheries-independent abundance indices from trawl and acoustic surveys.

A majority of panel members agreed that reliable estimates of mixing proportions could not be established from exiting data, and therefore voted to apply the current base assumption that Gulf king mackerel represent 100% of the population in the mixing zone. This assumption about mixing rates, used in previous assessments, was disputed by a minority of panel members, who argued that existing data supported an even split between Atlantic and Gulf migratory groups in the mixing zone. After a lively and thorough discussion, no consensus was reached on using estimated mixing rates instead of assuming 100% Gulf mackerel in the mixing zone.

3.2. Assessment and Projection Models

The Review Panel unanimously agreed that the FADAPT VPA method employed was appropriate given the available data, although it was suggested that alternative methods such as Integrated Catch at Age (ICA, Patterson and Melvin, 1996) be considered in future assessments because it might be more stable in the case of King mackerel where F is not much larger than M. The panel agreed with the base assessments and projection, with exception for a minority disputing the applied mixing rate between the two migratory groups. The panel documented its review findings in a Peer Review Panel Consensus Report that includes detailed comments on the individual species assessments and the Panel's findings on the status of the stock and the fishery. The panel also co-authored a Summary Stock Status Report in support of the Fisheries Management Council. I agree with these findings and recommendations, which incorporated all my input.

4. Conclusions and recommendations

In my opinion, this fifth SEDAR review process clearly supports the Council's objective to continually improve the quality of stock assessments and their relevance to support sound fishery management. The review process was open, and the assessment scientists from SEFSC did a great job presenting the assessments to the panel. The panel members had broad and complimentary expertise that covered all the review subjects. The panel greatly benefited from the input from the meeting support staff and other attendees, throughout the review process.

The review process worked well overall. The workshop meeting was competently chaired, and conducted in a spirit of cooperation and teamwork. The follow-up editing process via e-mail was suitable for dealing with minor technical editorial comments, but a conference call among all panel members might have been more appropriate for dealing with one dispute regarding the incorporation of mixing rate estimates in the assessment. I believe the SEDAR 5 was a very open peer review process that fairly evaluated the stock assessments based on scientific criteria. In contrast to the opinion provided by one panel member (Appendix 2 in the consensus report), I do not agree that management considerations unduly influenced the review process. I feel that the stock assessments were based on suitable methods and the best available data, and that the most likely sources of uncertainty were identified. I support the conclusions and recommendations that are detailed in the SEDAR 5 workshop review panel consensus and advisory reports, and side with the majority decision to adopt the assumption on mixing rates.

I strongly agree with the research recommendations provided in the consensus report. It is important that estimates of age-composition of commercial and recreational discards, and of discard mortality be obtained. It is strongly recommended that fisheries-independent surveys be expanded, and eventually assigned more weight in the tuning process. Fisheries-independent surveys should be designed to provide indices of abundance for the full age range in the stock. This would likely require multi-seasonal sampling and the combined use of multiple sampling gears and hydro-acoustics.

Improved estimates of mixing rates between the two migratory stocks should be obtained through carefully designed tagging programs. It is also recommended that the promising otolith shape and microchemistry analysis further pursued, and that mixing rates in the mixing zone be estimated for the summer and winter periods. Data from Mexican catches need to be obtained to improve the accuracy of Gulf king mackerel assessments.

If feasible, I recommend that the uncertainty in assessments caused by sampling variability in estimated landings in number by age be further evaluated. Sensitivity runs for current assessments indicate that the variability in catch-at-age may not be fully accounted for. I recommend that bootstrapping be applied to age-length keys from to port sampling data in connection with the model runs, with trips being the primary sampling unit for resampling. Results in Vølstad et al. (1997) indicate that the effective sample size for estimating proportions at age in landings can be substantially lower than the number of fish sampled for age, and is better approximated by the number of hauls (or trips) sampled. The latter approximation is used in the assessments of Alaska Pollock.

The use of multiple survey indices for "tuning" can introduce a bias of unknown magnitude in the assessments of Atlantic and Gulf king mackerel. In current assessments, the multiple abundance indices are assigned equal weights, regardless of their coverage with respect to size and distribution of king mackerel, or the precision of each series. One way to reduce such bias is to combine overlapping survey estimates by using a composite estimator with weights determined by coverage and precision of each abundance series, and then apply the combined series in tuning the model. Additional post-stratification might be appropriate when surveys overlap only in a sub-area or during a limited time. Examples of the combination of multiple indices are presented in Korn and Graubard (1999) and Rao (2003). The external analysis of multiple survey indices of abundance might provide a better understanding of the input data, make the weighting more transparent, and result in a more parsimonious stock assessment model.

References

Gunderson, D.R. 1994. Surveys of Fisheries Resources, John Wiley & Sons.

Korn, E.L. and B.I. Graubard. 1999. Analysis of Health Surveys. John Wiley & Sons.

Rao, J.N.K. 2003. Small Area Estimation. John Wiley & Sons.

Ulltang, Ø 1996. Stock assessment and biological knowledge: can prediction uncertainty be reduced? ICES Journal of Marine Science 53: 659-675.

Vølstad, J.H, W.R. Richkus, S. Gaurin, and R. Easton. 1997. Analytical and Statistical Review of Procedures for Collection and Analysis of Commercial Data Used for Management and Assessment of Groundfish Stocks in the U.S. Exclusive Economic Zone Off Alaska. Prepared for the U.S. Department of Commerce, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, Washington. 172 pp.