SEDAR

Southeast Data, Assessment, and Review

SEDAR 41

South Atlantic Red Snapper

SECTION V: Review Workshop Report

April 2016

SEDAR
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1. Introduction

1.1 Workshop Time and Place

The SEDAR 41 Review Workshop for South Atlantic Red Snapper (*Lutjanus campechanus*) was held March 15-18, 2016 in North Charleston, SC. Review Panel members were presented all information generated throughout the Data (DW) and Assessment (AW) Workshops and webinars, and the Review Workshop (RW) Panel then developed a consensus review and analysis of the stock assessment model and inputs according to a number of SEDAR Terms of Reference.

1.2 Terms of Reference

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
    a) Are data decisions made by the DW and AW sound and robust?
    b) Are data uncertainties acknowledged, reported, and within the normal or expected levels?
    c) Are data properly applied within the assessment model?
    d) Are data input series reliable and sufficient to support the assessment approach and findings?

2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and consider the following:
    a) Are methods scientifically sound and robust?
    b) Are assessment models configured properly and used consistent with standard practices?
    c) Are the methods appropriate for the available data?

3. Evaluate the assessment findings and consider the following:
    a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?
    b) Is the stock overfished? What information helps you to reach this conclusion?
    c) Is the stock undergoing overfishing? What information helps you reach this conclusion?
    d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?
    e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

4. Evaluate the stock projections, including discussing the strengths and weaknesses, and consider the following:
    a) Are the methods consistent with accepted practices and available data?
    b) Are the methods appropriate for the assessment model and outputs?
    c) Are the results informative and robust, and are they useful to support inferences of probably future conditions?
    d) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
    a) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
    b) Ensure that the implications of uncertainty in technical conclusions are clearly stated.

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
    b) Provide recommendations on possible ways to improve the SEDAR process.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

8. Compare and contrast assessment uncertainties between the Gulf of Mexico and South Atlantic stocks.

9. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Peer Review Summary Report in accordance with the project guidelines.

1.3 List of Participants

REVIEW WORKSHOP PANELISTS

Luiz Barbieri	Review Panel Chair	SAFMC SSC
Mike Armstrong	Reviewer	CIE
Jon Helge Vølstad	Reviewer	CIE
Stephen Smith	Reviewer	CIE
Steve Cadrin	Reviewer	SAFMC SSC
Churchill Grimes	Reviewer	SAFMC SSC

ANALYTICAL REPRESENTATIVES

Kevin Craig	Lead Analyst, GTF	SEFSC Beaufort
Kate Siegfried	Lead Analyst, RS	SEFSC Beaufort
Kyle Shertzer	Assessment Team	SEFSC Beaufort
Erik Williams	Assessment Team	SEFSC Beaufort
Rob Cheshire*	Assessment Team	SEFSC Beaufort
Eric Fitzpatrick*	Assessment Team	SEFSC Beaufort

APPOINTED OBSERVERS

Rusty Hudson	Recreational/Commercial	FL / SFA
Robert Johnson	For-Hire	FL

APPOINTED COUNCIL REPRESENTATIVES

Zack Bowen	Council Member	SAFMC
Mark Brown	Council Member	SAFMC
Chris Conklin	Council Member	SAFMC

COUNCIL AND AGENCY STAFF

Julia Byrd	Coordinator	SEDAR
Julie O'Dell	Admin	SEDAR / SAFMC
Chip Collier	Fishery Biologist	SAMFC
Mike Errigo	Fishery Biologist	SAFMC
Nick Farmer	Fishery Biologist	SERO

WORKSHOP ATTENDEES

Joey Ballenger, SCDNR
Peter Barile, SFA
Myra Brouwer, SAFMC
John Carmichael, SAFMC
Brian Cheuvront, SAFMC
Lora Clarke, PEW

Amy Dukes, SCDNR
Jimmy Hull, FL fisherman
Julie Neer, SAFMC
Adam Nelson, FL fisherman
David Nelson, FL fisherman
Michael Nelson, FL fisherman
Paul Nelson, FL fisherman
Marcel Reichert, SCDNR
Tracey Smart, SCDNR

*Appointees marked with a * were appointed to the workshop panel but did not attend the workshop.

1.4 Document List

SEDAR 41 review workshop working papers and reference documents.

Document #	Title	Authors
Documents Prepared for the Review Workshop		
SEDAR41-RW01	Addendum to SEDAR41-DW16: Report on Life History of South Atlantic Gray Triggerfish, *Balistes capriscus*, from Fishery-Independent Sources: UPDATE on analyses of maturity, spawning fraction, and sex ratio	Kolmos et al. 2016
SEDAR41-RW02	Age structured production model (ASPM) for U.S. South Atlantic Red Snapper (*Lutjanus campechanus*)	SFB-NMFS 2016
SEDAR41-RW03	Age structured production model (ASPM) for U.S. South Atlantic Gray Triggerfish (*Balistes capriscus*)	SFB-NMFS 2016
SEDAR41-RW04	Red Snapper: Additional BAM diagnostics, analyses, and code	SFB-NMFS 2016
SEDAR41-RW05	Model Diagnostics and Source Code for SEDAR 41 Gray Triggerfish (*Balistes capriscus*) Benchmark Stock Assessment	SFB-NMFS 2016
Reference Documents		
SEDAR41-RD01	List of documents and working papers for SEDAR 32 (South Atlantic Blueline Tilefish and Gray Triggerfish) – all documents available on the SEDAR website.	SEDAR 32
SEDAR41-RD02	List of documents and working papers for SEDAR 9 (Gulf of Mexico Gray Triggerfish, Greater Amberjack, and Vermilion Snapper) – all documents available on the SEDAR website.	SEDAR 9
SEDAR41-RD03	2011 Gulf of Mexico Gray Triggerfish Update Assessment	SEDAR 2011
SEDAR41-RD04	List of documents and working papers for SEDAR 24 (South Atlantic Red Snapper) – all documents available on the SEDAR website.	SEDAR 24
SEDAR41-RD05	List of documents and working papers for SEDAR 31 (Gulf of Mexico Red Snapper) – all documents available on the SEDAR website.	SEDAR 31

SEDAR41-RD06	List of documents and working papers for SEDAR 15 (South Atlantic Red Snapper and greater amberjack) – all documents available on the SEDAR website.	SEDAR 15
SEDAR41-RD07	2009 Gulf of Mexico Red Snapper update assessment	SEDAR 2009
SEDAR41-RD08	List of documents and working papers for SEDAR 7 (Gulf of Mexico Red Snapper) – all documents available on the SEDAR website.	SEDAR 7
SEDAR41-RD09	SEDAR 24 South Atlantic Red Snapper: management quantities and projections requested by the SSC and SERO	NMFS - Sustainable Fisheries Branch 2010
SEDAR41-RD10	Total removals of Red Snapper (*Lutjanus campechanus*) in 2012 from the US South Atlantic	NMFS - Sustainable Fisheries Branch 2013
SEDAR41-RD11	Amendment 17A to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2010
SEDAR41-RD12	Amendment 28 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 2013
SEDAR41-RD13	Total removals of Red Snapper (*Lutjanus campechanus*) in 2013 from the U.S. South Atlantic	NMFS - Sustainable Fisheries Branch 2014
SEDAR41-RD14	South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida for the 2012 season	Sauls et al. 2013
SEDAR41-RD15	South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida for the 2013 season	Sauls et al. 2014
SEDAR41-RD16	A directed study of the recreational Red Snapper fisheries in the Gulf of Mexico along the West Florida shelf	Sauls et al. 2014
SEDAR41-RD17	Using generalized linear models to estimate selectivity from short-term recoveries of tagged red drum *Sciaenops ocellatus*: Effects of gear, fate, and regulation period	Bacheler et al. 2009
SEDAR41-RD18	Direct estimates of gear selectivity from multiple tagging experiments	Myers and Hoenig 1997

SEDAR41-RD19	Examining the utility of alternative video monitoring metrics for indexing reef fish abundance	Schobernd et al. 2014
SEDAR41-RD20	An evaluation and power analysis of fishery independent reef fish sampling in the Gulf of Mexico and U.S. South Atlantic	Conn 2011
SEDAR41-RD21	Consultant's Report: Summary of the MRFSS/MRIP Calibration Workshop	Boreman 2012
SEDAR41-RD22	2013 South Atlantic Red Snapper Annual Catch Limit and Season Length Projections	SERO 2013
SEDAR41-RD23	Southeast Reef Fish Survey Video Index Development Workshop	Bacheler and Carmichael 2014
SEDAR41-RD24	Observer Coverage of the 2010-2011 Gulf of Mexico Reef Fish Fishery	Scott-Denton and Williams
SEDAR41-RD25	Circle Hook Requirements in the Gulf of Mexico: Application in Recreational Fisheries and Effectiveness for Conservation of Reef Fishes	Sauls and Ayala 2012
SEDAR41-RD26	GADNR Marine Sportfish Carcass Recovery Project	Harrell 2013
SEDAR41-RD27	Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2008
SEDAR41-RD28	A Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2010
SEDAR41-RD29	Continuation of Catch Characterization and Discards within the Snapper Grouper Vertical Hook-and-Line Fishery of the South Atlantic United States	Gulf and South Atlantic Fisheries Foundation 2013
SEDAR41-RD30	Amendment 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	SAFMC 1988
SEDAR41-RD31	Final Rule for Amendment 1 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region	Federal Register 1989
SEDAR41-RD32	Population Structure and Genetic Diversity of Red Snapper (Lutjanus campechanus) in the U.S.	Gold and Portnoy 2013

	South Atlantic and Connectivity with Red Snapper in the Gulf of Mexico	
SEDAR41-RD33	Oogenesis and fecundity type of Gulf of Mexico gray triggerfish reflects warm water environmental and parental care	Lang and Fitzhugh 2014
SEDAR41-RD34	Depth-related Distribution of Postjuvenile Red Snapper in Southeastern U.S. Atlantic Ocean Waters: Ontogenetic Patterns and Implications for Management	Mitchell et al. 2014
SEDAR41-RD35	Gray Triggerfish Age Workshop	Potts 2013
SEDAR41-RD36	Age, Growth, and Reproduction of Gray Triggerfish *Balistes capriscus* Off the Southeastern U.S. Atlantic Coast	Kelly 2014
SEDAR41-RD37	Assessment of Genetic Stock Structure of Gray Triggerfish (*Balistes capriscus*) in U.S. Waters of the Gulf of Mexico and South Atlantic Regions	Saillant and Antoni 2014
SEDAR41-RD38	Genetic Variation of Gray Triggerfish in U.S. Waters of the Gulf of Mexico and Western Atlantic Ocean as Inferred from Mitochondrial DNA Sequences	Antoni et al. 2011
SEDAR41-RD39	Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data	Scott-Denton et al. 2012
SEDAR41-RD40	Does hook type influence the catch rate, size, and injury of grouper in a North Carolina commercial fishery	Bacheler and Buckel 2004
SEDAR41-RD41	Fishes associated with North Carolina shelf-edge hardbottoms and initial assessment of a proposed marine protected area	Quattrini and Ross 2006
SEDAR41-RD42	Growth of grey triggerfish, *Balistes capriscus*, based on growth checks of the dorsal spine	Ofori-Danson 1989
SEDAR41-RD43	Age Validation and Growth of Gray Triggerfish, *Balistes capriscus*, In the Northern Gulf of Mexico	Fioramonti 2012
SEDAR41-RD44	A review of the biology and fishery for Gray Triggerfish, *Balistes capriscus*, in the Gulf of Mexico	Harper and McClellan 1997

SEDAR41-RD45	Stock structure of gray triggerfish, *Balistes capriscus*, on multiple spatial scales in the Gulf of Mexico	Ingram 2001
SEDAR41-RD46	Evaluation of the Efficacy of the Current Minimum Size Regulation for Selected Reef Fish Based on Release Mortality and Fish Physiology	Burns and Brown-Peterson 2008
SEDAR41-RD47	Population Structure of Red Snapper from the Gulf of Mexico as Inferred from Analysis of Mitochondrial DNA	Gold et al. 1997
SEDAR41-RD48	Successful Discrimination Using Otolith Microchemistry Among Samples of Red Snapper *Lutjanus campechanus* from Artificial Reefs and Samples of *L.campechanus* Taken from Nearby Oil and Gas Platforms	Nowling et al. 2011
SEDAR41-RD49	Population Structure and Variation in Red Snapper (Lutjanus campechanus) from the Gulf of Mexico and Atlantic Coast of Florida as Determined from Mitochondrial DNA Control Region Sequence	Garber et al. 2003
SEDAR41-RD50	Population assessment of the Red Snapper from the southeastern United States	Manooch et al. 1998
SEDAR41-RD51	Otolith Microchemical Fingerprints of Age-0 Red Snapper, *Lutjanus campechanus*, from the Northern Gulf of Mexico	Patterson et al. 1998
SEDAR41-RD52	Implications of reef fish movement from unreported artificial reef sites in the northern Gulf of Mexico	Addis et al. 2013
SEDAR41-RD53	Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species	Then et al. 2014
SEDAR41-RD54	Length selectivity of commercial fish traps assessed from in situ comparisons with stereo-video: Is there evidence of sampling bias?	Langlois et al. 2015
SEDAR41-RD55	MRIP Calibration Workshop II – Final Report	Carmichael and Van Vorhees (eds.) 2015
SEDAR41-RD56	Total Removals of Red Snapper (*Lutjanus campechanus*) in 2014 from the U.S. South Atlantic	SEFSC 2015
SEDAR41-RD57	Assessing reproductive resilience: an example with South Atlantic Red Snapper *Lutjanus campechanus*	Lowerre-Barbiere et al. 2015

SEDAR41-RD58	Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners	Smart et al. 2014
SEDAR41-RD59	MRIP Transition Plan for the Fishing Effort Survey	Atlantic and Gulf Subgroup of the MRIP Transition Team 2015
SEDAR41-RD60	Technical documentation of the Beaufort Assessment Model (BAM)	Williams and Shertzer 2015
SEDAR41-RD61	Stock Assessment of Red Snapper in the Gulf of Mexico 1872-2013, with Provisional 2014 Landings: SEDAR Update Assessment	Cass-Calay et al. 2015
SEDAR41-RD62	Excerpt from the December 2013 SAFMC SEDAR Committee Minutes (pages 11-21 where SEDAR 41 ToR were discussed)	SAFMC SEDAR Committee
SEDAR41-RD63	Population structure of Red Snapper (*Lutjanus campechanus)* in U.S. waters of the western Atlantic Ocean and the northeastern Gulf of Mexico	Hollenbeck et al. 2015
SEDAR41-RD64	SEDAR31-AW04: The Effect of Hook Type on Red Snapper Catch	Saul and Walter 2013
SEDAR41-RD65	SEDAR31-AW12: Estimation of hook selectivity on Red Snapper (*Lutjanus campechanus*) during a fishery independent survey of natural reefs in the Gulf of Mexico	Pollack et al. 2013
SEDAR41-RD66	Effect of Circle Hook Size on Reef Fish Catch Rates, Species Composition, and Selectivity in the Northern Gulf of Mexico Recreational Fishery	Patterson et al. 2012
SEDAR41-RD67	Effect of trawling on juvenile Red Snapper (*Lutjanus campechanus*) habitat selection and life history parameters	Wells et al. 2008
SEDAR41-RD68	SEDAR24-AW05: Selectivity of Red Snapper in the southeast U.S. Atlantic: dome-shaped or flat topped?	SFB-SEFSC 2010
SEDAR41-RD69	Hierarchical analysis of multiple noisy abundance indices	Conn 2010
SEDAR41-RD70	Data weighting in statistical fisheries stock assessment models	Francis 2011
SEDAR41-RD71	Corrigendum to Francis 2011 paper	Francis

SEDAR41-RD72	Quantifying annual variation in catchability for commercial and research fishing	Francis et al. 2003
SEDAR41-RD73	Evolutionary assembly rules for fish life histories	Charnov et al. 2012
SEDAR41-RD74	User's Guide for ASPIC Suite, version 7: A Stock-Production Model Incorporating Covariates and auxiliary programs	Prager 2015
SEDAR41-RD75	Standing and Special Reef Fish SSC, September 2015 Meeting Summary (see pages 4-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD76	Standing and Special Reef Fish SSC, January 2016 Meeting Summary (see pages 2-7 for SEDAR 43 review)	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD77	SEDAR 43 Gulf of Mexico Gray Triggerfish Stock Assessment Report	SEDAR 43
SEDAR41-RD78	Review of 2014 SEDAR 31 Gulf of Mexico Red Snapper Update Assessment	Gulf of Mexico Standing and Special Reef Fish SSC
SEDAR41-RD79	Influence of soak time and fish accumulation on catches of reef fishes in a multispecies trap survey	Bacheler et al. 2013

2. Review Panel Report

Executive Summary

The Review Workshop (RW) Panel was presented outputs and results of the SEDAR 41 South Atlantic Red Snapper stock assessment. The primary assessment model used was the Beaufort Assessment Model (BAM), a software package that implements a statistical catch-at-age framework. The formulation is an age-structured population model that is fit using standard statistical methods to data available from surveys and fishing fleets, such as landings, discards, indices of abundance, age compositions, and length compositions. The modeling framework is nearly identical to other common assessment packages, such Age Structure Assessment Program (ASAP) and Stock Synthesis (SS), and the programming language (AD Model Builder) is the same across all three. A secondary, surplus-production model (Stock Production Model Incorporating Covariates, ASPIC) provided a comparison of model results. The Review Panel concluded that the data used in the assessment were generally sound and robust. Likewise, data generally were applied properly and uncertainty in data inputs was appropriately acknowledged. Numerous sensitivity analyses and exploration of alternative scenarios were also presented during the RW, all of which agreed with the base model run conclusions of stock status. Note that a follow-up webinar on 8 April 2016 was necessary to continue discussion of projections and finalize the SEDAR 41 RW process. Based on these results the Review Panel concluded that the stock is overfished and overfishing is occurring. The current level of spawning stock biomass (SSB_{2014}) is estimated to be about 22% of MSST (SSB_{2014}/MSST= 0.22), and the current level of fishing mortality is about 2 ½ times $F_{30\%SPR}$ ($F_{2012\text{-}2014}/F_{30\%SPR}$= 2.52). Although the Review Panel concluded that assessment results represent the best available science, there were significant areas of uncertainty identified in both the data and in components to the model. The most significant sources of this uncertainty include: the stock-recruitment relationship, the composition and magnitude of recreational discards, potential changes in CPUE catchability, and the selectivities for the different fishery fleets. The Review Panel recognized that the perception of current selectivity used to derive reference points and projections is conditional on poorly-informed assumptions regarding recent fishing behavior. During the most recent years of the stock assessment series (i.e., the 2010-2014 moratorium), recreational discards are one of the most important and most uncertain sources of information. Also, a strong retrospective pattern in apical F indicates the base BAM model is very sensitive to terminal year of data and suggests higher uncertainty in exploitation status.

2.1 Statements Addressing Each ToR

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
    e) Are data decisions made by the DW and AW sound and robust?

f) Are data uncertainties acknowledged, reported, and within the normal or expected levels?
g) Are data properly applied within the assessment model?
h) Are data input series reliable and sufficient to support the assessment approach and findings?

General comments

Data decisions made by the DW and AW were sound and robust. The Review Panel acknowledges the considerable efforts of the DW and AW to compile the data and evaluate their strengths and weaknesses. The development of input data and parameters for the BAM and ASPIC models required an extremely thorough compilation and evaluation of all available data at the DW. Modifications made subsequently by the AW were fully explained.

Data uncertainties were acknowledged, reported, and were within the normal or expected levels. Where this could be ascertained from information provided to the RW. Data on fishery catches and length/age compositions, and fishery-dependent and independent relative abundance indices, varied widely in coverage and quality. Complex manipulations and standardisation methods were often required to try and develop coherent time series from diverse data sources of differing designs, coverage and accuracy, and the combined data will have biases that in some cases are poorly understood especially in earlier years of the time series. All decisions made by the DW and AW in compiling data were explained and justified in detail. Data quality metrics were provided by the DW in terms of numbers of samples, CVs, or alternative plausible data series or biological parameter values. These were used by the AW to weight data series in the assessment model, estimate the uncertainty in the assessment results using the Monte Carlo/bootstrap method, or to explore the sensitivity of the assessment to data decisions and uncertainty. The sensitivity analyses were carried out altering one input at a time, and did not explore the impact of combinations of adjustments.

The data were properly applied within the assessment model. Any issues with application of the data such as time periods for fitting, use of length and age data from the same sampling schemes, or weighting of data according to data quality metrics, were explored at the SEDAR-41 RW if not previously evaluated by the DW and AW.

Data input series were applied if considered reliable and sufficient to support the assessment approach and findings. Reliability and sufficiency was evaluated based on a-priori criteria where possible, supported by data quality metrics such as numbers of samples or CVs and by model fits. The assessment is supported primarily by a wide range of fishery-dependent data covering landings and discards, and therefore is heavily driven by these data and assumptions related to their reliability and use. An additional fishery-independent trap survey data set unfortunately covers only the period since 2010 due to

very low incidence of Red Snapper catches prior to the recent increase in abundance due to strong year classes.

An evaluation of the strengths and weaknesses of the data sources and decisions is given below for each type of data used.

Life history parameters

Life history data and assumptions used in the Red Snapper assessment include stock structure, reproductive biology and natural mortality. The assessment was sensitive to estimates of natural mortality (M) as is generally the case, although sensitivity to trends in M could not be evaluated as there is no information on this. An age-dependent, year-invariant estimate of M was determined by a meta-analysis approach using growth parameters and maximum observed age. Reproductive biology was included in the model by computing total annual egg production at age based on maturity, length, number of batches and batch fecundity, thus allowing the effect of age structure on reproductive output to be reflected in setting SSB reference points and stock status. This represents a significant change from previous assessments. Interannual variation in fecundity, a possible source of uncertainty, was not able to be included as historical information was not available. The low estimate of age at first maturity in females (43% at age 1) was considered by the RW to be unusual for snappers, and it was speculated if it has declined as a compensatory response to heavy exploitation. Annual maturity data from the SERFS chevron trap survey could not be used to test this because sample collections have been from different areas in different time periods.

Fishery removals

Reconstruction of a historical series of commercial and recreational fishery removals (landings and dead discards) was made back to 1950 to allow a sufficient burn-in period for the BAM model as well as to establish a period of stable age structure and low fishing mortality. Creation of a series of removals estimates since 1950 required a large number of decisions to infer historical values from more recent data or to calibrate data series where design has changed. This included calibration factors to adjust NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) surveys catch estimates from 1981 to 2003 to be consistent with catches from the Marine Recreational Information Programme (MRIP: 2004 to present), and to develop combined recreational landings back to 1955 using effort data from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR: SEDAR41-DW17) combined with average MRFSS and SRHS CPUE data for 1981-83.

The recording of landings of the commercial handline fleets have improved in accuracy over time, and the DW proposed CVs that could be used for MCB uncertainty analysis in the assessment. Recreational landings of headboats are estimated from the Southeast Region Headboat Survey (SRHS) logbook scheme which has improved in quality over

time due to introduction of mandatory reporting in 1996 and improved logbook supply from 2008 onwards. Private boat and charter boat landings since early 1980s were estimated from MRFSS/MRIP, which has a robust and peer-reviewed statistical design that has substantially reduced bias and improved precision over time, and for which CVs are estimated directly based on efficient estimators.

Discards estimates are inherently less reliable than landings for both the commercial and recreational fleets, and for the commercial handline fleet involved extrapolating observations for 2002-2009 to other years back to 1992, with zero discards assumed prior to that due to low minimum landing size. Similarly, headboat discard estimates are available from logbooks and some at-sea observation since 2004 but had to be extrapolated back in time based on changes in length frequencies recorded by dockside sampling before and after changes in minimum landing sizes, with zero discards assumed pre-1984. All these data manipulations introduce additional error in the time series. Discards estimates from MRFSS/MRIP are self-reported by anglers intercepted at landing sites and are not verified.

Sample sizes and allocation in MRIP have not been sufficient to provide reliable estimates of Red Snapper landings or discards for the very brief mini-seasons since 2012, and alternative data sources from State surveys were also used for these periods, based on collaboration between MRIP staff and State laboratories which the Review Panel was advised is continuing to develop options for future sampling, which the Review Panel encourages.

Discarding of Red Snapper has increased over time due to changes in minimum landing size to 20 inches in 1992 and increases in abundance of young fish from above-average year classes in some recent years. The introduction of the moratorium in 2010 and 2011, and the small commercial catch limits and recreational bag limits in the mini seasons for 2012 onwards, have resulted in most of the catch now being discarded. Estimates of discards are of poorer quality than for landings, and are often self-reported with no verification although some data are available from at-sea observations. The Review Panel notes that under the current management regime the quality of total fishery removals estimates may therefore have deteriorated significantly. The BAM model has estimated a very strong 2013 year class, based mainly on recreational discards data and CVID Chevron trap survey data. Preliminary 2015 CVID data shown to the Review Panel confirmed this by showing increased numbers of 2-year-olds. The accuracy of future BAM estimates for this year class, and projections of its contribution to future biomass and fishery catches will depend on quality of discard estimates to quantify the fishery removals. The Review Panel supports any initiatives to improve quality of discards estimates particularly as the BAM model requires these and any landings estimates to be treated as precise.

Length and age compositions

The AW used age composition data in preference to length composition data in BAM where both data exist, and length composition data were fitted only for commercial handline from 1984 to 1992, commercial discards in 2009 and 2013, and headboat discards from 2005 to 2014. Age compositions were fitted for commercial handline landings from 1990 onwards, for headboat landings in two widely separated blocks in the 1980s and 2000s, for general recreational landings since 2001, and for the CVID survey from 2010. The CVID age data were found towards the end of the Review Workshop to have not been converted to calendar ages, and revised data were provided along with some preliminary assessment results which indicated some relatively small changes to the overall assessment results and stock status.

The Review Panel heard testimony from recreational and commercial fishermen, documented also in SEDAR 41-RW6, expressing concern that the BAM assessment underestimates the numbers of large, older Red Snappers. In their experience these fish occur more frequently in midwater than is the case for smaller snappers, which are strongly benthic and therefore are less likely to enter traps, and also have behaviour and distribution that makes them less probable to be caught by commercial handline, suggesting that all fisheries have domed selectivity. The scientific sampling of fishery catches shows that the incidence of large snappers is lowest in headboats operating inshore, highest in commercial lines operating in deeper water on average, and intermediate in recreational private and charter boats which typically operate in intermediate depths. The age composition of Red Snappers caught in the Chevron trap survey, which extends across a wide depth range, is closer to the composition of commercial handline. Broad spatial coverage of the commercial fishery and survey has been used by the DW and AW to justify asymptotic selectivity for these catches. The relative selectivity of the different fisheries is shown clearly by the size and age compositions in samples collected over time, but it is more difficult to prove that the commercial fishery and Chevron trap survey have asymptotic selectivity based purely on model diagnostics or spatial fishery distribution. The Review Panel did not see any empirical data from independent studies to confirm the selection pattern for commercial handline or chevron traps. Studies are needed to provide independent data showing how Red Snapper behaviour and depth distribution affects the probability of encounter with a fishing operation or trap, and the probability of being caught when encountering the gear, to help define selectivity patterns and resolve the different perspectives on abundance of large snappers during the rebuilding period. The Review Panel suggests some approaches later in this report.

Relative abundance indices

The Review Panel considers the rationale for including abundance indices from the fisheries-independent combined CVID trap/video survey (2010-2014) and data from

three fisheries-dependent CPUE series in the BAM stock assessment model to be reasonable. The combination of trap/video survey indices of abundance for the years 2010-2014 is clearly supported since the video camera is mounted on the traps, and thus cannot be considered independent observations. The three fishery dependent indices of relative abundance consisted of data from headboat logbooks (1976–2009), headboat discards (2005–2014), and commercial handline logbooks (1993–2009). The CPUE series were standardized to account for potential biases related to spatial and temporal coverage, and trip type, among other factors. The application of the method of Stephens and MacCall (2004), which takes into account other species than Red Snapper to subset trips in Red Snapper habitats, seems reasonable. The CPUE series had data gaps that required imputations to fill in the missing data points. The pragmatic method of indexing recreational catches against commercial landings and then applying a multiplier to back calculate historic landings, and the imputed values for years with zero discards based on averaging across the current and two adjacent years were considered to be reasonable. The CPUE values from commercial handline and headboat fisheries are likely to be biased indices of abundance for the stock since relatively more fishing effort will be spent in areas with high catch rates (before the 2010 moratorium) , and since the spatial coverage cannot be controlled like in a fishery-independent survey. HB CPUE series cover shallower waters where younger and smaller Red Snapper occur disproportionately more than in the deeper water where the commercial handline fishery spends more effort. A combination of the CPUE series external to the model based on their spatial/depth coverage is an alternative that might be explored in future assessments.

The various sources of systematic errors (e.g., spatial coverage, selectivity) and random errors (e.g., sample sizes) in each individual relative abundance series are well documented. There is some indication of lower discards in the HB fishery immediately following the moratorium (Figure 1; SEDAR41-DW14), which could suggest changes in fishing patterns to avoid snapper catches. The Review Panel is of the opinion that changes in management actions such as the moratorium, mini-season and reductions in bag limits that are expected to alter fishing behavior and hence catchability in fishery-dependent indices should inform decisions on inclusion of data or periods of data in assessments. A member of the SAFMC stated on record that the behavior of anglers has changed substantially since the moratorium, to avoid catching and discarding Red Snapper. The Review Panel, therefore, considers the fishery CPUE series to be applicable only to 2009, the year before the moratorium. CPUE series are also likely to be affected by technology creep in catchability due to improvements in fishing gear, positioning (GPS) and communication systems, and also by rising fuel costs in recent years.

The application of the data in the model follows common practice and appears sound. However, since the CPUE indices of abundance partly cover different depths/areas it should be noted that they do not individually cover the entire stock. Of particular

concern is that the age and length composition of data from the headboat fishery likely differ from the data from the commercial fishery that tends to operate in deeper waters. Also, the precision of the CPUE series differs depending on survey design and sample sizes. The results of the stock assessment modeling depend on the relative weights assigned to different data sets. However, there is no consensus amongst practitioners as to the best approach to data weighting. This stock assessment follows the common practice of weighting compositional catch data and abundance indices in two stages. The input data are first assigned relative weights before the model is run, and then iteratively weighted during a model run to improve model fit. Ideally, stage 1 weighting would use information about sample sizes (primary sampling units, and lower level sample sizes) and the way in which the data were collected (i.e., multi-stage survey designs), through calculated precision and effective sample sizes (Francis 2011; Pennington and Vølstad 1994). In particular, abundance indices by cohorts are likely to have different precision due to differences in the number of primary sampling units (e.g., trips, or trap-sets) where the cohorts are caught (Aanes and Vølstad 2015). In general, the multi-stage sampling can introduce complex correlation structures among cohorts, and drastically reduce the effective sample sizes for estimating compositions, and indices of cohorts (Aanes and Vølstad 2015). This would allow different weighting to each data point. The current assessment appears to largely apply ad-hoc weighting of input data. In particular weighting of the fishery-independent abundance indices (across cohorts) in the base model is poorly justified. The inclusion of CPUE indices with fixed CVs (relative standard error) of 0.2 (i.e., equal weights) follows Francis (2003), based on the argument that the CVs of the fishery dependent indices do not reflect true variation in abundance. However, since sample sizes vary over the years, a fixed CV could cause bias. An estimate of the variance of CPUE indices based only on the between-trip variability in CPUE may indeed underestimate the true variance of the CPUE abundance indices if catchability varies over time, which is likely. Pennington and Godø (1995) estimated the actual variance of survey abundance indices by cross-calibrating independent VPA estimates and survey catch per tow indices. For the current BAM assessment, the fishery-independent trap data could potentially be used for cross-calibration of CPUE indices, but since the fishery-independent index only is considered to be from 2010 onwards this is problematic. A pragmatic alternative to the fixed CV of 0.2 for the CPUE series could be to apply this value for an average sample size (number of trips) for each series, and then adjust the CV for actual sample sizes every year.

The input data series appears adequate to support the assessment results and findings. However, the CPUE series are likely to have large uncertainties as measures of abundance, and the trap/video index only covers the recent years. In particular, the fishery-dependent CPUE abundance indices after 2010 are based on discards, and may be biased downwards if the HB and commercial fishery successfully avoids areas with high abundance of snappers.

2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and consider the following:
    d) Are methods scientifically sound and robust?
    e) Are assessment models configured properly and used consistent with standard practices?
    f) Are the methods appropriate for the available data?

The Review Panel agrees with the DW and AW decisions and confirms that the methods are sound and relatively robust. Many stock assessment decisions are somewhat subjective, but alternative decisions were considered and the final decisions were generally well justified. Sensitivity analyses explored a wide range of data decisions, model assumptions and model configurations to examine the robustness of stock status determination. The Monte Carlo Bootstrap procedure also explored many combinations of alternative data and model assumptions.

The Review Panel concluded that the assessment models were reasonably configured and are consistent with standard practices. The BAM is the approved assessment method for many stocks in the South Atlantic Snapper-Grouper complex and is well suited to the fishery-dependent and fishery-independent information available (e.g., life history information, commercial landings and discards, recreational landings and discards, standardized CPUE indices, trap survey indices, length and age sampling). The model has many assumptions and many estimated parameters, but the base model configuration appears to have reasonable assumptions and parameter estimates. The ASPIC model and an Age-Structured Production Model were also applied to aggregate catch and stock biomass indices to provide alternative perspectives on stock status. However, the age-aggregate models do not consider length and age composition data. Although the interpretation of length and age composition data are conditional on assumed forms of selectivity and estimates of selectivity at age, the Review Panel agrees with the AW that length and age composition information is an important source of information. Catch curves of age composition data were provided as exploratory information on trends in maturity, but results are not considered to be a valid basis for status determination, because estimates are imprecise and the implicit assumption of constant mortality rate at age do not appear to be valid. The BAM base configuration is considered to be the most appropriate basis for status determination, because it fully considers important information on demographic structure, including regulated changes in selectivity, age-based maturity and fecundity, and variable recruitment of new age classes. The base configuration of BAM from the AW ('base') was revised with corrected age compositions of the Chevron Trap survey. Results and diagnostics from the AW base model and the corrected base model ('newbase') were similar. The review of methods

was based on the Assessment Workshop report and the corrected base model, but conclusions from the RW were confirmed with corrected results.

During the most recent years of the stock assessment series (i.e., the 2010-2014 moratorium), recreational discards are one of the most important sources of information for the assessment. Unfortunately, recreational discards are also one of the most uncertain sources of information. Despite the imprecision in estimates of recreational catch, the BAM base configuration is conditional on catch estimates (e.g., the input CV for catch was 0.05). Exploratory analyses that allow error in landings could not produce a solution, but the Review Panel requested an exploratory analysis that allowed error in the estimates of recreational discards, assuming the MRIP estimates of CV. Exploratory assessment models with more or less catch had similar estimates for the last 30 years (BAM runs S17–S20).

Fishery CPUE indices suggest a greater recent increase in stock biomass and lower mortality (BAM run S4). However, the Review Panel agrees that the fishery-independent index is informative and should be included in the assessment model. Considering the Chevron Trap Survey and Video Survey as separate indices (BAM run S22) also estimates a greater recent increase in stock biomass and lower mortality, but the Review Panel agrees that the two series are not independent and should not be considered as separate indicators of stock trends. An alternative model configuration that included the entire series of Chevron Trap Survey provided similar estimates as the base model.

Accurate interpretation of length and age composition data relies on accurate assumptions about the form of selectivity and estimates of selectivity at age in the fisheries and the survey. The commercial fishery is assumed to be asymptotic (i.e., 'flat topped'), and the model estimated that all Red Snapper older than age-4 have been fully vulnerable to the commercial fishery since the minimum legal size regulation in 1992. The Review Panel agrees that the flat-topped selectivity assumption for the commercial fishery is justified, because the commercial fishery covers the entire resource area and targets large fish. Assuming 'dome-shaped' selectivity (i.e., oldest ages are not full vulnerable) for the commercial fishery (BAM run S21) produced similar results as the base model.

Selectivity of the headboat fleet was assumed to be dome-shaped, and the model estimated full selectivity at ages 3-4 and low selectivity of ages 10+. Selectivity of the general recreational fleet was also assumed to be dome shaped until 2010, with full selectivity at ages 3-4 and low selectivity of ages 10+. Results were not sensitive to how selectivity was estimated for ages 10+ (BAM run S31).

Since 2010 (during the moratorium, mini-seasons and 1-fish bag limit), selectivity of the general recreational fleet was assumed to be flat-topped, with full selection at ages 6+. The Review Panel could not agree on whether the flat-topped assumption is well-justified. The Review Panel requested a sensitivity analysis in which selectivity of the recent general recreational fleet was assumed to be the same as the recent headboat fleet.

Results suggest that the model does not fit age composition data well, underestimating catch at older ages, and estimates are not sensitive to the selectivity assumption of the recent general recreational fleet (Appendix A).

The Review Panel recognizes that the perception of current selectivity used to derive reference points and projections is conditional on poorly-informed assumptions regarding recent fishing behavior, and projections of alternative management scenarios should consider alternative selectivity assumptions that are consistent with each scenario. For example, alternatives that do not allow recreational landings (e.g., moratoria with no mini-seasons) should not assume the *status quo* composite selectivity that includes a flat-topped selectivity for general recreational landings.

The form of selectivity of the Chevron Trap Survey was assumed to be flat topped, and the model estimated that all Red Snapper older than age-3 are fully vulnerable to the trap survey. Public comment suggested that traps may not catch large Red Snapper as efficiently as small Red Snapper. However, some of the largest and oldest samples available are from the trap survey, and efforts to estimate lower selectivity of older ages produced estimates near full selectivity.

The flat-topped selectivity assumption for the Chevron Trap survey implies that relative abundance of old fish is represented by the survey. The assumed shift from dome-shaped selectivity to flat-topped selectivity of the general recreational fishery implies that the recent increase in catch of larger and older fish reflects a shift in selectivity, rather than a proportional increase in the abundance of older fish in the population. Alternative interpretations would require evidence that larger, older Red Snapper are not fully vulnerable to the fishery or the survey.

Attempts to sample larger and older Red Snapper than sampled in the fisheries or trap survey have not been successful. Mitchell et al. (2014 Marine and Coastal Fisheries 6: 142-155 and SEDAR41-RD34) investigated length-specific depth distributions of Red Snapper in the South Atlantic region from two fishery-independent surveys targeting hard-bottom habitats, and reported "*no evidence of a positive relationship between depth and age or length. Additionally, age and length distributions of Red Snapper ≥ 50 cm FL did not differ between fishery-independent surveys and the commercial hook-and-line fishery. These results provide no support for assertions of greater abundances of older and larger Red Snapper in deeper SE USA waters*."

The information available on size selectivity of Red Snapper by survey traps is equivocal on the form of selectivity. Wells et al. (2008, Fisheries Research 89: 294–299 and SEDAR31-RD36) compared catch rates of trawls, small fish traps, chevron traps, and underwater video for sampling Red Snapper in the Gulf of Mexico. They concluded that "*the chevron trap is most effective for sampling adults, while trawls were the most effective gear for sampling age-0 fish*." DeVries et al. (2012, SEDAR31-DW28) compared size samples of Red Snapper from traps and cameras and found that "*the traps*

do select against most Red Snapper >650 mm TL, although fish that large appear to be uncommon in the survey area based on the few stereo measurements obtained" and "*distributions of the trap fish and that from the stereo images, like in 2011, were very similar*." Therefore, there is insufficient evidence to reject the selectivity assumptions in the assessment. However, the assumptions of asymptotic selectivity of the trap survey and recent recreational fishery should be investigated further in future assessments.

3. Evaluate the assessment findings and consider the following:

    a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?

The Review panel accepted the new base model with the corrected age compositions for the CVID survey index as the best available model to provide advice for the South Atlantic red snapper fishery. However, the review panel did have concerns such as those discussed below.

The recent Red Snapper fishery comprises two periods of distinct exploitation patterns where the period up to and including 2009 consist of commercial and recreational fisheries with a moratorium on fishing from 2010 to the present. Since 2010 removals albeit reduced have continued through mini-seasons and discard mortality from the headboat and general recreational fishery. This change in the fishery has complicated the monitoring of the fishery because the fishery dependent indices (catch rates from the commercial handline, general recreational and headboat fleets) end in 2009. The SERFS combined video and trap survey index, CVID was introduced in this assessment to cover the moratorium period from 2010 to the present. The annual Red Snapper discard rate from the headboat fleet for 2005 to the present is used to link the fishery dependent indices in the earlier period with the CVID during the moratorium period.

The reliability of model estimates of abundance, biomass and exploitation depend on how well the monitoring indices included in the model track the population trends over time. In this assessment fishery dependent catch rates were used for the pre-moratorium period and were replaced by the CVID survey index for 2010 to the present. The MRIP annual red snapper discard rate from the headboat fleet for 2005 to the present was the only index that spanned the two time periods.

The consistency of the stock status determinations for this combination of monitoring indices was evaluated through a series of sensitivity runs. These runs indicated that the determination of stock status was actually fairly insensitive to changes such as using the longer time series for the CVID (S9), removing the CVID (S4), up-weighting the fishery dependent indices (S3), dropping the headboat discard index for 2010 to the present (S12), dropping the headboat discard index altogether (S16) or only using the CVID

(S23). All indices were well fit by the data, except for the headboat discard rate in the most recent years (Figure 13 of document).

All of these results suggest that the population trends in the model results probably have as much or more to do with the very close fit of the model to the landings, discard data, and associated age compositions as they do with the trends in the monitoring data. CVs were set to 0.05 for the landings and discards, which seems unreasonably low for the MRIP estimates of the latter but a higher CV of 0.20 for discards was investigated in MCB study and the results did not indicate a change in stock status from the base case.

b) Is the stock overfished? What information helps you reach this conclusion?

The estimated abundance for 2014 was at levels not seen in the model since the mid-1960s (Fig. 14 in the assessment report) however the 2014 population mainly consisted of ages 1-4 years (96% by number). Despite these high abundance levels the stock is overfished as $SSB_{2014}/SSB_{F30\%}$ =0.16 due to the lack of older fish in the population.

c) Is the stock undergoing overfishing? What information helps you reach this conclusion?

The review panel could not find any evidence against the overfishing determination in the assessment but did have a number serious concerns that are discussed below. The panel also reflected on issues with using <u>apical fishing mortality</u> to monitor the impact of the fishery on the stock over time (*see item e below*)

The determination of overfishing in the assessment relies on the geometric mean of apical F summed across fleets each year over 2012–2014 period. Currently, $F_{2012-2104}/F_{30\%}$=2.52. The retrospective analysis indicated that there was a substantial increase in apical F for 2010 to 2013 with the addition of the 2014 data (Figure 55 in the assessment report). The individual results for the different runs were not presented and it is not known whether the ages at which the apical F's occurred changed with the addition of 2014 data.

Given the retrospective pattern, it is likely that had the red snapper assessment been done a year ago, evidence for overfishing would have been much weaker than presented here. The main change between 2013 and 2014 was that landings and discards by the general recreational fleet were much higher in 2014 vs. 2013 by about 3.7 times for numbers landed and 3.4 times for discard numbers. Estimated increase in weight landed by the general recreational fleet was 3.4 times the 2013 landings. Fishing mortalities associated with general recreational landings and discards make up 78% of the 2014 apical F estimate (Table 14 in the assessment report). The mini-season in 2014 was longer than in previous years and recruits in 2014 were the highest in the time series.

The current determination that overfishing is occurring while the fishery is under moratorium generated much discussion during the panel review. The moratorium has not resulted in a complete closure as there have been landings from mini-seasons in 2011–2014 and removals due to discards during these seasons and throughout the year for recreational fisheries. The estimated fishing mortalities (Figure 27, in the assessment report) reflect the large decrease expected with the introduction of the moratorium in 2010. However since 2010 fishing mortalities have increased from this low point mainly due to discard mortalities and catches from the general recreational fishery. A comparison of mean Fs at ages 1, 2, 3, 4, and 5+ indicates that while fishing mortality was greatly reduced on all age groups in 2010, fishing mortality greatly increased on the older age 4 and 5+ group by 2014 while the Fs for the younger group ages level continued to be lower. The moratorium appears to have been a benefit to the younger fish but not so for fish 4 years and older as interpreted by the selectivity curves used for the moratorium years.

The panel asked for a sensitivity run to investigate the impact of the flat topped selectivity curve assumed for the general recreational fishery by substituting the domed curve used for headboats for 2010–2014. The domed selectivity did not result in any substantial change in stock status from the base case. The fishing mortalities-at-age were not presented by gear so it was not possible to see which age corresponded to apical F for the general recreational landings or discards for either selectivity curve.

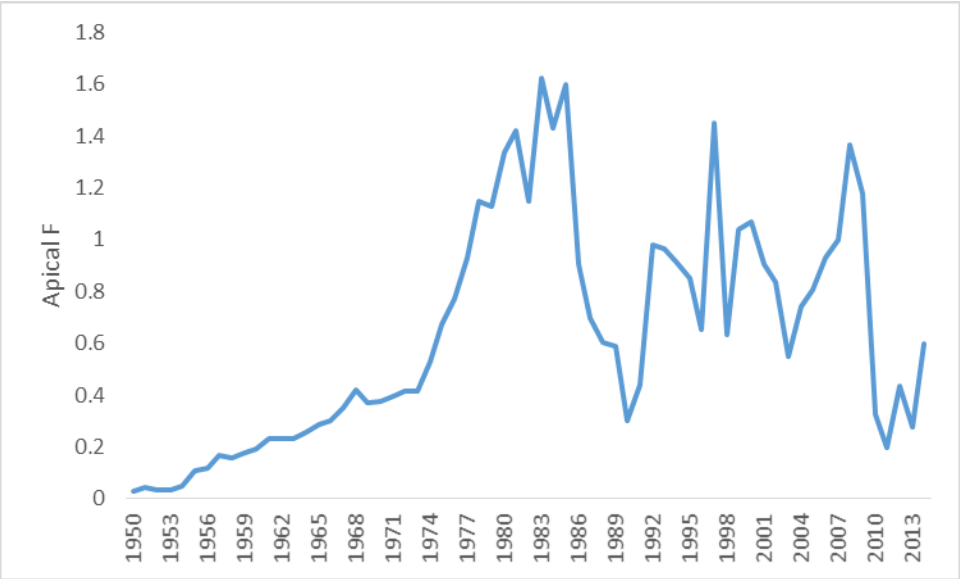
d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?

The stock recruitment curve was not informative and inference was based on setting steepness to 0.99 and assuming average recruitment. Mean annual recruitment was assumed and lognormal deviations around that mean were estimated in the model.

Recruitment is typically not well estimated in the last year of stock assessments, because there is little information to inform the estimate. The estimate of strong recruitment in the last year of the assessment is supported by the high CVID index as well as the length composition of the headboat fleet. Review Workshop participants reported continued signals of strong recruitment in 2015 fishery and survey data. The Review Panel recognizes that projections are largely dependent on the estimate of recent recruitment, but the estimates of abundance at age from the base model is the most reliable basis for stock status determination and projection.

e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

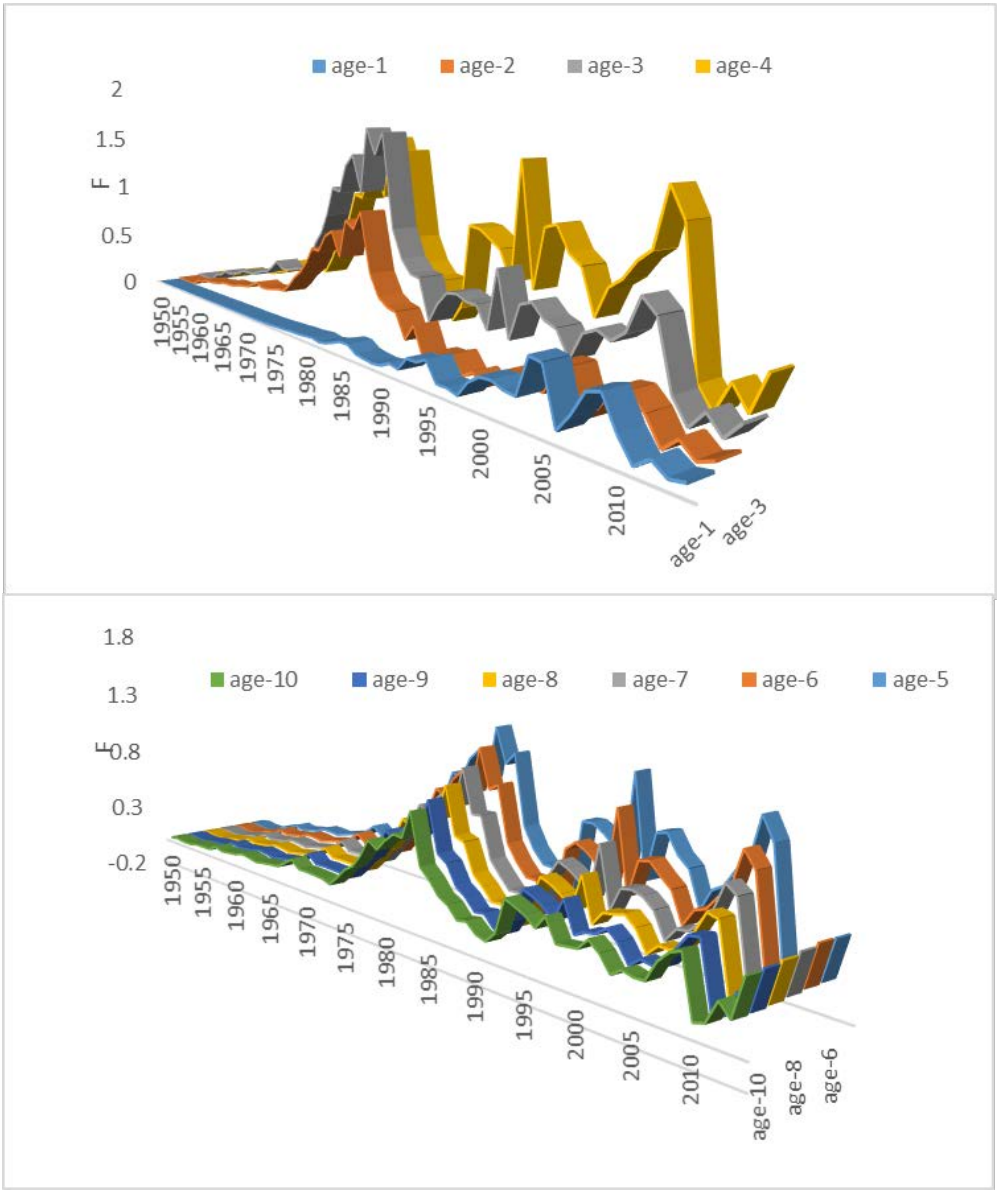
Evaluating trends in F over time requires a metric that is comparable among years and reflects exploitation across a range of ages. Apical F (maximum F at age, Figure 1) is based on a different range of ages among years, because of changing fleet contributions and fleet selectivities. Apical F also does not reflect F for partially selected ages.



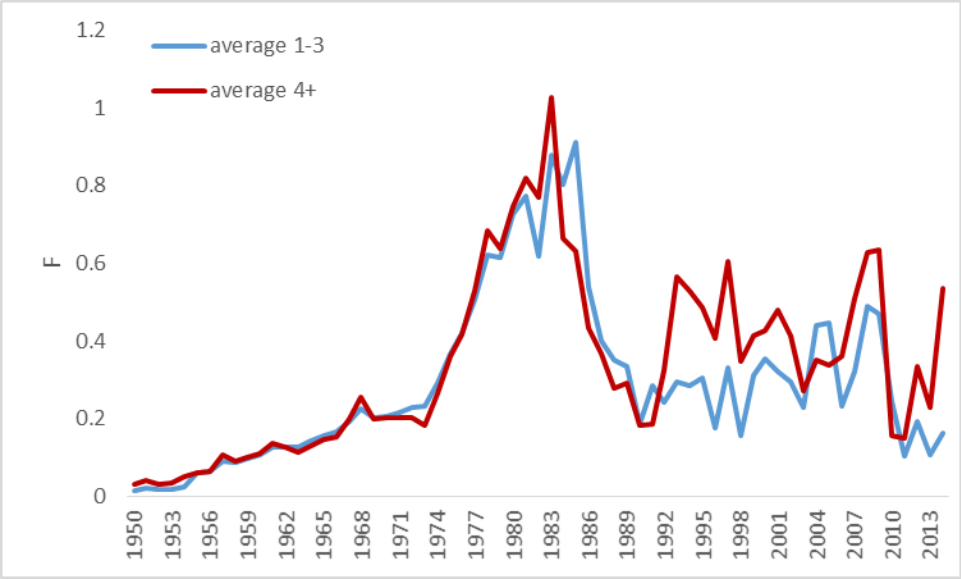
Deciding on a more appropriate metric of F for Red Snapper is challenging because of the complexity of patterns in estimated F at age:

- Age-1 F has one peak in 2004. F was negligible until the mid-1990s, peaked at 0.4 in 2004, then decreased to ~0.1 since 2010.
- Age-2 F had one peak at 1.0 in 1985. F decreased to ~0.1 in the late 1990s, increased to 0.2-0.3 from 1999 to 2010, then decreased to ~0.1 since 2010.
- Age-3 F also had a major peak at 1.6 in the early 1980s, decreased to 0.3-0.5 in the early 1990s, increased to a minor peak of 0.8 in 2008 and decreased to 0.2-0.3 since 2010.
- Age-4 F had three peaks at >1.0 in the early 1980s, 1.5 in 1997 and 1.4 in 2008, then increasing from 0.2 in 2010 to 0.5 in 2014.
- Ages 5 and older have similar patterns in F (three peaks in the early 1980s, 1997 and 2008-2009, then increasing from 2010 to 2014). For most of the time series F

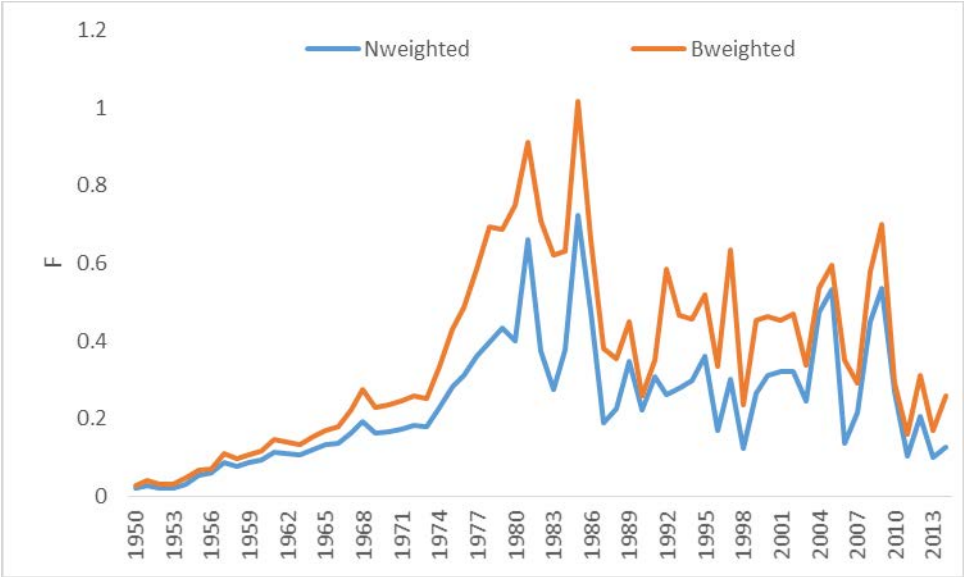
decreases with age, but since 2010, F at ages 5+ is similar, increasing from ~0.2 in 2010 to ~0.5 in 2014.



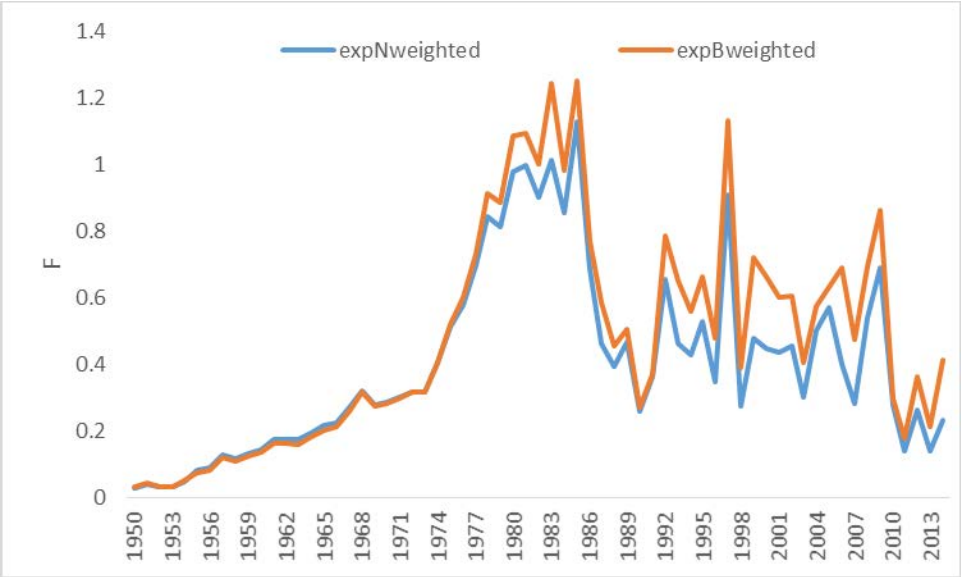
Alternative metrics of F will reflect these patterns differently. Simple average F at age can reflect trends for similar ages (e.g., ages 2-3, ages 4+), and show different recent trends. During the moratorium, F remained low for ages 1-3, but more than tripled for ages 4+.



Average F can be weighted by abundance at age or biomass at age to measure the average F exerted on the entire stock. With young ages typically having greater abundance, abundance weighted average F reflects patterns of F at young ages. Biomass peaks at different ages over the assessment time series (age-20 in 1950, age-2 in 2014), so biomass weighted average F reflects a varying age range.



Average F can also be weighted by exploitable abundance (the product of abundance at age and selectivity at age) or exploitable biomass (the product of biomass at age and selectivity at age) to measure the average F exerted on the exploitable stock. The two exploitable stock average F's are similar, but the exploitable biomass weighted F reflects older ages (e.g., more than doubles during the moratorium) and the exploitable abundance weighted F reflects younger ages (e.g., remains low during the moratorium.



The overfishing limit ($F_{30\%SPR}$) can be expressed in the same currency as the measure of F from the stock assessment. $F_{30\%}$ is currently expressed as Apical F, assuming the average selectivity for the last three years of the stock assessment, which peaks at age-5 (e.g., $F_{30\%}$ expressed as age-5 F is 0.15). All forms of $F_{30\%SPR}$ expressed as an average F are less than age-5 F, because they include some partially recruited ages. According to all of the alternative F metrics considered, overfishing is occurring, but to varying degrees.

Metric	2012-2014 Geo.Mean	F30%	F/F30%
F(age-5)	0.43	0.15	2.8
F(ages 1-3)	0.15	0.06	2.7
F(age-4+)	0.35	0.12	2.8
F(Nwtd)	0.14	0.08	1.8
F(Bwtd)	0.24	0.11	2.1
F(expNwtd)	0.20	0.10	2.0
F(expBwtd)	0.31	0.12	2.5

In conclusion, despite the Review Panel's concurrence that the base BAM configuration can be used for stock status determination the Panel has clearly expressed caveats on some key aspects such as selectivity changes, given the number of parameters being fitted vs. data quality. All the assessment runs clearly show a stock that is abundant at younger ages but overfished in terms of egg production and very slowly recovering. However it is of some concern that the retrospective analysis indicates a substantial upward adjustment of recent F's with addition of 2014 data. Remove 2014 data and the recent Fs are down to around the $F_{30\%}$ reference point (apical values). SSB's are correspondingly adjusted down. The recent strong year classes (age 1 in 2006-2008) appear more stable, but these are feeding progressively into the 5+ age groups from 2010 onwards, the period for which the model sees more adult fish and "wants" to estimate asymptotic selectivity for the general recreational fishery. The Panel expressed concerns that no diagnostics (e.g. parameter correlation tables) were provided to evaluate whether the model has an issue estimating fully selected F's in 2014 vs. recruitment estimates for the strong year classes. There is a potential large uncertainty in the F estimates from the assessment including 2014 data. Some of the age composition data are very well fitted in 2014 – the CVID comps are fitted extremely closely (perhaps too closely!) in 2012 and 2014 and close in 2013, whilst the general recreational age comps are fitted very poorly in 2014 despite a very large sample size and may be an indication of problems with the data for this fishery in 2014. Further, the retrospective analysis indicated that there was a substantial increase in apical F for 2010 to 2013 with the addition of the 2014 data. It is likely that had the red snapper assessment been done up to and including 2013 data, that evidence for overfishing would have been very much weaker than presented here.

4. Evaluate the stock projections, including discussing the strengths and weaknesses, and consider the following:
    e) Are the methods consistent with accepted practices and available data?
    f) Are the methods appropriate for the assessment model and outputs?
    g) Are the results informative and robust, and are they useful to support inferences of probably future conditions?
    h) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

Projections were run to predict stock status in years after the assessment, 2015–2044. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. A single selectivity curve was applied to calculate landings and one for discards, averaged across fleets using geometric mean F's from the last three years of the assessment period, similar to computation of $LF_{30\%}$ benchmarks (§3.22). Expected values of SSB (time of peak spawning), F, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the spawner-recruit relationship (*h* =

0.99) with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{30\%}$ would yield $LF_{30\%}$ from a stock size at $SSB_{30\%}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

The projection method is consistent with those used widely in SEDAR assessments based on statistical models such as BAM and Stock Synthesis, and is consistent with the available data. The method used stochastic projections that extended the Monte Carlo/ Bootstrap (MCB) fits of the assessment model with added stochasticity in recruitment, and hence the propagation of uncertainty from the assessment into the projection period is internally consistent.

The Review Panel concluded that the Red Snapper stock projections provided for SEDAR 41 are appropriate for the BAM assessment model and outputs. The results of the projections are informative and robust, and are useful to support inferences of probable future conditions. The projections provide the information needed to develop management advice, showing projections for F=0; $F=F_{CURRENT}$ (geometric mean of the last 3 years); $F=F_{30\%}$; $F=F_{TARGET}$; $F=F_{REBUILD}$ (max exploitation that rebuilds in greatest allowed time (2044). An additional projection was carried out with F from discards only. Each projection shows the 10th and 90th percentiles of the replicate projections allowing an evaluation of the probability of overfishing occurring, or the stock being overfished, for each year in the rebuilding time frame up to 2044. The projections are robust in terms of propagating realistic levels of uncertainty from the accepted base model run.

Key uncertainties in the projections are acknowledged, discussed, and reflected in the projection results. The MCB runs included ranges of values of natural mortality, discard mortality and fecundity at age agreed by the AW, together with bootstrap selection of data using well-justified error distributions and additional random process error in recruitment conditional on the fitted stock recruit pattern with steepness fixed at 0.99. Initial age structure at the start of 2015 was computed by the assessment model, and fishing rates for the projection started in 2017 following an initialization period in 2015-2016 where fishing mortality rates were derived to represent the management measures in place.

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
    c) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
    d) Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The Review Panel is concerned that many of the reported uncertainties on quantities of interest are a consequence of the assumed (and fixed) observation variance parameters. No clear evidence of the appropriateness of these assumed values has been presented.

Because of the large number of parameters in BAM a thorough evaluation of convergence and model sensitivity is necessary, but difficult. Uncertainties in the assessment were explored through (1) a mixed Monte Carlo and bootstrap (MCB) analysis to quantify random errors in the assessment output; (2) sensitivity analysis around the base BAM run; and (3) the use of alternative assessment models. The Monte Carlo Bootstrap procedure also explored many combinations of alternative data and model assumptions. In the bootstrapping of observed data on landings, information from the headboat program was used to specify a decreasing CV by time blocks (i.e. CV = 0.15 for 1981-1995, CV = 0.1 for 1996-2007, and CV = 0.05 thereafter). These CVs reflect random errors. However, landings from the headboat fishery are monitored through mandatory logbooks, and thus should in principle have zero sampling errors for the vessels in the sampling frame. The CVs may reasonably reflect random errors in reporting. However, various sources of systematic errors (bias) are not reflected through these CVs. It is known that under-reporting of trips does occur, that catch data may not always be 100% accurate (for example due to recall bias if logbooks are not filled in immediately after each trip), and that other variations in reporting likely occur. Because the distribution of such systematic errors is unknown, it is not possible to quantify the magnitude of the resulting uncertainty in the landings.

The input data on catch composition and abundance indices by cohort are obtained from multi-stage sampling programs where fishing trips typically are the primary sampling units (PSUs) for fisheries data, and locations/standardizes trap catches (90 min soak time) are the PSUs for the chevron trap. Substantial correlations can be expected in age or length composition data sets that are constructed from samples/sub-samples from multiple catches (whether from fisheries-independent surveys or fisheries) (e.g., Aanes and Vølstad 2015). The BAM model itself and the MCB is not likely to realistically account for complex error structure in data weighting without prior estimates of the actual variance-covariance matrices for the input data. The robust multinomial approach with number of PSU's as proxy effective sample sizes employed in the uncertainty evaluation of the BAM can only partly reflect the complex error structure. Ideally, it would be possible to run bootstrap resampling on the PSU's to create replicated BAM runs that reflect the complexity in input data, but given the complexity and configuration of BAM this is not possible. The Review Panel therefore considers the uncertainty in the assessment to be appropriately addressed given these restrictions.

The sensitivity analyses were used to explore a wide range of data decisions, model assumptions and model configurations to examine the robustness of stock status determination. The model was run for a plausible range of values for each factor. The

Review Panel noted that the sensitivity testing by alternating one factor at a time, although commonly done, may not fully reflect the uncertainty in model outputs from a complex model such as BAM with a large number of parameters where many are likely to be correlated (e.g., Saltelli and Annoni (2010). Global sensitivity analysis (Saltelli et al. 2008) may be used to untangle the contribution of single factors/parameters and interactions between parameters to the overall variability in model output. Anderson et al. (2011) provide an excellent overview of the literature, and many examples of applications of global sensitivity analysis to Integrated Assessment Models in climate research, and some of these are likely to be applicable to the BAM model. The following is a description of each of the model runs provided to the reviewers during the course of the RW:

S12: (based on the old base model) The headboat discard index was truncated to only include years 2005-2009.

S16: (based on the old base model) The headboat discard index was dropped entirely.

S32: (based on the old base model) The general recreational fleet was set to have the same selectivity as headboat in the last time block (dome-shaped, 2010-2014).

DroppedHBdiscindex: same as S16, except starting with the new base model (corrected chevron trap age compositions).

TruncatedHBdiscindex: same as S12, except starting with the new base model (corrected chevron trap age compositions).

Model uncertainty was mainly explored by running ASPIC (Version 7.03, 2005) that relies on length-age aggregated catch and CPUE indices, with no compositional catch being included. The ASPIC runs resulted in biomass estimates above B_{MSY} and estimates of F below F_{MSY}, and hence do not place the stock in the "overfished-overfishing" category. The difference between the ASPIC and the BAM results can however be explained by the fact that ASPIC does not take into account the age-structure of the catches and the stock. Thus, a biomass made up largely by recruits can result in a stock status of not overfished-overfishing. In addition to ASPIC, a simple catch curve analysis was performed that tended to support the Z values estimated from the BAM. Therefore, despite the many uncertainties and the concerns expressed above the BAM base configuration is therefore considered to provide the most appropriate basis for status determination, despite many sources of uncertainty.

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
    b) Provide recommendations on possible ways to improve the SEDAR process.

The Review Panel considers the first three of the following bullets to be the highest priority for assessment improvement.

- Increased fishery independent information, particularly maintaining reliable indices of abundance and composition data streams.
- Improve the reliability of discard data as an abundance index by improving knowledge of private recreational fisherman behavior.
- Research to determine the spatial distribution (horizontal and vertical) of large adult Red Snapper using tracking and telemetry.
- The Review Panel reiterates various research recommendations focused on Red Snapper population structure in the South Atlantic. Red Snapper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment, and spatially-explicit data of all types used in the assessment model. It is unclear whether a spatially-explicit model would improve the assessment. Given the robust ocean circulation in the South Atlantic Bight conditions creating population sub-structure. The research effort necessary to support such an effort would be extensive and probably unjustified on stock assessment improvement grounds, however, it would be needed to support MPA placement, performance evaluation, etc.
- More research to describe the juvenile life history of Red Snapper is needed, including more work to identify the location of juveniles before they recruit to the fishery.
- The effects of environmental variation on the changes in recruitment or survivorship.
- Investigate possible historical changes in sexual maturity. The current estimate of age of sexual maturity is low and unusual for other Lutjanids. Is it right or a compensatory response to heavy exploitation?
- Continue conducting studies to develop a time series of batch fecundity to obtain information on the inter-annual variation in reproductive output.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

   The Review Panel considers that the BAM assessment for Red Snapper constitutes the best scientific information available, and fulfils the following criteria:

Relevance: The SEDAR 41 assessment is highly relevant as the Red Snapper stock is depleted and undergoing rebuilding under a moratorium with limited landings permitted and most catches being discarded. The data and assessment provide the best means of establishing the rate of recovery of the stock, determining if measures are preventing overfishing, and providing information that can be used to adjust management actions where appropriate.

Inclusiveness: The SEDAR 41 assessment includes all data that have been quality assured and proved adequate for use in the assessment. This includes data from State as well as Federal sampling schemes where needed, for example to estimate discards during the mini-season where MRIP sampling is too limited for such a short season length.

Objectivity: The SEDAR 41 BAM model is a highly objective procedure based on well-tested statistical modeling principles, and using data sets and assumptions that have been rigorously documented and reviewed through the SEDAR data, assessment and peer-review process. Where fully objective decisions are difficult to make, such as some decisions on scenarios for historic catches where evidence is lacking, the uncertainties around the decisions made have been explored and included in sensitivity analyses and the Monte Carlo Bootstrap evaluation of assessment uncertainty.

Transparency: All outputs of the data, assessment and review workshops in SEDAR 41 are fully documented and publicly available. The discussions at the review workshop are also recorded for record. All data sets are thoroughly explored and the quality of data on which the assessment is based is documented and transparent, as are all decisions related to the choice of assessment model, how it is implemented, and the results of the base run and sensitivity and uncertainty analyses.

Timeliness: The SEDAR process in general is arranged to provide timely fishery management advice where it is needed, and to ensure that assessments are benchmarked and reviewed at appropriate intervals.

Verification: The SEDAR 41 assessment process and deliverables comply with legal requirements under the Magnuson Stevens Act (2007) for developing and monitoring of fishery management plans and providing information on stock status.

Validation: The SEDAR 41 process is designed to meet the needs of fishery managers for peer-reviewed stock assessments and associated advice on stock status and future catches, and the process is open and fully transparent to the fishery managers and to stakeholders from commercial and recreational fisheries, conservation groups or others with a stake in the outcomes and who have opportunity to give their views on record.

Peer review: The SEDAR 41 process includes full peer-review by experts appointed by the Center for Independent Experts (CIE, University of Miami) and by reviewers from

the SAFMC SSC. The review panel report and the independent CIE reviews are publicly available

8. Compare and contrast assessment uncertainties between the Gulf of Mexico and South Atlantic stocks.

   Both the South Atlantic and Gulf of Mexico Red Snapper stock assessments have multiple uncertainties. The table below summarizes the significant sources of assessment uncertainty in the population, data sources, and assessment methods for both stocks.

Sources of Uncertainty	**South Atlantic (SEDAR 41)**	**Gulf of Mexico (SEDAR 31)**
Population	• Juvenile life history, including the location of juveniles before they recruit to the fishery • Spatial distribution (horizontal and vertical) of large adult Red Snapper • Variability in batch fecundity and spawning frequency with size and age • Effects of environmental variation on changes in recruitment • Density-dependent changes in growth, reproduction, and natural mortality	• Population structure and connectivity between eastern and western Gulf (for both adults and juveniles) • The use and effect of artificial reef structures on red snapper population abundance, age and length composition, and spatial distribution Effects of environmental variation on changes in recruitment • Density-dependent changes in growth, reproduction, and natural mortality
	• Limited fishery independent indices of abundance • No fishery independent index of abundance for early juveniles	• Limited fishery independent index of abundance for early juveniles • Limited information on the magnitude, size, and age composition of discards

Data Sources	• Changes in selectivity, catch, and discard data due to changes in fisher behavior within and outside the mini-season • Poor information on the magnitude, size, and age composition of discards • Poorly-informed selectivity functions for most fleets	• Poorly-informed selectivity functions for most fleets
Assessment Methods	• Uninformative Stock-Recruitment relationship (had to use proxy reference points) • Uncertainty for certain parameters and data inputs was fixed to chosen values that could be considered arbitrary (e.g., CV for landings and discards set = 0.05) • Model uncertainty was mainly explored by running an alternative Stock Production Model	• Uninformative Stock-Recruitment relationship (had to use proxy reference points) • Uncertainty for certain parameters and data inputs was fixed to chosen values that could be considered arbitrary (e.g., CV for landings set = 0.05 and for discards = 0.5) • Model uncertainty was not explicitly explored by the use of different models

9. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

   The RW Panel recommends that given the data and model complexities inherently associated with stock assessment of South Atlantic Red Snapper, more realistic timelines be considered for the next assessment.

   Additionally, given that the input data on catch-at-age and abundance indices by cohort are likely to be cluster-correlated (Nelson 2014), and therefore have low effective sample sizes, it is problematic that the BAM model has a very large number of parameters. It

would therefore make sense to provide alternative runs using more parsimonious models to get a wider evaluation of the robustness of the assessment. One recommended candidate is a statistical assessment model (XSAM) (Sondre Aanes, Norwegian Computing Center) recently applied in the ICES Benchmark Assessment for Norwegian Spring Spawning Herring, and approved as the standard assessment model. This model template is based on a state-space model and structural time series models for fish stock assessment (inspired by Gudmundsson 1994), and includes the DTU Aqua SAM model (Nielsen and Berg 2014) that is widely used in ICES as a special case. The main advantage of this XSAM model template is that it can utilize the sampling distributions derived from analysis of sample survey data (estimated catch-at-age, and abundance indices at age) by giving appropriate weights to input-data points. It is coded in TMB (R library) which is efficient for nonlinear models with latent variables.

Another important point in addressing future assessments of South Atlantic Red Snapper is that it would be extremely useful for the Review Panel to see direct estimates of total removals by age-class across fleets (each fleet is essentially a stratum when it comes to estimating the age-composition of removals). This would allow the Panel to see how well cohorts are tracked in the fisheries data. The selectivity by fleet is only relevant when trying to use the fishery-dependent data as indices of abundance. However, selectivity in this context is muddled by the spatial coverage of each fleet. For example, two fleets using same gear (with same selectivity) would end up with different age-compositions if they operate in different areas (depths), if in fact the population by age-class differs by area (depths), which seems to the case for Red Snapper. Therefore, the Review Panel has struggled to understand how multiple abundance indices from fisheries-dependent data that each only covers portions of the stock can be pooled within the BAM model to yield representative indices for the entire stock. In the suggestions made above regarding the use of alternative assessment models (Gudmundsson 1994, and refinements by Aanes), input data from fisheries are total estimates across fleets of yearly removals by age-class and have an associated variance-covariance matrix that reflects the complex cluster sampling.

Another recommendation from the Review Panel concerns the process used for standardization of the CVID index of abundance. The CVID index was derived from fitting a Zero-Inflated Negative Binomial (ZINB) generalized linear model to individual catches with polynomials (degree) of depth (3), temperature (2) and Latitude (7) fit to catches greater than zero and polynomials (degree) of depth (3) and Latitude (4) fit to the zero-inflation portion of the model. Standardized index for each year was based on converting each covariate (all continuous except year) to a sequence of a small number of evenly space values over the range of each covariate over all the years. These converted covariates were used to predict catches over all years with the effect added and then averaged within each year to give annual indices. The variances of these indices were estimated by bootstrapping observed catches and associated covariates and running each

bootstrap through the above process. This standardization approach amounts to predicting the catch expected for the mean of the converted covariates. Bootstrapping the individual Chevron trap sets implicitly assumes that the covariates are a random sample from a population of potential covariate values. In this case, the range of covariate values will vary over bootstrap samples and so will mean of the converted covariates. This may be appropriate in a case of a one-off analysis of the survey data for any one year but the focus of standardization is to have a fixed set of covariate variables. In addition, changes in the range of the covariates in the bootstrap samples may not support the original fitted model, especially for coefficients of high degree polynomials.

As an alternative, bootstrapping of the residuals from the original model fit to the data may be more appropriately estimate the variance of the standardized survey index. In this case the residuals (in the appropriate scale) are randomly combined with the predicted values to give new observations that are then used to fit the ZINB model. The range of the covariates and mean of the converted covariates will stay the same over all of the bootstrap replications and the variances of the annual indices will be a function of the variability of the residuals from the fitted model.

10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Peer Review Summary Report in accordance with the project guidelines.

    This report constitutes the Review Panel's summary evaluation of the stock assessment and discussion of the Terms of Reference. The Review Panel will complete edits to its report and submit a final document to the SEDAR program for inclusion in the full set of documents associated with SEDAR 41.

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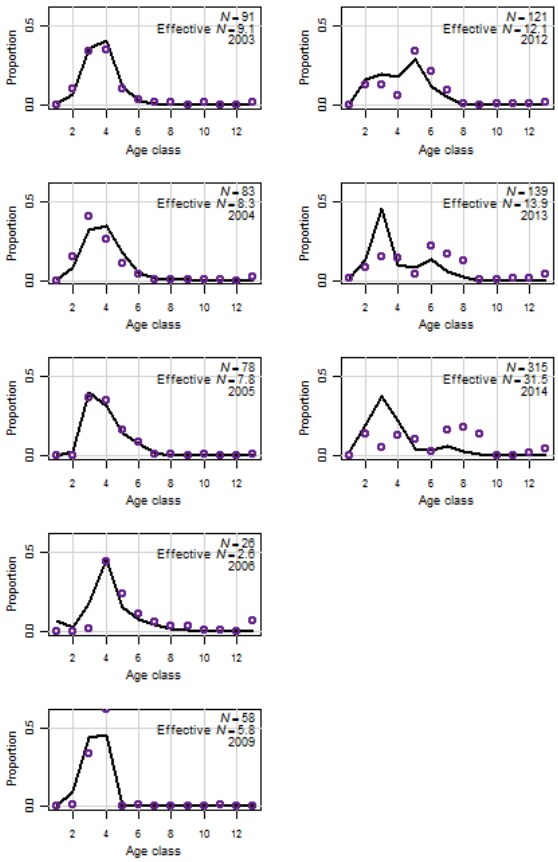
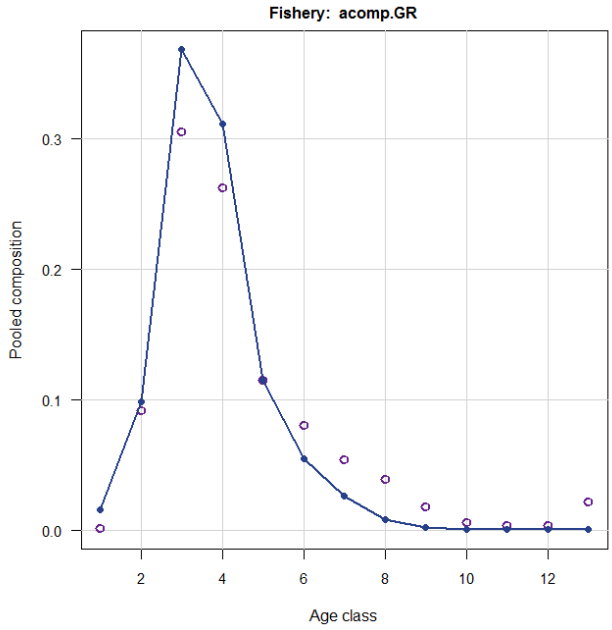
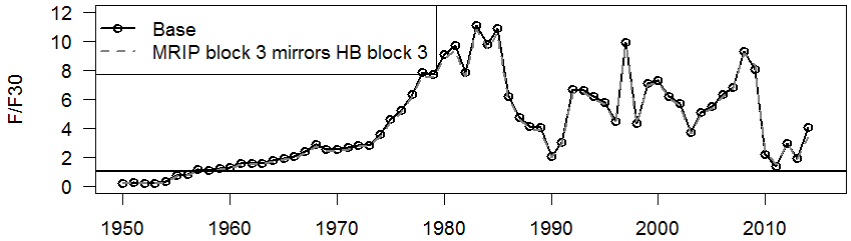
2.2 Summary Results of Analytical Requests

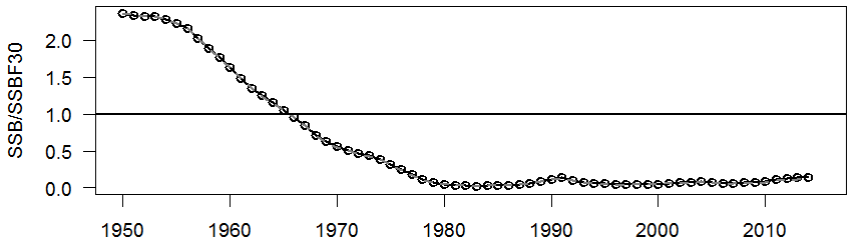
Additional analyses were provided to the Review Panel for consideration at the Panel's request. These materials are provided in Appendix A to the Review Workshop Report.

Appendix A. BAM sensitivity run assuming that selectivity of the general recreational fleet 2010-2014 is the same as the headboat fleet (block 3).




Fishery: acomp.GR
Pooled composition
0.0
0.1
0.2
0.3
2
4
6
8
10
12
Age class


Base
MRIP block 3 mirrors HB block 3
F/F30
0
2
4
6
8
10
12
1950
1960
1970
1980
1990
2000
2010


SSB/SSBF30
0.0
0.5
1.0
1.5
2.0
1950
1960
1970
1980
1990
2000
2010