PROPOSAL FOR CONSIDERATION OF UPDATED ASSESSMENT OF US SOUTH ATLANTIC WRECKFISH

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Background: In October 2011, the National Marine Fisheries Service ("NMFS"), Southeast Regional Office, submitted a document (updated in December 2011) entitled "Depletion-Corrected Average Catch Estimates for U.S. South Atlantic Wreckfish" (Ref. Doc. SERO-LAPP-2011-07) (hereunder referenced as "the DCAC Estimates") to the South Atlantic Fishery Management Council's ("Council") Scientific and Statistical Committee ("SSC"). The SSC reviewed the DCAC Estimates at its November 9, 2010 meeting; formed a subcommittee to review and refine the analysis; and, on November 10, 2010, recommended a new annual catch limit for the Atlantic wreckfish fishery based on this report as peer reviewed.[1]

In November 2012, the document attached, "An Application of Statistical Catch-at-Age Assessment Methodology to Assess US South Atlantic Wreckfish" (hereunder referenced as "SCAA Application", attached hereto as **Attachment 1**), prepared by myself with assistance from Dr. Rebecca Rademeyer, was briefly discussed the SSC meeting in Charleston, S.C. The SCAA Application raises questions about some of the conclusions of the analyses in DCAC Estimates and proposes an alternative methodological approach to the wreckfish assessment. The SSC recommended that the SCAA Application be subjected to a "SEDAR-like review."

The intent of the authors of the SCAA Application was to demonstrate the use of statistical catch-at-age analysis ("SCAA") methods to the data available to assess the Atlantic wreckfish fishery. SCAA methods have been widely used, such as in application to groundfish stocks off the New England coast and in applications elsewhere in the world where they have been subject to peer review both by panels of international scientists during workshops and in articles published in peer-reviewed journals. Given sufficient data (as appears to be the situation in this instance), SCAA is a more refined and likely more reliable form of analysis than the DCAC methodology upon which the current assessment is based.

However, as the SCAA Application document makes clear, the results presented were meant to be illustrative and not definitive. The authors' intent has been to confer with the author of the DCAC analysis and other scientists and technical experts affiliated with the Council and NMFS in order to discuss parameters, data, sensitivity analysis, and model specification. Following such discussion, the full assessment would occur.

Following the November 2012 SSC meeting and the Council's subsequent adoption of the SSC's recommendation in December 2012, discussions with NMFS have occurred as to how to move the analysis forward and fulfill the Council's recommendation to finalize the assessment and subject the results to a "SEDAR-like review." Before those discussions culminated in any final determinations, the Council adopted its new third-party peer review process and determined that this assessment should be subject to that process. The proposal that follows is intended to comply with this new process.

[1] A copy of the DCAC Estimates (December 2010 Update), and the SSC's peer review report are appended hereto as **Attachment**s **2** and **3**.

Proposal: This proposal details a process for further analyses and development of the SCAA Application into a full stock assessment representing "the best scientific information available" for the Atlantic wreckfish fishery. That would be followed by submission to the SSC for peer review. The proposal and its need are set forth in detail below. It follows the format provided in the Council's recently adopted SSC Peer Review Process (approved June 14, 2013).

1) *How the Work Addresses Council Priorities*

The Atlantic wreckfish fishery has not been assessed in any formal manner since 2001, and even prior to then stock status updates were simply produced "in-house" by scientists at the NMFS Beaufort Laboratory.[2] Subsequent, the Atlantic wreckfish fishery has been consistently bumped from the SEDAR schedule due to higher priorities and other constraints. The current "assessment" (*i.e.*, the DCAC Estimate) was the work of a single NMFS scientist, reviewed over the parts of two days during a regular SSC meeting. An informal sub-group acted as a review panel, working with the author in the evening to conduct additional sensitivity runs and characterize uncertainties. This proposal will use a higher order of analysis and will be more rigorously vetted than any prior stock assessment for the stock.

Further, while the wreckfish fishery is small, it is important to the industry, the Council, and NMFS. For fishermen, this individual transferrable quota (ITQ)-managed stock provides fishing opportunities and income throughout the year, during times when other fisheries are closed. The wreckfish was the Council's first ITQ program, both it and NMFS have made catch share programs like this a priority. As such, there is a vested interest in the wreckfish fishery's successful management.

Among recognized priorities this proposal meets are:

- Providing a peer-reviewed assessment for an unreviewed and data-poor fishery;
- Meeting the objective of increasing collaborative scientific efforts with industry;
- Providing the best scientific information available to manage a fishery, consistent with National Standard 2, and doing so in an efficient and cost-effective manner; and
- Fostering support and confidence in science and management measures upon which they are based among the regulated fishing communities.

2) *Data providers, sources, and means of validation*

The data to be used originate with NMFS and is the same utilized in the current DCAC Assessment used to manage the fishery. Specifically, the model uses landings, size frequency, and standardized catch-per-unit-of-effort data. These data are given in tabular or graphical form in Attachment 2 (as well as being listed in tabular form in Appendix A of

[2] *See* Vaughan *et al*. (2001): *Assessment of the Wreckfish Fishery on the Blake Plateau, in*: Sedberry, George R. (ed.), Island in the stream: oceanography and fisheries of the Charleston Bump, reprinted from American Fisheries Society Symposium, number 25, pp. 105-120.

Attachment 1). They have been reviewed by the SSC, although, as far as is known, they have not undergone a data workshop.

One issue that was raised during discussions with NMFS and which will have to be addressed prior to finalization of the assessment is a more detailed review of the CPUE data. This proposal incorporates processes that will help the authors better understand the nature of the date, how it has been standardised, and ensure that it is suitable for the assessment.

3) Scope of the work and documentation of the method

The scope of work includes developing the SCAA Application into a full stock assessment, in consultation with SSC members and NMFS scientists. The work will be undertaken by Drs. Douglas Butterworth and Rebecca Rademeyer, each of whom extensive experience with the SCAA methodology. Each conduct stock assessments for the South African fisheries ministry and Dr. Butterworth consults with governments, international management organizations, and private entities on stock assessment issues.

The basic methodology proposed is set out in Appendix B of Attachment 1. These methods have been widely applied and peer-reviewed internationally. The SCAA model was used in the most recent assessment for South Atlantic red grouper (SEDAR 19 2010). This model also has been used to assess the Atlantic Summer flounder fishery (Terceiro 2009); the Gulf of Maine cod stock (NEFSC 2011); South African hake (Rademeyer & Butterworth 2010); white hake (NESFC 2013); and many others. Finally, the SCAA is part of the NOAA Fisheries Toolbox, see http://nft.nefsc.noaa.gov/ STATCAM.html.

For more information on SCAA, see:

Larry Jacobson, Chris Legault, Loretta O'Brien and Kathy Sosebee (2008). Utility of statistical catch at age models for assessing Northeast groundfish stocks (a workshop report), Northeast Fisheries Science Center, Woods Hole, MA, pp. 31.

Doug S. Butterworth and Rebecca A. Rademeyer (2008). Statistical Catch-at-Age analysis vs ADAPT-VPA: the case of Gulf of Maine cod, GARM-III Working Paper 2.2-a, pp. 70.

4) Participation in review

We acknowledge the SSC's peer review process and commit to participating in the review. We commit to undertaking additional assessment runs deemed necessary by the review body and projections and evaluations of uncertainty as necessary.

A series of webinars and other consultations with NMFS and SSC members is envisaged, culminating in a one or two day roundtable meeting. The authors understand that this process will likely lead to requests for further assessment runs which they will carry out. They would similarly carry out possible similar further such run requests that might emanate from a Peer Review Panel appointed to consider the assessment and associated advice put forward, leading hopefully to a consensus view of the assessment and associated management advice that would be appropriate to put forward.

5) Timeline

The process discussed for the assessment includes an interactive process with a small group appointed by the SSC and Drs. Butterworth and Rademeyer. Following appointment of this group, it is envisaged that initial correspondence would lead to a webinar in the mid-September to late October period to set out runs additional to those already in Attachment 1 to be tabled at a two-day round table meeting of (most) members of the small group and one of the authors (the other participating electronically) to be held in the USA in the week of 11-15 November.

The extent of further work that may be required after that meeting is obviously unclear at this time, but would likely be limited. It is envisaged that after that meeting a hopefully consensus report (containing details of the assessment and associated management advice) would be developed and agreed by correspondence amongst those present at that meeting. This report would be available by mid-January 2014.

Attachment 1

An Application of Statistical Catch-at-Age Assessment Methodology to Assess US South Atlantic Wreckfish

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Summary

The available information on past catches, CPUE and catch-at-length distributions is sufficient to allow the application of Statistical Catch-at-Age methodology to assess the US South Atlantic wreckfish resource. The assessment is carried out for all combinations of four natural mortality (*M*) and three steepness values. A poor log-likelihood plus an inability to reflect a recent upward trend in CPUE rules out the lowest value of M = 0.025 yr^{-1} considered. Although the fit to the length distribution data improves steadily as *M* is increased, estimated abundances become realistically large as *M* approaches 0.1. For the range of *M* (0.05 to 0.075) over which reasonable and realistic fits to the data are obtained, the resource is not overfished and overfishing is not occurring. The corresponding estimates of *MSY* range from 278 to 1293 thousand lbs, and suggest that a yet more optimistic conclusion about the resource can be reached than that drawn from a recent DCAC based analysis, with an appreciable increase in the ABC above its current level of 250 thousand lbs being defensible.

Introduction

The most recent analysis of the South Atlantic wreckfish (*Polyprion americanus*) resource to provide advice on appropriate catch levels (Anon. 2011a) has been carried out using the Depletion Corrected Average Catch (DCAC) formula developed by MacCall (2009). This is a method developed to estimate sustainable yield in data poor situations. It requires relatively few inputs, including the sum of past catches, the number of years over which they have been taken, an estimate of the extent (in relative terms) to which these catches have reduced the biomass, the natural mortality *M*, and a relationship between F_{MSY} and *M*.

However there are more data than those listed amongst the inputs required for DCAC that are available for this wreckfish resource. These include time series of CPUE values and of the distribution of catch-at-length in the fishery. This allows for the application of Statistical Catch at Age (SCAA) methodology to assess the resource. By making use of more of the data available, and also avoiding some of the assumptions needed to derive the DCAC formula, it should be possible to achieve improved (more reliable) estimates of sustainable yield for the resource. This paper pursues initial analyses using the SCAA methodology towards that end.

Data and Methodology

The catch, CPUE and commercial catch-at-length (CAL) data used in the analyses of this paper are listed in Tables in Appendix A. Note the explanation accompanying Table A1 detailing the assumptions made for landings over the 2001-2008 period for which these data are not publically available.

The details of the SCAA assessment methodology are provided in Appendix B.

Because in particular of uncertainty about the most appropriate choice of a value for natural mortality *M* (see Anon. 2011a), assessments have been run across a grid of four values for *M* (0.025, 0.05, 0.075 and 0.1 yr^{-1}), and three values for the steepness *h* (see Appendix B for details) of the Beverton-Holt stock recruitment relationship assumed (0.6, 0.75 and 0.9), which would seem to cover the plausible range for this parameter. Steepness is frequently utilised as a parameter which characterises stock productivity relative to *M* in meta-analyses of comparative population dynamics across different resources. These two parameters were selected for the grid used as they are not well known *a priori* for this stock, and both are highly influential in determining sustainable yield levels with higher values of either reflecting a more productive resource.

Results

The results of applications of the model across the grid of four values of *M* and three of *h* considered are shown in Table 1. Quantities of management importance, such as the value of *MSY*, show greater sensitivity to the value of *M* than to that of *h*. The fit to the CPUE data is optimal for *M* = 0.05, whereas for the CAL data the fit improves monotonically as the value of *M* is increased. These fits are contrasted in Fig. 1: the lowest value of *M* is unable to reflect the recent CPUE increase, whereas higher values manifest an increasing inability to fit to the CPUE decline in the earlier years. For the lower *M* values, the model predicts a much greater proportion of larger fish in the catch than are observed.

Clearly there is some tension between the CPUE and CAL data in the context of fitting the model. However, taking an overview of the results, these would clearly seem to exclude both the lowest and the highest values of *M* considered. The overall fit is considerably worse in log-likelihood terms for *M* = 0.025, whereas for *M*=0.1 the biomass estimates become unrealistically large in absolute terms. Results for *M*=0.05 to 0.075 would seem to span the plausible range, with whichever end of this range is to be favoured depending on the reliability/weight to be accorded to the CPUE relative to the CAL data. More details of the model fits for these two values of *M* and the central choice of 0.75 for steepness *h* are shown in Fig. 2 for *M* = 0.05 and Fig. 3 for *M* = 0.075.

Discussion

Anon. (2011a, Table 2) reports estimates of sustainable yield from 18 different DCAC model parametrizations (including values of *M* ranging from 0.025 to 0.075) which range from 175 to 449 thousand lbs.

For the ranges of natural mortality *M* (0.05 to 0.075) and steepness *h* (0.6 to 0.9) considered plausible for the SCAA model evaluated here, the estimates of *MSY* range from 278 to 1293 thousand lbs. The spawning biomass at *MSY* is estimated to range from 33% to 21% of the corresponding pre-exploitation value K^{sp}, with the current spawning current from some 40% to 300% above this level. Current fishing mortality (*F*) values are below F_{MSY} throughout this range, so that the resource is neither overfished, nor is overfishing occurring.

The Anon. (2011a) concluded that "the level of current take appears sustainable and could potentially be increased (note that the ABC at present is 250 thousand lbs). The results from the arguably more extensive and rigorous approach of this paper suggest that a yet more optimistic conclusion can be drawn, with an appreciable increase in the ABC above its current level being defensible.

The greater flexibility of the SCAA approach compared to DCAC would allow for yet further analyses to be conducted, for example the computation of confidence intervals, or the impact of different functional forms from that assumed for the commercial selectivity-at-length. Before going further, however, it would seem best to first await a wider discussion of these initial results for a form of "first review".

References

Anon. 2011a. Draft for SSC review: Depletion-corrected Average Catch Estimates for U.S. South Atlantic Wreckfish. NOAA Fisheries Service.

Anon. 2011b. Amendment 20A to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region.

MacCall AD. 2009. Depletion corrected average catch: a simple formula for estimating sustainable yields in data poor situations. ICES Journal of Marine Science, 66: 2267-2271.

Peres MB and Haimovici M. 2004. Age and growth of southwestern Atlantic wreckfish Polyprion americanus. Fisheries Research 66: 157-169.

Vaughan DS, Manooch CS and Potts JC. 2005. Assessment of the Wreckfish Fishery on the Blake Plateau. American Fisheries Society Symposium 25: 195-120.

Table 1: Results for the 12 runs presented of this paper, with different *M* and *h* values. Values fixed on **input are bolded**.

Run	1	2	3	4	5	6	7	8	9	10	11	12
h	**0.6**	**0.75**	**0.9**	**0.6**	**0.75**	**0.9**	**0.6**	**0.75**	**0.9**	**0.6**	**0.75**	**0.9**
M	**0.025**	**0.025**	**0.025**	**0.05**	**0.05**	**0.05**	**0.075**	**0.075**	**0.075**	**0.1**	**0.1**	**0.1**
'-lnL:overall	-30.0	-30.8	-31.5	-50.8	-50.3	-49.9	-51.7	-51.6	-51.5	-51.9	-51.9	-51.9
'-lnL:CPUE	-28.7	-29.1	-29.4	-30.1	-29.7	-29.3	-23.6	-23.6	-23.5	-22.1	-22.1	-22.1
'-lnL:CAL	-1.3	-1.8	-2.1	-20.7	-20.7	-20.6	-28.1	-28.0	-28.0	-29.8	-29.8	-29.8
'-lnL:RecRes	-	-	-	-	-	-	-	-	-	-	-	-
γ	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
θ	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ζ	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
K^{sp} (tons)	7852	7745	7670	7842	7957	8062	16632	16823	17046	3268830*	3268850*	3268890*
B^{sp}_{2010} (tons)	2556	2545	2549	3694	3976	4208	13550	13907	14243	3266560	3266730	3266870
B^{sp}_{2010}/K^{sp}	0.33	0.33	0.33	0.47	0.50	0.52	0.81	0.83	0.84	1.00	1.00	1.00
$MSYL^{sp}$	0.32	0.28	0.22	0.33	0.28	0.23	0.33	0.28	0.21	0.32	0.26	0.23
B^{sp}_{MSY} (tons)	2550	2143	1725	2597	2258	1846	5493	4667	3567	1055890	860563	764284
$B^{sp}_{2010}/B^{sp}_{MSY}$	1.00	1.19	1.48	1.42	1.76	2.28	2.47	2.98	3.99	3.09	3.80	4.27
MSY ('000 lb and tons)	151 (68)	186 (84)	220 (100)	278 (126)	350 (159)	419 (190)	846 (384)	1,065 (483)	1,293 (587)	225,066 (102088)	282,456 (128120)	340,745 (154560)
F_{MSY}	0.03	0.04	0.07	0.06	0.10	0.17	0.11	0.20	0.44	0.22	0.46	0.92
F_{2010}	0.05	0.05	0.05	0.04	0.04	0.03	0.01	0.01	0.01	0.00	0.00	0.00
σ_{com}	0.14	0.14	0.14	0.13	0.14	0.14	0.19	0.19	0.19	0.20	0.20	0.20
σ_{len}	0.15	0.15	0.15	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10

* The actual estimate is infinity; the value given is simply where the numerical procedure ceases iterating further; this applies also to other biomass-related estimates.

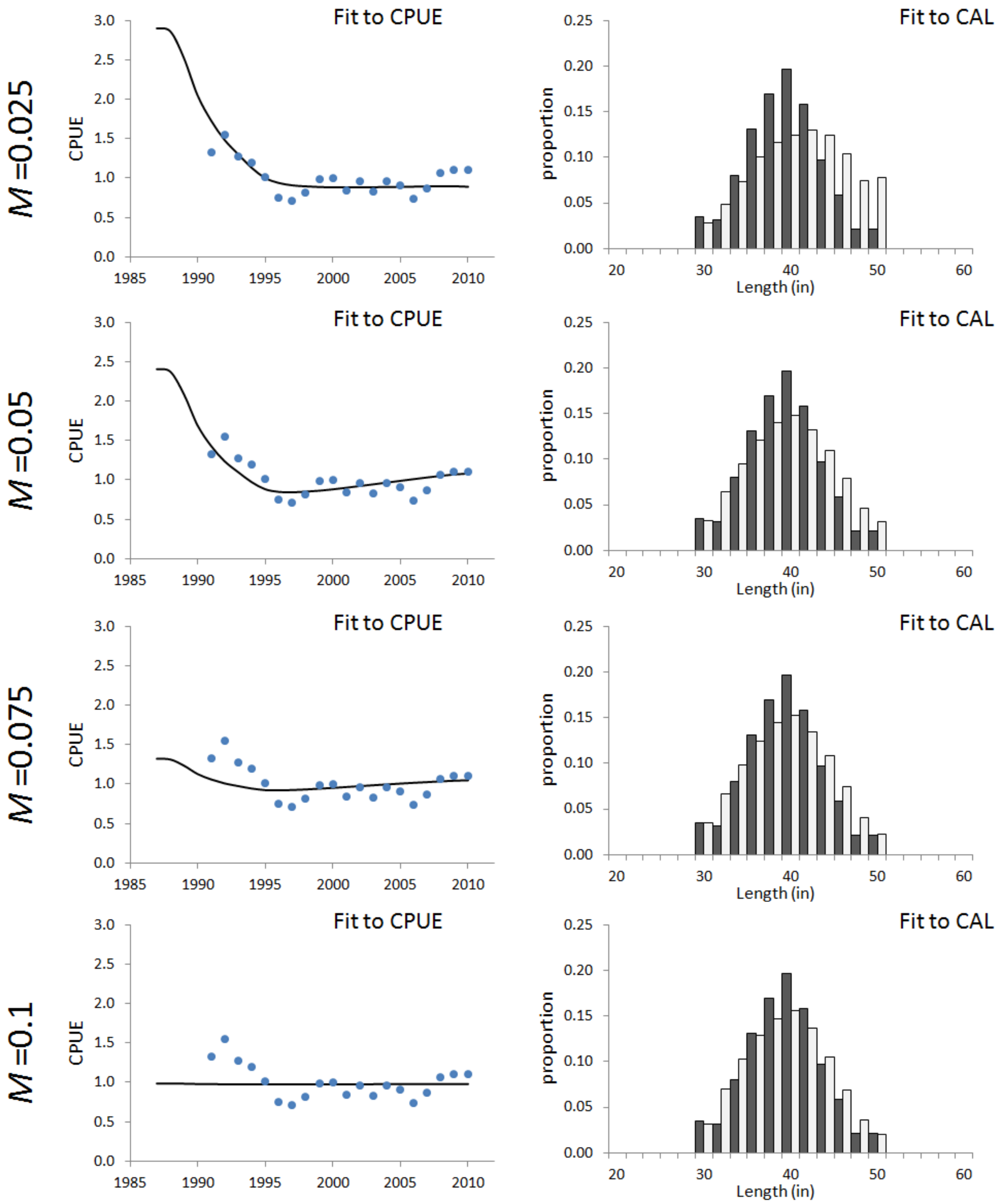


Fig. 1: Fit to the CPUE and CAL data (as averaged over all the years with data available; for the CAL, the filled bars reflect the data) for the four runs with *h*=0.75.

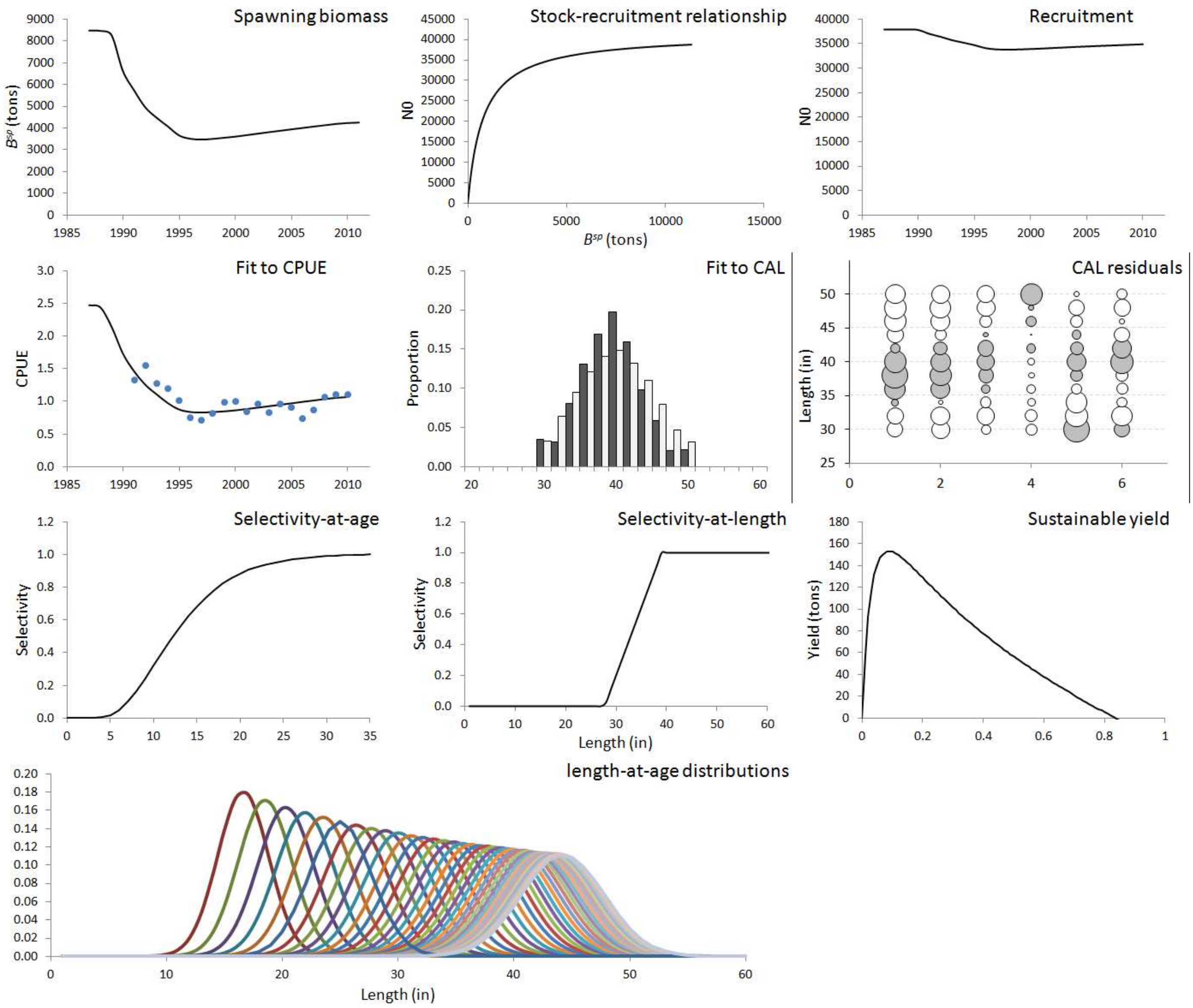


Fig. 2: Results for run 5 (h=0.75, M=0.05). The Fit to CAL is averaged over years for which data are available; for the CAL residuals, the size (area) of the bubble is proportional to the magnitude of the corresponding standardised residual (for positive residuals the bubbles are grey, whereas for negative residuals they are white); for the length-at-age distributions, the distributions, starting from the left, correspond to ages 0, 1, 2, ... , 35.

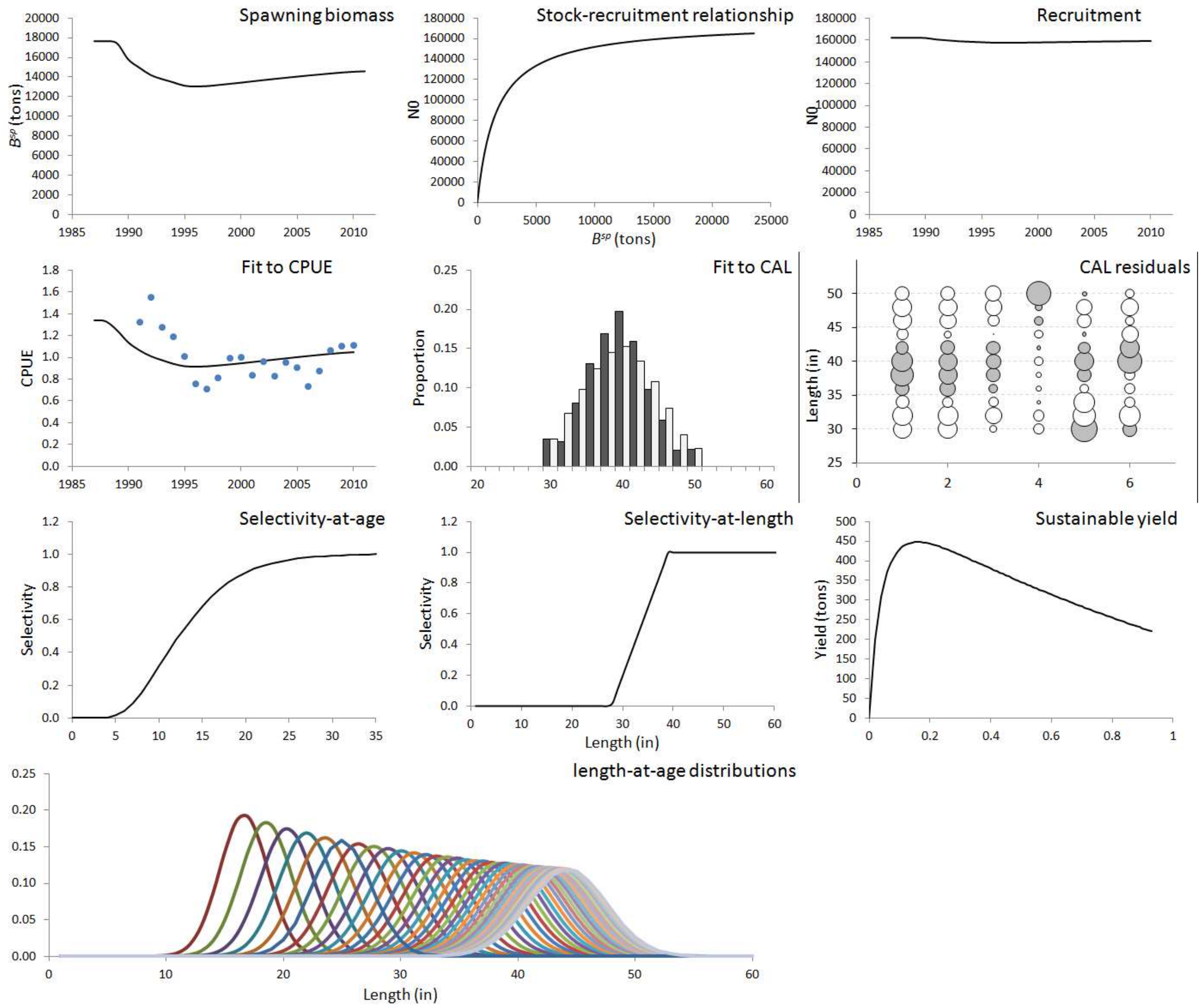


Fig. 3: Results for run 8 (h=0.75, M=0.075). The notations and conventions are as for Fig. 2.

APPENDIX A – Data

Table A1: Annual landings (thousand metric tons) of US south Atlantic wreckfish, 1967-2010 (Anon. 2011b,, Table 3-2).

Year	Landing (tons)	Year	Landing (tons)
1987	12.701	1999	95.481
1988	206.824	2000	76.246
1989	1680.54	2001	76.879*
1990	957.885	2002	76.879*
1991	873.658	2003	76.879*
1992	576.315	2004	76.879*
1993	519.243	2005	76.879*
1994	545.793	2006	76.879*
1995	292.562	2007	76.879*
1996	180.017	2008	76.879*
1997	113.268	2009	98.179
1998	95.618	2010	116.718

*Landings for 2001/2002 through 2008/2009 are confidential because there were fewer than three vessels that fished wreckfish during those years and/or fewer than three dealers purchased wreckfish in those years. Anon. (2011a) gives the sum of landings for 1989-2010 as 15.220 million pounds, so the remainder of the catch was attributed equally to the years 2001-2008. Results in this paper will not be very sensitive to this assumption.

Table A2: Wreckfish standardized catch-per-unit-effort data (summarized in Figure 1 of Anon. 2011a).

Year	Standardized CPUE	Year	Standardized CPUE
1991	1.325	2001	0.837
1992	1.552	2002	0.965
1993	1.272	2003	0.827
1994	1.190	2004	0.957
1995	1.009	2005	0.908
1996	0.755	2006	0.737
1997	0.712	2007	0.872
1998	0.810	2008	1.066
1999	0.991	2009	1.101
2000	1.003	2010	1.110

Table A3: Wreckfish size frequency data (summarized in Figure 3 of Anon. 2011a).

Total Length (in)	Frequency of Measured Lengths by Fishing Year					
	88-91	92-95	96-99	00-03	04-07	08-10
20	0	0	0	0	0	0
22	0	0	0	1	0	0
24	0	0	1	1	22	0
26	3	5	5	3	14	0
28	7	18	35	9	8	3
30	22	37	59	17	15	6
32	93	205	130	64	10	4
34	316	635	276	110	34	16
36	626	1125	406	137	85	21
38	937	1388	501	157	126	25
40	979	1456	526	152	149	46
42	745	1196	455	142	108	36
44	469	785	308	101	75	14
46	226	381	175	82	36	12
48	76	126	55	43	13	3
50	36	54	13	21	8	3
52	14	12	8	18	2	0
54	10	15	4	11	3	0
56	8	10	1	5	1	0
58	1	7	1	4	0	0
60	1	0	0	0	1	0
>60	1	0	0	0	0	0

Appendix B - The Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the SCAA followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is then applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

B.1. Population dynamics

B.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,0} = R_{y+1} \tag{B1}$$

$$N_{y+1,a+1} = \left(N_{y,a}\, e^{-M_a/2} - C_{y,a}\right)e^{-M_a/2} \qquad \text{for } 0 \le a \le m-2 \tag{B2}$$

$$N_{y+1,m} = \left(N_{y,m-1}\, e^{-M_{m-1}/2} - C_{y,m-1}\right)e^{-M_{m-1}/2} + \left(N_{y,m}\, e^{-M_m/2} - C_{y,m}\right)e^{-M_m/2} \tag{B3}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y* (which refers to a calendar year),

R_y is the recruitment (number of 0-year-old fish) at the start of year *y*,

M_a denotes the natural mortality rate for fish of age *a*,

$C_{y,a}$ is the predicted number of fish of age *a* caught in year *y*, and

m is the maximum age considered (taken to be a plus-group).

B.1.2. Recruitment

The number of recruits (i.e. new 0-year old) at the start of year *y* is assumed to be related to the spawning stock size (i.e. the biomass of mature fish) by a deterministic Beverton-Holt stock-recruitment relationship:

$$R_y = \frac{\alpha B_y^{\text{sp}}}{\beta + B_y^{\text{sp}}} \tag{B4}$$

where

α and β are spawning biomass-recruitment relationship parameters,

B_y^{sp} is the spawning biomass at the start of year *y*, computed as:

$$B_y^{\text{sp}} = \sum_{a=0}^{m} f_a w_a^{\text{strt}} N_{y,a} \tag{B5}$$

where

w_a^{strt} is the mass of fish of age *a* at the beginning of the year, and

f_a is the proportion of fish of age *a* that are mature.

In order to work with estimable parameters that are more meaningful biologically, the stock-recruitment relationship is re-parameterised in terms of the pre-exploitation equilibrium spawning biomass, K^{sp}, and the "steepness", *h*, of the stock-recruitment relationship, which is the proportion of the virgin recruitment that is realized at a spawning biomass level of 20% of the virgin spawning biomass. In the fitting procedure applied in this paper, K^{sp} is estimated, while *h* is fixed at either 0.6, 0.75 or 0.9.

B.1.3. Catches-at-age

The catches at age in number in year *y* are given by:

$$C_{y,a} = N_{y,a}\, e^{-M_a/2}\, S_{y,a}\, F_y^* \qquad \text{(B6)}$$

where

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age *a*, caught in year *y*,

F_y^* is the proportion of a fully selected age class that is fished, and

$S_{y,a}$ is the commercial selectivity (i.e. combination of availability and vulnerability to fishing gear) at age *a* for year *y*; when $S_{y,a} = 1$, the age-class *a* is said to be fully selected.

Selectivity is estimated as a function of length (see section B3.1) and then converted to selectivity-at-age:

$$S_{y,a} = \sum_l S_{y,l} A_{a,l} \qquad \text{(B7)}$$

where $A_{a,l}$ is the proportion of fish of age *a* that fall in the length group *l* (i.e., $\sum_l A_{a,l} = 1$ for all ages).

The matrix $A_{a,l}$ is calculated under the assumption that length-at-age is normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$L_a \sim N\left[L_\infty\left(1 - e^{-\kappa(a - t_o)}\right); \theta_a^2\right] \qquad \text{(B8)}$$

where

θ_a is the standard deviation of length-at-age a, which is modelled to be proportional to the expected length-at-age *a*, i.e.:

$$\theta_a = \beta L_\infty \left(1 - e^{-\kappa(a - t_o)}\right)^\gamma \qquad \text{(B9)}$$

with β an estimable parameter and $\gamma = 0.5$ (a value which was found to lead to reasonable fits to the data).

The model estimate of the mid-year exploitable ("available") component of biomass is calculated by converting the numbers-at-age into mid-year mass-at-age (using the individual weights of the landed fish) and applying natural and fishing mortality for half the year:

$$B_y^{\text{ex}} = \sum_{a=0}^{m} \tilde{w}_{y,a}^{\text{mid}} S_{y,a} N_{y,a} e^{-M_a/2}(1 - S_{y,a}F_y^*/2) \quad \text{(B10)}$$

where

$\tilde{w}_{y,a}^{\text{mid}}$ is the selectivity-weighted mid-year weight-at-age *a* landed in year y, and

$$\tilde{w}_{y,a}^{\text{mid}} = \sum_l S_{y,l} w_l A_{a,l} \Big/ \sum_l S_{y,l} A_{a,l}$$

with

w_l is the weight of fish of length *l*.

B.1.4. Initial conditions

In general, the first year for which annual catch data are available may not correspond to the first year of (appreciable) exploitation, so that one cannot necessarily make the assumption in the application of this SCAA model that this initial year reflects a population (and its age-structure) at pre-exploitation equilibrium. For the first year (y_0) considered in the model therefore, the stock is assumed to be at a fraction (θ) of its pre-exploitation biomass, i.e.:

$$B_{y_0}^{\text{sp}} = \theta \cdot K^{\text{sp}} \quad \text{(B11)}$$

with the starting age structure:

$$N_{y_0,a} = R_{\text{start}} N_{\text{start},a} \qquad \text{for } 1 \le a \le m \quad \text{(B12)}$$

where

$$N_{\text{start},0} = 1 \quad \text{(B13)}$$

$$N_{\text{start},a} = N_{\text{start},a-1} e^{-M_{a-1}}(1 - \phi S_{a-1}) \qquad \text{for } 1 \le a \le m-1 \quad \text{(B14)}$$

$$N_{\text{start},m} = N_{\text{start},m-1} e^{-M_{m-1}}(1 - \phi S_{m-1}) \Big/ (1 - e^{-M_m}(1 - \phi S_m)) \quad \text{(B15)}$$

where ϕ characterises the average fishing proportion over the years immediately preceding y_0.

For the applications considered here however, the population starts at its pre-exploitation equilibrium level (*K*) with an equilibrium age-structure, where

$$R_0 = K^{sp} \Bigg/ \left[\sum_{a=1}^{m-1} f_a w_a^{\text{strt}} e^{-\sum_{a'=0}^{a-1} M_{a'}} + f_m w_m^{\text{strt}} e^{\sum_{a'=0}^{m-1} M_{a'}} \right] \quad \text{(B16)}$$

In all the applications considered in this paper, however, the stock has been assumed to be at its pre-exploitation equilibrium level with the associated age structure at the start of 1987.

B.2. The likelihood function

The model is fit to a CPUE index and commercial catch-at-length data to estimate model parameters. Contributions by each of these to the negative of the (penalised) log-likelihood (- $\ell\text{n}L$) are as follows.

B.2.1 CPUE relative abundance data

The likelihood is calculated assuming that the observed CPUE abundance is log-normally distributed about its expected value:

$$I_y = \hat{I}_y \exp(\varepsilon_y) \quad \text{or} \quad \varepsilon_y = \ell n(I_y) - \ell n(\hat{I}_y) \tag{B17}$$

where

I_y is the CPUE abundance index for year *y*,

$\hat{I}_y = \hat{q}\ \hat{B}_y^{\text{ex}}$ is the corresponding model estimate, where $\hat{B}_y^{\text{ex}}$ is the model estimate of exploitable resource biomass as described in equation B10,

$\hat{q}$ is the constant of proportionality (catchability) for the CPUE abundance series, and

ε_y from $N\left(0,(\sigma_y)^2\right)$.

The contribution of the CPUE data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell n\, L^{\text{CPUE}} = \sum_y \left\{ \ell n\left(\sigma_{com}\right) + \left(\varepsilon_y\right)^2 / \left(2\sigma_{com}^2\right) \right\} \tag{B18}$$

where

σ_{com} is the standard deviation of the residuals for the logarithm of the CPUE index, which is estimated in the fitting procedure by its maximum likelihood value:

$$\sigma_{com} = \sqrt{\frac{1}{n}\sum_y \left[\ell n\left(I_y\right) - \ell n\left(\hat{I}_y\right)\right]^2} \tag{B19}$$

where *n* is the number of data points for the CPUE index.

The catchability coefficient q for the CPUE abundance index is estimated by its maximum likelihood value:

$$\ell n\, \hat{q} = 1/n \sum_y \left(\ln I_y - \ln \hat{B}_y^{\text{ex}}\right) \tag{B20}$$

B.2.2. Commercial catches-at-length

The contribution of the catch-at-length data to the negative of the log-likelihood function under the assumption of an "adjusted" lognormal error distribution is given by:

$$-\ell n\, L^{\text{CAL}} = w_{len} \sum_{y^*} \sum_l \left[\ell n\left(\sigma_{\text{len}} / \sqrt{p_{y^*,l}}\right) + p_{y^*,l}\left(\ell n\, p_{y^*,l} - \ell n\, \hat{p}_{y^*,l}\right)^2 / 2\left(\sigma_{\text{len}}\right)^2 \right] \tag{B21}$$

$p_{y^*,l} = C_{y^*,l} \Big/ \sum_{l'} C_{y^*,l'}$ is the average observed proportion of fish caught between years y_1 and y_2 that are of length *l*,

$\hat{p}_{y*,l} = \sum_{y=y_1}^{y_2} \hat{C}_{y,l} \bigg/ \sum_{y=y_1}^{y_2} \sum_{l'} \hat{C}_{y,l'}$ is the model-predicted average proportion of fish caught between years y_1 and y_2 that are of length l,

where

$$\hat{C}_{y,l} = N_{y,a}\ A_{a,l}\ S_{y,l} e^{-M_a/2} F_y \qquad \text{(B22)}$$

and

σ_{len} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_{\mathrm{len}} = \sqrt{\sum_{y*} \sum_{l} p_{y*,l} \left(\ell n\, p_{y*,l} - \ell n\, \hat{p}_{y*,l}\right)^2 / \sum_{y*} \sum_{a} 1} \qquad \text{(B23)}$$

The log-normal error distribution underlying equation (B21) is chosen on the grounds that (assuming no ageing error) variability is likely dominated by a combination of interannual variation in the distribution of fishing effort, and fluctuations (partly as a consequence of such variations) in selectivity-at-length, which suggests that the assumption of a constant coefficient of variation is appropriate. However, for lengths poorly represented in the sample, sampling variability considerations must at some stage start to dominate the variance. To take this into account in a simple manner, motivated by binomial distribution properties, the observed proportions are used for weighting so that undue importance is not attached to data based upon a few samples only.

Commercial catches-at-length are incorporated in the likelihood function using equation (B21), for which the summation over length l is taken from age l_{minus}= 30 in (considered as a minus group) to l_{plus}=50 in (a plus group).

The w_{len} weighting factor may be set to a value less than 1 to downweight the contribution of the catch-at-length data (which tend to be positively correlated between adjacent length groups) to the overall negative log-likelihood compared to that of the CPUE data. The calculations reported in this paper have, however, all been carried out with $w_{len} = 1$.

B.3. Model parameters

B.3.1. Fishing selectivity-at-length:

The commercial fishing selectivity, S_l , takes on the following form:

$$S_l = \begin{cases} 0 & \text{if } l < l_1 \\ (l - l_1)/(l_2 - l_1) & \text{if } l_1 \le l \le l_2 \\ 1 & \text{if } l > l_1 \end{cases} \qquad \text{(24)}$$

with l_1 and l_2 estimated in the fitting procedure.

The selectivity is assume to stay constant over time.

B.3.2. Biological parameters

Growth curve:

$$l_a = l_\infty\left(1 - e^{-\kappa(a-t_o)}\right) \tag{25}$$

where

l_∞=121 cm, κ=0.063 yr^{-1} and t_0=-6.3 yr^{-1} (from Peres and Haimovici, 2004).

Weight-at-age:

Begin-year:

$$w_a^{\text{strt}} = \alpha\left(l_a\right)^\beta \tag{26}$$

and mid-year:

$$w_a^{\text{mid}} = \alpha\left(l_{a+1/2}\right)^\beta$$

where α=6.20572x10^{-6} and β=3.21 (from Peres and Haimovici, 2004, with α taken as the average of the male and female values), and units in terms of gm and cm.

Percentage maturity-at-age:

Maturity-at-age is assumed to be 0 below 5, and 100% at age 8 with a linear relationship between these two ages (from Vaughan *et al*. 2001)

Natural mortality M:

Taken to be either 0.025, 0.05, 0.075 or 0.1 yr^{-1} (age-independent).

Attachment 2

Depletion-Corrected Average Catch Estimates for U.S. South Atlantic Wreckfish
NOAA Fisheries Service
Southeast Regional Office
October 23, 2011; updated December 20, 2011
SERO-LAPP-2011-07

Introduction

Wreckfish *Polyprion americanus* is large bass distributed globally in temperate waters, including the U.S. South Atlantic (Heemstra 1986). They constitute a single genetic stock across the north Atlantic ocean (Sedberry et al. 1996). Significant catches are reported off Spain, Portugal, and the Blake Plateau of the U.S. South Atlantic (Sadovy 2003). Wreckfish are caught at depths ranging from 1,500-2,400 feet over high relief and flat hard bottom habitat (Sedberry et al. 1999). Spawning occurs in late winter and early spring, and juveniles are pelagic to 20-24 inches total length (TL), associating with floating seaweeds and wreckage.

In 1990, the South Atlantic Fishery Management Council (SAFMC) added wreckfish to the Snapper-Grouper Fishery Management Plan due to a rapid increase in landings and effort that resulted in overfishing (SAFMC 1990; Vaughn et al. 2001). In 1991, the SAFMC approved an individual transferable quota (ITQ) program for commercial wreckfish to address excess capacity and economic inefficiency in the wreckfish fleet (SAFMC 1991). The ITQ program allocated shares of quota to eligible participants; initial allocations were partially based on landings histories. Since the 1992/93 fishing year, wreckfish have been managed under an ITQ program, a two-million pound quota, and a fishing season from April 16-January 14 each year. A fixed seasonal closure from January 15-April 15 each year is in effect to protect wreckfish during peak spawning.

The Magnuson-Stevens Reauthorization Act of 2006 requires regional fishery management councils to implement annual catch limits (ACLs) and accountability measures (AMs) for all stocks under federal management by 2011. In August 2010, the SAFMC's Scientific and Statistical Committee (SSC) established an acceptable biological catch (ABC) for wreckfish of 0.250 million pounds (mp) whole weight (ww). The SAFMC later allocated 95% of the ABC to the commercial wreckfish sector and set a commercial quota of 0.2375 mp ww (SAFMC 2011). This quota is 88% less than the current 2 mp ww commercial quota and is based on recent, non-confidential average catches (SAFMC 2010). At their August 2010 meeting, the SSC recommended conducting Depletion-Corrected Average Catch (DCAC) or Depletion-Based Stock Reduction Analysis (DB-SRA) in 2011 to compare with their 2010 catch-only recommendation (SAFMC 2010). The intent of this analysis is to estimate a sustainable yield level for the U.S. segment of the north Atlantic wreckfish stock using DCAC analysis (MacCall 2009) as recommended by the SSC.

Methods

Depletion-Corrected Average Catch Formula

MacCall (2009) developed the DCAC formula to estimate sustainable yield in data poor situations. The formula is an extension of the potential-yield formula developed by Alverson and Pereyra (1969) and (Gulland 1970). DCAC divides landed catches over an extended period of time into a sustainable yield component and a windfall component associated with a reduction in stock biomass (MacCall 2009). The

DCAC formula requires the following input parameters: 1) sum of catches; 2) number of years in the catch time series; 3) estimated reduction in biomass (Δ; expressed as a ratio); 4) natural mortality rate (M); and, 5) an assumed relationship (*c*) between the fishing mortality rate at maximum sustainable yield (F_{msy}) and M. The model also requires inputs on the coefficient of variation surrounding the sum of catches and standard deviations for M, *c, and* Δ. Users can also specify the type of distribution for *c* (lognormal or normal) and Δ (beta bounded, lognormal, or normal).

Sustainable yield (Y_{sust}) is calculated as:

$$Ysust = \frac{\sum C}{n + W/Y_{pot}} \qquad (1)$$

where *C* is the sum of catches, *n* is the number of years in the catch time series, and W/Y_{pot} is the windfall ratio. The windfall ratio is calculated as:

$$\frac{W}{Y_{pot}} = \frac{\Delta B_0}{0.4cM\mathrm{B}_0} = \frac{\Delta}{0.4cM} \qquad (2)$$

where *Δ is the decline in biomass from the first year to the last year of the catch time series relative to the unfished biomass level, c is the tuning adjustment for setting* F_{msy} *relative to M, M is the natural mortality rate,* B_{fyr} is biomass in the first year of the time series, B_{lyr} is biomass in the last year of the time series, and B_0 is the unfished biomass level.

Uncertainty in DCAC estimates is accomplished by Monte Carlo simulation. The distribution of sustainable catches is conditioned on the distribution of input parameters. For further details regarding the DCAC formula see MacCall (2009). The model, as well as reference manual for using DCAC, can be downloaded from the NOAA Fisheries Service stock assessment toolbox at: http://nft.nefsc.noaa.gov.

Model Inputs

<u>*Sum of Landings (C)*</u>

Wreckfish landings in whole weight (ww) were obtained from the Accumulated Landings System for 1987-1990 and from wreckfish ITQ logbooks for 1991-2010 (Gloeckner, pers. comm.). Table 1 summarizes total landings reported from 1987 through present and from 1989 through present. Two catch time periods were used in the DCAC analysis to explore the sensitivity of model results to the total sum of catches. Because DCAC calculates a windfall reduction in biomass, 1989 was chosen for sensitivity runs because landings significantly increased between the 1988 and 1989 fishing seasons. The highest reported annual landings were in 1990 (3.812 mp ww).

Table 1. Total wreckfish commercial landings (million pounds whole weight) for two different time periods and the number of years included in the sum of catches.

Years	Sum of Landings (mp ww)	Number of Years of Landings
1987-2010	15.556	24
1989-2010	15.220	22

Natural Mortality (M)

Vaughn et al. (2001) estimated wreckfish M from life history characteristics using the approaches of Pauly (1979) and Hoenig (1983). M ranged from 0.06-0.09 using Pauly (1979) and 0.11-0.14 using Hoenig (1983). Estimates of M for Hoenig (1983) were based on maximum ages of 30-39 years. More recent age and growth data from Peres and Haimovici (2004) indicate wreckfish may live considerably longer (up to 76 years). Based on Hoenig (1983) and Hewitt and Hoenig (2005) and a maximum age of 76 years, M ranged from 0.04-0.06. Vaughn et al. (2001) recommended 0.1 be used as the preferred estimate of M. This analysis evaluated the sensitivity of DCAC estimates for M = 0.025, 0.05, 0.075, and 0.1. A coefficient of variation (CV) for M of 0.5 was used for all sensitivity runs. MacCall (2009) indicated a CV of 0.5 should be used as a minimal default value and there appears to be no justification for assuming a CV<0.5 for data poor stocks.

Change in Biomass (Δ)

MacCall (2009) indicates that it is difficult to estimate the fractional depletion in biomass (Δ) and that informed judgment or expert opinions from fishermen may be useful in estimating Δ. To assess the depletion in wreckfish stock biomass, nominal and standardized catch per unit effort (CPUE) indices were developed using wreckfish logbook data from 1992 to 2010. The top 3 vessels reporting landings during the entire catch time series were selected for developing the CPUE index since these were the only vessels reporting landings continuously during the catch time series. These three vessels accounted for approximately 30% of the annual landings from 1992-1995 and 50% or more of the landings since 1996.

Variables reported in the wreckfish logbook data set include, but are not limited to: wreckfish permit number, vessel identification number, dealer number, state, day, month, and year of landing, days fished, lines fished, hooks per line, hours fished, pounds and numbers of wreckfish landed, area fished, and depth of fishing. A fixed-effects general linear model (using PROC GLM; SAS Institute 2008) was used to develop the CPUE index. The dependent variable was pounds landed per day. Other dependent variables were also explored, including numbers landed per day, pounds landed per hook-hour fished, and pounds landed per hook fished. Because DCAC requires specification of a windfall reduction in biomass, CPUE based on pounds caught per day was considered a better representation of changes in biomass than numbers caught per day. Hook-hours and hooks fished provided more temporally-refined metrics of effort, but were not used because plots of CPUE versus effort revealed decreasing catchability with increasing effort. In contrast, there was no trend in CPUE versus days-fished.

Wreckfish logbooks allow landings to be entered in both numbers and pounds for up to five additional species. If snapper-grouper, dolphin, wahoo, or mackerels are caught while fishing for wreckfish, then landings and effort for those species must be reported via separate coastal logbooks to the Southeast Fisheries Science Center. Landings (in pounds) of species other than wreckfish were summed from wreckfish logbooks. Landings of species other than wreckfish were also summed for trips reported in coastal logbooks and trip records were merged with wreckfish logbook data using vessel identification number and month, day, and year of landing. Of the 701 wreckfish logbook records, 22 had matching coastal logbook records. For each wreckfish trip, the ratio of wreckfish landings to total landings was determined. Total landings were determined using the maximum landings reported for all other species in either the wreckfish logbook or coastal logbook. Trips were then eliminated if less than 90% of the trip's total landings were not wreckfish. Of the 701 wreckfish trips, 44 were eliminated from CPUE analysis. These trips were eliminated to ensure only directly trips targeting wreckfish were included in CPUE calculations.

Log transformation of the dependent variable failed to satisfy GLM assumptions. A square root transformation of the dependent variable was performed to satisfy assumptions of normality and constant variance. Six factors were considered as possible influences on CPUE: fishing year, season (Apr-Jul, Aug-Oct, Nov-Jan) nested within fishing year, vessel ID, total hooks (i.e. lines fished*hooks per line), area fished, and depth fished. Factors were added to the base model using a forward stepwise procedure (α=0.05). Factors included in the final model were: fishing year, vessel ID, total hooks, and season nested within fishing year (Appendix 1). These variables explained 57.4% of the variation in CPUE. To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean CPUE of the series.

Figure 1 shows the nominal and standardized trend in catch per day from 1992-2010. Nominal and standardized catch rates declined from 1992-1997. From 1998 through 2005, standardized catch rates were stable, while nominal catch rates gradually declined. Since 2007, standardized and nominal catch rates have increased. The reduction in CPUE from 1992 to 2010 was 35% for nominal and standardized indices. Reductions in CPUE from 1992 to 2006 were ~57-58%. A 35% change in biomass was used as the lower bound for model runs and a 60% change in biomass was used as the upper bound for model runs. A middle run was also conducted using a 50% change in biomass. This run was based on personal communication with Paul Reiss (September 9, 2011), a wreckfish shareholder who currently lands a significant portion of the annual wreckfish landings. Mr. Reiss indicated that a 50% reduction in his CPUE has likely occurred since landings peaked in the early 1990s. Mr. Reiss also indicated that his CPUE has been increasing in recent fishing years.

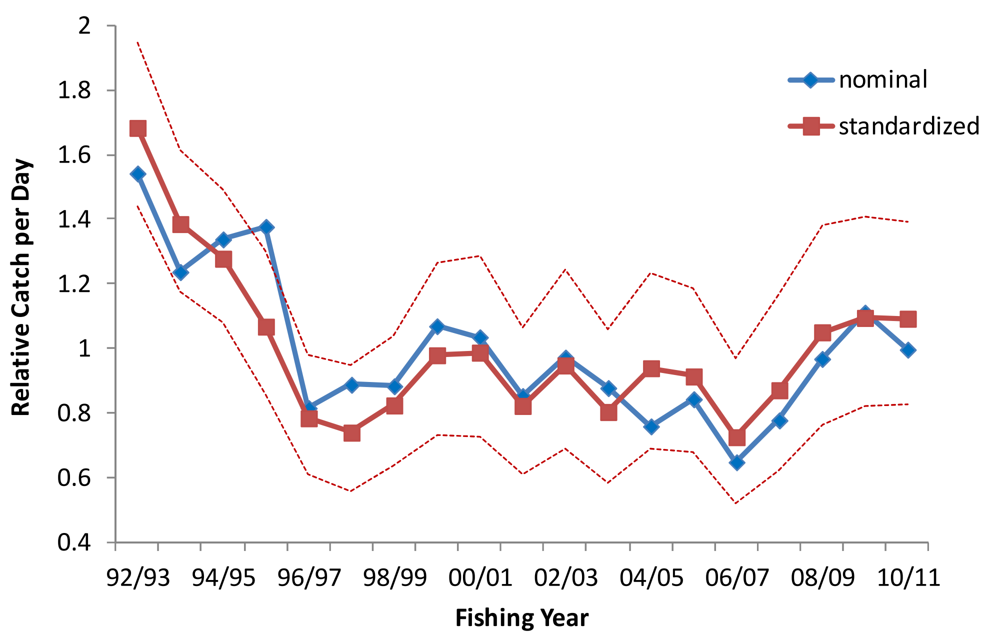


Figure 1. Nominal and standardized index of wreckfish abundance (± 80% confidence intervals) for High-3 fishing vessels, 1992-2010.

Fmsy relative to M (c)

There is currently no estimate for F_{msy}. M is often considered a conservative proxy for F_{msy} (Restrepo et al. 1998) and MacCall (2009) noted that a ratio of F_{msy} to M = 1 may be considered a target or upper limit for many stocks. Walters and Martell (2004) indicated ratios = 0.75-0.8 may be appropriate in data poor situations and that the ratio of F_{msy} to M may be as low as 0.6 for highly vulnerable stocks. For this analysis, sensitivity runs were conducted using F_{msy} to M ratios of 0.8 and 1.0.

Sensitivity Runs

Eighteen sensitivity runs were performed to evaluate how changes to various model parameters affect estimates of sustainable yield (Table 2). Runs 1-3 explored how changes in biomass affected yield estimates (35%, 50%, and 60%). Runs 4-6 explored how estimates of yield were affected by a different landing time series (1987-2010 vs. 1989-2010). Runs 7-15 evaluated how estimates of yield were affected by higher and lower assumed natural mortality rates (0.05 vs. 0.025, 0.075, and 0.10). Runs 16-18 evaluated how estimates of yield were affected by a lower F_{msy} to M ratio (0.8 vs 1.0).

Length-frequencies

Wreckfish lengths were obtained from the Trip Interview Program to evaluate trends in wreckfish length over time. A total of 16,962 length measurements collected between 1988 and 2010 were available. Lengths were reported as total length, fork length, or standard length in both centimeters and millimeters and were converted to total length in inches using length conversions summarized in Vaughn et al (2001). Sample sizes varied greatly over time, with most length measurements collected prior to 2000 (n = 14,984 lengths 1988-1999; n = 1,978 lengths 2000-2010). Most wreckfish length measurements were from South Carolina (52.6%) and Florida (36.1%), followed by North Carolina (10.3%) and Georgia (1.0%). Lengths were aggregated across years (1988-1991, … , 2008-2010) to determine if changes in length-frequency distributions have occurred over time. A two factor general linear model (α = 0.05) was used to test if the mean size of wreckfish was significantly affected by time period, state landed (Florida, Georgia, and other South Atlantic states), and the interaction between state landed and time period. Bonferroni t-tests were used to conduct multiple comparisons of main effects and summary statistics were generated to facilitate comparisons of mean, median, minimum, and maximum lengths over time by state of landing.

Results

Estimated DCAC yields

Figure 2 and Table 2 summarize estimated yields from Monte Carlo simulations using eighteen different DCAC model parameterizations for wreckfish. Estimated sustainable yields ranged from 0.175 to 0.449 mp ww. The lowest yield was based on model run 9, which assumed a 60% windfall reduction in biomass and an M of 0.025. The highest yield was based on model run 13, which assumed a 35% windfall reduction in biomass and an M = 0.1. Of the 18 model runs, 11 estimated a higher mean annual yield for wreckfish than the current 0.250 mp ABC, three estimated a lower mean yield than the current ABC, and four estimated a mean yield comparable to the current ABC. Mean annual yields for model runs 1-3 and 4-6 were nearly identical, indicating the time series of catch data had little influence on model results. Higher assumed M increased the estimated mean annual yields (runs 10-15), while lower M (runs 7-9) and an F_{msy} to M ratio equal to 0.8 decreased the estimated yields (runs 16-18).

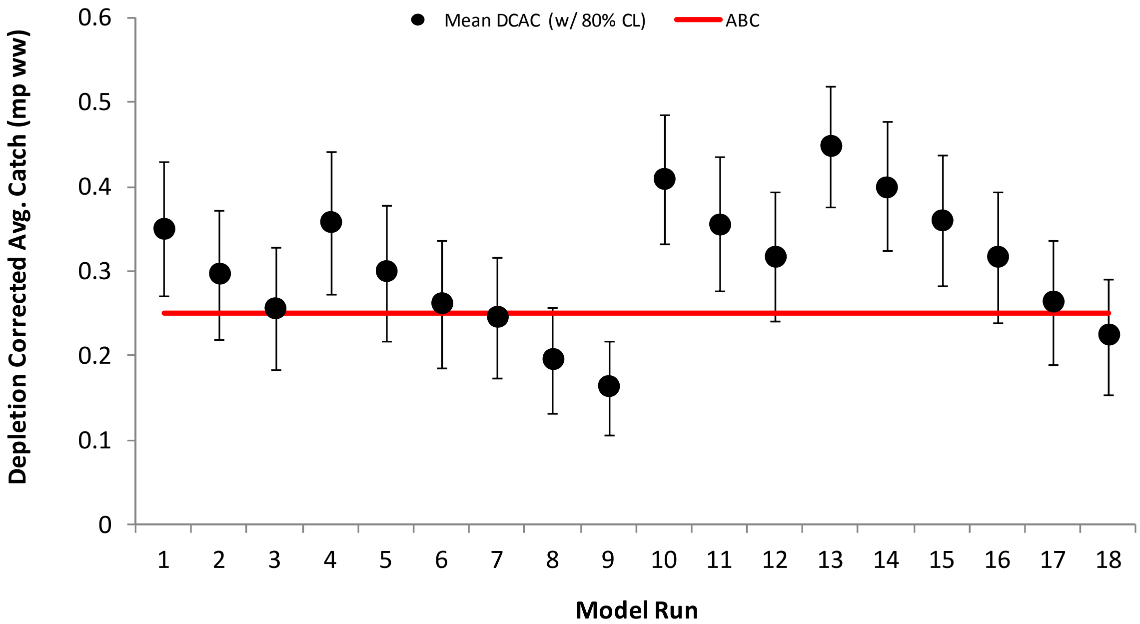


Figure 2. Mean yields (± 80% CL) estimated for eighteen different DCAC model parameterizations for wreckfish.

Length-frequencies

Length-frequency distributions of wreckfish were significantly different for time period (F = 78.6, p <0.0001), state landed (F = 90.45, p < 0.0001), and the interaction of time period by state landed (F = 61.7, p < 0.0001). Multiple comparison tests indicated that significant differences in mean length between time periods were no greater than 0.8 inches TL and significant differences in mean length between states of landing were no greater than 0.4 inches TL. There were no discernable trends in mean length over time by state of landing (Table 3, Figure 3). Lengths of 38 to 42 inches TL were the most frequent in all six aggregated time periods. Lengths collected during 2000-2003 showed the broadest distribution and highest proportion of fish above 44 inches TL, while lengths collected during 2004-2007 showed the largest proportion of fish collected below 28 inches TL.

Table 2. Estimated yields resulting from Monte Carlo simulations using eighteen DCAC model parameterizations for wreckfish.

Parameter	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**	**Run 9**	**Run 10**	**Run 11**	**Run 12**
Fishery performance												
Catch (mp ww)	15.556	15.556	15.556	15.220	15.220	15.220	15.556	15.556	15.556	15.556	15.556	15.556
Number of years	24	24	24	22	22	22	24	24	24	24	24	24
CV of sum of catch	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Average catch (mp ww)	0.648	0.648	0.648	0.692	0.692	0.692	0.648	0.648	0.648	0.648	0.648	0.648
DCAC												
Assumed M (yr^{-1})	0.05	0.05	0.05	0.05	0.05	0.05	0.025	0.025	0.025	0.075	0.075	0.075
Standard deviation ln(M) (yr -1)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Assumed Biomass Change (Δ)	0.35	0.5	0.6	0.35	0.5	0.6	0.35	0.5	0.6	0.35	0.5	0.6
Standard Deviation Δ	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Assumed c	1	1	1	1	1	1	1	1	1	1	1	1
Standard Deviation c	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Monte Carlo results (n=10,000)												
Monte Carlo mean (mp ww)	**0.351**	**0.298**	**0.269**	**0.359**	**0.301**	**0.275**	**0.247**	**0.197**	**0.175**	**0.410**	**0.356**	**0.330**
Percentiles (%)												
5	0.203	0.161	0.140	0.205	0.158	0.141	0.122	0.092	0.078	0.262	0.209	0.188
20	0.271	0.219	0.194	0.274	0.218	0.197	0.174	0.132	0.114	0.333	0.277	0.253
50	0.351	0.293	0.262	0.356	0.296	0.269	0.240	0.188	0.166	0.411	0.354	0.328
80	0.429	0.373	0.341	0.441	0.379	0.351	0.316	0.258	0.230	0.485	0.436	0.407
95	0.502	0.450	0.419	0.521	0.463	0.433	0.395	0.334	0.306	0.556	0.509	0.482

Table 2 (cont.) Estimated yields resulting from Monte Carlo simulations using eighteen DCAC model parameterizations for wreckfish.

Parameter	**Run 13**	**Run 14**	**Run 15**	**Run 16**	**Run 17**	**Run 18**
Fishery performance						
Catch (mp ww)	15.556	15.556	15.556	15.556	15.556	15.556
Number of years	24	24	24	24	24	24
CV of sum of catch	0.1	0.1	0.1	0.1	0.1	0.1
Average catch (mp ww)	0.648	0.648	0.648	0.648	0.648	0.648
DCAC						
Assumed M (yr^{-1})	0.1	0.1	0.1	0.05	0.05	0.05
Standard deviation ln(M) (yr -1)	0.5	0.5	0.5	0.5	0.5	0.5
Assumed Biomass Change (Δ)	0.35	0.5	0.6	0.35	0.5	0.6
Standard Deviation Δ	0.2	0.2	0.2	0.2	0.2	0.2
Assumed c	1	1	1	0.8	0.8	0.8
Standard Deviation c	0.2	0.2	0.2	0.2	0.2	0.2
Monte Carlo results (n=10,000)						
Monte Carlo mean (mp ww)	**0.449**	**0.400**	**0.373**	**0.318**	**0.265**	**0.237**
Percentiles (%)						
5	0.307	0.254	0.228	0.175	0.136	0.116
20	0.377	0.324	0.295	0.239	0.190	0.165
50	0.450	0.401	0.372	0.316	0.259	0.229
80	0.520	0.477	0.449	0.395	0.337	0.305
95	0.583	0.545	0.517	0.472	0.414	0.386

Table 3. Mean, median, minimum, and maximum wreckfish total lengths (in) by state landed for six time periods between 1988 and 2010.

State	Time Period	n	Mean	Median	Min	Max
eFL	1988-1991	718	37.9	37.8	26	60
	1992-1995	4,002	38.3	38.2	25.2	57.6
	1996-1999	781	38.2	38.3	25.2	52
	2000-2003	30	39.4	40	29.8	47.1
	2004-2007	509	38.7	38.9	23.9	55.1
	2008-2010	79	39.5	39.6	28.3	49.1
SC	1988-1991	2,376	38.9	38.6	25.6	58.7
	1992-1995	3,047	38.9	38.6	25.2	57.5
	1996-1999	2,178	38.1	38.2	23.6	57.6
	2000-2003	1,043	38.9	38.7	24.8	57.6
	2004-2007	172	39	38.5	24.8	59.6
	2008-2010	110	37.6	38.3	27.2	49.4
GA/NC	1988-1991	1,476	38.9	38.6	26.8	55.1
	1992-1995	406	38.8	38.6	27.6	55.5
	1996-1999	0	--	--	--	--
	2000-2003	5	26.4	24.8	21.5	32.6
	2004-2007	30	23.6	23.1	22.1	28.7
	2008-2010	0	--	--	--	--

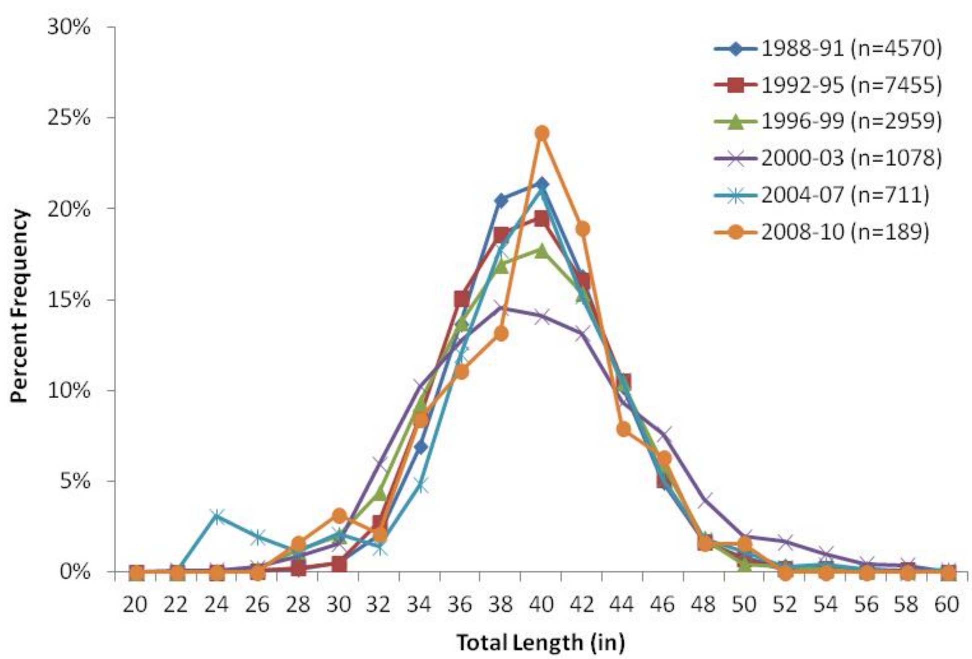


Figure 3. Frequency of wreckfish total lengths during six different time periods between 1988 and 2010.

Discussion

In September 2011, the SAFMC approved a Comprehensive Annual Catch Limit (ACL) Amendment, which specifies ACLs for most federally managed species in the South Atlantic, including wreckfish (SAFMC 2011). The SAFMC cannot establish an ACL above the 0.250 mp ww ABC recommended by the SSC, which was based on recent average wreckfish commercial catches. The Comprehensive ACL Amendment sets the wreckfish ACL equal to ABC and allocates 95% of the ACL to the commercial sector (0.2375 mp ww) and 5% of the ACL to the recreational sector (0.0125 mp ww). Upon implementation, this amendment will reduce the commercial wreckfish quota by 88%; from 2 mp ww to 0.2375 mp ww.

During their August 2010 meeting, the SSC recommended conducting Depletion-Corrected Average Catch (DCAC) or Depletion-Based Stock Reduction Analysis (DB-SRA) in 2011 to compare with the current catch-only recommendations (SAFMC 2010), resulting in the work summarized herein. The DCAC model results appear to indicate that ABC could be set slightly higher than the SSC's current 0.250 mp recommendation; however, this result is contingent on model parameters assumed for Δ, M, and F_{msy}.

Evaluation of model parameterizations indicated that results were most sensitive to changes in natural mortality rate, followed by reductions in biomass and the assumed ratio of F_{msy} to M. An M of 0.05 is consistent with a longevity of 70+ years, as determined by Peres and Haimovici (2004), whereas an M of 0.10 is more consistent with a longevity of 30-40 years, which is the oldest known age of wreckfish sampled from the South Atlantic (Vaughn et al. 2001). An M of 0.075 is intermediate to the above-mentioned natural mortality rates and is consistent with a life-span of 50-60 years, while an M of 0.025 is representative of a maximum age greater than currently observed for wreckfish. Based upon a review of recent stock assessments in the Southeast Region and estimates of M based on Hoenig (1983) and Hewitt and Hoenig (2005), values of M at or near 0.05 are more likely given the longevity (76 years) and life history of the species (Table 4).

Table 4. Summary of Fmsy or Fmsy proxies compared to M for recent stock assessments in the Gulf of Mexico and South Atlantic.

Region	Species	Fmsy or proxy	F value	M	F to M ratio	Max Age	Source
SA	Wreckfish	Fmax	0.14-0.16	0.05	2.8-3.2	39	Vaughn et al. 2001
SA	Wreckfish	$F_{0.1}$	0.14-0.15	0.10	1.4-1.5	39	Vaughn et al. 2001
SA	Wreckfish	$F_{0.1}$	0.23-0.25	0.15	1.5-1.6	39	Vaughn et al. 2001
SA/Gulf	Black Grouper	$F_{30\%SPR}$	0.216	0.136	1.6	33	SEDAR 19 2010
SA	Red Grouper	Fmsy	0.221	0.14	1.6	26	SEDAR 19 2010
SA	Red Snapper	F30%/F40%SPR	0.104-0.148	0.078	1.3-1.9	54	SEFSC 2009
Gulf	Gag	Fmax	0.22	0.15	1.5	31	GMFMC 2010
Gulf	Yellowedge Grouper	$F_{30\%SPR}$	0.0964	0.073	1.3	85	SEDAR 22 2011
Gulf	Yellowedge Grouper	$F_{30\%SPR}$	0.092	0.055	1.7	85	SEDAR 22 2011

The change in biomass is also an important factor in determining the DCAC. CPUE indices and one fishermen interview were conducted to gauge the decline in biomass that occurred after wreckfish exploitation began and reached peak landings in 1990. CPUE trends indicated a 35-60% drop in catch rate occurred from the early 1990s through present. Catch rates declined rapidly from 1992 to 1997 then remained stable for nearly a decade, before increasing from 2007-2010. Not surprisingly, results indicated that smaller windfall reductions in biomass resulted in higher sustainable yield estimates. A 35% reduction in biomass resulted in sustainable yields from 0.247-0.449 mp, whereas a 60% reduction in biomass resulted in sustainable yields that ranged from 0.175-0.373 mp. A 50% reduction in biomass resulted in sustainable yields that ranged from 0.197-0.400 mp. The 50% reduction level was based on expert opinion by a fisherman who has participated in the fishery since it began. This reduction in biomass is within the range of estimates provided by the CPUE index. Given that catch rates and fish lengths have remained stable for a decade or more and catch rates are showing signs of increase in recent years, a 50% reduction in biomass seems to be a reasonable proxy for the windfall reduction in biomass. This estimated reduction is considerably lower than Vaughn et al. (2001), who estimated ~85-90% reduction in biomass using wreckfish data through 1998.

Trends in CPUE are affected by a variety of factors. In this analysis, several effort metrics were evaluated and it was determined that landings in pounds per day was most appropriate for calculating CPUE. Because small changes in Δ can affect estimates of sustainable yield, estimates derived from the CPUE index are critical to how high or low sustainable yield can be set. CPUE can be affected by a variety of factors including changes in abundance, changes in fishing practices and geographic areas fished, concentration of fishing effort in areas of greatest fish abundance, environmental conditions, and many other factors. These factors can lead to CPUE not corresponding to trends in abundance. If hyperstabilization of CPUE occurs, then trends in CPUE will remain high as stock abundance declines (Hilborn and Walters 1992). Similarly, hyperdepletion may occur if CPUE declines faster than stock abundance (Hilborn and Walters 1992). Review of logbook records indicated that wreckfish were harvested from 10 different statistical areas between 1992 and 2010. Of the 10 statistical areas, three accounted for 98% of the wreckfish landings. Beginning in 2003 there was a shift to catching wreckfish in statistical areas closer to shore. The influence of this shift on CPUE is unknown. Similarly, it is unknown how fishing practices may have affected the CPUE index. Logbook records indicated trip length increased from slightly over 6 days to more than 9 days, while the number of lines fished per vessel has remained relatively stable over time and the number of hooks fished per line has declined. This latter change in gear usage was accounted for when standardizing CPUE.

Given that there is no estimate of F_{msy}, a proxy for F_{msy} must be assumed. In this analysis, F_{msy} was assumed to be equal to M or 80% of M. The lower F_{msy} is set, the less productive the stock is estimated to be; reducing the estimate of sustainable yield. Recent stock assessments from the Southeast Region were used to compare values of F_{msy} to M to assess if M is a reasonable proxy for F_{msy} (Table 4). For all assessments reviewed, the estimated ratio of F_{msy} to M was greater than 1. It should be noted that this conclusion is based on a limited number of assessments of species with differing life history characteristics and is not intended to be a comprehensive list of F_{msy} to M ratios for all species in the Southeast Region. Given these results, an F_{msy} to M ratio of 1 is considered a reasonable proxy for wreckfish.

In conclusion, the intent of this analysis was to provide additional information for SSC consideration based on their recommendation for conducting a DCAC or DBSRA analysis for wreckfish (SAFMC 2010). Given the sensitivity runs considered in this report, and the discussion above, it appears the ABC for wreckfish could be increased by 19,000 to 109,000 lbs given a windfall biomass reduction of 35-60%, M = 0.05, and an F_{msy} to M ratio of 1.0. Catch rates for wreckfish have been stable since the late 1990s and in recent years have been slightly increasing, while fish lengths have been stable since the fishery began in the late 1980s. This is evidence that a sustainable yield has been taken over a prolonged period of time without indication of a change in underlying resource abundance (MacCall 2009). Given the stability of catch rates over time, the level of current take appears sustainable and could potentially be increased.

It should be noted that yields summarized in Table 2 represent sustainable yields but may not represent maximum sustainable yield, given that wreckfish constitutes a single genetic stock across the North Atlantic ocean (Sedberry et al. 1996) and fishing mortality in other regions of the Atlantic Ocean could affect yields from U.S. South Atlantic waters. Similar to the U.S. segment of the wreckfish stock, landings of wreckfish in Portugal and Spain peaked in the early 1990s and then declined thereafter due to overexploitation (Sadovy 2003). Fishing records from the Azores indicate wreckfish landings have stabilized in more recent years after sharply declining from 1994-1999 (Damaso 2006). For this assessment of wreckfish, it was assumed that wreckfish stocks on U.S. fishing grounds would not be affected by fishing elsewhere. However, given that the source of juvenile wreckfish is unknown and European fish hooks are frequently found in wreckfish caught in U.S. waters (Sedberry et al. 1999), this is a tenous assumption. A north Atlantic assessment of wreckfish may be more appropriate, but would require reliable landings and CPUE data from numerous fishing grounds throughout the north Atlantic. Given the complexity of conducting a north Atlantic assessment, it is recommended that the U.S. South Atlantic portion of wreckfish be managed based on a target level of depletion, thus avoiding local overfishing. Regular review of U.S. trends in catch per unit effort and fish length would ensure annual catch limits are not resulting in stock depletion.

Literature Cited

Alverson, D. and W. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean – an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. Journal of Fisheries Research Board of Canada, 26: 1985-2001.

Damaso, C. 2006. Azorean Demersal Fishery Audit Report. Department of Oceanography and Fisheries. 118 pp.

Gulf of Mexico Fishery Management Council (GMFMC). 2010. Stock assessment of gag in the Gulf of Mexico: Report of assessment re-run webinars. GMFMC, Tampa, FL. 33 pp.

Gulland, J. 1970. Preface. *In* the Fish Resources of the Oceans pp. 1-4. Ed. By J. Gulland. FAO Fisheries Technical Paper, 97.

Heemstra, P.C. 1986. Family no. 165: Polyprionidae. Page 509 *in* M. M. Smith and P.C. Heemstra, editors. Smith's sea fishes, 6th edition. Spring-Verlag, Berlin.

Hewitt, D.A., and J.M. Hoenig. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin. 103(2): 433-437.

Hilborn, R., and C.J. Walters. 1992. Quantative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York, NY. 570 pp.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin, 82: 898-903.

MacCall, A.D. 2009. Depletion corrected average catch: a simple formula for estimating sustainable yields in data poor situations. ICES Journal of Marine Science, 66: 2267-2271.

Pauly, D. 1979. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil International Exploration Mer. 39: 175-192.

Peres, M.B., and M. Haimovici. 2004. Age and growth of southwestern Atlantic wreckfish *Polyprion americanus.* Fisheries Research, 66: 157-169.

Restrepo, V.R., convenor, and 10 coauthors. 1998. Technical guidance on the use of precautionary approaches to implementing National standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. National Oceanic and Atmospheric Administrations Technical Memorandum NMFS-F/SPO-31.

Sadovy, Y. 2003. *Polyprion americanus.* In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1 www.iucnredlist.org. Downloaded on 23 September 2011.

Sedberry, G.R., J.L. Carlin, R.W. Chapman, and B. Eleby. 1996. Population structure in the pan-oceanic wreckfish, *Polyprion americanus*, (Teleostei: Polyprinidae), as indicated by mtDNA variation. Journal of Fishery Biology 49 (Supplement A): 318-329.

Sedberry G.R., Andrade C.A.P., Carlin J.L., Chapman R.W., Luckhurst B.E., Manooch C.S. III, Menezes G., Thomsen B. and Ulrich G.F. 1999. Wreckfish *Polyprion americanus* in the North Atlantic: Fisheries, Biology, and Management of a widely distributed and Long lived fish. *American Fisheries Society Symposium* 23:27-50

South Atlantic Fishery Management Council (SAFMC). 1990. Amendment 3 to the fishery management plan for the snapper-grouper fishery of the South Atlantic region. SAFMC, Charleston, SC. 34 pp.

South Atlantic Fishery Management Council (SAFMC). 1991. Amendment 5 to the fishery management plan for the snapper-grouper fishery of the South Atlantic region. SAFMC, Charleston, SC. 87 pp.

South Atlantic Fishery Management Council (SAFMC). 2010. Scientific and Statistical Committee Meeting Report , August 16-17, 2010, Charleston, SC. 21 pp.

South Atlantic Fishery Management Council (SAFMC). 2011. Comprehensive annual catch limit amendment for the South Atlantic region. SAFMC, Charleston, SC.

Southeast Data, Assessment, and Review (SEDAR 19). 2010. Stock Assessment Report: Gulf of Mexico and South Atlantic Black Grouper. SEDAR 19, Charleston, SC. 661 pp.

Southeast Data, Assessment, and Review (SEDAR 19). 2010. Stock Assessment Report: South Atlantic Red Grouper. SEDAR 19, Charleston, SC. 612 pp.

Southeast Data, Assessment, and Review (SEDAR 22). 2011. Stock Assessment Report: Gulf of Mexico Yellowedge Grouper. SEDAR 22, Charleston, SC. 423 pp.

Southeast Fisheries Science Center (SEFSC). 2009. Red snapper projections V. SEFSC, Beaufort, NC. 34 pp.

Vaughn, D.S., C.S. Manooch III, and J.C. Potts. 2001. Assessment of the Wreckfish Fishery on the Blake Plateau. Pages 105-122 in G.R. Sedberry, editor. Island in the stream: oceanography and fisheries of the Charleston Bump. AFS, Symposium 25, Bethesda, MD.

Walters, C., and S. Martell. 2004. Fisheries ecology and management. Princeton University Press, Princeton, NJ. 399 pp.

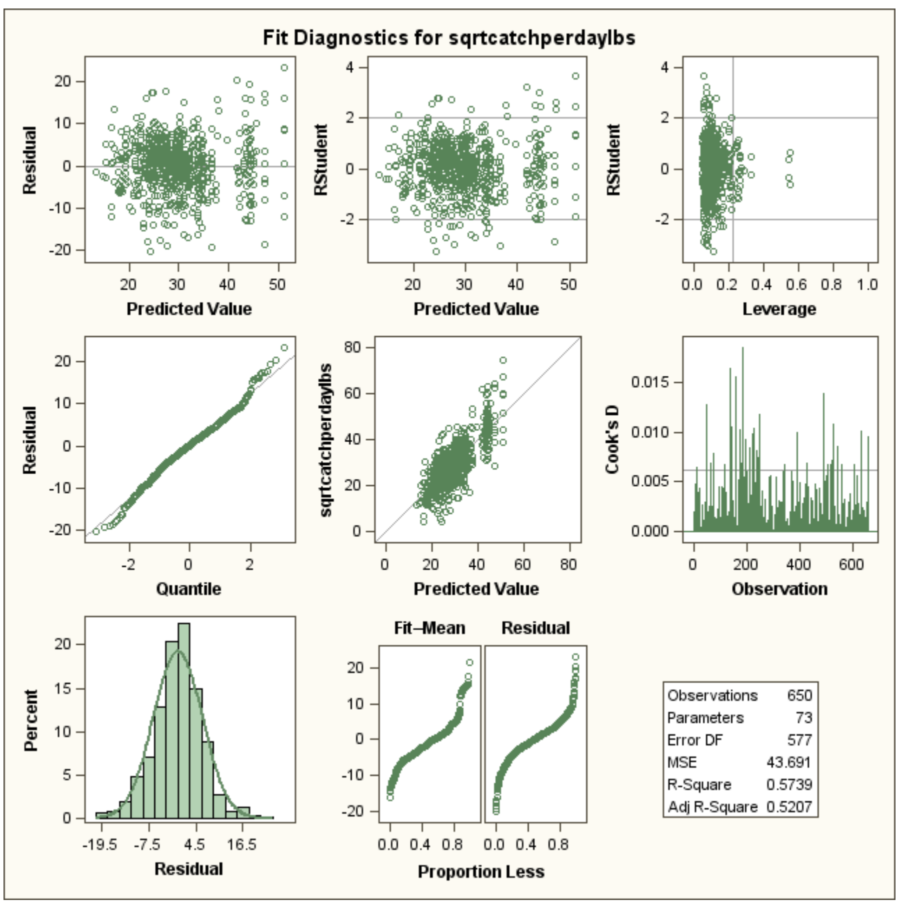
Appendix 1: GLM results and diagnostic plots for standardized pounds per day indices.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	72	33955.37356	471.60241	10.79	<.0001
Error	577	25209.94928	43.69142		
Corrected Total	649	59165.32284			

R-Square	Coeff Var	Root MSE	sqrtcatchperdaylbs Mean
0.573907	22.27010	6.609949	29.68083

Source	DF	Type I SS	Mean Square	F Value	Pr > F
vesselid	2	15950.71662	7975.35831	182.54	<.0001
fishingyear	18	11177.10363	620.95020	14.21	<.0001
seasons(fishingyear)	38	3342.52751	87.96125	2.01	0.0004
totalhooks	14	3485.02580	248.93041	5.70	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
vesselid	2	4783.766042	2391.883021	54.74	<.0001
fishingyear	18	4550.019905	252.778884	5.79	<.0001
seasons(fishingyear)	38	2769.711567	72.887146	1.67	0.0083
totalhooks	14	3485.025799	248.930414	5.70	<.0001



ADDENDUM

Background and Methods

During the November 8-10, 2011 SAFMC's Scientific and Statistical Committee (SSC) meeting, the SSC convened a subcommittee to review the wreckfish DCAC analysis. The subcommittee went through each one of the model input parameters and made the following recommendations:

1. Natural mortality should be set equal to 0.06 based on Hewitt and Hoenig (2005). A standard deviation of 0.5 on ln(M) should be used for Monte Carlo simulations.
2. Landings from 1992 through 2006 should be used as this time period is consistent with the CPUE time series used to derive the depletion estimate. A coefficient of variation of 10% should be used for catch as ITQ landings are well-estimated.
3. The ratio of F_{msy} to M should be set equal to 1.0. Meta-analysis of stocks in the region with known F_{msy} and M indicated that c was greater than 1. There is nothing about wreckfish life history or the fishery that would justify setting *c*<1.
4. Biomass depletion should be calculated as:

$$\Delta = \frac{CPUE_{max} - CPUE_{min}}{CPUE_{B0}}$$

where $CPUE_{max}$ corresponds to the CPUE in 1992/1993, $CPUE_{min}$ corresponds to the CPUE in 2006/2007, and $CPUE_{B0}$ corresponds to the CPUE in 1990/1991, the peak year of landings and effort.

Based on these updated model parameters, the subcommittee recommended model Run 19 as the base run. Three additional sensitivity runs (Runs 20-22) were also conducted. Run 20 included the same input parameters as model run 19, except landings through 2010/2011 were included and Δ was computed using $CPUE_{min}$ equal to CPUE in 2010/11. Model run 21 was similar to run 19, except two additional years of landings were included (1990/1991 and 1991/1992) and $CPUE_{max}$ was set equal to the estimated CPUE in 1990/1991 (see below). Run 22 was similar to run 21, except landings through 2010/11 were included and Δ was computed using $CPUE_{min}$ equal to CPUE in 2010/11.

The subcommittee also discussed estimating uncertainty in Δ using the standardized CPUE (e.g., the distribution of maximum and minimum year CPUE) rather than an assumed standard deviation of 0.2 and extending the CPUE time series back to 1991/1992. The subcommittee suggested doing a bootstrap analysis of the GLM to derive joint-distributions of the maximum and minimum year CPUE, and the resulting distribution in depletion. This recommendation was not completed due to time constraints; however, the CPUE time series was extended to include 1991/1992.

Review of logbook records indicated that permit data were available, but vessel IDs for the 1991/1992 fishing season were not available. The general linear model was updated to include data beginning in 1991/1992. The model was fit using the same methods as previously described, except permit number rather than vessel ID was used as factor in the model. Catch per day was the dependent variable and was square root transformed to satisfy model assumptions. Permit number, fishing year, season nested within fishing year, and total hooks were all significant factors included in the model. These parameters explained 57% of the variability in catch per day. An updated CPUE index is provided in Figure A1. Model results and fit diagnostics are summarized in Table A1.

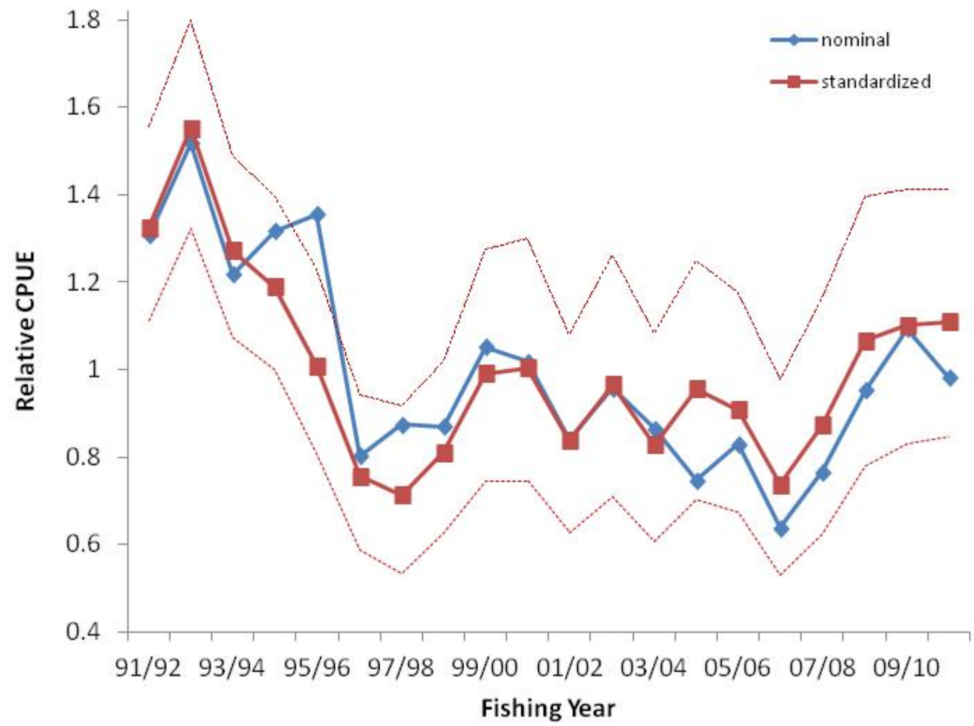


Figure A1. Nominal and standardized index of wreckfish abundance (± 80% confidence intervals) for High-3 fishing vessels, 1991/1992 through 2010/2011.

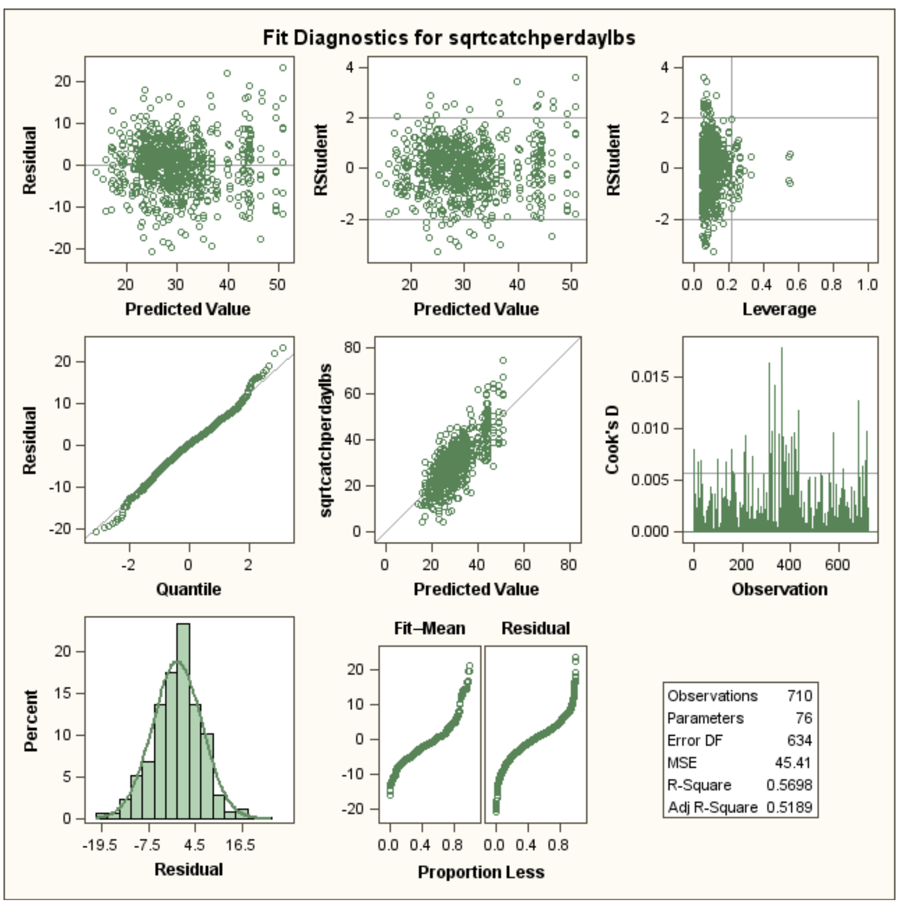
Table A1. Model fit and diagnostics for CPUE general linear model.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	75	38136.98156	508.49309	11.20	<.0001
Error	634	28789.94388	45.41001		
Corrected Total	709	66926.92544			

R-Square	Coeff Var	Root MSE	sqrtcatchperdaylbs Mean
0.569830	22.46560	6.738695	29.99562

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PERMNUM	2	17798.97630	8899.48815	195.98	<.0001
fishingyear	19	12388.33619	652.01769	14.36	<.0001
seasons(fishingyear)	40	4423.62357	110.59059	2.44	<.0001
totalhooks	14	3526.04550	251.86039	5.55	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PERMNUM	2	4751.142709	2375.571354	52.31	<.0001
fishingyear	19	4205.954099	221.366005	4.87	<.0001
seasons(fishingyear)	40	3502.258890	87.556472	1.93	0.0007
totalhooks	14	3526.045501	251.860393	5.55	<.0001



To estimate CPUE in 1990/1991, a linear regression was fit to CPUE data from 1992/1993 through 1997/1998. This provided a very good fit ($r^2 = 0.97$) to the data and allowed for CPUE in 1990/1991 to be estimated through extrapolation of the regression line (Figure A2). Non-linear regression lines were also explored, but did not improve the fit to the data. If CPUE is higher than estimated in Figure A2, then Δ would be lower for runs 19-20 and higher for runs 21-22.

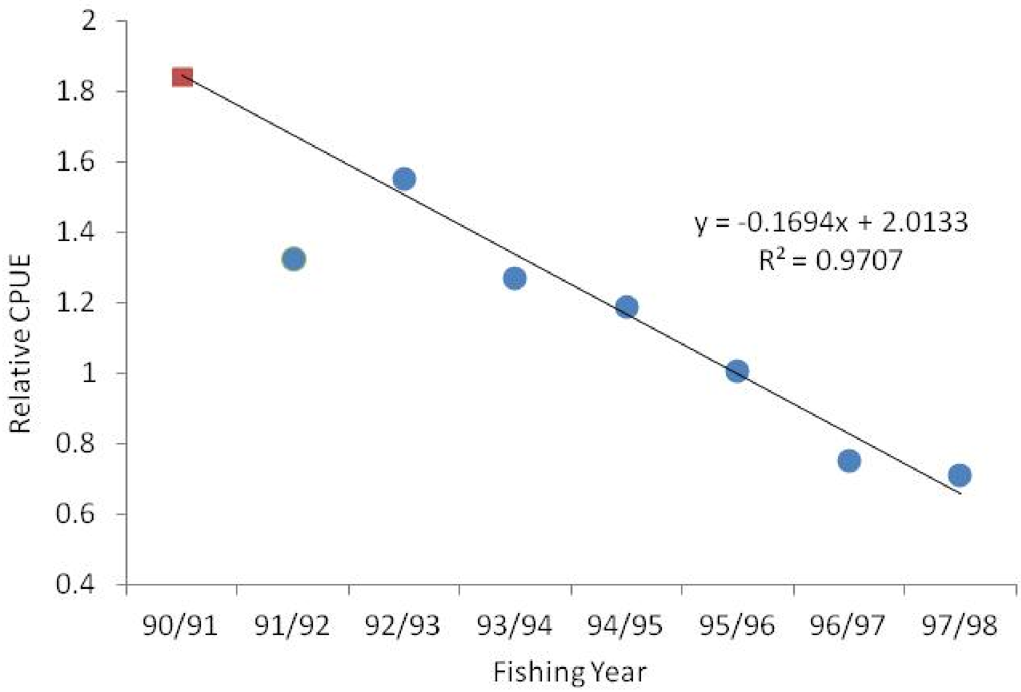


Figure A2. Linear regression of relative CPUE versus fishing year. Blue circles represent standardized CPUE values based on logbook data. The red square indicates the extrapolated CPUE value for 1990/1991.

Results

Relative CPUE in 1990/1991 was 1.84, or approximately 19% greater than the 1992/1993 CPUE estimate. CPUE in 1991/1992 was lower than the CPUE observed in 1992/1993 and consistent with results presented in Vaughn et al. (2001). Table A2 summarizes estimated yields for Runs 19-22. Sustainable yield was estimated to be 0.191 mp ww for Run 19, 0.247 mp ww for Run 20, 0.278 mp for Run 21, and 0.330 mp ww for Run 22. Figure A3 summarizes the frequency distribution of DCAC results for runs 19 and 21 based on Monte Carlo sampling of parameter values.

Discussion

The SSC recommended model runs 19 and 21 as preferred model runs that were equally plausible. Model run 19 was based on landings corresponding to the time period when CPUE data were available (1992+), while model run 21 relied on a projected estimate of CPUE to estimate biomass during the first year of catch. The SSC recommended averaging the two model runs, producing an ABC of 0.235 mp ww, which is 0.015 mp ww less than the current ABC based on non-confidential average landings.

MacCall (pers. comm.) indicated it was most appropriate to include only data in the model corresponding to when the depletion occurred, therefore, runs 20 and 22 were excluded from further consideration since CPUE has increased since 2006/2007.

Table A2. Estimated yields and model parameters for Runs 19-22.

Parameter	**Run 19**	**Run 20**	**Run 21**	**Run 22**
Fishery performance				
First yr of landings	1992/93	1992/93	1990/91	1990/91
Last yr of landings	2006/07	2010/11	2006/07	2010/11
Catch (mp ww)	6.776	7.559	12.499	13.281
Number of years	15	19	17	21
CV of sum of catch	0.1	0.1	0.1	0.1
Average catch (mp ww)	0.452	0.398	0.735	0.632
DCAC				
Assumed M (yr^{-1})	0.06	0.06	0.06	0.06
Standard deviation ln(M) (yr -1)	0.5	0.5	0.5	0.5
Assumed Biomass Change (Δ)	0.44	0.24	0.60	0.40
Standard Deviation Δ	0.2	0.2	0.2	0.2
Assumed c	1	1	1	1
Standard Deviation c	0.2	0.2	0.2	0.2
Monte Carlo results (n=10,000)				
Monte Carlo mean (mp ww)	**0.191**	**0.247**	**0.278**	**0.330**
Percentiles (%)				
5	0.099	0.154	0.139	0.190
20	0.137	0.199	0.197	0.254
50	0.187	0.247	0.270	0.329
80	0.242	0.294	0.356	0.405
95	0.297	0.337	0.444	0.472

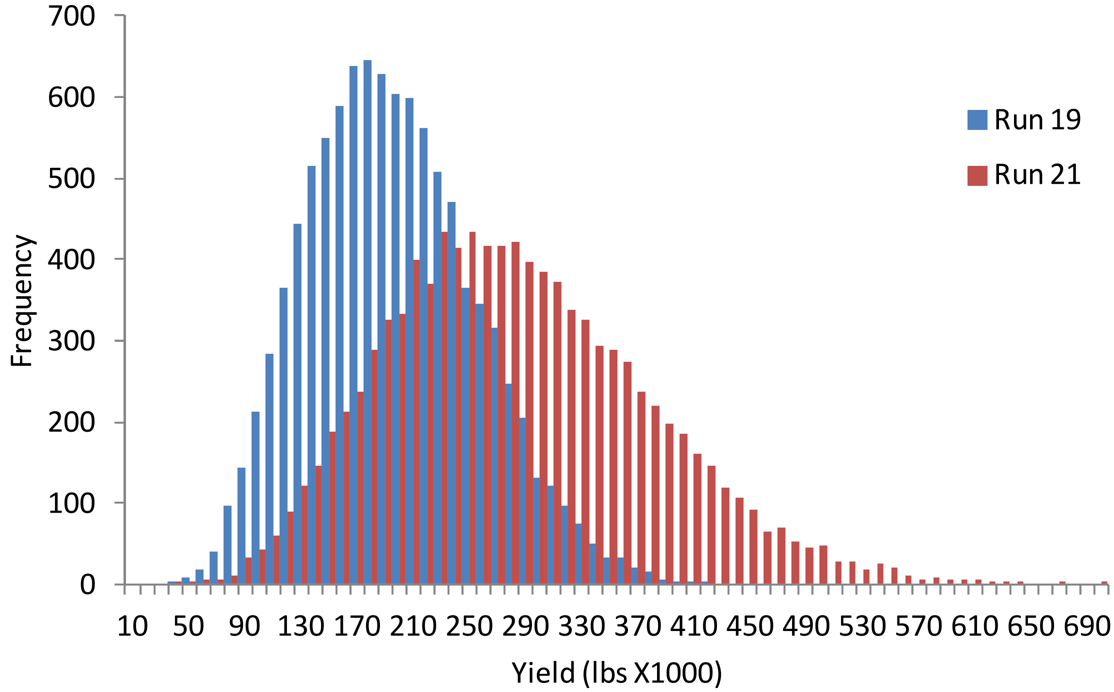


Figure A3. Frequency distribution of wreckfish DCAC results for Runs 19 and 21 based on Monte Carlo sampling of parameter values.

Attachment 3

Attachment 2.
Peer Review of "Depletion-Corrected Average Catch Estimates for U.S. South Atlantic Wreckfish"

SAFMC SSC Subcommittee
November 10, 2011

The report (NMFS SERO, October 23, 2011) was reviewed by a subcommittee of the SEFSC SSC (L. Barbieri, chair; J. Berkson; S. Cadrin, and Y. Jiao) and met with A. Strelcheck on November 9 2011. Each of the model inputs (landings series, natural mortality, depletion estimate, and the ratio of Fmsy to natural mortality) to attempt a determination of a 'best run' and a candidate ABC recommendation for review by the entire SSC.

1. Landings:
Time series: Two options for time series of landings were used in the report (1987-2010 and 1989-2010). The subcommittee requested revised analyses that use a time periods of landings that are consistent with the two options for periods used to derive the depletion estimate (1990 to 2006 and 1992 to 2006). The choice on period of rebuilding is discussed below. Total landings were 12.5 mil lb for the 17 years from 1990 to 2006, and 6.8 mil lb from the 15 years of 1992 to 1996.

Uncertainty in landings: The assumed variability in total catch (CV=10%) corresponds to a relatively well-estimated catch in this ITQ fishery with few fishery

2. Natural Mortality (M)
Most likely value of M: The report states: "*M ranged from 0.06-0.09 using Pauly (1979) and 0.11-0.14 using Hoenig (1983). Estimates of M for Hoenig (1983) were based on maximum ages of 30-39 years. More recent age and growth data from Peres and Haimovici (2004) indicate wreckfish may live considerably longer (up to 76 years). Based on Hoenig (1983) and Hewitt and Hoenig (2005) and a maximum age of 76 years, M ranged from 0.04-0.06. Vaughn et al. (2001) recommended 0.1 be used as the preferred estimate of M*."

The subcommittee agreed that calculations of M that are based on the most recent age data are most defensible (Peres et al. 2004; maximum age of 76 years). However, the subcommittee recommended that the estimate of M from Hewitt and Hoenig (2005; M=0.06) is an improvement for deriving M from maximum age than the Hoenig (1983) method.

Uncertainty in M: We can only approximate uncertainty in M, and a standard deviation of 0.5 in Ln(M) produces a reasonable distribution of M (0.04 to 0.10 +/- 1 SD).

3. Depletion:
CPUE standardization: Appendix 1 gives sufficient detail to accept the analysis to provide a standardized CPUE. A large portion of variance was explained (R^2=57%), and the model diagnostics (distribution of residuals, etc.) look quite good.

CPUE trends: The use of CPUE as a measure of relative abundance assumes that catchability of a GLM-standardized unit of effort is constant throughout the time series. Violation of this assumption should be expected to be in a direction of increasing catchability, because of technological advances since the early fishery (1992). Therefore, the apparent depletion from the trend in CPUE may be an underestimate of depletion.

Choice of depletion period: The report states that "*Since 2007, standardized and nominal catch rates have increased. The reduction in CPUE from 1992 to 2010 was 35% for nominal and standardized indices. Reductions in CPUE from 1992 to 2006 were ~57-58%. A 35% change in biomass was used as the lower bound for model runs and a 60% change in biomass was used as the upper bound for model runs. A middle run was also conducted using a 50% change in biomass. This run was based on personal communication with Paul Reiss (September 9, 2011), a wreckfish shareholder who currently lands a significant portion of the annual wreckfish landings. Mr. Reiss indicated that a 50% reduction in his CPUE has likely occurred since landings peaked in the early 1990s. Mr. Reiss also indicated that his CPUE has been increasing in recent fishing years*." (page 4).

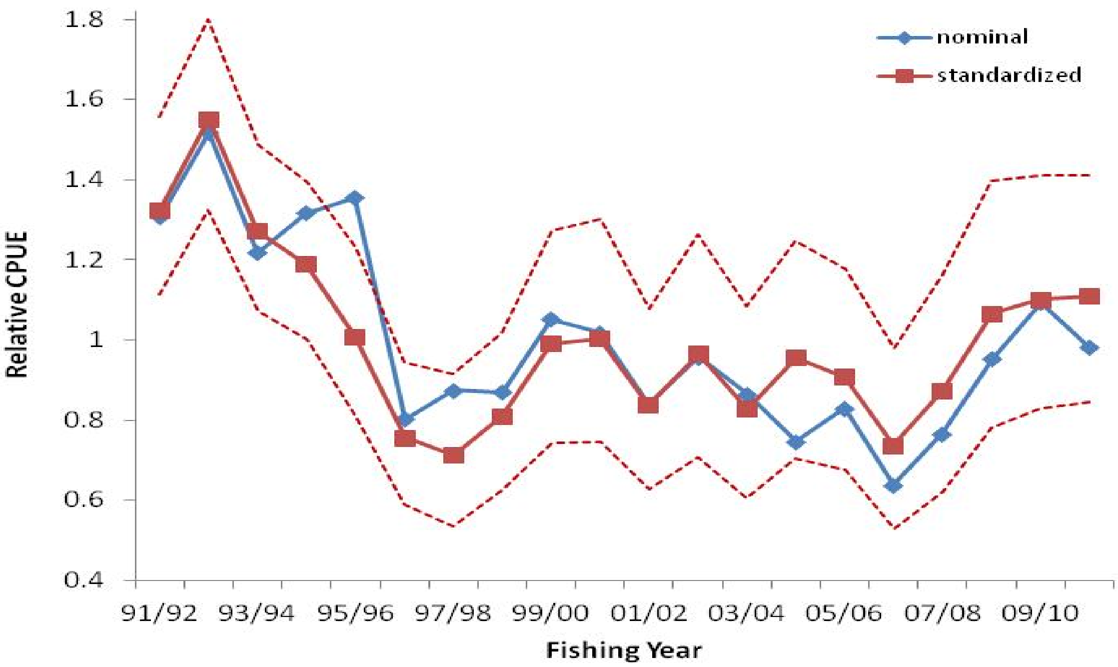


Figure 1. Extended series nominal and standardized index of wreckfish abundance (± 80% confidence intervals) for High-3 fishing vessels, 1991-2010.

The subcommittee supports the derivation of depletion based on the maximum year of CPUE (1992/1993) and the minimum year of CPUE (2006/2007). This choice of depletion period is consistent with MacCall's (2009) application of DCAC to Gulf of Maine redfish in which he chose the year of minimum biomass as the last year of the depletion, and excluded subsequent years of rebuilding to provide a good approximation of MSY from a more informative age-based assessment.

Unfished Biomass: The subcommittee felt that there were two valid options for calculating depletion relative to unfished biomass (B0):

1) $\Delta = \frac{CPUE_{max} - CPUE_{min}}{CPUE_{B0}}$

2) $\Delta = \frac{CPUE_{B0} - CPUE_{min}}{CPUE_{B0}}$

The CPUE standardization was extending further back in time. The Extended series back to 1991 had lower CPUE than 1992, similar to the CPUE series developed by Vaughan et al. (2001). In lieu of a CPUE observation that represents B0, the depletion trend in the CPUE series was extrapolated back to the beginning of the fishery to derive $CPUE_{B0}$ (1.82). The resulting calculations of depletion are 44% (equation 1) and 60% (equation 2).

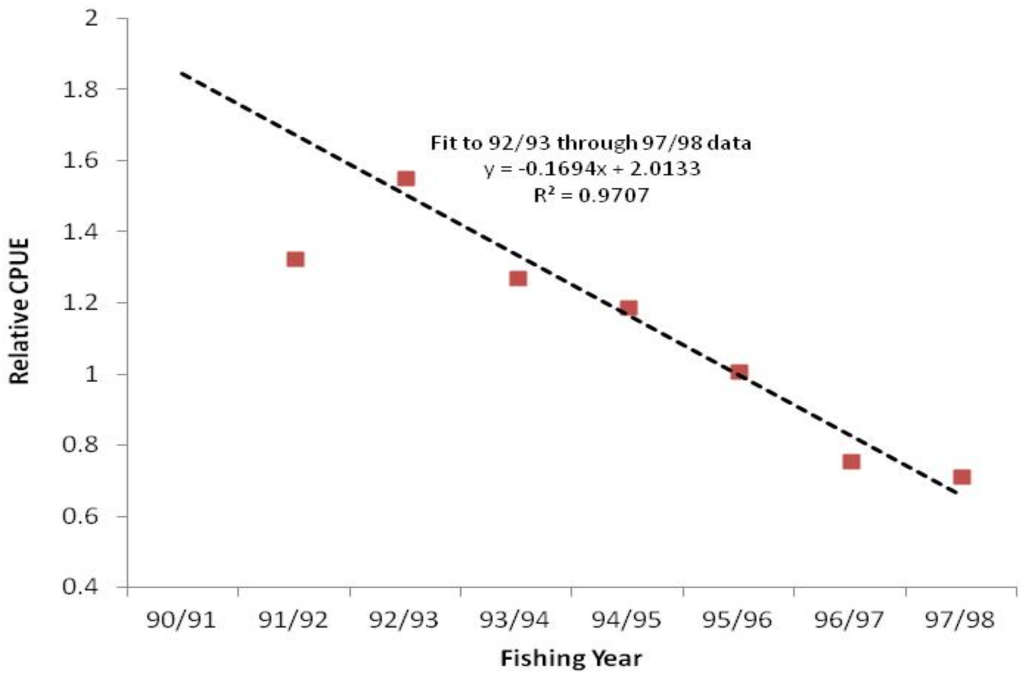


Figure 2. Extrapolation of depletion to the beginning of the fishery to approximate CPUE at B0.

Uncertainty in depletion: The distribution of delta should be a function of uncertainty in the standardized CPUE (e.g., the distribution of maximum and minimum year CPUE) rather than an assumed standard deviation of 0.2. This can be done using a bootstrap analysis of the GLM to derive joint-distributions of the maximum and minimum year CPUE, and the resulting distribution in depletion.

A crude approximation of such an analysis is calculating extremes of depletion using confidence limits of CPUE during the maximum and minimum years. The resulting range of depletion calculations around the point estimate of 44% depletion (17% to 68%) is similar to the distribution of depletions based on a standard deviation of 0.2 (24% to 64% +/- 1 SD).

4. Fmsy:

The report states that "*There is currently no estimate for Fmsy. M is often considered a conservative proxy for Fmsy (Restrepo et al. 1998) and MacCall (2009) noted that a ratio of Fmsy to M = 1 may be considered a target or upper limit for many stocks. Walters and Martell (2004) indicated ratios = 0.75-0.8 may be appropriate in data poor situations and that the ratio of Fmsy to M may be as low as 0.6 for highly vulnerable stocks. For this analysis, sensitivity runs were conducted using Fmsy to M ratios of 0.8 and 1.0.*"

The choice of the parameter c (Fmsy/M) is an expert judgment. Meta-analysis of all stocks in the region with known Fmsy and M indicated that c was greater than 1 for all stocks. There is nothing about wreckfish life history or the fishery that would justify c<1. Therefore, the most defensible value of c provided in the report is c=1.0.

Recommendation

The subcommittee concludes that two alternative analyses are equally valid, and have complementary strengths and weaknesses. The 44% depletion estimate is based directly on observed years of CPUE, whereas the 60% depletion estimate is based on the entire period of depletion. The average estimate of Ysust is 0.235 mil lb. This is 6% less than the previous ABC recommendation of 0.25 mil lb.

In the future, the catch and CPUE series may support a biomass dynamics approach to stock assessment of wreckfish, which would be a more informative basis for fishery management. Both DCAC and biomass dynamics models represent productivity in the fished area, and sustainable yield in the entire resource area may be greater.

Acknowledgments

The subcommittee thanks Andy Strelcheck for his efforts and responsiveness in providing alternative analyses. We are also grateful to Alec MacCall for his technical guidance.

References

MacCall, A.D. 2009. Depletion corrected average catch: a simple formula for estimating sustainable yields in data poor situations. ICES Journal of Marine Science, 66: 2267-2271.

Hewitt, D.A., and J.M. Hoenig. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin. 103(2): 433-437.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin, 82: 898-903.

Peres, M.B., and M. Haimovici. 2004. Age and growth of southwestern Atlantic wreckfish *Polyprion americanus*. Fisheries Research, 66: 157-169.Vaughn, D.S., C.S. Manooch III, and J.C. Potts. 2001. Assessment of the Wreckfish Fishery on the Blake

Plateau. Pages 105-122 in G.R. Sedberry, editor. Island in the stream: oceanography and fisheries of the Charleston Bump. AFS, Symposium 25, Bethesda, MD.

Wreckfish Proposal Review Addendum

Dr. Butterworth will be able to join the SSC conference scheduled for September 3 for the first hour due to time zone differences.   It is requested that technical questions be addressed during this time.

The proposal submitters recommend that for the November roundtable, it would be helpful if the SSC could form a subcommittee of technical experts and volunteers to participate. It would also be helpful to have NMFS personnel familiar with the fishery data (CPUE, etc.) and the prior analysis (*i.e.*, the DCAC analysis) as participants. A subcommittee of SSC members versed in stock assessment techniques is desired to serve as a point of contact with Drs. Butterworth and Rademeyer