Depletion-Corrected Average Catch Estimates for U.S. South Atlantic Wreckfish
NOAA Fisheries Service
Southeast Regional Office
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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:

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

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:

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

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

Sum of Landings (C)

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 of up to five additional species. If snapper-grouper, dolphin, wahoo, or mackerels are caught while fishing for wreckfish, than 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.

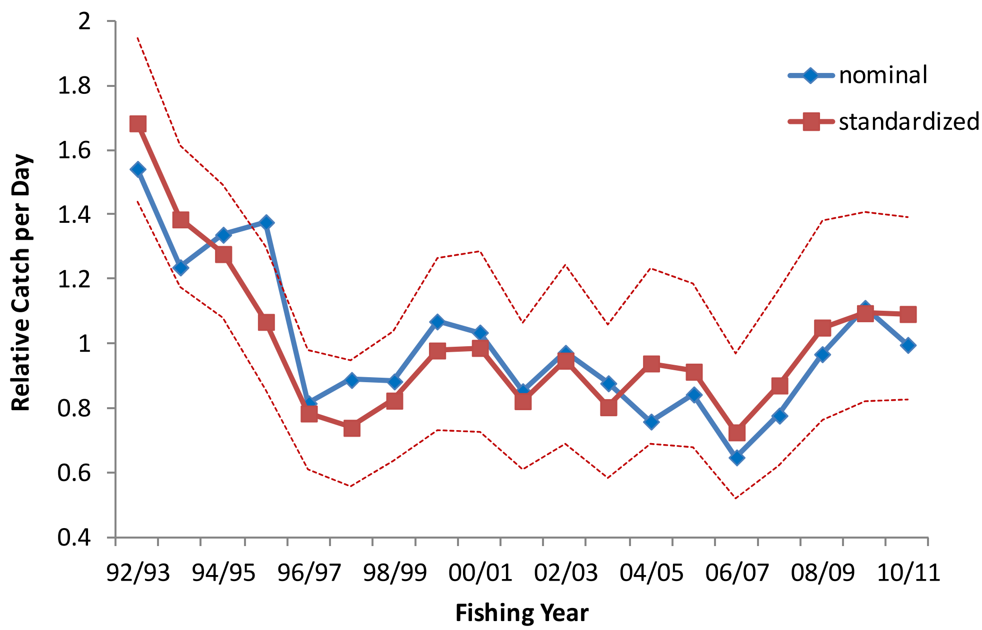

Figure 1. Nominal and standardized index of wreckfish abundance (± 80% confidence intervals) for High-3 fishing vessels, 1992-2010.

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).

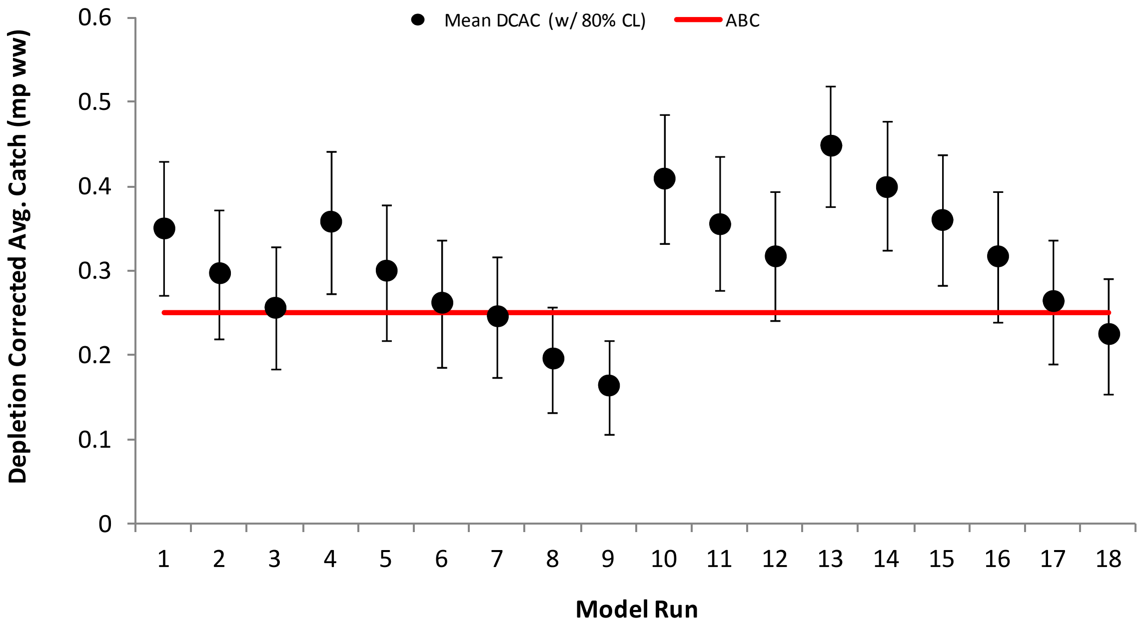

Figure 2. Mean yields (± 80% CL) estimated for eighteen different DCAC model parameterizations for wreckfish.

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	--	--	--	--

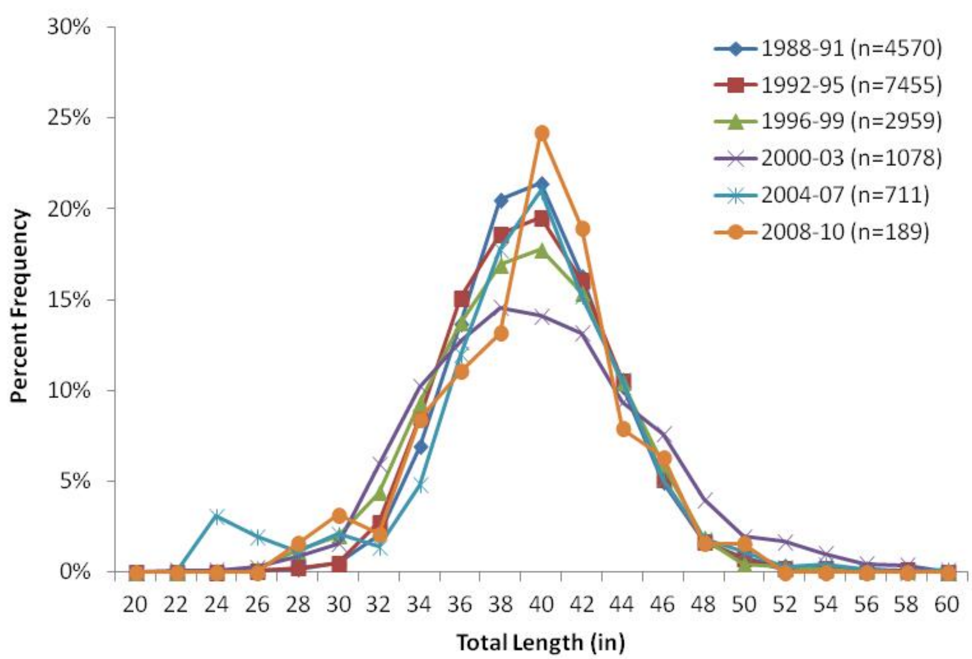

Figure 3. Frequency of wreckfish total lengths during six different time periods between 1988 and 2010.

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.

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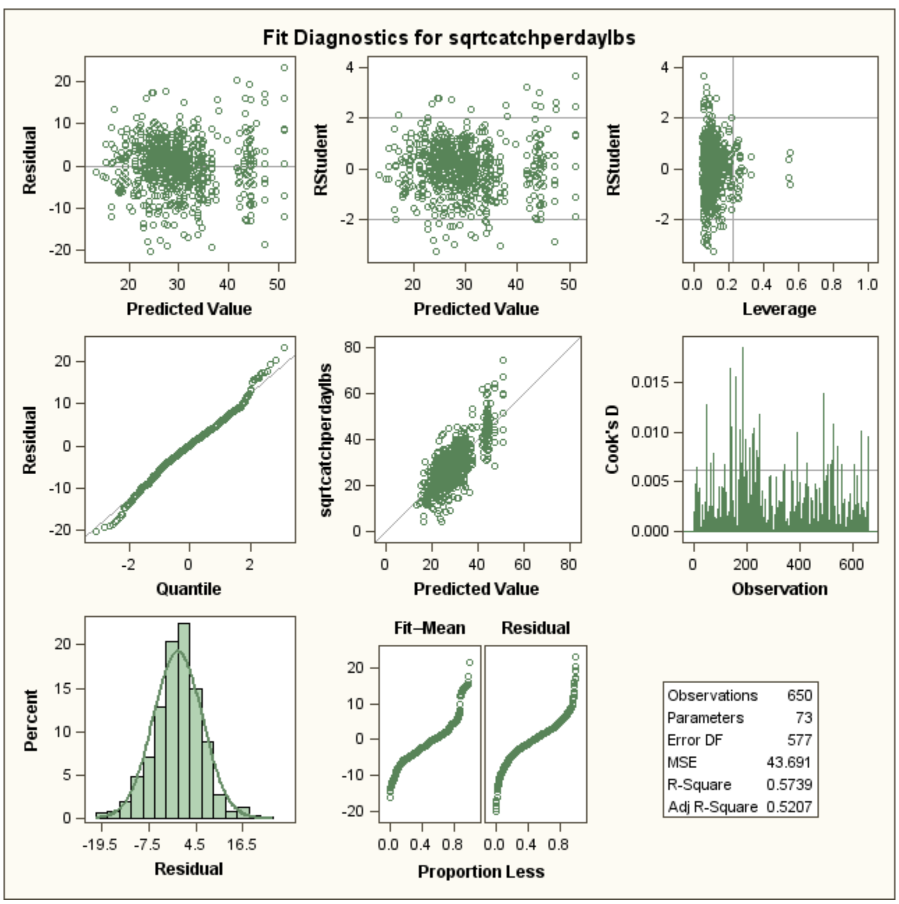
Appendix 1: GLM results and diagnostic plots for standardized pounds per day indices.

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.

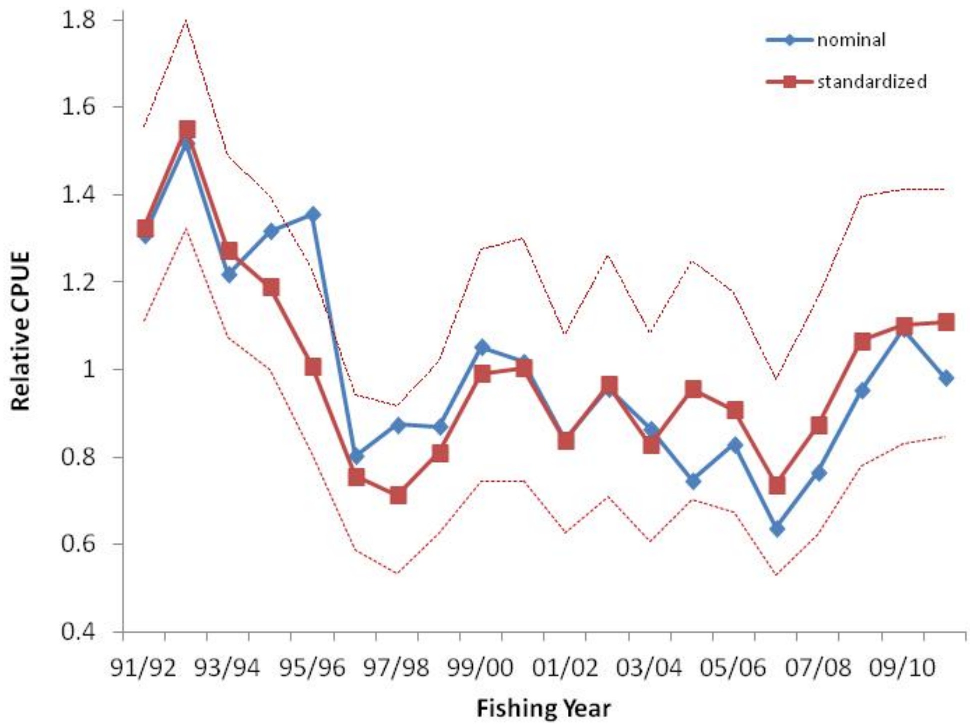


Figure A1. Nominal and standardized index of wreckfish abundance (± 80% confidence intervals) for High-3 fishing vessels, 1991/1992 through 2010/2011.

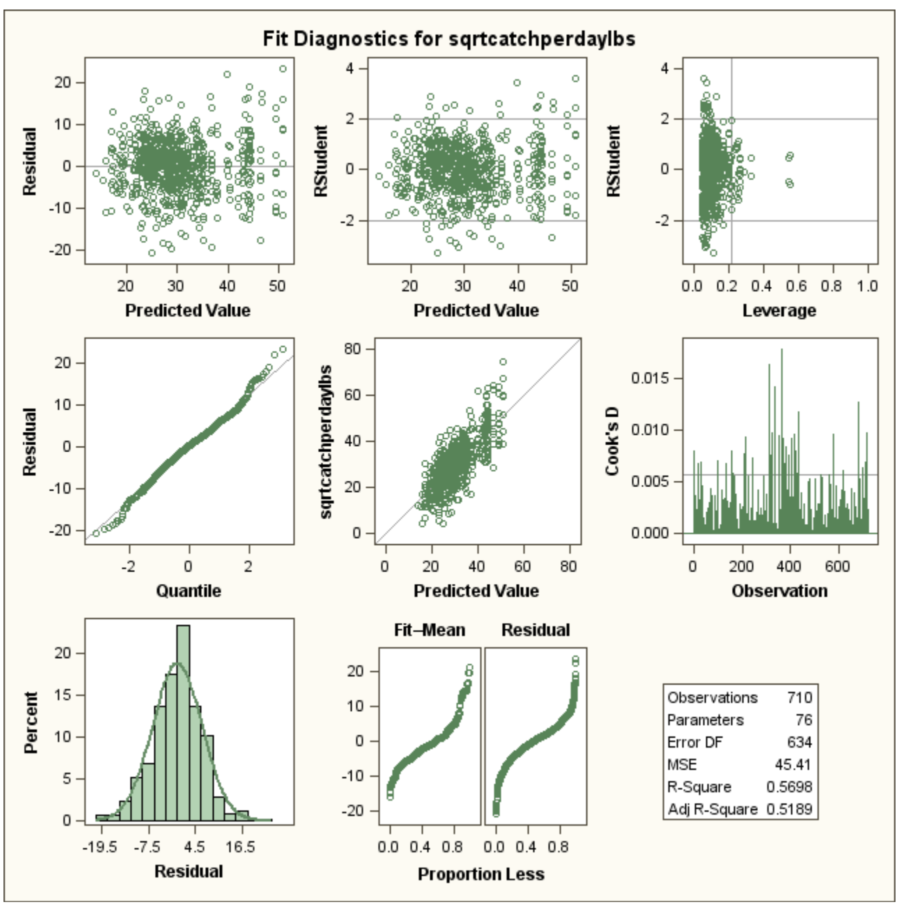
Table A1. Model fit and diagnostics for CPUE general linear model.

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.

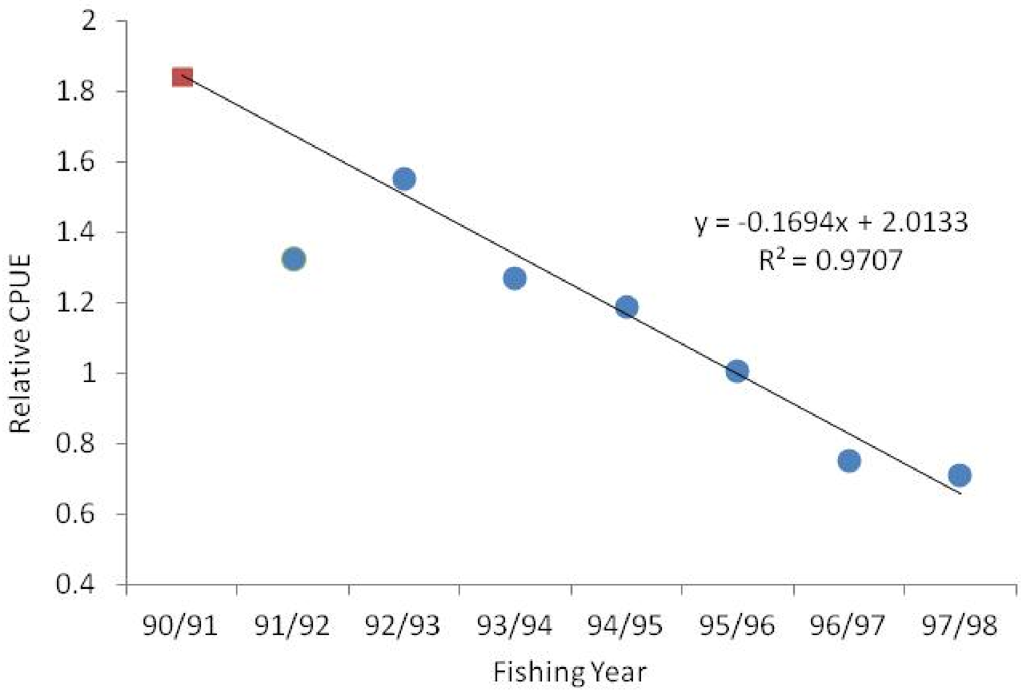


Figure A2. Linear regression of relative CPUE versus fishing year. Blue circles represent standardized CPUE values based on logbook data. The red square indicates the extrapolated CPUE value for 1990/1991.

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, 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

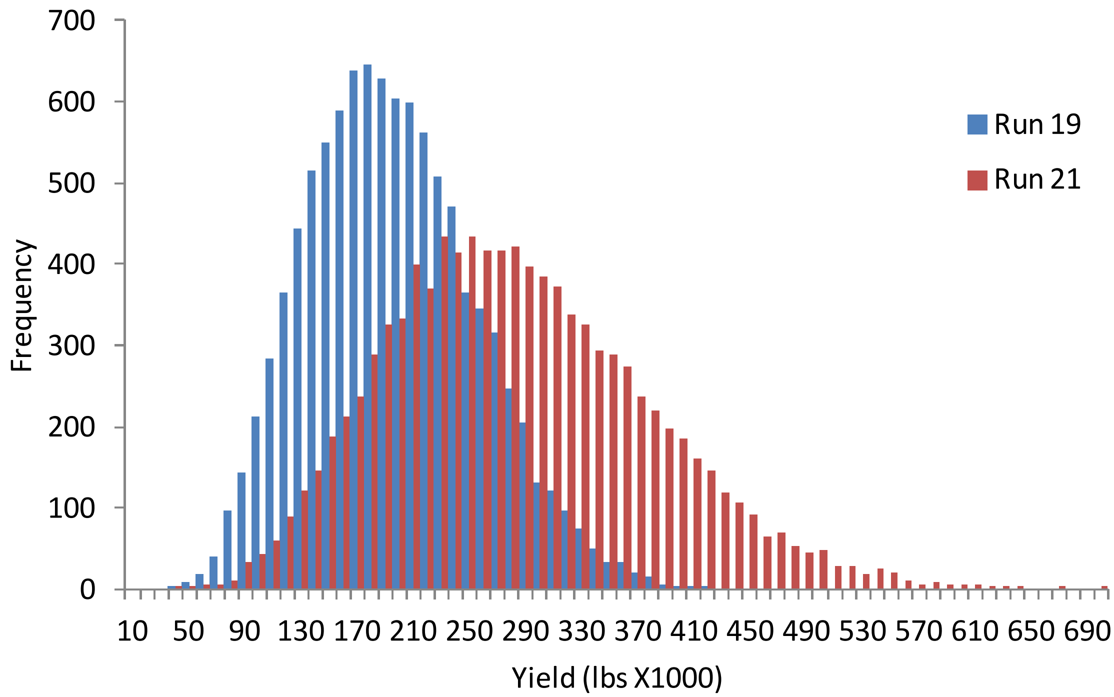


Figure A3. Frequency distribution of wreckfish DCAC results for Runs 19 and 21 based on Monte Carlo sampling of parameter values.