SEDAR 19-AW-01: A hierarchical analysis of south Atlantic red grouper CPUE indices

Prepared by Dr. Paul B. Conn
Sustainable Fisheries Branch
National Marine Fisheries Service
Southeast Fisheries Science Center
NOAA Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road, Beaufort, NC 28516

1. Introduction

Relative abundance indices recently developed for red grouper in the U.S. south Atlantic were only marginally correlated ($0.00 \leq \rho \leq 0.37$), with no correlations statistically significant at the $\alpha = 0.05$ level (SEDAR, 2009). While some differences in CPUE trends might be expected as a consequence of different gear selectivities, the lack of correlation suggests the presence of residual errors not reflected in estimated CVs. Such errors could be a function of changing catchability, differences in spatial coverage, or any factor that leads to non-random sampling of vulnerable fish. For instance, the University of Miami/NMFS reef fish visual survey (which was suggested for use in the SEDAR 19 assessment of red grouper) is prosecuted in southern Florida, while a MARMAP Chevron trap survey was conducted between North Carolina and northern Florida.

Given that some stock assessment models (e.g., surplus production models; Prager, 1994) run into numerical difficulties when confronted with conflicting indices, I used a recently developed hierarchical modeling approach (Conn, In Review) to estimate a common population trend from this group of indices. The approach works by assuming that each index is attempting to summarize relative abundance, but that it is subject to process errors in addition to known levels of sampling errors (sampling errors being computed from knowledge of the sampling design and/or from output of model fitting exercises).

2. Materials & Methods

I gathered red grouper indices and accompanying levels of precision from the SEDAR 19 data workshop report (Table 1) for use in hierarchical analysis. All indices were assumed to be subject to lognormally distributed sampling error (the CV for this error was assumed known) as well as unknown, lognormally distributed process error. Given these assumptions, one can apply the model of Conn (In Review) to estimate the relative abundance time series most likely to have generated the data. The parameters of this model include χ_i, the natural log of a scaling parameter for index i, ν_t, the natural log of the combined index in year t, and σ_i^p, the standard deviation for process errors for index i. The method assumes that catchability can randomly vary over the time series, but that it is stationary (i.e., no long term trends in catchability).

This model was fit using WinBUGS software (Spiegelhalter et al., 2003) using the same set of prior distributions as employed by Conn (In Review). In their study, Conn (In Review) showed that this combination of prior distributions proved to be relatively robust for estimating relative abundance trends in a number of different biological and sampling scenarios, including several that violated modeling assumptions. Four Markov chains of length 60,000 were fit to the data, with the last half of each being combined to provide a sample from the posterior distribution of model parameters.

Several different scenarios were considered. First, the model was fit to raw index data, after conversions were made so that all indices were in weight (see working paper documenting ASPIC/surplus production model runs). Second, the model was fit to a revised data set in which fishery dependent indices were assumed to have 2% annual increases in catchability from 1978 through 2003. Increases in catchability were implemented to reflect technology creep, mirroring an assumption used in several previous SEDAR assessments (e.g., SEDAR 10 gag grouper, SEDAR 15 red snapper and greater amberjack, SEDAR 17 vermilion snapper and Spanish mackerel). Catchability increases were thought to plateau around 2003 when global positioning systems became commonplace, and no new technologies were since introduced (SEDAR 2009).

3. Results

Inspection of standard MCMC diagnostics indicated that Markov chains had indeed converged to the posterior distribution in all cases. Estimates of relative abundance from the hierarchical approach suggested a decrease of abundance from the late 1970s through the early 1990s, with increasing abundance since that time (Figures 1 and 2, Table 2). The magnitude of the abundance increase was more extreme when the data were unadjusted (Figure 1) than when fishery dependent indices were adjusted to account for a 2% annual increase in catchability (Figure 2). Estimated process error standard deviations were identical for the two approaches (at least to the hundredths place), indicating substantial process error for the RVC index (Figure 3). Point estimates and posterior standard deviations for process errors were 0.88 (SD 0.22) for the RVC data; 0.23 (SD 0.17) for the MARMAP survey; 0.35 (SD 0.13) for the for the headboat survey; 0.42 (SD 0.17) for the MRFSS survey; and 0.28 (SD 0.14) for the logbook index.

4. Discussion

This analysis suggests that the relative abundance of red grouper decreased from the late 1970s to the early 1990s and has since been increasing. The magnitude of this final increase depends on what assumptions are made about trends in catchability. On the one hand, increases should be expected for fishery dependent indices because of gear improvements (GPS, etc.). On the other hand, if catchability is density dependent, it is possible to get very different patterns (e.g., an overall decrease in catchability; Thorson and Berkson, Unpublished manuscript).

Considerable process error was estimated for the RVC index. In addition to this survey being conducted at the southern range of the stock, it also tended to sample smaller fish. Thus, there are several reasons why the observed trend from this survey did not conform to the "overall" trend in biomass suggested by the hierarchical model. However, we urge caution in dismissing the RVC index, since it was a well designed, fishery independent survey. The survey likely provides a reasonable picture of relative abundance of shallow water red grouper in southern Florida.

References

Conn, P. B. Hierarchical analysis of multiple noisy abundance indices. *Can. J. Fish. Aquat. Sci.* .

Prager, M. H. (1994). A suite of extensions to a nonequilibrium surplus-production model. *Fish. Bull., Washington, D.C.* **92**, 374–389.

SEDAR (2009). *SEDAR 19 Data Workshop Report - Red grouper.*

Spiegelhalter, D. J., Thomas, A., Best, N. and Lunn, D. (2003). *WinBUGS User Manual Version 1.4 [online].*

Thorson, J. and Berkson, J. Multi-species estimation of catchability trends and density dependence in the gulf of mexico.

Figure 1. Scaled relative abundance as approximated with the posterior mean (solid line), together with 95% credible intervals (dashed lines) when unadjusted index data were analyzed

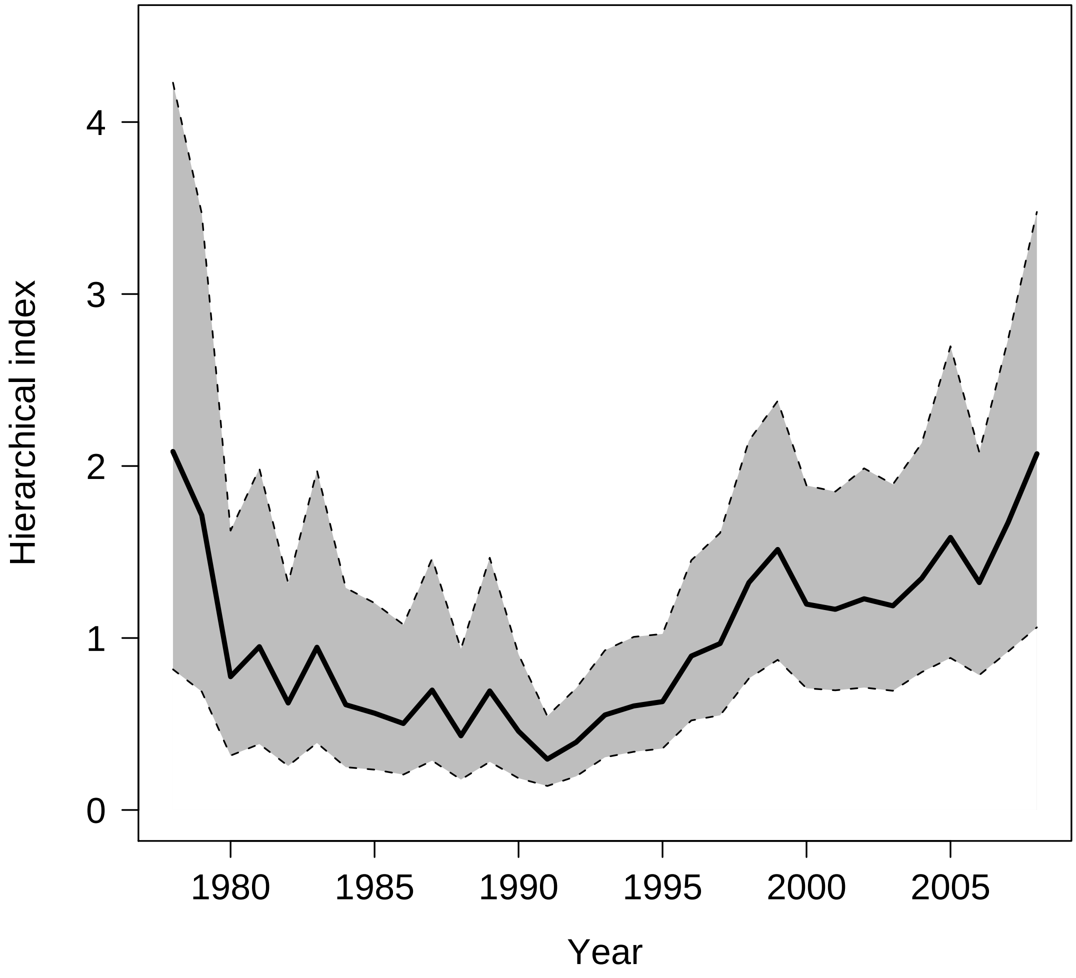

Figure 2. Scaled relative abundance as approximated with the posterior mean (solid line), together with 95% credible intervals (dashed lines) when fishery dependent indices were adjusted to account for a 2% annual increase in catchability from 1978-2003

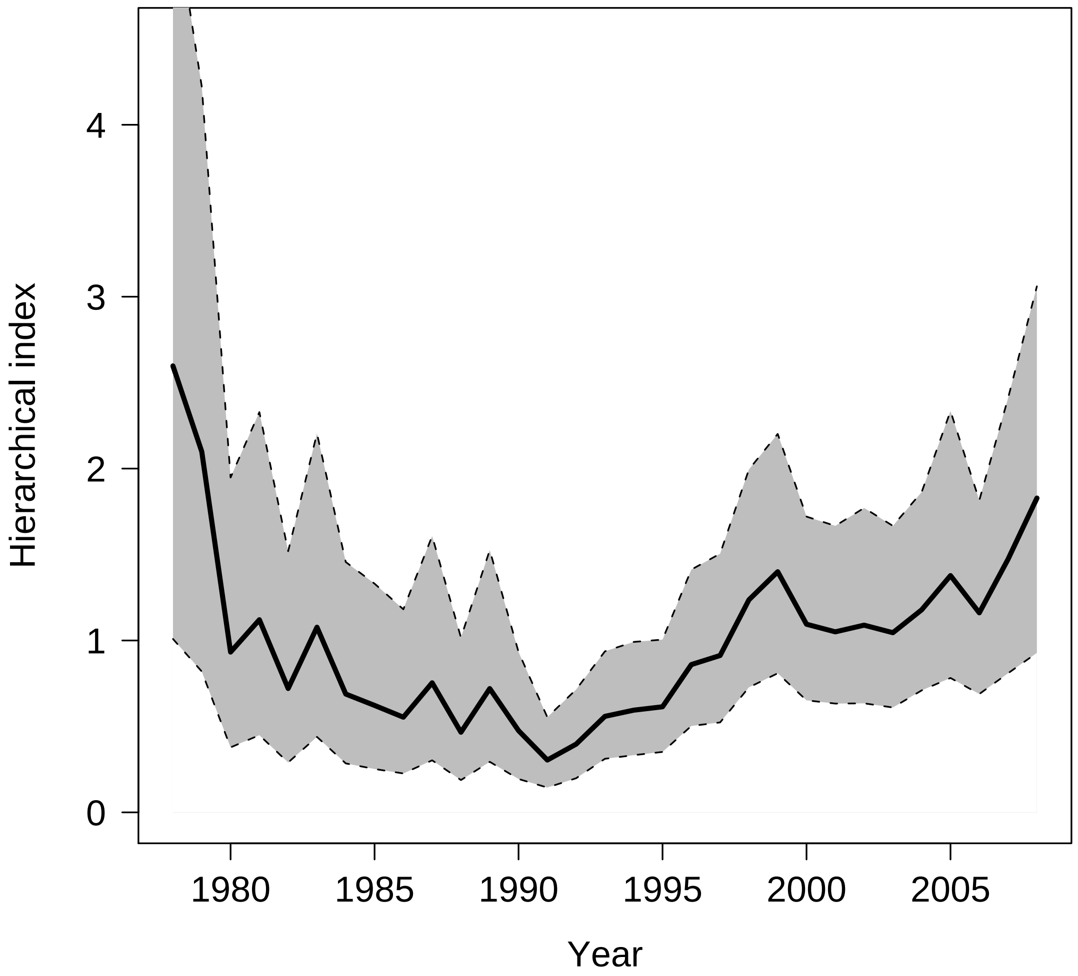

Figure 3. Estimated process standard deviation for each index as represented by the posterior mean (circles) and 95% credible intervals (bars) when unadjusted index data were analyzed. Since a lognormal error structure was chosen, σ_p is approximately equivalent to the coefficient of variation for process error in normal space.

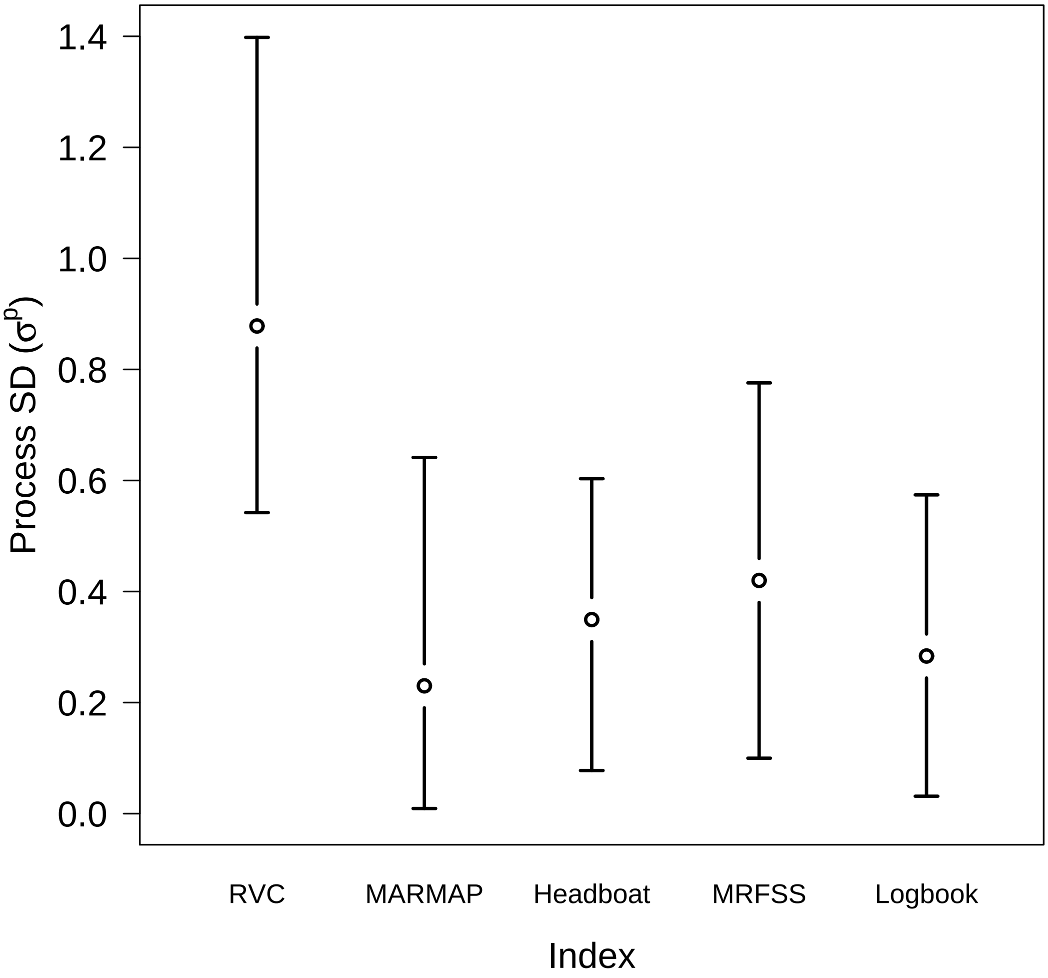

Table 1

Red grouper indices used in hierarchical analysis (sampling error CV in parentheses). The indices include two fisheries independent indices: one from a U. Miami/NMFS reef fish visual census (RVC) in south Florida and one from a MARMAP Chevron trap survey (prosecuted from north Florida up through Cape Hatteras, NC). Also available were three fishery dependent indices, including those developed from general recreational data (MRFSS), from headboats, and from commercial logbooks.

Year	RVC	MARMAP	Headboat	MRFSS	Logbook
1978	.	.	2.24 (0.20)	.	.
1979	.	.	1.78 (0.18)	.	.
1980	.	.	0.7 (0.20)	.	.
1981	.	.	0.89 (0.21)	.	.
1982	.	.	0.54 (0.22)	.	.
1983	.	.	0.89 (0.20)	.	.
1984	.	.	0.53 (0.20)	.	.
1985	.	.	0.48 (0.21)	.	.
1986	.	.	0.42 (0.21)	.	.
1987	.	.	0.62 (0.21)	.	.
1988	.	.	0.35 (0.22)	.	.
1989	.	.	0.61 (0.22)	.	.
1990	.	0.05 (1.13)	0.57 (0.23)	.	.
1991	.	0.12 (0.94)	0.35 (0.23)	0.14 (0.51)	.
1992	.	0.45 (0.75)	0.45 (0.23)	0.23 (0.36)	.
1993	.	0.86 (0.65)	0.52 (0.22)	0.95 (0.84)	0.39 (0.27)
1994	0.18 (0.65)	1.10 (0.62)	0.65 (0.22)	0.89 (0.37)	0.31 (0.26)
1995	0.12 (0.28)	0.52 (0.76)	0.71 (0.22)	0.27 (0.59)	0.50 (0.21)
1996	0.15 (0.42)	2.61 (0.61)	0.88 (0.21)	1.05 (0.35)	0.58 (0.17)
1997	0.25 (0.42)	0.32 (0.88)	1.38 (0.21)	0.74 (0.61)	0.65 (0.15)
1998	0.27 (0.53)	0.33 (0.65)	1.94 (0.20)	1.20 (0.50)	0.99 (0.12)
1999	0.69 (0.30)	1.70 (0.53)	1.84 (0.21)	0.58 (0.32)	1.45 (0.10)
2000	0.84 (0.13)	1.13 (0.49)	1.1 (0.22)	0.56 (0.33)	1.05 (0.13)
2001	1.69 (0.11)	1.70 (0.53)	1.22 (0.21)	0.71 (0.26)	0.84 (0.15)
2002	1.87 (0.12)	1.16 (0.52)	0.79 (0.22)	1.83 (0.25)	0.90 (0.15)
2003	2.73 (0.12)	1.02 (0.52)	0.79 (0.22)	1.28 (0.26)	1.03 (0.14)
2004	1.91 (0.21)	1.03 (0.53)	1.45 (0.20)	1.53 (0.27)	0.96 (0.14)
2005	1.37 (0.12)	1.15 (0.48)	3.11 (0.19)	1.28 (0.22)	0.86 (0.15)
2006	0.67 (0.17)	1.70 (0.52)	1.1 (0.22)	0.95 (0.27)	1.22 (0.13)
2007	0.99 (0.15)	1.51 (0.49)	1.17 (0.23)	0.78 (0.39)	1.94 (0.11)
2008	1.27 (0.11)	0.56 (0.66)	0.93 (0.23)	3.02 (0.28)	2.35 (0.10)

Table 2

Scaled index values from the hierarchical analysis ("Combined") and accompanying CVs when analysis is performed on raw indices ('Combined0') and when analysis is performed on data incorporating a 2% annual increase in catchability from 1978-2003 for fishery dependent indices ('Combined2').

Year	Combined0	Combined2
1978	2.08 (0.43)	2.60 (0.43)
1979	1.71 (0.42)	2.10 (0.42)
1980	0.78 (0.44)	0.93 (0.44)
1981	0.95 (0.44)	1.12 (0.44)
1982	0.62 (0.45)	0.72 (0.45)
1983	0.95 (0.43)	1.08 (0.43)
1984	0.61 (0.45)	0.69 (0.44)
1985	0.56 (0.45)	0.62 (0.45)
1986	0.50 (0.46)	0.55 (0.46)
1987	0.70 (0.44)	0.75 (0.45)
1988	0.43 (0.46)	0.47 (0.47)
1989	0.69 (0.45)	0.72 (0.45)
1990	0.46 (0.41)	0.48 (0.40)
1991	0.30 (0.35)	0.30 (0.35)
1992	0.39 (0.34)	0.40 (0.34)
1993	0.55 (0.29)	0.56 (0.29)
1994	0.60 (0.28)	0.59 (0.28)
1995	0.63 (0.27)	0.61 (0.27)
1996	0.90 (0.27)	0.86 (0.27)
1997	0.97 (0.28)	0.91 (0.28)
1998	1.32 (0.27)	1.24 (0.26)
1999	1.51 (0.26)	1.40 (0.25)
2000	1.20 (0.25)	1.09 (0.25)
2001	1.17 (0.25)	1.05 (0.25)
2002	1.23 (0.27)	1.09 (0.27)
2003	1.19 (0.26)	1.05 (0.26)
2004	1.35 (0.25)	1.18 (0.25)
2005	1.58 (0.30)	1.38 (0.29)
2006	1.32 (0.25)	1.16 (0.25)
2007	1.67 (0.28)	1.47 (0.28)
2008	2.07 (0.30)	1.83 (0.30)