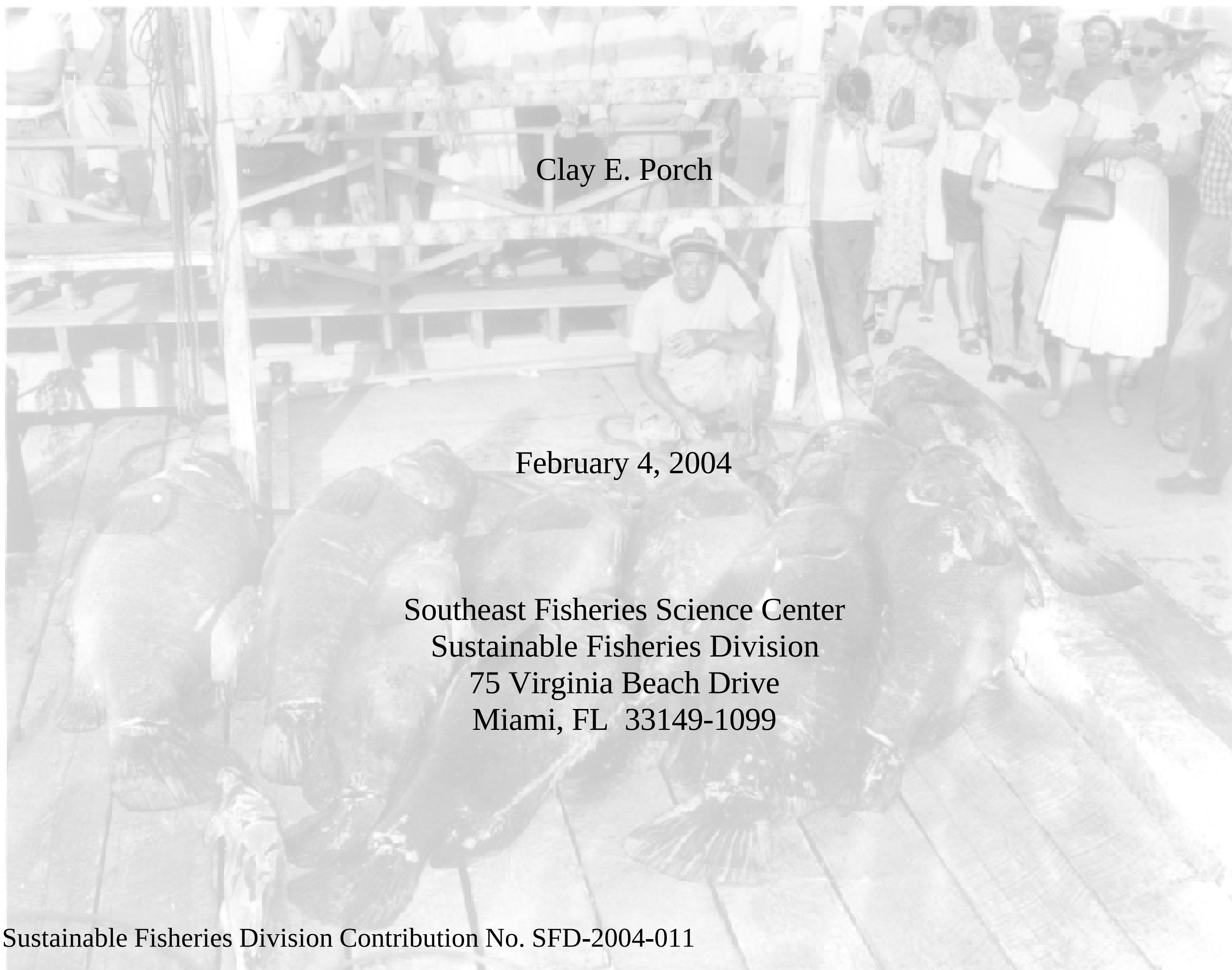
A REASSESSMENT OF REBUILDING TIMES FOR GOLIATH GROUPER WITH MODIFICATIONS SUGGESTED BY THE SEDAR REVIEW PANEL



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This paper updates the previous assessment of goliath grouper (Porch et al. 2003) by incorporating two changes in model structure and two changes recommended by the SEDAR stock assessment review panel[1] related to the input data. Apart from these changes, described below, the model and data are as described in Porch et al. (2003) and summarized here in Table 1.

Methods

Changes in the way fishing mortality is modeled

The fishing mortality rate on the most vulnerable age class is now modeled by a two-line function,

$$(1) \qquad F_y = \begin{cases} F_1 + \dfrac{F_{\text{modern}} - F_1}{y_{\text{modern}} - y_1}(y - y_1) & y_1 \le y < y_{\text{modern}} \\ F_{\text{modern}} & y_{\text{modern}} \le y < 1990 \end{cases}$$

where the parameter F_1 represents the fishing mortality rate in the first year of the time series (y_1 = 1950) and F_{modern} represents the average fishing mortality rate during the 'modern period' (here y_{modern} = 1980). The earlier formulation differed from (1) in that $F_y = F_1 + my$ for $y_1 \le y < y_{modern}$, where m is a slope parameter independent of the values of F_{modern}. The new formulation avoids the artificial discontinuity at y_{modern} (Figure 1) while at the same time eliminating m (a nearly superfluous parameter) and improving the overall precision of the estimates.

The fishing mortality rate from 1990 forward was originally set by Porch et al. (2003) to an arbitrary low value (0.01 yr^{-1}) to reflect the effect of the harvest moratorium. The SEDAR panel was divided as to whether the actual fishing mortality rate was higher or lower than this. They suggested bracketing this value by assuming the moratorium was probably not more than 99% effective at reducing F, but at least 90% effective. Given that the estimated average mortality rate immediately prior to the moratorium was on the order of 0.3 yr^{-1}, the two scenarios are roughly equivalent to assuming 0.3 to 3 percent of the goliath grouper population is killed each year by human activities (e.g., poaching and release mortality).

Changes in the way the variance of the indices of abundance are modeled

In the case of survey data, the variances associated with sampling variability are often estimated extraneous to the population model (e.g., during the standardization procedure). However, there may be additional variance owing to fluctuations in the distribution of the stock relative to the survey area (IWC 1994). Previously, to accommodate such possibilities, the log-scale variances were modeled as

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[1]Anon. Goliath Grouper Stock Assessment Workshop Report, Southeast Data, Assessment and Review (SEDAR). January 2003. xx pp.

(2)
$$s^2_{c,i,y} = \log\left((c_{c,i,y}CV)^2 + 1\right)$$
$$s^2_{n,y} = \log\left((c_{n,y}CV)^2 + 1\right)$$

where $c_{c,i,y}$ and $c_{n,y}$ are relative coefficients of variation (estimated outside the model and scaled by the maximum value in the time series) and CV is a coefficient of variation that reflects some overall process variance (estimated within the model). The new model assumes the variances of the logged quantities are additive such that

(3)
$$s^2_{c,i,y} = c^2_{c,i,y} + \log(\mathrm{CV}^2 + 1)$$
$$s^2_{n,y} = c^2_{n,y} + \log(\mathrm{CV}^2 + 1)$$

where the $c^2_{c,i,y}$ and $c^2_{n,y}$ are now the annual observation variances for the logarithms of the count data and anecdotal reports of relative abundance (again, estimated outside the model). Besides being more intuitively appealing, the additive model produced more realistic process CV's (about 60% compared with over 300% in the previous model) and stabilized the likelihood profiling algorithm provided in the AD Model Builder package.

Other changes

The SEDAR review panel did not reject any of the model inputs per se, however it did question why the early data points (1982-1984) of the DeMaria index were excluded from the fitting procedure. It was generally agreed that the drastic decline from 1982 to 1983 was attributable to heavy fishing pressure applied when the sites were first discovered and probably did not reflect the trend of the goliath grouper population as a whole. Nevertheless the panel suggested that this problem may have been less severe in subsequent years and recommended that the 1983 and 1984 points be included.

Another point of contention was the point when the population was assumed to be near virgin levels (i.e., when substantive fishing began), with some members of the panel indicating that the date should be pushed back to as early as 1900. This was done as a sensitivity analysis.

Results and discussion

The base model assumes the fishing mortality rate is nearly zero in 1950, increases linearly through 1979, is relatively constant between 1980 and 1989, and then drops off from 1990 onwards to 1% or 10% of the 1980-89 level owing to the moratorium. The model fits to the data are statistically identical under both post-moratorium levels of F shown (Figure 2). Neither model was able to reconcile the rapid increase in relative abundance indicated by the REEF survey with the more gradual trends indicated by the other surveys (the same was true of the runs reported on in Porch et al, 2003).

The key parameters affecting the estimated recovery rate of the stock are the maximum lifetime fecundity parameter a and natural mortality rate M. The data appear to be sufficiently informative to influence the estimates of the latter, but have almost no effect on the former (figure 3). Thus the prior for the natural mortality rate must be regarded as highly influential in regards to the point estimates. The model that assumes a 90% effective moratorium estimates a greater value of a than the model with a 99% effective moratorium in order to reconcile the higher presumed mortality rates with the increase in abundance indicated by the surveys. Nevertheless, the estimated increase in productivity is offset by the increased fishing mortality rates so that the trends in spawning biomass and fishing mortality rates under the two scenarios are almost identical until about 1998. After that, the trends obtained with the 90% effective moratorium become increasingly less optimistic compared to the results with the 99% effective moratorium. As a result, the probability that the population will have recovered to a level at or above are the equilibrium level corresponding to an SPR of 50% ($\tilde{s}_{50\%}$) is lower for any given year (Figure 4). For example, under the 99% effective scenario it is estimated that there is a 50% chance the population will recover by 2005 and an 80% chance that it will recover by 2009. Under the 90% effective scenario, however, these dates are pushed back to 2009 and 2015.

The sensitivity runs where nearly pristine conditions were assumed to occur in 1900 are less optimistic than the runs above (Figures 5 and 6). They suggest a 50% chance of recovery by 2009 or 2015 with the 99% and 90% effective moratoriums, respectively. In both cases the 80% probability level is not reached until after 2020. It should be noted, however, that several member of the SEDAR review panel felt the results might be overly pessimistic because the fishing mortality rate was not likely to have increased linearly over the entire time period from 1900 to 1980 (more likely it continued at a relatively low level until about 1950 and them began increasing more rapidly).

It is important to reiterate that the data considered focus on a relatively small portion of the potential range of goliath grouper (see Porch and Eklund 2003). It is believed that the center of abundance for the population in U.S. waters is southern Florida, particularly the Ten Thousand Islands area, but goliath grouper are known to have occurred throughout the coastal waters of Gulf of Mexico and along the east coast of Florida, and on up through the Carolinas. Inasmuch as goliath grouper are not highly migratory, it is possible it may take some additional time for the species to fully occupy its historical range, thus delaying the overall recovery of the stock.

Acknowledgments

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Literature cited

Porch, C. E., and Eklund, A.-M. 2003. Standardized visual counts of goliath grouper off South Florida and their possible use as indices of abundance. Sustainable Fisheries Division Contribution SFD-0017. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Porch, C. E., A.-M. Eklund, and G. P. Scott. 2003. An assessment of rebuilding times for goliath grouper. Sustainable Fisheries Division Contribution SFD-0018. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Table 1. Summary of likelihood and prior components of log-posterior distribution. Note that CV refers to the estimated 'overall' coefficient of variation.

Component	distribution	median	standard deviation
Prior for a-1	lognormal	2.65	$s_{\ln a} = 1.14$
Prior for M	lognormal	0.095	$s_{\ln M} = 0.4$
Prior for F_1	normal*	0.1	$s_{F_1} = 0.2$
Prior for F_{modern}	normal*	0.3	$s_{F_{\mathrm{modern}}} = 0.3$
Prior for catchabilities q	normal*	0.5	$s_q = 1.0$
Prior for CV	normal	0.5	$s_{CV} = 0.25$
Prior for recruitment devs.	lognormal	0	$s_{\ln r} = 0.4$, $r = 0.5$
Likelihood for surveys	lognormal	model expectation	$s^2_{c,i,y} = c^2_{c,i,y} + \log(\mathrm{CV}^2 + 1)$
Likelihood for anecdotes	lognormal	model expectation	$s^2_{n,y} = c^2_{n,y} + \log(\mathrm{CV}^2 + 1)$

*relatively uninformative priors.

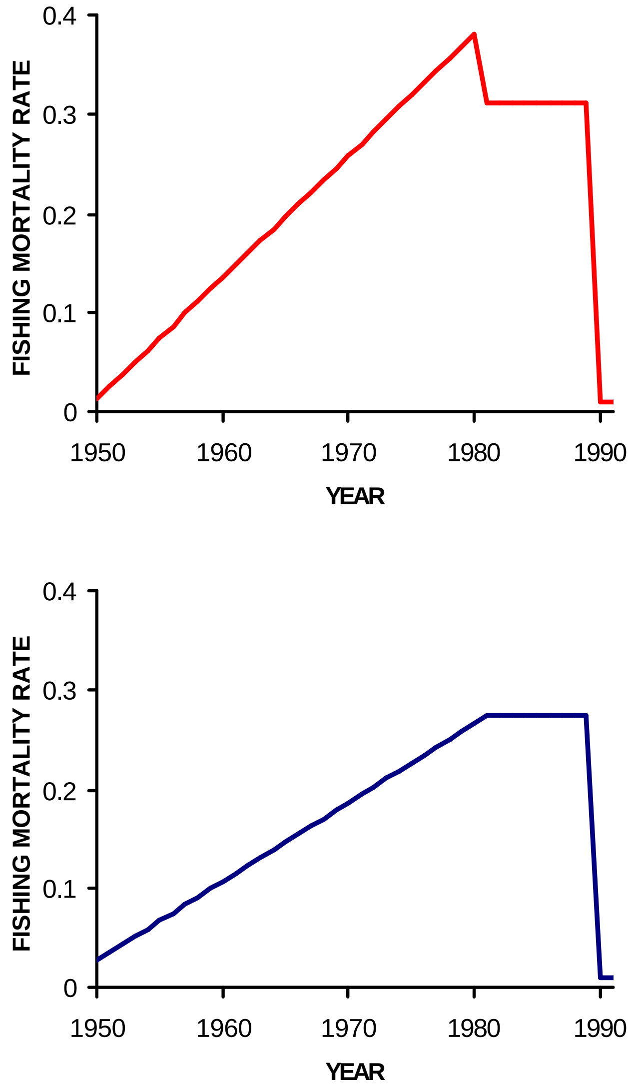

Figure 1. Estimated patterns of fishing mortality rate under the old (top) and new (bottom) formulations.

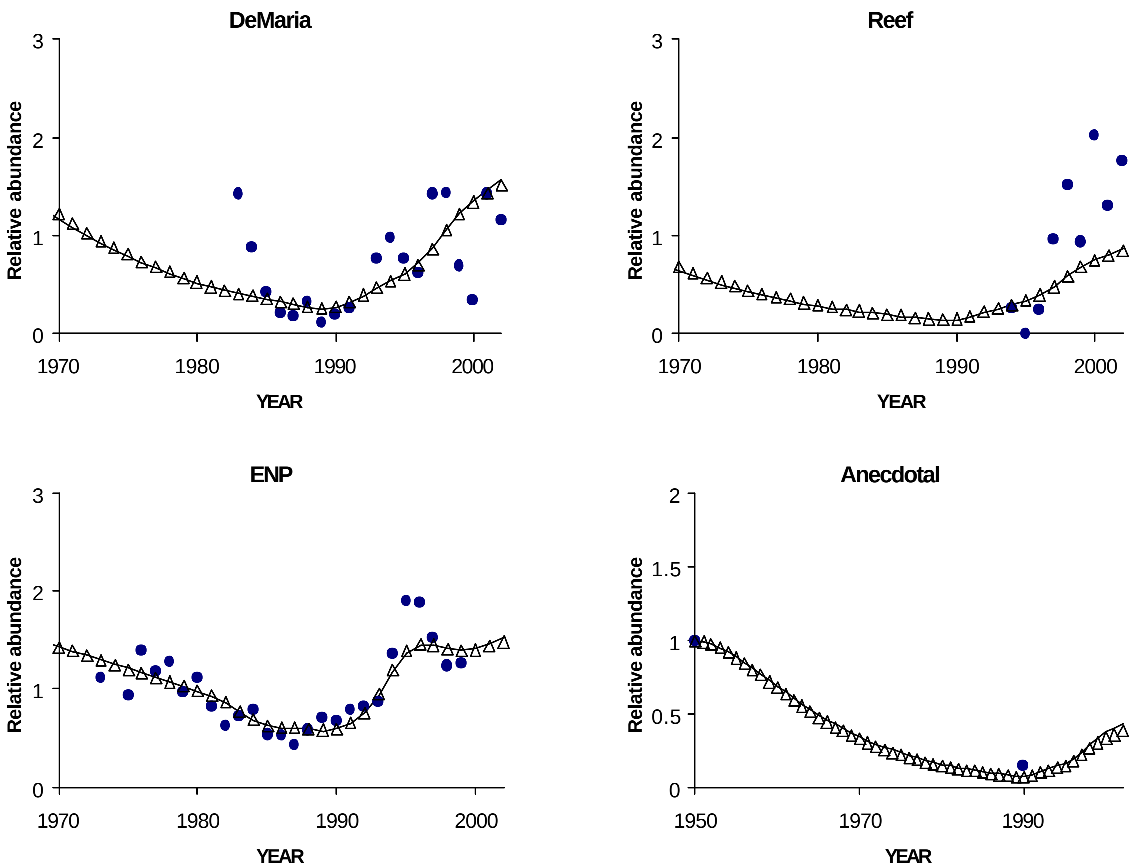

Figure 2. Model fits to the four indices of abundance. Lines denote predicted values with a 99% effective moratorium and triangles denote predicted values with a 90% effective moratorium.

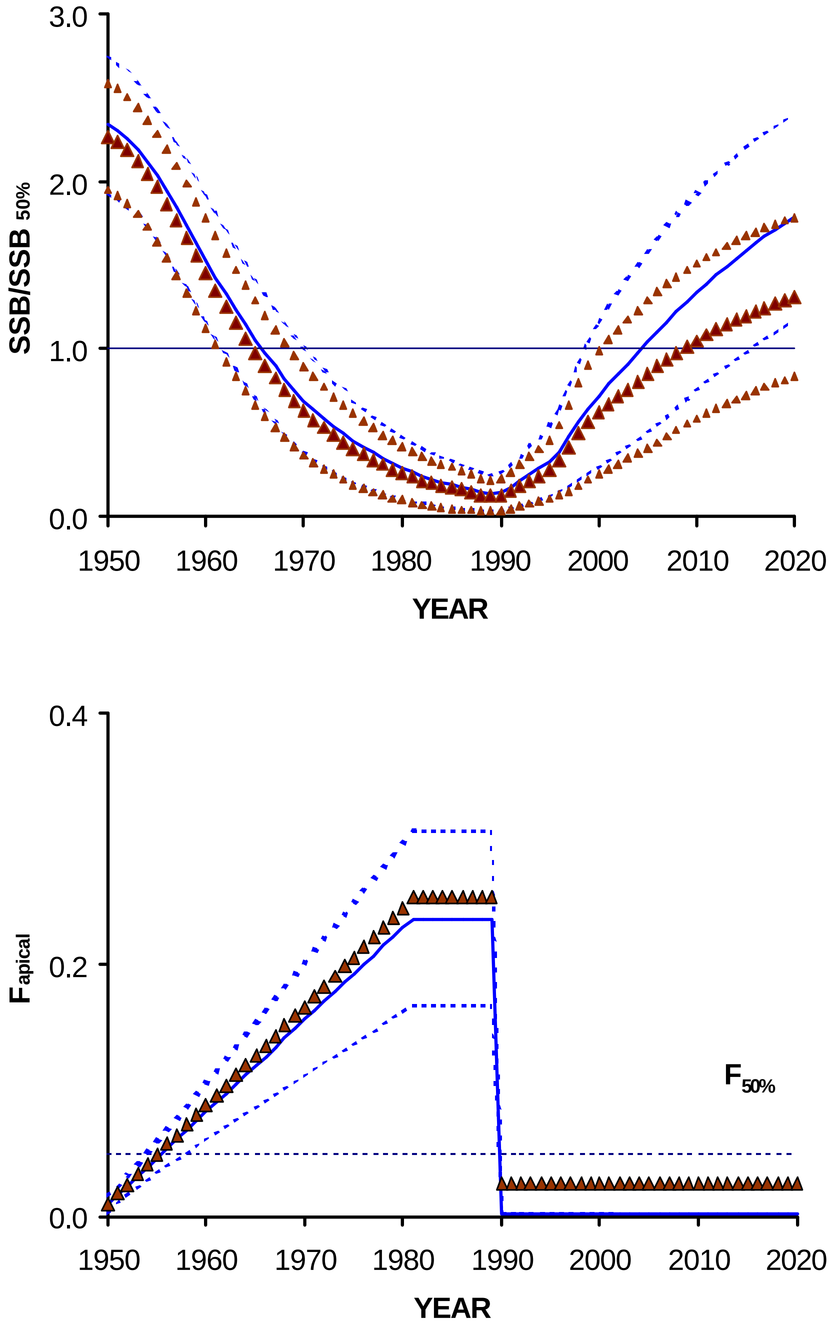

Figure 3. Predictions of relative spawning biomass and fishing mortality rate with approximate 80% confidence limits from the models assuming the moratorium was 99% effective (lines) or 90% effective (triangles).

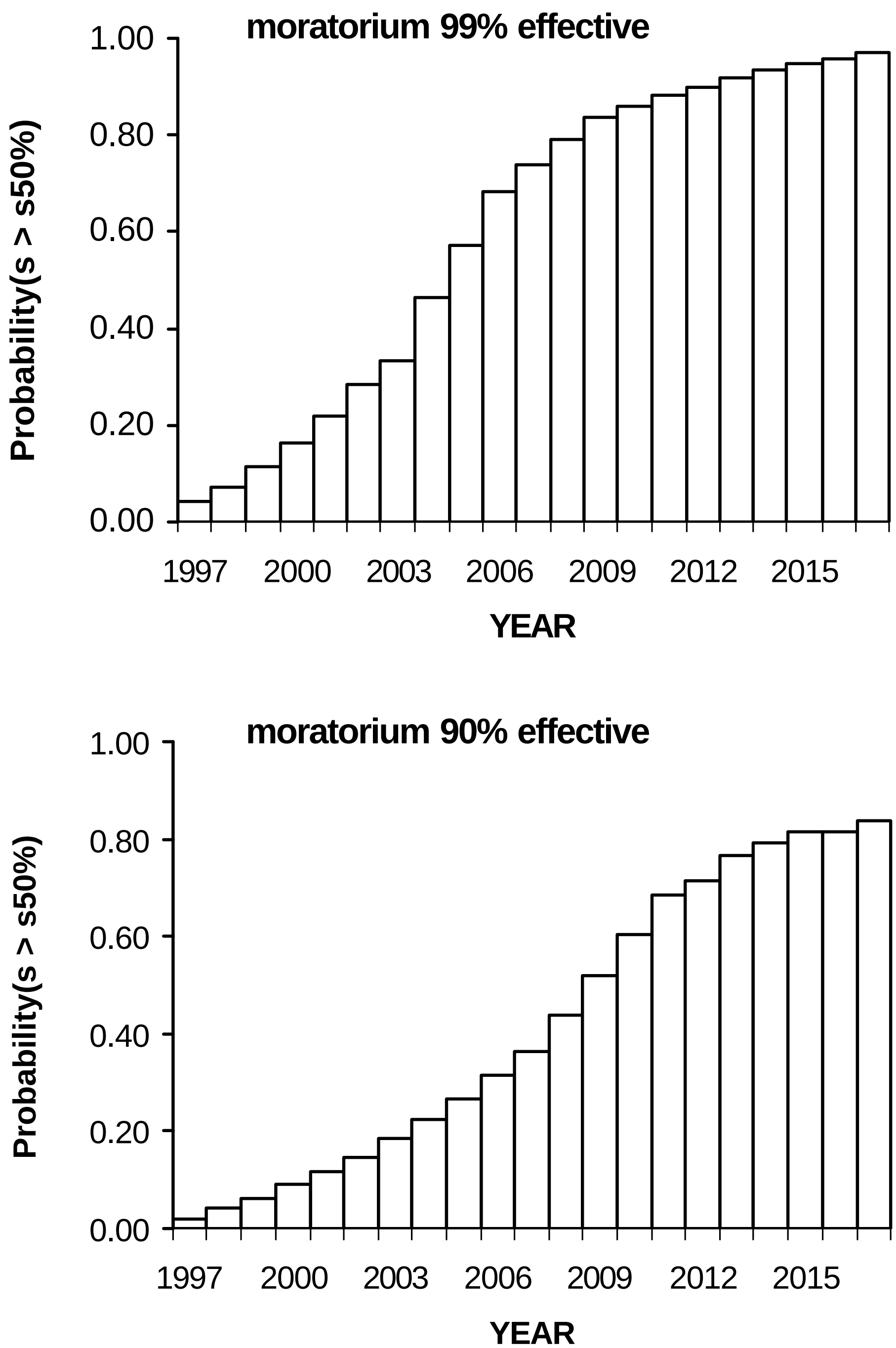

Figure 4. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR assuming the moratorium was 99% effective (top panel) or 90% effective (bottom panel).

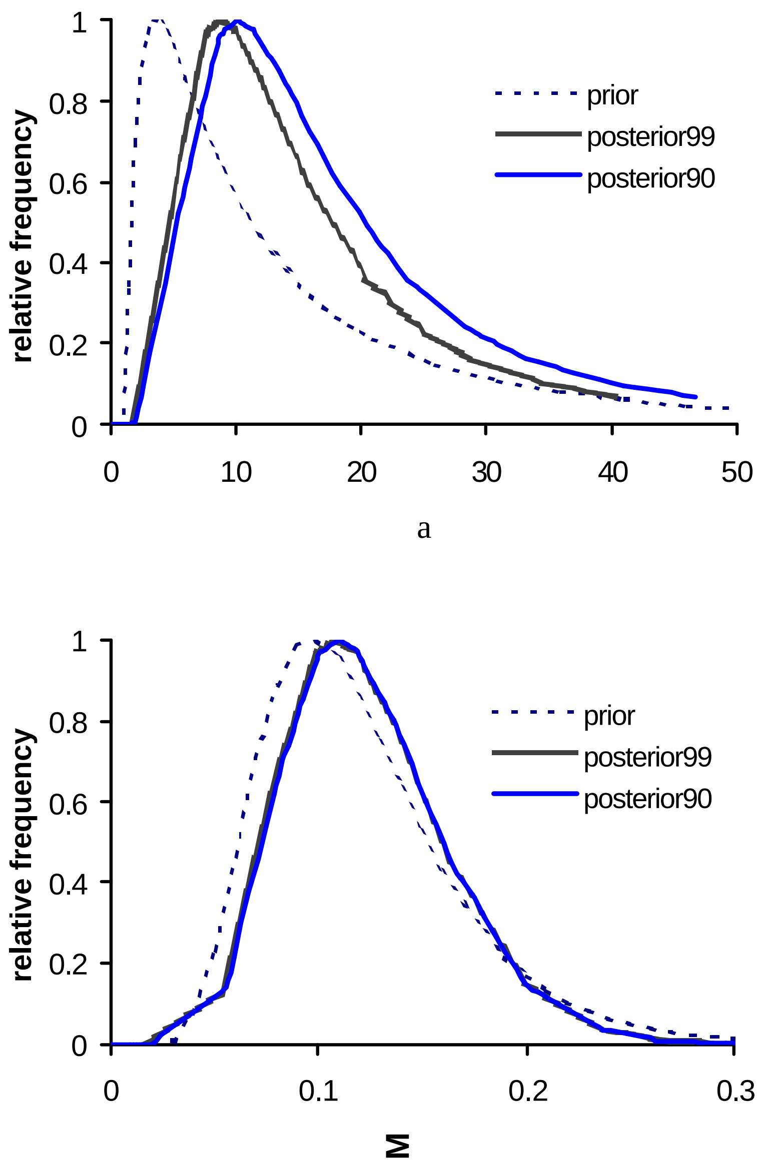

Figure 5. Prior and posterior distributions for the maximum lifetime fecundity parameter (α) and natural mortality rate (M) obtained when the moratorium was assumed to be 99% or 90% effective in reducing F.

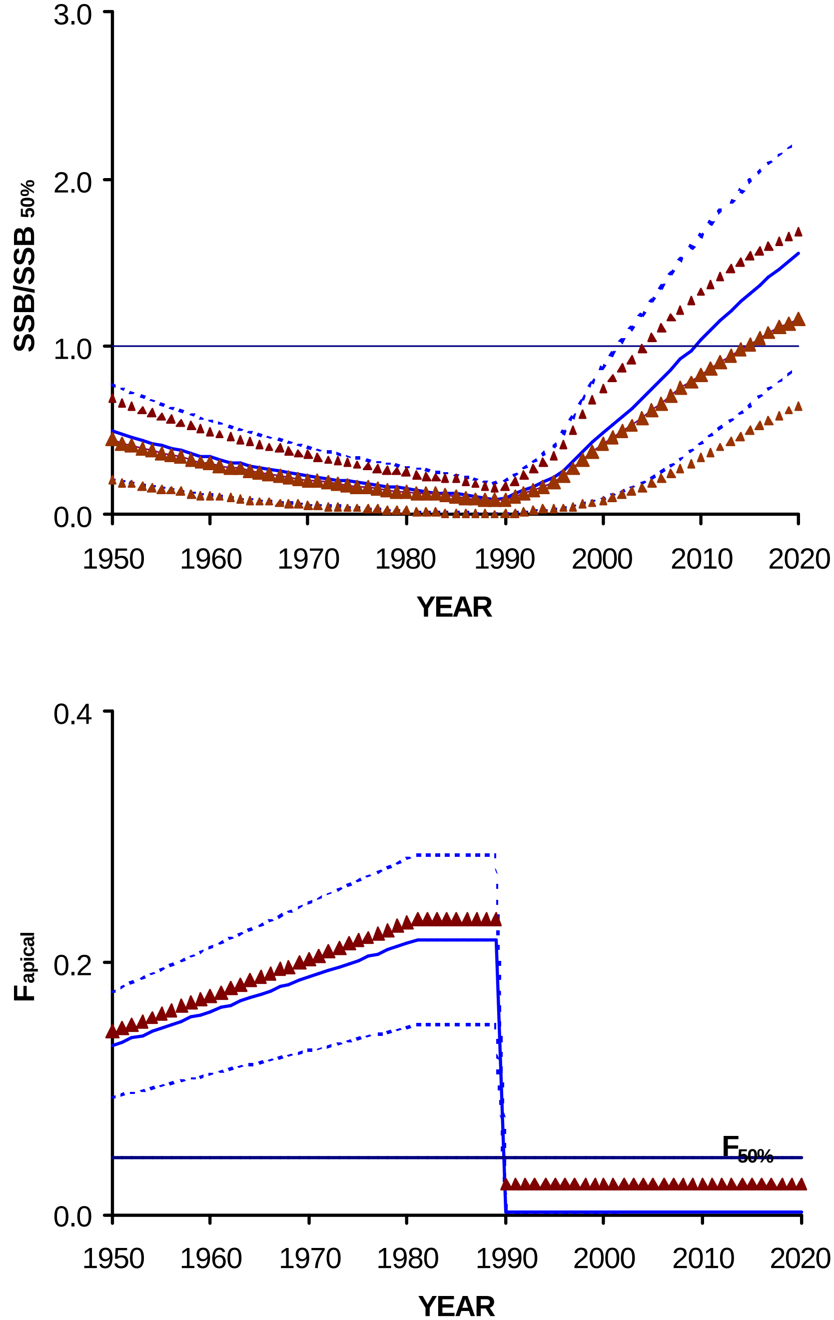

Figure 6. Predictions of relative spawning biomass and fishing mortality rate resulting when substantive exploitation is assumed to begin in 1900 rather than 1950.

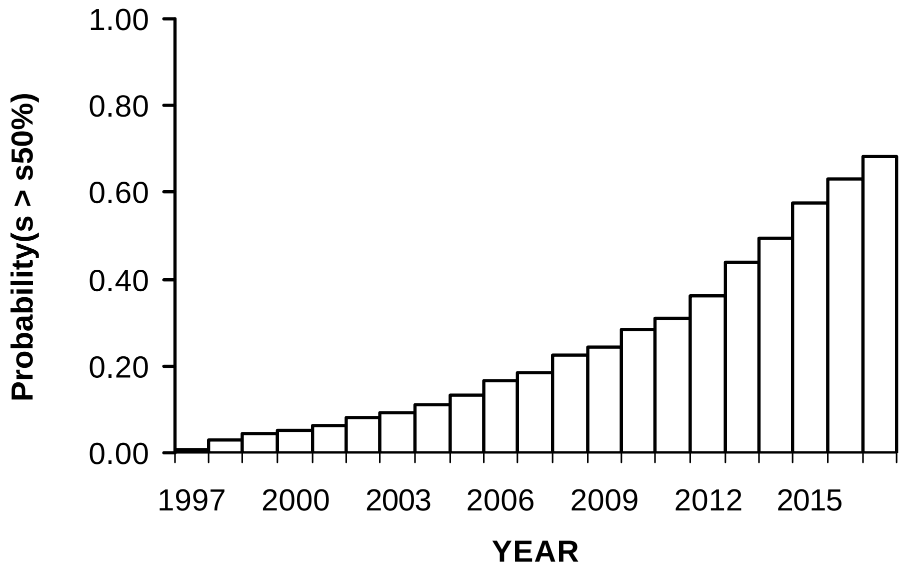

Figure 7. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR when substantive exploitation is assumed to begin in 1900 and the moratorium is 90% effective.