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Biological Reference Points for Red Grouper: Effects of Uncertainty about Growth

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Abstract. - The effects of uncertainty about growth of U.S. Gulf of Mexico red grouper (*Epinephelus morio*) on estimates of their population statistics was evaluated by computing the statistics for each of several competing von Bertalanffy growth equations fitted to length at age data from different sources and time periods. Estimates of asymptotic lengths varied from 27.7 inches to 68 inches total length. These equations were used to estimate the age composition of the 1986-1992 combined harvest and to estimate total mortality through means of catch curves constructed for 1986-1989, before the 20 inch minimum size and for 1990-1992 when the minimum size was in place. All of the mortality rate estimates and Yield Per Recruit (YPR) and Spawning Potential Ratio (SPR) evaluations assume equilibrium conditions. The catch curve estimates of mortality that were derived from ages estimated from lengths were biased low. Simulated data were analyzed to develop bias correction equations which were subsequently used in an attempt to remove the bias. Estimated total mortality for fully recruited ages ranged from Z=0.286 to Z=0.548 for 1986-1989 and from Z=0.453 to Z=1.545 for 1990-1992 depending on the growth model selected. This equilibrium assumption is known to be violated for the later period, because of the introduction of the 20-inch minimum size, hence the latter estimates are suspect. The consequence of this defect was not evaluated.

For natural mortality of M=0.2 the corresponding SPR ranged from 20 to 52 percent for 1986-1989. Equilibrium SPR estimates range between 13 and 42 percent for 1990-1992 fishing mortality rates assuming discard mortality of undersize fish is negligible. SPR estimates ranged from 7.1 to 32 percent for the same period if discard mortality of undersize fish is assumed to be 33 percent and the undersize fish are caught according to the selectivity ogive estimated for the 1986-1989 period. Analyses of YPR were conducted to estimate mean recruitment and potential equilibrium yield for each of the growth equations for the conditions of no minimum size and 16, 18 and 20-inch TL minimum sizes; fishing mortality rates corresponding to both time periods; and natural mortality of 0.15, 0.20 and 0.25. The results of this study support additional detailed examination of red grouper growth rates. Furthermore, if age-structured assessment methods are to be employed with this stock we must begin routine collection of data to develop annual age-length keys to estimate the age composition of the catch of this fishery.

Introduction

Goodyear and Schirripa (1991) noted in the first stock assessment for U.S. Gulf of Mexico red grouper (*Epinephelus morio)* recent data indicated that red grouper were larger at size than Moe found for the early 1960s (Moe 1969). This observation prompted a request for additional research (Muller 1991). Subsequent evaluations of the growth of red grouper found an important increase in size at age through time for specimens sampled from the U.S. Gulf of Mexico (Eklund, 1992; Goodyear and Schirripa 1993; Johnson and Collins ms). This trend led to the development and application of a time-corrected growth model based on the von Bertalanffy growth equation to estimate the age composition of the catch (Goodyear and Schirripa 1993). However, the results of application of virtual population analysis methods (Gavaris 1988, Powers and Restrepo 1991) to the resulting catch at age data lead to solutions that provided widely disparate views of the status of the stock and consequent low confidence in the results (Goodyear and Schirripa 1993). A recent evaluation of the underlying data concluded that the temporal trend in size at age in the available data is probably the result of sample bias rather than actual changes in growth rate through time (Goodyear ms). The present study characterizes the effect of the uncertainty in growth on important population statistics such as mortality, yield per recruit (YPR), recruitment, spawning potential ratio (SPR), $F_{0.1}$, F_{max} and equilibrium catch.

Methods

The data available for this study were from samples collected from the Gulf of Mexico red grouper recreational and commercial fisheries and analyzed by either Moe (1969) or Johnson and Collins (ms) for age determinations. All age estimates were based on otolith annuli counts. Lengths were converted to inches total length (TL) using the conversions presented in Goodyear and Schirripa (1993). Examination of the available data lead to eight groupings including seven time-gear strata and an eighth consisting of all samples pooled (see Table 1 for acronyms used to specify groupings).

Age at capture was estimated as the integer age assigned from the otolith reading and the fraction of a year that had passed since the prior June 1. Von Bertalanffy equations were fit to the resulting ages and total lengths at capture using the SAS NLIN procedure. As a test, the resulting growth model was used to estimate the ages from lengths for the fitted data set. Catch curves estimates of total mortality for the observed and predicted ages for the data sets were contrasted to characterize possible bias.

The length at full recruitment and the proportions of smaller length classes that were available to the fishery were estimated from the 1986-1989 average length composition of the combined harvest estimated by Goodyear and Schirripa (1993). The estimate was derived by smoothing the normalized ratios of the realized catch at length to simulated annual mean numbers at length at a total annual mortality of $Z=0.5$ using the growth model constructed from the pooled data. Fish larger than the first fully recruited size class were assumed equally available to the fishery.

Correction factors to adjust for the bias in the total mortality estimates were developed by sampling simulated age-length compositions of the population for several levels of mortality for each of the growth models (Goodyear ms). The correction factor was derived from regressing the mortality rate estimated from the actual age composition of the simulated sample on the mortality rate derived from the ages estimated from the simulated lengths for the same sample. Separate correction factors were estimated for the unregulated condition and for the 20-inch minimum size that was enacted in 1990 for each of the eight growth equations.

Estimates of total mortality in the population were derived from catch curves constructed from the 1986-1989 and 1990-1992 age compositions of the harvest using each of the growth models. Catch-curve estimates based on observed ages are denoted Z_A. Those estimated from ages assigned from lengths are denoted Z_L (i.e., total mortality estimated from slope of catch curve fitted to ages predicted from observed lengths using a growth equation), and F_L (i.e., fishing mortality estimated as Z_L - M). The bias corrected estimates are denoted Z_{COR} (i.e., total mortality estimated from Z_L using a bias correction regression equation), and F_{COR} (i,e., fishing mortality estimated as Z_{COR} - M).

Yield per recruit (YPR), Spawning Potential Ratio (Goodyear 1993), $F_{0.1}$ and F_{max} were estimated for each of the growth models for $M=0.15$, 0.2, and 0.25 for no size limit, and size limits of 16, 18 and 20 inches total length using the Ricker approach and partial recruitment vectors based on the length selectivity ogive derived for the 1986-1989 catch. Where minimum sizes were evaluated, fish continued to be caught according to the selectivity ogive. The catch of fish of the minimum size or larger was removed from the population and added to the yield. Those caught less than the minimum size were removed from the population in proportion to the discard mortality and did not add to the yield. Discard mortalities of 0, 20 and 33 percent were evaluated.

Mean recruitment was evaluated as the ratio of the 1979-1989 average catch to the 1986-1989 estimate of YPR given fishing mortality estimated at natural mortality of 0.15, 0.20 and 0.25 for each of the growth models. The resulting values were used to estimate the equilibrium catch associated with no size limit, and 16, 18 and 20-inch size limits for each of the growth models. Where size limits were evaluated, equilibrium catch estimates were made for both the 1986-1989 and 1990-1992 levels of F_{COR}.

Results

Scattergrams of observed lengths at age and the fitted equations for each of the growth models are presented in Figure 1. Maximum mean size at the oldest age (L_∞) ranged from 27.7 to 68.1 inches total length, K ranged from .03 to 0.27 and t_0 ranged from -6.7 to 0.62. The lengths at age predicted by each of these equations are presented in Table 2. The age during which the average red grouper is predicted to attain the current 20 inch TL minimum size ranges from age 3 to age 5 depending on the model. Similarly, all other factors being equal, the mean age of a sample of 25 inch TL red grouper might range from 5 to 10 years depending on the growth model selected. Inspection of the scattergrams demonstrates that the difference between the smallest and largest members of ages beyond about age 5 is much greater than the difference between the mean sizes of the prior and subsequent ages. Consequently, precise assignment of age from length for these ages is impossible even if true growth were known.

Total mortality was estimated from catch curves for

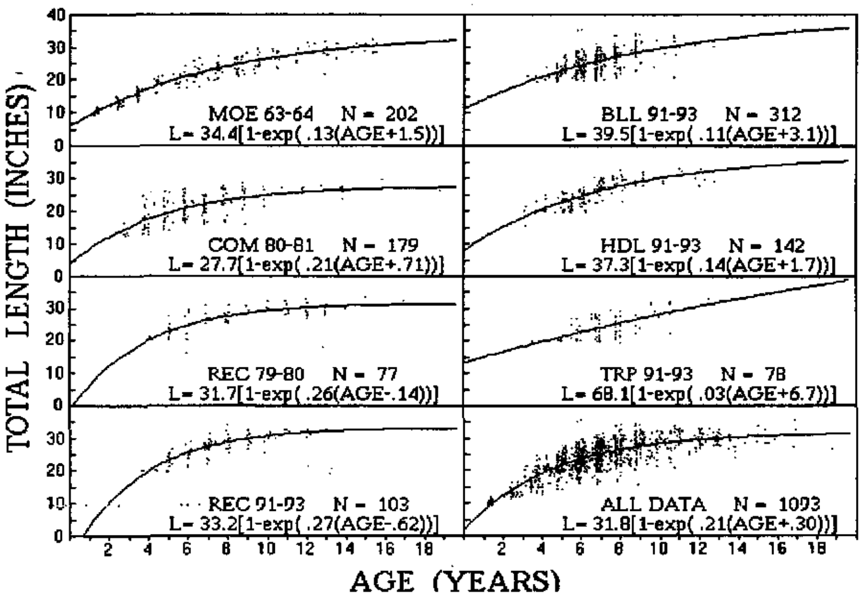

Figure 1. Von Bertanlanffy growth equation fitted to observed size at age for the data sets used in this study.

1986-1989, before the 20 inch TL minimum size, and 1990-1992 after the 20 inch minimum size was imposed. The catch curves were constructed from the length composition of the combined harvest using the ages predicted using each of the growth models (Figure 2). Estimates of Z_L ranged from 0.291 to 0.457 for the earlier period and from 0.282 to 0.5 for the latter period. There was a shift in the apparent age of full recruitment from about age 1-3 to about age 5-6 associated with the introduction of the minimum size. However, there was about as much difference among the models as their was between the periods.

As with other catch-curve analyses, recruitment and mortality are assumed to have been constant for a sufficient period to allow the age structure to achieve equilibrium (Ricker 1975). It is possible that this condition is met for the former period but seems unlikely for the latter period because of the effects of the minimum size. Consequently, the levels of Z_L for the latter period are presented only to evaluate how the selection of the growth model affects the value of the estimate.
The data sets used to develop the growth equations consist of samples with known ages and lengths. This permits construction of catch curves based on known ages and on ages predicted from lengths to contrast the values of Z_A and Z_L (Figure 3). The catch-curve estimates of total mortality (Z_A) constructed from the observed age composition of these samples were not well estimated by Z_L although they were derived from the same samples. It is also evident from these analyses that the difference between Z_A and Z_L increased with increasing Z_A. Consequently, it is apparent that Z_L is a biased estimator which tends to underestimate total mortality and the bias apparently increases as total mortality increases.

The trend of increasing error with increasing mortality suggests the possibility of constructing a model that could be used to correct for the bias. This possibility was explored by simulating the age-length composition of the red grouper population for several levels of total mortality using the simulation model described by Goodyear (ms). For the simulations, natural mortality was 0.20 for all 30 ages considered and growth was assumed to be according to the model fitted to the pooled data set (ALL DATA of Figure 1). Fishing mortality increased with size up to about 18 inches TL according to the product of a scaler and the selectivity ogive of Figure 4, which was estimated from the length composition of the 1986-1989

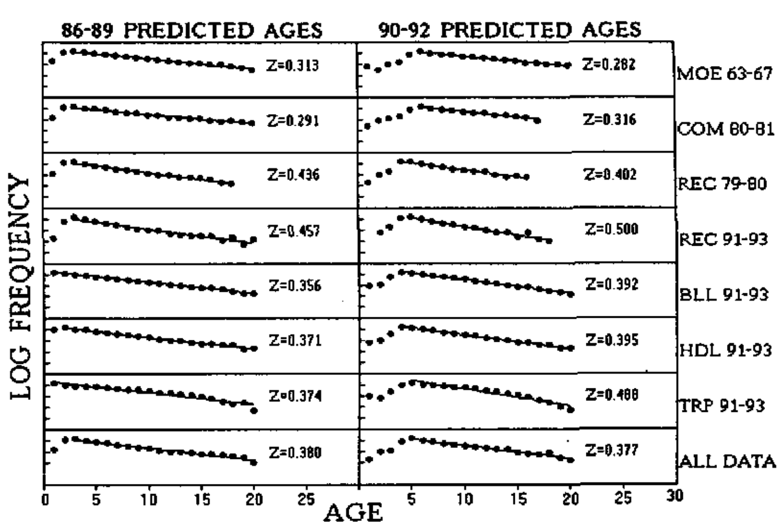

Figure 2. Estimates of Z_L from the 1986-1988 and 1990-1992 catch length compositions for each of the red grouper growth models evaluated.

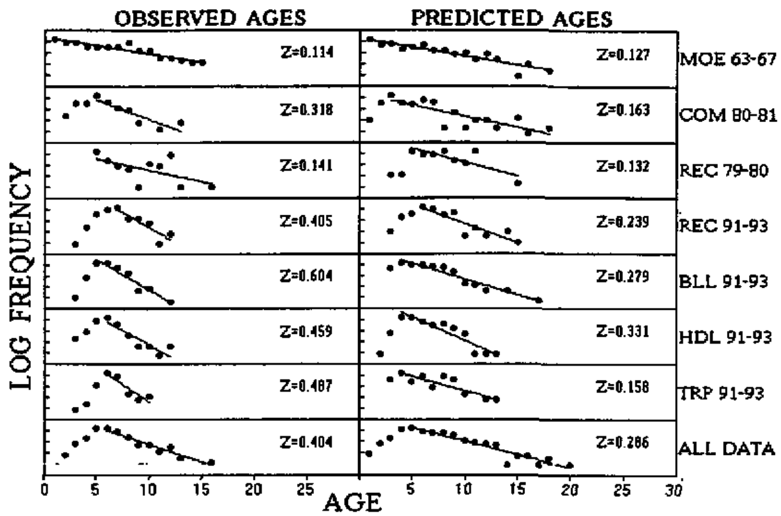

Figure 3. Catch curve estimates of total mortality from the observed and predicted age compositions of the samples used to construct the growth models.

harvest of red grouper. Ten levels of the scaler were employed so that fishing mortality for the fully-recruited sizes ranged from F=0.002 to F=2.00. Estimates of Z_A and Z_L were constructed from 24000 random samples of the simulated catch (Figure 5). The increasing bias of Z_L as and estimator of Z_A with increasing total mortality observed with the age-length data used to construct the growth model is also clearly evident with the simulated data.

Z_A was plotted against Z_L and proved to be quite linear for this particular range of values (Figure 6). Consequently, Z_A was regressed on Z_L to provide a linear regression that could be used to estimate Z_A from Z_L (Figure 6). The negative intercept of the relation suggests that the bias would reverse at low levels of natural mortality. And, in fact, Z_L was greater than Z_A where Z_A was estimated to be 0.201 (the specified fully recruited mortality was 0.202). This shift in the direction of the bias is the result of the interaction of misclassification probability and the shape of the growth curve. It is also noteworthy that Z_A tended to be somewhat lower than the specified total mortality for fully recruited fish. This phenomenon was the result of the gradual recruitment of ages 2 through 9 as a result of the variability of size at age.

The process was repeated to see if the same correction equation would apply for the conditions existing after the 20-inch minimum size was established. This was accomplished using the same method as before but the simulated sample harvest was restricted to red grouper of 20 inches TL or greater. Again, 24000 samples were taken at each level of fishing mortality and Z_A and Z_L were estimated (Figure 7). The effect of the partial recruitment of ages containing some members below the minimum size is clearly evident in the shape of the scattergrams, particularly at the higher levels of fishing mortality. For this growth model the age of nearly full recruitment given a 20 inch TL minimum size is about age 9, although some individuals begin to recruit to the fishery as early as age 3. Consequently, the shoulder of the catch curve extends over several ages, and the effect becomes more pronounced as fishing mortality increases.

In contrast to the linear relation observed between Z_A on Z_L for the 1986-1989 condition that preceded the size limit, the scattergram of Z_A on Z_L for the post size-

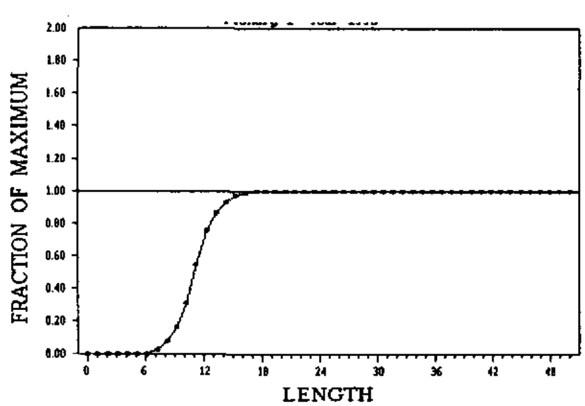

Figure 4. Selectivity ogive estimated from the 1986-1989 length composition of the harvest of Gulf of Mexico red grouper.

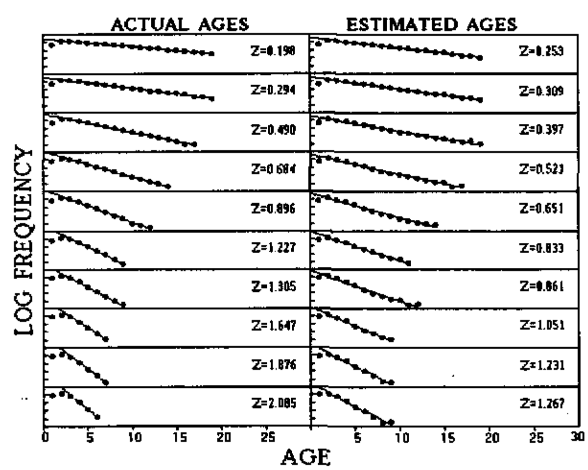

Figure 5. Estimates of Z_A and Z_L from simulated observations at several levels of mortality in the absence of size limits.

limit period was highly nonlinear (Figure 8). As a consequence a power function was fitted by linear regression a region of the data defined by the value of Z_L estimated from the length composition of the harvest by the 1990-1992 (post size limit) fishery for this growth model (Figure 2).

The dissimilarity between the two bias correction models of Figures 6 and 8 was also found to be the case for each of the other growth models. Consequently, bias correction models were developed for each of the growth models for the conditions existing before and after the 20 inch minimum size was established. The resulting regression coefficients are presented in Table 3. Note that the pre size-limit model uses a linear regression as presented in Figure 6, and the post size-limit model is the linearized power function fitted to the region of interest as presented in Figure 8. R-square values for the fitted equations were all 0.99 or better except for the post size-limit condition for the growth model fitted to the commercial samples from 1980 and 1981 (COM 80-81 of Figure 1). For this case the scattergram of Z_A on Z_L was vertical in the region of interest and no bias correction equation was possible.

The bias correction equations were applied to the Z_L values from the pre and post size limit combined catch analyses of Figure 2 to arrive at estimates of Z_{COR} for each growth model and period. The resulting values were used to provide uncorrected and bias corrected estimates of fishing mortality (F_L and F_{COR}) and corresponding estimates of SPR for natural mortality of 0.15, 0.20 and 0.25 (Tables 4-6). Where the uncorrected estimates of F_L were employed to estimate SPR, fishing mortality for the partly recruited ages was estimated from the ratios of the length based estimates of catch at age to those predicted by extending the catch curve backward to the age of interest. The selectivity ogives applied with F_{COR} for estimates of SPR were based on the proportions by age (averaged over 12 months) that corresponded to the selectivity ogive of Figure 4.

The values of SPR estimated from the various growth models for F_L and F_{COR} for 1986-1989 ranged from 13 to 33 percent for M=0.15, from 20 to 52 percent for M=0.20, and from 29 to 78 percent for M=0.25. Although the F_{COR} were generally higher than F_L, the calculated selectivities for ages below actual full recruitment were higher for the SPR estimates corresponding to F_L than for those used in the estimation of F_{COR} because of the misclassification error. As a result the estimates of SPR were similar for the two methods, at least for the period preceding the minimum size.

The growth-model effect on the estimates of F_L and F_{COR} and corresponding estimates of SPR for the period

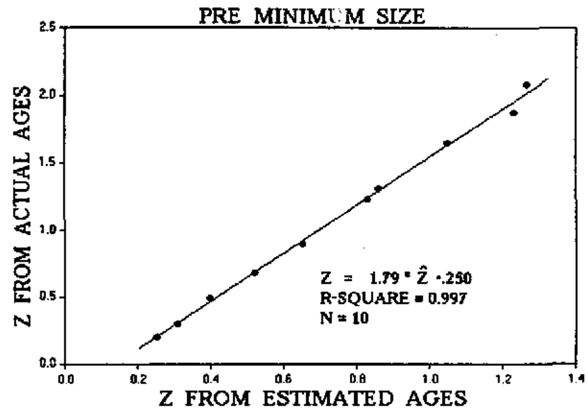

Figure 6. Regression of Z_A on Z_L from simulated data to provide a bias correction model to estimate total mortality from the 1986-1988 catch length composition.

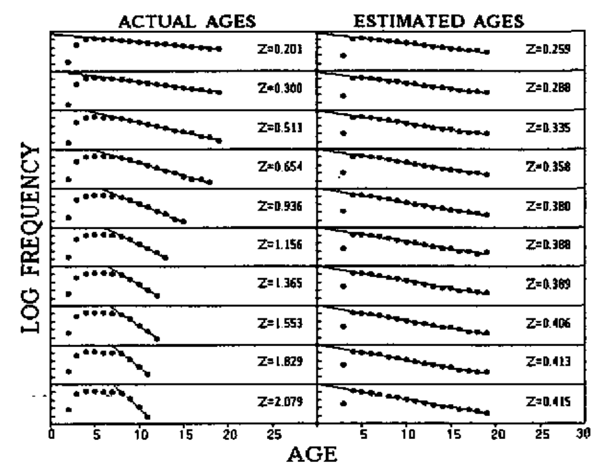

Figure 7. Estimates of Z_A and Z_L from simulated observations at several levels of mortality and a 20-inch TL minimum size in the fishery.

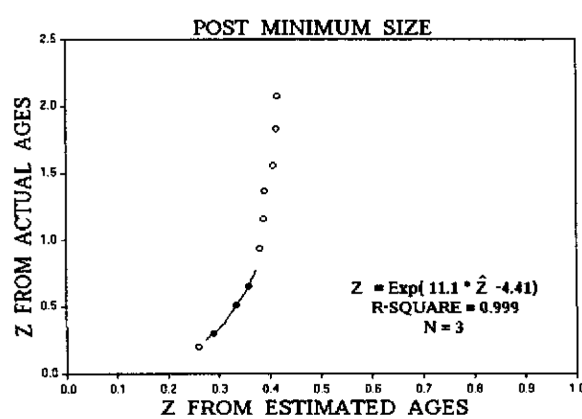

Figure 8. Regression of Z_A on Z_L from simulated data to provide a bias correction model to estimate total mortality from the 1986-1988 catch length composition.

after the minimum size went into effect were much greater than those observed for the condition of no minimum size. F_L at M=0.2 ranged from 0.08 to 0.3 and associated SPR ranged from 18 to 53 percent in the absence of discard mortality. The bias corrected estimates, F_{COR}, varied between 0.25 and 1.3 and the associated estimates of SPR ranged from 13 to 42 percent in the absence of discard mortality at M=0.20

The value of fishing mortality and associated YPR and SPR at $F_{0.1}$ and F_{MAX} were determined for each of the growth equations at M=0.2. Separate determinations were made for discard mortality rates of 0, 20 and 33 percent at no minimum size and minimum sizes of 16, 18, and 20 inches TL (Table 7). Plots of the results for discard mortalities of 0 and 33 percent are presented in Figures 9-56. F_{COR} estimated at M=0.20 for the conditions existing before the minimum size exceeded $F_{0.1}$ for six of the eight growth models, but was less than F_{MAX} for seven of the eight growth models. In the absence of discard mortality, YPR at $F_{0.1}$ was highest for the 20-inch TL minimum size for six of the eight growth models and at the 18-inch TL size limit for the other 2 cases. The estimates of SPR at $F_{0.1}$ ranged from 30 to just over 50 percent regardless of discard mortality or size limit.

At a discard mortality of 33 percent, YPR at $F_{0.1}$ and YPR at F_{MAX} were maximum with a 16-inch TL minimum size for five of the eight models and with no size limit for the other 3 cases. Also at 33 percent discard mortality, SPR at Fmax was below the 20% threshold in half the cases when no minimum size was imposed, in one case at a 16-inch TL minimum size, but in no cases at larger minimum sizes.

At a discard mortality of 20%, YPR at $F_{0.1}$ was maximum with a 16-inch TL minimum size for seven of the eight models. YPR at F_{MAX} was maximum with a 16-inch TL minimum size for six of the eight models. YPR was maximum for the 18-inch TL minimum size for the other three cases (Table 7).

The 1979-1989 mean combined yield for Gulf of Mexico red grouper was slightly over 9 million pounds whole weight (Table 8). If this average is assumed to represent equilibrium conditions then equilibrium (mean) recruitment is given by the ratio of the mean yield to YPR for the fishing mortality rate estimated for each growth model. At M=0.15 the recruitment estimates varied a factor of 1.8 from 3.4 to 6.2 million fish; at M=0.20 the recruitment estimates varied by a factor of 2.5 from 4.5 million to 11.2 million fish; and at M=0.25 the recruitment estimates varied by a factor of 5.0 from 6.1 to 30.4 million fish (Table 8).

These recruitment rates were used to estimate equilibrium combined harvest (millions of pounds whole weight) for each of the growth models as the product of recruitment and YPR at F_{COR}. Estimates were made for the 1986-1989 and 1990-1992 periods, at M=0.15, M=0.20, and M=0.25; and for discard mortalities of 0, 20, 33 percent and minimum sizes of 16, 18 and 20 inches TL (Tables 9-11). The estimates utilize the selectivity ogive of Figure 3 to estimate the catch and release of fish below the minimum size. The results indicate that each of the growth models leads to the prediction that higher levels of SPR would be attained for all minimum sizes evaluated that maintain F constant at the F_{COR} levels estimated for 1986-1989 conditions by increasing the minimum size. Increases in equilibrium mean yield over the 1979-1989 average were also predicted for many parameter combinations.

At a minimum size of 16 inches TL the equilibrium yields corresponding to the 1986-1989 F_{cor} estimates for each of the growth models were higher in all cases where the discard mortality was less than 0.33 for M=0.15 and in seven of eight cases for discard mortality of 0.33. At M=0.20 seven of eight cases showed improved yield with a no discard mortality, six of eight at 20 percent discard mortality and five of eight at 33 percent discard mortality. At M=0.25, six of eight cases show improved yield if discard mortality is negligible but the number drops to two at 20 percent discard mortality and none at 33% discard mortality.

At a minimum size of 18 inches TL the results are similar for M=0.15. However at M=0.20 only two of the eight models predicted increased yields if discard mortality is 0.33, and at M=0.25 a 18 inch minimum size would result in increased yield only if discard mortality is negligible.

At a minimum size of 20 inches TL seven of the eight growth models predict increased yield at M=0.15 if discard mortality is no more than 20%. At 33% discard mortality half the cases showed improved yield. At M=0.20, six of eight cases had higher yield if discard mortality is negligible, 3 of eight at 20% discard mortality and none at 33% discard mortality. At M=0.25 only two of eight cases showed improved yield even if discard mortality is negligible.

The data in Tables 9-11 that pertain to the 1990-1992 F_{COR} estimates should be applied with caution and are only presented so that the reader may examine the model effect on the estimates. However, it is clear from these data that even with a 20-inch TL minimum size, several of the models predict that SPR can be driven below the 20 percent threshold.

Discussion

The disparity among predicted sizes at age among the growth models fitted to size at age data from the various sources is in agreement with the conclusion that sample bias was the likely source of the apparent temporal trend that resulted in the growth model used in the last assessment (Goodyear ms, Goodyear and Schirripa 1993). The present work is based on observed size at age rather than backcalculated size at age based on the results of Vaughan and Burton (1994) and the desire to use the models to estimate ages of fish in the catch. The inclusion of back-calculated lengths at age into the fit would add a large number of points to the least squares minimization that lay below the range of sizes to which the model would be applied. These points could possibly bias the resulting growth curve in the region of interest.

On the other hand, the estimates of yield per recruit rely on accurate characterization of growth, particularly if they are made for conditions (such as size limits) which change the selectivity patterns of the fishery. The influence of this consideration for the results presented here is uncertain and may be worthy of further research to contrast YPR for alternative growth models that may result from alternative treatments of the source data.

The bias correction model developed in this analysis would seem to have promise for situations were catch curve analysis is appropriate (equilibrium conditions), size at age is known, and the included length composition of the samples are sufficiently responsive to mortality. In the case of the data sets examined here, each of the alternative growth models produced linear, highly predictive relationships between the actual mortality and that estimated from the length compositions when there was no size limit. However, for the condition of a 20-inch size limit the relation between actual and predicted mortality was highly curvilinear, and for one of the eight growth models the slope was nearly vertical in the region of interest. This finding is the result of the misclassification of large young fish to older ages and the effect of the minimum size. I suspect that the application of the bias correction equations to correct Z_L for data collected with a 20-inch minimum size would be prone to error because of shape of the curve. However, since (as noted earlier) the catch curves themselves cannot be in equilibrium, this point was not further evaluated here.

The estimates of fishing mortality for the period before the 20-inch minimum size was enacted varied from $F_{COR}=0.086$ to $F_{COR}=0.348$ for $M=0.20$ depending on the growth model selected. Corresponding levels of SPR varied from 0.52, indicative of a stock in good condition, to 0.20, the threshold for the definition of overfishing. The post-size-limit estimates for fishing mortality ranged from $F_{COR}=0.25$ to $F_{COR}=1.35$ for models where estimates were possible. These levels of fishing mortality would lead to estimates of SPR ranging from 7% to 32% for a discard mortality of 33% depending on the growth model selected. Although the estimates for the later period are suspect for other reasons, it is clear that the differences among the results for the various growth models confirm the importance of the uncertainty caused by the application of the growth models.

It is clear from the present work and previous analyses (Goodyear ms), that the age composition of the red grouper catch cannot reliably be estimated from the sizes of the fish, and the problem is exacerbated by the presence of the 20-inch size limit. Present data are insufficient to adequately characterize growth. The data which do exist imply that the variation in age at length for fish larger than the size limit will prohibit useful application of length-based estimates of the age composition for use in age structured assessments. It would appear that the development of future management advise based on such methods will require samples of the actual age composition of the catch, perhaps using age-length keys such as those proposed by Ketchen (1950) and Hoenig and Heisey (1987).

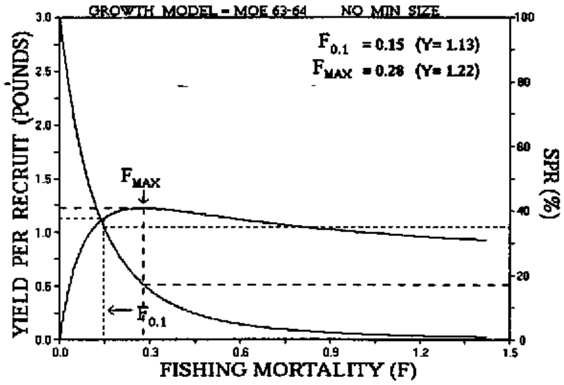

Figure 9. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

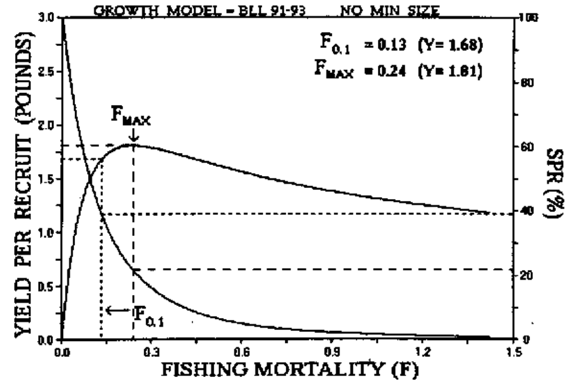

Figure 10. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

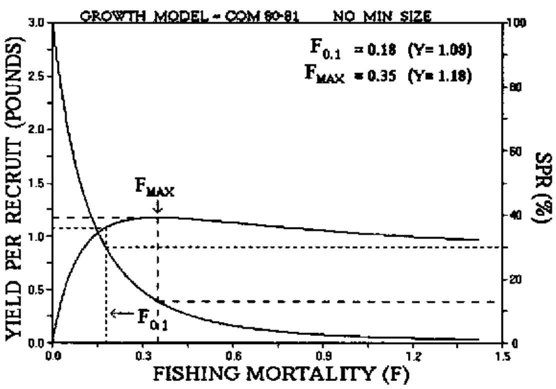

Figure 11. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

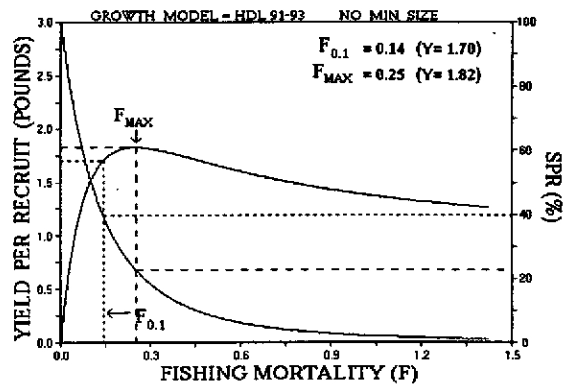

Figure 12. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

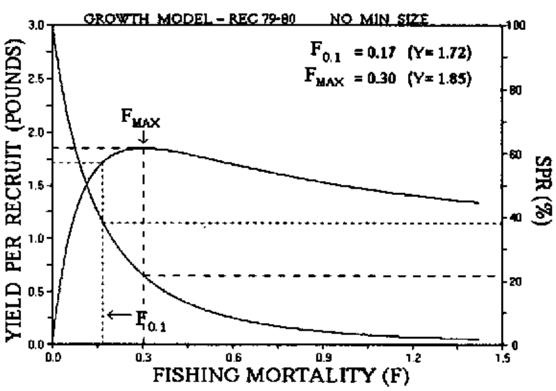

Figure 13. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

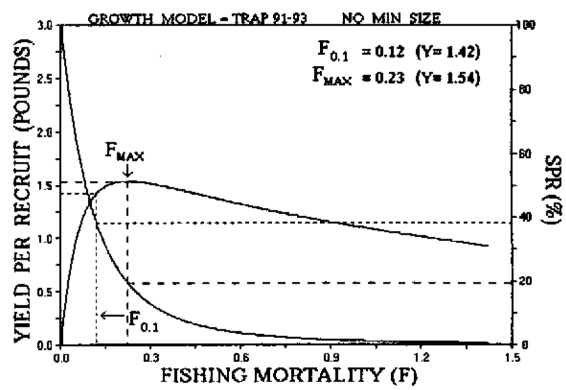

Figure 14. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

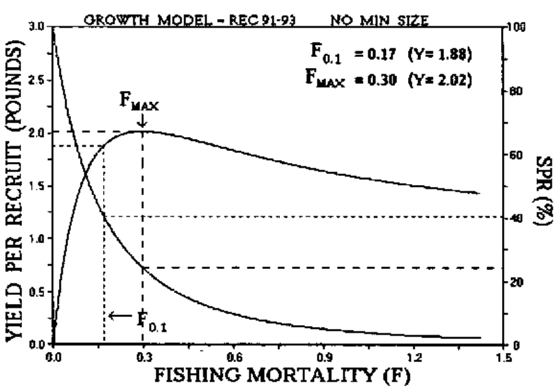

Figure 15. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

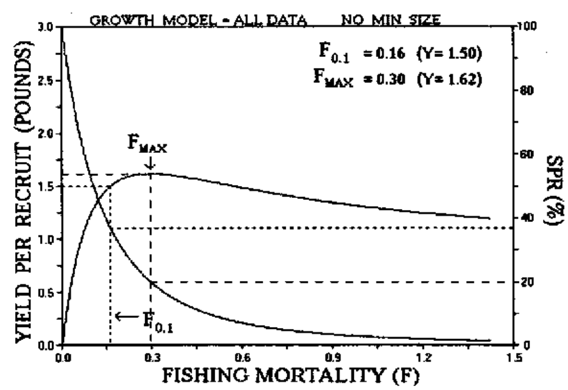

Figure 16. Yield per recruit for red grouper assuming no minimum size and the indicated growth model.

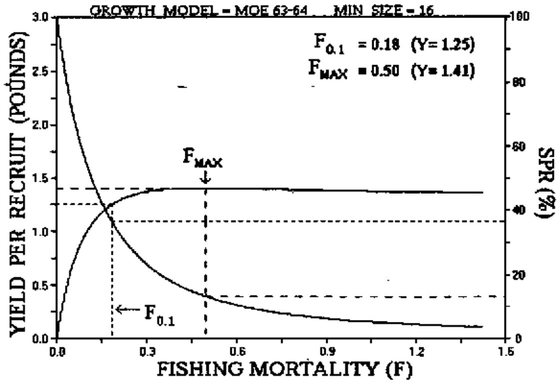

Figure 17. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

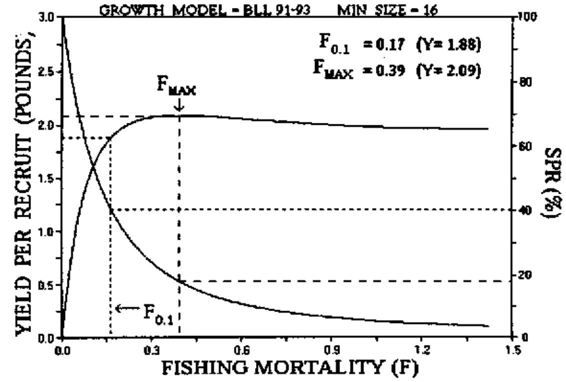

Figure 18. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

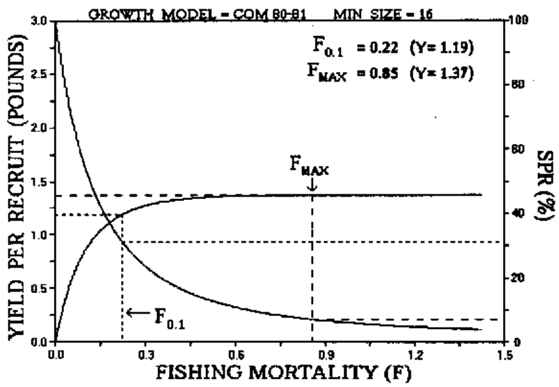

Figure 19. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

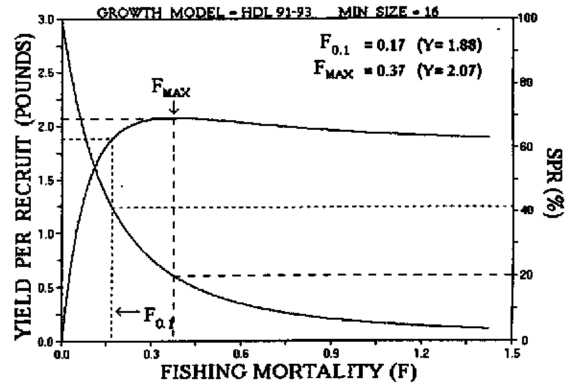

Figure 20. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

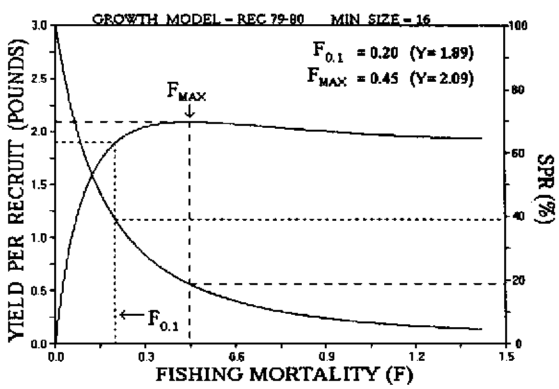

Figure 21. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

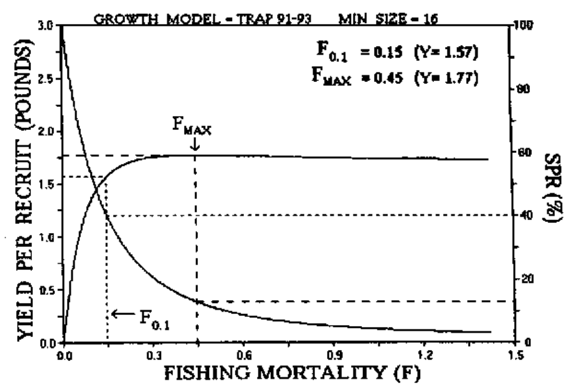

Figure 22. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

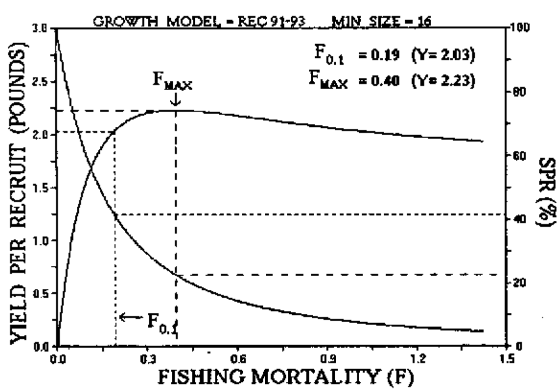

Figure 23. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

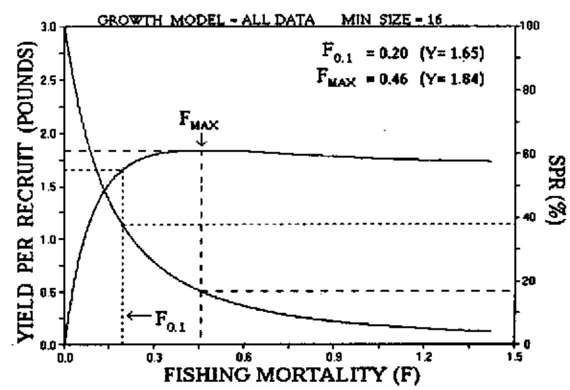

Figure 24. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with no discard mortality.

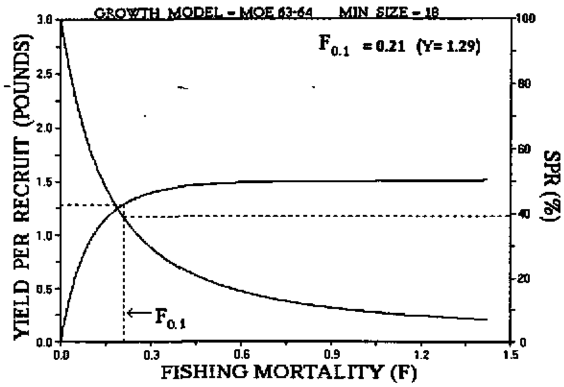

Figure 25. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

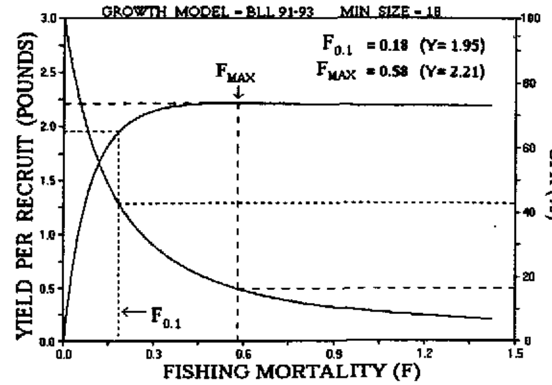

Figure 26. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

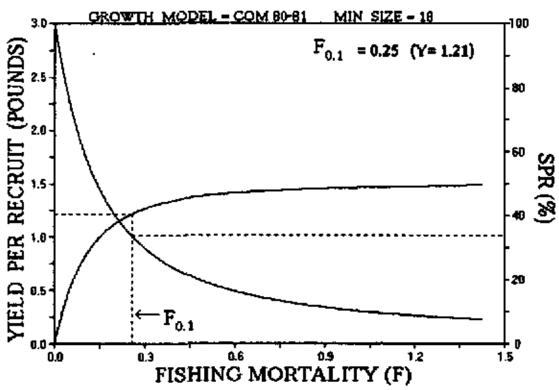

Figure 27. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

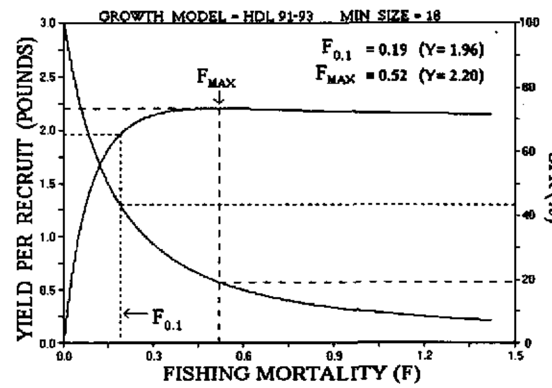

Figure 28. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

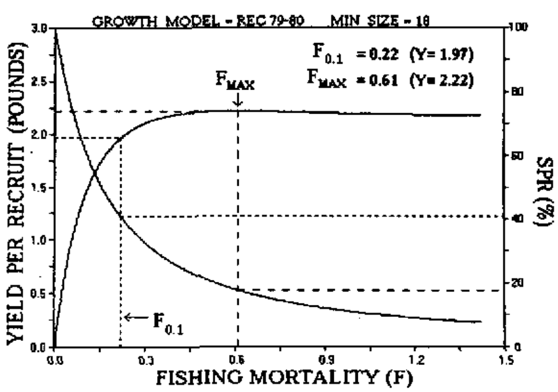

Figure 29. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

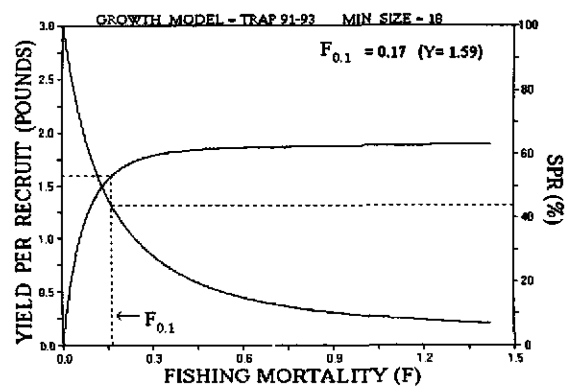

Figure 30. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

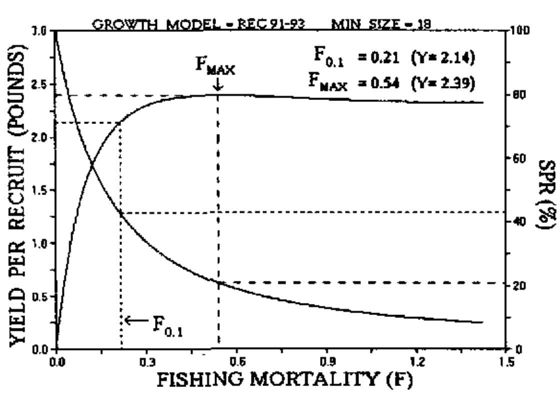

Figure 31. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

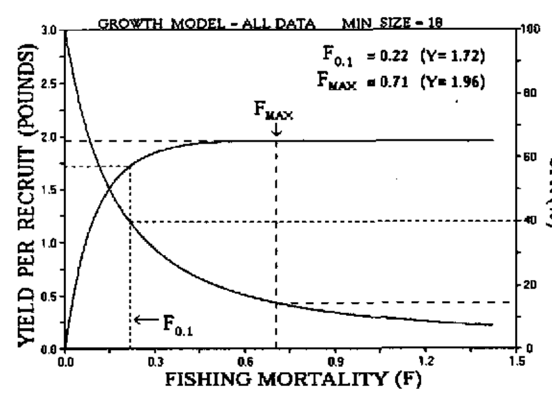

Figure 32. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with no discard mortality.

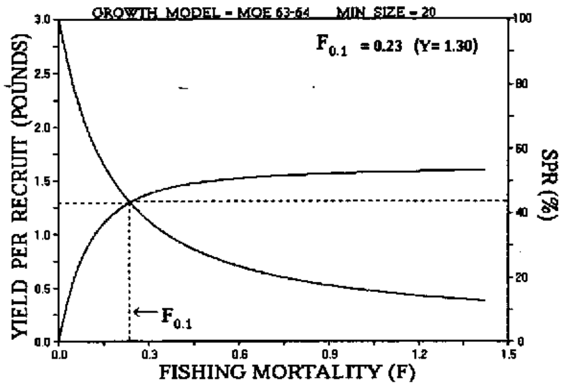

Figure 33. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

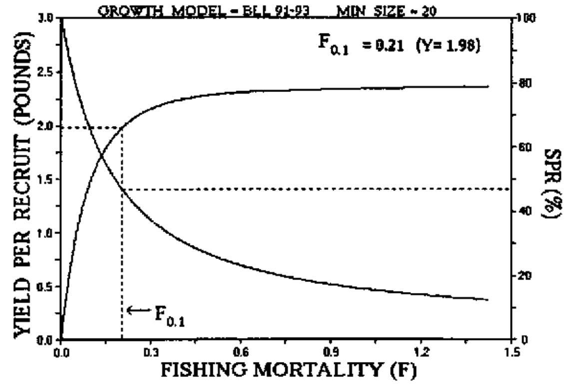

Figure 34. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

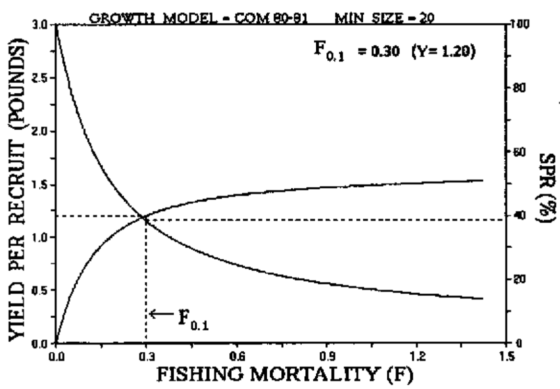

Figure 35. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

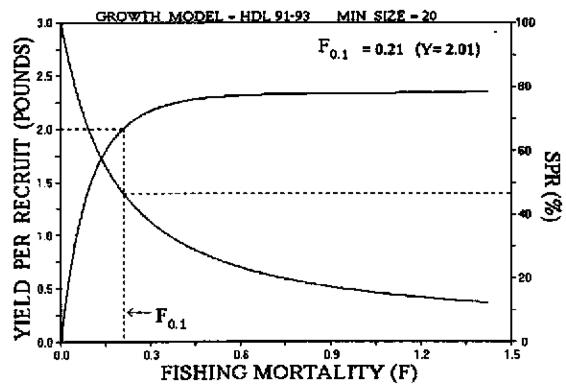

Figure 36. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

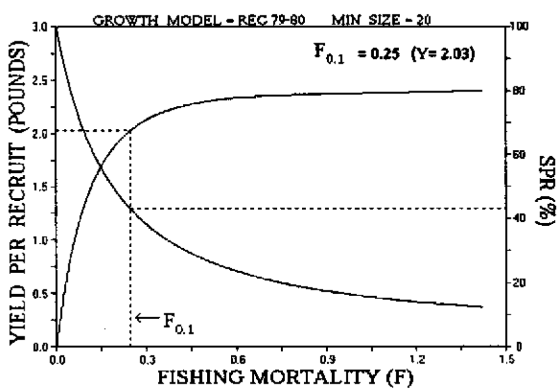

Figure 37. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

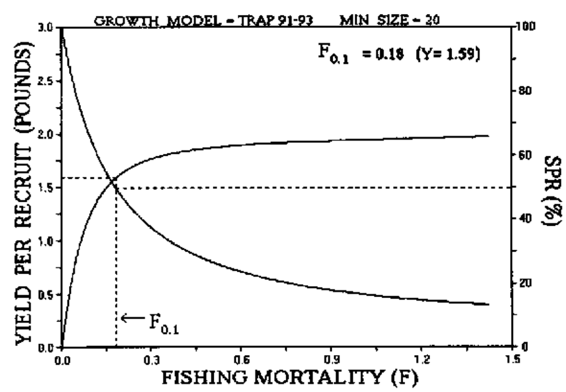

Figure 38. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

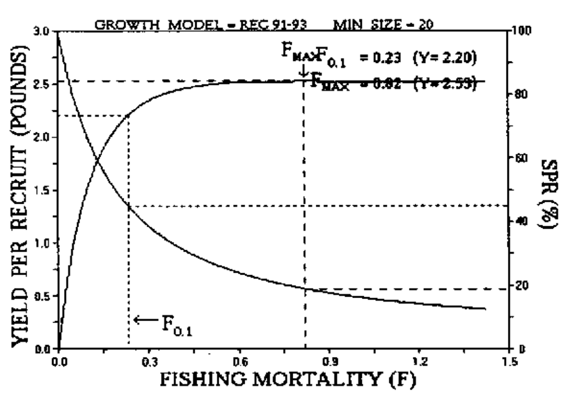

Figure 39. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

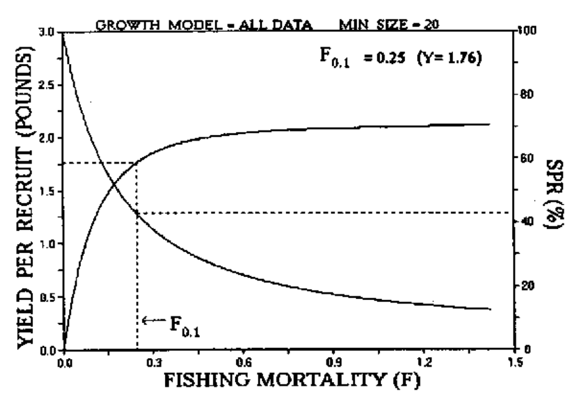

Figure 40. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with no discard mortality.

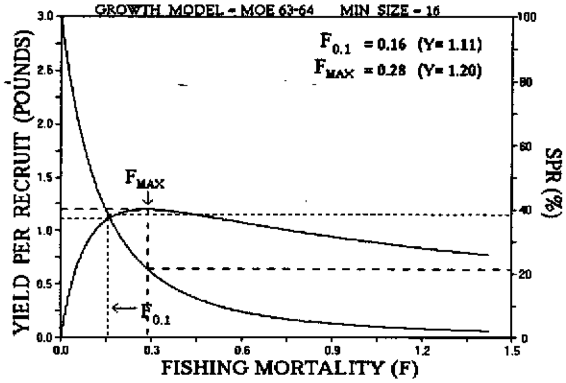

Figure 41. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

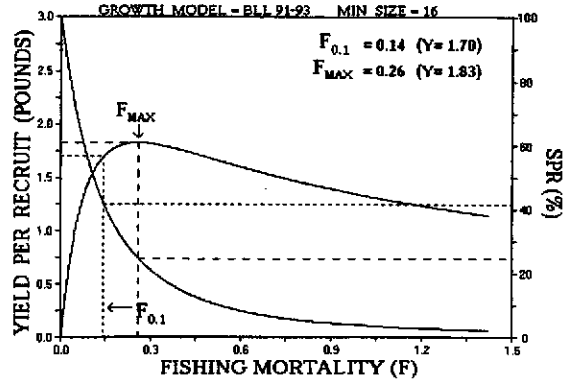

Figure 42. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

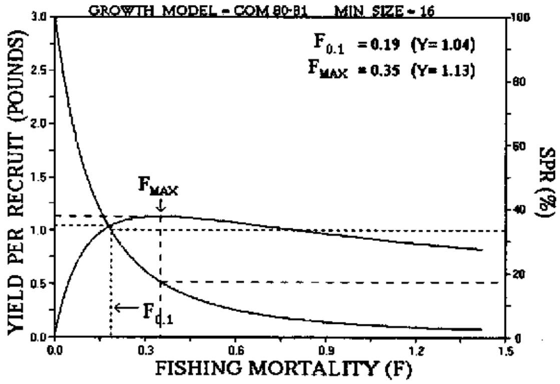

Figure 43. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

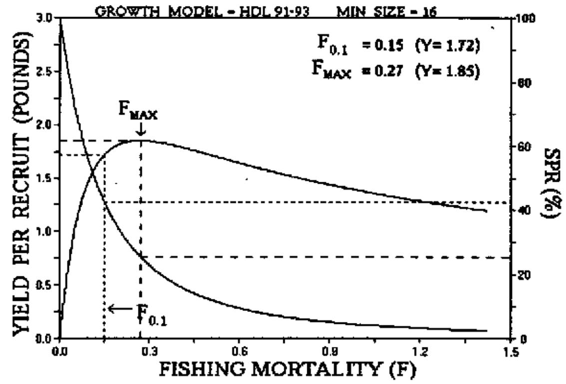

Figure 44. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

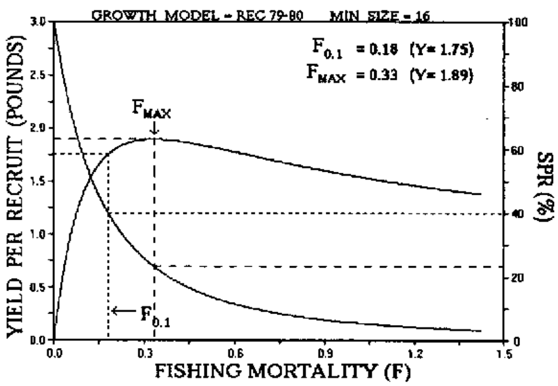

Figure 45. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

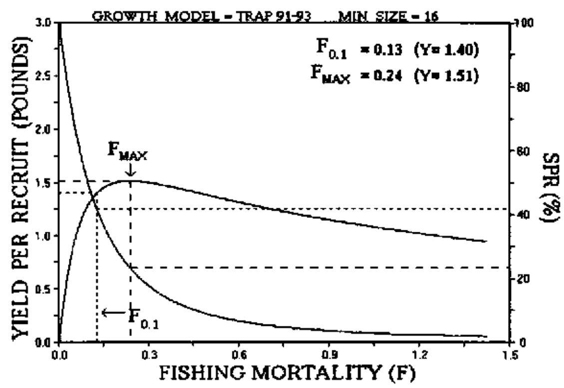

Figure 46. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

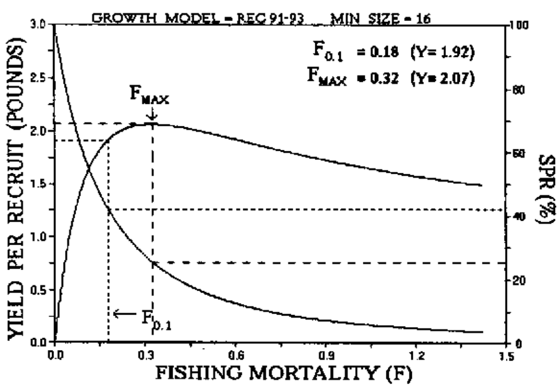

Figure 47. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

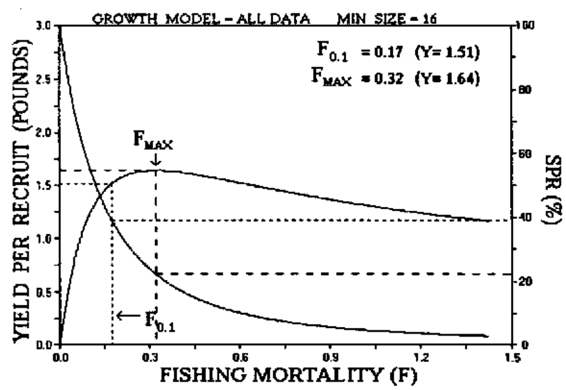

Figure 48. YPR for red grouper assuming a 16 inch minimum size and the indicated growth model with a discard mortality of 33%.

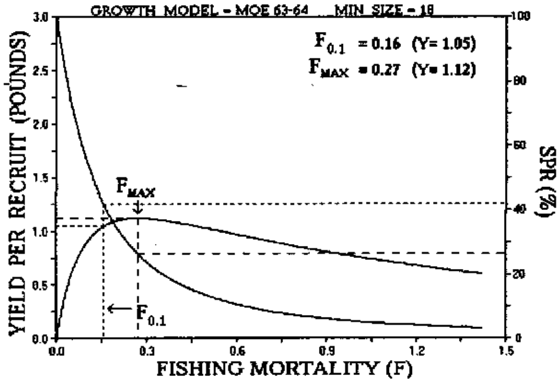

Figure 49. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

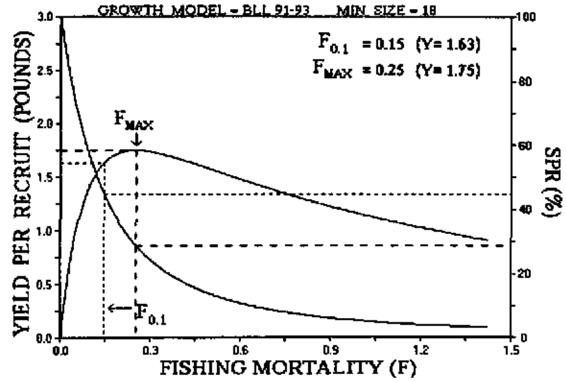

Figure 50. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

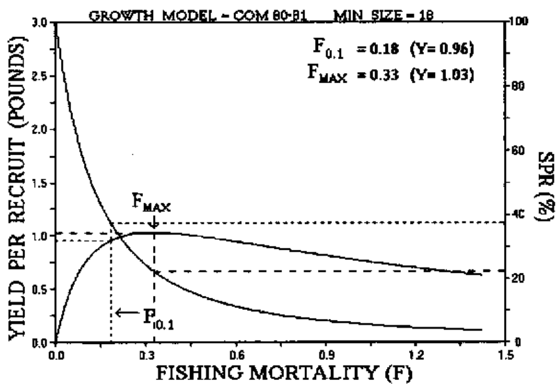

Figure 51. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

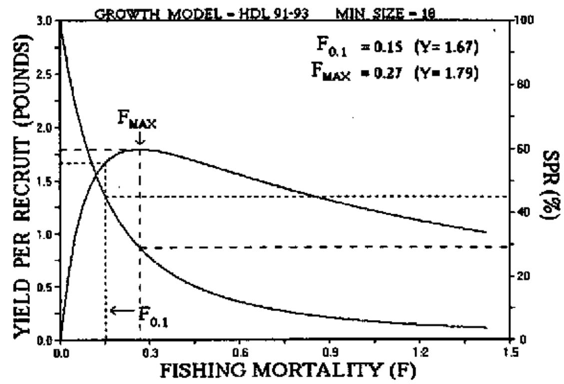

Figure 52. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

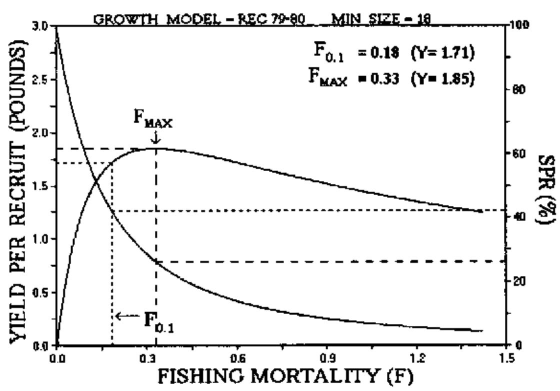

Figure 53. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

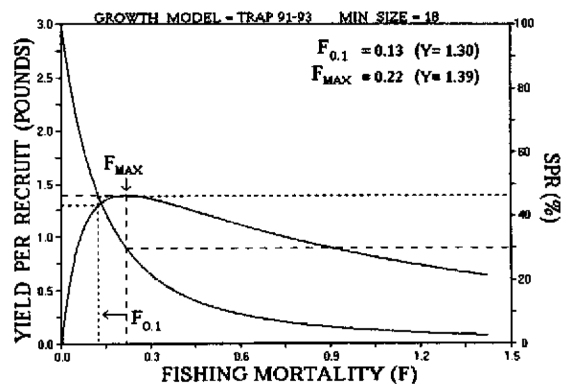

Figure 54. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

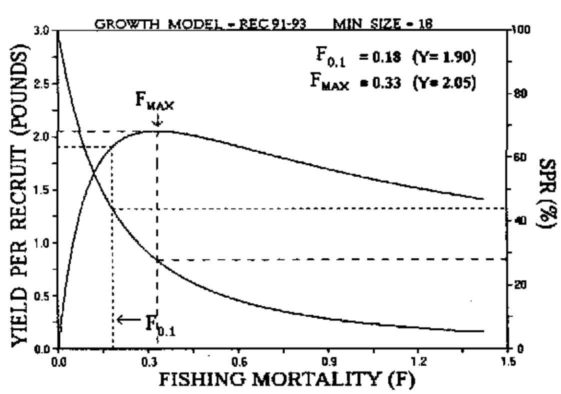

Figure 55. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

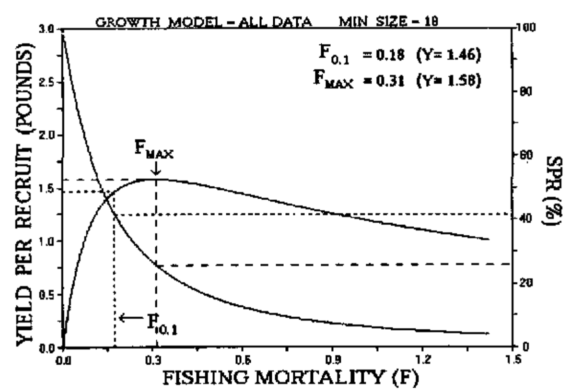

Figure 56. YPR for red grouper assuming a 18 inch minimum size and the indicated growth model with a discard mortality of 33%.

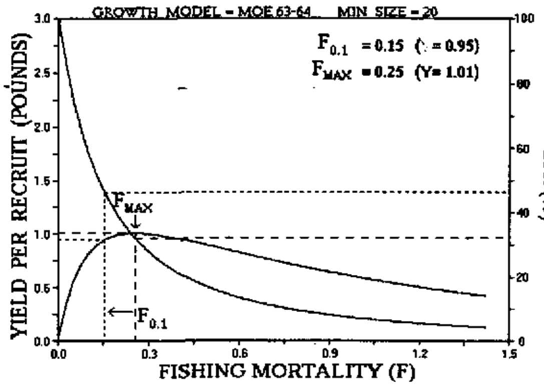

Figure 57. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

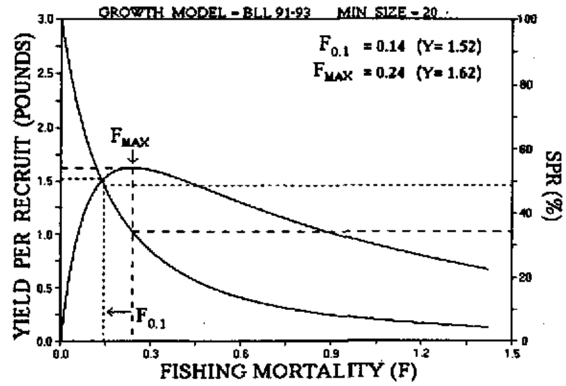

Figure 58. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

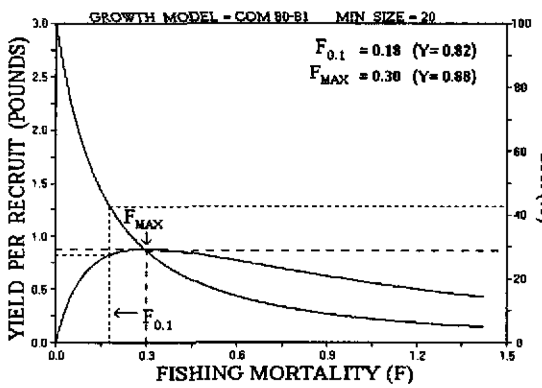

Figure 59. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

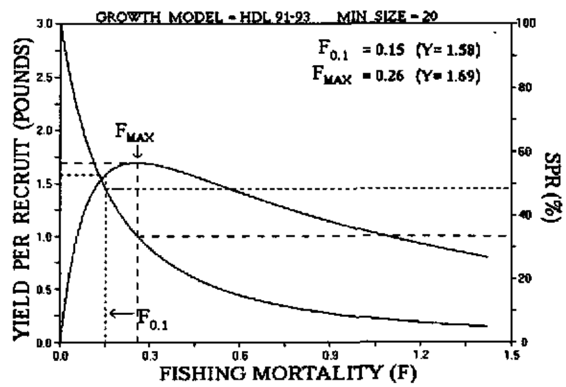

Figure 60. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

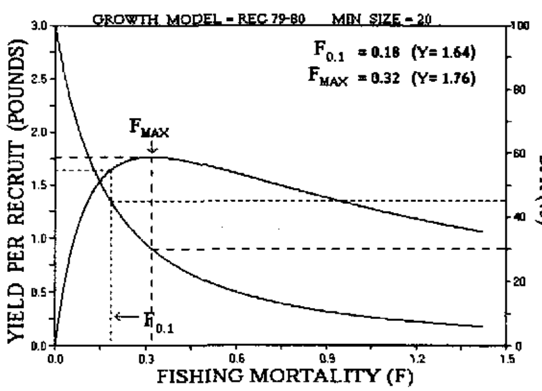

Figure 61. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

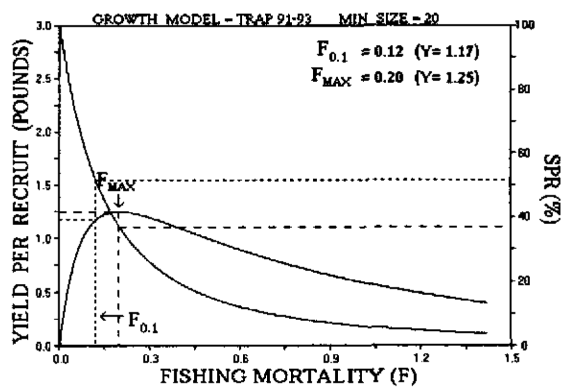

Figure 62. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

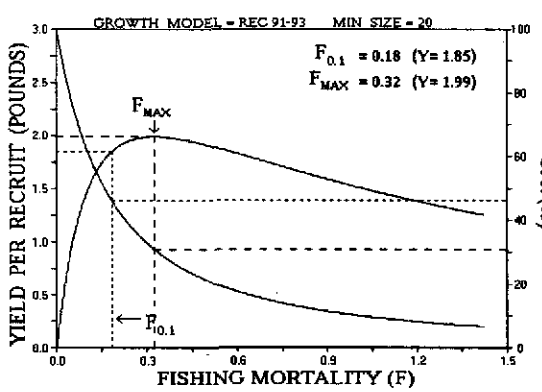

Figure 63. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

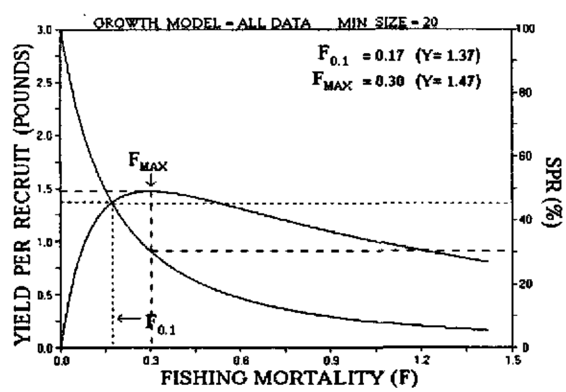

Figure 64. YPR for red grouper assuming a 20 inch minimum size and the indicated growth model with a discard mortality of 33%.

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Table 1. Sources of data used in this study.

Data Set	Description
MOE 63-64.	Samples from sport and commercial fisheries off the west central Florida Coast, October 1963 through November of 1964. Age determinations were made for 1261 specimens, but the growth data were restricted to 202 individuals selected because of the clarity of the annuli. Ages were determined by Moe (1969).
COM 80-81.	Samples from the hook and line commercial fishery collected in 1980 and 1981 by biologists with the NMFS Panama City Laboratory. Ages were determined by Johnson and Collins (ms for more details). N=179.
REC 79-80.	Samples from the recreational fishery collected in 1979 and 1980 by biologists with the NMFS Panama City Laboratory. Ages were determined by Johnson and Collins (ms for more details). N=77.
REC 91-93.	Samples from the recreational fishery collected from 1991 to 1993 by biologists with the NMFS Panama City Laboratory. Ages were determined by Johnson and Collins (ms for more details). N=103.
BLL 91-93.	Samples from the commercial bottom longline fishery collected from 1991 to 1993 by biologists with the NMFS Panama City Laboratory. Ages were determined by Johnson and Collins (ms for more details). N=312.
HDL 91-93.	Samples from the commercial hand line fishermen collected in 1991 to 1993 by biologists with the NMFS Panama City Laboratory. This sample contains fish caught with power assisted and hand operated bandit rigs as well as a few caught with conventional rod and reel. Ages were determined by Johnson and Collins (ms for more details). N=142.
TRP 91-93.	Samples from the commercial trap fishery collected from 1991 to 1993 by biologists with the NMFS Panama City Laboratory. Ages were determined by Johnson and Collins (ms for more details). N=78.
ALL DATA.	All of the above sources of data pooled. N=1093.

Table 2. Total lengths at age for the fitted Von Bertalanffy growth equations fitted to observed length at age for Gulf of Mexico red grouper used in this analysis.

	Growth Equation							
Age	MOE 63-64	COM 80-81	REC 79-80	REC 91-93	BLL 91-93	HDL 91-93	TRP 91-93	ALL DATA
1	9.268	8.364	6.359	3.218	13.932	11.724	14.861	7.727
2	12.290	12.026	12.150	10.318	16.506	15.060	16.533	12.371
3	14.948	14.994	16.618	15.739	18.821	17.961	18.153	16.117
4	17.287	17.399	20.064	19.879	20.903	20.483	19.722	19.141
5	19.344	19.349	22.723	23.039	22.776	22.676	21.242	21.581
6	21.154	20.928	24.774	25.452	24.459	24.583	22.714	23.550
7	22.747	22.208	26.356	27.295	25.974	26.240	24.139	25.138
8	24.148	23.246	27.577	28.702	27.336	27.682	25.520	26.421
9	25.380	24.087	28.518	29.776	28.561	28.935	26.858	27.455
10	26.465	24.768	29.245	30.596	29.662	30.024	28.153	28.290
11	27.419	25.320	29.805	31.222	30.653	30.971	29.408	28.963
12	28.258	25.768	30.237	31.700	31.544	31.795	30.624	29.507
13	28.996	26.131	30.571	32.065	32.345	32.511	31.801	29.946
14	29.646	26.425	30.828	32.344	33.066	33.134	32.942	30.300
15	30.217	26.663	31.026	32.557	33.714	33.675	34.046	30.585
16	30.720	26.856	31.179	32.719	34.297	34.145	35.116	30.816
17	31.162	27.012	31.298	32.843	34.821	34.555	36.152	31.002
18	31.552	27.139	31.389	32.938	35.292	34.910	37.156	31.152
19	31.894	27.242	31.459	33.011	35.716	35.220	38.129	31.273
20	32.195	27.325	31.513	33.066	36.098	35.489	39.070	31.371
21	32.460	27.393	31.555	33.108	36.441	35.722	39.982	31.450
22	32.693	27.447	31.587	33.140	36.749	35.926	40.866	31.513
23	32.898	27.492	31.612	33.165	37.026	36.102	41.722	31.565
24	33.079	27.528	31.631	33.183	37.276	36.256	42.551	31.606
25	33.237	27.557	31.646	33.198	37.500	36.390	43.354	31.639
26	33.377	27.580	31.658	33.209	37.702	36.506	44.131	31.666
27	33.500	27.599	31.666	33.217	37.883	36.607	44.885	31.688
28	33.608	27.615	31.673	33.223	38.046	36.695	45.614	31.706
29	33.703	27.628	31.678	33.228	38.193	36.771	46.321	31.720
30	33.787	27.638	31.683	33.232	38.325	36.838	47.005	31.731

Table 3. Slope and intercepts for the bias correction equations used to estimate total mortality from the catch curve estimates derived from the age composition of the catch based on observed lengths. These equations were derived from simulated data.

Growth Equation	Period: Pre 20 inch (1986-1989) intercept	slope	Post 20 inch (1990-1992) intercept	slope
MOE 63-64	-0.147	1.542	-3.965	11.243
COM 80-81	-0.250	1.841	-	-
REC 79-80	-0.472	2.209	-6.982	17.739
REC 91-92	-0.383	2.040	-4.203	9.269
BLL 91-92	-0.052	1.310	-2.806	6.104
HDL 91-92	-0.065	1.280	-3.034	6.691
TRP 91-92	-0.083	1.299	-2.048	3.380
ALL DATA	-0.250	1.790	-4.411	11.133

Table 4. Mortality rate and Spawning Potential Ratio (SPR) estimates for Gulf of Mexico red grouper derived from catch curves fitted to the 1986-1989 and 1990-1992 catch age composition estimated from several different growth models and assuming natural mortality (M) is 0.15.

Growth Equation	1986-1989 Length Composition of Combined Harvest: Predicted Ages			1986-1989 Length Composition of Combined Harvest: Bias Corrected			1990-1992 Length Composition of Combined Harvest: Predicted Ages					1990-1992 Length Composition of Combined Harvest: Bias Corrected				
	Z_L	F_L	SPR_0	Z_{COR}	F_{COR}	SPR_0	Z_L	F_L	SPR_0	SPR_{20}	SPR_{33}	Z_{COR}	F_{COR}	SPR_0	SPR_{20}	SPR_{33}
MOE 63-64	0.313	0.163	0.204	0.335	0.185	0.237	0.282	0.132	0.331	0.317	0.307	0.453	0.303	0.306	0.254	0.225
COM 80-81	0.291	0.141	0.263	0.286	0.136	0.331	0.316	0.166	0.265	0.254	0.248	-	-	-	-	-
REC 80-81	0.436	0.286	0.136	0.491	0.341	0.154	0.402	0.252	0.199	0.191	0.186	1.152	1.002	0.123	0.088	0.071
REC 91-93	0.457	0.307	0.128	0.548	0.398	0.140	0.500	0.350	0.156	0.143	0.136	1.545	1.395	0.096	0.065	0.051
BLL 91-93	0.356	0.206	0.183	0.414	0.264	0.157	0.392	0.242	0.188	0.179	0.173	0.661	0.511	0.206	0.155	0.129
HDL 91-93	0.371	0.221	0.165	0.409	0.259	0.182	0.395	0.245	0.181	0.172	0.166	0.678	0.528	0.203	0.158	0.134
TRP 91-93	0.374	0.224	0.148	0.402	0.252	0.134	0.488	0.338	0.117	0.107	0.101	0.672	0.522	0.201	0.139	0.110
ALL DATA	0.380	0.230	0.170	0.430	0.280	0.177	0.377	0.227	0.213	0.204	0.199	0.803	0.653	0.172	0.131	0.110

Z_L = estimated from slope of catch curve fitted to ages predicted from observed lengths using the indicated growth equation.
F_L = estimated as Z_L - M.
Z_{COR} = estimated from Z_L using bias correction regression equation.
F_{COR} = estimated as Z_{COR} - M.
SPR_0 = SPR estimated for discard mortality = 0.0.
SPR_{20} = SPR estimated for discard mortality = 0.20.
SPR_{33} = SPR estimated for discard mortality = 0.33.

Table 5. Mortality rate and Spawning Potential Ratio (SPR) estimates for Gulf of Mexico red grouper derived from catch curves fitted to the 1986-1989 and 1990-1992 catch age composition estimated from several different growth models and assuming natural mortality (M) is 0.20.

	1986-1989 Length Composition of Combined Harvest						1990-1992 Length Composition of Combined Harvest									
	Predicted Ages			Bias Corrected			Predicted Ages					Bias Corrected				
Growth Equation	Z_L	F_L	SPR_0	Z_{COR}	F_{COR}	SPR_0	Z_L	F_L	SPR_0	SPR_{20}	SPR_{33}	Z_{COR}	F_{COR}	SPR_0	SPR_{20}	SPR_{33}
MOE 63-64	0.313	0.113	0.353	0.335	0.135	0.375	0.282	0.082	0.527	0.512	0.503	0.453	0.253	0.416	0.356	0.322
COM 80-81	0.291	0.091	0.445	0.286	0.086	0.523	0.316	0.116	0.423	0.411	0.403	-	-	-	-	-
REC 80-81	0.436	0.236	0.212	0.491	0.291	0.227	0.402	0.202	0.299	0.290	0.284	1.152	0.952	0.167	0.121	0.099
REC 91-93	0.457	0.257	0.199	0.548	0.348	0.203	0.500	0.300	0.227	0.212	0.202	1.545	1.345	0.130	0.089	0.071
BLL 91-93	0.356	0.156	0.299	0.414	0.214	0.246	0.392	0.192	0.291	0.279	0.272	0.661	0.461	0.281	0.218	0.185
HDL 91-93	0.371	0.171	0.269	0.409	0.209	0.278	0.395	0.195	0.281	0.269	0.262	0.678	0.478	0.275	0.219	0.189
TRP 91-93	0.374	0.174	0.249	0.402	0.202	0.222	0.488	0.288	0.183	0.170	0.161	0.672	0.472	0.278	0.200	0.162
ALL DATA	0.380	0.180	0.271	0.430	0.230	0.266	0.377	0.177	0.326	0.315	0.309	0.803	0.603	0.234	0.182	0.155

Z_L = estimated from slope of catch curve fitted to ages predicted from observed lengths using the indicated growth equation.
F_L = estimated as Z_L - M.
Z_{COR} = estimated from Z_L using bias correction regression equation.
F_{COR} = estimated as Z_{COR} - M.
SPR_0 = SPR estimated for discard mortality = 0.0.
SPR_{20} = SPR estimated for discard mortality = 0.20.
SPR_{33} = SPR estimated for discard mortality = 0.33.

Table 6. Mortality rate and Spawning Potential Ratio (SPR) estimates for Gulf of Mexico red grouper derived from catch curves fitted to the 1986-1989 and 1990-1992 catch age composition estimated from several different growth models and assuming natural mortality (M) is 0.25.

Growth Equation	1986-1989 Length Composition of Combined Harvest: Predicted Ages			1986-1989: Bias Corrected			1990-1992 Length Composition of Combined Harvest: Predicted Ages					1990-1992: Bias Corrected				
	Z_L	F_L	SPR_0	Z_{COR}	F_{COR}	SPR_0	Z_L	F_L	SPR_0	SPR_{20}	SPR_{33}	Z_{COR}	F_{COR}	SPR_0	SPR_{20}	SPR_{33}
MOE 63-64	0.313	0.063	0.575	0.335	0.085	0.560	0.282	0.032	0.789	0.781	0.775	0.453	0.203	0.532	0.470	0.434
COM 80-81	0.291	0.041	0.709	0.286	0.036	0.777	0.316	0.066	0.633	0.623	0.616	-	-	-	-	-
REC 80-81	0.436	0.186	0.314	0.491	0.241	0.315	0.402	0.152	0.426	0.416	0.409	1.152	0.902	0.213	0.158	0.130
REC 91-93	0.457	0.207	0.290	0.548	0.298	0.277	0.500	0.250	0.313	0.295	0.284	1.545	1.295	0.165	0.116	0.092
BLL 91-93	0.356	0.106	0.460	0.414	0.164	0.363	0.392	0.142	0.424	0.412	0.404	0.661	0.411	0.360	0.288	0.249
HDL 91-93	0.371	0.121	0.414	0.409	0.159	0.401	0.395	0.145	0.410	0.398	0.390	0.678	0.428	0.351	0.287	0.252
TRP 91-93	0.374	0.124	0.393	0.402	0.152	0.343	0.488	0.238	0.269	0.253	0.242	0.672	0.422	0.361	0.270	0.224
ALL DATA	0.380	0.130	0.410	0.430	0.180	0.378	0.377	0.127	0.470	0.459	0.452	0.803	0.553	0.299	0.238	0.205

Z_L = estimated from slope of catch curve fitted to ages predicted from observed lengths using the indicated growth equation.

F_L = estimated as Z_L - M.

Z_{COR} = estimated from Z_L using bias correction regression equation.

F_{COR} = estimated as Z_{COR} - M.

SPR_0 = SPR estimated for discard mortality = 0.0.

SPR_{20} = SPR estimated for discard mortality = 0.20.

SPR_{33} = SPR estimated for discard mortality = 0.33.

Table 9. Estimates of yield per recruit (YPR), yield and spawning potential ratio (SPR) for Gulf of Mexico red grouper with a 16 inch minimum size for several growth models at three levels of natural mortality (M), three levels of discard mortality, and two levels of fishing mortality rates. The estimates assume equilibrium conditions and the 1979-1989 recruitment estimated for respective growth equation.

M = 0.15

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.892	10.02	30.84	1.796	9.51	29.27	1.736	9.19	28.30	1.952	10.34	18.66	1.795	9.50	17.15	1.699	9.00	16.24
COM 80-81	1.519	9.43	39.38	1.467	9.11	38.01	1.434	8.90	37.14	-	-	-	-	-	-	-	-	-
REC 79-80	2.817	10.41	20.22	2.668	9.86	19.14	2.575	9.52	18.48	2.466	9.11	5.26	2.121	7.84	4.52	1.924	7.11	4.10
REC 91-93	3.024	10.39	18.19	2.872	9.87	17.27	2.778	9.55	16.70	2.398	8.24	3.60	2.045	7.03	3.05	1.846	6.34	2.74
BLL 91-93	2.753	10.72	22.39	2.567	9.99	20.87	2.452	9.55	19.94	2.581	10.05	10.07	2.262	8.81	8.82	2.077	8.09	8.09
HDL 91-93	2.805	10.45	24.31	2.648	9.86	22.94	2.551	9.50	22.09	2.607	9.71	10.58	2.325	8.66	9.43	2.158	8.04	8.75
TRP 91-93	2.329	10.75	20.25	2.148	9.92	18.66	2.038	9.41	17.69	2.171	10.03	7.84	1.851	8.55	6.67	1.670	7.71	6.01
ALL DATA	2.486	10.28	23.07	2.357	9.74	21.87	2.276	9.41	21.12	2.339	9.67	8.39	2.074	8.58	7.43	1.919	7.93	6.88

M = 0.20

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.134	9.32	45.49	1.092	8.98	43.79	1.065	8.76	42.72	1.340	11.02	27.56	1.250	10.27	25.68	1.194	9.82	24.54
COM 80-81	0.790	8.83	58.36	0.773	8.64	57.07	0.762	8.51	56.24	-	-	-	-	-	-	-	-	-
REC 79-80	2.039	10.00	28.62	1.946	9.54	27.31	1.888	9.26	26.50	1.992	9.77	7.47	1.727	8.47	6.47	1.574	7.72	5.89
REC 91-93	2.222	10.06	25.46	2.125	9.61	24.33	2.064	9.34	23.62	1.951	8.83	5.05	1.674	7.58	4.31	1.517	6.87	3.89
BLL 91-93	1.991	10.02	32.82	1.881	9.47	31.00	1.813	9.12	29.88	2.082	10.48	14.79	1.849	9.30	13.12	1.712	8.61	12.15
HDL 91-93	1.971	9.87	35.09	1.881	9.42	33.49	1.825	9.14	32.49	2.058	10.31	15.30	1.855	9.29	13.78	1.735	8.69	12.88
TRP 91-93	1.677	9.91	30.79	1.572	9.29	28.84	1.507	8.91	27.64	1.772	10.47	11.98	1.535	9.07	10.36	1.398	8.27	9.42
ALL DATA	1.721	9.79	33.12	1.647	9.37	31.70	1.601	9.11	30.80	1.824	10.38	12.07	1.632	9.29	10.80	1.519	8.64	10.04

M = 0.25

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	0.587	8.68	63.19	0.573	8.47	61.70	0.564	8.34	60.75	0.885	13.09	38.33	0.836	12.37	36.23	0.806	11.93	34.93
COM 80-81	0.272	8.27	81.24	0.270	8.19	80.48	0.268	8.14	80.00	-	-	-	-	-	-	-	-	-
REC 79-80	1.432	9.60	38.24	1.378	9.24	36.79	1.344	9.01	35.88	1.605	10.76	10.00	1.402	9.40	8.73	1.285	8.61	8.00
REC 91-93	1.600	9.73	33.68	1.539	9.36	32.40	1.501	9.13	31.59	1.586	9.65	6.71	1.369	8.33	5.76	1.246	7.58	5.22
BLL 91-93	1.361	9.37	45.29	1.304	8.97	43.35	1.267	8.72	42.14	1.660	11.42	20.45	1.493	10.27	18.39	1.394	9.59	17.16
HDL 91-93	1.305	9.33	47.76	1.260	9.00	46.09	1.231	8.80	45.04	1.607	11.48	20.86	1.465	10.47	19.00	1.379	9.85	17.89
TRP 91-93	1.134	9.14	43.95	1.080	8.71	41.84	1.047	8.43	40.52	1.430	11.53	17.18	1.258	10.14	15.09	1.158	9.33	13.87
ALL DATA	1.135	9.32	44.86	1.096	9.01	43.34	1.072	8.81	42.38	1.412	11.60	16.38	1.276	10.48	14.79	1.194	9.81	13.85

Table 10. Estimates of yield per recruit (YPR), yield and spawning potential ratio (SPR) for Gulf of Mexico red grouper with a 18 inch minimum size for several growth models at three levels of natural mortality (M), three levels of discard mortality, and two levels of fishing mortality rates. The estimates assume equilibrium conditions and the 1979-1989 recruitment estimated for respective growth equation.

M = 0.15

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.939	10.27	36.04	1.782	9.43	33.15	1.687	8.93	31.40	2.058	10.89	23.83	1.795	9.50	20.84	1.643	8.70	19.11
COM 80-81	1.502	9.32	44.30	1.415	8.78	41.76	1.361	8.45	40.19	-	-	-	-	-	-	-	-	-
REC 79-80	2.973	10.99	24.10	2.715	10.04	22.03	2.559	9.46	20.77	2.789	10.31	8.12	2.170	8.02	6.36	1.846	6.82	5.43
REC 91-93	3.272	11.25	22.15	2.982	10.25	20.21	2.808	9.65	19.04	2.932	10.08	6.38	2.165	7.44	4.77	1.781	6.12	3.96
BLL 91-93	2.911	11.34	27.43	2.600	10.13	24.54	2.417	9.41	22.83	2.845	11.08	14.45	2.301	8.96	11.74	2.005	7.81	10.27
HDL 91-93	2.964	11.04	28.99	2.697	10.04	26.40	2.536	9.45	24.85	2.887	10.75	14.74	2.393	8.91	12.27	2.119	7.89	10.90
TRP 91-93	2.468	11.40	26.68	2.145	9.91	23.25	1.958	9.04	21.26	2.396	11.07	12.93	1.815	8.38	9.89	1.516	7.00	8.32
ALL DATA	2.603	10.76	27.47	2.380	9.84	25.14	2.245	9.28	23.73	2.590	10.71	12.08	2.117	8.75	9.93	1.858	7.68	8.75

M = 0.20

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.112	9.14	50.95	1.046	8.60	47.94	1.005	8.26	46.09	1.353	11.12	33.77	1.207	9.92	30.21	1.121	9.22	28.10
COM 80-81	0.747	8.35	62.86	0.719	8.04	60.56	0.702	7.84	59.11	-	-	-	-	-	-	-	-	-
REC 79-80	2.095	10.27	33.23	1.938	9.51	30.78	1.843	9.04	29.28	2.197	10.77	11.25	1.732	8.49	8.93	1.485	7.28	7.70
REC 91-93	2.343	10.60	30.23	2.160	9.78	27.91	2.049	9.27	26.50	2.324	10.52	8.76	1.736	7.86	6.62	1.438	6.51	5.54
BLL 91-93	2.021	10.17	38.68	1.845	9.28	35.35	1.738	8.75	33.34	2.205	11.10	20.45	1.821	9.17	16.98	1.609	8.10	15.05
HDL 91-93	2.009	10.06	40.43	1.862	9.33	37.50	1.772	8.87	35.72	2.201	11.02	20.63	1.858	9.30	17.49	1.664	8.33	15.71
TRP 91-93	1.675	9.90	38.38	1.497	8.85	34.38	1.391	8.22	32.01	1.845	10.91	18.76	1.436	8.49	14.74	1.221	7.22	12.63
ALL DATA	1.744	9.92	38.21	1.620	9.22	35.53	1.545	8.79	33.89	1.956	11.13	16.88	1.624	9.24	14.09	1.440	8.19	12.54

M = 0.25

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	0.550	8.14	67.86	0.529	7.83	65.31	0.516	7.64	63.71	0.855	12.64	45.09	0.780	11.54	41.24	0.735	10.87	38.92
COM 80-81	0.246	7.47	83.80	0.242	7.36	82.51	0.240	7.28	81.68	-	-	-	-	-	-	-	-	-
REC 79-80	1.432	9.60	43.27	1.343	9.00	40.61	1.288	8.64	38.97	1.726	11.57	14.73	1.378	9.24	11.84	1.192	7.99	10.29
REC 91-93	1.643	10.00	39.01	1.533	9.32	36.43	1.465	8.91	34.85	1.840	11.19	11.36	1.390	8.46	8.70	1.160	7.06	7.33
BLL 91-93	1.327	9.13	51.35	1.237	8.51	47.93	1.182	8.13	45.83	1.690	11.62	27.27	1.425	9.80	23.11	1.276	8.78	20.76
HDL 91-93	1.284	9.18	53.19	1.212	8.66	50.23	1.167	8.34	48.40	1.660	11.86	27.24	1.426	10.19	23.50	1.292	9.23	21.36
TRP 91-93	1.067	8.60	51.84	0.981	7.90	47.73	0.928	7.48	45.24	1.406	11.33	25.56	1.124	9.06	20.64	0.973	7.84	17.98
ALL DATA	1.113	9.15	50.16	1.051	8.64	47.38	1.012	8.32	45.67	1.468	12.06	22.25	1.238	10.17	18.86	1.109	9.11	16.95

Table 11. Estimates of yield per recruit (YPR), yield and spawning potential ratio (SPR) for Gulf of Mexico red grouper with a 20 inch minimum size for several growth models at three levels of natural mortality (M), three levels of discard mortality, fishing mortality rates estimated for the post 20 inch minimum size period. The estimates assume equilibrium conditions and the 1979-1989 recruitment estimated for respective growth equation.

M = 0.15

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.944	10.29	42.54	1.721	9.11	37.83	1.589	8.42	35.06	2.116	11.20	30.67	1.739	9.20	25.45	1.530	8.10	22.56
COM 80-81	1.430	8.88	50.90	1.306	8.11	46.65	1.231	7.65	44.08	-	-	-	-	-	-	-	-	-
REC 79-80	3.099	11.45	28.98	2.714	10.03	25.51	2.489	9.20	23.48	3.102	11.47	12.33	2.152	7.96	8.79	1.700	6.28	7.08
REC 91-93	3.435	11.81	26.29	3.011	10.35	23.17	2.765	9.50	21.34	3.254	11.18	9.62	2.132	7.33	6.53	1.624	5.58	5.11
BLL 91-93	3.023	11.77	33.80	2.573	10.02	28.97	2.318	9.02	26.22	3.065	11.93	20.58	2.264	8.82	15.50	1.861	7.25	12.92
HDL 91-93	3.076	11.46	34.64	2.688	10.01	30.43	2.463	9.17	27.98	3.118	11.61	20.29	2.388	8.89	15.78	2.009	7.48	13.42
TRP 91-93	2.556	11.80	34.51	2.087	9.64	28.50	1.830	8.45	25.18	2.565	11.85	20.12	1.714	7.92	13.92	1.321	6.10	11.00
ALL DATA	2.675	11.06	32.96	2.347	9.70	29.06	2.155	8.91	26.79	2.794	11.55	17.24	2.085	8.62	13.11	1.725	7.13	11.00

M = 0.20

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	1.060	8.71	57.46	0.970	7.97	52.77	0.915	7.52	49.93	1.324	10.88	41.62	1.123	9.24	35.65	1.010	8.30	32.25
COM 80-81	0.672	7.51	68.59	0.634	7.09	64.93	0.611	6.83	62.66	-	-	-	-	-	-	-	-	-
REC 79-80	2.117	10.38	38.87	1.891	9.27	34.87	1.757	8.61	32.50	2.374	11.64	16.68	1.678	8.23	12.12	1.341	6.58	9.88
REC 91-93	2.400	10.86	35.11	2.139	9.68	31.44	1.985	8.98	29.27	2.524	11.42	12.96	1.680	7.60	8.94	1.293	5.85	7.06
BLL 91-93	2.005	10.09	45.77	1.760	8.86	40.41	1.617	8.14	37.28	2.272	11.44	28.07	1.730	8.71	21.76	1.450	7.30	18.48
HDL 91-93	2.005	10.04	46.66	1.799	9.01	42.04	1.676	8.40	39.29	2.289	11.47	27.49	1.798	9.01	21.92	1.538	7.70	18.95
TRP 91-93	1.630	9.64	47.07	1.386	8.19	40.42	1.248	7.38	36.62	1.860	10.99	27.80	1.293	7.64	19.98	1.022	6.04	16.19
ALL DATA	1.727	9.83	44.36	1.551	8.83	40.01	1.447	8.23	37.43	2.038	11.59	23.37	1.556	8.85	18.18	1.306	7.43	15.47

M = 0.25

	1986-1989 Fishing Rates									1990-1992 Fishing Rates								
	Discard 0.00			Discard 0.20			Discard 0.33			Discard 0.00			Discard 0.20			Discard 0.33		
Growth Model	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR	YPR	Yield	%SPR
MOE 63-64	0.499	7.38	73.15	0.471	6.97	69.35	0.455	6.72	66.99	0.796	11.77	53.24	0.698	10.32	47.06	0.641	9.48	43.44
COM 80-81	0.209	6.35	86.90	0.204	6.20	84.93	0.201	6.10	83.68	-	-	-	-	-	-	-	-	-
REC 79-80	1.404	9.41	49.25	1.278	8.57	45.02	1.203	8.06	42.47	1.812	12.14	21.32	1.305	8.75	15.78	1.056	7.08	13.02
REC 91-93	1.642	9.99	44.32	1.488	9.06	40.33	1.396	8.49	37.94	1.955	11.89	16.53	1.322	8.04	11.58	1.028	6.25	9.24
BLL 91-93	1.258	8.65	58.36	1.138	7.83	53.08	1.067	7.34	49.91	1.665	11.46	36.05	1.307	8.99	28.78	1.116	7.68	24.90
HDL 91-93	1.233	8.81	59.28	1.135	8.11	54.77	1.075	7.68	52.03	1.662	11.88	35.15	1.340	9.57	28.73	1.165	8.32	25.23
TRP 91-93	0.976	7.87	60.34	0.865	6.97	53.85	0.799	6.44	50.02	1.334	10.75	36.10	0.965	7.77	26.96	0.782	6.30	22.38
ALL DATA	1.063	8.73	56.33	0.977	8.03	51.98	0.925	7.60	49.34	1.476	12.13	29.91	1.153	9.48	23.79	0.983	8.08	20.54