

RED GROUPEL

Harvest Trends

Gulf of Mexico red grouper harvested by U.S. fishermen are primarily caught in the eastern Gulf from Panama City, Florida to the Florida Keys. The greatest part of the present commercial and recreational harvest is from Tampa southward, and about half of the commercial harvest is landed in the Tampa - St. Petersburg area. Commercial landings for red grouper have been separated from other grouper species only since 1986.

Prior to the introduction of bottom longline gear in the early 1980's, commercial landings of all groupers exhibited a slow decline from about 7.8 million pounds (gutted weight) in 1965 to about 5 million pounds in the late 1970's (Figure 1). Handlines, and power-assisted reels accounted for almost all the landings during this period and decline in landings of groupers caught with handlines during the 1980's resulted from a partial replacement of this gear by bottom longlines. Introduction of long line gear resulted in a sharp increase in total grouper landings to a maximum of about 12.5 million pounds in 1982. Traps increased in importance in the mid 1980's but contribute only a small proportion of the grouper catch.

Red grouper accounted for 69% of the total classified grouper commercial landings since 1986 and contributed about 7.5 million pounds in 1989; however, the relative dominance of the various grouper species vary by state and year. If the proportion of red grouper in the total grouper catch was the same before species were separated in the landings, then the maximum commercial harvest for this species was about 8.5 million pounds in 1982 (Figure 2). Commercial red grouper landings were stabilized between 6 and 7 million pounds during the period 1983-1987, however, landings in 1988 dropped significantly to 4.6 million pounds. Landings in 1990 were 4.8 million pounds as a result of the closure of the shallow water grouper fishery in November 1990.

Estimates of the recreational harvest of red grouper are highly variable over the period 1979-1990, but average about 700 thousand individuals (Figure 3) and 2.6 million pounds from 1982-1989. Much of the recreational harvest was in Florida's territorial sea. The 1990 landings declined about 70% by number and 41% by weight, primarily as a result of a 20-inch minimum size adopted in 1990. The effect of minimum size regulations have been observed in a clearly increasing fraction of the total recreational catch released over the period 1979-1990 (Figure 4).

The estimate of the combined harvest of red grouper in the commercial and recreational fisheries increased from a 1979-1980 average of 6.5 million pounds to a 1984-1985 average of almost 11 million pounds (Figure 5). Total landings then declined to about 6.2 million pounds. Decrease in landings from 1985 to 1987 was the result of a decline in the estimate for the recreational fishery in response to Florida's 18-inch minimum size. Both the recreational and commercial components of the 1990 harvest declined from the 1989 estimate, but neither estimate declined to a level much less than had been experienced in the previous three years.

Reproduction

Red grouper are categorized as protogynous hermaphrodites, which first mature as females and then change to males at an older age. Fecundity and length data on red grouper are insufficient for regression analysis but additional data are currently being collected by several research programs (see Nichols 1991). Normally, these data would be incorporated into an estimate of the spawning potential ratio (SPR) upon which to judge the condition of the spawning stock. It has been noted, however, that the estimation of the potential recruit fecundity (required for estimation of SPR) posed a problem for species that change sexes during their life history. The problem arises because fishing mortality not only reduces the life expectancy of individuals in the population, it may also reduce the proportion of a surviving fish's life spent as a female by

exacerbating the transition of females to males at higher levels of exploitation. Additional research is needed to properly estimate potential recruit fecundity and to fully comprehend the impact of this reproductive strategy on the ability of such species to sustain fisheries. Because of this problem, in the analyses the ratio of fished to unfished spawning stock biomass per recruit is used as a surrogate for SPR.

Growth and Size

Recent measures of length at age suggest that the growth rate of red grouper in the Gulf of Mexico has increased since the first studies were performed in the mid 1960's (Figure 6). A possible explanation for this apparent change in growth is a reduction in density-dependent suppression of growth which may have resulted from a significant reduction in red grouper density caused by fishing. Uncertainty about the current growth characteristics of red grouper is a significant impediment to the application of age-structured methods to the analysis of the status of the stock, therefore, additional data to confirm or refute the available growth information are needed. For the purpose of this assessment the growth equation derived from Burton and Stiles (1991) data was adopted because it generated more credible mortality estimates derived from catch curve analyses.

Size frequency distributions from commercial landings are available for the period 1984-1990 by day of sample. Inspection of these data (Figure 7) reveals a significant decline in the number of fish measured that began in 1988 and extended through 1989. The impact of the 20-inch minimum size is also apparent from the 1990 samples. These data, and other samples obtained by NMFS Panama City Laboratory in 1980 and 1981, were used to construct length frequencies of red grouper by gear type and year of capture. However, inspection of these data indicated that the samples are not random samples of the catch such that they could not be used directly to estimate the size composition of the landings. In general, size frequency information is characterized by disproportionate representation by gear, location of capture and area of landing; therefore, samples were stratified by gear and area of capture, which appear to be the best compromise with the available data.

Length samples from the recreational fishery are available from 1979-1990 by day of sampling. As a result of the expansion of the headboat survey into the Gulf in 1986, a gradual increase in the number of fish measured has been observed since that year (Figure 8). As with the commercial data, there is clear signal of the impact of the 20-inch minimum size in the 1990 samples and a drop in sample size in the latter half of 1985 as a response to Florida's 1985 18-inch minimum size. It is observed that there is a significant paucity in the data base and also some noticeable differences in the level of sampling by fishing mode. In spite of these deficiencies, it is possible to identify a trend of increasing average size of red grouper harvested by anglers in a northward direction along Florida's west coast (Figure 9). This trend, which is also apparent in the commercial landings, suggests small red grouper are comparably more scarce in the northern part of the region. Consequently, it is reasonable that the harvest of red grouper in the northerly part of their range in the eastern Gulf of Mexico may be dependent on emigration from a center of abundance to the south. If this is the case, then one of the more important effects of overfishing would be to greatly reduce the catch north of the Tampa-St. Petersburg area.

As with the commercial length frequencies, several constraints limit the possibility of aggregating recreational size data to estimate size composition of the harvest. The most important constraint is the lack of resolution of landings by area within state from MRFSS. After review of the spatial variability of the length-frequency data and the constraints imposed by the catch estimates, the annual recreational catch was partitioned by mode. Length distribution for the combined commercial and recreational harvest (Figure 10) show the propensity for commercial fishermen to harvest red grouper that have an average larger size than those harvested by recreational fishermen.

Mortality

Natural mortality is not well known for red grouper. Values adopted in other studies of red grouper range from 0.17 to 0.20. In the analyses, a natural mortality rate of 0.20 was adopted although it may be too high given the frequency of older age classes in the population.

Release mortality among red grouper less than 20 inches total length is not accurately known. Release mortality in a small sample of 21 red groupers caught by hook and line from a depth of 44 m was 29%; however, anecdotal comments from fishermen suggest significant numbers of released red grouper do not survive the fishing experience. In the analyses three values (33, 50, and 66%) were arbitrarily used to evaluate the impact of such mortality on yield. The Panel thinks that release mortality is probably between 33% and 50%.

Fishing mortality rates were estimated from catch curves because the lack of age samples from the fishery and the lack of details of red grouper growth precluded using virtual population analyses. For either Moe's (1969) growth curve or Burton and Stiles (1991) growth curve, there was not a significant difference between mortality rates derived for the time periods of 1986-1989 and 1990. Based upon the choice of growth curve, total mortality could be 0.27 per year or 0.40 per year. The slope (total mortality) did not change when the age distributions were truncated to the Amendment 1 20-inch minimum size which suggests that the increased harvest of older fish by bottom long-lines has not had sufficient time to alter the age distributions even if we knew the appropriate model for the population.

With a natural mortality of 0.2 per year, it is unlikely that approximately 9 million pounds are harvested with a fishing mortality rate of 0.07 per year. Fishing mortality rate is calculated as the difference between the annual total mortality (0.27 per year) and annual natural mortality. Therefore, for the purposes of analysis, we used the Burton and Stiles curve which indicates a fishing mortality of approximately 0.20 per year.

Estimation of $F_{0.1}$

The status of red grouper was assessed with a yield-per-recruit model. Separate estimates were developed for the period 1986-1989 and 1990. The 20-inch minimum size with Amendment 1 shifted $F_{0.1}$ from $F = 0.14$ per year prior to regulations to $F = 0.19$ per year after the regulations. The current fishing mortality rate of 0.2 per year is similar to $F_{0.1}$. These estimates assume that there is no release mortality associated with the 20 inch minimum size. Since there is little likelihood of no release mortality, the Panel investigated $F_{0.1}$ with release mortalities of 33, 50, and 66% (Table 1). As expected, $F_{0.1}$ decreases with increased release mortality and the corollary is that the current level of fishing mortality moves beyond $F_{0.1}$ with increasing release mortality. With no release mortality, the current fishing mortality is equal to $F_{0.1}$ and with a release mortality of 66%, the current fishing mortality rate is equal to F_{MAX} .

Spawning Potential Ratio (SPR)

The equilibrium Spawning Potential Ratio (SPR) at the current fishing mortality rate of 0.2 with no release mortality is approximately 39%. This ratio exceeds the Council's target of 20% by the year 2000. If release mortality is considered, then SPR decreases to 36% with a release mortality of 33% and down to 30% with a release mortality of 66%.

Recommendation of Acceptable Biological Catch (ABC)

Because the SPR values exceeded the Council's standard of 20 percent, the Panel defined Acceptable Biological Catch (ABC) in terms of the yield to be expected from fishing at rates of $F_{0.1}$ and release mortality. The yield is calculated from the average recruitment of 1986 through 1990 and the corresponding yield-per-recruit estimate. When release mortality is considered, then the most likely ABC range for red grouper is from $F_{0.1}$ with a minimum size of 20 inches and a release mortality of 50% which has an estimated yield of 8.2 million pounds to the current fishing mortality rate and a release mortality of 33% which is estimated to produce a yield of 9.2 million pounds (Table 1). The corresponding ABC levels (expressed in terms of commercial quotas) for the shallow-water groupers are 8.9 million pounds to 10.0 million pounds (Table 2). This recommended ABC range is an increase of 0.7 million pounds to 1.8 million pounds above the current shallow-water grouper quota. The 1991 quota of 9.2 million pounds is equivalent to 8.2 million pounds with the revised factor for converting gutted weight to whole weight (i.e., gutted weight represents a five percent loss rather than an 18 percent loss).

If the Council chooses to consider alternative minimum sizes for red grouper then the expected yield could increase to 10.4 million pounds with the current fishing level and a minimum size of 16 inches. The reduced minimum size may adversely affect the other species in the shallow water grouper complex.

Research and Data Needs

The following biological research and data needs emerged during our discussions.

- Annual sampling of commercial and recreational landings to obtain data for age and growth analysis is needed. The observed changes in the growth rates from the mid-1960's to 1990 being so far apart (Figure 6) that traditional models incorporating growth can not be used with any degree of certainty. It was suggested that this difference in growth rates is density dependent; thus, clearly, annual age and growth analyses are needed.
- Knowledge of the magnitude of release mortality and the factors which influence release mortality in both the commercial and recreational fisheries is critical. These studies should incorporate gear and depth as components of the analysis. This information, coupled with the age and growth above, will allow for a more realistic approach to stock analysis. Discussions by members of the Panel indicated that they considered release mortality to have an important component of total mortality (Table 1). The panel members thought that release mortality was at least 30% and perhaps as high as 50%.
- The Trip Interview Program's (TIP) sampling of commercial data to obtain catch, effort, age, length, sex ratios and species composition data should be increased. Hard parts for aging such as otoliths or scales should be collected more extensively. In addition, material for reproductive analysis should be collected routinely by TIP samplers.
- The basic reproductive biology of the species should be researched because it's protogynous hermaphroditism could have a significant effect on future stock assessments. Data will have to be collected from both the recreational and commercial fisheries as they collect different sizes of fish (Figures 7 and 8).

Red Grouper Stock Assessment

The Panel reviewed the Miami Laboratory Contribution No. MIA-92/93-75 titled "Red Grouper Fishery of the Gulf of Mexico" prepared by Dr. C. Phillip Goodyear and Michael Schirripa. The document contains new analyses of growth and reproduction of red grouper. Also an update of harvest trends is included and an assessment of the fishery is accomplished with the best data available to date.

Harvest Trends: Gulf of Mexico red grouper harvested by U.S. fishermen are primarily caught in the eastern Gulf from Panama City, Florida to the Florida Keys. The greatest part of the present commercial and recreational harvest is from Tampa southward, and about half of the commercial harvest is landed in the Tampa - St. Petersburg area. Commercial landings for red grouper have been separated from other grouper species only since 1986, historically however, 60 to 75 percent of all grouper landings correspond to red grouper. These percentages were applied to reconstruct U.S. commercial red grouper landings during the period 1950-1985. Red grouper catch by Cuban fleets operating off the west coast of Florida are available for the period 1950-1975. U.S and Cuban commercial landings are presented in **Figure 11**. It is observed that a very substantial portion of the commercial landings in the 1950's is attributable to the Cuban grouper fishery when the fishery reached 12 million pounds in 1957. In the 1960's the Cuban catch dropped off to approximately 2-3 million pounds per year and then increased again in the early 1970's to 4-5 million pounds. With the adoption of the U.S. Fishery Conservation Zone extending fishing rights 200 miles off shore in 1976, operation of the Cuban longline fleets stopped.

Prior to the introduction of bottom longline gear in the early 1980's, U.S. commercial landings of red grouper exhibited a slow decline from about 5 million pounds (gutted weight) in 1965 to about 3.5 million pounds in 1978 (**Figure 11**). Handlines and power-assisted reels accounted for almost all the landings during this period and decline in landings of groupers caught with

handlines during the 1980's resulted from a partial replacement of this gear by bottom longlines. Introduction of long line gear resulted in a sharp increase in red grouper landings to a maximum of about 8.3 million pounds in 1982. Traps increased in importance in the mid 1980's but contribute only a small proportion of the grouper catch. Commercial red grouper landings were varied between 6 and 7 million pounds during the period 1983-1987, however, landings in 1988 dropped significantly to 4.6 million pounds and then increased to 7.5 million pounds in 1989. As a result of the closure of the shallow water grouper fishery in November 1990 and the adoption of a 20" minimum size in that year, landings in the period 1990-1992 varied between 4 and 4.8 million pounds (**Figure 11**).

Estimates of the recreational harvest of red grouper are available only since 1979. Recreational landings are highly variable over the period 1979-1992, but average about 2.4 million pounds from 1982-1989 (**Figure 12**). Much of the recreational harvest was in Florida's territorial sea. The 1990 landings declined to 1.3 million pounds, primarily as a result of a 20-inch minimum size adopted in 1990 but landings increased to 2.9 million pounds in 1992 (**Figure 12**). The effect of minimum size regulations have been observed in a clearly increasing fraction of the total recreational catch released over the period 1979-1992 (**Figure 13**).

The estimate of the combined harvest of red grouper in the commercial and recreational fisheries increased from a 1979-1980 average of 5.5 million pounds to a 1984-1985 average of almost 11 million pounds (**Figure 12**). Total landings then declined to about 6.2 million pounds in 1990. Decrease in landings from 1984 to 1987 was the result of a decline in the estimate for the recreational fishery in response to Florida's 18-inch minimum size. Both the recreational and commercial components of the 1990 harvest declined from the 1989 estimate, but neither estimate declined to a level much less than had been experienced in the previous three years. An increasing trend in landings from 6.2 to 7.2 million pounds is observed during the period 1990-1992.

Reproduction: Red grouper are categorized as protogynous hermaphrodites, which first mature as females and then change to males at an older age. Results of new analyses of fecundity and length data on red grouper were incorporated into estimates of the spawning potential ratio (SPR) as a means to judge the condition of the spawning stock. Fecundity data, however, are highly uncertain. It has been noted that the estimation of the potential recruit fecundity (required for estimation of SPR) posed a problem for species that change sexes during their life history. The problem arises because fishing mortality not only reduces the life expectancy of individuals in the population, it may also reduce the proportion of a surviving fish's life spent as a female by increasing the transition of females to males at higher levels of exploitation. Additional research is needed to properly estimate potential recruit fecundity and to fully comprehend the impact of this reproductive strategy on the ability of such species to sustain fisheries.

Growth and Size: Recent measures of length at age suggest that the growth of red grouper in the Gulf of Mexico has increased since the first studies were performed in the mid 1960's. One possible explanation for this apparent change in growth may be due to a reduction in density-dependent suppression of growth resulting from a significant reduction in red grouper density caused by fishing and/or changes in the environment. Uncertainty about the growth characteristics of red grouper was a significant impediment to the application of age-structured methods in previous analysis of the status of the stock, however, a new time dependent growth model was developed with the available growth information. This equation replaced the equations derived from Burton and Stiles data from the South Atlantic and Moe's data from west Florida that were used in the 1991 assessments of mortality estimates derived from catch curve analyses (Goodyear and Schirripa 1991).

Size frequency distributions from commercial landings are available for the period 1984-1992 by day of sample. Inspection of these data (**Figure 14**) reveals a significant decline in the number of fish measured in 1988 and 1989. The impact of the 20-inch minimum size also is apparent from the 1990 through 1992 samples. In general, size frequency information is characterized by disproportionate representation by gear, location of capture and area of landing; therefore, samples were stratified by gear and area of capture, which appear to be the best compromise with the available data.

Length samples from the recreational fishery are available from 1979 to 1992 by day of sampling. As a result of the expansion of the headboat survey into the Gulf in 1986, increase in the number of fish measured has been observed in some years (**Figure 15**). As with the commercial data, there is clear signal of the impact of the 20-inch minimum size in the 1990-1992 samples and a drop in sample size in the latter half of 1985 as a response to Florida's 1985 18-inch minimum size. It is observed that there is a significant paucity in the data base and also some noticeable differences in the level of sampling by fishing mode.

As with the commercial length frequencies, several constraints limit the possibility of aggregating recreational size data to estimate size composition of the harvest. The most important constraint is the lack of resolution of landings by area within state from MRFSS. Therefore, stock assessment considers spatial variability of the length-frequency data and the constraints imposed by the catch estimates to partition the annual recreational catch by mode. Length distribution for the combined commercial and recreational harvest (**Figure 16**) show the propensity for commercial fishermen to harvest red grouper that have an average larger size than those harvested by recreational fishermen.

Mortality: Natural mortality is not known for red grouper. Values adopted in other studies of red grouper range from 0.17 to 0.20. In the analyses, a natural mortality rate of 0.20 was adopted as in previous assessments.

Release mortality among red grouper less than 20 inches total length is not accurately known. Release mortality in a small sample of 23 red groupers caught by hook and line from a depth of 44 m was 35 percent; however, anecdotal comments from fishermen suggest significant numbers of released red grouper do not survive the fishing experience. In the analyses three values (33, 50, and 60 percent) were arbitrarily used to evaluate the impact of such mortality on yield.

Fishing mortality rates were estimated from catch curves and from virtual population analyses. Catch at age data for these analyses are different from those provided in previous assessments. This is due to the adoption of a new time dependent growth equation to estimate age frequencies from length frequencies in the landings. The Panel notes that age-length keys are more appropriate than growth equations to develop annual age compositions, however, such keys are not currently available for this fishery. Based upon the choice of method, fishing mortality could be between 0.29 to 0.30 per year when using equilibrium catch curve analysis and an average of 0.31 per year with a peak of 0.44 per year at age 8 from VPA. However, estimates derived from VPA are highly uncertain due to lack of fishery independent estimates of abundance to calibrate the algorithm. CPUE series from commercial and recreational fisheries statistics are not accurate and they lack a sufficient time series to contribute to the calibration procedure.

Optimum Yield Definition: The Panel does not have explicit definitions from the Council on optimum yield strategies for red grouper. Presently, there is a minimum fishing mortality threshold (F generating 20 percent SPR) defined to prevent recruitment overfishing. This limit should not be confused with management goals to optimize yield, economics or social benefits. In effect, $F_{20\%SPR}$ will drive a lightly exploited fishery to the limit of acceptable protection to avoid recruitment overfishing. The Panel recommend the Council to consider the adoption of $F_{0.1}$ as a possible reference mortality rate defining optimum yield for fisheries that are not overfished.

Spawning Potential Ratio (SPR): Spawning Potential Ratio (SPR) estimates for the conditions existing in 1989 was about 17 percent to 24 percent. Presently, the SPR is only slightly above that in 1989, but the equilibrium SPR at $F=0.44$ with 33 percent release mortality is approximately 30 percent. This ratio exceeds the Council's target of 20 percent by the year 2000. If release mortality is 50 percent, then SPR decreases to 28 percent. The 20 percent SPR minimum threshold is more uncertain for groupers given their life history of being protogynous hermaphrodites.

Recommendation of Acceptable Biological Catch (ABC): If the Council adopts a catch level within the ABC range then in the long term the ABC will be increased to between 10.0 and 10.6 million pounds. Because the equilibrium SPR values exceeded the Council's standard of 20 percent, the Panel defined Acceptable Biological Catch (ABC) in terms of the yield to be expected from fishing at rates of F_{01} and current F with both 33 percent and 50 percent release mortalities for a 20 inch minimum size limit. At the 33 percent release mortality the ABC range for the red grouper component of the shallow water grouper fishery is from 4.4 to 7.6 million pounds. At the 50 percent release mortality the ABC range for the red grouper component of the shallow water grouper fishery is from 4.1 to 7.6 million pounds. The Panel notes that the TAC for F_{max} at 33 percent mortality is 7.4 million pounds and with a 50 percent mortality the TAC is 6.6 million pounds. For an 18 inch minimum size limit, at the 33 percent release mortality the ABC range for the red grouper component of the shallow water grouper fishery is from 4.8 to 7.6 million pounds. At the 50 percent release mortality the ABC range for the red grouper component of the shallow water grouper fishery is from 4.5 to 7.6 million pounds. The Panel notes that the TAC for F_{max} for an 18" minimum size limit at 33 percent mortality is 7.7 million pounds and with a 50 percent mortality the TAC is 7.1 million pounds (see Table 1).

If the Council wishes to lower the minimum size from 20" to 18", the ABC range recommended by the Panel will be achieved at slightly lower fishing mortality rates, however SPR does not change noticeably. The Panel notes that adoption of a lower minimum size may bring economic and social consequences which were not considered in the stock assessments.

Research and Data Needs: The following biological research and data needs emerged during our discussions.

- Annual sampling of commercial and recreational landings to obtain data for age length keys and growth analysis is needed. The observed changes in the growth rates from the mid-1960's to 1990 may be density dependent; thus, clearly, annual age and growth analyses are needed. For this purpose the Panel recommends that new growth models should be developed to include density dependent effects as well as possible environmental effects.
- Knowledge of the magnitude of release mortality and the factors which influence release mortality in both the commercial and recreational fisheries is critical. These studies should include field observations on harvest manipulation prior to release, as well as gear and depth as components of release mortality variability.
- Catch per unit of fishing effort and fishery independent estimates of abundance are critically required for better calibration of virtual population analyses. The Panel encourages studies leading to the development of statistically valid indexes of abundance derived from the different gears and sectors as well as development of innovative direct evaluations of population biomass.
- The basic reproductive biology of the species should be researched because it's protogynous hermaphroditism could have a significant effect on future stock assessments. Data will have to be collected from both the recreational and commercial fisheries as they collect different sizes of fish

Table 1. Summary of TACs, Fishing Mortality Rates, and associated SPR estimates from which the red grouper ABC ranges were derived.						
Note: A TAC of 9.8 represents the present TAC but with both the commercial and recreational allocations filled. A TAC of 7.6 represents the current amount of commercial and recreational landings. The TACs ranging from 4.1 to 4.8 represent the TACs that would have to be achieved next year to effect an immediate $F_{0.1}$ fishing mortality rate.						
Release Mortality = 33 %						
	18 Inch Minimum Size			20 Inch Minimum Size		
TAC Level	F	Amount of Discards	SPR	F	Amount of Discards	SPR
9.8 MP	0.49	0.60 MP	22%	0.60	1.10 MP	23%
8.6 MP	0.42	0.52 MP	26%	0.51	0.96 MP	26%
7.6 MP	0.36	0.45 MP	30%	0.44	0.84 MP	30%
4.8 MP	0.22	0.28 MP	44%			
4.4 MP				0.24	0.48 MP	46%
Release Mortality = 50 %						
	18 Inch Minimum Size			20 Inch Minimum Size		
TAC	F	Amount of Discards	SPR	F	Amount of Discards	SPR
9.8 MP	0.49	0.90 MP	21%	0.61	1.66 MP	21%
8.6 MP	0.42	0.78 MP	25%	0.52	1.45 MP	24%
7.6 MP	0.36	0.68 MP	29%	0.44	1.27 MP	28%
4.5 MP	0.21	0.40 Mp	44%			
4.1 MP				0.22	0.68 MP	47%

CORRECTED TABLE (1993 Reef Fish Stock Assessment Panel Report)

Red Snapper Stock Assessment

A review of red snapper commercial and recreational harvest trends, reproduction, growth and size and mortality rates is contained in the 1992 red snapper stock assessment (Goodyear 1992) and in the 1992 Assessment Update (Goodyear 1993). This report reviews changes from the 1992 red snapper stock assessment to the Update.

Changes to Red Snapper Analyses for 1993: The 1993 stock assessment update for red snapper included the 1993 commercial harvest, the 1992 recreational harvest and recruitment indices for the 1991 and 1992 year classes, and revisions to the existing projection model to incorporate the new data and projected impacts of proposed size limit increases. As in 1992, both

Update on Red Grouper Assessment

Both the 1991 and the 1993 stock assessments for red grouper were clouded by the difficulties in assigning ages to the catch. In 1991, a difference was noted between the early work by Moe (1969) and a recent study by Burton and Stiles (1991). In the original assessment ages were assigned using lengths sampled from the fishery and it was estimated that red grouper had a spawning potential ratio (SPR) in excess of 30% and, thus, were not overfished. In 1993, a year-dependent growth model was used to assign ages to red grouper catches. The SPR values were lower and closer to the Council's overfishing level of 20 percent. The Panel noted that age-length keys were more appropriate than the growth models. This year, the National Marine Fisheries Service (NMFS) produced an in-depth analysis of red grouper growth data and concluded that the differences among growth models could be explained by sampling (Goodyear, 1994a & b).

To some, it may seem like an inordinate amount of work has been spent on just one aspect of the fishery; however, the Council's choice of SPR as the measure of whether a stock is overfished requires an age structured population model. In other words, the validity of the estimate of the condition of the stock depends upon being able to accurately assign ages to the catch.

Dr. Goodyear presented an analysis of the influence of sampling procedures and minimum size on red grouper growth predictions and concluded that substantial bias is introduced into the stock assessments when ages are assigned using growth models developed from observations collected with length-stratified sampling, size selective gears, or from fisheries with minimum size regulations. Further work with simulations of known lengths and ages indicated that it was possible to correct the total mortality estimates for the bias introduced by assigning ages from lengths if the length samples are randomly drawn from the harvest and the selectivity curve is reasonably known. Such estimates were made for the years before the pre-20 inch minimum size, 1986-1989. However, the additional bias from the 20-inch minimum size limit precluded similar corrections for the years after 1989. The implications of this analysis is that the stock assessment process cannot calculate a valid estimate of mortality from the data collected after the minimum size was enacted in 1990. After much discussion, the Panel concluded that it is imperative to develop annual area-gear specific age-length keys using a statistically sound sampling protocol before the status of the red grouper stock can be evaluated. This rationale applies to all stocks that currently are being assessed using VPA's

Although the Panel concluded that it could not provide the Council with an estimate of current fishing mortality nor with an estimate of current SPR, the group discussed what advice it could provide to the Council. Since the pre-regulation mortality estimated can be corrected for the bias associated with the assignment of age from length, the age data suffices to estimate the pre-regulation status (Table 2) that indicates SPR values from 20% to 52% depending upon the growth model and there is no sound biological reason to choose one value in that range over any other value. Without analysis but arguing from fisheries theory, the Panel thinks that the current SPR may be higher than before 1990 because the 20-inch minimum size on red grouper is beyond the minimum size producing the maximum yield-per-recruit and those extra fish are probably remaining in the population and reproducing.

Research Needs and Management Advice

The Panel recommends that the Council do everything in its power to convince NMFS that reef fish need adequate samples collected under a sound design for developing age-length keys. Under the requirement that the Council work with the best scientific advice, the Panel prefers not to recommend estimates of mortality or SPR that has been documented to lack validity.

In the interim, the Panel recommends status quo until a meaningful assessment can be conducted from valid length and age samples. Furthermore, the Panel thought that providing the Council with a total allowable catch (TAC) estimate was moot because the current quota is not being harvested. The assessment can be updated once representative age-at-length data is collected, but it may take 3-4 years of additional data collection before we become comfortable with the assessment results.

Note: that the same biases occur in other species except that the 20-inch minimum size has a greater effect on red grouper because of the overlapping of ages and because of the greater age that must be attained such that no fish in that age category are below 20 inches.

Red Snapper Stock Assessment Update

Changes to Red Snapper Analysis in 1994

The 1994 stock assessment for red snapper included new data and updates to the projection model used to evaluate progress toward attaining the target goal of 20 percent SPR by the year 2009. Data revisions included recreational and commercial harvests through 1993.

Harvest Trends

The TAC levels established by the Council since Amendment 1 were 4 MP in 1991 and 1992, and 6 MP in 1993 and 1994. Total directed fishery harvests during 1990 through 1993 were: 4.1 MP, 1990; 4.8 MP, 1991; 6.6 MP, 1992; and 8.2 MP, 1993 (Figure 6).

The 1991 to 1993 commercial harvest has been curtailed by quotas to 2.2, 3.1, and 3.0 million pounds respectively. Preliminary estimates indicate the 1994 commercial harvest

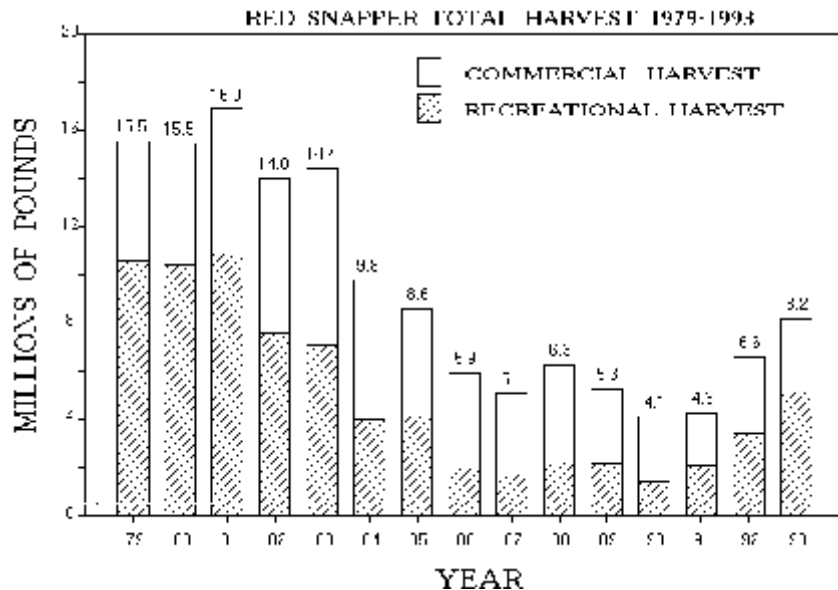


Figure 6. Estimated biomass of the combined commercial and recreational harvest of Gulf of Mexico red snappers (1979-1993).

RED GROUPER STOCK ASSESSMENT

Review of Red Grouper Assessment

This year's stock assessment (Schirripa et al. 1999) includes several major changes from past stock assessments, as well as updates of the commercial and recreational catches of red grouper in U.S. waters. Major changes include a new growth curve obtained from a tagging study, an estimate of the total catch of red grouper since 1940, and the use of two different models (a surplus-production model and the ASAP model) to evaluate the current condition of the red grouper stock. Both models indicated that the red grouper stock is overfished and that overfishing is occurring.

Previous RFSAPs found that estimates of current fishing mortality or current SPR could not be generated because of problems in assigning ages to individuals in the catch. These problems resulted from differences in available growth models caused by sampling. Since the last stock assessment, a new growth curve was calculated, based on the lengths at capture and recapture from a tagging study conducted by Mote Marine Lab. This new growth curve, although obtained independently of the data used in the past, provided estimates of the parameters of the growth curve (termed L_4 and K) that were very similar to the values obtained by pooled otoliths (Figure 4). The similarity gives confidence that the recent estimates of growth rates for red grouper were accurate, thus allowing estimation of current stock status.

With the addition of recent data points, trends in both commercial and recreational catches showed a continuing decline since the last stock assessment in 1993. To expand the time series and to make use of the historic commercial catch data that are available, historic recreational catches were estimated using a

relationship between the population size on the West Coast of Florida and the number of private angler trips. Although this method makes many assumptions about recruitment and stock size, the trends in catch are likely to be dominated by the much larger commercial catches, implying that any errors in the historic recreational catch were inconsequential. The historical time series of total catch shows a continuing decline in catches since the peak in the 1950s (Figure 5).

Two models were applied to red grouper: a surplus production model (ASPIC) and the ASAP model. The RFSAP felt that, while the surplus-production model was useful because it required fewer assumptions, the ASAP model was a better representation of the stock. The ASAP model took full advantage of all available data and allowed for uncertainty in parameter estimation. The RFSAP therefore used the ASAP model to determine ABC recommendations for red grouper. As with the red snapper stock assessment, the ASAP model depends on a spawner-recruit curve for estimating future harvest trajectories for any proposed level of fishing mortality, for estimating the present value of spawning stock biomass, and for estimating the relative positions of current biomass and B_{MSY} . For red grouper, spawner-recruit curves were based on either a long dataset (1940-1997) or short dataset (1986-1997). The short dataset only used years when the catch was known to be red grouper and could be aged for all gears. Model simulations based on the long dataset were used by the RFSAP. The long dataset provided enough contrast so that both steepness and virgin spawning stock size could be estimated from the data, rather than having to specify values as was necessary when the short dataset was used.

Tuning Indices

The long dataset included nine estimates of CPUE, whereas the the short dataset included eight time series of CPUE. Fishery-dependent estimates of CPUE used by both models were based on logbook data from the handline, longline, and trap fisheries (1990-1997), and the MRFSS data for charter/private boats and headboats (1981-1997). Fishery-independent estimates of CPUE used by both models were trap and video indices of abundance from SEAMAP surveys (1992-1995), and tag and release data from Mote Marine Lab (1991-1997). The major difference in the tuning indices between the long and short datasets was the inclusion of the historical catch data from the Cuban fleet (1940-1977) and from the US fleet (1950-1997) in the long dataset.

The landings of red grouper were estimated for the period 1940-1985. Reporting of commercial grouper landings by species began in 1986. The estimated recreational landings in 1997 are the lowest since 1981. The 1997 commercial landings were only 55% of the peak landings observed in 1982.

Estimates of spawning stock biomass of females was dependent in part on the estimated proportion of females within each age group. Available data indicated some change may have occurred between Moe's (1969) work in 1964 and Koenig's (1993) work in 1992, with a higher proportion of females at age in Moe's analysis. These data were combined in the present assessment.

The estimated catch-at-age was also estimated using the probabilistic method with the assumption of constant recruitment. The growth function used in this method was further validated using estimates of growth made from tag-recapture data. Several indices of abundance were derived from available data and used in the analyses.

Comparison of Assessment Models

The RFSAP noted that both the surplus production and ASAP models generated similar predictions of stock status, thereby increasing our confidence in ASAP model results. The surplus production model results showed that in 1997 red grouper biomass was about 20% of the biomass expected at MSY, and that the 1997 fishing mortality was about two times that needed to produce MSY. Absolute estimates of MSY were about 11 to 12 million pounds. The ASAP model showed that the best estimate for MSY was 8.4 million pounds, which is achieved at an F of 0.27 per year. The spawning stock biomass at MSY was 563 million pounds. The estimated F and spawning stock biomass in 1997 is 0.88 per year and 144 million pounds. Thus, the 1997 estimated biomass was 26% of stock biomass at MSY.

Both models showed an increase in fishing mortality in recent years. With decreased catch, this implied a reduced abundance of red grouper. Estimated fishing mortalities doubled since the late 1970's (ASPIC model) and increased from an average of about 0.3 on 1986 to 0.5 in 1997 (ASAP model). Estimates of spawning stock biomass and recruitment have declined since at least 1985. In all model simulations, the red grouper stock was overfished and overfishing is still occurring.

Red Grouper ABC Recommendation and Rationale

The RFSAP chose to use the long dataset with the ASAP model to project MSY and time-to-recovery. The combination of the long dataset and the ASAP model allowed for all available tuning data to be used, including the historical perspective, and allowed for statistical estimation of the parameter values of the stock-recruit function. Two management strategies were examined: constant F and constant catch. Two recovery periods were considered: 10 years (by 2010) under zero fishing mortality, and 18 years (by 2018) given zero fishing mortality is not practical. Under no directed or bycatch fishing mortality, the estimated time to recovery is about 9 years. The MSFCMA states that the time period to rebuild overfished stocks

shall not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or international agreements dictate otherwise. Although it appears theoretically possible to recover the red grouper stock within 10 years, the RFSAP felt it was impractical to assume that fishing mortality could be reduced to zero, given the mixed-species nature of the fisheries for groupers and their high release mortality from some fishing gears. Consequently, the RFSAP recommends a rebuilding schedule for red grouper consistent with the policy allowing recovery time at $F=0$ plus 1 generation time, resulting in a target date for stock restoration of 2018. Recommendations for acceptable catch are therefore presented for a constant F strategy under the extended recovery date of 2018, and for the constant catch strategy for both the short (10 year) and extended recovery dates.

The RFSAP strongly recommends that the Council adopt a constant F fishing strategy for red grouper at this time, indicating an ABC range of 0 to 1.5 million pounds in 2000. Additionally, the yield stream under constant F indicates an ABC range of 0 to 1.9 million pounds in 2001. Further changes in the upper limit of ABC under constant F are provided in Table 5. While a constant F strategy requires a more drastic reduction in catches in the near term than a constant catch strategy, catches in the future will increase commensurate with increases in available biomass.

The assessment indicates that stock recovery to B_{MSY} can be achieved under a constant catch fishing strategy with an ABC range of 0 to 1.5 million pounds for the 10-year (2000-2009) recovery period, or 0 to 3.5 million pounds for the extended (2000-2018) recovery period. Under the constant F strategy, an ABC range of 0 to 3.5 is achievable in 2005, and higher ABC would be available from that point forward through the recovery period. The complete 18-year projected yield stream is in Table 5.

FUTURE RESEARCH: RED SNAPPER AND RED GROUPE

The RFSAP suggests additional research be performed in the following areas to help increase the accuracy and precision of future stock assessments.

Red Snapper

1. Construction of an index time series of abundances based on older individuals to monitor stock rebuilding. Ideally, this index could be generated from fishery-independent estimation of age-structure of the population;
2. Reconstruction of historical landings to better estimate the steepness and maximum recruitment

- parameters of the spawner-recruit function under conditions of moderate to higher stock biomass;
3. Investigation into the mechanisms that underlie the very high value of the steepness parameter that available data indicate is appropriate for red snapper;
 4. Continuation of the ageing work, with additional effort devoted to aging of archived, historical samples.

Red Grouper

1. Obtaining information on the effects of fishing during the spawning season, and the identification of areas of abundance that might be used for special areal management. Identification of primary habitat associations for both juvenile and adult red grouper is needed for effective management;
2. Additional measurements of fecundity and age-at-maturity. Also, data collection in general should be based on random age sampling of the fishery;
3. Measurements of discards and effects of discard mortality. Observers on fishing vessels may be the best method to obtain this information. At minimum, development of a methodology to incorporate self-reporting of catch and disposition of catch into assessment information base. The use of VMS in the directed fishery could provide the useful information on the spatial distribution of effort on fine scales;
4. Examination of potential methods for developing a fishery-independent index of abundance for adults (e.g. trap video systems, ROVs, etc.);
5. Evaluation of the effect of density-dependent compensation related to the protogynous life history strategy on population dynamics, including how to realistically include such compensation in assessment models.

General

1. Evaluation of methods to identify appropriate steepness values for species based on their life history strategy; such an evaluation could also include the examination of the utility of and model sensitivity to other spawner-recruit functions;
2. Development of a multispecies assessment framework for the Gulf of Mexico reef fish complex. Available methodologies, data requirements, and data availability should be examined. A multispecies framework could result in improved overall management and avoid the need for individual species assessments for the "hot" species.;
3. Effort put into reconstruction of the historical catch history of the Gulf of Mexico reef fish fishery.

Data Review Requests for the Possibility of Future Stock Assessments

The following species in the Reef Fish FMP should be given consideration for a future stock assessment.

1. Deepwater groupers, with a concentration on yellowedge grouper, if data is available;
2. Scamp (also examining yellowmouth mis-identification);
3. Yellowtail snapper;
4. Gray triggerfish;
5. Vermilion snapper;
6. Gray snapper;
7. Red porgy - The RFSAP recommends that this stock be examined as being appropriate for inclusion in the Reef Fish FMP, and that a stock assessment be developed.

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Table 5. Red grouper constant F time stream based on long time series data-set for SPR at MSY in year 2018 goal.

B_{MSY} in 2018 - Projection of $F = 0.2275$

$F/F_{MSY} = 0.829$

Year	Yield	Cumulative Yield	SS/SS _{MSY}
2000	1.525	1.525	0.250
2001	1.941	3.466	0.310
2002	2.368	5.834	0.370
2003	2.784	8.618	0.425
2004	3.168	11.785	0.476
2005	3.517	15.303	0.522
2006	3.849	19.151	0.567
2007	4.172	23.324	0.611
2008	4.497	27.820	0.656
2009	4.819	32.639	0.701
2010	5.136	37.775	0.745
2011	5.445	43.220	0.787
2012	5.745	48.965	0.827
2013	6.027	54.992	0.863
2014	6.286	61.278	0.897
2015	6.521	67.799	0.927
2016	6.733	74.532	0.955
2017	6.924	81.455	0.979
2018	7.095	88.550	1.001

B_{MSY} in 2010 - Projection of $F = 0.1069$

Year	Yield	Cumulative Yield
2000	0.737	0.737
2001	0.987	1.724
2002	1.264	2.988
2003	1.553	4.541
2004	1.840	6.381
2005	2.119	8.500
2006	2.395	10.895
2007	2.670	13.565
2008	2.949	16.514
2009	3.227	19.741
2010	3.505	23.246

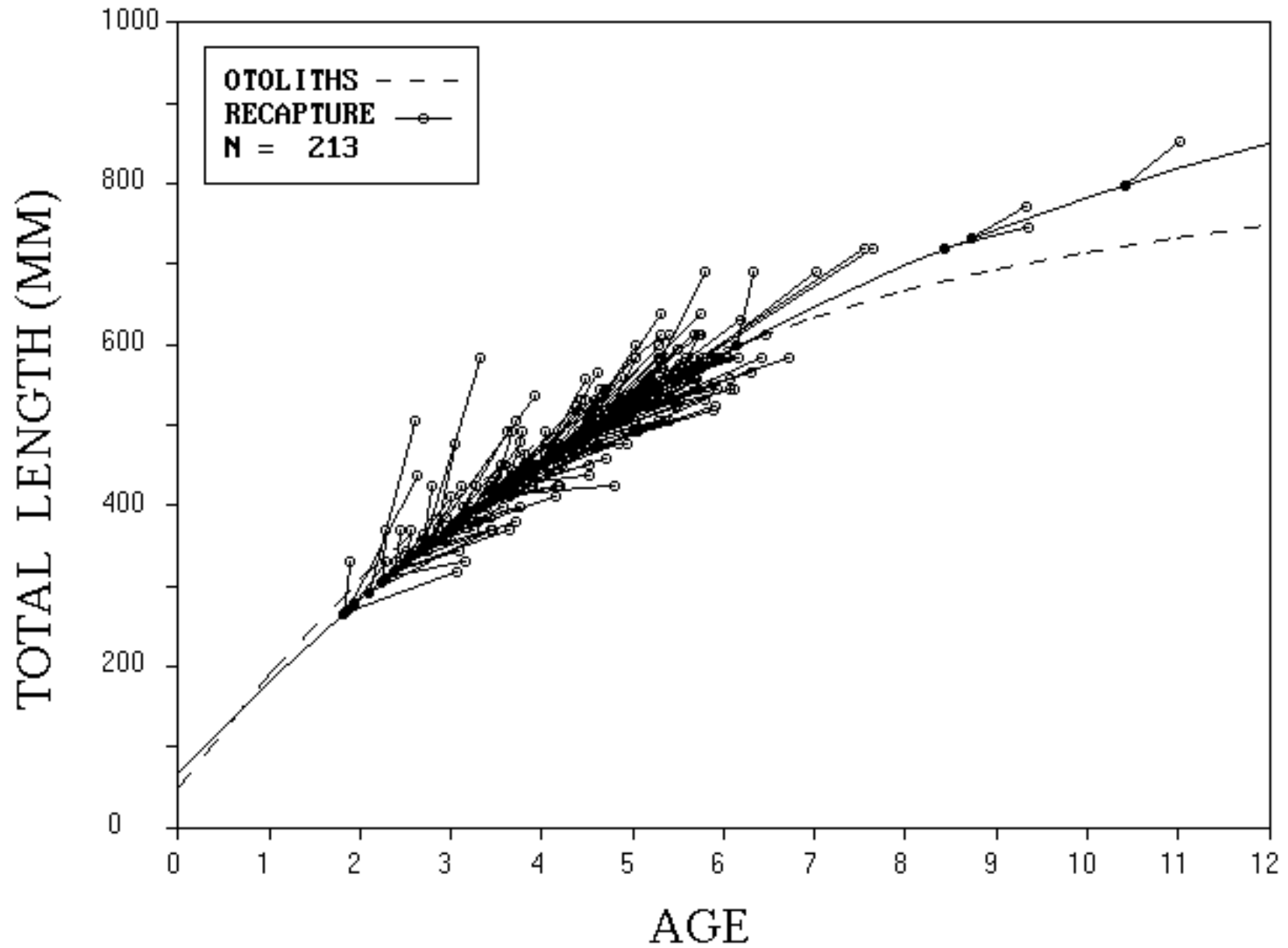


Figure 4 (Figure 16 in Schirripa et al. 1999). Estimated growth curve from otoliths and tag-recapture data for red grouper.

ESTIMATED TOTAL LANDINGS - FL WEST COAST

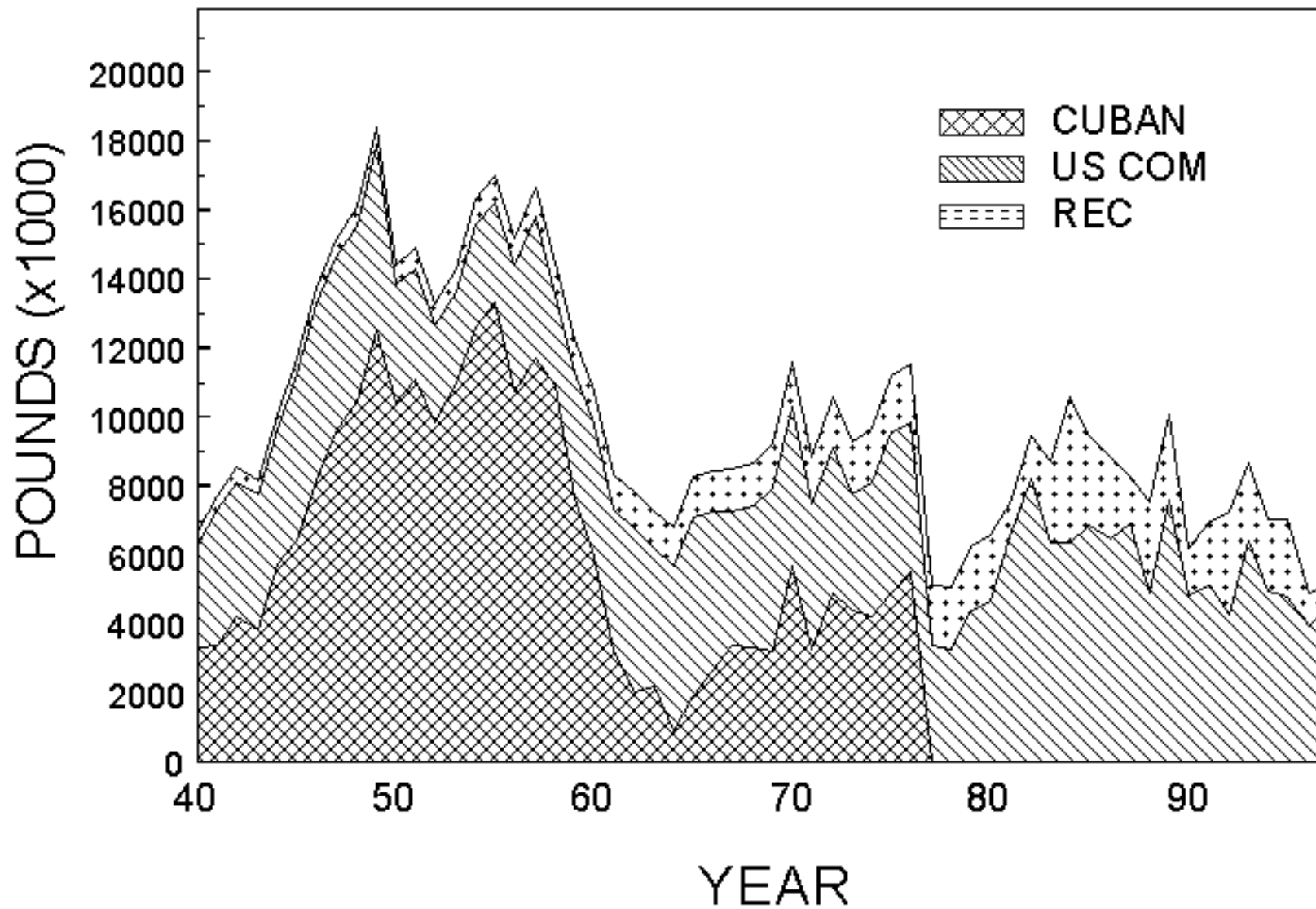


Figure 5 (Figure 33 in Schirripa et al. 1999). Estimated total landings of red grouper from Florida west coast, 1940-1997.

INTRODUCTION

At the direction of the Gulf of Mexico Fishery Management Council (Council), the Reef Fish Stock Assessment Panel (Panel) met in Miami on December 4 to 7, 2000 to: 1) re-evaluate the 1999 red grouper stock assessment and several additional analyses conducted by NMFS at the request of the Panel; 2) recommend a range of allowable biological catch (ABC) for red grouper; and 3) evaluate the proposed red snapper rebuilding plan based on five-year management intervals, along with additional scientific information presented by outside biologists. This report also includes the Panel's discussion and recommendations on the following items from the August 28 to September 1, 2000 meeting that were not included in the September 2000 Panel report (RFSAP 2000): 1) NMFS responses to questions raised by the Standing and Special Reef Fish Scientific and Statistical Panel regarding various aspects of the red grouper stock assessment; 2) review the 2000 greater amberjack stock assessment (Turner et al. 2000, with supporting documents from Cummings 2000, Cummings and McClellan 2000, Turner 2000a and Turner 2000b) and, 3) a method to reorganize the grouper complex management units based on biological and management reference points. The Council charged the Panel with evaluating the analyses presented and providing guidance to the Council as to whether the biological analyses presented were the best available scientific information.

RE-EVALUATION OF RED GROUPEL STOCK ASSESSMENT

The Panel initially evaluated the 1999 red grouper stock assessment (Schirripa et al. 1999) in September 1999 (RFSAP 1999). However, the Standing and Special Reef Fish Scientific and Statistical Committee (SSC) subsequently questioned several portions of the assessment and Panel report, including questions related to the validity of the long-term Cuban data upon which the Panel ABC recommendations were based. The Panel met in August 2000 and reviewed updated landings, the SSC report, the NMFS response to the SSC report, and an independent review of the red grouper assessment by Dr. Patrick J. Sullivan, Cornell University (Sullivan 1999). In addition, the Panel heard a presentation by Dr. Trevor Kenchington and comments from participants in the grouper fishery who attended the meeting.

The Panel's discussion focused on the data, methods, and assumption used in the 1999 stock assessment. Based on information in Wilson and Burns (1996) and data collected during the 1994 NMFS bycatch observer study (NMFS 1995) which was provided to the Panel by the NMFS Galveston laboratory, a release mortality rate of 33 percent was used for the new analyses. Rather than using release mortality rates specific to handlines (33 percent) and longlines (90 percent), as done in the original assessment, the Panel decided to use the handline value of 33 percent for both gears.

The Panel was concerned that the discard rates predicted in the assessment appeared greater than suggested by the limited observer data available. A discard rate of 30 percent was deemed to be reasonable and near the low end of the likely range. This conclusion was based on the size distribution of red grouper catches by depth (TIP data) prior to the 1990 implementation of a 20-inch minimum size limit and the 1994 observer data. In addition, the panel discussed the validity of treating the Cuban time series as a single time series versus two independent time series due to the change in political regimes and retooling of the fishing fleet.

The Panel requested four model simulations to assess sensitivity of the assessment to discard rate and release mortality and to assess the effect of splitting the Cuban long time series of landings. For the spawner-recruit relationship, a steepness of 0.7 was used in the short time series simulations to match the estimated steepness in the long time series. The specific analyses requested were:

- (1) A-1: Break the long time series into two independent time series (1940-57 and 1963-76) due to political upheaval in Cuba and resulting changes in the fishing fleet (steepness estimated by the model);
- (2) A-2: Set the release mortality of longlines to the 33% values used for handlines, use a discard rate of 30% for the longlines, use the short-time series data (1986 to present) and a steepness value of 0.7 to match the steepness used by the long time series;
- (3) A-3: Set the release mortality of longlines to the 33% values used for handlines, use a discard rate of 30% for the longlines, use the long-time series data and let the model estimate steepness;

- (4) A-4: Combine (A-1) and (A-3) into one analyses.

The Panel met in December 2000 to review the results of the requested analyses. In addition to the analyses requested, NMFS had conducted three additional analyses (These were essentially repeats of runs A2, A-3, and A-4, but with the discard rates set at the estimate4d values from the original assessment):

- (1) B-1: Set the release mortality of longlines to the 33% values used for handlines but maintain the discard rate used in the original 1999 assessment, use the short-time series data and a steepness value of 0.7 to match the steepness used by the long time series;
- (2) B-2: Set the release mortality of longlines to the 33% values used for handlines but maintain the discard rate used in the original 1999 assessment, use the long-time series data and let the model estimate steepness;
- (3) B-3: Break the long time series into two independent time series (1940-57 and 1963-76), set the release mortality of longlines to the 33% values used for handlines but maintain the discard rate used in the original 1999 assessment, (steepness estimated by the model).

The Panel also heard a presentation by Dr. Trevor Kenchington (Gadus Associates) regarding the Cuban grouper catch data collected prior to 1963 and received three publications dealing with the historical Cuban database (Fiedler et al. 1947, Martinez 1948, and Suarez Caabro 1957). The Panel again discussed the Cuban data at length.

All of these model runs showed the stock to be overfished and that overfishing was occurring, except for A-4, which showed that the stock was overfished but that overfishing may not be occurring. However, in both this model run and the A-1 model run, the steepness was estimated by the model to be 1.0, a highly unrealistic steepness value. Based on these analyses additional analyses and the ensuing discussion, NMFS repeated these runs using a fixed steepness of 0.68:

- (1) C-1: Split Cuban time series, steepness of 0.68;
- (2) C-2: Modified release mortality and discard rate, steepness of 0.68.

Both of these additional runs showed that the stock was overfished and overfishing was occurring. However, the Panel was still unsatisfied with the method used to estimate discard rates. The method of discard estimation used in the original assessment and some of the subsequent analyses appeared to result in discard rates that were higher than those estimated in the NMFS 1994 bycatch characterization study (NMFS 1995). Recent observations by fishermen present at the Panel meeting also suggested lower discard rates and were considered by the Panel. However, the Panel felt that assigning a constant discard rate of 30% was overly simplistic and did not adequately account for variations in year class strength. The Panel requested additional analyses using both the original (probabilistic) method for estimating

discards, and the original method tuned so that the predicted discard rate in 1994 matched the observed discard rate from the 1994 observer program (NMFS 1995). These runs all used a 33 % release mortality rate for the commercial fishery, the short time series (from 1986), and fixed spawner-recruit steepness values of 0.6, 0.7, and 0.8. These analyses also included updated harvest estimates for 1998 and 1999:

- (1) D-1: original discard rate, 33% release mortality rate, and short time series (analyses repeated for fixed steepnesses of 0.6, 0.7, and 0.8);
- (2) D-2: Use the tuned discard rate, 33% release mortality rate, and short time series (analyses repeated for fixed steepnesses of 0.6, 0.7, and 0.8).

These model runs also showed that the stock was overfished and that overfishing was occurring. After a review of these analyses, the Panel requested one final analysis that included the tuned discard method and Cuban and U.S. landings from 1963 onward (E-1). The purpose of this analysis was to attempt to estimate steepness using data based on a truncated version of the long-term data. The surplus production model (ASPIC) was also applied to the truncated long-term time-series. The Panel felt that the results of these analyses failed to provide resolution to the question of a specific steepness value, although the management implications of the results were consistent with the D series runs.

The Panel judged that the tuned discard runs with steepness values of 0.7 and 0.8 (D-2 and D-3) provided the best scientific advice and that this range of steepness values was most consistent with values reported for other stocks.

Based upon these analyses, t_{\min} (recovery time in the absence of fishing mortality) was estimated to be 2 to 4 years. Thus, the allowable rebuilding period is not to exceed ten years.

STOCK STATUS AND ABC RECOMMENDATION

The Panel concurs with the NMFS determination that, based on a minimum stock size threshold (MSST) set to 80 percent of B_{msy} , the red grouper stock is overfished. Furthermore, the stock is undergoing overfishing, based on the fishing mortality rate exceeding F_{msy} .

The following ABCs are based on a ten-year rebuilding plan. The rebuilding plan begins in year 2000 because catch data were only available through 1999. **Under a constant catch strategy starting in the year 2000, the maximum ABC is 4.3 to 5.2 million pounds. For a constant F strategy starting in the year 2000, ABC would be 3.0 to 4.2 million pounds in 2000, and 3.3 to 4.4 in 2001.** The complete yield stream (through 2009) is in Table 2. Estimates of MSY, B_{msy} , MSST, and MFMT are in Table 3.

If actual catches in the year 2000 exceed the ABC ranges indicated above, then reduced ABCs may be needed in future years to rebuild to target levels within ten years.

Table 1. Red Grouper ASAP Analyses Permutations

Analyses category		Years Used in Analyses	LL Release mortality	LL Discard rate	S-R Steepness
Original analyses	O1	U.S. short data	90%	probabilistic method	0.4, 0.5, 0.6, 0.7, 0.8 (fixed)
	O2	U.S. long data All Cuban data	90%	probabilistic method	0.68 (est.)
RFSAP Requested Additional Analyses	A-1	U.S. long data Split Cuban data	90%	probabilistic method	1.0 (est.)
	A-2	U.S. short data	33%	30%	0.7 (fixed)
	A-3	U.S. long data All Cuban data	33%	30%	0.6 (est.)
	A-4	U.S. long data Split Cuban data	33%	30%	1.0 (est.)
Additional Analyses 2	B-1	U.S. short data	33%	probabilistic method	0.7 (fixed)
	B-2	U.S. long data All Cuban data	33%	probabilistic method	?? (est.)
	B-3	U.S. long data Split Cuban data	33%	probabilistic method	1.0 (est.)
Additional Analyses 3	C-1	U.S. long data Split Cuban data	90%	probabilistic method	0.68 (fixed)
	C-2	U.S. long data Split Cuban data	33%	30%	0.68 (fixed)
Additional Analyses 4	D-1	U.S. short data plus 98/99 harvest update	33%	probabilistic method	0.6, 0.7, 0.8 (fixed)
	D-2	U.S. short data plus 98/99 harvest update	33%	tuned to 1994	0.6, 0.7, 0.8 (fixed)
Additional Analyses 5	E-1	1963-97 U.S. data plus 98/99 harvest update Cuban data 1963-76	33%	tuned to 1994	0.6, 0.7, 0.8 (fixed)

Note: This table shows the relevant differences between each analyses. It is not intended to be a full description of each analysis.

U.S. short data = 1986-1997 (years when commercial grouper landings were separated by species)

U.S. long data = 1940-1997 (pre-1986 red grouper landings were estimated as a proportion of total commercial grouper landings, landings for 1941-1944 were missing and were estimated as the average of the 1940 and 1945 landings)

All Cuban data = 1940-1976

Split Cuban data = 1940-1957 and 1963-1976 treated separately for CPUE tuning, 1958-1962 excluded from tuning

Table 2. Red Grouper ABC Constant Catch and Constant F Yield Streams for a 10-Year Recovery, 2000-2009. Catch is in millions of pounds.

	S-R steepness = 0.7 (lower ABC)	S-R steepness = 0.8 (upper ABC)
Constant Catch		
	4.288	5.241
Constant F		
Year	S-R steepness = 0.7 (lower ABC)	S-R steepness = 0.8 (upper ABC)
2000	3.031	4.235
2001	3.320	4.441
2002	3.636	4.694
2003	3.967	4.976
2004	4.279	5.247
2005	4.561	5.488
2006	4.814	5.693
2007	5.043	5.863
2008	5.250	6.003
2009	5.437	6.117

Model parameters:

- tuned discard rate using data from 1994 bycatch observer program (NMFS 1995)
- 33 percent release mortality rate for all commercial fishing gear
- inclusion of updated harvest estimates for 1998 and 1999
- inclusion of U.S. catch data only (short time series)

Table 3. Red grouper biological characteristics

	S-R steepness = 0.7	S-R steepness = 0.8	Comments
MSY	7.012	6.705	million pounds
F _{current}	0.302	0.302	
F _{MSY}	0.223	0.270	
F _{current} /F _{MSY}	1.356	1.117	values greater than 1 indicate that overfishing is occurring
SS ₉₇	244.3	246.3	SS = million grams female gonad weight (used as a proxy for stock biomass)
SS _{MSY}	433.2	350.7	
SS ₉₇ /SS _{MSY}	0.564	0.702	values less than 0.8 indicate that stock biomass is below the MSST in the NMFS recommended default control rule (Restrepo et al. 1998)
T _{min}	2004	2002	year in which rebuilding to MSY level would occur if F=0 starting in 2000.

Model parameters:

- tuned discard rate using data from 1994 bycatch observer program (NMFS 1995)
- 33 percent release mortality rate for all commercial fishing gear
- inclusion of updated harvest estimates for 1998 and 1999
- inclusion of U.S. catch data only (short time series)

RED GROUPER STOCK ASSESSMENT

Review of the Fishery

The first records of grouper landings of the west coast of Florida from the United States fleet date back to 1880. Annual records are sporadic from 1880 to 1927, but increase in consistency from 1927 to 1950. In 1850, Cuban sailing vessels known as “viveros” began fishing off Florida. Groupers and other reef fishes were caught using handlines with the catch being brought back to Havana. During this same time it is documented that the U.S. red snapper/grouper fishing fleet operated in the eastern Gulf of Mexico. This fleet was made up of sail powered vessels that, like the Cuban vessels, were equipped with a live well. In the mid 1940's the Cuban fleet, known as the “Flota del Alto”(Deep Water Fishing Fleet) converted to “neveros”, which are vessels capable of icing their catch. Also, 1940 is the first year that catch and effort estimates for the Cuban fleet were available. Starting in 1950 consistent records of Florida west coast grouper landings and gear- specific operating units for the U.S. commercial fleet were kept. In 1955 the Cuban fleet consisted of a total of 68 vessels, 6 of which were sail powered and 62 of which had both motor and sail. Handline gear was still being used and red grouper made up approximately 90% of the total catch. The Cuban Gulf Fleet size increased from 65 vessels in 1963 to about 140 vessels in 1967; in 1967 there were 267 U.S. operating units. Although the traditional handline was the gear of choice for both fleets, bottom longline came into general use by the Cuban fleet about 1965 and remained their principle fishing gear. Estimated total landings of red grouper from the west coast of Florida for both the U.S. and Cuban fleets peaked at approximately 16 million pounds in the mid 1950s, but declined rapidly until 1965. After this year, perhaps due to the Cuban's fleet deployment of bottom longline gear, the landings increased again until 1976, when the Cuban fleet was expelled from U.S. waters.

Present day Gulf of Mexico red grouper harvested by U.S. fishers are primarily caught in the eastern Gulf from Panama City, Florida, to the Florida Keys. The greatest part of the present commercial and recreational harvest is from Tampa southward and about half of the commercial harvest is landed in the Tampa - St. Petersburg area. Commercial landings of red grouper have been separated from other groupers only since 1986. Before 1986 they were included in landings statistics along with other grouper species as “unclassified groupers”.

Prior to the introduction of bottom longline gear to the U.S. commercial fleet in the early 1980s, landings of all groupers exhibited a slow decline from about 7.5 million pounds (gutted weight) in 1962 to about 5 million pounds in the late 1970s. Handlines, and power-assisted (electric or hydraulic) reels accounted for almost all the landings during this period. With the expansion of bottom longline gear in the early 1980s, total grouper landings increased sharply to about 12.5 million pounds in 1982. This is the predominant gear employed for red grouper harvest to date. Traps increased in importance in the mid 1980s but contribute only a small proportion to the total grouper catch.

Red grouper accounted for nearly two-thirds of the total commercial grouper catch since 1986 and contributed about 7 1/2 million pounds in 1989. If the proportion of red grouper in the total grouper catch was the same before species were separated in the landings, then the maximum U.S. commercial harvest for this species was about 8 1/2 million pounds in 1982 while the total landed yield likely exceeded approximately 16 million pounds in the 1950s. Estimates of the recreational harvest of red grouper are highly variable but averaged about 2.6 million pounds (ca. 700,000 fish) from 1982-1989, or about 29% of the total harvest by weight.

Florida enacted an 18-inch (total length) minimum size for groupers in July 1985, a

recreational bag-limit of 5 fish/day in December 1986, and a 20-inch minimum size limit in February 1990. In April 1990 the Gulf of Mexico Fisheries Management Council (GMFMC) established three conservation measures for groupers in Federal waters. These measures included a 20-inch minimum size, a 5-fish/day recreational bag-limit, and a 9.2-million pound (total weight) commercial quota for the shallow water groupers (which include red grouper) occurring in the waters of the Gulf of Mexico under GMFMC jurisdiction.

Red grouper landings by commercial fishermen increased slightly in 1986 after the 18-inch minimum size went into effect. Length frequencies of red grouper sampled from the commercial harvest provide little evidence that Florida's minimum size had any significant conservation effect on the commercial harvest. Commercial landings showed a gradual decline until 1997 following a peak in 1992, although catches in 1998-2001 have rebounded to levels similar to those landed prior to 1992 (Table 1).

Available data suggest an initial decline in the recreational harvest of red grouper from Florida state territorial seas after the 18-inch minimum size was established in Florida, however the total recreational harvest was little affected by this regulation with the bulk of the remaining recreational harvest of red grouper consisting of fish harvested from the EEZ. Most of these were less than 18 inches in length.

The regulations that became effective in 1990 (20-inch minimum size, 5-fish/day bag limit, and 9.2 million pound commercial quota), at least in part, accounted for a 70% decline in the recreational harvest by number and a 41% decline by weight from the average of the two preceding years. Commercial harvest declined by 21% in 1990 from the two prior years. However, the decline could have been less than 15% if the fishery had not been closed before the quota had been reached. The effect of the 1990 minimum size is clearly evident in the length-frequency samples from all sectors of the fishery.

Previous Assessments

This is the fourth stock assessment completed for red grouper. The first stock assessment was completed by Goodyear and Schirripa (1991), which was followed by Goodyear and Schirripa (1993). A more extensive (with data from 1950 and later rather than 1986 and later) stock assessment for red grouper was completed by Schirripa et al. (Assessment 3.0) (1999).

Current Assessment

The NMFS assessment scientists noted that the present assessment (SEFSC 2002) was produced based on recommendations from the December 2000 report of the Reef Fish Stock Assessment Panel.

The Panel applauds the efforts of the NMFS assessment team to attempt to duplicate the procedures of the prior assessment (Schirripa et al. 1999; Assessment 3.0) along with new assessment methodologies incorporating new age and fecundity information. This allowed the presentation of new information, while maintaining a level of comparison to prior assessments. This allowed the Panel to see which changes were due to analysis procedures and which changes were due to new information.

Natural Mortality

The natural mortality rate (M) of red grouper has never been estimated directly. It is assumed here to be 0.2 yr^{-1} , as was done in the previous assessment.

Estimation of Yield, Harvest and Catch

Catch is generally used to refer to the number of fish caught and often includes live releases. Harvest is used to refer to the number of fish killed in the fishing process and may include fish landed, discarded dead at sea and fish used for bait; this is particularly used for the AB1 estimates from MRFSS (Marine Recreational Fisheries Statistics Survey, A=observed kill, B1=unobserved kill). Yield is used to refer to landings in pounds for the commercial fishery and the headboat fishery; it is also used to refer to weight of the harvest (MRFSS). Values used in the 2002 assessment are summarized in Table 1.

Commercial Yield: Commercial yields were tabulated from the Accumulated Landings System (ALS) database maintained at the Southeast Fisheries Science Center (SEFSC). The system consists of subsets with different degrees of resolution. The primary database consists of dealer reports of landed yield by year, month and species; for some states that information also includes gear and fishing area (water body), but not for Florida in 1986-1996 nor Louisiana and Texas since the early 1990's. Information on grouper landings by species is available only from 1986 and later; prior to that time only unclassified groupers were recorded; since 1986 unclassified grouper have been recorded, but the quantity has declined substantially. A portion of the unclassified groupers were assumed to be red grouper; that proportion was calculated by dividing the west Florida landing of red grouper by the west Florida landings of all identified groupers (excluding goliath and warsaw groupers) as did Schirripa *et al.* (1999). All reported commercial landings of red grouper from west Florida through Texas were tabulated by year as done in the previous assessment. Landings recorded from Florida inland counties were not included.

Estimates of Harvest: Yield for each of two commercial gear categories was used in the assessment to create derived age composition. The two commercial gear categories were (1) longline and (2) handline combined with other gears. For 1986 through 1989, the annual proportion of the total commercial landings by longline was assumed from Schirripa *et al.* (1999). For 1990-2001, the annual proportions of total commercial landings by gear category were calculated from reef fish logbooks. The 1990-1997 commercial landings proportions by gear category used in this assessment were moderately different from the proportions used in the 1999 assessment due to improvements in the way catch and effort levels are being extracted and interpreted from the reef fish logbooks (see below).

Recreational Catch and Yield: Recreational catches (harvests and releases) were tabulated from the MRFSS, the SEFSC Headboat Survey and the Texas Parks and Wildlife (TPWD) data sets. MRFSS data was available through 2001, headboat catch estimates were available through 1999 and TPWD estimates were available through 2000. For MRFSS both harvests (A+B1) and live releases (B2) were tabulated; estimated weight of the harvest was calculated from mean weights derived from observed weights and weights predicted from lengths if weight was not recorded. For the headboat data the numbers of fish landed and the associated yields were tabulated from the Headboat Survey estimates. For the headboat survey the average catch and yield from 1995-1999 was used to estimate the 2000 and 2001 values. Red grouper were not recorded in the TPWD data set during 1986-2000, though small numbers were recorded as landed in the headboat survey. Discard mortality rates were determined as was done by Schirripa *et al.* (1999).

Indices of Abundance

Several indices of abundance were developed based on observations of catch-per-unit-effort (CPUE) and limited fishery-independent surveys. The data were standardized using essentially the same methods as used by Schirripa et al. (1999).

Commercial Operating Units: Schirripa et al. (1999) developed a CPUE index based on estimates of the U.S. fleet effort derived from the total landings and the NMFS operating units file. Due to time limitations, no attempt was made to update this index to 2001 because the recent time period is amply covered by the logbook indices discussed below.

Reeffish Logbooks: Data available from the Reefish Logbook Program were used to develop standardized CPUE series for commercial fish traps, handlines and bottom longlines from August 1990 to December 2001. The Reefish Logbook Program was initiated in 1990. At that time, the program required all vessels holding reefish permits in Alabama, Mississippi, Louisiana and Texas, as well as all trap fishermen in Florida, to report each fishing trip made. For other Florida permitted vessels, only a randomly selected sub-sample (20%) was required to report until 1993, when mandatory reporting for all Florida vessels began. Only landings (in pounds) were recorded; releases and discards were not. Thus, these CPUE series are really harvest per unit effort (HPUE) measures and are affected to varying degrees by size regulations.

The standardization procedures were intended as an update to the analyses conducted for the 1999 assessment and therefore followed the methods detailed in Schirripa et al. (1999). Only trips landing red grouper were used. Catch was defined as total pounds landed in whole weight. Effort was defined as hook*hours for handline and days-at-sea for bottom longline and trap gears (the description by Schirripa et al. 1999 mistakenly indicates otherwise). Standardized indices were developed using generalized log-linear models where catch rates were modeled as a function of the factors YEAR, MONTH, and GRID (fishing area). (Apparently much of the data were inadvertently excluded during the trap CPUE analysis conducted for the 1999 assessment. This has been corrected for the current, updated assessment).

MRFSS Recreational: The catches of recreational vessels fishing in the Gulf of Mexico and Atlantic Ocean are monitored by the National Marine Fisheries Service's Marine Recreational Fisheries Statistical Survey (MRFSS). Anglers intercepted at fishing access sites are interviewed to determine, among other things, the number of each species that were landed and observed by a sampler (type A), the number of fish killed not seen by a sampler (B1, including dead discards) and the number released alive (B2). They are also asked the number of hours they spent fishing. Thus, it is possible to construct catch per unit effort (CPUE) indices of abundance by dividing the total catch (A+B1+B2) by the number of angler-hours (number of anglers in the party times the number of hours fished). One may also compute harvest per unit effort (HPUE), using the type A and B1 catches, but this measure is directly affected by size and bag limit regulations.

A GLM standardization procedure was adopted following the methods used for the previous assessment, where the CPUE of private vessels was expressed as a linear function of the factors YEAR COUNTY (the description given by Schirripa et al. (1999) mistakenly asserts that both private and charter vessels were used and attributed significant effects to year, month, area and mode).

Fishery Independent: Fishery independent trap and video surveys were conducted as part of the

Southeast Area Monitoring Program (SEAMAP) during the months of June, July and August from 1992-1997 (data courtesy of C. T. Gledhill, NMFS, Pascagoula Laboratory). An abbreviated video survey was conducted in 2001, and a complete survey in 2002; however the data are still being quality assured. The trap survey was not continued in 2001 or 2002 and therefore was not updated. Accordingly, no updates were possible and the indices from the 1999 assessment were retained.

Tag-recapture Index: Estimates of the loss rate of red grouper tagged by the Mote Tagging program were derived using the methods discussed in Legault et al. (1999). As was done in the previous assessment, these estimates were converted to a relative abundance index by solving the catch equation for numbers of fish (where the catches were the MRFSS estimates of the number of fish released alive and the natural mortality rate was assumed to be 0.2 yr^{-1}). This conversion approach makes the implicit assumptions that tag shedding is negligible and that the tagged fish mix randomly with the untagged population, neither of which appear to be true of red grouper. However, the relative abundance index was found to be relatively insensitive to the assumed levels of tag-shedding and incomplete mixing. No doubt the relative index would be more sensitive to systematic changes in the level of mixing or tag shedding, but this is akin to asserting that CPUE indices are sensitive to systematic changes in factors not included in the standardization process. Accordingly, while further investigation is warranted, we can offer little basis for rejecting the tag-recapture index over some of the other CPUE indices used in this assessment. (In principle, a more appropriate use of the loss rate estimates would be to treat them as an index of relative mortality rate in the manner of Porch 2002, but there was insufficient time to incorporate this approach into the ASAP model for this assessment.)

Age and Growth Determination and Age Composition of the Catch

For this assessment, new data found in Lombardi-Carlson et al. (2002) on catch-at-age and growth rate, based upon their 1992-2001 red grouper ageing analyses, were available. Although their sampling levels differed among sectors (commercial and recreational) and among commercial gears (almost 80% of their sample came from longlines from NW Florida), the Panel felt this to be an improvement over the age-slicing technique used in the previous assessment by Schirripa et al. (1999) (based upon Goodyear 1994). As such, the length-at-age function produced by using data from Lombardi-Carlson et al. (2002) was compared to the equation used in the Schirripa et al. (1999) assessment and found to be similar within the range of ages for which observations existed (Figure 1 = Assessment figure 2), but to diverge outside of the range, particularly for younger ages. The Panel considers the new catch-at-age information to be the best available data and thus the new data on catch-at-age were incorporated into assessments runs from which management advice was proffered.

Age Composition: Two types of age composition information were used. The first, referred to as derived age composition, was calculated primarily from the observed length samples by use of the probabilistic method of Goodyear (1997). Derived age composition was the only type of age composition used in the previous 1999 assessment. The second type of age composition used in the assessment was based on ages read from otoliths (Lombardi-Carlson et al. 2002) and will be referred to as sampled age composition.

When the sampled age composition was included in the assessment, it was weighted by the distribution of the catch for each of the three fishery categories included in the assessment

(longline, handline plus other commercial gears, and recreational) with geographic (northwest FL, central west FL and southwest FL) and gear/mode strata. For longline there were three geographic strata; for handline and other gears there were six strata (three geographic and two gears: handline and trap), and for recreational there were three strata (headboat, charter and private: geographic stratification could not be used because MRFSS estimates were for the entire west Florida).

New Fecundity Data and Assessment Model Selection

Collins et al. (2002) have recently analyzed over 2,000 red grouper gonads sampled from the eastern Gulf of Mexico during 1992 and 2001, and also provided age-specific data on sex ratio and an estimate of the proportion of the female population that is actively spawning. They expressed batch fecundity (BF) as an exponential function of total length and as a function of age. In so much as the assessment requires fecundity-at-age, the batch fecundity-at-length curve must be converted to batch fecundity-at-age by use (FECvsTL) of the growth equation. The base runs in the 2002 Assessment used this new relationship (fecundity as a function of age converted from length), as well as the original function derived by Schirripa et al. (1999) for comparison. For statistical reasons, one would prefer a curve fit directly to age over the use of an imprecise growth equation to convert a curve fit to length.

The previous assessment (Schirripa et al. 1999) did not have access to the new data on fecundity reported by Collins et al. (2002) and therefore used the product of gonad weight and the proportion of each age class that was females as a proxy for per capita fecundity. Gonad weight was expressed as a power function of total length (GWTvsTL), which was converted to a function of age via the old growth equation.

While the gonad weight-by-length curve (GWTvsTL) used by Schirripa et al. (1999) and the fecundity-by-length relationship (FECvsTL) reported by Collins et al. (2002) are quite similar, both differ from the fecundity-by-age curve developed by Collins et al. (FECvsAGE). The Panel recognized that the shape of the Collins et al. fecundity-by-age relationship appeared to be driven by one observation for a 20 year old female (Figure 2=Assessment Figure 3). It should be noted, however, that the assessment model outcomes were very sensitive to the form of the fecundity-at-age vector. As such, there was much discussion among Panel members about the appropriate use of the new reproductive information.

Accordingly, the Panel requested two additional sets of runs patterned after the 'base' model run described in the 2002 Assessment but using either the new batch fecundity-at-age relationship reported by Collins et al. (2002) (FECvsAGE) discussed earlier, or a new gonad weight-at-age relationship (GWTvsAGE) derived at the Panel meeting from age-specific gonad weight data from about 300 red grouper, provided by Allan Collins and Gary Fitzhugh at the meeting (for details see Figure 3=Porch Addendum A1 and Figure 4=Porch Addendum Figure A2, Table 2=Porch Addendum Table A1). In these runs, the release mortality for the longline fleet was assumed to be 33% and steepness was assumed to be either 0.7 or 0.8 (the Panel continues to believe that while there is uncertainty in the steepness values, a value of 0.7 is more realistic than 0.8).

The stock-status estimates obtained under the two alternative reproductive scenarios are compared to those of the original 'base' run in Figure 5 (=Porch Addendum Figure A3) and Table 3(=Porch Addendum Table A2). The base run, which used the FECvsTL vector, gave the most optimistic picture of stock status (not overfished and no overfishing regardless of steepness). The runs using the GWTvsAGE and FECvsAGE vectors were somewhat less

optimistic, suggesting the stock was not overfished, but that overfishing was occurring (with steepness values of 0.7 or less). This result was somewhat unexpected in as much as the FECvsAGE vector ascribes relatively more productivity to age 15 and older animals than either of the other alternative fecundity vectors (Figure 6 = 2002 Assessment Figure 5), and it is the older animals which are estimated to have declined the most. However, even under virgin conditions only a small proportion of fish survive beyond age 15 where this divergence in relative fecundity estimates occurs, hence these older age groups contribute little to the overall fecundity of the stock (Figure 7= Porch Addendum Figure A4). Instead, the assessment is most sensitive to the differences in the modeled fecundity of younger fish. A comparison of the four fecundity curves in Figure 4 (= Porch Addendum Figure A2) reveals that the two curves based upon the new fecundity data (Collins et al., 2002) ascribe relatively greater productivity to ages 3-5 than the original GWTvsTL curve derived by Schirripa et al. (1999). Of the new curves, the FECvsTL vector ascribes the most productivity to ages 3-5, which are the age groups that have declined the least, therefore it leads to the most optimistic estimates of stock status.

The Panel believed that, of the four fecundity-by-age or fecundity-by-length vectors examined, the GWTvsAGE fecundity vector was the most appropriate. It was preferred over the original GWTvsTL vector derived by Schirripa et al. (1999) because it incorporated additional data (Collins et al. 2002) and avoided the possible inaccuracies that may occur when converting length to age via a growth curve. It was favored over the corresponding batch fecundity curves because there were a great deal more observations of gonad weight than batch fecundity, making the relationship with age better determined. Accordingly, the Panel requested projections of the constant harvest and constant effort scenarios using the GWTvs AGE fecundity relationship that would lead to recovery above SS_{MSY} by 2012. These are shown in Figure 8 for constant catch (= Porch Addendum Figure A5) and Figure 9 for constant F scenarios (= Porch Addendum Figure A6), respectively. It should be noted that the panels on the left hand side of these figures are for steepness =0.7, and the panels on the right are for steepness 0.8

Stock Status and Current F

Depending upon whether steepness values of 0.7 or 0.8 are used in the new assessment model runs described above, which incorporate all of the new biological data on red grouper, the outcomes indicate that red grouper is no longer overfished, but in the case of steepness = 0.7, the population is experiencing overfishing. It should be noted, however, that while the population currently appears to be recovering, biomass levels in 1999 indicate that when the stock first was determined to be overfished, indeed it was based upon levels determined in this 2002 assessment (Figures 8 and 9), thus warranting the development of a rebuilding schedule. The Panel remains cautiously optimistic about the apparent rapid recovery from the overfished condition, but it is concerned that recent increases in landings may be attributable to a single strong year class moving through the fishery, albeit that it has no direct evidence that this is the case. Current estimates of F range from 0.315 (steepness = 0.7) to 0.316 (steepness = 0.8), and $F_{current}/F_{msy}$ range from 1.031 to 0.869 and $F_{current}/F_{oy}$ range from 1.374 to 1.159, respectively, with the different values of steepness (Table 3= Porch Addendum Table A2), thus necessitating the need for only modest harvest reductions if the actual steepness value is assumed to be closer to 0.7.

Red Grouper ABC Rationale and Recommendations

Based upon the rationale given above, the Panel recommends that the ABC range for red grouper under a constant catch yield stream to be 7.03 to 7.12 million pounds per year. This

level of harvest should lead to recovery of the red grouper population to levels approaching B_{msy} by 2012.

However, the Panel strongly recommends that the Council adopt a constant F_{msy} fishing strategy for red grouper at this time, indicating an ABC range of 6.17 to 7.36 million pounds in 2003 (Table 4). Additionally, the yield stream under constant F_{msy} indicates an ABC range of 6.59 to 7.63 million pounds in 2004. It should be noted, however, that the high end of the ABC range in all cases is based upon assessment model runs that assume a steepness value of 0.8. While a steepness value of 0.8 is not out of the question, it is on the high end of the range for species with life history characteristics similar to those of red grouper (Rose et al. 2001), and higher than the best fit to the limited spawner-recruit data (steepness = 0.68) currently available for this species (Schirripa et al. 1999). Moreover, because red grouper life history is made additionally complex by hermaphroditism, which has unknown consequences with respect to spawner-recruit relationships, some caution is recommended when biological benchmarks are hovering around threshold levels. Furthermore, while B_{msy} is a threshold biomass level, B_{oy} is the ultimate biomass target and constant F_{oy} catch levels necessary to achieve B_{oy} within the rebuilding schedule are lower when steepness = 0.8 (5.67 million pounds in 2003 and 6.14 million pounds in 2004). As such, if the Council wishes to take a conservative approach and begin to manage red grouper towards B_{oy} , a constant $F_{msy \rightarrow oy}$ yield of 5.67 to 6.17 million pounds in 2003 and 6.14 to 6.59 million pounds in 2004 is recommended.

Additionally, it should be noted that the increasing stock size seen in recent years appears to be due in large part to increased recruitment entering the fishery. Recruitment is variable, and variation in recruitment is difficult to predict. This creates the real possibility that setting a TAC at any given level may be acceptable one year under current standards, and unacceptable in another. The result is a stock that varies between being fished within acceptable limits one year, and being overfished in another. This is one of the benefits of moving to a strategy based on OY rather than MSY. Annual fluctuations in recruitment would be much less likely to result in an overfishing situation under an OY management strategy.

Research Priorities

The Panel suggests additional research be performed in the following areas to help increase the accuracy and precision of future stock assessments. The assessment would be greatly improved by the use of known age/length data, as are being measured at the Panama City NMFS Laboratory to:

- 1) obtain adequate random samples of age composition with the long-term goal of eliminating as many conversions as possible in stock assessments;
- 2) improve the ability to make known-age estimates of batch fecundity, age-at-maturity, percent of the females by age and season that are actively spawning, spawning frequency and behavior, etc, especially for fish that are younger and older than those for which data currently are available; and,
- 3) assess the ability of the age-slicing method used in Schirripa et al. (1999) to adequately represent the age distribution obtained through sampled ages.

In addition, work should be focused on the design of a strategy to:

- 1) obtain representative samples of landings, developed in cooperation with assessment scientists and fishers;
- 2) develop, or piggy back on existing monitoring, fisheries-independent indices of

abundance, e.g., the exploratory trap sampling that will be started this Fall by the Panama City NMFS Laboratory; and,

- 3) continue exploration of historical data to develop indices of abundance.

Table 5. Red grouper constant F time stream based on long time series data-set for SPR at MSY in year 2018 goal.

B_{MSY} in 2018 - Projection of $F = 0.2275$

$F/F_{MSY} = 0.829$

Year	Yield	Cumulative Yield	SS/SS _{MSY}
2000	1.525	1.525	0.250
2001	1.941	3.466	0.310
2002	2.368	5.834	0.370
2003	2.784	8.618	0.425
2004	3.168	11.785	0.476
2005	3.517	15.303	0.522
2006	3.849	19.151	0.567
2007	4.172	23.324	0.611
2008	4.497	27.820	0.656
2009	4.819	32.639	0.701
2010	5.136	37.775	0.745
2011	5.445	43.220	0.787
2012	5.745	48.965	0.827
2013	6.027	54.992	0.863
2014	6.286	61.278	0.897
2015	6.521	67.799	0.927
2016	6.733	74.532	0.955
2017	6.924	81.455	0.979
2018	7.095	88.550	1.001

B_{MSY} in 2010 - Projection of $F = 0.1069$

Year	Yield	Cumulative Yield
2000	0.737	0.737
2001	0.987	1.724
2002	1.264	2.988
2003	1.553	4.541
2004	1.840	6.381
2005	2.119	8.500
2006	2.395	10.895
2007	2.670	13.565
2008	2.949	16.514
2009	3.227	19.741
2010	3.505	23.246

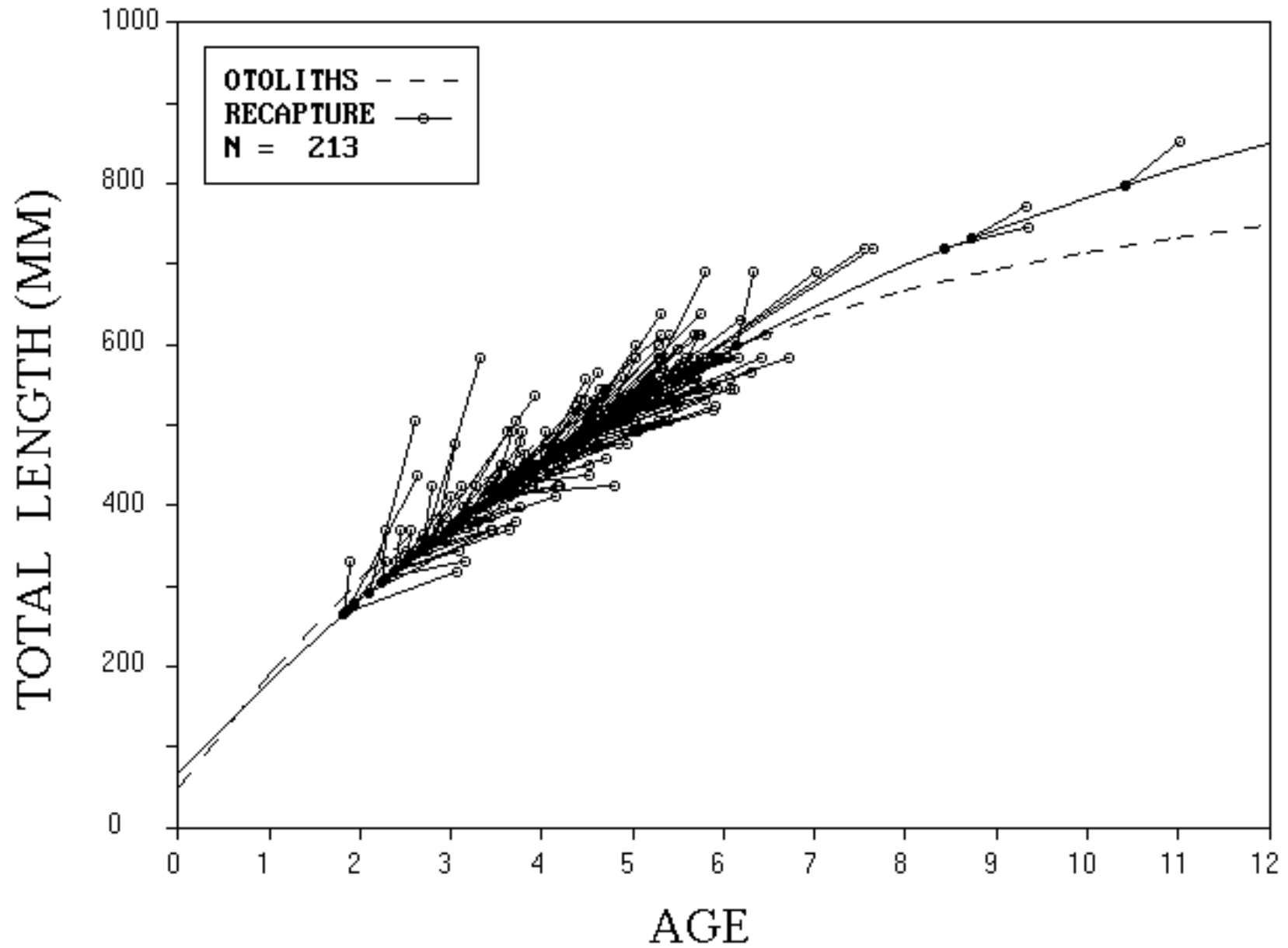


Figure 4 (Figure 16 in Schirripa et al. 1999). Estimated growth curve from otoliths and tag-recapture data for red grouper.

ESTIMATED TOTAL LANDINGS - FL WEST COAST

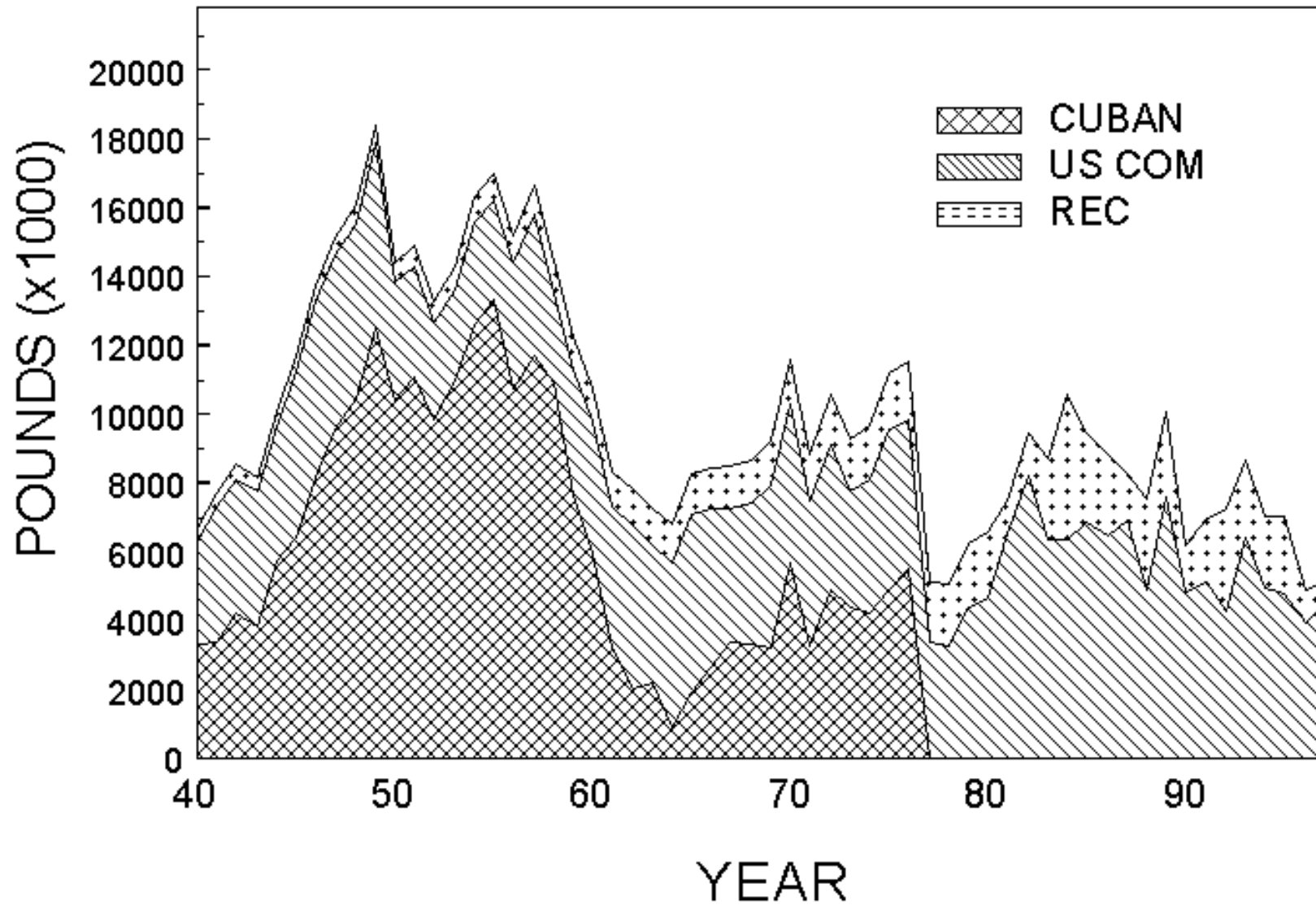


Figure 5 (Figure 33 in Schirripa et al. 1999). Estimated total landings of red grouper from Florida west coast, 1940-1997.

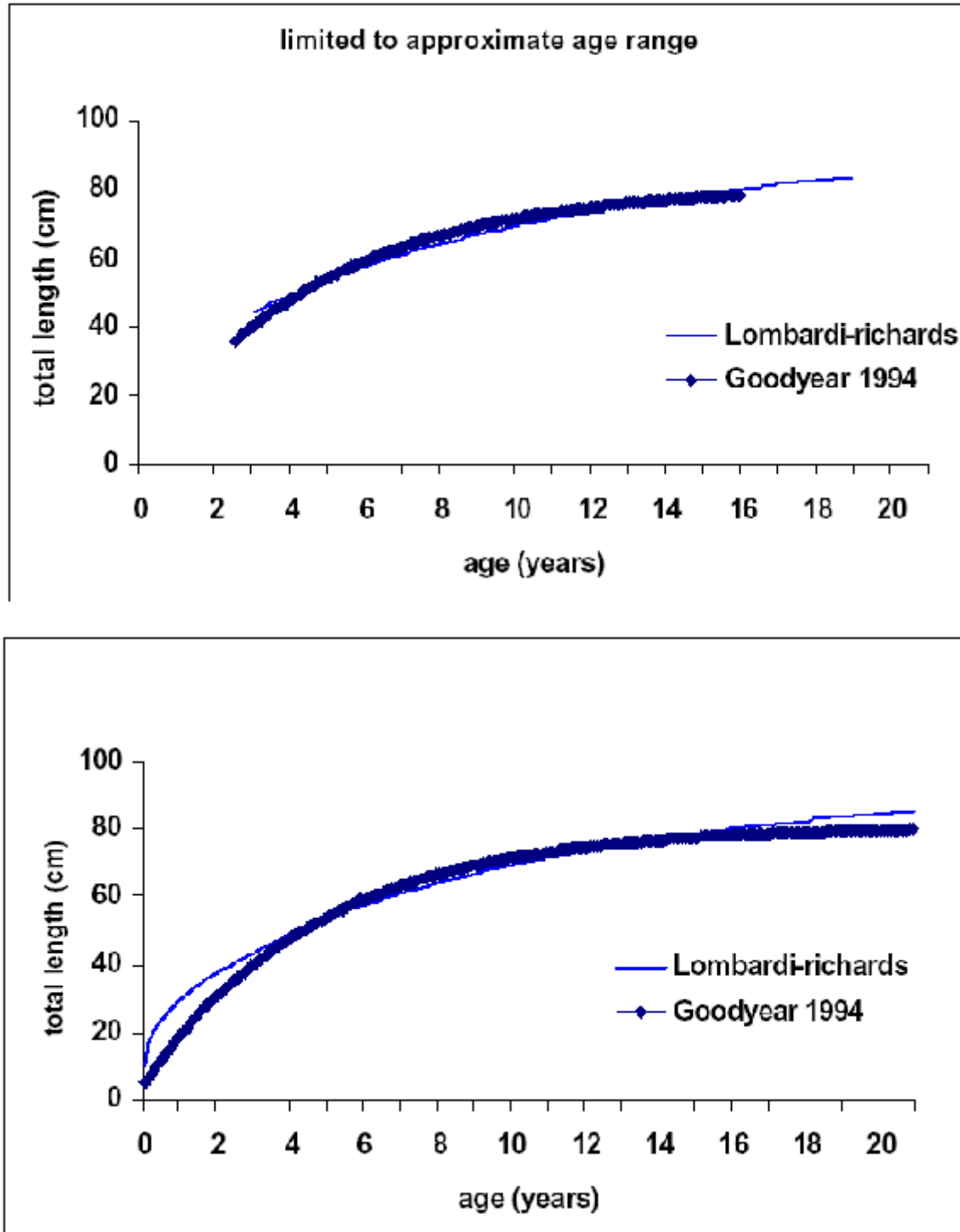


Figure 1. Estimated length (cm) at age for red grouper from Goodyear (1994) and the Richards curve from Lombardi-Carlson *et al.* (2002). In the upper panel each curve is shown for the approximate range of ages to which the curves were fit.

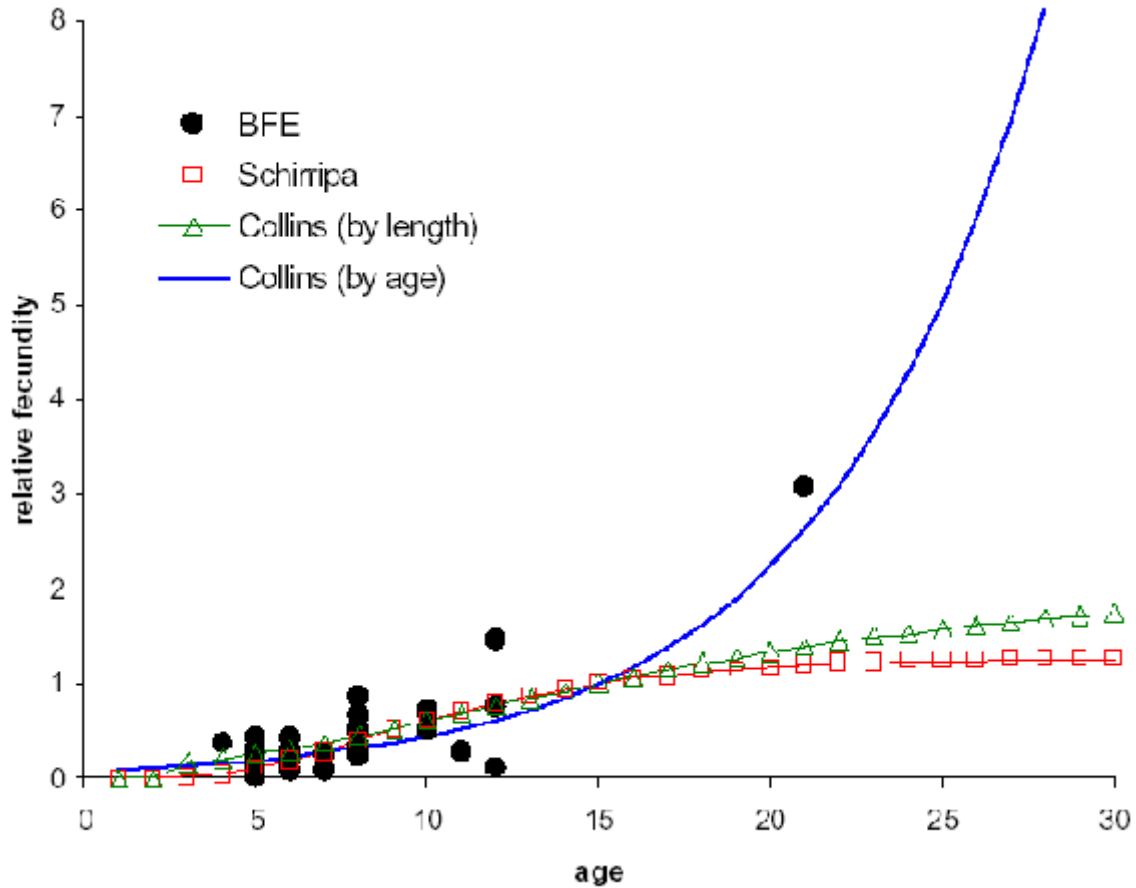


Figure 2. Relative fecundity of mature, active females. Circles are observations of batch fecundity (BFE) from Collins et al. 2002. The curve labeled “Schirripa” is the power function used by Schirripa et al 1999 to express gonad weight as function of length (converted to a function of age by use of the growth curve). The curve labeled “Collins (by length)” is the exponential function given by Collins et al. 2002 to express batch fecundity as function of length (converted to a function of age by use of the growth curve). The curve labeled “Collins (by age)” is the exponential function given by Collins et al. 2002 to express batch fecundity as function of age.

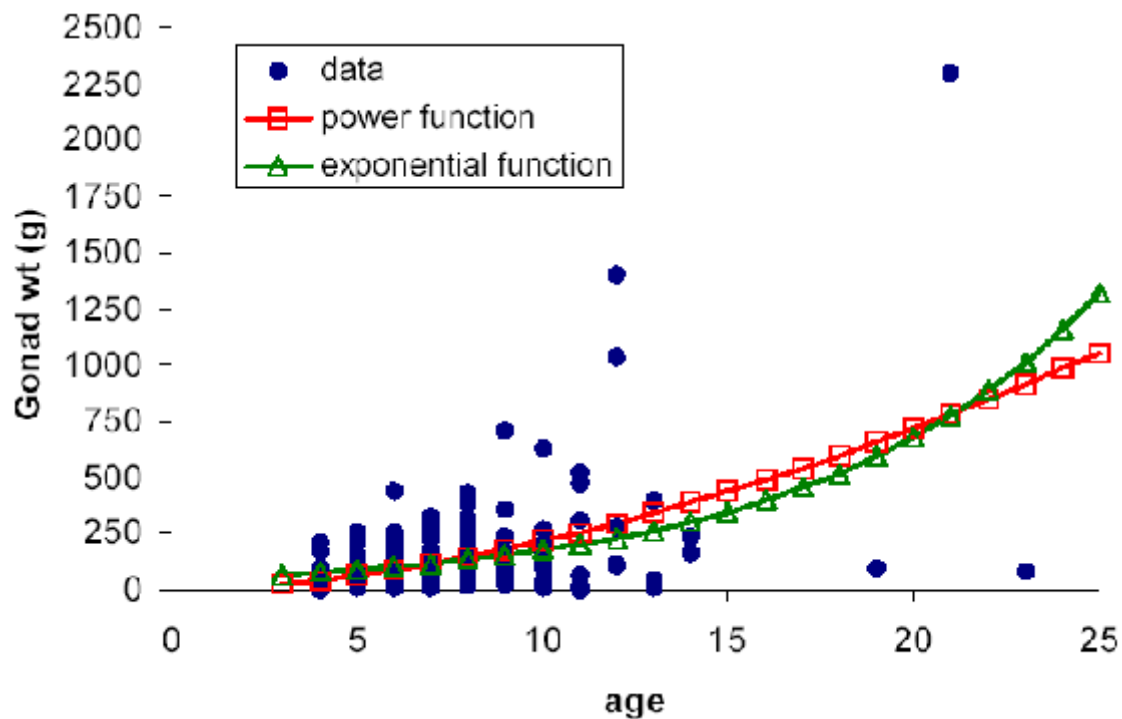


Figure 3. Least-squares fits of the power function ($GWT = 4.0739age^{1.7259}$) and exponential function ($46.130e^{0.13425age}$) to gonad weight at age data. The power function gave the best fit (lowest residual sum of squares). Only gonad weights of active females (vitellogenic or hydrated ova present, but excluding spent ovaries) sampled during the peak spawning months (March, April and May) were used. This is essentially an update of the data from the previous assessment (Schirripa and Legault 1999, Figure 8), but instead the curve fit is based on those females whose ages were determined directly (Lombardi-Carlson et al. 2002) rather than estimated from length.

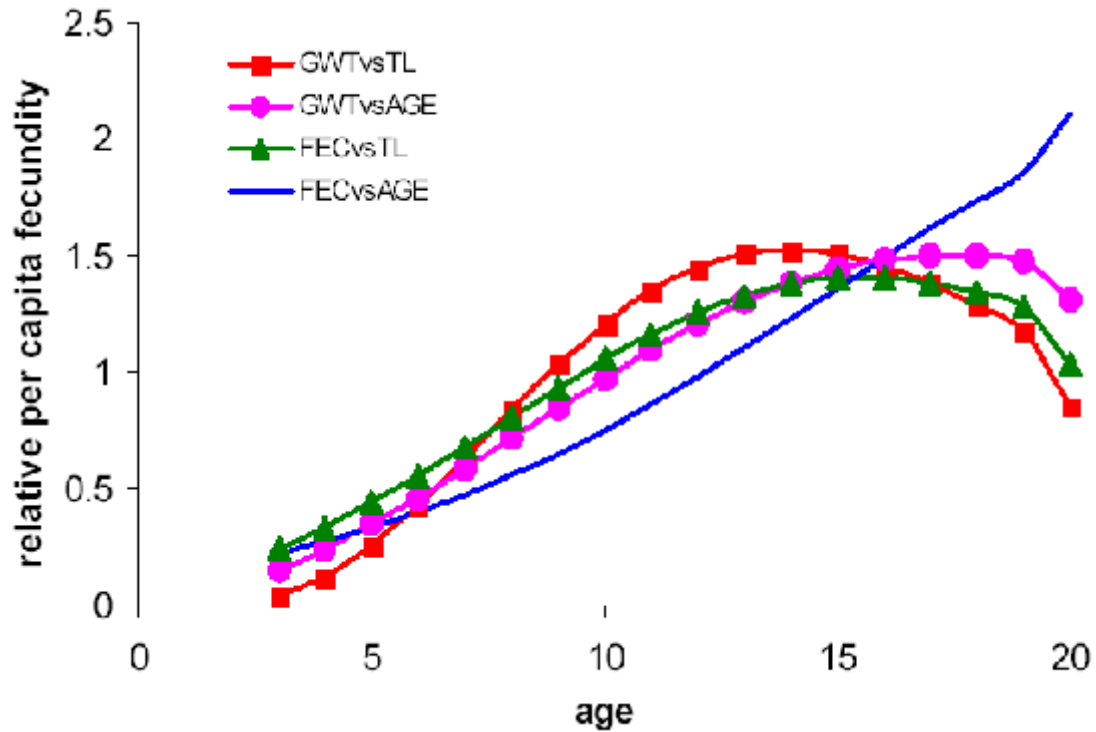


Figure 4. Comparison of the four measures of per capita fecundity on a relative scale. Note that the vectors based on gonad weight do not include estimates of the percent of females active in any given spawning year (the RFSAP felt that percent activity was, to some degree, implicitly accounted for in that gonad weight would be lower for inactive females).

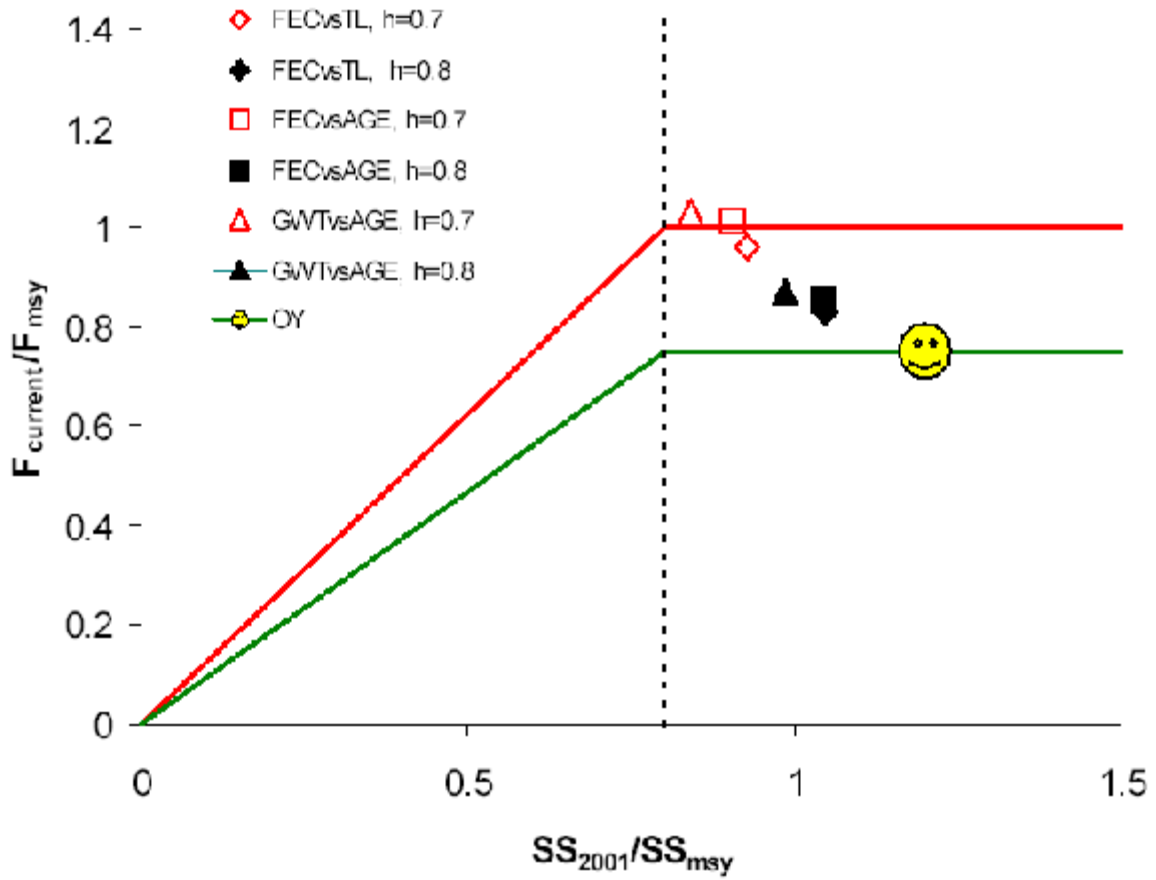


Figure 5. Control rule diagram contrasting the stock status estimates from the runs requested by the 2002 RFSAP. Lower solid line represents control rule for management based on an OY target (point marked by the ‘happy face’).

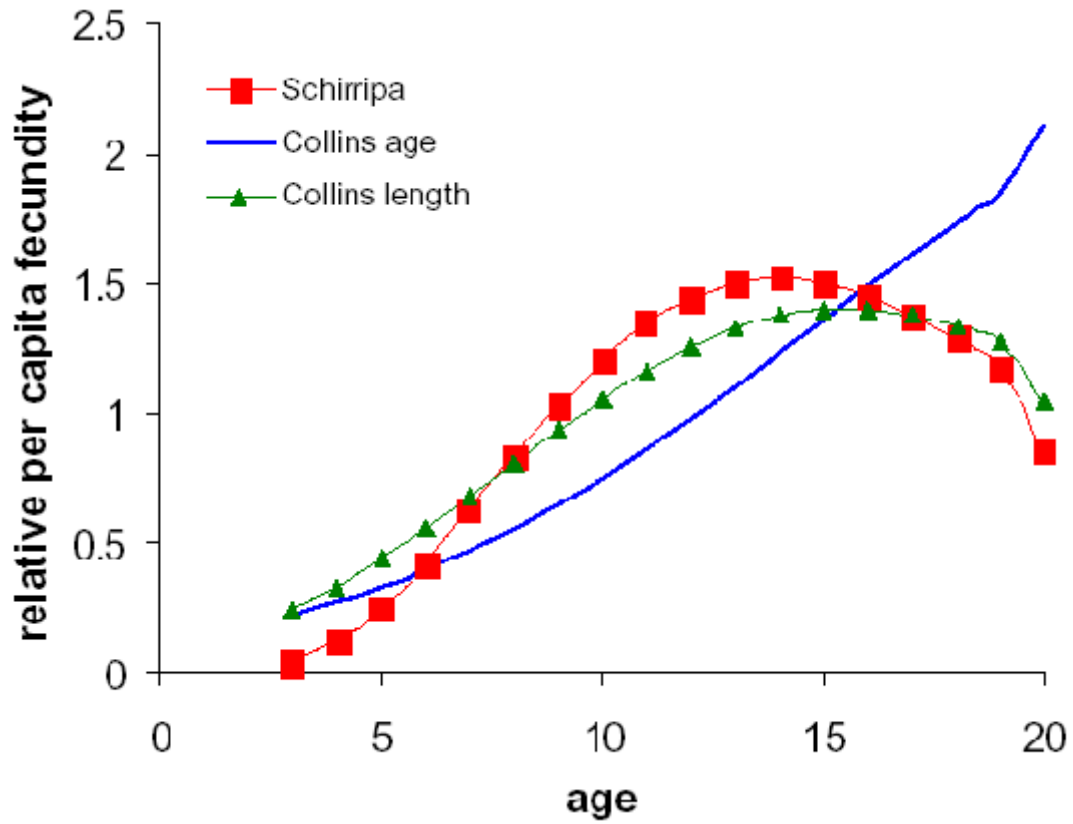


Figure 6. Comparison of relative fecundity at age derived by Schirripa *et al.* (1999) and for this assessment.

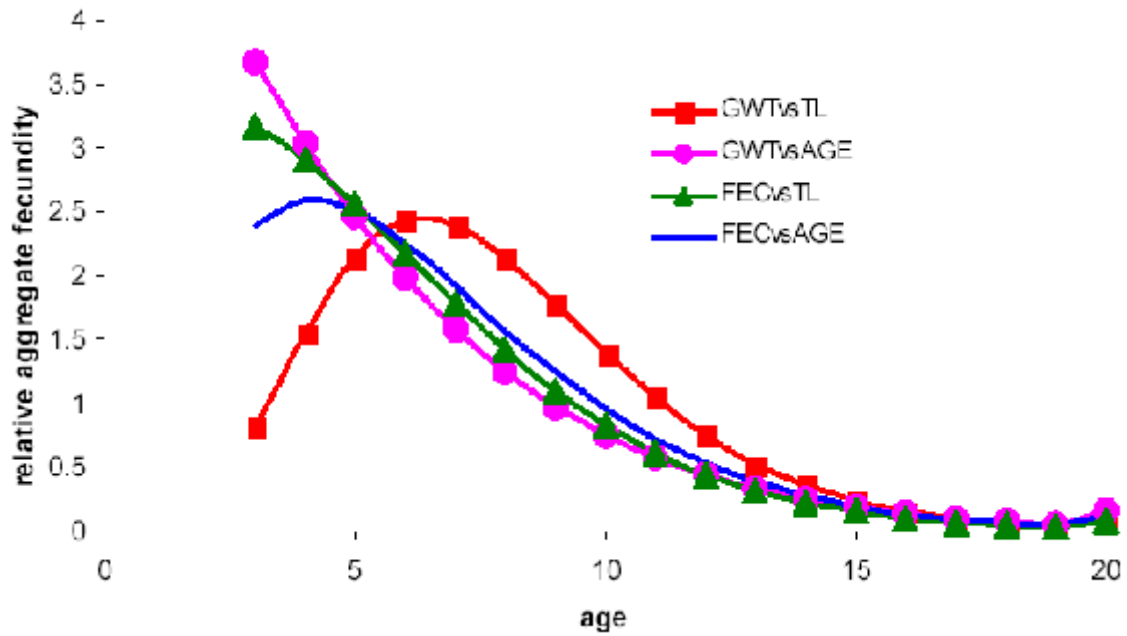


Figure 7. Relative fecundity of each age class under virgin condition assuming a natural mortality rate of 0.2 yr⁻¹ (this is the product of the per capita fecundity at age and the relative abundance of each age class, normalized to average a value of 1.0).

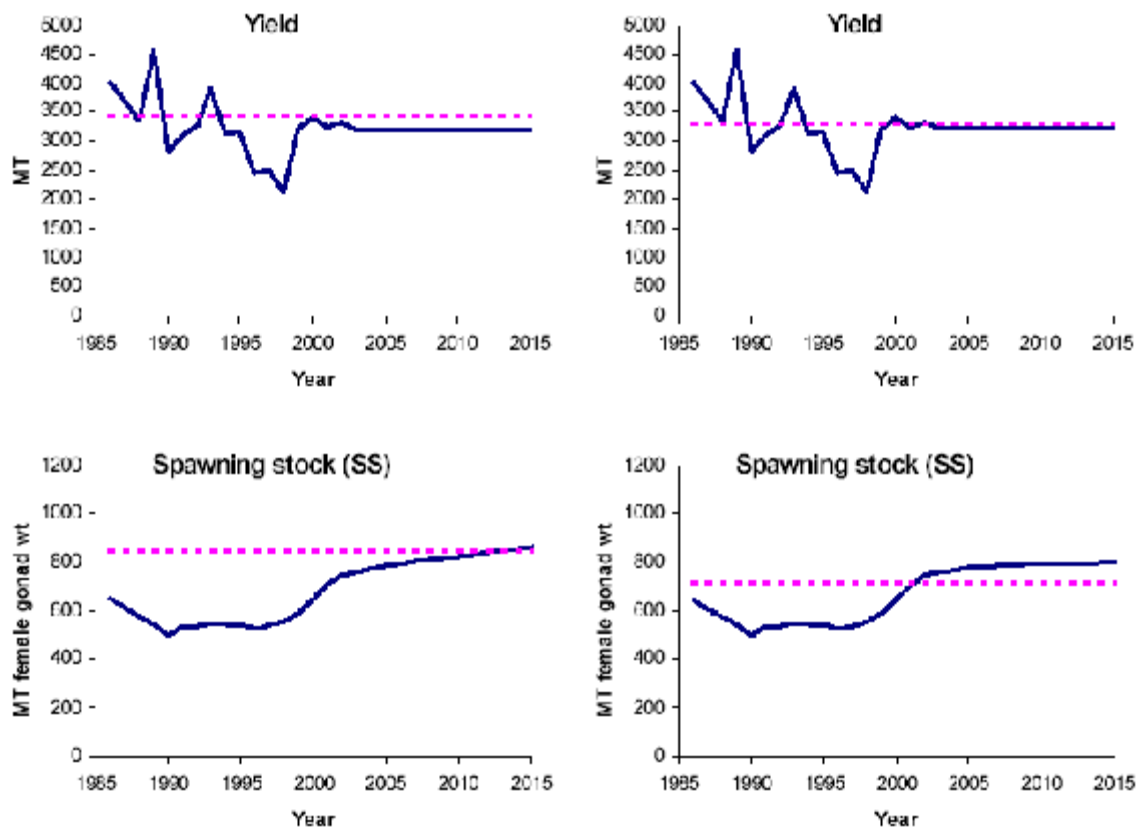


Figure 8. Projections of landings and aggregate fecundity (spawning stock) under the constant level of landings that will permit recovery to SS_{MSY} by 2012 assuming fecundity at age follows the GWTvsAGE vector. In the case where steepness = 0.7, $C_{\text{recover}} = 3190$ mt. However, if steepness = 0.8 the stock is estimated to recover even if $C > MSY$, therefore a projection with C_{recover} set to OY (= 3229 mt or 7.119 million lbs.) is shown instead. Dashed lines represent equilibrium yield (landings) and spawning stock corresponding to F_{MSY} . All projections assumes the landings in 2002 are equal to the average from 2000 and 2001, future selectivity = estimated selectivity for 2001, and future recruitment is a deterministic Beverton and Holt function of projected spawning stock.

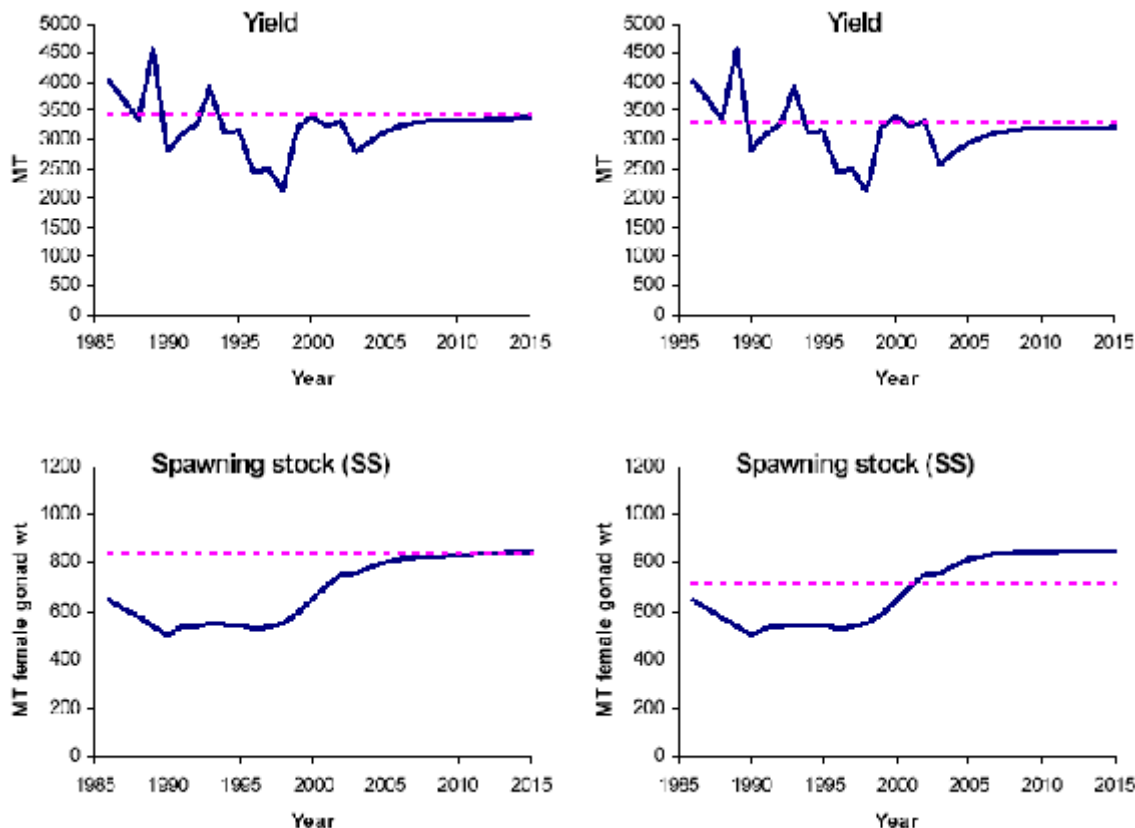


Figure 9. Projections of landings and aggregate fecundity (spawning stock) under the constant level of fishing mortality rate that permits recovery to SS_{MSY} by 2012 assuming fecundity at age follows the GWTvsAGE vector. In the case where steepness = 0.7, $F_{recovery} = 0.298$. However, if steepness = 0.8 the stock is estimated to recover even if $F > F_{MSY}$, therefore a projection with $F_{recovery}$ set to $F_{OY} (= 0.273)$ is shown instead. Dashed lines represent equilibrium yield (landings) and spawning stock corresponding to F_{MSY} . All projections assume the landings in 2002 are equal to the average from 2000 and 2001, future selectivity = estimated selectivity for 2001, and future recruitment is a deterministic Beverton and Holt function of projected spawning stock.