A Preliminary Assessment of the Populations of Seven Species of Grouper (Serranidae, Epinephelinae) in the Western Atlantic Ocean from Cape Hatteras, North Carolina to the Dry Tortugas, Florida

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ABSTRACT

Models of yield per recruit (Y/R) and spawning stock per recruit ratio (SSR) based on samples taken (mostly) in 1988 from the Atlantic Ocean between Cape Hatteras, North Carolina and Dry Tortugas, Florida, under the assumption that stocks were in equilibrium with the fishery were created for seven species of grouper (Serranidae, Epinephelinae): gag *Mycteroperca microlepis*, scamp *M. phenax*, black grouper *M. bonaci*, speckled hind *Epinephelus drummondhayi*, Warsaw grouper *E. nigritus*, snowy grouper *E. niveatus*, and red grouper *E. morio*. Gains in yield per recruit available calculated by adjusting fishing mortality rate (F) or recruitment age were, for the most part, minimal (<20 percent). But large gains in SSR are available. Four of the seven species exhibited SSR values of less than 0.30 (snowy grouper, 0.15; warsaw grouper, 0.002; speckled hind, 0.25; and scamp, 0.28), the criterion value set by the South Atlantic Fishery Management Council to designate overfishing. SSR for red grouper was 0.41, for black grouper, 0.37, and for gag, 0.332. Managing the deep-dwelling (>100 m) *Epinephelus* groupers poses special problems because they are rare, occur as a by-catch with more abundant reef species, and are difficult to release alive.

INTRODUCTION

Using data from catches made primarily in 1988 we herein estimate values of yield per recruit (Y/R) (Ricker 1975) and spawning stock per recruit ratio (SSR) (Gabriel *et al.*, 1989) for seven species of grouper (Serranidae, Epinephelinae): gag, *Mycteroperca microlepis*; scamp, *M. phenax*; black grouper, *M. bonaci*; speckled hind, *Epinephelus drummondhayi*; warsaw grouper, *E. nigritus*; snowy grouper, *E. niveatus*; and red grouper, *E. morio*. The measures represent the condition of stocks over the entire jurisdiction of the South Atlantic Fisheries Management Council (SAFMC), for practical purposes the Atlantic Ocean from Cape Hatteras, North Carolina to the Dry Tortugas, Florida. Within the limits of the data and of necessary assumptions, this report provides a region-wide perspective on stock status.

At least 18 species of grouper occur on the Atlantic continental shelf of the United States. Of these, 14 are, or have been, important in supporting

Table 1. Groupers regularly occurring in fisheries of the United States' South Atlantic Continental Shelf.

Species				
Common Name	**Scientific Name**	**Usual Depth (m)**	**Principal Atlantic Range**	**Comments**
Gag	*Mycteroperca microlepis*	20 - 100	Cape Hatteras to Dry Totugas	The most abundant and important grouper in U.S. South Atlantic
Scamp	*M. phenax*	20 - 100	Cape Lookout to Dry Tortugas	
Yellowmouth grouper	*M. interstitialis*	20 - 100	" "	Almost certainly marketed as scamp
Yellowfin grouper	*M. venenosa*	20 - 100	Irregular - Cape Hatteras to Dry Tortugas - most common in Keys and Dry Tortugas	Uncommon in continental waters; common in the Bahamas and Caribbean
Black grouper	*M. bonaci*	5 - 100	Palm Beach to Dry Tortugas FL	Largest *Mycteroperca* species reported to 75kg in Bermuda
Snowy Grouper	*Epinephelus niveatus*	100 - 300	Cape Hatteras to Dry Tortugas	Locally very abundant, dominant deepwater grouper
Yellowedge grouper	*E. flavolimbatus*	100 - 300	Cape Hatteras to Dry Tortugas	Occasional with snowy; dominant in deep water of Gulf of Mexico
Misty grouper	*E. mystacinus*	100 - 300	Cape Hatteras to Dry Totugas	Occasional with snowy; dominant in deep water of Caribbean
Warsaw grouper	*E. nigritus*	75 - 300	Cape Hatteras to Dry Tortugas	Apex predator of deep reef; regular but rare
Speckled hind	*E. drummondhayi*	60 - 100	Cape Hatteras to Dry Tortugas	Apex predator of mid-depth reefs, aggressive, easily caught
Red grouper	*E. morio*	60 - 100	Cape Lookout to Dry Tortugas	Most abundant near Florida Keys
Nassau Grouper	*E. striatus*	50 - 80	South Florida to Dry Tortugas	Formerly (to 1979's) common. Extremely rare, depleted now.

Table 1. (continued)

Common Name	Species Scientific Name	Usual Depth (m)	Principal Atlantic Range	Comments
Jewfish	*E. itajara*	5 - 50	Principally South Florida	Giant (to 300kg) of shallow waters, now totally protected
Rock hind y	*E. adscensionis*	5 - 80	Cape Lookout to Dry Tortugas. Most frequent near Cape Fear and in lower Keys.	Widely distributed but rarely abundant on U.S. Continental shelf
Red hind	*E. guttatus*	5 - 80	" "	One of most common Caribbean groupers.
Coney	*E. fulvus*	5 - 60	Cape Lookout to Dry Tortugas principally South Florida	
Graysby	*E. crutentatus*	5 - 60	" "	Small grouper; very wary of divers.An uncommon small species, to about 30 cm total length.
Marbled grouper	*E. inermis*	50 - 100	Cape Lookout to Dry Tortugas	Enigmatic, rare, occurrences. Perhaps least commonly observed grouper of region.

commercial and recreational fisheries (Table 1). The seven species studied here are either numerically important to the catch or are (or were) important trophies, or both.

The history of management measures for groupers in the U.S. South Atlantic region is brief. In Florida waters minimum size limits (based principally on good intentions) of 13 inches fork length for red, Nassau (*E. striatus*) and black groupers, jewfish (*E. itajiara*) and gag were instituted prior to 1970. In 1985 Florida established size limits [based somewhat on Beverton and Holt (1957) Y/R models] of 18 inches for yellowfin (*M. venenosa*), black, red and Nassau groupers, jewfish and gag, along with a daily bag limit of five groupers. In 1990 scamp and yellowmouth (*M. interstitialis*) grouper were added to the list of protected species, jewfish were given total protection from harvest, and the minimum size was increased to 20 inches. For Federal waters the only extant regulations are size limits of 12 inches total length for red and Nassau groupers. South Carolina has adopted the Federal regulations for its state waters. These limits were based on Beverton and Holt (1957) yield per recruit models (Huntsman and Manooch 1979; Huntsman *et al.*, 1984) modified by economic analyses (Waters and Huntsman, 1986). Although the yield models alone indicated that size limits for some other species would produce increases in yield per recruit, the economic analyses indicated that these gains were insufficient to offset opportunity costs of short term decreases in catches.

Perceptions by both fishermen and managers that, despite Federal regulation, grouper populations have continued to decline in number, mean size, and age prompted reexamination of their status.

For the reexamination we chose two models. The Ricker (1975) yield per recruit model differs from the Beverton and Holt model used earlier in being arithmetic rather than integral and in allowing the easy imposition of age-specific fishing mortality rates (F). Therefore, the assumption of so-called knife-edge recruitment is not required. The spawning stock biomass per recruit ratio model (Gabriel *et al.*, 1989) is also based on Ricker-type computations. It provides estimates at various combinations of F and recruitment ages (t_r) of the ratio of the spawning stock biomass per recruit produced at equilibrium with any fishing mortality rate (F) and recruitment age (t_r) to the spawning stock biomass per recruit produced if no fishing occurred ($Z = M$, $F = 0$ where Z = the total instantaneous fishing mortality rate and M = the instantaneous natural mortality rate).

It is crucial to realize that the ratios presented here are of spawning stock biomass per recruit and not of spawning stock biomass. It is conceivable that a given fishing strategy could produce a high ratio per recruit but that the ratio of actual spawning stocks has decreased, because recruitment itself is smaller.

METHODS

The region-wide assessment entailed, for each species, two phases:

1. Construction of a region-wide estimate of catch in numbers at each age.
2. Application of analytical techniques to produce estimates of current spawning stock ratio and yield per recruit.

These analyses assume that equilibrium has been established between the population and fishing.

Estimating Catch by Age

Estimating catch by age required consolidating six data sets:

1. Commercial landings records in weight.
2. Records of sizes of individual fish from intercept sampling of the commercial catch.
3. Estimates of catch in number by species from the Marine Recreational Fishing Statistics Survey (MRFSS) (Essig *et al.*, 1991).
4. Records of Sizes of individual fish from the MRFSS.
5. Estimates of catch in number by species from the headboat survey (Huntsman, 1976).
6. Records of sizes of individual fish from the headboat survey.

The procedures were simple. For the commercial catch, total catch in weight for area and gear strata were divided by mean weights appropriate to the strata to estimate the total number of fish caught. Then catches in number for the commercial catch, as well as for the catches for the two recreational sectors already estimated in number, were subdivided into total catches in various length strata by multiplying a sample relative length frequency appropriate to the area-gear strata by the total catch.

Finally, age frequencies were created by arithmetically applying age-length keys to length-frequencies for subregions (so that later partitioning, if necessary, was possible), and the region-wide age frequency was established by summing the age-frequencies of subregions. Thus, to the extent possible, sample size frequencies were weighted by catches pertinent to specific areas and gears before their combination. While the use of age-length keys can result in flawed analyses (Westrheim and Ricker, 1978), we judge such use to be sufficiently accurate for the general assessment of stock status undertaken here.

Often there were no samples of fish sizes to apply to the commercial or MRFSS catches of certain strata (Table 2). When data were missing we used size samples from either adjacent geographic areas, preceding or subsequent years, or another sector of the fishery, often the headboat fishery. The determination of which adjustment to make was based on knowledge of location of fishing, trends in size for the species in question, and other pertinent factors. The numerous necessary adjustments as well as all data bases and analyses

Table 2. Number of fish sampled for length by source.

Headboat Data 1988

Species	Carolinas	N. Florida[1]	S. Florida
Speckled hind	66	1	8
Snowy grouper	49	—	1
Warsaw grouper	—	1	—
Black grouper	3	2	11
Scamp	548	7	214
Red Grouper	42	33	210
Gag	445	103	70

[1] Includes Georgia

Trips Data - Commercial Fishery

Species	Source - Area and Year			
	Carolinas	N. Florida[1]	S. Florida	Gear type
Speckled hind	850 (1988)	390 (1983-88)	59 (1983-88)	HLL
Snowy grouper	1043 (1988)	938 (1983-88)	417 (1983-88)	AG
" "	1035 (1988)	—	—	HLL
Warsaw grouper		—	#176 (1983-88)	—
	AG			
Black grouper	—	—	167 (1984-88)	AG
Scamp	2696 (1988)	770 (1984-88)	—	AG
Red grouper	964 (1983-88)	—	—	AG
" "	—	—	123 (1983-88)	HLL
" "	—	—	109 (1987)	T
Gag	—	334 (1987-88)	—	AG
"	—	—	713 (1983-88)	HLL
"	1749 (1988)	—	—	AG

Key:
HLL = Hand or longline, AG = All gear, OG = Other gear, N = Nets, T = Traps, # = All Areas Combined

MRFSS 1988

Species	NC	SC	GA	FL
Speckled hind	—	—	—	—
Snowy grouper	1	—	—	1
Warsaw grouper	1	—	—	16
Black grouper	—	—	—	10
Scamp	72	5	—	—
Red grouper	24	—	—	31
Gag	123	21	2	21

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at the Beaufort Laboratory.

For some species (*e.g.*, speckled hind, warsaw grouper) samples of fish sizes were combined for all the years 1983 through 1988 in order to provide sufficient observations to establish a useful length frequency (Table 2). This aggregation of data will, assuming fishing mortality increased over time, cause overestimation of SSR in more recent years.

Modeling Yield and Spawning Stock Ratio

Modeling of yield per recruit (Y/R) and spawning stock ratio (SSR) was accomplished with Ricker-type models constructed with the computer program YRSSR.SAS (Vaughan, 1990) based on Gabriel *et al.* (1989) and Ricker (1975). Estimates of natural mortality rate (M) (Table 3), in general, were obtained from formulae relating M to life history parameters (Pauly, 1980-81; Hoenig, 1983). Estimates of age-specific values of fishing mortality (F_i) resulted from analysis of deviations from the regression fit to the descending limb of the catch curve.

To explore the sources of variation in SSR we computed values for gears and subareas (Table 4). The results obtained are the values that would exist were the whole stock subject to, and in equilibrium with, the conditions peculiar to that stratum. The overall values for the region reflect a combination of these subregional values approximately weighted by catch in number (Table 4). Because of generally small sample sizes, we did not generate separate estimates of SSR for strata defined by the MRFSS but we, of necessity, included the MRFSS data in the estimates for the entire region. Inclusion of data from the MRFSS often drastically reduced the region-wide SSR values from those that might have been expected from examining the stratum estimates based on data from the commercial and headboat fisheries.

As a convention, we computed a single weighted value of F to be applied to all fully recruited age classes. The weighting factor was the estimated population at age i (N_i) subject to the age specific F_i. The estimates of N_i were derived under the equilibrium assumption from analysis of the catch curve. Because the preponderance of any population (in numbers) is in its younger age classes, the result of this weighting was to estimate F of all fully recruited age classes as being more like that of the youngest three or four fully recruited ages than like the F of the oldest age classes, which represent relatively fewer fish.

The values of age at maturity required for the models of SSR were estimated by the convention of the age of attainment of one half the asymptotic length. Both male and female biomass were included.

Discussions are based on total length except for scamp for which fork length is used because of the exaggerated and fragile exserted filaments on the tail.

Table 3. Parameters used in analyses.

Species	**K**	**L**	t_0	**a**	**b**	**M**	$t_{L/2}$	t_r
Speckled hind[1]	0.130	967	-1.01	1.1x10-5	3.073	0.20	4.32	3
Snowy grouper[1]	0.074	1255	-1.92	7.0x10-5	2.755	0.13	7.4	4
Red grouper[2]	0.167	922	0.299	4.0x10-6	3.22	0.20	4.45	6
Warsaw grouper[3]	0.054	2394	-3.616	2.09x10-5	2.98	0.10	9.22	2
Gag[4]	0.122	1290	-1.13	1.2x10-5	2.99	0.20	4.55	5
Scamp[5]	0.092	985	-2.45	2.4x10-5	2.91	0.17	5.08	4
Black grouper[3]	0.116	1352	-0.927	5.55x1-6	3.14	0.28	5.05	8

K, L , t_0 = Parameters of growth equation: $L_t = L\ (1-e^{-K(t-t_0)})$

a, b = parameters of length-weight equation: $W = aL^b$

M = instantaneous natural mortality rate

$t_{L/2}$ = estimated age at sexual maturity

t_r = youngest fully recruited age

[1] Source: Matheson and Huntsman (1984).

[2] Source: Unpublished Ms. Growth of red grouper from the Atlantic Ocean off the southeast United States by Michael Burton and Todd Stiles, Beaufort Laboratory, Southeast Fisheries Science Center, National Marine Fisheries Service, Beaufort, NC 28516.

[3] Source: Manooch and Mason (1987).

[4] Source: Manooch and Haimovici (1978).

[5] Source: Matheson *et al.* (1986).

Table 4. SSR for selected groupers of the U.S. South Atlantic Region.

Species	Data Source									Overall	Under Proposed Regulations
	Headboat			Commercial							
	Caro	NFL	SFL	Caro		NFL	SFL				
				AG	HLL	AG	AG	HLL	T		
Speckled hind	.22		.48	.37		.42	.45			.25	
Snowy grouper	.10			.15	.25	.36	.40			.15	
Red grouper	.24	.11	.28	.34				.45	.15	.41	0.50
Warsaw grouper										.002	
Gag	.19	.32	.30	.47		.54	.56			.32	0.34
Scamp	.18	.42		.28		.49				.28	0.42
Black Grouper			.40			.45				.37	0.42

TIP GEAR TYPES
- OG = Other gear
- HLL = Handline and longline
- N = Nets
- T = Traps
- AG = All gear

CARO = North Carolina and South Carolina
NFL = East Coast of Florida south to Ft. Pierce
SFL = Ft. Pierce through the Dry Tortugas

RESULTS

Gag

Of three groupers of the genus *Mycteroperca* included in this assessment, two have SSR values exceeding the overfishing criterion and the value for one (scamp) is slightly below. SSR for the gag (Figure 1) is 0.32, marginally greater than the overfishing criterion. Essentially no gain in Y/R (Figure 3) is available by establishing a size limit if F remains at 0.29, but a 19% gain could be had (as always, with total survival of released fish) if F increases by 50% to 0.48 and a size limit of 30 inches were established. That combination would yield an SSR of about 80%. A proposed 20-inch TL size limit for Federal waters provides an SSR of >0.30 only for F <0.35, a value about 20% greater than F in 1988.

Scamp

For scamp (Figure 1) the SSR is 0.28. A mere 6% reduction in F or a size limit of 17 (16.6) inches (total length) (with total survival of released fish) will provide an SSR of 0.30. The proposed 20-inch size limit would yield a 19% increase in yield per recruit (Figure 3) and an SSR of more than 0.30 if F remains below about 0.3 (that is, F might more than double). However, scamp is one of the species for which size data from the commercial fishery were aggregated over years, and the commercial catch is numerically greater, with greater effect on the SSR estimate than the recreational catch. Thus SSR estimate is almost certainly optimistic.

Black Grouper

SSR for black grouper (Figure 1) as well as for two other species (mutton snapper, *Lutjanus analis*, and yellowtail snapper, *Ocyurus chrysurus*; not discussed further in this report) limited almost exclusively to south Florida are remarkably similar (black grouper, 0.37; yellowtail and mutton snappers, 0.38), tempting the belief that a regional pattern exists. Whether one does or not, it appears that by the Council's definition these species are not overfished. A 20 inch size limit for black grouper will provide 19% increase in Y/R (Figure 3) and maintain the SSR at >0.30 for F=0.52, about 140% of current F.

Speckled Hind

SSR for speckled hind (Figures 1 and 3) is 0.25. A 21% reduction in F to 0.19 is needed to achieve an SSR of 0.30. The catch would need to be adjusted downward from about 7,000 individuals (1988) to about 5,500 (Table 5).

Given the scale of the fishery, the imprecision of any conceivable control procedure, and the relatively minute size of the speckled hind catch, it might be unrealistic to protect this species with catch limits (other than a total closure). A size limit of 16 inches would provide an SSR of 0.30 at present F (0.24) but a 20-inch size limit would be needed to ensure (assuming successful releases are

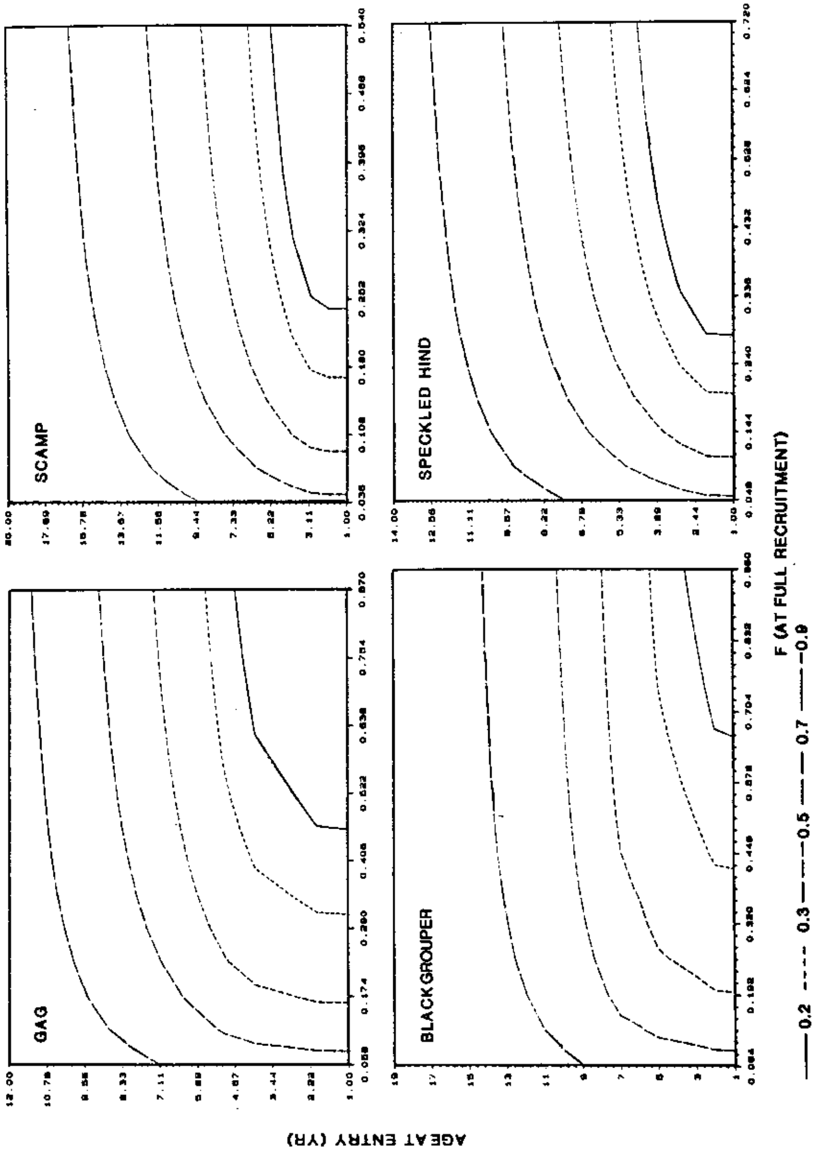

Figure 1. Equilibrium estimates of spawning stock ratio for gag, scamp, black grouper, and speckled hind in the region from Cape Hatteras to the Dry Tortugas, 1988.

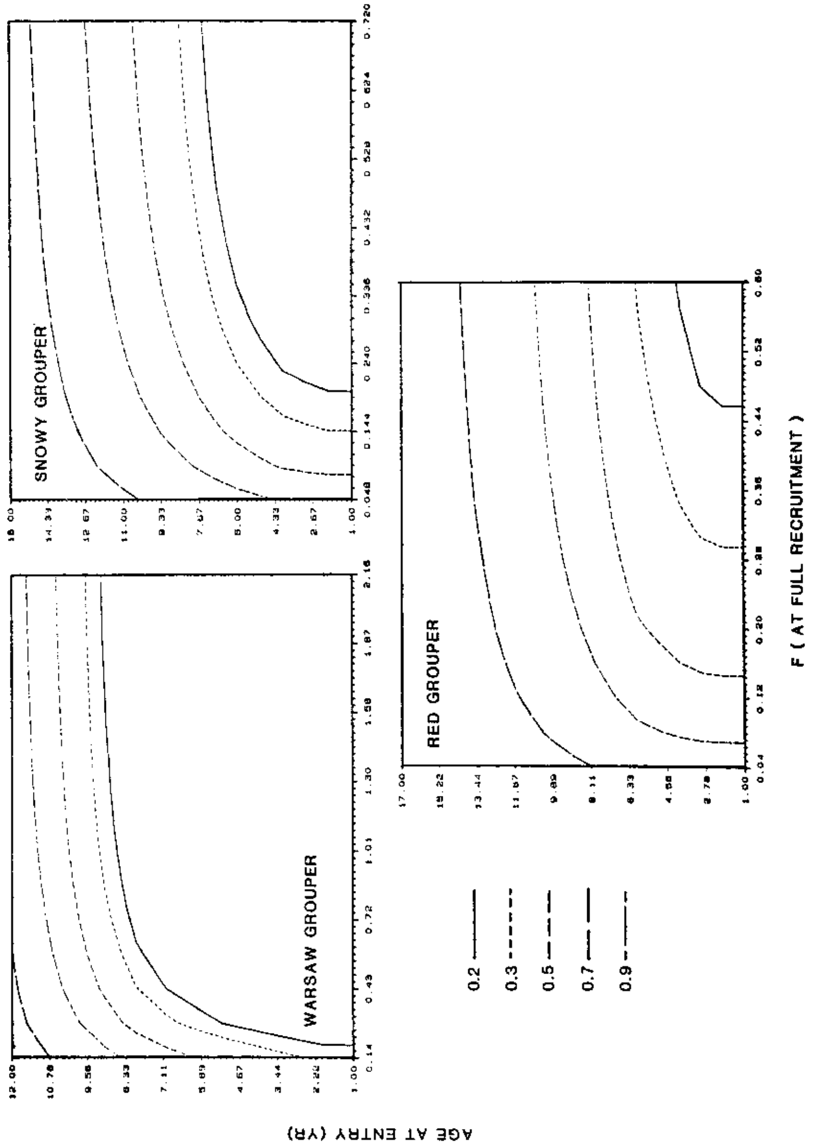

Figure 2. Equilibrium estimates of spawning stock ratio for warsaw, snowy, and red grouper in the region from Cape Hatteras to the Dry Tortugas, 1988.

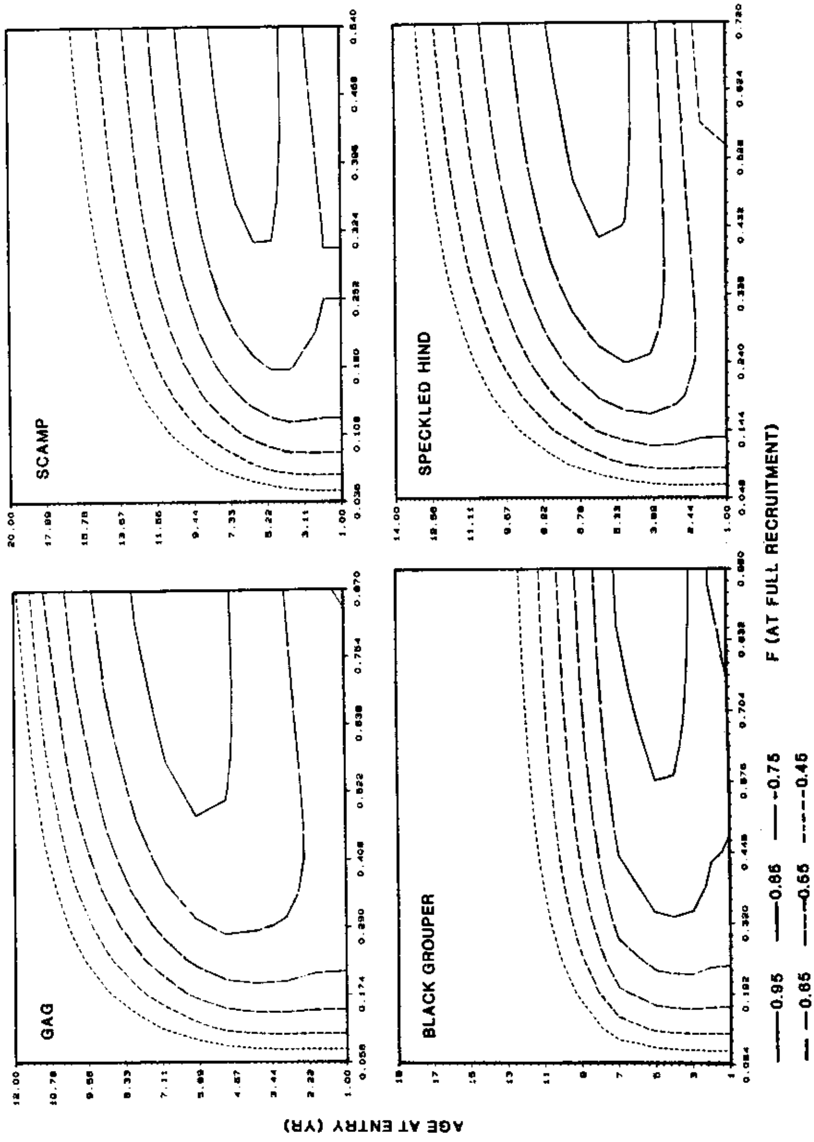

Figure 3. Yield per recruit models for gag, scamp, black grouper, and speckled hind in the region from Cape Hatteras to the Dry Tortugas, 1988.

Table 5. 1988 Estimated catch of seven species of grouper from Cape Hatteras, to the Dry Tortugas.

Species	Commercial		Headboat		MRFSS		Total	
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)
Speckled hind	4,872	10,985	2,138	3,761	0	0	7,010	14,746
Snowy grouper	56,502	169,089	953	1,488	2,621	1,735	60,076	172,312
Red grouper	135,782	246,846	5,101	10,615	34,108	36,868	171,991	294,329
Warsaw grouper	59,259	1,197	18,759	249	1,591	7,564	38,909	9,010
Gag	57,040	372,649	24,213	91,269	111,295	333,922	192,548	797,840
Scamp	92,012	204,098	13,975	23,590	9,205	*8,320	115,192	236,008
Black grouper	66,007	224,051	2,290	9,353	21,926	7,072	90,223	240,476

* Estimated weight does not correspond to estimated number of fish.

[1] Tip and MRFSS estimates occasionally are adjusted. Such adjustments are usually minor and will not materially affect results presented in this document.

possible) an SSR of 0.30 if major (>50%) increases in F occur, and any increase in F over the present value would require some upward adjustment in the size limit. The species is often taken at >33 fathoms and appears difficult to release alive. Further, speckled hind are taken in association with species that conceivably could support a legitimate catch. Thus the unintentional catch of speckled hind could be considerable unless the catch of associated species is sufficiently limited. And finally the SSR value presented largely reflects commercial catches, and size data from commercial catches, and size data from commercial catches were aggregated for the years 1983-1988 and includes years when F was probably less. Thus the SSR presented is probably an overestimate. Far less than 0.05% of the entire reef fish catch is of speckled hind. Given the rareness of the species and its current numerical unimportance to the catch, perhaps special goals for management of speckled hind should be considered.

Warsaw Grouper

Warsaw grouper (Figures 2 and 4) are only slightly less rare in the estimated catch than speckled hind (9,000 vs 7,000 fish out of a total catch for the 19 most commonly taken reef fishes of 12 million in 1988). Samples of warsaw grouper lengths are very rare (n = 80, 1988) and the only aging study available was based necessarily on relatively few fish (n = 124). Based on these samples and the estimated aggregate commercial and recreational catch the SSR was 0.002 for 1988. The difficulty of landing older warsaw grouper (>100 kg) could result in their disproportionate rareness in the catch and consequent overestimates of F and underestimates of SSR.

To achieve an SSR of 0.30 an 89% reduction in F appears to be required. Thus the allowable catch would be on the order of only 1,000 fish. Conversely a size limit, were it possible to apply one to these deep (>50 fathom) dwelling fish, would need to be about 44 inches. Like the speckled hind, the warsaw grouper is apparently so rare that special goals and approaches must be employed in its management. Given that the warsaw is most often taken as a bycatch to snowy grouper and other deep-dwelling species, its management could require more stringent regulation of the catch of co-occurring species than their status alone would indicate.

Snowy Grouper

The SSR for snowy grouper (Figures 2 and 4) in 1988 was only 0.15. A 42% reduction in F is needed over the region as a whole to provide an SSR of 30%. Snowy grouper apparently live in localized units, some of which are far more accessible to fishermen and far more depleted than others. Thus establishing a region-wide goal for catch reduction might not achieve a meaningful improvement in many of the substocks. The 42% reduction in F would allow a catch of only about 35,000 fish over the region, and it might be

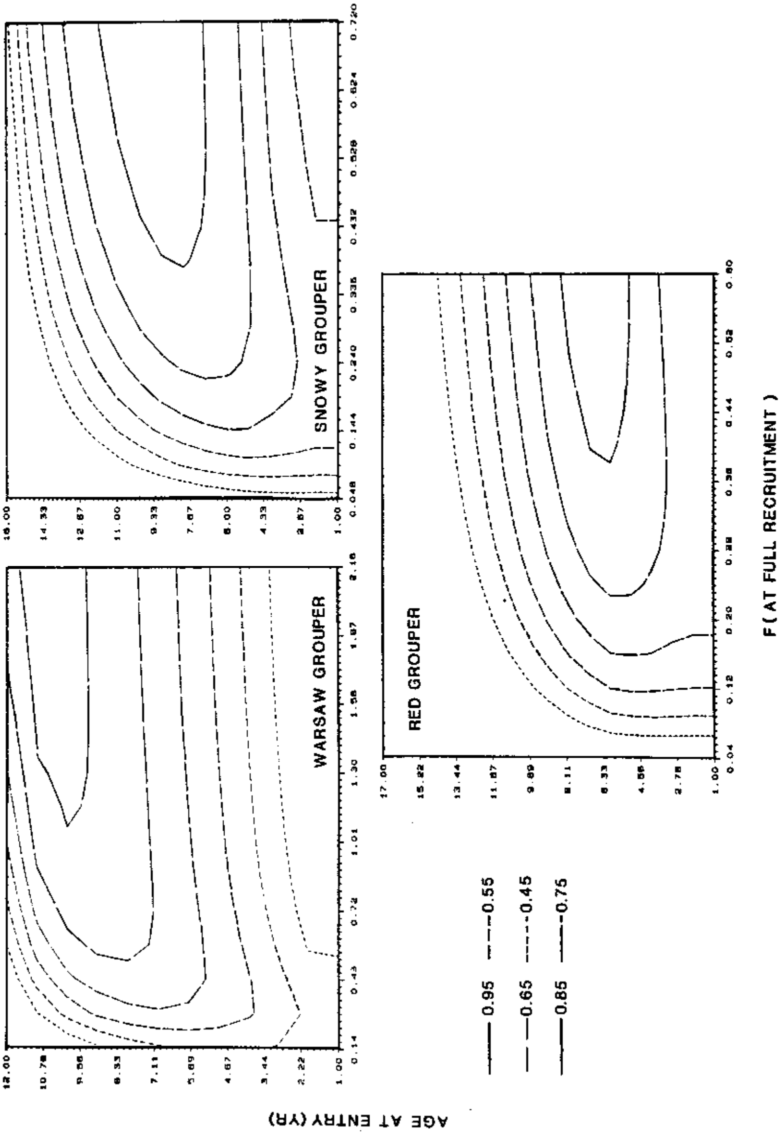

Figure 4. Yield per recruit model for warsaw, snowy, and red grouper in the region from Cape Hatteras to the Dry Tortugas, 1988.

necessary to entirely prohibit fishing on some heavily impacted areas to allow them to achieve the mean abundance for the region and to allow the species maximum use of its original range. Area specific management would entail far more detailed examination of the geographic distribution of catches and more expensive site-oriented enforcement than now exist.

Red Grouper

Of the four *Epinephelus* groupers included in this assessment, only one, the red grouper (Figures 2 and 4), displayed an SSR of >0.30, in this case, 0.41. Generally occupying shallower water (15-30 fathoms) than speckled hind, snowy, or warsaw groupers, red grouper appear more resilient to fishing. However, the region-wide SSR must be used carefully. It largely represents huge catches of red grouper landed in the Florida Keys, many of which might not come from waters in the jurisdiction of the SAFMC (despite our attempts to expunge Gulf-produced fish from the records). Further, the regional value masks the fact that the local sub-population off the Carolinas is more severely impacted (SSR-headboat=0.24, commercial=0.34) (Table 4). But from the relatively simplistic region-wide perspective, the population appears to be reproductively sound and there seems to be no need for regulation of the fishery. The proposed 20-inch size limit will yield an SSR of 0.50 at current F and will maintain SSR at >0.30 against a 250% increase in F. Only negligible gains in Y/R result from a 20-inch size limit.

DISCUSSION

The consolidation of data sets resulted, for most species, in almost textbook-perfect catch curves (Figure 5). The descending limbs of the age frequencies commonly were smooth curves even for species (especially gag and scamp) that had presented troubling and unconventional catch curves in earlier analyses (Manooch and Haimovici; 1978, Matheson *et al.*, 1986). As usual, those species for which larger samples of lengths were available (Table 2) displayed the most uniform curves.

The apparent low variability of points around the descending limb of these curves tempts speculation that for many species the assumption of equilibrium conditions is appropriate. Radically varying recruitment ought to be reflected in variation around the smooth curve. Equilibrium, if it occurs, is at the regional level. Individual reef systems possibly could experience annually varying recruitment within stable annual recruitment over the region as a whole. In fact statistical sampling theory predicts exactly such a phenomenon, with smaller sampling units exhibiting more variability than larger ones.

Historically fluctuating levels of fishing also ought to produce visible variability. However, trending levels of fishing or recruitment will not be readily discerned from inspection of the catch curves. A major assumption embedded in

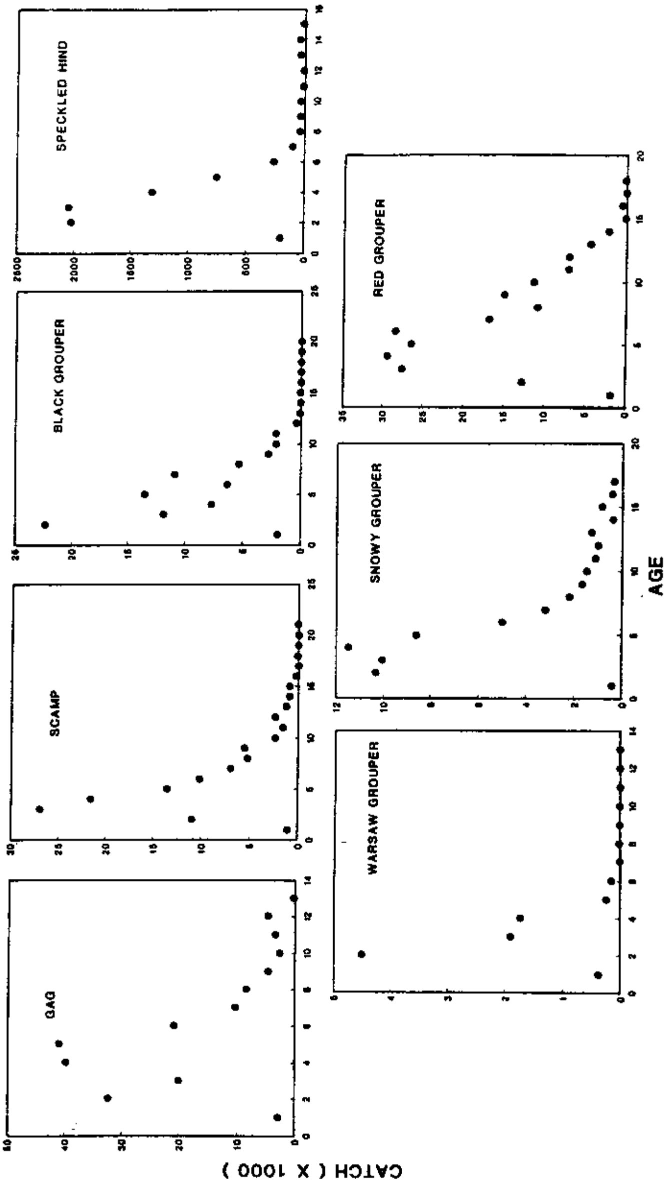

Figure 5. Estimated catch at age of seven species of grouper for all recreational and commercial fisheries operating in the region form Cape Hatteras to the Dry Tortugas, 1988.

the catch curve analysis concerns that of constant recruitment for those year classes appearing in the catch curve. Violation of this assumption, if trends occur, will result in biased estimates of fishing mortality and SSR. If recruitment is trending upwards, older fish (recruited earlier) will be under-represented compared to younger fish (recruited more recently). Hence, estimated fishing mortality will be biased upwards and resultant estimates of yield per recruit and spawning stock ratio will be too low. If recruitment is trending downward, the converse results: estimated fishing mortality will be biased downward, and estimates of yield per recruit and spawning stock ratio will be too high. If there is no trend the variation in recruitment merely results in variance about the estimates not in bias. Trends in fishing mortality could also bias the results. Increasing fishing mortality, which is almost certainly the case for much of our reef fishery, results in underestimates of F and overly optimistic estimates of SSR. While exact measures of overall fishing effort are difficult to construct, most would agree that there are more participants in the reef fishery than there were a decade ago, and it is universally acknowledged that improvements in vessel speed and marine electronics (*e.g.*, LORAN C and inexpensive fathometers) and even better weather forecasting have greatly increased the effectiveness of fishermen.

Another major assumption concerns that of a single stock. To the extent that catches come from multiple, independent substocks, overfishing in some substocks might be masked (fishing mortality underestimated) by "underfishing" in other substocks. That is, as some substocks are fished out, fishing pressure shifts to other substocks that have not yet been heavily fished. This can lead to an underestimate of the fishing mortality rate and overestimates of yield per recruit and spawning stock ratio. If our combined data represent only a portion of a stock for which mixing is slow, estimated fishing mortality from this subarea might either under-represent, over-represent, or by happenstance, accurately represent the overall level of fishing mortality of the entire stock.

For most groupers, overall regional estimates of SSR and present Y/R predominantly reflect values resulting from commercial fishing. The estimates are affected more by numbers of fish caught than by weight caught and despite a recreational fishery that took more, often smaller, individuals of many other species of reef fish, the commercial fishery took most (by number) groupers.

Overall, four of seven species studied have SSR values of less than 0.30, the criterion value chosen by the South Atlantic Fishery Management Council (SAFMC) to designate overfishing. The other three species (Table 1) have values in the range 0.32 – 0.41.

We realize that there are variances associated with these estimates and that in truth an estimate of 0.28 might not be different from one of 0.30, or for that matter, 0.35. Indeed the true SSR value for some species that appear "safe"

(SSR >0.30) might actually be less than 0.30. However, given ignorance of the variances, we have no choice but to use the point estimates with caution.

Finally, as will become apparent in subsequent text, the models of SSR provide options for increasing SSR in terms of increasing the age of the youngest fish taken (size limits) and in terms of reducing F. The projected value of size limits is based on the assumption that survival of released undersized fish is complete. As mortality of released fish increases, the effect of the size limit in increasing SSR diminishes. The diminution could be offset by a still greater size limit which in turn would have to be adjusted to account for the longer period of the fish's life when it is too small for legal retention and subject to mortality upon release. Ultimately if release mortality is too high (the exact situation varies by species and levels of fishing mortality), SSR can be increased only by reducing fishing mortality.

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