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NOAA TECHNICAL MEMORANDUM NMFS-SEFSC-442

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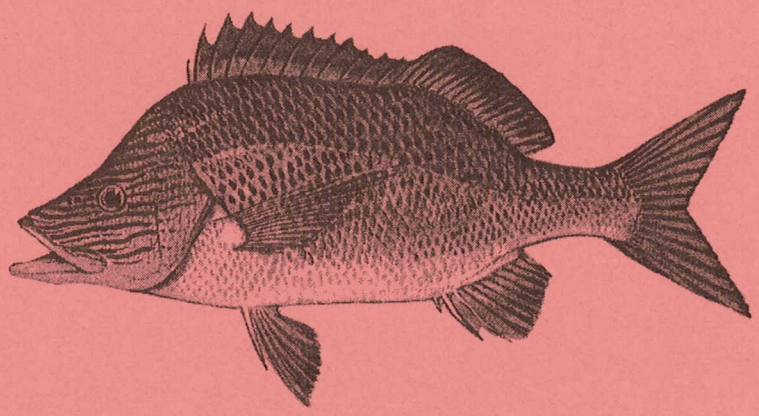

June 2000

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, NC 28516-9722

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U.S. DEPARTMENT OF COMMERCE
Norman Y. Mineta, Secretary
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
D. James Baker, Administrator
NATIONAL MARINE FISHERIES SERVICE
Penelope Dalton, Assistant Administrator for Fisheries

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NOTICE

Illustration of fish species on front cover is from Manooch, C. S. III. 1984. Fisherman's guide to the fishes of the southeastern United States. North Carolina Museum of Natural History, Raleigh, NC . 364p.

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Beaufort, NC 28516-9722

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ABSTRACT

Changes in the age structure and population size of white grunt, *Haemulon plumieri*, from North Carolina through the Florida Keys were examined using records of landings and size frequencies of fish from commercial, recreational, and headboat fisheries from 1986-1998. Data were stratified into two geographical areas: North Carolina and South Carolina; and southeast Florida. Population size in numbers at age was estimated for each year and geographical area by applying an uncalibrated separable virtual population analysis (SVPA) to the landings in numbers at age. A calibrated virtual population analysis, FADAPT, was also run for data from North Carolina and South Carolina. SVPA and FADAPT were used to estimate annual, age-specific fishing mortality (F) for four levels of natural mortality (M = 0.20, 0.25, 0.30, and 0.35). The best estimate of M for white grunt is 0.30. Landings of white grunt in the Carolinas for the three fisheries have generally decreased in recent years, but have held fairly steady for the species in southeast Florida. Age at entry and age at full recruitment were age-1 and age-4 for the Carolinas, and age-1 and age-3 for southeast Florida. With M = 0.30, levels of fishing mortality (F) on the fully-recruited ages were 0.23 for the Carolinas and 0.33 for southeast Florida. Spawning potential ratio (SPR) at M = 0.30 was 57% for the Carolinas and 61% for

southeast Florida, which indicates that the species, by definition, has not been over-exploited by fishing. The results of this assessment of the white grunt population off the Carolinas agree with the recent F/F_{MSY} analysis of white grunt (Anonymous, 1999).

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INTRODUCTION

The white grunt, *Haemulon plumieri*, is a tropical and warm-temperate water species that inhabits irregular bottom areas of the continental shelf from Virginia to Brazil, including Bermuda, the Caribbean, and the Gulf of Mexico. Although the species is frequently caught off North Carolina, South Carolina, and southeast Florida, it is seldom landed off Georgia and northeast Florida.

One of the more colorful members of the family Haemulidae, the white grunt is sliver-gray with numerous blue and yellow stripes on the head and body. Like many grunts, the white grunt has a bright red interior of the mouth. The genus name, *Haemulon*, is derived from the Greek words *haimia* meaning "blood", and *oulon*, meaning "mouth" (Manooch, 1984).

Like most reef fishes, the white grunt is a generalized carnivore that feeds on a variety of bottom-dwelling invertebrates. The easily protrusible jaws allow the species to root through the sand and shell that are found between rock or coral formations. Preferred foods are crabs, shrimps, mollusks, and worms (Manooch, 1984). Spawning occurs during the warmer months, March through September, with a peak from May through July. About half of the females were found to be mature as age-1; 88% as age-2; and virtually all were sexually mature by age-3 (Padgett et al., 1997).

White grunt are reported to attain a length of approximately 25 inches (Manooch, 1976), and live for at least 13 years off the Carolinas (Potts and Manooch, in press). White grunt off southeast Florida were reported as large as 15 inches, but live for at least 15 years (Potts and Manooch, in press). Sizes at ages were different for the two geographical areas. White grunt from the Carolinas were significantly larger at a given age than were those captured off southeast Florida (Potts and Manooch, in press). This species has a disjunct distribution along the southeastern coast of the U.S. It is abundant off North Carolina and South Carolina, but then it is absent or rare off Georgia and northeast Florida. Catches of white grunt occur off Palm Beach County, Florida through the Florida Keys. The distribution of white grunt coupled with the size difference between the two geographic areas suggests that white grunt off the Carolinas should be treated as a separate stock from white grunt off southeast Florida.

In terms of commercial finfish value, the species ranked from 43rd to 59th place for the entire southeastern United States from 1990-1998 (Table 1). Fishermen were able to sell white grunt at dockside for $0.46 to $0.70 per pound (Table 1). The species is relatively important to the commercial fisheries of South Carolina, where it has ranked from 17th to 32nd for all finfish from 1990-1998 (Table 2). By contrast, the white grunt is

relatively less important to commercial fisheries off South Florida and North Carolina (Table 2).

The above discussion of monetary value is complicated because commercial white grunt landings, as recorded in the General Canvass, are included in a "grunts unclassified" category. Therefore, I consulted with port sampling agents in each area along the coast, as well as made cross comparisons with length frequency data that were identified to species. This enabled me to conclude that virtually all "grunts" landed in the Carolinas are white grunt, as are 88% of those for southeast Florida.

Table 1. Rank by value ($) of total southeastern U.S. landings of grunts landed commercially.

Year	Rank	Price/lb
1990	43	0.48
1991	46	0.48
1992	56	0.46
1993	59	0.46
1994	55	0.51
1995	53	0.54
1996	54	0.57
1997	44	0.64
1998	48	0.70

Table 2. Rank by value($) of grunts landed commercially in North Carolina, South Carolina, and southeast Florida.

	North Carolina		South Carolina		SE Florida	
Year	Rank	$/lb	Rank	$/lb	Rank	$/lb
1990	36	0.44	19	0.69	36	0.37
1991	36	0.46	17	0.70	37	0.39
1992	38	0.50	25	0.54	43	0.37
1993	38	0.48	27	0.53	42	0.40
1994	37	0.52	25	0.59	40	0.48
1995	38	0.54	26	0.56	32	0.57
1996	45	0.58	32	0.59	30	0.63
1997	43	0.69	31	0.63	32	0.62
1998	39	0.72	28	0.74	27	0.69

The South Atlantic Fishery Management Council (SAFMC) has taken no action to regulate the harvest of this species, other than to ban commercial trawl gear in 1989 [Amendment 1 to the Snapper-Grouper Fishery Management Plan (FMP)]. The FMP for the snapper-grouper fishery was implemented on 31 August 1983. Neither Amendment 4 to the FMP, effective 1 January 1992, nor Amendment 9, which was implemented in February 1999, placed restrictions on the harvest of white grunt. The harvest of many other species in the snapper-grouper complex was impacted by the amendments.

This assessment of the white grunt stock(s) from North Carolina (south of Cape Hatteras) through the Florida Keys was conducted to facilitate decision-making by the SAFMC. Previous assessments of the species have been inadequate for establishing sound management recommendations. The SAFMC FMP (SAFMC, 1983)

includes only discussions of the species, Huntsman et al. (1992) provided an assessment for the species using data from 1990, and Potts et al. (1998) derived a static Spawning Potential Ratio (SPR) using 1996 data.

In this report I compute and document changes in the age structure and population size for the species over a period of 13 years and for two geographic areas. Specifically, age-specific estimates of instantaneous fishing mortality rates and information on growth, sex ratios, maturity and fecundity, analyses of yield per recruit (YPR) and spawning potential ratio (SPR) are used to determine the status of the southeastern U.S. white grunt stock(s).

METHODS

Trends

For purposes of this report, white grunt are landed by three fisheries: Commercial, headboat, and other recreational (Marine Recreational Fisheries Statistical Survey -- MRFSS). Although landings are available for different years depending on fishery, only data from 1986-1998 were available for all three fisheries, and thus, useful for this assessment.

The commercial fishery statistics are reported in three databases. General Canvass is the official record of landings;

the Trip Interview Program (TIP) contains the length samples; and the Snapper-Grouper Logbook Program provides effort information and was initiated in 1992 as a pilot program. In that year, 25% of the snapper-grouper permittees reported their catch. Since 1993, 100% have participated in the program (NMFS, Miami, Florida). As mentioned previously, assumptions had to be made concerning "unclassified grunts" as reported by the commercial General Canvass. After analysis of the length samples and personal communications with port samplers, it was determined that in North Carolina and South Carolina 100% of "grunts unclassified" were white grunt, and in southeast Florida, 88% were white grunt. We used the water body codes of Monroe County to include only the Atlantic portion of grunt landings and TIP samples.

Headboats are those vessels usually carrying more than six passengers, charge on a per person basis, thus by the "head", and are considered separate for our analyses from the other recreational vessels. The headboat statistics include a landings database and a "bioprofile" (sampling) database, each started in 1972 (NMFS, Beaufort, North Carolina).

The recreational fishery (MRFSS) includes hook and line fishing from shore or any platform other than headboats. The survey includes small private boats and charter boats (six passengers or less). The MRFSS statistics, available from 1981-

1998, are also broken into two sets: Aggregate files containing the estimated landings, and intercept files which contain on-site sampling information (NMFS, Silver Spring, Maryland).

Landings data and length samples were used to describe annual trends in catches, including catch in number, catch in weight, and mean fish size. Catch-per-effort was provided for the commercial data, the headboat data, the MRFSS data, and fishery-independent data. The databases were stratified into two areas: 1) North Carolina and South Carolina, and 2) southeast Florida (from St. Lucie County through the Atlantic portion of Monroe County).

Because the MRFSS landings are recorded only by "sub-region" and state, I used the ratio of length samples by county from the intercept files to divide Northeast Florida from Southeast Florida. Also, Monroe County, FL landings are included in the west coast of Florida MRFSS statistics and had to be apportioned out and added to east coast Florida landings. For estimates of Monroe County, I used the proportion of white grunt from the county versus the rest of the west coast of Florida. All Monroe County landings were considered to be part of the southeastern U.S. Atlantic landings.

To draw conclusions about the white grunt population from fish that were sampled from catches, it is very important that samples were representative of the stock (e.g., size, sex,

distribution, etc.), and were adequate in number. Although some assumptions must be made for the former, biologists and managers should have more control over the latter. To evaluate the adequacy of sampling intensity for the three fisheries (headboat, recreational, and commercial), and for the Carolinas and southeast Florida, I used the informal criterion of 100 fish sampled per 200 metric tons of that species landed (USDOC, 1996).

Age/Growth

Growth parameters, weight-length relationships, and fish age-fish length keys were obtained from a recent study of white grunt from the Carolinas and southeast Florida [fish sampled from 1990-98 by Potts and Manooch (in press)].

Development of Catch-in-Numbers-at-Age Matrix

Data used in the construction of the catch matrix for years 1986-1998 were derived from the sampling databases and landings databases discussed previously, and from the Potts and Manooch (in press) age-length keys. The data covered the geographical areas of North Carolina through South Carolina, and St. Lucie County, Florida through the Florida Keys. The two areas were analyzed separately.

Derivation of catch in numbers at fish age consisted of multiplying the catch in numbers (n, scalar) by the fish age-fish length key (A, matrix) by a length frequency distribution (L, vector) to obtain the catch in numbers by fish age (N, vector):

$$N_{ax1} = n \cdot A_{axb} \cdot L_{bx1} \quad \text{(Vaughan et al., 1992)},$$

where "a" is the number of ages (1 to 15 years), and "b" is the number of length intervals. The length frequencies were generated from each fishery by year, area, and gear. When samples were lacking for a particular strata (e.g., gear, year), I used samples from a previous year and gear or lumped same gear type samples across years, keeping the two areas separate. Since commercial landings are reported by weight only, the commercial catch of white grunt was converted to numbers by dividing the weight landed by the mean weight, stratified by year, geographical area, and gear. The mean weights were estimated from the length samples (TIP) converted to weights by area-specific weight-length equations from Potts and Manooch (in press).

Mortality Estimates

Total Instantaneous Mortality (Z)

Total instantaneous mortality for each area was estimated by analyzing catch curves (Beverton and Holt, 1957) based on fully-

recruited age fish. Mortality estimates under equilibrium assumption were obtained by regressing the natural log of the catch in numbers against age for fully-recruited fish.

Natural Mortality (M)

Natural mortality is often estimated from relatively weak life history and ecological analogies, yet is a very important step in determining that portion of total mortality which may be attributed to fishing. Natural mortality can perhaps be best estimated by using bioprofiles characteristics as demonstrated by Pauly (1979) and later by Hoenig (1983).

Pauly (1979) used von Bertalanffy parameters (L_∞ and K) as well as mean water temperature (T ^{0}C) for the general habitat:

$$\log_{10}M = 0.0066 - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T.$$

Sea surface temperature readings from buoys operated by NOAA's National Oceanographic Data Center were used to calculate mean annual seawater temperature for the Carolinas and southeast Florida. Buoys recorded temperature every hour or half hour, and monthly averages were calculated for one location off the Carolinas and two locations off southeast Florida. These monthly averages provided mean annual temperatures for the Carolinas (22^{0}C) and for southeast Florida (26^{0}C). I used 1996 and 1998 data from Edisto off South Carolina, and 1998 data from Fowey

Rocks off Miami, and the Dry Tortugas. The locations of the buoys used are

1) Edisto - 32.5° N 79.1° W

2) Fowey Rocks - 25.6° N 80.1 W

3) Dry Tortugas - 24.6 N 82.9 W

Hoenig (1983) utilizes the maximum age (t_{max}) in an unfished stock of a species:

$$\ln M = 1.46 - 1.01 \ln t_{max}.$$

Because this relationship is based on Z, rather than M, the maximum age in the virgin population (F = 0; M = Z-F) would provide an approximate estimate of natural mortality.

Hoenig (1983) also provides an estimate of Z which takes into account the sample size used in the study, the rationale being one has a greater chance of encountering the true maximum age of the fish with increasing sample size. The equation used is

$$Z = \ln(2n + 1)/(t_{max} - t_c),$$

where t_c = first age fully represented in the catches.

Natural mortality was also estimated following the methods of Roff (1984), which used optimal length at maturity, and Rikhter and Efanov (1977) using age at 50% maturity. For both methods, I incorporated the information from Padgett et al. (1997) for the Carolinas to obtain length at 50% maturity, and then used the inverse of the von Bertalanffy growth equation to

solve for the corresponding age at 50% maturity. No maturity information was available on white grunt from south Florida. Instead, I used observations from Darcy (1983) and an age-length key from Potts and Manooch (in press) to estimate age and size of maturity for white grunt from south Florida.

I also derived estimates of M from the empirical equation of Ralston (1987): $M = 0.0189 + 2.06*K$. This regression equation was developed by surveying the literature for instances in which the von Bertalanffy growth parameter K was jointly estimated with M. Nineteen populations of snapper and grouper species were used, and data were pooled to develop the regression. Another method to estimate M was the method of Alverson and Carney (1975), which allows prediction of M from estimates of maximum age and the Brody growth coefficient, K. One final method used to estimate M was the relationship developed by Alagaraja (1984): $S(t_\lambda) = e^{-Mt\lambda}$, where t_λ = maximum age and $S(t_\lambda)$ = survivorship to the maximum age.

Fishing Mortality (F) and Virtual Population Analysis (VPA)

Once natural mortality and total instantaneous mortality have been estimated, it is an easy exercise to obtain fishing mortality, F (e.g., $Z = M + F$; $F = Z - M$). However, a problem arises from the equilibrium assumption of constant F and recruitment. In this assessment, age-specific fishing mortality

rates and estimates of white grunt age-specific population size in each area were obtained by applying an uncalibrated separable virtual population analysis (SVPA) technique. Because of the short time frame of the catch matrix (1986-1998) relative to the number of reported ages for the species (1-13 for the Carolinas and 1-15 for southeast Florida), this was not completely successful. The SVPA methods are explained briefly below.

The catch matrix was interpreted using the separable virtual population analysis (SVPA) approach to obtain annual age-specific estimates of population size and fishing mortality rates. Virtual population analysis sequentially estimates population size and fishing mortality rates for younger ages of a cohort from a starting value of fishing mortality for the oldest age (Murphy, 1965). An estimate of natural mortality, usually assumed constant across years and ages, is also required. The separable method of Doubleday (1976) assumes that age- and year-specific estimates of F can be separated into products of age and year components. I used the FORTRAN program developed by Clay (1990), based on Pope and Shepherd (1982).

The uncalibrated separable VPA estimated age-specific availability, or the partial recruitment vector, was then used to set up the calibrated VPA. A method of VPA that uses fishery-independent indices of abundance in the calibration process was used for the Carolinas. No fishery-independent data were

available from southeast Florida. The specific calibration approach was developed by Gavaris (1988) and modified by Victor Restrepo (Cooperative Institute of Fisheries Oceanography, University of Miami, Miami, FL) as the program FADAPT. The index used for tuning the VPA was from MARMAP data for Chevron traps (1990-1998).

Yield Per Recruit

The yield per recruit model was used to estimate the potential yield in weight for white grunt from each area and was based on the method of Ricker (1975). The model estimates total weight of fish taken from a cohort divided by the number of individuals of that cohort that recruited into the fishery. Because I do not have enough data to run the analysis on cohorts, I used the equilibrium assumption on the stock to run the model. Unlike the full-dynamic pool model (Beverton and Holt, 1957), the Ricker-type model only requires parameters that are relatively easily obtainable: M, F, K, L_∞, t_r (age at recruitment to the fishery), and fishing at ages prior to full recruitment. All shape the response surface (i.e., how the white grunt yield per recruit reacts to various levels of fishing effort). The above-mentioned parameters were estimated as discussed previously.

Spawning Potential Ratio

Gabriel et al. (1989) developed percent maximum spawning potential (%MSP) as a biological reference point. The currently-favored acronym for this approach is referred to as equilibrium or static spawning potential ratio (SPR). A recent evaluation of this reference point is given in a report by the Gulf of Mexico SPR Management Strategy Committee for the Gulf of Mexico Fishery Management Council [see Mace and Sissenwine (1993), and Mace (1994)]. Equilibrium, or static, SPR was calculated as a ratio of spawning stock size when fishing mortality was equal to the observed or estimated F divided by the spawning stock size calculated when F was equal to zero. All other life history parameters were held constant (e.g., maturity schedule and age-specific sex ratios). Hence, the estimate of static SPR increases as fishing mortality decreases.

The SAFMC defines and explains static spawning potential ratio (SPR) as "a measure of an average female's egg production over its lifetime compared to the number of eggs that could be expected if there was no fishing. When there is fishing pressure, a fish's life expectancy is reduced, and so is its average lifetime egg production. A species is considered overfished if its SPR drops below a level beyond which the ability of the stock to produce enough eggs to maintain itself is in jeopardy" (SAFMC,

1996). The SAFMC defines a reef fish stock as overfished if the SPR is < 0.30 (< 30%), and recovering with SPR values ranging from 0.30-0.39 (30-39%). The target is to obtain an SPR of 0.40 or greater (> 39%) (Gregg Waugh, SAFMC, Charleston, SC, pers. comm.). Longevity, age-specific fecundity, and age-specific fishing mortality are critical to the derivation of SPR.

Because this species is gonochoristic and does not change sex, comparisons of age-specific spawning stock biomass were based on mature female biomass. I derived the sexual maturity schedule for white grunt from information provided by Padgett et al. (1997) for North Carolina and South Carolina, and as referenced in Darcy (1983) for southeast Florida.

RESULTS

Sampling Adequacy

I used an informal standard developed by the NMFS, Northeast Regional Stock Assessment Workshop (USDOC, 1996) to determine the adequacy of biological sampling of white grunt landings by year and area (Table 3a and b). According to this standard, 100 fish lengths should be recorded for each 200 mt of the species landed. Thus, a value less than 100 samples/200 mt indicates an inadequate sample. Using 1986-1998 data, for the Carolinas and southeast Florida, I found drastic differences by fishery and

area. Samples for the Carolinas for all three fisheries were adequate for every year (Table 3a). However, samples were frequently inadequate for southeast Florida recreational (MRFSS) and commercial landings. MRFSS samples were inadequate for six of the 13 years (1988, 1989, 1990, 1991, 1992, and 1997), and commercial landings samples were inadequate for five years, 1986, 1987, 1988, 1989, and 1991 (Table 3). By contrast, headboat sampling provided adequate samples each year.

The problem identified here for MRFSS-sampled white grunt holds true for four species for which recent population assessments have been prepared by the Beaufort Laboratory : Red snapper, *Lutjanus campechanus,* (Manooch et al., 1998a), scamp, *Mycteroperca phenax* (Manooch et al., 1998b), vermilion snapper, *Rhomboplites aurorubens* (Manooch et al., 1998c), and gag, *Mycteroperca microlepis* (Potts and Manooch, 1998). This is the first time I have encountered a problem with commercial biological sampling.

Table 3. Level of sampling per year by fishery for white grunt in the Carolinas and southeast Florida. Adequate level of sampling is equivalent to 100 length samples per 200mt (the ratios that are blocked indicate the year and fishery where samples were determined to be inadequate.)

a. Carolinas

	MRFSS		Headboat		Commercial	
Year	# of samples/mt	Equivalent	# of samples/mt	Equivalent	# of samples/mt	Equivalent
1986	0/0	-	1272/48.3	5267	310/59.9	1034
1987	30/23.3	258	2472/55.1	8973	656/90.2	1455
1988	116/29.7	781	1947/53.9	7224	408/101.6	803
1989	50/27.3	366	1470/51.5	5709	359/111.5	644
1990	78/146.3	107	1467/62.9	4665	605/137.7	879
1991	94/32.0	588	1643/109.2	3009	400/119.0	672
1992	100/75.9	264	1678/55.8	6014	580/93.5	1241
1993	119/57.1	417	1845/57.9	6373	911/84.7	2151
1994	77/59.2	260	1676/64.2	5221	544/100.5	1083
1995	60/23.8	504	2154/60.7	7097	1053/88.1	2390
1996	52/20.1	517	908/39.4	4609	674/52.5	2568
1997	48/22.4	429	1034/47.6	4345	1129/70.5	3203
1998	41/ 5.8	1414	1167/41.7	5597	1117/58.2	3838

b. Southeast Florida

	MRFSS		Headboat		Commercial	
Year	# of samples/mt	Equivalent	# of samples/mt	Equivalent	# of samples/mt	Equivalent
1986	73/60.4	242	1476/40.9	7218	0/36.3	**0**
1987	175/170.0	206	824/58.4	2822	0/59.7	**0**
1988	108/224.0	**96**	643/69.3	1856	0/46.8	**0**
1989	0/152.2	*	806/59.5	2709	0/40.4	**0**
1990	52/140.1	**74**	851/60.1	2832	45/49.4	182
1991	119/447.4	**53**	697/31.1	4482	0/44.2	**0**
1992	107/225.7	**95**	491/38.1	2577	67/18.1	740
1993	225/252.2	178	781/38.3	4078	83/21.4	776
1994	382/397.9	192	1045/39.4	5305	241/28.3	1703
1995	215/270.7	159	1216/38.1	6383	129/40.0	645
1996	84/114.9	146	1764/48.8	7230	374/41.5	1802
1997	32/39.2	**92**	1844/37.0	9968	506/77.3	1309
1998	128/85.0	301	1970/36.4	10824	1148/49.5	4638

Trends - Landings

Commercial

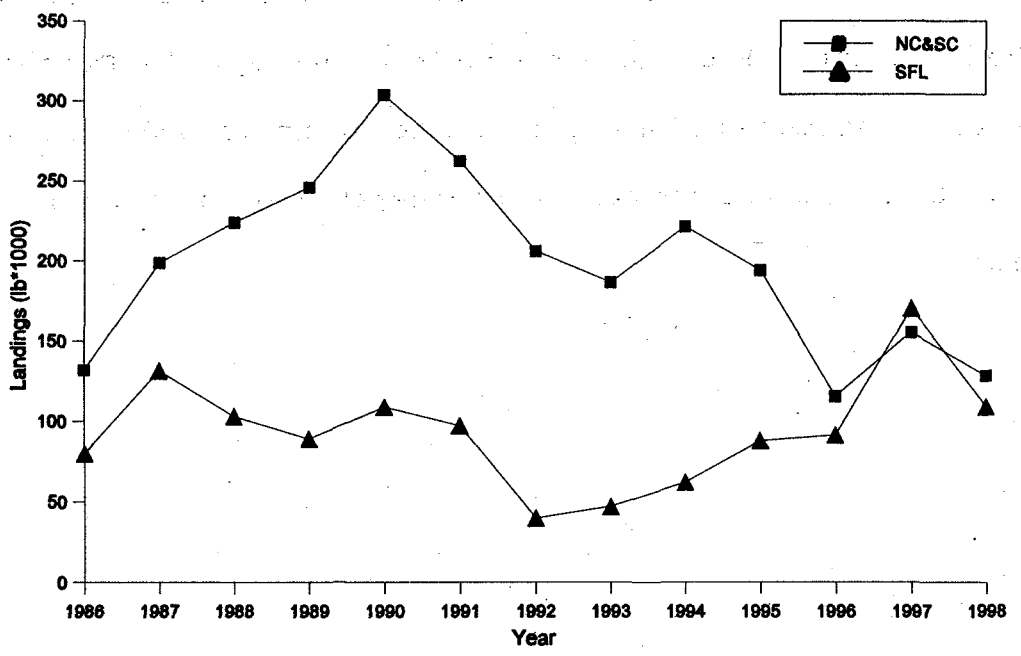
The most reliable and uninterrupted time series for commercial landings is from the General Canvass and begins in 1986. From 1986-1998, landings in the Carolinas averaged 198,071 pounds (N = 13), but only averaged 93,743 pounds in southeast Florida (Table 4). In contrast, the estimated number of white grunt landed in the Carolinas averaged 123,279, while in southeast Florida, the estimated number landed averaged 152,101.

Landings have generally decreased since 1990 in the Carolinas (Fig. 1). In southeast Florida, landings have been increasing since a low in 1992. Most white grunt by weight were landed at ports from North Carolina and South Carolina. The species is absent or rare in reef fish landings in Georgia and northeast Florida. Landings of white grunt pick up again around Palm Beach County, Florida and continue through the Florida Keys (Table 4). Estimated numbers of white grunt landed indicate they are caught in greater number in southeast Florida than in the Carolinas.

Table 4. Commercial white grunt landings (weight in lb and estimated numbers) in North Carolina and South Carolina and in southeast Florida.

	NC & SC		SE Florida	
Year	Wt.	No.	Wt.	No.
1986	132,099	74,271	80,089	113,881
1987	198,835	118,334	131,528	187,021
1988	224,073	120,969	103,066	146,552
1989	245,877	140,231	89,062	126,640
1990	303,519	253,022	108,961	154,935
1991	262,266	188,932	97,345	138,417
1992	206,227	130,730	39,877	56,879
1993	186,818	93,263	47,135	83,189
1994	221,644	136,299	62,345	117,828
1995	194,128	113,660	88,121	165,171
1996	115,637	67,242	91,509	186,972
1997	155,417	94,966	170,481	324,912
1998	128,377	70,712	109,135	174,921

Figure 1. Commercial landings of white grunt from North Carolina and South Carolina and from southeast Florida.



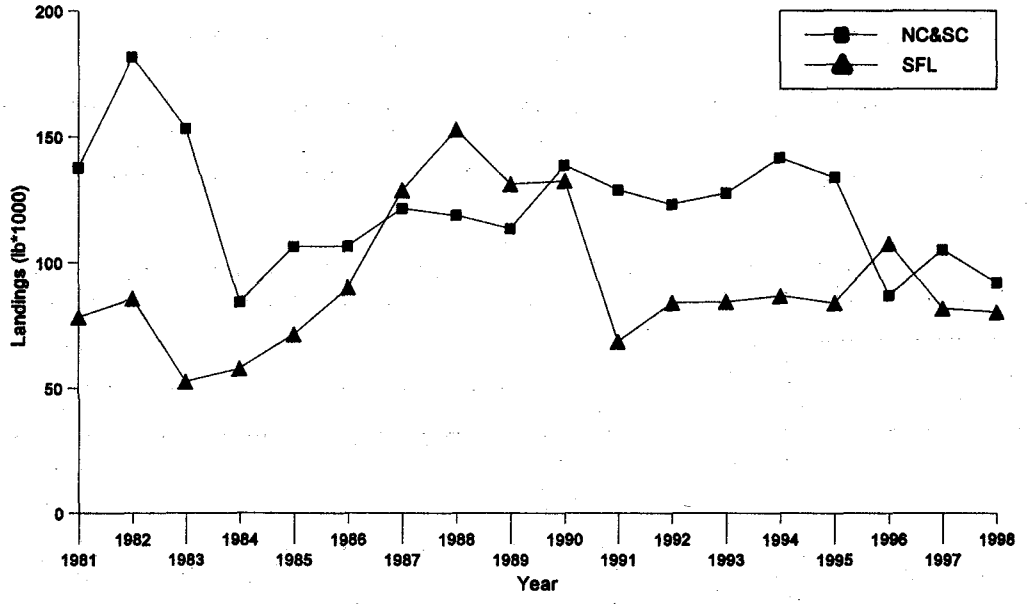
Headboat

Headboat data are available for both areas for the years 1981 through 1998 (Table 5; Fig. 2). For the 18-year period, landings averaged 121,902 pounds in the Carolinas and 92,138 pounds in southeast Florida. Catches have generally remained steady since 1984 in the Carolinas, but have been decreasing since a peak in 1988 in southeast Florida. White grunt landings from each area followed a similar trend as the commercial landings. The total weight landed in the Carolinas is higher than in southeast Florida, but the number of fish is higher in southeast Florida than in the Carolinas (Table 5). In the Carolinas, landings in number have generally increased through 1990, held relatively steady through 1995, but then declined in 1996-1998. In southeast Florida, number of white grunt landed peaked in 1988 and declined somewhat after 1990, but are still higher than the early 1980's (Table 5).

Table 5. White grunt headboat landings (lb and #) from North Carolina and South Carolina and from southeast Florida.

	NC & SC		SE Florida	
Year	Wt.	No.	Wt.	No.
1981	62,485	72912	35,532	98,643
1982	82,397	97853	38,884	107,789
1983	69,523	70657	23,853	83,416
1984	38,286	48,811	26,254	88,153
1985	48,236	68,279	32,433	108,813
1986	48,332	68,891	40,880	130,619
1987	55,134	104,638	58,400	207,515
1988	53,881	95,387	69,320	240,061
1989	51,509	103,259	59,520	196,648
1990	62,897	128,457	60,062	221,698
1991	58,414	122,824	31,071	114,529
1992	55,835	113,911	38,124	140,894
1993	57,859	117,002	38,271	144,266
1994	64,227	122,017	39,367	140,787
1995	60,689	113,614	38,105	124,849
1996	39,383	65,952	48,772	169,171
1997	47,603	80,708	37,036	137,942
1998	41,723	70,867	36,391	132,712

Figure 2. Headboat landings of white grunt in North Carolina and South Carolina and in southeast Florida.



Recreational (MRFSS)

Recreational fishing statistics are available for 1981 through 1998. Landings of white grunt are presented by number and weight (pounds) in Table 6 by year and area. Prior to 1986, charter boat landings were lumped with headboat landings. The two were separated based on the proportion of length samples from each source, and the headboat portion was eliminated. During the 18-year period, the average recreational catch was 84,778 pounds in the Carolinas and 455,274 pounds in southeast Florida. Landings in the Carolinas peaked in 1990 at approximately 325,969 pounds and then decreased to 29,099 by 1998. Landings in southeast Florida peaked in 1991 at 986,596 pounds and fell to

187,533 pounds in 1998 (Table 6, Fig. 3).

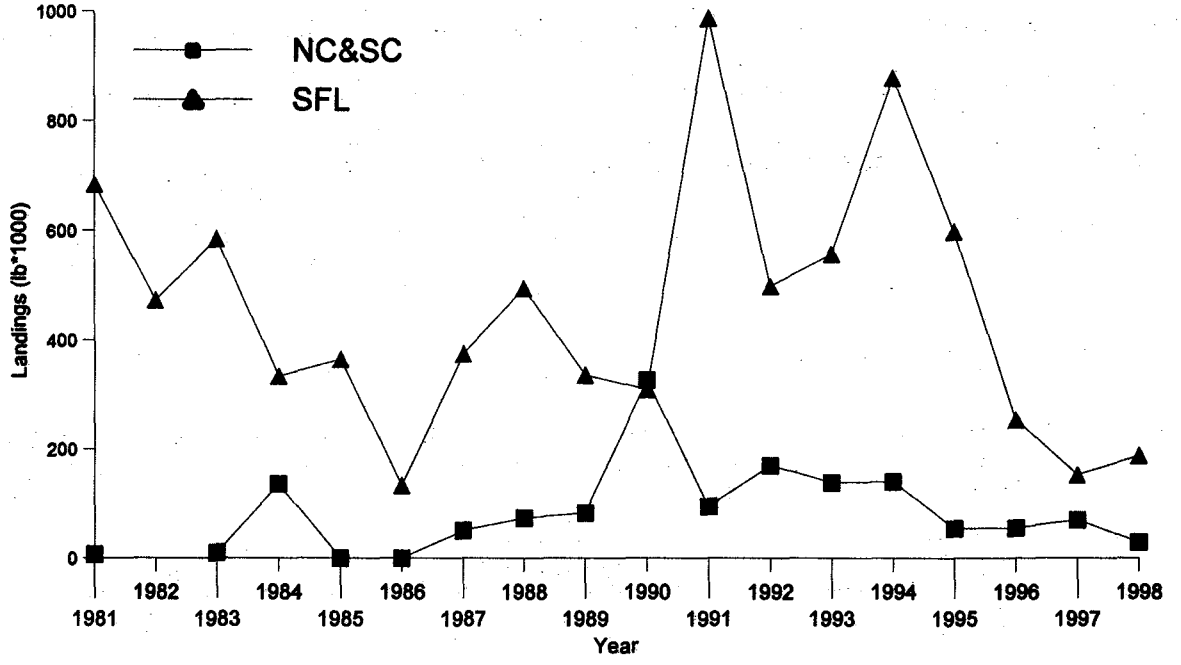
Recreational landings in the Carolinas are equal to approximately one half of the commercial landings and three fourths of the headboat landings. On the other hand, recreational landings in southeast Florida are five times the commercial landings and five times the headboat landings.

Table 6. MRFSS landings of white grunt by weight (lb) and number of fish from North Carolina and South Carolina and from southeast Florida.

	NC & SC		SEFL	
Year	Wt.	#	Wt.	#
1981	6,731	5,497	684,240	1,556,718
1982	*	804	473,217	1,107,794
1983	10,445	11,844	584,631	1,386,807
1984	135,567	126,813	333,528	1,020,340
1985	328	1487	364,759	756,255
1986	0	0	133,245	387,525
1987	51,429	42,727	374,788	762,363
1988	73,916	59,664	493,970	671,980
1989	83,177	68,247	335,731	516,222
1990	325,969	209,428	308,891	480,996
1991	94,735	89,782	986,596	1,272,921
1992	169,972	112,500	497,575	676,422
1993	138,734	134,838	555,992	834,518
1994	140,584	162,087	877,448	1,377,100
1995	54,512	66,048	596,856	827,342
1996	55,588	42,293	253,279	359,255
1997	70,447	47,382	152,649	217,089
1998	29,099	20,036	187,533	390,380

* No landings in weight were given in the database, though landings in number of white grunt was.

Figure 3. Recreational (MRFSS) landings of white grunt from North Carolina and South Carolina and from southeast Florida.



Trends - Catch/Effort

Commercial

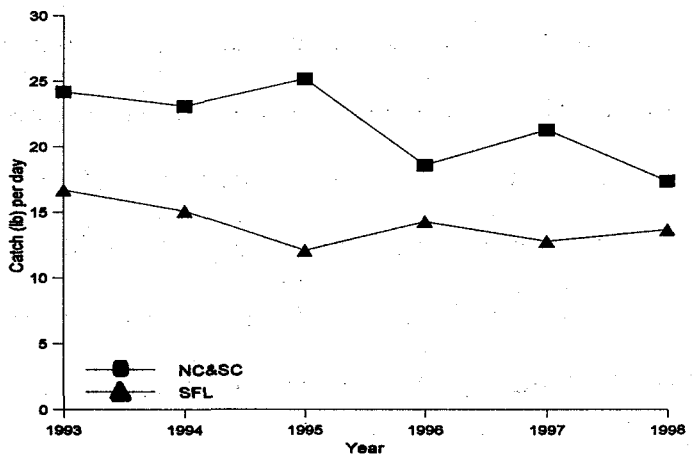
Commercial catch per unit effort (CPUE) data are available from 1993 through 1998 from the Snapper-Grouper Logbook Program. Effort was measured as pounds landed per number of days away from the dock. I used number of days away rather than number of trips as effort because "trips" were not standardized and could be any number of days long. CPUE was estimated for all gears combined by the two separate areas: Carolinas and southeast Florida. White grunt are landed primarily by vertical hook and line gear

with a small portion caught in traps. In the Carolinas, CPUE has decreased from a high of 24.2 pounds per day in 1993 to 17.4 pounds per day in 1998 (Table 7, Fig. 4). CPUE for white grunt landed in southeast Florida was slightly lower than in the Carolinas. It has remained fairly steady ranging from a high of 16.7 lb/day in 1993 to a low of 12.1 lb/day in 1995 (Table 7, Fig. 4).

Table 7. Commercial catch (lb) per number of days away from the dock of white grunt landed in the Carolinas and southeast Florida, using Snapper-Grouper Logbook data.

Year	Carolinas	Southeast Florida
1993	24.2	16.7
1994	23.1	15.1
1995	25.2	12.1
1996	18.6	14.3
1997	21.3	12.8
1998	17.4	13.7

Figure 4. Commercial CPUE of white grunt from Snapper-Grouper Logbook data.



Headboat

Catch per unit effort data are available for 1972 through 1998 for North Carolina and South Carolina, and 1982 through 1998 for southeast Florida. Annual CPUE values for areas separately are presented in Table 8 and Figs. 5 and 6 as number of white grunt, or weight in pounds of white grunt, caught per angler day.

In the Carolinas, catch rates were at their highest from 1972 through 1976. They were low in the late 1970's, but then started increasing again to a fairly constant level between 1989 and 1995 when the rates decreased again by 1/3 from 1996-1998 (Table 8, Fig. 5). In southeast Florida, CPUE was at its lowest in 1982 through 1986. Between 1987 and 1990, CPUE averaged one fish per angler day, then dropped to under one through 1995. CPUE in the last three years averaged over one fish per angler day. CPUE in weight of fish follow a similar trend as the number of fish (Table 8, Fig. 6). The peaks in CPUE correspond with peaks in the landings except for southeast Florida in 1996 through 1998. The landings in southeast Florida were not at the level of the late 1980's, but the number of angler days decreased dramatically from an average of 204,000 angler days in 1982 through 1991 to drop to an average of 126,000 between 1996 and 1998. It is also interesting to note that though the number of white grunt landed in southeast Florida is twice the number landed in the Carolinas, CPUE is about the same from both areas.

Table 8. Headboat catch (number and pounds) per angler day of white grunt from the Carolinas and southeast Florida.

	Carolinas		Southeast Florida	
Year	#	lb	#	lb
1972	2.78	4.65		
1973	1.36	2.45		
1974	1.47	2.03		
1975	1.87	1.65		
1976	1.87	1.57		
1977	0.73	1.23		
1978	0.44	0.85		
1979	0.57	1.01		
1980	0.47	0.99		
1981	0.93	1.76		
1982	1.04	1.91	0.48	0.37
1983	0.79	1.72	0.43	0.26
1984	0.51	0.88	0.45	0.31
1985	0.70	1.10	0.58	0.37
1986	0.70	1.08	0.64	0.44
1987	0.92	1.06	0.95	0.60
1988	0.80	0.99	1.25	0.79
1989	1.02	1.12	0.92	0.62
1990	1.28	1.39	0.99	0.60
1991	1.13	1.18	0.59	0.35
1992	1.11	1.19	0.81	0.49
1993	1.09	1.19	0.89	0.53
1994	1.22	1.41	0.80	0.49
1995	1.11	1.30	0.88	0.60
1996	0.73	0.97	1.11	0.71
1997	0.83	1.08	1.14	0.68
1998	0.72	0.93	1.28	0.77

Figure 5. Headboat catch (# and lb) per angler day of white grunt caught off North Carolina and South Carolina.

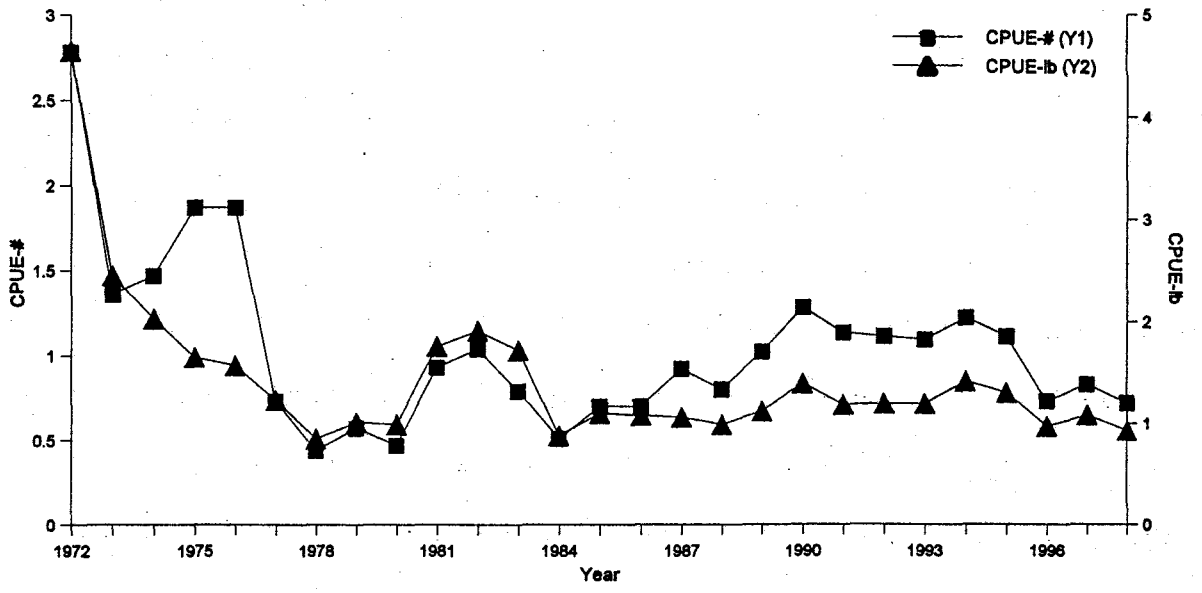
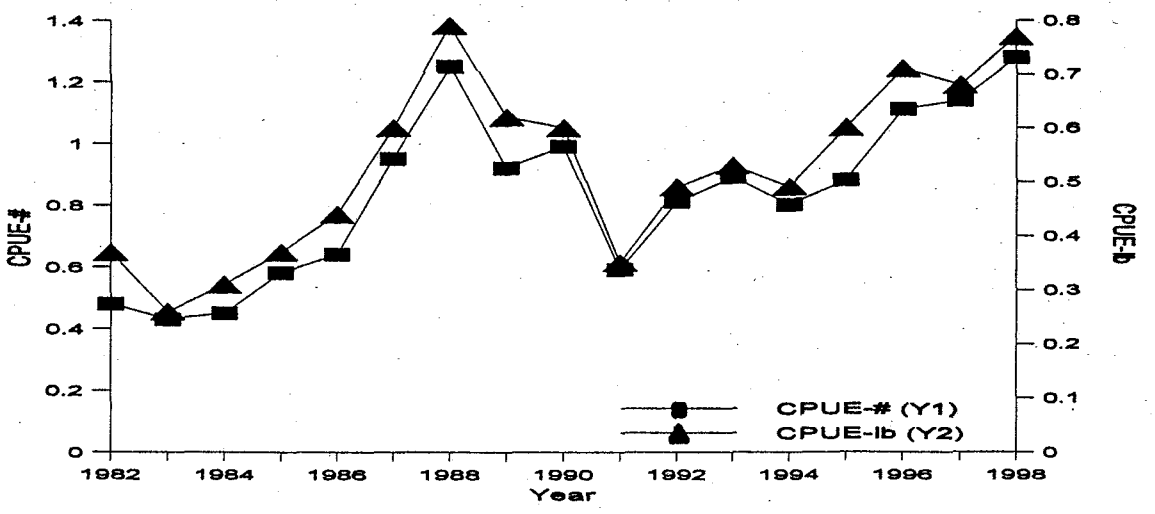


Figure 6. Headboat catch (# and lb) per angler day of white grunt caught off southeast Florida.



Recreational (MRFSS)

Recreational CPUE data are available for the southeastern United States from 1981 through 1998 (Table 9 and Fig. 7). Catch rates were recorded as number of white grunt caught per angler trip. Prior to 1986, CPUE was a crude estimate because charter boats and headboats landings were lumped together. Annual CPUE values were high compared with the headboat CPUE data. This difference is at least partially due to the way CPUE was calculated. An angler trip from MRFSS data was included only if white grunt was identified as the primary or secondary species sought on that trip. The headboat angler day was from every trip whether white grunt were landed or not.

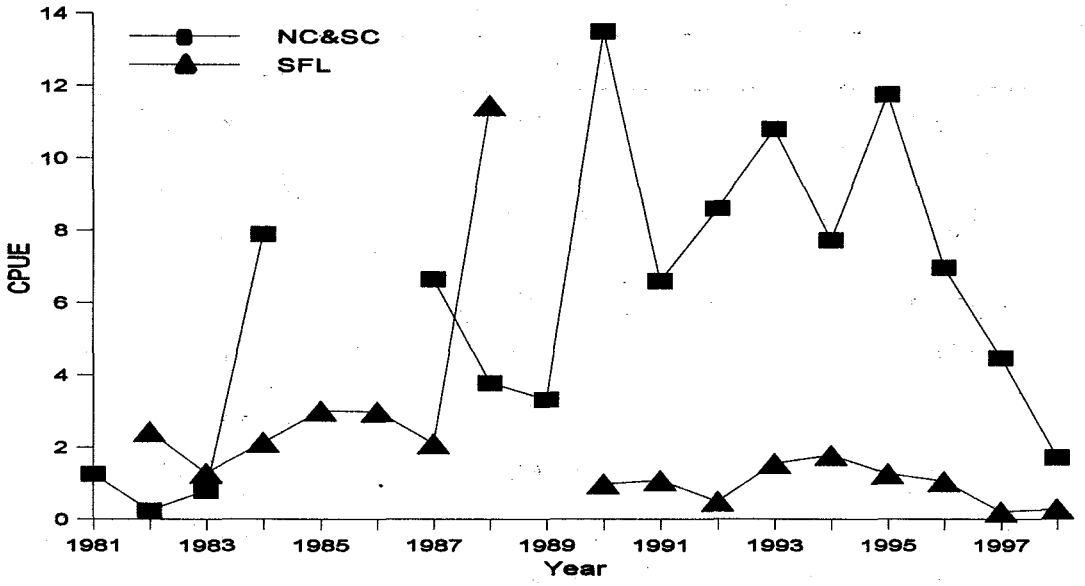
Recreational catch rates for white grunt caught off the Carolinas were relatively high from 1981 through 1998 averaging six fish per angler trip. In contrast, the catch rates off southeast Florida only averaged 1.5 fish per angler trip between 1982 and 1998 (omitting 1988 due to the excessively large number). This trend is similar to what was seen with the headboat effort: Number of white grunt landed in southeast Florida was at least an order of magnitude higher that the number landed in the Carolinas, but CPUE was much lower in southeast Florida than the Carolinas.

Table 9. Catch (No.) per angler trip of white grunt landed by recreational fishermen in the Carolinas and southeast Florida (excluding headboats; MRFSS data).

Year	NC&SC	SEFL
1981	1.26	*
1982	0.25	2.44
1983	0.80	1.29
1984	7.90	2.13
1985	*	3.01
1986	*	2.99
1987	6.65	2.10
1988	3.78	11.45
1989	3.32	*
1990	13.49	0.98
1991	6.60	1.08
1992	8.61	0.50
1993	10.79	1.55
1994	7.73	1.78
1995	11.75	1.27
1996	6.97	1.06
1997	4.47	0.21
1998	1.72	0.29

* No intercept data available to estimate number of angler trips.

Figure 7. MRFSS Catch (#) per angler trip of white grunt caught off the Carolinas and off southeast Florida.



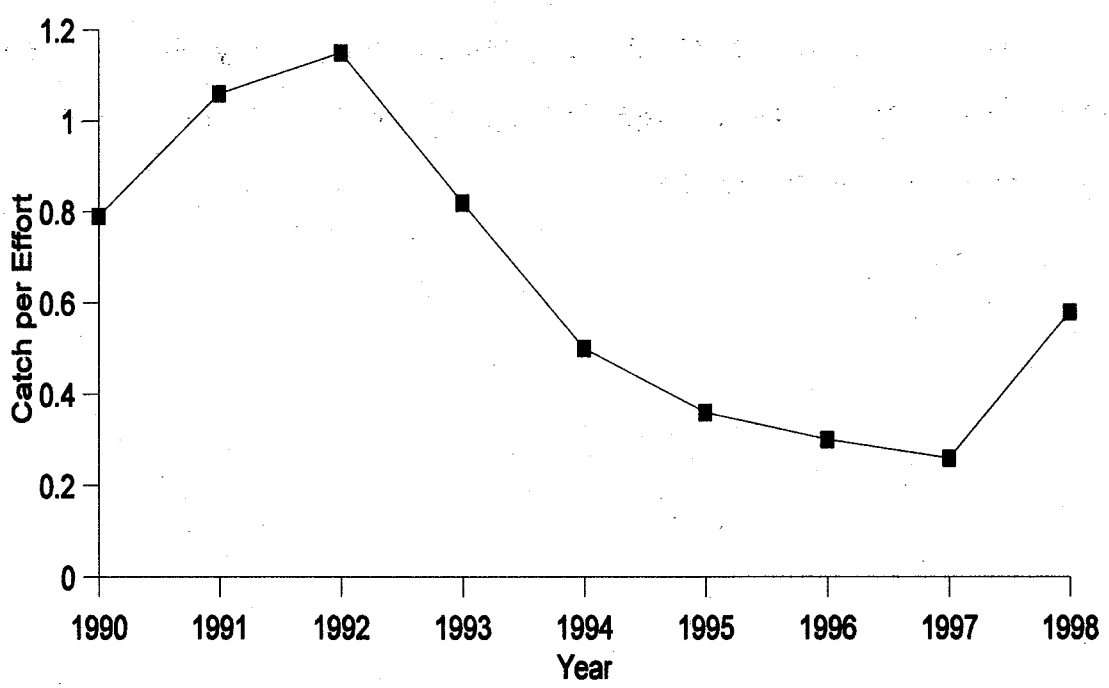
Fishery-Independent Data (SCDNR)

From 1988 through 1998 South Carolina Department of Natural Resources personnel used baited chevron traps to capture white grunt and other species of reef fish in the South Atlantic Bight: Cape Hatteras, NC to Cape Canaveral, FL (Table 10; Fig. 8). Data were reported as number of white grunt caught per trap hour (CPE). CPE by number peaked in 1992, and has generally decreased since then (Table 10; Fig. 8). These data have been incorporated into FADAPT runs for the Carolinas. No fishery-independent data were available from southeast Florida.

Table 10. Catch per effort and coefficient of variation from fishery-independent Chevron traps deployed off North Carolina and South Carolina (MARMAP data).

Year	CPE	CV
1990	0.79	5.18
1991	1.06	4.51
1992	1.15	3.45
1993	0.82	4.77
1994	0.50	5.35
1995	0.36	4.89
1996	0.30	4.54
1997	0.26	4.79
1998	0.58	3.79

Figure 8. Fishery-independent CPE from Chevron traps (MARMAP data).



Trends - Mean Weights

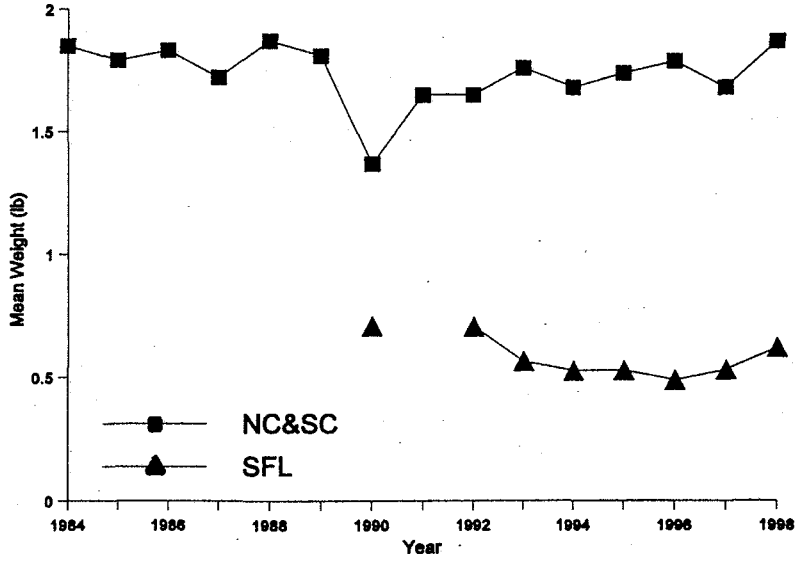
Commercial

Mean size data are available for the commercial fishery from 1984 through 1998 in the Carolinas and 1990 through 1998 in southeast Florida. They are presented in Table 11 and Fig. 9 by lengths and weights. Data were based predominantly on vertical hook and line caught white grunt. In the Carolinas, mean size has not changed in the 15 years of data recorded and averaged 1.76 lb and 363 mm total length. The largest mean size was recorded in 1998 at 1.87 lb and 377 mm TL. White grunt off the Carolinas are on average three times heavier and 100 mm longer than those off southeast Florida. Southeast Florida white grunt were largest in 1990, 0.71 lb and 284 mm TL. They were at their smallest in 1996, 0.49 lb and 247 mm TL, but had increased to 0.62 lb and 271 mm TL in 1998.

Table 11. Commercial mean size of white grunt landed in North Carolina and South Carolina and in southeast Florida.

	North Carolina and South Carolina		Southeast Florida	
Year	Mean Wt (Lb)	Mean Size (mm, TL)	Mean Wt (Lb)	Mean Size (mm, TL)
1984	1.85	375		
1985	1.79	369		
1986	1.83	376		
1987	1.72	366		
1988	1.87	376		
1989	1.81	373		
1990	1.37	337	0.71	284
1991	1.65	360		
1992	1.65	360	0.71	282
1993	1.76	368	0.57	261
1994	1.68	362	0.53	255
1995	1.74	368	0.53	254
1996	1.79	371	0.49	247
1997	1.68	363	0.53	252
1998	1.87	377	0.62	271

Figure 9. Commercial mean size of white grunt from North Carolina and South Carolina and from southeast Florida.



Headboat

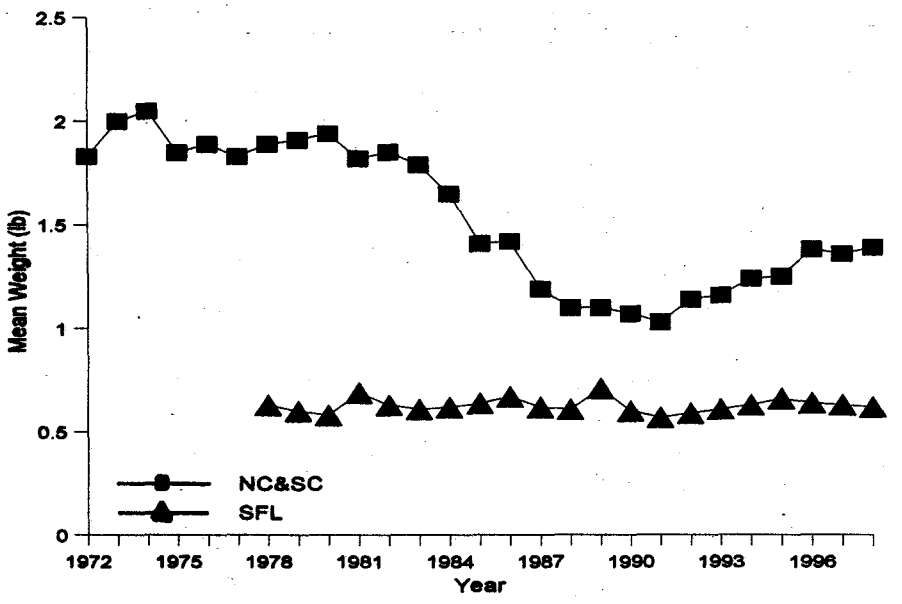
Mean size of white grunt from the Carolinas' headboat fleet is available from 1972 through 1998. Mean weights have ranged from a high of 2.05 lb in 1974 to a low of 1.03 in 1991 (Table 12; Fig. 10). White grunt from 1972 through 1984 averaged 1.87 lb, but only averaged 1.23 lb between 1985 and 1998.

Mean weight of white grunt landed in southeast Florida by headboat anglers is available from 1978 through 1998. The mean weight has not changed much in the 21 years of landings history. It peaked at 0.69 in 1981 and was lowest in 1991 at 0.57 lb. The trends in headboat caught white grunt between areas is similar to the trends in the commercial data in that the Carolinas' fish are two to three times bigger than those fish from southeast Florida.

Table 12. Headboat mean weights (lb) of white grunt landed in North Carolina and South Carolina and in southeast Florida.

Year	NC & SC	S.Florida
1972	1.83	
1973	2.00	
1974	2.05	
1975	1.85	
1976	1.89	
1977	1.83	
1978	1.89	0.63
1979	1.91	0.60
1980	1.94	0.58
1981	1.82	0.69
1982	1.85	0.63
1983	1.79	0.61
1984	1.65	0.62
1985	1.41	0.64
1986	1.42	0.67
1987	1.19	0.62
1988	1.10	0.61
1989	1.10	0.71
1990	1.07	0.60
1991	1.03	0.57
1992	1.14	0.59
1993	1.16	0.61
1994	1.24	0.63
1995	1.25	0.66
1996	1.38	0.64
1997	1.36	0.63
1998	1.39	0.62

Figure 10. Headboat mean weights of white grunt landed in North Carolina and South Carolina and in southeast Florida.



Recreational (MRFSS)

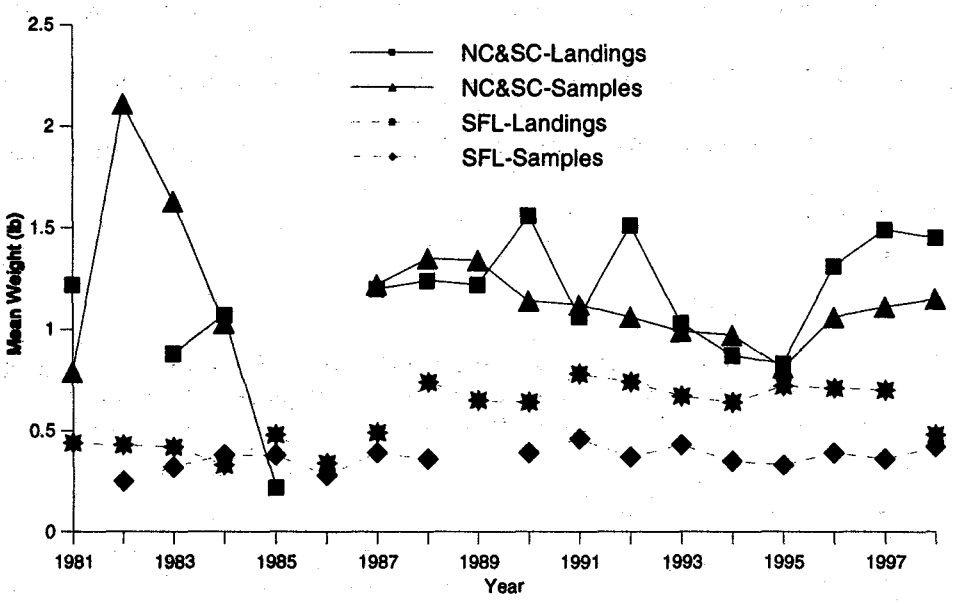
Recreational mean weights (lb) by area were generated from estimated landings, and from the intercept length samples converted to weights with the weight-length equations from Potts and Manooch (in press). In the Carolinas, mean weights were erratic prior to 1987. Sample sizes were very low in those years (Table 13; Fig. 11). From 1987 through 1998, mean weights remained steady, averaging 1.11 pounds from samples and 1.23 from landings. Headboat mean weights were similar in those years. Mean weights of white grunt from the Carolinas were two to three times the weight of those landed in southeast Florida. This trend follows the headboat and commercial trends. In southeast Florida, mean weights based on landings have increased from 1981

to 1997, and averaged 0.58 pounds over that time period and was similar to the headboat mean weight of 0.62 pounds (Table 13; Fig. 11). On the other hand, mean weights determined from the intercept samples have remained steady between 1982 and 1998 and averaged 0.37 lb.

Table 13. Recreational (MRFSS) mean weights (lb) of white grunt from North Carolina and South Carolina and from southeast Florida based on landings and on length samples.

	NC & SC			S. Florida		
Year	Landings	Length Samples	n	Landings	Length Samples	n
1981	1.22	0.79	2	0.44		
1982		2.11	1	0.43	0.25	261
1983	0.88	1.63	1	0.42	0.32	124
1984	1.07	1.03	19	0.33	0.38	97
1985	0.22			0.48	0.38	97
1986				0.34	0.28	73
1987	1.20	1.22	30	0.49	0.39	175
1988	1.24	1.35	116	0.74	0.36	108
1989	1.22	1.34	50	0.65		
1990	1.56	1.14	78	0.64	0.39	52
1991	1.06	1.12	94	0.78	0.46	119
1992	1.51	1.06	100	0.74	0.37	107
1993	1.03	0.99	119	0.67	0.43	226
1994	0.87	0.97	77	0.64	0.35	385
1995	0.83	0.81	60	0.72	0.33	215
1996	1.31	1.06	52	0.71	0.39	84
1997	1.49	1.11	48	0.70	0.36	32
1998	1.45	1.15	41	0.48	0.42	128

Figure 11. Recreational (MRFSS) mean weights of white grunt landed in North Carolina and South Carolina and in southeast Florida.



Age/Growth

Potts and Manooch (in press) conducted an age and growth study of white grunt from the southeastern U.S. because previous studies were either outdated (Manooch, 1976), not published in peer-reviewed literature (Padgett et al., 1997), or examined fish from a different geographic region (Murie and Parkyn, 1999). Potts and Manooch (in press) included samples from the Carolinas and southeastern Florida. No other aging of white grunt from southeast Florida has been done. The growth rates are very different between the two areas. Because of the differences between the areas, the analysis of trends and stock status have been pursued separately. The von Bertalanffy growth and weight-

length equations for the Carolinas are $L_t = 591(1-e^{-0.08(t+4.21)})$ and $W = 1.12x10^{-5}(L)^{3.05}$ (W = weight in g; L = total length in mm). In contrast, the von Bertalanffy and weight-length equations for white grunt from southeast Florida are $L_t = 327(1-e^{-0.31(t+4.21)})$ and $W = 6.33x10^{-5}(L)^{2.73}$ (W = weight in g; L = total length in mm). The average lengths at specific ages and derived growth parameters of white grunt from the Carolinas have not changed in 20+ years as compared to the study by Manooch (1976). When landings samples were reported in fork lengths, instead of total lengths, I converted them using an equation presented by Billings and Munro (1974): TL = 1.15(FL). Age-length keys for the two areas came from Potts and Manooch (in press). Ages and lengths ranged from 1 to 13 years and 173 to 512 mm TL for the Carolinas, and 1 to 15 years and 192 to 360 mm TL for southeast Florida.

Development of Catch-in-Numbers-at-Age Matrix

Annual application of the catch-in-numbers-at-age matrix equation (see Methods section) to each fishery (commercial, recreational, and headboat) was performed separately by area and gear and tabulated for each year. Thus, annual estimates of catch in numbers by area for different ages for 1986-1998 were obtained and produced weighted catch matrices (Tables 14 and 15). Only one age-length key for each area was available due to insufficient data for annual keys. Though, I had to use length frequency data from 1990 for the previous four years for

Table 14. Catch at age matrix for white grunt from North Carolina and South Carolina weighted by landings from MRFSS, Headboat and commercial fisheries. Boxes indicate modal age.

Age/year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	132	658	559	530	1766	794	238	211	298	338	48	341	214
2	2501	10456	9764	9019	26686	20071	8607	3697	4505	4409	2823	3864	2855
3	10490	25695	28157	30161	91585	67547	40679	33295	37401	26139	11660	17651	10063
4	29765	55731	57725	66619	157434	109656	91377	96812	105880	78839	36471	54616	33555
5	21046	37414	36449	42596	81962	51928	55753	59693	70220	50286	28588	34435	25174
6	23982	40841	38174	44576	72457	45608	52361	54058	70952	46036	31775	33706	27665
7	19932	34682	32934	37775	57957	36235	40923	43472	54150	35518	25029	28379	23154
8	19423	32043	37496	43576	55951	37972	38150	38881	44208	30009	21051	27472	21706
9	7928	13013	14620	16779	21052	14569	14312	15212	18228	11510	9027	11461	8995
10	4017	6433	8348	7294	10911	7260	6481	7001	7823	4922	4243	5379	4249
11	1657	2707	4492	3125	5564	3706	2897	3254	3299	2248	1843	2325	1805
12	1673	2408	4218	5118	4612	4150	2937	3048	3262	2057	1623	2727	1973
13	570	650	3021	4237	2967	2026	2469	1150	274	1038	315	704	225

Table 15. Catch at age matrix for white grunt from southeast Florida weighted by landings from MRFSS, Headboat, and commercial fisheries. Boxes indicate modal age.

Age/year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	6636	4345	3108	2447	2309	10693	14292	13874	51917	30778	1069	8511	861
2	31834	30104	38899	29885	29921	57628	32104	35606	79173	81501	21590	26727	17532
3	290290	464727	436786	336192	328040	387250	338577	427012	808705	456942	282420	281666	241943
4	146547	326431	289130	227053	229770	397259	240245	313220	475256	291107	204970	191179	237134
5	70291	157443	129723	106649	117899	255584	112359	137073	185423	126001	94413	78993	117537
6	39807	79274	76016	63251	60829	193624	61306	68419	93144	63051	54520	44641	64121
7	21026	35248	37182	31289	29244	87164	26575	26263	40753	26046	24555	21376	29141
8	11776	20476	22206	18472	17026	46267	15692	16303	25710	15939	14372	13499	16323
9	8901	27718	17430	17056	26804	64965	20786	14582	19824	20324	12192	8075	15513
10	3383	5904	4932	4046	4479	11223	4135	4552	6517	4217	3577	2851	4974
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	808	1097	1576	1320	999	1764	722	730	1524	787	857	933	872
15	808	1097	1576	1320	999	1765	722	730	1524	787	857	933	872

southeast Florida, none of the trends from the headboat or recreational surveys suggest any change in mean size over the years.

Mortality Estimates

Total Instantaneous Mortality

Catch curves from 1986 through 1998 were plotted separately for the two areas: Carolinas and southeast Florida (Figs. 12 and 13). Because no management restrictions have been placed on this species, the time series is continuous. In the Carolinas, the modal age was four in all years. The estimated Z's on ages 4 though 13 ranged from 0.34 in 1988 to 0.59 in 1994. The mean total instantaneous mortality for all years was 0.46.

In contrast, the modal age of white grunt caught in southeast Florida was three for all years except 1991 when it was three to four. Because of the discontinuity in the age-length key between ages 10 and 15, the estimates of Z were based on ages 3-10. The Z's ranged from 0.47 in 1991 to 0.67 in 1994, and the mean total instantaneous mortality was 0.60 for all years.

Figure 12. Natural log of the catch-at-age for white grunt from North Carolina and South Carolina landed in 1986-1998.

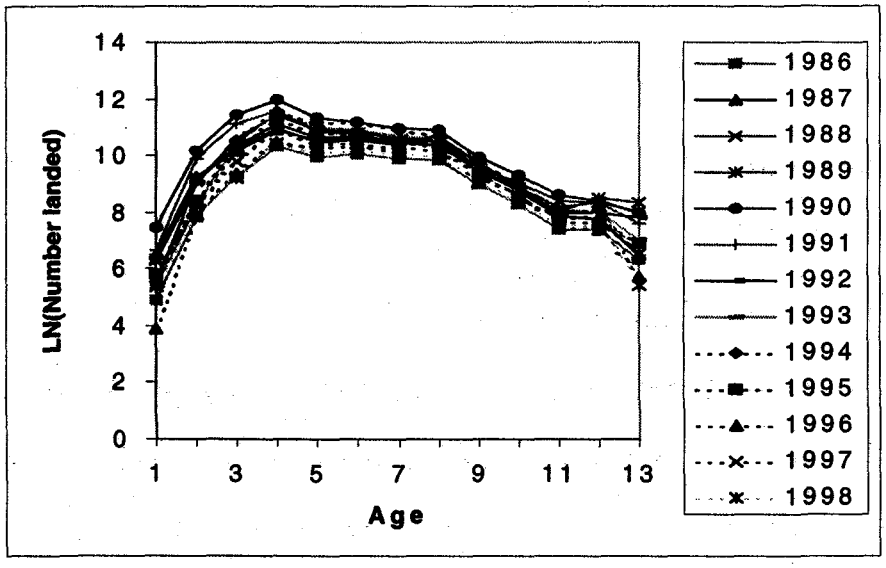
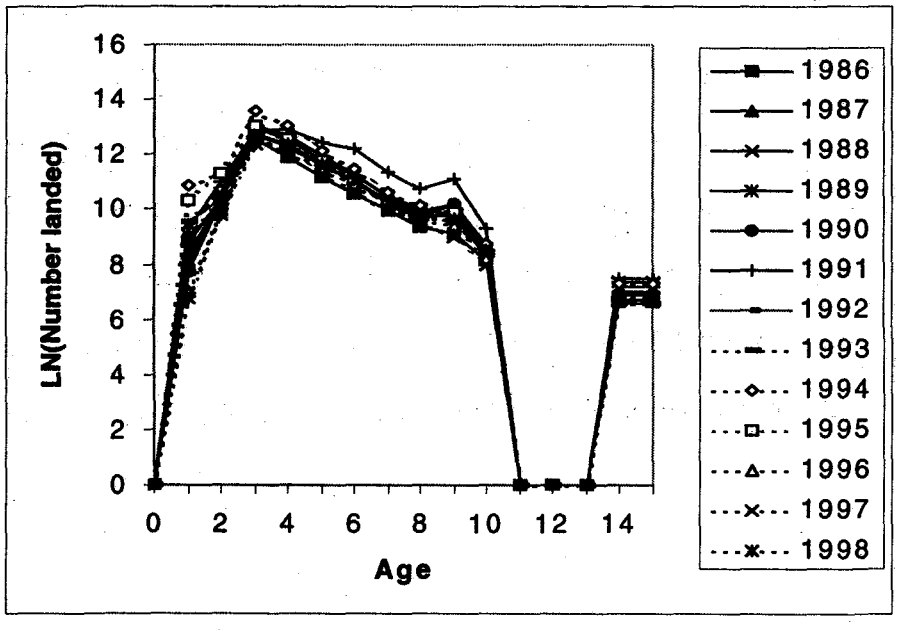


Figure 13. Natural log of the catch-at-age for white grunt from Southeast Florida landed in 1986-1998.



Natural Mortality

There is often great uncertainty in deriving a value for natural mortality (M). Yet this is an important parameter input for stock assessment analyses, and ultimately dictates the selection of the initial values of fishing mortality (F) to be used in the analyses. Caution suggests using a range of possible values for M in the analyses, and I have done this for the two separate areas in this assessment. I estimated natural mortality using several methods, and then four values were chosen as a range to use in the SVPA runs. Methods used to estimate M and their resulting values are

	NC&SC	SFL
Hoenig (1983) - original equation	0.32	0.28
- adjusted for sample size	0.61	0.51
Pauly (1979)	0.14	0.41
Ralston (1987)	0.18	0.66
Roff (1984) - using length at 50% maturity	0.61	0.45
- using length at 100% maturity	0.32	0.24
Rikhter and Efanov (1977)	0.15	0.15
Alverson and Carney (1975)	0.50	0.19
Alagaraja (1984) - survivorship to max age = 1%	0.35	0.31
- survivorship to max age = 2%	0.30	0.26
- survivorship to max age = 5%	0.23	0.20

Hoenig (1983) uses maximum age in his equations for calculating M. I used a maximum age of 13 years for the Carolinas

and 15 for southeast Florida from Potts and Manooch (in press). Hoenig's original equation gave estimates of M that were close to what was expected and used in previous assessments. The Hoenig method further relates maximum observed age to total mortality and sample size, and assumes random sampling. Since the samples from the Potts and Manooch age-growth study came from recreationally and commercially landed white grunt and from MARMAP sampling, I feel the assumption of randomness is met. The values of M are very different because of the use of K. Because of the inverse relationship of K to L_∞, estimated K's for white grunt from the two areas are very different (K_{CAR} = 0.08 and K_{SFL} = 0.31).

The Rikhter and Efanov (1977) method produced an estimate of M that is unrealistically low (0.15 for both areas). However, this estimate was not unexpected for an equation that is based solely on age at sexual maturity. This estimate of M is more suitable for species which are more long-lived (e.g., gag, scamp, snowy grouper).

The values for the Pauly (1979) estimate, M_{CAR} = 0.14 and M_{SFL} = 0.41, indicate the difference in M is a function of water temperature, though the Carolinas estimate is lower than expected. Mean seawater temperature input into Pauly's (1979) equation was 22° C for the Carolinas and 26° C for southeast Florida. The Alverson and Carney (1975) equation gave an

estimate of M_{CAR} = 0.50 and M_{SFL} = 0.19. This disparity in range is due to the different estimates of K for the two areas. Because K and L_∞ from the von Bertalanffy equation are inversely related, estimates of M are also suspect.

Roff (1984) predicts M using the Brody growth coefficient K and the optimal length at maturity. Uncertain as to the true optimal size at maturity, I utilized lengths corresponding to both 50% and 100% maturity. The Carolinas and southeast Florida estimates of M at 50% maturity, 0.61 and 0.45, respectively, are unreasonable, again for the same reason as that provided for the results using the Rikter and Evanov equation. These estimates are very high for a species with a lifespan of 15 years. The respective estimates of M based on length at 100% maturity, 0.32 and 0.24, are closer to what I expect for this species. The optimal lengths at maturity from the two areas (250 mm for the Carolinas and 260 mm for southeast Florida) are most likely closer to a true estimator of the optimum.

The empirical equation of Ralston (1987) yielded a value of M_{CAR} = 0.18 and M_{SFL} = 0.66. The Carolinas estimate seems low, and the southeast Florida high, and this is partly explained by the fact that Ralston used pooled data from 14 snapper stocks and five grouper stocks in developing his regression. An estimate of natural mortality for a haemulid derived from a regression developed from a pooled data set, dominated by lutjanid species,

could result in the artificially low value. Also, as explained in the Alverson and Carney estimates, K is linked to L_∞, and the Ralston equation only used K which can bias the results.

I derived a final estimate of M using the equation of Alagaraja (1984), which utilized a predetermined survivorship criteria (percent of initial cohort surviving to maximum age). It seems unlikely that survivorship to this maximum age would be 5%, as recently applied by Ault et al. (1998), so I derived estimates of M using three levels of survivorship for comparative purposes: 1, 2, and 5%. The respective values of M were 0.35, 0.30, and 0.23 for the Carolinas and 0.31, 0.26, and 0.20 for southeast Florida. They all agree reasonably well with each other, and with what is expected to be most appropriate for white grunt (M = 0.30).

My estimates of M vary widely and range 0.15 to 0.61 for the Carolinas, and 0.15 to 0.66 for southeast Florida. It seems unlikely that a haemulid would have an M greater than 0.40 or lower than 0.20; therefore, I discount the estimates returned using approaches of Pauly (1979), Alverson and Carney (1975), Rikhter and Evanov (1977), Roff (1984), and Ralston (1987). The expected value of M for white grunt falls between 0.20 and 0.35. To provide evaluation latitude in my analyses, I choose to run the analyses with a range of values for natural mortality from 0.20 to 0.35.

Fishing Mortality and Virtual Population Analysis

For the separable VPA runs, two catch matrices were analyzed consisting of catch in numbers for fishing years 1986-1998 for ages 1 through 13 for the Carolinas, and ages 1-10 for southeast Florida. Modal ages for the two areas were age-4 for the Carolinas, and age-3 for southeast Florida. For the SVPA, starting values for F were based on the mean estimates of Z from the two areas. Sensitivity of estimated F to uncertainty in M was investigated by conducting the above SVPAs with alternate values of M (0.20, 0.25, 0.30, and 0.35).

Because of the short duration of the catch matrix and large number of ages, mean values only for the two areas were considered. For the YPR and SPR models, mean values of age-specific estimates of F were obtained from the separable VPA applied to the catch at age data (Tables 14 and 15) using the uncalibrated separable (SVPA). Estimates of F were averaged over fully-recruited ages (ages 4-13 for the Carolinas and ages 3-10 for southeast Florida), weighted by catch in numbers for those ages (referred to as full F). Full F's on white grunt off the Carolinas was lowest in 1986 and climbed steadily to a peak in 1990 (Fig. 14). After 1990, F varied widely with no clear trend. Full F's on white grunt off southest Florida was also lowest in 1986 and did not increase much in the following years, except in 1991 and 1994 (Fig. 15). Those two years reflect the landings

trends from the MRFSS database when landings were 2 to 2.5 times higher than in other years (Table 6). Employing the uncalibrated separable approach (SVPA) with M of 0.30, I obtained mean estimates of full F of 0.23 for the Carolinas and 0.33 for southeast Florida (Table 16).

Figure 14. Estimated full F's from uncalibrated separable VPA on white grunt from the Carolinas.

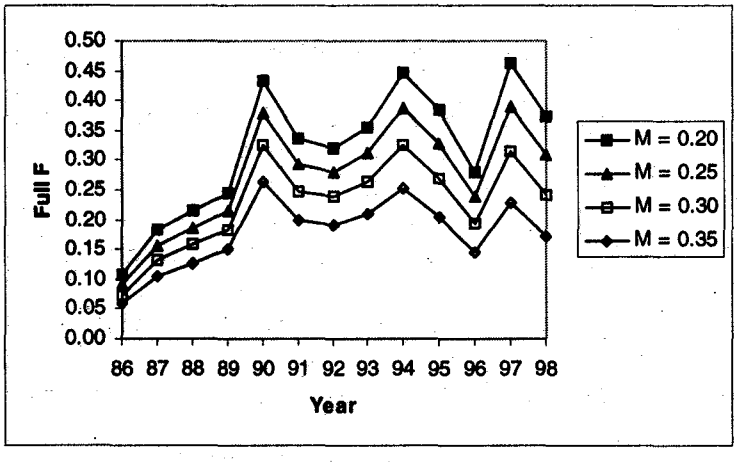


Figure 15. Estimated full F's from uncalibrated separable VPA on white grunt from southeast Florida.

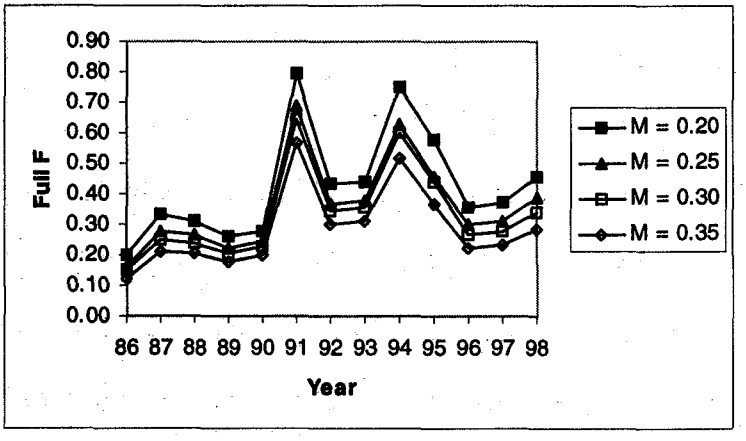


Table 16. Spawning potential ratio (SPR) and yield per recruit (YPR) in pounds of white grunt from North Carolina and South Carolina and southeast Florida landed during 1986 to 1998. Results are based on estimates of full F from uncalibrated separable VPA.

M	Full F		SPR		YPR	
	NC&SC	SFL	NC&SC	SFL	NC&SC	SFL
0.20	0.32	0.43	0.36	0.44	0.40	0.39
0.25	0.27	0.36	0.47	0.53	0.29	0.30
0.30	**0.23**	**0.33**	**0.57**	**0.61**	**0.21**	**0.24**
0.35	0.18	0.29	0.69	0.68	0.14	0.19

The calibrated VPA, FADAPT, for the Carolinas data used the MARMAP catch per effort (Table 10) and age-specific catch matrix from Chevron traps using fishery-independent age-length key from Padgett et al. (1997). The starting partial recruitment vector used in FADAPT was based on a separable VPA run on the Carolinas data, 1986-1998. Again, to test the sensitivity of F to M, FADAPT was run using the four levels of M. Fishing mortality on the fully recruited ages was weighted by the fishery-dependent catch matrix as was done for the full F from the separable VPA. Full F's by year followed a similar pattern to the full F's estimated by the uncalibrated separable VPA (Fig. 16). By tuning the VPA, full F's from 1995 through 1998 were back at the levels seen in 1987 through 1989. The resulting mean full F's ranged from 0.29 to 0.20 for M = 0.20 to M = 0.35 (Table 17).

Figure 16. Estimated full F's from calibrated VPA (FADAPT) on white grunt from the Carolinas.

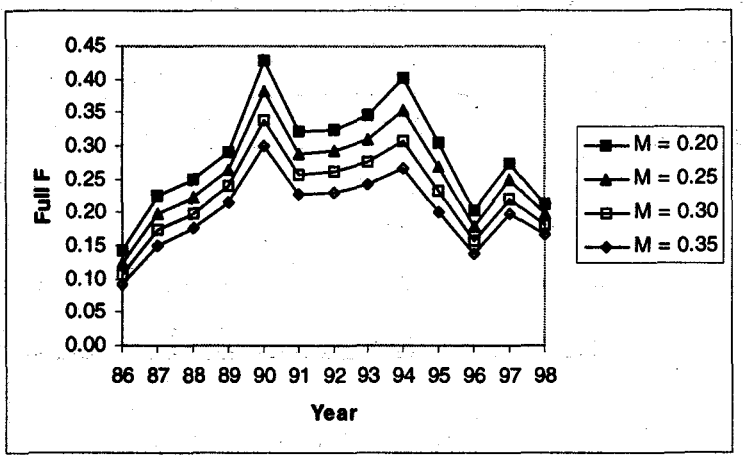


Table 17. Spawning potential ratio (SPR) and yield per recruit (YPR) in pounds of white grunt from North Carolina and South Carolina landed during 1986 to 1998. Results are based on estimates of full F from calibrated VPA (FADAPT).

M	Full F	SPR	YPR
0.20	0.29	0.39	0.39
0.25	0.26	0.48	0.29
0.30	**0.23**	**0.58**	**0.21**
0.35	0.20	0.66	0.15

Yield Per Recruit

Yield per recruit with M = 0.30 was approximately the same for the two areas, 0.21 and 0.24 pounds, for the Carolinas and southeast Florida respectively (Table 16 and 17; Fig. 17). The similarity is most likely due to the fact that white grunt first recruit to the fisheries at age-1 and around 175 mm TL. Though

the Carolinas white grunt grow bigger and heavier than those from southeast Florida, they are not caught at the same rate as those from southeast Florida. Under current conditions in the Carolinas, white grunt could be fished at 2.6 times the current F and increase yield per recruit 30% and maintain the stock above 40% SPR (Fig. 17a). In southeast Florida, current F could be increased 3.0 times and increase yield per recruit 40% and also maintain the stock above 40% SPR (Fig. 17b).

Figure 17. Ricker yield per recruit and spawning potential ratio for white grunt from the Carolinas and southeast Florida (M = 0.30). Results are based on separable VPA.

a. Carolinas; Full F = 0.23.

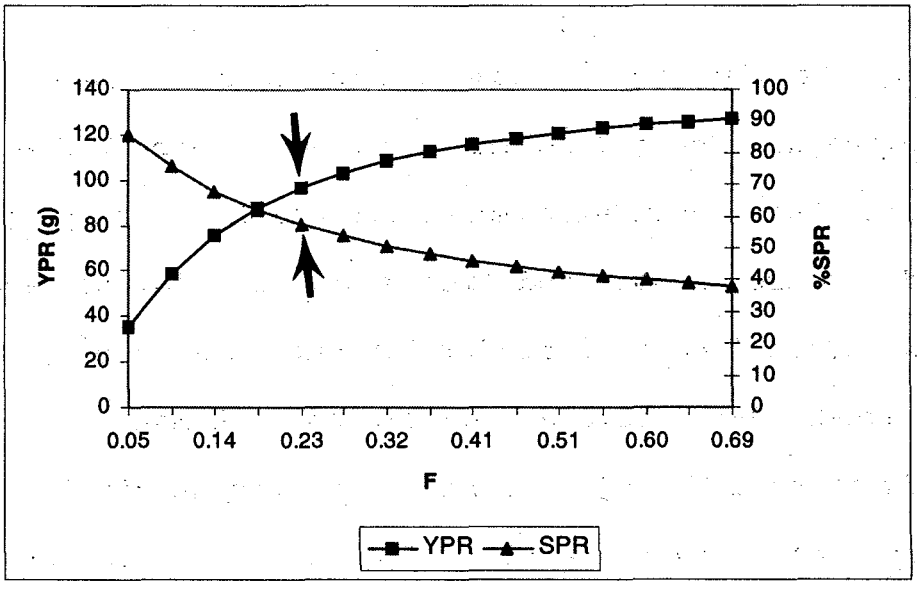
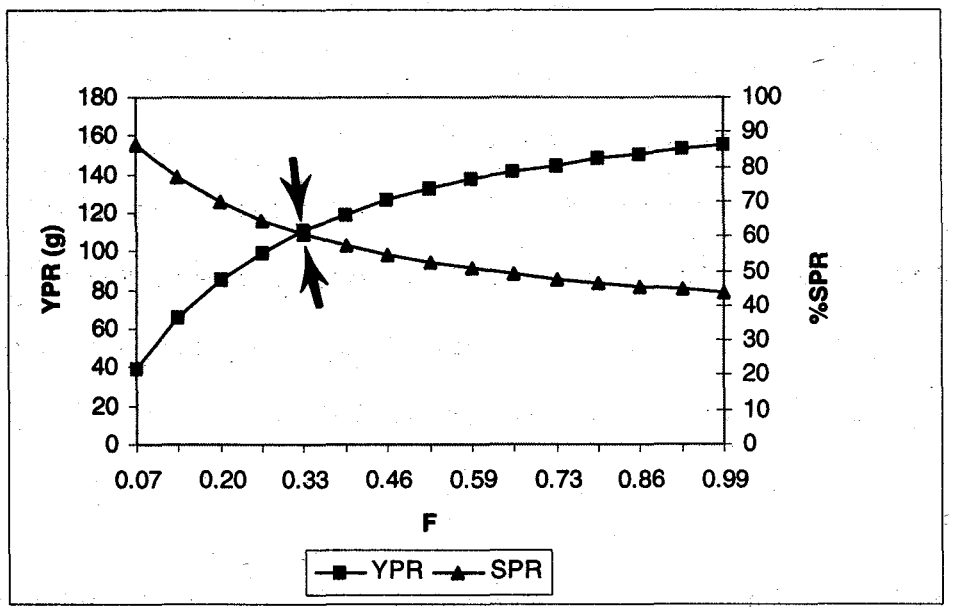


Figure 17b. Southeast Florida; Full F = 0.33.



Spawning Potential Ratio

A comprehensive reproductive study of white grunt from North Carolina and South Carolina was completed by Padgett et al. (1997). The study included samples from fishery-independent traps, and commercial hook and line gear. I used the female maturity schedule from that study: 50% mature at age-1; 88% mature at age-2; 99% mature at age-3; and 100% mature at age-4. Though Padgett et al. (1997) found a significant difference in the sex ratio of males to females (1:1.16), they did not find any differences among different age classes.

No study exists on the reproduction of white grunt in south

Florida. An assumption was made that white grunt from south Florida were more like those from the Caribbean as opposed to white grunt from the Carolinas. Observations on reproduction of white grunt from the Caribbean by Billings and Munro (1974), as reported in Darcy (1983), state that the smallest mature female was 143 mm FL (164 mm TL) and females were fully mature at 260 - 279 mm FL (299 -320 mm TL). Using the back-calculated lengths and age-length key from Potts and Manooch (in press), the observed lengths at maturity were converted to ages. The smallest mature female was estimated to be age-1, and the fully mature females were estimated to be age-4. Based on this limited information, the maturity schedule used in the SPR model was the same as the one used for the Carolinas: 50% at age-1; 88% at age-2; 99% at age-3; and 100% at age-4.

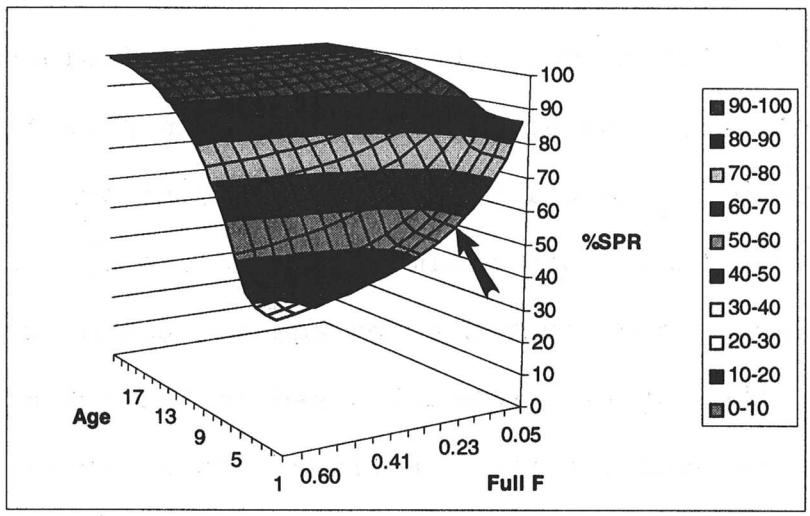
Spawning potential ratio (SPR), or percent maximum spawning potential, of white grunt was calculated for the two areas based on mean age-specific fishing mortality from a uncalibrated SVPA analysis using the four different levels of natural mortality (Table 16). At M = 0.30, percent maximum spawning potential was well above the target level of 40% for both areas: 57% for the Carolinas and 61% for southeast Florida (Figs. 17 and 18; Table 16).

SPR was also calculated based on mean specific fishing mortality from FADAPT using four levels of M (Table 17). The

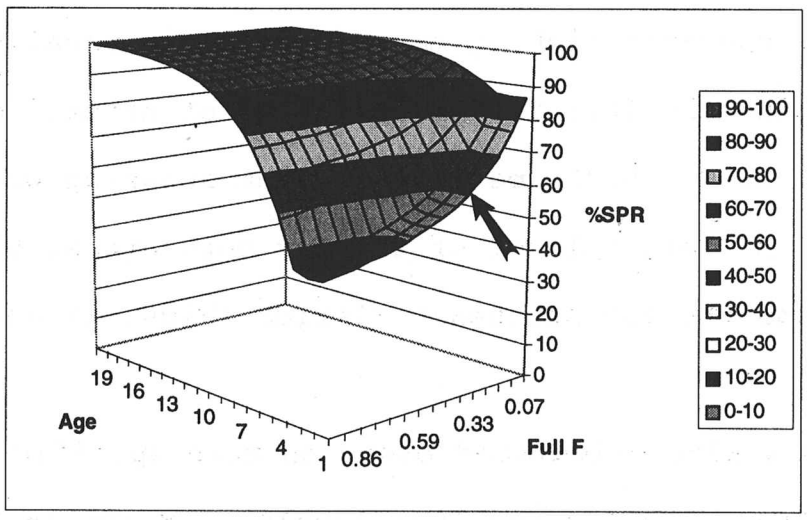
resulting SPR's were very similar to the ones from the uncalibrated data (Table 17).

Figure 18. Spawning potential ratio of the white grunt from North Carolina and South Carolina and from southeast Florida (M = 0.30). Results are based on the separable VPA.

a. Carolinas: Full F = 0.23; age at entry = 1.



b. Southeast Florida: Full F = 0.33; age at entry = 1.



CONCLUSIONS

Overall, the two stocks of white grunt are satisfactory at all levels of M considered in this assessment. Because white grunt has not been as important a reef fish species to commercial or recreational fisheries, as compared to some other species, such as gag or vermilion snapper, data for the assessment were limited. The assessment is an estimate of static SPR, but current levels of F (0.23 and 0.33 Carolinas and south Florida, respectively) are equal to or below the best estimate of M (0.30). The white grunt stocks will need to be monitored closely to avoid overfishing.

Trends in a fishery may be good indicators of cycles in populations or overall stock health. The longest time series of landings of white grunt from the Carolinas is from the Headboat Survey, and the landings have decreased in the recent years, 1996-1998. The General Canvass and recreational (MRFSS) landings have also decreased in 1996-1998. CPUE has followed a similar trend to the landings. However, mean size of white grunt landed in the Carolinas commercial catch remained steady from 1986 through 1998. Mean weights from headboat caught white grunt have remained steady since 1986, but averaged ½ pound lighter than those landed from 1972 to 1985.

White grunt headboat and commercial landings in weight in

southeast Florida were lower than the landings in the Carolinas. In southeast Florida, commercial landings have increased in recent years (1996-1998). Headboat landings were down from a peak in 1987. On the other hand, recreational landings in weight are five to six times the recreational landings in the Carolinas. Recreational landings were also on average five times the commercial and five times the headboat landings in southeast Florida. Landings in number of fish in southeast Florida were at least double the number landed in the Carolinas for all three databases. In spite of the large number of white grunt landed by recreational fishermen in southeast Florida, the CPUE is much lower than CPUE in the Carolinas. Headboat CPUE has increased in 1996 through 1998 and is similar to CPUE in the Carolinas. Mean weights have remained steady in all three fisheries.

SPR values were derived using natural mortality (M) values of 0.20, 0.25, 0.30, and 0.35. I believe that the most realistic estimate of M is 0.30. In the Carolinas, an M of 0.30 resulted in a SPR value of 0.57, and in southeast Florida a SPR value of 0.61. These two stocks of white grunt are in good shape by definition. However, landings and mean weights need to be monitored to tract the status of the stocks.

In a report on several reef fish stocks in the southeastern U.S. based on biomass estimates, the white grunt stock off the Carolinas is not considered overfished (Anonymous, 1999). The

Technical Guidelines as interpreted from the National Standard Guidelines of the Magnuson-Stevens Fishery Conservation Act, sets the proxy for B/B_{MSY} at $CPUE_{current}/½\ CPUE_{initial}$ from the headboat data. The Carolinas stock of white grunt is currently at 0.47/0.37, suggesting current B (biomass) is above B_{MSY}. The resulting SPRs from this assessment agree with the biomass level assessment.

Previous assessments of white grunt from the southeastern U.S. are not comparable to the results in this assessment. Assessments using 1988 data and 1990 data separately were catch-curve analyses (Huntsman et al., 1992), and combined all fisheries landings from the entire southeastern U.S. applied to an age-length key for white grunt from the Carolinas only. Potts and Manooch (in press) illustrated the differences in the age-structure and growth rates of the white grunt from the Carolinas and southeast Florida. Also, no maturity schedule was available at the time of the earlier assessment, so the proxy of age at $L_\infty/2$ was used for 100% maturity (5.41 years). This age is older than reported by Padgett et al. (1997). Resulting SPRs using M = 0.30 were 0.17 in 1988 and 0.19 in 1990. Potts et al. (1998) used headboat and MRFSS landings data from 1996 for the entire southeastern U.S. applied to the Carolinas caught white grunt age-length key from Manooch (1976). Potts et al. (1998) used the maturity schedule listed in Padgett et al. (1997). The resulting

SPR was 0.39. I feel that the large number of small south Florida white grunt as applied to the Carolinas age-length key depressed the SPR estimate, even though F for 1996 data was essentially the same as the F used in this assessment for the Carolinas (0.24 and 0.23, respectively).

Another assessment of white grunt from south Florida was part of a multispecies assessment of coral reef fish in the Florida Keys (Ault et al., 1998). These authors estimated SPR to be approximately 0.15 for the species using M of 0.37. Their input data came from a fishery-independent, visual census by divers in the Florida Keys and Dry Tortugas. The fishery-independent white grunt were on average smaller than the headboat caught white grunt. The other input parameters for the Ault et al. (1998) study were not referenced, and do not match what was used in this assessment.

At this time, white grunt off the southeastern U.S. are not overfished. This conclusion is supported by the data reported here and the analysis of B_{MSY} as reported in Anonymous (1999). As white grunt become more important to overall reef fish landings due to strict management regulations placed on other reef fishes, managers will need to follow the trends of white grunt closely. White grunt in the Carolinas need to be managed as a separate stock from white grunt in southeast Florida due to the differences in age and growth from the two areas.

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