NOAA TECHNICAL MEMORANDUM NMFS-SEFSC-411

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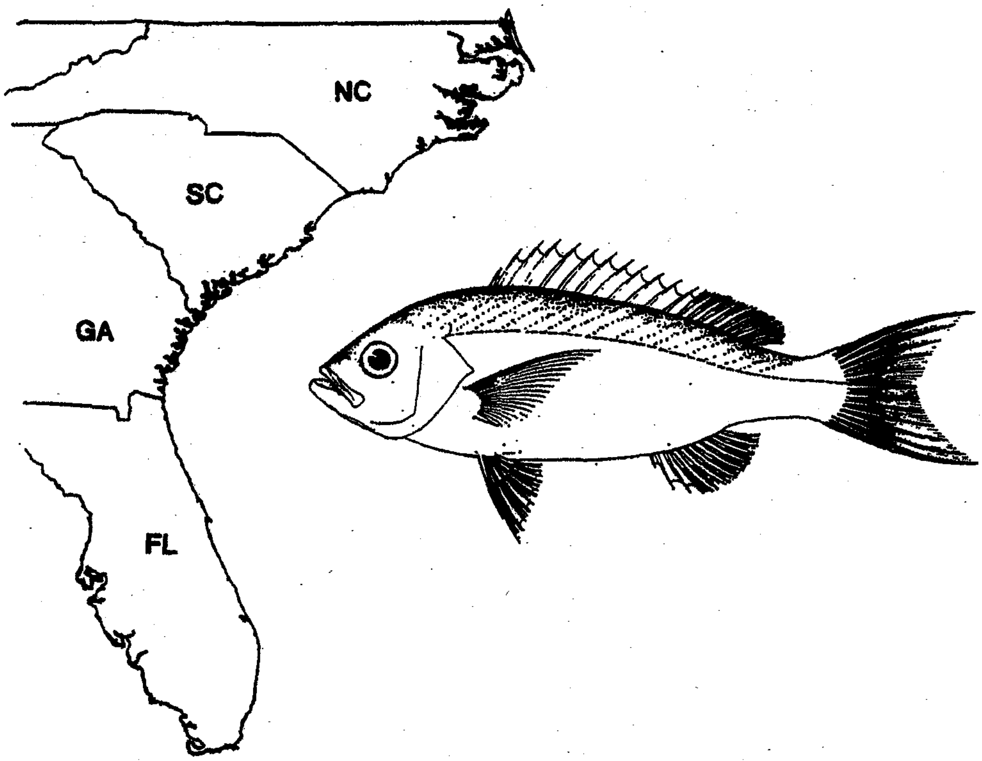

March 1998

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
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U.S. DEPARTMENT OF COMMERCE
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NOTICE

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ABSTRACT

Changes in the age structure and population size of vermilion snapper, Rhomboplites aurorubens, 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 1986-1996. Population size in numbers at age was estimated for each year by applying separable virtual population analysis (SVPA) to the landings in numbers at age. SVPA was 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). Although landings of vermilion snapper for the three fisheries have declined, minimum fish size regulations have resulted in an increase in the mean size of fish landed. Age at entry and age at full recruitment were age-1 and age-3 for 1986-1991, compared with age-1 and age-4, respectively, for 1992-1996. Levels of mortality from fishing (F) ranged from 0.38 - 0.61 for the entire period. Current spawning potential ratio (SPR) is 21% or 27% depending on the natural mortality estimate. SPR could be raised to 30% or 40% with a reduction in F, or by increasing the age at entry to the fisheries. The latter could be enhanced now if fishermen, particularly recreational, comply with minimum size regulations. However, released fish mortality, modeled in the assessment at 27%, will continue to make the achievement of 30% and 40% SPR more difficult.

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INTRODUCTION

The vermilion snapper, *Rhomboplites aurorubens*, a member of the Lutjanidae family, is the most frequently caught snapper throughout the southeastern region of the United States. Off South Florida it is replaced in importance by the yellowtail snapper, *Ocyurus chrysurus*, which inhabits the same depth range and feeds on similar foods.

The species is found in tropical and warm temperate waters of the western Atlantic from Cape Hatteras to southeastern Brazil, including Bermuda, the West Indies, and the Gulf of Mexico. Off the United States the preferred habitat is irregular reeflike substrates in waters ranging in depth from 80-400 feet (24-122 m) (Manooch 1984). Adults occupy a wide horizontal and vertical range, but do not display marked seasonal movements (SAFMC 1983a).

In terms of commercial finfish value, the species ranks from sixth to 13th place for the entire southeastern United States from 1990-1996 (Table 1). Fishermen were able to sell vermilion snapper at dockside for about $2.00 per pound (Table 1). The species is particularly important to the commercial fisheries of Georgia, where it has ranked above all finfish from 1990-1996, and in South Carolina (Table 2), where it has ranked in the top five for most of those years (Table 2). By contrast, the vermilion snapper is relatively unimportant to commercial fisheries off South Florida (Table 2).

Table 1. Vermilion snapper ranking in commercial finfish value ($) for the southeastern U.S.

Year	Rank	Value	$/Lb.
1990	9	2,620,636	1.96
1991	6	2,766,785	1.96
1992	12	1,538,718	2.07
1993	11	1,779,835	2.03
1994	10	2,010,097	2.07
1995	11	2,080,573	2.19
1996	13	1,660,312	2.19

Table 2. Vermilion snapper ranking in commercial finfish value ($) by state/area.

	NC		SC		GA		NFL		SFl	
Year	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
1990	8	1,105,153	3	747,278	1	217,717	9	514,614	42	35,874
1991	7	1,088,334	2	992,162	1	233,603	10	421,175	40	31,511
1992	8	697,728	4	477,340	1	101,750	15	247,335	51	14,565
1993	8	805,482	4	525,530	1	152,988	14	276,300	51	19,535
1994	11	903,367	4	463,448	1	227,124	13	405,446	54	10,641
1995	11	867,648	5	396,910	1	250,319	7	535,423	43	30,273
1996	12	718,493	6	353,865	1	179,847	8	383,679	53	24,428

Unlike most snappers, which feed on fishes and crustaceans that inhabit the bottom, vermilion snapper forage on small animals found off the bottom. Preferred foods are small crustaceans (copepods, amphipods, stomatopods, crabs, and shrimps), squids, small fishes, and fish eggs (Manooch 1984). The species remains the same sex throughout its lifespan; it is not hermaphroditic. Sexual maturity may occur as early as the second year of life (or before) for females as small as eight inches total length (203 mm TL)(SAFMC 1983a). Spawning occurs in waters 70-77° F (21-25° C) during the warmer months, beginning as early as April and extending through September off North Carolina. The spawning grounds are poorly defined, but are known to occur in continental shelf waters which are 102-392 feet (31-119 m) deep (SAFMC 1983a). Fecundity is related to fish size. A 10-inch (254 mm TL) female may lay eight thousand eggs and a fish 22 inches (559 mm TL) in length is capable of producing 1.8 million (Manooch 1984). The free-floating eggs hatch after several days. The species is relatively slow growing, and may attain a length of 26 inches (670 mm TL) and an age of 14 years (Potts 1997).

This assessment of the vermilion snapper stock from North Carolina (south of Cape Hatteras) through the Florida Keys was conducted to facilitate decision-making by the South Atlantic Fishery Management Council (SAFMC). Although the SAFMC Snapper-Grouper Fishery Management Plan (FMP)(SAFMC 1983b) does include discussions of the species, no separate stock assessment has been made for the vermilion snapper along the southeastern United States.

The SAFMC has taken actions to regulate the harvest of the species. The FMP for the Snapper-Grouper Fishery was implemented on August 31, 1983. The FMP required that a 4-inch trawl mesh size be used to achieve a 12-inch total length (TL) minimum size for vermilion snapper. Amendment 1 to the FMP, implemented on January 12, 1989, prohibited the use of trawl gear south of Cape Hatteras. Amendment 4 to the FMP, effective January 1, 1992, required a 10-inch minimum size for recreationally-caught vermilion snapper, and a 12-inch minimum size for those harvested commercially. A 10-fish bag limit was also placed on recreational anglers. On August 22, 1997 the SAFMC finalized Amendment 9 to the Plan. The Amendment increased the minimum size from 10 inches to 11 inches for recreational anglers, and maintained the 12-inch size limit for commercial fisheries. Potential impacts of the above regulations must be considered in this assessment.

In this report we compute and document changes in the age structure and population size for the species. Specifically, given 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. vermilion snapper stock.

METHODS

Landings

For purposes of this report, vermilion snapper are landed by three fisheries: commercial, recreational, and headboat. The commercial fishery is principally prosecuted by hydraulically- and manually-operated hook-and-line gear, although a few landings are made by trawls and traps. The recreational fishery includes hook and line fishing from shore or any platform other than headboats. This includes small private boats and charter boats (six passengers or less). Headboats are those usually carrying more than six passengers and charge on a per person basis, thus by the "head", and are considered separate for our analyses from the other recreational vessels. Although landings are available for different years depending on fishery, only data from 1986-1996 were available for all three fisheries. Landings were used with fish length at age information to develop a catch-in-numbers-at-age matrix, which is found under the appropriate heading below.

Landings data are used to describe annual trends in catches, including catch in number, catch in weight, mean fish size, and mean fish age. Catch-per-effort are provided for the headboat data, recreational data, and fishery independent data. Whenever possible, the databases were stratified by state or area: North Carolina, South Carolina, Georgia, North Florida, and South Florida (both East Coast only).

To draw conclusions about the vermilion snapper population from fish that are sampled from catches, it is very important that samples are representative of the stock (e.g., size, sex, distribution, etc.), and are adequate in number. Although assumptions must be made for the former, biologists and managers should have some control over the latter. To evaluate the adequacy of sampling intensity for the three fisheries (headboat, recreational, and commercial), we used the informal criterion of 100 fish sampled per 200 metric tons of that species landed (USDOC 1996).

Age/Growth

Growth parameters, length-length conversions, weight-length relationship, and a fish age-fish length key were obtained from a recent study of vermilion snapper by Potts (1997). This study was selected over another contemporary study by Zhao et al. (1997), which utilized data from smaller fish obtained primarily from fisheries independent sources, and therefore may not be representative of the fishable stock for our assessment purposes.

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

Data used in the construction of the matrix were derived from several sources and covered the geographical area extending from North Carolina through the Florida Keys. Fishery independent information, including fish age and CPUE data for hook and line and trap gear were provided by fisheries personnel of the South Carolina Department of Natural Resources, MARMAP (Marine Resources Monitoring, Assessment, and Prediction) Program, Charleston, SC for 1981-1996. Recreational landings and fish lengths and weights were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS) data base (NMFS, Washington DC) for 1981-1996. Headboat catch estimates, fish length, and fish weight data were obtained from the NMFS for 1972-

1996 (NMFS, Beaufort, NC). Commercial fishery data were obtained from two data sets: the General Canvas for catch statistics for 1986-1996, and from the Trip Interview Program (TIP) for length and weight statistics for 1983-1996 (NMFS, Miami, FL).

Derivation of catch in numbers at fish age consists 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 14 years), and b is the number of length intervals. Since commercial landings are reported by weight only, the catch of vermilion snapper 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 the length equation from Potts (1997).

Mortality Estimates

Total Instantaneous Mortality (Z)

Total instantaneous mortality was estimated by analyzing catch curves (Beverton and Holt 1957) based on fully recruited age fish and older. The fish age-fish length key was used to construct catch curves by assigning ages to the landed unaged vermilion snapper. Mortality estimates under equilibrium assumption were obtained by regressing the natural log of the catch in numbers against age for fully recruited fish (ages 3 through 12, or 4-12, depending on time period, 1986-1991 and 1992-1996).

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, yr^{-1}) as well as mean water temperature (T ^{0}C) for the general habitat:

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

Sea surface temperature readings from buoys operated by NOAA's National Oceanographic Data Center were used to calculate mean annual seawater temperature. Buoys recorded temperature every 30 minutes, and monthly averages were calculated at four different locations throughout the South Atlantic Bight (SAB). These monthly averages were averaged across locations and a SAB-wide value for mean annual temperature obtained. All data were from 1996 for all buoys except Edisto, where 1995 data were used for October through December. Buoys used and their locations are

1) Edisto - 32.5° N 79.1° W
2) Savannah - 31.9° N 80.7° W
3) St. Augustine - 29.9° N 81.3° W

4) Cape Canaveral - 28.5° N 80.2° 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.

We also estimated natural mortality using the methods of Roff (1984), using optimal age at maturity, and Rikhter and Efanov (1977), using age at 50 % maturity. For both methods, we used the logistic function to obtain length at 50 % maturity, and then used the von Bertalanffy growth equation to solve for the corresponding age at 50 % maturity. One final method we used 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.

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). The problem arises from the equilibrium assumption of constant F and recruitment. In this assessment, age-specific fishing mortality rates, and estimates of vermilion snapper age-specific population size were obtained by applying separable virtual population analysis (VPA) technique to get around this equilibrium assumption. However, because of the short time frame of the catch matrix (1986-1996) relative to ages (1-14), this is not completely successful. Especially because two temporal periods (1986-1991 and 1992-1996) are required, due to the minimum size limits imposed at the beginning of 1992. The VPA method is explained briefly below:

The catch matrix was interpreted using the separable virtual population analysis (VPA) 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, was 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. There are obvious problems with applying this technique to the full time period, 1986-1996, because of the imposition of a 10-inch size limit for recreational anglers and a 12-inch size limit for commercial fishermen in January, 1992. Therefore, the technique was applied separately to the two time periods (1986-1991 and 1992-1996). We used the FORTRAN program developed by Clay (1990), based on Pope and

Shepherd (1982).

Yield Per Recruit

The yield per recruit model was used to estimate the potential yield in weight for vermilion snapper 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 entered the fishing grounds. 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 vermilion snapper 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 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 also 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 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, also known as Percent Maximum Spawning Potential (%MSP)) 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 considers a stock to be overfished if the SPR is < 0.30 (< 30%), and is recovering with SPR values ranging from 0.30-0.39 (30-39%). The target is to obtain a SPR of 0.40 or greater (> 39%) (Gregg Waugh, SAFMC, Charleston, SC, pers. comm.). These ranges in SPR values and respective definitions are being debated. Longevity, age-specific fecundity, and age-specific fishing mortality are critical to the derivation of SPR.

In this study, comparisons of age-specific spawning stock biomass were based on mature female biomass and egg production. Two sources of information pertaining to vermilion snapper reproductive characteristics were utilized. The first is a published study by Cuellar et al. (1996). The report contains sexual maturity schedule and fecundity information for the species sampled along the southeastern United States. The second source of information is sexual maturity at age (size) data provided by the SCDNR (Jack McGovern, pers. comm.) as part of an ongoing study.

RESULTS

Sampling Adequacy

We used an informal standard developed by the NMFS, Northeast Regional Stock Assessment Workshop (USDOC 1996) to determine the adequacy of biological sampling of vermilion snapper landings (Table 3). According to this standard, 100 fish lengths should be recorded for each 200 mt of the species landed. Thus, a value greater than 200 mt/100 samples indicates an inadequate sample. Using 1986-1996 data, we found that recreational (MRFSS) landings of vermilion snapper were much less frequently sampled than were headboat or commercial landings (Table 3). Samples were judged to be inadequate for 1996, and fewer than 100 fish were sampled regionwide for all years except 1988 and 1992. The problem identified here for vermilion snapper holds true for red snapper, Lutjanus campechanus, and probably other species of reef fish as well (Manooch et al. 1998). We encourage an increase of biological sampling intensity of reef fish by MRFSS personnel.

Table 3. Level of sampling per year by fishery (mt/100 length samples) for vermilion snapper landed in the U.S. South Atlantic. Informal criteria is set at 200mt/100 length samples (e.g. <200mt/100 length samples, sampling is adequate; >200mt/100 length samples, sampling is inadequate = bold numbers).

Year	MRFSS		Headboat		Commercial Hook and Line	
	mt/#of samples	Level	mt/# of samples	Level	mt/# of samples	Level
1986	5.11/ 19	27	158.45/6160	3	364.21/ 7954	5
1987	33.06/ 36	92	205.00/6327	3	294.44/ 7176	4
1988	61.11/145	42	189.89/4761	4	370.30/ 5370	7
1989	48.07/ 80	60	157.19/4769	3	516.28/ 5314	10
1990	54.70/ 75	73	175.44/5308	3	563.42/ 5181	11
1991	47.58/ 50	95	275.69/4028	7	622.04/ 9478	7
1992	53.72/114	47	113.22/2829	4	335.11/ 6093	5
1993	44.55/ 75	59	116.67/3318	4	395.33/ 7907	5
1994	33.33/ 77	43	127.76/5726	2	440.44/ 7059	6
1995	19.96/ 74	27	123.31/4799	3	429.74/11841	4
1996	35.85/ 16	**224**	125.33/3858	3	340.47/ 5016	7

Trends - Landings

Commercial

Although some commercial landings data are available dating back to 1962 (table 4), the most reliable and uninterrupted time series begins in 1986, when all vermilion snapper were identified to species and not merely placed in an "unclassified snapper" category as they were prior to 1986. From 1986-1996, landings averaged 964,545 pounds

(N = 11) with catches exceeding a million pounds in 1989, 1990, and 1991. Landings have remained relatively stable since 1991 (Figure 1) ranging from 742,000 to 972,000 pounds. Some of the decrease in catches for recent years is attributable to regulations, such as those imposed in 1992 (minimum sizes for recreational and commercial fisheries and bag limit for anglers) rather than abundance of the species. Most vermilion snapper were landed at ports in North Carolina and South Carolina (unweighted mean = 70% of the southeastern U.S. catch for 1986-1996). Relatively few vermilion snapper were landed in South Florida and the Keys (Table 4). The extremely low landings for 1962-1976 are attributed to an undeveloped commercial fishery for most of the geographical area, and the few snappers landed were recorded as "unclassified snappers", and therefore, do not appear in this figure.

Headboat

Headboat data are available for all geographical areas for the years 1982 through 1996 (Table 5; Figure 2). For the 15-year period, landings averaged 324,403 pounds. Catches have remained relatively stable since 1992. Overall, commercial landings of vermilion snapper are two to three times greater than those reported by headboat anglers for 1982-1996 (Tables 4 and 5).

Most vermilion snapper were landed by headboat anglers fishing out of North Carolina, South Carolina, and Northeast Florida ports. Conversely, the species is less frequently caught off Georgia and Southeast Florida. However, it should be noted that since 1972 there have been relatively few headboat trips made off Georgia compared to the other states/areas.

From 1982 to 1990 the headboat landings from the Carolinas averaged 46% of the total southeast landings, but in 1991 the Carolinas' landings made up 71% of the total. With the minimum size limits instituted in 1992, the Carolinas contributed 81%-88% of the total headboat landings. This shift in proportion of landings can be attributed to North Florida vermilion snapper mean size being smaller than those from the Carolinas, thus Florida is more affected by the minimum size regulation on this species.

Recreational (MRFSS)

Recreational fishing statistics are available for 1981 through 1996. Landings of vermilion snapper are presented by number and weight (pounds) in Table 6 by year and area. During the 16-year period, the average recreational catch was 140,483 pounds. Landings peaked in 1985 when approximately 434,000 pounds were landed (Figure 3). Recent landings, 1993-1996, have been much less than they were from 1988 - 1992.

Unlike the commercial fishery data, where North Carolina and South Carolina ports produced most of the landings, recreational catches were not consistently dominated by one or two states. For example, Florida landings were 70% of the area total for 1987, but only 1.5% in 1996 (Table 6).

Table 4. Vermilion snapper commercial landings-- weight (lbs*10^3) and value from U.S. South Atlantic.

	NC		SC		GA		FL		Total	
Year	Wt	Value	Wt	Value	Wt	Value	Wt	Value	Wt	Value
1962			48	2313			8	1693	56	4006
1963			10	1200			12	2357	22	3557
1964			0.3	24			7	1502	8	1526
1965			3	202			23	5849	25	6051
1966							4	1037	4	1037
1967							15	4903	15	4903
1968							33	13329	33	13329
1969			0.6	241			22	14030	33	14271
1970							21	10479	21	10479
1971			10	3188			53	20159	63	23347
1972			15	6707					15	6707
1973			6	2832	0.1	93			6	2925
1974			3	1270					3	1270
1975			2	1205					2	1205
1976			55	55881					55	55881
1977			58	63737	7	8721	154	167329	219	239787
1978	52	64997	74	92634	20	30335	116	148144	263	336110
1979	129	188436	92	133331	5	6261	149	199824	375	527852
1980	191	326305	276	327219	37	39420	116	139563	621	832507
1981	144	257	265	321012	48	56192	71	94184	529	728281
1982	172	292104	355	497524	16	16065	74	76381	617	882074

1983	101	187236	356	497322	15	15207	85	119872	557	819637
1984	216	406479	268	406655	90	121837	120	149607	694	1084578
1985	377	683993	176	274157	170	248911	148	225484	871	1432545
1986	391	735029	163	289479	148	272124	114	177910	816	1474542
1987	272	529704	230	440159	82	120300	95	159704	679	1249867
1988	365	702829	347	575979	70	108681	133	226058	915	1613547
1989	504	1028182	370	722631	58	97957	224	370454	1156	2219224
1990	564	1105153	358	747278	113	217717	295	544477	1330	2614625
1991	560	1088334	483	992162	129	233603	241	451531	1413	2765630
1992	306	697728	227	477340	54	101750	155	260047	742	1536865
1993	369	805482	250	525530	86	152988	171	294646	876	1778646
1994	402	903367	220	463448	119	227124	231	414428	972	2008367
1995	376	867648	183	396910	126	250319	267	565697	952	2080574
1996	331	718493	154	353865	84	179847	190	407544	759	1659749

Figure 1. Commercial landings for vermilion snapper from the southeastern U.S.

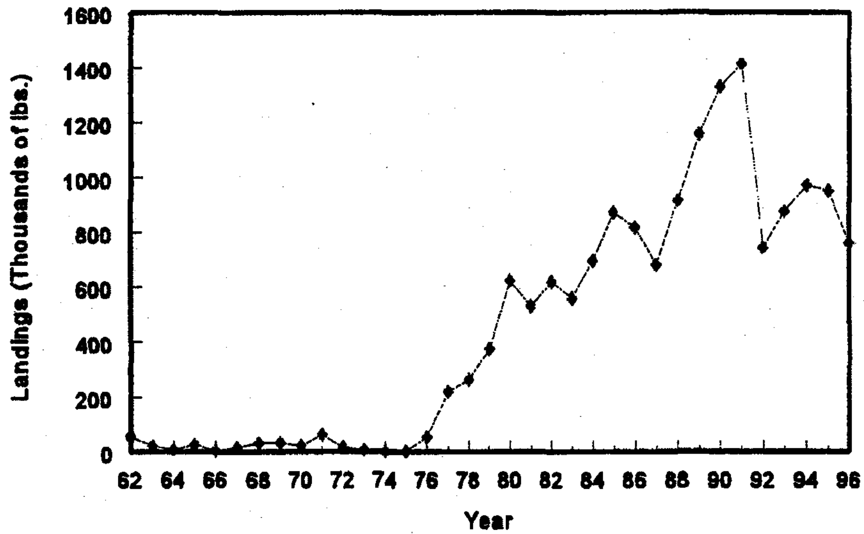


Table 5. Vermilion snapper headboat landings -- number and weight (lbs) from the southeastern U.S.

	North Carolina		South Carolina		NE Florida-Georgia		SE Florida		Total	
Year	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
1972	41165	66896	39679	40322					80844	107218
1973	51610	112736	32030	43797					83640	156533
1974	51661	63835	56294	55385					107955	119220
1975	71669	95758	82918	88396					154587	184154
1976	22558	45504	55624	53414	226681	155165			304863	254084
1977	11634	33291	19665	26943	200480	92934			231779	153167
1978	13434	44289	28025	37493	315545	162828			357004	244610
1979	14887	45161	5586	5178	285935	132850			306408	183189
1980	24548	71121	20253	21936	194586	81306			239387	174363
1981	37829	81295	26297	35758	171029	85412			235155	202465
1982	66210	123833	104075	88987	159093	97630	32943	29090	362321	339540
1983	50194	93284	73285	59044	192548	96141	83013	46652	399040	295121
1984	31146	47346	60353	47901	190516	121150	42514	28348	324529	244744
1985	43907	53716	106273	98104	284923	156222	94700	63797	529803	371839
1986	53796	54982	114206	93275	283153	145639	81946	55110	533101	349007
1987	41904	38991	176757	134641	330108	154817	182238	123090	731007	451540
1988	53807	46392	169034	130996	366423	149996	151627	90883	740891	418267
1989	48541	41101	140114	91496	284303	105300	188293	108337	661251	346233
1990	123396	108068	167102	109218	231284	81366	134077	87780	655859	386432
1991	159682	122917	174055	109289	200209	65725	66555	29958	600501	327889
1992	105240	95742	147838	105577	32112	20575	60076	27480	345266	249374
1993	86532	73482	171996	138293	28722	16744	39777	28453	327027	256973
1994	98288	92863	216215	154172	24549	13903	30668	20458	369720	281397
1995	102328	92205	199748	145925	19386	10767	33304	22723	354766	271619
1996	87806	77581	198287	158185	15481	10029	38766	30268	340340	276064

Figure 2. Vermilion snapper headboat landings by weight (lbs) from the U.S. South Atlantic.

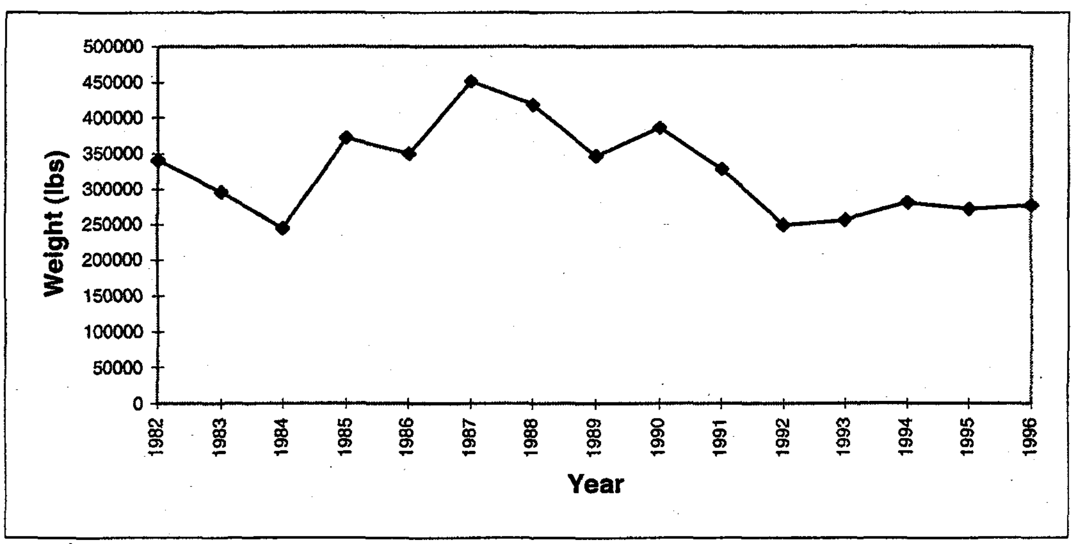
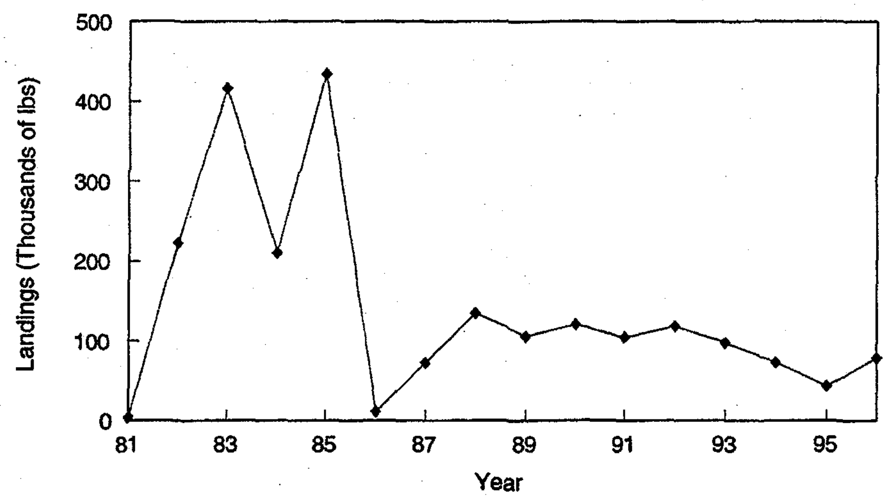


Table 6. Vermilion snapper recreational (MRFSS) landings ---number of fish and weight (lbs) from U.S. South Atlantic.

	NC		SC		GA		FL		Total	
Year	#	lbs	#	lbs	#	lbs	#	lbs	#	lbs
1981	178	118	313	—	—	—	19,069	4,394	19,560	4,512
1982	—	—	253,217	187,043	18,818	13,777	40,381	21,993	312,416	222,813
1983	124,357	216,132	7,505	5,432	—	—	185,781	193,776	317,643	415,340
1984	—	—	159,835	118,252	—	—	86,160	91,566	245,995	209,818
1985	—	—	263,167	145,463	6,942	6,056	400,679	282,274	670,788	433,793
1986	—	—	2,494	1,097	20,031	738	25,784	9,404	48,309	11,239
1987	48,096	19,043	4,703	1,589	3,417	1,425	71,013	50,669	127,229	72,726
1988	39,717	51,180	53,418	58,634	3,191	1,844	28,031	22,781	124,357	134,439
1989	39,830	30,767	43,047	50,097	11,954	3,108	139,163	21,772	233,994	105,744
1990	99,178	98,214	2,371	6,521	—	—	17,330	15,600	118,879	120,335
1991	24,434	20,329	14,759	15,058	12,839	8,772	118,769	60,511	170,801	104,670
1992	29,372	30,133	22,710	12,991	20,007	47,542	9,759	27,523	81,848	118,189
1993	15,436	12,628	3,483	3,907	41,505	50,218	32,780	31,247	93,204	98,000
1994	23,255	27,641	2,161	2,296	12,293	19,135	20,971	24,257	58,680	73,329
1995	15,987	12,058	14,236	11,570	21,098	13,367	11,982	6,925	63,303	43,920
1996	13,228	13,183	9,368	17,061	53,112	47,448	1,266	1,174	76,794	78,866

Figure 3. MRFSS landings of vermilion snapper from the southeastern U.S.



Trends - Catch/Effort

Commercial

Catch per unit effort (CPUE) data are not available for the commercial data base.

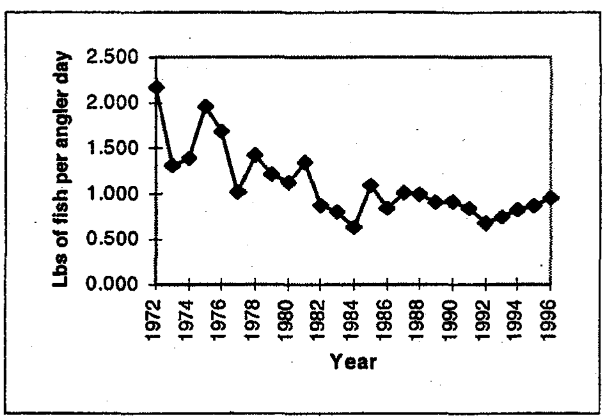
Headboat

Catch per unit effort data are available for 1972 through 1996 for North Carolina and South Carolina, and from 1976 through 1996 for North Carolina to the Florida Keys. Annual CPUE values for all areas combined are presented in Table 7 and Figure 4 as weight in pounds of vermilion snapper caught per angler day. Catch rates have increased slightly since 1984 (Table 7; Figure 4). The highest catch rates were recorded in 1972, 1975, 1976, and 1991, all greater than 1.5 pounds. Regulations have obviously had an impact on catch rates as indicated by the low CPUE for 1992 (0.679). Since then, CPUE has increased by 40.2% and may reflect a response to SAFMC fisheries management.

Table 7. Vermilion snapper catch-per effort
Headboats - all areas combined.

Year	Cpue-Wt
1972	2.167
1973	1.314
1974	1.393
1975	1.960
1976	1.682
1977	1.015
1978	1.426
1979	1.214
1980	1.122
1981	1.346
1982	0.876
1983	0.803
1984	0.635
1985	1.090
1986	0.840
1987	1.010
1988	0.994
1989	0.910
1990	0.913
1991	0.840
1992	0.679
1993	0.747
1994	0.821
1995	0.870
1996	0.952

Figure 4. Vermilion snapper CPUE - headboats all areas combined



CPUE in number of fish and weight are presented by area (NC, SC, NEFL-GA, and SEFL) in Tables 8-11; Figures 5-8). Catch rates are up slightly for North Carolina since 1989 (Figure 5); up for South Carolina anglers since the late 1970s (Figure 6); down for NEFL-GA since 1988, particularly since 1991 (Figure 7); and up slightly for SEFL since 1994 (Figure 8).

Table 8. North Carolina headboat catch-per-effort (by number and weight) for vermilion snapper.

Year	Number	Weight	Angdays	Cpue-#	Cpue-wt
1972	41165	66896	30659	1.343	2.182
1973	51610	112736	38768	1.331	2.908
1974	51661	63835	33223	1.555	1.921
1975	71669	95758	32725	2.190	2.926
1976	22558	45504	31314	0.720	1.453
1977	11634	33291	22660	0.513	1.469
1978	13434	44289	26032	0.516	1.701
1979	14887	45161	26490	0.562	1.705
1980	24548	71121	23714	1.035	2.999
1981	37829	81295	19372	1.953	4.197
1982	66210	123833	26939	2.458	4.597
1983	50194	93284	23830	2.106	3.915
1984	31146	47346	28865	1.079	1.640
1985	43907	53716	31346	1.401	1.714
1986	53796	54982	31187	1.725	1.763
1987	41904	38991	35261	1.188	1.106
1988	53807	46392	42421	1.268	1.094
1989	48541	41101	38678	1.255	1.063
1990	123396	108068	43240	2.854	2.499
1991	159682	122917	40936	3.901	3.000
1992	105240	95742	41177	2.556	2.325
1993	86532	73482	42785	2.022	1.717
1994	98288	92863	36693	2.679	2.531
1995	102328	92205	40294	2.540	2.288
1996	87806	77581	35142	2.499	2.208

Figure 5. Vermilion snapper CPUE - North Carolina headboats.

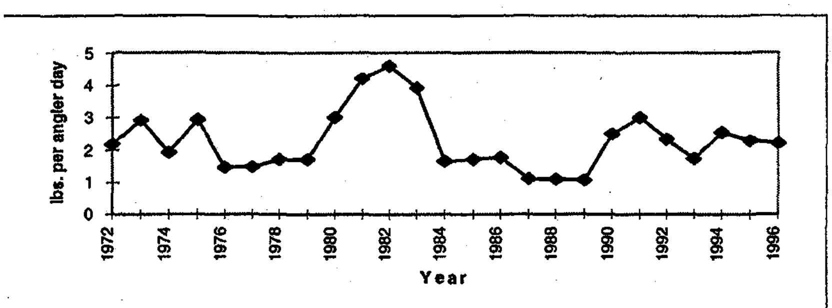


Table 9. South Carolina headboat catch-per-effort (by number and weight) for vermilion snapper.

Year	Number	Weight	Angdays	Cpue-No	Cpue-wt
1972	39679	40322	18830	2.107	2.141
1973	32030	43797	80352	0.399	0.545
1974	56294	55385	52384	1.075	1.057
1975	82918	88396	61225	1.354	1.444
1976	55624	53414	61318	0.907	0.871
1977	19665	26943	69910	0.281	0.385
1978	28025	37493	67462	0.415	0.556
1979	5586	5178	56935	0.098	0.091
1980	20253	21936	64244	0.315	0.341
1981	26297	35758	59030	0.445	0.606
1982	104075	88987	67539	1.541	1.318
1983	73285	59044	65713	1.115	0.899
1984	60353	47901	67313	0.897	0.712
1985	106273	98104	29042	3.659	3.378
1986	114206	93275	67227	1.699	1.387
1987	176757	134641	78806	2.243	1.709
1988	169034	130996	76468	2.211	1.713
1989	140114	91496	24861	5.636	3.680
1990	167102	109218	57151	2.924	1.911
1991	174055	109289	67982	2.560	1.608
1992	147838	105577	61790	2.393	1.709
1993	171996	138293	64457	2.668	2.146
1994	216215	154172	63231	3.419	2.438
1995	199748	145925	61739	3.235	2.364
1996	198287	158185	54929	3.610	2.880

Figure 6. Vermilion snapper CPUE - South Carolina headboats.

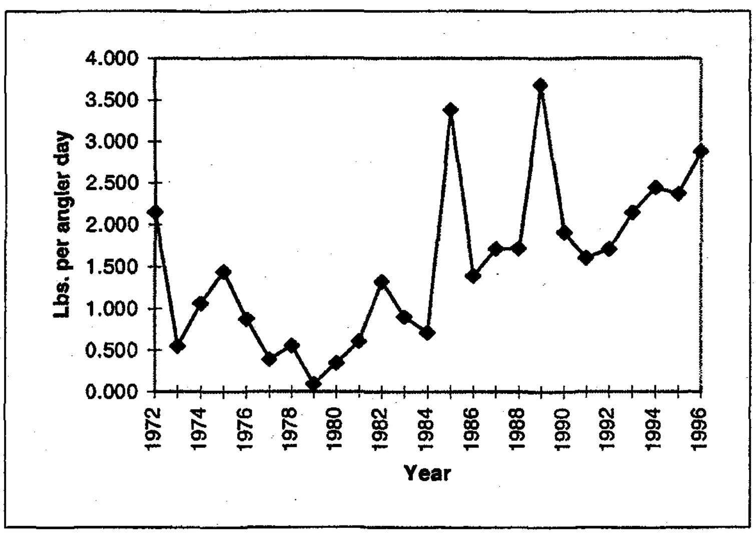


Table 10. Northeast Florida - Georgia headboat catch-per-effort (by number and weight) for vermilion snapper.

Year	Number	Weight	Angdays	Cpue-#	Cpue-wt
1976	226681	155165	58404	3.881	2.657
1977	200480	92934	58330	3.437	1.593
1978	315545	162828	78099	4.040	2.085
1979	285935	132850	67461	4.239	1.969
1980	194586	81306	67466	2.884	1.205
1981	171029	85412	72069	2.373	1.185
1982	159093	97630	66961	2.376	1.458
1983	192548	96141	83499	2.306	1.151
1984	190516	121150	95234	2.001	1.272
1985	284923	156222	94446	3.017	1.654
1986	283153	145639	113101	2.504	1.288
1987	330108	154817	114144	2.892	1.356
1988	366423	149996	109156	3.357	1.374
1989	284303	105300	102920	2.762	1.023
1990	231284	81366	98234	2.354	0.828
1991	200209	65725	85111	2.352	0.772
1992	32112	20575	90810	0.354	0.227
1993	28722	16744	74494	0.386	0.225
1994	24549	13903	65745	0.373	0.211
1995	19386	10767	59104	0.328	0.182
1996	15481	10029	47239	0.328	0.212

Figure 7. Vermilion snapper CPUE - NEFL -GA headboats.

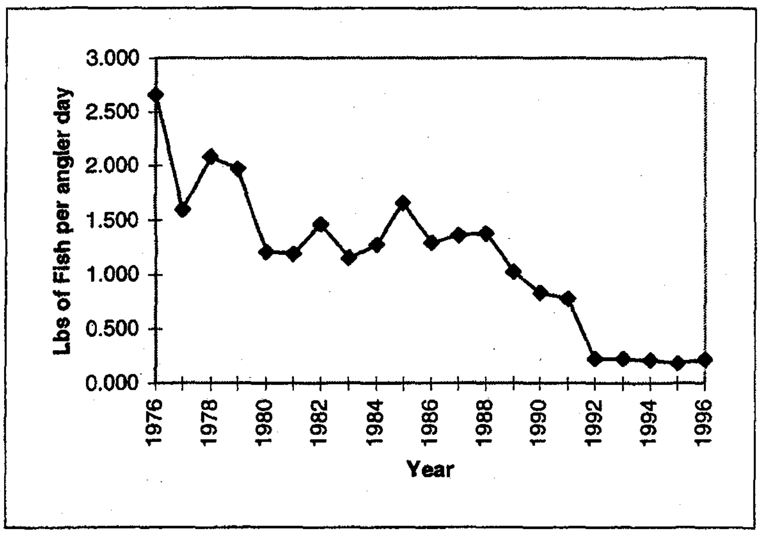
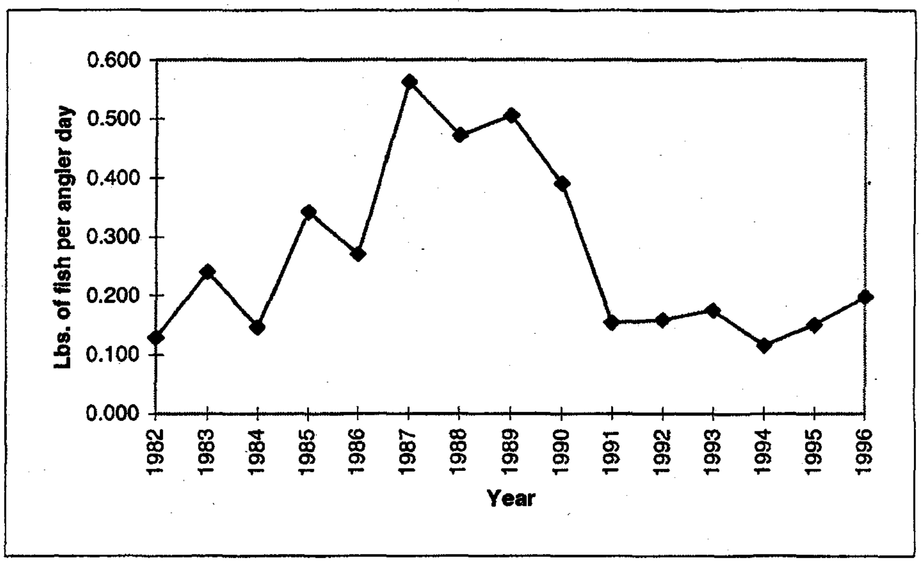


Table 11. South Florida catch-per-effort (by number and weight) for vermilion snapper.

Year	Number	Weight	Angdays	Cpue-#	Cpue-Wt.
1982	32943	29090	226172	0.146	0.129
1983	83013	46652	194364	0.427	0.240
1984	42514	28348	193760	0.219	0.146
1985	94700	63797	186398	0.508	0.342
1986	81946	55110	203960	0.402	0.270
1987	182238	123090	218897	0.833	0.562
1988	151627	90883	192618	0.787	0.472
1989	188293	108337	213944	0.880	0.506
1990	134077	87780	224661	0.597	0.391
1991	66555	29958	194991	0.341	0.154
1992	60076	27480	173714	0.346	0.158
1993	39777	28453	162478	0.245	0.175
1994	30668	20458	177035	0.173	0.116
1995	33304	22723	150957	0.221	0.151
1996	38766	30268	152618	0.254	0.198

Figure 8. Vermilion snapper CPUE - Southeast Florida headboats.



Recreational (MRFSS)

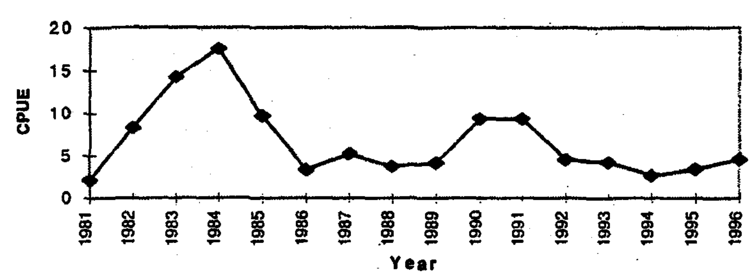
Recreational CPUE data are available for the southeastern United

States from 1981 through 1996 (Table 12 and Figure 9). Catch rates are recorded as number of vermilion snapper per angler trip. CPUE values seem unexpectantly high compared with the headboat CPUE data, particularly in 1983 and 1984. Recreational catch rate for vermilion snapper peaked in 1984 (17.5 fish/angler trip), dropped to 9.7 in 1985, and then remained at 3-5 vermilion snapper/ angler trip from 1986-1989, and rose to over 9 from 1990 to 1991. CPUE has increased slightly during the past two years.

Table 12. Recreational (MRFSS) catch-per-effort for vermilion snapper from the southeastern United States.

Year	Total Catch #	Total Angler Trips	CPUE
1981	19559	9241	2.12
1982	346610	42058	8.24
1983	313300	22017	14.23
1984	261112	14890	17.54
1985	399446	41220	9.69
1986	35193	10718	3.28
1987	91572	17656	5.19
1988	150289	40634	3.70
1989	293619	70940	4.14
1990	159240	17089	9.32
1991	213375	22907	9.31
1992	137516	30710	4.48
1993	138801	33237	4.18
1994	119410	45320	2.63
1995	171040	51114	3.35
1996	108932	23747	4.59

Figure 9. Recreational (MRFSS) catch-per-effort for vermilion snapper.



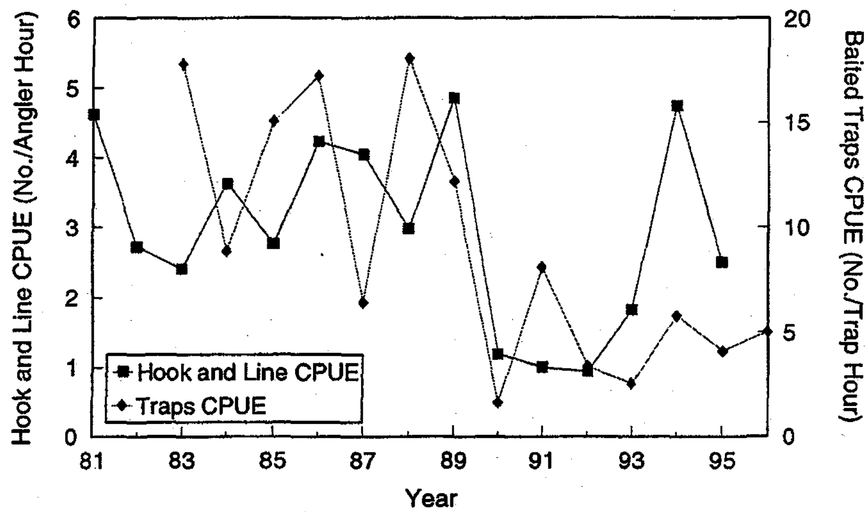
Fishery Independent Data (SCDNR)

From 1981 through 1996 South Carolina Department of Natural Resources personnel used hook and line and baited traps (Florida snapper traps and Chevron traps) to capture vermilion snapper and other species of reef fish (Table 13; Figure 10). Data are reported for CPUE and size (age) distributions in the catch by year. Although sampling efforts are concentrated off South Carolina, collections were also made off North Carolina, Georgia, and northeast Florida. Catch per unit effort was recorded in number per angler hour or trap hour. CPUE for hook and line was highest in 1981, 1986-1987, 1989, and 1994, all over 4.0 vermilion snapper/angler hour. The highest CPUE for traps was in 1983, 1985-1986, and 1988-1989 (Table 13; Figure 10).

Table 13. Fishery independent CPUE for vermilion snapper collected by hook and line and baited traps in the South Atlantic Bight (SCDNR, MARMAP, Charleston, SC).

Year	Source			
	Hook and Line		Florida Traps and Chevron Traps	
	N	CPUE	N	CPUE
81	27	4.621		
82	13	2.719		
83	14	2.396	107	17.82
84	20	3.624	158	8.86
85	15	2.763	122	15.05
86	17	4.239	165	17.24
87	27	4.041	232	6.43
88	264	2.979	171	18.09
89	201	4.858	131	12.19
90	85	1.192	292	1.62
91	24	1.000	247	8.10
92	15	0.933	282	3.36
93	33	1.808	323	2.50
94	33	4.747	340	5.79
95	12	2.500	253	4.09
96	No sampling with hook and line		352	5.01

Figure 10. Fishery independent CPUE for vermilion snapper collected by hook and line and Florida snapper traps and Chevron traps in the South Atlantic Bight (SCDNR, MARMAP, Charleston, SC).



Trends - Mean Weights

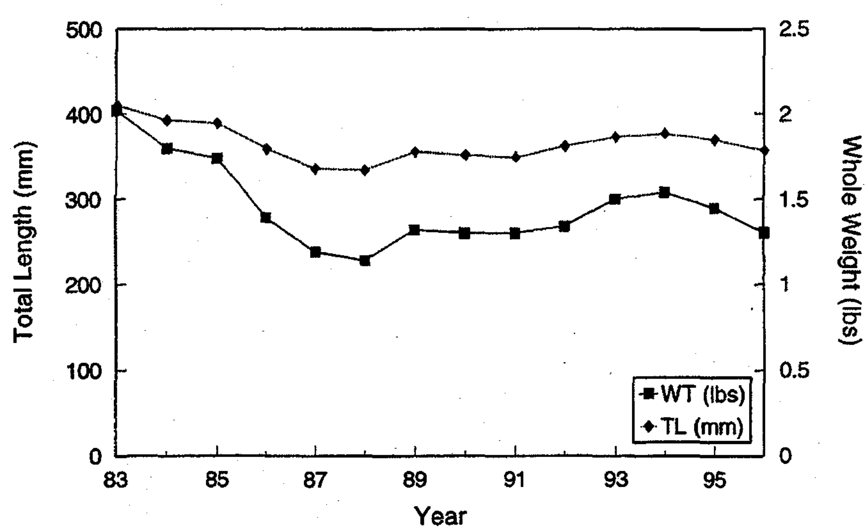
Commercial

Mean size data are available for the commercial fishery from 1983 through 1996 and are presented in Table 14 and Figure 11 by lengths and weights. Mean size for vermilion snapper was largest in 1983 and smallest in 1988. Mean sizes were larger for 1983-1985, decreased from 1986-1988, and increased slightly and remained relatively stable (1.3-1.5 pounds) for 1989-1996. It appears that the commercial fishery typically catches vermilion snapper larger than the size limit imposed in 1992, therefore mean size landed has not changed drastically.

Table 14. Vermilion snapper commercial mean total lengths (mm) and whole weights (kg) weighted by sample size of gear types.

	NC/SC		GA/NFL		SFL		Overall	Weighted Mean
Year	TL	lbs.	TL	lbs.	TL	lbs.	TL	lbs.
1983	410	2.02	-	-	-	-	410	2.02
1984	393	1.80	-	-	-	-	393	1.80
1985	395	1.80	309	0.86	-	-	389	1.74
1986	367	1.47	316	0.92	-	-	359	1.39
1987	345	1.25	283	0.77	-	-	336	1.19
1988	336	1.19	321	0.99	282	0.59	334	1.14
1989	356	1.32	353	1.30	-	-	356	1.32
1990	353	1.30	366	1.43	477	2.93	352	1.30
1991	351	1.32	333	1.10	262	0.48	349	1.30
1992	363	1.34	355	1.28	368	1.39	362	1.34
1993	378	1.56	359	1.32	375	1.54	373	1.50
1994	377	1.54	377	1.54	385	1.65	377	1.54
1995	379	1.56	361	1.32	-	-	370	1.45
1996	364	1.39	347	1.17	-	-	357	1.30

Figure 11. Mean weight and mean total length of vermilion snapper landed commercially in the southeastern U.S.



Headboat

The mean weights of vermilion snapper caught by headboat anglers have generally increased since 1991 (Table 15; Figure 12) for all geographic areas combined. This increase is most probably caused by the size restrictions intended to reduce the harvest of smaller fish. Mean weight, which had been about one pound in 1982, declined to 0.5 to 0.6 pound from 1989-1991, and increased to 0.7 to 0.8 pound from 1992 through 1996. Overall, there has not been much change in mean weight in 15 years (Table 15).

The same pattern of moderate increase in mean weights did not prevail for each geographic area (Tables 16-19; Figures 13-16). The decrease in mean size of vermilion snapper landed in North Carolina is dramatic since 1979, but has remained about the same for 1986-1996 (Figure 13). The species averaged two-three pounds from 1976 through 1982, and has declined to about one pound from 1985-1996. Vermilion snapper landed in South Carolina revealed a similar mean size pattern by year as those from North Carolina, except the mean size of South Carolina fish increased in the most recent years, 1992-1996 (Table 17). Mean size for the NEFL-GA and SEFL areas increased from 1991-1996 (Tables 18 and 19), again reflecting the 10-inch minimum size regulation. As sizes increased, numbers of fish sampled generally decreased.

Table 15. Mean weight (lbs) of vermilion snapper from headboats for all areas combined.

Year	Mean Weight	N
1982	0.94	2782
1983	0.77	4506
1984	0.80	4548
1985	0.71	5925
1986	0.66	6191
1987	0.64	6332
1988	0.64	4774
1989	0.52	4776
1990	0.51	5333
1991	0.45	4042
1992	0.64	2835
1993	0.71	3325
1994	0.69	5738
1995	0.73	4811
1996	0.77	3867

Figure 12. Vermilion snapper mean weight from headboat landings in the southeastern U.S.

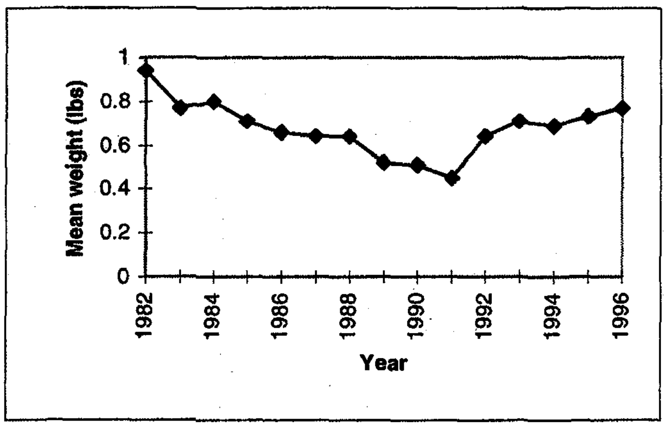


Table 16. Vermilion snapper mean weights (lbs) from North Carolina headboats.

Year	Mean Weight	N
1972	1.22	753
1973	2.18	320
1974	1.51	527
1975	1.53	686
1976	2.15	450
1977	3.01	144
1978	3.12	221
1979	3.37	269
1980	2.77	322
1981	2.10	174
1982	1.90	591
1983	1.55	864
1984	1.44	542
1985	1.18	816
1986	0.99	1175
1987	0.91	1250
1988	0.86	1307
1989	0.83	871
1990	0.91	838
1991	0.77	1047
1992	0.87	530
1993	0.79	613
1994	0.90	565
1995	0.89	700
1996	0.85	747

Figure 13. Vermilion snapper mean weights from North Carolina headboats.

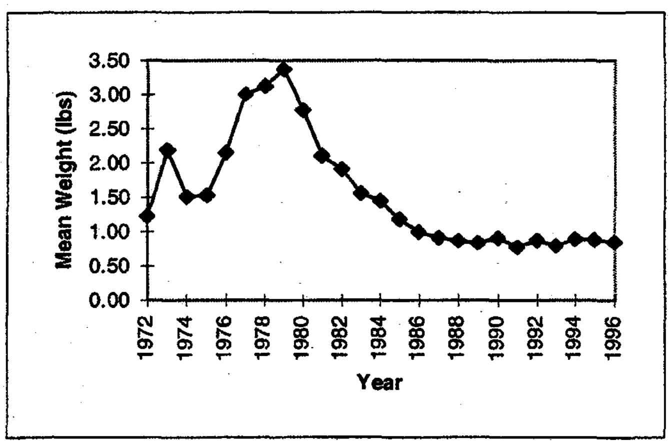


Table 17. Vermilion snapper mean weights (lbs) from South Carolina headboats.

Year	Mean Weight	N
1972	1.06	344
1973	1.29	250
1974	1.10	714
1975	1.21	604
1976	1.16	293
1977	1.33	214
1978	1.27	219
1979	0.81	52
1980	1.22	171
1981	1.19	137
1982	0.88	686
1983	0.83	587
1984	0.80	1516
1985	0.90	627
1986	0.75	691
1987	0.74	1022
1988	0.87	728
1989	0.65	914
1990	0.65	1196
1991	0.61	868
1992	0.72	1575
1993	0.78	2002
1994	0.72	3979
1995	0.73	3684
1996	0.80	2708

Figure 14. Vermilion snapper mean weights from South Carolina headboats.

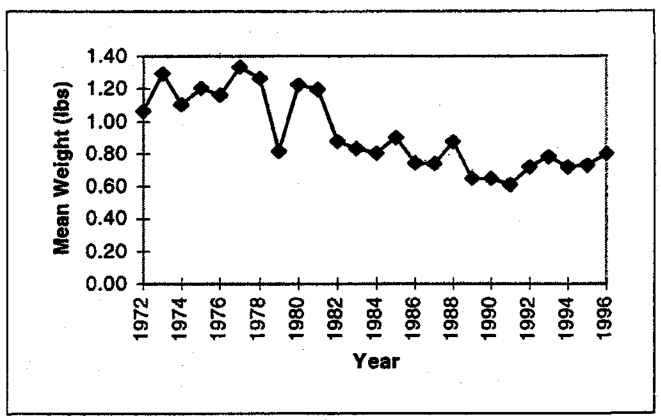


Table 18. Vermilion snapper mean weights (lbs) from Northeast Florida-Georgia headboats.

Year	Mean Weight	N
1976	0.57	400
1977	0.46	669
1978	0.50	864
1979	0.42	898
1980	0.40	601
1981	0.50	853
1982	0.57	1331
1983	0.50	1574
1984	0.65	1918
1985	0.55	3012
1986	0.51	3211
1987	0.47	3103
1988	0.42	2193
1989	0.37	2156
1990	0.35	2726
1991	0.32	1477
1992	0.61	234
1993	0.63	307
1994	0.64	376
1995	0.61	181
1996	0.61	202

Figure 15. Vermilion snapper mean weights from Northeast Florida-Georgia headboats.

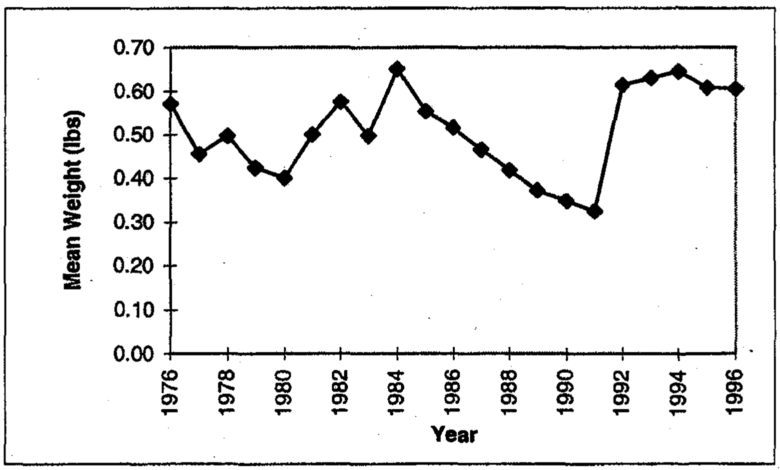
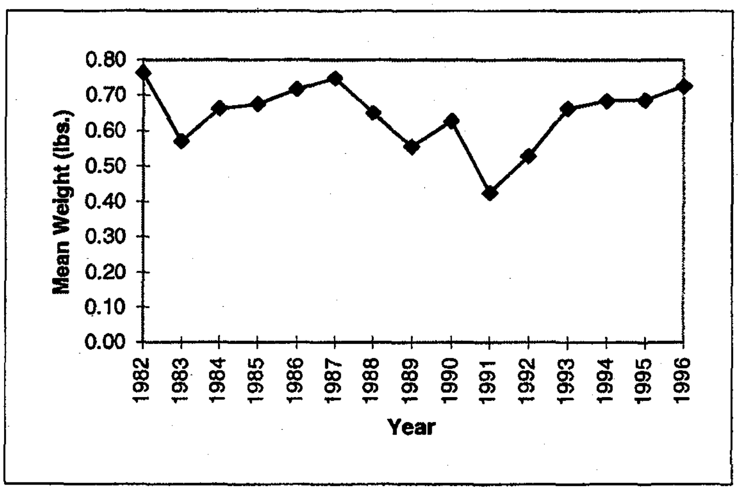


Table 19. Vermilion snapper mean weight (lbs) from southeast Florida headboats.

Year	Mean Weight	N
1982	0.76	167
1983	0.57	1478
1984	0.66	569
1985	0.68	1466
1986	0.72	1092
1987	0.75	940
1988	0.65	536
1989	0.55	652
1990	0.63	339
1991	0.42	172
1992	0.53	156
1993	0.66	194
1994	0.68	508
1995	0.69	123
1996	0.72	63

Figure 16. Vermilion snapper mean weights from Southeast Florida headboats.



Recreational (MRFSS)

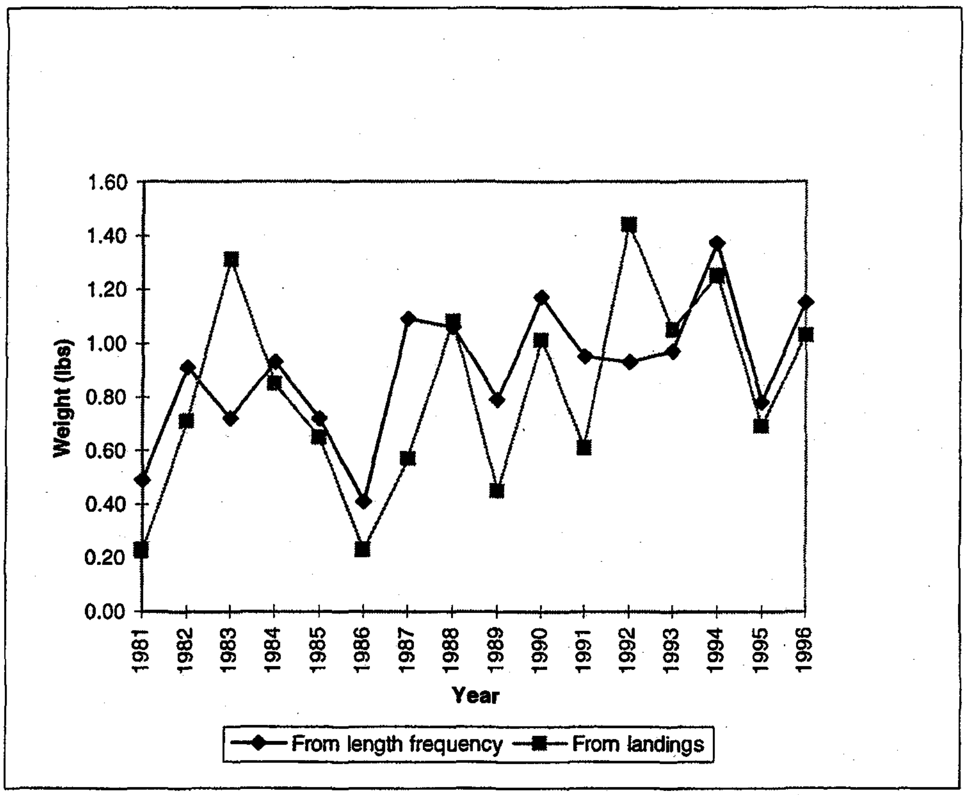
Mean size data are available for the recreational fishery from 1981 through 1996 (Table 20; Figure 17). The data could not be stratified by geographic area because of small sample sizes. Less than 20 vermilion snapper were sampled for the entire southeastern United States for each of the years: 1981, 1986, and 1996 (N = 10, 19, and 19, respectively), and less than 100 fish were sampled in 1982, 1987, 1989, 1990, 1991, 1993, 1994, and 1995. Mean fish length derived from length frequency sampling, for the entire area was relatively small, averaging less 350 mm TL (13.8 inches) for all years except 1994 (360 mm; 14-inches and 1.4 pounds). For most of the years, vermilion snapper averaged about a pound or slightly less (Table 20; Figure 17).

Table 20. Recreational (MRFSS) mean weights of vermilion snapper landed in the southeastern United States, generated from the length samples (sample size is in parenthesis)and l-w relationship and from the landings.

	Mean weight (lbs) - Source	
Year	Length samples (N)	Landings
1981	0.49 (10)	0.23
1982	0.91 (91)	0.71
1983	0.72 (148)	1.31
1984	0.93 (608)	0.85
1985	0.72 (187)	0.65
1986	0.41 (19)	0.23
1987	1.09 (37)	0.57
1988	1.06 (145)	1.08
1989	0.79 (80)	0.45

1990	1.17 (75)	1.01
1991	0.95 (53)	0.61
1992	0.93 (120)	1.44
1993	0.97 (75)	1.05
1994	1.37 (77)	1.25
1995	0.78 (74)	0.69
1996	1.15 (19)	1.03

Figure 17. Mean weights of vermilion snapper landed recreationally (MRFSS) in the southeastern U.S.



Age/Growth

Potts (1997) conducted an age and growth study of vermilion snapper because two previous studies were either outdated (Grimes 1978), or of questionable usefulness for a regionwide stock assessment (Zhao et al. 1997). Vermilion snapper were aged 1-14 years, although few fish lived longer than nine years (Potts 1997). Back-calculated length at the last annulus for each individual was used to estimate the von Bertalanffy growth parameters to avoid violating the assumption of independence (Vaughan and Burton 1994): $L_t = 670\ (1-e^{-0.117(t\ +\ 0.613)})$ (Potts 1997)(Figure 18). Fish lengths were converted into fish weights and vice versa using the following equation; $W = 9.55 \times 10^{-9}\ (L)^{3.04}$, where W = whole weight in kilograms and L = total length in millimeters (Potts 1997)(Figure 19). Fish total lengths in millimeters at time of capture were used to create a fish age-fish length key (Table 21).

Figure 18. Comparison of theoretical growth curves for vermilion snapper from the southeastern U.S. (Potts 1997), the Carolinas (Grimes 1978), and the South Atlantic Bight (Zhao et al. 1997).

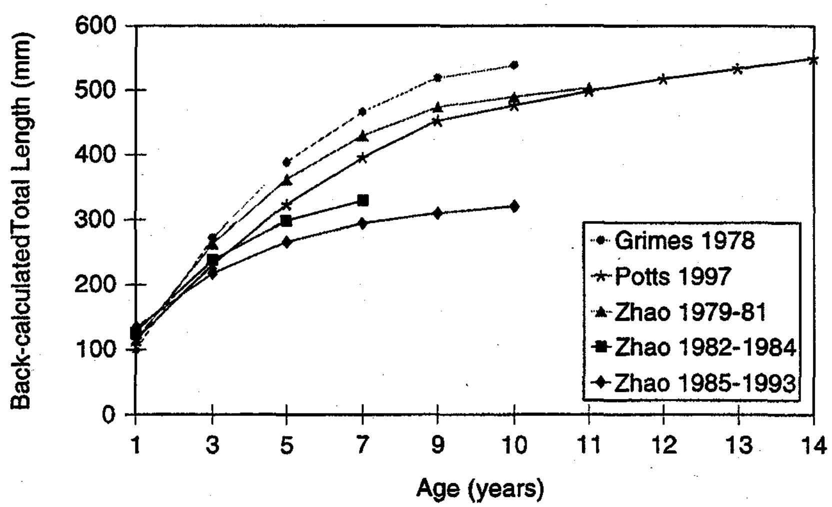


Figure 19. Whole weight - total length relationship for vermilion snapper from the southeastern U.S. (Potts 1997).

$W = 9.55 \times 10^{-9} (L)^{3.04}$
$r^2 = 0.95$, MSE = 0.026
n = 443

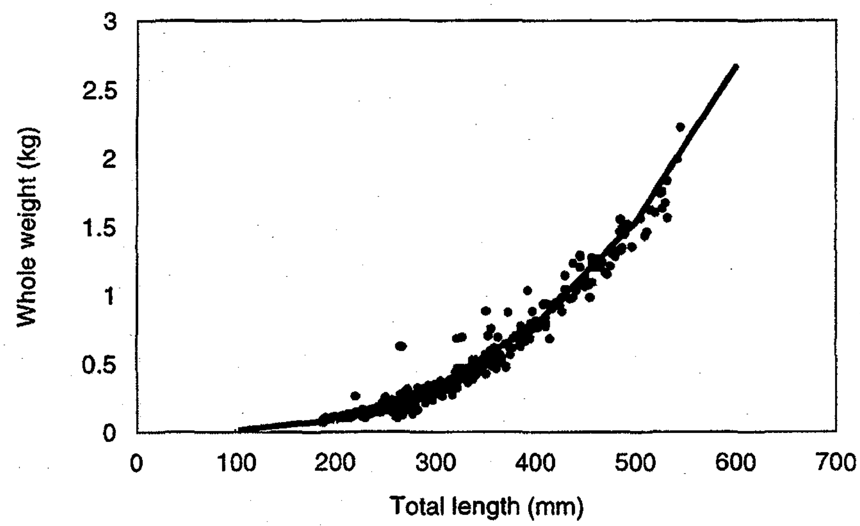


Table 21. Age-total length key of the vermilion snapper collected from the southeastern U.S. Total fish in age class (percent) from Potts (1997).

Age (yr) / Total Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
175	2 (10.53)	14 (73.68)	3 (15.7 9)											
200	3 (5.36)	11 (19.64)	40 (71.43)	2 (3.57)										
225		8 (8.89)	62 (68.89)	19 (21.11)	1 (1.11)									
250		5 (4.95)	52 (51.49)	32 (31.68)	11 (10.89)	1 (0.99)								
275		4 (3.13)	52 (40.63)	51 (39.84)	15 (11.72)	5 (3.91)	1 (0.78)							
300		1 (0.66)	70 (46.36)	60 (39.74)	16 (10.60)	1 (0.66)	3 (1.99)							
325		2 (1.27)	28 (17.72)	88 (55.70)	31 (19.62)	6 (3.80)	3 (1.90)							
350			12 (10.17)	45 (38.14)	44 (37.29)	15 (12.71)	2 (1.69)							
375			2 (2.60)	13 (16.88)	40 (51.95)	17 (22.08)	5 (6.49)							
400				6 (10.53)	16 (28.07)	19 (33.33)	15 (26.32)	1 (1.75)						
425				2 (3.77)	10 (18.87)	22 (41.51)	15 (28.30)	4 (7.55)						
450					5 (10.42)	10 (20.83)	23 (47.92)	9 (18.75)	1 (2.08)					
475						3 (7.69)	18 (46.15)	14 (35.90)	2 (5.13)	2 (5.13)				
500						1 (3.13)	9 (28.13)	11 (34.38)	7 (21.88)	2 (6.25)	2 (6.25)			
525						1 (3.03)	5 (15.15)	10 (30.30)	10 (30.30)	4 (12.12)	1 (3.03)	1 (3.03)		1 (3.03)
550									3 (50.00)	1 (16.67)	1 (16.67)	1 (16.67)		
575												1 (33.33)	2 (66.67)	
600													1 (100.0)	

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 and tabulated for each year to obtain annual estimates of catch in numbers for different ages for 1986-1996. This is the catch matrix.

Mortality Estimates

Total Instantaneous Mortality

Catch curves using data for 1986-1991 were different from those calculated for 1992-1996. We believe this to be mainly attributable to minimum size regulation differences for the two time periods. Smaller (younger) fish could be landed in the earlier period than the later.

Catch curves for 1986-1991 were based on vermilion snapper aged 3-12 years; those produced for 1992-1996 were based on fish aged 4-14 years (Figures 20 and 21). Therefore, total instantaneous mortality estimates were different for the two periods: $Z = 0.77$ for 1986-1991 and $Z = 0.86$ for 1992-1996 computed as means for the two time periods.

Figure 20. Natural log of the catch-at-age for vermilion snapper from the southeastern U.S. landed from 1986 through 1991.

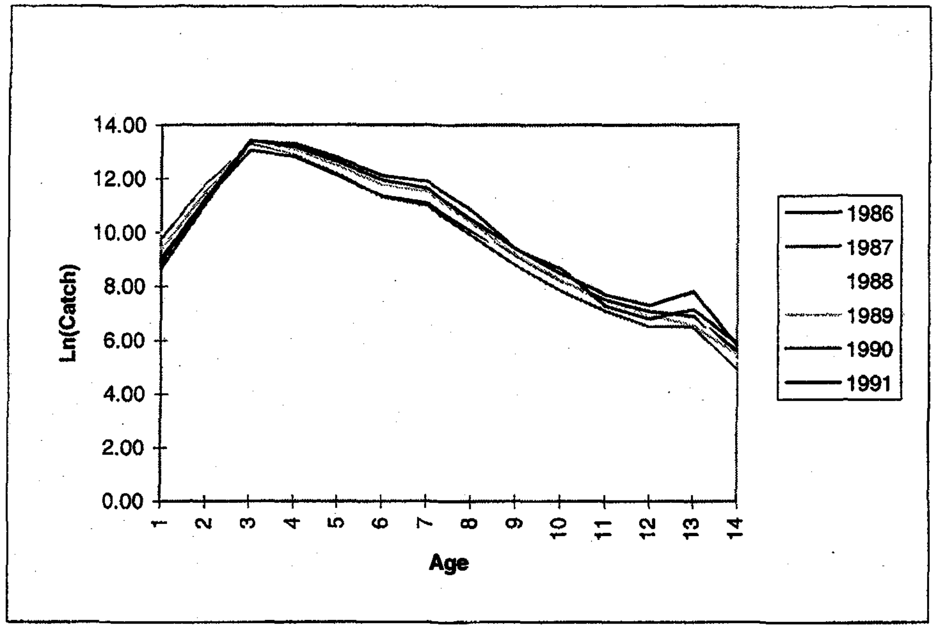
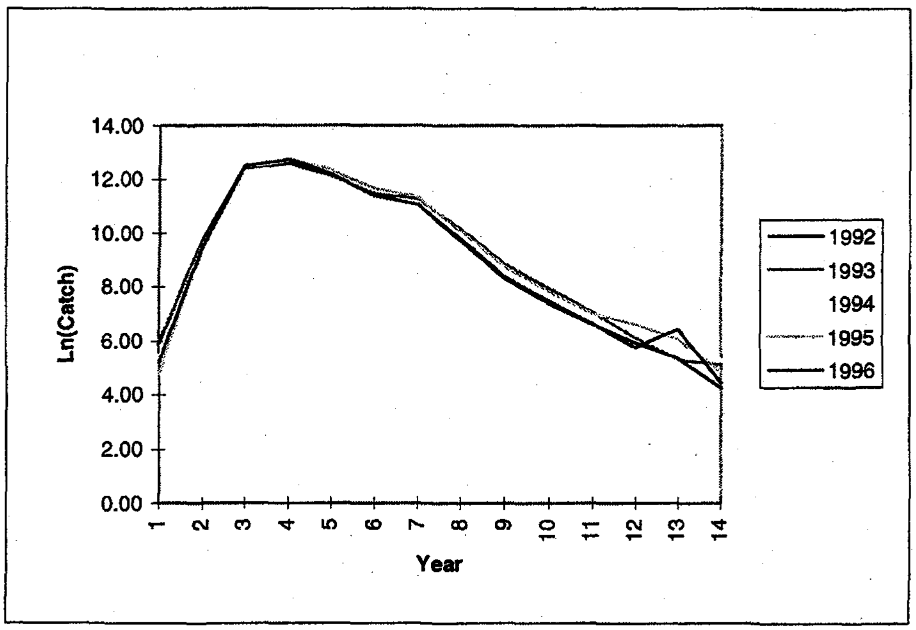


Figure 21. Natural log of the catch-at-age for vermilion snapper from the southeastern U.S. landed from 1992 through 1996.



Natural Mortality

There is often great uncertainty in deriving a value for natural mortality, M. Yet this is an important parameter input into stock assessment analysis, 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 that is what we have done in this assessment. We estimated natural mortality using several methods, and then four values were chosen as a range to use in the VPA runs. Methods used to estimate M and their resulting values are:

Hoenig (1983) - original equation -		0.30
	adjusted for sample size -	0.60
Pauly (1979) -		0.31
Roff (1984) -	unrealistically high	(>0.90)
Rikhter and Efanov (1977)-	unrealistically high	(0.53 & 0.77)
Alverson and Carney (1975) -		0.41

Both Hoenig (1983) and Alverson and Carney (1975) use maximum age in their equations for calculating M. Using a maximum observed age of 14 years from the Potts (1997) study, the two methods return relatively similar values of M. The Hoenig method relates maximum observed age to total mortality and sample size, and assumes random sampling. Since most of the samples from this age-growth study came from the South Atlantic headboat survey and the NMFS commercial sampling program, we feel this assumption is met. The Alverson and Carney (1975) method uses von Bertalanffy growth equation parameters as well as the oldest fish in the population to estimate T_{max}, the age at which a cohort has its maximum biomass in the absence of fishing. Since our data came from a fished stock, the estimate of M = 0.41 is probably high.

The Rikhter and Efanov (1977) method produced estimates of M that were unrealistically high (0.53 and 0.77). However, these estimates were not unexpected for an equation that is based solely on age at sexual maturity. Early age at maturity, such as that demonstrated for vermilion snapper, usually applies to a faster-growing, shorter-lived species (herring for example).

Our value for the Pauly (1979) estimate of M = 0.31 compares favorably with the value (0.23) reported by Ault et al. (1998) for the Florida Keys and 0.25 presented by Schirripa (1996) for the Gulf of Mexico. Our mean seawater temperature input into Pauly's (1979) equation was 21.95° C.

Roff (1984) predicts M using the Brody growth coefficient K and the age at maturity. He does not define age at maturity, so we used ages corresponding to both 50% and 75% maturity. It seems improbable that a fish with a maximum age of at least 14 years would have a natural mortality value as high 0.94 or 0.99 as the Roff (1984) method estimates using 50% maturity.

Our estimates of M generally fall into the range 0.30 to 0.60. It seems unlikely that a reef fish would have an M greater than 0.40. And, we believe that the true value of M for vermilion snapper probably falls between 0.30 and 0.35. To be conservative in our interpretations, we choose to run the analyses with a range of values for natural mortality including 0.20, 0.25, 0.30, and 0.35.

Fishing Mortality and Virtual Population Analysis

For the separable VPA runs, two catch matrices were analyzed consisting of catch in numbers for ages 1 through 12 for fishing years 1986-1991 (modal age generally 3) and ages 1 through 12 for 1992-1996 (modal age 4). For the VPA, starting values for F were based on the mean estimates of Z from the two time periods (0.77 yr^{-1} for 1986-1991 and 0.86 yr^{-1} for 1992-1996). Sensitivity of estimated F to uncertainty in M was investigated by conducting the above VPAs 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 pre- and post-minimum size limit are considered. Mean values of age-specific estimates of F were obtained from the separable VPA applied to the catch at age data (Table 22) using the uncalibrated separable (VPA). Estimates of F were averaged over fully-recruited ages (ages 3-12 for 1986-1991 and ages 4-12 for 1992-1996), weighted by catch in numbers for those ages (referred to as full F).

Using the uncalibrated separable approach (VPA) with M of 0.30, mean estimates of full F (ages 3+) tended to be lower for the period 1986-1991 (mean of 0.42 for full F) compared to the period 1992-1996 (mean of 0.51 for full F; ages 4+) (Table 23).

Table 22. Catch-at-age for vermilion snapper landed in all fisheries operating in the southeastern United States from 1986 to 1996.

Year/Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1986	8231	77069	467817	362700	180768	83262	65731	23289	9286	3558	1822	1167	973	264
1987	17616	140725	600330	409733	189172	80408	60048	19879	6322	2524	1191	671	661	136
1988	21494	153772	639559	430359	216984	100598	76282	25509	8219	3201	1581	913	1185	184
1989	12088	101991	638005	493617	264334	132259	101289	32524	9514	3739	1696	1004	696	242
1990	5756	66946	659778	596153	349258	179267	146967	50615	11663	5757	1435	888	1273	354
1991	7169	80189	669650	529624	299220	151747	113395	35673	11879	4706	2216	1468	2473	326
1992	356	18489	271113	324281	194495	91020	62839	16531	4125	1610	744	376	205	70
1993	397	15393	243034	294038	183195	96462	78167	25397	6878	2771	1156	440	196	167
1994	209	14873	255249	326367	211945	109686	89369	30248	9503	3756	1806	1012	5408	188
1995	118	13412	250470	346078	229127	114896	84473	23734	6288	2497	1108	726	422	127
1996	176	14023	266324	348113	197647	87324	63001	17594	4448	1773	763	308	613	85

Yield Per Recruit

Yield per recruit increased for the later years due to the imposition of the minimum size limits. Data are presented graphically in Figures 22a-d. We incorporated an adjustment for released fish mortality to determine what impact this would have on yield at entry to the fishery. The value 27%, obtained from field studies conducted by NMFS researchers (Bob Dixon and Pete Parker, NMFS, Beaufort Laboratory, Beaufort, NC), was used. At this level of release mortality, the age of recruitment to the fishery in order to obtain a 30% SPR is increased from four to six. To reach a SPR of 40%, the age of recruitment is increased from five to seven.

Table 23. Spawning potential ratio (SPR) and yield per recruit (Y/R) of female vermilion snapper based on mean age-specific fishing mortality rates for two time periods (1986-1991 and 1992-1996) and two maturity schedules (50% mature at age 1 and 50% mature at age 2) from separable virtual population analysis.

		Natural Mortality (M)			
Time Period		0.20	0.25	0.30	0.35
1986 - 1991	Full F	0.50	0.46	0.42	0.38
	SPR (50% mature at age 1)	0.11	0.15	0.20	0.26
	SPR (50% mature at age 2)	0.11	0.15	0.20	0.25
	YPR (50% mature at age 1)	88	72	58	46
	YPR (50% mature at age 2)	88	72	58	46
1992 - 1996	Full F	0.61	0.55	0.51	0.46
	SPR (50% mature at age 1)	0.12	0.17	0.22	0.28
	SPR (50% mature at age 2)	0.12	0.16	0.21	0.27
	YPR (50% mature at age 1)	99	81	65	51
	YPR (50% mature at age 2)	99	81	65	51

Spawning Potential Ratio

We received vermilion snapper reproductive data from SCDNR personnel collected throughout the year for 1990-1993. A total of 1,676 fish were collected by hook and line and fish traps; 1,546 were sexed. Of the sexed fish, 332 (21%) were males, and 1,214 (79%) were females. All females that were aged were sexually mature; the smallest was 186 mm TL. Since the sample sizes of age-1 females were very small for the published Cuellar et al. (1996) study, and these SCDNR data, we decided to conduct our analyses using two relatively conservative sexual maturity schedules. One considered no (0%) age-1 females mature, 50% age-2 mature, and 100% ages-3-14 mature (our preferred schedule). The other included 50% of the age-1 females as mature, and 100% of the females aged 2-14 years as mature. Both are conservative because Cuellar (1996) and the SCDNR data indicate that all age-1 vermilion snapper are sexually mature.

Spawning potential ratio, or percent maximum spawning potential, of female vermilion snapper was calculated for two time periods (1986-1991 and 1992-1996) based on mean age specific fishing mortality from separable virtual population analysis using four different levels of natural mortality (M = 0.20, 0.25, 0.30, and 0.35) (Table 23). Percent maximum spawning potential was greater for the more recent time period, particularly for M = 0.30, and M = 0.35; SPR = 0.21 and 0.28 (Figure 23a-d). These values are slightly higher than those which have been previously presented to the SAFMC (SAFMC 1997): SPR = 0.16 for data through 1991; and SPR = 0.19 for data through 1994.

Estimates of equilibrium spawning potential ratio (static SPR) using estimated F from the two VPA approaches are summarized by time period and assumed level of M (Table 23). Using separable VPA estimates of F (with M of 0.30) for two periods, SPR estimates based on female biomass are compared (Table 23). Note that even though full F may be higher for the latter time period, it is applied to fewer older ages, so that SPR is actually lower.

Two management options are evaluated in Table 24 that would each increase SPR to 30% and 40%. The two options are reduce F and increase minimum size, thus raising the age at entry to the fisheries.

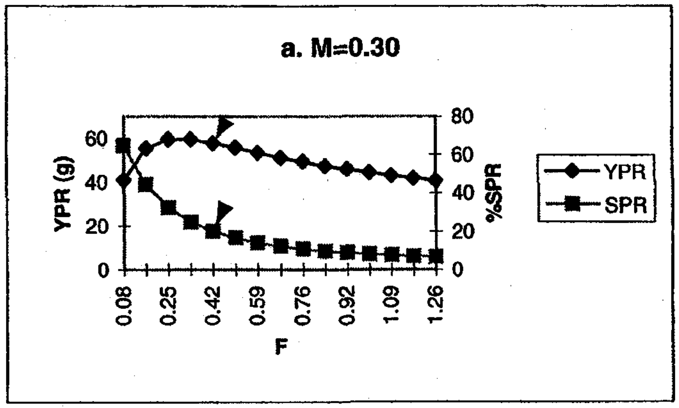
Table 24. Two management actions that could each increase vermilion snapper SPR to 20%, 30%, and 40%, based on 1992-1996 data. RM = release mortality.

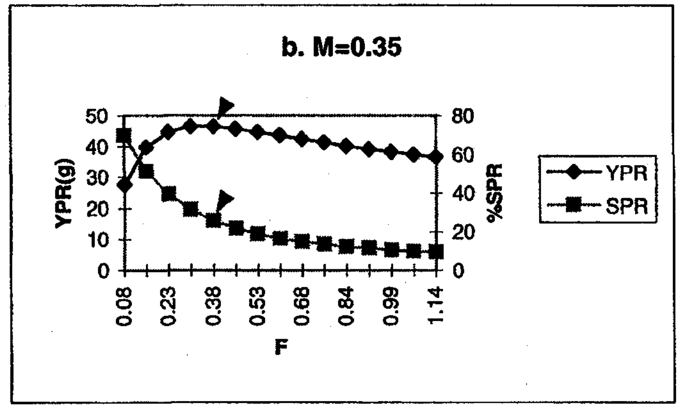
Action	Current SPR	Current F	% Reduction in F to Achieve 20%	30%	40%
1. Reduce F					
M = 0.30	21%	0.51	N/A	31% (F = 0.35)	51% (F = 0.25)
M = 0.35	27%	0.46	N/A	11% (F = 0.41)	39% (F = 0.28)

2. Raise Minimum Size (Age)	To Achieve SPR Level 20%	30%	40%
M = 0.30	N/A	12.7" (5 yrs)	14.2" (6 yrs)
[RM = 27%		12.7" (5 yrs)	15.5" (7 yrs)
M = 0.35	N/A	11.0" (4 yrs)	12.7" (5 yrs)
[RM = 27%		11.0" (4 yrs)	14.2" (6 yrs)

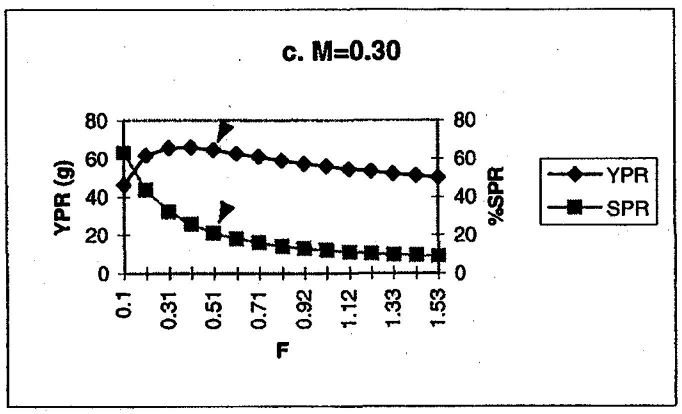
Figure 22. Ricker yield -per-recruit and spawning potential ratio for vermilion snapper landed in the southeastern U.S. during two time periods: 1986-1991 and 1992-1996, and two levels of M: 0.30 and 0.35.

1986-1991





1992-1996



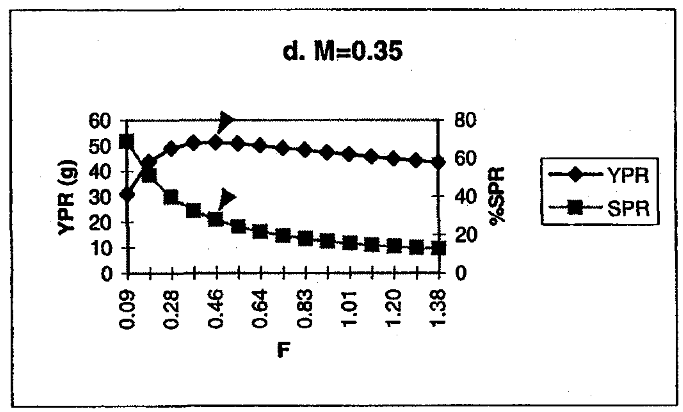
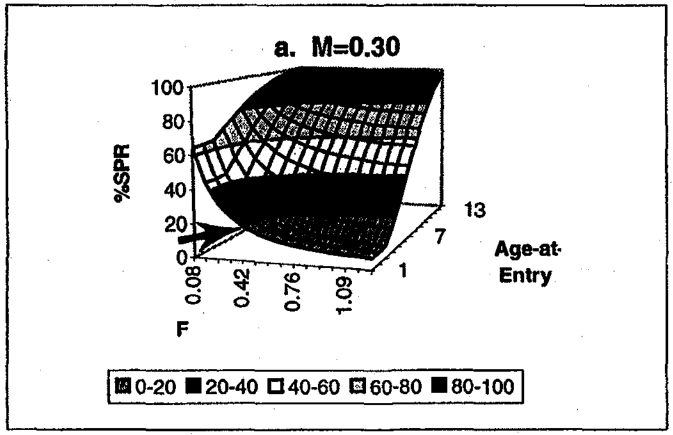
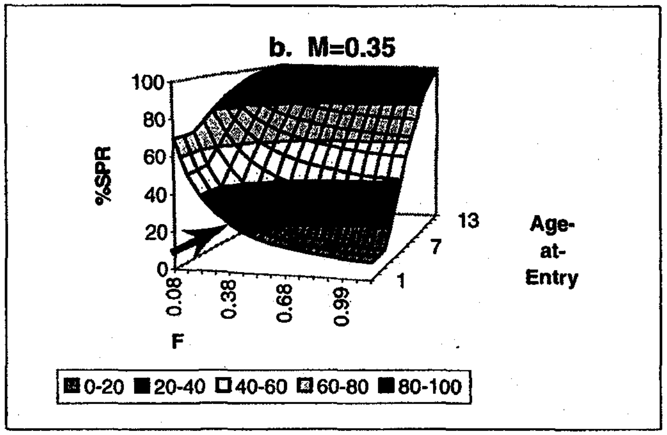


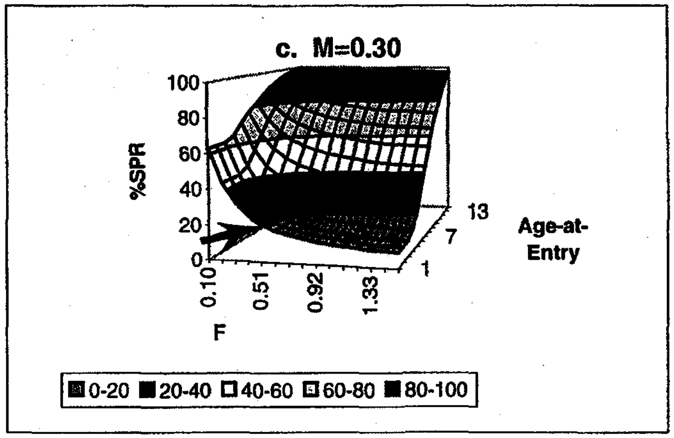
Figure 23. Spawning potential ratio of the vermilion snapper population from the southeastern U.S. during two time periods: 1986-1991 and 1992-1996, and two levels of M: 0.30 and 0.35.

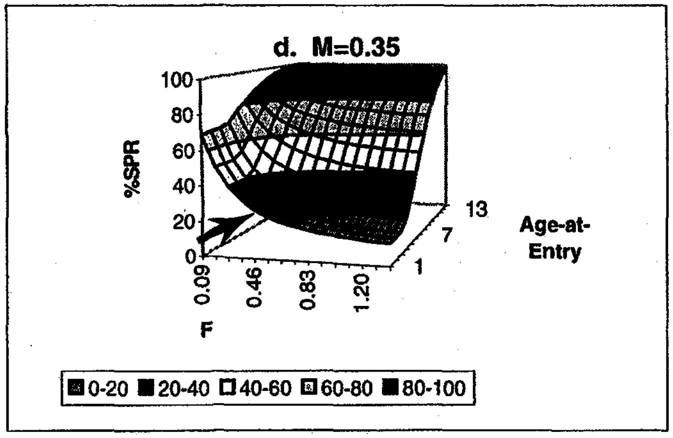
1986-1991





1992-1996





CONCLUSIONS

We believe that our assessment of vermilion snapper is on the one hand conservative, and on the other flexible enough in its presentation to allow the reader to independently judge the status of the stock. It is conservative in that our use of the MRFSS data, which often include inadequate sample sizes for length frequency analysis (Mays and Manooch 1997), and present questionably large estimates of small fish landed, would tend to underestimate age of fish at entry to the fishery, thus erroneously lowering SPR. Also, the sexual maturity schedules that we used do not consider all age-1 fish mature, but rather conservatively scale the maturity schedule. More younger, sexually mature snapper would result in a greater spawning potential for the species throughout life.

Although landings have generally decreased, the mean size of vermilion snapper landed and catch per unit effort have generally increased during the past several years. These are positive indications that the minimum size limits are having an effect on landings, and are increasing age at entry to the fishery. Fully recruited age and age at entry are age-3 and age-1 for 1986-1991, and age-4 and age-1, respectively, for 1992-1996.

SPR values were derived using natural mortality (M) values of 0.20, 0.25, 0.30, and 0.35. We believe that the most accurate estimate of M is between 0.30 and 0.35. This would result in an SPR ranging from 0.21 to 0.27 for the most recent time period, 1992-1996, depending on M. SPR could be improved to 30% with a 31% reduction in

F, if M = 0.30, and to 40% with a 51% reduction. If M = 0.35, SPR could be increased to 30% with a 11% reduction in F and to 40% with a 30% reduction (Table 24). Age-at-entry could be increased if fishermen, particularly recreational, comply fully with the newly imposed 11-inch minimum size regulation. However, released fish mortality (RM) will continue to make the achievement of higher levels of SPR more difficult.

We conclude that the vermilion snapper stock is in a "transitional" condition. That is, the status is less than desirable, but does appear to be responsive to recent management actions. The recent management action taken by the SAFMC should certainly accelerate the process of rebuilding the stock.

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