The Effect of Spawning Season Closures on Landings of Two Reef Associated Species

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ABSTRACT

I examined records of landings of mutton snapper, *Lutjanus analis*, and greater amberjack, *Seriola dumerili*, from southeast Florida to determine if limited spawning season closures were effective in reducing harvest. Data were divided into two time strata, a pre-closure period (1982 - 1991), and a regulated-by-closure period (1992 - 1996). I compared mean annual and mean monthly landings between periods. Headboat landings of mutton snapper were not significantly lowered by the enactment of regulations limiting harvest in May and June to the recreational bag limit. Commercial landings in May were significantly lower in May in the closure period, but June closure landings were slightly higher than the pre-closure period. Closure period July landings were significantly higher than in the pre-closure period. Trends in headboat CPUE mimic trends in effort. Headboat landings of greater amberjack were significantly greater in April (closed month), May and June in the pre-closure period than in the closure period. Commercial landings of greater amberjack were significantly lower in April in the closure period, while March landings were significantly greater and May landings were slightly greater than in the pre-closure period. Mean annual landings of both species were not significantly different between periods. The management action effectively reduced commercial fishing pressure on both species during the designated closed months. Annual harvest levels were not reduced, possibly due to increased landings in months adjacent to the closed months. Headboat landings, not expected to be affected by the regulations, were significantly lowered for greater amberjack but not for mutton snapper.

KEY WORDS: Seasonal closures, greater amberjack, mutton snapper

INTRODUCTION

In general, fisheries managers are often tasked with reducing fishing mortality (F) as a means of optimizing the long term sustainable yield of fisheries resources. Reduction of F is usually accomplished via size limits, bag limits, quotas, closures or some combination of the above techniques. Size limits prevent fishing intensity from reaching the level where fish are caught

before they attain sexual maturity (growth overfishing). Bag limits, quotas and closures attempt to reduce fishing mortality before population biomass becomes so low that future reproduction and production of larvae are jeopardized (recruitment overfishing).

Many reef fish form spawning aggregations, especially the groupers (Serranidae). Spawning aggregations of red hind, *Epinephelus guttatus*, and Nassau grouper, *E. striatus*, have been documented by numerous observers in the Caribbean (Burnett-Herkes, 1975; Colin *et al.*, 1987; Colin, 1992; Shapiro *et al.*, 1993; Sadovy *et al.*, 1994b; Aguilar-Perera and Aguilar-Davila, 1996). Groupers (Serranidae) tend to utilize this strategy widely. Sadovy *et al.* (1994a) have documented spawning aggregations of tiger grouper, *Mycteroperca tigris*, off Puerto Rico. Samoilys and Squire (1994) observed spawning concentrations of coral trout, *Plectropomus leopardus*, in the western Pacific. Aggregating behavior has also been observed in the gag, *M. microlepis* (Gilmore and Jones, 1992), and black grouper, *M. bonaci* (Fine, 1990). Spawning aggregations of other species are not as widely documented. Wicklund (1969) described spawning aggregations of lane snapper, *Lutjanus synagris*, off southeast Florida. Dog snapper (*L. jocu*) have been observed spawning in aggregations on the reefs off Belize (Carter and Perrine, 1994). Colin and Clavijo (1978) documented mass spawning (>400 fish) in spotted goatfish, *Pseudupeneus maculatus*, in the U.S. Virgin Islands.

Fish populations that aggregate in large numbers in a finite area are vulnerable to excessive fishing mortality in a short period of time if local fishermen have knowledge of the aggregation site and time. Olsen and LaPlace (1979) documented spawning aggregations of Nassau grouper off St. Croix, U.S. Virgin Islands, that ceased to exist after years of intensive fishing pressure. Johannes (1978) reported that local fishermen in Palau have exploited local spawning aggregations for many years. Fishes that aggregate in this manner are also more vulnerable to excessive natural mortality via catastrophic events such as an oil spill or severe predation by apex predators.

Fishery closures, as management options to reduce excessive fishing pressure, can be temporal, spatial, or a combination of the two. Closures seek to alleviate fishing pressure on a species during times of increased vulnerability. The Florida Department of Natural Resources manages snook, *Centropomus undecimalis*, under two closed seasons: one in the winter (December 15 - January 31) when fish are lethargic due to cold temperatures and therefore susceptible to capture via snagging; and the other in summer (June - August), when the fish form large spawning aggregations (R. Taylor, Florida Marine Research Institute, personal communication).

The Gulf of Mexico Fishery Management Council (GMFMC) imposed a May-June closure on Riley's Hump, a coral reef (25 - 30 m) near the Dry

Tortugas, in an attempt to protect the remnants of an historical spawning aggregation of mutton snapper, *L. analis* (GMFMC, 1994). Earlier, in 1992, the South Atlantic Fishery Management Council (SAFMC) imposed seasonal closures on mutton snapper (May - June) and on greater amberjack, *Seriola dumerili* (Apr), by reducing the allowable commercial catch during these months to the recreational bag limits (three fish per person per day for greater amberjack; mutton snapper regulated by a 10 fish per person per day aggregate bag limit including all snappers except vermilion snapper, *Rhomboplites aurorubens*) (50 FR 56016). Closed months coincided with existing knowledge of spawning seasons for the two species (Burch, 1979; Claro, 1981; M. Burton, unpubl. data). In this study, I attempt to determine what effect the enactment of spawning season closures has had on the magnitude of landings of mutton snapper and greater amberjack off the southeast U.S. coast.

METHODS

I examined landings of mutton snapper and greater amberjack from headboat and commercial fisheries from southeast Florida for 1982 - 1996. Comparisons of mean annual and mean monthly landings were made for two time frames: the pre-closure period (1982 - 1991), and a closure period (1992 - 1996). Since extensive commercial markets for greater amberjacks did not exist prior to 1987, I narrowed the pre-closure period for commercially caught amberjack to 1987 - 1991. Using SAS (PROC GLM; SAS, 1987), I compared the mean monthly landings across years for each species and fishery by period to determine significant differences in landings before and after enactment of the regulations. Multiple t-tests were ineffective for the comparisons because of the increased probability of rejecting the null hypothesis, and thus the increased probability of finding a significant result where one does not exist (SAS, 1987). Annual landings were analyzed to discern if annual variability between periods was significant. Catch per unit of effort (CPUE) data (kg of fish per angler day) were available only for the headboat survey. These were analyzed both monthly and annually between periods to determine the regulatory effect on overall CPUE.

The headboat survey data were available in three strata: southeast Florida (Ft. Pierce-Miami), the Florida Keys, and the Dry Tortugas. The commercial data were available in two strata, southeast Florida and the Florida Keys-Dry Tortugas combined. Monthly landings from the Dry Tortugas were unavailable separate from the rest of Monroe County, FL (the Florida Keys). Statistical analyses on these data were performed by fishery with all areas combined.

RESULTS

Mutton Snapper

The majority of mutton snapper are landed from the combined Florida Keys-Dry Tortugas area for both fisheries, with the commercial harvest substantially exceeding the headboat catches in all years (Tables 1 and 2). Headboat landings were relatively constant through 1994, with a recent downward trend since 1994 from 54,736 kg to 19,059 kg in 1996. Commercial landings varied from 88,875 kg in 1984 to 198,632 kg in 1989, but have declined since then, with 102,654 kg landed in 1996 (Figure 1).

Mean monthly commercial landings of mutton snapper from pre-closure and closure periods were similar for most months except May through July (Figure 2). Pre-closure landings in May were 23,556 kg, compared to 12,870 kg during the closure period, a 45 % decrease ($p < 0.0005$, $F = 12.73$). June (26,045 kg) landings are slightly higher during the closure period than during the pre-closure period (25,089 kg). Moreover, closure landings in July, 20,434 kg, were significantly higher ($p < 0.0010$, $F = 11.23$) compared to pre-closure landings (10,402 kg).

Monthly headboat landings of mutton snapper during the closure period were less than pre-closure landings for all months except November. A significant difference was detected only for March ($p < 0.0283$, $F = 4.90$) and December ($p < 0.0266$, $F = 5.01$). Mean landings during the regulated months of May and June are lower in period 2, but they are lower in all months in period 2 except November.

Annual headboat CPUE for mutton snapper (Figure 4) was variable and saw-toothed. The overall trend appeared slightly downward, declining from a high of 0.34 kg per angler day in 1983 to a low of 0.12 kg per angler day in 1996.

Trends in mean monthly CPUE for mutton snapper were similar for pre-closure and closure periods (Figure 5). CPUE was highest October through February when traditionally recreational effort increases due to the influx of winter tourists.

Greater Amberjack

Commercial landings of greater amberjack in southern Florida have exceeded headboat catch for all study years, most strikingly since 1987 (Figure 6). Headboat landings were variable, ranging from 32,514 kg in 1984 to 3,378 kg in 1995. Commercial landings of greater amberjack were less than 75,000 kg until 1986, when the blackened fish market developed for greater amberjack. Commercial landings nearly tripled, from 50,660 kg in 1985 to 144,257 kg in 1986. Peak commercial landings occurred in 1991, with 728,994 kg landed from south Florida.

Table 1. Annual headboat landings (kg) of mutton snapper from the southeastern United States

Year	Southeast Florida	Florida Keys	Dry Tortugas	Total
1982	23,175	16,832	22,512	62,519
1983	15,615	19,326	30,108	66,049
1984	11,076	12,530	14,404	38,010
1985	15,075	11,329	20,026	46,430
1986	14,673	8,685	31,173	54,531
1987	14,124	9,212	20,986	43,422
1988	23,544	7,757	10,667	41,968
1989	28,081	6,781	13,438	48,300
1990	24,888	8,495	35,091	68,474
1991	17,545	7,691	10,101	35,337
1992	10,187	14,610	12,644	37,441
1993	22,695	12,753	9,006	44,454
1994	21,541	15,153	18,060	54,763
1995	11,624	10,362	6,952	28,938
1996	4,917	6,444	7,698	19,059

Table 2. Annual commercial landings (kg) of mutton snapper from the southeastern United States

Year	Southeast Florida	Florida Keys - Dry Tortugas	Total
1982	17,982	17,612	135,594
1983	18,532	83,136	101,668
1984	20,337	68,538	88,875
1985	24,980	66,923	91,903
1986	37,840	80,056	117,896
1987	42,280	123,892	166,172
1988	41,875	83,696	125,571
1989	73,759	124,873	198,632
1990	61,379	102,193	163,572
1991	59,920	119,274	179,194
1992	28,835	112,357	141,192
1993	50,430	114,118	164,548
1994	31,168	100,535	131,703
1995	27,154	73,284	100,438
1996	28,298	74,356	102,654

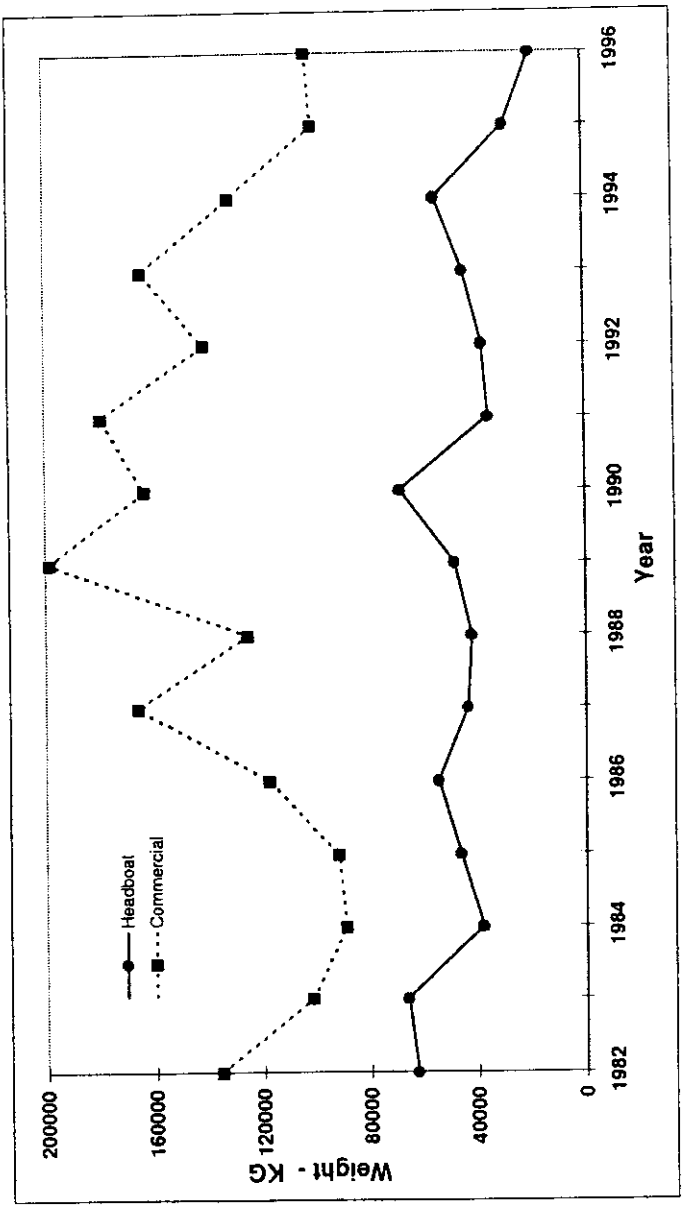

Figure 1. Annual landings of mutton snapper from southeast Florida.

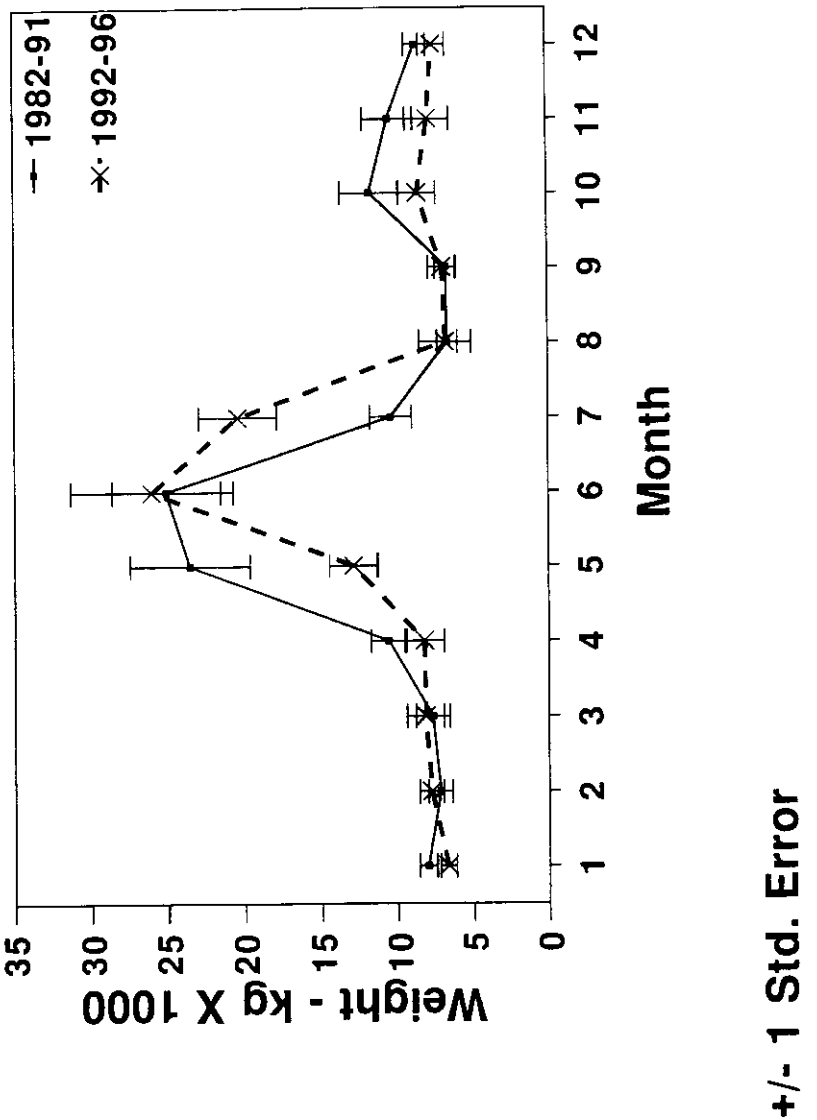

Figure 2. Mean monthly commercial landings - mutton snapper southeast Florida - Dry Tortugas.

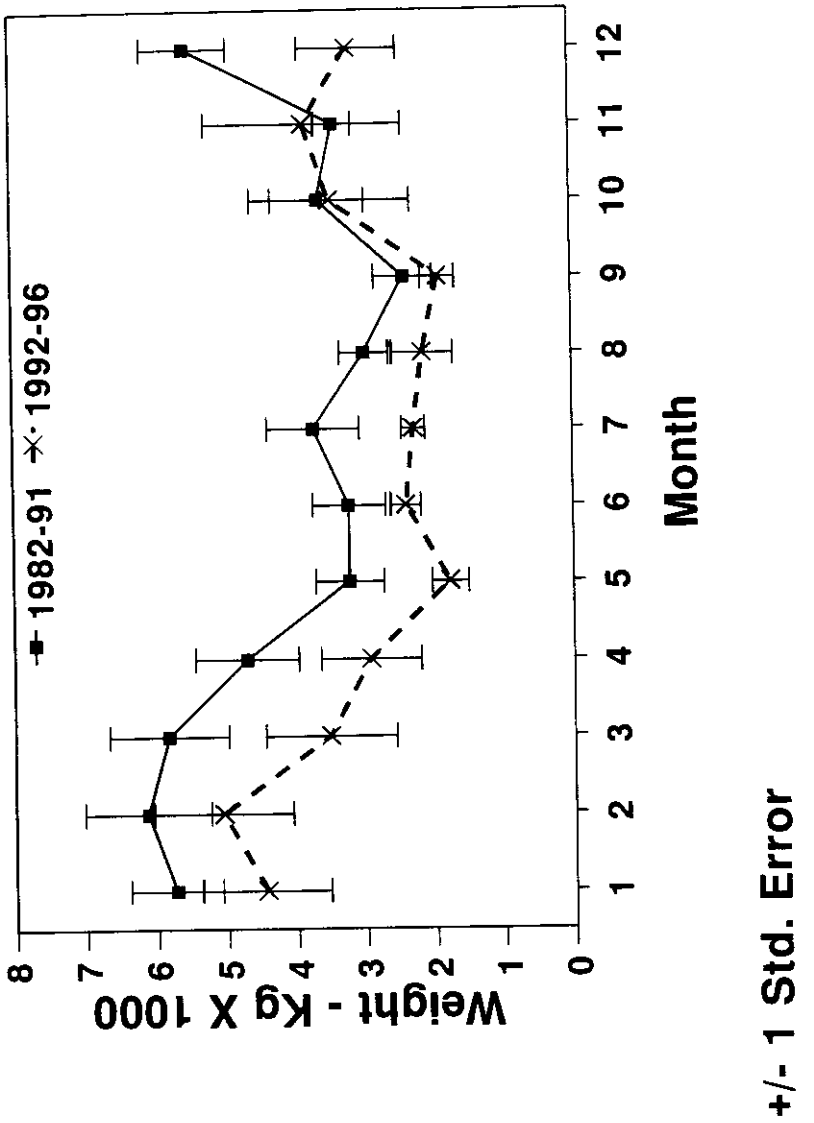

Figure 3. Mean monthly headboat landings - mutton snapper southeast Florida - Dry Tortugas

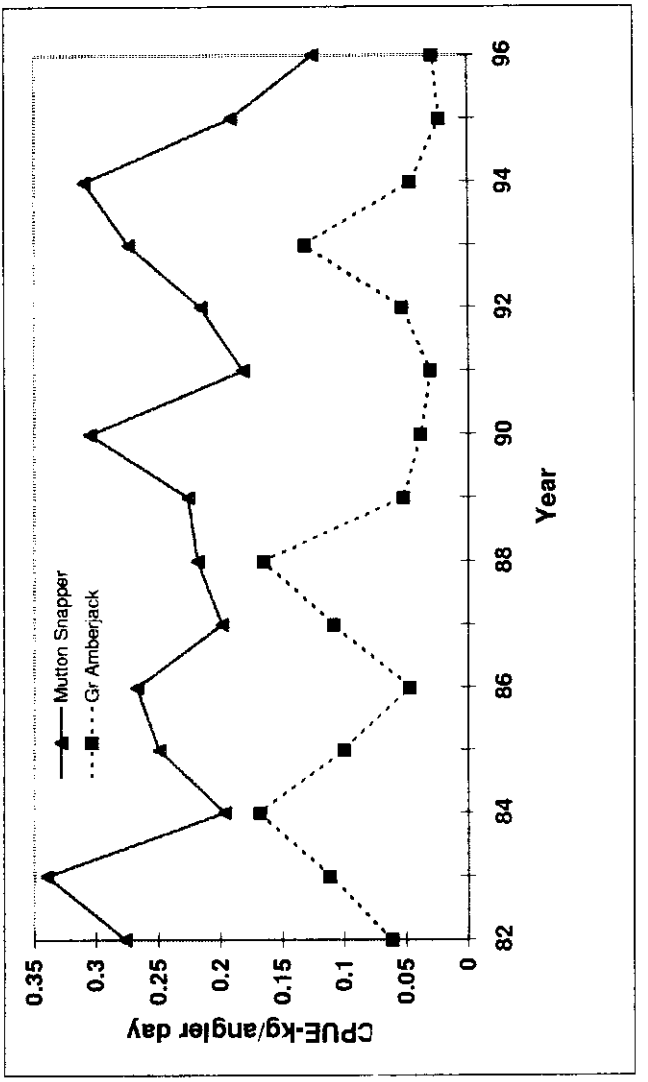

Figure 4. Annual catch per unit effort from the southeast Florida headboat fishery.

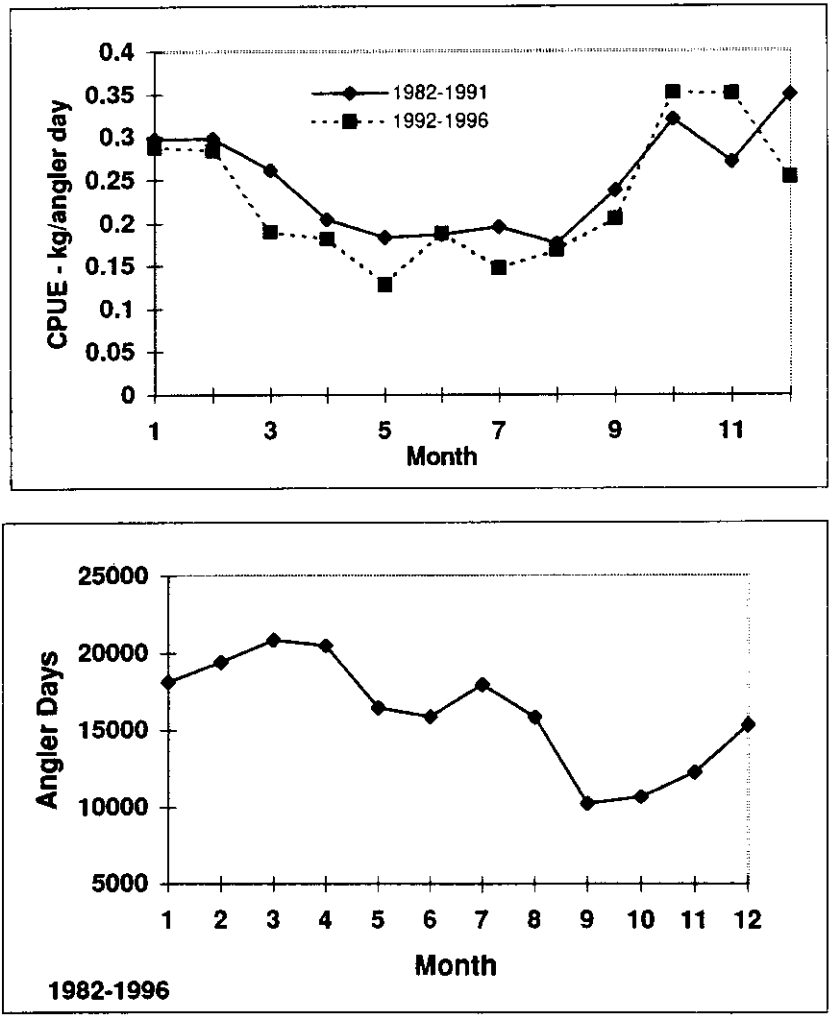

Figure 5. Mean monthly catch per unit effort for mutton snapper and mean monthly effort in the southeast Florida headboat fishery.

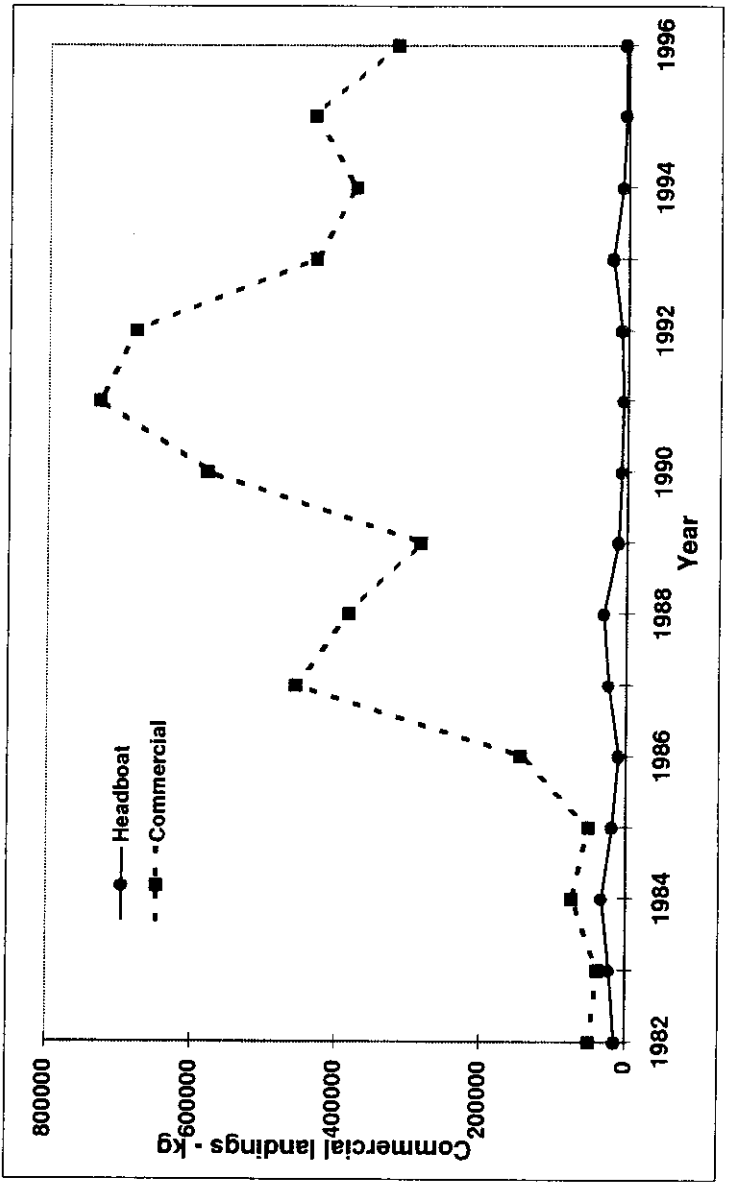

Figure 6. Annual landings of greater amberjack from the southeastern United States

By area headboat landings in southeast Florida dominated landings over adjacent areas for most years (Table 3). Amberjack landings from the Florida Keys-Dry Tortugas area dominated commercial landings (Table 4).

Mean monthly headboat landings of greater amberjack were remarkably consistent during the pre-closure period throughout the year, except for April and May (Figure 7). Additionally, landings in April and May are five-fold greater in the pre-closure versus the closure period. Contrasts of headboat landings of greater amberjack between periods indicate significant differences for April ($p < 0.0001$, $F = 21.00$), May ($p < 0.0001$, $F = 25.67$) and June ($p < 0.0001$, $F = 4.67$).

As with mutton snapper, annual catch per unit effort (CPUE) for greater amberjack (Figure 4) was saw-toothed over the study period. Values for CPUE ranged from 0.17 kg per angler day in 1984 to 0.02 kg per angler day in 1995.

Mean monthly CPUE for greater amberjack (Figure 8) was significantly different for the two periods. During the pre-closure period CPUE was low from January through March, then increased five-fold in May. CPUE then declined and leveled off for the remainder of the year. For the closure period, the mean monthly CPUE remained at a relatively low and constant rate throughout the year.

During the pre-closure period, commercial landings of greater amberjack increased to a peak in April (136,413 kg), declined through July (14,000 kg), and then averaged less than 9,000 kg for the remaining months. During the closure period landings decreased in April to an average of 32,341 kg, or 24% of the pre-closure average. However landings in adjacent months increased substantially. Landings in March averaged 116,251 kg compared with 69,535 kg in the pre-closure period (a 67% increase); landings in May averaged 159,000 kg compared with about 134,000 kg (18% increase). Contrasts of commercial landings show significant differences between periods for March ($p < 0.0001$, $F = 17.91$), April ($p < 0.0122$, $F = 6.43$) and May ($p < 0.0001$, $F = 21.95$). The mean annual commercial landings for greater amberjack were not significantly different ($p < 0.7030$, $t = 0.3952$) between the pre-closure and closure periods, 485,922 kg and 446,605 kg, respectively.

Table 3. Annual headboat landings (kg) of greater amberjack from the southeastern United States

Year	Southeast Florida	Florida Keys	Dry Tortugas	Total
1982	9,372	1,543	2,829	13,744
1983	18,361	2,659	712	21,732
1984	17,093	12,466	2,955	32,514
1985	14,037	4,295	136	18,468
1986	6,697	2,265	683	9,645
1987	13,562	9,111	1,188	23,861
1988	23,288	5,550	2,282	31,120
1989	8,193	2,460	422	11,075
1990	3,674	3,680	847	8,201
1991	3,049	1,355	1,523	5,927
1992	5,340	1,637	2,154	9,131
1993	5,967	1,987	13,415	21,369
1994	3,534	1,064	3,455	8,053
1995	2,158	663	557	3,378
1996	2,215	1,072	579	3,866

Table 4. Annual commercial landings (kg) of greater amberjack from the southeastern United States

Year	Southeast Florida	Florida Keys - Dry Tortugas	Total
1982	7,107	42,405	49,512
1983	7,324	30,928	38,252
1984	27,124	46,854	73,978
1985	24,303	25,357	50,660
1986	66,002	78,255	144,257
1987	261,657	193,902	455,559
1988	149,744	232,282	382,026
1989	183,422	99,507	282,929
1990	149,233	430,827	580,105
1991	173,219	555,775	728,994
1992	184,590	495,186	679,776
1993	66,212	364,359	430,571
1994	75,274	298,901	374,175
1995	71,471	360,639	432,110
1996	69,205	247,191	316,396

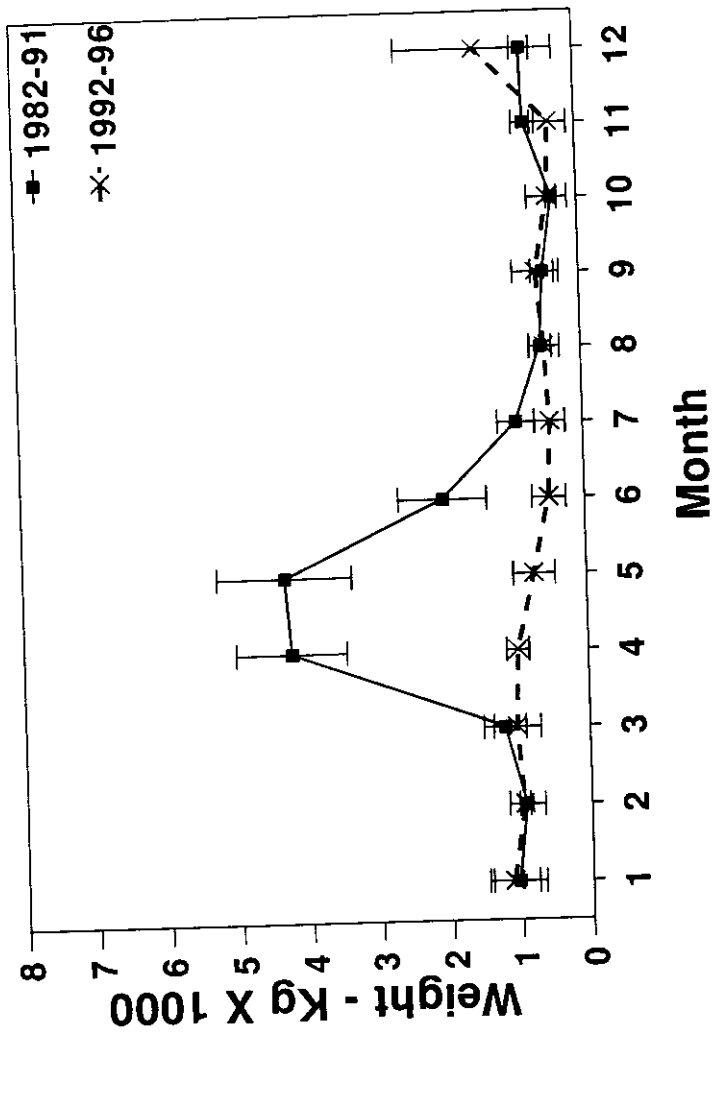

Figure 7. Mean monthly headboat landings - greater amberjack southeast Florida - Dry Tortugas.

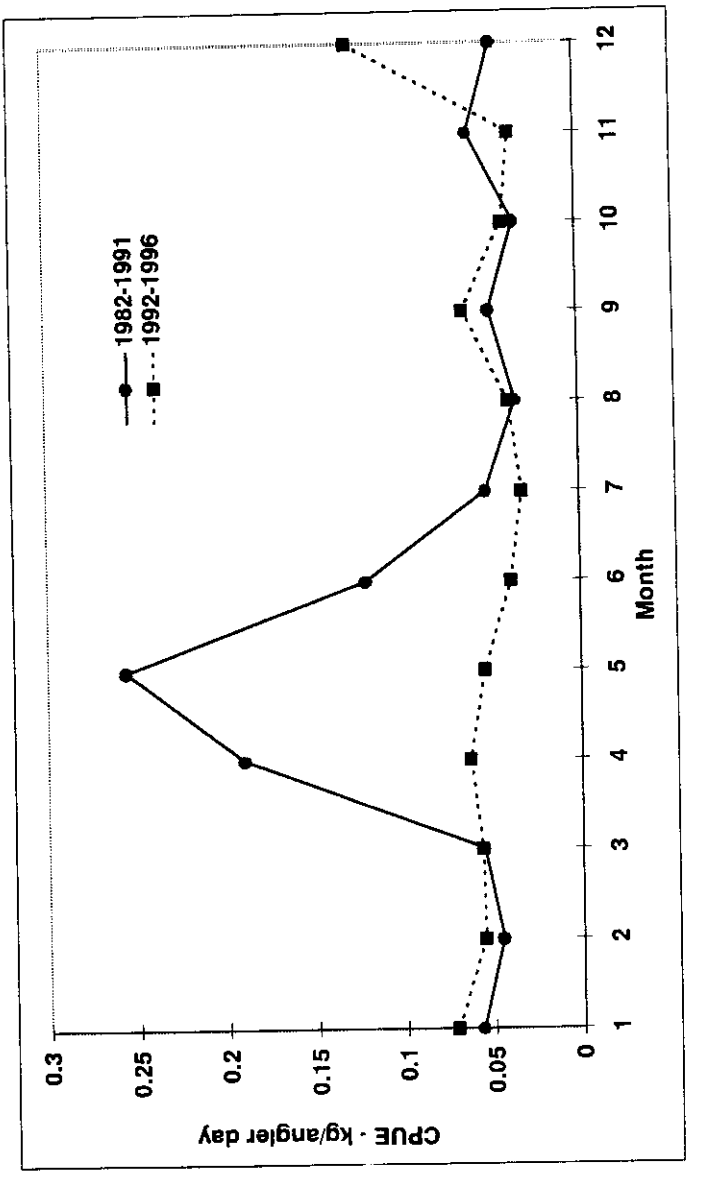

Figure 8. Mean monthly catch per unit effort - greater amberjack southeast Florida headboat fishery

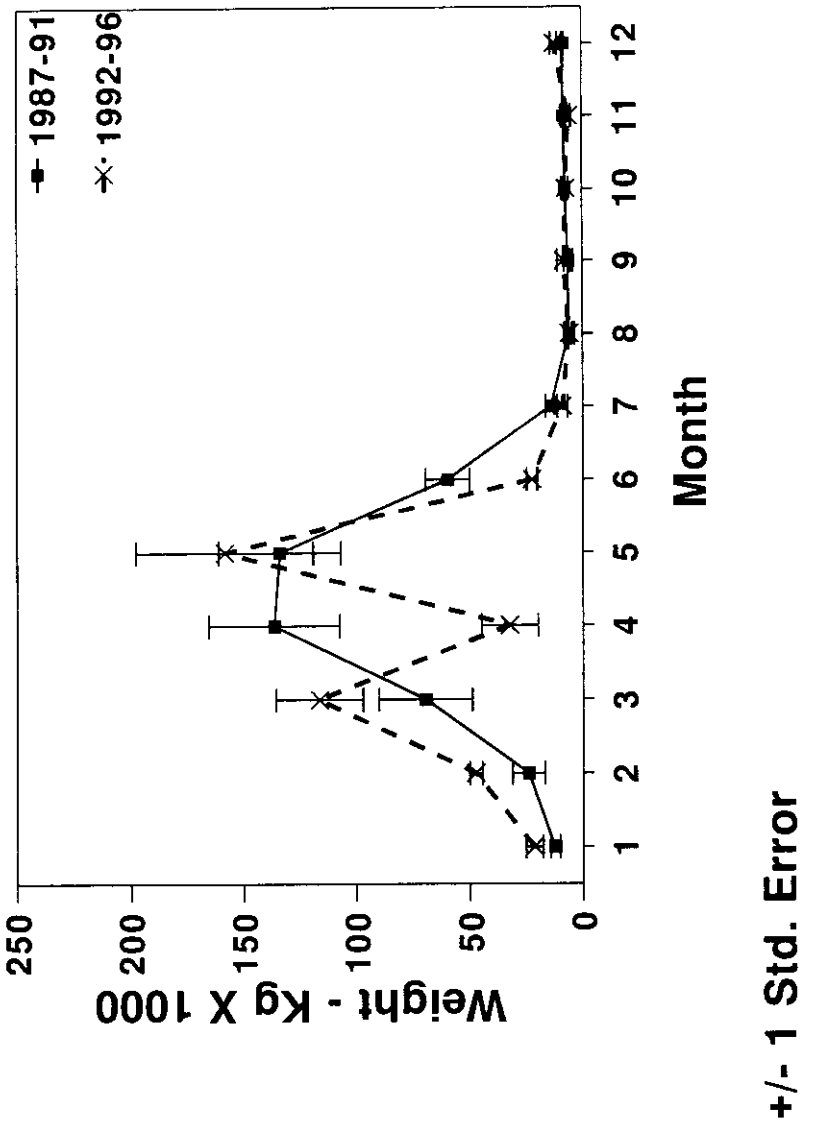

Figure 9. Mean monthly commercial landings - greater amberjack southeast Florida - Dry Tortugas

DISCUSSION

Mutton Snapper

Many of the species in the snapper-grouper complex off the southeast U.S. coast have been subjected to increasing exploitation over the last two decades. The availability of more precise navigation and positioning equipment has contributed to this increased exploitation. During the 1970s and 1980s, Loran-A evolved into the more precise Loran-C. Given the structure oriented nature of most reef fishes, the current Global Positioning System (GPS) allows even the most novice of fishermen to relocate prime fishing locations at a future date.

As a current example, there has been a real concern that a traditional spawning aggregation of mutton snapper at Riley's Hump in the Dry Tortugas is overfished. The decline in annual landings of mutton snapper for the region attest to this. Domeier and Colin (1997) looked for spawning aggregations at the site in 1991, and noted that mutton snapper were less abundant than on spawning aggregations in the Turks and Caicos. I went to Riley's Hump during May - June 1995 to collect spawning mutton snapper for reproductive studies. I noted that fish were scattered and not highly aggregated. Anecdotal information from knowledgeable commercial fishermen in the area indicate that mutton snapper were far less abundant at the site than previously (Don DeMaria, personal communication). Despite the season closure in 1992, a few commercial fishermen continue to exploit the species during closed months with spears and fish traps (personal observation, May 1995).

Due to their tendency to spawn at the same location on the same calendar lunar phase (Domeier *et al.*, 1997), the mutton snapper is a likely candidate for overexploitation via fishing on spawning aggregations. Considering its reproductive biology, trends in landings, and anecdotal information from fishermen, mutton snapper may be susceptible to recruitment overfishing. Closure strategies designed by the SAFMC and the GMFMC were enacted to reduce fishing effort on spawning aggregations of mutton snapper. The comparison of mean monthly landings from my study indicate that although the trends in headboat landings did not change between pre-closure and closure periods, the landings, on average, were lower during the closure period. This could be attributed to lower population levels due to heavy fishing in pre-closure years. Headboat harvests of mutton snapper were not higher during spawning months, but instead seemed to mirror the general trend of effort (Figure 3). Commercial harvest of mutton snapper were highest during May and June in the pre-closure period. Enactment of the closure in 1992 had probably reduced the mean monthly catch in May by 45% from the pre-closure mean. However, there was no reduction in catch during June for the closure period. Probably resulting from the closure, mean commercial landings in July doubled during the closure

period. Possibly, fishermen rescaled effort to make up what was lost during the closed months.

Greater Amberjack

Greater amberjack were probably lightly exploited until the mid- 1980s. Commercial landings increased in 1987, most likely a result of the species utilization in the blackened fish recipes of the restaurant trade. In 1988, when the National Marine Fisheries Service (NMFS) closed the Gulf of Mexico red drum (*Sciaenops ocellatus*) fishery (53 FR 24662), annual landings for greater amberjack, a substitute for red drum, soared through 1991. At that point, the SAFMC limited allowable catch of greater amberjack in April to the recreational daily bag limit of three fish per person.

Even though the 1992 bag limit regulations were directed at the commercial fishery for greater amberjack, the regulations seem to have reduced headboat catches during April, as mean headboat catches for the month declined during the closure. The new commercial regulations and promulgation thereof may have encouraged stricter adherence to the recreational bag limit on headboats.

Regulation of commercial landings of greater amberjack had immediate effects on mean monthly landings. Landings in April after the closure declined 24% During adjacent months, March and May, landings during the closure period were higher than in respective months during the pre-closure period. Perhaps commercial fishermen shifted their efforts to pre- and post-closure months in an opportunistic effort to capture what was lost during the closure.

Results of this study show that monthly fishing closures for aggregating species such as greater amberjack and mutton snapper reduced catches significantly during target months. The regulations may assist in preventing recruitment overfishing by protecting spawning aggregations. Landings were reduced during April for commercial and headboat fisheries for greater amberjack, and for mutton snapper, landings were lower after regulation for all instances except commercial landings in June of the closure period.

The increase in landings during months adjacent to the closed months requires closer examination. Spawning seasons may be broader than previously recognized. The increased landings of mutton snapper in July during the closure could be due to protracted continuation of spawning into that month. Recent field work shows highest gonadosomatic indices values for mutton snapper in May and July (M. Burton, unpublished data). The spawning season for greater amberjack may also be protracted. High commercial catches in March and May suggest aggregation (for spawning?). Recently, the SAFMC has proposed the addition of March and May to the April closure "to further provide biological protection to greater amberjacks during the spawning season" (SAFMC, 1997). It should be emphasized here that closure is used to mean a limitation on harvest

in excess of the recreational bag limit (effectively a commercial closure). This is an area where further research is needed. Regulation by closure during spawning season will only be effective if the managers are certain of the extent of the spawning season.

The regulations enacted in 1992 did not effectively reduce annual F on either species. The overall trend in landings of mutton snapper has been downward for the commercial fisheries since 1989, and for the headboat fishery since 1994. It is most likely this is due to previous exploitation and not to the effect of regulations imposed in 1992. In fact, mean annual commercial landings of mutton snapper are not significantly different between periods. Annual commercial landings of greater amberjack have been declining since 1991, but again there is no significant difference between the pre-closure period and the closure period annual means.

The closure regulation did reduce fishing mortality on the greater amberjack during April. However, lost landings were apparently made up for during March and May, as March-May landings accounted for 69% of total annual landings during the closure period, as compared to 70% percent during the pre-closure period.

In conclusion, the intent of the closure regulations, to reduce F on spawning fish during certain months, was achieved for most instances. If subsequent assessments for these species conclude that greater reductions in F are needed to prevent recruitment overfishing, I suggest that additional research be conducted on the reproductive biology of these species. We will need to know: 1) the temporal extent of the reproductive season, and 2) that these fish are actually aggregating to spawn. Presently, the SAFMC is considering extending the closed period for amberjacks to March through May to further provide biological protection for greater amberjack during spawning season (SAFMC, 1997). If the intent is just to reduce overall F, as in the case of an extremely overexploited species, it may be enough to know the fish aggregate for some reason, and that substantial reductions in F are available by limiting fishing on the aggregations.

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