STOCK ASSESSMENT AND FISHERY EVALUATION REFORT
SOUTHEAST RED DRUM FISHERIES

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History of Management, Gulf of Mexico[1]

During the mid-1980's, directed commercial harvest of red drum in the Gulf of Mexico increased substantially in response to escalating market demands to satiate the growing appetite for "blackened redfish." The Council and the Gulf State Marine Fisheries Commission utilized a state/federal task force to develop a fishery profile for red drum. The document produced by the task force concluded that red drum were growth overfished in Texas and Florida; however, evidence of recruitment overfishing did not exist. Based on this conclusion, the Council elected not to proceed with an FMP.

The offshore fishery continued to escalate in terms of landings of adult fish, which reportedly peaked during the 1985-6 fishing season. In 1986, Congressman John Breaux held a hearing in New Orleans on behalf of the House Subcommittee on Fisheries, Wildlife Conservation and the Environment, to hear testimony on the expanding fishery and the need for future management. Congressman Breaux subsequently introduced H.R. 4690 to require the Secretary to implement emergency regulations to manage the fishery. Accordingly, the Secretary established an emergency quota on red drum commercial harvest and incidental catch restrictions in other fisheries in the exclusive economic zone (EEZ) of the Gulf of Mexico on June 25, 1986, for a 90-day period (later extended to 180 days total with Council concurrence).

While the emergency rule was in effect, a new stock assessment was prepared by the NMFS Southeast Fisheries Center that indicated high mortality on juvenile red drum in state waters, and decreased recruitment to the adult spawning population. The assessment report concluded that continuation of fishing mortality on adult red drum, coupled with reduced recruitment, posed significant long-term risks to the spawning stock, and triggered development of a Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico by the Secretary. The primary objective of the FMP was to ensure adequate recruitment from the adult spawning population to accommodate harvest in state waters, and to encourage and support state efforts to ensure adequate escapement of juveniles to achieve offshore spawning levels that provide long-term harvest for the recreational and commercial fisheries. The FMP implemented a red drum management program for the EEZ on December 19, 1986, including: (1) a prohibition on directed commercial harvest, (2) a recreational bag limit of one fish per person per trip, (3) an incidental catch allowance for commercial net and shrimp fishermen, and (4) a quota adjustment procedure.

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[1]Prepared by Robert Sadler, National Marine Fisheries Service, 9450 Koger Blvd., St. Petersburg, FL 33702.

Amendment 1, prepared by the Council, restated the problems in the fishery, namely: (1) the possibility of recruitment failure resulting from continued intensive fishing mortality on the juvenile population in state waters, and (2) the potential for recruitment overfishing resulting from increased fishing mortality on the spawning population in the EEZ. Amendment 1 provided a new primary objective: in cooperation with the states, provide at least a 20 percent escapement rate of juvenile fish to the offshore spawning stock, relative to that rate occurring without a directed inshore fishery. The final rule for Amendment 1 was implemented by the Secretary on October 16, 1987. Various management changes were made, including continuation of the prohibition on directed commercial harvest in the EEZ, and establishment of: (1) a primary area in federal waters off Louisiana, Mississippi, and Alabama, with certain allowances for incidental catch, (2) a secondary area in federal waters off Florida and Texas, where incidental catch is prohibited, and (3) an annual schedule for stock assessments.

The Center prepared a red drum stock assessment in 1987, in accordance with the schedule specified in Amendment 1. The assessment documented excessively high fishing mortality on juvenile red drum in state waters, and a continued decline of fish under 12 years of age in the offshore spawning population. The 1987 stock assessment panel report recommended an allowable biological catch (ABC) level of zero for the EEZ, and stated the need for management changes by the states in waters under their jurisdiction to allow a juvenile escapement rate of 30 percent, as a means of restoring the offshore population to former levels of abundance.

In response to the 1987 stock assessment, the Secretary implemented emergency action that set ABC at zero in the EEZ, retroactive to January 1, 1988. The emergency rule was extended for an additional 90 days (180 days total), thereby providing uninterrupted protection of the red drum resource during development of Amendment 2 by the Council. Amendment 2, implemented on June 29, 1988, continued the prohibition on harvest and possession of red drum in the EEZ.

Subsequent red drum stock assessments, prepared by the Center in 1989 and 1991, noted that gaps occur in several successive age classes, and fishes are not recruited to the offshore spawning stock biomass until they are 3 or 4 years old. The 1989 and 1991 stock assessments therefore recommended continuation of the zero ABC level established in 1988, recognizing the spawning stock rebuilding program as a long-range project of unknown duration. The states have recently implemented various management measures designed to reduce fishing mortality on red drum in waters under their jurisdiction, thereby increasing escapement to the offshore spawning population. In the meantime, the prohibition on the harvest or possession of red drum will continue until stock assessments

indicate that the resource has been restored to levels that would safely allow resumption of the offshore fishery.

History of Management
South Atlantic[2]

The FMP for the red drum fishery of the South Atlantic Region was prepared by the South Atlantic Council in cooperation with the Mid-Atlantic Council and implemented by the Secretary of Commerce on December 11, 1990. The management unit is the population of red drum occurring off the Atlantic coastal states from the east coast of Florida to the New Jersey/New York border. The FMP regulates only the EEZ portion of the management unit; however, recommendations for management in applicable state waters are included in the FMP. The FMP prohibits the harvest of red drum in the EEZ off the Atlantic coastal states south of the New Jersey/New York border.

Objectives of the FMP, by working cooperatively with the states, are: (1) To provide 30 percent escapement of juvenile red drum to the spawning stock and to control fishing mortality to achieve at least a 30 percent SSBR level, thus maintaining a spawning stock biomass sufficient to prevent recruitment failure; (2) to provide a management system to address incompatibility and inconsistency among state and Federal regulations; and (3) to promote cooperative collection of the biological, economic, and sociological data required to effectively monitor and assess the status of the red drum resource and evaluate management efforts.

The FMP requested states to achieve a 30% SSBR through increasing escapement to a 30 percent level.

Additional Management Needs: The 1991 assessment indicated that the coastwide SSBR for Atlantic coast red drum was between 1 and 2 percent. Therefore, the assessment group recommended and the Council concurred that there be no allowable catch for the EEZ in 1992.

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[2]Prepared by Peter Eldridge, National Marine Fisheries Service, 9450 Koger Blvd., St. Petersburg, FL 33702.

Economic Assessment for Red Drum[1]

This report updates previous analysis of trends in Atlantic and Gulf coast commercial and recreational landings, exvessel prices and supplies, using data mostly for 1962-90.

Previous economic assessments are contained in fishery profiles (Perret et al., 1980; Swingle et al., 1984; SAFMC, 1990), the Secretarial plan for the Gulf coast (NMFS, 1986) and a Council plan for the Atlantic coast (SAFMC/MAFMC, 1990). In their stock assessments, Goodyear (1991) and Vaughan (1992) provide data on landings that would require much effort to obtain otherwise. Green (1989) analyzed sport fishing for red drum in the Gulf. Thurman and Easley (1991) used Gulf red drum as an example in an analysis of the cost of catch restrictions up to the consumer level. Thunberg (1991) is updating a harvesting level analysis of the nearshore, multi-species commercial fisheries in Florida, including effects of catch restrictions (Thunberg et al., 1990; Thunberg et al., 1991). However, most of the data collection and analysis recommended by a 1987 economics workshop on red drum has not been funded (SFI, 1987).

Growth in Red Drum Resource Use

Gulf coast commercial landings of red drum started to rise above their historical range of about 2-3 million pounds in the early 1970s to about 3-5 million pounds, excepting in 1985-86 when they were greater and in 1987-90 when they were sharply reduced by regulation (Table 1). By comparison, Atlantic coast commercial landings also rose between the early 1970s and early 1980s, but they did not surge in the mid-1980s, and they were less affected by regulation (Figures 1-2). Their expansion appears to have represented more of a recovery to the norm of earlier years, not growth beyond it. It may be added that the pattern for the Gulf overall did not characterize Mississippi and the west coast of Florida, where landings behaved much as they did on the Atlantic coast through the mid-1980s, that is, they remained within their historical range.[2]

Gulf commercial landings began to surpass their historic range in the early 1970s because of growth in the Texas and Louisiana nearshore fisheries, but it was not until 1983-86 that the offshore purse seine fishery added to production and demand

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[1]Prepared by John Vondruska, National Marine Fisheries Service, 9450 Koger Blvd., St. Petersburg, FL 33702, May 28, 1992. Helpful suggestions on earlier drafts from Richard Raulerson and Peter Eldridge are acknowledged, along with help from Robert LaFollette, Margery Bastian, Guy Davenport, and Richard Schween in obtaining commercial fishery landings data.

[2]Gulf landings by state for 1887-1990 are shown in Table 1, Goodyear, 1991, p. 8. Atlantic coast landings by state for 1950-88 are shown in Table 4, SAFMC/MAFMC, 1990, p. 49. Other data on trends for the Atlantic states as a whole is provided by Vaughan (1992). Table 3 of this report provides data by state for 1962-90, not really a sufficient time span to judge historic ranges or norms.

for larger red drum in Alabama and in 1985-86 in Louisiana. Because of regulatory curtailment elsewhere in the late 1980s, landings mostly from North Carolina nearshore waters now account for about half of the greatly reduced U.S. commercial market supply, and imports account for the other half (Table 1).

U.S. consumption of red drum rose from an estimated 5-6 million pounds in the 1950s to 15-20 million pounds in the mid-1980s, dominated by the increase in southeast sport fishery landings from an estimated 2-3 million pounds to 8-10 million pounds (Table 1). How much of the growing southeast landings of angler-caught red drum entered the market is unclear, though the amount could have been substantial.[3] Regardless, it is likely that traditional consumer tastes and preferences for smaller red drum developed locally based on a century of nearshore commercial fishing, subsistence fishing, and what was, say before the 1940s, a small amount of sport fishing.

Economic, Environmental and Regulatory Change

Several changes in what may be viewed as a pattern of more or less traditional, local market supply and demand for red drum began in the 1970s in the context of what was becoming a much stronger U.S. market for seafood. The 1970s and 1980s brought significantly increased per capita consumption of poultry and seafood and declines for red meat, though red meat is still the mainstay of the American diet. There has been greater demand for seafood and a limited worldwide supply of traditional species, implying rising real prices for seafood as a whole (Vondruska, 1991). As some of the attitudes and perceptions affecting seafood have been addressed, there has been a greater willingness (less reluctance) to try "new" ("unfamiliar") kinds of fish, recipes, menu items, and cooking methods. This era saw more fresh seafood counters in grocery stores and more restaurants with a seafood motif or seafood items added to their menu.

Among the "unfamiliar" kinds of fish that gained acceptance in the 1970s and 1980s outside of the coastal areas where they were well known, red drum had several things going for it. It was marketed fresh and its prices were relatively low. For restaurants, Louisiana fish and cooking that had long attracted local residents and tourists were being promoted out of state. Later, Chef Paul Prudhomme's innovation of the early 1980s, blackened redfish, was associated with the short-lived (1983-86) offshore, purse-seine fishery for larger fish.

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[3] An informal survey of NMFS port agents in the Gulf region suggests that recreational fishermen contributed substantially to the supplies of red drum in commercial channels (Perret et al., 1980, p. 22). On the other hand, keeping fish to eat was the leading use for anglers who targeted on red drum and for anglers who targeted on other species and virtually none was sold, according to an analysis of 1981 and 1986 recreational fishing survey data for the Gulf by Green (1989, p. 48).

Growing American affluence and changing population patterns help explain greater consumer demand not only for seafood, but for saltwater angling, other recreation, travel and tourism.[4] In this vein, coastal counties have touted sport fishing, beaches and other natural attractions, not to mention home and business relocation with these amenities in mind. Among coastal zones of the nation, those of the South Atlantic and Gulf regions are projected to have the largest rates of population growth in 1960-2010,[5] and this area accounts for much of the nation's saltwater angling and most of its red drum harvest.

Decades of growth in the number of southeastern saltwater anglers led to expanding demand for use of fishery resources, including red drum in nearshore waters where most are small and caught relatively easily. Apparently, the attitudes of anglers vary, some may retain large quantities of sub-legal size fish, while others readily release alive the large trophy fish (SAFMC, 1990, p. 106). Most states from Virginia to Texas have had minimum and/or maximum size regulations for red drum since 1925 (Matlock, 1980, p. 50). Smaller and larger red drum appear to have had much lower market value since the early days of commercial fishing in the 1800s, though the regulations could have precluded fisheries and markets for them (Ibid).

In major population centers of the northeast that were long the source of tourists and people who later became residents of the southeast, larger red drum ("channel bass") had gained an excellent reputation as a trophy fish. Prior to decline of the fishery, large red drum were "the ultimate challenge in the surf" in fishing (guide) camps and in nearshore charter boat fishing on the New Jersey coast in the early 1900s (SAFMC, 1990, p. 106). Fishing clubs, published International Gamefish Association world records and tournaments have maintained the trophy reputation for red drum in what is today the main fishing area along the Atlantic coast (SAFMC, 1990, pp. 84-85). On the Gulf coast, the Alabama Deep Sea Fishing Rodeo has awarded prizes for the largest red drum since its inception in 1927 (NMFS, 1986, p. 8-1), and the first state regulations for red drum in the early 1900s

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[4]According to 1981 survey data (Hu, 1985, p. 61), seafood consumption was 3.967 pounds per capita at the lowest income level (under $2,500 per capita) and it increased to 11.464 pounds at the highest income level ($15,000). Similarly, in 1985, participants in saltwater sport fishing represented 3% of the people 16 years and older in households with income less than $10,000 and 12% of those in households with income of $75,000 or more (USFWS, 1988, pp. 64-65).

[5]Regarding population projections, see Culliton et al. (1990). The five coastal-state regions are Northeast, Southeast (North Carolina to Florida's east coast, which is equivalent to South Atlantic in NMFS breakouts, as used in this report), the Gulf, Pacific and Great Lakes. A sixth coastal-state region, Alaska is omitted for this purpose by Culliton et al. (1990). Among the coastal-county portions of the five regions, that of the South Atlantic is projected to have 181% growth in population between 1960 and 2010, while that of the Gulf is projected to have 144% growth. These rates are the highest among the five regions. Within the 1960-2010 period, both the South Atlantic (36%) and Gulf (33%) are expected to have had their largest decennial growth rates in 1970-80. By 2010, Florida's population will rank fourth among all states in the nation, up from tenth in 1960, while that of Texas will rank second.

attest to long standing importance of the fish to sport fishermen in Texas (Matlock, 1980, pp. 48-50).

Coastal development has acted like a two-edged sword; it has led both to increased fishing pressure and to reduced environmental quality, which in turn has affected natural fish production. Quoting Culliton, et al. (1990, p. 1):

> While direct causes of environmental quality problems are often difficult to document, evidence is mounting that many are the result of general coastal development. Natural processes of coastal ecosystems are being disrupted, and the ecological and economic values of coastal areas threatened. . . . As coastal population grows, many of the qualities that attracted people initially are diminishing.

Red drum are among the most estuarine dependent species, but estuarine area has been reduced via mangrove and wetland loss associated with coastal development, and the quality of remaining estuaries has been reduced in varying degrees by the cumulative effects of pollutants and lower freshwater inflow (McKinney, 1991). Besides agriculture, forestry, fishing and tourism, the southeast has other natural resource dependent activities, including a large proportion of the nation's oil and gas production and refining, petrochemical manufacturing, waterborne transportation, and major port facilities.

The 1970s and 1980s represent an era of growing demand for seafood and sport fishing that also brought concerns about a deteriorating coastal environment and in 1976 new Federal legislative authority for marine fisheries management. For red drum, this became the basis for regulation of what had become in the 1980s an unprecedented commercial harvest (of adult, spawning-size fish) from the Federal Exclusive Economic Zone (EEZ) of the Gulf coast. Finally, any possession of red drum in the EEZ was prohibited on the Gulf and Atlantic coasts, whether it was sport or commercial catch.

Nevertheless, most red drum have been caught by sport fishermen in nearshore waters (where a greater proportion of the fish are small, including juvenile fish), and it was state regulation that restricted the long-established commercial harvest by small, nearshore, multi-species fishing firms. As Texas had done in 1981, other states prohibited or sharply curtailed commercial fishing on the Gulf coast, the east coast of Florida, and South Carolina, judging by landings and regulations (Tables 1-2 and Figures 1-2; SAFMC, 1990, pp. 60-64). States did impose more conservative regulations on sport fishing, but their efficacy varied (Table 4, discussed later), and they were much less disruptive to landings as a whole (Table 1).

Regulatory Reallocation

While biological stock and fishery assessments may have been prompted by concerns about red drum resources (Perret et al., 1980), the ensuing fishery regulations had an immediate and unmistakable effect on allocation of resource use. Sport fishing continues at a relatively high rate, especially on the Gulf coast and less so on the Atlantic coast. For both coasts the landings are well in excess of what was a typical year's commercial landings (Table 1 and Figures 1-2), specifically:

(1) Gulf coast recreational landings leveled out at a sizeable 6-7 million pounds in 1988-90. Commercial landings by contrast were still declining sharply in 1988-90 when they averaged a nominal 200,000 pounds, well below their historic norm of 2-3 million pounds and the 3-5 million pounds for most years since the early 1970s.

(2) For the Atlantic coast, recreational landings were declining during 1988-90 in number and weight of fish; they averaged about a million pounds, compared with about 230,000 pounds for commercial landings, which had averaged about 280,000 pounds in 1950-90.

Regulatory reallocation of use of the common property red drum resource was contentious and involved partisans of both sides, each with their own numbers and arguments, and it has political dimensions (Thunberg, et al., 1991; Fritchey, 1992; and Fee, 1992). Some degree of reallocation seems to have qualified support in the net economic benefits estimated by Green (1989).

Green's model did provide values for hypothetical regulatory changes in the rate of Gulf red drum sport fishing, but a comparison of models by Milon (1991) indicates that model results can differ significantly, implying that management agencies need to be quite cautious in using them to assess regulations (see the section of this paper on sport fishing). Second, for want of analysis of commercial fishing, Green assumed that values associated with change in its rate were much lower. Counting effects up to the consumer level, Thurman and Easley (1991) later concluded in an empirical study using red drum as an example that there can be significant economic losses associated with restriction of commercial fishing and that they can be much larger than previously supposed. Also, Thunberg et al. (1990 and 1991) concluded from an analysis of Florida nearshore multi-species commercial fisheries that economic losses at the harvesting level due to regulatory restrictions can go unmitigated; that is, depending on gear type and location, some businesses would be unable to redirect fishing effort to unrestricted species of similar economic value.

Landings and Prices by State

Tables 2-3 and Figures 3-5 suggest some degree of traditional, more or less localized consumer preferences and markets for red drum. That is, significant differences are apparent in the patterns of real exvessel prices and landings among geographic areas even at the state level of breakout over the period 1962-90. These differences persisted, (1) despite growth starting in the 1970s in U.S. seafood demand overall and in red drum demand particularly in Texas and Louisiana, and (2) contrary to allusions in some accounts to a "blackened red fish craze" and the associated, short-lived (1983-86) offshore red drum fishery, as if they had brought a singular, unifying driving force to disrupt the traditionally local and relatively stable commercial markets and fisheries for red drum that date at least to the late 1800s.

Price trends and swings attributable to factors affecting the market for seafood in general are indicated by the real price index for fish shown in Figures 4-5.[6] Note that the real prices of red drum in the upper tier (Figure 4) seemed to follow prices of all seafood more closely, though they lacked comparable strength in the first half of the 1962-90 period, while real prices of red drum in the lower tier (Figure 5) appeared to lose ground until the late 1980s.

Consider first some data on prices by state and decade:

(1) In the early 1960s, there were three tiers of prices (Table 3 and Figure 3). Real exvessel prices (in 1990 cents per pound) were highest in Texas, about 80-90 cents, lowest in Virginia and North Carolina, about 30 cents, and in between for other states.

(2) Moving from the early 1960s to the mid 1970s, real exvessel prices seemed to lack strength in many states, and they declined. There were exceptions in South Carolina, Georgia and Florida's east coast, where they advanced to some 60 cents a pound, and on Florida's west coast where they advanced to 50 cents, suggesting growth in demand, given the patterns of landings in these states. There were now four states with real prices roughly at 20-35 cents, Virginia, North Carolina, Alabama and Mississippi. Among these four states, prices in Alabama and Mississippi could have fallen in response to increased landings and/or reduced demand, but prices in North Carolina seemed to be less affected by changes in landings. Prices in Texas and

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[6]The real prices shown in Table 3 and Figures 3-5 were deflated by the Bureau of Labor Statistics (BLS) producer price index for finished consumer goods to provide prices in terms of 1990 dollars. That index is published with a 1982 base of 100 and was readjusted for this report to obtain a 1990 base of 100, and thereby real prices of red drum in dollars of 1990 purchasing power. The BLS producer price index for unprocessed and packaged fish (PPI 0223), the broadest index for seafood at the producer level, was similarly deflated and is shown as the real price index for fish, 1982=100, in Figures 4-5.

Louisiana suggest that increases in demand kept pace reasonably well with increases in landings. These two states surpassed Florida's west coast; in 1975, Louisiana landings were nearly four times the 1962 level and Texas landings were three times the 1962 level.

(3) In the late 1970s and early 1980s, real exvessel prices were rising in many states, though the lower prices in Virginia, North Carolina and Alabama lacked much in the way of upturn until the late 1980s.

Consider next the period 1983-86 when landings from the short-lived offshore purse seine fishery grew rapidly in Alabama, began in Louisiana (landings in 1985-86 only), and equaled as a whole all other Gulf red drum catch in 1986. For Alabama as a whole, real exvessel prices fell, but then rose to a record for that state of 61 cents a pound (in 1990 dollars) by 1986 when landings of the offshore, purse-seine fishery were far higher. It seems that production and marketing in the fishery was a cohesive activity that had a positive effect on demand and prices specifically for that fishery's output and probably on stressed local economies of the northern Gulf coast, given the collapse of income and employment associated with oil and gas producing industries in the mid-1980s.[7] Other producing states did not seem to be much affected, contrary to what one would expect if the alleged "blackened redfish craze" had driven their fisheries as seems to be implied in some accounts.

Cautious use of less aggregated data than shown in Tables 2-3 (but for 1977-90 for North Carolina to Texas only) adds to the understanding of the fisheries for red drum, but the discussion can become cumbersome. According to this less aggregated data, it is incorrect to attribute the growth in commercial landings for the Gulf through the mid-1980s only to the offshore purse seine fishery, although that fishery did push landings in Alabama in 1984-86 well beyond their historic range. Apart from this, Alabama's landings had tended to be from offshore waters and caught mostly by shrimp otter trawls. Purse seines had been used to catch red drum landed in Mississippi from nearshore waters in

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[7] To envision the apparent effect of marketing on demand specifically for the offshore, purse-seine caught fish, consider that the amount landed in Alabama (from waters 3-12 miles from shore) roughly doubled each year between 1983 and 1986 to about five million pounds in 1986, and real prices rose from about 20 cents a pound (in 1990 dollars) in 1983-84 to about 60 cents. Prices of the longer standing and sizeable amounts of Alabama shrimp-trawl caught red drum from the same area behaved differently; they had been about 30-40 cents in 1978-83, rose to 45 cents in 1984, fell to 19 cents in 1985, and recovered to about 30 cents in 1986-88.

The fishery began during the recovery from an extended period of national economic downturn or weakness, 1979-82, also a time of stress in the shrimp fisheries, which are among the most economically important in the southeast. Furthermore, this was a time of far reaching decline (or collapse) in the Gulf oil, gas and related industries which a few years earlier were associated with new investment, employment and income (because of abrupt rises in world prices in 1973-74 and again in 1979-80). States and local communities were encouraging other natural resource based development. Nance et al. (1991) report that nearshore fisheries in rural areas can be an important employment safety net during times of economic hardship.

1977-81 and in smaller amounts on average from offshore waters in 1982-83 and 1987. In Louisiana, there was a 1985-86 surge in landings by purse seine vessels from offshore waters, although a greater increase in landings occurred from nearshore waters in 1980-86 based on more traditional gear types (notably gill nets, drift gill nets, trammel nets and hand lines).

After 1986, the landing of red drum from offshore Gulf waters virtually ceased. Although there were significant landings in 1987 from Louisiana nearshore waters, sharply diminishing production characterized the fisheries of most states. Today, North Carolina remains as the main source of commercially landed red drum, followed by historically smaller amounts in Mississippi, Georgia and Virginia. While market disruption and the small amounts reported as being landed suggest spurious prices for some states in 1988-90, it appears that real prices were about 60 cents a pound (in 1990 dollars) in North Carolina, and about $1.25-$1.50 a pound in the higher priced markets of Georgia, Louisiana and Mississippi (Table 3 and Figure 3). Real prices at both ends of the market had at least doubled since the late 1970s.

U.S. Processing of Red Drum

Turning to processing of red drum, a preliminary analysis of data for 1970-89 from the voluntary, annual NMFS survey of U.S. seafood processing plants was conducted. Results indicate that only a very small proportion of what was landed was reported as having been processed, at most 274,000 pounds (product weight) in 1986. The total may be low perhaps because the firms involved were numerous and scattered with each processing only such a small amount that it went unreported or not reported as red drum per se. For the United States as a whole, something in the range of 0-10 plants a year reported processing red drum during 1970-89, there being more than 2 plants only in 1975-76 and 1985-87.

Real prices (expressed in 1989 dollars) received by processors for fresh and frozen fillets, the only items reported, rose from an average of about $1.40 a pound in 1975-76 to about $3.40 in 1985-86 and to about $4.90 in 1987. The real prices remained in the range of $4-5 through 1989, though the amount reported as being processed fell off again. If indicative, the real price pattern during 1970-89 for processors suggests somewhat stronger growth than for red drum at the exvessel level (Table 3 and Figure 3).

Sport Fishing

Sport fishing has accounted for much greater landings of red drum than commercial fishing from 1979 onward, the period for which adequate, though not perfect sport fishery survey data is

available, but this period of record is too short for assessing growth, trends and current conditions.[8] Consequently, as discussed earlier in this paper, it is estimated that U.S. consumption of red drum rose from 5-6 million pounds in the 1950s to 15-20 million pounds in the mid-1980s, dominated by the increase in sport fishery landings from an estimated 2-3 million pounds to 8-10 million pounds (Table 1). For what follows, basic summaries of data from 1979-90 marine sport fishing surveys were obtained from Goodyear (1991) and Vaughan (1992).[9] Keeping in mind that the statistical properties of the survey indicate need for cautious interpretation in some instances, especially at the disaggregated level and for relatively small amounts, the three measures of sport fishing in Figures 6-7 suggest the following:

(1) All three measures seem to indicate relatively more variation in sport fishing for red drum on the Atlantic coast than the Gulf coast in 1979-90. A less pronounced pattern of rise and decline characterizes both the Gulf fishery and overall Atlantic and Gulf sport fishing (NMFS, 1991b, pp. 23-24).

(2) On both coasts the number and weight of red drum landed exhibited downward trends from 1983-84 to 1990. These trends began before the late 1980s when more conservative regulations were imposed.

(3) Also for both coasts, the proportion and amount of released catch began to rise before the late 1980s. The release rate began lower for red drum, but rose more than the rate for all Atlantic and Gulf saltwater angling, which was a bit more than 30% in 1980 and 43% in 1988-89 (NMFS, 1991a).

(4) On the Gulf coast, there was a greater decline in the number of fish landed than in their weight, indicating an increase in average weight.

Summarizing, red drum sport fishing has changed during the past decade on both the Atlantic and Gulf coasts in terms of the numbers of fish caught, released and landed, and the weight of fish landed. Depending on the time period and the measure chosen, Figures 6-7 may suggest either a gain or loss in *current*

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[8]The historical record in survey data prior to 1979 is viewed as inadequate or misleading at the species level in terms of the number and weight of fish caught and landed (Swingle et al., 1984, pp. 8-5 to 8-21, especially the discussion of national survey data in Table 8-8). For later surveys, Goodyear (1991) shows sample data for Gulf red drum and NMFS (1991a) shows commonly cited point estimates of the survey along with standard errors.

[9]The data obtained from Goodyear (1991) and Vaughan (1992) is used in Table 1 and Figures 1-2, and after some adjustment in Figures 6-7. Vaughan included 0.1 of sport fishing catch B2 (that released alive), assuming that this proportion of those fish died. This amount was not deducted from the number of fish landed in Table 1, but was deducted for Figure 6; the weight is the same in both instances. Goodyear provided the number and weight of fish landed for the Gulf as a whole, but not the number released alive (catch B2), which is provided for the Florida-Louisiana area only. Annual ratios based on the number of landed fish (ratio = number for Gulf / number for Florida-Louisiana) were used to obtain the estimated numbers of fish released alive for the Gulf as a whole from the numbers for Florida-Louisiana.

economic benefits associated with sport fishing. Increased total catch may suggest more value from sport. On the other hand, the decline in landings suggests an economic loss if harvest for consumption is actually as important as 1981 survey data on motivational factors and angler disposition of fish indicates (Green, 1989, p. 48).

Based on analysis of that 1981 survey's data on motivating factors, Green (1989, p. 45) concluded that "catching fish" (harvest for consumption) ranked almost as high as sport for fishermen who targeted on red drum, though sport and relaxation together far outranked it.[10] That is, harvesting fish for consumption is only one of several factors motivating angler participation. Given the many motivating factors and the effect of regulatory bag and size limits on kept catch, Milon (1991) used total catch in one model, as Green (1989) did for Gulf red drum, and kept catch and released catch in a comparison model, and both models were applied to Gulf king mackerel. Results differed significantly. Therefore, the estimated economic gains or losses from change in the fishery would depend on which model was used. The disparity in model results for king mackerel and in angler perceptions of the two fish suggests need for further analysis for red drum, and need for caution on the part of management agencies in the use of results of various models to assess regulatory options. One would also hope for explicit modeling of economic gains and losses from change for the commercial fishery (Thurman and Easley, 1991; Thunberg et al., 1991).

Without modeling economic and biological factors, it is not clear how restrictive the reported 1 to 20 fish bag limits for red drum are, except possibly for Florida's 1-fish bag limit and Louisiana's 5-fish bag limit.[11] Using a biological model, Vaughan (1992) estimated that there could be potential savings of

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[10] Green found that almost as many anglers who targeted on red drum listed catching fishing (27.5%) first as those who listed sport first (34.3%), though it may be noted that sport and relaxation together were listed first by 55.9%. Catching fish (27.7%) was an equally important leading motivation to anglers who targeted on other species, for whom sport and relaxation together were listed first by 50.9%. Catching fish was less important to non-target anglers (17.3% listed it first), and for them sport and relaxation together were listed first by 66.2%.

[11] Regulations are shown by SAFMC (1990, pp. 60-64; GFMC, one page update, circa 1991; Atlantic data may not be current). For the Gulf states, the cited regulations and landings data from Goodyear (1991, p. 20) were compared informally, but the landings are quite volatile, making assessment difficult. The number of fish landed on Florida's west coast declined significantly from earlier years in 1987-90, as did the number landed in Louisiana in 1988-90. These declines could reflect reduced bag limits, or other changes. Florida had no bag limit in April 1986, but a limit of one fish per angler per day by November 1987. Louisiana had a 50-fish bag limit in November 1987, and a 5-fish bag limit by September 1989 (which appears to have become effective in 1988).

fish of 59% for a hypothetical Atlantic coast 1-fish bag limit and 5% for a 15-fish bag limit under 1989-90 conditions.[12]

While it does not pretend to model red drum sport fishing *with and without* regulation, which is more defensible, Table 4 does show data for 1984 and 1988, two years which may represent fishing *before and after* widespread regulation. Keeping in mind that the underlying statistical properties of the survey data may require cautious interpretation, it appears that apart from North Carolina and South Carolina, the numbers of fish landed declined in each state, especially Florida.

Each state had an increase in red drum released alive (data for Texas for 1988 catch in Table 4 does not include the amount released alive). Between 1984 and 1988, it would seem that something more than regulations per se could have affected angler behavior, increasing the proportion and number of red drum released alive. For example, following a trend that had begun in 1982 (Goodyear, 1991, Table 23), Florida's west coast release rate was relatively high in 1984, without any bag limit.

Florida contributed in a disproportional way to the saving of red drum on both coasts, judging by the reduction in landings between 1984 and 1988 (Table 4), though it still accounts for considerable mortality of fish released alive.[13] It was the leading state for red drum landings in 1984, having accounted for 41% of the fish landed, but it accounted for only 3% in 1988. Florida accounted for 56% of all saltwater angler trips in the main red drum harvest area (Virginia to Texas) in 1984 and 66% of a greater number of trips in 1988.

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[12]Based on sport fishing survey data, Vaughan indicates that of the successful angler trips for red drum (at least one red drum was caught), 55% in 1986-90 resulted in only one red drum being caught and 65% in 1989-90 resulted in only one red drum being caught. During 1986-90, 14% of the successful red drum angler trips involved a catch of more than five red drum, but only 10% of the successful trips did in 1989-90.

For the Atlantic states as a whole, Vaughan used a biological model to estimate the potential saving (to the living resource) of red drum for a range of bag and size limits, and seasonal closures. For 1989-90 conditions and comparing with regulations in place, Vaughan estimated a 59% saving of fish if there were instead a 1-fish bag limit, and a 5% saving for a 15-fish bag limit. Under 1986-90 stock and fishery conditions, the savings were higher, apparently because of higher abundance; i.e., as abundance increases, the number of fish caught per trip increases, and bag limits offer a greater saving of fish.

[13]The data in Table 4 for red drum leaves something to be desired, one notable concern being that the actual number of red drum landed on Florida's west coast in 1988 might have been closer to 150,000 to 200,000 rather than 43,000 (Goodyear, 1991, p. 20). Supposing that any understatement by the survey affected the Florida east coast as well, then the 1988 landings there might have been say 50,000 fish instead of 11,000 as shown in Table 4. For what follows, it is assumed that landings for Florida in 1988 totaled 250,000 rather than the 54,000 shown in Table 4.

An estimated 1.4 million red drum released alive by Florida anglers in 1988 could have resulted in a mortality of some 140,000 fish, which is more than the mortality from the landings of some other states. The estimates were obtained as follows (in million fish): number of fish released alive = (number caught - number landed) = 1.665 - 0.250 = 1.415; Vaughan (1992) estimated for the Atlantic coast that 10% of those released alive would die and his percentage is applied here, resulting in mortality of 140,000 fish.

So to speak, red drum appears to have become something of a catch and release fish especially in Florida, and such activity does have current economic value so far as sport, relaxation and other "non-consumptive" motivational factors of angler participation are concerned. From the standpoint of resource recovery, catch and release appears to be less harmful than for some other fish, assuming an estimate of 10% mortality for fish released alive is indicative (Vaughan, 1992). From the standpoint of increasing future economic value from use of the marine resources, stock recovery will be instrumental. It has been projected that Florida, already the leading state, will experience an increase in *resident* saltwater angler fishing days of about 55% in 1985-2025 compared with about 44% for the main red drum harvest area (Virginia to Texas) and 36% for the nation as a whole (SFI, 1992).

Louisiana, the leading sport fishing state for red drum by 1988, exhibited some decline in the number landed between 1984 and 1988, but a large increase in total catch (and in the number released alive). It would seem that the Louisiana 5-fish bag limit was a constraint on landings from 1988 onward (Goodyear, 1991, Table 23).[14] By way of very crude illustration, simply using the numbers of fish in Table 4 and disregarding differences in economic value, sport fishermen of Florida would have foregone more than their Louisiana counterparts in *current* economic value for landed red drum (for consumption), and they would have foregone something in terms of *current* sport value (total catch) while Louisiana sport fishermen would have gained more in terms of *current* sport value (total catch).

Concluding Comments

Given what has been recommended in the way of economics work for red drum, the purpose of this report is modest. It provides an updated descriptive assessment of trends in recreational and commercial landings, imports, supplies, exvessel prices, and markets.

From such data it is clear that the red drum resources of the Atlantic and Gulf coasts supported relatively stable commercial harvests of 2-3 million pounds for nearly a century, mostly in nearshore waters of states from Virginia to Texas. During the 1970s and 1980s commercial landings rose above their historic norm mostly to 3-5 million pounds, and they were much less than the 8-11 million pounds for recreational landings in all but one (1986) of the years from 1979 onward for which survey data allows comparison. Because of the regulatory restrictions

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[14] From Table 4, Louisiana had a postulated 92,000 red drum fishing trips in 1984, and 1,105,000 fish were landed for an average of 12 fish per trip. In 1988, there were a postulated 216,000 trips and 891,000 fish landed, or an average of 4 fish per trip.

of the late 1980s, commercial landings fell below 200,000 pounds by 1990, while recreational landings leveled out at about 6-8 million pounds in 1989-90. Regulation caused a reallocation of resource use from commercial to sport fishing.

Much of the readily documented expansion in red drum landings occurred prior to and apart from the controversial and short-lived (1983-86), northern Gulf (two-state) offshore purse seine commercial fishery, which seems to be implicated for more than its share of the growth in fishing pressure on red drum resources. While some accounts leave the impression that the surprisingly successful integrated production and marketing activity for the larger fish specifically from that fishery represented a "blackened redfish craze" that was driving all commercial fishing for red drum, that argument lacks support in landings data. Rather, annual commercial landings and exvessel prices for 1962-90 for the states from Delaware to Texas suggest that the century old pattern of traditional, localized fisheries and markets for small red drum persisted, despite significant overall change and regulatory curtailment.

Economic losses to the small, nearshore multi-species commercial fishing firms attributable to regulatory prohibition and curtailment of red drum landings have gone unmitigated to the extent that some cannot redirect fishing effort to replace red drum with an equally valued, but unrestricted species in their catch mix. While the proportion that cannot satisfactorily redirect effort is unknown, Thunberg et al. (1991) did conclude that fishermen in some areas of Florida bore the brunt of red drum regulation in that state. And the economic cost of the regulatory restriction is likely to be much larger than previously supposed when effects up to the consumer level are considered (Thurman and Easley, 1991).

In rural communities where occupational alternatives are fewer than in more developed areas, nearshore fisheries have served as an employment safety net during times of economic hardship, such as the decline of the Gulf oil and gas production industries during the 1980s (Nance et al., 1991). The dependence of nearshore fisheries on red drum is not well understood, though it is reported that red drum (41%) and seatrout accounted for 64% of the nearshore Louisiana net fishery revenue in 1982-85, a fishery which also depends on flounder, black drum, sheepshead and mullet (Fritchey, 1992).

In contrast to the commercial fishery, the growth of sport fishery use of red drum resources and its implications for fishery management seem to be virtually ignored in most accounts. For want of an adequate historical record in pre-1979 survey data, it is estimated in this paper that sport fishery landings of red drum rose from 2-3 million pounds in the 1950s to 10-11 million pounds by the mid-1980s (Table 1). The estimated growth

over three decades, some 8 million pounds, exceeds the entire commercial catch from nearshore waters at its peak in 1986.

Survey based landings and catch data for 1979 onward does suggest change in *current* economic values associated with sport fishery use of red drum resources. For both coasts, the number and proportion of fish that were released alive began to grow in the early 1980s, and they grew far more sharply in the late 1980s. An increase in catch may suggest a gain in *current* economic value associated with sport, relaxation and other "non-consumptive" factors motivating angler participation, but a decline in landings suggests a loss in *current* economic value associated with angler motivation to harvest for consumption.

For purposes of illustration, Table 4 compares sport fishing activity in states from Virginia to Texas in 1984 and 1988, the latest year for which data for all states was available at the time. While factors other than regulations per se appear to have affected angler behavior between 1984 and 1988, greater regulatory constraint could have resulted in even more saving of fish and faster stock recovery. For example, using a biological model, Vaughan (1992) estimated that a 1-fish bag limit would have resulted in a 59% saving of fish on the Atlantic coast under 1989-90 stock and fishery conditions.

Florida is the leading sport fishing state in terms of total angler trips and it now has a 1-fish bag limit for red drum, the most restrictive among the states. It was the leading state for red drum landings in 1984, having accounted for 41% of the fish landed by sport fishermen, but it accounted for only 3% in 1988. The total number of red drum landed by sport fishermen fell sharply between 1984 and 1988, from about 4 million fish to 2 million fish, and about three fourths of that saving to the resource occurred in Florida. Florida has contributed in a disproportional way to the saving of fish at the expense of *current* economic value associated with angler motivation to harvest for human consumption, but there is the prospect of growing numbers of anglers especially in Florida (SFI, 1992) and stock recovery is essential to achieving greater economic value from resource use in the future. Catch and release works to that end, but even live release has some mortality, perhaps 10% (Vaughan, 1992) and this can mount up when a large number of fish are caught and released alive as in Florida.

References

Adams, Charles M. and Frank J. Lawlor. 1989. Trends in the importation of selected fresh and frozen seafood products into the southeastern United States. Univ. of Florida, Food and Resource Economics Dept., Gainesville, FL 32611, Florida Sea Grant College Program, technical paper TP-59, November 1989.

Culliton, Thomas J., Maureen A. Warren, Timothy R. Goodspeed, Davida G. Remer, Carol M. Blackwell, and John J. McDonough, III. 1990. 50 years of population change along the nation's coasts, 1960-2010. U.S. Dept. of Commerce, National Ocean Service, Ocean Assessments Div., Strategic Assessment Branch, Rockville, MD 20852, April 1990.

Essig, Ronald J., John F. Witzig and Mark C. Holliday. 1991. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1987-1989. U.S. Dept. of Commerce, National Marine Fisheries Service, Fisheries Statistics Div., Silver Spring, MD 20910, current fisheries statistics no. 8904, May 1991.

Fee, Russ. 1992. Was a high-profile Florida netter the target of government harassment? National Fisherman 73:2(June 1992):26-28.

Fritchey, Robert. 1992. Louisiana netters fight back. National Fisherman 73:2(June 1992):20-22.

Goodyear, C. Phillip. 1991. Status of the red drum stocks of the Gulf of Mexico, report for 1991. U.S. Dept of Commerce, National Marine Fisheries Service, 75 Miami Beach Drive, Miami, FL 33149-1099, Miami Laboratory contribution MIA-90/91-87, Sept. 26, 1991, 25 p.

Green, Trellis G. 1989. The economic value and policy implications of recreational red drum success rate in the Gulf of Mexico. Univ. of Southern Mississippi, Dept. of Economics and International Business, Marfin Cooperative Agreement NA87WC-H-06146.

Hu, Teh-wei. 1985. Analysis of seafood consumption in the U.S.: 1970, 1974, 1978 and 1981. A contract report for the National Marine Fisheries Service, available as report no. PB-86-135043 from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Matlock, Gary C. 1980. History and management of the red drum fishery. In proceedings of the colloquium on the biology and management of red drum and seatrout (October 19-20, 1978, Holiday Inn Central, Tampa, Florida), pp. 37-53. Gulf States Marine Fisheries Commission, P.O. Box 726, Ocean Springs, Mississippi 39564, no. 5, May 1980.

McKinney, Larry. 1991. Managing America's sea--the Gulf of Mexico. In Gretchen Flock, editor, The environmental and economic status of the Gulf of Mexico (a symposium, December 2-5, 1990, Clarion Hotel, New Orleans, Louisiana, sponsored by several federal and state agencies, organizations and businesses), pp. 173-184. Obtain copies from William Whitson, Gulf of Mexico Program Office, John C. Stennis Space Center, Building 1103, Room 202, Stennis, MS 39529-6000.

Milon, J. Walter. 1991. Measuring the economic value of anglers' kept and released catches. North American Journal of Fisheries Management 11:185-189.

Nance, James M., Nina Garfield and J. Anthony Paredes. 1991. A demographic profile of participants in two Gulf of Mexico inshore shrimp fisheries and their response to the Texas closure. Marine Fisheries Review, 53(1):10-18.

NMFS. 1976. Final Secretarial fishery management plan, regulatory impact review, and regulatory flexibility analysis for the red drum fishery of the Gulf of Mexico. U.S. Dept. of Commerce, National Marine Fisheries Service.

NMFS. 1991a. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1987-89. U.S. Dept. of Commerce, National Marine Fisheries Service, Fishery Statistics Div. (F/RE1), 1335 East West Highway, Silver Spring, MD 20910, current fishery statistics no. 8904.

NMFS. 1991b. Fisheries of the United States, 1990. U.S. Dept. of Commerce, National Marine Fisheries Service, Fishery Statistics Div. (F/RE1), 1335 East West Highway, Silver Spring, MD. 20910, current fishery statistics no. 9000.

Perret, William S., James E. Weaver, Roy O. Williams, Patricia L. Johansen, Thomas D. McIlwain, Richard C. Raulerson and Walter M. Tatum. 1980. Fishery Profiles of red drum and spotted seatrout. Gulf States Marine Fisheries Commission, P.O. Box 726, Ocean Springs, Mississippi 39564, no. 6, April 1980.

South Atlantic Fishery Management Council (SAFMC). 1990. Profile of the Atlantic coast red drum fishery and source document for the Atlantic coast red drum fishery management plan, July 1990.

South Atlantic Fishery Management Council and Mid-Atlantic Fishery Management Council (SAFMC/MAFMC). 1990. The Atlantic coast red drum fishery management plan, including an environmental impact statement and regulatory impact review.

Sport Fishing Institute (SFI). 1987. A research agenda for the economics of the red drum fishery. Prepared by the Sport Fishing Institute, 1010 Mass. Ave. NW, Suite 100, Washington, D.C. 20001, with accompanying memo from Wayne E. Swingle to Richard B. Stone, dated March 7, 1989, transmitting the report and an analysis of January 1988 by Council staff. Workshop sponsored by the Gulf and South Atlantic Fisheries Development Foundation, the National Marine Fisheries Service and the Sport Fishing Institute, May 7-8, 1987, Tampa, Florida.

Sport Fishing Institute (SFI). 1992. Compendium of sport fishing statistics--participation, economics, licensing and boating. Sport Fishing Institute, 1010 Massachusetts Ave., NW, Suite 320, Washington, DC 20001.

Swingle, Wayne, Terry Leary, Connor Davis, Vito Blomo, Walter Tatum, Mike Murphy, Ron Taylor, Gerald Adkins, Tom McIlwain and Gary Matlock. 1984. Fishery profile of red drum. Gulf of Mexico Fishery Management Council, 5401 West Kennedy Blvd., Tampa, FL 33609, and Gulf States Marine Fisheries Commission, Gulf Coast Research Laboratory, East Beach, Ocean Springs, MS 39564, January 1984.

Thunberg, Eric, Charles Adams, Darrel Brannan and Timothy Taylor. 1990. An economic assessment of multi-species production in Florida's commercial near-shore fishery. Univ. of Florida, Dept. of Food and Resource Economics, 1170 McCarty Hall, Gainesville, FL 32611, staff paper 390, August 1990.

Thunberg, Eric, Charles Adams, Darrel Brannan and Timothy Taylor. 1991. Commercial fishing revenue losses under harvest restrictions: the case of the Florida red drum. Univ. of Florida, Dept. of Food and Resource Economics, 1170 McCarty Hall, Gainesville, FL 32611, staff paper 91-4, February 1991.

Thunberg, Eric. 1991. Personnel communication. Univ. of Florida, Dept. of Food and Resource Economics, 1170 McCarty Hall, Gainesville, FL 32611.

Thurman, Walter N. and J. E. Easley, Jr. [circa 1991]. Valuing changes in commercial fishery harvests: a general equilibrium demand analysis. Unpublished draft in review, North Carolina State Univ., Dept. of Agricultural and Resource Economics, Raleigh, NC 27607.

U.S. Fish and Wildlife Service (USFWS). 1988. 1985 National survey of fishing, hunting, and wildlife associated recreation. U.S. Dept. of Interior, Fish and Wildlife Service, November 1988.

Vaughan, Douglas S. 1992. Status of the red drum stock of the Atlantic coast: stock assessment report for 1991. U.S. Dept. of Commerce, National Marine Fisheries Service, 101 Pivers Island Road, Beaufort, NC 28516-9722, NOAA Technical Memorandum NMFS-SEFC-297, February 1992, 62 p.

Vondruska, John. 1991. A review of the U.S. seafood market. In David S. Liao, editor, Proceedings of the symposium on seafood advertising and promotion: research and experience (Orlando, Florida, October 30-31, 1989), 1991, pp. 1-17. Copies available from Oregon State Univ., International Institute of Fisheries Economics and Trade, Dept. of Agricultural and Resource Economics, Corvalis, OR 97331 or from South Carolina Wildlife and Marine Resource Dept., P.O. Box 12559, Charleston, SC 29412.

Table 1.--Estimated U.S. supplies of red drum
(Thousands of pounds, round or live weight basis, except as noted)

Year	Landings, Gulf of Mexico				Landings, Atlantic				Imports prod. weight	Commercial market supply	Total recreational landings	Total supply
	Commercial	Recreational			Commercial	Recreational						
		Weight	Number	Avg. wt.		Weight	Number	Avg. wt.				
1950	2,032	2,095	759		628	306	152		341	3,070	2,401	5,470
1951	1,615				529				349	2,563		
1952	1,321				428				332	2,148		
1953	1,418				439				438	2,382		
1954	1,824				492				330	2,712		
1955	1,668	2,855	1,035		474	417	208		296	2,497	3,273	5,770
1956	1,932				320				317	2,633		
1957	1,588				163				247	2,047		
1958	1,798				278				135	2,238		
1959	2,232				181				529	3,047		
1960	2,112	3,926	1,424		163	574	285		874	3,324	4,500	7,824
1961	2,327				205				142	2,702		
1962	2,845				224				361	3,502		
1963	2,334				207				158	2,731		
1964	1,625				236				99	1,980		
1965	1,954	4,668	1,693		314	682	339		109	2,398	5,350	7,749
1966	2,107				194				32	2,339		
1967	2,091				161				9	2,263		
1968	2,703				185				224	3,157		
1969	2,686				127				874	3,861		
1970	3,240	5,538	2,008		157	809	403		841	4,406	6,347	10,754
1971	3,613				107	-			600	4,439		
1972	3,451				182				623	4,381		
1973	4,208				247				740	5,343		
1974	4,923				301				479	5,798		
1975	4,493	8,159	2,958		339	1,193	593		403	5,316	9,351	13,331
1976	5,435				303				394	6,210		
1977	3,577				129				561	4,379		
1978	3,849				133				519	4,605		
1979	2,875	8,912	4,080	2.18	225				362	3,534		
1980	2,843	9,809	3,404	2.88	440	717	285	2.52	358	3,712	10,526	14,238
1981	2,906	6,023	2,076	2.90	353	633	188	3.37	145	3,433	6,656	10,088
1982	2,547	7,929	3,054	2.60	195	682	390	1.75	285	3,084	8,611	11,695
1983	3,241	9,240	4,000	2.31	330	1,065	642	1.66	219	3,834	10,305	14,139
1984	4,454	8,851	2,968	2.98	422	2,179	1,075	2.03	167	5,077	11,030	16,107
1985	6,418	8,140	2,625	3.10	249	2,032	1,054	1.93	252	6,969	10,172	17,141
1986	14,127	8,209	3,041	2.70	342	1,817	447	4.07	626	15,220	10,026	25,246
1987	4,891	7,922	2,392	3.31	312	1,472	724	2.03	272	5,530	9,394	14,924
1988	291	5,883	1,469	4.00	229	1,672	564	2.96	200	760	7,555	8,315
1989	166	7,236	1,594	4.54	286	908	297	3.05	200	692	8,144	8,836
1990	8	6,127	1,233	4.97	186	512	249	2.05	200	434	6,639	7,073

Recreational landings for 1955, 1960, 1965, 1970 and 1975 were estimated from the respective 1980-85 averages and the ratio of the number of saltwater fishing days (from USFWS, 1988, p. 150) in the specified year to the number in 1985; 1950, author's estimate. Imports are assumed to be dressed (headed & gutted) fish and the data was converted to a live weight basis using the factor 1.2; author's estimate for 1988-90. The import data was compiled by NMFS port agents from U.S. Customs records for ports of entry from North Carolina to Texas. Imports of red drum are not reported separately in publications of the U.S. Bureau of Census. The imports are mostly from Mexico (Adams and Lawlor, 1989). Commercial market supply = landings + imports (on a round or live weight basis). Total supply = commercial market supply + recreational landings. Sources: Perret et al. (1980), SAFMC/MAFMC (1990), Goodyear (1991) and Vaughan (1992).

Table 2.--U.S. landings of red drum
(Thousands of pounds, round or live weight basis)
(By region and state)

Year	Middle Atlantic & Chesapeake				South Atlantic					Gulf of Mexico						
	DL	MD	VA	Region total	FL ec	GA	NC	SC	Region total	AL	FL wc	LA	MS	TX	Region total	U.S. total
62	.	.	13	13	149	.	61	.	210	13	1,307	567	76	699	2,663	2,886
63	.	.	3	3	134	.	71	.	205	20	968	466	59	686	2,199	2,407
64	.	.	5	5	119	.	102	12	232	19	696	312	50	447	1,524	1,761
65	.	1	95	96	146	.	71	.	218	4	801	471	33	533	1,841	2,155
66	.	0	3	3	153	3	35	0	191	6	645	531	37	797	2,017	2,211
67	.	.	1	1	147	6	13	1	167	9	496	654	96	768	2,022	2,190
68	.	.	0	0	167	6	13	.	185	16	707	741	215	925	2,604	2,789
69	.	0	1	1	119	3	4	1	126	51	586	782	100	1,083	2,603	2,730
70	.	.	0	0	147	2	8	0	157	35	668	789	70	1,586	3,148	3,305
71	.	.	1	1	85	1	17	1	105	32	708	724	59	1,991	3,513	3,619
72	.	.	6	6	128	3	43	1	176	77	843	889	56	1,468	3,333	3,515
73	1	.	6	7	167	4	70	1	241	172	954	1,184	86	1,678	4,073	4,321
74	.	.	16	16	137	3	142	2	285	120	1,191	1,436	89	1,922	4,757	5,058
75	0	.	20	20	83	10	214	12	320	74	759	1,362	72	2,120	4,387	4,727
76	.	.	19	19	106	7	168	3	284	67	905	2,213	95	2,029	5,309	5,611
77	0	.	0	1	103	5	20	1	129	65	845	1,435	164	951	3,460	3,590
78	0	.	2	2	105	0	22	4	131	86	899	1,219	658	861	3,723	3,857
79	.	0	2	2	93	1	127	2	222	85	745	1,057	194	690	2,771	2,995
80	.	.	0	0	191	1	243	4	440	53	817	725	20	1,114	2,729	3,169
81	.	.	0	0	258	0	93	1	353	38	1,131	899	67	614	2,748	3,101
82	.	.	2	2	139	0	53	2	194	69	861	1,455	41	.	2,425	2,621
83	.	0	42	42	105	1	220	2	328	361	804	1,939	24	.	3,127	3,497
84	.	.	3	3	131	2	283	4	420	854	849	2,608	24	.	4,334	4,757
85	.	.	1	1	89	4	153	4	249	2,843	539	2,934	27	.	6,343	6,592
86	.	1	5	6	75	3	249	12	340	5,305	878	7,818	126	.	14,126	14,472
87	.	.	3	3	43	5	250	15	312	14	241	4,571	53	.	4,879	5,194
88	.	8	4	12	0	3	220	0	224	1	4	245	41	.	291	527
89	.	1	8	9	.	3	274	0	277	2	.	25	140	.	166	453
90	.	.	2	2	0	2	183	.	185	.	0	2	5	.	8	194
Total	2	12	261	274	3,321	78	3,421	85	6,905	10,491	20,846	40,051	2,775	22,961	97,124	104,303

Table 3.--Real exvessel prices of U.S. landings of red drum
(1990 cents per pound, round or live weight basis)
(By region and state)

Year	Middle Atlantic & Chesapeake			South Atlantic				Gulf of Mexico				
	DL	MD	VA	FL ec	GA	NC	SC	AL	FL wc	LA	MS	TX
62	.	.	30	51	.	28	.	52	40	55	53	86
63	.	.	30	52	.	24	.	54	40	60	45	85
64	.	.	30	64	.	31	50	55	45	57	50	88
65	.	31	36	61	.	41	.	52	46	61	51	89
66	.	30	30	62	41	34	33	50	47	57	48	90
67	.	.	28	61	59	32	47	49	47	55	48	83
68	.	.	36	49	72	22	.	40	49	44	48	75
69	.	16	19	60	59	26	49	40	50	46	41	67
70	.	.	18	60	49	26	51	31	50	49	38	67
71	.	.	11	62	62	29	53	35	51	56	37	72
72	.	.	23	65	57	35	76	33	51	50	36	79
73	35	.	29	70	58	28	66	34	52	50	35	83
74	.	.	33	62	51	25	66	29	48	46	31	71
75	25	.	20	65	61	20	60	27	49	49	31	76
76	.	.	16	66	64	25	65	26	50	53	35	86
77	12	.	20	68	76	25	62	25	53	64	33	99
78	26	.	11	77	111	19	55	34	59	74	47	117
79	.	8	13	82	84	26	40	39	55	81	70	127
80	.	.	20	74	86	26	34	37	55	78	48	123
81	.	.	29	66	87	25	51	41	56	88	29	139
82	.	.	15	93	79	28	71	39	74	77	28	.
83	.	23	24	88	80	28	81	25	71	84	45	.
84	.	.	19	87	92	33	82	24	61	96	61	.
85	.	.	21	85	100	38	99	36	66	108	54	.
86	.	45	30	101	107	50	101	61	104	85	80	.
87	.	.	40	109	108	68	92	47	122	129	89	.
88	.	34	31	137	117	63	100	36	139	156	111	.
89	.	82	40	.	132	67	103	38	.	113	148	.
90	.	.	46	200	126	58	.	.	200	75	147	.

Table 4a.--Estimated number of fishing trips in 1984 by saltwater anglers, red drum trips, and numbers of red drum caught and landed (data in thousands)

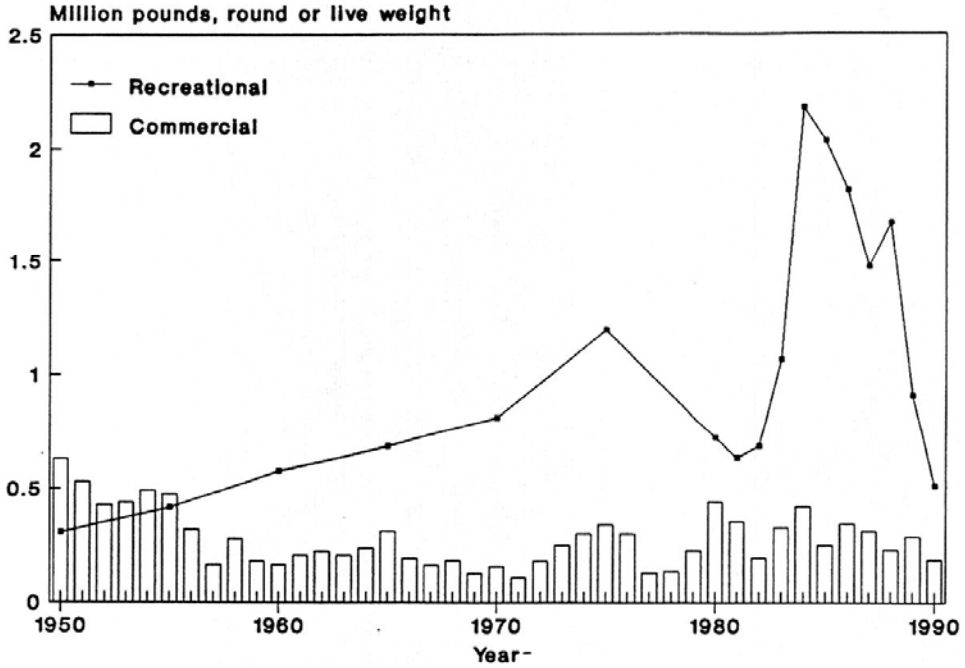
State or region	Trips by location of residence: Coastal	Non-coastal	Out of state	Total	% of trips by state	Red drum seeking fishing trips	Number of red drum caught	Number of red drum landed	% of red drum landed
Virginia	2,729	178	1,071	3,978	10%		3	3	0%
North Carolina	1,684	1,054	2,084	4,822	13%	155	96	93	2%
South Carolina	1,097	394	1,120	2,611	7%	84	142	142	4%
Georgia	360	97	60	517	1%	17	220	218	5%
Florida, e.c.	8,291	18	1,582	9,891	26%	318	671	613	15%
South Atlantic	11,432	1,563	4,846	17,841	47%	573	1,130	1,066	26%
+ Virginia	14,161	1,741	5,917	21,819	57%		1,133	1,069	26%
Florida, w.c.	7,715	22	3,713	11,450	30%	737	1,705	1,062	26%
Alabama	353	48	120	521	1%	34	23	23	1%
Mississippi	355	56	135	546	1%	35	68	68	2%
Louisiana	1,349	39	46	1,434	4%	92	1,291	1,105	27%
Texas	1,915	381	149	2,445	6%	157	729	709	18%
Gulf	11,687	546	4,163	16,396	43%	1,056	3,816	2,967	74%
Selected states	25,848	2,287	10,080	38,215	100%		4,949	4,036	100%
	68%	6%	26%	100%					
Atlantic & Gulf	43,895	2,790	15,281	61,966					
	71%	5%	25%	100%					

Table 4b.--Estimated number of fishing trips in 1988 by saltwater anglers, red drum trips, and numbers of red drum caught and landed (data in thousands)

State or region	Trips by location of residence: Coastal	Non-coastal	Out of state	Total	% of trips by state	Red drum seeking fishing trips	Number of red drum caught	Number of red drum landed	% of red drum landed
Virginia	2,558	152	592	3,302	8%		7	3	0%
North Carolina	2,197	865	1,546	4,608	11%	138	144	128	6%
South Carolina	1,052	309	475	1,836	4%	59	599	348	17%
Georgia	515	70	25	610	1%	20	291	103	5%
Florida, e.c.	10,603	26	1,911	12,540	30%	403	259	11	1%
South Atlantic	14,367	1,270	3,957	19,594	47%	629	1,293	590	29%
+ Virginia	16,925	1,422	4,549	22,896	55%		1,301	593	29%
Florida, w.c.	10,002	38	3,783	13,823	33%	893	1,406	43	2%
Alabama	534	333	237	1,104	3%	71	18	13	1%
Mississippi	662	40	97	799	2%	52	51	47	2%
Louisiana	3,016	139	183	3,338	8%	216	3,175	891	43%
Texas	.	.	.	.	.	.	475	475	23%
Gulf	14,214	550	4,300	19,064	45%	1,228	5,125	1,469	71%
Selected states	31,139	1,972	8,849	41,960	100%		6,426	2,062	100%
	74%	5%	21%	100%					
Atlantic & Gulf	48,518	3,066	14,514	66,098					
	73%	5%	22%	100%					

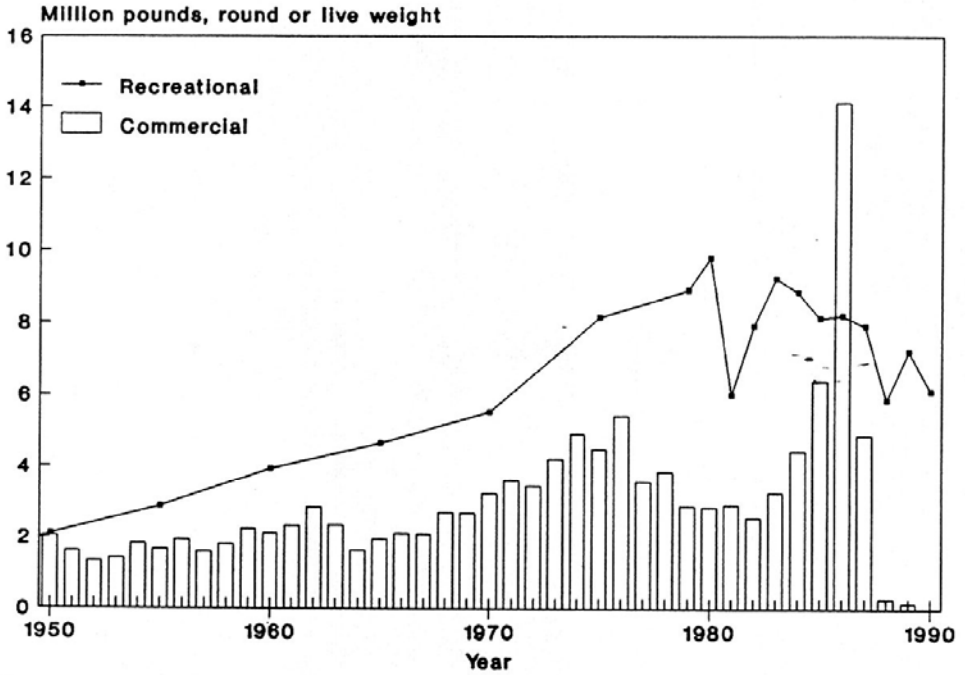
According to the NMFS Marine Recreational Fishery Statistics Survey, red drum was indicated as the species sought on 3.21% of South Atlantic sport fishing trips in the intercept survey in 1984, and 6.44% of the Gulf trips; the respective percentages for 1988 were 2.99% and 6.46%. These percentages were applied to the total number of trips by state to estimate the number of fishing trips for which red drum was sought. Sources: NMFS (1985 and 1991a); last two columns, SAFMC (1990, p. 90-91) and Goodyear (1991, Tables 18 and 23).

Figure 1.--Atlantic landings of red drum



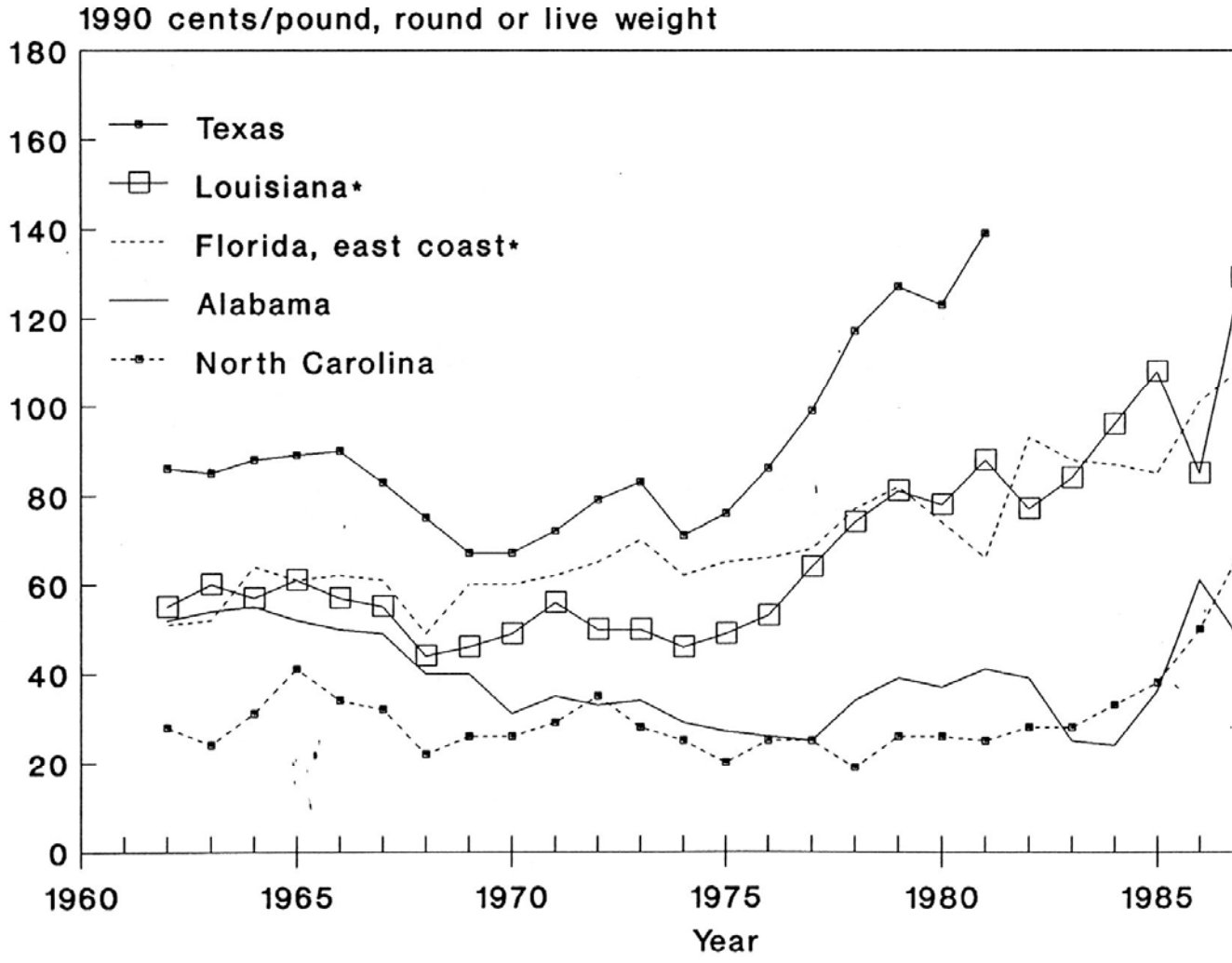
Recreational landings for 1950-75 estimated.

Figure 2.--Gulf landings of red drum



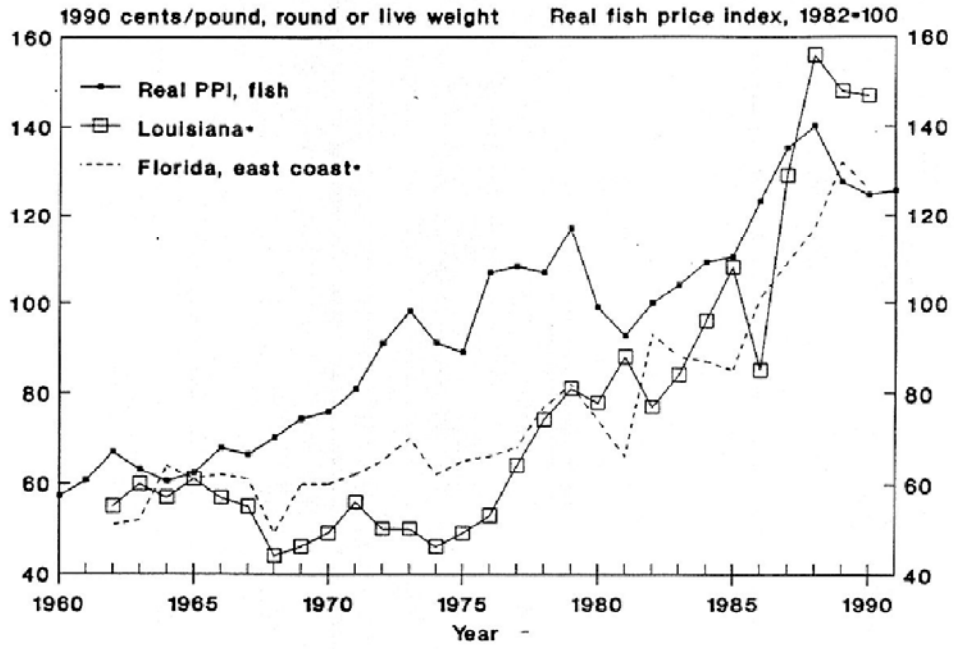
Recreational landings for 1950-75 estimated.

Figure 3.--Real prices of red drum
(Exvessel prices, selected states)



*MS for LA in 1989-90, and GA for FL ec in 1987-90.

Figure 4.--Real prices of red drum
(Florida, east coast and Louisiana)



*MS for LA in 1989-90, and GA for FL ec in 1987-90.

Figure 5.--Real prices of red drum
(North Carolina and Alabama)

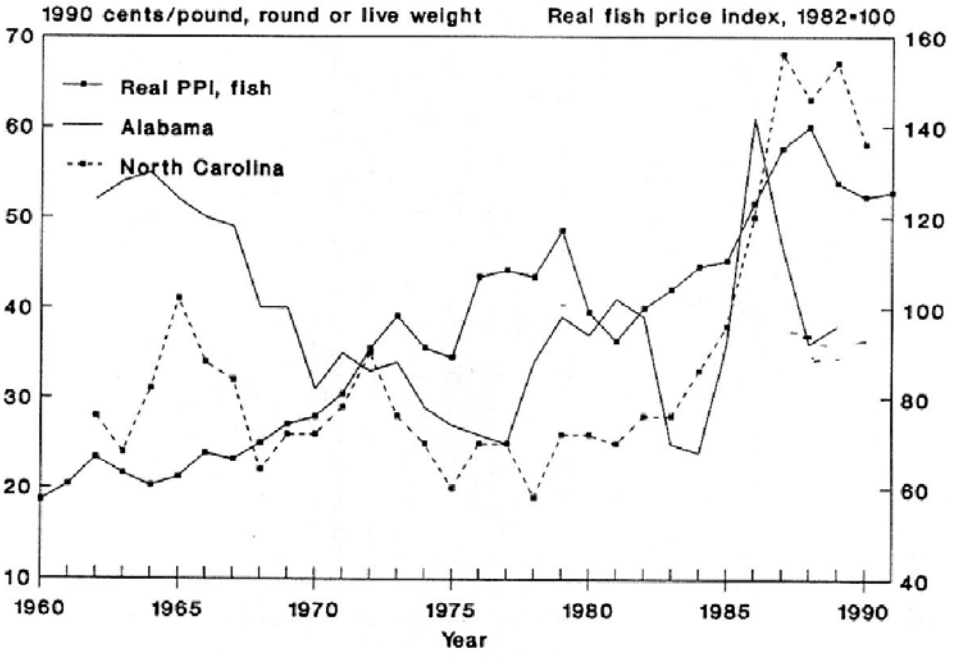


Figure 6.--Atlantic sport fishing for red drum

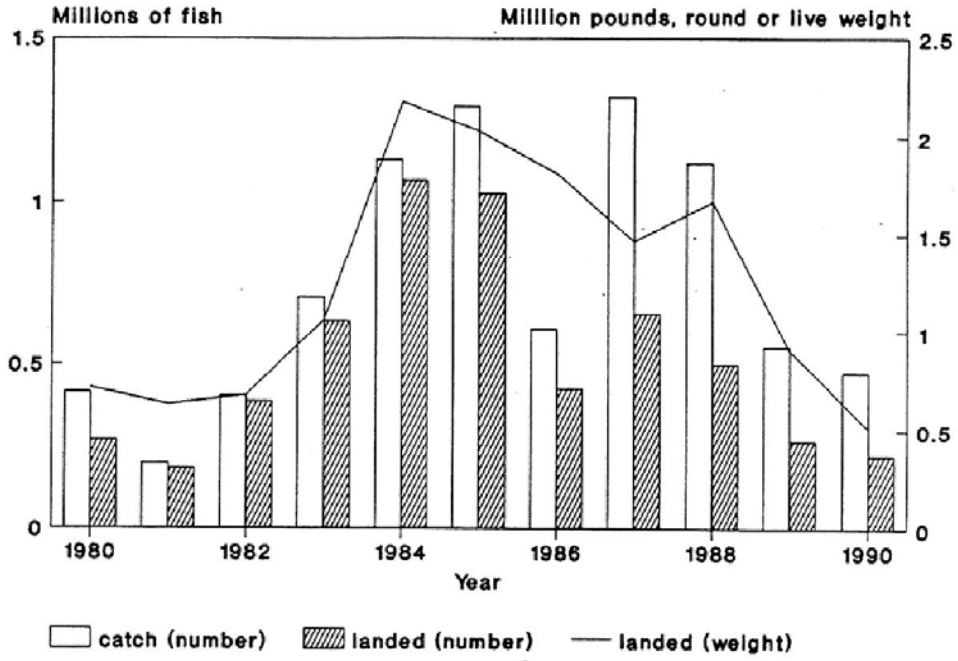
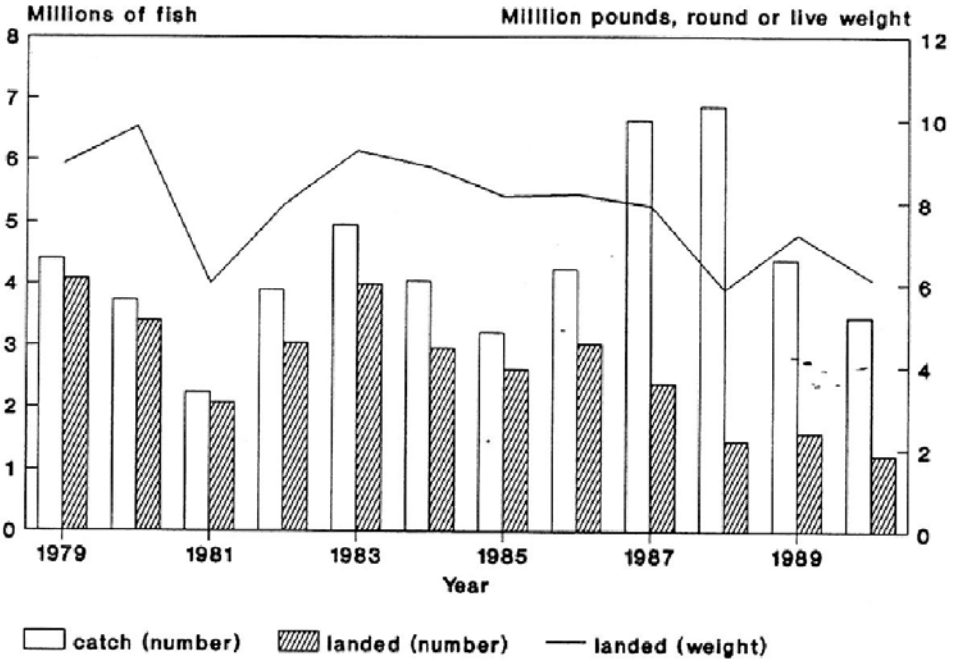


Figure 7.--Gulf sport fishing for red drum



STATUS OF THE RED DRUM STOCKS OF THE GULF OF MEXICO REPORT FOR 1991

C. Phillip Goodyear

26 September 1991

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Miami Laboratory Contribution: MIA - 90/91 - 87

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SUMMARY

Commercial landings statistics for red drum have been collected since 1880 and have been compiled annually since 1950. Gulfwide, the reported annual commercial landings totaled from about 1 to 3 million pounds until 1970. During the 1970s the total commercial landings increased to a peak of 5.4 million pounds in 1976, then subsided to a minimum of 2.5 million pounds in 1982. Commercial landings then increased dramatically and reached an all time high of 14.1 million pounds in 1986. Most of this increase was landed in Alabama and was taken from statistical grid 11 in the EEZ by the newly developed purse-seine fishery. Estimates of the recreational harvest of red drum substantially exceeded the commercial landings prior to 1985 when the two were about equal. In 1986 the commercial landings were substantially in excess of the weight of the recreational harvest.

Conservation measures were subsequently introduced to protect the resource and the combined recreational and commercial harvest declined by the end of the decade. Much of this reduction was the result of a decline of the commercial harvest to a historic minimum of less than 10 thousand pounds in 1990.

The number of red drum harvested by recreational fishermen also declined sharply after 1986 to about less than half the 1986 level in 1990. However, an increase in mean size of the fish harvested by recreational fishermen caused the recreational harvest in biomass to remain relatively stable. The 1987-1990 recreational statistics also show a dramatic increase in both the absolute magnitude and the fraction of the recreational catch of red drum that were released after capture.

These observed changes in mean weight of the harvest and the increased incidence of angler releases are expected results of the conservation efforts taken by the states to increase escapement rates and rebuild the spawning stock. As a consequence, the current statistics provide evidence that the conservation actions are having the desired effect of reducing fishing mortality in the stock. However, the extent to which these measures have increased escapement of juveniles into the adult stock has not yet been evaluated. This issue will be addressed in a future assessment or research report.

INTRODUCTION

This is the fifth of the annual assessments for the stock of Gulf of Mexico red drum (Sciaenops ocellatus) required by Amendment 1 (GMFMC 1987) to the Fishery Management Plan (FMP) for red drum (USDOC 1986). The intent of the assessment is to provide information related to the questions posed in Section 12.6.2 of the amended FMP. This document updates the commercial and recreational landings estimates and is intended as a working document for the Gulf of Mexico Fisheries Management Council's Red Drum Stock Assessment Group, which specifies a range of acceptable biological catch (ABC) for the EEZ.

DESCRIPTION OF THE FISHERY

A discussion of the history of exploitation appears in the FMP for red drum (USDOC 1986) and the prior annual assessments (Goodyear 1987, 1988, 1989). Since annual updates of the fisheries statistics are an integral component of the anticipated annual stock assessment, some of the relevant background is included here for the convenience of the reader.

COMMERCIAL FISHERY

Landings statistics for commercially caught fish have been collected since 1880. Annual landings data were collected at irregular intervals until about 1950. Since then, annual landings statistics have been reported for each state for each year. These estimates (Table 1) are thought to account for most of the commercial catch passing through dealers; however, that part of the catch that bypasses the dealers and processors and enters the retail market directly is not included in the catch estimates. No attempt has been made to adjust the commercial landings estimates for the fraction which are not included in the landing statistics.

Gulfwide, the reported annual landings totaled from about 1 to 3 million pounds until 1970 (Figure 1). During the 1970s the total landings increased to a peak of 5.3 million pounds in 1976, then subsided to a minimum of 2.4 million pounds in 1982. Landings then increased dramatically and reached an all-time high of 14 million pounds in 1986.

Commercial landings declined to 4.9 million pounds in 1987 coincident with the prohibition of a directed commercial fishery in the EEZ and the introduction of conservation measures in

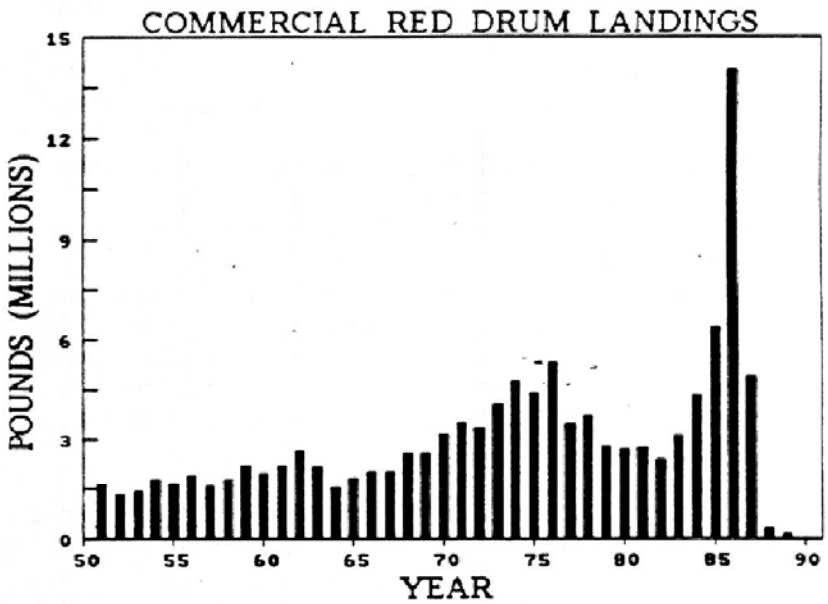

Figure 1. Reported commercial landings of red drum from the Gulf of Mexico, 1951-1988.

Florida. Commercial landings further declined to the lowest level on record in 1990 as a result of strict conservation actions in all of the major producing states.

The effect of the prohibition of the directed fishery in the EEZ is clearly seen in markedly reduced offshore catches in 1987 from prior years, as reflected in the estuarine/oceanic and state/EEZ proportions (Tables 2 and 3).

It is clear from Table 2 that before 1985 the commercial catches primarily occurred in estuarine habitats rather than in oceanic areas (estuarine areas are inside bays and lagoons; oceanic areas include both state waters and the EEZ). The contribution from oceanic areas averaged about 20 percent of the total estimated catches from 1968 through 1984. About 59 percent was from oceanic areas in 1985, and oceanic catches were slightly in excess of 65% for 1986. About 58 percent of the total reported commercial catch was taken from the EEZ (Table 3).

Florida - Reported commercial landings in Florida since 1950 ranged from 495 thousand pounds to a high of 1.3 million pounds (Table 1). The estimate for 1987 declined to 252 thousand pounds, largely as a result of conservation actions. The 1988 estimate of 4.2 thousand pounds resulted from a complete closure of the fishery for red drum in Florida that year. No red drum appeared in the Florida commercial landings for 1989 and the small amount seen in the preliminary 1990 data may reflect coding errors.

Much of Florida's reported commercial catch of red drum historically came from the Charlotte Harbor area and adjacent offshore waters in NMFS statistical grids 3 and 4 (Table 4). These areas accounted for about 63 percent of Florida's red drum reported catch in 1982, but the contribution had declined to about 38% by 1985 and 22% by 1986. The reduced proportion of the take in these areas in 1986 was augmented by an increase in landings from grids 7 and 8 which peaked in 1986.

Part of this decline can also be explained by over-reporting of landings (to an unknown extent) by a single dealer in the Charlotte Harbor area prior to 1984. However, even with the suspect data removed, this area accounted for 51% of Florida's reported landings in 1982. Over-reporting in this area extends back to at least 1978 (perhaps earlier). This factor must be considered if these particular data contribute significantly to management decisions involving calculations based on the absolute levels of landings.

Reported commercial catch for several of the estuarine areas showed marked annual variations. The reported catch for the St. Joseph Bay system increased from 4.8 to 193 thousand pounds in two years (1977 to 1979) and subsequently fell to 4.4 thousand pounds 2 years later (1981). Such large (40- fold) changes in estimated catch could reflect local shifts in the fishery or real changes in the abundance associated with occasional strong, locally significant year classes. Reported catches from several historically important areas fell to 0 in 1986.

Gill nets were the principal gears used to harvest red drum in Florida from 1968 though 1985 (Table 5). Haul seines were second and trammel nets third in importance until 1982 when they switched relative positions. The relative importance of handlines decreased from an average of over 10 percent of the catch before 1977 to 2 percent in 1986, and recovered to about 5 percent in 1987. Gill and trammel nets accounted for the 94% of the Florida catch in 1987. The limited 1988 and 1990 commercial catches were from unknown gear.

Alabama and Mississippi - Reported catches in Alabama and Mississippi and adjacent offshore waters since 1968 are given in Table 6. Landings from the Mississippi Sound have typically been higher than those reported for Mobile Bay. Prior to 1970, the trammel net was the most important gear in the Sound; but it was replaced by the gill net in the early 1970s (Table 7). Reported catch from the Mississippi Sound rose sharply in 1977 and peaked at 588 thousand pounds in 1978 as a result of the introduction of purse seines in the fishery (Tables 6 and 7). This gear was prohibited in Mississippi state waters effective

December 19, 1979.

Red drum catches from areas offshore of Alabama and Mississippi have been largely from grid 11 (Table 6). Catches in this area were predominantly taken as incidental catch in otter trawls until 1981 (Tables 6 - 8). The catches from this area increased rapidly from 1981 to 1986 as a consequence of the expanded use of purse seines and accounted for 43 percent of the total estimated commercial landings in the Gulf in 1986. Most of these fish were landed in Alabama (Table 9). The 1987 prohibition of a directed commercial fishery in the EEZ reduced the contribution from grid 11 to 0.7% of the total annual reported catch. Small numbers of red drum continued to be harvested from this area in 1990.

Louisiana - Estimates of commercial catches of red drum from areas along the Louisiana Coast since 1968 are given in Table 10. Fishermen from Alabama, Mississippi, and Texas have traditionally fished off Louisiana. Although their percentage of the Louisiana catch was small (range of 3.5 to 15.8 percent), these catches were often larger than the catches in Alabama and Mississippi waters. Most of the Louisiana catch landed in Texas came from grid 17.

The 1986 catch was higher than the 1985 catch for each of the regional groupings and the highest since 1968 for six out of the nine regional sums. The greatest proportional increase from 1984 to 1986 was for NMFS grids 14-15. However, there were substantial increases in 1986 catch estimates for many of the estuarine areas as well. Reported catches from the oceanic areas decreased markedly in 1987, however the combined catches from estuarine waters were still higher than the levels observed in prior years.

Louisiana closed its commercial fishery in 1988 with a resulting large reduction in reported catch. The red drum landed in Louisiana have primarily been taken by trammel and gill nets (Table 11). Trammel nets predominated in the earlier years of record but were replaced by gill nets in the most recent years. Purse seines were not important before 1985 but accounted for 36.3 percent of the landings in 1986. Many of these fish were caught in NMFS grid 11 (Table 11). The EEZ prohibition in 1987 left gill nets as the predominant gear employed in Louisiana. This gear accounted for all of the limited 1989 Louisiana commercial catch. The small amount in the preliminary 1990 estimates are from unknown gear, and may reflect coding errors.

Texas - Estimated commercial catches of red drum for areas along the Texas Coast are presented in Table 12 for the period 1968-1981. Commercial fishing for red drum in Texas ended by regulation in May of 1981. Nearly all of the Texas commercial catch had come from estuarine areas, and the greatest proportion of that was taken with trot lines (Table 13). Nearly all of the rest of the estimated Texas commercial catch was taken in trammel nets, with haul seines important in only a few years in the early 1970s. Matlock (1984) reported that the Texas commercial fishery in 1975 and 1976 harvested red drum that averaged 20.2 inches in length and 2+ years of age.

RECREATIONAL FISHERY

The recreational harvest estimates for red drum are derived from a combination of three sources. The primary data source for the recreational harvest of red drum is the National Marine Fisheries Service (NMFS), Marine Recreational Fishery Statistics Survey (MRFSS), which covers the period 1979-1990. This survey provides estimates of the numbers of red drum harvested during bimonthly periods (waves) by state, mode (shorebound, private/rental boats and party/charterboats) and distance from shore with several exceptions. There were no estimates of harvest for wave 1 (January-February) in 1981. Texas boat mode was not sampled from 1982-1984. Texas initiated its own survey in 1986 and was not included in the MRFSS survey thereafter. Party boat (headboat) sampling was discontinued after 1985 for all waves and states.

The suspension of the party boat sampling by the MRFSS coincided with an expansion of NMFS Headboat Survey conducted by the NMFS Beaufort Laboratory (data courtesy G. Huntsman, SEFC Beaufort Laboratory) to include U.S. Gulf of Mexico ports. This latter data provide estimates of landings by partyboats for all states after 1985 and constitutes the second source of data for the recreational harvest.

The third source of recreational harvest estimates was provided by the Texas Parks and Wildlife Department (TPWD) coastal sport fishing survey (data provided by Texas Parks and Wildlife). This survey provides estimates for numbers harvested by boat modes exclusive of party boats for Texas for 1986-1988. Also, the catch of shorebound fishermen has not been included in the Texas estimates since 1985.

The combination of these three sources provided estimates for all areas, modes, and periods except for wave 1 of 1981, the 1982-1984 Texas boat modes, Texas shore modes after 1985.

Values for the missing strata were generally estimated from their respective proportional contributions for years where they were sampled. Specifically, the 1981 wave 1 estimates were derived from the 1981 totals using the mean fraction of the annual harvest that occurred in wave 1 in other years. The harvest by shore modes in Texas after 1985 was estimated from the Texas boat mode catch and the average proportion of the total annual landings contributed by the Texas shore modes in years when they were sampled. The 1982-1984 estimates of boat mode harvest from Texas were derived from a regression of the boat mode catch on year for years where this strata was sampled.

The biomass of the annual recreational harvest was estimated as the sum of the products of the estimated number of red drum harvested in each state, mode, wave, and area and the estimated mean weight of the drum harvested in these strata. If fewer than 10 red drum were measured within a strata then the annual mean weight of red drum for the state was substituted for the strata mean.

Mean weights of fish sampled from recreational landings are given in Table 14 by state and year. The gulfwide average size of red drum harvested has increased since 1979, primarily as a result of conservation actions which increased the minimum size (Figure 2). However, the average weights in Table 14 vary considerably by state and year, ranging from slightly less than 1½ pound in Alabama in 1981 to slightly less than 13 pounds for the 1983 samples in Mississippi.

Undoubtedly, some of this variation in mean weight is due to the distribution of sampling effort. Tables 15-17 indicate substantial spatial and temporal variability in both sample sizes and mean weights. There does, however, appear to be a trend of increasing mean weights with increasing distance from shore.

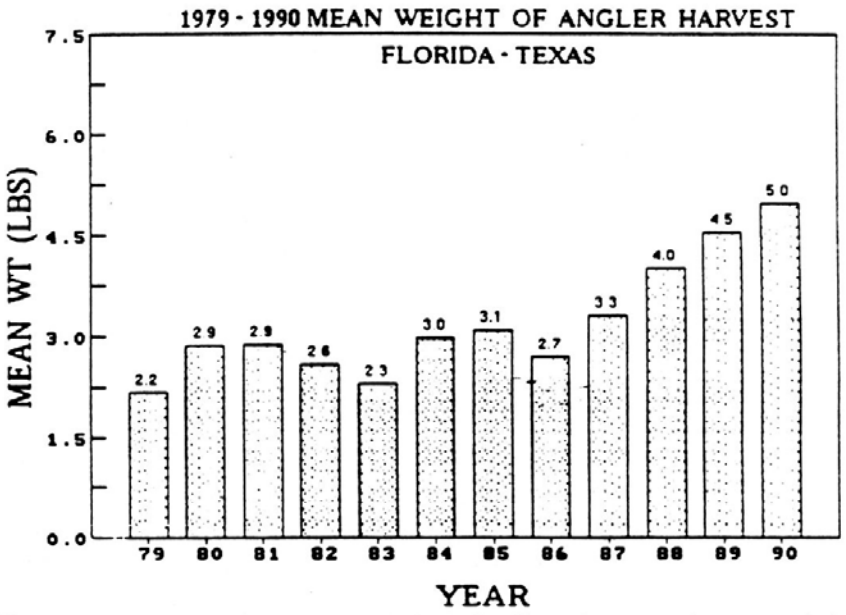

Figure 2. Estimated mean weight of all red drum harvested by recreational anglers, 1979-1990.

However, occasional large fish are also encountered in the nearshore waters (e.g., Mississippi in 1980, Table 17).

Annual estimates of the recreational harvest of red drum from the Gulf of Mexico for 1979-1990 are given by state and area in Tables 18-21. The highest gulfwide recreational harvest estimate occurred in 1979 with a value of over 4 million fish and about 9 million pounds harvested (Figures 3 and 4).

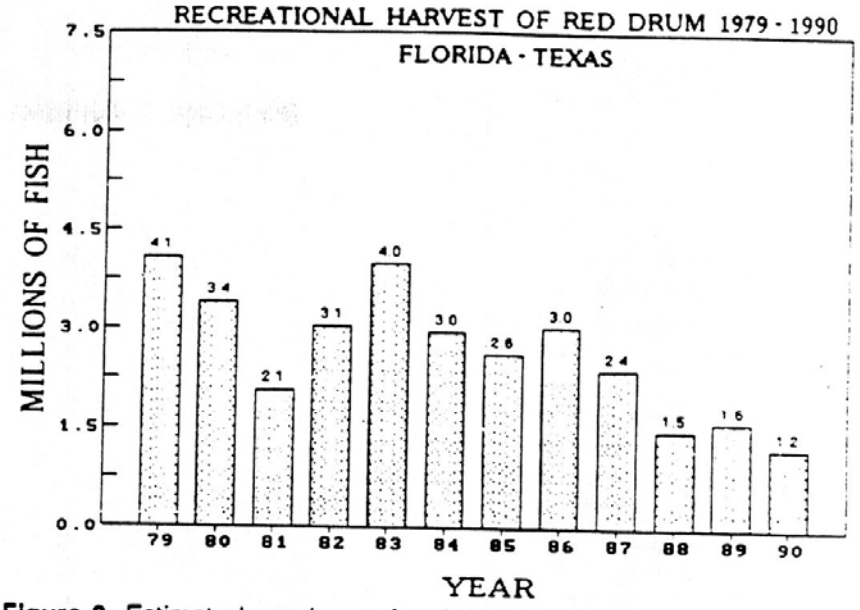

Figure 3. Estimated numbers of red drum harvested from the Gulf of Mexico and adjacent waters by anglers, 1979-1990.

These estimates are somewhat lower than those previously reported because the catch values for two cells were reduced from unreasonably high levels. Both adjustments involved charter boats catches. The first was for 1981, wave 5, area 1, in Mississippi, and the second was for 1982, wave 5, area 3 in Florida. Both values were adjusted downward by substituting the second highest estimates for the mode, area, distance, state strata in the time series. In addition, the current estimates include new catch estimates for the Texas survey (data courtesy TPWD) which were lower than previous estimates.

There is no clear trend in the estimates of the numbers of red drum harvested by recreational fishermen from 1979 through 1986 but the numbers declined thereafter, primarily as a result of conservation efforts (Figure 3). The decline in numbers harvested has been partly offset by an increase in mean size (Figure 2) so that the recreational harvest by weight has remained comparatively stable (Table 18, Figure 4).

Historical recreational harvest estimates indicate that, on average, Louisiana anglers have harvested the most red drum in both numbers and weight. Florida is next, followed by Texas,

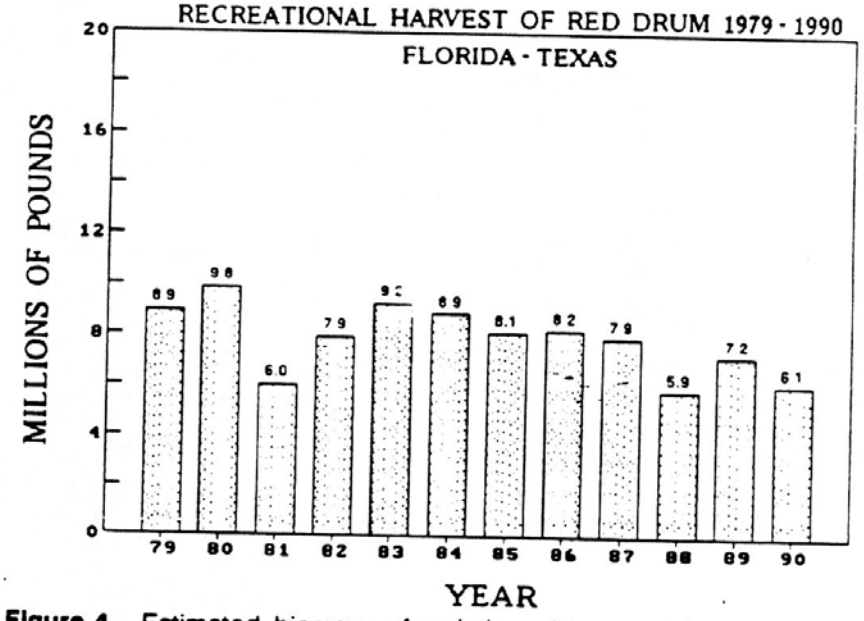

Figure 4. Estimated biomass of red drum harvested by recreational fishermen from the Gulf of Mexico and adjacent waters, 1979-1990.

Mississippi, and Alabama. Annual variations in estimated harvest among the states do not show any apparent trends and do not appear to be strongly correlated, except for the reduced numbers harvested in the last few years in response to conservation measures.

Estimated numbers of red drum harvested by anglers by fishing mode and habitat type are presented in Table 22. These data indicate that although the percentage, by number, of red drum taken from boats versus those taken from the shore has varied during the period, most are harvested from boats.

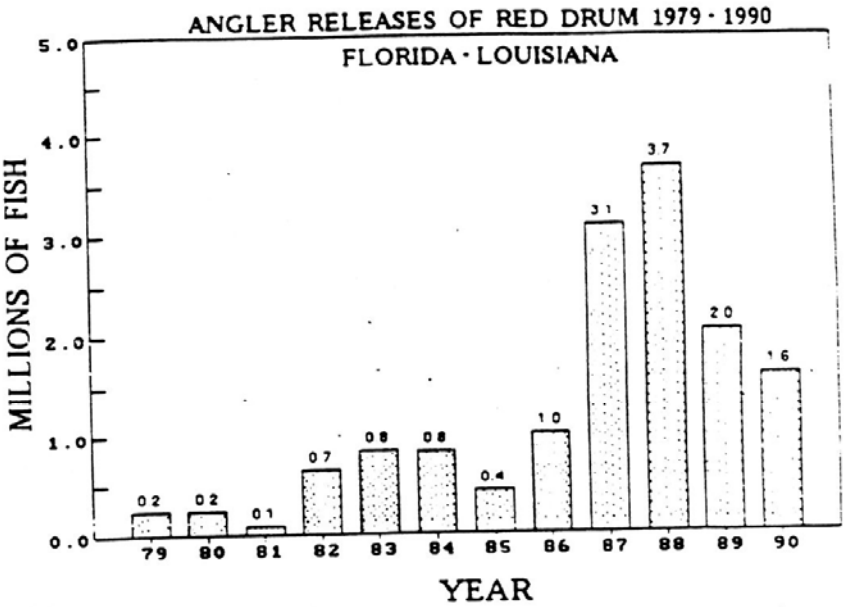

Figure 5. Estimated numbers of Gulf of Mexico red drum caught and released by recreational fishermen 1979-1990.

Similarly, the estimated fraction of the recreational harvest taken from oceanic waters versus estuaries has been highly variable over the period (Table 22). Overall these data indicate that effect of the conservation actions on the traditional recreational fishery has been a reduction in harvest numbers and an increase in the mean size of harvested fish.

The harvest numbers, however do not reflect the large increase in the number of red drum which are reported to have been released from 1979 to 1990 (Table 23). Both the absolute number of releases and the fraction of the total catch is reported to have increased (Figures 5 and 6) with well over half of the total catch being released during the last three years. Texas data are not included in these statistics because of the change in survey design after 1981.

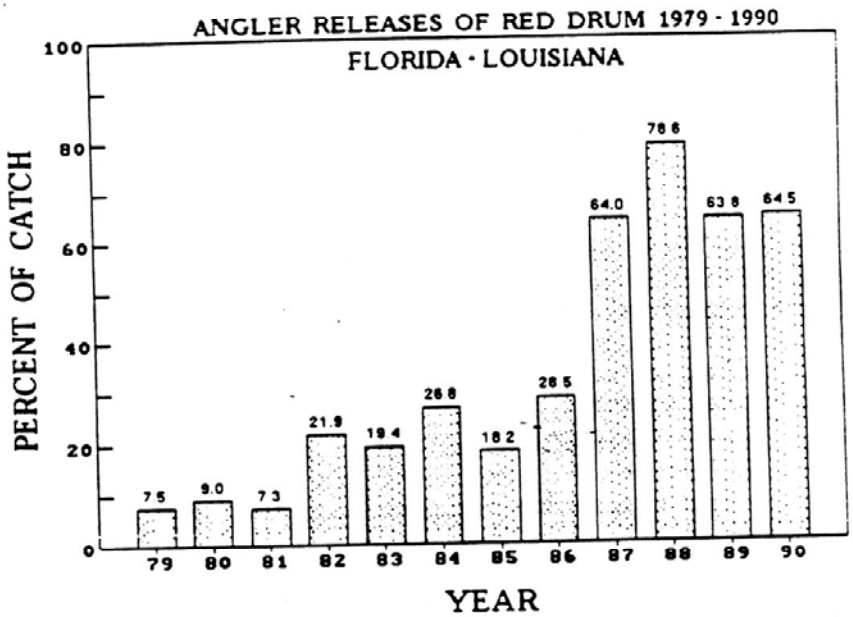

Figure 6. Estimated fraction of the recreational catch of Gulf of Mexico red drum that were released by anglers 1979-1990.

COMBINED HARVEST

Because recreational landings statistics are available only since 1979, the combined harvest can only be estimated since then (Figure 7). During the 1979-1986 period the combined harvest increased from 12 million pounds in 1979 to about 22 million pounds in 1986. The 1986 peak resulted from the growth in the commercial catch in that year. Conservation actions caused landings to decline to 13 million pounds in 1987 and a low of about 6.2 million pounds in 1988. The 1989 landings increased to 7.4 million pounds primarily as a result of an increase in average size of fish harvested by recreational fishermen. The estimate for combined landings for 1990 was 6.1 million pounds, about the same as in 1988.

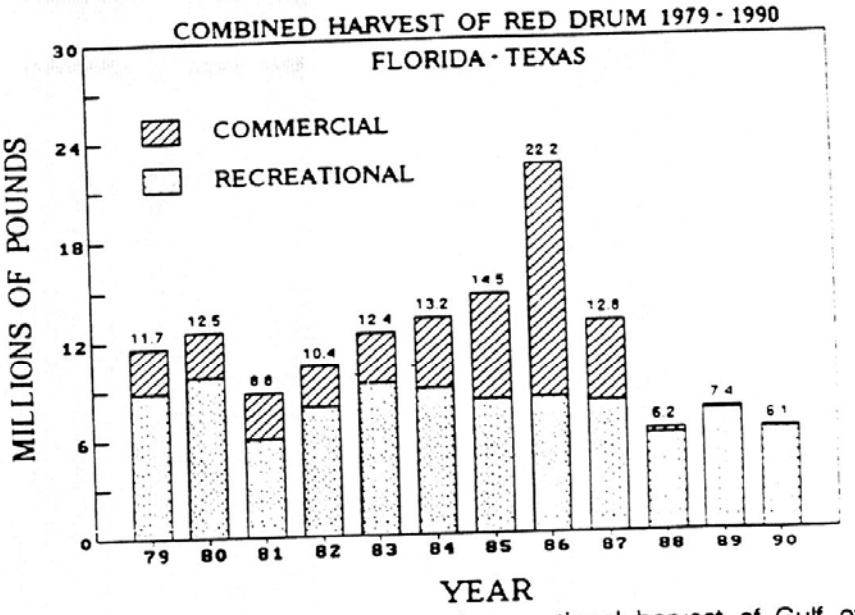

Figure 7. Combined commercial and recreational harvest of Gulf of Mexico red drum, 1979-1987.

REFERENCES

Goodyear, C.P. 1987. Status of the red drum stocks of the Gulf of Mexico. USDOC, NMFS, SEFC, Miami Laboratory Contribution CRD 86/87-34. 113 pp.

Goodyear, C.P. 1988. Status of the red drum stocks of the Gulf of Mexico. USDOC, NMFS, SEFC, Miami Laboratory Contribution CRD 87/88-32. 34pp.

Goodyear, C.P. 1989. Status of the red drum stocks of the Gulf of Mexico: Report for 1989. USDOC, NMFS, SEFC, Miami Laboratory Contribution CRD 87/88-32. 64pp.

Gulf of Mexico Fishery Management Council. 1987. Amendment number 1 and environmental assessment and supplemental regulatory impact review, regulatory flexibility analysis for the red drum fishery of the Gulf of Mexico.

Perret, W.S., J.E. Weaver, R.C. Williams. F.L. Johanson, T.D. McIlwain, R.C. Raulerson and W.M. Tatum. 1980. Fishery profiles of red drum and spotted seatrout. Gulf States Marine Fisheries Commission, Ocean Springs, MS. No. 6, 60pp.

USDOC. 1986. Secretarial fishery management plan, regulatory impact review, and regulatory flexibility analysis for the red drum fishery of the Gulf of Mexico. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Washington, DC.

Table 1. Gulf of Mexico landings of red drum, 1880-1990 (1000s of Pounds).

Year	Florida WC	Alabama	Mississippi	Louisiana	Texas	Total
1887	NA	NA	141	289	1005	NA
1888	55	0	165	288	944	1452
1889	391	64	185	314	1063	2017
1890	458	54	201	339	1108	2160
1897	236	213	199	465	1144	2257
1902	1104	70	93	442	898	2607
1908	608	151[a]	244[a]	716[a]	1309[a]	3028
1918	995[a]	23	116	566	1337	3037
1923	1398	15	177	665	878	3133
1927	776	55	237	556	1248	2872
1928	889	49	208	434	1030	2610
1929	992	105	129	445	934	2605
1930	937	104	122	335	873	2371
1931	934	62	100	369	864	2329
1932	719	44	75	282	825	1945
1934	873	65	73	492	1579	3082
1936	927	34	88	347	956	2352
1937	948	67	123	450	954	2542
1938	1012	32	106	522	860	2532
1939	908	31	165	694	470	2268
1940	647	27	55	183	265	1177
1945	1294[b]	260	66	596	1297	3513
1948		157	54	254	621	NA
1949	1670	112	76	480	520	2858
1950	942	16	52	455	567	2032
1951	919	44	31	384	237	1615
1952	646	56	41	328	250	1321
1953	526	46	62	273	511	1418
1954	752	19	61	271	721	1824
1955	754	19	57	344	494	1668
1956	763	50	71	407	641	1932
1957	667	10	54	353	504	1588
1958	627	19	65	488	599	1798
1959	692	18	71	488	963	2232
1960	931	9	39	428	705	2112
1961	967	24	53	666	617	2327
1962	1490	13	76	567	699	2845
1963	1104	20	59	466	685	2334
1964	797	19	50	312	447	1625
1965	913	4	33	471	533	1954
1966	735	6	37	532	797	2107
1967	564	9	96	654	768	2091
1968	806	16	215	741	925	2703
1969	668	51	100	782	1085	2686
1970	760	35	70	789	1586	3240
1971	807	32	59	724	1991	3613
1972	961	77	56	889	1468	3451
1973	1088	172	86	1184	1678	4208
1974	1358	120	88	1436	1921	4923
1975	865	74	72	1362	2120	4493
1976	1032	67	95	2212	2029	5435
1977	962	65	164	1435	951	3577
1978	1025	86	658	1219	861	3849
1979	849	85	194	1057	690	2875
1980	931	53	20	725	1114	2843
1981	1289	38	67	899	613	2906
1982	982	69	41	1455	0	2547
1983	917	361	24	1939	0	3241
1984	968	854	24	2608	0	4454
1985	614	2843	27	2934	0	6418
1986	878	5304	126	7818	0	14127
1987	252	14	53	4572	0	4891
1988	4	1	41	245	0	291
1989	0	2	140	25	0	166
1990	T	0	5	T	0	8

NA Not Available
[a] Includes Black Drum
[b] Less than 500 reported

Sources: Perret et al. (1980)
NMFS Landings Data 1978-1990

Table 2. Reported commercial catch of red drum (thousands of pounds) from estuarine and oceanic areas of the Gulf of Mexico

	Florida			Alabama/Mississippi			Louisiana			Texas			Gulf of Mexico	
Year	Estuarine	Oceanic(%)		Estuarine	Oceanic(%)		Estuarine	Oceanic(%)		Estuarine	Oceanic(%)		Estuarine	Oceanic
1968	402.2	404.0	(50)	212.5	18.5	(8)	620.7	120.2	(16)	888.3	36.6	(4)	2123.7	579.3
1969	346.2	322.0	(48)	91.0	59.9	(40)	661.9	120.2	(15)	1035.6	47.7	(4)	2134.7	549.8
1970	385.9	375.1	(49)	44.5	61.0	(58)	687.8	101.4	(13)	1460.7	125.5	(8)	2578.9	663.0
1971	442.5	364.8	(45)	42.9	47.6	(53)	597.0	126.7	(18)	1793.9	196.8	(10)	2876.3	735.9
1972	524.6	436.8	(45)	43.1	89.3	(67)	734.4	154.3	(17)	1369.9	97.9	(7)	2672.0	778.3
1973	683.9	403.7	(37)	106.8	151.0	(59)	1039.8	143.9	(12)	1515.4	162.1	(10)	3345.9	860.1
1974	772.9	585.0	(43)	87.2	120.8	(58)	1314.0	122.1	(9)	1783.4	138.1	(7)	3957.5	966.0
1975	490.3	375.3	(43)	56.5	88.5	(61)	1117.0	245.1	(18)	2026.1	94.3	(4)	3689.9	803.1
1976	622.0	409.5	(40)	67.1	94.6	(59)	1923.1	289.3	(13)	1950.5	78.9	(4)	4562.7	872.3
1977	517.4	445.9	(46)	133.4	95.6	(42)	1120.6	314.8	(22)	909.3	41.5	(4)	2680.7	897.1
1978	417.7	607.5	(59)	636.9	107.4	(14)	998.2	220.5	(18)	853.5	7.5	(1)	2906.3	942.1
1979	525.9	323.2	(38)	199.7	79.6	(28)	832.2	224.8	(21)	677.0	13.1	(2)	2234.8	640.1
1980	690.5	240.5	(26)	13.2	59.7	(82)	680.6	44.2	(6)	1106.4	8.1	(1)	2490.7	352.8
1981	792.0	497.4	(39)	66.7	38.5	(37)	770.1	128.5	(14)	604.4	8.9	(1)	2233.2	673.3
1982	747.5	233.9	(24)	26.9	82.7	(75)	1278.7	175.8	(12)	0.0	0.0	(0)	2053.1	492.4
1983	718.1	198.1	(22)	31.8	352.9	(92)	1760.9	177.7	(9)	0.0	0.0	(0)	2510.8	728.6
1984	590.5	377.5	(39)	24.8	852.4	(97)	2247.6	360.8	(14)	0.0	0.0	(0)	2862.9	1590.3
1985	398.1	215.9	(35)	12.7	2857.9	(100)	2229.5	704.1	(24)	0.0	0.0	(0)	2640.3	3777.0
1986	295.4	583.0	(66)	105.6	5325.5	(98)	4465.9	3351.8	(43)	0.0	0.0	(0)	4866.9	9260.4
1987	198.2	53.7	(21)	28.3	39.1	(58)	4530.4	41.5	(1)	0.0	0.0	(0)	4756.9	134.3
1988	4.2	0.0	(0)	38.9	3.0	(7)	243.8	1.5	(1)	0.0	0.0	(0)	286.9	4.5
1989	0.0	0.0	(0)	138.7	2.9	(2)	24.8	0.0	(0)	0.0	0.0	(0)	163.5	2.9
1990	T	0.0	(0)	4.5	0.7	(13)	T	0.0	(100)	0.0	0.0	(0)	4.8	3.7

Table 3. Reported commercial catch of red drum (thousands of pounds) in State and EEZ waters of the G
Mexico 1973-1990 regardless of where landed. Catch in state waters includes estuaries.

	Florida		Alabama/Miss		Louisiana		Texas		Gulfwide Total	
Year	State 0-9 mi	EEZ 9-200 mi	State 0-3 mi	EEZ 3-200 mi	State 0-3 mi	EEZ 3-200 mi	State 0-9 mi	EEZ 9-200 mi	State	EEZ
1973	1084.3	3.3	169.9	87.8	1183.8	0.0	1677.5	0.0	4115.5	91.
1974	1358.0	0.0	136.1	71.9	1436.1	0.0	1921.5	0.0	4851.7	71.
1975	865.6	0.0	95.9	49.0	1329.1	32.9	2420.4	0.0	4711.0	81.
1976	1031.5	0.0	102.3	58.8	2212.2	0.2	2029.4	0.0	5375.4	59.
1977	963.3	0.0	158.3	70.5	1426.9	8.4	950.8	0.0	3499.3	78.
1978	1025.2	0.0	656.3	87.9	1218.8	0.0	862.3	0.0	3762.6	87.
1979	849.1	0.0	201.7	77.5	1054.3	2.4	690.1	0.0	2795.2	79.
1980	931.0	0.0	25.5	47.5	724.4	0.4	1114.2	0.0	2795.1	47.
1981	1289.3	0.0	73.9	31.4	898.6	0.0	613.4	0.0	2875.2	31.
1982	981.5	0.0	32.8	76.8	1454.5	0.0	0.0	0.0	2468.8	76.
1983	916.1	0.0	174.4	210.3	1922.9	15.8	0.0	0.0	3013.4	226.
1984	967.4	0.0	33.8	843.3	2464.2	144.1	0.0	0.0	3465.4	987.
1985	614.0	0.0	22.2	2848.3	2325.1	608.5	0.0	0.0	2961.3	3456.
1986	878.4	0.0	122.6	5308.5	4936.7	2881.0	0.0	0.0	5937.7	8189.
1987	251.7	0.2	37.6	29.7	4571.2	0.8	0.0	0.0	4860.5	30.
1988	4.2	0.0	38.9	3.0	245.4	0.0	0.0	0.0	288.5	3.
1989	0.0	0.0	138.7	3.0	24.8	0.0	0.0	0.0	163.5	3.
1990	T	0.0	4.5	0.7	T	0.0	0.0	0.0	7.2	0.

Table 4. Reported commercial catch of red drum (thousands of pounds) by water area for Florida, 1968-1990

	Estuarine Areas								Oceanic Ar		
									NMFS Statistic		
Year	Charlotte Harbor[a]	Tampa Bay[b]	Apalachicola Bay[c]	St. Joseph Bay	St. Andrews Bay[d]	Choctawhatchee Bay	Pensacola Bay[e]	Other Estuaries[f]	1-2	3-4	5-
1968	144.9	47.9	46.5	7.5	5.3	1.3	7.1	102.8	2.2	226.3	7
1969	133.2	43.9	36.5	4.4	4.9	1.8	4.6	84.2	1.4	201.9	5
1970	150.2	51.2	29.9	6.9	2.9	1.3	3.9	100.9	2.0	233.7	6
1971	166.7	71.1	22.4	7.1	7.1	1.5	5.5	115.6	1.8	249.2	5
1972	192.5	92.6	21.4	3.7	3.2	1.5	6.6	147.5	1.3	282.1	7
1973	289.3	86.8	26.6	6.2	5.5	2.4	7.9	183.6	2.2	251.1	7
1974	253.4	105.1	25.9	7.7	3.9	2.8	16.1	271.4	1.2	371.5	9
1975	227.1	55.4	33.4	8.3	5.0	2.1	7.6	100.0	1.1	232.9	5
1976	264.1	54.2	35.7	20.3	4.6	10.1	14.8	150.6	1.1	263.5	5
1977	212.0	51.4	20.1	5.9	58.0	1.1	9.7	98.8	1.1	329.5	4
1978	230.9	49.5	10.4	11.9	3.8	1.6	10.7	54.4	1.1	365.3	2
1979	147.1	51.1	10.7	194.1	10.0	4.0	7.7	45.6	1.1	255.1	1
1980	286.2	73.5	9.7	168.0	13.1	7.3	10.6	51.6	1.1	130.5	
1981	331.0	192.2	9.9	5.5	54.9	10.3	17.1	90.9	1.1	146.3	
1982	382.8	170.8	7.1	5.5	6.0	9.5	9.0	81.2	1.1	160.7	
1983	329.4	111.5	14.1	84.9	2.3	11.2	5.5	88.9	1.1	140.7	
1984	260.0	97.9	9.6	77.5	2.8	3.9	7.0	74.9	2.1	94.4	
1985	155.2	66.9	8.6	41.7	5.7	9.8	6.2	64.3	1.5	51.5	
1986	153.0	73.7	0.0	0.0	15.5	0.0	0.0	51.9	0.5	44.7	1
1987	68.0	35.6	0.0	0.2	9.0	0.0	0.7	84.7	0.1	19.6	3
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	

[a] includes Lemon Bay, Pine Island Sound and San Carlos Bay.

[b] includes Hillsborough Bay, Johns Pass, Boca Ciega Bay, and Old Tampa Bay.

[c] includes St, George Sound.

[d] includes West Bay.

[e] includes Escambia Bay, East Bay, and Santa Rosa Sound.

[f] includes Florida, Clearwater, Crystal, Chassahowitzka, Apalacheem, Dead Man, Waccasassa, Withlahoochee, Ockl
Sarasota Bays, and Suwanee Sound.

Less than 0.1% were landed in Alabama, and only in 1974 and 1976.

Table 5. Florida West Coast reported commercial landings (thousands of pounds) of red drum by method of capture 1968-1990.

Year	Percent of Landings							Landings
	Haul Seines	Gill Nets	Trammel Nets	Hand Lines	Troll Lines	Purse Seines	Shrimp Trawls	
1968	20.6	58.1	9.9	11.1	0.2	0.0	0.0	708.3
1969	20.1	58.8	10.1	10.3	0.7	0.0	0.0	587.1
1970	20.1	57.2	11.3	10.6	0.7	0.0	0.0	668.6
1971	22.9	58.4	8.4	10.0	0.3	0.0	0.0	709.3
1972	20.0	59.9	9.3	10.6	0.2	0.0	0.0	844.5
1973	21.2	58.0	8.8	16.7	0.2	0.0	0.0	955.1
1974	18.9	59.4	9.7	11.8	0.2	0.0	0.0	1192.3
1975	18.9	59.4	8.6	12.9	0.1	0.0	0.0	760.4
1976	19.1	60.2	8.1	12.4	0.2	0.0	0.0	905.2
1977	20.0	60.6	8.7	10.6	0.0	0.0	0.0	844.0
1978	28.9	52.6	10.6	7.8	0.0	0.0	0.0	899.6
1979	36.0	47.7	6.9	9.4	0.0	0.0	0.0	745.9
1980	30.3	41.2	23.2	5.3	0.0	0.0	0.0	818.1
1981	28.0	42.7	22.6	6.7	0.0	0.0	0.0	1132.1
1982	7.1	53.9	31.2	7.8	0.0	0.0	0.0	862.1
1983	14.9	48.7	29.9	6.7	0.0	0.0	0.0	805.1
1984	23.0	36.3	37.4	3.3	0.0	0.0	0.0	850.2
1985	19.2	52.5	21.7	5.1	0.0	0.0	1.4	540.1
1986	35.0	38.3	24.6	2.0	0.0	0.0	0.0	878.4
1987	1.0	49.0	45.0	4.9	0.0	0.0	0.0	251.8
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3

Table 6. Reported commercial catch of red drum (thousands of pounds by water area off Alabama and Mississippi, 1968-1990.

Year	Estuarine Areas		Oceanic Areas NMFS Grids		Percent Landed in	
	Mobile Bay[a]	Mississippi Sound[b]	10	11	Alabama	Miss.
1968	9.3	75.1	0.0	7.5	16.6	83.4
1969	3.2	24.6	0.1	41.3	60.0	40.0
1970	2.1	19.1	0.0	39.1	50.0	50.0
1971	2.5	18.0	0.2	19.2	54.9	45.1
1972	5.4	11.1	0.2	49.0	76.4	23.6
1973	3.9	20.2	0.2	68.8	67.6	32.4
1974	5.7	11.4	0.1	64.5	69.9	30.1
1975	5.1	18.5	0.0	51.5	60.2	39.5
1976	1.7	30.7	0.1	37.6	56.4	43.6
1977	1.8	113.0	0.5	57.2	21.1	78.9
1978	8.3	588.2	0.0	57.1	9.1[c]	90.8
1979	12.0	145.0	0.0	29.3	19.5[c]	80.4
1980	7.7	3.5	0.0	24.6	54.1[c]	40.8
1981	6.6	6.3	0.0	21.3	80.1	19.9
1982	6.3	9.6	0.0	73.4	63.0	37.0
1983	5.8	10.9	0.0	305.5	99.5	0.5
1984	6.5	11.5	0.5	847.1	97.3	2.7
1985	0.6	8.2	0.0	2834.7	83.9[d]	0.1
1986	0.1	15.6	0.1	6006.3	62.9[d]	0.5
1987	0.8	15.9	0.0	33.1	22.5	77.5
1988	0.5	38.2	0.0	2.1	1.9	98.1
1989	0.0	133.4	0.0	2.9	1.4	98.6
1990	0.0	4.2	0.0	0.7	0.0	100.0

[a] includes Bon Secour Bay.
[b] includes Biloxi Bay.
[c] 0.1 percent landed in Florida.
[d] remainder landed in Louisiana

Table 7. Mississippi reported commercial landings of red drum (thousands of pounds) by method of capture, 1968-1990.

Year	Percent of Landings						Landings
	Purse Seines	Fish Trawls	Shrimp Trawls	Gill Nets	Trammel Nets	Hand Lines	
1968	0.0	2.3	2.4	0.0	95.3	0.0	214.6
1969	0.0	4.8	11.3	0.0	83.8	0.0	99.6
1970	0.0	16.2	12.5	9.2	62.0	0.0	70.3
1971	0.0	2.4	23.6	16.8	56.8	0.3	58.8
1972	0.0	5.8	24.0	46.6	23.0	0.7	55.5
1973	0.0	10.0	8.7	69.2	8.9	3.2	85.6
1974	0.0	13.8	9.8	72.1	2.4	1.9	88.5
1975	0.0	7.6	25.4	56.5	6.0	4.5	71.4
1976	0.0	9.9	19.2	65.9	0.6	4.4	95.1
1977	0.0	5.1	10.4	27.9	0.0	2.5	163.6
1978	54.2	1.2	2.3	14.4	0.0	0.5	658.0
1979	81.6	1.1	8.0	19.1	0.0	1.5	194.4
1980	1.0	0.0	19.5	62.2	0.0	17.4	20.4
1981	77.2[a]	0.7	11.2	10.9	0.0	0.0	67.0
1982	51.5	0.0	19.8	27.3	0.0	1.4	40.6
1983	12.4	0.0	30.8	46.7	0.0	10.1	24.2
1984	0.0	1.4	24.2	61.5	0.0	12.8	23.7
1985	0.0	37.6	19.1	37.4	0.0	5.9	27.4
1986	0.0	3.0	7.7	84.2	0.0	5.2	126.4
1987	37.1	1.0	4.5	49.4	2.7	5.3	53.1
1988	0.0	0.2	6.6	66.1	10.9	16.1	41.1
1989	0.0	0.0	0.5	76.1	15.6	7.8	139.8
1990	0.0	0.0	11.8	41.6	12.4	34.2	5.2

[a] Landed in Alabama and trucked to Mississippi.

Table 8. Reported shrimp and fish otter trawl catches of red drum (thousands of pounds) entering commercial markets by distance from shore (statute miles) and landed by Alabama and Mississippi vessels, 1973-1990.

Year	Alabama Vessels				Mississippi Vessels			
	Estuarine Areas	Offshore Areas			Estuarine Areas	Offshore Areas		
		0-3 mi.	3-12 mi.	12-200 mi		0-3 mi.	3-12 mi.	12-200 mi
1973	0.2	1.7	27.7	53.1	1.3	11.1	3.6	-
1974	0.1	0.9	10.5	54.4	0.5	15.4	5.0	-
1975	1.7	0.0	4.1	42.6	8.7	13.2	1.7	-
1976	0.3	0.0	44.2	2.4	4.8	10.9	12.0	-
1977	0.4	0.0	61.6	0.0	13.3	3.1	9.0	-
1978	0.1	0.1	79.0	0.0	10.3	5.8	7.2	-
1979	0.7	1.3	72.7	0.2	13.6	0.4	3.7	-
1980	0.2	0.0	43.6	0.0	0.9	2.8	0.3	-
1981	0.6	0.0	30.4	0.3	0.9	6.4	0.7	-
1982	1.0	0.3	54.7	0.1	5.9	1.3	0.9	-
1983	1.0	0.8	45.1	0.0	5.8	1.7	0.0	-
1984	0.1	0.2	14.9	0.0	1.3	2.2	2.5	-
1985	0.9	3.7	41.7	1.7	0.1	5.0	10.4	0.0
1986	0.3	3.2	13.4	4.9	0.7	5.8	2.8	4.2
1987	0.6	2.7	5.9	3.1	0.8	1.6	0.5	0.0
1988	0.0	0.1	0.1	0.1	0.7	1.5	0.6	0.0
1989	1.3	0.0	0.0	0.5	0.0	0.0	0.6	0.1
1990	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.2

Table 9. Alabama reported commercial landings of red drum (thousands of pounds) by method of capture, 1968-1990.

	Percent of Landings					
Year	Shrimp Trawls	Gill Nets	Trammel Nets	Hand Lines	Purse Seines	Landings
1968	56.7	0.0	43.3	0.0	0.0	16.4
1969	85.0	0.8	14.0	0.2	0.0	51.3
1970	93.2	0.0	6.8	0.0	0.0	35.2
1971	72.9	1.6	24.9	0.6	0.0	31.7
1972	70.3	0.0	29.4	0.3	0.0	77.0
1973	48.1	10.5	41.2	0.3	0.0	172.2
1974	55.1	7.5	37.1	0.3	0.0	119.6
1975	65.6	0.0	34.0	0.3	0.0	73.7
1976	70.5	0.2	29.2	0.2	0.0	66.6
1977	94.8	0.0	5.1	0.0	0.0	65.4
1978	91.7	0.0	7.8	0.5	0.0	86.4
1979	88.2	0.1	11.7	0.0	0.0	85.0
1980	83.1	0.7	15.4	0.8	0.0	52.5
1981[a]	81.5	0.9	17.6	T	0.0	38.3
1982	81.1	1.6	16.4	0.9	0.0	69.1
1983	14.6	0.9	2.3	0.8	81.4	360.5
1984	1.8	0.6	0.7	0.2	96.6	853.5
1985	1.7	0.0	0.0	0.0	98.3	2843.1
1986	0.4	0.0	0.0	0.0	99.6	5304.9
1987	86.9	0.0	10.3	2.8	0.0	14.3
1988	39.4	60.6	0.0	0.0	0.0	0.8
1989	94.6	0.5	0.0	4.9	0.0	1.9
1990	0.0	0.0	0.0	0.0	0.0	0.0

[a] Additional red drum were landed in Alabama but were not recorded as no transaction occurred in Alabama.
T = Less than 0.1 percent.

Table 10. Reported commercial catch of red drum (thousands of pounds) by water area for Louisiana, 1968-1990.

	Estuarine Areas						Oceanic Areas		
							NMFS Grids		
Year	Lake Pontchartrain & Borgne	Chandeleur & Breton Sounds[a]	Miss. River to Bayou La Fourche[b]	Bayou La Fourche to Atchafalaya R[c]	Atchafalaya to Tigre Pt[d]	Tigre Pt. to Louisiana Pt[e]	12-13	14-15	16-17
1968	55.8	424.0	113.7	149.5	0.0	6.8	94.4	35.8	3.6
1969	65.2	312.3	231.3	113.4	2.0	0.9	84.6	47.5	4.9
1970	61.6	241.7	253.2	130.4	14.7	2.6	79.2	44.1	6.8
1971	15.4	187.2	226.4	156.8	31.5	2.1	147.8	6.1	1.4
1972	13.6	248.2	285.3	190.5	23.1	0.5	172.9	18.9	13.3
1973	6.9	314.7	419.4	357.0	23.9	0.4	222.6	1.0	2.0
1974	7.8	419.8	527.9	414.6	14.4	0.5	172.9	0.2	18.1
1975	4.7	315.0	506.8	286.8	23.8	13.0	266.1	6.2	21.9
1976	48.5	306.0	714.4	757.0	20.7	111.5	321.9	12.9	11.8
1977	29.3	266.9	610.1	171.3	39.0	62.6	321.4	31.1	3.1
1978	6.4	76.7	487.2	183.6	263.1	29.5	246.2	7.9	17.4
1979	1.6	19.5	663.5	[illegible]	50.1	49.2	264.4	8.8	1.6
1980	0.7	13.0	394.6	[illegible]	81.6	107.8	75.4	3.9	0.2
1981	9.3	111.0	471.3	50.3	38.8	121.5	137.7	1.8	0.0
1982	3.6	202.9	715.0	212.8	76.7	67.8	159.0	16.8	0.0
1983	44.1	400.2	871.3	203.8	75.4	164.7	66.2	2.4	103.9
1984	43.2	834.5	892.8	218.9	118.2	140.1	210.4	8.2	122.3
1985	6.8	562.1	1141.3	182.2	232.6	106.7	224.3	478.9	0.0
1986	57.0	903.1	2267.2	689.3	400.0	239.1	801.5	1898.7	15.1
1987	84.4	708.8	2447.4	832.7	353.7	114.7	32.6	13.4	1.4
1988	0.7	29.0	134.6	42.7	32.3	4.7	2.5	0.0	0.0
1989	0.0	5.3	24.8	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Includes Garden Island Bay.

[b] Includes Barataria Bay, Caminada Bay, Lake Salvador, Little Lake, East Bay and Bay Adam.

[c] Includes Timbalier Bay, Terrebonne Bay, Caillou Bay, Lake Barre, Lake Pelto, Lake Decade, Lake Merchant, Lake Felicity, Lost Lake, and Four Leagues Bay.

[d] Includes Vermilion and Cote Bays.

[e] Includes Calcasieu Lake.

Source NMFS Landings Data, sequenced for catch by area.

Table 11. Louisiana reported commercial landings of red drum (thousands of pounds) by method of capture, 1968-1990.

Year	Percent of Landings								Landings
	Haul Seines	Shrimp Trawls	Hoop Nets	Gill Nets	Trammel Nets	Hand Lines	Trot Lines[a]	Purse Seines	
1968	5.9	2.3	0.0	4.5	85.0	2.3	T	0.0	740.9
1969	7.6	1.9	0.0	3.1	85.1	1.9	0.2	0.0	782.1
1970	10.2	1.7	0.0	3.7	82.2	1.8	[illegible]	0.0	789.2
1971	2.2	2.4	0.0	5.8	87.9	1.6	[illegible]	0.0	723.7
1972	4.5	1.7	0.0	17.6	65.0	11.3	[illegible]	0.0	889.0
1973	1.0	0.4	0.0	25.7	70.7	2.1	0.0	0.0	1183.5
1974	2.1	0.6	0.0	30.7	62.9	4.2	0.1	0.0	1436.1
1975	2.7	0.7	0.0	52.3	41.3	1.5	1.5	0.0	1362.3
1976	2.4	0.1	0.0	53.1	43.6	0.6	0.1	0.0	2212.5
1977	3.4	0.5	0.1	63.1	32.6	0.2	T	0.0	1435.5
1978	1.0	0.4	0.0	58.9	39.4	0.2	T	0.0	1218.8
1979	0.0	0.3	0.0	45.0	54.6	0.1	T	0.0	1058.3
1980	0.0	0.3	0.0	28.4	71.1	0.1	0.0	0.0	742.8
1981	0.0	0.6	0.0	40.1	58.8	0.3	T	0.0	898.6
1982	1.3	0.3	0.0	48.6	48.9	0.1	0.8	0.0	1455.0
1983	1.3	0.9	0.0	67.1	29.7	1.0	0.0	0.0	1939.0
1984	0.0	5.0	0.0	66.3	26.1	2.6	0.0	0.0	2608.0
1985	0.2	9.1	0.0	44.6	31.6	1.1	T	13.3	2933.6
1986	1.2	2.2	0.0	44.1	13.6	2.4	3.7	36.3	7817.7
1987	0.1	1.3	0.0	76.7	20.1	1.9	0.0	0.0	4571.2
1988	0.0	0.7	0.0	92.0	6.8	0.0	0.4	0.0	245.4
1989	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	24.8
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	T

T= Less than 0.1 percent.
[a] includes unbaited long lines and snaglines.

Table 12. Reported commercial catch of red drum (thousands of pounds) by water area for Texas, 1968-1981.

Year	Estuarine Areas								Oceanic Areas	
	Sabine Lake	Galveston Bay System[a]	Matagorda Bay System[b]	San Antonio System[c]	Aransas Bay System[d]	Corpus Christi System[e]	Upper Laguna Madre[f]	Lower Laguna Madre	NMFS 18-19	Grids 20-21
1968	9.1	21.2	121.2	31.8	105.6	14.5	167.6	417.3	22.9	10.1
1969	4.0	38.1	109.0	33.7	151.4	16.7	254.3	428.4	17.6	25.2
1970	0.0	35.3	128.7	110.6	160.7	38.7	393.1	593.6	27.2	91.5
1971	0.0	18.1	65.6	96.8	222.2	72.6	545.4	773.3	52.4	144.0
1972[g]	0.3	33.6	76.9	55.5	264.1	101.5	244.4	594.0	43.4	43.9
1973	0.7	49.6	70.5	78.1	229.2	153.3	258.4	695.8	53.7	98.4
1974	0.0	34.9	52.5	168.6	244.0	216.7	398.7	668.0	93.9	31.0
1975	0.5	79.5	72.1	179.4	282.0	167.6	416.9	828.1	43.9	38.5
1976	2.8	97.5	47.9	144.5	484.3	121.9	321.7	729.9	47.7	21.5
1977	0.7	24.0	45.7	64.5	158.4	86.7	142.2	378.1	30.3	8.7
1978	0.0	14.8	32.9	69.8	121.5	83.4	79.9	455.1	6.9	0.1
1979	0.3	18.7	24.2	43.4	74.7	62.4	81.5	371.7	13.2	0.0
1980	1.6	13.1	27.6	102.8	169.8	103.7	243.1	444.7	8.0	0.0
1981	0.4	6.2	13.2	46.8	32.0	185.8	0.0	320.2	1.1	0.1

[a] Includes West Bay, Trinity Bay, Upper Galveston,Bay, East Bay, and Lower Galveston Bay.

[b] Includes Matagorda Bay, East Matagorda Bay, and Lavaca Bay.

[c] Includes San Antonio Bay, Espirito Bay, and Mesquite Bay.

[d] Includes Aransas Bay, and Copano Bay.

[e] Includes Corpus Christi and Neuces Bay.

[f] Includes Baffin Bay.

[g] Less than 0.1 percent of the catch was landed in Louisiana these years.

Table 13. Texas reported commercial landings of red drum (thousands of pounds) by method of capture, 1968-1981.

Year	Percent of Landings						Landings
	Haul Seines	Shrimp Trawls	Gill Nets	Trammel Nets	Hand Lines	Trot Lines[a]	
1968	3.5	0.4	6.0	32.7	2.6	54.6	924.9
1969	3.8	0.3	5.6	33.0	5.3	52.1	1083.3
1970	7.6	0.4	4.0	22.1	2.3	63.6	1586.2
1971	9.4	0.2	3.7	16.2	1.8	68.7	1990.7
1972	5.9	0.2	3.5	24.7	2.2	63.4	1467.8
1973	9.3	0.6	1.7	26.8	1.1	60.3	1677.5
1974	7.3	0.1	1.9	20.2	0.3	70.2	1921.5
1975	3.3	1.4	1.0	24.1	1.5	68.9	2120.4
1976	3.6	0.1	3.4	36.6	0.7	55.5	2029.4
1977	3.0	3.5	4.6	35.2	1.9	51.8	950.8
1978	0.3	0.6	0.3	32.2[b]	0.8	65.7[c]	864.9
1979	0.0	1.9	0.0	29.6[b]	0.0	68.4[d]	960.1
1980	0.0	0.7	0.0	37.4	0.0	61.9	1114.4
1981	0.0	1.5	0.0	23.4	0.0	75.6	613.5

[a] includes long and set lines with hooks.

[b] Includes some trot line catches.

[c] Includes some trammel and gill net catches.

[d] Includes some trammel net catches.

T= Less than 0.1 percent.

Table 14. Sample sizes and estimated mean weights in pounds of red drum harvested by recreational fishermen by state and year, for all modes combined 1979-1990.

All Modes and Areas Combined

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	28	2.29	10	4.04	29	5.94	202	1.97	146	2.14	415	2.38
1980	164	2.21	34	3.95	114	3.50	866	2.21	115	4.06	1293	2.54
1981	159	2.05	14	1.43	68	3.37	133	2.28	97	3.58	471	2.60
1982	99	3.27	26	4.35	81	3.78	687	2.02	37	3.14	930	2.41
1983	130	2.35	7	9.42	172	12.89	406	1.64	4523	3.31	5238	3.48
1984	131	3.34	27	8.91	104	10.60	516	2.68	2234	4.11	3012	4.10
1985	61	3.86	24	3.39	27	7.66	615	2.17	3935	3.97	4662	3.75
1986	51	3.50	46	6.53	122	5.75	2421	1.94	5018	4.03	7658	3.41
1987	37	4.95	31	5.27	175	12.68	719	2.67	6076	4.47	7038	4.50
1988	9	2.74	11	6.03	100	6.34	773	4.44	4946	4.89	5839	4.86
1989	71	5.29	10	4.10	60	4.50	751	4.68	4570	5.05	5462	4.99
1990	67	5.50	11	5.17	68	11.87	603	6.47	3168	5.08	3917	5.42

Table 15. Sample sizes and estimated mean weights in pounds of red drum harvested by recreational fishermen by state and year, for all modes combined 1979-1990.

All Modes in State Inshore Waters

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	23	2.24	5	1.15	28	6.15	170	2.13	129	1.91	355	2.36
1980	127	2.12	23	2.14	68	4.09	406	1.65	79	2.62	703	2.10
1981	55	1.82	12	1.56	25	3.59	52	2.15	64	4.13	208	2.81
1982	27	5.13	5	3.18	30	2.08	151	2.50	10	1.61	223	2.74
1983	29	3.79	-	-	14	2.11	39	1.93	4458	3.29	4540	3.28
1984	22	2.64	-	-	7	3.12	143	1.78	2071	4.18	2243	4.01
1985	1	2.20	-	-	8	7.16	202	1.64	3865	3.97	4076	3.86
1986	17	4.19	13	3.41	92	2.18	1389	1.55	4979	4.02	6490	3.47
1987	9	5.14	8	1.71	35	1.80	335	1.96	5965	4.45	6352	4.30
1988	3	1.47	1	2.20	39	5.58	493	3.07	4898	4.88	5434	4.72
1989	43	5.03	5	2.20	23	2.80	620	4.02	4549	5.04	5240	4.91
1990	20	4.71	4	3.75	3	2.64	260	4.23	3065	5.05	3352	4.98

Table 16. Sample sizes and estimated mean weights in pounds of red drum harvested from the state territorial sea by recreational fishermen by state and year, for all modes combined 1979-1990.

All Modes in State Territorial Seas

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gu[illegible]	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	
1979	5	2.51	3	0.44	1	0.22	18	0.88	17	3.93	44	2.20
1980	33	2.26	10	5.87	5	15.40	36	4.93	19	10.29	103	5.66
1981	91	2.16	-	-	11	1.32	30	1.85	20	1.78	152	1.99
1982	64	2.19	19	5.00	19	2.09	323	2.05	25	3.92	450	2.30
1983	91	1.98	7	9.42	12	1.52	158	1.28	61	4.14	329	2.19
1984	104	3.07	20	4.27	18	1.35	206	2.58	137	2.89	485	2.80
1985	59	3.92	22	2.92	5	0.53	115	2.44	64	3.72	265	3.08
1986	31	3.26	31	7.79	6	11.47	941	2.43	34	4.70	1043	2.74
1987	25	5.04	20	6.01	26	9.19	326	2.57	90	5.51	487	3.73
1988	5	2.47	9	6.91	27	4.27	172	7.88	40	6.57	253	7.15
1989	27	5.55	5	6.00	29	5.51	109	8.14	21	5.53	191	7.03
1990	40	5.63	5	2.20	46	11.72	313	8.02	93	5.94	497	7.72

Table 17. Sample sizes and estimated mean weights in pounds of red drum harvested by recreational fishermen by state and year, for all modes combined 1979-1990.

All Modes Reported from the EEZ

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	-	-	2	16.65	-	-	5	1.06	-	-	7	5.51
1980	-	-	-	-	15	0.62	53	8.74	3	12.05	71	7.17
1981	7	2.96	-	-	-	-	3	2.65	8	2.01	18	2.49
1982	1	0.66	-	-	27	7.44	9	3.87	-	-	37	6.39
1983	2	1.10	-	-	134	16.08	33	3.62	4	5.23	173	13.28
1984	4	14.89	7	22.18	73	14.22	50	7.07	26	5.17	160	10.88
1985	-	-	2	8.49	[illegible]	10.50	23	6.56	6	4.28	45	7.57
1986	3	1.98	2	7.27	24	18.02	91	2.88	5	6.55	125	5.98
1987	3	3.68	3	9.85	114	16.81	58	7.34	21	6.28	199	12.64
1988	-	-	-	-	34	8.86	49	7.00	8	5.82	91	7.59
1989	1	9.92	-	-	8	5.76	22	6.20	-	-	31	6.21
1990	7	7.03	2	15.43	19	13.69	30	9.75	10	7.05	68	10.34

Table 18. Recreational harvest estimates for Gulf of Mexico red drum by state and distance from shore for the period 1979-1990. The estimates are based on the 1979-1990 NMRFSS, the 1986-1990 NMFS Headboat Survey, and 1981-1990 length-frequency samples and 1986-1990 catch estimates compiled by Texas Parks and Wildlife. The weight estimates for the MRFSS and Texas surveys are the products of the annual harvest and mean weight estimates for each state where the sample size available to estimate mean weight exceeded 9 individuals. Where the sample size was less than 10, the annual state mean for was substituted for the sample mean. The estimates have been adjusted for missing data in January and February, 1981 in all states, and for 1982-1984 boat mode and 1986-1990 shore modes in Texas by the average proportions observed in years where these strata were sampled. Units are in thousands of fish and pounds.

All Areas Combined

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	453	1037	13	53	108	566	2455	5130	1051	2126	4080	8912
1980	555	1172	27	102	177	498	1705	4141	940	3897	3404	9809
1981	706	1425	29	45	130	441	438	997	774	3114	2076	6023
1982	775	2285	42	181	109	407	1406	2789	722	2266	3054	7929
1983	771	1567	8	77	172	2029	2551	3947	497	1620	4000	9240
1984	1062	3590	23	165	68	968	1105	2438	709	1690	2968	8851
1985	485	2140	30	100	49	469	1360	2654	701	2777	2625	8140
1986	544	1940	53	344	101	291	1814	3484	528	2149	3041	8209
1987	146	720	28	150	78	742	1479	3333	662	2975	2392	7922
1988	43	118	13	81	47	258	891	3084	475	2343	1469	5883
1989	192	1014	7	28	22	94	931	3872	442	2230	1594	7236
1990	151	839	34	178	29	293	662	3019	357	1798	1233	6127

Table 19. Recreational harvest estimates for Gulf of Mexico red drum by state and distance from shore for the period 1979-1990. The estimates are based on the 1979-1990 NMRFSS, the 1986-1990 NMFS Headboat Survey, and 1981-1990 length-frequency samples and 1986-1990 catch estimates compiled by Texas Parks and Wildlife. The weight estimates for the MRFSS and Texas surveys are the products of the annual harvest and mean weight estimates for each state where the sample size available to estimate mean weight exceeded 9 individuals. Where the sample size was less than 10, the annual state mean was substituted for the sample mean. The estimates have been adjusted for missing data in January and February, 1981 in all states, and for 1982-1984 boat mode and 1986-1990 shore modes in Texas by the average proportions observed in years where these strata were sampled. Units are in thousands of fish and pounds.

State Inshore Waters

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	433	991	10	39	106	553	2248	4818	973	1961	3770	8363
1980	475	997	8	25	81	194	724	1350	611	2432	1899	4998
1981	173	280	22	35	29	97	97	198	592	2503	913	3114
1982	141	462	7	30	12	38	454	964	646	2028	1260	3542
1983	147	346	0	0	43	100	160	478	425	1379	775	2304
1984	55	117	0	0	6	59	394	766	298	928	753	1870
1985	69	268	0	0	29	218	1058	1783	522	2051	1678	4320
1986	108	493	7	44	80	133	1095	1793	528	2147	1817	4610
1987	61	302	7	37	40	250	989	1943	658	2958	1755	5488
1988	5	13	3	18	16	84	727	2266	473	2335	1224	4717
1989	91	483	5	21	11	47	729	2812	437	2202	1273	5565
1990	44	240	9	46	1	9	421	1778	355	1783	829	3856

Table 20. Recreational harvest estimates for Gulf of Mexico red drum by state and distance from shore for the period 1979-1990. The estimates are based on the 1979-1990 NMRFSS, the 1986-1990 NMFS Headboat Survey, and 1981-1990 length-frequency samples and 1986-1990 catch estimates compiled by Texas Parks and Wildlife. The weight estimates for the MRFSS and Texas surveys are the products of the annual harvest and mean weight estimates for each state where the sample size available to estimate mean weight exceeded 9 individuals. Where the sample size was less than 10, the annual state mean was substituted for the sample mean. The estimates have been adjusted for missing data in January and February, 1981 in all states, and for 1982-1984 boat mode and 1986-1990 shore modes in Texas by the average proportions observed in years where these strata were sampled. Units are in thousands of fish and pounds.

State Territorial Seas

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	20	46	2	7	2	12	128	155	77	166	230	386
1980	33	70	18	71	75	262	93	317	60	373	278	1093
1981	355	782	0	0	72	243	138	237	77	237	643	1499
1982	612	1751	34	146	16	61	621	1304	67	211	1350	3473
1983	569	1091	8	77	21	269	931	1270	60	198	1588	2905
1984	991	3418	16	107	13	133	327	668	410	760	1757	5085
1985	412	1859	26	85	4	32	261	749	178	722	881	3447
1986	430	1426	45	291	18	106	656	1528	0	1	1149	3352
1987	75	371	20	107	24	312	384	839	2	11	505	1641
1988	38	105	8	47	21	130	137	677	1	5	205	964
1989	95	505	2	7	9	40	178	956	5	27	290	1535
1990	83	467	24	122	24	233	202	994	2	13	335	1829

Table 21. Recreational harvest estimates for Gulf of Mexico red drum by state and distance from shore for the period 1979-1990. The estimates are based on the 1979-1990 NMRFSS, the 1986-1990 NMFS Headboat Survey, and 1981-1990 length-frequency samples and 1986-1990 catch estimates compiled by Texas Parks and Wildlife. The weight estimates for the MRFSS and Texas surveys are the products of the annual harvest and mean weight estimates for each state where the sample size available to estimate mean weight exceeded 9 individuals. Where the sample size was less than 10, the annual state mean was substituted for the sample mean. The estimates have been adjusted for missing data in January and February, 1981 in all states, and for 1982-1984 boat mode and 1986-1990 shore modes in Texas by the average proportions observed in years where these strata were sampled. Units are in thousands of fish and pounds.

EEZ

	Florida		Alabama		Mississippi		Louisiana		Texas		Total Gulf	
YEAR	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt	Numb	Wt
1979	0	0	2	7	0	0	12	23	0	0	13	30
1980	1	2	0	0	6	4	114	852	6	25	127	883
1981	74	151	0	0	0	0	35	81	8	28	117	260
1982	1	4	0	0	66	250	11	23	0	0	79	277
1983	28	66	0	0	86	1373	275	560	0	0	390	2000
1984	16	53	5	48	48	747	93	407	1	3	162	1258
1985	3	13	4	15	16	219	35	110	1	4	60	361
1986	6	22	1	9	3	52	64	163	0	1	75	246
1987	10	47	1	6	13	181	106	552	1	6	131	793
1988	0	0	0	0	10	43	21	122	0	3	32	168
1989	5	26	0	0	1	6	25	103	0	1	31	136
1990	24	132	2	10	4	51	38	247	0	2	68	443

Table 22. Recreational harvest estimates for Gulf of Mexico red drum by mode and area for the period 1979-1990. The estimates are based on the 1979-1990 NMRFSS, the 1986-1990 NMFS Headboat Survey, and 1981-1988 length-frequency samples and 1986-1990 catch estimates compiled by Texas Parks and Wildlife. The estimates have been adjusted for missing data in January and February, 1981 in all states, and for 1982-1984 boat mode and 1986-1990 shore modes in Texas by the average proportions observed in years where these strata were sampled. Units are in thousands of fish and pounds.

	Fishing Mode				Fishing Area						
	Boat		Shore		Estuaries		Ocean		Unknown		Total Gulf
Year	No.	%	No.	%	No.	%	No.	%	No.	%	
1979	3704	90.8	376	9.2	3770	92.4	243	6.0	67	1.6	4080
1980	2873	84.4	531	15.6	1899	55.8	405	11.9	1100	32.3	3404
1981	1641	79.0	435	21.0	913	44.0	759	36.6	404	19.5	2076
1982	2346	76.8	708	23.2	1260	41.3	1429	46.8	365	12.0	3054
1983	2783	69.6	1218	30.4	775	19.4	1978	49.4	1247	31.2	4000
1984	2040	68.7	927	31.3	753	25.4	1919	64.7	296	10.0	2968
1985	1993	75.9	633	24.1	1678	63.9	941	35.9	6	0.2	2625
1986	2676	88.0	365	12.0	1817	59.8	1223	40.2	0	0.0	3041
1987	2039	85.2	353	14.8	1755	73.4	637	26.6	0	0.0	2392
1988	1212	82.5	257	17.5	1224	83.3	237	16.1	8	0.5	1469
1989	1403	88.0	191	12.0	1273	79.9	321	20.1	0	0.0	1594
1990	1022	82.9	211	17.1	829	67.3	403	32.7	0	0.0	1233

Table 23. NMRFSS harvest and release estimates for Gulf of Mexico red drum east of Texas for the pe
data are omitted because there are no release estimates for 1982-1990 boat and 1986-1990 shore modes.
of fish.

All Modes and Areas Combined

	Florida			Alabama			Mississippi			Louisiana			
YEAR	Har.	Rel.	%Rel	Har.	Rel.	%Rel	Har.	Rel.	%Rel	Har.	Rel.	%Rel	
1979	453	8	1.7	13	0	0.0	108	13	10.8	2455	224	8.4	3
1980	555	119	17.7	27	4	12.2	177	4	2.5	1705	118	6.5	2
1981	612	71	10.4	28	12	29.8	129	3	1.9	413	7	1.7	1
1982	775	453	36.9	42	26	38.0	109	15	12.2	1406	160	10.2	2
1983	771	483	38.5	8	2	19.2	172	6	3.3	2551	350	12.1	3
1984	1062	643	37.7	23	0	0.0	68	0	0.0	1105	186	14.4	2
1985	485	280	36.6	30	0	0.0	49	3	5.5	1360	144	9.6	1
1986	544	641	54.1	53	0	0.2	101	21	17.4	1814	338	15.7	2
1987	146	1674	92.0	28	3	10.1	78	32	29.3	1478	1372	48.1	1
1988	43	1363	96.9	13	5	26.3	47	4	7.9	890	2284	72.0	
1989	192	859	81.8	7	3	28.7	22	13	38.1	931	1156	55.4	1
1990	151	655	81.3	34	31	47.3	29	61	68.0	661	841	56.0	

NOAA TECHNICAL MEMORANDUM NMFS-SEFC-297

STATUS OF THE RED DRUM STOCK OF THE ATLANTIC COAST: STOCK ASSESSMENT REPORT FOR 1991

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EXECUTIVE SUMMARY

An assessment of the status of the Atlantic stock of red drum is conducted using recreational and commercial data from 1986 through 1990. This assessment updates data and analyses from the 1989 stock assessment on Atlantic coast red drum (Vaughan and Helser 1990). Since 1980, coastwide recreational catches ranged between 511,800 pounds in 1990 and 2,179,100 pounds in 1984, while commercial landings ranged between 186,400 pounds in 1990 and 422,100 pounds in 1984. In numbers of fish caught, Atlantic red drum constitute predominantly a recreational fishery (generally 80 to 95% by age in recent years). Commercially, red drum continue to be harvested as part of mixed species fisheries.

Using available length frequency distributions and age-length keys, recreational and commercial catches are converted to catch in numbers at age. Cohort-based and separable virtual population analyses are conducted on the catch in numbers at age to obtain estimates of fishing mortality rates and population size (including recruitment to age 1). In turn, these estimates of fishing mortality rates combined with estimates of growth (length and weight), sex ratios, sexual maturity and fecundity are used to estimate yield per recruit, escapement to age 6, and maximum spawning potential [MSP, equivalent to spawning stock ratios (SSR) based on both female biomass and egg production].

The question of when offshore emigration or reduced availability begins (during or after age 3) continues to be a source of bias that tends to result in overestimates of fishing mortality. However, the continued assumptions (Vaughan and Helser 1990) of no fishing mortality on adults (ages 6 and older) and selection of a relatively high subadult natural mortality (M_1) of 0.5, causes a bias that tends to result in underestimates of fishing mortality. For subadult natural mortality of 0.5, escapement ranges between 0.8 and 1.5% while maximum spawning potential ranged between 1.4 and 2.4%. These estimates are only slightly below those obtained in the 1989 stock assessment. It needs to be reiterated that the population models used in this assessment (specifically yield per recruit and maximum spawning potential) are based on equilibrium assumptions. Because no direct estimates are available as to the current status of the adult stock, model results imply potential longer term, equilibrium effects.

To follow up on the management options investigated at the request of Council staff following the 1989 stock assessment (SAFMC 1990b; Appendix 1), a comparable analysis is provided using more recent data (specifically 1989-1990). Recreational fishery data (MRFSS) is employed to investigate potential savings in numbers of fish, and subsequent improvements in escapement and maximum spawning potential, through bag and size limits. In general bag and size limits are assumed to be applied only to the recreational fishery, and a 10% release mortality is introduced. Although not specifically considered, seasonal closures can easily be incorporated into this analysis.

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INTRODUCTION

This, the second assessment for the Atlantic coast stock of red drum (Sciaenops ocellatus), updates analyses presented in Vaughan and Helser (1990) (referred to as the 1989 assessment) with two additional years of fishery data (1989-1990). Following submission of the 1989 assessment to the South Atlantic Fishery Management Council, three management measures, adopted by the Council, are in the Atlantic Red Drum Fishery Management Plan (SAFMC 1990b). The first management measure establishes the fishing year from January 1 through December 31. The second management measure requires that NMFS prepare assessments for the Atlantic red drum stock as requested by the Council, and creates a scientific stock assessment review group to review assessment analyses and to make recommendations to the Council based on these data. The third management measure prohibits the harvest or possession of Atlantic red drum in or from the extended economic zone (EEZ, 3 to 200 miles) until a total allowable catch (TAC) is specified by plan amendment.

Some of the questions raised by the SAFMC Plan Development Team and Red Drum Committee following completion of the first assessment are addressed in this assessment to the extent that data permit. In general, this assessment follows the outline of the 1989 stock assessment (Vaughan and Helser 1990). Catches from recreational and commercial sources for fishing years 1986-1990 are converted to catches in numbers at age using length frequency information and age-length keys. As before, the assessment is limited to the subadult phase (ages 0 through 5). Additional information on weight as a function of length and length as a function of age are estimated for use in the population level analyses. In addition to yield per recruit (Ricker 1975) and maximum spawning potential (Gabriel et al. 1989) analyses, estimates are also made of escapement to age 6 as defined in SAFMC (1990b; Appendix 1). As before, concern remains about the apparent reduced availability and/or emigration of red drum between age 3 and age 5, although sensitivity analyses are presented that explore the assumption that reduced availability/emigration begins following age 3 rather than during age 3. Finally, the effect of various management options (bag limits, size limits, and seasonal closures) on escapement to age 6 are investigated.

DESCRIPTION OF THE DATA

Recreational landings and length frequency information were obtained from NMFS's Marine Recreational Fishery Statistic Survey (MRFSS; Essig et al. 1991). Because of the similarity between the 'MRFSS' and 'Alternate' scenarios on population level results compared in the previous assessment (Vaughan and Helser 1990), only the 'MRFSS' scenario is used in this assessment. Commercial landings collected by the Southeast Fisheries Science Center

(Florida through North Carolina) and by the Northeast Fisheries Science Center (north of North Carolina) were used in these analyses. Commercial length-frequency information by gear for 1989 and 1990 were obtained from the North Carolina Division of Marine Fisheries.

To assess the potential effects of a fishery on a population it is useful to examine the age classes of fish which are vulnerable to the force of fishing. In constructing an age frequency distribution, it is first necessary to estimate the total catch in weight by gear of red drum from the commercial fishery. Catch in numbers by gear are then obtained by dividing by the mean weight of an individual red drum (catch for the recreational fishery is already estimated in numbers as well as in weight). Application of length frequency distributions by gear and annual age-length keys allows catch in numbers by gear to be converted to catch in numbers at age by gear. The smaller the degree which the data allows the temporal/geographic fishing to be subdivided in this conversion process, the greater the precision in the final coastwide estimates of red drum catch in numbers at age that is used in virtual population analysis to estimate fishing mortality and population size.

Recreational Fishery Data

Recreational catches of red drum during the 1980's increased from a low of 632,500 pounds in 1981 to a peak of 2,179,100 pounds in 1984, and then declined to 511,800 pounds in 1990 (Table 1). The weight of the catches include all of the type A and B1 and 10% of the type B2 caught red drum. Definitions of these catch types as used by the MRFSS are given in footnote a to Table 1. When comparing type A and B1 catches (Fig. 1), most of the catches belong to type A caught fish for which direct measurements were available. The mean weight of type A red drum show no particular trend (Fig. 2), averaging about 2.6 pounds between 1979 and 1990.

Total recreational catches by number (A+B1+B2) show an increase importance of type B2 caught red drum in recent years (especially 1987 and 1988) (Fig. 3). Hence, 10% of the type B2 caught red drum by numbers are shown in Table 1 to represent a 10% hook and release mortality. Jordan (1990) suggests that hook and release mortality of red drum may range from 8.4% when hooked in the maxilla area, 32.5% when hooked in the gill region, to 52.8% when hooked in the gut region. In Jordan's (1990) study most red drum were hooked in the maxilla area (about 77% of 513 red drum collected); thus, a value of 10% was used in the analyses that follow. Although catch in numbers are used directly in the subsequent analyses, catch in weight that includes 10% of the type B2 catch is shown in Table 1 using the ratio of the catch in weight of type A+B1 divided by the catch in numbers of type A+B1. This may tend to overestimate the weight loss from catches of type B2 red drum, but the use in this assessment is solely for comparing recreational with commercial catches in weight.

Recreational length frequency distributions for 1979-1988 are presented in Vaughan and Helser (1990). Length frequency distributions for 1989-1990 are included in this report (Figs. 4c and 5c), and are in 2 inch increments with the mid-point plotted on the x-axis, which correspond approximately to the 50 millimeter increments used in the 1989 assessment. As in the earlier report, the Atlantic coast has been subdivided geographically at the South Carolina/North Carolina border. Hence, annual length measurements from above this border are pooled without a weighting factor to represent the length frequency for the 'north' (Figs. 4a and 5a), while annual length measurements from below this border are also pooled without a weighting factor to represent the length frequency for the 'south' (Figs. 4b and 5b). These are applied separately to corresponding catch estimates (and single annual age-length key) to estimate catch in numbers at age. In the earlier assessment, all lengths were converted to fork length in millimeters based on equations in Murphy and Taylor (1990). Because management options are presented to the public in total length in inches, this assessment has converted all lengths to total lengths in inches (and weight from kilograms to pounds).

Commercial Fishery Data

Historical commercial landings in weight are summarized for years 1950-1990 (Fig. 6). Landings prior to 1980 are from SAFMC (1990a; Table 22), and landings for years 1980-1990 are shown in Table 1. Landings were high during the early 1950's (exceeding 400,000 pounds), and have generally fluctuated between 200,000 and 300,000 pounds since then. Landings reached their lowest level at 106,600 pounds in 1971, and the recent high was 439,900 pounds in 1980. The majority of commercial landings have been in North Carolina (55% to 98% by weight), except in 1981 and 1982 when 71% and 73% of the commercial landings occurred in Florida. Beginning in 1985, Florida's commercial landings declined, and were virtually non-existent after 1987. North Carolina's share of commercial landings have exceeded 95% since 1988. As reported in the previous assessment, North Carolina's commercial fishery for red drum is a bycatch fishery.

In the earlier assessment, commercial gears were collapsed into three primary categories due to limited data. Landings for these categories are shown in Fig. 7a. Use of commercial length frequencies for these primary categories for 1986-1988 are as described in Vaughan and Helser (1990). Additional length frequency data from North Carolina in 1989 and 1990 permitted the category labelled as pound nets to be further subdivided into pound/trawl and haul seine (landings for four categories summarized in Fig. 7b). Catch in numbers for years 1986-1990 are compared for the three primary categories in Fig. 8. Conversion from catch in weight to catch in numbers is accomplished based on gear-specific length frequency distributions and a weight-length relationship in the procedure described in the previous assessment. Commercial length frequency distributions by gear for 1989 and 1990 are shown in Figs. 9 and 10. Recreational length frequency distributions for

1989 and 1990 are applied respectively to commercial hook and line landings for those years (note the relative insignificance of these landings to total landings).

Since 1980, relatively small but constant commercial landings and higher and more variable recreational landings have been made (Fig. 11a). Since 1986, both recreational and commercial landings in numbers of red drum have generally declined (Fig. 11b).

STOCK CHARACTERIZATION

Aspects of the biology of red drum can be found in the Atlantic Coast Red Drum Fishery Management Plan (SAFMC 1990b). In this section, updated biological information not included in that document or in the 1989 stock assessment is reported along with aspects of red drum biology relevent to this stock assessment.

Life History and Distribution

Summarizing from the 1989 stock assessment, the red drum is an estuarine-dependent species which inhabits coastal and oceanic waters and ranges from southwest Florida to Mexico in the Gulf of Mexico and from Florida to Massachusetts in the Atlantic. Commercial landings were historically reported as far north as Massachusetts, however, none have been documented north of the Chesapeake Bay since 1950. Management units of red drum include U.S. Atlantic and Gulf of Mexico stocks. The life histories of Gulf and Atlantic stocks of red drum are very similar. The distribution of the adult and subadult red drum populations appears to be determined by habitat type, where subadult red drum inhabit shallow coastal estuarine environments and move into the deeper oceanic environment during maturation. For the purpose of this assessment, the subadult phase extends through age 5. The adults are often found in large schools which move inshore and offshore seasonally, while sub-adults remain in the estuaries. Adult red drum have been found year round in the Pamlico Sound and behind the barrier islands in North Carolina. These data suggest that no clear distinction exists between the "inshore" and "offshore" stocks. Terms defining a particular life stage, therefore, will be restricted to "subadult" and "adult" stocks, implying no spatial reference for the purposes of this assessment.

Movement

Results of recent tagging studies on movements and mortality of subadult red drum are discussed in Pafford et al. (1990), Wenner et al. (1990), and Ross and Stevens (1989). They generally conclude that little movement occurs during the first few years of life when movement is over relatively short distances and recapture rates are high. With the onset of sexual maturity about ages 3 or

4, reduced availability presumably due to movements offshore is noted.

Age and Growth

The von Bertalanffy (1938) growth model has been used extensively to describe the growth of many marine fishes. This is a three parameter exponential function and is written:

$$L_t = L_{inf}*(1 - \exp(-k*(t-t_0))), \quad (1)$$

where L_t is length at age t, and L_{inf}, k, and t_0 are estimable parameters. Traditional von Bertalanffy growth kinetics, however, are inadequate to describe the growth of red drum which exhibits two very distinct life history stages. As in the 1989 stock assessment, the double von Bertalanffy growth curve (Condrey et al. 1988) is used for red drum using a non-linear iterative least squares approach [PROC NLIN, SAS Institute Inc. (1987)]. Data sets of aged fish were available during 1986-1990 from Georgia Department of Natural Resources, South Carolina Wildlife and Marine Resources Division, and North Carolina Division of Marine Fisheries, with the preponderence of specimens being ages 0 to 3. Regression fits using both the single and double von Bertalanffy growth curves are summarized by state and for the coastwide in Table 2 (using age in years and length as total length in inches). The double von Bertalanffy growth curve is able to fit the rapid growth at earlier ages, while adequately describing the slower growth in later years (Fig. 12). This formulation joins two single von Bertalanffy growth curves with a common L_{inf} into a continous curve at some transition age (t_x) defined as:

$$t_x = (k_2*t_{02}-k_1*t_{01})/(k_2-k_1), \quad (2)$$

Data less than or greater than the transition age were fit by the appropriate equations using the statements:

$$\text{if } t < t_x, \text{ then } L_t = L_{inf}*(1 - \exp(-k_1*(t-t_{01}))), \text{ and}$$
$$\text{if } t > t_x, \text{ then } L_t = L_{inf}*(1 - \exp(-k_2*(t-t_{02})))$$

where L_{inf} = asymptotic total length of the average fish in the population, k_1 = growth rate for fish in the population less than the transition age, k_2 = growth rate for fish in the population greater than the transition age, t_{01} = theoretical age at which length is 0 for fish less than transition age, and t_{02} = theoretical age at which length is 0 for fish greater than transition age. In the coastwide model the transition age (t_x, Eq. 2) was computed to be approximately age 5.9. Parameters from the coastwide model are used in later population analyses to represent the growth of red drum during the period 1986-1990.

In April 1990, unpublished data collected by William Foster, while a graduate student at North Carolina State University, was made available through the South Atlantic Fisheries Management Council. Red drum were collected by Foster on Hatteras and

Ocracoke islands of North Carolina between Avon and Ocracoke Inlet from 1969-1971. About 230 red drum were aged using otoliths. Obvious from Table 2 is the much larger estimate of t_x for this early data set compared to estimates from the late 1980's. With respect to the double von Bertalanffy growth equation, L_{inf} and k_2 estimates are similar between Foster's data and the more recent North Carolina data. However, the subadult growth rate parameter (k_1) is smaller for Foster's data than the more recent North Carolina data.

Age-length keys are used in the decomposition of catch in numbers by length category into catch in numbers at age. Using the observed data sets of aged fish from the North Carolina Division of Marine Fisheries, South Carolina Wildlife and Marine Resources Division, and Georgia Department of Natural Resources, age-length keys were developed directly for 1989 and 1990 (Table 3). Age-length keys for 1986-1988 are given in Vaughan and Helser (1990). Keys were developed annually, rather than to a finer temporal scale, because of the scarcity of older subadult red drum (ages 3 through 5) in the aged data sets. The primary assumptions in using annual coastwide age-length keys concern a constancy in growth across geographic areas and relative uniformity in fishing mortality.

Catches of red drum in numbers at age for the recreational and commercial fisheries from 1986-1990 (Table 4) were calculated by multiplying length-frequency distributions by age-length keys. It appears that red drum less than age 1 are not yet fully recruited into the recreational or commercial fishery. These data suggest that the recreational fishery for red drum exploits mostly ages 1 and 2 red drum, although large number of age 0 red drum were caught during the period 1980-1985. The commercial fishery exploits generally younger red drum than the recreational fishery, largely age 1 red drum, with declining catches of age 0 red drum.

Length-Length/Weight-Length Relationships

In preparing population level analyses, some of the length data were converted to total length from fork or standard lengths. As in Vaughan and Helser (1990; Table 8), length-length relationships presented in Murphy and Taylor (1990) formed the basis of all such transformations.

Also, total lengths were converted to weight when calculating mean weight of fish by commercial gear and year, and for calculating spawning stock biomass. The weight (lbs)-total length (in) relationships based on the MRFSS data for years 1986-1990 is used in subsequent analyses (Table 5 and Fig. 13).

Sex Ratios, Maturity and Fecundity

The proportion of females at age [2 and younger (0.5), and 3 and older (0.61)] were estimated from South Carolina and North

Carolina data. These estimates are very similar to those used in the 1989 stock assessment (0.52 and 0.61, respectively).

Additional maturity information on red drum sampled in South Carolina and North Carolina is combined with the South Carolina information to produce a mean female maturity schedule representative of the period 1985-1989 (Fig. 14). Hence a single maturity schedule is used in the maximum spawning potential estimates presented in this assessment. Female red drum are immature at age 1 and younger, 3.5% female red drum are mature at age 2, 49% female mature at age 3, and all female red drum are mature at age 4 and older.

In general the spawning season for red drum (August through October, SAFMC 1990a) is similar for both the Gulf and Atlantic coasts. Fecundity information on the Atlantic red drum are unavailable. However, in the Gulf of Mexico Overstreet (1983) found a linear relationship between the logarithm of the number of oocytes (N) and red drum standard length (SL, mm):

$$\log_{10} N = 3.6976 + 0.0050\ (SL),\ r^2 = 0.95,\ n = 22. \qquad (3)$$

NATURAL AND FISHING MORTALITY

Coastwide Total Mortality (Z)

The total mortality from all causes on a fish population is defined as the annual expectation of death of an individual fish which is expressed as the ratio of the number of fish that actually die from all causes during a year to the number of fish present at the beginning of the year (A). This annual mortality rate is related to survival rate (S):

$$(1-A) = S = N_1/N_0 = e^{-Z}, \qquad (4)$$

where N_1/N_0 expresses the number alive at the end of the year (fishing season) to the number alive at the start of that year and can ultimately be expressed as the instantaneous total mortality rate Z. In assessments of fish populations, Z is typically expressed on an annual basis and is equal to minus the natural logarithm of S.

Estimates of Z are most often obtained using a catch curve analysis where the natural logarithm of the catch is regressed against age for the ages at and beyond full recruitment (Ricker 1975). Bias can be introduced if fish are not sampled randomly from the population (i.e., sampled in relation to their actual abundance) or, when applied to catch data from a single fishing year, recruitment and mortality is not constant from year to year.

Rates of instantaneous total mortality (Z) are estimated from the annual catch curves using the MRFSS data (1980-1990; Table 4)

for ages 1 through 3 (Table 6). These estimates assume that recruitment to the fishery is complete by age 1, and that the recreational fishery is representative of the population from that age through age 3. Estimates of Z range from 1.04 in 1981 to 2.57 in 1986. Because these are based on catch in numbers at age within individual fishing years, the assumption of constant recruitment is necessary. Similar estimates of Z are made from the annual catch in numbers at age data that combine the recreational and commercial estimates (1986-1990; Table 4). These estimates of Z range from 1.52 in 1990 (ages 1-5) to 2.57 in 1987 (ages 1-4).

Additional coastwide estimates of Z are obtained from the combined recreational/commercial catch at age data (1984-1988 year classes; Table 4) by following a single year class or cohort through its estuarine residence (through age 5). This approach does not require the assumption of constant recruitment, but does assume constant fishing mortality at age for the ages and years included in the catch curve. Estimates of Z range from 2.57 for the 1984 year class (ages 2-5) to 1.70 for the 1988 year class (ages 1-2). Although only a small difference is noted in estimates of Z for the 1985 year class between using ages 1-5 (1.88) and ages 1-3 (1.90), a larger difference is noted in estimates of Z for the 1986 year class between using ages 1-4 (1.82) and ages 1-3 (2.09).

Fishing and Natural Mortality

In fisheries science, Z is partitioned into M (mortality due to natural causes) and F (mortality due to fishing) and expressed as $Z = F+M$. F is estimated from Z by subtracting an independent estimate of M (e.g.; $F = Z-M$). A source of bias for estimating F for red drum arises when older fish exhibit emigration or reduced availability to capture by the gear. Z becomes the sum of M, F and E (losses due to emigration or other reasons) (i.e.; $Z = M+F'+E$, where $F'<F$). It is uncertain when partitioning Z from catch data in numbers at age whether one has estimated F or F'.

Whether red drum in the Atlantic emigrate from an estuarine habitat at the onset of maturity to join the spawning stock offshore as in the Gulf of Mexico or whether fish of mature age simply become less vulnerable to the fishery is not clear. Nor is it clear at which age red drum begin to move offshore if they do emigrate or what the rates of emigration might be. Because of these uncertainties, it is difficult to ascertain the proportion of declining numbers of red drum at age that are truly due to deaths compared to losses from emigration.

Natural mortality can be estimated from Pauly's (1979) equation, which estimates M from the von Bertalanffy growth parameters (L_{inf} and k) and the average annual water temperature. Natural mortality is estimated separately for subadults and adults using k_1 and k_2, respectively, from the double von Bertalanffy growth model and average annual water temperatures recorded in South Carolina (Mathews and Shealy 1978). Estimates of the instantaneous rate of natural mortality for the subadults (M_1) and

adults (M_2) were 0.51 and 0.17, respectively. These estimates are slightly higher than those estimates determined for the 1989 stock assessment (0.44 and 0.13, respectively), because of the new estimates of L_{inf}, k_1, and k_2. In addition, an estimate of M (assumed constant over all ages) was made based on Hoenig (1983). Given a maximum age 55 for an unfished stock, M equals 0.075.

Estimates of Z are also available from some individual states. Pafford et al. (1990) obtained estimates of Z in the St. Simons system ranging 1.26 to 3.23 based on tagging, and estimates of 1.13 to 2.96 from catch curves applied to fishery independent collections throughout Georgia. Estimates of Z for North Carolina range 1.44 to 2.76 based on tagging, and range 1.56 to 2.88 based on catch curves from MRFSS data for North Carolina and Virginia (Ross, pers. comm.).

Virtual Population Analysis

Application of two types of virtual population analysis (VPA) is made to the catch in numbers at age matrix for ages 0 to 5 and years 1986 to 1990. Application is made of VPA techniques to only the subadult population (ages 0-5) and not to the adult population (ages greater than age 5) because sufficient data on the exploitation of older fish is currently unavailable. Both VPA techniques (Murphy 1965 and Doubleday 1976) require estimates of natural mortality (on subadults) and a starting value of a particular age-specific fishing mortality rate.

Application of both types of virtual population analysis requires adequate estimates of catch in numbers at age. This depends primarily on the adequacy of length frequency distributions and age-length keys. If the length frequency distributions are not representative of the length structure of the Atlantic coast red drum catch by gear, then resultant estimates of population size and fishing mortality will be in error. Likewise, if the age-length keys are inadequate, then resultant estimates of population size and fishing mortality will be biased. If natural mortality is overestimated, then age-specific fishing mortality will be underestimated, and vice versa. Because of the limited number of ages and years in our assessment, a poor selection of a starting F can result in significant error carried through to estimates at earlier ages and/or years.

The first type of virtual population analysis conducted parallels the cohort-based analyses made in the 1989 stock assessment. This approach is based on Murphy (1965) and uses the approximate estimate of M_1 (0.5) for subadults based on Pauly (1979). As in the 1989 stock assessment, age 3 is used as a pivotal age about which backward and forward calculations are made. Although backward calculations tend to converge towards more accurate estimates of age specific F and population numbers, forward calculations tend to diverge. The mean of four cohort-based estimates of Z (year classes 1985-1988 in Table 6) was used to start the VPA for year classes 1986-1988 ($F = Z - M = 1.43$ with

M = 0.5). Starting F (at age 3) for earlier year classes (1983-85) were obtained using the linking assumption of Murphy (1965) such that F for age 2 is assumed equal to F for age 3 in the same fishing year. Mean age specific F for these analyses are summarized in Table 7 under the column labeled 'Linked Murphy'.

The second type of virtual population analysis used is based on a separability assumption described in Doubleday (1976). This method assumes that age/year specific F can be decomposed or is 'separable' into the product of an age component and a year component. Clay (1990) developed a Fortran program based on separable VPA as described in Pope and Shepherd (1982). This computer program was applied to catch at age data for ages 0 to 3 from 1986-1989 with three levels of natural mortality for subadults (0.1, 0.3 and 0.5). Pope and Shepherd (1982) recommend specifying the reference age as that age with the greatest number of fish caught (age 1). Using this recommendation and assuming a flat topped partial recruitment causes F for age 1 and 3 in the same fishing year to be the same. Starting F is based on a Z of 1.7 (mortality from 1988 year class - age 1 in 1989 and age 2 in 1990; Table 6). To obtain estimates for ages 4 and 5, Murphy's (1965) forward calculations were used given F for age 3 obtained from the Separable VPA. Mean age specific F for these sets of Separable VPA with three levels of subadult M are summarized in Table 7 under the three columns labelled 'Separable'.

Annual results from all four VPA computer analyses (1 Linked Murphy and 3 Separable) are compared with respect to estimates of recruitment to age 1 (Fig. 15) and age specific estimates of F (Fig. 16). Recruitment to age 1 was relatively high during 1986-1988 (700,000 to 1,100,000 recruits). The lower estimates of recruitment in 1989 (340,000 to 460,000 recruits) are more sensitive to the starting values used in the VPA process. Age specific estimates of F are generally low on age 0 red drum (only partially recruited), high on ages 1-3 (fully recruited), declining for age 4, and very low for age 5.

Separate sets of all VPA computer analyses were made using age 2 instead of age 3 as the pivotal age (both Linked Murphy and Separable). The intent was to compare mean age specific estimates of F between the two pivotal ages. However, with very few exceptions, forward calculations from age 2 quickly diverged to unacceptably high values (F exceeding 10). This instability in the VPA forward calculations when using the pivotal age 2 suggests that catches in number for age 3 are relatively high compared to ages 1 and 2, and therefore do not suggest any significant reduced availability at age 3 from emigration.

POPULATION MODELS

Several population models are applied using age-specific estimates of F averaged across years from the virtual population analysis on the subadult stock (ages 0-5). These include: 1) a

yield per recruit analysis to address the question of growth overfishing, or whether greater yields can be obtained from the subadult stock if fishing is delayed on younger fish so as to benefit from their rapid growth in weight (Ricker 1975); 2) escapement to age 6 to address whether there is adequate survival through the subadult phase; and 3) maximum spawning potential (ratio of spawning stock biomass per recruit with and without fishing mortality) based on both female biomass and egg production (Gabriel et al. 1989). The latter is investigated in the light of the SAFMC goal of 30% (SAFMC 1990b). Approaches 2 and 3 address the question of recruitment overfishing. In particular, they attempt to determine whether sufficient spawning stock will be present to support the continuing viability of the coastwide stock.

Caveats and sources of error in estimating parameters of growth, mortality, and reproduction must be kept in mind when estimating yield per recruit, escapement and maximum spawning potential. To the extent that the above estimated parameters accurately reflect the underlying processes, the results of these population models are reasonable and produce useful information. Nevertheless, because of the sparseness of much of the data for which many assumptions were made, one must be careful about judgements derived from them. They are intended as best available estimates and are supportive of the results obtained from many of the individual states (e.g., North Carolina, South Carolina, and Georgia).

Yield Per Recruit Analysis

The trade off between decreasing numbers of fish and increasing biomass per average individual fish conceptually forms the basis for the yield per recruit analysis. As in the 1989 stock assessment, the Ricker (1975; eq. 10.4) formulation is used for yield per recruit, allowing use of age-specific estimates of size and fishing mortality. Estimates for size are based on the overall double von Bertalanffy growth equation (Table 2), the overall weight-length relationship (Table 5), and age-specific fishing mortality rates (F) (Table 7).

Reiterating from the 1989 stock assessment, some implicit assumptions in applying the Ricker yield per recruit model include: (1) Estimates of natural and fishing mortality are accurate representations for the time periods to which they are applied, (2) these mortality estimates are independent of population density, (3) the double von Bertalanffy growth function accurately describes individual growth during the exploited phase (subadult), (4) recruitment occurs instantaneously on the same date each year, and (5) there is no appreciable net migration. Furthermore, the population processes represented by the yield per recruit model are stochastic and the input parameters under the best of conditions are point estimates with some associated uncertainty. Typically, uncertainty exists in any set of input parameters; however, this uncertainty in input parameters is augmented by additional uncertainty due to the sparseness of the data base, which results

in greater uncertainty in the model predictions. Uncertainty arises from lack of precision (variability about a point estimate), lack of accuracy (or bias in a point estimate), and application of an inappropriate model. Restrepo and Fox (1988) note that "due to the nonlinearity in yield-per-recruit models, the input of apparently extreme parameter values does not necessarily result in extreme outcome ranges." They present a Monte Carlo-based method for incorporating parameter uncertainty into a Beverton and Holt formulation of yield per recruit. However, since the form that much of the uncertainty in our application of yield per recruit is itself unknown (especially with respect to potential bias), we attempt to use the most reasonable parameters estimates, and in some cases ranges of estimates, that are available in the model analyses that follow.

Yield per recruit increases with age at entry to the fishery until about age 3, and then declines through age 5 (Fig. 17). Values for the current age at entry (age 0) and level of fishing mortality are summarized in Table 7 (and corresponding estimates used for adult M_2). For an M_1 of 0.1, Y/R rose from 1.6 lbs with an age at entry of 0 to 7.5 lbs with an age at entry of 3. Meanwhile, for an M_1 of 0.5, Y/R rose from 0.9 lbs with an age at entry of 0 to 1.8 lbs with an age at entry of 3. Higher M implies greater rate of removal of red drum from the stock, and hence lower estimates of Y/R. The lower the underlying natural mortality rate (M), the greater the peak value of yield per recruit. Because M for the subadult phase (M_1) is likely closer to 0.5 than to 0.1, estimates of Y/R based on M_1 of 0.5 are likely to be more realistic.

Escapement

As a follow up to the 1989 stock assessment, an investigation was requested concerning the effects of different management options (i.e., bag limits, size limits, and seasonal closures) on the escapement of red drum from state waters to the EEZ (SAFMC 1990b; Appendix 1). For the purposes of these analyses, escapement (E) is defined as the relative survival of red drum from age at entry to the fishery to the beginning of age 6; i.e.,

$$E = \prod R \exp(-(M_1+F_t)) / \prod R \exp(-M_1) = \prod \exp(-F_t), \qquad (5)$$

where R equals the number of recruits at the age at entry, M_1 equals subadult natural mortality, F_t equals age-specific subadult fishing mortality (Table 7), and $\prod$ indicates the product from t equals 0 to t equals 5. The numerator represents the number of survivors to age 6 with fishing mortality while the denominator represents the number of survivors without fishing mortality.

Escapement, expressed as a percent of survivorship to age 6 without fishing mortality, declines with increasing multiples of fishing mortality (Fig. 18). Escapement for greater ages at entry decline more slowly. A series of contour plots of escapement (Figs. 19-22) show how escapement varies with ranges of age at

entry (0 to 5 yr) and F multiples (0.1 to 2.8 times the F vectors summarized in Table 7). Escapement for age at entry of 0 yr and F multiple of 1 are summarized in Table 7. Escapement is estimated as low as 0.2% for M_1 = 0.1 (based on Separable VPA), and as high as 1.5% for M_1 = 0.5 (based on Linked Murphy VPA).

A series of computer analyses was made in which increasing emigration at age 3 was assumed by simply subtracting from F_3 a fixed amount (E_3) to test the sensitivity of population estimates to the questions raised concerning emigration at age 3. This fixed amount was varied from 0 (no emigration at age 3) up to 0.7 (closed to the value of F_3 for M_1 = 0.5). Based on the Separable VPA's, escapement increased from 0.8% to 1.6% when M_1 = 0.5 (M_2 = 0.17) with increasing emigration rate at age 3, and escapement increased from 0.4% to 0.8% when M_1 = 0.3 (M_2 = 0.135) (Fig. 23).

Maximum Spawning Potential

Confusion over terminology has arisen with this modeling approach. Gabriel et al. (1989) refer to the percent maximum spawning potential (MSP) as the ratio of spawning stock biomass per recruit with and without fishing mortality. Hence, the equilibrium spawning stock with an estimated level of fishing mortality is compared to a maximum potential spawning stock when no fishing occurs (ignoring adjustments to population parameters through compensatory mechanisms). Other labels have been applied to this ratio including spawning stock biomass per recruit (SSB/R) (SAFMC 1990a,b), spawning stock ratio (SSR) (Vaughan and Helser 1990), and spawning potential ratio (SPR) (Goodyear 1989). To reduce the level of confusion, the original nomenclature from Gabriel et al. (1989) is used in this assessment.

As in the 1989 stock assessment, percent maximum spawning potential is calculated in two ways. The first method, described by Gabriel et al. (1989), accumulates female spawning stock biomass per recruit across all ages. Female biomass (B) is calculated by summing over female biomass at age i (B_t) as follows:

$$B = \Sigma B_t = \Sigma N_t * S_t * W_t * P_t, \qquad (6)$$

where N_t = cohort numbers at age t, S_t = proportion of females, W_t = mean weight females at age t, P_t = proportion females mature at age t (maturity schedule), and Σ represents the summation over all ages. Cohort numbers for the youngest age (recruits) is the same when calculating female biomass with and without fishing mortality. Because sexual dimorphism in growth was not found in the 1989 stock assessment, the equations actually used for growth in length and weight (Tables 2 and 5) were developed from both sexes combined. The second method uses Eq. 3 (Overstreet 1983) to estimate an age-specific index of egg production (E_t) and substitute this for W_t in Eq. 6, as suggested by Goodyear (1989).

As with the yield per recruit analysis, a range of natural mortality rates are used: 0.1 to 0.5 for subadults and 0.10 to

0.17 for adults. The assumption from the 1989 stock assessment that F for adults is 0 is continued in this assessment (no estimates available). This assumption causes estimates of percent maximum spawning potential to be high. In addition estimates of sex ratios, schedules of female maturity, and fecundity relationships are needed.

The assumptions described in the yield per recruit section apply here as well. In addition, assumptions as to the validity of sex ratios, maturity schedules and fecundity estimates are needed. How uncertainty in the input parameters are expressed in the model output has not been described in the literature. Results of computer runs, which bracket some of the uncertainty in specific input parameters (e. g., natural and fishing mortality), are intended to partially address these questions.

Corresponding to plots for escapement are similar contour plots for percent maximum spawning potential based on female biomass and egg production (Figs. 19-22). Percent maximum spawning potential for age at entry of age 0 and F multiple of 1 are summarized in Table 7. Based on female biomass, %MSP increases from 0.3% for M_1 = 0.1 (based on Separable VPA) to 1.9% for M_1 = 0.5 (based on Linked Murphy VPA). Based on egg production, %MSP similarly increases from 0.4% for M_1 = 0.1 (based on Separable VPA) to 2.4% for M_1 = 0.5 (based on Linked Murphy VPA). %MSP based on egg production tends to produce higher estimates than %MSP based on female biomass, and both types of estimates of %MSP produce higher estimates than escapement.

Concern was indicated about the sensitivity of %MSP to variability in adult M_2 (Fig. 24). To address this, a series of analyses were made with a range of values for M_2 with the sets of fishing mortality rates based on the Separable VPA for M_1 = 0.3 and 0.5. For M_1 = 0.3, %MSP (based on egg production) increases from 0.8% with M_2 = 0.1 to 1.1% with M_2 = 0.2.

Corresponding to the sensitivity analyses made for escapement, increasing emigration at age 3 was assumed by simply subtracting from F_3 a fixed amount (E_3). This fixed amount was varied from 0 (no emigration at age 3) up to 0.7 (closed to the value of F_3 for M_1 = 0.5). Based on the Separable VPAs, %MSP (based on egg production) increased from 2.2% to 3.0% when M_1 = 0.5 (M_2 = 0.17) with increasing emigration rate at age 3, and %MSP increased from 0.9% to 1.4% when M_1 = 0.3 (M_2 = 0.135) (Fig. 25).

MANAGEMENT CONSIDERATIONS

An evaluation of a range of potential management options is updated from the 1989 stock assessment and Appendix 1 in SAFMC (1990b). This section has four parts, the first three separately describe potential savings of red drum by means of bag limits, size limits, and seasonal closures based on data from the recreational

fishery since 1986. These estimates of savings refer to the initial proportion of fish saved and will tend to overestimate the long term savings. When savings are translated into fishing mortality rates and subsequently in maximum spawning potential, the implication is that there is no increase in fishing mortality on those sizes/ages not effected by management measures. In the final part, these savings are related through the population models described in the previous section to escapement and maximum spawning potential. One should keep in mind that saving a single age 1 red drum is not equivalent to saving a single age 4 red drum. The former has to undergo several years of natural and fishing mortality before it attains the likelihood of spawning or reaches age 6, while the latter has attained spawning age and has 3 fewer years of mortality to undergo before reaching age 6.

Savings from Bag Limits

The number of fish caught per angler trip based on MRFSS data for years 1986-1990 is useful in evaluating potential benefits from bag limits (Fig. 26). Of 1238 successful angler trips sampled (at least one red drum caught) during 1986-1990, 684 angler trips resulted in only a single red drum caught (55%). A greater percentage of angler trips during 1989-1990 resulted in only a single red drum caught (65% or 235 out of 363 angler trips). Meanwhile, 14% of the angler trips caught more than 5 fish during 1986-1990 compared to only 10% of the angler trips caught more than 5 fish during 1989-1990.

Calculation of potential bag limit savings are made for two time periods: 1986-1990 and 1989-1990 (Table 8). The latter should be more representative because of recent management changes. The number of legal red drum is calculated by summing all fish caught less than or equal to the bag limit. The percent saved is calculated from 100 times the difference between the number of legal and total number of fish (3821 for 1986-1990 and 888 for 1989-1990 sampled in the MRFSS) divided by the total number of fish. This can be adjusted for release mortality by multiplying the proportion of red drum saved by the proportion surviving release (e.g., multiply by 0.9 if 10% release mortality is assumed).

The number of red drum caught per angler trip is probably related to the population abundance at that time. As population abundance increases, the effectiveness of bag limits increase. However, as population abundance decreases, the effectiveness of bag limits decrease. The effectiveness of bag limits cannot be assessed once in place without an independent data source that is unaffected by the bag limit. Furthermore, one cannot assume that the proportion protected by the bag limit can be simply multiplied by the age-specific estimated F's, because angler's are likely to retain the larger red drum while they catch and release (alive or dead) smaller red drum. Thus, most of any reduction in F is likely to occur for the younger ages and less for the older aged red drum.

Savings from Size Limits

An analysis is also made of the MRFSS data base (1986-1990) to explore what proportion of the recreational catch would have been protected if a minimum size limit (12 to 22 inches) or a maximum size limit (24 to 32 inches) were instituted (Table 9). Of course, most coastal Atlantic states have instituted a minimum size limit and a combination of bag limit combined with a maximum size (SAFMC 1990a, Fig. 13). Most of these size limits were instituted in 1986 and 1987. Length measurements are available on 2581 red drum during the period 1986-1990. Potentially significant savings are available from minimum size limits increasing from 12" TL (6%) to 14" TL (23%) to 18" TL (75%). Again, to account for a release mortality of 10%, these savings should be multiplied by 0.9.

Comparatively small savings are available when reducing the maximum size limit from 32" TL (2%) to 27" TL (4%) (Table 9). As suggested in the 1989 stock assessment, data supplied by North Carolina (Ross, pers. comm.) indicate considerably greater gains likely from a maximum size limit than does the MRFSS data. Although maximum size limits show much less potential reduction in F than minimum size limits, they do protect those fish that have managed to survive to maturity.

Because most states with maximum size limits would continue to permit the retention of 1 red drum over this size limit, the MRFSS data set for 1986-1990 was investigated for the catch frequency of red drum exceeding a maximum size limit (27" TL through 32" TL). The proportion of these large fish that would be saved with a 1 fish over allowance ranged between 34% for 27" TL maximum size limit to 41% for 29" TL maximum size limit. No trend in percent saved was evident for the range of maximum size limits investigated (27" to 32" in 1" increments), so a mean value of 38% savings from a maximum size limit is used for subsequent analyses when 1 fish over is allowed.

Savings from Seasonal Closure

Seasonal closures for periods that do not coincide with the two month waves used for the catch expansions by the MRFSS (Essig et al. 1991) cannot be directly assessed. However, the intercept sampling for fish size information closely agree with the catch estimates when compared by 2-month wave (Fig. 27). Based on this relationship, potential savings of red drum (all ages) can be approximated monthly based on the MRFSS intercept data (1986-1989; 1990 data for all waves were not available at the time this assessment was conducted) (Fig. 28). This, of course, assumes no shifting of effort due to the closure. Even with no shift in effort, some of the seasonal closure gains are lost due to the greater availability of fish following the closure (F is a proportional cropping).

Population Level Considerations

To incorporate savings from bag limits, size limits, and seasonal closures at the population level, their effects on age specific estimates of fishing mortality rates must be considered. Because bag limits only apply to recreational fishing and size limits may not be applied identically between recreational and commercial fishing, age-specific fishing mortality rates need to be separated into recreational and commercial components. This is accomplished proportional to the relative catch in numbers at each age (0 to 5). The proportion of catch in numbers that are recreational are summarized in Table 10 for fishing years 1986-1990, and for the periods 1986-1990 and 1989-1990. An annual mean for ages 0 through 5 was determined as most representative of recent fishing conditions and is used in subsequent analyses described in this section.

Savings from bag limits (Table 8) are applied to the recreational fishing mortality component for all ages. However, this savings is reduced by 10% to reflect a release mortality of that amount (i.e., proportion that F is to be reduced is multiplied by 0.9). In the analysis presented, bag limit savings are based on the MRFSS data during 1989-1990.

To determine the reduction of age-specific F for a given size limit, it is first necessary to determine the age equivalent to the size limit. One method would be to simply solve the von Bertalanffy growth equation so that age (t_{vb}, yr) is expressed as a function of length (TL, in):

$$t_{vb} = -0.077 - (\log_e(1 - TL/45.93))/0.316. \quad (7)$$

Statistically this presents certain theoretical problems. The preferred method is to re-estimate age (t_d, yr) as a function of length (TL, in) directly:

$$t_d = \exp(-0.666 + 0.061\ TL + \tfrac{1}{2}(0.204)^2. \quad (8)$$

The expression $[\frac{1}{2}(0.204)^2]$ is a correction factor from the lognormal distribution when retransforming back to the original units. Parameter estimates in Eq. (8) were estimated from MRFSS data between 10" and 35" TL for the period 1986-1990. Because age equals 1 at 10" TL (Table 9), a minimum size limit of 10" would imply that all age 0 red drum were protected (i.e., $F_0 = 0$ or 10% of the original value with release mortality). However 14" TL produces an estimate of age of 1.24. As applied in this analysis, it is assumed that all (or 90%) of the age 0 red drum are protected, and 24% (or 90% of 24%) of the age 1 red drum are protected. Similar calculations are carried out for maximum size limits. These savings can be applied to both recreational and commercial fishing mortality components, but for the analysis that follows they are generally applied only to recreational fishing mortality components.

As programmatically constructed, savings from seasonal

closures would be applied to both recreational and commercial fisheries, all ages, and with or without release mortality.

Once these adjustments to age-specific fishing mortality rates are made, the SAS program then performs simultaneous calculations of escapement to age 6 and maximum spawning potential (female biomass and egg production) to those described in the previous section. These parallel the analysis presented in SAFMC (1990b, Appendix 1) except as follows: 1) all the data are updated as described above, 2) a direct estimate of age from length is used, and 3) reductions from size limits are based directly on age.

Estimates of escapement and maximum spawning potential from separate application of bag and size limits to recreational fishing only are summarized in Table 11 (these are conditioned on the bag and size limits extant during the late 1980's). A 10% release mortality is assumed for the recreational fishery, and the fishing mortality rates are based on the Separable VPA with $M_1 = 0.5$ (and $M_2 = 0.17$). A bag limit of one red drum produces an escapement to age 6 of 8% and a maximum spawning potential (eggs) of 11%. Minimum size limits of at least 16" to 20" TL are need for appreciable gains in escapement and %MSP, although absolute values of these are still very small. Greater gains in escapement and MSP are possible from maximum size limits, except when one red drum over the maximum size limit is permitted.

Higher estimates of %MSP (eggs) occur when different management options are combined. Again, a 10% release mortality for the recreational fishery is assumed and the estimated fishing mortality rates are based on the Separable VPA with $M_1 = 0.5$ (and $M_2 = 0.17$). Estimates of %MSP (eggs) for a range of bag limits and minimum size limits are summarized in Table 12 with two different maximum size limits (32" and 27" TL with no fish over this limit). Estimated %MSP values above 30% are only obtained with a zero fish bag limit for a maximum size limit of 32" TL and with a one fish or fewer bag limit for maximum size limit of 27" TL. Higher estimates of %MSP (eggs) are obtained when size limits are applied to both recreational and commercial fisheries (Table 13). For example, a bag limit of 5 fish and minimum size limit of 18" TL, yields an estimate of %MSP (eggs) of 12% with no fish kept over 32" TL and an estimate of %MSP (eggs) of 27% with no fish kept over 27" TL. Allowance of one fish over the maximum size limit significantly reduces the expected %MSP (eggs).

RESEARCH NEEDS

As referred to in this and the 1989 stock assessments, a major weakness in the analyses concerns the rates at which ages 3-5 emigrate or become less available to the fisheries. This is of special concern with the rate for age 3, because the rates for ages 4 and 5 are probably largely reflected in the reduced estimates of F from the forward calculations of the VPA's. Continued tag-

recapture studies are important and useful, partly because they provide parallel information on fishing mortality rates that tend to confirm those obtained in this assessment. Also they may ultimately provide useful estimates of emigration rates at age.

Primary needs for continued stock assessments imply continued and improved collection of the following data sets: 1) Catch statistics (appear adequate, but must maintain at least this level of quality), 2) length frequency distributions by gear (appear adequate from MRFSS [at least for subadults], but need better sampling for commercial gears [e.g., differentiate between pound net and trawl caught red drum]), and 3) age-length keys (need improved coastwide coverage, although greatly improved since about 1988, before which only data from South Carolina was available).

Parameters for population models still require better estimates of natural mortality rates (subadult M_1 and adult M_2), although implications from sensitivity analyses suggest that model results will not change appreciably. Escapement and MSP are very low for all reasonable estimates of natural mortality. A determination of fecundity as a function of Atlantic red drum length or weight would prove useful, although it is not unreasonable to assume a similar relationship as red drum from the Gulf of Mexico. As used in this and the 1989 stock assessments, it is not necessary that the absolute value of the estimates be correct, but that the rate of increase in egg production with female age be similar.

Population models used in this report assume equilibrium conditions and reflect short-term, initial percent savings from management regulations. These limitations are largely due to the data available for analyses. However, better refinement of these models is desirable to obtain longer term estimates of gains from management regulations.

Some fishery independent indices are highly desirable. First, coverage of adult red drum is needed probably in terms of a fisheries independent index of spawning stock (e.g., possibly by areal counting of schools as in the Gulf of Mexico). Conceptually, the application of a VPA to the entire age structure (i.e., through age 50 or 55) is not practical. There are too many ages with relatively small growth from ages 6 through 55, thus an age-length key is not likely to be useful. Furthermore, few red drum of these ages are caught for application of VPA techniques. It needs to be reiterated that the population models used in this assessment (specifically yield per recruit and percent maximum spawning potential) are based on equilibrium assumptions. These model results are valid in assessing long-term effects, but direct estimates are unavailable as to the current status of the adult (or spawning) stock.

Continued standardized sampling of subadults is also needed to develop long-term indices of recruitment. This is necessary to permit short-term warning of potential recruitment failure that otherwise could result from a collapse of spawning stock. When a

collapse occurs, it may appear in the catch or other fishery statistics too late for a recovery to occur.

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REFERENCES CITED

Clay, D. 1990. TUNE: a series of fish stock assessment computer programs written in FORTRAN for microcomputers (MS DOS). International Commission for the Conservation of Atlantic Tunas, Collected Volume of Scientific Papers 32:443-460.

Condrey, R., D. W. Beckman, and C. A. Wilson. 1988. Management implications of a new growth model for red drum. Appendix D. In J. A. Shepherd (ed.), Louisiana Red Drum Research, MARFIN final report, Contract No. NA87-WC-H-06122. Louisiana Department of Wildlife and Fisheries, Seafood Division, Finfish Section, Baton Rouge, LA. 26 p.

Doubleday, W. G. 1976. A least squares approach to analysing catch at age data. Canadian Journal of Fisheries and Aquatic Sciences 39:1195-1207.

Essig, R. J., J. F. Witzig, and M. C. Holliday. 1991. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1987-1989. U.S. Department of Commerce, Current Fisheries Statistics No. 8904. 363 p.

Gabriel, W. L., M. P. Sissenwine, and W. J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. North American Journal of Fisheries Management 9:383-391.

Goodyear, C. P. 1989. Status of the red drum stocks of the Gulf of Mexico: Report for 1989. U.S. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL, Contribution CRD 87/88-32. 64 p.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin, U.S. 82:898-903.

Jordan, S. R. 1990. Mortality of hook-caught red drum and spotted seatrout in Georgia. Georgia Department of Natural Resources, Brunswick, GA. 27 p.

Mathews, T. D., and M. H. Shealy, Jr. 1978. Hydrography of SOuth Carolina estuaries, with emphasis on the North and South Edisto and Cooper Rivers. South Carolina Marine Resources Center, Technical Report No. 30. 148 p.

Murphy, G. I. 1965. A solution of the catch equation. Journal of the Fisheries Research Board of Canada 22:191-201.

Murphy, M. D., and R. G. Taylor. 1990. Reproduction, growth, and mortality of red drum Sciaenops ocellatus in Florida waters. Fishery Bulletin, U.S. 88:531-542.

Overstreet, R. 1983. Aspects of the biology of the red drum, Sciaenops ocellatus, in Mississippi. Gulf Research Report, Supplement 1:45-68.

Pafford, J. M., A. G. Woodward, and N. Nicholson. 1990. Mortality, movement, and growth of red drum in Georgia. Georgia Department of Natural Resources, Brunswick, GA. 85 p.

Pauly, D. 1979. On the inter-relationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil 39:175-192.

Pope, J. G., and J. G. Shepherd. 1982. A simple method for the consistent interpretation of catch-at-age data. Journal du Conseil 40:176-184.

Restrepo, V. R., and W. W. Fox, Jr. 1988. Parameter uncertainty and simple yield-per-recruit analysis. Transactions of the American Fisheries Society 117:282-289.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1-382.

Ross, J. L., and T. M. Stevens. 1989. Marine fisheries research: red drum. North Carolina Department of Natural Resources and Community Development, Morehead City, NC. 36 p.

SAS Institute Inc. 1987. SAS/STAT guide for personal computers. Version 6 Edition. SAS Institute Inc., Cary, NC. 1028 p.

South Atlantic Fishery Management Council (SAFMC). 1990a. Profile of the Atlantic coast red drum fishery and source document for the Atlantic coast red drum fishery management plan. South Atlantic Fishery Management Council, Charleston, SC. 147 p.

South Atlantic Fishery Management Council (SAFMC). 1990b. The Atlantic coast red drum fishery management plan including an environmental impact statement and regulatory impact review. South Atlantic Fishery Management Council, Charleston, SC. 116 p.

Vaughan, D. S., and T. E. Helser. 1990. Status of the red drum stock of the Atlantic coast: Stock assessment report for 1989. NOAA Technical Memorandum NMFS-SEFC-263. 117 p.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology 10:181-213.

Wenner, C. A., W. A. Roumillat, J. E. Moran, Jr., M. B. Maddox, L. B. Daniel, III, and J. W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina: Part I. South Carolina Wildlife and Marine Resources Department, Charleston, SC.

Table 1. Red drum catches for recreational and commercial fisheries, 1980-1990. Recreational catches are in numbers and weight, commercial catches are in weight, and total catches are in weight.

Year	Recreational[a]			Commercial	Total
	Numbers		Weight[b]	Weight	Weight
	A+B1 (1000)	0.1*B2 (1000)	A+B1+0.1*B2 (1000 lbs)	(1000 lbs)	(1000 lbs)
1980	269.8	14.7	716.9	439.9	1156.8
1981	186.1	1.4	632.5	353.1	985.6
1982	388.6	1.8	682.0	195.3	877.3
1983	635.0	7.3	1064.5	330.2	1394.7
1984	1068.6	6.4	2179.1	422.1	2601.2
1985	1027.3	26.6	2032.3	249.1	2281.4
1986	428.6	18.2	1816.9	341.9	2158.8
1987	657.3	66.3	1471.9	312.3	1784.2
1988	502.2	61.9	1672.0	229.2	1901.2
1989	268.5	28.7	907.6	286.0	1193.6
1990	224.0	25.3	511.8	186.4	698.2

[a] Definitions of catch type (Essig et al. 1991):
A = "fish brought ashore in whole form which were available for identification, enumeration, weighting and measuring by the interviewers",
B = "those not brought ashore in whole form were separated into":
B1 = "those used as bait, filleted, or discarded dead", and
B2 = "those released alive".

[b] Mean weight of B2 assumed same as expanded mean weight of A+B1. Since numbers of fish, rather than weight, are used in assessment, this assumption does not effect assessment results, but only visual representation in this table and in Figure 11a.

Table 2. Red drum growth characterized by single and double von Bertalanffy equations, 1986-1990. L_{max} is total length in inches; k, k_1, and k_2 are in yr^{-1}, and t_0, t_{01}, t_{02} and t_x are in years.

Region	Single Parameters			
	n	L_{max}	k	t_0
GA	341	40.8	0.25	-1.94
SC	5939	41.3	0.35	0.09
NC	823	46.6	0.19	-1.63
All	7103	42.4	0.36	0.09
Foster[a]	230	46.6	0.21	-0.82

Region	Double Parameters					
	L_{max}	k_1	k_2	t_{01}	t_{02}	t_x
GA	41.1	0.27	0.16	-1.64	-6.14	4.9
SC	41.8	0.38	0.26	0.16	-0.85	2.3
NC	49.1	0.29	0.06	-0.14	-16.66	4.5
All	45.9	0.32	0.06	0.08	-25.30	5.9
Foster[a]	49.3	0.19	0.04	-1.00	-35.76	8.8

[a] Data from North Carolina during 1969-1971.

Table 3. Red drum age-length keys for 1989 and 1990.

Length Class (TL, in)	Age (yr) 0	1	2	3	4	5	6+
			1989 (n = 1638)				
7	1.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.439	0.561	0.0	0.0	0.0	0.0	0.0
11	0.223	0.777	0.0	0.0	0.0	0.0	0.0
13	0.063	0.937	0.0	0.0	0.0	0.0	0.0
15	0.016	0.984	0.0	0.0	0.0	0.0	0.0
17	0.009	0.932	0.059	0.0	0.0	0.0	0.0
19	0.012	0.711	0.277	0.0	0.0	0.0	0.0
21	0.0	0.135	0.865	0.0	0.0	0.0	0.0
23	0.0	0.108	0.878	0.014	0.0	0.0	0.0
25	0.0	0.053	0.713	0.234	0.0	0.0	0.0
27	0.0	0.020	0.505	0.465	0.010	0.0	0.0
29	0.0	0.021	0.291	0.646	0.042	0.0	0.0
31	0.0	0.0	0.277	0.532	0.191	0.0	0.0
33	0.0	0.0	0.111	0.482	0.370	0.037	0.0
35	0.0	0.0	0.0	0.368	0.529	0.053	0.053
37	0.0	0.0	0.0	0.067	0.133	0.0	0.800
39	0.0	0.0	0.0	0.0	0.0	0.0	1.0
41	0.0	0.0	0.0	0.0	0.0	0.0	1.0
			1990 (n = 1564)				
7	1.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.845	0.155	0.0	0.0	0.0	0.0	0.0
13	0.195	0.805	0.0	0.0	0.0	0.0	0.0
15	0.016	0.979	0.005	0.0	0.0	0.0	0.0
17	0.009	0.982	0.009	0.0	0.0	0.0	0.0
19	0.0	0.967	0.033	0.0	0.0	0.0	0.0
21	0.0	0.475	0.525	0.0	0.0	0.0	0.0
23	0.0	0.427	0.573	0.0	0.0	0.0	0.0
25	0.0	0.274	0.655	0.071	0.0	0.0	0.0
27	0.0	0.089	0.759	0.127	0.025	0.0	0.0
29	0.0	0.0	0.569	0.379	0.052	0.0	0.0
31	0.0	0.0	0.541	0.243	0.216	0.0	0.0
33	0.0	0.0	0.087	0.304	0.478	0.0	0.131
35	0.0	0.0	0.0	0.133	0.667	0.067	0.133
37	0.0	0.0	0.0	0.0	0.139	0.194	0.667
39	0.0	0.0	0.0	0.0	0.0	0.048	0.952
41	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Table 4. Red drum catch in numbers at age for recreational (1980-1990) and commercial (1986-1990) fisheries.

Year	Age (yr)						
	0	1	2	3	4	5	6+
				Recreational Only			
1980	149839	100970	28600	5102	492	267	362
1981	69166	73046	34200	9083	1567	262	231
1982	222056	137278	16116	8865	3110	1144	91
1983	336263	259042	34577	5246	659	699	5807
1984	446947	552465	25692	24529	25376	0	0
1985	498363	513518	32477	7486	2064	0	0
1986	34231	356245	39198	2082	0	405	13737
1987	46290	588581	70509	14489	258	0	2219
1988	46830	450634	46874	13651	831	0	2842
1989	6801	207317	69643	11024	667	0	1193
1990	14330	175753	44780	4956	2654	425	4924
				Commercial Only			
1986	154051	252350	1241	40	0	30	156
1987	158276	225848	2045	204	5	0	76
1988	19787	143465	2085	77	6	0	22
1989	1153	55573	10992	1365	288	20	7551
1990	1070	42891	3103	716	292	21	4264
				Total (Recreational and Commercial)			
1986	188283	608594	40439	2122	0	435	13893
1987	204566	814429	72554	14693	264	0	2295
1988	66617	594099	48958	13728	837	0	2864
1989	7955	262890	80634	12390	955	20	8744
1990	15401	218644	47883	5672	2947	446	9188

Table 5. Red drum weight (lbs)-total length (in) relationships from MRFSS data base, 1986-1990.

Year	ln(a)	b	n	r^2	RMSE[a]
1986	-7.73	2.98	487	0.92	0.220
1987	-7.53	2.91	746	0.93	0.188
1988	-7.42	2.91	379	0.93	0.220
1989	-7.18	2.81	731	0.93	0.187
1990	-7.63	2.96	138	0.98	0.154
1986-1990	-7.58	2.94	2181	0.93	0.204

[a] RMSE equals root mean squared error.

Table 6. Red drum estimates of total instantaneous mortality rates (Z) from catch curve analysis using data within a single year or by cohort over several fishing years.

	Z	r^2	n	Ages
Using Recreational Data Only				
Fishing Year				
1980	1.49	0.98	3	1-3
1981	1.04	0.95	3	1-3
1982	1.37	0.81	3	1-3
1983	1.95	0.999	3	1-3
1984	1.56	0.52	3	1-3
1985	2.11	0.94	3	1-3
1986	2.57	0.99	3	1-3
1987	1.85	0.99	3	1-3
1988	1.75	0.97	3	1-3
1989	1.47	0.96	3	1-3
1990	1.78	0.96	3	1-3
Using Recreational/Commercial Data				
Fishing Year				
1986	1.79	0.86	4	1-4
1987	2.57	0.95	4	1-4
1988	2.10	0.97	4	1-4
1989	2.34	0.94	5	1-5
1990	1.52	0.98	5	1-5
Using Recreational/Commercial Data				
Cohort				
1984	2.57	0.92	4	2-5
1985	1.88	0.97	5	1-5
1985	1.90	0.99	3	1-3
1986	1.82	0.95	4	1-4
1986	2.09	0.92	3	1-3
1987	2.33	0.99	3	1-3
1988	1.70	1.0	2	1-2

Table 7. Red drum mean fishing mortality rates (1986-1989) from different virtual population analyses (M = instantaneous natural mortality rate for subadults, ages 0-5). Assumes reduced availability or offshore movement begins following age 3. Estimates of adult mortality based on Hoenig (1983) when M_1 = 0.1 (note: M_1 = M_2), based on Pauly (1979) when M_1 = 0.5, and average of 0.1 and 0.17 when M_1 = 0.3. In addition, estimated values for yield per recruit (Y/R), escapement to age 6, and maximum spawning potential (MSP) based on female biomass and egg production are presented.

Age/ Values	Separable			Linked Murphy
	M_1=0.1	M_1=0.3	M_1=0.5	M_1=0.5
0	0.183	0.149	0.118	0.150
1	1.92	1.69	1.46	1.59
2	1.31	1.14	0.98	1.09
3	1.92	1.69	1.46	1.09
4	0.98	0.88	0.77	0.25
5	0.026	0.025	0.024	0.005
Adult M (M_2)	0.100	0.135	0.170	0.170
Y/R (lbs)	1.6	1.2	0.9	0.8
Escapement (%)	0.2	0.4	0.8	1.5
MSP Biomass (%)	0.3	0.6	1.4	1.9
MSP Eggs (%)	0.4	0.9	2.2	2.4

Table 8. Potential savings of red drum from management bag limits based on MRFSS data base for 1986-1990 and 1989-1990 (assumes no release mortality).

Bag Limit	1986-1990		1989-1990	
	No. Caught[a]	% Saved	No. Caught[a]	% Saved
1	1238	68	363	59
2	1792	53	491	45
3	2155	44	574	35
4	2429	36	635	29
5	2643	31	678	24
6	2816	26	713	20
7	2957	23	741	17
8	3074	19	763	14
9	3167	17	782	12
10	3245	15	797	10
11	3312	13	809	9
12	3372	12	820	8
13	3424	10	830	7
14	3471	9	837	6
15	3513	8	843	5
None	3821	0	888	0

[a] Number of red drum that would have been caught if bag limit had been in effect.

Table 9. Potential savings of red drum from management size limits based on MRFSS data base for 1986-1990 (assumes to release mortality).

Size Limit	Age[a]	No. Fish Legal	Percent Savings
12	1.01	2436	6
13	1.17	2248	13
14	1.24	1988	23
15	1.32	1461	43
16	1.41	1088	58
17	1.49	803	69
18	1.59	654	75
19	1.69	546	79
20	1.80	472	82
21	1.91	401	85
22	2.03	357	86
24	2.30	2347	9
25	2.44	2410	7
26	2.60	2453	5
27	2.76	2476	4
28	2.94	2498	3
29	3.12	2512	3
30	3.32	2521	2
31	3.53	2527	2
32	3.76	2534	2
Total	-	2581	-

[a] Age at length estimated by linearized regression from the model:

$$A = \exp(-0.666 + 0.061*L + \tfrac{1}{2}(0.216^2))$$

where A = age in years, L = total length in inches, 0.216 is the root mean squared error and corrects for bias between normal and lognormal error models, and $r^2 = 0.99$. Age-length data from Georgia, South Carolina, and North Carolina, between 1986-1990, and restricted to total lengths of 10" and 35".

Table 10. Proportion of red drum in numbers by age (0-5) that were caught by the recreational fishery.

Year	Age (yr)						Total
	0	1	2	3	4	5	(0-5)
1986	0.182	0.585	0.969	0.981	-	0.931	0.515
1987	0.226	0.723	0.972	0.986	0.977	-	0.651
1988	0.703	0.759	0.957	0.994	0.993	-	0.772
1989	0.855	0.789	0.864	0.889	0.698	0.0	0.767
1990	0.931	0.804	0.935	0.875	0.898	0.953	0.835
Total[a] (1986-90)	0.308	0.712	0.933	0.951	0.880	0.039	0.672
Total[a] (1989-90)	0.905	0.796	0.890	0.885	0.849	0.021	0.796
Mean[b]	0.893	0.797	0.939	0.945	0.891	0.942	0.708

[a] Total proportion based on sum of recreational catches in numbers across years divided by sum of all catches in numbers across years.

[b] Mean proportion based on selected years: Age 0 and 1 used mean of 1989-90 because increasing trend apparent with 1989-90 representing recent conditions, age 2, 3 and 4 used mean of 1986-90 with no apparent trend (no estimate available for age 4 in 1986), age 5 used mean of 1986 and 1990 with no estimate for 1987 and 1988, and 1989 estimate believed to be unrepresentative of current conditions).

Table 11. Escapement and percent maximum spawning potential for Atlantic red drum expressed as percent based on separate application of bag and size limits with a 10% release mortality to recreational fishery only. Fishing mortality rates from Separable VPA with $M_1 = 0.5$.

Limit (data source)	Escapement	% Maximum Spawning Potential	
		Biomass	Eggs
No Limits	1	1	2
Bag Limit (MRFSS 1989-90)			
0	38	40	42
1	8	10	11
2	5	6	7
3	3	4	6
4	2	3	5
5	2	3	4
6	2	3	4
7	2	2	3
8	1	2	3
9	1	2	3
10	1	2	3
Minimum Size Limit (MRFSS 1986-1990)			
12" TL	1	2	3
14"	1	2	3
16"	1	2	4
18"	2	3	4
20"	2	4	6
Maximum Size Limit (MRFSS 1986-1990)			
No fish allowed over:			
27" TL	7	7	7
30"	4	4	5
32"	2	3	3
One fish allowed over:			
27" TL	2	2	3
30"	1	2	3
32"	1	2	2

Table 12. Percent maximum spawning potential (eggs) for Atlantic red drum expressed as percent based on combined application of bag and size limits with a 10% release mortality to recreational fishery only (no fish permitted over maximum size limit). Fishing mortality rates from Separable VPA with $M_1 = 0.5$.

Bag Limit	Minimum Size Limits (TL)					
	None	12"	14"	16"	18"	20"
	Maximum Size Limit = 32" TL					
0	45	46	46	47	48	49
1	15	16	17	19	20	23
2	10	11	12	14	15	17
3	8	9	10	11	13	15
4	6	8	8	10	11	13
5	6	7	8	9	10	12
6	5	6	7	8	9	11
7	5	6	6	7	9	11
8	4	5	6	7	8	10
9	4	5	6	7	8	10
10	4	5	6	7	8	9
None	3	4	4	5	6	8
	Maximum Size Limit = 27" TL					
0	49	50	51	52	53	54
1	22	25	26	29	31	35
2	17	19	21	23	26	30
3	14	16	18	20	23	27
4	12	14	16	18	21	25
5	11	13	15	17	20	24
6	11	12	14	16	19	23
7	10	12	13	15	18	22
8	9	11	13	15	18	21
9	9	11	12	14	17	21
10	9	11	12	14	17	20
None	7	9	10	12	15	18

Table 13. Percent maximum spawning potential (eggs) for Atlantic red drum expressed as percent based on combined application of bag and size limits with a 10% release mortality to recreational and commercial fishery (no fish permitted over maximum size limit). Fishing mortality rates from Separable VPA with $M_1 = 0.5$.

Bag Limit	Minimum Size Limits (TL)					
	None	12"	14"	16"	18"	20"
	Maximum Size Limit = 32" TL					
0	48	51	53	57	61	66
1	15	18	20	22	26	30
2	10	12	14	16	19	23
3	8	10	11	13	16	19
4	7	8	10	11	14	17
5	6	7	8	10	12	16
6	5	7	8	9	12	15
7	5	6	7	9	11	14
8	5	6	7	8	10	13
9	4	6	7	8	10	13
10	4	5	6	8	10	12
None	3	4	5	6	8	10
	Maximum Size Limit = 27" TL					
0	56	59	62	66	71	77
1	25	29	32	36	42	49
2	19	22	26	30	35	42
3	16	19	22	26	31	38
4	14	17	20	23	28	35
5	13	16	18	22	27	33
6	12	15	17	21	25	32
7	11	14	16	20	24	31
8	11	13	16	19	24	30
9	10	13	15	18	23	29
10	10	12	15	18	22	29
None	8	10	12	15	20	26

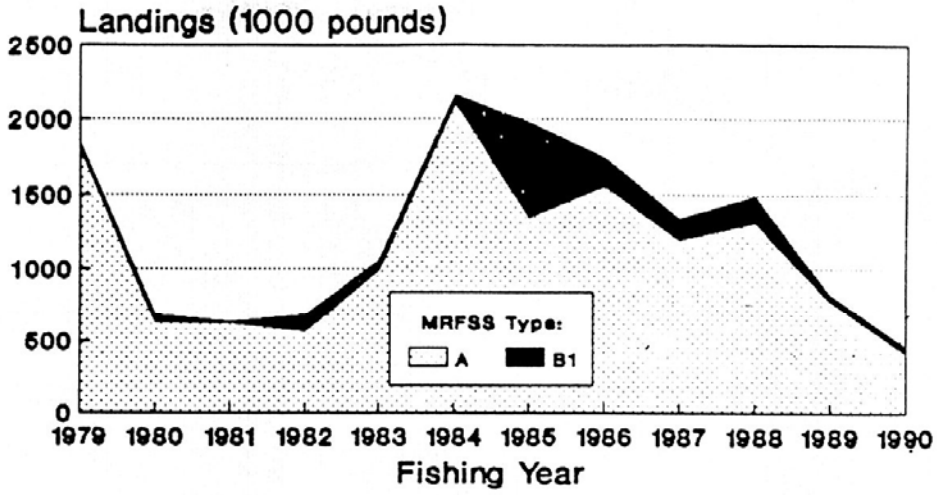


Fig. 1. Red drum recreational catches in weight.

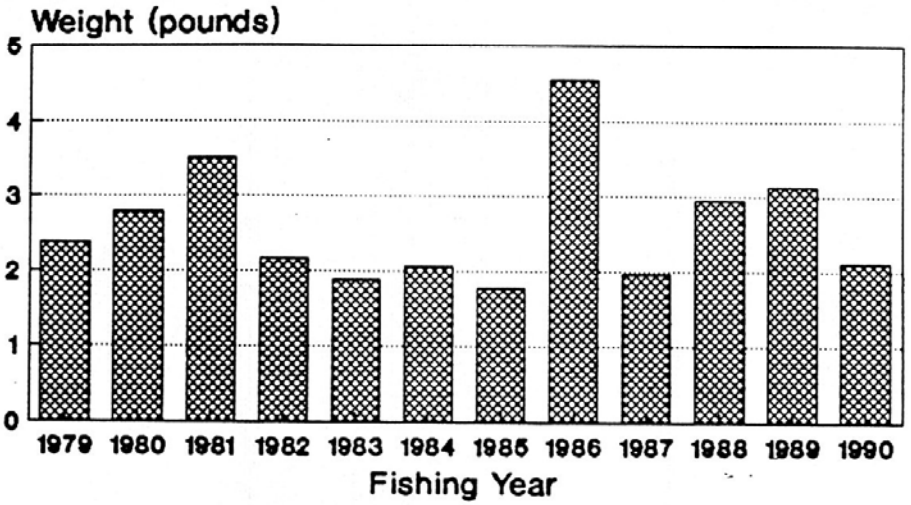


Fig. 2. Red drum recreational mean weight (Type A)

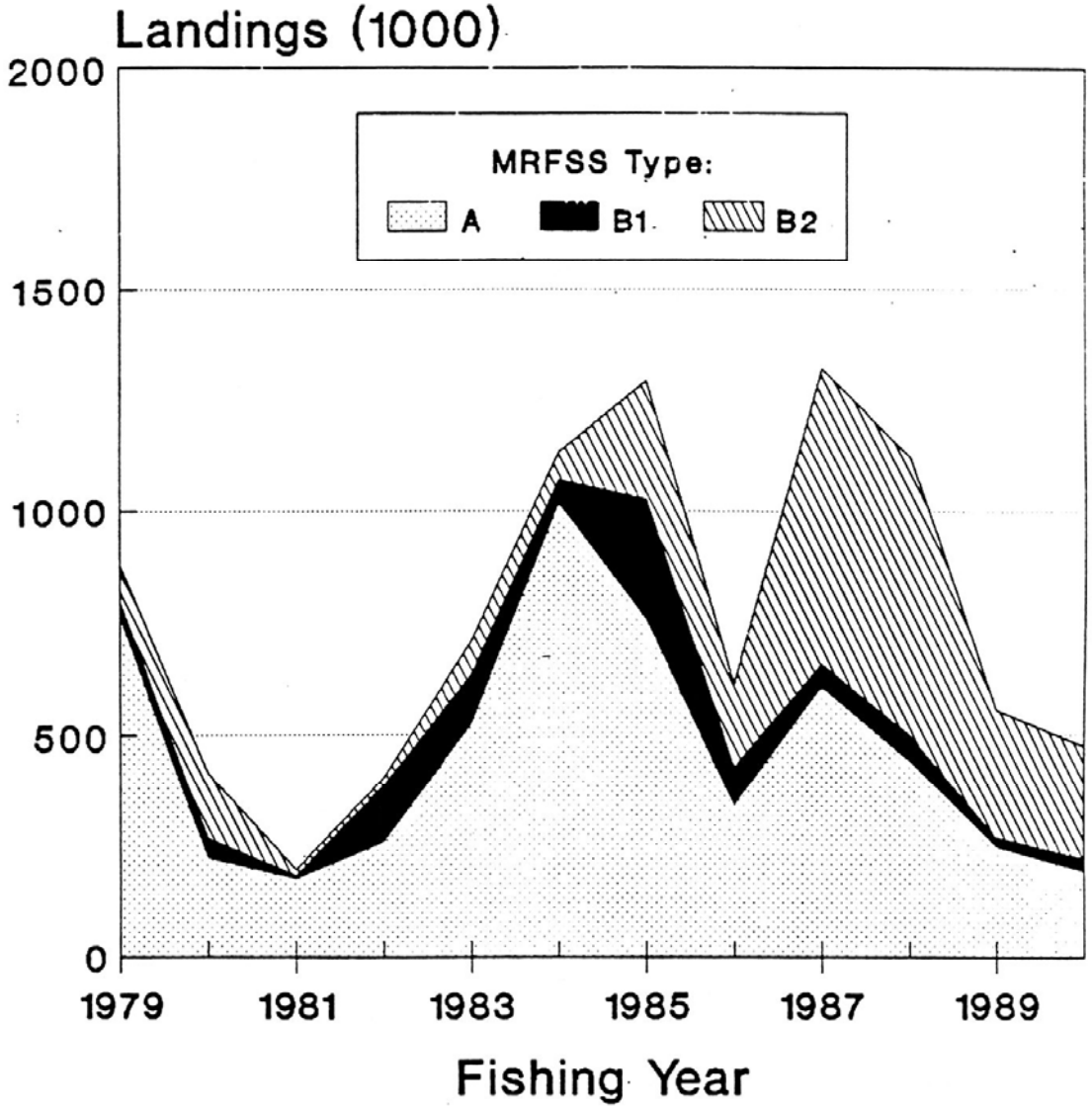


Fig. 3. Red drum recreational catches in numbers.

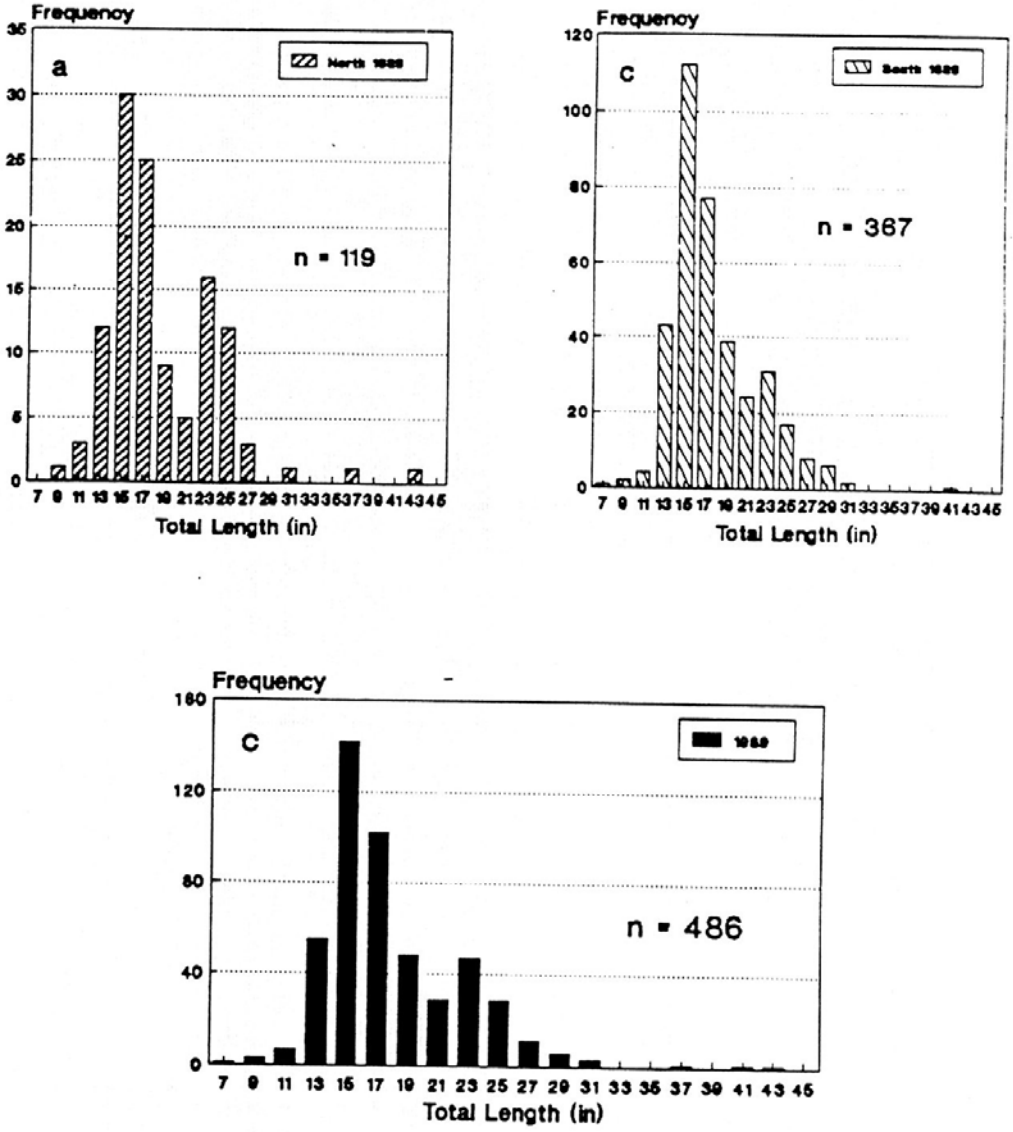


Fig. 4. Red drum recreational length frequencies, 1989.

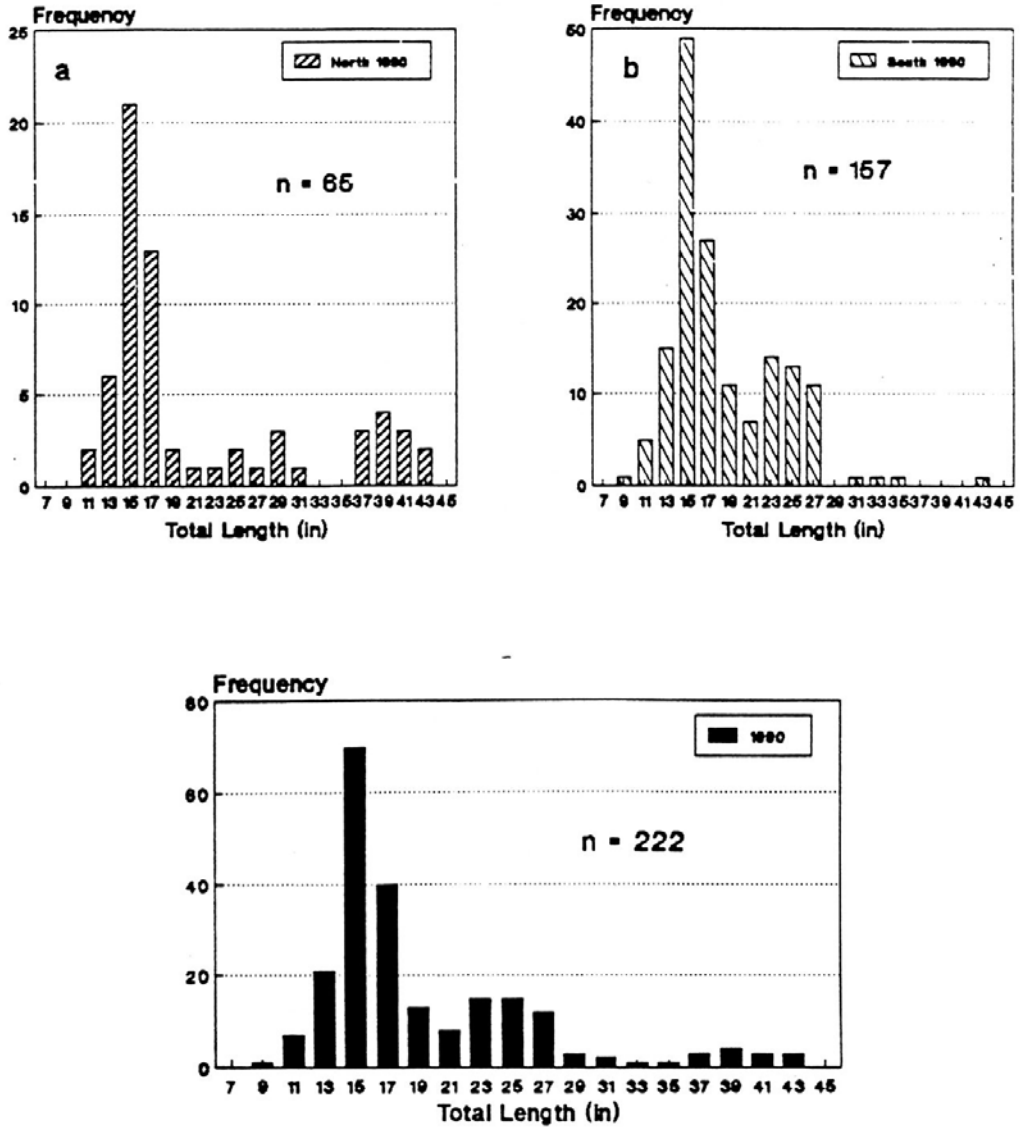


Fig. 5. Red drum recreational length frequencies, 1990.

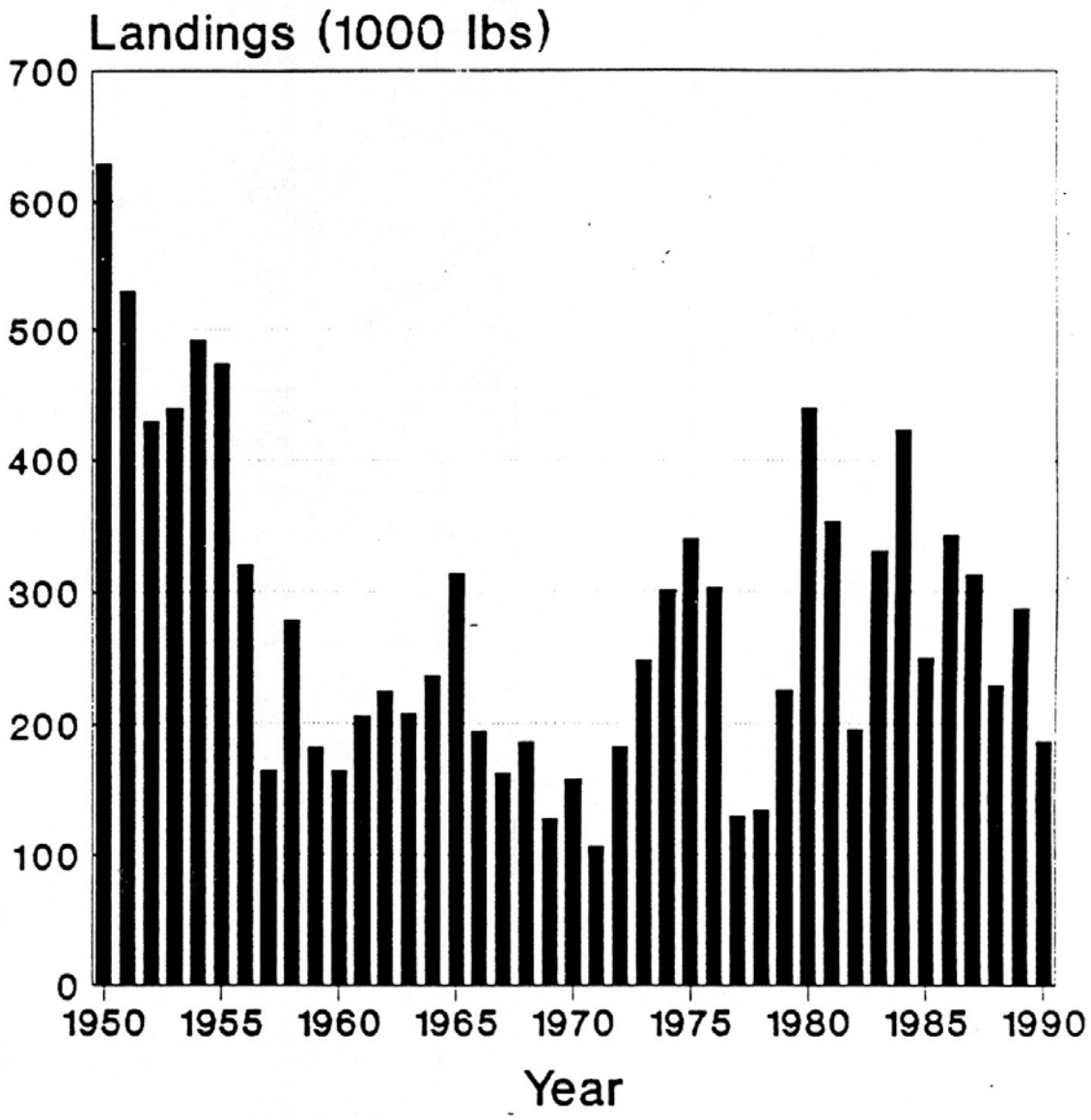
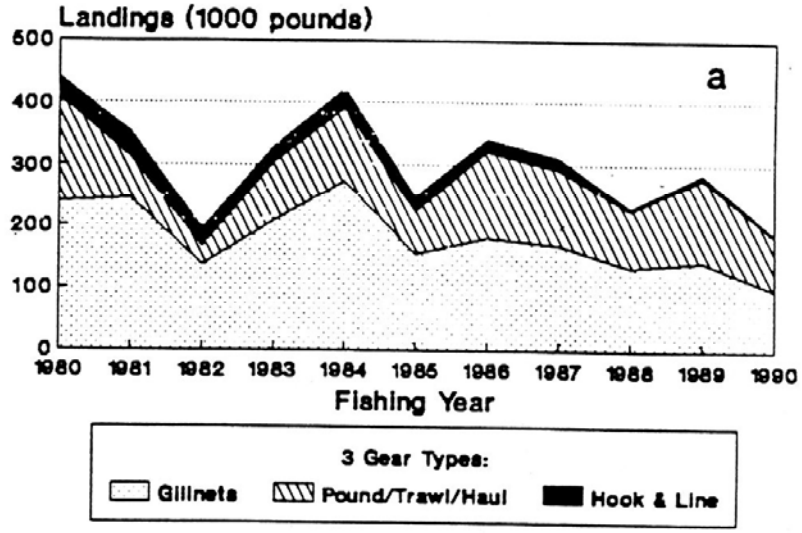


Fig. 6. Red drum commercial landing (1950-1990).



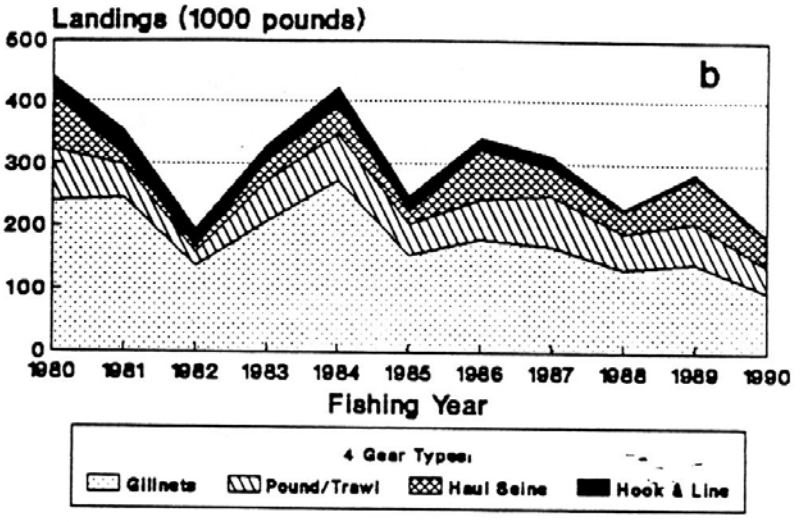


Fig. 7. Red drum commercial landings in weight by a) 3 or b) 4 gears.

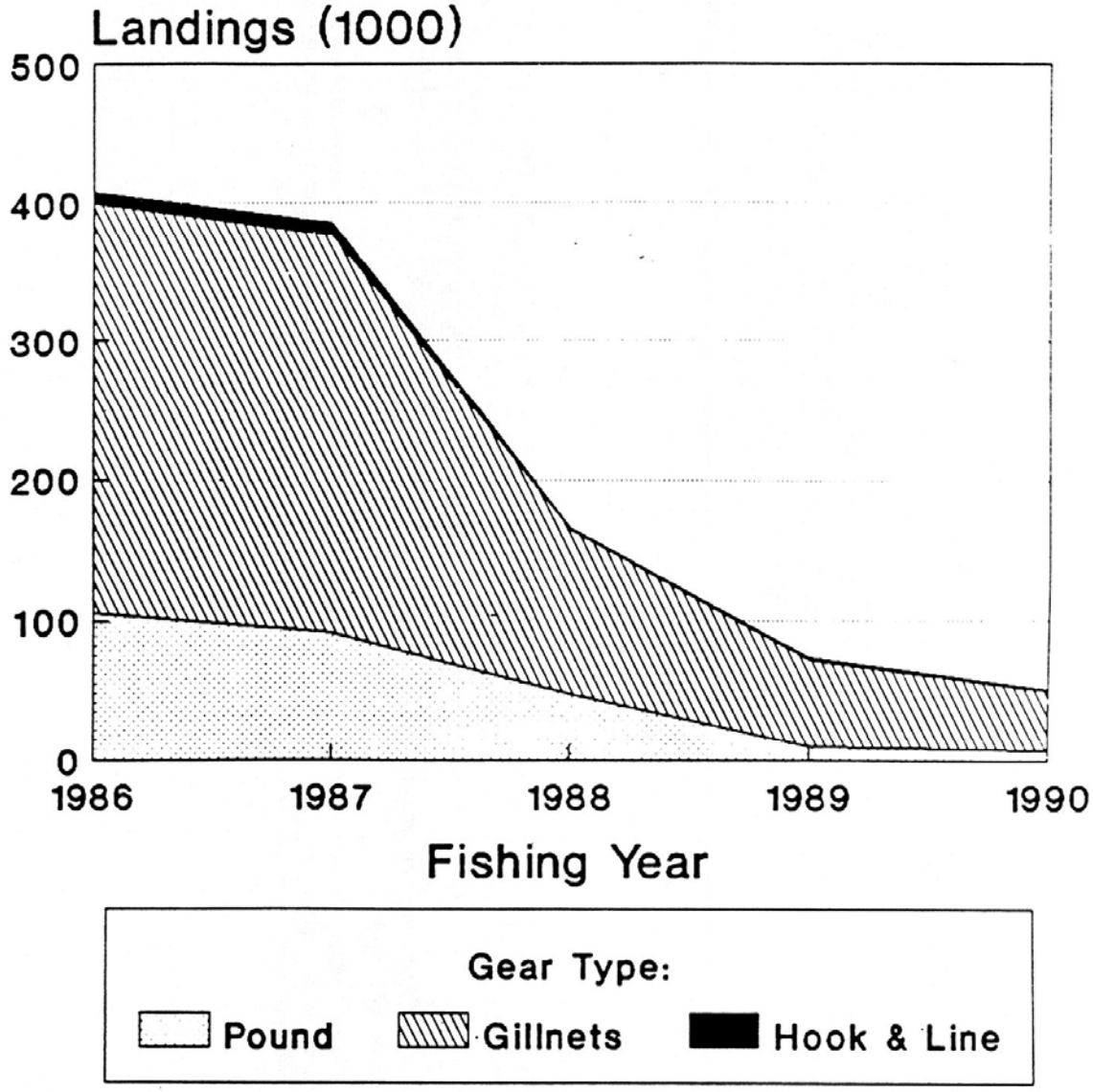


Fig. 8. Red drum commercial landing in numbers by gear.

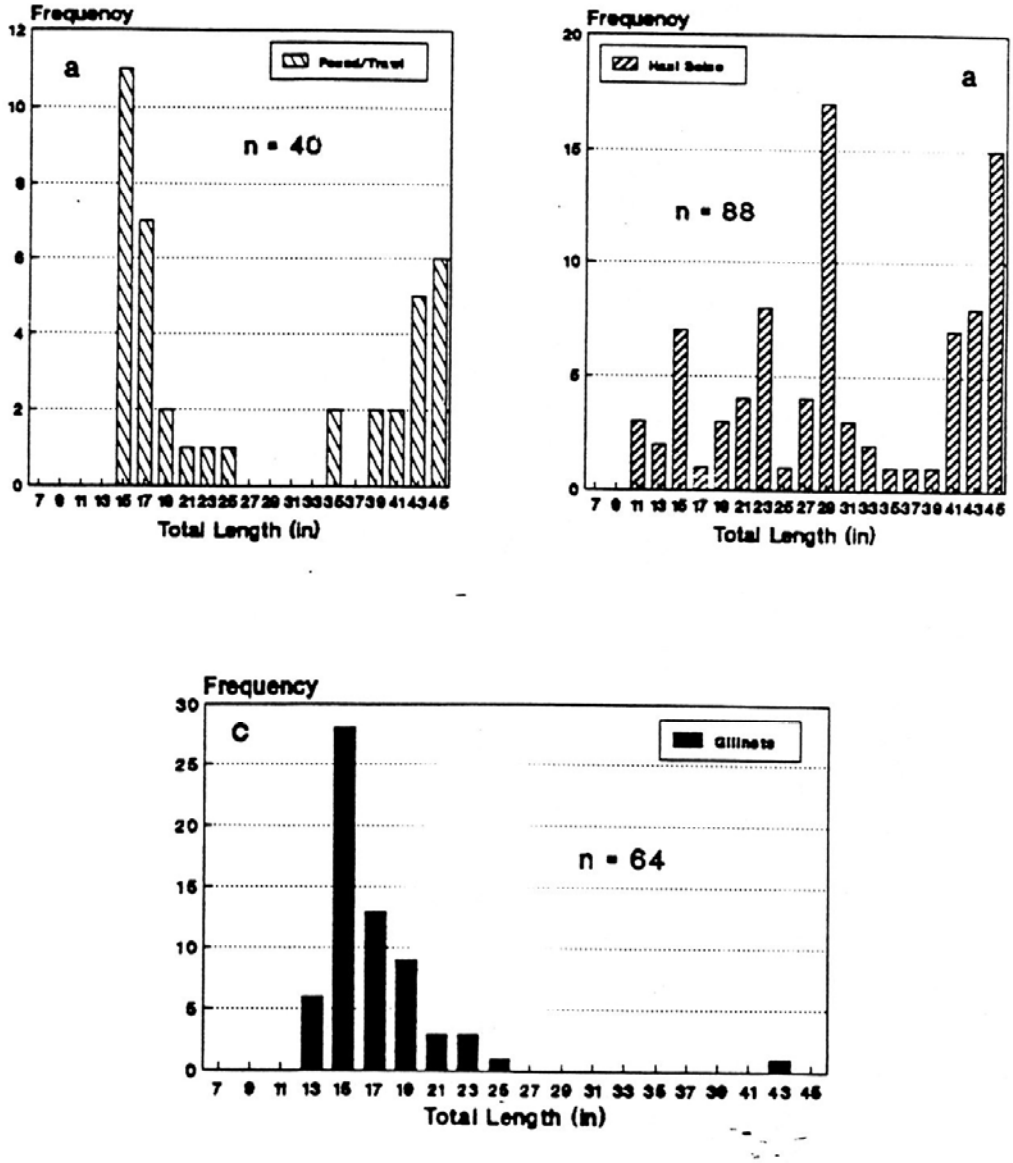


Fig. 9. Red drum commercial length frequencies, 1989.

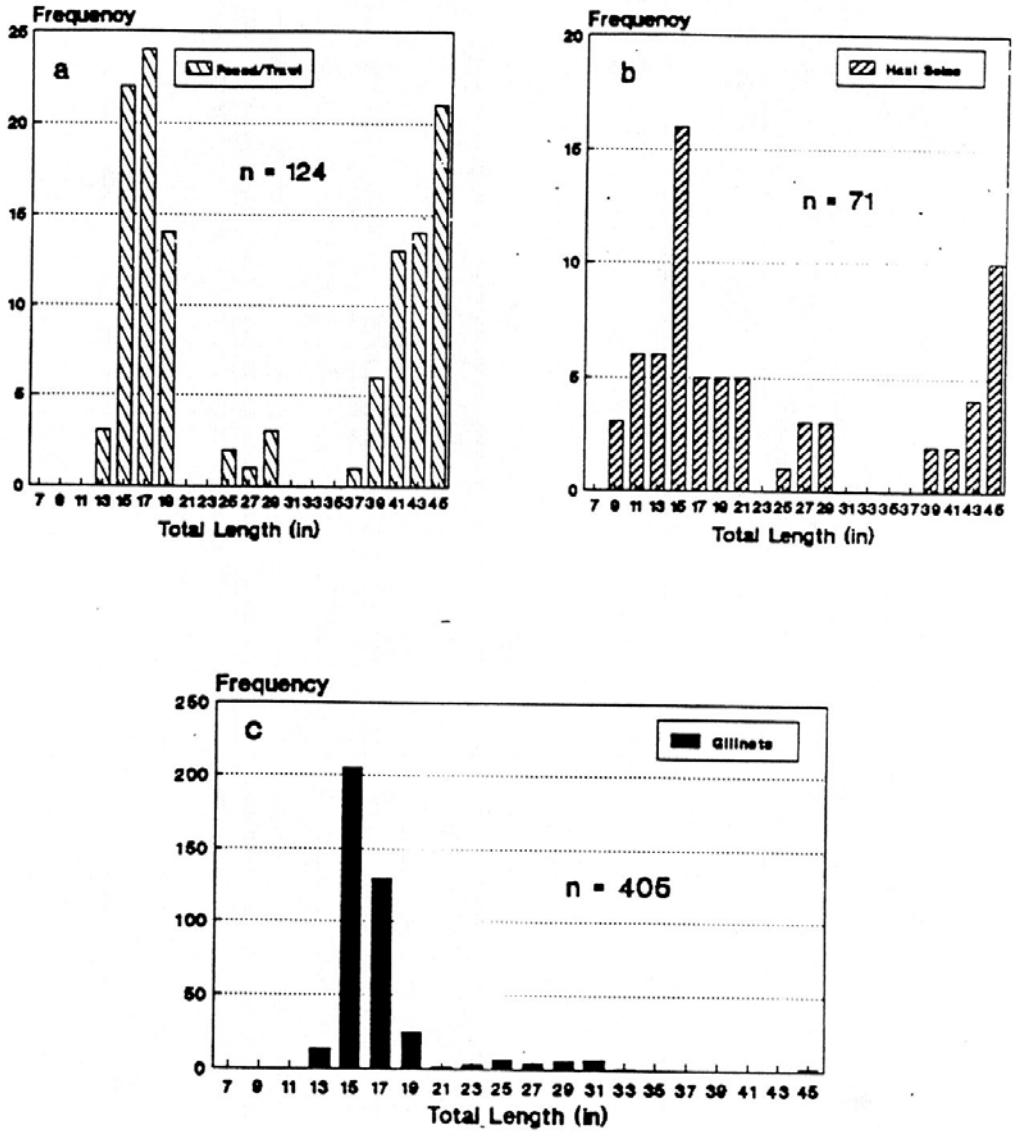
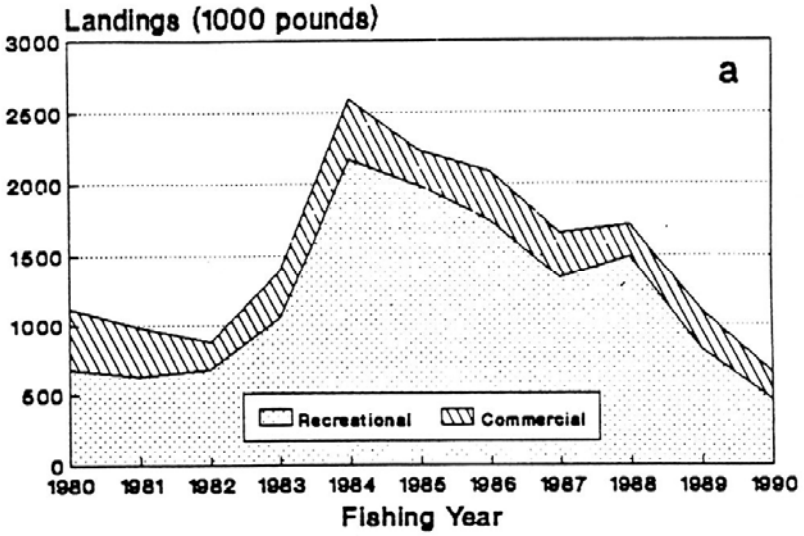


Fig. 10. Red drum commercial length frequencies, 1990.



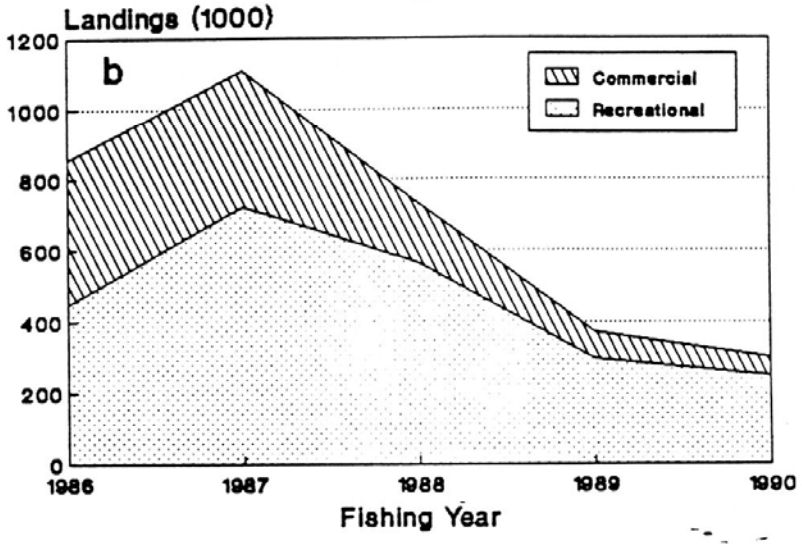


Fig. 11. Total red drum catch: a) weight and b) numbers.

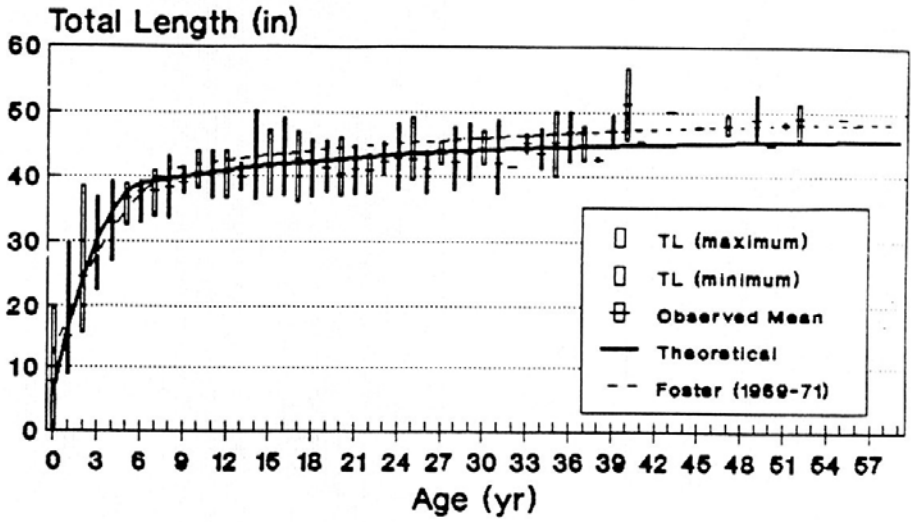


Fig. 12. Red drum double von Bertalanffy growth curve (1986-1990 data).

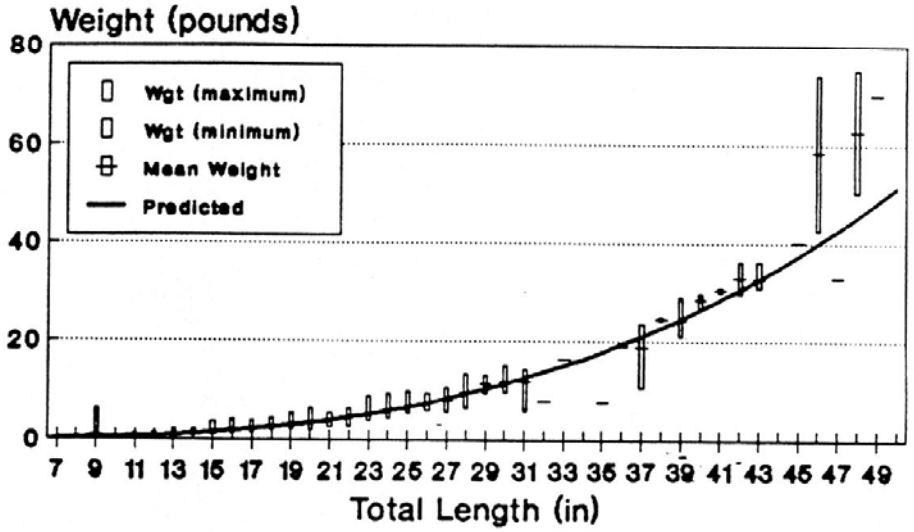


Fig. 13. Red drum mean weight at Length (MRFSS: 1986-1990).

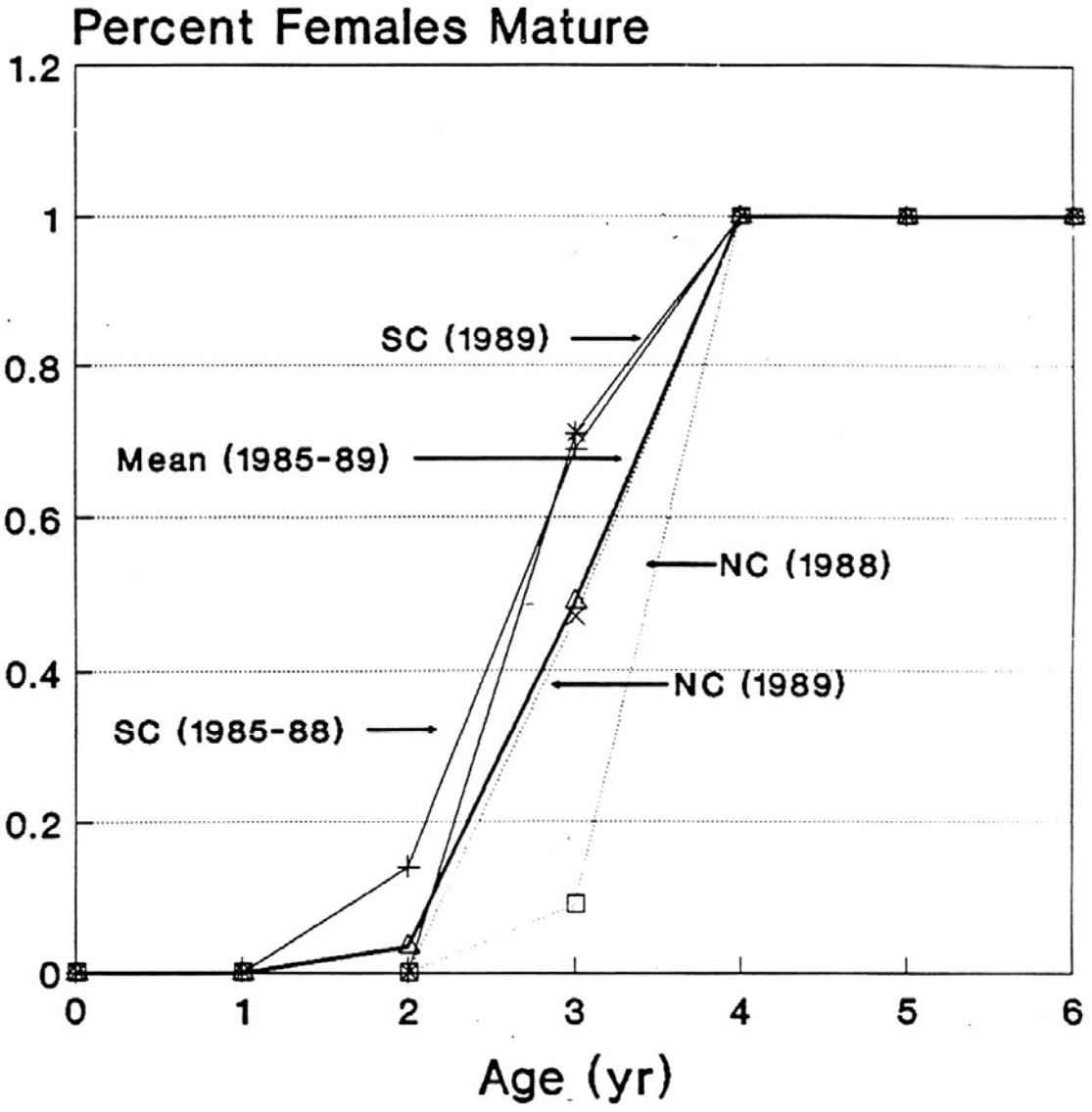


Fig. 14. Recent red drum maturity schedules.

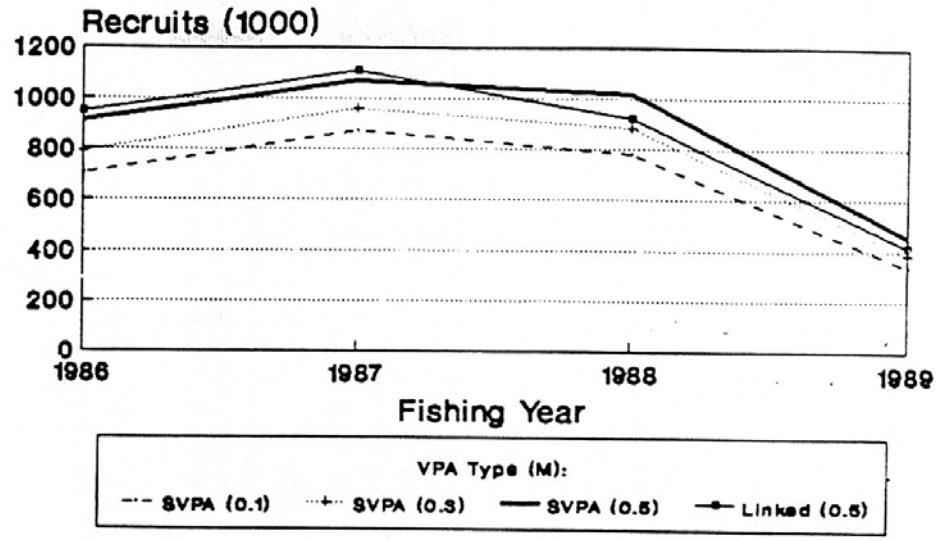


Fig. 15. Red drum recruitment to age 1.

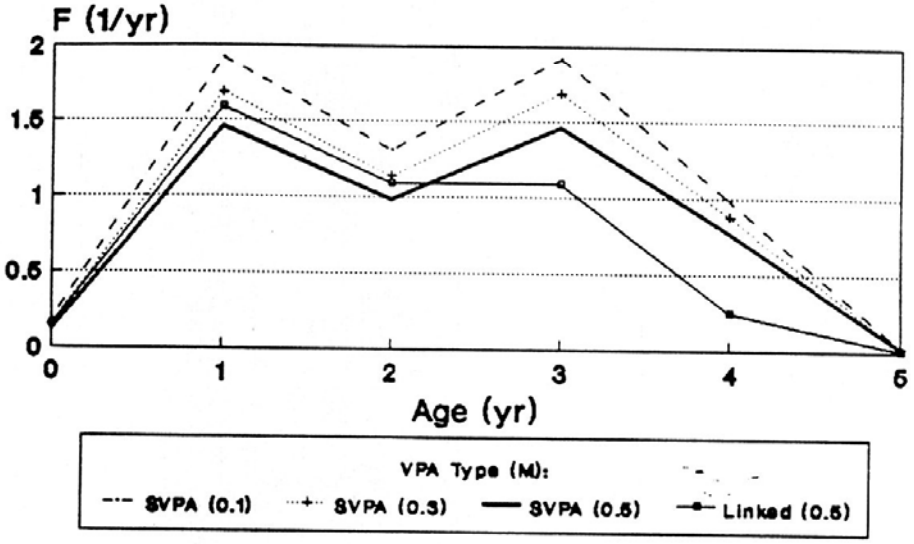


Fig. 16. Red drum mean F vectors.

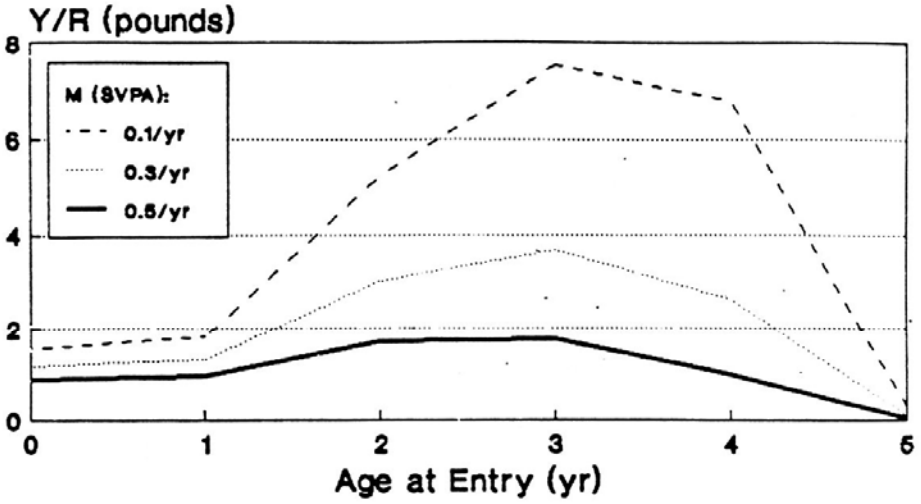


Fig. 17. Red drum yield per recruit with F multiple = 1.

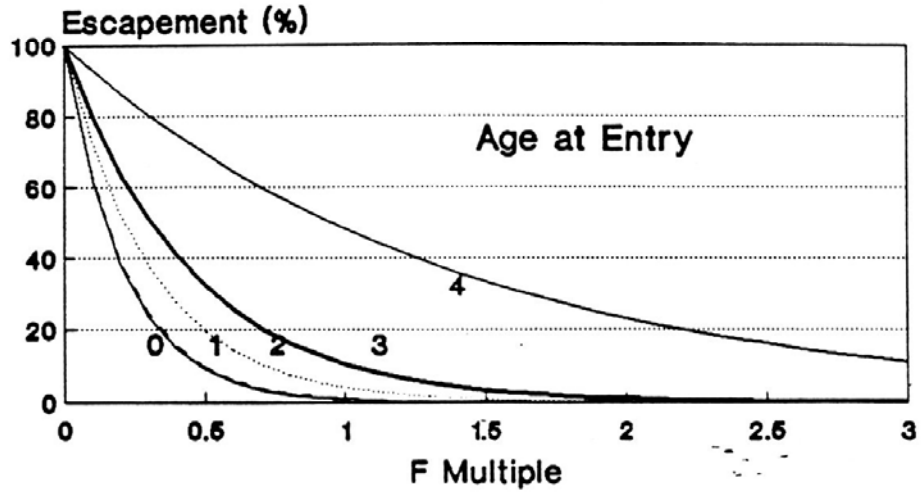


Fig. 18. Red drum escapement based on SVPA with subadult M = 0.5.

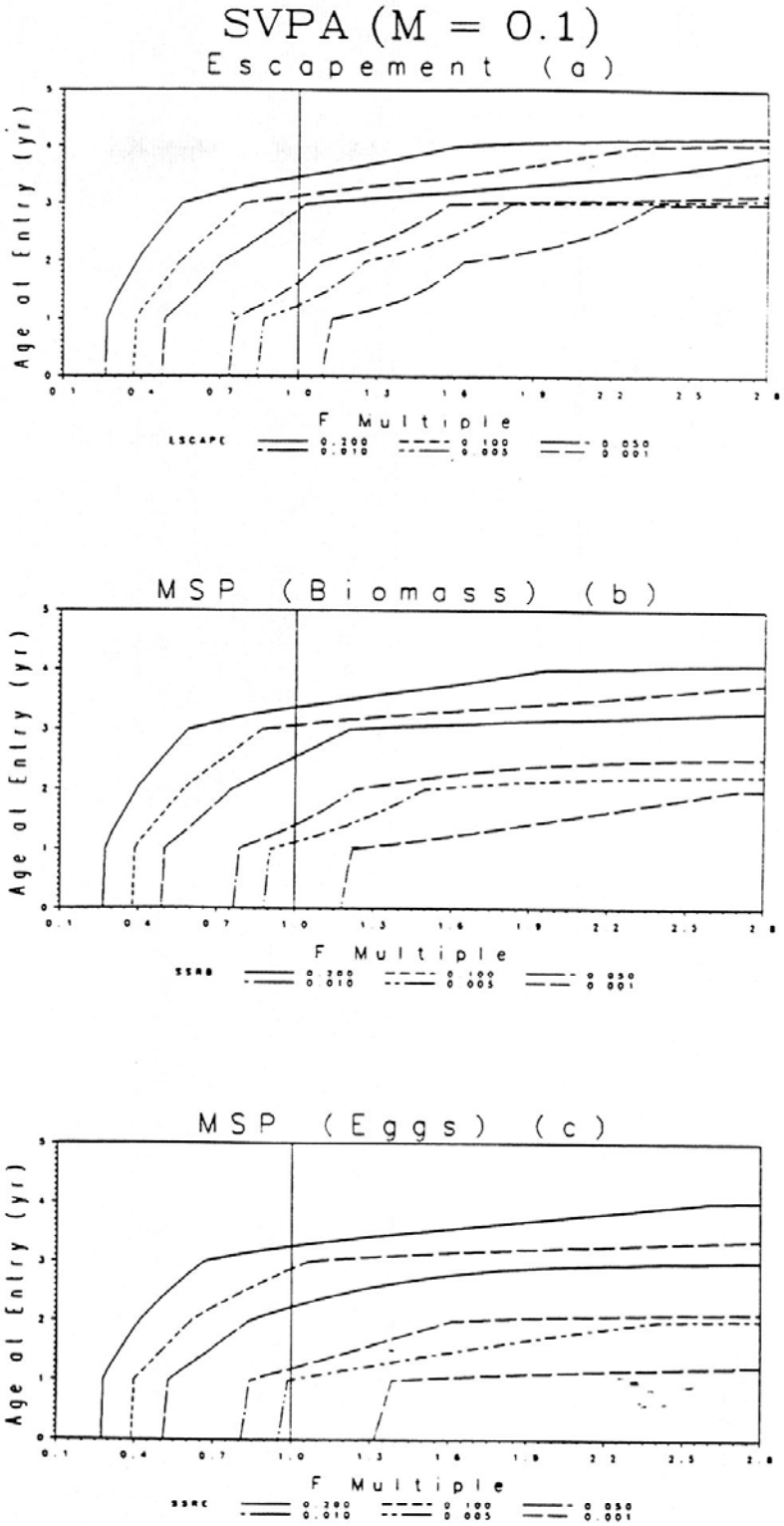


Fig. 19. **Escapement and maximum spawning potential isopleths for red drum based on fishing mortalities estimated with subadult M_1 = 0.1 using Separable VPA (M_2 = 0.1). Contours are of proportion of a) escapement to age 6, b) maximum spawning potential in biomass, and c) maximum spawning potential in egg production.**

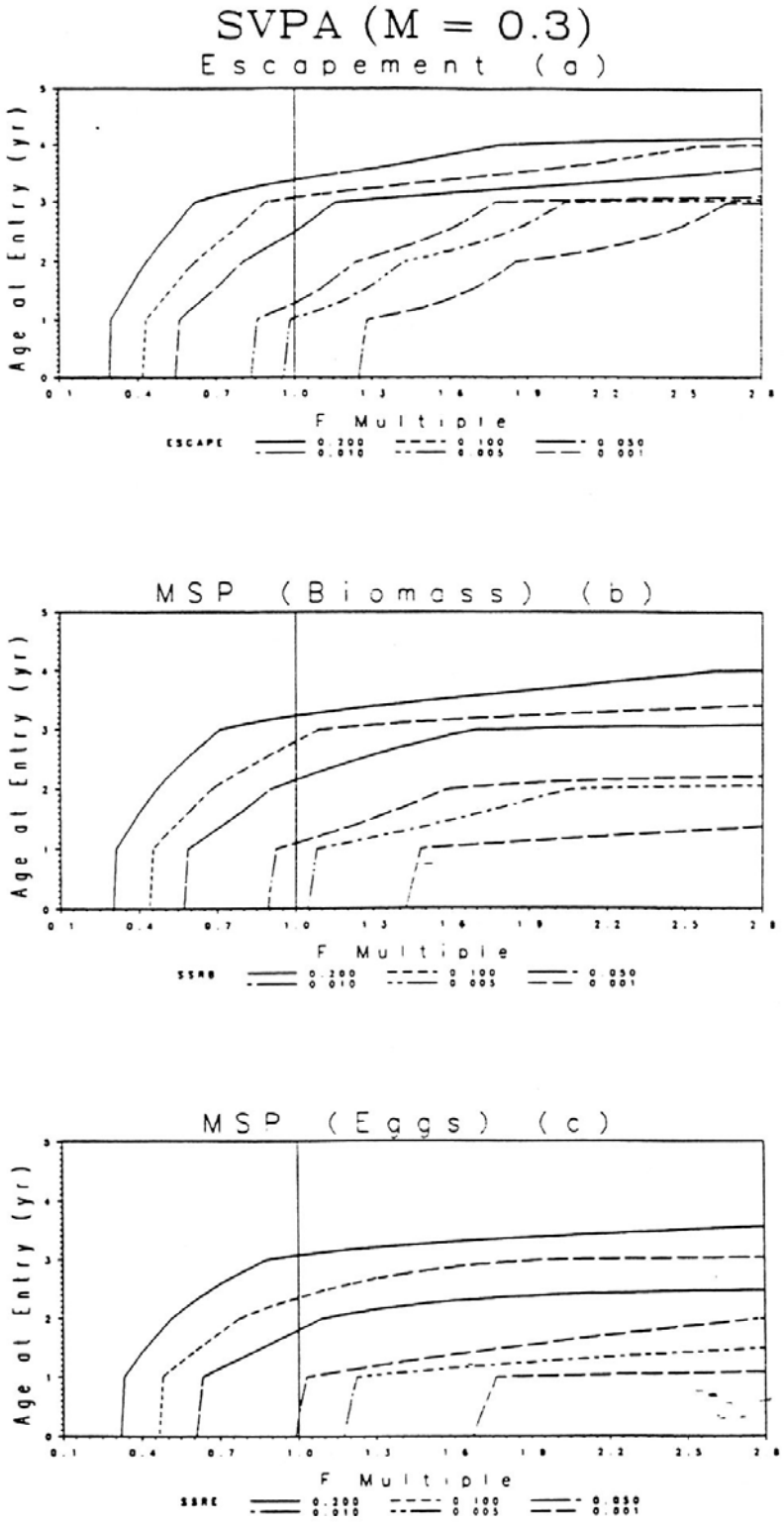


Fig. 20. Escapement and maximum spawning potential isopleths for red drum based on fishing mortalities estimated with subadult M_1 = 0.3 using Separable VPA (M_2 = 0.135). Contours are of proportion of a) escapement to age 6, b) maximum spawning potential in biomass, and c) maximum spawning potential in egg production.

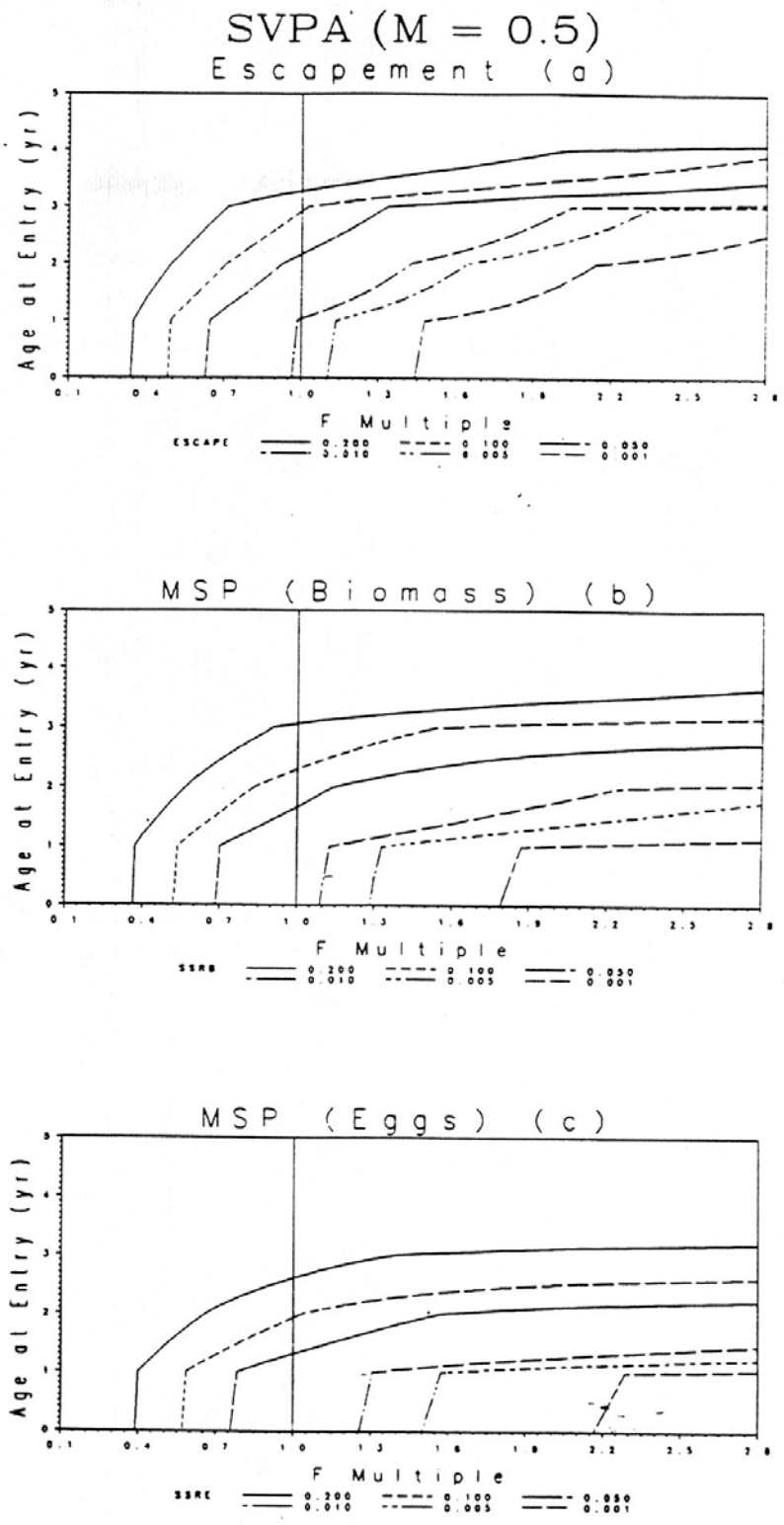


Fig. 21. Escapement and maximum spawning potential isopleths for red drum based on fishing mortalities estimated with subadult M_1 = 0.5 using Separable VPA (M_2 = 0.17). Contours are of proportion of a) escapement to age 6, b) maximum spawning potential in biomass, and c) maximum spawning potential in egg production.

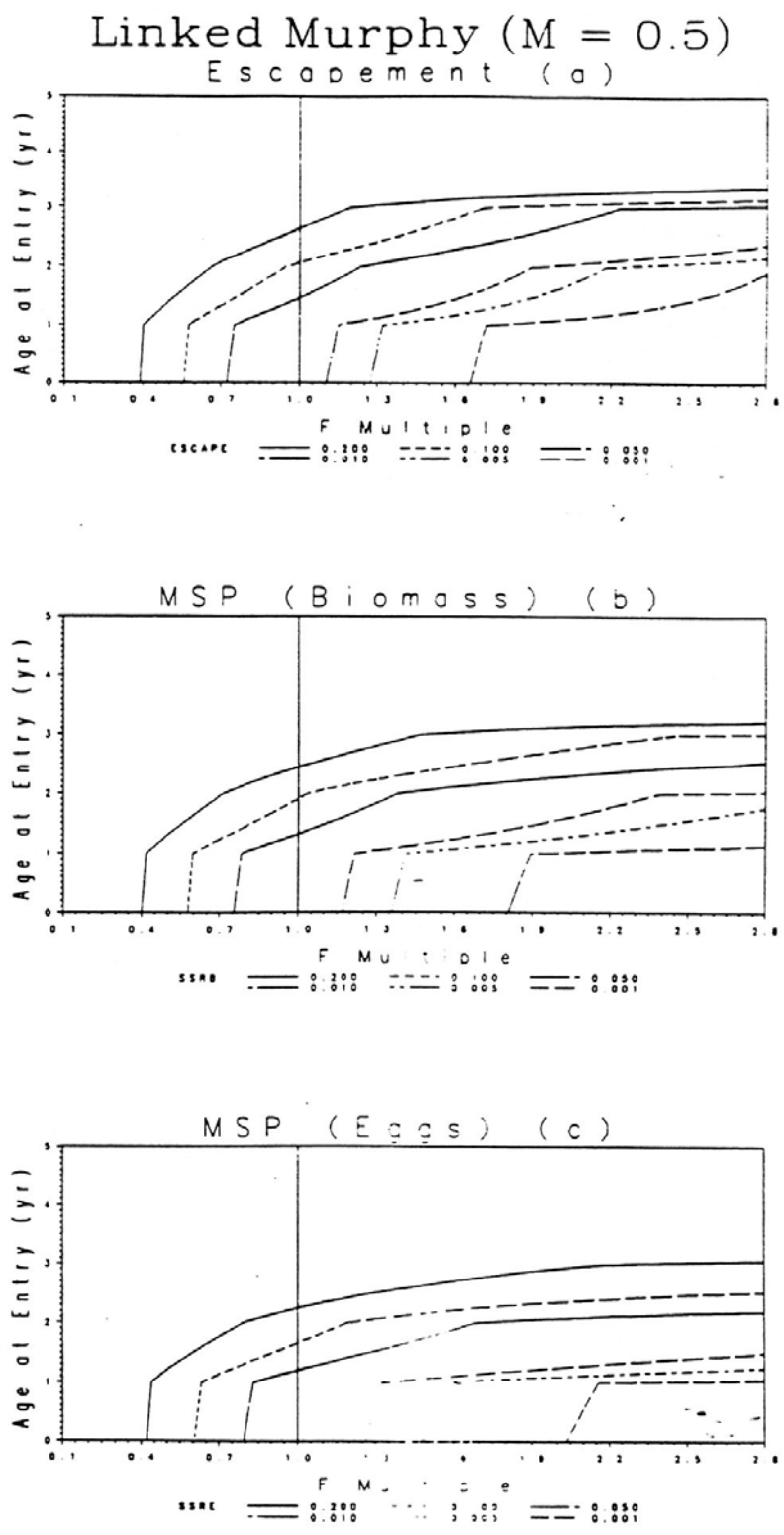


Fig. 22. Escapement and maximum spawning potential isopleths for red drum based on fishing mortalities estimated with subadult M_1 = 0.5 using Linked Murphy VPA (M_2 = 0.17).. Contours are of proportion of a) escapement to age 6, b) maximum spawning potential in biomass, and c) maximum spawning potential in egg production.

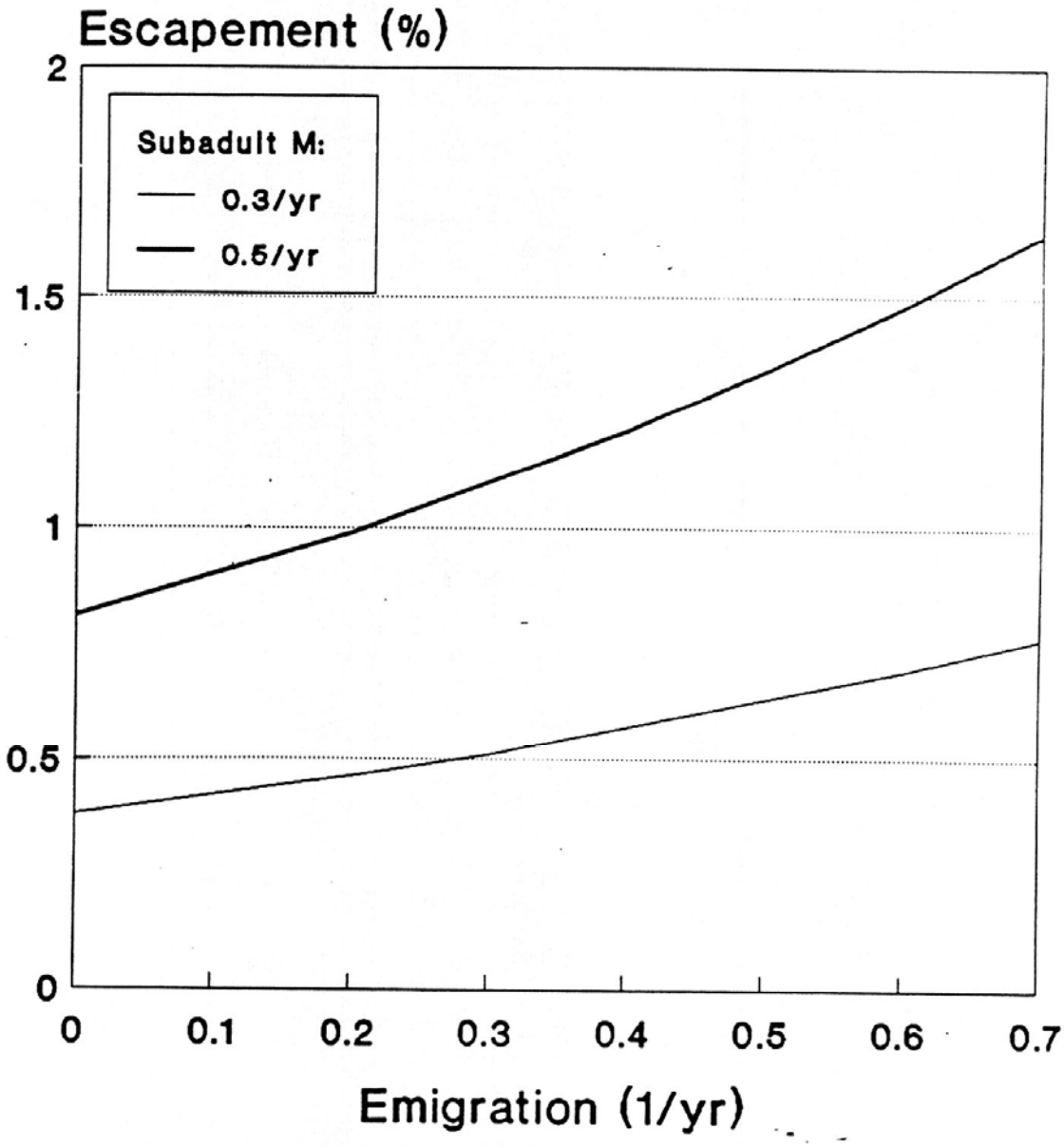


Fig. 23. Red drum escapement varying with emigration during age 3.

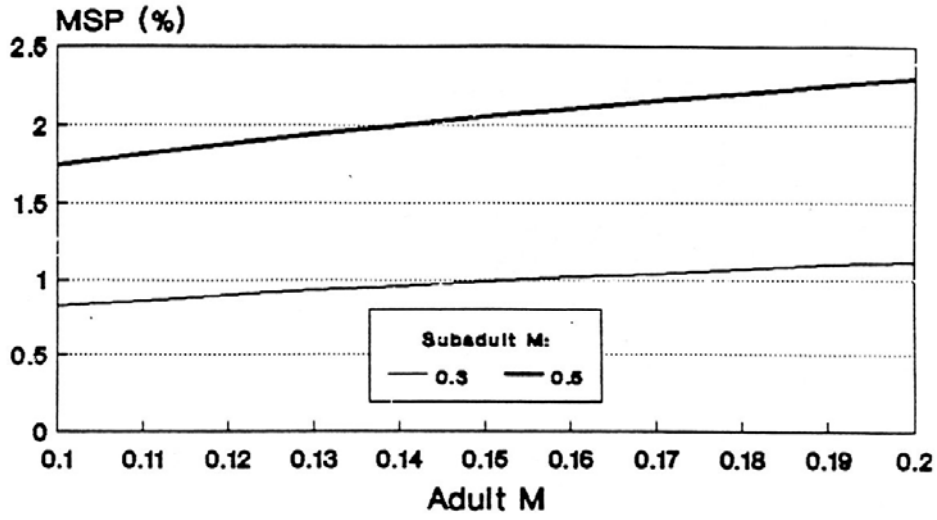


Fig. 24. Red drum MSP (egg production) varying with adult M.

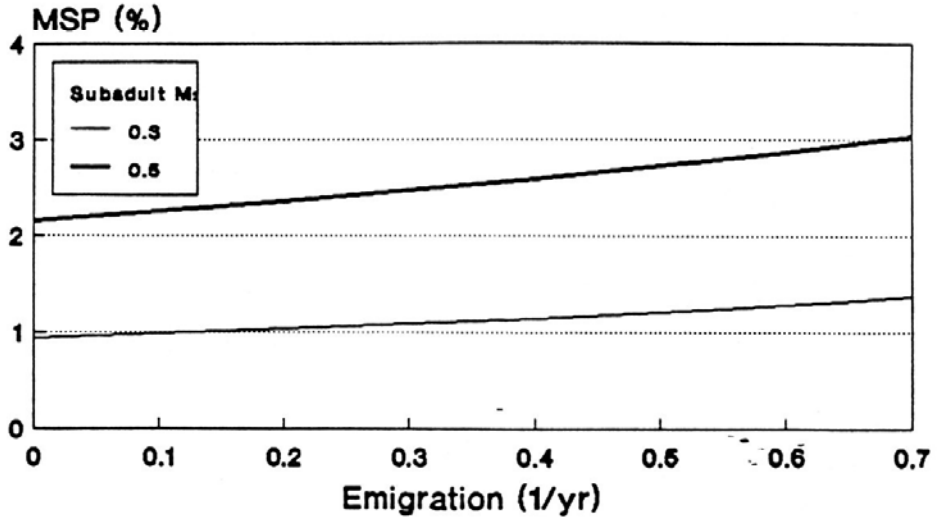


Fig. 25. Red drum MSP (egg production) varying with emigration during age 3.

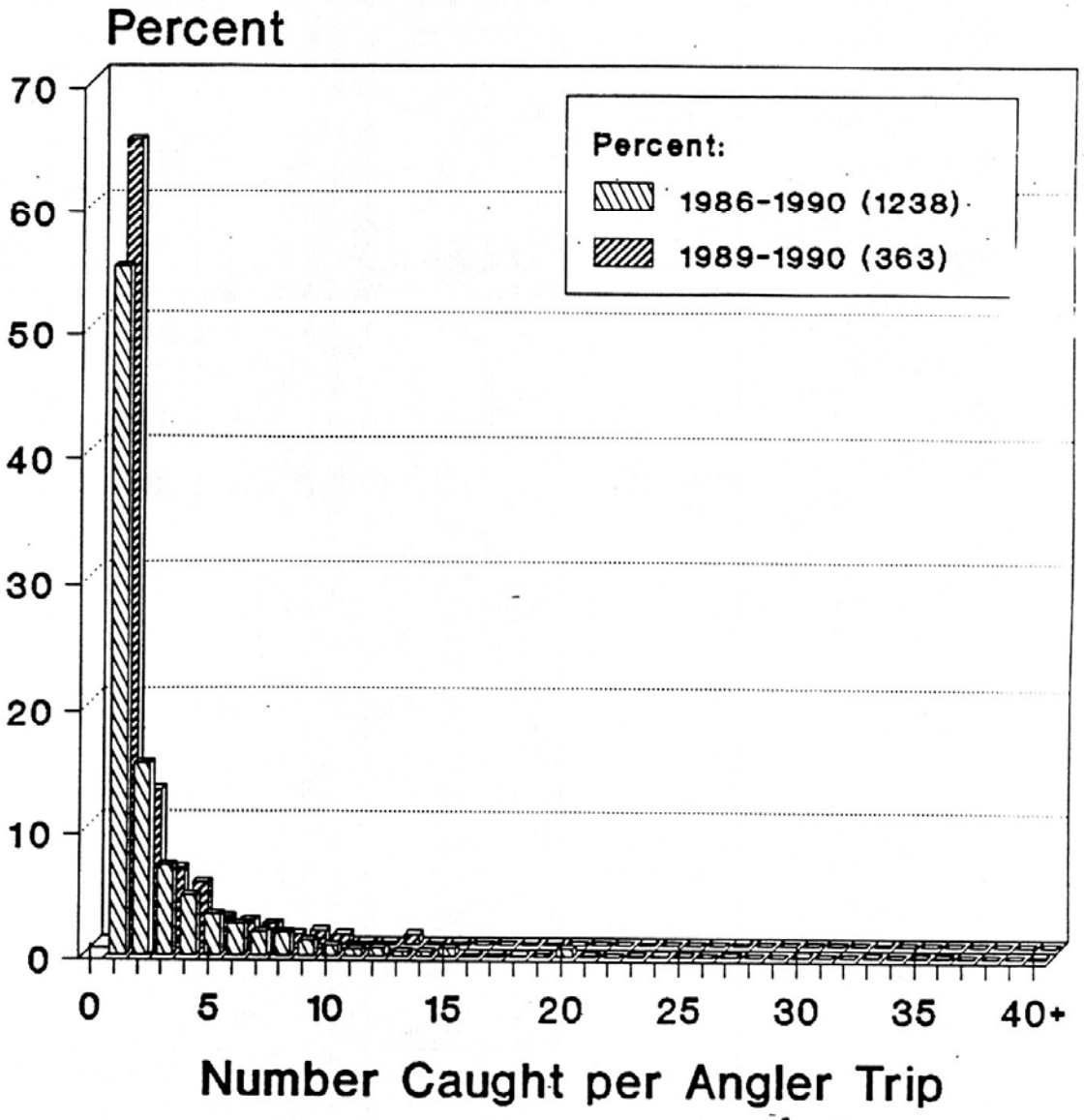


Fig. 26. Red drum catch in numbers per angler trip.

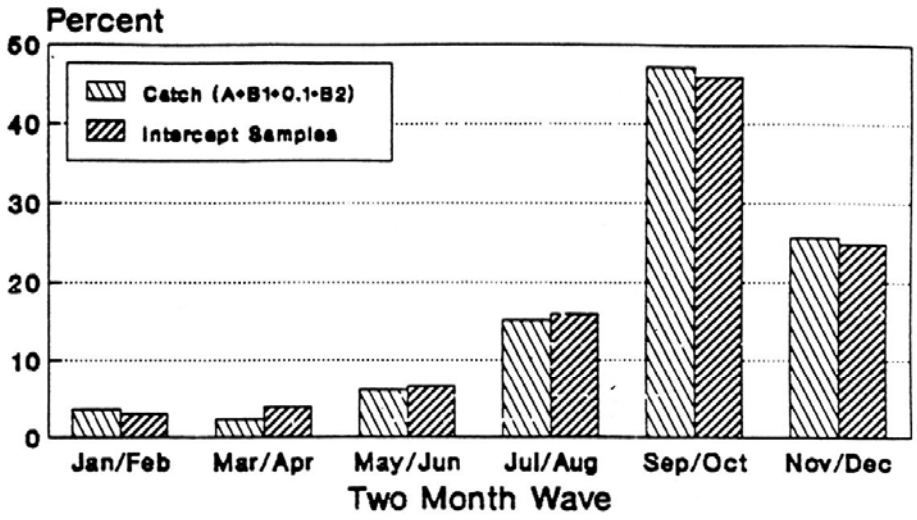


Fig. 27. Red drum recreation catch and sampling in 2-month waves (1986-90).

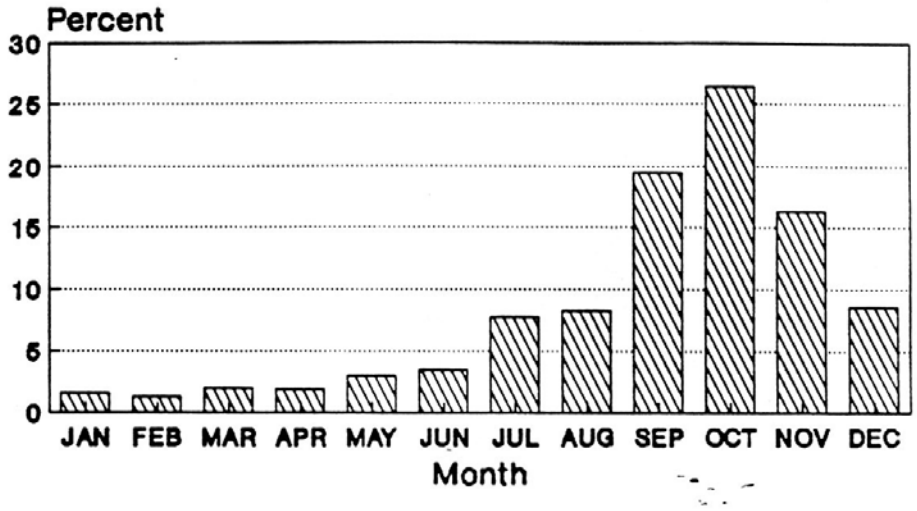


Fig. 28. Red drum monthly intercept sampling for seasonal savings.