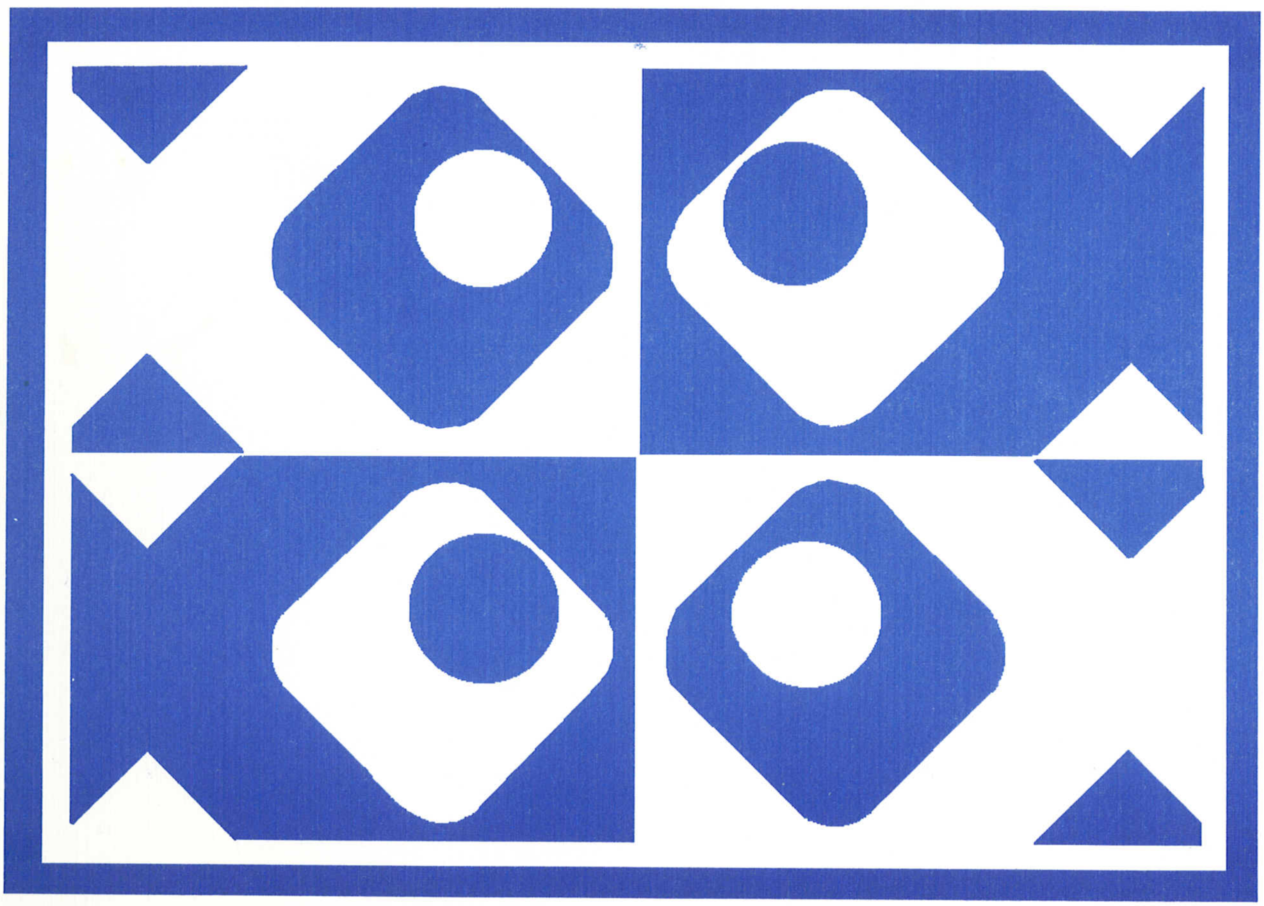
NOAA Technical Memorandum
NMFS-SEFSC-368

Status of Fishery Resources Off the Southeastern United States for 1993



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

NOAA Technical Memorandum
NMFS-SEFSC-368

Status of Fishery Resources Off the Southeastern United States for 1993

U.S. DEPARTMENT OF COMMERCE
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National Oceanic and Atmospheric Administration
D. James Baker, Undersecretary for Oceans and Atmosphere

National Marine Fisheries Service
Rolland A. Schmitten, Assistant Administrator for Fisheries

Southeast Fisheries Science Center
Miami, Florida

February 1995

NOTICE

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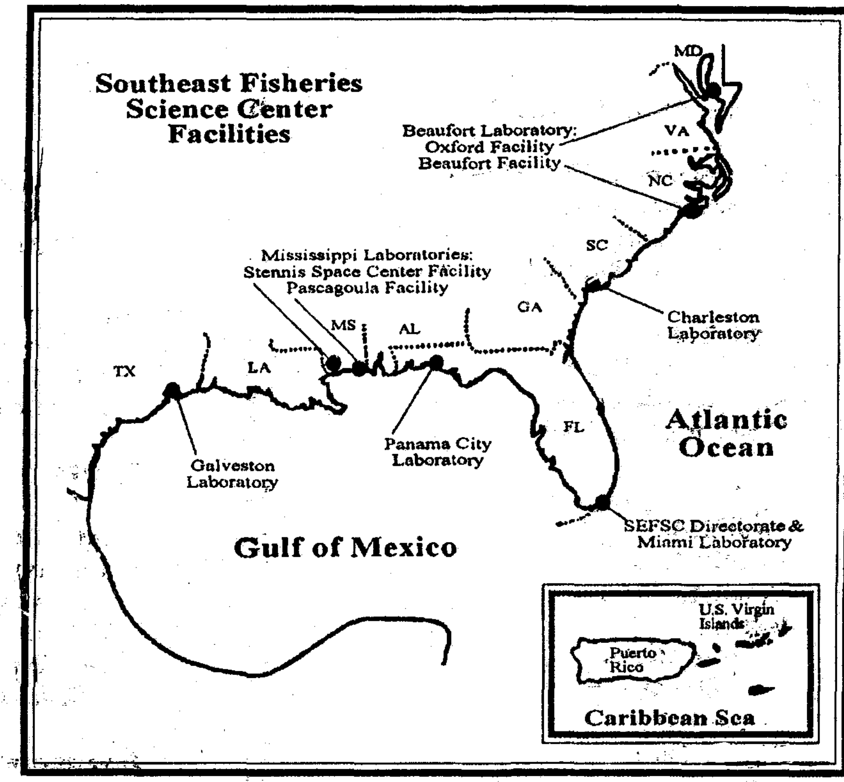
Southeast Fisheries Science Center



Dr. Bradford E. Brown, Director
75 Virginia Beach Drive
Miami, Florida 33149
(305) 361-4286

The Southeast Fisheries Science Center is comprised of six laboratories and a headquarters office in Miami, Florida. Scientists within the laboratories collect data, conduct research, and provide scientific information concerning the status and well being of living marine resources of southeastern United States, Puerto Rico, U.S. Virgin Islands, and in the open Atlantic Ocean for large pelagic species.

BEAUFORT LABORATORY
Dr. Ford A Cross, Director
101 Pivers Island Rd.
Beaufort, North Carolina 28516
(919) 728-8724

Scientists at the Beaufort Laboratory investigate the location, extent, spatial change, functions, and qualities of estuarine and marine habitats including natural and restored wetland systems. Research and stock assessments are conducted on menhaden, Atlantic reef resources, coastal pelagics, and sea turtles.

CHARLESTON LABORATORY
Dr. Robert R. Kifer, Director
217 Fort Johnson Road
Charleston, South Carolina 29412
(803) 762-1200

Scientists at the Charleston Laboratory investigate fishery issues dealing with seafood safety, wholesomeness, fishery management, habitat use, molluscan shellfish, and protected species. Research areas include marine biotoxins, pathogens, chemical contaminants, fishery forensics, molecular biology, and marine lipid chemistry.

MIAMI LABORATORY
Dr. Joseph E. Powers, Director
75 Virginia Beach Drive
Miami, Florida 33149
(305) 361-4284

Scientists at the Miami Laboratory investigate fisheries for tunas, marlins, sailfish, swordfish, sharks, and Gulf and Caribbean reef resources. Research is also conducted on population dynamics of regional fishery resources and protected species of sea turtles and marine mammals.

PANAMA CITY LABORATORY
Dr. Churchill B. Grimes, Director
3500 Delwood Beach Road
Panama City, Florida 32408
(904) 234-6541

Scientists at the Panama City Laboratory conduct research to provide life history information such as stock identification, age, growth, and reproduction of southeastern fishery stocks. Laboratory scientists also conduct studies of regional charterboat fisheries.

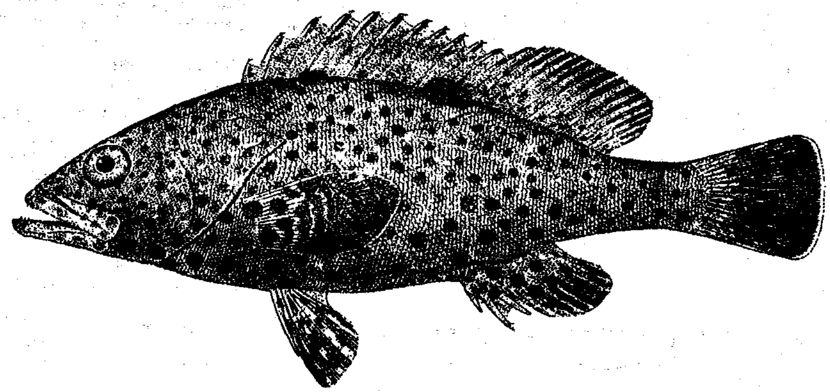
MISSISSIPPI LABORATORIES
Dr. Scott Nichols, Director
3209 Frederic Street
Pascagoula, Mississippi 39567
(601) 762-4591

Scientists at Mississippi Laboratories (consisting of facilities at Pascagoula and the Stennis Space Center) conduct investigations and surveys using research vessels and aircraft of fishery and marine mammal resources in the Gulf of Mexico. Research is also conducted on space technology applications for recreational and commercial fisheries. The NOAA fishery research vessels, *Oregon II* and *Chapman*, are docked at the Pascagoula facility and managed for fishery research missions.

GALVESTON LABORATORY
Dr. Roger J. Zimmerman, Director
4700 Avenue U
Galveston, Texas 77550
(409)766-3500

Scientists at the Galveston Laboratory investigate fisheries of shrimp and demersal fish. Research is conducted on brown, pink, and white shrimp forecasting, stock assessment, and on the biological value of marshlands and estuarine habitats for fishery resources. A nursery at the head-start facility is used to rear sea turtles for use in testing turtle excluder devices and other savings gear. Additional research is directed towards turtle habitat and physiology.

Stock Assessment Techniques



Rock hind (*Epinephelus adscensionis*)

The Southeast Fisheries Science Center, with headquarters in Miami, Florida, periodically updates its assessments of important living marine resources in the U.S. Atlantic Ocean, U.S. Gulf of Mexico, Puerto Rico, and the U.S. Virgin Islands. These assessments using data gathered from commercial, recreational, and fishery independent sources provide detailed information for state and federal fishery administrators, the fishing community, and the public in general. This report is based on those assessments and summarizes the general status of fishery resources.

The report is divided into major sections: Fishery Trends; Oceanic Pelagics; Coastal Pelagics; Reef Fish; Sciaenids; Sharks; Menhaden, Butterfish, and Coastal Herrings; Invertebrates; Marine Mammals; and Sea Turtles. Some sections represent species groups that are very numerous (e.g., reef fish with hundreds of species), and in those sections only selected species are covered.

OVERVIEW OF ASSESSMENT APPROACHES

In fisheries science, assessments are conducted in various ways depending on the nature of the fishery, the type and amount of data available, and the information required for management. **Figure 1** is a diagram of several generic ways in which survey and catch data, in the lower left and right boxes respectively, can be combined to provide assessment advice, illustrated at the top of the diagram. The simplest approach is when catch data are used to generate indices of abundance, as seen by moving vertically along the right side of **Figure 1**. A more complex approach is when the catch data are combined with research vessel survey data to generate indices of abundance, as seen by moving vertically along the left side of **Figure 1**. These two approaches are frequently supplemented with knowledge of the life history generated from biological data from sampling fisheries and research catches. A third approach is to use the information about total stock size and population productivity generated under the first two approaches to determine the relationship between productivity and stock size; this is referred to as production models. Finally, for those species where the age composition can be determined reliably, more detailed analytic assessments can be developed that use the information in the age structure of the population and the catches to determine productivity.

The different information paths in **Figure 1** result in assessment information having different levels of sophistication and reliability. The actual level of complexity of an assessment is determined by the amount of information available and by the amount of research required to interpret this information.

FISHERY MANAGEMENT

Fisheries occurring primarily in the Exclusive Economic Zone of the southeastern United States are managed under Fishery Management Plans developed by the Gulf of Mexico Fishery Management Council (GMFMC), the South Atlantic Fishery Management Council (SAFMC), the Caribbean Fishery Management Council (CFMC) and in a few instances, under Preliminary Fishery Management Plans or Secretarial Fishery Management Plans developed by the National Marine Fisheries Service (NMFS). Fisheries occurring primarily in state waters are managed by the individual states or under Interstate Agreements under the auspices of the Gulf States Marine Fisheries Commission or the Atlantic States Marine Fisheries Commission. Management plans currently in place are shown in **Tables 1** and **2**.

In 1993, Congress passed the Atlantic Coastal Fisheries Cooperative Management Act to support and encourage development, implementation, and enforcement of effective interstate conservation and management of Atlantic coastal fishery resources. The Act directs the Atlantic States Marine Fisheries Commission to adopt fishery management plans for coastal fisheries and establishes an obligation on the part of the states to implement the Commission's plans. The Commission must adopt standards and procedures to ensure that fishery resources are conserved, the best scientific information is used, and the public has adequate opportunity to participate in the process. The Commission is required to continually review state implementation and report its results to the Secretaries. If it finds a state not in compliance, the Commission must report that finding to the Secretaries of Commerce and Interior. If the Secretary of Commerce agrees with the Commission, the Secretary of Commerce may impose a moratorium on all fishing of the species in question within the respective state until compliance is accomplished.

DEFINITION OF TECHNICAL TERMS

Biological Reference Points: Fishing mortality rates that may provide acceptable protection against growth overfishing and/or recruitment overfishing for a particular stock. They are usually calculated from equilibrium yield per recruit curves and stock recruitment data. Examples are F_{max}, $F_{0.1}$, and $F_{30\%SPR}$.

Exploitation pattern: The distribution of fishing mortality over the age composition of the fish, determined by the type of fishing gear and spatial and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear; for example, increasing mesh or hook size or changing the ratio of harvest by gears exploiting the fish (e.g., gill net, trawl, hook and line).

Exploitation rate: The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Fishing mortality rate: The part of the total mortality rate applying to a fish population that is caused by man's harvesting. Fishing mortality is usually expressed as an instantaneous rate, as discussed under Mortality rate, and can range from 0 for no fishing to very high values such as 1.5 or 2.0. Fishing mortality rates are estimated using a variety of techniques, depending on the available data for a species or stock.

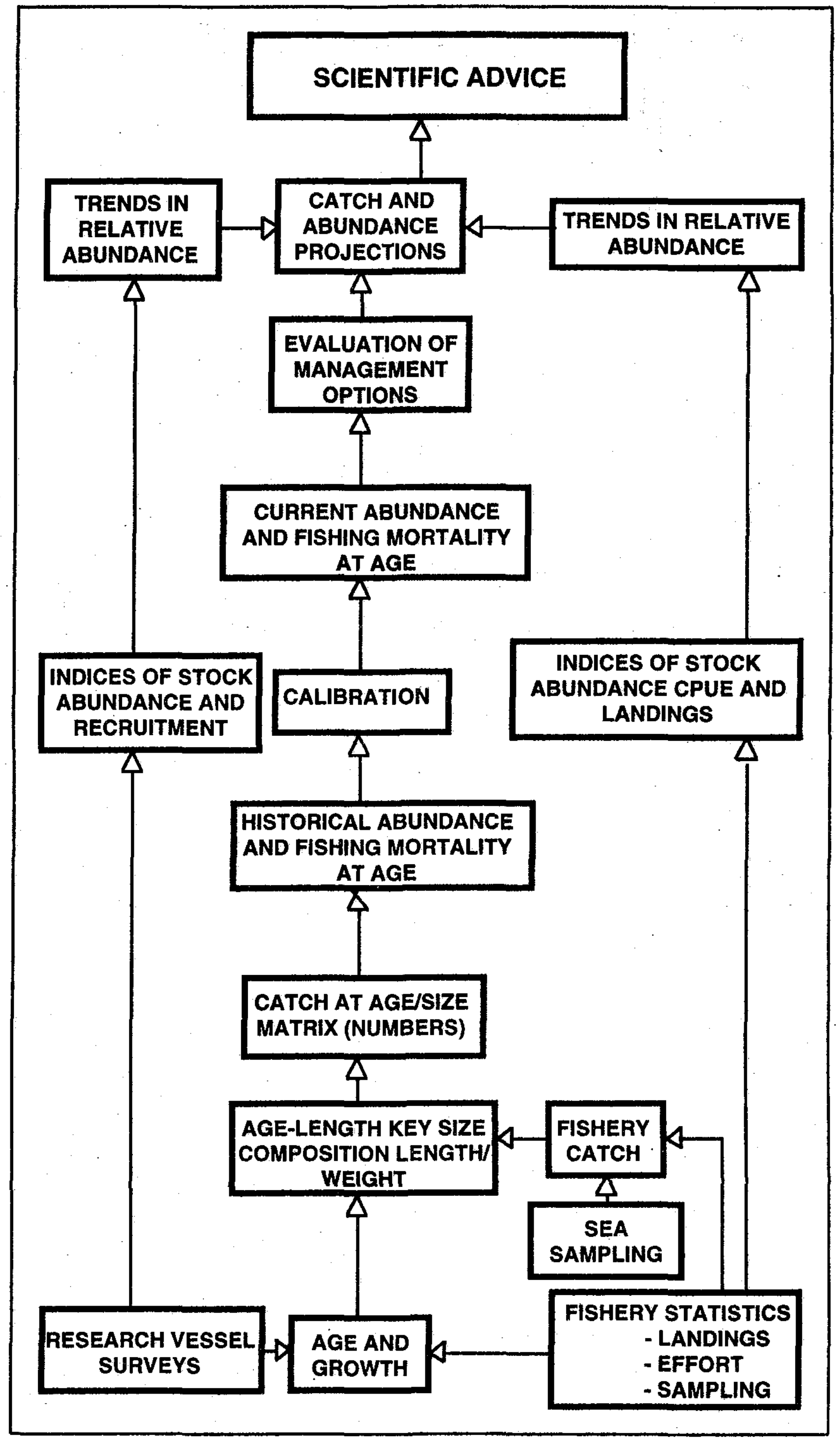


Figure 1. Alternative ways in which data from the fishery and data from research (lower right and left boxes, respectively) are combined to provide scientific advice concerning the status of the stocks.

For example, if F = 1.5, then approximately 1.5/365 or 0.411% of the population dies each day from fishing. If fishing were the only cause of death, then the number of fish that survive the fishery over the year from a population of 1 million alive at the beginning of the year is 1 million multiplied by $e^{-1.5}$ or 223,130 fish. During fishing, there are other causes of death that also act on the population of fish, and must be considered in calculating the number that die from fishing. The number of fish that die from fishing is the proportion of the total mortality that is caused by fishing, multiplied by the number of fish that die from all causes [i.e., F/Z multiplied by $(1-e^{-Z})$ multiplied by 1 million]. If the total mortality rate is 1.7 then this calculation is:

$$(1.5/1.7)\,(1-e^{-1.7})\,(1{,}000{,}000)$$

or

$$(0.8824)\,(0.8173)\,(1{,}000{,}000)$$

or

$$721{,}186$$

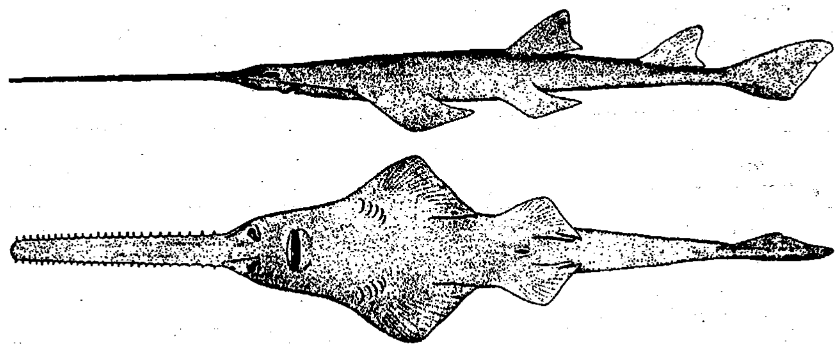
fish that die from fishing.

F_{max}: The rate of fishing mortality for a given exploitation pattern, rate of growth and natural mortality, that results in the maximum level of yield per recruit. This is the point that defines growth overfishing.

$F_{0.1}$: The fishing mortality rate at which the increase in yield per recruit in weight for an increase in a unit of effort is only 10% of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield per recruit curve for the $F_{0.1}$ rate is only 1/10 the slope of the curve at its origin).

$F_{30\%\ SPR}$: The fishing mortality rate for a given exploitation pattern, rate of growth, natural mortality, and reproductive schedule that will reduce the spawning potential per recruit to 30% of what it would be with no fishing mortality.

Growth overfishing: A range of fishing mortality which is above the rate of fishing as indicated by an equilibrium yield per recruit curve at which the loss in weight from total mortality exceeds the gain in weight due to growth. This range is defined as beyond F_{max}.



Smalltooth sawfish (*Prisitis pectinata*)

Long-term potential yield: The largest annual sustainable harvest in weight which could be removed from a fish stock year after year, under existing environmental conditions. This can be estimated in a variety of ways, ranging from maximum values from production models to average observed catches over a suitable period of years.

Mortality rate: The rate at which fish die from natural causes (disease, predation, old age) or fishing. Mortality rates can be described in several ways. Conceptually the easiest way is the total annual mortality rate, the fraction of the fish alive at the beginning of a year that die during the year. For example, a total annual mortality rate of 0.50 means that 50% of the population of fish died for whatever reason during the year. In general, annual mortality rates can range from 0 to 1.0, that is 0% to 100% mortality. Note that the exploitation rate is the same as the annual fishing mortality rate.

Annual rates are easy to understand, but difficult to use when describing the relative contribution of different types of mortality, such as fishing and natural causes, to the total mortality of fish during a year because they cannot be added. One way to describe mortality and overcome this limitation of annual rates is by using instantaneous rates, although this approach is conceptually more difficult. An instantaneous mortality rate is the fraction of the population of fish that dies in each very short period of time.

The derivation of instantaneous rates is mathematically complex, but there is a relatively simple connection between them and the simpler annual rates. Any particular instantaneous mortality rate, often denoted by Z, is equivalent to one specific annual rate A, according to the formula:

$$A = 1 - e^{-Z}$$

That is, the annual rate is equal to e, (this is the number 2.718, the base of the natural logarithms) raised to the negative power of the instantaneous rate, subtracted from 1.0. For example, the instantaneous mortality rate of 1.1 is equivalent to an annual mortality rate of 0.67, or 67%. In practice, instantaneous rates range from 0 to values as high as 1.5 or 2.0, but theoretically could take on any large value. Because instantaneous rates make comparing the relative importance of different sources of mortality very easy, as discussed next, they are frequently used by fishery biologists, and are used throughout this report. To aid in interpretation, **Table 3** shows the relationship between instantaneous mortality rate and annual percentage mortality.

Instantaneous rates are used in assessments because they are mathematically easy to use (e.g., they can be added directly while annual percentage rates cannot). If a year is divided into a large number (n) of equal time intervals, Z/n is the proportion of the population which dies during each time interval. For example, if Z = 1.7 and a day represents the time interval, then approximately

Table 1. Federal fishery management plans for marine fisheries of the southeastern continental United States, Puerto Rico, and U.S. Virgin Islands.

Plan	Responsible Organization*	Date	Amendments Number	Amendments Last
Coastal Migratory Pelagics	GMFMC, SAFMC	2/83	6	12/92
Coral	GMFMC, SAFMC	7/84	1	2/91
Snapper/Grouper	SAFMC	9/83	5	4/92
Spiny Lobster (Gulf and Atl.)	GMFMC, SAFMC	7/82	3	3/91
Spiny Lobster (Caribbean)	CFMC	1/85	1	4/91
Swordfish	NMFS	9/85	2	12/91
Reef Fish	CFMC	9/85	2	3/95
Gulf Reef Fish	GMFMC	9/84	7	4/94
Gulf Shrimp	GMFMC	5/81	6	4/93
Stone Crab	GMFMC, SAFMC	9/79	4	2/91
Gulf Red Drum	GMFMC	12/86	3	10/92
Atlantic Billfish	NMFS	10/88	None	
Shark	NMFS	12/92	None	
Atlantic Red Drum	SAFMC	12/90	None	
South Atlantic Shrimp	SAFMC	11/93	None	
Gulf Butterfish	GMFMC	(In preparation)		
Queen Conch	CFMC	(In preparation)		
Coral	CFMC	(In preparation)		

*GMFMC: Gulf of Mexico Fishery Management Council, SAFMC: South Atlantic Fishery Management, Council, CFMC: Caribbean Fishery Management Council, NMFS: National Marine Fisheries Service, Secretarial Plan

1.7/365 or 0.466% of the population is dying daily, but the instantaneous rate is constant. (Actually 0.465% of the population dies each day instead of 0.466% because a day only approximates an instantaneous time period. If hours were used, the approximation would be even closer.) During the first day of the year, about 4,660 fish will die and 995,340 will survive out of a population of 1 million. The survival rate over the year is $e^{-1.7}$ or 0.1827. Multiplying 0.1827 by the number of fish alive at the beginning of the year (1 million) gives 182,684 fish that survive to the beginning of the next year. The proportion that actually dies during the year is, therefore, $1-e^{-1.7}$ or 0.8173. This is called the annual mortality rate (A) which, of course, can never exceed 1.0.

The part of the total mortality rate applying to a fish population attributed to natural causes is usually assumed to mean all causes other than fishing. These many causes of death are usually lumped together for convenience since they often account for much less than fishing mortality in adult fish, and are usually of less immediate interest. Natural mortality is usually expressed as an instantaneous rate and can range from 0 to very high values 0.5 or 1.0. The corresponding annual mortality due to natural causes acting alone can be computed in the same manner shown for total mortality rates. The most important causes are predation, disease, cannibalism, and perhaps increasingly, environmental degradation such as pollution. When particular natural mortality factors are of interest, separate instantaneous mortality terms are often defined. Natural mortality rates have proven very difficult to estimate, and often values are assumed based on the general life history of a particular fish.

Following the examples given above, M is equal to Z-F or 1.7 - 1.5 = 0.2. The number of fish that die during the year from natural causes is, therefore, the proportion of total mortality (M/Z) due to natural causes multiplied by the total number that actually die:

$$(M/Z)\ (1-e^{-Z})\ (1{,}000{,}000)$$

or

$$(0.1176)\ (0.8173)\ (1{,}000{,}000)$$

Therefore, 96,114 fish or 9.6% of the population of one million die from natural causes during the year when the fishing mortality rate is 1.5 and the total mortality rate is 1.7. If fishing mortality were less, more fish would die from natural causes because some fish are caught by the fishery before they die from natural causes. For example, if the fishery did not exist, an M of 0.2 applied over the year to 1 million fish would cause a mortality of $(1-e^{-0.2})$ multiplied by 1 million or 181,269 fish and 18.1% of the beginning population.

Nominal catch: The sum of catches that have been reported as live weight or equivalent of the land-

Table 2. State fishery management plans.

Plan	Date	Amendments Number	Last
		ATLANTIC STATES MARINE FISHERIES COMMISSION	
Shellfish Transport	1989	1	1990
Spotted Seatrout	1984	1	In preparation
Weakfish	1985	1	1992
Summer Flounder/Seabass	1982	2	In preparation
American Shad/Herring	1985	None	
Atlantic Croaker	1987	None	
Spot	1987	None	
Spanish Mackerel	1990	None	
Atlantic Sturgeon	1990	None	
Bluefish	1989	Under review	
Atlantic Red Drum	1984	1	1991
Striped Bass	1981	Under review	
Atlantic Menhaden	1981	1	In preparation (approved 1992)
American Eel	------	Proposed	
		GULF STATES MARINE FISHERIES COMMISSION	
Gulf Menhaden	1977	3	In preparation
Striped Bass	1986	1	1992
Blue Crab	1990	None	
Gulf Shrimp	1977	None	
Oysters	1991	None	
Spanish Mackerel	1989	None	
Red Drum/Spotted Seatrout (Profile document)	1980	Not Applicable	
Black Drum	1993	None	
Gulf Sturgeon	In Preparation	Not Applicable	
Alabama Shad	In Preparation	Not Applicable	
Stone Crab (Profile document)	In Preparation	Not Applicable	
Spotted Seatrout	In Preparation	Not Applicable	
Striped Mullet	In Preparation	Not Applicable	

ings. Nominal catches do not include such measures as unreported discards. Remember these are not catches but landings.

Quota: A portion of a TAC (Total Allowable Catch) allocated to a fishery or to an operating unit, such as a size class of vessels or a country.

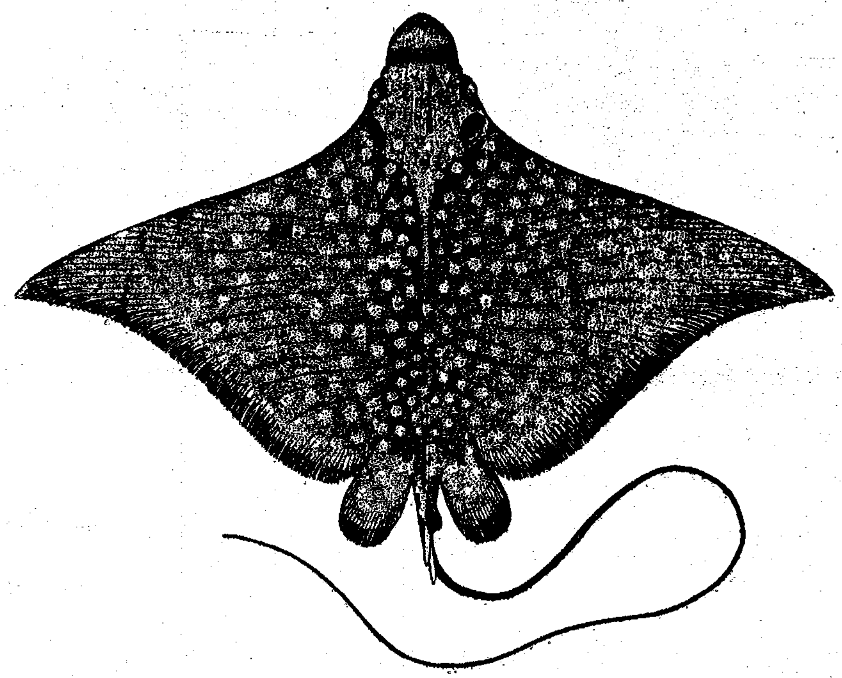
Recruitment: The amount of fish, added to the fishery each year due to growth and/or migration into the fishing area. For example, the weight or number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population in that year. This term is also used in referring to the number or weight of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age-2 recruits.

Spawning Potential Ratio (SPR or %MSP): The ratio of spawning potential per recruit under a given fishing regime relative to the spawning potential per recruit with no fishing. The spawning potential ratio assumes a density dependence on growth and fecundity. Often spawning potential per recruit is measured in spawning biomass per recruit.

Recruitment overfishing: The rate of fishing above which the recruitment to the exploitable stock becomes significantly reduced. This is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and

Table 3. Relationship between instantaneous mortality rate and percentage mortality if no other mortality exists on the fish.

Instantaneous Mortality Rate	Percentage Mortality
0.0	0
0.1	10
0.2	18
0.3	26
0.4	33
0.5	39
0.6	45
0.7	50
0.8	55
0.9	59
1.0	63
1.5	78
2.0	86



Spotted eagle ray (*Aetobatus narinari*)

generally very low recruitment year after year.

Spawning Stock Biomass (SSB): The total weight of all sexually mature fish in the population. This quantity depends on the abundance of year classes, the exploitation pattern, the rate of growth, both fishing and natural mortality rates, the onset of sexual maturity, and environmental conditions.

Spawning Stock Biomass per Recruit (SSB/R): The expected lifetime contribution to the spawning stock biomass for a recruit for a specific age (e.g., per age-2 individual) such as the spawning stock biomass divided by the number of fish recruited to age-2. For a given exploitation pattern, rate of growth, natural mortality, an equilibrium value of SSB/R is calculated for each level of F. This means that under constant conditions of growth, natural mortality, and exploitation patterns over the life span of the species, an expected average SSB/R would result from each constant rate of fishing.

Status of exploitation: An appraisal of the status of exploitation is given for each stock of each species in the Species Synopses section, using the terms unknown, protected, not exploited, underexploited, moderately exploited, fully exploited, and overexploited. These terms are used to describe the effect of current fishing effort on each stock, and represent the educated opinion of assessment scientists based on current data and the knowledge of the stocks over time.

Sustainable yield: The number or weight of fish in a stock that can be taken by fishing while maintaining the stock's biomass at a steady level from year to year, assuming that environmental conditions remain the same.

TAC: Total Allowable Catch is the total regulated catch allowed from a stock in a given time period, usually a year.

Total mortality rate: The combined effect of all sources of mortality acting on a fish population. This is conveniently expressed in terms of instantaneous mortality rates because the total instantaneous mortality rate is simply the sum of the instantaneous fishing and natural mortality rates. For example, the total instantaneous mortality rate that is occurring when the instantaneous fishing mortality rate is 0.5 and the instantaneous natural mortality rate is 0.2 would be 0.7, which is equivalent to an annual rate of 50%.

Virtual population analysis (VPA) or Cohort Analysis: An analysis of the catches from a given year class over its life in the fishery. If 10 fish were caught each year from the 1968 year class for 10 successive years from 1970 to 1979 (age-2 to age-11), then 100 fish would have been caught from the 1968 year class during its life in the fishery. Since 10 fish were caught during 1979, then 10 fish must have been alive at the beginning of that year. At the beginning of 1978, there must have been at least 20 fish alive because 10 were caught in 1978 and 10 more were caught in 1979. By working backward year by year, one can be virtually certain that at least 100 fish were alive at the beginning of 1970. A virtual population analysis (VPA) goes a step further and calculates the number of fish that must have been alive if some fish also died from causes other than fishing. For example, if the instantaneous natural mortality rate was known in addition to the 10 fish caught per year in the fishery, then a virtual population analysis calculates the number that must have been alive each year to produce a catch of 10 fish each year in addition to those that died from natural causes.

If one knows the fishing mortality rate during the last year for which catch data are available (in this case 1979), then the exact abundance of the year class can be determined in each and every year if the catches are known with certainty. If the fishery removes a large proportion of the stock each year so that the population declines quite rapidly over time, then an approximate fishing mortality rate can be used in the last year (1979), and by calculating backward year by year for the year class, a very precise estimate of the abundance can be determined for the previous three or four years (1976 or 1975). Accuracy depends on the rate of population decline and the correctness of the starting value of the fishing mortality rate (in the most recent year). Normally, the starting value is estimated by calibrating the VPA estimates with auxiliary information, such as indices of abundance. This technique is used extensively in fishery assessments since the conditions for its use are so common: many fisheries are heavily exploited, the annual catches for a year class can be determined, and the natural mortality rate is known within a fairly small range.

Year Class (or Cohort): Fish of the same stock born in the same year. For example, the 1987 year class of a stock includes all fish of that stock born in 1987, and they would be age-1 in 1988. Occasionally a stock produces a very small or very large year class and this group of fish is followed closely by assessment scientists since it can be pivotal in determining the stock abundance in later years.

Yield Per Recruit Analysis: The expected lifetime yield per fish of a specific age (e.g., per age-2 individual). For a given exploitation pattern, rate of growth, and natural mortality, an equilibrium value of Y/R is calculated for each level of F. This means that under constant conditions of growth, natural mortality, and exploitation patterns over the life span of the species, an expected average Y/R would result from each constant rate of fishing.

Fishery Trends

In cooperation with the eight southeastern states, the Commonwealth of Puerto Rico, and the Territory of the U.S. Virgin Islands, the Southeast Fisheries Science Center collects and maintains fishery statistics of commercial and recreational importance. State and federal fishery agents routinely gather data on fish and invertebrates landed at various ports in the southeastern region. These data are archived and provided to the public through various publications of the National Marine Fisheries Service. Also, fishery data are analyzed and information from the analyses are provided along with fishery statistics to state and federal agencies, Gulf of Mexico Fishery Management Council, South Atlantic Fishery Management Council, Caribbean Fishery Management Council, Gulf States Marine Fisheries Commission, Atlantic States Marine Fisheries Commission, International Commission for the Conservation of Atlantic Tunas, and similar organizations concerned with management and conservation of U.S. fishery resources.

Commercial fishery statistics for the southeast region are comprised of data collected through many sources. Typical sources include seafood dealer records, landings weigh-out sheets, commercial fishermen interviews, fishermen logbooks, and trip-ticket systems operated by several southeastern states.

The principal source of recreational fishery statistics in the southeastern region is the Marine Recreational Fishery Statistics Survey. The survey is conducted by the National Marine Fisheries Service's Washington, D.C. office. It uses a telephone survey of households and an intercept survey of anglers at fishing sites to estimate total catch and fishing effort by species. These estimates do not, however, include catches made in Texas or catches made aboard headboats (vessels that are routinely chartered by anglers who pay individually, rather than as a group, to fish). Estimates of headboat catches are obtained by a headboat fishery survey conducted by NMFS, Beaufort Laboratory, from North Carolina through Texas.

Commercial and recreational fishery statistics contained in **Tables 4 and 5** are considered preliminary and can vary slightly as new information is provided. Also, the statistics can be summed in many categories. For more current, more detailed, or different aggregations of statistics on a particular species or geographic area, please contact:

Statistics Office
Southeast Fisheries Science Center
National Marine Fisheries Service
75 Virginia Beach Drive
Miami, Florida 33149
Telephone: (305) 361-4462

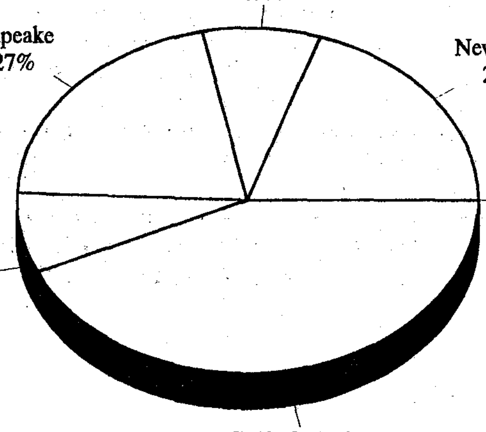


Figure 2. Regional distribution of commercial yield by weight for the eastern United States in 1992.

COMMERCIAL YIELD

Commercial yield reported in the southeastern United States declined 15.6% from 1991 to 1992 (**Figures 2 and 3**). Yield in the U.S. Gulf of Mexico declined 15% from 761 thousand metric tons in 1991 to 647 thousand metric tons in 1992. Yield along the southeastern Atlantic coast of the United States declined 19% from 133 thousand metric tons in 1991 to 108 thousand metric tons in 1992.

All the Gulf states reported decreases from 1991 to 1992 except Alabama which showed a 9% increase. Western Florida, Mississippi, Louisiana, and Texas reported declines of 10, 21, 15, and 11% respectively. Along the Atlantic coast, the predominant change was North Carolina that reported a 27% decrease from 1991 to 1992. Landings in South Carolina were almost equal while Georgia and eastern Florida increased 10% and 3% respectively.

Table 4. Commercial and recreational yields for the southeastern states in 1992.

State	Commercial Yield (1000 t)	Commercial Exvessel Revenue ($1000)	Recreational Yield * (1000 fish)	Angler Trips** (1000 trips)
U.S. Atlantic Coast				
North Carolina	69.9	$57,458	7,879	4,471
South Carolina	8.7	25,621	3,345	1,216
Georgia	8.0	22,957	1,625	507
Eastern Florida	21.2	46,001	20,191	11,454
U.S. Gulf of Mexico				
Western Florida	47.8	$108,888	45,300	12,797
Alabama	10.8	35,566	3,671	696
Mississippi	85.1	31,348	2,264	839
Louisiana	459.8	294,986	13,036	2,490
Texas	43.6	181,353	4,182	n.a.

*Estimates from the NMFS Marine Recreational Fishery Statistics Survey (Catch types $A+B_1$), State of Texas, and the NMFS headboat survey (n.a.=not available).
**Does not include headboat data.

RECREATIONAL YIELD

The 1992 recreational yield in the southeast region (**Table 4**) was estimated from three sources: 1) the Marine Recreational Fishery Statistics Survey (catch types $A+B_1$), 2) Southeast Fishery Science Center headboat surveys, and 3) surveys conducted by the State of Texas. Recreational yield along the U.S. Atlantic coast increased from 30 million fish in 1991 to 33 million fish in 1992. Recreational yield along the U.S. Gulf coast decreased from 75 million fish in 1991 to 68 million fish in 1992 (**Figure 4**). Between 1991 and 1992 angler trips (excluding Texas) increased 51% from 23 million trips in 1991 to 34 million trips in 1992. Angler trips in the U.S. Atlantic increased 49% while angler trips in the U.S. Gulf increased 53% (**Figure 5**).

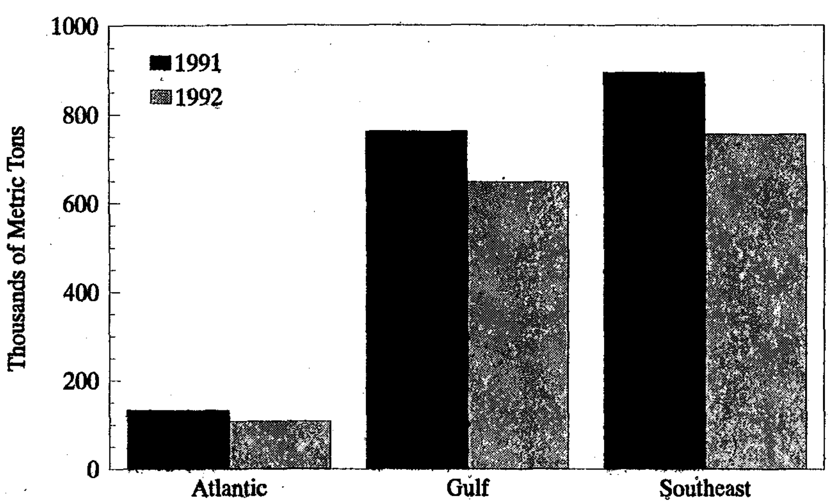


Figure 3. Commercial yield in weight for the southeastern United States in 1991 and 1992.

U.S. CARIBBEAN YIELD

Fisheries of Puerto Rico and the U.S. Virgin Islands are predominantly artisanal. Most anglers concentrate their effort on shallow-water reef fish and a variety of shellfish, mainly lobster and conch. Fishery statistics are gathered by port agents from fishermen, fish buyers, and fishing associations in municipalities and other fishing centers in the islands.

Commercial fishery yields in Puerto Rico are comprised primarily of snappers, lobster, grunts, groupers, and other reef species (**Table 5**). But pelagic species such as tunas, dolphins, mackerels, billfish, and sharks also appear in the fishery and comprised about 13% of the yield in 1992.

In the U.S. Virgin Islands, the number of licensed fishermen varied from 281 to 846 during 1974 - 1980 and from 370 to 530 during 1980 - 1992 (**Figure 6**). Since catch reporting was made mandatory in the early

Table 5. Commercial yield and exvessel revenue reported in Puerto Rico in 1992.

Species	Metric Tons	Exvessel Revenue	Species	Metric Tons	Exvessel Revenue
Tuna	31.8	$89,633	Triggerfish	12.6	$39,078
Ballyhoo	11.4	27,369	Barracuda	4.5	13,016
Grunt	53.3	155,660	Porgy	4.6	13,770
Hogfish	9.6	40,314	Snook	13.1	41,154
Croaker	0.0	0	Tarpon	1.4	2,476
Trunkfish	18.2	61,301	Goatfish	3.4	12,641
Dolphin	38.7	136,416	Sardine	8.3	20,783
Swordfish	0.0	0	Mackerel	31.7	119,604
Squirrelfish	2.7	7,490	Shark	16.1	48,562
Mullet	11.8	31,110	Margate	0.4	1,249
Jack	12.8	35,911			
Parrotfish	41.8	124,394	Classified		
Marlin	2.3	6,882	First	74.8	263,746
Amberjack	0.4	429	Second	42.9	80,365
Grouper			Third	17.2	37,066
Red Hind	19.1	72,266	Trash	2.4	1,722
Nassau	3.0	10,776	Other Fish	30.3	--
Other Grouper	12.3	53,461			
Mojarra	9.0	27,459	Queen Conch	41.3	200,993
Snapper			Land Crab	1.2	21,410
Lane	41.3	169,362	Lobster	72.9	783,977
Yellowtail	67.6	275,874	Oysters	0.1	760
Silk	94.4	476,515	Octopus	5.8	29,844
Mutton	14.8	62,473	Other Shellfish	0.5	3,426
Other Snapper	23.4	98,083			

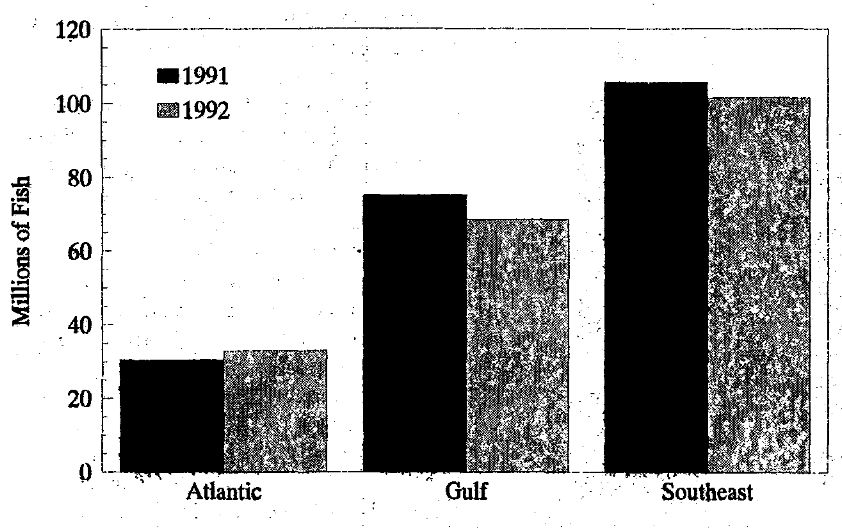


Figure 4. Recreational yield in millions of fish estimated for the southeastern United States in 1991 and 1992.

1970s, the rates of reporting have varied from 16-75% along with estimates of finfish landings.

FOR MORE INFORMATION:

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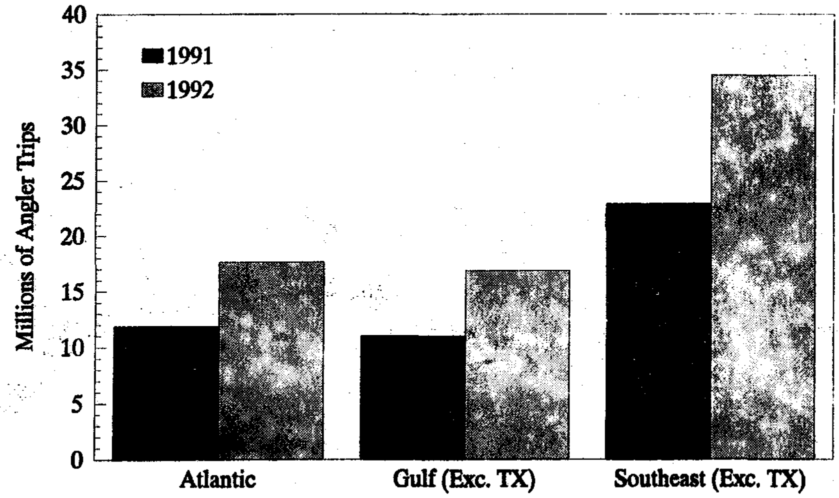

Figure 5. Recreational angler trips estimated in the southeastern United States in 1991 and 1992 (excluding headboat trips and trips in Texas).

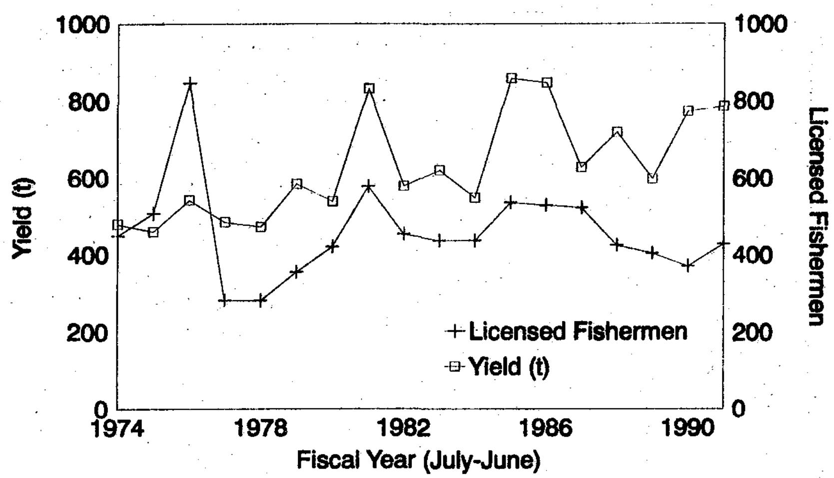

Figure 6. Commercial yield and number of licensed fishermen reported in the U.S. Virgin Islands.

Service. 1992. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1990-1991. Washington: GPO.

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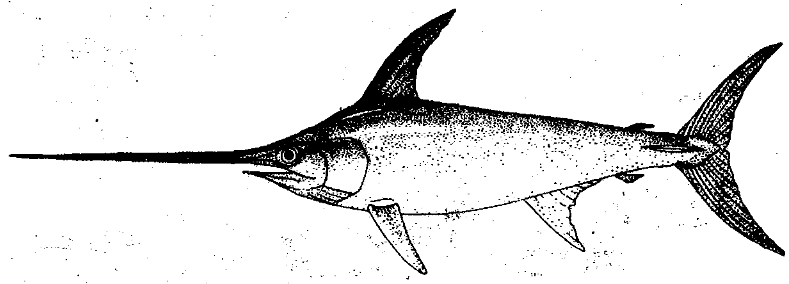
United States Virgin Islands Department of Planning and Natural Resources, Division of Fish and Wildlife, Cooperative Fishery Statistics Program. 1993. Annual summary report: 1992 - 1993. SF54 (NA27 FT0301-01).

Oceanic Pelagics



Swordfish (*Xiphias gladius*)

The Atlantic Oceanic pelagic resources are wide ranging and highly migratory. There is a broad array of species which comprises the complex harvested by international fishing fleets. The United States is among the major harvesting nations for some of these species, including North Atlantic swordfish, western Atlantic bluefin tuna, and more recently, yellowfin tuna in the western Atlantic. U.S. North Atlantic billfish harvests are of significance, both in recreational harvests and as incidental bycatch in commercial fisheries directed at tunas and swordfish. U.S. domestic fisheries range throughout the northwestern Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. Because of their highly migratory nature and ocean-wide distributions, both national and international management bodies are concerned with conservation of these resources.

In U.S. waters, fisheries may now be regulated under authority of the Magnuson Fishery Conservation and Management Act as well as by international agreements through the International Commission for the Conservation of Atlantic Tunas (ICCAT). The member nations of ICCAT include Angola, Benin, Brazil, Canada, Cape Verde, Cuba, Equatorial Guinea, France, Gabon, Ghana, Côte d'Ivoire, Japan, Korea, Morocco, Portugal, Senegal, São Tomé & Principe, South Africa, Spain, Uruguay, United States, Russia, and Venezuela. Resource status evaluations for ICCAT are carried out by its Standing Committee on Research and Statistics (SCRS).

The Southeast Fisheries Science Center has lead research responsibility in the United States for stock assessments of Atlantic large pelagic resources. These assessments provide the scientific bases for national and international management of the fisheries. U.S. Fishery Management Plans have been developed for swordfish and billfishes. International agreements for regulating swordfish harvest were implemented in 1991 and international restrictions of bluefin tuna harvest have been in effect for nearly a decade. Regulations regarding the harvest of other tuna species have generally not been implemented.

SWORDFISH

Swordfish (*Xiphias gladius*) are the most widely distributed billfish and occur worldwide in all tropical, subtropical, and temperate seas. They appear to have the widest water temperature tolerance among the billfish, since they are found in waters with surface temperatures ranging from about 5-27°C. ICCAT recognizes several possible stock hypotheses for Atlantic swordfish, including a discrete stock in the North Atlantic. Swordfish preferred habitat is believed to be near the edge of the continental shelf in waters from 100-3,000 m deep, near oceanic frontal zones, and near seamounts and mid-ocean islands.

Swordfish are considered apex predators and as adults are believed to eat whatever prey is available in greatest abundance in their immediate vicinity. Their large eyes and predominance of white muscle tissue appear to be adaptations for stalking prey during dark periods and at depths to about 600 m. Swordfish are thought to be nocturnal feeders, feeding in near-surface waters at night. The major part of their diet consists of squids, pelagic fishes, and occasionally crustaceans.

Swordfish grow rapidly and may live 25 or more years. Females are believed to mature at about 5 years. On average, swordfish attain weights of approximately 14, 25, 41, 61 and 104 kg at ages 1, 2, 3, 4, and 5. The recent average size of swordfish harvested by U.S. fishermen before minimum size regulations were implemented was 38 kg. Approximately 85% of the recent catch in numbers of swordfish from the North Atlantic were fish less than 5 years old.

The swordfish fishery is prosecuted mainly by longline fleets, with the Spanish and U.S. fleets dominating recent catches. These two nations accounted for about 76% of the total North Atlantic swordfish catch in the most recent three year period. Drift gillnets were recently employed by U.S. fishermen operating in a relatively restricted part of the North Atlantic Ocean. The drift gillnet fishery operated under a 36 t quota in 1992. The United States eased its mercury-content regulation in 1978 and in consequence catches and effort directed at swordfish in the North Atlantic increased continually until 1987 and 1988 (**Figure 7**). Peak catches of about 20,000 t from the North Atlantic in 1987 and 1988 were followed by declining yields for 1989-1991, due in large part to 1) a shift of

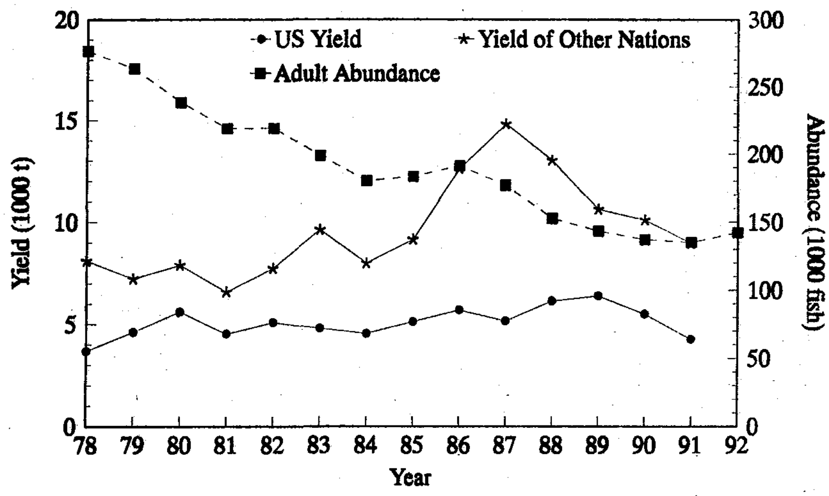


Figure 7. North Atlantic swordfish yield and age 5+ stock size. Age structured assessments of stock status use data only from 1978 to present because of concern over size frequency sampling and reported landings from earlier years.

fishing effort south of 5° N, the statistical boundary for the North Atlantic swordfish management unit, and 2) the implementation of a minimum size measure in 1991. Total Atlantic yields of swordfish were highest in 1989, reaching a level of 50,500 t, in contrast to 19,800 t in 1978. Since 1989, total Atlantic yields of swordfish have declined to about 37,600 t. Yields of North Atlantic swordfish for 1989-1991 averaged 15,271 t. The recent annual yield to U.S. fishermen during this period was 5,378 t.

Because of concern over the status of the north Atlantic swordfish resource, in 1990, ICCAT recommended several management measures, including a 15% reduction from 1988 levels of Spanish and U.S. fishing mortality rates and a 25 kg (whole weight) minimum size for all Atlantic swordfish. ICCAT management recommendations were not binding on signatory nations until the middle of 1991.

The 1992 SCRS swordfish assessment workshop was held in September 1992 in Madrid, Spain, during which catch and effort information for north Atlantic swordfish through 1991 was analyzed. The results of the assessment indicate effort and yields have been reduced from levels estimated for 1987 and 1988, primarily as a result of effort reduction and/or diversion to other regions of the oceans and reduction in the landed catch by the Spanish and U.S. fleets. Reported landed catch from the stock declined from 19,959 metric tons in 1987 to 13,212 t in 1991. This 34% decline in weight of the landed catch reflects a corresponding decline in the estimated number of fish landed of about 41% from levels estimated in 1987 and 1988. The 1992 assessment, which incorporates the most recent information, reflects changes in the fishery and the assessment indicates that the population decline has slowed or stabilized and that fishing mortality rates have also declined since peak values in 1987 and 1988. The assessment indicates that the prospects for the north Atlantic swordfish resource have improved to some degree relative to the condition of the resource in recent prior years.

The most recent assessment includes only a 6-month period during which the ICCAT regulatory measures were binding on the signatory nations. Data from 1992 and 1993 will provide more information on the effect of the 1990 ICCAT recommendations. Of critical importance to determination of current and likely future status of the resource is accurate estimation of the effects of the management recommendations in terms of actual reduction of fishing mortality. To accurately estimate the effectiveness of these recommendations, accurate accounting of the total number of fish killed as a result of fishing by all the fishing nations is needed, including those fish caught, but not landed. Measures to control the level of swordfish fishing mortality rate attributed to nations other than Spain and the United States may also be needed to avoid loss of any gains in resource status and future potential yield due to the present management recommendations.

Two forms of analytical assessments were conducted at the 1992 swordfish assessment. These included the application of an age-structured model (VPA) and a lumped biomass model (non-equilibrium stock production model). The non-equilibrium stock production model applied at the meeting provided estimates of MSY, the fishing mortality rate needed to produce MSY (F_{MSY}), annual estimates of fishing mortality rates, and annual estimates of stock biomass level. MSY represents the maximum sustainable long-term average yield which might be obtained by the fishery, providing the stock is at a level that could produce MSY (B_{MSY}) and the fishery is harvesting that biomass at a rate equal to F_{MSY}. Analyses conducted at the 1991 swordfish assessment provided estimates of MSY in the range of 13,100 to 14,300 t. A revised biomass index of abundance was developed by standardizing data from the United States, Spain, Canada, and Japan. The time series extended from 1962 through 1991. The 1960s data were primarily from the Canadian fishery, although some data from the U.S. fishery from the 1960s were also used in the analysis. When all of the annual index values are used in production modelling (base case analysis) the median estimate of MSY, after adjusting for possible bias in the estimation procedure used, was 14,200 t with an estimated standard error of 2,600 t. From this analysis, the results indicated there was an approximate 84% chance that the actual value of MSY is less than 16,800 t (16% chance it is higher) and approximately an 84% chance that the actual value of MSY is greater than 11,600 t (16% chance it is lower). With respect to current (1992) condition of the stock, the median estimate of B_{92}/B_{MSY} was 0.84 (with an estimated standard er-

SWORDFISH

Longterm potential yield	11,600 - 16,800 t
Current potential yield	8,000 - 14,200 t *
Recent average annual yield	15,300 t (stocks)
	5,400 t (United States)
Status of exploitation	Overexploited
Age at 50% maturity	5 years
Generation time	10 - 15 years
Natural mortality rate	0.1 - 0.25
Spawning stock biomass per recruit in equilibrium	About 5%
Fishing mortality rate at F0.1	0.2
Fishing mortality rate at Fmax	0.4
Fishing mortality rate in most recent year (1991)	0.37 - 0.66
	(95% CI, mean 0.5)
F_{91}/F_{MSY}	0.8 - 1.4
	(68% CI, median 0.97)
B_{92}/B_{MSY}	0.65 - 1.03
	(68% CI, median 0.84)

*From production model using F_{MSY} and B_{92} base case B/B_{MSY} (0.65-1.03).

ror of 0.19), indicating approximately even odds that the stock biomass at the beginning of 1992 was either higher or lower than 84% of that level which could produce MSY (approximately 84% of the estimates were greater than 0.65 and approximately 84% were less than 1.03). The adjusted estimate of median F_{91}/F_{MSY} was 0.97 indicating approximately even odds that the 1991 fishing mortality rate was higher or lower than 97% of the rate that could result MSY (approximately 84% of the estimates were greater than 0.8 and approximately 84% were less than 1.4).

The reported yields of north Atlantic swordfish in 1991 were 13,212 t. This value is approximately 1,000 t lower than the median estimate of MSY from the base case analysis (14,200 t), approximately 3,000 t lower than the 84th percentile estimate of MSY and approximately 1,600 t higher than the 16th percentile estimate of MSY. The 1991 reported yields (13,212 t) are about the same as the estimated median equilibrium yield at current stock size. However, it must be recognized that the estimates of equilibrium yield include that portion of the catch which is thrown back to the sea dead because of the minimum size regulation. Thus, catch limits that do not account for mortality due to discarding or other forms of mortality can result in further decline in stock biomass and lower levels of production from the stock.

Exclusion of certain annual index values from the production model fits were also conducted to evaluate the model's sensitivity to these CPUE values. From these sensitivity analyses, the median estimates of MSY, after adjusting for possible bias, ranged from 14,300 to 15,200 t. The median estimates of B_{92}/B_{MSY}, after adjusting for possible bias, ranged from 0.85 to 0.95. These estimates are within the 68% confidence ranges estimated for the base case analysis. Sensitivity of the model to errors in the assumed yield, such as possible under-reporting of catch during the period of mercury restrictions, or unreported discard mortality due to the minimum size regulation were not considered in the 1992 analyses.

In all of the models and data set combinations considered, it was assumed that the fishery had not changed in terms of its pattern of exploitation from 1962-1991 and that the yield estimates used in modelling represented a more or less constant proportion of the actual yields. Changes in the exploitation pattern of the fishery, such as through the implementation of a minimum size limit, that are not accounted for in the estimation procedure, can result in errors of the estimates of MSY and F_{MSY} that are not obvious. Likewise, changes in the proportion of under or over reported yield, such as might have resulted during the period of mercury restriction, or failure to account for discard mortality if this mortality changes over time can also result in errors in estimates of MSY and F_{MSY}. Current status interpretations from the stock production model results did not take into account possible effects of change in selectivity pattern, especially in the last few years, nor account for discard mortality of undersized fish and may be optimistic for these reasons. Sensitivity of the model results to these and other effects need to be evaluated.

The age-structured analytical model applied provided estimates of age-specific fishing mortality rates and abundance (stock size) of a year-class (all fish born in the same year) over the time period analyzed. ICCAT swordfish VPAs have been limited to the period after 1977, because of limited size samples from earlier years and since some of the reported yields during the mercury restriction period of the 1970s are thought to be under-reports of actual harvest. VPAs have formed the basis of recent ICCAT management recommendations for North Atlantic swordfish.

As in previous ICCAT analyses, there are alternative biological and/or fishery assumptions (i.e. sexual dimorphism, procedures for estimating numbers at age, selectivity patterns, and index time series) that could influence the results and our perception of the status of the resource. These were addressed in a more exhaustive number of sensitivity analyses than the production model analysis. The sensitivity analyses results raise the possibility that the base case VPA may impart some degree of underestimation of the abundance of the older age fish, but also may impart some degree of overestimation of the youngest age fish for the most recent years in the analysis.

Results of the VPA indicated that stock size estimates at the beginning of the year of age 1 swordfish (recruits) increase gradually from 1978 through 1987, remained at the same level in 1988 and increased in 1989 and declined in 1990. The 1990 year-class (age 1 fish in 1991) may be considerably higher than in previous years, but the estimate is very uncertain. The 1991 year class may be smaller than in recent years, but the estimate of this is even more uncertain. Stock size of the ages 2-4 juvenile group increased throughout the period 1978-87 and has been variable since then. The age 2-4 stock size at the beginning of 1992 increased substantially due to the calculated increase in the 1990 year class. Adult stock size (ages 5+) declined continuously throughout the time series to approximately half of what it was in 1978. There was a small increase in the estimated abundance of age 5+ in 1992. The fishing mortality rate of age 1 and the ages 2-4 group fluctuated, but with a generally increasing trend through 1988, with a constant decline in 1989-1991. Fishing mortality rate on ages 5+ appears to have increased significantly during 1978-87 with a gradual decline from 1988 to 1991. The weighted average fishing mortality rate estimated for ages 2-5+ in 1991 is 64% of the 1988 level and 141% of the 1978 level.

The results of the 1992 VPA show a small improvement in adult stock size in 1992 compared to the previous year. The estimate of abundance for age 5+ fish in 1992 is 56% of that estimated for 1978. The increase in age 5+ abundance between 1991 and 1992 appears to be due to relatively strong recruitment during the late 1980s and somewhat reduced fishing mortality rates since 1987-1988. Although the estimates of current (1991) fishing mortality rates have decreased from 1987-88, the base case VPA suggests that current (1991) fishing mortality rate is in excess of $F_{0.1}$ and F_{max}. The VPA results indicate that current harvest levels (1991) could be maintained in the short term (through 1993) and allow for a stable or slightly increased stock size.

There is uncertainty in the VPA results, as in the production model results. Much of the uncertainty results from questions about the effectiveness of the ICCAT minimum size recommendation for reducing the actual mortality on small fish. Because we have not yet been able to estimate discard mortality for the entire fleet, this uncertainty cannot be easily resolved. To a large extent, the ability of the North Atlantic swordfish stock to support current harvest levels and the potential for rebuilding depends on the effectiveness of the minimum size regulations in reducing fishing mortality rates on undersized swordfish. The reductions in fishing mortality and possible change in selectivity pattern from 1988 to 1991 could provide gains in realized long-term yields from the stock.

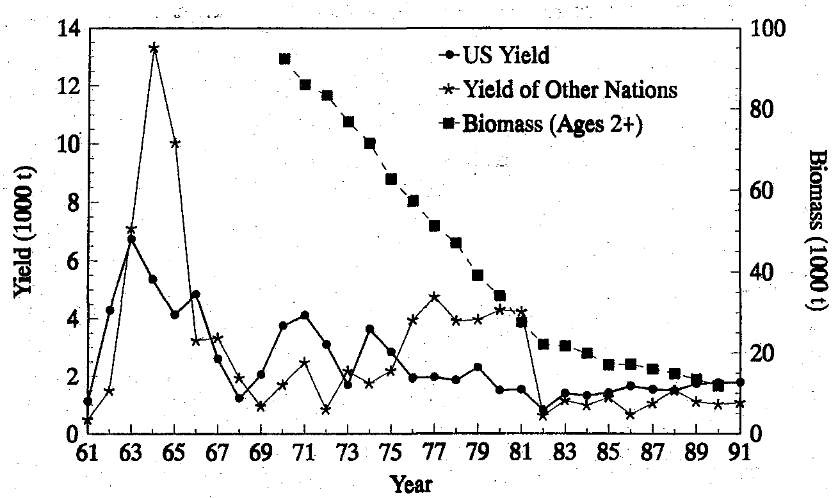


Figure 8. Western Atlantic bluefin tuna yield and stock biomass. Assessments of stock status using data only from 1970.

BLUEFIN TUNA

Northern bluefin tuna (*Thunnus thynnus thynnus*) is a large oceanic pelagic scombrid species that is found in the Atlantic and Pacific Oceans. In the western Atlantic, bluefin occur from Labrador and Newfoundland south into the Gulf of Mexico and Caribbean Sea, and also off Venezuela and Brazil. In the eastern Atlantic, they occur from off Norway south to the Canary Islands, in the Mediterranean Sea and off Africa. ICCAT recognizes two management units of northern bluefin tuna in the Atlantic

BLUEFIN TUNA

Longterm potential yield	3,000 - 13,000 t
Current potential yield	About 2,000 t
Recent average annual yield	2,850 t (stock) 1,760 t (U.S.)
Status of exploitation	Overexploited
Age at 50% maturity	6-8 years
Current spawning potential ratio (SPR)	Less than 10%
Generation time	16-20 years
Natural mortality rate	0.1 - 0.18
Fishing mortality rate at F0.1	0.1
Fishing mortality rate at Fmax	0.14
Fishing mortality rate in most recent year (1990)	0.35

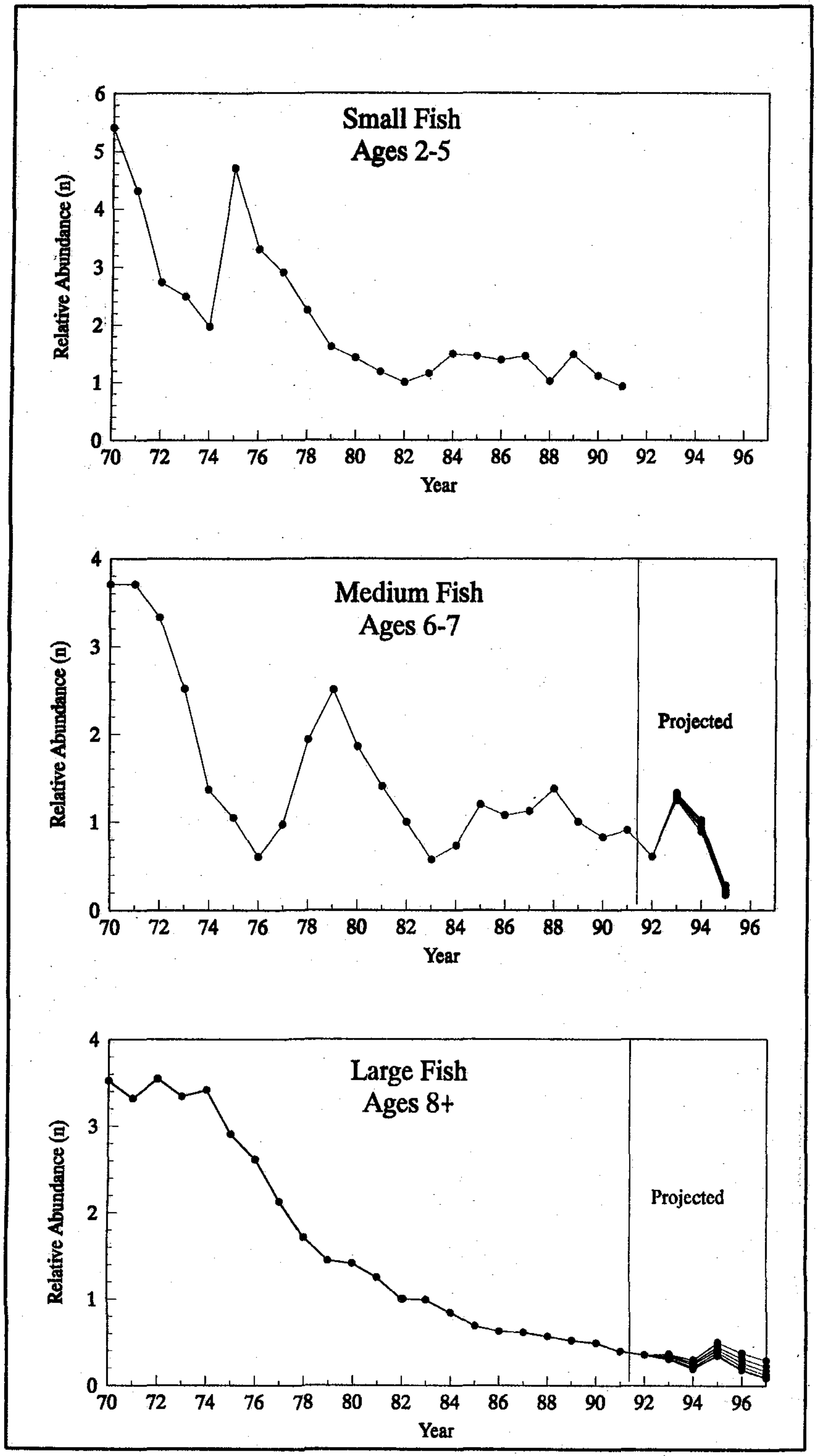


Figure 9. Relative stock size for western Atlantic bluefin tuna. The trajectories shown represent the median values from 1,000 iterations of the ICCAT assessment model which incorporates uncertainty in the model input parameters. Stock size is expressed relative to the 1982 level which is the first year bluefin harvests were restricted based on the 1981 SCRS recommendation. Projected stock sizes (after 1991) are based on the 1992 ICCAT management program (10% reduction) and several other yield reduction scenarios.

separated at 45° W longitude above 10° N latitude and at 25° W below the equator with an eastward shift in the boundary between those parallels. Some interchange of fish between the eastern and western Atlantic is known to occur. The management units were defined based primarily on the existence of spawning areas in the Gulf of Mexico and the Mediterranean Sea; additional supportive evidence included: 1) coastal abundance of juveniles on each side of the ocean, 2) the high proportion of juvenile bluefin tagged on one side of the Atlantic and at liberty for at least a year which were recaptured on the same side of the ocean, and 3) relatively low catch rates by high seas longline vessels in the central Atlantic during most time periods.

Northern bluefin are among the largest teleosts. Specimens have been known to reach 320 cm fork length and up to 680 kg. Bluefin feed on a variety of fishes, cephalopods, and crustaceans, depending on seasonal prey availability. Bluefin generally grow to larger size at age than the other tunas. Like many other tunas, bluefin tend to be found in schools of similar sized individuals. Small bluefin also occur in mixed schools with other species of similar size, such as albacore and yellowfin, bigeye, and skipjack tunas. In western Atlantic waters, individuals that reach 196 cm fork length are believed to be approaching 8 years. Spawning females in the Gulf of Mexico are thought to be at least 8 years old. The recent average size of bluefin caught in the western Atlantic in recent years is about 68 kg. The age corresponding to an individual of this size would be about 6 years. However, the average age of fish caught in the western Atlantic is closer to 2 years because many more small, young fish are caught than are the large, older fish.

In the eastern Atlantic Ocean and Mediterranean Sea, bluefin tuna have been exploited for thousands of years. Bluefin tuna in the western Atlantic have been fished primarily by the United States, Japan and Canada; substantial catches from the western Atlantic were not made until the early 1960s when Japanese longline vessels and United States and Canadian purse seine vessels accounted for most of the catch. Small recreational fisheries for bluefin existed in the early part of this century. However, available data are too sparse for use in stock assessments which track the catches since 1960, just after extensive commercial fishing began.

The peak yields of bluefin from the western Atlantic (about 8,000-19,000 t) occurred in 1963-1966 when much of the catch was taken by longlines off of Brazil (**Figure 8**); since then catch rates off Brazil have been very low. During the late 1960s and 1970s yields averaged about 5,000 t. In 1982 a catch restriction of 1,160 t was imposed; the catch limit was increased to 2,660 t in 1983 and has been held at that level through 1991. Yields generally have been within 15% of the target catch levels since 1982. The United States generally caught 40-60% of the total yield during 1960-1975, about 30% during 1976-1981 and has taken about 60% of the yield since 1982. During the 1960s and 1970s a North American purse seine fishery for juveniles and the longline fishery usually took 70-80% of the yield and recreational fisheries usually took 10%. During the period of catch restrictions a U.S. purse seine fishery for adults and the longline fishery usually have taken 50-60% of the U.S. yield and rod and reel fisheries about 20%. The balance of the U.S. yields have been taken by gears such as traps, harpoons, handlines and tended lines. The value of bluefin tuna increased substantially during the 1980s with the increased importance of the Japanese market. As a result, many of the fish now caught by rod and reel are sold.

By 1973, ICCAT expressed concern about the decrease in the abundance of bluefin tuna in the North Atlantic. In response to this concern, a minimum size regulation was put into effect in 1975. In spite of the minimum size regulation, west Atlantic bluefin stock abundance continued to decline. After conducting a series of stock assessments, ICCAT's SCRS recommended in 1981 that catches from the west Atlantic bluefin stock be reduced to as near zero as possible to stem the decline of the stock. Based on this recommendation, allowable landings of western Atlantic bluefin have been restricted since 1982.

The most recent assessment of west Atlantic bluefin tuna status was carried out by ICCAT's SCRS in November 1991, using catch and effort data through 1990. Estimated stock abundance trends continued to show that all size classes were substantially below the 1970 levels (see **Figure 9**). The assessment showed that in the face of catch restrictions, the fishing mortality rate on both small and large bluefin increased to values as high or higher than those estimated immediately before implementation of catch restrictions. The results indicated, although it was likely that the ICCAT management strategy for reducing fishing mortality had been a partial success, recent fishing mortality rates near record high levels for medium and large bluefin were likely cropping the potential benefits to the adult stock before they could be realized. On the basis of this assessment, ICCAT implemented regulations to further restrict catch levels by an additional 10% for 1992-1993.

Evaluation of the future prospects for the bluefin stock from the newly implemented management program and other possible harvest restrictions was conducted via a risk analysis, incorporating uncertainty in the assessment of current (1991) abundance (see **Figure 9**). The risk analysis focussed on the adult (age 8+) and medium size classes (ages 6-7). To avoid basing the analysis entirely on assumed recruitment levels, the analysis was restricted to the time frame during which year classes estimated by the 1991 stock assessment were included in the age group being examined. Under the assumptions used in the analysis, there are approximately even odds that 1997 large fish abundance will exceed, and also approximately even odds of being below the projected 1992 abundance level, given a 50% harvest reduction scenario. Under the 10% reduction scenario simulated (the 1992 ICCAT management program), the results of the analysis indicate less than 1 chance in 4 that 1997 large fish abundance will exceed the 1992 level (approximately 3 chances in 4 that it will be below 1992). During the interim (1995-96), an increase in abundance relative to 1994 is projected, followed by an expected decline to 1997 levels under all scenarios simulated. The projected increase in abundance in 1995 is due to the relatively strong 1987 year class entering the age 8+ group, but because no sufficiently strong year classes follow 1987, the age 8+ group is projected to decline from the 1995 level under the scenarios simulated. For the medium fish (ages 6-7), oscillations in abundance were projected under all scenarios simulated. In all cases, there are good odds (approximately 3 chances out of 4) that the 1993 stock size would exceed that projected for 1992, although these probabilities fell to less than 33% in 1995, after the relatively strong 1987 year class was projected to pass through this age group.

Since 1970 the estimated biomass of bluefin tuna age-2 and older in the western Atlantic has declined (**Figure 8**). The rate of decline slowed with the imposition of catch restrictions in 1982. The long term potential yield for the stock has been estimated to range from about 3,000 to 13,000 t, depending on assumed fishing patterns and assumed natural mortality rates. Recent estimates of current potential yield for bluefin in the western Atlantic have been on the order of 2,000 t. The recent average yield for 1989-1991 is estimated to have been 2,850 t. The average yield to U.S. fishermen during this period was approximately 1,760 t.

YELLOWFIN TUNA

Populations of yellowfin tuna (*Thunnus albacares*) are found worldwide in tropical waters. In the Atlantic their distribution is tropical, cosmopolitan, and migratory with the greatest oceanic concentrations found between the equator and ±15° latitudes. However, migrations take place to the north and the south along the American coast, and as a result, coastal concentrations of yellowfin are found seasonally off the northeastern United States and Uruguay. In addition, substantial concentrations of yellowfin are found in the Gulf of

Mexico, especially during the spring and summer months. The habitat is mainly oceanic, and the distribution of yellowfin is in large part determined by the presence of prey species, mainly small pelagic fishes and squids, as well as by the temperature of the water.

The yellowfin is a fast-growing species. It attains a maximum length of about 170 cm fork length, corresponding a weight of about 70 kg. If an individual fish were to live for about seven years, it would attain such a size, but such specimens are not common. Occasionally yellowfin as large as 180 kg have been taken. The average size in the Gulf of Mexico longline fishery is about 140 cm, corresponding to a weight of about 50 kg and an estimated age of 3 to 4 years.

Sexual maturity is attained when the fish weigh about 25 kg, an average age of 3 years. In the western Atlantic, spawning takes place mainly during April through June; spawning grounds include the Gulf of Mexico. It is believed that larger spawning grounds are found in the eastern Atlantic; however, research remains to be done on the spawning biology. An individual fish may spawn repeatedly during a single spawning season.

For assessment, ICCAT's SCRS considers Atlantic yellowfin tuna to comprise two stocks, one in the eastern and one in the western Atlantic. Research during the ICCAT Yellowfin Year Program supported the widely held belief that some mixing occurs between western and eastern Atlantic stocks. The degree of mixing is still unknown. As of January 1993, a total of 16 trans-Atlantic movements of yellowfin (all from west to east) had been documented in collaborative studies conducted by scientists of the United States and Côte d'Ivoire.

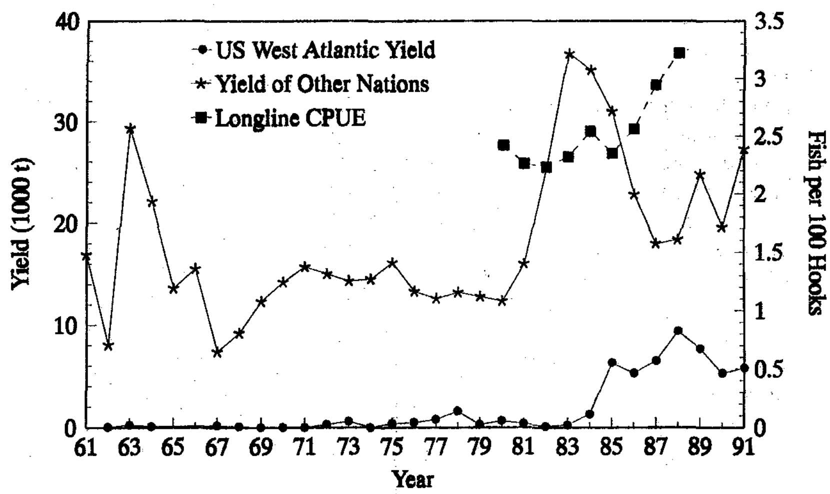


Figure 10. Western Atlantic yellowfin tuna yield and standardized abundance index. The abundance index was developed for 1980-1988 based on U.S. and Oriental high seas longline catch and effort data.

The SCRS has not conducted formal assessments of western Atlantic yellowfin stocks, but several exploratory assessment models have been described. At the 1990 SCRS meeting, a preliminary production model of western Atlantic yellowfin, based on Venezuelan purse seine effort from 1972–1989, was presented. That analysis estimated a long-term potential yield of 33,000 t for the stock and suggested that the stock could be near full exploitation. However, the yellowfin tuna working group considered the data and assumptions underlying the analysis too preliminary to permit conclusive results. Furthermore, the analysis may have reflected the status of yellowfin only in waters around Venezuela. In April 1991, the ICCAT Working Group on Western Atlantic Tropical Tunas convened at the Southeast Fisheries Science Center's Miami Laboratory to review the analytical data base for western Atlantic yellowfin tuna. The Group did not conduct a formal assessment of western Atlantic yellowfin but did arrive at an agreed data base for future assessment work. At the 1991 SCRS meeting, an exploratory production model of yellowfin tuna in the Gulf of Mexico was presented based on the working hypothesis of a closed population in the Gulf. The data base and assumptions underlying this analysis were considered to have many shortcomings, but the estimate of long-term yield from the Gulf, about 10,000 to 12,000 t, suggests that yellowfin in the Gulf may be gradually approaching full exploitation.

About 75% of the yield of yellowfin tuna from the western Atlantic during 1989–1991 was taken by two countries, Venezuela and the United States. The average annual yield during this period was 30,000 t, of which about 40% was taken in longline fisheries and the remainder by surface gear (mainly baitboats and purse seines). The average estimated yield to U.S. fishermen was 6,200 t, mainly from longline harvests from the Gulf of Mexico. The average estimate of

YELLOWFIN TUNA

Longterm potential yield	33,000 t (stock) 10,000 - 12,000 t (Gulf of Mexico)
Current potential yield	Unknown
Recent average annual yield	30,000 t (stock) 6,200 t (United States)
Status of exploitation	Unknown
Age at 50% maturity	2-3 years
Generation time	5 years
Natural mortality rate	0.8 (fish less than or equal to 2 years old) 0.6 (fish greater than 2 years old)

annual U.S. recreational harvest of yellowfin tuna during this period was about 800 t. **Figure 10** shows the recent yield and the standardized longline catch per unit effort abundance index developed for assessment purposes.

BILLFISH

In the Atlantic Ocean, blue marlin, white marlin, sailfish, and longbill spearfish are a bycatch of the United States and foreign commercial tuna and swordfish longline fisheries. In addition to the incidental catches of billfish in the longline fisheries, other major fisheries in the western Atlantic include the directed recreational fisheries of the United States, Venezuela, the Dominican Republic, Costa Rica, Mexico, Jamaica, Bahamas, and Brazil. Smaller recreational fisheries are also found in Cuba, Bermuda, Portugal (Azores, Madeira), Senegal and many other countries in the Caribbean Sea and the eastern Atlantic. Artisanal fisheries for marlins and sailfish along the west African coast and in the Caribbean and South America are of increasing local importance. Recent development and geographical expansion of longline fisheries in the Gulf of Mexico for tuna and in the Caribbean Sea for swordfish and tunas, and the geographical expansion of the longline fleet off Africa raise concern for billfish. Because these areas are known to have significant concentrations of billfish, bycatch of these species may increase. The incidental billfish catch of some of these fisheries (e.g. U.S. and Spanish longline fleets, tropical purse seine fleets) is expected to result in increased discard mortalities of billfish, which are difficult to document and result in uncertainties in basic catch statistics.

Assessment of Atlantic billfish stocks has generally been hampered by data limitations. In the early 1980s, assessments of blue and white marlin based on production models (which assume equilibrium) using total fishery yield and an index of abundance developed from the Japanese longline fleet were attempted. Changes in the method of fishing and the main targets of the Japanese longline fleet in much of the Atlantic have prevented the use of these data for updated assessments of billfish prior to 1992. However, as a result of the work accomplished at the Second Intercessional ICCAT Billfish Workshop in Miami in 1992, standardization of the Japanese longline index, as well as resolution of other data problems, facilitated the first assessments for blue and white marlin in over a decade. In addition, use of a production model (ASPIC), which does not assume equilibrium, allowed analysis of multiple data inputs simultaneously (the Japanese index was no longer relied upon exclusively) and this resulted in assessments which provided a vastly improved view of the status of the stocks.

Due to domestic concerns over the future prospects for billfish resources, U.S. restrictions of billfish landings were implemented in October 1988 under the U.S. Fishery Management Plan for Atlantic Billfishes. The Plan eliminates possession and sale of billfish by commercial fishermen and restricts the allowable catch of billfish by recreational gear (rod and reel) by size limits. U.S. catches of each billfish species are estimated from various data sources. Because the Management Plan imposed "no sale" and "no possession" regulations on commercial fisheries, no official U.S. commercial landings have been reported for any of the three Atlantic species since the plan was implemented. Estimates of bycatch mortality, known to occur in the U.S. longline fleet, are made using data reported by U.S. captains and vessel owners permitted to fish for Atlantic swordfish and data from limited observer coverage on these vessels. The estimated proportion of billfish retrieved dead on longline gear ranges from 0.30 to 0.68, depending on species and geographical area. Estimates of capture-induced mortality of billfish released by recreational anglers are generally not available, although this source of mortality is believed to be low.

BLUE MARLIN

Longterm potential yield	1,718 t
Current potential yield	Unknown
Recent average annual yield	1183 t (stock) 253 t (United States)
Status of exploitation	Overexploited
B_{90}/B_{MSY}	0.82
F_{89}/F_{MSY}	1.05

WHITE MARLIN

Longterm potential yield	593 t
Current potential yield	Unknown
Recent average annual yield	253 t (stock) 63 t (United States)
Status of exploitation	Overexploited
B_{91}/B_{MSY}	0.52
F_{90}/F_{MSY}	0.65

SAILFISH

Longterm potential yield	Unknown
Current potential yield	Unknown
Recent average annual yield	619 t (stock) 32 t (United States)
Status of exploitation	Moderately exploited

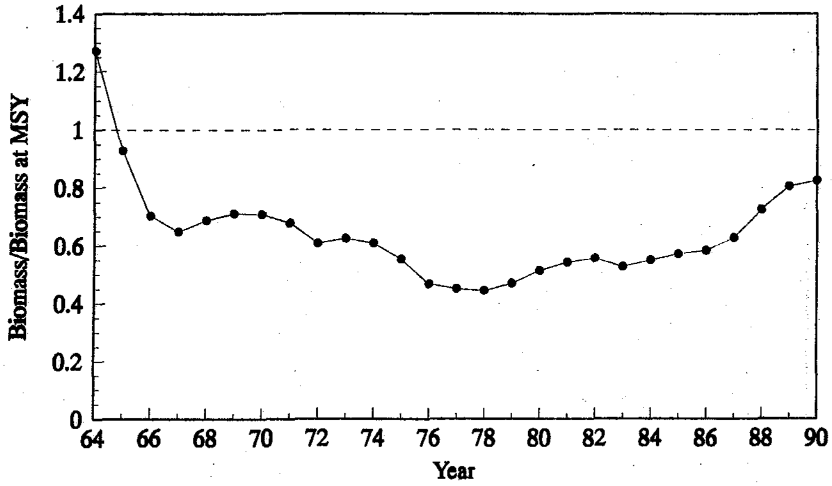


Figure 11. Estimated biomass/biomass at MSY ratio (B/B_{MSY}) for north Atlantic blue marlin.

Blue Marlin

Blue marlin (*Makaira nigricans*) are sparely distributed over wide areas of the tropical and temperate waters of the world oceans. In the Atlantic Ocean, the latitudinal range varies seasonally from about 40°N to about 35° S. Two main seasonal concentrations appear to occur in the Atlantic: from January through April in the southwestern Atlantic and from June through October in the northwestern Atlantic. Transatlantic movements have been documented from the western to eastern Atlantic, along with the seasonal migrations which correspond to cooling of temperate waters during the winter.

The types of food eaten by blue marlin vary somewhat with the region where they occur. The diet of blue marlin is mostly piscivorous (particularly tuna-like fishes), but also frequently contains cephalopods. The range in size of food items can vary from large tuna (greater than 30 kg) to postlarval teleosts. Blue marlin, like all istiophorids, often extend their stomach outside of their mouth when hooked in an attempt to avoid capture. This reaction also empties the stomach so information on the diet is fragmentary and not well quantified.

Blue marlin are one of the fastest growing of all teleosts, particularly during the first year of life when maximum growth can be as high as 16 mm per day. Sustained growth rate during the first 100 days can average about 10 mm per day. Blue marlin are long lived and are reported to attain ages of at least 25-30 years. Blue marlin are also one of the largest marine teleosts; in the Atlantic they can reach a length of over 4.5 m and weight of over 600 kg.

The age at 50% maturity for blue marlin is difficult to determine, in part due to the difficulty of examining large numbers of specimens and the substantial difference in sexually dimorphic growth between males and females. Mature males in the Atlantic Ocean have been reported as small as 35 kg and the smallest mature females were 44 kg.

There appears to be two widely separated concentrations of blue marlin spawning in the western Atlantic. In the north Atlantic, blue marlin spawn mainly in the Caribbean Sea during the summer but often have a smaller peak of spawning in the early fall. In the southwestern Atlantic, spawning occurs primarily in January through March. The are no data indicating that blue marlin change their sex (i.e., protandry).

ICCAT recognizes several possible stock structure hypotheses for blue marlin, including a north and south Atlantic stock and a total Atlantic stock. The north Atlantic-wide catch of blue marlin increased rapidly after 1960, reaching a peak of more than 5,000 t by 1963. Thereafter, landings declined substantially. Production model fits to data from 1960-1980 suggested that by 1980, the size of the north Atlantic stock, at best, had been reduced to about the level expected to produce its long-term potential yield. The worst case interpretation was that the stock had been overexploited by the late 1970s.

Updated assessments included an additional 10 years of data compared to previous assessments. In addition, a more flexible model (ASPIC) was used which does not assume equilibrium and allows analysis of several data series simultaneously. Since this model estimates relative levels of biomass better than absolute levels, these data are illustrated in terms of ratios relative to optimal biomass (B_{MSY}). General results from the updated assessments indicate that biomass trajectories were below B_{MSY} (i.e. stock

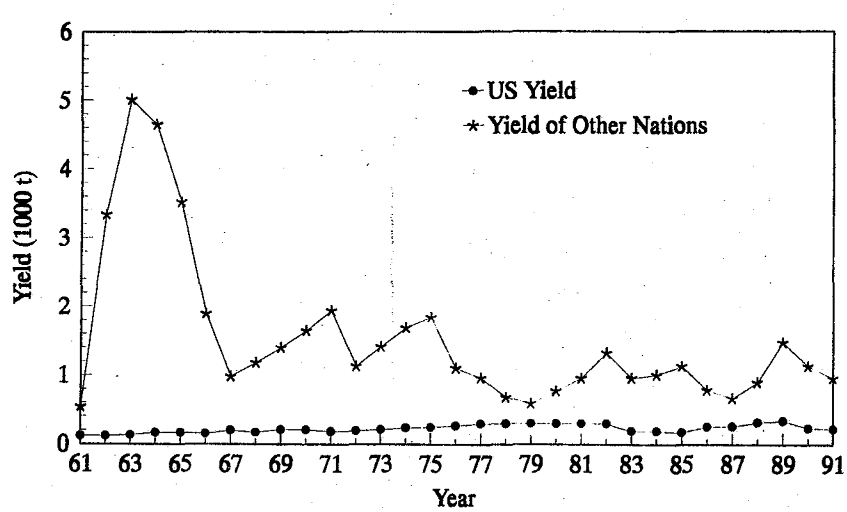


Figure 12. Yield for north Atlantic blue marlin.

biomass that can produce MSY) after 1966 (**Figure 11**). Longterm potential yield for north Atlantic blue marlin from this assessment were estimated to be 1,718 t. The last few years were more optimistic and did show signs of a modest recovery in biomass level, although estimated biomass is still below that which could produce MSY. Several sensitivity runs were made to assess the effect of under-reporting on the assessment results. As expected, proportional increases in estimates of MSY were observed but estimated trajectories did not change in pattern. Based on these results, ICCAT presently considers the north Atlantic stock of blue marlin overexploited. However, apparent stabilization in some CPUE indices and production model results showing signs of a modest recovery during the most recent years, are encouraging.

The recent average yield of north Atlantic blue marlin for 1989-1991 is estimated to have been 1,183 t. The average yield to U.S. fishermen during this period was approximately 332 t (**Figure 12**). About 82% of the recent average yield (1989-91) to the United States has been as a bycatch on longline gear; the remainder of the U.S. yield results from recreational harvest.

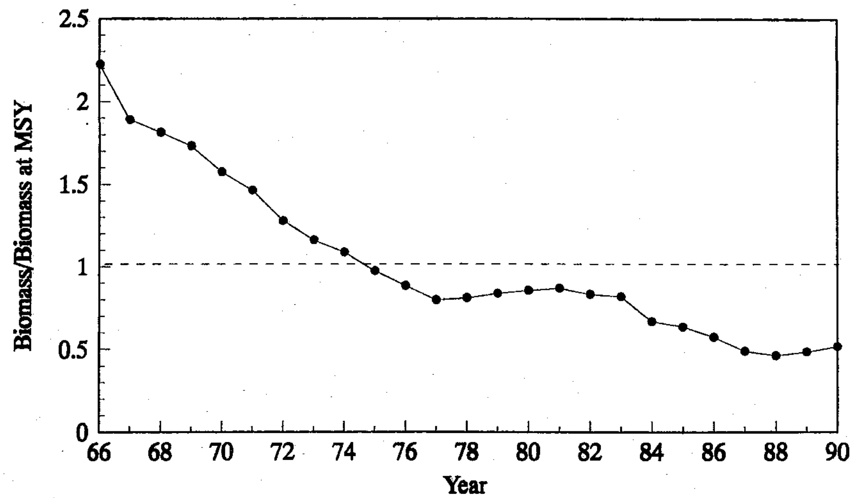


Figure 13. Estimated biomass/biomass at MSY ratio (B/B_{MSY}) for north Atlantic white marlin.

White Marlin

White marlin (*Tetrapturus albidus*) are distributed over nearly all of the Atlantic Ocean from 35° S to 45° N, including the Gulf of Mexico and the Caribbean Sea. Their distribution varies seasonally, reaching into the higher latitudes during the warm summer periods of either hemisphere. In general, white marlin are found in waters greater than 100 m deep with surface temperatures over 22°C. In contrast to blue marlin, white marlin reach higher latitudes in the warm summer months and tend to congregate in areas accessible to shore-based fisheries in much greater numbers. Along the U.S. Atlantic coast, white marlin are seasonally abundant from North Carolina to Massachusetts. White marlin concentrate off Venezuela during the winter, and in spring some fish from this area are thought to move northward to feeding grounds in the northern Gulf of Mexico and U.S. east coast. White marlin, like blue marlin, are found in the Caribbean region throughout the year. White marlin are thought to be mainly daytime feeders. Their diet, like other species in this unit, varies depending on location and availability of prey. Squid and smaller pelagic fishes tend to predominate in their diet.

As with blue marlin, the modal age at first reproduction is not well known for white marlin. However, female white marlin are thought to reach maturity at an eye orbit to fork length of about 130 cm or 20 kg body weight. Spawning for white marlin in the western north Atlantic is believed to occur throughout the Caribbean, in the Gulf of Mexico, and in the Straits of Florida during April and May. Larval collections and relatively high catch rates of large white marlin in pelagic longline fisheries suggest that spawning by this species in the north Atlantic may occur between 10° N and 20° N for as long as November through June.

As for blue marlin, ICCAT recognizes several stock hypotheses for white marlin, including a north and south Atlantic stock and a total Atlantic stock. The north Atlantic-wide catch of white marlin peaked in 1965 with a yield in excess of 2,000 t. Catch has been below that level since, generally fluctuating between 243 and

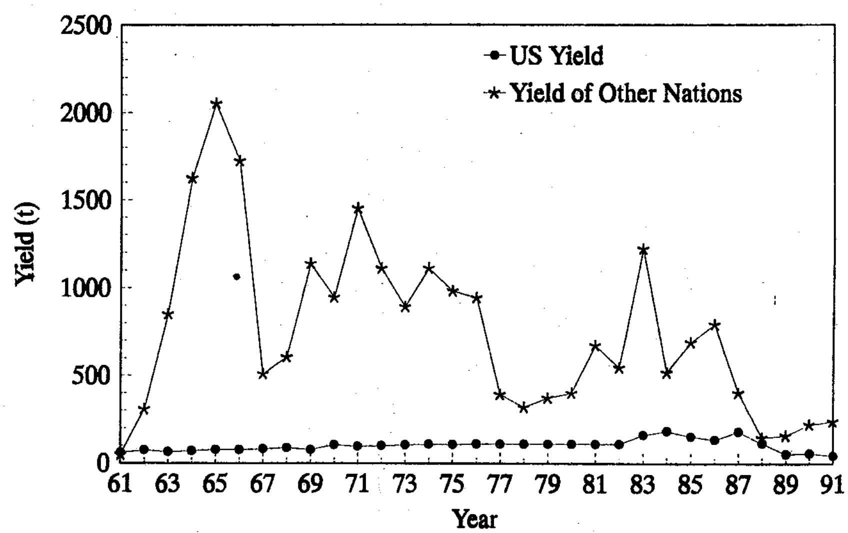


Figure 14. Yield for north Atlantic white marlin.

1,500 t. Production model fits for 1960-1980 data, based on the Japanese longline index, suggested a sharp decline in biomass from the early 1960s through 1970, with continued but more moderate declines (with variation) to low levels through 1980. The stocks were considered by ICCAT to be at least fully exploited and likely overexploited by the later part of this time series (mid to late 1970s). The U.S. index showed a continuous downward trend from 1980 to the end of the available standardized effort series in 1990. Catch per unit effort information from the Venezuelan recreational fishery indicates a similar trend, as does the U.S. recreational index since 1980, but continues to historic lows by the end of the time series (1990).

The differences between early assessments (1979-82 SCRS) and those presented to the 1992 SCRS, in terms of methodology and available data, for white marlin are the same as stated previously for blue marlin. Analysis using a non-equilibrium production model (ASPIC) were initially conducted for the entire time series (1961-1990). However, the north Atlantic model would not converge to a solution, due to the large variation in CPUEs during the first five years. Therefore, the data were considered from 1966-1990 and the model again applied. The general results from the analysis illustrate declines in stock biomass to levels well below estimated B_{MSY}. Although there was a slight upswing in estimated biomass in the last few years (**Figure 13**), ICCAT considered this a slowing of the downward trend and not a sign of recovery. White marlin results in this case were less optimistic than for blue marlin. Longterm potential yield for north Atlantic white marlin was estimated to be 593 t. Numerous sensitivity runs were made to gain insight into how under-reporting of landings might affect assessment results. As with blue marlin, proportional increases in estimates of MSY were observed but the biomass trajectories were virtually unchanged. Also, since the first five years of data, which include the largest declines in CPUEs, could not be used in this model, these results could be considered conservative. The model estimates that for decades stock biomass has been below that which could produce MSY (**Figure 13**) and fishing mortality rates are too high to allow a rapid recovery. As a result, ICCAT considers these stocks to be overexploited.

The recent average yield of north Atlantic white marlin for 1989-1991 is estimated to have been 253 t. The average yield to U.S. fishermen during this period was about 63 t (**Figure 14**). Approximately 79% of the recent average yield (1988-90) for the United States has been bycatch on longline gear, the remainder of the U.S. yield is due to low recreational harvest. Estimated U.S. longline bycatch of white marlin has decreased from total of 72 t in 1989 to 38 t in 1991.

SAILFISH

Sailfish (*Istiophorus platypterus*) are circumtropical in distribution, occurring in all warm marine waters of the world. Sailfish generally have a more coastal distribution than blue and white marlins, although they are also capable of extensive open water movements. In the western Atlantic, sailfish usually range between 30° S and 30° N, although fish thought to be stragglers occasionally occur outside of these latitudes. In the eastern Atlantic, the latitudinal range for sailfish is more restricted, with fish generally occurring between 10° S and 20° N. During the colder months, sailfish concentrate in warmer water areas within these latitude ranges and foray into the higher latitudes during warm months. For instance, along the U.S. Atlantic coast, there is a concentrated abundance of sailfish near the Florida coast, and fish remain in that area year-round. However, in spring with warming waters to the north, large numbers move northward along the coast toward Cape Hatteras. Conversely, in the fall with cooling water temperatures, fish move again to the south. Sailfish are one of the smaller members of the billfish family. Fish caught along the eastern U.S. coast generally average around 18 kg, although they can range upwards to 64 kg. Sailfish are believed to have a relatively high rate of natural mortality (estimates of M range upward from 0.35). Most of the Atlantic fish caught in fisheries are thought to be less than 4 years old. Like the other billfishes, sailfish are thought to be fairly opportunistic feeders, although fish and squid form the major part of their diets.

ICCAT recognizes eastern Atlantic and western Atlantic stock hypotheses for sailfish. As indicated earlier, the catches of sailfish and spearfish are not generally separated in the statistics provided by the high-seas longline nations. Attempts have been made by ICCAT scientists to separate the historical catches into east and west categories, most recently at the 1992 intersessional

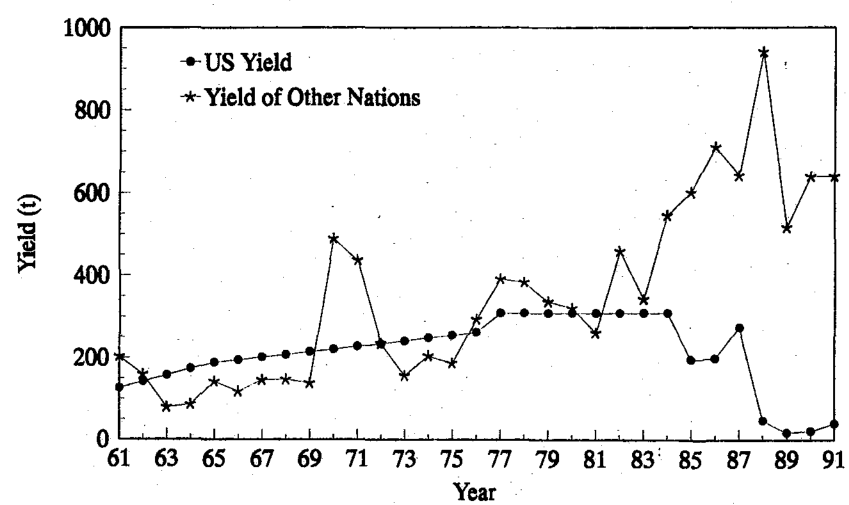


Figure 15. Yield for west Atlantic sailfish and spearfish.

ICCAT billfish workshop. Catch of western Atlantic sailfish and spearfish have increased steadily, to a peak of over 1000 t in 1988, although the 1989 reported catch was approximately 500 t. Recent U.S. recreational harvests are not well estimated and reports are conservative. Assessments of stock status completed in 1983, based on yield per recruit analyses, indicated that the sailfish resource in the western Atlantic was moderately exploited at that time. Although attempts to estimate long-term potential yield for western Atlantic sailfish have been made, the data have not been sufficient for that purpose. The recent average yield of western Atlantic sailfish for 1989-1991 is estimated at 619 t. The average yield to U.S. fishermen during this period was about 32 t. However, the estimate of U.S. recreational harvest estimate for this period is likely conservative. **Figure 15** shows the recent sailfish and spearfish harvest in the western Atlantic through 1991.

BIGEYE TUNA

BIGEYE TUNA

Longterm potential yield	61,200 - 74,000 t
Current potential yield	Unknown
Recent average annual yield	69,200 t (stock) 782 t (United States)
Status of exploitation	Fully exploited
Age at 50% maturity	3-5 years
Generation time	6-9 years
Natural mortality rate	0.8 (≤2 years), 0.6 (>2 years)
F_{90}/F_{opt}	0.7 - 1.15
B_{91}/B_{MSY}	1.33 - 0.96

Bigeye tuna (*Thunnus obesus*) are circumtropical in distribution, occurring in all of the world's oceans. In the Atlantic they are widely distributed in tropical and temperate waters, between 45° N and 45° S. Bigeye, like other similar-sized tunas, feed on a variety of fish, cephalopods, and crustaceans, depending on availability. Feeding is believed to occur in daytime as well as at night. Bigeye are considered a large tuna, although they do not reach the sizes of northern bluefin. On average, bigeye grow to a maximum fork length approaching 285 cm, and approaching 450 kg. However, individuals of this size are quite uncommon. Individuals that reach 175 cm and about 115 kg are believed to be at least 8 years old. The recent average size of bigeye taken by U.S. fishermen is approximately 44 kg, corresponding to a fork length of about 125 cm and an age of about 4 years. Bigeye are thought to mature after 4-5 years. Spawning of this species is known to occur throughout the year in the tropical band from 15° N to 15° S. The only known nursery area in the Atlantic for small bigeye is in the Gulf of Guinea, off the west African coast.

ICCAT recognizes a single Atlantic stock hypothesis for bigeye tuna. Bigeye catch has increased from the levels seen in the early 1960s to a peak of 74,500 t in 1985. Roughly two-thirds of the catch is taken in longline fisheries with the remainder taken by surface gear. Japan is the major longline harvesting nation taking Atlantic bigeye. Japanese longliners accounted for slightly more than 40% of the total landings in 1991. The long-term potential yield for Atlantic bigeye has been estimated, based on production model analysis using Japanese longline catch per unit effort and total landing statistics for 1961-1990, to range from 61,200 - 74,000 t depending upon assumptions made about the effectiveness of Japanese longline gear. The recent average yield of Atlantic bigeye tuna for 1989-1991 is estimated to have been 69,200 t. The average yield to U.S. fishermen during this four-year period was approximately 782 t. The estimated U.S. recreational harvest of this species for the period was 96 t. The yield and relative abundance for this species are shown in **Figure 16**.

ALBACORE

Albacore (*Thunnus alalunga)* are cosmopolitan in tropical and temper-

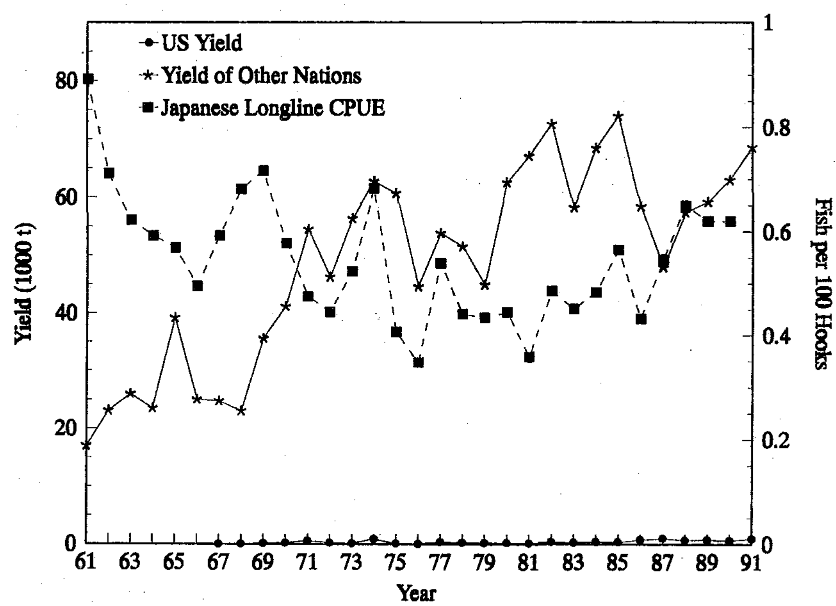


Figure 16. Atlantic bigeye tuna yield and relative abundance.

ALBACORE

Longterm potential yield	37,000-69,000 t
Current potential yield	Unknown
Recent average annual yield	30,850 t (stock) 376 t (United States)
Status of exploitation	Fully exploited
Age at 50% maturity	4-5 years
Current spawning potential ratio (SPR)	20-40%
Generation time	8-10 years
Natural mortality rate	0.3
Fishing mortality rate at F0.1	About 0.3
Fishing mortality rate at Fmax	About 0.5
Fishing mortality rate in most recent year	0.23

ate waters of all oceans, including the Mediterranean Sea, and range from 40° S to 50° N. Albacore generally do not grow as large as bluefin, bigeye, or yellowfin tuna of a similar age. At times, albacore may form mixed species schools with bluefin, yellowfin, and skipjack of similar size. On average, albacore are thought to grow to a maximum fork length approaching 125 cm, and weight approaching 40 kg. Individuals that reach 93 cm fork length and approximately 18 kg are believed to be approaching 5 years old. In the Atlantic, albacore are thought to reach maturity at about 5 years.

ICCAT recognizes several possible stock hypotheses for albacore including a North Atlantic stock hypothesis. North Atlantic albacore catches have declined from 1961-1989. Peak landings occurred in 1964, when 64,400 t were removed. In 1992, 29,700 t were taken from this stock. Most of the recent catches have been made in surface fisheries, mainly baitboats and trolled lines, although drift gillnets and pelagic trawls are also applied. Prior to 1987, up to 50% of the catch was made by longline gear. Reduction of the Taiwanese fleet in the North Atlantic grounds resulted in significant reductions in longline catch of albacore. Spain and France have been the major harvesting nations for North Atlantic albacore in the most recent period. Since 1987, Spain has accounted for approximately 80% of the reported North Atlantic albacore landings. In recent years, catches of immature fish (less than 5 years) have increased substantially in contrast to earlier periods. In 1993, ICCAT's SCRS reassessed the status of the North Atlantic albacore stock and found the stock could be highly exploited based on virtual population and yield per recruit analyses. Non-equilibrium production model analysis based on several surface fishery catch per unit effort series and total landings from 1959-1991 resulted in estimates of the long-term potential yield for North Atlantic albacore that range from 37,340 - 68,930 t. Catches were consistently within or above this range from 1962-1986, but have remained below since 1987. The estimated range of MSY results from an equilibrium production model analysis which might overestimate MSY and lead to an overly optimistic assessment of stock status. Application of a non-equilibrium method to the South Atlantic albacore stock at the 1992 SCRS assessment demonstrated this. The recent average yield of North Atlantic albacore for 1989-1992 is estimated to have been 30,850 t. The average yield to U.S. fishermen during this period was approximately 376 t. The estimated U.S. recreational harvest of this species for the period was 179 t. The yield and estimated exploitable stock biomass for this species are shown in **Figure 17**.

SKIPJACK TUNA

Skipjack tuna (*Katsuwonus pelamis*) is a cosmopolitan species, occurring in tropical and warm-temperate seas and feeding opportunistically on crustaceans, mollusks, and small fish. It is a relatively small tuna. The maximum size observed for skipjack from all oceans is about 110 cm, corresponding to a weight of about 34 kg; however, fish in the range of 80 cm or less and up to 10 kg are most common. Skipjack are thought to first spawn at about 45 cm or at about 1 year old. They mature at an earlier age and have a higher natural mortality rate than either yellowfin or bigeye tunas.

ICCAT recognizes several possible stock hypotheses for skipjack including a western Atlantic stock hypothesis. The western Atlantic skipjack catch has dramatically increased in recent years from relatively low

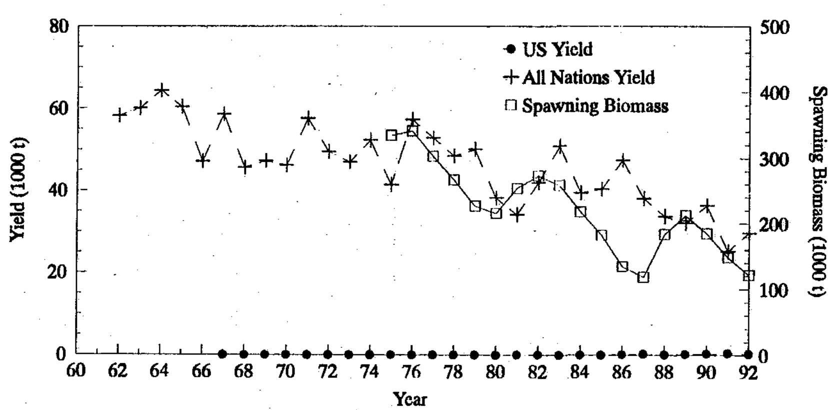


Figure 17. North Atlantic albacore yield and spawning biomass.

SKIPJACK

Longterm potential yield	33,000 t
Current potential yield	Unknown
Recent average annual yield	26,900 t (stock)
	357 t (United States)
Status of exploitation	Fully exploited
Age at 50% maturity	1 - 1.5 years
Generation time	2 - 3 years
Natural mortality rate	0.6 - 0.8

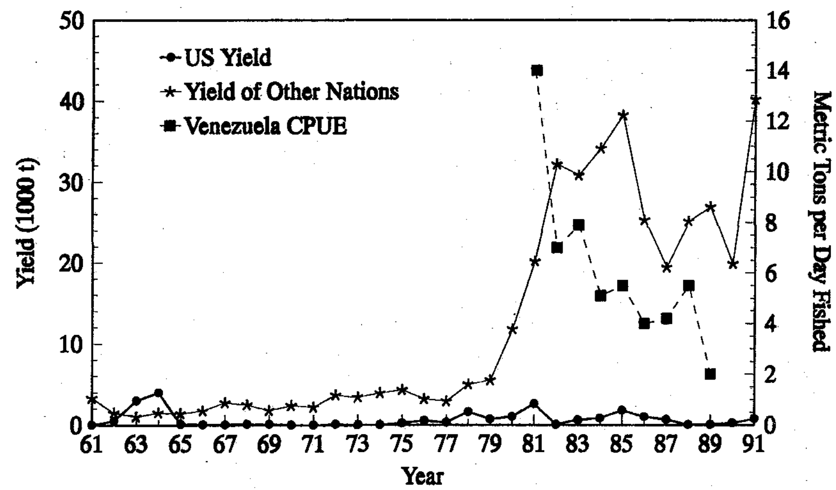


Figure 18. Yield and relative abundance for skipjack tuna in the western Atlantic. Abundance index is based on Venezuelan surface fishery catch per unit effort.

levels seen in the early 1960s to 1979, rising to a peak of 40,000 t in 1985. Almost all of this catch was taken in surface fisheries, mainly by baitboats. Brazil, Venezuela, and Cuba accounted for more than 95% of the 1991 catch of western Atlantic skipjack. A preliminary production model analysis, based on Venezuelan baitboat catch per unit effort and the total landings from 1981-1989, resulted in an estimate of the long-term potential yield for western Atlantic skipjack of approximately 33,000 t. The analyses indicate that some gain in yield might be realized by reducing effective effort on this species. The degree to which this conclusion is influenced by insufficient catch per unit effort information to cover the stock range has yet to be determined.

The recent average yield of western Atlantic skipjack tuna for 1989-1991 is estimated to have been 26,900 t. The average yield to U.S. fishermen during this period was approximately 357 t. The estimated U.S. recreational harvest of this species for the period was 17 t. The yield and relative abundance for this species are shown in **Figure 18**.

OTHER TUNAS

At least five species are included in the other tuna category. They include: Atlantic bonito *(Sarda sarda)*, little tunny *(Euthynnus alletteratus)*, frigate tuna *(Auxis thazard)*, blackfin tuna *(Thunnus atlanticus)*, and wahoo *(Acanthocybium solandri)*. Others may also be included but are not discriminated to species level in the international landings statistics. In the Atlantic, the recent average yield for these species in aggregate for 1989-1991 was 51,600 t (**Figure 19**). The recent average yield to U.S. fishermen during the same period was 732 t. The estimated recent average yield to U.S. recreational fishermen for this group was conservatively estimated as 36 t.

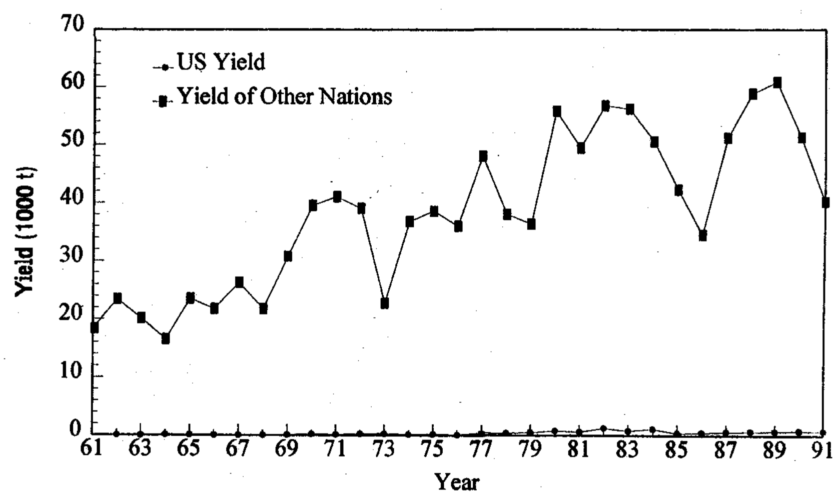


Figure 19. Yields of other tunas.

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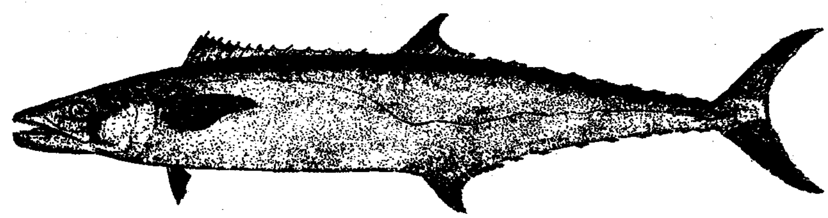
Coastal Pelagics



King mackerel *(Scomberomorus cavalla)*

Five principal species comprise the coastal-pelagic fisheries of the southeastern United States. These are king mackerel, Spanish mackerel, dolphin, cobia, and cero. In general, they form schools, swim fast, feed voraciously, grow rapidly, exhibit sexual dimorphism, mature moderately early, and spawn for extended periods of time. They range from nearshore to the edge of the continental shelf and constitute important resources for recreational and commercial fishermen.

KING MACKEREL

Populations of king mackerel, *Scomberomorus cavalla*, inhabit the neritic zone, extending from shore to the outer edge of the continental shelf. Their range begins in the Gulf of Maine and extends southward along the U.S. Atlantic coast, Gulf of Mexico, Caribbean Sea, and as far south as the northern coast of Brazil. King mackerel concentrate along the Carolinas in the spring through fall, the northern Gulf of Mexico in the summer, and the southeastern coast of Florida in the winter. Distributions of king mackerel are controlled by water temperature and salinity. The 20°C isotherm limits their northern range and largely affects their contracted winter range in the Atlantic. Salinity also controls pelagic distribution with the adult and large juveniles considered non-estuarine dependent.

Adult and juvenile king mackerel are pelagic carnivores and consume both fish and invertebrates. Their predominant prey is schooling pelagic fish such as herrings, sardines, and other clupeids. Along the southeastern coast of Florida they often feed on ballyhoo. Squid and penaeid shrimp constitute their principal invertebrate prey. King mackerel are preyed upon by a variety of larger species. Tunas and cobia feed on the larval and small juvenile stages. Pelagic sharks, tuna, dolphins, and various marine mammals including bottlenose dolphin feed on the larger sizes.

King mackerel exhibit sexual dimorphism. Maximum length in males is about 122 cm fork length and about 135 cm fork length in females. Although growth is quite variable, females appear to grow faster and live longer than males. The maximum age is about 15 years for males and 20 years for females. King mackerel along the Atlantic coast are believed to live longer than king mackerel in the Gulf of Mexico. Average size to sexual maturity is near 91 cm fork length (age 5-6) with females maturing before the males. The average age of fish in the fishery is about 5-6 years.

King mackerel spawn in coastal waters along the northern Gulf of Mexico and southeastern Florida. The spawning season is protracted as evidenced from their appearance as larvae from May through October with a peak in September. It has been suggested that the spawning season in the northern Gulf of Mexico may be bimodal with one peak from May to July and a second peak from August through October.

Commercial fishermen have fished king mackerel since the 1800s using gill nets, troll lines, handlines, purse seines, otter trawls, and pound nets. Recreational fishermen use hook and line gear from private and charter boats. Today, major commercial fisheries occur in North Carolina, Florida (between Sebastian and Key West), and Louisiana. Recreational charterboat and private boat hook-and-line fisheries occur in the Carolinas, throughout Florida, the northern Gulf of Mexico, and Texas. A minor recreational fishery is conducted by anglers fishing from headboats in southeast Florida, the Florida Keys in winter months, and in Texas during summer.

Mackerels within the southeastern United States are jointly managed by the South Atlantic and Gulf of Mexico Fishery Management Councils under the 1982 Coastal Pelagics Fishery Management Plan. The two councils establish total allowable catch quotas (TACs) for two distinct migratory groups: the Gulf Migratory Group and the Atlantic Migratory Group. Allowable biological catches (ABCs) are defined for separate geographical areas within the Gulf group and for separate user groups. Quota management began in the 1985/1986 fishing year in the Atlantic and Gulf of Mexico. Both commercial and charterboat operators must hold permits to fish king mackerel, Spanish mackerel, or other coastal pelagics. Recreational catches are further regulated by creel and size limits. In addition to quota limits, commercial catches are under minimum size restrictions and in some states daily landing limits and/or trip limits apply. In the Gulf of Mexico purse seines and drift gill nets are prohibited fishing gear for all mackerel stocks. Drift gill nets are prohibited gear in the Atlantic for king mackerel stocks.

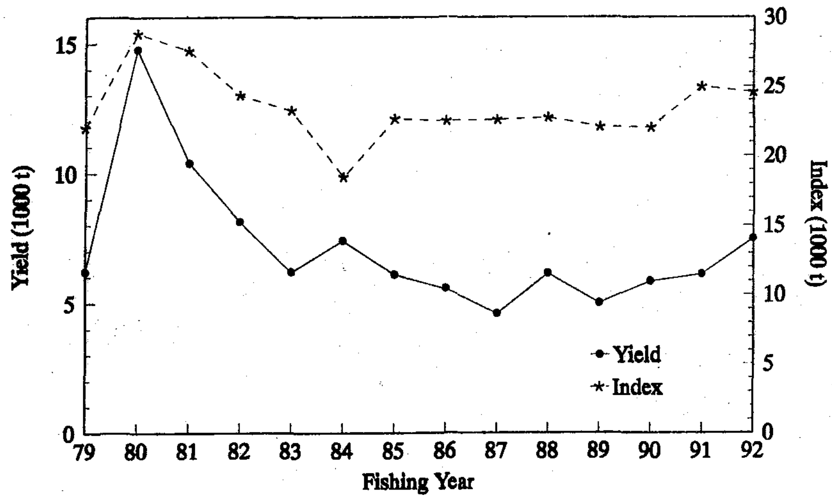


Figure 20. Combined Gulf and Atlantic king mackerel yield and index of abundance by fishing year (fishing year defined as: 1979 = 1979-1980, etc.).

Growth information from tagging studies has been used to verify growth information obtained from traditional hard-part studies. Current stock boundaries are determined from information obtained from tag return data and from electrophoretic tissue analyses. The Gulf migratory group of king mackerel is considered overfished. It has been managed under a closely monitored rebuilding schedule since 1986 and is most likely to contribute the greatest production over the long term, but it is also the most severely depressed and yields at present are relatively low in relation to the long-term potential. Yield in the 1992 fishing year from the Gulf of Mexico was 4,177 t of which 1,571 t was commercial and 2,606 t was recreational (**Figure 20, Table 6**). Recent spawning potential from this unit is estimated to be 20% of maximum spawning potential. Reductions in current stock size and subsequent lost production potential are due to excessive mortality from fishing in the late 1970s and 1980s.

The Atlantic migratory group is not presently considered overfished. It is, however, believed to be near maximum production, and this group is currently producing at 45% of SPR. In the 1992 fishing year, the U.S. Atlantic yield was 3,242 t of which 1,004 t was commercial and 2,238 t was recreational.

SPANISH MACKEREL

Spanish mackerel, *Scomberomorus maculatus*, are found from Maine to the Yucatan Peninsula of Mexico in waters above the continental shelf. Although the species is sometimes found in Bermuda, it is absent from most of the West Indies. In waters from Belize to Brazil *S. maculatus* is replaced by a similar species, *S. brasiliensis*.

Distribution of Spanish mackerel is controlled by salinity and water temperature. Larval stages are found most frequently offshore over the inner shelf in saline to estuarine waters and abundance is greatest in the northern Gulf of Mexico. Small juveniles are found from offshore to estuarine waters but are not considered estuarine dependent. Adults are neritic along the coast and are rarely encountered beyond 75 m of water depth.

In the western part of the Gulf of Mexico, a spring migration occurs as schools move north and east. Large schools are encountered off Alabama and Mississippi from the spring through the fall. Migrations in the fall result in a net movement southward and fish may overwinter off the Mexican coast, particularly the Yucatan Peninsula.

Juvenile and adult Spanish mackerel are pelagic carnivores. Prey include schooling pelagic fishes such as anchovies and herring. Invertebrate prey is primarily squid and shrimp.

Spanish mackerel exhibit sexual dimorphism with the females being larger than the males. The initial growth phase is rapid in the males, but females quickly attain similar sizes and eventually grow larger than males. The maximum sizes are 64 cm fork length for females and 56 cm fork length for males. The maximum ages reported are 7 years for males and 10 years for females. The average age of fishes in the fishery is about 3 years.

Sexual maturity is achieved during the second and third years. Spawning occurs from April though September along the northeastern Florida coast and from April through August off North Carolina to Cape Canaveral, Florida.

Commercial fisheries for Spanish mackerel have existed since the 1850s. Commercial fishermen originally used trolling gear but now the predominant gear of choice is gill nets. Historical fisheries operated in the late 1800s and early 1900s along the east coast of Florida and in Chesapeake Bay. Present day fisheries occur mainly along Florida's east coast and the Florida Keys. Increased production has occurred in the late 1980s in Chesapeake Bay. Although recent landings have increased for this region, historical levels of production have not been attained. There is a significant recreational fishery using hook and line gear, and the total recreational catch represents about one half of the total annual harvest.

The status of Spanish mackerel stocks is assessed annually as required by the Coastal Pelagics Fishery Management Plan. As with king mackerel, two migratory groups, the Gulf and the Atlantic, are recognized for management. In the 1992 fishing year, Spanish mackerel yield in the Gulf of Mexico was about 2,461 t of which 1,299 t was commercial and 1,162 t was recreational (**Figure 21, Table 6**). In the 1992 fishing year, the Atlantic yield was about 2,641 t with 1,702 t commercial and 938 t recreational. Commercial catches are regulated by quotas and daily landing limits in some states. Recreational catches are managed by quotas and

KING MACKEREL

	U.S. Atlantic	U.S. Gulf
Longterm potential yield	3,632 t	9,750 t
Current potential yield	3,263 t	3,546 t
Recent average annual yield	3,121 t	3,004 t
Status of exploitation	Under exploited	Over exploited
Age at 50% maturity	5-6 years	5-6 years
Current spawning potential ratio	45%	20%
Projected SPR at current fishing patterns	Greater than 30%	Less than 30%
Generation time	12 years	12 years
Natural mortality rate	0.15	0.15
Fishing mortality rate at $F_{30\% SPR}$	0.29	0.12
Fishing mortality rate in most recent year	0.12	0.39

SPANISH MACKEREL

	U.S. Atlantic	U.S. Gulf
Longterm potential yield	3,715 t	5,457 t
Current potential yield	2,702 t	2,895 t
Recent average annual yield	2.274 t	2,705 t
Status of exploitation	Over exploited	Over exploited
Age at 50% maturity	2 years	2 years
Current spawning potential ratio	Greater than 42%	25%
Projected SPR at current fishing patterns	25%	42%
Generation time	7 years	7 years
Natural mortality rate	0.3	0.3
Fishing mortality rate at F_{SPR}	0.17	0.18
Fishing mortality rate in most recent year	0.51	0.71

creel limits. Both the Atlantic and Gulf migratory groups are considered to be overfished and management is based on a rigid rebuilding schedule.

DOLPHIN

Dolphin, *Coryphaena sp..*, are fast swimming pelagic fishes found worldwide in tropical and subtropical waters. The genus, the only one in the family Coryphaenidae, is composed of two species, *C. hippurus* and *C. equisetis*. In the western Atlantic, dolphin are found as far north as Georges Bank, Nova Scotia, and as far south as Brazil. They are particularly abundant in the Gulf of Mexico and in the Florida Current. Their distribution appears to be temperature dependent and they are rarely found in waters of less than 20°C and above 41°N. Dolphin are year round residents throughout their range and demonstrate seasonal changes in distribution that are temperature induced. Along the southeastern United States, dolphin are common off North Carolina from late spring through the summer. Off the Florida east coast, they are commonly encountered by recreational fishermen in the winter and early spring. In the Gulf of Mexico, they are almost exclusively fished in the summer with peaks in August.

Dolphin are an open ocean species that are opportunistic carnivores. They feed primarily on crustaceans and shift to fish as juveniles and adults. A major component of the stomach contents in western Atlantic dolphin is sargassum weed which is probably ingested with the prey that inhabit sargassum. Dolphin are commonly associated with lines of sargassum and are known to associate with any floating objects that would tend to attract smaller types and sizes of fish.

Sexual dimorphism is strongly exhibited in the shape of the head. Males have a very steep forehead and are referred to as "bulls." The head of the female is more streamlined at the

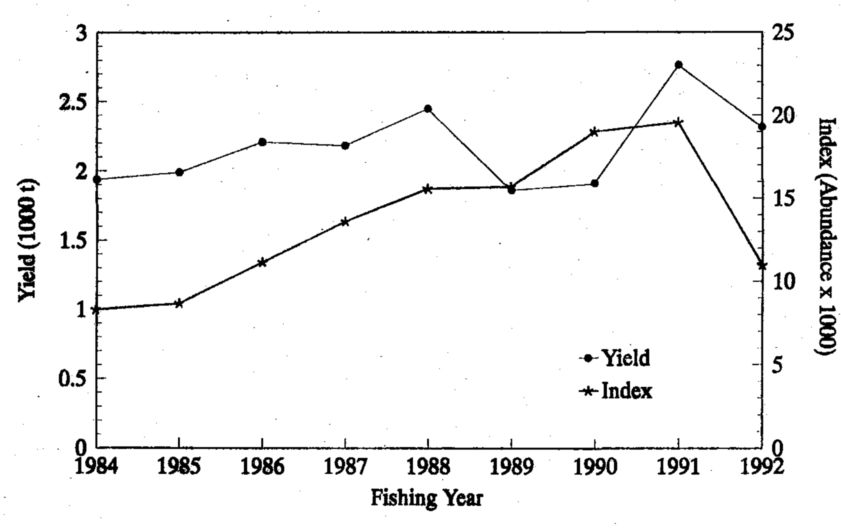


Figure 21. Combined Gulf and Atlantic Spanish mackerel yield and index of abundance by fishing year (fishing year defined as: 1979 = 1979-1980, etc.).

Table 6. Coastal mackerel yields in thousands of metric tons.

Fishing Year*	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
KING MACKEREL														
U.S. Gulf of Mexico														
Commercial	2.0	2.8	2.7	2.2	1.4	1.4	1.6	0.5	0.4	0.6	0.9	0.8	0.8	1.6
Recreational	2.0	6.2	3.6	1.7	1.0	1.7	1.2	1.4	0.9	1.9	1.5	2.2	2.0	2.6
U.S. Atlantic														
Commercial	1.0	1.4	1.2	1.9	1.2	0.9	1.1	1.3	1.6	1.4	1.2	1.2	1.1	1.0
Recreational	1.2	4.4	2.9	2.4	2.7	3.4	2.2	2.4	1.7	2.2	1.5	1.6	2.1	2.3
SPANISH MACKEREL														
U.S. Gulf of Mexico														
Commercial	-	-	-	-	-	1.6	1.5	0.9	1.1	1.7	0.9	0.9	1.8	1.3
Recreational	-	-	-	-	-	0.6	0.7	2.4	1.4	0.8	0.7	0.8	1.0	1.2
U.S. Atlantic														
Commercial	-	-	-	-	-	1.5	1.8	1.1	1.6	1.6	1.8	1.6	2.1	1.7
Recreational	-	-	-	-	-	0.7	0.4	0.5	0.6	1.2	0.6	0.9	1.0	0.9

* Fishing years for Gulf king mackerel: July 1 - June 30; Atlantic king mackerel and Spanish mackerel: April 1 - March 30

forehead. The bull-head shape appears at about 40 cm fork length during the first year of life. Females reach sexual maturity in the first year of life at about 35 cm fork length.

Spawning is protracted and may be multi-modal. In the Florida Current, spawning appears to occur year-round with peak spawning in January, February, and March. Off North Carolina spawning peaks in June and July. Individual growth is very variable; however, growth is considered very rapid and generation time short. Longevity in this species is estimated to be about 6 years and natural mortality extremely high. Maximum lengths and weights reported are for males and are 150 cm fork length and 46 kg.

There are no complete data on the number of commercial vessels fishing dolphin. However, before 1987 commercial landings occurred mainly as a bycatch. Since 1987, dolphin have been targeted occasionally by commercial yellowfin tuna surface longline vessels and sometimes are landed by pelagic longline vessels. Commercial landings have tremendously increased since 1984 .

In 1992 total commercial yield of dolphin was 728 t . Recreational yields are significant with the production of this sector ranging from 3,084 t in 1984 to 3,933 t in 1992 (**Figure 22, Table 7**).

Under the Coastal Pelagics Fishery Management Plan, dolphin are managed by daily creel limits and a minimum size of 45.7 cm fork length and several states have adopted daily creel limits. The current status of the resource is unclear. Atlantic yield of dolphin fluctuated without trend around 3,100 t between 1984 - 1987. During 1988-1991, total production

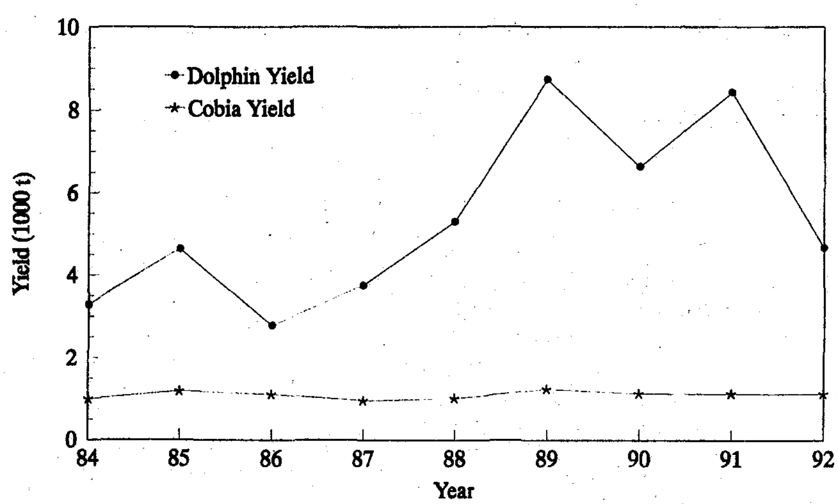


Figure 22. Dolphin and cobia yields.

has increased from 3,598 t to 4,991 t. Gulf of Mexico production has ranged from 722 t in 1984 to 1,739 t in 1992.

The primary user group remains the recreational sector, and there is no extensive time series of recreational data on this species from which to adequately evaluate trends regarding the condition of the stock. Management measures are temporally short time based because of the biological nature of the species.

COBIA

Found worldwide in temperate waters, cobia, *Rachycentron canadum*, range in the western Atlantic from New England to Argentina. Their distribution appears to be controlled by water temperature associated with the continental shelf. The limiting water temperature for adults is about 19°C. Cobia are considered voracious carnivores and often consume prey whole. Prey include crabs, other bottom invertebrates, and fish.

Cobia grow rapidly and may live up to 15 years. The maximum length reported is about 60 cm fork length and a maximum weight of 70 kg. Females probably grow larger than males. Males mature in their second year of life at about 50 cm fork length and females mature in their third year at about 55 cm fork length. There are little data on size or age of fishes in the fishery.

Spawning may be multi-seasonal and peaks in the summer. In the southeastern United States, spawning occurs off the Carolinas, off the Texas coast and in the Caribbean Sea. Fishery statistics are limited, but catches have been stable since 1981 and average 68 t in the Gulf of Mexico and 45 t in the Atlantic. The commercial removals are taken primarily under the bag limit allowance to vessels holding coastal pelagic fishing permits.

Cobia are managed under the joint council Coastal Pelagic Fishery Management Plan. Two stocks, one for the U.S. Atlantic and one for the U.S. Gulf of Mexico, are assumed for purposes of management. There are no commercial quotas established and the recreational fishery has daily creel limits and a minimum size of 50.8 cm fork length. Total yields of cobia have varied from 994 t in 1984 to 1,121 t in 1992 without a definitive trend. Currently the yield from the Gulf of Mexico accounts for about 60% of the total annual production. The current status of the resource is not known; however, the resource is thought to be fully exploited. Based on recent information from revised fishery catch statistics and biological samples, maximum sustainable yield is estimated to be about 1,089 t. Currently the fishery is producing on average about 1,000 t annually. The stock is thought to be experiencing a fishing intensity that will maintain a 30% SPR.

CERO

Cero, *Scomberomorus regalis*, commonly range from Massachusetts to the Yucatan Peninsula. Cero are considered neritic, schooling carnivores. Cero are the least abundant of the mackerels off the southeastern U.S. coast. This species is most frequently encountered off the Bahamian and West Indian waters and supports a small commercial fishery in Cuba. Biological information on this species is primarily limited to reproductive biology. Cero spawn throughout the year. Males are thought to be reproductively mature at 33 cm and females at 35 cm. Age at maturity has not been estimated. The species is not targeted by any particular fishery in the United states, and it is currently not under any quota or creel limit under the Coastal Pelagics Management Plan.

Table 7. Cobia and dolphin yields in thousands of metric tons.

Calendar Year	1984	1985	1986	1987	1988	1989	1990	1991	1992
COBIA									
U.S. Gulf of Mexico									
Commercial	0.06	0.06	0.07	0.08	0.07	0.09	0.07	0.08	0.10
Recreational	0.48	0.51	0.68	0.52	0.57	0.57	0.64	0.44	0.48
U.S. Atlantic									
Commercial	0.01	0.02	0.03	0.44	0.42	0.05	0.05	0.06	0.06
Recreational	0.43	0.60	0.33	0.32	0.33	0.52	0.37	0.29	0.47
DOLPHIN									
U.S. Gulf of Mexico									
Commercial	0.13	0.12	0.22	0.18	0.23	0.47	0.49	0.77	0.51
Recreational	0.59	0.71	1.04	0.60	1.48	1.65	1.46	1.16	1.22
U.S. Atlantic									
Commercial	0.07	0.06	0.09	0.10	0.10	0.19	0.25	0.29	0.21
Recreational	2.49	3.76	2.37	2.87	3.50	6.43	4.43	4.70	2.71

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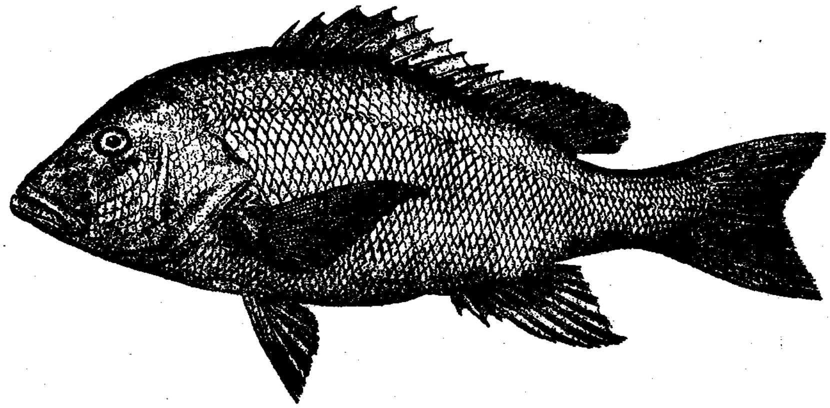
Reef Fish



Red snapper (*Lutjanus campechanus*)

Reef fish are species that tend to show high site fidelity to specific bottom features including coral reefs, hard bottoms, artificial structures, and, in the case of tilefish, sand areas. As a unit, reef fish extend from the shoreline to approximately 275 m depending on the species and area. Excluding fishes in the marine aquarium trade, the unit includes approximately 100 species with wide geographical ranges.

Within the southeastern region, the reef fish unit is managed by three Councils for Federal waters, eight states, the Territory of U.S. Virgin Islands, and the Commonwealth of Puerto Rico. Species composition and fishery characteristics vary greatly with location. The fishery is complex with commercial, artisanal, and recreational components. Many fishing methods are used (e.g., fish traps, hook and line, longlines, bandit rigs, spears, and trammel and barrier nets). The recreational fishery includes fishermen that specialize in food, sport, and trophies and operates from charterboats, headboats, private boats, and shore.

Although landings of individual species are not great on a national scale, the reef fish unit is extremely important in aggregate because of its high recreational and commercial use. A significant economic value also exists in its non-consumptive uses (e.g. ecotourism, sport diving, education, scientific research) which often conflict with fishery use. The reef fish fishery is ecologically integrated with and closely associated with other reef fisheries including spiny lobster, conch, stone crab, corals, "live" rock, and ornamental aquarium fishes.

The reef fish fishery has operated for over 200 years, but statistical data became available for most areas only since the late 1970s. The number of fishing components, geographical spread, and numerous ports used for landing make data collection difficult. Fishing pressure has recently increased due to higher human populations in coastal areas and greater demand for fishery products. Fishing power has increased due to technological innovations such as bottom longlines (introduced in the late 1970s), wire fish traps (expanded in the mid 1970s), inexpensive navigational aids (LORAN, fish finders), and inexpensive and more powerful boats. Reef fish are prone to overfishing because of their characteristics that include long lives, slow growth, low natural mortality, large body size, delayed reproduction, and sex changes for some species. The status of the fishery varies greatly depending on the area and species. In most cases the current potential yield and long-term potential yield are unknown. Most traditional fisheries are probably fully exploited or overfished.

Short-term issues of concern are: 1) reducing the bycatch mortality of red snapper in the Gulf of Mexico shrimp fishery, 2) assessing and increasing the survival rate of released undersized fishes, especially those caught from deeper waters, 3) identifying stocks (i.e. determining genetic structure and sources of recruitment on a geographical basis), 4) determining the importance and causes of recruitment variability, 5) determining long term potential yield by area and species, 6) overcoming the overfishing of specific stocks (e.g., jewfish, Nassau grouper), 7) assessing overfishing and bycatch mortality by specific gears (e.g., longlines, wire fish traps), and 8) assessing the appropriateness of artificial reefs and hatcheries to augment stock size.

Major long-term issues are: 1) evaluating the use of marine fishery reserves to manage reef fisheries, 2) applying non-destructive, fishery-independent video technology to assess stocks, 3) obtaining adequate routine statistical data coverage of the various components of the fishery, 4) developing adequate models to describe and predict dynamics of multiple-species reef fisheries and reef ecosystems, 5) determining stock effects of habitat alteration and degradation (e.g. sea grasses, coral reefs, mangroves, estuaries), and 6) assessing the potential for altering stock genetics by fishery removal. A problem unique to reef fisheries is to balance consumptive fisheries use with non-consumptive uses (i.e. ecotourism, sport diving).

GULF OF MEXICO

More than 70 reef fish species are caught in the Gulf of Mexico. The most important commercial reef fishes landed in 1992 were: groupers (4,300 metric tons (t)), snappers (4,000 t), and amberjacks (1,200 t). Commercial yields are shown in **Figure 23**. Most commercial reef fishes are landed in Florida. In recent years the composition of the landings has changed with declines of red snapper and increases of vermilion snapper and amberjack. In the early 1980s the development of the bottom longline increased the amount of deeper water reef fish landings, especially yellowedge grouper. In 1992, red grouper was the most important reef fish species accounting for approximately 55% of all reported commercial grouper landings and 16% of the total reported reef fish landings. The red snapper was the most important commercial snapper species harvested, comprising approximately 36% of all snappers and 10% of total reef fish landings. Other dominant snapper species were the vermilion snapper (27% of snappers and 7% of total reef fish) and yellowtail snapper (20% of snappers and 5% of total reef fish). The methods used to land reef fishes in order of importance were handlines (hook and line, bandit rigs, traditional handline), bottom longlines, fish traps, and spearfishing.

The Reef Fish Fishery Management Plan for the Gulf of Mexico was implemented in 1984. Regulations, designed to rebuild declining reef fish stocks, included prohibitions on the use of fish traps, roller trawls, and powerheads on spearguns within an inshore stressed area; a 33 cm total length minimum size limit on red snapper (with some exceptions); and data reporting requirements. A spawning potential ratio of 20% was established as a basis to measure overfishing. Amendment 1 (1990) implemented a five fish recreational bag limit and a 5 thousand t commercial quota on groupers (divided into a 4.2 thousand t shallow-water quota and a 0.8 thousand t deep-water quota. Also, procedures were made to facilitate annual management changes. Amendment 2 (1990) prohibited the harvest of jewfish. Amendment 3 (1991) provided additional flexibility by allowing the target date for rebuilding an overfished stock to be changed depending on changes in scientific information. A revised target year of 2007 was established for achieving a 20% spawning potential ratio goal for red snapper. Changes were made in the classification of shallow- and deep-water grouper.

RED SNAPPER
(U.S. Gulf of Mexico)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Over exploited
Current spawning potential ratio	1%
Projected SPR at current fishing patterns	20%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.12
Fishing mortality rate at F_{max}	0.18
Fishing mortality rate in most recent year	0.80

VERMILION SNAPPER
(U.S. Gulf of Mexico)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Unknown
Natural mortality rate	0.23-0.30
Fishing mortality rate at $F_{0.1}$	Unknown
Fishing mortality rate at F_{max}	Unknown
Fishing mortality rate in most recent year	Unknown

RED GROUPER
(U.S. Gulf of Mexico)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Fully exploited
Current spawning potential ratio	40%
Projected SPR at current fishing patterns	40%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.19
Fishing mortality rate at F_{max}	0.59
Fishing mortality rate in most recent year	Unknown

SNAPPERS
(Gulf of Mexico)

Snappers (family Lutjanidae) are one of the most widely distributed fish groups in the western Atlantic. Snappers are small to mid-sized predators and may occur in very large numbers in local habitats, especially reefs. They are a major component of the reef fish fishery. The Gulf of Mexico has 5 genera and 14 snapper species. All snappers are gonochoristic (separate sexes) and fecundity increases exponentially with size. In the Gulf spawning appears to peak during summer months. In general, snappers are slow growing, long-lived, and have relatively low rates of natural mortality. Relatively few estimates of population parameters have been developed specifically for the Gulf of Mexico. Fishing regulations vary by species but usually employ minimum sizes and bag limits.

RED SNAPPER (Gulf of Mexico)

The red snapper (*Lutjanus campechanus*) is traditionally the most important commercial reef fish in the Gulf of Mexico. It is found from Cape Hatteras, North Carolina through the Gulf of Mexico and to the Campeche Shelf of Mexico. Adults are widespread but usually associate with hard bottom structure during the day and feed on flat bottom away from home structures at night. Spawning may occur throughout the year although in the Gulf spawning is concentrated in summer months. Growth rates vary between locations. Individuals were reported to reach 11-13 cm at age-1 and 20-23 cm at age-2 in Texas waters while off Louisiana they may reach 17.7 cm at age-1 and 29.8 cm at age-2. They continue to grow 6-9 cm each year through the 4th or 5th spawning period when growth slows considerably. Maturity occurs after age-2 at variable sizes. Fecundity increases exponentially with size. Maximum reported fecundity was a 60.5 cm, 12.5 kg fish with 9.3 million eggs. Maximum adult size is around 97 cm. Natural mortality is low, perhaps averaging around 17% annually. Most adults appear to be sedentary throughout much of their lives.

Red snapper are primarily caught in the northern Gulf of Mexico from Panama City, Florida, to Galveston, Texas, with most harvested to the south and west of the Mississippi River. Commercial landings were relatively stable at 3 thousand t in the 1960s to mid 1970s and then declined to a low of 1.3 thousand t in 1989. The recreational harvest of red snapper also declined sharply in numbers and weight from an estimated peak of 4.6 thousand t (4.0 million fish) in 1980 to a low of 0.7 thousand t (0.8 million fish) in 1987.

Fishing mortality rates within the directed fishery are high. They rise rapidly with age after the juvenile red snapper enter the fishery at age-2, peak at F = 0.8 to 0.9 at age-3 and then decline with age to F = 0.5 to 0.6 at age-5 and beyond. Red snapper are growth and recruitment overfished partly because of the directed commercial and recreational fisheries but also due to bycatch mortality from bottom trawls from the shrimp fishery. Juvenile red snapper (ages 0 and 1) are killed in the normal operation of shrimp trawls and discarded at sea. From recent estimates, only about 25% of the original number of juveniles survive to enter the directed fishery although the accuracy of these estimates is uncertain. Research efforts are underway to develop fish excluders to reduce this bycatch mortality although no new management efforts regarding the shrimp bycatch issue are anticipated until 1994.

Spawning potential is currently estimated to be about 1% of the unfished condition, considerably below the 20% minimum required by the Gulf of Mexico Reef Fish Management Plan.

Current regulations in the Gulf of Mexico include a 33 cm total length minimum size, a 0.9 thousand t commercial quota adjusted annually, and a recreational harvest bag limit of 7 per person per day.

VERMILION SNAPPER (Gulf of Mexico)

The range of the vermilion snapper (*Rhomboplites aurorubens*) extends from North Carolina to southeastern Brazil. They are found in moderately deep waters over rock bottom near the edge of the continental shelf. They often form large schools, especially when young, and feed on fishes, shrimps, crabs, polychaetes, other benthic invertebrates, cephalopods and planktonic organisms. Compared to the red snapper, vermilion snapper is more of a midwater species.

Reproduction extends throughout the summer with older females spawning more frequently than the younger ones. Age of sexual maturity varies but may extend from as early as age-1 to as late as age-3 or 4. There is some evidence that the age of first reproduction may have shifted to younger ages in areas with intense fishing pressure. Males mature at approximately 14 cm total length while females mature at approximately 20 cm total length. Growth rates are uncertain because of conflicting results between studies. Individuals may live to be 13 years old with a total length of 76 cm. Movement after settlement appears to be minimal.

Annual landings of vermilion snapper from the Gulf of Mexico increased from 0.36 thousand t in 1979 to 1.4 thousand t in 1992. Historically, the fishery was concentrated around the mouth of the Mississippi River, but since 1973, has expanded into the western Gulf of Mexico. Commercial landings account for approximately 75% of the weight and 50% of total numbers compared to the recreational sector, in which over 90% of the harvest was by the charter and party boats. Based on samples from the recreational catch, the landings have not shown a meaningful change in average size in response to the increased harvest.

Regulations include a minimum size of 20 cm total length in Florida and in federal waters of the Gulf of Mexico.

GROUPERS (Gulf of Mexico)

Groupers (family Serranidae, specifically the genera *Epinephelus* and *Mycteroperca*) are important food fishes with cosmopolitan distributions in tropical and temperate waters. Many reach large size and most feed primarily on fishes or large invertebrates. They have a wide depth distribution ranging from shallow inshore grass beds out to the continental shelf break. Most prefer hard substrate habitats. The Gulf of Mexico has approximately 14 species of groupers. Most, if not all, groupers are protogynous hermaphrodites (juveniles mature as females and change sex to males at older ages). Spawning characteristically takes place at localized grounds for relatively brief periods, typically from early spring through the summer. Fecundity increases exponentially with body size. Population parameters suggest that most groupers exhibit slow growth, low natural mortality, and long life spans (40 years in some cases).

Grouper species were not identified in commercial landings prior to 1986. Prior to the introduction of bottom longline gear in the early 1980s, commercial landings of all groupers exhibited a slow decline from about 3.5 thousand t (gutted weight) in 1965 to about 2.3 thousand t in the late 1970s. With the introduction of bottom longline gear, total grouper landings increased to about 5.7 thousand t in 1982. Since 1982, total annual landings have fluctuated between 3.0 and 5.8 thousand t.

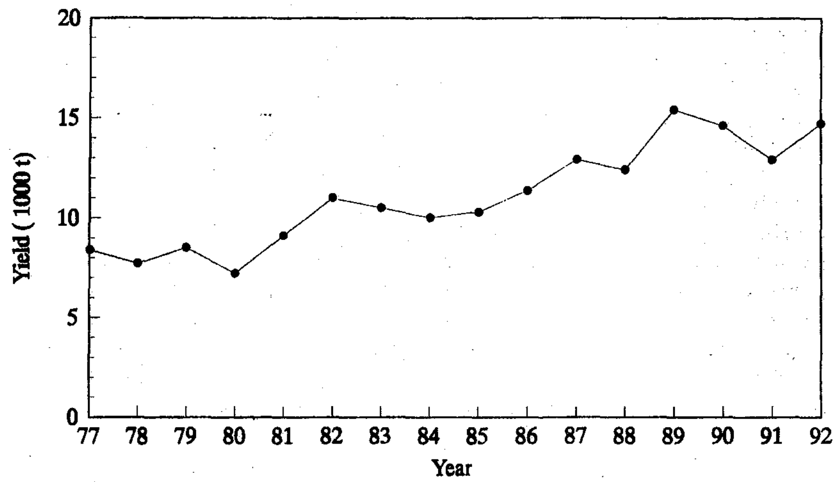


Figure 23. U.S. Gulf of Mexico commercial reef fish yield.

RED GROUPER
(Gulf of Mexico)

Red grouper (*Epinephelus morio*) are widely distributed along the coastal Atlantic from Massachusetts southward to Brazil, including the Bahamas, Bermuda, Gulf of Mexico, and West Indies. Generally adult red grouper prefer rocky, hard bottom areas near reefs in 30-120 m water depths, while small adults and juveniles are frequently found at shallower depths inshore among turtle grass and sandy holes. This species is the most common grouper caught by commercial and recreational fishermen in the U.S. Gulf of Mexico. Most of the U.S. fishery for this species occurs in the eastern Gulf of Mexico from Panama City, Florida to the Florida Keys.

Red grouper grow to 1.1 m total length, weigh 25 kg and live as long as 30 years. Individual fish attain a size of about 40 cm after 5 years. They are protogynous hermaphrodites and generally change from females to males at a length of 30-80 cm. Spawning occurs in aggregations with peak spawning during April and May, but some fish may be reproductively active January through November. One female may produce as many as 1.5 million eggs.

Handlines, power-assisted (electric or hydraulic) reels, bottom longlines, traps, and spears are used to harvest red grouper. Most fish are marketed within the 2 - 10 kg range. Red grouper comprised nearly two-thirds of the total grouper harvest from the U.S. Gulf of Mexico since 1986 and averaged 3,862 t during 1990 - 1992. Estimates of the recreational harvest of red grouper are highly variable but on average account for 29% of the total red grouper harvest.

U.S. ATLANTIC

Reef fish in the southern U.S. Atlantic are managed by the South Atlantic Fishery Management Council under the Snapper-Grouper Fishery Management Plan. Although the plan is titled snapper-grouper, only 32 of the 73 species listed are snappers or groupers. Commercial yields are shown in **Figure 24**.

Regulations emphasize minimum size limits and commercial quotas for various species. Seasonal closures exist for wreckfish and the taking of jewfish or Nassau grouper is prohibited. Various gear restrictions exist including a prohibition of roller trawls and fish traps with the exception of sea bass traps. Certain commercial fishing methods are prohibited in designated special management zones around some artificial reefs. Measures of overfishing are based on spawning potential, adjusted for each species.

BLACK SEA BASS
(U.S. Atlantic)

The black sea bass (*Centropristis striata*) is a temperate marine species that inhabits irregular hard-bottom areas such as wrecks, reefs, and rock outcroppings. There are three populations, one north of Cape Hatteras, North Carolina, one south of Cape Hatteras, and a third in the Gulf of Mexico. The two Atlantic populations spawn at different times of the year and have different rates of growth. Black sea bass generally occur inshore of and along with the most inshore tropical reef fishes -- snappers, groupers, porgies, and grunts -- which also prefer hard-bottom habitats.

Black sea bass are protogynous hermaphrodites. Females reach reproductive condition for the first time during their second year, (19 cm total length). Males mature at 3 years and 23 cm total length. The spawning season extends from February-May in the southern U.S. Atlantic. The number of eggs produced in a season is estimated at 30,000 to more than 500,000.

Black sea bass may live 20 years, but fish older than 9 years are rare. The maximum size attained is 4.3 kg, but most are much smaller, especially south of Cape Hatteras. Black sea bass grow slowly. A 1-year old fish is only 12.7 cm total length; a 5-year old is 30.5 cm total length; and one 8 years of age is only 38.1 cm total length. Black sea bass are opportunistic feeders and eat crabs, shrimps, worms, clams, and small fishes.

Both recreational and commercial anglers fish black sea bass. The most common gear in the commercial fishery is the "handline" including electric or hydraulic reels with a terminal rig of two to eight hooks. Handline gear occurred on 250 vessels in 1985 and increased to 297 vessels in 1987. The other major commercial gear is the trap used almost exclusively in North Carolina and South Carolina. In the winter, black sea bass appear to be particularly vulnerable to this gear as they congregate around shallow (15-50 m) rock outcroppings perhaps in preparation for spawning. The number of vessels equipped with traps decreased from 194 in 1981 to 119 in 1988. Recreational anglers fish for black sea bass from approximately 70 headboats (usually more than 15 passengers), about 1,000 charter boats (6-14 passengers), and an unknown number of personally owned and operated boats.

In the southern U.S. Atlantic, most of the black sea bass catch is made from North Carolina to northeast Florida. The North Carolina and South Carolina headboat catch had no trend and varied from 1.1 million fish (480 t) in 1974 to only 291 thousand fish (72 t) in 1992. The catch from the Carolina commercial fishery was 208 t in 1990, 176 t in 1991, and 362 t in 1992.

The northeast Florida headboat catch also does not seem to have a pattern and was 259 thousand fish (75 t) in 1990 but only 91 thousand fish (25 t) in 1992. Commercial landings from northeastern Florida decreased from 52 t in 1972 to 18 t in 1988, but were 23 t in 1990.

Mean weight of black sea bass from the Carolina headboat fishery declined from an average of 0.41 kg (1974-1978) to an average of 0.24 kg (1984-1988) and was 0.25 in 1990. Mean weights from northeast Florida headboats varied from 0.39 kg in 1978 to 0.28 kg in 1990 and was 0.27 in 1991 and 1992. The mean weight for the Carolina commercial fishery was 0.28 kg in 1981 but was 1.0 kg in 1990. In northern Florida, the mean weight of commercially taken black sea bass was 2.0 kg in 1990.

Management of black sea bass is based on models of spawning stock biomass per recruit and yield per recruit using fishery data from 1988 and the assumption that the population is in equilibrium with the fishery. In the southern U.S. Atlantic, size limits (20.3 cm) exist for all state and federal waters.

The 1990 equilibrium spawning potential ratio is 0.29 and the yield per recruit is 90% of the maximum. The current 20.3 cm total length (age 3.5 years) size limit will provide a spawning potential ratio of 0.38 at the current fishing mortality rate and should maintain a spawning potential ratio of at least 0.30 (with total survival of released fish) even if the fishing mortality rate more than doubles.

WRECKFISH
(U.S. Atlantic)

The wreckfish (*Polyprion americanus*) is a member of the family Polyprionidae, and occurs over a worldwide-temperate geographic range. In the western Atlantic wreckfish extend from Grand Banks, Newfoundland to the La Plata River, Argentina, and they are also found in Australian and New Zealand waters. Wreckfish are found at depths of from 66 -1000 m. Their habitat, in our fishing grounds of the Blake Plateau off Georgia, is characterized by a rocky ridge system with much vertical relief (greater than 50 m) and a slope greater than 15 degrees. Wreckfish tend to be associated more with manganese-phosphate pavements than with coral mounds or banks, and elsewhere occur not only on steep slopes but also on those of less than three degrees. Wreckfish are pelagic the first several years of their life (up to 30 cm length) and are often associated with floating debris (thus their name). Their maximum size is near 2 m in length and 100 kg weight. The majority of fish landed in the southeastern U.S. fishery are between 88 and 105 cm total length and apparently are between eight and 12 years old. Wreckfish are fully recruited to the U.S. fishery at age 11+. The oldest observed age in Blake Plateau samples is 31 years. Spawning occurs from January to mid April based on microscopic and histological inspection of gonads. Preliminary evidence shows full sexual maturity at age-8 with some females maturing as early as age-5. The smallest mature female found in the southeastern fishery was 85 cm total length and the smallest mature male was 78.6 cm total length. Other fisheries for wreckfish exist in Portugal and Spain which, in combination with landings by other European and African nations, average a total of 400-500 t per year. Bermuda reports about one metric ton per year on average (1980-1990).

The southeastern U.S. commercial fishery for wreckfish began in 1987, with two vessels fishing on the Hoyt Hills area of the Blake Plateau. Gear used consisted of heavy-duty hydraulic reels spooled with 0.32 cm cable and a terminal rig consisting of 22.7 kg of weight and about a dozen large circle hooks. Initial catch rates ranged from 4.5-5.5 t per week-long trip. The fishery expanded rapidly after 1987, to six vessels participating in 1988, 25 vessels fishing by 1989, 74 vessels by 1990, 83 vessels by 1991. Landings of wreckfish totalled 13 t in 1987, increasing to 174, t in 1988. During the 1989-90 fishing season (April 1989 through April 1990), 40 vessels landed 1,835 t, with one-half of those landed during the spawning season (January - April 1990). The South Atlantic Fishery Management Council then set the 1990-91 season opening date (April 16), a 908 t catch quota, and an annual spawning season closure (mid January - mid April). Fishing effort increased to 74 vessels and the quota was reached in less than four months. Landings for the 1991-92 fishing year (April 1991 through April 1992) totalled 910 t. An individual transferable quota (ITQ) system for wreckfish went into effect in 1992 with 908 t total allowable catch (TAC). Shares were assigned and a coupon system put in place for the 1992-93 season. Fleet size included 39 permitted vessels with 20 vessels landing 577 t of wreckfish during the 1993-1994 season.

It is unclear what wreckfish stock relationships exist or if there are other

BLACK SEA BASS
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Fully exploited
Age at 50% maturity	2.69
Current spawning potential ratio	29%
Projected SPR at current fishing patterns	38%
Natural mortality rate	0.30
Fishing mortality rate at $F_{0.1}$	0.81
Fishing mortality rate at F_{max}	0.90
Fishing mortality rate in most recent year	0.81

GAG
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Fully exploited
Age at 50% maturity	4.55
Current spawning potential ratio	35%
Projected SPR at current fishing patterns	39%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.32
Fishing mortality rate at F_{max}	0.38
Fishing mortality rate in most recent year	0.23

RED PORGY
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Over exploited
Age at 50% maturity	5.33
Current spawning potential ratio	8%
Projected SPR at current fishing patterns	12%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.31
Fishing mortality rate at F_{max}	0.58
Fishing mortality rate in most recent year	0.51

sites of aggregations (spawning or feeding) in the North Atlantic Ocean. Stock identity, biology in eastern Atlantic locations, and reproductive biology studies are underway. The present scarcity of life history, fishing trend and population level data, coupled with the potential of this fishery for similarities to tilefish or the snapper-grouper complex in the South Atlantic Council area of jurisdiction, argue strongly for a very conservative TAC in the wreckfish fishery management.

GAG
(U.S. Atlantic)

The gag (*Mycteroperca microlepis*) is the most widely distributed grouper off the continental United States. Adults occur from North Carolina to Brazil over low and high profile hard bottom in waters 15 to 80 m depth. The species is found throughout the Gulf of Mexico but not in the West Indies. Young gag inhabit estuaries from Massachusetts to Cape Canaveral, Florida.

Spawning off the southeastern United States apparently occurs from February to March. Sexual maturity is attained at age-5 or 6, when fish are 68.6 to 76.2 cm total length. Gag are protogynous hermaphrodites. Sexual transition usually occurs between 10 and 11 years. Very little is known about egg production; however, one 94 cm total length female contained 1.5 million eggs that were considered pelagic.

Gag live for at least 15 years, and may reach a weight of 32 kg and a total length greater than 129.5 cm. Average total lengths for fish ages 1 to 13 years are 27.9, 40.6, 53.3, 61.0, 68.6, 76.2, 81.3, 86.4, 91.4, 94.0, 99.1, 101.6 and 109.2 cm. Principal foods include round scad, sardines, porgies, snappers, grunts, crabs, shrimp, and squids.

Gag are the most common grouper in the southern U.S. Atlantic commercial reef fish fishery. Most vessels use handlines including electric or hydraulic reels with terminal rigs of two to eight hooks. The number of vessels equipped with handlines has ranged from 250 (1985) to 297 (1987). The other major gear used is the bottom longline. The number of vessels deploying this gear increased dramatically from 1 (1980) to 74 (1987).

The annual commercial catch of gag has increased from 56 t (1980) to 400 t (1989) and was 353 t in 1990. However, these numbers may be less than half of the actual catch since the "unclassified" grouper category in the commercial data ranged from 48 t (1983) to 794 t (1988). Recent catches of gag remain at 300 to 400 t (335 t in 1991 and 381 t in 1992).

Gag are sought by a wide variety of recreational fishermen fishing from an unknown number of private boats, approximately 1,000 charter boats (6-14 passengers) and 90 headboats (usually more than 15 passengers). Generally, the annual recreational harvest has been on an increase from 209 t (1980) to 590 t (1989). However, in 1984 the total recreational catch was estimated at 690 t, but it was only 104 t in 1990 and 162 t in 1992.

Management of gag is proposed based on spawning stock/recruit ratios and yield per recruit models using fishery data from 1988 and 1990 and the assumption that the population is in equilibrium with the fishery. In the southern U.S. Atlantic, a size limit (50.8 cm) and bag limit (5 fish aggregate) exist for waters of Florida, South Carolina, and the Exclusive Economic Zone.

The spawning potential ratio for the gag is 0.32, based on data from 1988. Data from 1990 give similar results, marginally greater than the overfishing criterion (SPR less than 0.30). Essentially no gain in yield per recruit is available by establishing a size limit if fishing mortality remains at 0.29, but a 19% gain could be had (assuming total survival of released fish) if fishing mortality increases by 50% to 0.48 and a size limit of 76.2 cm total length were established. That combination would yield a spawning potential ratio of about 40%. The proposed 50.8 cm total length size limit provides a spawning potential ratio of less than 0.30 only for a fishing mortality of less than 0.35, a value about 20% greater than fishing mortality in 1988.

SCAMP
(U.S. Atlantic)

The scamp (*Mycteroperca phenax*) is a medium-sized serranid related to the gag and several other slender-bodied groupers found in the region (yellowmouth, yellowfin, black). It inhabits continental shelf waters from the Campeche Banks, in the Gulf of Mexico, to Florida, and northward along the east coast to North Carolina. Although the species occasionally congregates over high-profile bottom, such as wrecks and rock outcroppings, the preferred habitat is low-profile, live-bottom areas in waters 20 to 90 m deep from Cape Lookout, North Carolina to the Dry Tortugas, Florida. These areas are characterized by profuse growths of soft corals and sponges populated by red grouper, white grunt, red porgy, and numerous species of small, tropical reef fish.

In April and May, sexually mature scamp, those at least 3 years old and larger than 40 cm, spawn thousands of pelagic eggs in offshore waters. Recently hatched larvae are also pelagic, and continue this surface-associated existence for days before settling to the bottom to populate favorable habitats.

Scamp have been aged as old as 21 years, but they probably live for 25 to 30 years based on their projected maximum size of about 109.2 cm total length and 16 kg in weight. Average total lengths (and weights) for fish aged 1, 2, 3, 4, 5, 10, 15, 20, and 21 years are 21.6 cm (0.15 kg), 33.3 cm (0.54 kg), 41.4 cm (1.0 kg), 47.0 cm (1.4 kg), 51.6 cm (1.9 kg), 66.3 cm (3.9 kg), 77.0 cm (6.9 kg), 88.4 cm (8.9 kg), and, 89.4 cm (9.3 kg). During low-light periods of the day, scamp are aggressive predators, capturing crabs, shrimps, and fishes and swallowing them whole.

In the recreational fishery, North Carolina and South Carolina headboats (approximately 35 vessels) consistently account for more than 90% of the annual headboat catch, indicating the bulk of the population resides in those waters. Georgia and northeast Florida headboats (approximately 20 vessels) account for a portion of the catch for this species, although in less significant numbers.

In the Carolinas, the total headboat catch in numbers was 11,309 fish in 1972, dropped to 2,419 in 1981, and increased to 12,746 fish in 1988. While total numbers of fish show recent increases, total weights show steady decreases, dropping from 53 t in 1972 to 22 t in 1988, and 28 t in 1990 with a low in 1981 of 6 t. The 1992 headboat catch in the Carolinas was 27 t (11 thousand fish).

Headboat catch data for Georgia and northeast Florida show a trend in early years, with total numbers beginning low (320 fish in 1981), peaking in mid-decade (1,201 in 1985), then declining to 686 fish in 1988 and 898 in 1990. In examining these numbers, however, the relatively small sample size should be considered. Total weight from 1981 to 1985 increased from 1.1 t to 3.6 t, then declined to 0.9 t in 1988. The Florida headboat catches remained trivial in 1991 (793 fish, 2.8 t) and 1992 (272 fish, 2.4 t).

Approximately 1,000 charter vessels and an unknown number of privately owned boats also contribute to the recreational catch of scamp. Catch estimates of scamp (excluding headboat catches) from the Marine Recreational Fishery Statistics Survey were 8 t in 1991 and 4 t in 1992.

In the commercial fishery, most vessels use handlines including electric and hydraulic reels with terminal rigs of two to eight hooks. The number of craft equipped with handline gear was about 1,500 in 1989. The other major gear used are bottom longlines. The number of vessels deploying this gear increased dramatically from 1 (1980) to 74 (1987).

The commercial catch, combined for the Carolinas, Georgia, and Florida increased from 17 t in 1980 to 163 t in 1990, with the early 1980s having lower catches than the latter years. Commercial catches in 1991 and 1992 were 182 t and 133 t. The newly imposed size limit may have reduced catches in 1992.

The mean weight of fish caught from headboats dropped steadily from 4.70 kg in 1981 to 1.24 kg in 1988 for the Carolinas but was 1.52 in 1990 and was up to 2.4 kg in 1992. Similarly, Georgia and northeast Florida mean weight dropped consistently from 3.52 kg in 1981 to 1.25 kg in 1988, but was 1.78 kg in 1990 and 3.29 kg in 1992.

Commercial handline/longline mean weight data show a similar decline in North Carolina and South Carolina. From 1985 to 1989, mean weight decreased nearly 33%. Georgia and northeast Florida data show a similar trend. Over the region, commercially caught scamp averaged 2.2 kg in 1988 and 2.4 kg in 1990.

For purposes of scamp fishery management, and until additional information indicates otherwise, the entire southern U.S. Atlantic is considered one stock. Management is based on models of spawning stock biomass per recruit ratio and yield per recruit using fishery data from 1988 and 1990 and the assumption that the population is in equilibrium with the fishery. In the southern U.S. Atlantic, size limits (50.8 cm) and bag limits (5 grouper aggregate) exist only for waters of Florida, South Carolina, and the Exclusive Economic Zone.

The present spawning potential ratio is about 0.25 (0.28 in 1988; 0.20 in 1990). Reduction in fishing mortality to 0.17 and implementing the 50.8 cm size limit will barely achieve a spawning potential ratio of 0.3. Any increase in fishing mortality will decrease the spawning potential ratio below 0.3.

GRAY SNAPPER
(U.S. Atlantic)

The gray or mangrove snapper (*Lutjanus griseus*) occurs in the tropical and subtropical western Atlantic from northern Florida to Rio de Janeiro and lives around coral reefs, rock outcroppings, and shipwrecks, to a depth of about 300 feet as well as inshore near pilings, rock piles, seagrass meadows, and mangroves. Larger fish are generally found offshore, and smaller ones in shallow water.

Spawning takes place in the summer, usually during the full moons of June, July, and August. Fish 3 years old and older, or larger than about 23 cm, take part in spawning, which is characterized by one female being courted by one to several males. The gray snapper may live for as long as 21 years and grow to a length of 89 cm and a weight of 11.3 kg. Average lengths of fish aged from 1 to 19 years are 9.4, 19.8, 27.7, 33.5, 38.1, 42.4, 46.5, 50.3, 53.6, 56.6, 59.7, 62.5, 64.5, 67.1, 69.3, 72.1, 73.7, 75.7, and 77.2 cm.

The diet consists primarily of crustaceans and fishes and changes as the fish grow larger. Juveniles feed on copepods, amphipods, and palaemonid shrimps. Adults eat fishes, crabs, and penaeid shrimps. Like other large lutjanids, adult gray snapper may leave their residence reef to feed on nearby grass flats late in the afternoon and at night.

The gray snapper is important to recreational and commercial fisheries because it is a game fighter on sporting tackle and is excellent to eat. It is caught mostly by hook and line (rod and reel, handlines, and longlines), beach and boat seines, and traps.

The number of commercial vessels concentrating on gray snapper is difficult to determine given that they are part of the overall reef fish-spiny lobster fleet. The number is probably in the range of 300. Approximately 90 headboats (usually more than 15 passengers) and 1,000 charter vessels (6-14 passengers) contribute to the recreational catch. Participation by recreational anglers in personally owned boats is legion. The stock is managed as a single unit and management is based on models of spawning stock biomass per recruit ratio and yield per recruit using fishery data from 1988 and the assumption that the population is in equilibrium with the fishery.

Size limits (25.4 cm in Florida, 30.0 cm in the Exclusive Economic Zone) and bag limits (5 maximum in Florida, 10 maximum in the Exclusive Economic Zone) exist for waters of Florida and the Gulf of Mexico.

Gray snapper catches made from headboats ranged from approximately 22,000 fish in 1982 to about 32,000 fish in 1985. After a slight decline from 1986-1987, landings increased in 1988 and were 36,000 fish in 1990. Weight caught increased from approximately 16,500 kg in 1982 to about 33,000 kg in 1984. Landings declined slightly from 1984-1987 but increased in 1988 and were 28,000 kg in 1990. In 1992, 46,184 gray snapper weighing 47,425 kg were taken by headboat anglers.

The Marine Recreational Fishery Statistics Survey in 1992 estimated total landings at 155,000 kg by recreational anglers from shore, private, and charter vessels. But because of the high variance associated with Marine Recreational Fisheries Statistics Survey estimates, they should be used with caution.

Florida's commercial catch in 1972 was 235,000 kg, but decreased annually to below 50,000 kg in 1981, climbed to over 300,000 in 1983, again peaked slightly in 1987, and fell to 200,000 kg in 1988 and was 150,000 kg in 1990. Commercial catches remained at about 150,000 kg for 1991 (162,921 kg) and 1992 (158,078 kg)

A steady increase (0.8 kg to 1.0 kg) in mean weight of gray snapper taken from headboats is apparent during 1985-1988. Mean size was largest in 1984 (1.1 kg) but only slightly greater than the mean size for 1988 (1.0 kg). In 1990 it was only 0.76 kg and increased to 1.03 kg in 1992. The mean weight for commercially caught gray snapper off south Florida for 1985-1988 decreased from about 0.8 kg in 1985 to less than 0.4 kg in 1988, but was 0.7 kg in 1990. Estimates of the spawning potential ratio for gray snapper vary greatly depending on the year in which the underlying data were collected.

The correct estimate of fishing mortality and spawning potential ratio for gray snapper is difficult to discern. The estimates of spawning potential ratio for 1990 and 1991, regardless of the ages used to estimate fishing mortality, are 0.30 or above. Only the estimates based on data from 1988 are below 0.30. There is no conclusive evidence that gray snapper are, by Council definition, overfished. The model of spawning potential ratio for 1991 suggests that a 12-inch (305 mm) size limit will produce, at equilibrium, a spawning potential ratio of 0.45 if the distribution of fishing mortality by age remains that of 1991.

YELLOWTAIL SNAPPER
(U.S. Atlantic)

The yellowtail snapper (*Ocyurus chrysurus*) is a colorful tropical reef fish distributed from North Carolina to southeastern Brazil, but it is most abundant in the Bahamas, off south Florida and in the Caribbean Sea. Yellowtail snapper form large schools and are found above the bottom over hard substrates in waters 10 to 100 m deep. Maximum age is around 15 years, although two to five year old fish comprise the bulk of the catch. Maximum size is greater than 71 cm and 3.7 kg. All females are sexually mature by age-4, most by age-3 and some by age-2. Spawning occurs April through August with a peak in June and July. Mature fish migrate offshore to deeper water to spawn. Yellowtail snapper feed mainly on small pelagic crustaceans, pelagic worms, gastropods, ctenophores and salps.

Yellowtail snapper is one of the most commonly taken reef fish, by numbers and weight, in the jurisdiction of the South Atlantic Fishery Management Council. Commercially the species is caught principally by hook and line. The number of commercial vessels concentrating on yellowtail snapper is difficult to determine given that they are part of the overall reef fish-spiny lobster fleet. The number is probably in the range of 300. Yellowtail landings from the south Florida commercial fishery increased from 587 t in 1982 to 838 t in 1989 but were only 767 t in 1990. Commercial catches were 832 t in 1991 and 810 t in 1992. Yellowtail snapper are caught offshore by sport anglers fishing over reefs, while inshore they are caught by fishermen using cut fish and squid and bottom fishing off bridges and piers.

Yellowtail snapper is also the most important species in the south Florida headboat fishery. South Florida headboat landings totalled 123 t in 1981, rose to near 200 t in 1982-1983, then declined to 127 t in 1985 before rising to a peak of near 262 t in 1988. Headboat landings of yellowtail snapper decreased 45%, to about 143 t in both 1989 and 1990, and were 123 t in 1991 and 113 t in 1992. Effort in the headboat fishery, while fluctuating from month to month within years, has remained remarkably constant from year to year in the south Florida area. Forty-eight headboats operated in this area (Ft. Pierce-Key West, Florida) in 1983 as compared to 44 headboats in 1990.

Approximately one thousand charter vessels and untold numbers of personally owned boats contribute to the recreational catch in the southeastern United States. Landings reported by the Marine Recreational Fishery Statistics Survey are highly variable over the years and ranged from over 110 t in 1980 to over 838 t in 1982, and then dropped to about 100 t in 1986 before rising to near 437 t in 1989. They were 216 t in 1990, 642 t in 1991, and 106 t in 1992.

Mean weight of headboat-caught yellowtail snapper has changed little over the last ten years, remaining at about 0.55-0.65 kg since 1982. Mean weight of commercially caught fish has actually increased from 0.7 kg in 1986 to 1.0 kg in 1988, but was 0.5 kg in 1990.

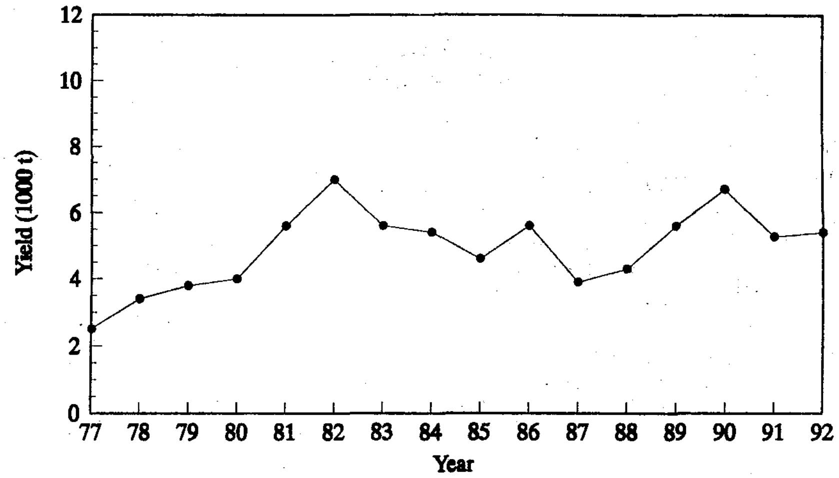


Figure 24. U.S. Atlantic commercial reef fish yield.

Stock assessments for yellowtail snapper are based on Ricker yield-per-recruit and spawning potential ratio models and on data from 1988 and 1990. As applied, these models assume equilibrium conditions over the fishery. Samples from different years give very different pictures of the status of the yellowtail snapper. The estimate of spawning potential ratio for yellowtail snapper based on data from 1991 was 0.24, near the estimate obtained from 1990 data and substantially below the estimate from 1988, 0.38. The estimate of fishing mortality for 1991 was 0.44, again near that for 1990, 0.48, and much higher than that for 1988, 0.28. The existing 12-inch size limit should produce a spawning potential ratio of 0.3 if most released fish survive. Because yellowtail snapper are usually taken from shallow water, high survival of released fish is likely.

RED PORGY
(U.S. Atlantic)

The red porgy (*Pagrus pagrus*) formally was an important reef fish and ranked second only to black sea bass as the fish most frequently caught while bottom fishing offshore from Cape Hatteras to Cape Canaveral, Florida. Now (1992) the population is much reduced and it ranks fourth or fifth. Red porgy occur in deep and warm water on continental shelves on both sides of the Atlantic from the Azores and British Isles south to Angola and from North Carolina to Argentina, but it has not been reported from the Caribbean Sea. Preferred habitat along the southeastern United States is rough bottom at depths ranging from 27-183 m.

Red porgy are protogynous hermaphrodites. Most fish longer than 45.7 cm are males. Approximately 37% of the females are mature at age-2, 81% by age-3, and all are capable of reproducing by the fourth year. A female 30.5 cm long may lay 40 thousand eggs and an exceptionally large female 50.8 cm long may lay 489 thousand eggs. Spawning takes place at sea from January through April. The eggs and young are pelagic before settling to the bottom.

The life of a red porgy can extend to 15 years, but most caught are from 4 to 7 years old. Average lengths for both sexes aged 1 to 15 years are 17.8, 25.4, 31.5, 36.8, 41.1, 43.7, 46.2, 48.5, 50.3, 52.6, 55.1, 57.2, 60, 61.9, and 64 cm. Red porgy feed on the bottom, taking worms, snails, crabs, and sea urchins. Occasionally they eat small fishes such as round scad and tomtate.

SCAMP
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Over exploited
Age at 50% maturity	5.08
Current spawning potential ratio	20%
Projected SPR at current fishing patterns	30%
Natural mortality rate	0.17
Fishing mortality rate at $F_{0.1}$	0.20
Fishing mortality rate at F_{max}	0.38
Fishing mortality rate in most recent year	0.24

YELLOWTAIL SNAPPER
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Not over exploited
Age at 50% maturity	2.1 years
Current spawning potential ratio	19%
Projected SPR at current fishing patterns	28%
Generation time	4.53 years
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.34
Fishing mortality rate at F_{max}	0.39
Fishing mortality rate in most recent year	0.48

GRAY SNAPPER
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Not over exploited
Age at 50% maturity	6.54 years
Current spawning potential ratio	49%
Projected SPR at current fishing patterns	Unknown
Generation time	4 years
Natural mortality rate	0.22
Fishing mortality rate at $F_{0.1}$	0.18*
Fishing mortality rate at F_{max}	0.45*
Fishing mortality rate in most recent year	0.34*

*Based on 1988 data.

Off the southeastern United States hook and line is the most important gear to both sport and commercial fishermen. Because the bulk (greater than 95% by number) of the red porgy catch is made off the Carolinas, and the population is apparently centered there (although some are taken even in the Florida Keys) the Carolina statistics are most indicative of population changes. The stock is managed as a single unit by the South Atlantic Fishery Management Council.

The number of commercial vessels concentrating on red porgy is difficult to determine given that they are part of the overall reef fish-spiny lobster fleet. The number is probably in the range of 300. Approximately 90 headboats and 1,000 charter boats contribute to the recreational catch. Participation by recreational anglers in personally owned boats is legion.

Headboat catch in numbers from off North and South Carolina has declined almost steadily since 1973 when 300,000 individuals were taken. Weight caught diminished from 350,000 kg, in 1973 to only 48,000 kg (81,000 fish) in 1992.

Marine Recreational Fishery Statistics Survey data for 1980-1989 suggest a tremendous increase in landings from a low of 5.8 t in 1986 to a high of 1,057 t in 1982. Catches have generally increased for 1986-1989. But given the high variance attached to red porgy data in the Marine Recreational Fishery Statistics Survey, these estimates must be used with caution. Only 35,000 red porgy weighing 17 t were reported taken in 1990 by the Marine Recreational Fisheries Statistics Survey. Estimated catches continue to be small.

Commercial catch in the Carolinas was very low (less than 20 t) until 1976 after which catches rose to 535 t by 1982 and then diminished to 246 t by 1986 and remain low. There were 319 t taken commercially off the Carolinas in 1990 and only 125 t in 1992. Total headboat and commercial landings peaked at 750 t in 1982 and were only 390 t in 1986.

Catch-per-unit of effort is available only for headboats where effort is in angler days and catch-per-unit of effort patterns largely mimic those of the catch. Generally the catch-per-unit of effort (number) has diminished by 50% or more (e.g., from 6-10 fish per angler day off South Carolina in the early 1970s to 3 per angler day in 1988, or off Central North Carolina from 1 to 2 per angler day in the early seventies to less than 0.1 fish per angler day in 1988).

For all areas, mean weight of headboat-caught red porgy has diminished from values around 0.9 to 1.2 kg in the early 1970s to 0.54 kg in 1990. For the entire Carolina region, mean weight was 0.96 kg in 1983 and diminished through the late 1980s to annual values of 0.48 to 0.59 kg in the 1990s.

Based on computations performed separately from data collected in 1988 and 1990, the present spawning potential ratio is about 0.10 and about 80% of the maximum yield per recruit is being taken. Equilibrium spawning potential ratio off the Carolinas (for both sexes) in 1980 was 0.65 but declined to 0.27 by 1987. To achieve a spawning potential ratio of 0.30 requires reducing the fishing mortality rate by about 50% or, with total survival of released fish, establishing a minimum size of 38.1 cm. A 30.5 cm size limit will provide a spawning potential ratio of only 0.15, and only if the fishing mortality rate does not increase. A 38.1 cm size limit in addition to providing an acceptable spawning potential ratio will also increase yield per recruit by a modest 15%. Achieving the 51% reduction in the fishing mortality rate requires reducing the catch to approximately 303,000 individuals or 262 t (from 535 t).

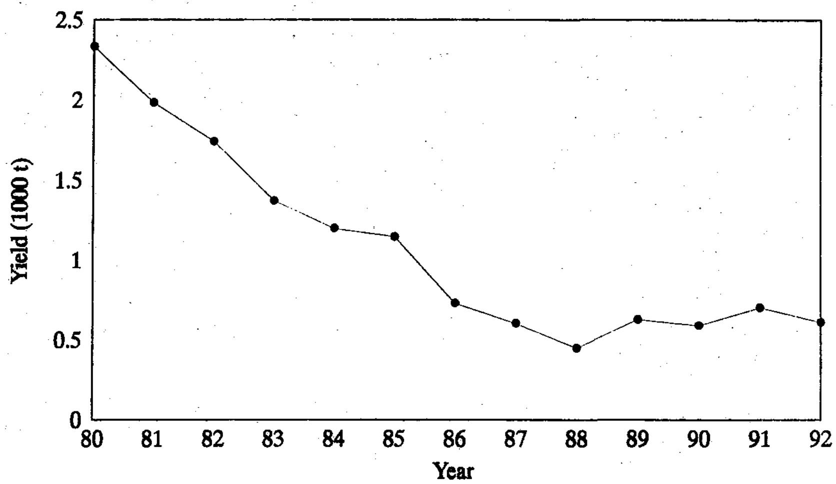


Figure 25. Reef fish yield in Puerto Rico and U.S. Virgin Islands.

U.S. CARIBBEAN

The U.S. Caribbean Exclusive Economic Zone is managed by the Caribbean Fishery Management Council. Territorial waters are managed by the U.S. Virgin Islands and the Commonwealth of Puerto Rico. The Fishery Management Plan for the Shallow-Water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands became effective on September 22 1985.

Little is known about the basic biology for many Caribbean tropical reef fish species, including age, growth, reproduction, fecundity, natural mortality, and population dynamics. In general, reproductive seasons are believed to be more prolonged when compared to more temperate areas. Sources of recruitment are unknown for most populations.

The Caribbean reef fish fishery is very complex with large numbers of species being caught by various commercial, artisanal, and recreational components, each using a variety of fishing methods including fish traps, hook and line, longlines, bandit rigs, spears, and trammel and barrier nets. Commercial yield is shown in **Figure 25**. Fishing pressure has increased due to higher human populations in coastal areas, greater demand for fishery products, and increased technology. The management unit includes 64 of the most commonly landed species in 14 families. Most species in the traditional fisheries are probably fully exploited or overfished. In most cases the current potential yield and long-term potential yield are unknown although for many species potential yield is probably higher than present average yields would indicate. Landings for most reef fish species in Puerto Rico, for example, are only a small fraction of the highest reported annual landings. In the Caribbean, traditional mainstays of the fishery such as Nassau grouper have practically disappeared and the major target species in recent years such as red hind show declines in total landings and average size since the late 1970s. Increased landings for some deeper water species (queen, vermilion, and silk snapper) can be attributed to shifts in the fishery away from major traditional species.

The fishery management plan established regulations to rebuild declining reef fish stocks in the fishery and reduce conflicts among fishermen. It established criteria for the construction of fish traps; required owner identification and marking of gear and boats; prohibited the hauling of or tampering with another person's traps without the owner's written consent; prohibited the use of poisons, drugs, other chemicals, and explosives for the taking of reef fish; established a minimum size limit on the harvest of yellowtail snapper and Nassau grouper; and established a closed season for the taking of Nassau grouper. Amendment 1, May 1990, established an area closure during the red hind spawning season in the Exclusive Economic Zone southwest of St. Thomas; included a provision for the collection of socio-economic data; and modified two management measures: 1) increased the minimum mesh size requirement for fish traps to 5.08 cm (2 inches) by September 1991, and 2) prohibited the harvest of Nassau grouper. In September 1991, provisions were approved that 1) defined overfishing at 20% of the spawning stock biomass per recruit that would occur in the absence of fishing; 2) delayed the 5.08 cm mesh requirement until September 14, 1993; 3) allowed the use of 3.81 cm (1.5 inch) hexagonal mesh wire until September 14, 1993; and 4) made specific requirements for fish traps that included two required degradable escape panels on opposite sides of fish traps attached by 3.18 mm (1/8 inch) diameter, untreated jute twine.

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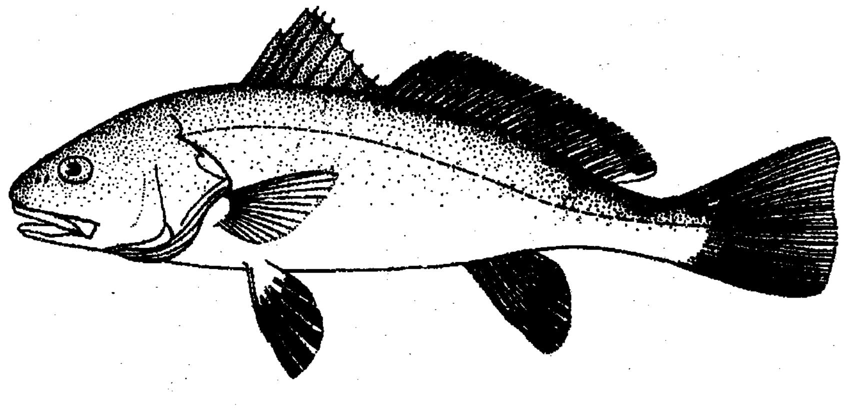
Sciaenids

In the southeastern United States, important recreational and commercial species in the family Sciaenidae include red drum, weakfish, Atlantic croaker, spot, black drum, kingfishes (whiting), and seatrouts. Since the late 1800s sciaenids have represented an important fishery resource, although significant increases in landings did not occur until the 1950s when a pet food industry targeting drum and croaker developed in the northern Gulf of Mexico. Pet food landings of drum and croaker peaked in 1956 at more than 32 thousand metric tons (t).

Large numbers of sciaenids are caught and killed as an incidental catch in the shrimp fishery. The most recent estimates of the 1972-1989 bycatch in the Gulf of Mexico offshore shrimp fishery averaged about 500 million spot, 1 billion seatrout, and 7.5 billion croaker. These species constitute the bulk of biomass of the offshore finfish bycatch in the shrimp fishery which averaged about 175 thousand metric tons (t) during the 1980s.

The recreational harvest of sciaenids has almost equaled the commercial harvest sold for human consumption. Most recreational fishing for these species occurs within state jurisdiction and therefore is under state management authority. In recent years, several states have established regulations that favor recreational use of the resources. This is particularly true for red drum and spotted seatrout where some states have prohibited commercial harvests.



Red drum (*Sciaenops ocellatus*)

RED DRUM

Red drum (*Sciaenops ocellatus*) are carnivorous fish found worldwide in tropical, subtropical, and temperate coastal waters. In the western Atlantic, red drum range from Chesapeake Bay through the Gulf of Mexico and as far south as Veracruz, Mexico. The species appears off the northeastern Atlantic coast in the spring and summer and probably moves southward in the fall. They are present in the Gulf of Mexico throughout the year with greatest abundance in late summer to early winter.

Red drum are harvested in a mixed species fishery by a number of gear types: haul seines, fish trawls, pound nets, gill nets, handlines, trammel nets and shrimp trawls. Commercial and recreational yields are shown in **Figure 26** for the Gulf of Mexico and in **Figure 27** for the U.S. Atlantic. The majority of the commercial catch is made in the estuaries. Red drum landings along the Atlantic coast have perennially been lower than those along the Gulf coast. Landings from the northern part of their range have declined since the 1930s with the exception of eastern Florida. Total Atlantic coast landings declined from 1960-1970, while the Gulf coast landings increased during the same period. The recreational catch of red

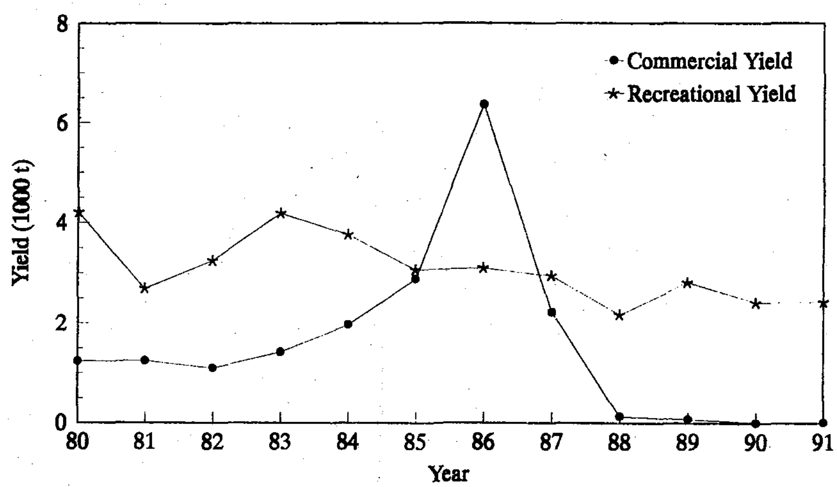


Figure 26. Commercial and recreational red drum yields in the U.S. Gulf of Mexico.

drum exceeded commercial landings by an estimated factor as high as 162.

Fishing mortality in most southern U.S. Atlantic and Gulf of Mexico estuarine areas is higher than natural mortality.

Adults are normally found close to shore and feed near the bottom on crustaceans. Along southeastern Florida they feed primarily on penaeid shrimp and xanthid crabs. Small sizes of red drum feed primarily on fish but as they grow diet changes to a predominance of crustaceans.

The maximum size of red drum is 127 cm FL and 37.3 kg. They mature at the end of the third or fourth year with age-5 fish comprising the majority of mature fish. Average size to sexual maturity is 70-80 cm FL. Concerns exist concerning aging of older red drum from otolith banding patterns; however, a red drum caught recently off North Carolina was aged at 55 years.

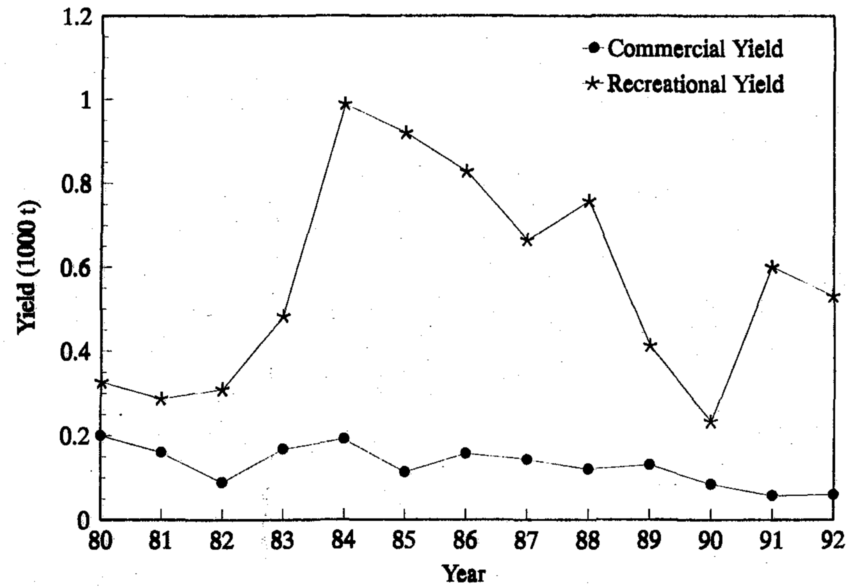


Figure 27. Commercial and recreational red drum yields in the U.S. Atlantic Ocean.

Spawning in the Atlantic probably occurs in nearshore waters from Virginia to St. Lucie, Florida, beginning in July and extending through December. The Atlantic spawning probably peaks in late September or October. In the Gulf, spawning occurs from Cape Sable, Florida, to the northern Mexican coast, beginning in mid-September and lasting through mid-November. The Gulf spawning peaks in October. Fecundity ranges from 3 females (9-15 kg) producing 60 million fertilized eggs in 52 spawns during a 76 day period, to four females (1.68-7.95 kg) producing 8.43 million eggs over 90 days.

Atlantic red drum stocks are overexploited. Three management measures were adopted by the South Atlantic Fishery Management Council in the Atlantic red drum fishery management plan. The first measure establishes the fishing year as the calendar year. The second requires the National Marine Fisheries Service to prepare red drum stock assessments as required by the Council for review by a special stock assessment review group. The latter makes recommendations to the Council based on the assessments and data. The third measure prohibits harvests and possession of Atlantic red drum in or from the Exclusive Economic Zone until a total allowable catch is specified by the plan when the maximum spawning potential is in excess of 30%.

Since 1980, coast-wide recreational catches ranged from 233 t in 1990 to 988 t in 1984, while commercial landings ranged from 85 t in 1990 to 192 t in 1984. In numbers of fish caught, Atlantic red drum is predominantly a recreational fishery. Commercially, Atlantic red drum are harvested as part of mixed species fisheries.

A commercial purse seine fishery for adult red drum in federal waters of the Gulf of Mexico developed rapidly in the mid-1980s as a market developed based upon a new recipe for blackened redfish. Prior to that time, nearly all red drum were harvested in inshore state waters as juvenile fish. As the offshore fishery developed, it became evident that the schooling behavior of the adult fish made them extremely vulnerable to harvest by fisheries using spotter planes and purse seines. Yield per recruit analyses showed that the long term maximum biomass yields to support this developing fishery required delaying first harvest to sizes well in excess of the traditional fishery. Additionally, there was evidence that rates of recruitment from inshore to offshore adult stocks decreased significantly in the late 1970s. Thus, the growth in the inshore fishing mortality imposed by recreational and commercial fishermen coupled with some yet to be determined factor had decreased the number of fish surviving to replenish the offshore adult stocks.

This situation eventually led to the development of a fishery management plan for the Gulf of Mexico red drum by the Gulf of Mexico Fishery Management Council. The fishery for red drum is banned in federal waters until prescribed escapement rates of juveniles into the adult stocks are achieved. This effectively bars any significant fishery on the adults so long as state regulations favor the continuation of substantial inshore fisheries on juveniles. State management actions to date have preserved the inshore nature of the harvest and allocated most or all of the harvest to recreational users.

WEAKFISH (U.S. ATLANTIC)

Weakfish *(Cynoscion regalis)* are sciaenids distributed along the Atlantic coast of the United States from Florida to Massachusetts. They are most abundant in shallow coastal and estuarine waters from North Carolina to New York. Weakfish are considered year round residents of the Carolinian province and appear only seasonally to the north. The fisheries

RED DRUM

	U.S. Gulf of Mexico	U.S. Atlantic
Longterm potential yield	7,900 t	Unknown
Current potential yield	2,828 t	Unknown
Recent average annual yield	2,828 t	523 t
Status of exploitation	Overexploited	Overexploited
Age at 50% maturity	4 years	3 years
Current spawning potential ratio	13%	0.6-1.5%
Projected SPR at current fishing patterns	20%	Not applicable
Natural mortality rate	0.21	0.23

WEAKFISH

	U.S. Atlantic
Longterm potential yield	Unknown
Current potential yield	Unknown
Recent average annual yield	5,131 t
Status of exploitation	Overexploited
Age at 50% maturity	1 year
Current spawning potential ratio	7-12%
Natural mortality rate	0.3

ATLANTIC CROAKER

	Southeastern United States
Longterm potential yield	50,000 t
Current potential yield	Unknown
Recent average annual yield	4,946 t
Status of exploitation	Unknown

for weakfish along the Atlantic coast coincide with the north-south migrations of the species.

Weakfish is a schooling, active fish that feeds in the upper to middle water column by sight. Young weakfish feed primarily on mysid shrimp and anchovies, while older weakfish feed mainly on clupeid species and anchovies. Most weakfish reach sexual maturity (17-23 cm total length) during their second summer, although the smaller members of a given year class may not reach maturity until 2 years of age. Weakfish spawning, hatching, and larval development occur in estuarine and near-shore oceanic waters along the Atlantic coast during spring and summer.

Weakfish have been important to the Atlantic coast fisheries since at least the 1800s. Recent commercial and recreational landings are shown in **Figure 28**. The commercial fishery, largely in North Carolina to New Jersey, consists of an inshore spring and early summer fishery employing haul seines, pound nets, gill nets and trawls and a fall-winter fishery from North Carolina to Delaware employing trawls and gill nets. Recreational exploitation occurs during the spring and summer in estuarine and near shore coastal waters with the bulk of harvest occurring in the mid-Atlantic region. Bycatch of young weakfish in southeastern shrimp trawl fisheries is an issue. Young fish captured and discarded as part of shrimping might negatively impact recruitmet to more northern weakfish stocks.

ATLANTIC CROAKER (U.S. ATLANTIC)

Atlantic croaker (*Micropogonias undulatus*) is a bottom dwelling species associated with mud and sand substrate and live bottoms from Massachusetts to Campeche Bank, Mexico. In the spring, Atlantic croaker move into bays and estuaries; in the fall they migrate offshore to spawn.

In the U.S. Atlantic, a successful commercial fishery has operated since at least the late 1880s. The commercial fishery consists of an inshore summer fishery employing haul seines, pound nets, gill nets, and trawls; and an offshore winter fishery employing trawls and gill nets. In the recreational fishery, anglers take Atlantic croaker from ocean beaches and the banks of estuaries as well as by fishing in estuarine and nearshore waters from private, party, and charter boats.

In the U.S. Gulf of Mexico, total landings of croaker have increased as a result of the development of the pet food industry in the northern Gulf. This fishery has targeted croaker which represents about 76% of total landings. Croakers are also a significant component of the fish bycatch made by the shrimp trawl fishery . From 1972-1989, it was estimated that the annual average bycatch was 7.5 billion croaker.

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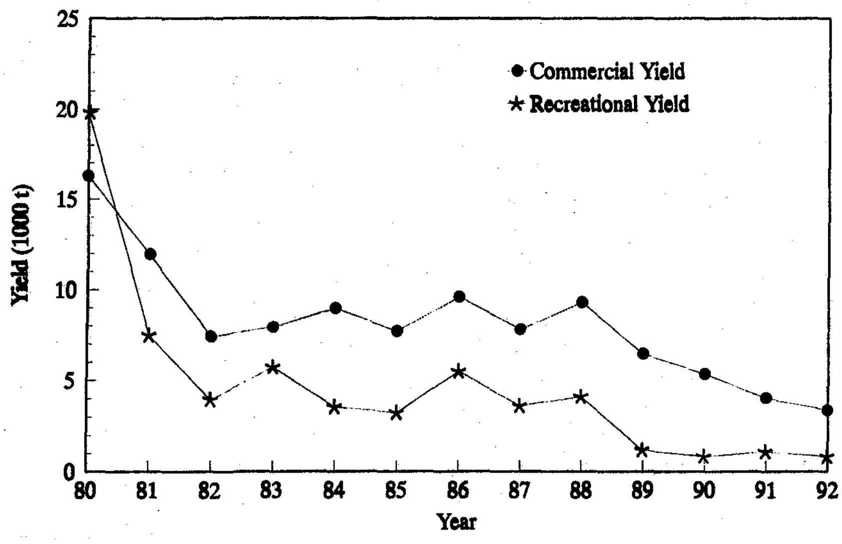

Figure 28. Commercial and recreational yields of Atlantic weakfish.

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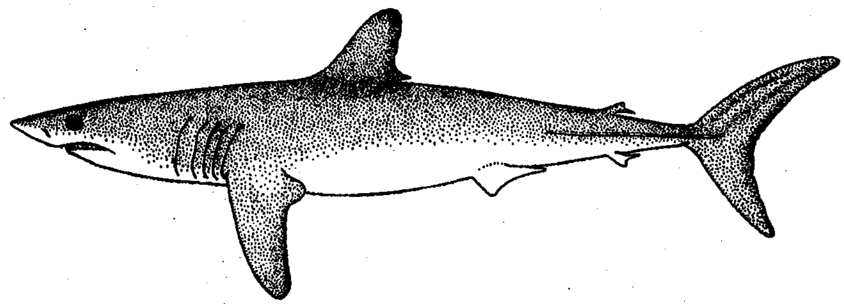
Sharks

Sharks belong to a group of fishes that includes the rays, skates, and chimaeras (ratfishes). These fishes are grouped together because they all have cartilaginous skeletons as well as other features in common. Over 350 species of sharks have been described throughout the world. Seventy-three species are known to inhabit the waters along the U.S. East Coast including the Gulf of Mexico and the waters around Puerto Rico and U.S. Virgin Islands.



Shortfin mako (*Isurus oxyrinchus*)

Although the number of species of sharks is relatively small when compared to the number of species of fishes with bony skeletons (over 20,000), sharks are a diverse group. They range in size from the gigantic 12-m whale shark, the largest fish in the oceans, to the tiny pygmy shark that is fully grown at only 20 to 25 cm. Fast-moving, streamlined species such as mako and thresher sharks contrast to sharks with flattened, ray-like bodies, such as the angel sharks. Basking sharks and whale sharks feed by filtering small organisms from the water, tiger sharks eat large turtles, and the tiny cookiecutter shark feeds by carving plugs of flesh out of large fishes and whales. Some sharks reproduce by laying eggs; other sharks nourish their embryos through a placenta. Despite the great diversity in size, feeding habits, habitat, and behavior, some adaptations are common to nearly all sharks. These adaptations have contributed greatly to the evolutionary success of sharks. Most of these common adaptations involve their reproductive modes and feeding habits.

The most significant reproductive adaptations of sharks which have contributed to their evolutionary success are internal fertilization and the production of small numbers of large young, which hatch or are born as fully developed young or "pups." All sharks have internal fertilization. In most species, the embryos spend their entire developmental period protected within their mother's body. When development is complete, the young are born as active, miniature sharks. The young are large at birth. Large size reduces the number of potential predators and competitors, thus enhancing survival.

The number of young produced by most shark species in each brood is small, usually ranging from 2 to 25, although large females of some species can produce broods of 100 or more pups. The production of large-sized young requires great amounts of nutrients to nourish the developing embryos. Thus, sharks have evolved diverse means of nourishing their embryos, such as the production of eggs with very large yolks, the ingestion of egg yolks by the embryos, and the direct transfer of nutrients from mother to embryo through a yolk sac placenta. Traditionally, these adaptations have been grouped into three modes of reproduction: oviparity, ovoviviparity, and viviparity.

Oviparous sharks lay large eggs that contain sufficient yolk to nourish the embryo through development and allow it to emerge fully developed. These eggs are enclosed in leathery cases that are deposited on the sea bottom, usually attached to plants or rocks. There is no parental care or brooding in oviparous sharks. The only protection for the embryo is its tough leathery case composed of protein fibers. The development of these eggs is temperature-dependent and hatching usually occurs in a few months to a year. The pups of oviparous sharks are somewhat small because their growth is limited by the amount of nutrients stored in the egg. The embryos of the oviparous whale shark, the largest living fish, measure only 36 cm, a size exceeded by the embryos of many smaller ovoviviparous or viviparous sharks. Oviparity is found in only four families of sharks: bullhead sharks, nurse sharks, cat sharks, and whale sharks.

Ovoviviparity is the most common mode of reproduction in sharks. The eggs of ovoviviparous sharks hatch in the uterus before the embryos are fully developed. The embryos continue to grow in the uterus, nourished by yolk stored in the yolk sac, but do form a placenta connection with the mother. The embryos are born after their development is completed. The brood size is highly variable, depending on the reproductive strategy of the species. In some ovoviviparous sharks, such as the sand tiger shark, the yolk is absorbed very early in development. Thereafter, the embryos nourish themselves by swallowing unfertilized eggs and smaller embryos in the uterus as a form of embryonic cannibalism. Having eaten its smaller siblings, usually only one embryo survives in each of the two uteri. Ovoviviparous sharks include cow, frill, sand tiger, goblin, mack-

LARGE COASTAL SHARKS [A]

Long Term Potential Yield	3,400 t
Current Potential Yield	1,900 t
Recent Average Annual Yield	3,800 t
Status of Exploitation	Over exploited

SMALL COASTAL SHARKS [B]

Long Term Potential Yield	3,600
Current Potential Yield	3,000
Recent Average Annual Yield	3,000
Status of Exploitation	Fully exploited

PELAGIC SHARKS [C]

Long Term Potential Yield	--
Current Potential Yield	--
Recent Average Annual Yield	2,730 t
Status of Exploitation	Unknown

[a] Includes sandbar, reef, blacktip, dusky, spinner, silky, bull, bignose, Galapagos, night, tiger, lemon, ragged-tooth, nurse, scalloped, smooth and great hammerhead, whale, basking and white sharks.

[b] Includes Atlantic and Caribbean sharpnose, finetooth, blacknose, bonnethead and Atlantic angel; virtually all of small coastal shark yields are caught as bycatch in Gulf of Mexico shrimp fishery and discarded without landing.

[c] Includes longfin and shortfin mako, blue, porbeagle, thresher, bigeye thresher, oceanic whitetip, sevengill, sixgill and bigeye sixgill.

erel, basking, thresher, false cat sharks, saw, angel, squaloid, ribbontail cat sharks, some nurse sharks, some smooth dogfishes, and some cat sharks.

Viviparity is the most advanced mode of reproduction. The embryos of viviparous sharks are initially dependent on stored yolk but are later nourished by the mother through a placental connection. Being connected to the blood supply of the mother, the embryo can be nurtured to a relatively large size at birth. Most placental sharks produce broods of two to a dozen, with a few exceptional pelagic species producing 20 to 40 young. Viviparity is confined to some smooth dogfishes, requiem sharks, and hammerheads.

Females of most species of sharks travel to specific nursery areas to give birth to their young at certain times of the year. These nurseries are discrete geographic areas, usually in shallow waters, or at least shallower waters than those inhabited by the adults. Frequently the nursery areas are in highly productive coastal or estuarine waters where abundant small fishes and crustaceans provide food for the growing pups. These areas are also free of large predators, thus the young sharks have a higher chance of survival. In temperate zones, the young exit the nursery with the onset of winter; in tropical areas, the young may stay in the nursery for a few years.

Sharks are slow growing and slow maturing fishes. The most economically important sharks, the large coastal carcharhinids, have very slow growth rates. Several of the commercially important species, such as sandbar, lemon, and bull sharks do not reach maturity until 12 to 18 years. The life span of sharks in the wild is not known, but it is believed that many species may live 30 to 40 years or longer. The reproductive life span of these sharks is unknown.

In summary, sharks have a very low reproductive potential. Various factors determine this low reproductive rate: slow growth, sexual maturity not reached until 4 to 18 years, one to two-year reproductive cycles, a small number of young per brood, and specific requirements for nursery areas. Therefore, shark populations must be managed very conservatively.

Sharks are aggressive predators, at or near the top of the food chain, with three exceptions: whale sharks, basking sharks, and megamouth sharks. The latter are filter-feeders, similar to some whales in feeding habits. Most sharks, however, are flesh eaters that have evolved very sensitive receptors that allow them to track wounded or injured prey. They have extremely sensitive smell receptors, eyes that can adapt to very dim light, electroreceptors that in the absence of scent or visual clues can detect prey buried in the sand, and lateral line receptors that sense movement in the water.

In addition to their fine senses, sharks are armed with a formidable set of teeth and jaws that can produce considerable force. The teeth are replaced often, so sharks always have a sharp set capable of inflicting a clean bite.

Ecologically, sharks can be divided into four broad categories; 1) coastal, 2) pelagic, 3) coastal-pelagic, and 4) deep-dwelling. Coastal species inhabit nearshore areas and the continental shelves. Examples are blacktip, finetooth, and sharpnose sharks. Pelagic species, on the other hand, range widely in the upper zones of the oceans, often traveling over entire ocean basins. Examples include mako, blue, and oceanic whitetip sharks. Coastal-pelagic species such as sandbar, scalloped hammerhead, and dusky sharks are intermediate in that they occur both inshore and beyond the continental shelves, but have not demonstrated mid-ocean or transoceanic movements. Deep-dwelling species inhabit the deeper cold waters of the continental slopes and ocean basins. Examples of this category are most cat sharks and gulper sharks.

Tagging studies have shown that assignment of species to these ecological categories is somewhat arbitrary because several coastal-pelagic sharks show movements from the United States to the Bahamas, West Indies, and Mexico. For example, the sandbar shark moves north and south along the U.S. east coast between Cape Cod and Texas. Sandbar sharks tagged off the northeast coast of the United States have traveled across the Florida Straits to Cuba and to Mexican waters as far south as the Yucatan. Some tagged sandbar sharks have traveled almost 5,000 km along the coast of North America and have been recaptured after 24 years. Other species (dusky, blacktip, night, silky, blue, shortfin mako, longfin mako, tiger, whitetip, spinner, and bignose sharks) have also traveled between the U.S. east coast and the Gulf of Mexico. Detailed knowledge of the migrations of sharks between the U.S. Exclusive Economic Zone and international waters will be required for the most effective management of these wide ranging species.

The shark management unit consists of 39 species in the Western North Atlantic Ocean. The management unit extends across state, federal, and international jurisdictional boundaries. The species in the management unit were chosen for one or more of the following reasons: 1) they are frequently caught in commercial or recreational fisheries; 2) their low fertility and/or slow growth make them particularly vulnerable to overfishing; and their habits make them vulnerable to indiscriminate killing. Sharks in the management unit were separated into three species groups for abundance assessments: 1) large coastal sharks, 2) small coastal sharks, and 3) pelagic sharks. The assessment groups are not ecological groups. They are groupings based on fisheries or where those species appear in the yield.

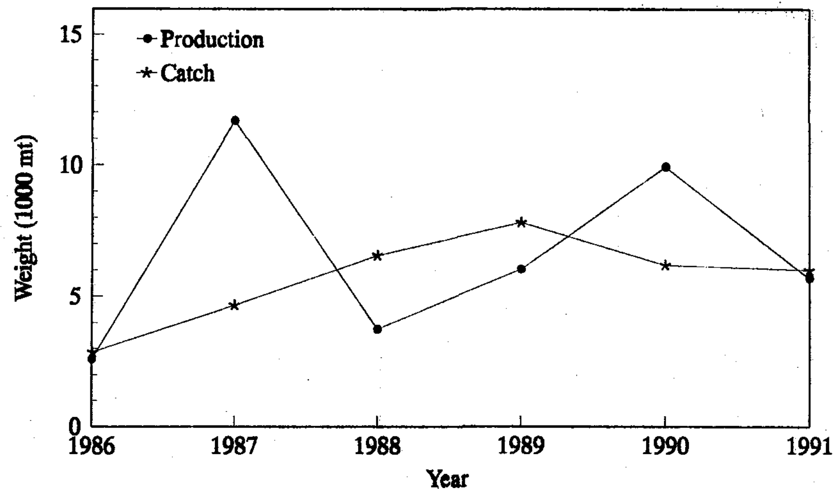


Figure 29. Production and catch of Atlantic and Gulf of Mexico large coastal sharks.

Additional species are included in the management plan for data collection purposes, but are not included in the management unit. Most of these species are small, deepwater sharks that are not target species, but are taken incidentally in directed shark fisheries, or in swordfish or tuna longline fisheries. The management plan group also includes two species known locally as "dogfish;" the spiny dogfish (*Squalus acanthias*) and the smooth dogfish (*Mustelus canis*). These two species are taken in considerable numbers in directed fisheries, and as bycatch in other fisheries, because they enter shallow water and are extremely abundant. These species are not overfished at this time nor confronted with such problems as finning, as are the species in the management unit, although finning of dogfish has been reported.

Historically, sharks have been an underused resource in North America. Small, localized shark fisheries have existed along all U.S. coasts for many years, but organized intensive shark fisheries have been scarce and have lasted only a few years.

A shark longline fishery operated in Salerno, Florida nearly continuously from 1936 to 1950. The maximum number of these shark-fishing boats in use at any one time was five. The greatest number of shark-fishing boats known to have been operating off the southeastern coast of the United States concurrently was 16. Sharks were fished primarily for their livers and hides. The liver oil was used in the production of vitamin A, and the hides were processed into leather. Products also included fresh and salted meat, fins, and fish meal.

From 1938 to 1946, most shark fishing was done with chain sets. The weight of the chain line normally confined fishing to depths less than 46 m. In the last years of the fishery (1947 to 1950), the catch per unit of effort increased due both to expansion of the fishery and to a bonus arrangement that encouraged cooperation among the fishermen. This operation ended in 1950 because of the appearance of low-cost, synthetic vitamin A.

Another small shark fishery for porbeagle existed in the early 1960s off the U.S. Atlantic coast involving Norwegian fishermen. Between the world wars, the Norwegians and Danes pioneered fishing for porbeagles in the North Sea and in the region of the Shetland, Orkney, and Faroe Islands. Around 1960 these fishermen began fishing the Newfoundland Banks and the waters east of New York. Between 1961 and 1964, their annual catches increased from 1,800 to 9,300 t, then quickly declined to 200 t.

Use of sharks as food and gamefish by U.S. fishermen increased in popularity in the 1970s. In recent years, economic changes in Asia broadened the sharkfin market. The increased demand for shark meat and the high price of fins encouraged U.S. fishermen to enter shark fisheries. Fishermen in other directed fisheries, such as tuna and swordfish, began to retain sharks for the fins instead of releasing them as was done previously. Both directed and nondirected commercial fisheries, as well as recreational anglers, now exploit shark resources.

Recreational fishermen pursue sharks for sport. This practice has become popular in the last 15 years as evidenced by the increased number of shark tournaments. Shark fishing is a popular sport at all socioeconomic levels, largely because of accessibility to the resource. Sharks can be caught virtually anywhere in salt water with even large specimens available in the nearshore area to surf anglers or small boaters. Beach or surf fishing for sharks became popular in the early 1970s. Pier fishing for sharks was also popular for many years (the largest tiger shark on record was caught from a pier in Cherry Grove, South Carolina in 1964). Most recreational shark fishing takes place from small to medium-size boats. Shark tournament fishing is usually conducted from boats that vary in size from small outboards to sportfishing yachts. As many as 15 different species, depending upon tournament locale, are caught during these events.

Commercial fishermen, who derive some portion of their income by selling their shark catch, are grouped as those engaged in directed fisheries (targeting sharks), or those involved in indirect fisheries (targeting other species with sharks as bycatch). Commercial fishermen in the directed shark fisheries use either longlines or gillnets. Longliners use modified swordfish longlines in coastal waters during a long season, often following stocks as they move north or south along the Atlantic coast. The primary species caught by longline fishermen are sandbar, blacktip, bull, bignose, tiger, sand tiger, lemon, spinner, scalloped hammerhead and great hammerhead sharks.

Gillnet fishing for sharks in the southeast has existed for many years. These fishermen operate small boats from May to November when sharks are in shallow water. Some of these estuarine waters, 2 to 5 m deep, are nursery areas for many species of sharks. Gillnet fishermen catch sandbar, blacktip, finetooth, blacknose, bull, spinner, dusky, sharpnose, sand tiger, scalloped hammerhead, and others. Recent legislation in South Carolina essentially terminated the use of commercial gillnets in its waters. This action has forced fishermen into deeper, federal waters where their gillnets are less effective.

Tuna and swordfish longline fisheries catch large numbers of sharks as bycatch. Dominant in the tuna fisheries are blue, porbeagle, hammerhead, and unidentified sharks. In the domestic swordfish fishery, mako, thresher, and "unidentified" sharks are the major species. These unidentified species are probably bignose, dusky, silky, and night sharks. Other fisheries also take sharks as bycatch in the summer months. Shallow-water shrimp trawls catch large quantities of Atlantic sharpnose sharks and the juveniles of several species. Shrimping is common in areas that serve as nurseries, and many newborn sharks are caught at this time. Gillnet vessels in the New England multispecies fishery catch and land sharks during the summer and early fall, with porbeagle and mako the dominant species.

The practice of finning (i.e., removing the fins and discarding the remainder of the shark at sea), probably arose in the indirect longline fisheries to save freezer space for the more valuable swordfish and tuna. Over the years, shark discards from both the commercial and recreational fisheries have been extensive. The amount of sharks finned was about the same as harvested and landed from 1987 to 1991.

Commercial shark fishing gear includes longlines, gillnets, trawls, and to an unknown extent, harpoons. Most Atlantic and Gulf longlines are pelagic gear used by the swordfish and tuna fleets, and capture sharks incidentally. In recent years a directed longline shark fishery has emerged, with many vessels converted from shrimp trawl or snapper-grouper bottom-longline fisheries. A typical shark vessel is 10 to 15 m long and deploys pelagic or bottom longlines.

Commercial shark yield is seasonal. In the Gulf and southern U.S. Atlantic, the lowest yield from 1979 to 1987 occurred in January with the maximum Atlantic yield in March and the maximum Gulf yield in May.

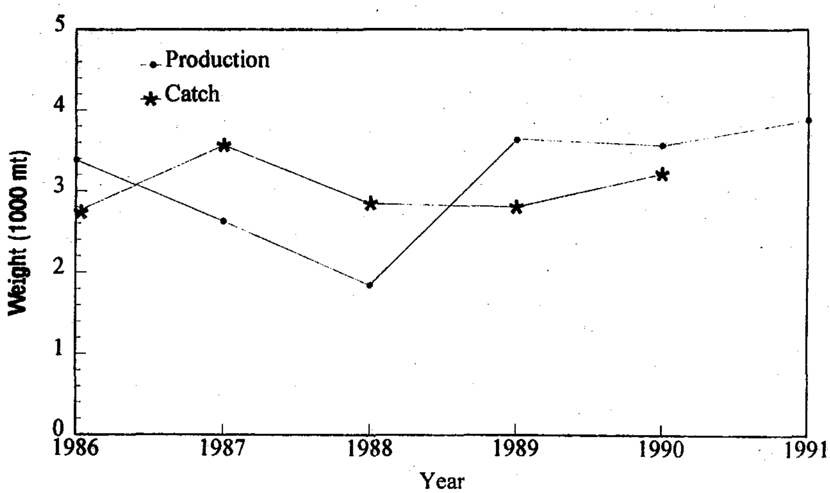


Figure 30. Production and catch of Atlantic and Gulf of Mexico small coastal sharks.

Recreational yield is estimated by the Marine Recreational Fishery Statistics Survey (MRFSS) which is carried out annually by NMFS. The MRFSS data on fishing modes for 1979 to 1988 indicate that approximately 10% of the sharks were taken by headboats and charter boats.

Scientific stock assessments defined several gear-specific and area-specific fisheries and three species groups. Each gear-specific fishery exploits one of the three species groups. A directed shark longline/gillnet fishery and a southern area tournament fishery both target large coastal sharks. Small coastal sharks are targeted by rod-and-reel fishermen and are also a significant bycatch of the shrimp fishery in the Gulf of Mexico. Pelagic sharks are most often taken by longline vessels incidental to tuna and swordfish, although rod-and-reel fishermen and commercial fishing vessels in northern areas sometimes target these species.

The status of the small coastal sharks and pelagic sharks species groups were assessed separately using 1986-1989 or later fishery statistics. Due to the transoceanic nature of pelagic shark catches and the international fleets that exploit them, the necessary fisheries information was not yet complete enough to assess that resource.

Despite the limitations and uncertainties of the data, the analyses provided statistics necessary for developing harvest limitations and management advice. The results of that advice are summarized in the following sections.

Large coastal sharks are those normally targeted by commercial shark longline and gillnet fisheries and by the southern shark tournament fisheries. Typical species in this group include sandbar, blacktip, dusky, bull, tiger, hammerhead, lemon, white, spinner, bignose, silky, and night sharks. Many of these make extensive migrations along the U.S. Atlantic coast. The assessments reported evidence of overfishing for the large coastal sharks during 1986 through 1992 (except for 1987 and 1990). Fishing mortality has increased from about F=0.2 in 1986 to the current level of F=0.3. The replacement F, which is the fishing mortality rate at which the current population level is neither decreasing or increasing, is about F=0.25. Therefore, the current level of fishing mortality may be slowly depleting abundance. The yield in 1991 was estimated to be 6,003 t (whole weight, metric tons) and is higher than the 1986-1991 average of 5,688 t (**Figure 29**). The shark fishery management plan recommends reductions in yield to reduce fishing mortality and stabilize abundance.

Small coastal sharks are typically caught in recreational fisheries (headboats and privately owned boats) and as discarded bycatch in the Gulf of Mexico penaeid shrimp trawl fishery. The largest component of the catch, by far, is the shrimp trawl bycatch. The predominant species in this group are the sharpnose, with bonnethead, blacknose, and finetooth sharks forming the majority of the remainder. For small coastal sharks, the assessments suggest that catches exceeded production in 1987 and 1988 but not in 1986, 1989, and 1990 (**Figure 30**). Hence, a reduction in abundance is not indicated, and the small coastal sharks are considered to be fully exploited. The annual production potential for small coastal sharks is high and it is expected that abundance could rapidly increase if fishing mortality were reduced.

Pelagic sharks are a bycatch of the commercial tuna and swordfish longline fisheries and are directly exploited by recreational fisheries from Virginia to New York. Typical species in this group include makos, threshers, blues, oceanic whitetips, and porbeagles. Trans-Atlantic migrations of these sharks are common. Therefore, this species group is exploited by several nations, removals often occur outside of U.S. territorial waters, and discarding at sea is common but not recorded. For the above reasons, data were not available to develop production estimates as was done for the large and small coastal sharks. The average annual U.S. commercial yield of this species group during 1986-91 was about 580 t (with an unknown amount of discards). The average recreational pelagic shark yield in the southern area are estimated to have been about 94 t. Recreational shark yield in the northern area is estimated to have averaged about 885 t. The sum of these (1,559 rounded to 1,560 t) is considered the best available estimate of the current potential yield for this species group.

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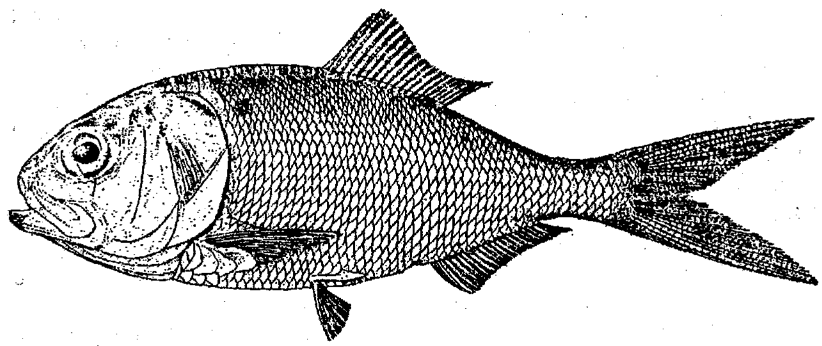
Menhaden, Butterfish and Coastal Herrings

GULF MENHADEN



Gulf menhaden (*Brevoortia patronus*)

The Gulf menhaden (*Brevoortia patronus*) is a euryhaline clupeid species found in coastal and inland tidal waters in the Gulf of Mexico from Tampa Bay, Florida, to Mexico's Yucatan Peninsula. Adult menhaden are filter feeders (feeding primarily on phytoplankton) and, in turn, support predatory food fishes. They attain a maximum fork length of about 24 cm and weigh up to about 300 g. Maximum age is approximately 5 or 6 years, although age-1 and age-2 fish comprise the bulk of the landings (with a mean fork length of about 16 cm and weight of about 90 g). Gulf menhaden form large surface schools which appear in the nearshore Gulf waters from about April to November. Although no extensive coastwide migrations are known to occur, there is evidence that older fish move towards the Mississippi River delta. Sexual maturity is attained by age-2; spawning occurs in offshore waters during winter, peaking during December and January. Eggs hatch at sea and the larvae are carried to estuaries by ocean currents where they develop into juveniles. Juveniles migrate offshore during winter and move back to coastal waters the following spring as age-1 fish.

Relative to stock assessments, Gulf menhaden are treated as a single stock; they are subject to an extensive purse-seine fishery in the northern Gulf of Mexico from mid-April through mid-October as regulated by the states and coordinated by interstate compact. Menhaden are processed into fish meal, fish oil, and fish solubles. A small commercial bait fishery also occurs along the northern Gulf of Mexico. The only recreational take of Gulf menhaden is as live bait for king mackerel and other piscivores.

The purse-seine reduction fishery for Gulf menhaden is managed cooperatively among the U.S. Gulf states through the Gulf States Marine Fisheries Commission. A Fishery Management Plan was developed in 1977, with updates prepared in 1983 and 1988. Another update is in progress. The primary management measure is a temporal limit on purse seine fishing for menhaden between mid-April and mid-October. In addition, inside waters of the coastal states are closed to purse seine fishing.

During the 1993 fishing season, 52 vessels (consisting of a large carrier ship with two small purse boats that set the purse seine about all or a portion of the menhaden school) operated out of 6 reduction plants (5 plants in Louisiana and 1 plant in Mississippi). Purse-seine landings of Gulf menhaden by the reduction fishery increased 28% in 1993 from 421,400 metric tons (t) to 539,200 t (**Figure 31, Table 8**). Only limited data are available from bait fisheries for Gulf menhaden, and no data exist

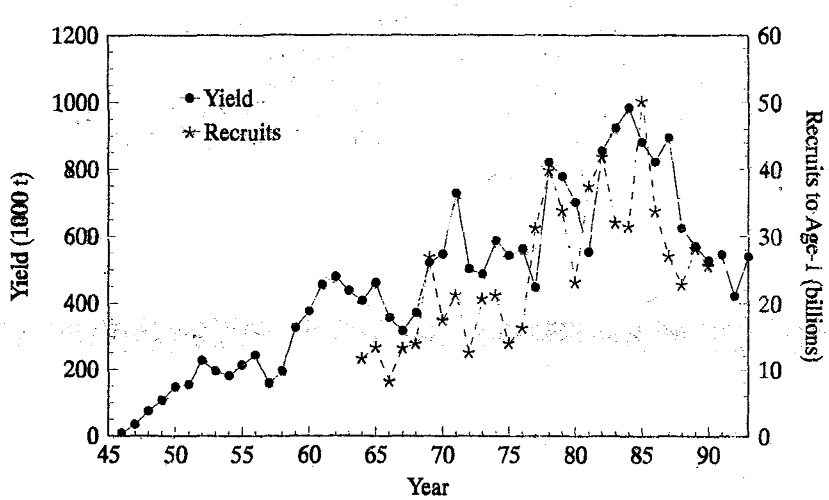


Figure 31. U.S. Gulf of Mexico menhaden yield and recruitment to age-1.

MENHADEN

	U.S. Gulf of Mexico	U.S. Atlantic
Longterm potential yield	660, 000 t	480,000 t
Current potential yield	500,000 t	330,000 t
Recent average annual yield (1000 t)	500,000 t	330,000 t
Status of exploitation	Fully exploited	Fully exploited
Age at 50% maturity	2 years	3 years
Current spawning potential ratio	48%[a]	8%[b]
Generation time	2.1 years	3.2 years
Natural mortality rate	1.1	0.45
Fishing mortality rate at $F_{30\% SPR}$[c]	1.9[a]	0.4[b]
Fishing mortality rate at F_{max}[c]	5.0[a,d]	1.3[b]
Fishing mortality rate in most recent year:		
Age 0	0.0[a]	0.16[b]
Age 1	0.34[a]	0.09[b]
Age 2+	0.98[a]	1.25[b]

[a]Equilibrium, based on F's from 1990 fishing year.
[b]Equilibrium, based on F's from 1990 fishing year, population simulations suggest stock can replenish itself at this level of %MSP.
[c]Multiples of F_{recent}; 1990 for Gulf and 1990 for Atlantic menhaden.
[d]Maximum yield per recruit is at maximum F-multiplier (5.0) used in Y/R analysis.

on the take by recreational fishermen.

Historical landings rose from the fishery's beginnings following World War II to its peak in 1984 (982,800 t). Landings were generally high during the mid-1980s (greater than 800,000 t between 1982 and 1987), but have declined steeply between 1987 and 1992 (from 894,200 t to 421,400 t).

In general, estimates of nominal effort from a purse-seine fishery are not useful as an index of fishing mortality. Consequently, estimates of CPUE (catch per unit effort) from the Gulf menhaden stock are not useful as an index of population abundance.

Age composition data from the purse-seine fishery for reduction are dominated by age-1 and age-2 Gulf menhaden (55.5% and 38.3%, respectively in 1992), with the remaining 6.2% comprised of age-3 and older Gulf menhaden. This pattern of age-1 and age-2 Gulf menhaden dominating the landings has occurred since the collection of age composition data began in 1964.

Population abundance and fishing mortality rates are estimated by traditional virtual population analytic techniques, with the most recent analysis including catch in numbers at age estimates from 1964 through 1992. Estimates of annual instantaneous fishing mortality rates for 1990 (the most recent year that reliable estimates are available) are 0.34 for age-1, and 0.98 for age-2 and older. Because this species is short-lived and has a high natural mortality rate (1.1), growth overfishing has not been of major concern. Estimates of the spawning potential ratio have generally been high (greater than 30%).

ATLANTIC MENHADEN

Atlantic menhaden *(Brevoortia tyrannus)* is a euryhaline clupeid species found in coastal and inland tidal waters along the Atlantic coast from Nova Scotia, Canada, to West Palm Beach, Florida. Adult menhaden are filter feeders (feeding primarily on phytoplankton) and, in turn, support predatory food fishes. They attain a maximum fork length of about 32 cm and weigh up to about 650 g. Maximum age is approximately 11 or 12 years, although age-0 through age-3 fish comprise the bulk of the landings (the majority are age-2 fish that are about 22 cm in fork length and 205 g in weight). As coastal waters warm in April and May, large surface schools form off Florida, Georgia, and the Carolinas. Schools move northward, stratifying by age and size during summer (older and larger fish are generally found farther north). A southern migration begins in early fall, with surface schools disappearing in late December or early January off the Carolinas. Sexual maturity is attained at age-3; spawning is protracted and occurs in offshore waters generally during fall and winter, although near-ripe fish may occur during most months. Eggs hatch at sea and the larvae are carried to estuaries by ocean currents where they develop into juveniles. Juveniles migrate southward and probably offshore during winter and move back to coastal waters the following spring as age-1 fish.

Table 8. Yields of menhaden in the U.S. Gulf of Mexico and Atlantic Ocean.

Year	Gulf (1000 t)	Atlantic (1000 t)
1980	701.3	401.5
1981	552.6	381.3
1982	853.9	382.4
1983	923.5	418.6
1984	982.8	326.3
1985	881.1	306.7
1986	822.1	238.0
1987	894.2	326.9
1988	623.7	309.3
1989	569.6	322.0
1990	528.3	401.2
1991	544.3	381.4
1992	421.4	297.6
1993	539.2	320.7

For stock assessments, Atlantic menhaden are treated as a single stock. They are subject to an extensive purse-seine fishery along the U.S. Atlantic coast, generally from May through January. Menhaden are then processed into fish meal, fish oil, and fish solubles. A commercial bait fishery is also found along the U.S. Atlantic coast. The only recreational take of Atlantic menhaden is as live bait for king mackerel, striped bass, bluefish, and other piscivores.

The purse-seine reduction fishery for Atlantic menhaden is managed cooperatively among the U.S. Atlantic coastal states through the Atlantic States Marine Fisheries Commission. A Fishery Management Plan was developed in 1981 and adopted in 1982, a limited update was prepared in 1986, and a complete rewrite is currently in preparation with adoption in September 1992. The primary management measure proposed in 1982 was a variable seasonal closure. However, this measure was not adopted in those states where most menhaden are landed (i.e., North Carolina and Virginia). Several U.S. Atlantic coastal states have closed their waters completely or partially to purse seine fishing (South Carolina, Maryland, Delaware, and New Jersey). During the 1993 fishing season, 30 vessels (generally consisting of a large carrier ship with two small purse boats that set the purse seine about all or a portion of the menhaden school) operated out of 5 shore-based reduction plants (1 in North Carolina, 2 in Virginia, and 1 each in New Brunswick and Nova Scotia, Canada) and 1 internal waters processing operation in Maine (with two Soviet factory ships). Purse-seine landings of Atlantic menhaden by the reduction fishery increased 8% in 1993 from 297,600 t in 1992 to 320,700 t (**Figure 32**). Only limited data are available for bait fisheries for Atlantic menhaden, and no data exist on the catch by recreational fishermen.

Historical landings rose during the 1940s and early 1950s (peaked at 712,100 t in 1956), remained high during the late 1950s and early 1960s, dropped precipitously during the mid-1960s, and remained low during the late 1960s (minimum of 161,600 t in 1969). Since 1970, landings have improved, but not to the levels of the late 1950s (recent peak of 418,600 t in 1983).

In general, estimates of nominal effort from a purse-seine fishery are not useful as an index of fishing mortality. Consequently, estimates of CPUE (catch per unit effort) from the Atlantic menhaden stock are not useful as an index of population abundance.

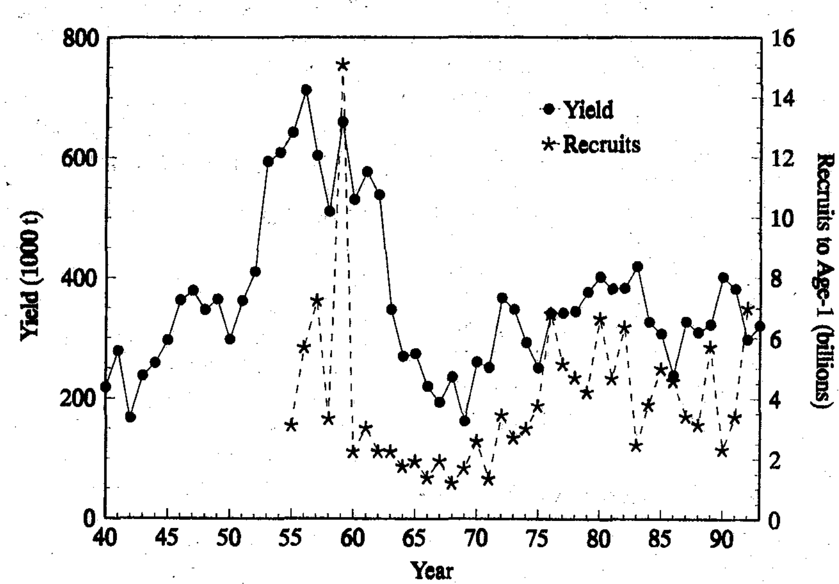


Figure 32. U.S. Atlantic menhaden yield and recruitment to age-1.

Age composition data from the purse-seine fishery for reduction are dominated by age-0, age-1 and age-2 Atlantic menhaden (18.7%, 39.2% and 36.2%, respectively in 1992), with the remaining 5.9% comprised of age-3 and older Atlantic menhaden. Age-1 and age-2 Atlantic menhaden have typically dominated the landings in the middle and southern U.S. Atlantic regions, with occasional large landings of age-0 fish. Older fish (age-3 and age-4 Atlantic menhaden) typically dominate the landings in the U.S. north Atlantic region.

Population abundance and fishing mortality rates are estimated by traditional virtual population analytic techniques, with the most recent analysis including catch in numbers at age estimates from 1955 through 1992. Estimates of annual instantaneous fishing mortality rates for 1990 (the most recent year that reliable estimates are available) are 0.16 for age-0, 0.09 for age-1, 1.25 for age-2 and older, which are generally below the mean values of fishing mortality rates for the 1980s (0.09, 0.25, and 1.58 respectively).

Even though recruitment to age-1 is comparable between the 1950s and 1980s, landings during the 1980s have been substantially below those of the 1950s. However, the collapse of the stock in the 1960s resulted in a southward shift in fishing effort and processing capacity, where the menhaden are generally younger and smaller than those found farther north. The primary management concern for this stock has been growth overfishing, but maximum spawning potential also has remained low (less than 10%) since 1962.

GULF BUTTERFISH

The gulf butterfish, *Peprilus burti*, is a semipelagic fish distributed in the Gulf of Mexico and along the Atlantic coast of Florida. Gulf butterfish school near the sea bottom during daylight but disperse and move up into the water column at night. Young of the year fish are found in inshore waters with larger or older fish distributed in depths up to 365 meters. Larval gulf butterfish are associated with jellyfish. As they grow,

GULF BUTTERFISH

	U.S. Gulf of Mexico
Longterm potential yield	26,500 t
Current potential yield	26,500 t
Recent average annual yield	19,700 t
Status of exploitation	Under exploited
Natural mortality rate	1.3-1.5
Fishing mortality rate at $F_{0.1}$	0.4
Fishing mortality rate at F_{max}	0.6
Fishing mortality rate in 1988	0.4-0.5

gulf butterfish feed on jellyfish. Butterfish move into deeper water as their size increases and their diet switches to include small shrimp, worms and small fish. The largest gulf butterfish captured measured 22.9 cm and 0.2 kg. Maximum age is 2+ years. Sexual maturity is reached at 100-160 mm fork length as they approach age-1. Spawning probably occurs in offshore waters from early fall through the spring, although fish with ripe gonads are found year round.

In the Gulf of Mexico, gulf butterfish have been a component of the catch in the industrial bottomfish and shrimp fisheries and were either discarded or processed for petfood or fish meal. In 1986, a directed bottom trawl fishery for gulf butterfish started with the arrival of New England freezer trawlers. The New England vessels fished in the Gulf during the springs of 1986 and 1987, the spring and summer of 1988, and briefly during the spring of 1988. In 1987, several Gulf vessels experimented with fishing for gulf butterfish. These early trips led to major retrofits of a number of shrimp trawlers and one purse seiner in 1988. At one point in 1988, 15 vessels were engaged in the directed fishery for butterfish. The market for gulf butterfish saturated early during the summer of 1988. As a result the New England vessels returned north and most of the Gulf vessels switched back to shrimping. The directed fishery for gulf butterfish continued in 1989, 1990 and 1991 with one or two Gulf vessels targeting butterfish.

Gulf butterfish are assessed as a single stock. The fishery is not under management. Total catch in 1991 was approximately 20,000 t, about the average annual catch for the 1986-1991 period of 19,700 t (**Figure 33, Table 9**) Incidentally captured butterfish by the offshore Gulf of Mexico shrimp fleet has comprised 80 % to 97 % of the total annual catch since 1986. Length composition data indicate that annual catch is dominated by age-1 fish, with few age-0 and 2+ fish.

Long-term potential catch has been estimated as 26,500 t. Fishing mortality for all ages since 1984 has been steady and averaged 0.3 to 0.4.

Since age-0 fish are found inshore, NMFS research vessels in offshore waters survey age-1+ butterfish. The 1991 catch per tow index was lower than the 1990 index. Research survey catch indices have fluctuated since 1972 but show no increasing or decreasing trend.

The gulf butterfish stock is in good condition. The survey catch indices have been steady. The average fishing mortality is lower than F_{MAX}. Total catch, however, is near the estimated level of long-term potential catch.

COASTAL HERRINGS

Coastal herrings refers to a complex of small herrings (clupeids), an-

Table 9. Gulf butterfish annual yield and survey index.

Year	Yield (1000 t)
1980	8.51
1981	13.73
1982	5.48
1983	6.42
1984	21.70
1985	6.69
1986	11.91
1987	24.20
1988	23.08
1989	18.47
1990	20.80
1991	20.00

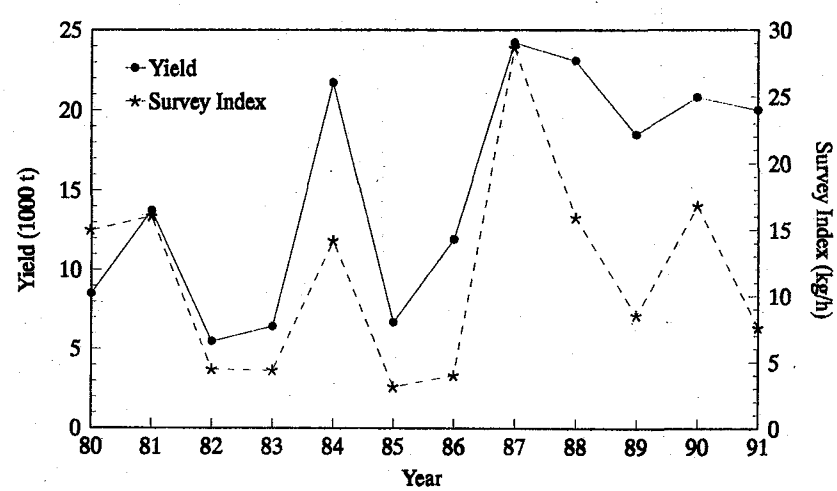


Figure 33. U.S. Gulf of Mexico butterfish yield and index of abundance.

chovies (engraulids), jacks (carangids), and one mackerel (scombrid). The coastal herrings complex is dominated by Spanish sardine, scaled scardine, Atlantic thread herring, round herring, bay anchovy, striped anchovy, silver anchovy, rough scad, bigeye scad, round scad, Atlantic bumper, and chub mackerel. Coastal herrings represent a large underused fishery resource with a potential yield of 1-2 million t.

Coastal herrings are distributed along the U.S. Atlantic coast and through the Gulf of Mexico. They can be divided into inshore and offshore groups. The inshore group consists of sardines, anchovies, Atlantic thread herring, and Atlantic bumper. These species are found from the shoreline to 70 m depths. The offshore group contains round herring, scads, Atlantic bumper, and chub mackerel. These are concentrated in waters deeper than 70 m and have been captured in bottom trawls at 365 m.

Coastal herrings range in size from 6 cm to 28 cm in length. They undergo diel changes in schooling behavior and in vertical distribution within the water column.

Coastal herrings are not managed within the U.S. Exclusive Economic Zone. Spanish sardine, scaled sardine, and Atlantic thread herring are exploited by a purse seine bait fishery along the Florida Atlantic and Gulf of Mexico coasts. In North Carolina, menhaden vessels target migratory schools of thread herring during September and October. U.S. landings of Spanish sardine, scaled sardine, and Atlantic thread herring totaled 4,466 t in 1989 and 2,596 t in 1990. Atlantic bumper, scads, round herring, and chub mackerel are taken incidentally by the shrimp, industrial bottomfish, and Gulf butterfish fisheries. Annual catch estimates have not been determined. There is no information available for these species on population dynamics within the jurisdiction of the United States, and no stock assessments have been made.

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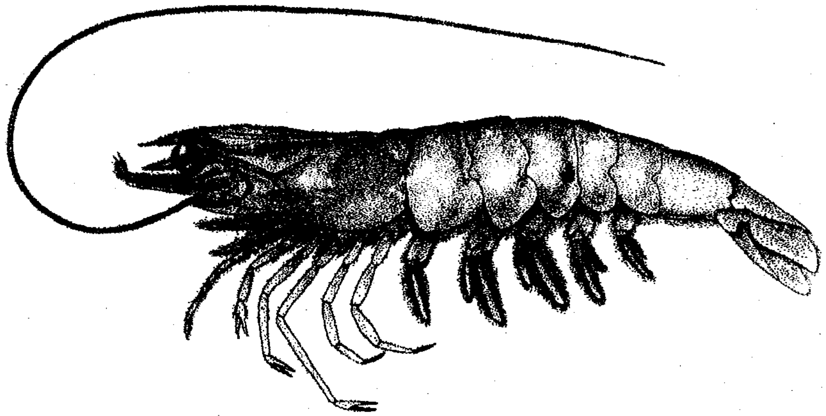
Invertebrates

SHRIMP

Nine species of shrimp contribute to the U.S. shrimp fishery in the Gulf of Mexico and Atlantic Ocean. Of the nine, the brown, white and pink shrimp of the genus *Penaeus* comprise over 89% of the commercial harvest and are the only species besides royal red shrimp (*Pleoticus robustus*) currently regulated by a federal fishery management plan. These species are generally found in all continental shelf waters in the U.S. Atlantic and Gulf of Mexico inside 110 m depths. The greatest portion of the reported offshore catch of brown shrimp (*Penaeus aztecus*) is taken at depths of 20-37 m, white shrimp (*P. setiferus*) in 18 m or less, and pink shrimp (*P. duorarum*) in 20-27 m. In the Gulf of Mexico the greatest densities of brown shrimp occur off the Texas-Louisiana coast; the largest concentrations of white shrimp occur off the Louisiana coast; and the greatest densities of pink shrimp occur off the southwestern coast of Florida. In the U.S. Atlantic, the center of abundance for white shrimp is off the Georgia-South Carolina coasts, while the center of abundance for brown shrimp is off the North-South Carolina coasts.

Brown, white, and pink shrimp all have similar life cycles in which spawning occurs offshore. However, the times when recruits enter the fishery and the time spent there differs for the three species. Generally eggs hatch into planktonic larvae after 10-12 hours. During the next 12-15 days these larvae metamorphose through additional planktonic stages into postlarvae as they move from offshore waters towards inshore areas. Upon entering the estuaries, these post-larvae become benthic and develop quickly into juvenile shrimp. These small shrimp have a voracious appetite and their diet includes diatoms, polychaete worms, and small crustaceans. Any natural or man-induced changes in estuarine habitat can alter shrimp survival at this stage in their life cycle. After 6-8 weeks in the estuaries, young subadult shrimp begin migrating back into the offshore areas. The average life span of these three species is thought to be about 12 months although some live for 2-3 years. Sexual maturity usually is attained between ages 5-8 months depending on the species.

Brown shrimp enter the estuaries in February and continue through April. However, depending on water temperature and environmental conditions, immigration into the bays in some years can occur through July. Several "waves" of postlarvae may enter an estuary, but peak recruitment occurs in March and April with a small peak in August or September. While in the bays, juvenile shrimp are harvested by recreational and commercial fishing during the spring and summer months. Emigration of juveniles to offshore waters begins in May



Pink shrimp (*Penaeus duorarum*)

Table 10. U.S. Gulf of Mexico shrimp yield in metric tons.

Year	Brown	White	Pink
1980	46,390	27,747	9,348
1981	72,928	32,245	13,627
1982	54,961	27,454	8,455
1983	44,891	29,190	9,174
1984	59,999	39,173	10,658
1985	63,227	41,176	11,523
1986	71,955	49,432	8,467
1987	67,267	37,351	7,560
1988	59,342	31,566	6,577
1989	68,738	25,429	6,217
1990	75,518	30,949	5,359
1991	64,075	32,012	4,785
1992	50,077	33,373	4,560

and ends in August with peak emigration occurring in May, June and, to some extent, July.

White shrimp postlarvae enter estuaries from May to November with peaks in June and September. These postlarvae use the estuaries as nurseries during the summer and fall and grow to a size of 12-16 cm total length in the bays. While in the estuaries they are harvested by recreational and commercial fishermen during late summer. White shrimp emigration is a function of size and environmental conditions within given bay systems. Usually the shrimp begin emigrating in September and end in December.

Pink shrimp postlarvae begin to enter the estuaries in the summer with peak recruitment occurring in the fall. They spend two to six months in nursery areas. Pink shrimp attain a size of 9.5 to 10 cm total length before emigrating from estuarine nursery areas to offshore waters. Size, however, is probably seasonally and spatially dependent. Emigration occurs year-round with peaks in the spring and fall.

Each shrimp species is assessed as two stocks: Gulf of Mexico and U.S. Atlantic. Important commercial fisheries occur in both regions. The harvest usually is conducted year-round with otter trawls. However, traps, butterfly nets, cast nets and seines also are employed in some areas. As noted above, peak seasonal fishing activity is species specific.

Shrimp fishery management is under both state and federal jurisdiction. Recreational and commercial shrimp fisheries in state territorial seas are managed by individual states. Each of the eight states involved (Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina and North Carolina) have unique management measures used to control the harvest of shrimp. The commercial shrimp fisheries in the Exclusive Economic Zone are managed under federal fishery management plans. Currently, only the fisheries in the Gulf of Mexico are under a plan developed by the Gulf of Mexico Fishery Management Council. The South Atlantic Fishery Management Council is developing a management plan for the shrimp fisheries in the Exclusive Economic Zone of the eastern coast of the United States.

The Gulf of Mexico shrimp fishery management plan was initiated in 1977 and implemented in 1981. The principal objectives of the plan are to optimize the yield of shrimp recruited to the fishery and to reduce the discard of undersize shrimp. Presently there are two state-federal cooperative closures that exist to fulfill these objectives. The first closure was developed for the brown shrimp fishery off Texas. Usually the total closure of

GULF BROWN SHRIMP

Longterm potential yield	62,5121 t
Status of exploitation	Fully exploited
Natural mortality rate	0.275 per month
Fishing mortality rate in 1992	Greater than 1.0 per month

GULF WHITE SHRIMP

Longterm potential yield	34,995 t
Status of exploitation	Fully exploited
Natural mortality rate	0.275 per month
Fishing mortality rate in 1992	Greater than 1.0 per month

GULF PINK SHRIMP

Longterm potential yield	7,488 t
Status of exploitation	Fully exploited
Natural mortality rate	0.30 per month
Fishing mortality rate in 1992	Greater than 1.0 per month

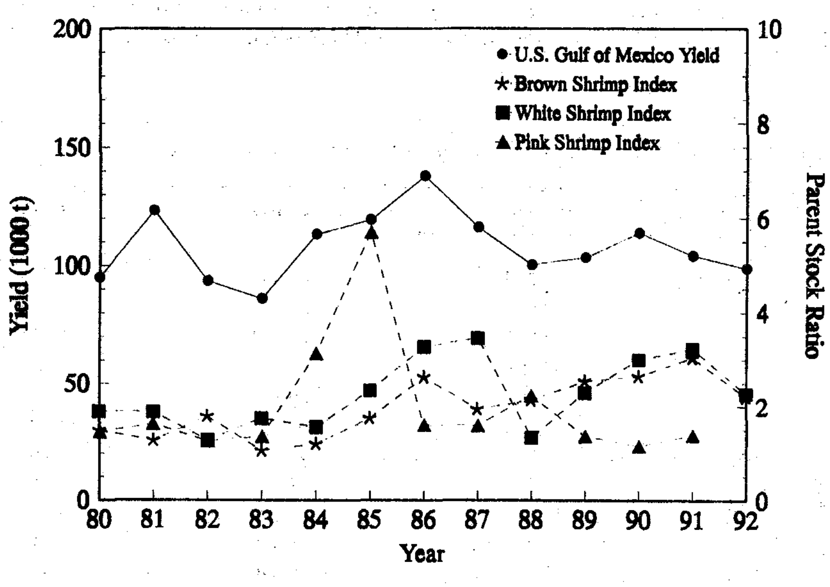


Figure 34. Total U.S. Gulf of Mexico yield and parent stock ratio for brown, white, and pink shrimp.

Table 11. U.S. Atlantic shrimp yield in metric tons.

Year	White	Other
1980	5,014	6,407
1981	3,794	3,801
1982	4,772	7,219
1983	5,630	6,479
1984	1,842	7,019
1985	3,521	8,906
1986	5,084	6,487
1987	5,822	5,063
1988	5,065	6,475
1989	6,179	9,858
1990	5,716	8,681
1991	8,248	7,561
1992	5,321	4,782

the offshore waters to shrimp fishing begins in mid-May, when the small juvenile shrimp are emigrating from the inshore waters, and ends in mid-July. The second closure was developed for the Tortugas pink shrimp fishery off the southeastern coast of Florida. It is a year-round closure which restricts fishing for small shrimp in coastal waters.

GULF OF MEXICO

Average annual commercial shrimp whole weight catch for all species combined during the last thirteen years (1980-1992) is 107,340 metric tons (t) (**Figure 34, Table 10**). The greatest harvest occurred in 1986 (137,949 t) while the lowest occurred in 1983 (86,484 t). On the average, brown shrimp accounted for 57%, white shrimp 31%, and pink shrimp 8% of the total catch. The other six commercially harvested shrimp species combined accounted for only 4% of the total. The peak brown shrimp harvest occurred in 1990 (75,518 t), white shrimp in 1986 (49,432 t), and pink shrimp in 1981 (13,629 t). The peak season for the other six shrimp species combined was in 1992 (8,450 t).

The average annual nominal fishing effort for the last twelve years (1981-1992) is around 7.0 million hours. The greatest level of fishing occurred in 1987 (8.9 million hours) with the lowest in 1981 (5.4 million hours). Currently the fishery is in an overcapitalized state with more effort being expended than is reasonably necessary to harvest the shrimp. Growth overfishing is a problem in some of the fisheries. Currently, it is estimated that about 5,000 vessels are participating in the fishery with an unknown number of smaller boats fishing in the inshore and nearshore waters.

Definitions of recruitment overfishing were established in June 1990 for brown, pink and royal red shrimp and in May 1992 for white shrimp. For the three *Penaeus* species, parent stock number calculated from virtual population analyses was selected as the best parameter to monitor for signs of overfishing. Since recruitment overfishing has not been observed in any of the three major Gulf of Mexico shrimp fisheries, even with the large amount of effort expended in the Gulf, the lowest recent parent stock number values for each species are used as the limit beyond which overfishing could occur with present environmental conditions. Parent stock is defined for brown shrimp as the number of age-7+ (months) shrimp during November-February with a level of 125 million shrimp set as the lower limit. White shrimp parent stock is defined as the number of age-7+ (months) shrimp during May-August with a level of 330 million shrimp set as the lower limit. Pink shrimp parent stock is defined as the number of 5+ (months) shrimp during July-June with a level of 100 million shrimp set as the lower limit. During 1992, brown and white shrimp parent levels were well above the overfishing index. Pink shrimp parent stock estimates were close to the index again in 1991, but farther away than the value observed during 1990.

Recruitment overfishing was defined for the royal red shrimp as fishing greater than optimal yield as defined in the fishery management plan. Optimal yield was set at maximum sustainable yield which was estimated to be 178.2 t tail weight at a level of 1,290 days fished. During 1992, only 61.0 t of royal red shrimp were caught in the Gulf of Mexico. This value is under the overfishing index level set for the species.

U.S. ATLANTIC

Average annual commercial shrimp whole weight catch for the last thirteen years (1980-1992) is 11,903 t (**Table 11**). This is about ten times less than the catch in the Gulf of Mexico.

The greatest harvest occurred in 1989 (16,037 t), while the lowest occurred in 1981 (7,595 t). On the average, brown shrimp account for 32%, white shrimp 43%, and rock shrimp 17% of the total catch. Pink shrimp and royal red shrimp harvest combined accounted for 8% of the total. The peak brown shrimp harvest occurred in 1980 (5,609 t), white shrimp in 1991 (8,248 t) and rock shrimp in 1989 (4,092 t). The peak season for the other two shrimp species combined was in 1989 (1,581 t).

Average annual nominal fishing effort for the last twelve years (1981-1992) is around 839,000 hours. The greatest level of effort occurred in 1983 (1.1 million hours) while the lowest was in 1992 (437,000 hours). Currently it is estimated that about 1,700 offshore vessels are participating in the fishery with another 1,300 boats fishing in the inshore and nearshore waters.

SPINY LOBSTER

The Caribbean spiny lobster (*Panulirus argus*) is of considerable importance to commercial and recreational fishermen in Florida and in the U.S. Caribbean . In the commercial fishery, wooden slat or wire traps are the primary means of harvest. In the recreational fishery, divers take spiny lobster by hand.

The minimum size at maturity is 8 - 9.5 cm carapace length. In Florida, spiny lobster reproduce most frequently from May to June, but reproduction extends into April and September. Sex ratios are often equal, and one female can lay from 400 thousand to 1.7 million eggs.

In waters offshore, males and females molt during the non-reproductive period of September - March. Local migrations occur and may be linked to the onset of reproduction or molting.

SOUTHEASTERN UNITED STATES

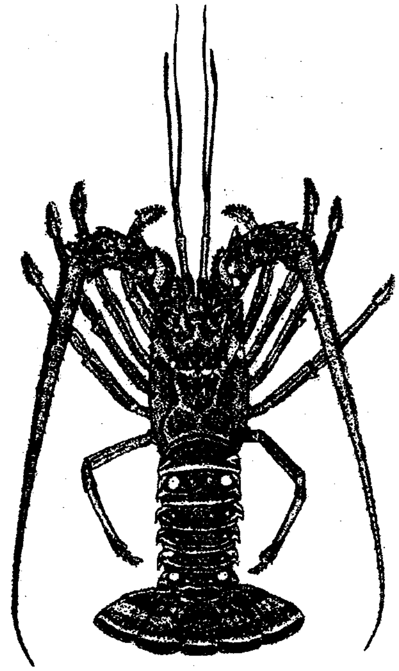
Spiny lobster are managed under a joint Gulf of Mexico and South Atlantic Council Fishery Management Plan which is coordinated with regulations set by the state of Florida. Management is based on a 7.6 cm minimum carapace size, a closed season from April 1 to August 5, protection of egg bearing females, some closed nursery areas, and recreational bag limits (6 per person per day or 24 per boat, whichever is greater). A two day "sport" season occurs before opening the regular season in August.

Annual spiny lobster landings have been fairly stable during the 1980s having fluctuated around 2,700 metric tons (t) in the Gulf of Mexico. Record landings of 3,300 t occurred in 1989 (**Figure 35**). In the U.S. Atlantic region, landings have averaged around 230 t with a value of $2 million. The fishery is considered overcapitalized with approximately 977,000 traps in use. It is estimated that the same yield could be obtained with half the number of traps fished. A trap reduction/limited entry program for Florida's commercial spiny lobster fishery was established during the 1992-1993 season.

The fishery uses live, undersized lobsters to bait traps and attract other lobsters. But due to mortality of the smaller lobsters, approximately 30 to 50% of the potential yield is lost.

The recreational fishery is concentrated at the beginning of the season and was estimated to be around 29% of the commercial harvest in 1991-1992 fishing season. Yield depends on recruitment; few lobster large enough to enter the fishery escape capture to survive into the next season.

The stock structure of the fishery is unknown due to a larval dispersal stage which is capable of drifting for nine months at sea. The stock is most likely of pan-Caribbean origin, and the amount of recruitment originating from local areas is unknown. Spiny lobster are very dependent on shallow water algal flats for recruitment, habitat, and feeding.



Caribbean spiny lobster
(*Panulirus argus*)

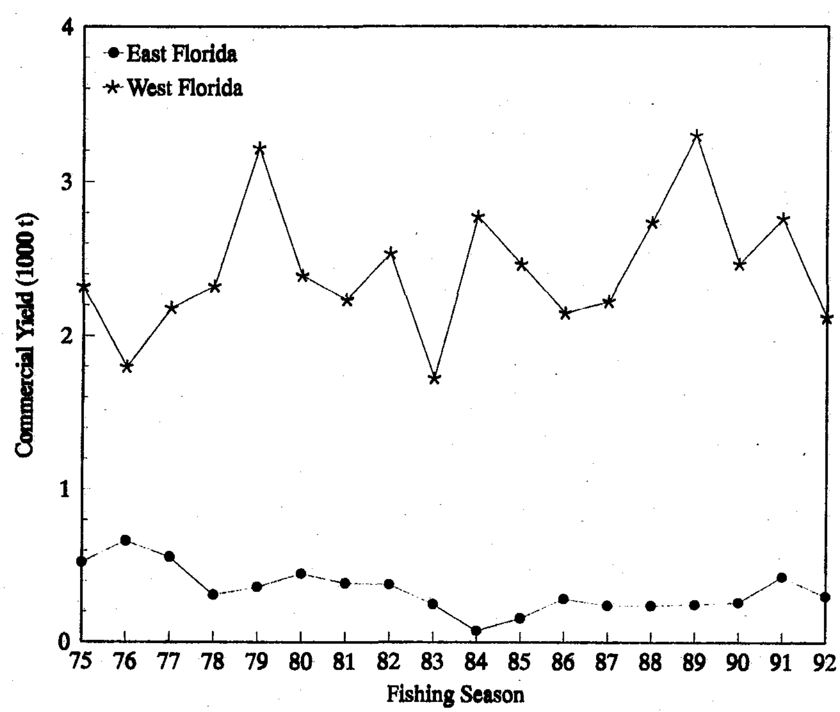


Figure 35. Spiny lobster commercial yield for Florida (fishing season is from July/August of year one through March 31 of year two).

U.S. CARIBBEAN

Spiny lobster in the Caribbean are caught primarily by fish traps, lobster traps, and divers. The Caribbean Spiny Lobster Fishery Management Plan includes federal waters surrounding Puerto Rico and the U.S. Virgin Islands. Management is based on a minimum size of 8.9 cm carapace length and protection of egg bearing females.

Annual spiny lobster landings for Puerto Rico averaged 136 t over 23 years (1970-1992) but have averaged only 82 t since 1986. Landings increased from 103 t in 1972 to 223 t in 1979 and then declined to a low of 63 t in 1988 (**Figure 36**). Landings in the U.S. Virgin Islands during 1980-1991 have been increasing slightly and averaged 27 t over this period. Spiny lobster landings during 1991 were 110 t for Puerto Rico and 52 t for the U.S. Virgin Islands.

Growth overfishing appears to be a significant problem in Puerto Rico. The possibility of growth overfishing is indicated by the large number of undersized lobster landed and a nine-year decline in total landings.

Precise data are not available on fishing effort. The fishery appears fully exploited and probably over exploited in Puerto Rico.

STONE CRAB

Stone crabs, genus *Menippe*, range from Cape Hatteras, North Carolina, through the Gulf of Mexico and Leeward Islands of the Caribbean Sea. The greatest stone crab concentration, however, occurs within Florida Bay which is bounded by Naples on the north and Key West on the south.

In Florida Bay, spawning extends year-round. But in the northern parts of the range, the period for spawning is shorter. Temperature seems to be the most important regulator of spawning frequency. Soon after spawning, the female stone crab molts and mates.

Female stone crabs reach sexual maturity as small as 3.4 cm carapace width but typically begin spawning at 6.0 cm carapace width. A spawning female bears an egg mass ranging from 160 thousand to 350 thousand eggs depending on the size of the crab.

SPINY LOBSTER

	Southeastern United States	U.S. Caribbean
Longterm potential yield	3,565 t	376 t
Current potential yield	2,400 t	Unknown
Recent average annual yield	3,000 t	132 t
Status of exploitation	Over exploited	Over exploited
Age at 50% maturity	3.5 years	3.5 years
Current spawning potential ratio	6%	56%
Natural mortality rate	34%	Unknown
Fishing mortality rate in most recent year	2.0	Unknown

STONE CRAB

	Southeastern United States
Longterm potential yield	976 t
Current potential yield	1,121 t
Recent average annual yield	1,404 t
Status of exploitation	Fully exploited
Age at 50% maturity	2 years
Current spawning potential ratio	96%
Projected SPR at current fishing patterns	96%
Natural mortality rate	1.9 per year
Fishing mortality rate in most recent year	0.1 per month

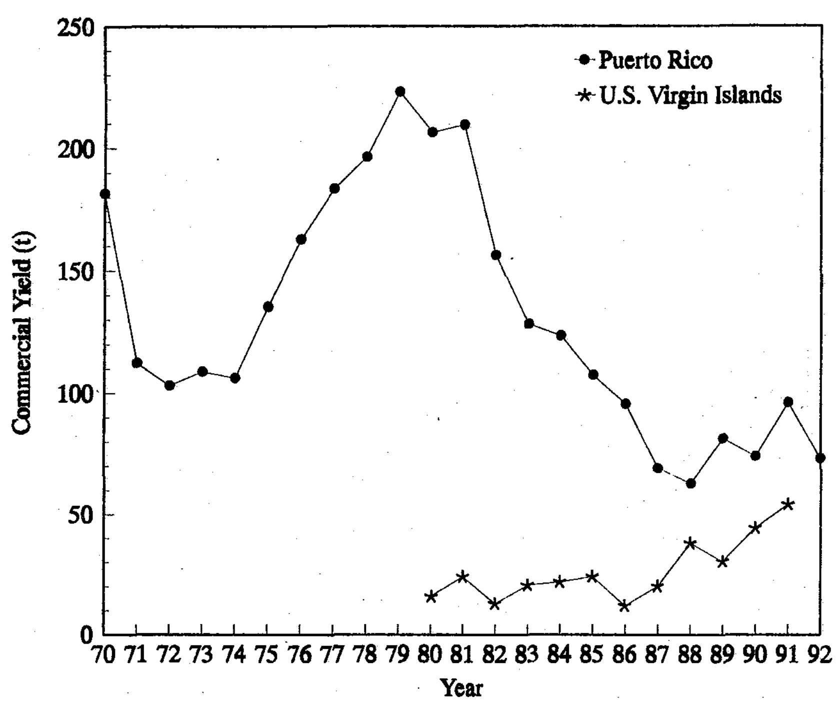


Figure 36. Spiny lobster commercial yield for the U.S. Caribbean Sea.

The stone crab fishery occurs primarily in southern Florida with some landings from more northern areas along the west coast of Florida. The Gulf of Mexico Stone Crab Fishery Management Plan was implemented in September 1979, and the regulations of the Plan generally extend the regulations set by the State of Florida into federal waters. Regulations are based on a minimum claw size of 2 3/4 inches, biodegradable panels on traps, protection of egg-bearing females, and closed seasons.

A gear conflict occurred in Florida Bay between stone crab fishermen using traps and shrimp fishermen using trawls. The shrimp trawls become entangled with the crab traps and cause a loss of time and extra expense. The problem has been mostly resolved by establishing a demarcation line to separate the two fisheries.

Annual catches (claw weight) have averaged 1,000 t in the Gulf of Mexico since 1980 (**Figure 37**). Landings in the southern U.S. Atlantic

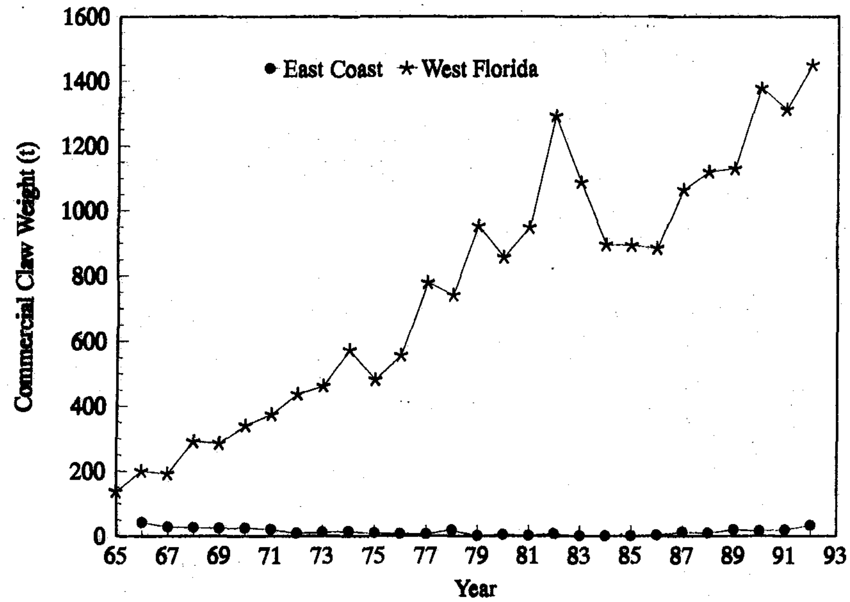


Figure 37. Stone crab (claw weight) commercial yield.

region were much smaller, averaging around 10 t. The number of traps increased from 295,000 in 1979-80 to an all time high of 686,000 in 1992-93. The estimated seasonal fishing effort increased from 3.6 million trap-hauls in 1985 to 7.7 million in 1992. As a result of the increased gear and effort, a greater proportion of the total landings are harvested early in the season thus tending to shorten the effective length of the season.

Recruitment to the fishery is probably dependent on habitat, particularly water quality and water flow management through the Everglades. The minimum size regulations ensure that harvested crabs have reproduced at least once before entering the fishery. It is unlikely under present recruitment conditions that the maximum production can exceed recent ranges on a sustainable basis.

CONCH

Conch fisheries include primarily the queen conch (*Strombus gigas*) but can include other species. Conch are mostly harvested by divers and are easily overfished. Conch fisheries are currently closed in state and federal waters in Florida and in U.S. Virgin Islands territorial waters. A Caribbean fishery management plan is being developed for federal waters in Puerto Rico and the U.S. Virgin Islands.

CORALS

Corals are managed as two groups: hard corals and soft corals. Hard corals are currently protected from harvest except for very small collections, under permit, for research and educational purposes. Harvest is severely restricted because hard corals are generally slow growing and provide critical habitat for a host of species. The habitat value of corals is considered more important than their commercial value.

Soft corals include gorgonians and sea fans. Gorgonians are exploited on a limited basis (approximately 50,000 colonies per year) for the aquarium and pharmaceutical industries. Growth potential for most species is considered limited. Sea fans are protected from all exploitation except under permit for research and educational purposes.

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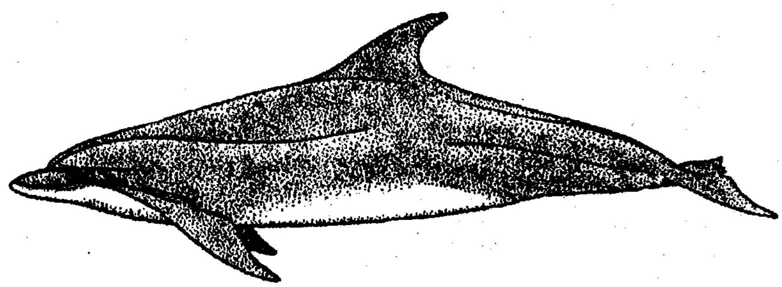
Marine Mammals

The marine mammal fauna of the southeastern United States is comprised of some 36 species of marine mammals. All but one of these species, the West Indian manatee (*Trichechus manatus)*, are under the jurisdiction of the National Marine Fisheries Service. The rest of the marine mammals are cetaceans, except for a few species of pinnipeds. These pinniped species include one now believed extinct, the Caribbean monk seal (*Monachus tropicalis*), occasional transients (harbor seals, *Phoca vitulina*), oceanarium escapees (California sea lion, *Zalophus californianus*), and animals stranded far outside of their normal range (hooded seal, *Cystophora cristata*). The cetacean species include eight species of large whales, 14 species of small-medium whales, 10 species of dolphins, and one species of true porpoise.

Management of marine mammals is regulated under the Marine Mammal Protection Act of 1972, as amended. Most of the large whales are listed as endangered or threatened under the Endangered Species Act of 1973, as amended. Both Acts restrict activities which could prove harmful to marine mammals, unless the activities have slight or no impacts on the stock or population in question, and are authorized by permit, or by legislative or regulatory action.

The most commonly observed cetacean in the southeastern United States is the bottlenose dolphin (*Tursiops truncatus)*. The bottlenose dolphin is the numerically dominant cetacean in the nearshore and estuarine waters of the southeast. This species is frequently seen by the casual observer throughout the year, both from shore and from small boats. The population of bottlenose dolphins includes resident groups in numerous bays, a coastal migratory stock along the U.S. Atlantic coast, and nearshore and pelagic components in the Gulf of Mexico and the U.S. Atlantic.



Bottlenose dolphin (*Tursiops truncatus)*

The other cetacean species are generally pelagic, and are rarely observed nearshore, except when stranded. One notable exception is the endangered northern right whale (*Balaena glacialis*). Some of these whales, particularly mothers with calves, are seen along the coast of Georgia and northern Florida during the winter. This area serves as the principal calving and nursery area for the northern right whale. Recent surveys indicate that the sperm whale (*Physeter catodon*) may be the most numerous large whale, and the pantropical spotted dolphin (*Stenella attenuata*) the most numerous small cetacean, in the pelagic waters of the northern Gulf of Mexico. The Atlantic spotted dolphin (*S. frontalis*) may be the most numerous small cetacean in the pelagic southeastern U.S. Atlantic.

Evidence of mortality due to net entanglement, vessel strikes, and other causes exists for numerous species of cetaceans in the southern United States. The levels of these and other sources of human-induced mortality of cetaceans in the southeastern United States are generally not well known. However, vessel strikes and entanglement may be a serious source of mortality for the endangered northern right whale.

The following sections provide summaries of the available, pertinent information on the cetacean fauna of the southeastern United States, in the northern Gulf of Mexico and the southeastern U.S. Atlantic coast. One section is devoted to the bottlenose dolphin, due to the extensive research that has been directed at this species. Another section is on the pelagic delphinid complex, and the last section summarizes the large whales and remaining species.

BOTTLENOSE DOLPHIN

The bottlenose dolphin is a medium-sized dolphin, with a maximum reported length in the southeastern United States of about 3 meters. Although these dolphins are frequently described as being a uniform gray in color, they do possess a distinctive, though faint, color pattern. This color pattern usually includes a dark gray dorsal cape, lighter sides, and generally a white belly. Some have a clearly evident "shoulder blaze," and most have a faint eye to flipper stripe. In the southeastern United States, the bottlenose dolphin population consists of resident groups in numerous bays, a coastal migratory stock along the U.S. Atlantic coast, and nearshore and pelagic components in the Gulf of Mexico and the U.S. Atlantic.

Two ecotypes are known to occur in the southeast. One, a "warm, shallow-water ecotype" is commonly found throughout the southeastern United States, in bays, nearshore waters, and over the continental shelf. This ecotype is characterized by, among other things, smaller size and proportionally larger flippers. These features are thought to be adaptations for increased maneuverability and heat dissipation.

The other ecotype is believed to occur mainly in deeper waters beyond the continental shelf. This "cool, deep-water ecotype," exhibits a larger size and proportionally smaller flippers. This ecotype also differs in hematological parameters, having higher hemoglobin concentrations, hematocrit, and red blood cell counts than the shallow-water ecotype. These morphological and blood characteristics are hypothesized to be adaptations for deeper and/or longer dives required to obtain prey in cooler waters.

The principal prey species of bottlenose dolphins have been identified primarily from examination of stomach contents of stranded dolphins. These principal prey species are: Atlantic croaker (*Micropogonias undulatus*), seatrout (*Cynoscion* sp.), silver perch (*Bairdiella chrysura)*, spot (*Leiostomus xanthurus*), and mullet (*Mugil* sp.). Bottlenose dolphins use a variety of methods to obtain prey, including forcing fish up on mud banks, "tail-whacking" (where the prey is hit with tail flukes, and stunned), and feeding on the bycatch of shrimp trawlers.

Bottlenose dolphins usually occur in small groups of 2-5 animals. Long-term studies of resident populations of the shallow-water ecotype along the west coast of Florida indicate that related females with calves make up the core social unit. Mature males, which are slightly larger than mature females, may form long-lasting pair-bonds with other males, and travel between female groups. Although these social units have been defined, there is mixing with neighboring groups, and with the occasional transient. It is not known if the social structure observed along the west coast of Florida is unique or if it occurs throughout the southeast.

Bottlenose dolphins are known to live in the wild at least up to more than 40 years, although the average is probably about 25-30 years. Females become reproductively active at 5-8 years, producing a calf about every 2-5 years thereafter. Gestation lasts about 12 months. Males become sexually and socially mature at about 9-12 years. The overall natural mortality rate has been estimated at 4-14% annually by several investigators; mortality of young of the year may, at times, exceed 50%.

Bottlenose dolphins are the most common species held in captivity in various oceanaria and aquaria around the world. Most of the bottlenose dolphins held in captivity in the United States and many of the animals held in other countries, were captured along the Gulf of Mexico and eastern Florida coasts. Because of concern over the effects of live capture removals, in addition to human-induced mortality resulting from activities such as fishing, collisions with boats, shooting, pollution, or other human activities, the removal of animals from the wild is strictly regulated. In general, no more than 2% of the stock abundance may be removed by live capture or other forms of removal. The so-called 2% rule was developed in recognition of the fact that marine mammal productivity rates are low and annual removals at levels greater than 2% may cause dolphin stocks to fall below their optimum sustainable levels.

The bottlenose dolphin is the numerically dominant cetacean over the continental shelf in the northern Gulf of Mexico. Bottlenose dolphins accounted for nearly 95% of cetacean sightings during aerial surveys of the northern Gulf shelf, and the remaining 5% was composed of 6 other species. The population of bottlenose dolphins in the northern Gulf of Mexico is conservatively estimated at 35,000 to 45,000 animals. As indicated above, the population in the gulf, and elsewhere, is organized into both resident and transient stocks. A significant increase in bottlenose dolphin strandings was observed in the northern Gulf during 1990, but available information does not suggest a concurrent significant decline in population size.

The bottlenose dolphin is also the numerically dominant cetacean in the nearshore area of the southeastern U.S. Atlantic coast. There may be at least three stocks or types of bottlenose dolphins in the southeastern U.S. Atlantic coast: bay residents, a mid-Atlantic coastal migratory stock, and an offshore stock. There is no comprehensive estimate of bottlenose dolphin numbers in the U.S. Atlantic, although the abundance of bottlenose dolphins from Cape Hatteras, North Carolina to Nova Scotia, Canada was estimated to range from 4,300-12,900 individuals in 1981. This estimate included individuals from both the mid-Atlantic coastal stock and the offshore stock, but did not include an estimate for the bay residents in the southeastern U.S. Atlantic coast.

The mid-Atlantic coastal migratory stock ranges from central eastern Florida to as far north as Long Island, New York, in the summer. During the winter, the range of this stock appears to contract to the area between central eastern Florida to central Georgia. This stock was estimated to number at least 1,200 animals prior to a dieoff of this stock during 1987-88. Based on an analysis of strandings, the dieoff was estimated to have resulted in the mortality of more than 50% of the pre-dieoff stock abundance. Historically about 15,000 animals are thought to have lived in mid-Atlantic coastal waters. This estimate is based on North Carolina shore-based fishery records from the turn of the century. It is possible that the mid-Atlantic coastal migratory stock of dolphins was below its optimum sustainable population level before the 1987-88 dieoff. With a reduction of 50% of stock abundance since 1987, it is likely that the stock is well below its optimal range, and thus is depleted under the terms of the Marine Mammal Protection Act.

Increases in the number of reports of stranded bottlenose dolphins have elevated concern for the status and health of both the bottlenose dolphin stocks and the health of our coastal environment. General increases in stranding rates of bottlenose dolphins were observed in 1987 and 1988 along the eastern seaboard and in 1990 and 1992 in the Gulf of Mexico (**Figure 38**). The highest bottlenose dolphin stranding rates yet observed in the Gulf of Mexico occurred during the winter-spring of 1994, when large numbers stranded along the Texas coast. These high levels were preceded bye numerous strandings on the Florida panhandle and the Alabama coast during July-December 1993.

The Southeast Fisheries Science Center (SEFSC closely monitors stranding rates in the Southeastern United States via the Marine Mammal Electronic Reporting System (MMR) The MMR system is a PC based host-remote system which allows remote users to update a monitoring database for strandings in the Southeastern United States. This monitoring system is used to identify anomalous mortality events by comparing historic mean stranding rates with current stranding rates. The MMR was instrumental in identifying an anomalous mortality event of bottlenose dolphins along the north-central and western Gulf of Mexico in 1993-1994.

The rapid identification of the anomalous mortality event, which began in the Florida panhandle during 1993, facilitated the diagnosis of a cetacean morbillivirus as the cause of the event. The disease is most likely transmitted through infectious exhalations. When an infected dolphin surfaces and "blows", the cloud of aerosol droplets produced contains numerous viruses. Nearby dolphins may inhale the viruses and become infected. Once infected, a transient bottlenose dolphin can potentially infect healthy bottlenose dolphins across a wide geographic area. Infection with morbillivirus believed to he fatal in most cases.

These increases have contributed to the concern about our coastal environment. The apparent increases in frequency of anomalous mortality events in the southeastern United States may be indicator of habitat degradation and the bottlenose dolphin may, in some ways be like a "miner's canary," warning of adverse alterations to our environment.

PELAGIC DELPHINID COMPLEX

The pelagic delphinid complex appears to vary in species composition between the northern Gulf of Mexico and the southeastern U.S. Atlantic coast. In the northern Gulf of Mexico, the pelagic delphinid complex consists of those species distributed along the edge of the continental shelf and into deeper waters. In the southeastern U.S. Atlantic coast, this complex includes cetaceans found within the Gulf Stream and farther offshore.

The northern Gulf of Mexico delphinid complex is comprised of mainly three species, and includes smaller numbers of several other species. The three main species are bottlenose dolphins, Atlantic spotted dolphins, and pantropical spotted dolphins. The other species include, but are not limited to, short-snouted spinner dolphins (*S. clymene*), striped dolphins (*S. coeruleoalba)*, Risso's dolphins (*Grampus griseus*), short-finned pilot whales (*Globicephala macrorhynchus*), and pygmy killer whales (*Feresa attenuata)*.

Recent vessel surveys for Gulf of Mexico marine mammals indicate that the pantropical spotted dolphin is the numerically dominant cetacean in waters outside of the continental shelf. This species appears to occur primarily in deeper waters beyond the edge or slope of the continental shelf. Pelagic bottlenose dolphins and Atlantic spotted dolphins appear to occur mostly along the edge or slope of the continental shelf of the Gulf of Mexico. The available sighting information of the other delphinid complex species is too limited to derive possible distribution information.

The southeastern U.S. Atlantic coast delphinid complex appears to consist of primarily two species, bottlenose dolphins and Atlantic spotted dolphins. The available sighting information indicates that pilot whales, either the long-finned pilot whale (*G. melaena*) or the short-finned pilot whale, may be the third most common delphinid species of the southeastern U.S. Atlantic coast. Pantropical spotted dolphins have not been observed during surveys of the southeastern U.S. Atlantic coast, although they have stranded along the coast of the southeastern U.S. Atlantic coast.

LARGE WHALES AND OTHER SPECIES

Most species of northern hemisphere balleen whales (Balaenopteridae and Balaenidae) have been documented as occurring in the waters of the southeastern United States, as strandings, sightings, or both. Sperm whales (*Physeter catodon*), pygmy and dwarf sperm whales (*Kogia breviceps* and *K. simus*), and beaked whales (Ziphiidae) have also been documented from strandings and sightings.

Recent vessel and aerial surveys for marine mammals indicate that sperm whales are likely the most common large whale in the northern Gulf of Mexico. Although other species of large whales have been stranded and/or sighted in the northern Gulf of Mexico, Bryde's whale (*Balaenoptera edeni*) seems to be the only other large whale to occur with any regularity. Based on sighting data, pygmy and dwarf sperm whales appear to be at least as abundant as sperm whales. Concern over the possible effects of offshore development activities on these species has resulted in initiation of new studies on the distribution, abundance and behavior in Gulf of Mexico waters.

The large whale fauna of the southeastern U.S. Atlantic coast appears to be composed of four species, and at least two of these, the northern right whale and the humpback whale (*Megaptera novaeangliae*), are seasonal components. The other two species are sperm and Bryde's whales.

Northern right whales display well-defined migratory movements along the western North Atlantic Ocean. These whales are found as far north as Nova Scotia in late summer and early fall. Adults and calves are frequently sighted during the winter in the nearshore areas along the coasts of Georgia and northern Florida. This area has been identified as the principal calving ground for the western North Atlantic stock of this species.

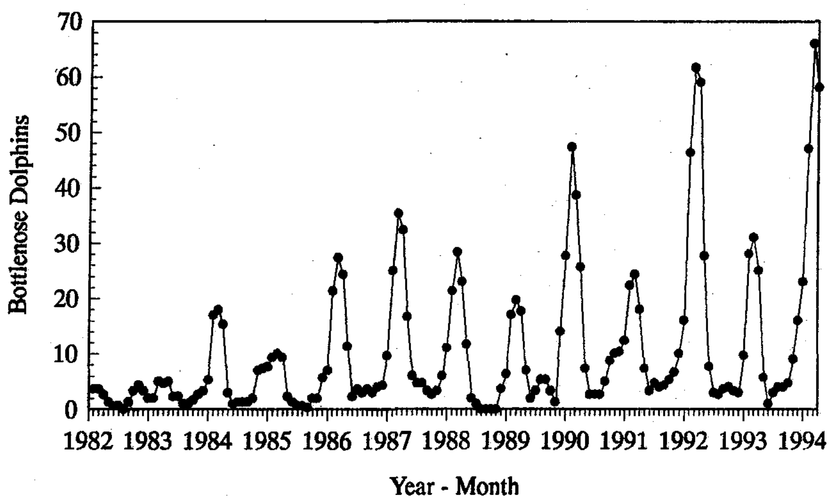


Figure 38. Monthly reports of numbers of stranded bottlenose dolphins along the Texas coast since 1982 , displayed as a three-month running average. In recent years (1990, 1992 and 1994 in particular), unusually high numbers of strandings have occurred that may be related to environmental changes. The relatively low numbers reported prior to 1986 are believed due to inadequate coverage of the beachfront in earlier years.

However, it is unknown if this stock also uses other areas for calving. Concern over habitat degradation and the extremely endangered status of northern right whales has resulted in new studies of right whale habitat characteristics in the southeastern U.S. Atlantic coast region.

The northern right whale population was severely reduced in size by whaling activities from the late 1600s through the early 1900s. Whaling records suggest pre-exploitation levels of 10,000-15,000 animals for the western North Atlantic right whale. Current population size is estimated at approximately 350, which easily justifies the endangered status of this stock. Although this species has received complete protection since 1937, signs of recovery in the western North Atlantic stock are lacking.

Humpback whales are sighted in nearshore areas of the northern portion of the southeastern U.S. Atlantic during the winter. There is no indication that humpback whales use this area as a calving ground. These whales are most likely in transit from high-latitude, summer feeding grounds to winter breeding and calving areas in the Caribbean. The pre-exploitation size of North Atlantic humpback whales is unknown; the population is currently estimated at about 5,500 animals.

One other winter and early spring visitor to the southeastern U.S. Atlantic in nearshore waters is the harbor porpoise (*Phocoena phocoena*). Strandings of this species in the southeast occur during the winter and early spring primarily along the coasts of North and South Carolina.

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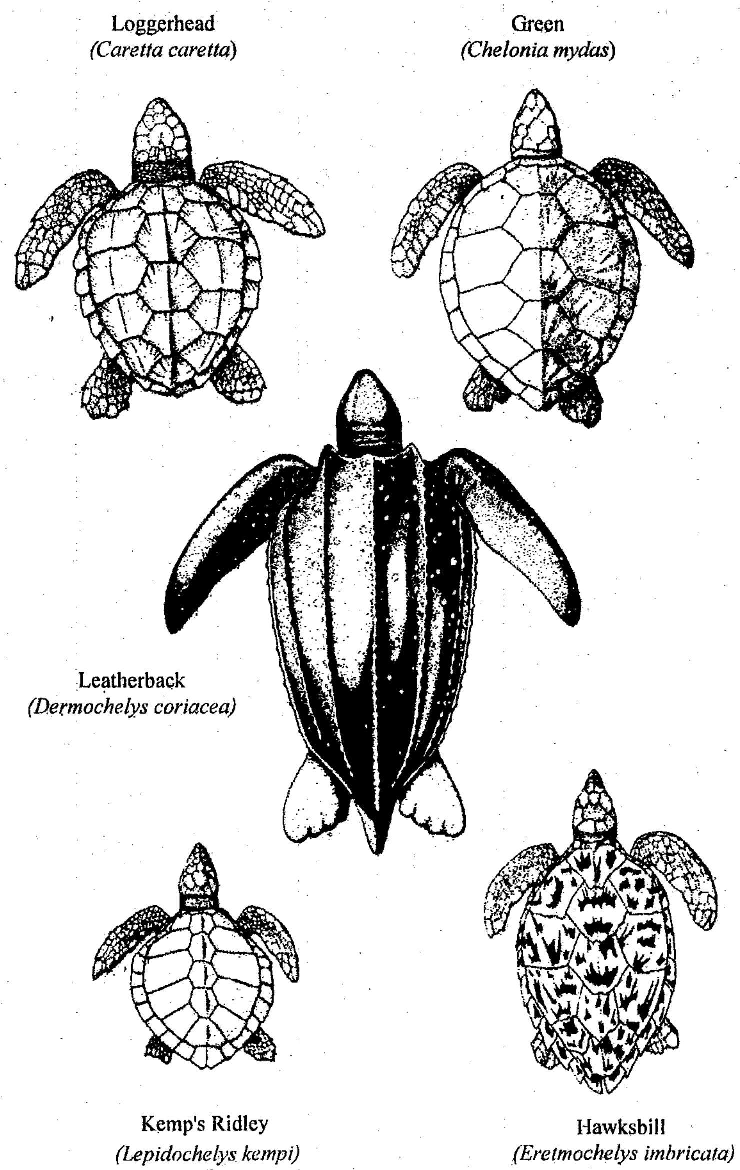
Sea Turtles

Sea turtles are highly migratory and ply the world's oceans. Under the Endangered Species Act of 1973, all marine turtles are listed either as endangered or threatened. The NMFS has authority to protect and conserve marine turtles in the seas and the U.S. Fish and Wildlife Service maintains authority while turtles are on land.

The Kemp's ridley, hawksbill, and leatherback turtles are listed as endangered throughout their ranges. The loggerhead and olive ridley turtles are listed as threatened throughout their U.S. ranges, as is the green turtle, except the Florida nesting population which is listed as endangered.



STATUS

The loggerhead, green, leatherback, hawksbill, and olive ridley turtles are all found in the Atlantic Ocean, but the olive ridley does not commonly enter U.S. waters. Historical data on sea turtle numbers are limited. In addition, the length of time that data have been collected has been short when compared with the long life and low reproductive rate of a turtle species. It is difficult to assess the long-term status of sea turtles due to the limited data.

The estimated number of female loggerheads nesting annually in the southeastern U.S. is approximately 20,000-28,000. Most nest along Florida's east coast where nest numbers have been stable for 5 years. However, only about 700-800 female Kemp's ridley turtles nest annually along a limited portion of Mexico's Atlantic coast, where in 1947, on a single day, 40,000 females were seen nesting. The documented decline in the Kemp's ridley is probably indicative of similar population trends for other sea turtles, though the periods of their various declines may have differed (**Figure 39**).

Historically, the green sea turtle has supported large fisheries along the Florida and Texas coasts, although its nesting on U.S. beaches has probably always been limited. Currently, perhaps 400-500 green turtles nest annually along the Florida coast. There are no historical estimates for the numbers of hawksbill or leatherback turtles nesting on U.S. Caribbean beaches. The hawksbill has been heavily exploited, and continued trade of products from this species suggests that further declines are possible. The trend over time of the leatherback turtle in U.S. waters is unknown.

ISSUES

Turtles are also killed incidentally in various commercial fisheries. Turtles are caught and killed in pelagic longline fisheries targeting tunas and billfishes. As many as 11,000 sea turtles may have been killed annually in shrimp trawls. Fortunately, turtle excluder devices (TEDs) have been developed for shrimp and fish trawls. TEDs enable turtles to escape the trawl net and prevent them from drowning. These devices reduce the turtle kill by shrimp trawls by as much as 97% and studies indicate that the use of TEDs minimally reduces shrimp catches. TED use is presently mandated for most of the Atlantic and Gulf of Mexico shrimp and summer flounder trawl fisheries.

ANNUAL NUMBER SEA TURTLES NESTING ON U.S. BEACHES

	Current Level	Current Trend	Status in U.S.
Loggerhead	20,000 - 28,000	Stable	Threatened
Green	400 - 500	Increasing	Threatened and Endangered in Florida
Kemp's ridley	700 - 800	Stable	Endangered
Leatherback	Unknown	Unknown	Endangered
Hawksbill	Unknown	Unknown	Endangered

HABITAT CONCERNS

Coastal development is reducing nesting and foraging habitats. Floating tar balls and plastics, if eaten, can harm or kill sea turtles. The magnitude of these problems is not fully known, but they occur worldwide, and international cooperation for marine turtle protection and recovery is needed.

ACCOMPLISHMENTS

The joint NMFS/FWS Atlantic Sea Turtle Recovery Plans have been developed, finalized, and approved. These plans prioritize turtle research requirements and delineate reasonable actions which are believed to be required to recover and/or protect the species.

A major factor affecting the recovery of turtle populations is the mitigation of commercial fishing/sea turtle interactions. The incidental capture of sea turtles in various commercial fisheries has been studied and summarized, and was the focal point of a meeting at the recent 13th Annual Sea Turtle Symposium. Recent legislation has allowed NMFS to use observers in selected fisheries to document the occurrence of incidental turtle captures. Also, several new TED models have been recently tested and approved for commercial use, and research continues on the development of a new TED design which would accommodate small inshore turtles.

Considerable progress has been made concerning inshore juvenile developmental habitat research and remote sensing. NMFS research projects have been initiated on juvenile ridleys and greens in the Cedar Keys and Biscayne Bay, Florida, and in the northwestern Gulf of Mexico. Additionally, a comprehensive research project concerning the incidence, etiology, and epidemiology of fibropapilloma tumor disease in Atlantic green turtles has been initiated. There is growing concern that this disease may seriously affect the recovery of world-wide green turtle populations.

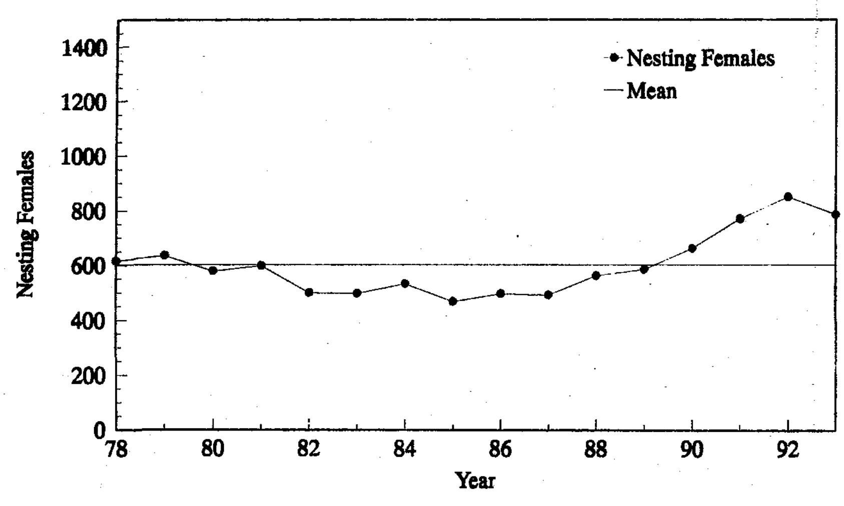


Figure 39. Number of nesting Kemp's ridley sea turtles.

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