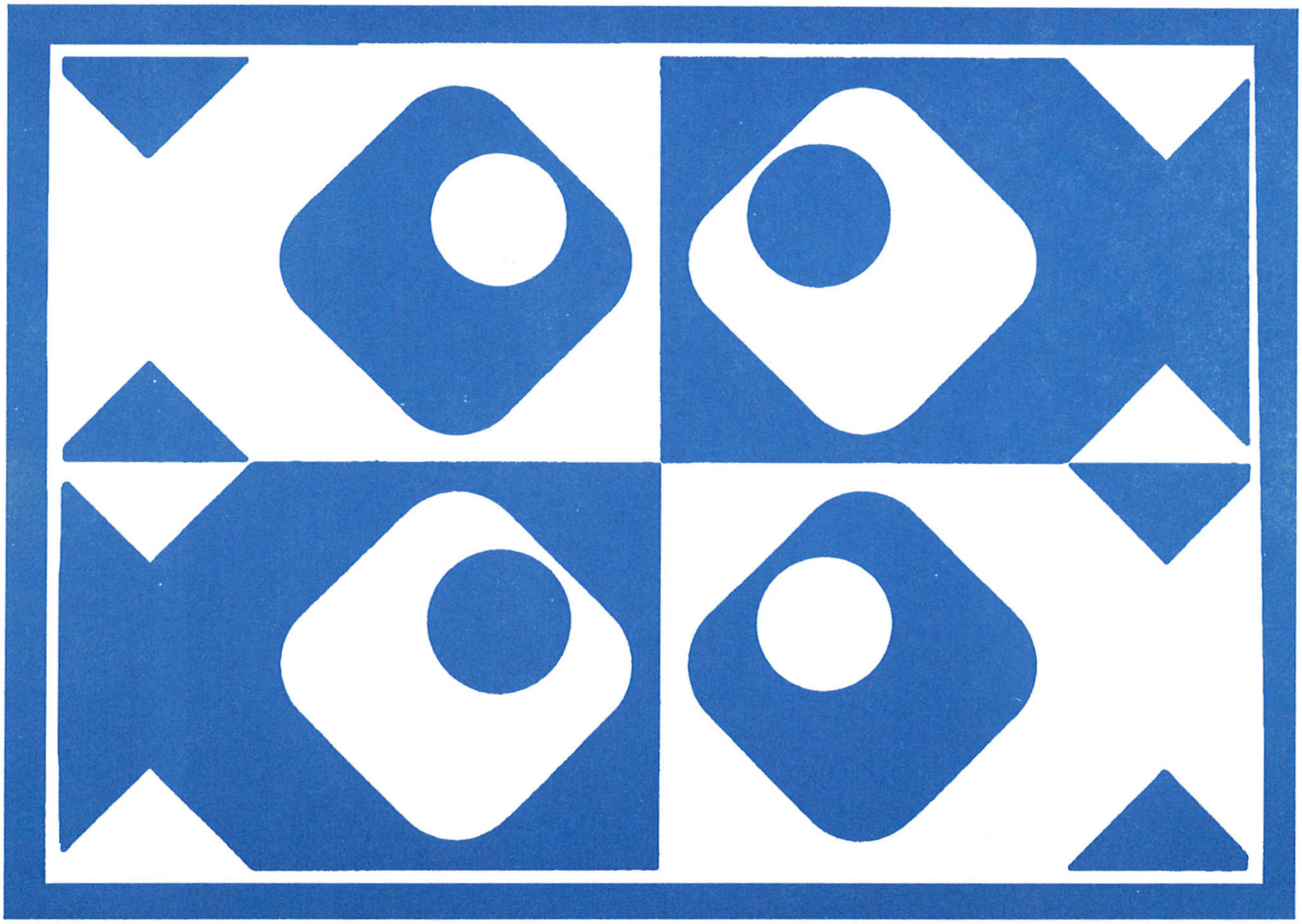
NOAA Technical Memorandum NMFS-SEFSC-306

Status of Fishery Resources off the Southeastern United States for 1991



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-306

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Status of the Fishery Resources Off the Southeastern United States for 1991

Southeast Fisheries Science Center

U.S. DEPARTMENT OF COMMERCE
Barbara Hackman Franklin, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Undersecretary for Oceans and Atmosphere

National Marine Fisheries Service
William W. Fox, Jr., Assistant Administrator for Fisheries

Southeast Fisheries Science Center
Miami, Florida

April 1992

NOTICE

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National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
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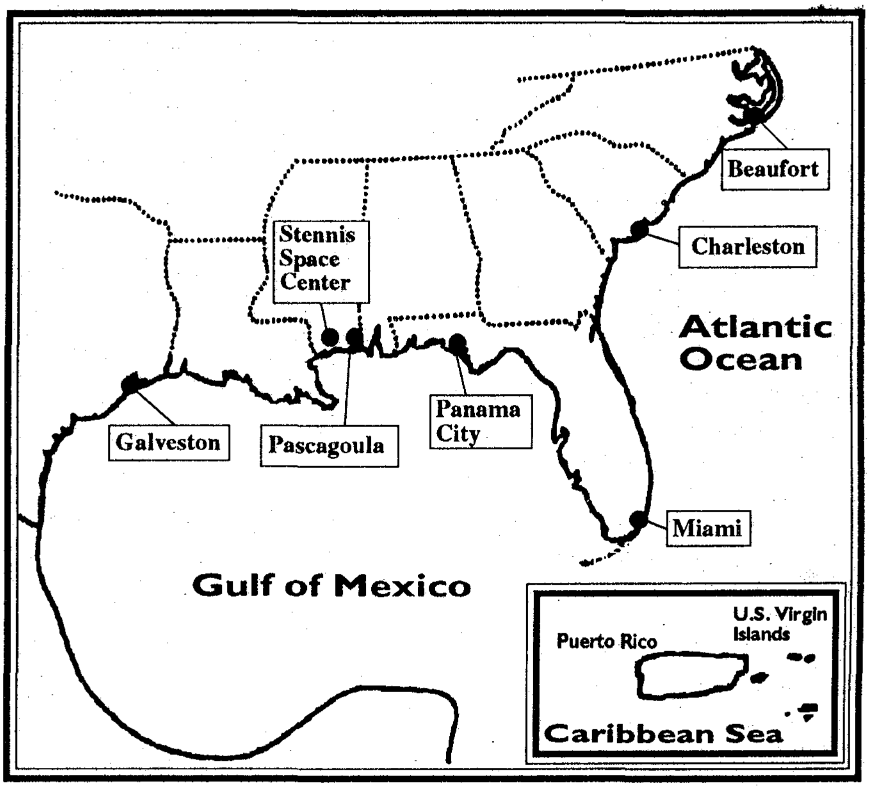
or

National Technical Information Service
5258 Port Royal Road
Springfield, Virginia 22161

Table of Contents

Southeast Fisheries Science Center



Facilities of the Southeast Fisheries Science Center

SOUTHEAST FISHERIES SCIENCE CENTER
Dr. Bradford E. Brown, Acting 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 functions and qualities of estuarine and marine habitats. 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
Eugene L. Nakamura, 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.

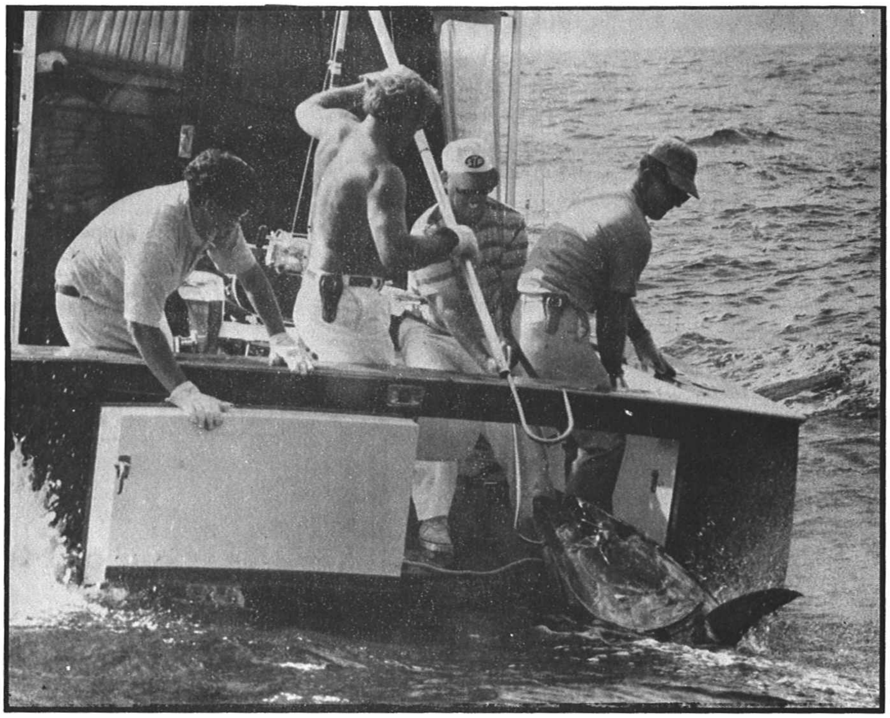
MISSISSIPPI LABORATORIES
Dr. Scott Nichols, Acting Director
3209 Frederic Street
Pascagoula, Mississippi 39567
(601) 762-4591

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. Edward F. Klima, Director
4700 Avenue U
Galveston, Texas 77550
(409)766-3500

Scientists at the Galveston Laboratory investigate fisheries for species of shrimp and demersal fish. Research is conducted on shrimp migrations and on the biological value of marshlands and estuarine habitats for fishery resources. A hatchery at the facility is used to rear the endangered Kemp's ridley sea turtle from eggs taken from its natural nesting beach in Mexico. Additional research is directed towards turtle habitat and physiology.

Stock Assessment Techniques



Bluefin tuna capture

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 through 1991.

The report is divided into three major sections: Fishery Trends, Resource Surveys, and Species Synopses. The Species Synopses section is comprised of ten subsections which discuss the status of individual species: oceanic pelagics, coastal pelagics, shrimp, reef fish, groundfish, sharks, menhaden, reef invertebrates, marine mammals, and sea turtles. Some sections represent species groups that are very numerous (e.g., reef fish with more than 300 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 (CRFMC) 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.

DEFINITION OF TECHNICAL TERMS (Alphabetical Order)

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 by changing the ratio of harvest by gears exploiting the fish (e.g., gill net, trawl, hook and line, etc.).

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

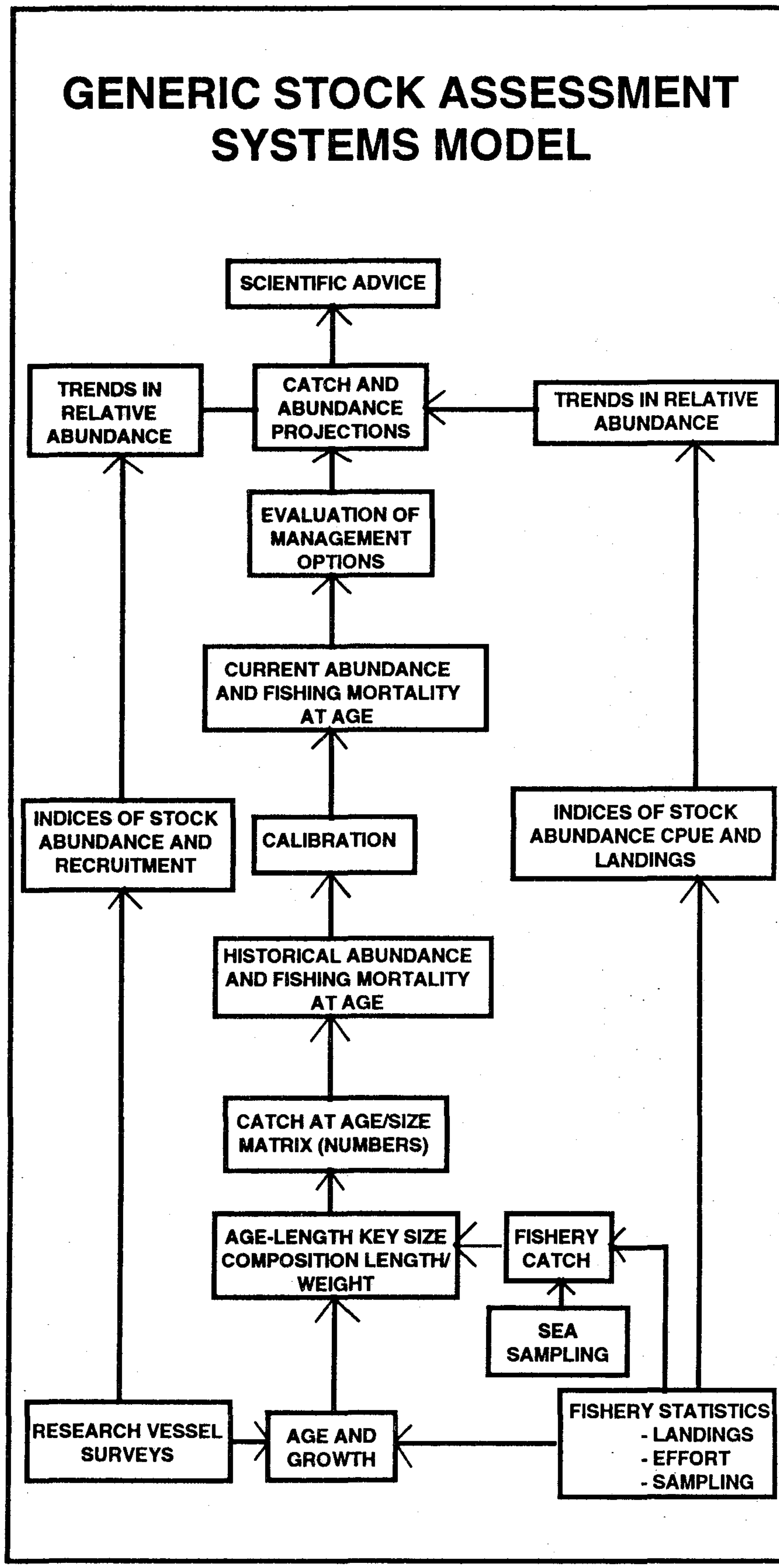


Figure 1. Diagram of alternative ways in which fishery-generated data and research data (lower right and left boxes, respectively) are combined to provide scientific advice on the status of the stocks.

variety of techniques, depending on the available data for a species or stock.

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, as given above, then this calculation is:

$$(1.5/1.7)\,(1-e^{-1.7})\,(1{,}000{,}000)$$
or
$$(0.8824)(0.8173)(1{,}000{,}000)$$
or
$$721{,}186$$

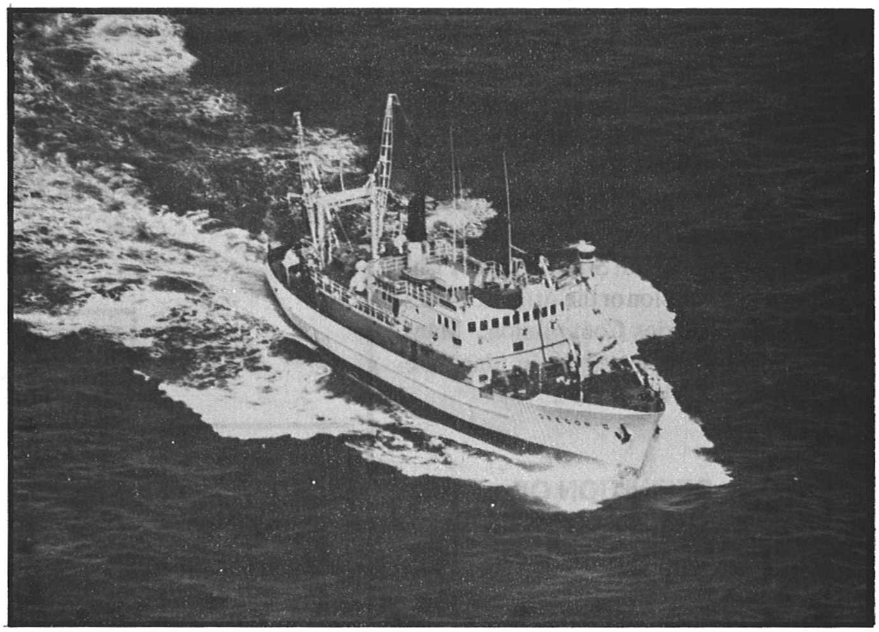
fish that die from fishing.

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}.



NOAA Fishery Research Vessel Oregon II

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

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	5	6/90
Coral	GMFMC, SAFMC	7/84	1	2/91
Snapper/Grouper	SAFMC	9/83	4	10/91
Spiny Lobster (Gulf and Atl.)	GMFMC, SAFMC	7/82	3	3/91
Spiny Lobster (Caribbean)	CRFMP	1/85	1	4/91
Swordfish	NMFS	9/85	2	12/91
Shallow-water Reef Fish	CRFMC	9/85	2	9/91
Gulf Reef Fish	GMFMC	9/84	3	2/91
Gulf Shrimp	GMFMC	5/81	5	7/91
Stone Crab	GMFMC, SAFMC	9/79	4	2/91
Gulf Red Drum	GMFMC	12/86	2	6/88
Atlantic Billfish	NMFS	10/88	None	
Shark	NMFS	3/92	None	
South Atlantic Red Drum	SAFMC	12/90	None	
South Atlantic Shrimp	SAFMC	(In preparation)		
Gulf Butterfish	GMFMC	(In preparation)		
Queen Conch	CRFMC	(Being considered)		

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

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 percentages 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 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 usually 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 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

Table 2. State fishery management plans.

Plan	Date	Amendments Number	Amendments Last
	Atlantic States Marine Fisheries Commission		
Shellfish Transport	1989	1	1990
Spotted Seatrout	1984	1	In preparation
Weakfish	1985	1	In preparation
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	
Red Drum	1984	Under review	
Striped Bass	1981	Under review	
Atlantic Menhaden	1981	Under review	
American Eel	------	Proposed	
	Gulf States Marine Fisheries Commission		
Menhaden	1977	2	1988
Striped Bass	1986	2	In preparation
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	In Progress	None	
Gulf Sturgeon	In Progress	None	
Alabama Shad	In Progress	None	
Stone Crab (Profile document)	In Progress	Not applicable	

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 landings. 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

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

Instantaneous Mortality Rate	Percentage Mortality
0.00	0
0.10	10
0.20	18
0.30	26
0.40	33
0.50	39
0.60	45
0.70	50
0.80	55
0.90	59
1.00	63
1.50	78
2.00	86

Groundfish catch in the northern Gulf of Mexico

stock, a decreasing proportion of older fish in the catch, and 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, and 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 Synopsis 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 assessment scientist's educated opinion 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 without reducing the stock's biomass from year to year, assuming that environmental conditions remain the same.

TAC: Total Allowable Catch is the total regulated catch 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

The southeastern region of the National Marine Fisheries Service includes the coastal states from North Carolina through Texas, the Commonwealth of Puerto Rico, and the Territory of the U.S. Virgin Islands. Excluding Puerto Rico and the U.S. Virgin Islands, the southeastern states in 1990 produced 856 thousand metric tons (mt) of commercial fishery products valued at $810 million. The landings comprised 19% of the total U.S. fishery yield in weight and 23% in exvessel value (Figure 2).

This section provides fishery statistics for the southeastern United States. The commercial and recreational data shown in Tables 4-8 are preliminary and can change slightly as new information is provided. Current or more detailed statistics can be requested through:

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

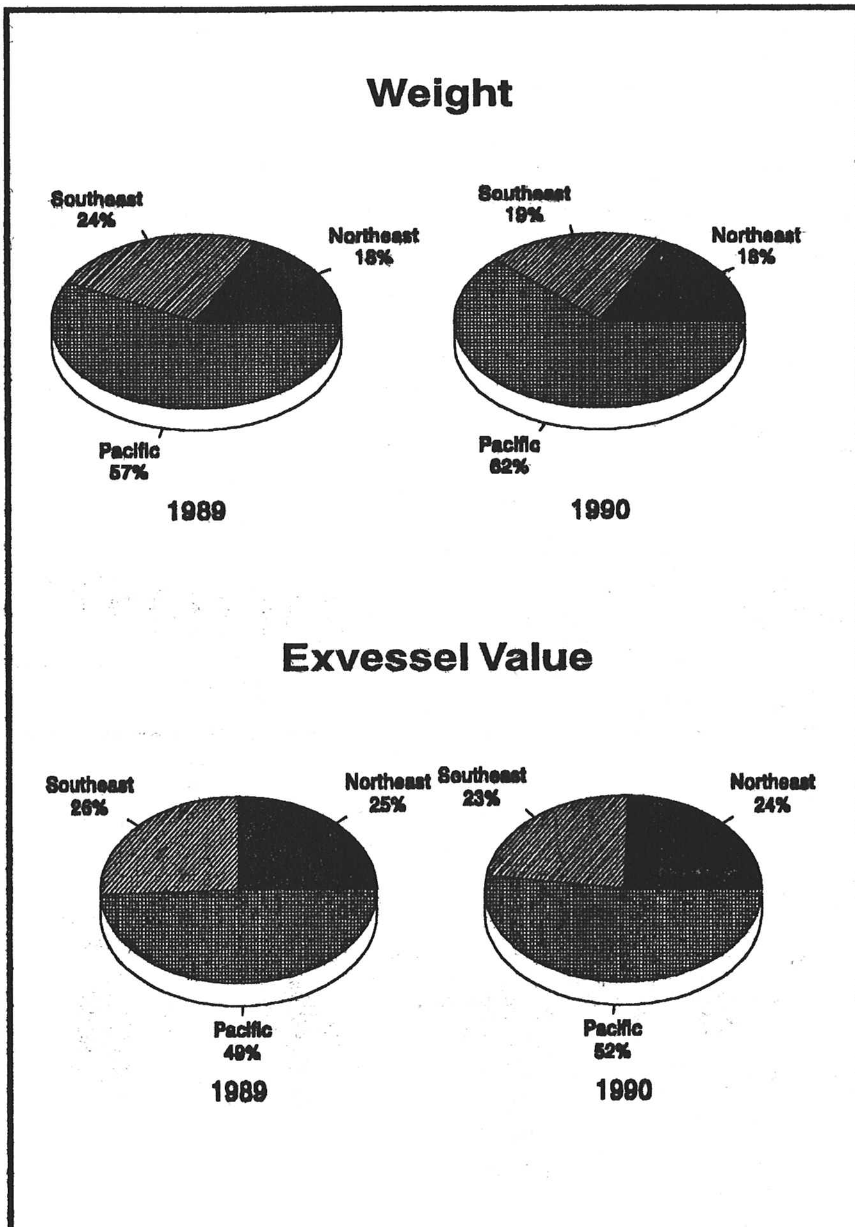


Figure 2. Commercial landings within the U.S. states.

COMMERCIAL LANDINGS

Landings and total value of fish and shellfish in the southeastern United States decreased between 1989 and 1990. Landings decreased 7.8%, from 928 thousand to 856 mt, primarily because of a decrease of 61 thousand mt in menhaden. Likewise, the exvessel value of total landings decreased from $818 million to $810 million between 1989 and 1990. The $8 million difference represented a 1% decrease.

As in past years, menhaden led other species in total weight landed with 553 thousand mt. Shrimp led other species in value with $454 million. The largest gains in landings among key food fish and shellfish stocks were king mackerel, 0.2 thousand mt, and stone crabs, 0.2 thousand mt.

Louisiana led other southeastern states. Total Louisiana landings in 1990 were 481 thousand mt valued at $263.5 million. Louisiana also led in shrimp landings with 54 thousand mt worth $152.6 million.

South Carolina recorded the largest percentage decrease in landings for 1990. Landings were down 2.5 thousand mt between 1989 and 1990 and represented a 28% decrease in weight landed. There was a corresponding decrease in value of

Table 4. Commercial and recreational yield for southeastern continental fishery resource

State	1989 Commercial Yield (1000 mt)	1989 Commercial Exvessel Value ($1000)	1989 Recreational Yield (1000 fish)	1990 Commercial Yield (1000 mt)	1990 Commercial Exvessel Value ($1000)	1990 Recreational Yield (1000 fish)	1990 Angler Trips* (1000 trips)
U.S Atlantic Coast							
North Carolina	74.6	$70,582	17,175	79.8	$71,542	11,944	3,815
South Carolina	9.1	24,893	5,436	6.6	24,012	2,064	900
Georgia	7.2	19,791	2,196	6.0	19,761	2,018	599
Eastern Florida	25.4	53,463	23,028	26.3	54,266	12,299	8,830
U.S. Gulf of Mexico							
Western Florida	64.1	$132,395	74,074	55.3	$116,228	33,318	9,492
Alabama	11.5	38,293	2,258	10.3	35,931	2,718	649
Mississippi	135.3	43,949	4,040	145.0	42,379	2,462	586
Louisiana	557.0	264,153	21,271	481.4	263,467	9,784	2,113
Texas	43.7	170,118	2,658	45.0	182,351	1,973	n.a.

Recreational estimates are from the NMFS Marine Recreational Fishery Statistics Survey, State of Texas, and the NMFS headboat survey (n.a.=not available).

*Does not include headboat data. Headboat effort is measured in angler days.

Table 5. Commercial and recreational yield for selected southeastern continental species (Note: landings of fish, lobster, and shrimp in live weight; oysters in meat weight).

Species	1989 Commercial Yield (1000 mt)	1989 Commercial Exvessel Value ($1000)	1989 Recreational Yield (1000 fish)	1990 Commercial Yield (1000 mt)	1990 Commercial Exvessel Value ($1000)	1990 Recreational Yield (1000 fish)
Groupers	6.9	$25,588	3,941	5.5	$20,603	768
Snappers	4.3	18,572	8,974	4.1	13,631	5,846
King Mackerel	1.7	4,276	866	1.9	4,749	1,134
Spanish Mackerel	2.9	2,872	2,648	2.4	2,346	2,688
Menhaden	614.3	54,250	n.a.	553.3	56,546	n.a.
Sharks	6.9	7,291	1,065	5.7	6,032	346
Swordfish	2.3	18,669	n.a.	1.9	13,886	n.a.
Tuna	6.4	27,937	1,066	4.2	20,881	625
Oysters	7.3	44,332	n.a.	5.2	38,338	n.a.
Shrimp	118.9	427,574	n.a.	126.1	453,981	n.a.
Spiny Lobster	2.9	18,733	n.a.	2.6	15,631	n.a.
Stone Crabs	2.4	12,546	n.a.	2.6	17,817	n.a.

Recreational estimates are from the NMFS Marine Recreational Fishery Statistics Survey, State of Texas, and the NMFS headboat survey (n.a.=not available).

Table 6. Total 1989 and 1990 continental southeastern shrimp landings and values by state (heads-on weight).

State	1989 Yield (1000 mt)	1989 Exvessel Value ($1000)	1990 Yield (1000 mt)	1990 Exvessel Value ($1000)
U.S. Atlantic Coast				
North Carolina	3.2	$12,209	3.3	$14,583
South Carolina	3.7	12,876	2.2	12,201
Georgia	3.4	16,235	3.0	16,415
Eastern Florida	5.0	12,241	4.4	12,173
U.S. Gulf Coast				
Western Florida	7.4	$33,125	6.0	$25,122
Alabama	7.6	33,944	6.8	30,968
Mississippi	7.1	28,544	6.9	21,620
Louisiana	45.7	127,834	54.0	152,554
Texas	35.8	150,566	39.4	168,345

$0.9 million representing approximately 4%.

RECREATIONAL CATCH

The principal source of recreational fishery statistics in the southeastern region is the Marine Recreational Fishery Statistics Survey conducted by the National Marine Fisheries Service through the Washington, D.C. office. Using a telephone survey of households and intercept survey of anglers at fishing sites, analysts with the Survey estimate total yield and fishing effort by species for the southeastern United States. These estimates do not include catches made in Texas and catches made aboard headboats (vessels where fishermen pay by the individual, or head, to fish from the vessel), because estimates for these sectors of the fishery are based on separate surveys.

The Marine Recreational Fishery Statistics Survey estimated recreational catch for the United States in 1990 at about 144 thousand mt. Of that total, the recreational catch in the southeastern region constituted about 44% or about 64 thousand mt. Some estimates of recreational catch are reported in the Species Synopses sections.

U.S. CARIBBEAN

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

Table 7. *July 1989 - June 1990 commercial yield in weight (metric tons) and value (dollars) from U.S. Virgin Islands.*

Species	Metric Tons	Exvessel Value
Reef fish	238.7	$1,578,805
Pelagics	102.4	790,118
Lobster	54.6	602,159
Whelk	1.3	29,453
Conch*	0.1	935

*St. Thomas and St. John only.

Table 8. 1990 commercial yield in weight (metric tons) and value (dollars) from Puerto Rico.

Species	Metric Tons	Exvessel Value	Species	Metric Tons	Exvessel Value
Tuna	60.6	$105,307	Triggerfish	12.9	$31,220
Ballyhoo	13.8	32,191	Barracuda	3.6	8,534
Grunt	53.6	119,043	Porgy	4.1	10,750
Hogfish	9.9	39,929	Snook	9.0	29,277
Croaker	0.2	888	Tarpon	2.9	3,306
Trunkfish	21.6	69,238	Goatfish	6.1	17,371
Dolphin	44.7	121,206	Sardine	4.6	8,135
Swordfish	4.3	18,826	Mackerel	44.3	149,481
Squirrelfish	2.9	6,802	Shark	18.4	46,411
Mullet	9.7	20,892	Margate	0.4	991
Jack	13.8	30,458			
Parrotfish	16.7	38,180	Classified		
Marlin	2.3	6,723	First	82.8	243,297
Amberjack	0.5	777	Second	66.6	131,605
Grouper			Third	23.2	54,594
Red Hind	17.9	51,944	Trash	3.5	4,966
Nassau	1.1	3,277	Other Fish	48.6	---
Other Grouper	28.3	96,546			
Mojarra	7.0	18,341	Queen Conch	49.0	209,155
Snapper			Land Crab	0.9	8,200
Lane	51.3	172,167	Lobster	76.9	746,928
Yellowtail	48.7	177,291	Oysters	0.2	1,112
Silk	80.2	379,964	Octopus	11.2	53,571
Mutton	11.4	43,364	Other Shellfish	0.9	6,006
Other Snapper	21.1	62,827			

For more information:

United States Department of Commerce, NOAA, National Marine Fisheries Service. Fisheries of the United States 1990. Washington: GPO, May 1991.

United States Department of Commerce, NOAA, National Marine Fisheries Service. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1987-1989. Washington: GPO, May 1991.

United States Department of Commerce, NOAA, National Marine Fisheries Service. Preliminary catch and trip estimates, 1990, marine recreational fishery statistics survey, Atlantic and Gulf coasts. Prepared by MRFSS Program, NMFS, 1335 East-West Highway, Silver Spring, MD 20910. October, 1991.

United States Department of Commerce, NOAA, National Marine Fisheries Service. Fishing trends and conditions in the southeast region. Ed. Kim Newlin. NOAA Technical Memorandum NMFS-SEC-292. July 1991 (Contact Kim Newlin at the SEFSC, Miami, Florida).

Resource Surveys

Since 1972, personnel of the Mississippi Laboratories of the Southeast Fisheries Science Center have conducted routine research trawl surveys of bottom species found on the continental shelf of the northern Gulf of Mexico. The longest single time series of data is collectively known as the Fall Groundfish Survey. For most of its history, the survey concentrated on the north-central part of the Gulf of Mexico, particularly in the region from Alabama through Louisiana. The original intent of the survey was to document the decline of major bottomfish species (primarily sciaenids) as reported by the industrial groundfish fishery. Of particular concern was the variation in spatial distributions. In recent years, however, fishery management has required the survey to focus more on the year to year variations in abundance and for a much wider range of species than in years past.

All groundfish survey data were taken aboard the NOAA research vessel *Oregon II* using a standard semi-balloon shrimp trawl fished with mud rollers and a tickler chain. Sampling designs and bottom-trawl times varied slightly through the survey years, but in 1987 a standardized system was adopted. The standard survey design uses a stratified-random sampling format with one tow per sampling site and a tow length determined by the size of the stratum being sampled. Generally the survey region includes the offshore waters between Pensacola, Florida, and Brownsville, Texas from 9 to 110 m in depth.

To illustrate the finfish catch rate for 1972-1990 (Figure 3), all data were treated as if the trawl samples were selected from a completely randomized design. In the 17-year time series, approximately 800 taxa were reported. Most stocks extend well beyond the primary fishing area in an alongshore direction, and many species have a wider depth range than covered by the sampling region.

For more information:

Nichols, Scott and Gilmore Pellegrin, Jr. 1989. Trends in catch per unit effort for 157 taxa caught in the Gulf of Mexico fall groundfish survey, 1972-1988. Southeast Fisheries Science Center, Pascagoula, MS.

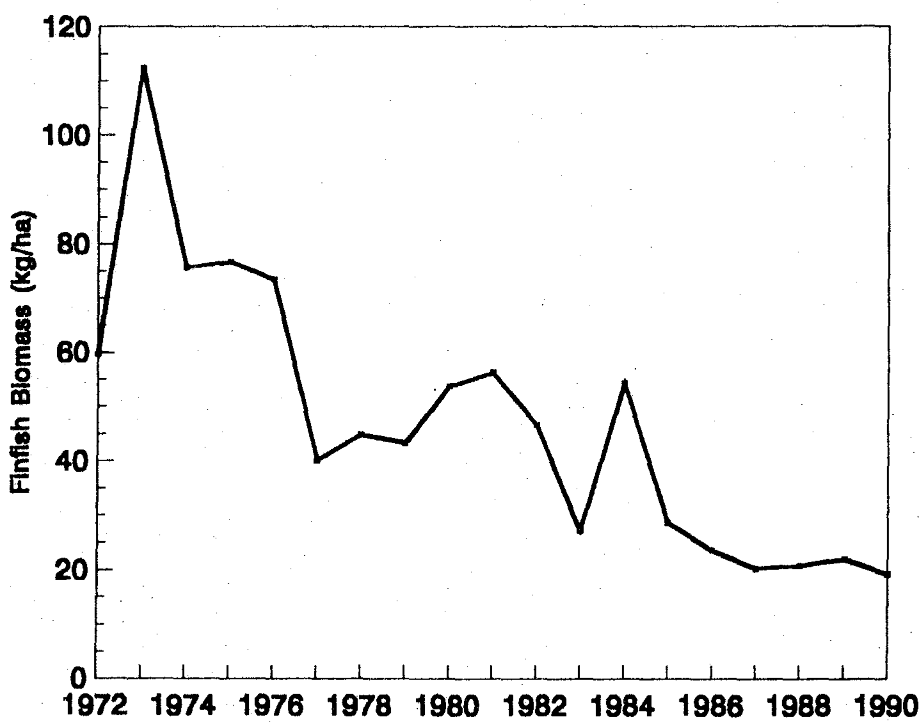
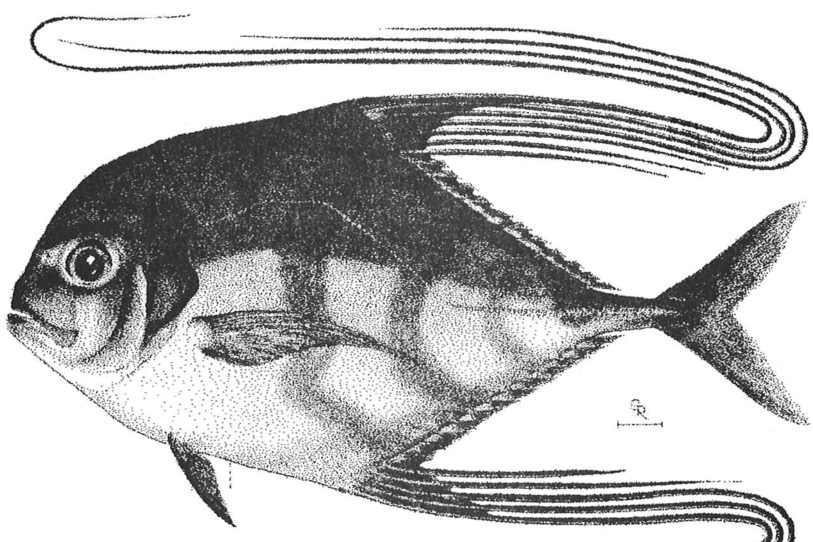


Figure 3. Bottom-trawl catch rates for demersal finfish in the U.S. Gulf of Mexico (mostly sciaenids; generally does not include pelagics, menhaden, coastal herrings, butterfish, most reef resources and sharks).

Species Synopses

The following sections contain information on the biology, fishery, yield, and status of important species within the jurisdiction of the Southeast Fisheries Science Center. Each section corresponds to the following species groups: Oceanic Pelagics; Coastal Pelagics; Shrimp; Reef Fish; Groundfish; Sharks; Menhaden, Butterfish and Coastal Herrings; Reef Invertebrates; Marine Mammals; and Sea Turtles.

In the southeast, there is a vast diversity of marine resources. In the case of reef fish, for example, there are more than three hundred species found in the southeastern, continental United States, Puerto Rico, and the U.S. Virgin Islands. Some of the following sections, therefore, include detailed discussions only on a selection of species. Additional information, may be obtained by contacting the Director's Office of the Southeast Fisheries Science Center. Publications listed in the synopses may be requested from the author at the appropriate Southeast Fisheries Science Center laboratory.

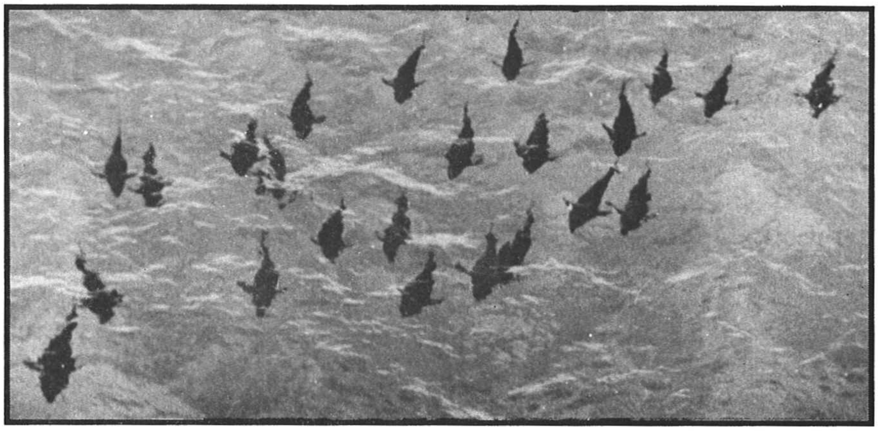


1. Oceanic Pelagics

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 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.

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. These assessments provide the scientific bases for national and international management of the fisheries.



Bluefin tuna school

U.S. Fishery Management Plans have been developed for swordfish and billfishes. International agreements for regulating swordfish harvest are being implemented, 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 (*Xiphius 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 continental shelfs 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

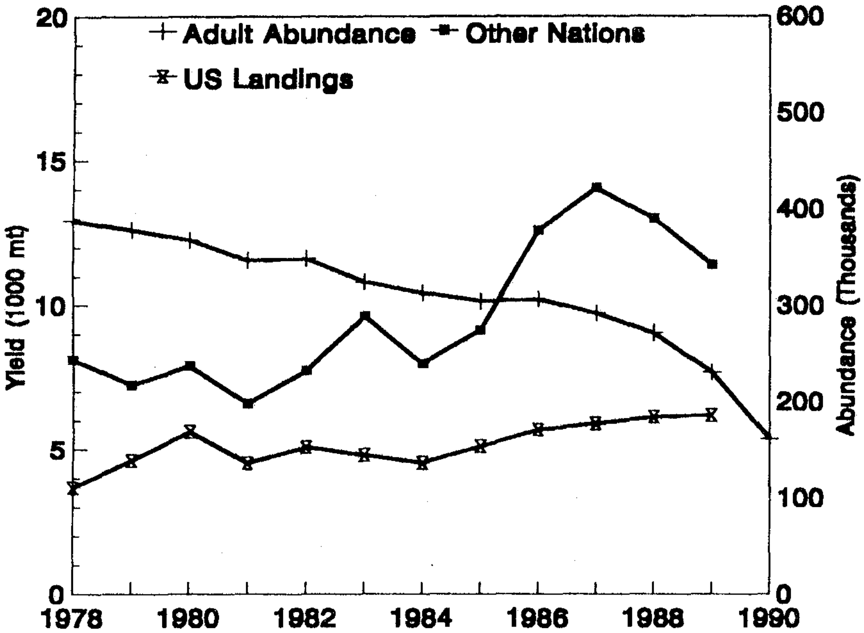


Figure 4. North Atlantic swordfish yield and age 5+ stock size trajectory. Assessments of stock status use data only from 1978 to present.

for 78% of the total NorthAtlantic 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 NorthAtlantic Ocean. The drift gillnet fishery operated under a 36 mt quota in 1991. The catch of and effort directed at swordfish in the NorthAtlantic has shown a continual increase from 1978 when the United States eased its mercury-content regulation until peak landings of nearly 20,000 mt were made by U.S. fishermen in 1987. North Atlantic landings in 1988 were nearly equal to 1987 while 1989 landings declined to about 17,600 mt, mainly due to a shift of Spanish longline effort to just south of 5°N, the statistical boundary for the NorthAtlantic swordfish management unit. Total Atlantic landings of swordfish were highest in 1989, reaching a level of 50,500 mt, in comparison to 19,800 mt in 1978. Landings of NorthAtlantic swordfish for the period 1987-1989 averaged 18,896 mt. The recent annual yield to U.S. fishermen during this period was 5,975 mt. The recent yield trajectory and associated adult stock size trend are shown in Figure 4.

In September, 1990, the status of the Atlantic swordfish resource was again assessed by the ICCAT swordfish working group using updated catch at age and effort information through 1989. The results of this assessment were consistent with results of previous assessments. Due to concerns raised about uncertainties identified in prior analyses, the working group addressed the sensitivity of the assessment results to a number of factors, including alternative stock structure hypotheses, possible error in estimation due to sexually dimorphic growth, possible changes in catchability of small fish over the available time series of data, a dome-shaped partial recruitment pattern and uncertainty in the estimates of total catch, natural mortality rates, and in catch per unit effort series used to tune the virtual population analyses. The results of the analyses conducted by the working group and the results presented to the group in numerous working documents, indicated that the estimate of current (1989) fishing mortality rate expressed relative to an $F_{0.1}$ or F_{max} target rate, is largely unaffected by potential errors in analysis due to these uncertainties.

The ICCAT's 1990 SCRS swordfish assessment concluded that, in spite of the uncertainties examined, present yield cannot be maintained over the long-term without either a decreasing fishing mortality or continued increases in recruitment. The working group further concluded that continued increases in recruitment were unlikely to occur. Results of the analyses indicated that there is a high likelihood that the reduction from current (1989) estimated fishing mortality needed to reach optimum is in excess of 50%. The working group recommended that fishing mortality be reduced below the 1988 level.

Under the Atlantic Tunas Convention Act, the management objective is defined as maximum sustainable yield. A constant harvest rate strategy applying $F_{0.1}$ is frequently used as a relatively resource risk-averse strategy that tends to avoid overfishing and still provides for long-term yields near theoretical maximum sustainable yield levels. Due to the difficulties of precisely knowing theoretical maximum sustainable yield, its associated effective fishing effort, and the degree of ecosystem variability that leads to change in maximum sustainable yield levels, several independent domestic and international scientific panels have recommended that applying a constant harvest rate strategy associated with $F_{0.1}$ was appropriate for swordfish. Based on the results of the 1989 ICCAT swordfish assessment, the long-term potential yield to the NorthAtlantic swordfish stock under an $F_{0.1}$ harvest rate strategy, was estimated to be approximately 16,000 mt. Given the results of the 1990 assessment for the NorthAtlantic stock hypothesis, the current potential yield of NorthAtlantic swordfish for 1991 under an $F_{0.1}$ harvest rate strategy based on 500 simulation trials, ranged from 1,760 mt to 8,800 mt with a median value of approximately 5,300 mt.

ICCAT developed minimum size and fishing mortality reduction agreements to restrict the harvest of

Swordfish

Longterm potential yield	13,000 - 16,000 mt
Current potential yield	5,300 mt
Recent average annual yield	18,900 mt
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	3%
Fishing mortality rate at F0.1	0.2
Fishing mortality rate at Fmax	0.41
Fishing mortality rate in most recent year (1989)	0.73-0.93 (95%ci 0.83 mean)

North Atlantic swordfish in 1991. These agreements imply:

1) North Atlantic stock hypothesis,
2) Fish greater than the minimum size (25 kg) are equivalent to ages three and older (these will be referred to as large fish),
3) Spain and the United States will reduce the mortality rate at age on large fish by 15% from the 1988 levels; the fishing mortality rate at age on large fish by all other nations combined will be maintained at 1989 levels (the last year for which we have data),
4) All nations will adhere to the minimum size and the 15% allowable bycatch of small catch; the 15% allowance was calculated by nation for the United States, Spain and then all other nations combined.

Based on these conditions, and assuming status quo during the 1990 fishing year and recruitment equal to the average of the available time-series, swordfish population projections were made to estimate the expected yield to the U.S. fishery in 1991. The resulting expected yield was 4,173 mt. There are several points which should be considered in interpreting this result.

The ICCAT minimum size regulation could reduce overall landings more than the expected yield. This would be true, for instance, if the 15% allowance of small fish is not large enough to allow a trip to be economically feasible. It is likely that some operations would be curtailed for that reason. The minimum size might also reduce bycatch in the tuna fishery in that some operations would not be able to catch enough large swordfish to cover the small fish allowance.

The ICCAT minimum size regulation is expected to reduce the landed fishing mortality rate on small fish to approximately 30% of what it was in 1989. But, the realized 1991 mortality rates on small fish could be substantially higher, depending on discard mortality rates and fleet behavioral practices. Available information from U.S., Japanese, and Venezuelan longline fleets suggests the average percentage of longline caught swordfish brought to the side of the vessel dead is nearly 70% (on average, 30% survival; size-specific survival rates might differ). However, further redistribution of fishing effort into tropical zones where small fish are thought to be more concentrated could result in increased catchabilities and higher fishing mortality rates for small fish that are not modeled in the projections.

It should be noted that the minimum size regulation may result in database degradation with respect to the mortality of small fish unless a well designed observer program is put in place. In the absence of observer coverage, the expectation is that future assessments will become more uncertain and controversial.

Expected fishing mortality rates in 1991 under ICCAT regulations for fish of ages four and older are approximately 87% of what they were in 1989. The expected 1991 fishing mortality rate on age three fish remains the same as estimated for 1989 under the ICCAT regulations due to the distribution of catch at age among the nations that are assumed not to reduce large fish fishing mortality by 15% from 1988 levels and due to the changes in the population age distribution between 1988 and 1989. Increases in fishing mortality rates by the nations not affected by the fishing mortality reduction regulation could increase the realized fishing mortality in 1991. Under the projections, approximately 30% of the expected total North Atlantic landings in 1991 are attributed to other nations.

Based on the ICCAT's 1990 SCRS swordfish working group analyses using Monte Carlo estimation techniques, reductions in current fishing mortality (*i.e.* 1989) needed to achieve $F_{0.1}$ were on the order of 70% to 90%. In addition to some reduction in fishing mortality rate, implementation of the ICCAT minimum size regulations may result in a different partial recruitment vector in 1991 than previously observed. Changes in age-specific selectivity influences $F_{0.1}$. In a deterministic sense, the reduction from the expected 1991 fully recruited fishing mortality (ages 5^+) required to achieve $F_{0.1}$, assuming perfect implementation of the ICCAT minimum size and other measures, would likely require a further reduction in fishing mortality of more than 60%.

BLUEFIN TUNA

Northern bluefin tuna (*Thunnus thynnus*) is a large oceanic pelagic scombrid species that is found in the Atlantic and Pacific Oceans. In the western Atlantic, bluefin occur from Laborador 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 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.

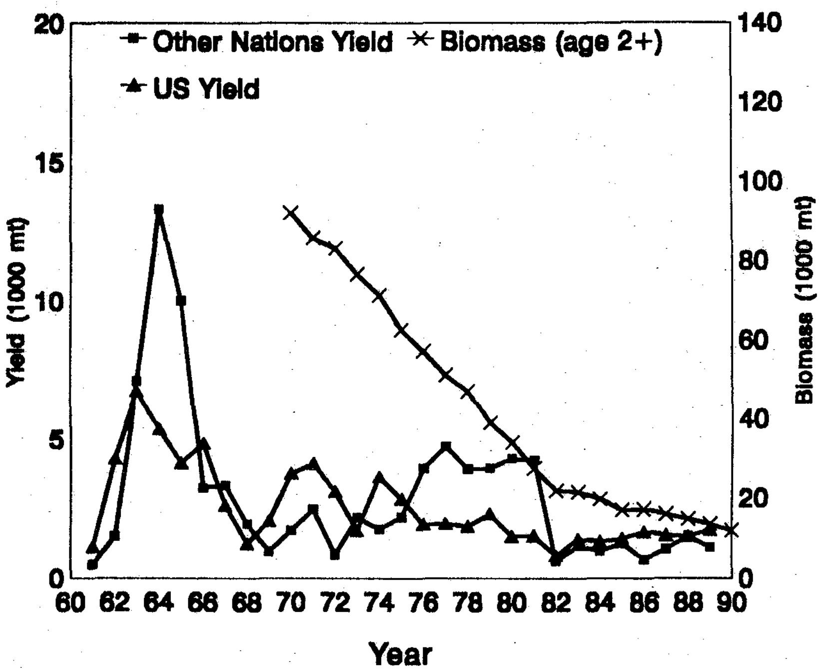


Figure 5. Western Atlantic bluefin tuna yield and stock biomass trajectory. Assessments of stock status using data only from 1970.

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 mt) occurred in 1963-1966 when much of the catch was taken by longlines off

Bluefin Tuna

Longterm potential yield	11,000 mt
Current potential yield	2,000 mt
Recent average annual yield	2,900 mt
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 (1989)	0.35

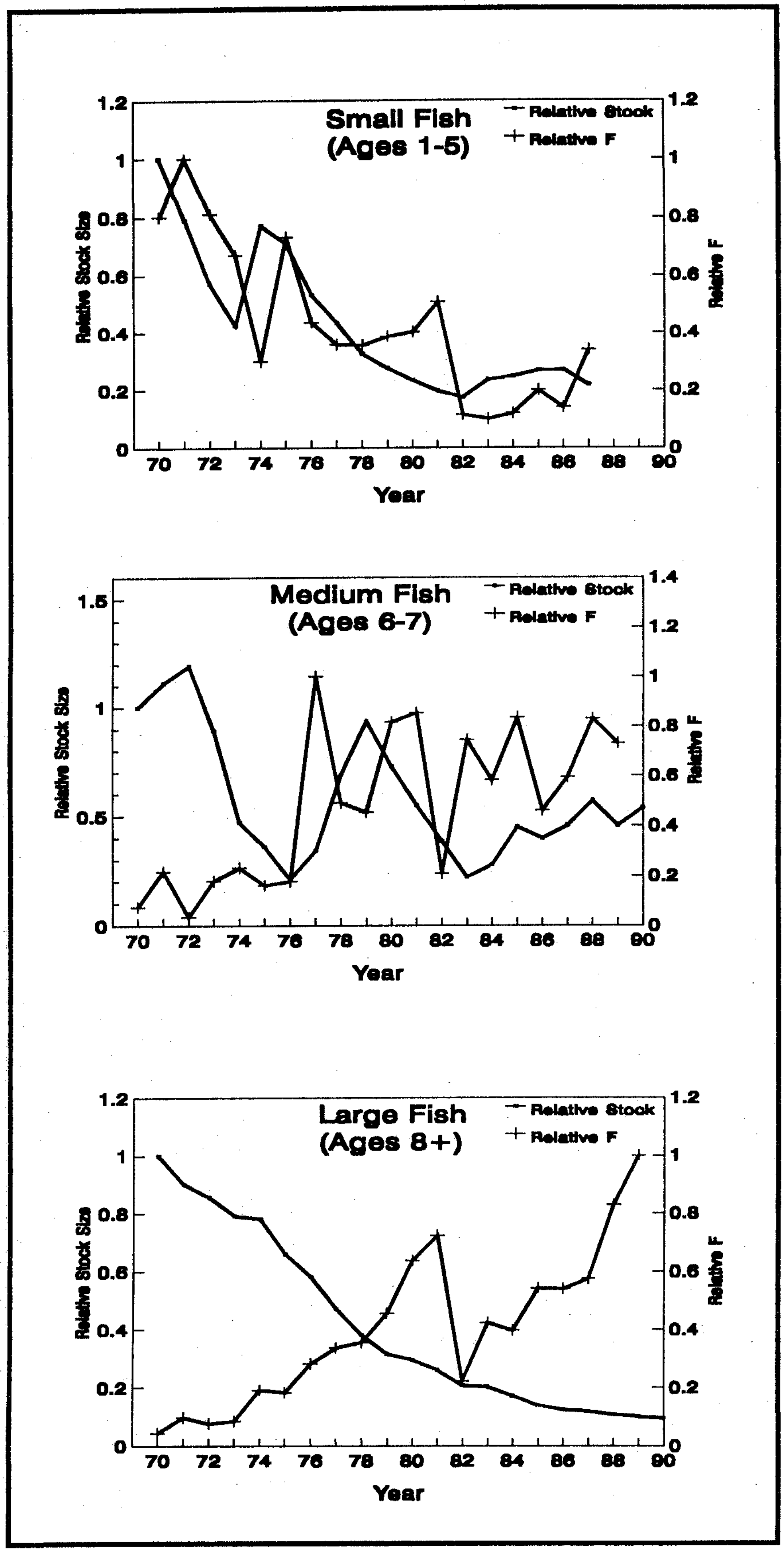


Figure 6. Relative stock size and relative fishing mortality rate trajectories for western Atlantic bluefin tuna.

of Brazil (Figure 5); since then catch rates off Brazil have been very low. During the late 1960s and 1970s yields averaged about 5,000 mt. In 1982 a catch restriction of 1,160 mt was imposed; the catch limit was increased to 2,660 mt 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.

In November 1990, an updated assessment of western Atlantic bluefin tuna stocks was carried out by ICCAT's SCRS, using catch and effort data through 1989. The 1990 SCRS bluefin assessment results were generally consistent with recent SCRS assessments in estimated population trends (Figure 6). Those trends continued to show that abundance estimates of all size classes were substantially below the 1970 levels and that there was little evidence of significant, sustained increases since the early 1980s. The assessment indicated that the 1986 year class was the lowest on record. As in other recent annual assessments of western Atlantic bluefin stock status, the abundance estimates for small fish (1-5 year old fish) were about a quarter of the 1970 level and mediums (ages 6-7) were about half of the 1970 level; both groups were at relatively low levels since the imposition of catch restrictions in 1982.

The estimated abundance of large fish (ages 8+) were about 10% of 1970 levels, and projection of 1992 stock sizes indicated further declines would be likely if catches were not reduced. Estimated fishing mortality rates on small and large fish have increased since the imposition of catch limitations, especially for the large fish. In fact, estimated fishing mortality rates in the most recent years have increased to levels nearly equal to or greater than the rates just prior to implementation of harvest restrictions (Figure 6).

Since 1970 the estimated biomass of bluefin tuna age-2 and older in the western Atlantic has declined (Figure 5). 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 mt, 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 mt. The recent average yield for the period 1987-1989 is estimated to have been 2,900 mt. The average yield to U.S. fishermen during this period was approximately 1,600 mt. The estimated yield to U.S. fishermen in 1990 is 1,750 mt.

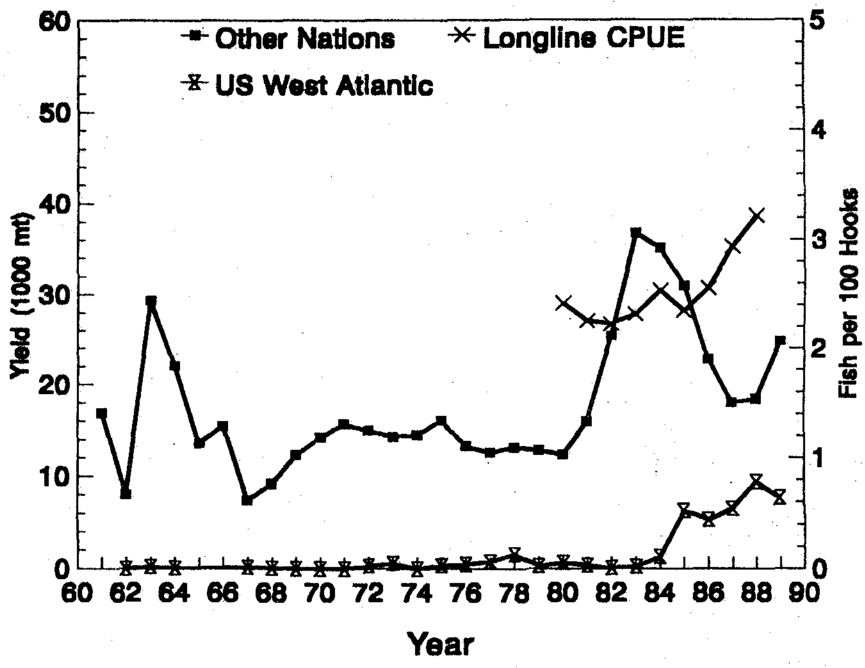


Figure 7. Western Atlantic yellowfin tuna yield and standardized abundance index. The abundance index was developed for 1980-1988 based on U.S. and Oriental high seas longline catch and effort data.

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 substantial 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. A few tagged fish have migrated across the Atlantic, but the degree of migration between the east and western Atlantic is unknown.

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 about seven years, it would attain such a size, but such specimens are not common. Occasional 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 age of about 3 to 4 years.

The average age of sexual maturity is about 3 years, when the fish weigh about 25 kg. In the western Atlantic, spawning takes place mainly during the months of April through June; spawning grounds include the Gulf of Mexico. An individual fish may spawn repeatedly during that season. It is believed that bluefin feed on a variety of fishes, cephalopods, and crustaceans, depending on the availability of seasonal prey. Also, it is believed that larger spawning grounds are found in the eastern Atlantic; however, research remains to be done on the spawning biology of this species.

For assessment purposes, ICCAT's SCRS considers Atlantic yellowfin tuna to be comprised of two stocks, one in the eastern and one in the western Atlantic. The conclusions drawn from data collected during ICCAT's Yellowfin Year Program confirmed the widely held belief that some mixing occurs between the western and eastern Atlantic stocks. A total of 13 (as of May 1991) trans-Atlantic migrations of yellowfin have now been documented in collaborative scientific studies conducted by scientists from the United States and Côte d'Ivoire.

The SCRS has not yet conducted formal assessments of western Atlantic yellowfin stocks. However, in 1990 a preliminary production model analysis of western Atlantic yellowfin was presented to SCRS based on Venezuelan purse seine effort from 1972-1989. Results of this analysis suggested that the stock could be near full exploitation based on an estimated long-term potential yield of 33,000 mt for the

Yellowfin Tuna

Longterm potential yield	31,000 mt (stock)
	10,000 mt (Gulf of Mexico)
Current potential yield	Unknown
Recent average annual yield	28,000 mt (stock)
	7,900 mt (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)

stock. However, the yellowfin tuna working group considered the data and assumptions on which the analysis was based too preliminary to consider the results of the model to be conclusive. This analysis may only be reflective of the resource status in and 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. Although the Group did not complete any formal assessment of western Atlantic yellowfin, it did arrive at an agreed data base for future assessments. The major harvesting nations, which realized nearly 90% of the yield of this species in the western Atlantic for the most recent three year period were Venezuela, the United States, and Brazil. During this period, approximately 45% of the yield was taken in longline fisheries and the remainder was taken by surface gear (mainly baitboats and purse seines). Recent average yield from the western Atlantic stock for the period 1987-1989 was 28,300 mt. During this period, the average estimated yield to U.S. fishermen was 7,900 mt, mainly due to longline harvest from the Gulf of Mexico. The average annual U.S. recreational harvest of yellowfin tuna during this period is conservatively estimated as 900 mt. Figure 7 shows the recent yield trajectory 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 include the directed recreational fisheries of the United States, Venezuela, the Dominican Republic, Senegal, Costa Rica, Mexico, Jamaica, Bahamas, and Brazil. Smaller recreational fisheries are also found in Cuba, Bermuda, Portugal (Azores, Maderia), 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) 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 model fits using total fishery yield and an index of abundance developed from the Japanese longline fleet were attempted for blue marlin and white marlin. 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. To facilitate improved assessment research for billfish, ICCAT initiated an Enhanced Billfish Research Program in 1987. The objectives of the program are to overcome deficiencies identified in billfish basic landings and size data, as well as to develop more precise estimates of basic biological parameters (age, growth, maturity, fecundity, biological stock affinities, etc.) needed for more definitive assessments.

Due to concerns over the future prospects for billfish resources, domestic 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. catch 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

Billfish

BLUE MARLIN

Longterm potential yield	2,400 mt
Current potential yield	Unknown
Recent average annual yield	773 mt (stock)
	301 mt (United States)
Status of exploitation	Fully exploited

WHITE MARLIN

Longterm potential yield	Unknown
Current potential yield	Unknown
Recent average annual yield	351 mt (stock)
	116 mt (United States)
Status of exploitation	Fully exploited

SAILFISH

Longterm potential yield	Unknown
Current potential yield	Unknown
Recent average annual yield	812 mt (stock)
	113 mt (United States)
Status of exploitation	Moderately exploited

from 0.30 to 0.68, depending on species and geographical area.

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 inability of examining large numbers of specimens and the substantial difference in sexually dimorphic growth between males and females.

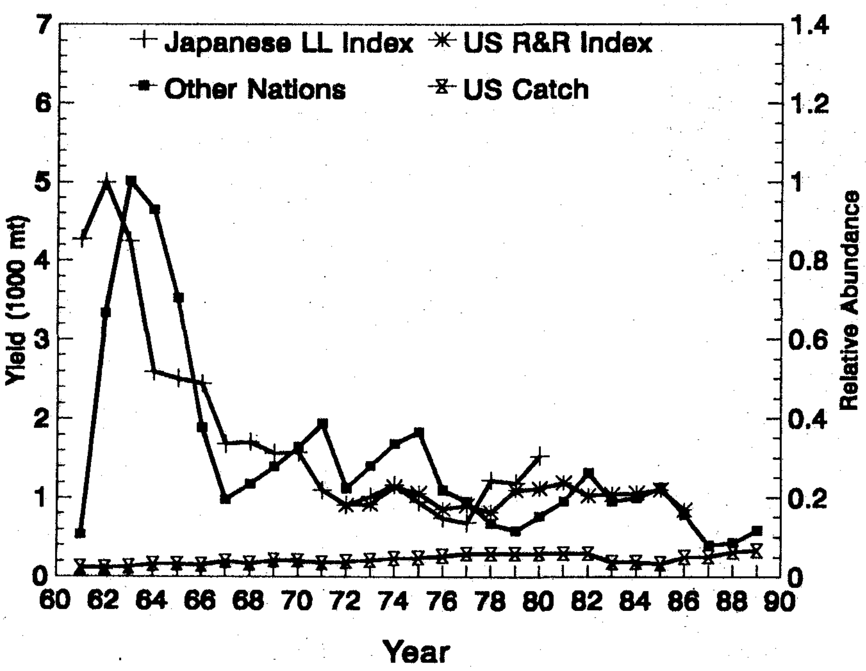


Figure 8. Yield and relative abundance trajectories for north Atlantic blue marlin. Relative abundance trajectories are scaled.

Mature males in the Atlantic Ocean have been reported as small as 35 kg and the smallest mature females were 44 kg.

There appear to be two widely separated concentrations of blue marlin spawning in the western Atlantic. In the NorthAtlantic, 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 Atlantic, north and south of the equator, spawning occurs primarily in February 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 NorthAtlantic and a South Atlantic stock hypothesis. North Atlantic-wide catch of blue marlin increased rapidly after 1960, reaching a peak of more than 5,000 mt by 1963. Thereafter, landings declined substantially. Catch per unit effort in the Japanese longline index also showed a substantial decline during this period (Figure 8). Changes in the method of fishing and target species for the Japanese longline fleet after 1980 have made these data difficult to apply to more recent billfish assessments. An abundance index based on blue marlin hooked per unit effort from the U.S. recreational fishery reflects the general pattern of the Japanese index from 1972-1977, but shows a somewhat less optimistic trend for the last years of the Japanese index set (Figure 8). Production model fits to data from 1960-1980 suggested that by 1980 the size of the western Atlantic blue marlin stock had been reduced to approximately the level expected to produce its long-term potential yield. For this stock, long-term potential yield was estimated to range from 2,200-2,600 mt. Since the early 1980s, ICCAT has continually expressed concern that blue marlin stocks would further decline should effort increase. The recent average yield of NorthAtlantic blue marlin for the period 1987-1989 is estimated to have been 773 mt. The average yield to U.S. fishermen during this period was approximately 301 mt. Approximately 50% of the recent average yield (1987-89) to the United States has been bycatch on longline gear; the remainder of the U.S. yield results from recreational harvest.

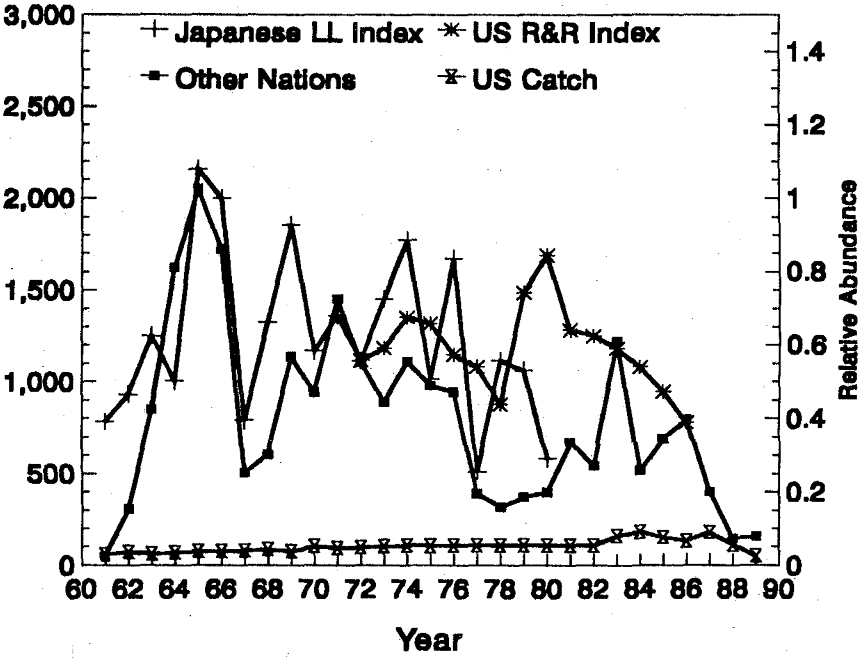


Figure 9. Yield and relative abundance trajectories for north Atlantic white marlin. Relative abundance trajectories are scaled.

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 for 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 NorthAtlantic 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 NorthAtlantic and a South Atlantic hypothesis. North Atlantic-wide catch of white marlin peaked in 1965 with a yield in excess of 2,000 mt. Catch has been below that level since, generally fluctuating between 250 and 1,500 mt (Figure 9). Catch per unit effort in the Japanese longline fleet was found to fluctuate considerably, but showed a general decline from a peak in 1965 to a low level in 1980 (Figure 9). An abundance index based on fish hooked per unit effort in the U.S. recreational fishery showed a downward trend similar to the Japanese longline index over the period 1972-78, although with less variation. The U.S. index showed a continuous downward trend from 1980 to the end of the available standardized effort series in 1986 (Figure 9). 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 the lowest level observed in 1989. Due to the high degree of interannual variability in the available catch per unit effort series for white marlin, no adequate production model fits have been produced which provide much information about stock status. However, based primarily on the steadily declining catch per unit effort trend for white marlin, ICCAT considered the stock to be fully used by 1980. Decreases in the available catch per unit effort series since 1980 have resulted in continued concern by ICCAT's SCRS over the status of white marlin in the Atlantic. The recent average yield of NorthAtlantic white marlin for the period 1987-1989 is estimated to have been 351 mt. The average yield to U.S. fishermen during this period was approximately 116 mt. Approximately 60% of the recent average yield (1987-89) to the United States has been bycatch on longline gear, the remainder of the U.S. yield is due to recreational harvest. Estimated U.S. longline bycatch of blue marlin has decreased from 89 mt in 1987 to 36 mt in 1989.

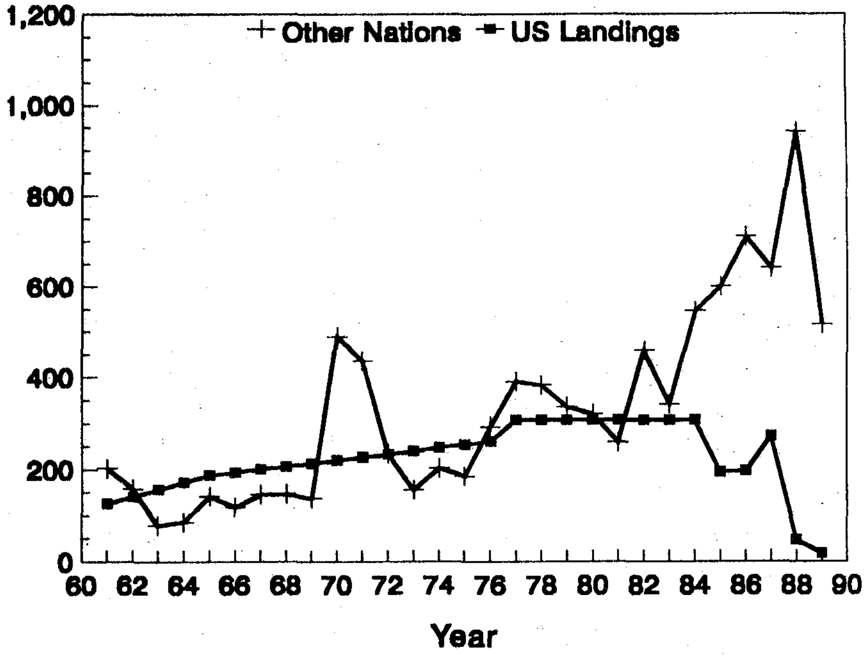


Figure 10. Yield trajectory for west Atlantic sailfish/spearfish.

Sailfish

Sailfish (*Istiophorus platypterus*) are circumtropical in distribution, occurring in all warm marine waters of the world. Sailfish are more coastal distributed than blue and white marlins. In the western Atlantic, sailfish generally 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 were made by ICCAT scientists to separate the historical catches. Catch of western Atlantic sailfish/spearfish have increased steadily, to a peak of over 1000 mt in 1988, although the 1989 reported catch was approximately 500 mt. 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

Bigeye Tuna

Longterm potential yield	79,000 mt
Current potential yield	Unknown
Recent average annual yield	55,600 mt (stock)
	824 mt (United States)
Status of exploitation	Under exploited
Age at 50% maturity	3-5 years
Generation time	6-9 years
Natural mortality rate	0.8 ($\leq$2 years)

recent average yield of western Atlantic sailfish for the period 1987-1989 is estimated at 812 mt. The average yield to U.S. fishermen during this period was approximately 113 mt. However, the estimate of U.S. recreational harvest estimate for this period is likely conservative. Figure 10 shows the recent sailfish/spearfish harvest trajectory in the western Atlantic.

BIGEYE TUNA

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 mt in 1985. Approximately two-thirds of the catch is taken in longline fisheries with the remainder taken by surface gear. Japan and Korea are the major longline harvesting nations taking Atlantic bigeye. These two nations accounted for approximately two-thirds of the total landings in 1989. 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 1961-1988, to range from 66,700 - 74,900 mt. The analyses indicate that some gain in yield could be attained by increased effective effort for this species. The recent average yield of Atlantic bigeye tuna for the period 1987-1989 is estimated to have been 55,600 mt. The average yield to U.S. fishermen during this period was approximately 824 mt. The estimated U.S. recreational harvest of this species for the period was 120 mt. The yield and relative abundance trajectories for this species are shown in Figure 11.

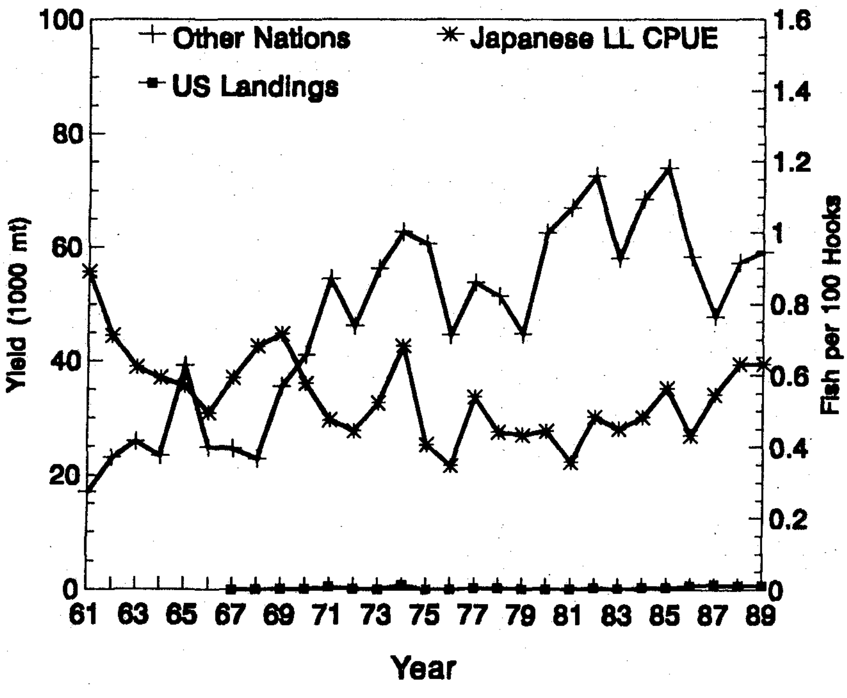


Figure 11. Yield and relative abundance trajectories for Atlantic bigeye tuna.

Albacore

Longterm potential yield	48,000 mt
Current potential yield	Unknown
Recent average annual yield	34,500 mt (stock)
	215 mt (United States)
Status of exploitation	Moderately 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 0.36
Fishing mortality rate at Fmax	About 0.5
Fishing mortality rate in most recent year	0.23

ALBACORE

Albacore (*Thunnus alalunga*) are cosmopolitan in tropical and temperate 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 NorthAtlantic stock hypothesis. North Atlantic albacore catches have declined over the period from 1961-1989. Peak landings occurred in 1964, when 64,400 mt were removed. In 1989, 32,000 mt 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 NorthAtlantic grounds resulted in significant reductions in longline catch of albacore. Spain and France have been the major harvesting nations for NorthAtlantic albacore in the most recent period. Since 1987, Spain has accounted for approximately 80% of the reported NorthAtlantic albacore landings. In 1990, ICCAT's SCRS assessed the status of the NorthAtlantic albacore stock and found the stock to be moderately exploited based on virtual population and yield per recruit analyses. The analyses indicated that further gains in long-term yield might be expected by increased effort. Production model analysis, based on several surface fishery catch per unit effort series and total landings from 1959-1988 resulted in estimates of the long-term potential yield for NorthAtlantic albacore that range from 38,300 - 58,400 mt. The recent average yield of NorthAtlantic albacore for the period 1987-1989 is estimated to have been 34,566 mt. The average yield to U.S. fishermen during this period was approximately 215 mt. The estimated U.S. recreational harvest of this species for the period was 130 mt. The yield and estimated exploitable stock biomass trajectories for this species are shown in Figure 12.

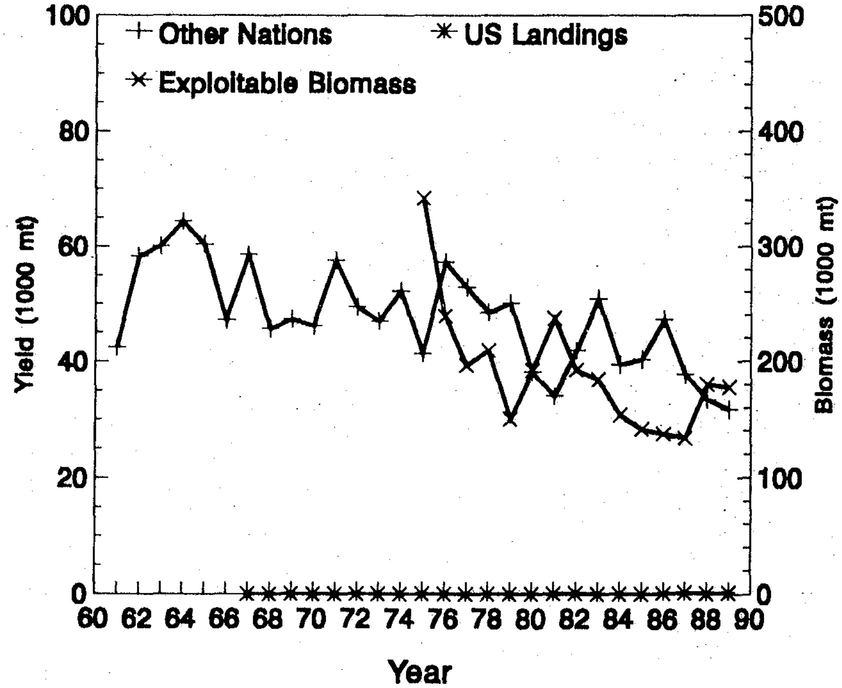


Figure 12. Yield and exploitable biomass trajectories for north Atlantic albacore. Biomass abundance is based on virtual population analyses.

Skipjack

Longterm potential yield	33,000 mt
Current potential yield	Unknown
Recent average annual yield	26,200 mt (stock)
	19 mt (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

SKIPJACK TUNA

Skipjack tuna (*Katsuwonus pelamis*) is a cosmopolitan species, occurring in tropical and warm-temperate seas. 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. Skipjack are considered to be an opportunistic feeder. 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 levels seen in the early 1960s to 1979, rising to a peak of 40,000 mt in 1985. Almost all of the catch is taken in surface fisheries, mainly by baitboats. Brazil, Venezuela, and Cuba accounted for more than 90% of the recent 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 mt. 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 a lack of catch per unit effort information from throughout the stock range has yet to be determined. The recent average yield of western Atlantic skipjack tuna for the period 1987-1989 is estimated to have been 26,200 mt. The average yield to U.S. fishermen during this period was approximately 250 mt. The estimated U.S. recreational harvest of this species for the period was 19 mt. The yield and relative abundance trajectories for this species are shown in Figure 13.

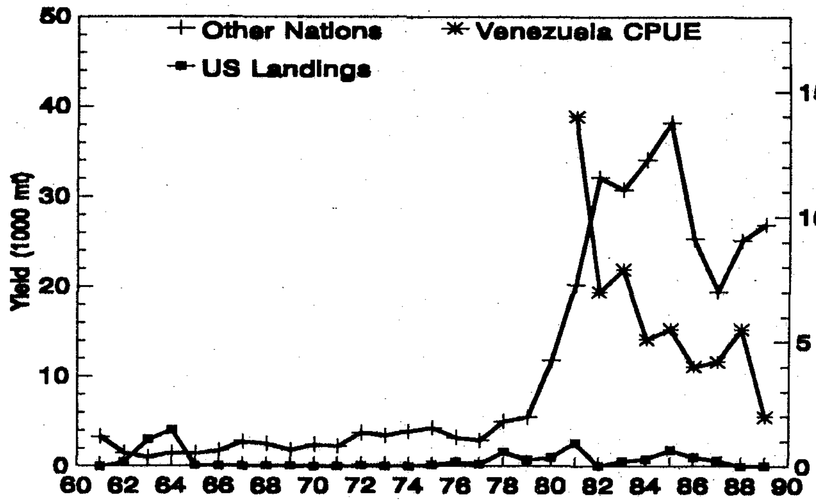


Figure 13. Yield and relative abundance trajectories for skipjack tuna in the western Atlantic. Abundance index is based on Venezuelan surface fishery catch per unit effort..

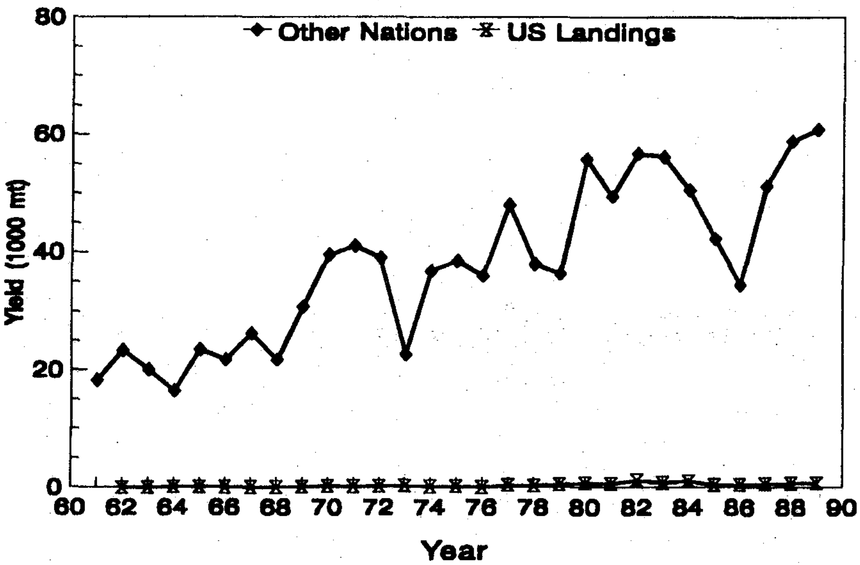


Figure 14. Yields of other tunas.

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 the period 1987-1989 was 57,700 mt.ffi (Figure 14) The recent average yield to U.S. fishermen during the same period was 699 mt. The estimated recent average yield to U.S. recreational fishermen for this group was conservatively estimated as 28 mt.

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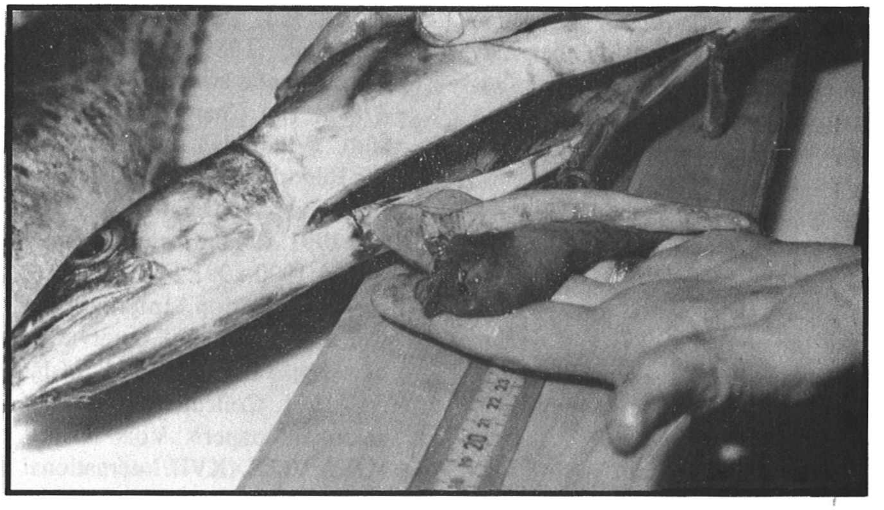
2. Coastal Pelagics

The principal coastal pelagic species in the southeastern United states are king mackerel, Spanish mackerel, dolphin, cobia, and cero. In general, they form schools, swim fast, feed voraciously, grow rapidly, 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 sampled for feeding habits and sexual maturity.

KING MACKEREL

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 accounts for 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 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 along 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 Coastal Pelagics Fishery Management Plan that was implemented in 1982. The two councils establish total allowable catch quotas (TACs) for two distinct migratory groups: the Gulf Migratory

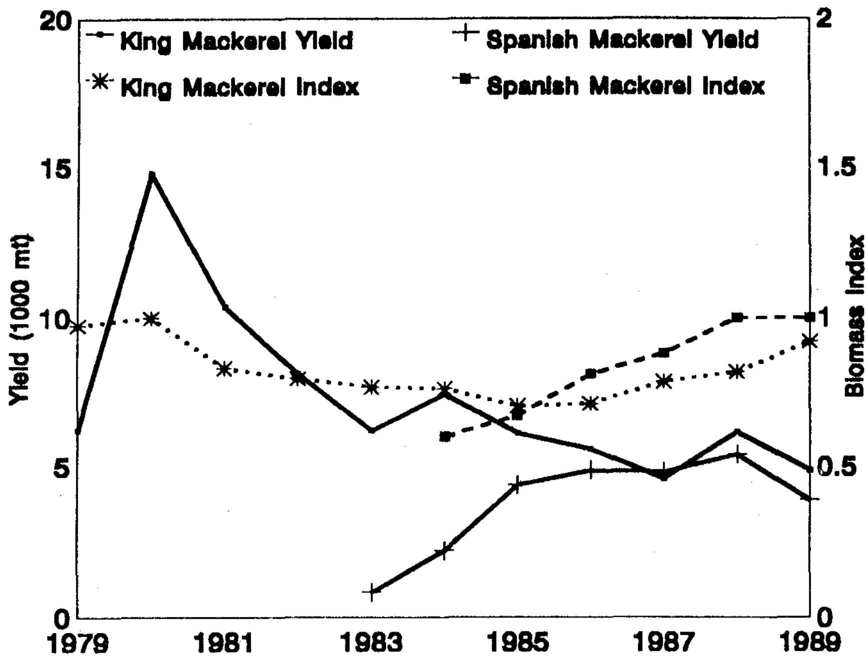


Figure 15. King and Spanish mackerel catch and index of abundance trends for 1979-1989 fishing years (fishing years for mackerel are defined as: 1979 = 1979-1980, 1980 = 1980-1981, etc.*).*

Group and the Atlantic Migratory Group. Allowable biological catches (ABCs) are defined for separate geographical areas within the Gulf group and for separate constituencies. Quota management began in the 1985/1986 fishing year in the Atlantic and Gulf of Mexico, and at present 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 and in the Gulf of Mexico for king mackerel stocks.

The number of commercial permit holders in the 1990-1991 fishing year was 1,652. The number of charterboat permit holders was 1,654.

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 and is 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. Recent production from this unit is estimated to be at about 25% of maximum. Reductions in 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.

SPANISH MACKEREL

As with king mackerel, Spanish mackerel, *Scomberomorus maculatus*, are found from the Gulf of Maine to the northern coast of Brazil. Spanish mackerel distributions are also controlled by salinity and water temperature. The 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 numbers 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. Growth is faster in the males in their early life, but the females quickly catch up 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 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 gear of choice is gill nets. Historical fisheries operated in the late 1800s and early 1900s along the east coast of Florida and in the Chesapeake Bay. Present day fisheries occur mainly along Florida's east coast and the Florida Keys. Increased production has occurred in the late 1980s along the Chesapeake Bay. Although recent landings have increased for this region, historical

Table 9. Coastal pelagic yield in thousands of metric tons.

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

* Fishing year: 1979 = 1979 - 1980, 1980 = 1980 - 1981, etc.

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 are assessed annually as required by the Coastal Pelagics Fishery Management Plan. As with king mackerel, two migratory groups, the Gulf and Atlantic, represent the basis for resource allocation. Commercial catches are regulated by quotas and daily landing limits in some states. Recreational catches are managed by quotas and 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 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. Commercial landings have doubled since 1987 from about 113 metric tons (mt) to 227 mt. This species supports a significant recreational fishery but there is very little data on the recreational sector (Figure 15, Table 9).

Under the Coastal Pelagics Fishery Management Plan, dolphin are managed by daily creel limits and a minimum size of 45.7 cm fork length. Several states have also adopted daily creel limits. The current status of the resource is unclear. The primary user group remains the recreational sector, and there is no extensive time series of 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.

Coastal Pelagics

KING MACKEREL

	U.S. Atlantic	U.S. Gulf
Longterm potential yield	3,632 mt	9,750 mt
Current potential yield	5,221 mt	2,670 mt
Recent average annual yield	2,942 mt	2,413 mt
Status of exploitation	Underexploited	Overexploited
Age at 50% maturity	5-6 years	5-6 years
Current spawning potential ratio	48%	12%
Projected SPR at current fishing patterns	Greater than 30%	30%
Generation time	10-12 years	10-12 years
Natural mortality rate	0.15	0.15
Fishing mortality rate at $F_{0.1}$	0.18	0.21
Fishing mortality rate in most recent year	0.06	0.19

SPANISH MACKEREL

	U.S. Atlantic	U.S. Gulf
Longterm potential yield	3,715 mt	5,457 mt
Current potential yield	3,178 mt	4,722 mt
Recent average annual yield	2.403 mt	1,934 mt
Status of exploitation	Overexploited	Overexploited
Age at 50% maturity	2 years	2 years
Current spawning potential ratio	Greater than 30%	22%
Projected SPR at current fishing patterns	30%	30%
Generation time	5-6 years	5-6 years
Natural mortality rate	0.3	0.3
Fishing mortality rate at $F_{0.1}$	0.12	0.29

COBIA

Cobia, *Rachycentron canadum*, are found worldwide in tropical, subtropical, and in warm temperate waters. In the western Atlantic they range 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 mt in the Gulf of Mexico and 45 mt 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. There are no commercial quotas established and the recreational fishery has daily creel limits and a minimum size of 50.8 cm fork length. The current status of the resource is not known; however, the resource is thought to be fully exploited.

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.

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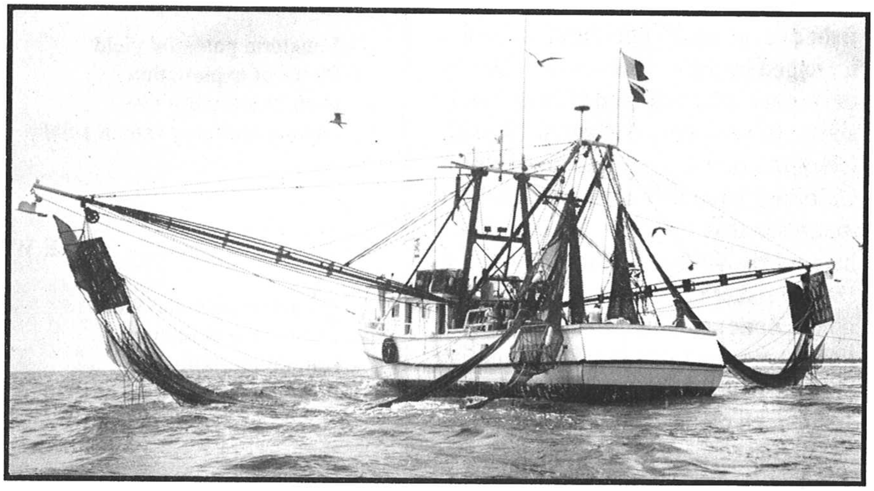
3. Shrimp



Gulf shrimp boat

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 95% of the commercial harvest and are the only species besides royal red shrimp (*Hymenopenaeus 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 largest 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 that recruits enter the fishery differ for the three species. Eggs generally 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 postlarvae 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 a few weeks in the estuaries, young subadult shrimp begin migration 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 is usually 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 sometimes in September. The postlarvae use the estuary as a nursery and eventually migrate back into the offshore waters as subadults. 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 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 is usually conducted year-round with otter trawls, but traps, butterfly nets, cast nets and seines are also employed in some areas. As noted above, peak seasonal fishing activity is species specific.

Shrimp fishery management is under both state and federal control. 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 different management measures that they use 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 beginning to develop a management plan for the shrimp fisheries in the Exclusive Economic Zone of the eastern coast of the United States.

Gulf of Mexico Shrimp

GULF BROWN SHRIMP

Longterm potential yield	63,865 mt
Status of exploitation	Fullyexploited
Natural mortality rate	0.275 per month
Fishing mortality rate in 1990	Greater than 1.0 per month

GULF WHITE SHRIMP

Longterm potential yield	34,377 mt
Status of exploitation	Fullyexploited
Natural mortality rate	0.275 per month
Fishing mortality rate in 1990	Greater than 1.0 per month

GULF PINK SHRIMP

Longterm potential yield	10,619 mt
Status of exploitation	Fullyexploited
Natural mortality rate	0.30 per month
Fishing mortality rate in 1990	Greater than 1.0 per month

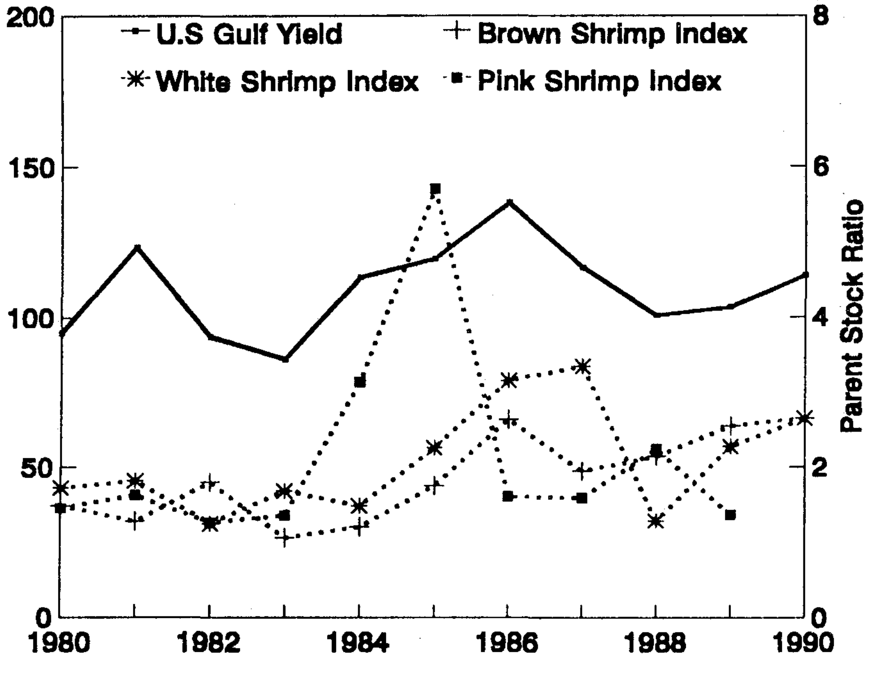


Figure 16. Total U.S. Gulf of Mexico yield and parent stock ratio for brown, white, and pink shrimp.

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 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. The total closure of the offshore waters to shrimp fishing usually 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.

Table 10. U.S. Gulf of Mexico shrimp harvest.

	U.S. Gulf of Mexico Yield (mt)		
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

GULF OF MEXICO

Average annual commercial shrimp whole weight catch for all species combined during the last eleven years (1980-1990) is 108,213 metric tons (mt) (Figure 16, Table 10). The greatest harvest occurred in 1986 (137,949 mt) while the lowest occurred in 1980 (86,719 mt). On the average, brown shrimp accounted for 58%, white shrimp 31%, and pink shrimp 8% of the total catch. The other six commercially harvested shrimp species combined accounted for only 3% of the total. The peak brown shrimp harvest occurred in 1990 (75,518 mt), white shrimp in 1986 (49,432 mt), and pink shrimp in 1981 (13,627 mt). The peak season for the other six shrimp species combined was 1986 (8,096 mt).

The average, annual nominal-fishing effort for the last eleven years (1980-1990) is around 6.7 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 offshore 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 the four species currently included in a federal fishery management plan. 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-5+ (months) shrimp during April-August with a level of 600 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 1990, brown and white shrimp parent levels were well above the overfishing index, while pink shrimp parent stock estimates were closer to the index.

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 mt tail weight at a level of 1,290 days fished. During 1990, only 41.5 mt of royal red shrimp were caught in the Gulf of Mexico. This value is under the overfishing index level set for the species.

Table 11. U.S. Atlantic shrimp harvest.

	U.S. Atlantic Shrimp Yield (mt)	
Year	**White**	**Other**
1980	5,018	6,409
1981	3,797	3,802
1982	4,777	7,222
1983	5,637	6,484
1984	1,845	7,023
1985	3,525	8,911
1986	5,091	6,491
1987	5,830	5,067
1988	5,072	6,479
1989	6,186	9,861
1990	5,736	8,746

U.S. ATLANTIC

Average annual commercial shrimp whole weight catch for the last eleven years (1980-1990) is 11,728 mt (Table 11). This is about ten times less than the catch in the Gulf of Mexico.

Average annual nominal fishing effort for the last eleven years (1980-1990) is around 504,000 hours. The greatest level of effort occurred in 1989 (695,000 hours) while the lowest was in 1985 (372.000 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.

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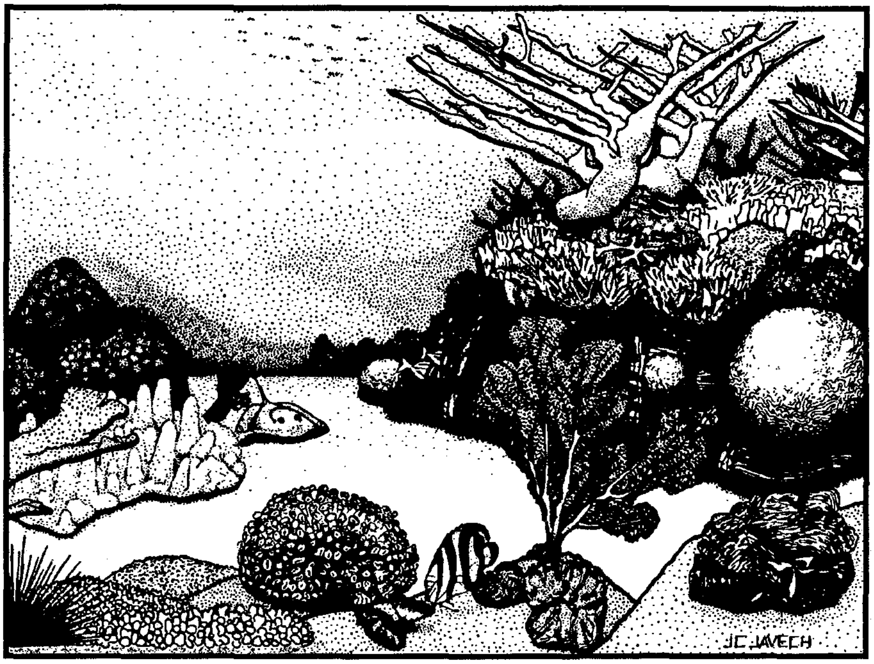
4. Reef Fish



Coral Reef

Reef fish are species that 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, long lines, 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., long-lines, 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, protection of biodiversity, sport diving).

GULF OF MEXICO

The most important commercial reef fishes in the Gulf of Mexico based on dealer reports are groupers (3 thousand metric tons (mt)), snappers (2.4 thousand mt), and amberjacks (0.5 thousand mt). Commercial and recreational yields are shown in Figure 17. 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 yellow-edged grouper. In 1990, red grouper was the most important reef fish species accounting for approximately 69% of all reported commercial grouper landings and 27% of the total reported reef fish landings. Red snapper was the most important snapper species accounting for approximately 47% of all commercial snapper landings (13% total reef fish landings) followed by vermilion snapper with 28% of snapper and 8% of total reef fish landings. 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. Recreational fishermen accounted for a significant proportion of reef fish landings and tended to catch smaller and younger fish nearshore.

Reef Fish

RED SNAPPER
(U.S. Gulf of Mexico)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Overexploited
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

NASSAU GROUPER
(U.S. Gulf of Mexico)

Longterm potential yield	Unknown but very limited
Current potential yield	Unknown
Status of exploitation	Unknown

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 mt commercial quota on groupers (divided into a 4.2 thousand mt shallow-water quota and a 0.8 thousand mt 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.

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 snapper 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 mt in the 1960s to mid 1970s and then declined to a low of 1.3 thousand mt in 1989. The recreational harvest of red snapper also declined sharply in numbers and weight from an estimated peak of 4.6 thousand mt (4.0 million fish) in 1980 to a low of 0.7 thousand mt (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 mt commercial quota adjusted annually, and a recreational harvest bag limit of 7 per person per day.

VERMILION SNAPPER (Gulf of Mexico)

Vermilion snapper (*Rhomboplites aurorubens*) extend from North Carolina to southeastern Brazil. They are found in moderately deep waters over rock bottom near of 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 mt in 1979 to 1.3 thousand mt in 1990. 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 mt (gutted weight) in 1965 to about 2.3 thousand mt in the late 1970s. With the introduction of bottom longline gear, total grouper landings increased to about 5.7 thousand mt in 1982. Since then total annual landings have fluctuated between 4.4 and 5.8 thousand mt.

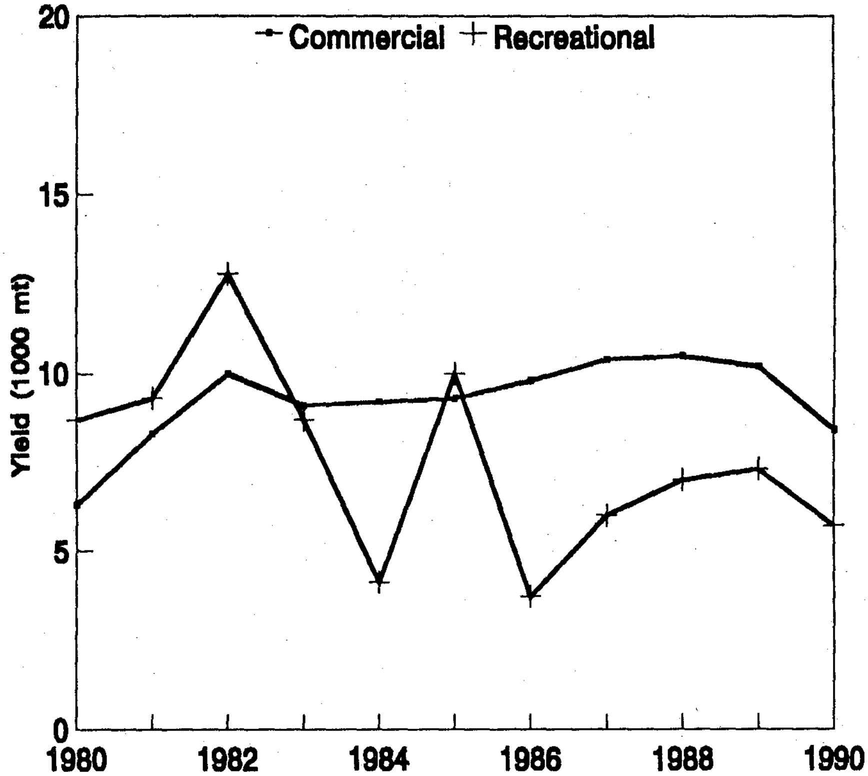


Figure 17. U.S. Gulf of Mexico reef fish yield.

NASSAU GROUPER
(Gulf of Mexico)

Nassau grouper (*Epinephelus striatus*) is an insular species found in the eastern and western Gulf of Mexico in 1 to 90 m of water and in the West Indian coral reef habitats. In the Gulf of Mexico, they are found on inshore and offshore reefs and in the Caribbean Sea. They are readily harvested by fishermen working from small boats.

Extensive information is available on fecundity, longevity, food, feeding habits, growth rates, mortality and population dynamics. However, there is inadequate information on spawning, sex ratios, and reproductive rates.

Nassau grouper grow to 1.2 m total length and weigh 20 kg. Most are marketed within the 2-10 kg range. They are protogynous hermaphrodites, and generally change from females to males at a length of 30-80 cm. Spawning occurs during the warmer months through the formation of spawning aggregations. Aggregations have been observed off Bimini and the southern Berry Islands, Bahamas; Belize; Bermuda; and Virgin Islands. Fecundity was estimated at 785 thousand eggs at 44.5 cm standard length. Growth rates have been estimated at 4.55 mm per month for fish 25.1 - 32.5 cm total length; and 1.92 mm per month for fish 32.6 - 45.1 cm total length.

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 and recreational yields are shown in Figure 18.

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. Between 1974 and 1981 the North Carolina and South Carolina headboat catch had no trend and varied from 1.1 million fish (480 mt) in 1974 to 680 thousand fish (182 mt) in 1988. The catch from the Carolina commercial fishery ranged from 310 mt in 1976 to 564 mt in 1989 with no particular trend evident.

The northeast Florida headboat catch also does not seem to have a pattern and ranged from 166 thousand fish (61 mt) in 1979 to 326 thousand fish (100 mt) in 1988. Commercial landings from northeastern Florida have decreased from 52 mt in 1972 to 18 mt in 1988.

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). Mean weights from northeast Florida headboats varied from 0.39 kg in 1978 to 0.31 kg in 1988. The only mean weight for the Carolina commercial fishery was 0.28 kg in 1981 and no data were available for the northeast Florida commercial fishery.

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 1988 equilibrium spawning potential ratio is 0.34 and the yield per recruit is 79% of the maximum. The current and proposed 20.3 cm total length (age 3.5 years) size limit will provide a spawning potential ratio of 0.48 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 temperate basses, family Percichthyidae, 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 between eight and 12 years old. Spawning occurs from January to mid April based on microscopic and histological inspection of gonads. Age and size at sexual maturity are not definitively known, but 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. In addition to the commercially fished aggregations off Georgia, fisheries for wreckfish exist in Portugal and Spain, and there are reported landings of under 4500 kg per year in Bermuda.

The southeastern U.S. commercial fishery for wreckfish began in 1987, with two vessels fishing on the Hoyt

Reef Fish

BLACK SEA BASS
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Fullyexploited
Age at 50% maturity	2.69
Current spawning potential ratio	34%
Projected SPR at current fishing patterns	34%
Natural mortality rate	0.30
Fishing mortality rate at $F_{0.1}$	1.78
Fishing mortality rate at F_{max}	0.93
Fishing mortality rate in most recent year	0.81

GAG
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Fullyexploited
Age at 50% maturity	4.55
Current spawning potential ratio	32%
Projected SPR at current fishing patterns	32%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.31
Fishing mortality rate at F_{max}	0.48
Fishing mortality rate in most recent year	0.29

RED PORGY
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Overexploited
Age at 50% maturity	5.33
Current spawning potential ratio	11%
Projected SPR at current fishing patterns	11%
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.25
Fishing mortality rate at F_{max}	0.58
Fishing mortality rate in most recent year	0.51

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 4500-5500 kg per week-long trip. The fishery has expanded rapidly since 1987, with six vessels participating in 1988, 25 vessels fishing by 1989, 74 vessels by 1990, and 83 vessels fishing by 1991. Landings of wreckfish totalled 13,097 kg in 1987, increasing to 174,647 kg in 1988. During the 1989-90 fishing season (April, 1989 through April, 1990), 40 vessels landed 1.835 million kg, 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 and a 908 mt catch quota, effort increased to 74 vessels and the quota was reached in less than four months, without fishing pressure during the spawning season (January-April, 1991). Landings for the first quarter of the 1991-92 fishing year (April, 1991 through April, 1992) totalled 388,864 kg, with 41 vessels fishing for wreckfish. This decrease in effort was attributed to several factors: 1) an expectation that the quota would close the fishery very early on, 2) an exceptionally good shrimp year throughout the southeastern U.S. and 3) an unexpected increase in snowy grouper landings in the Carolinas.

At this time, it is unclear what wreckfish stock relationships exist or if there are other sites of aggregations (spawning or feeding) in the North Atlantic Ocean. Age, growth and reproductive studies are underway. In addition, landings of wreckfish are being intensively monitored to obtain length frequency data and quota fulfillment. 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 approach to the wreckfish fishery development and 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. 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 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).

Before 1975, the commercial fishery for reef fishes was very small. The annual catch of gag has increased from 56 mt (1980) to 400 mt (1989). However, these numbers may be less than half of the actual catch since the "unclassified" grouper category in the commercial data ranged from 48 mt (1983) to 794 mt (1988).

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 mt (1980) to 590 mt (1989) however, in 1984 the total recreational catch was estimated at 690 mt.

Management of gag is proposed based on spawning stock/recruit ratios and yield per recruit models utilizing fishery data from 1988 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 fish aggregate) exist only for waters of Florida.

The spawning potential ratio for the gag is 0.32, 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 mt in 1972 to 22 mt in 1988, with a low in 1981 of 6 mt.

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. In examining these numbers, however, the relatively small sample size should be considered. Total weight from 1981 to 1985 increased from 1.1 mt to 3.6 mt, then declined to 0.9 mt in 1988.

Approximately 1,000 charter vessels and an unknown number of privately owned boats also contribute to the recreational catch of scamp. The catch estimates of scamp (excluding headboat catches) from the Marine Recreational Fishery Statistics Survey range from 2.9 mt (1981) to 220 mt (1982).

In the commercial fishery, most vessels use handlines including electric and hydraulic reels with terminal rigs of two to eight hooks. The number of vessels equipped with handline gear has ranged from 250 (1985) to 297 (1987). 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 and Georgia, increased from 17 mt in 1980 to 146 mt in 1989, with the early 1980s having lower catches than the latter years.

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. Similarly, Georgia and northeast Florida weights dropped consistently from 3.52 kg in 1981 to 1.25 kg in 1988.

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.

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 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.

The present spawning potential ratio is 0.28. A mere six percent reduction in fishing mortality or a size limit of 42.2 cm total length (with total survival of released fish) will provide a spawning potential ratio of 0.30. The proposed 50.8 cm size limit would yield a 19% increase in yield per recruit and a spawning potential ratio of over 0.30 if fishing mortality remains below about 0.30 (that is fishing mortality may more than double). Scamp is one of the species for which size data from the commercial fishery from 1983 to 1988 were aggregated, and the commercial catch is numerically greater than the recreational catch. Thus, the spawning potential estimate is almost certainly optimistic.

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, and 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 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 (45.7 cm) and bag limits (5 grouper aggregate) exist for waters of Florida and the Gulf of Mexico.

Gray snapper catches 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. 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.

The Marine Recreational Fishery Statistics Survey estimates landings ranged from 12,990 kg in 1983 to 426,118 kg in 1985. Catches have remained relativity steady for 1988 and 1989 after peaking during 1984 and 1985. 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.

Catch per unit effort is only available for headboats and is recorded as catch per angler day (by number and by weight). Catch per unit effort trends are virtually identical to those for catch. After a slight decline from 1985 through 1987, catch per unit effort increased in 1988. Highest catch per unit effort was approximately 0.17 fish in 1985 and 0.17 kg in 1984. Catch per unit effort for the most recent year of record, 1988, was 0.15 fish (and 0.15 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). The mean weight for commercially caught gray snapper off south Florida for 1985-1988 has decreased from about 0.8 kg in 1985 to less than 0.4 kg in 1988.

Gray snapper exhibits the second lowest spawning potential ratio (0.12) of any snapper examined. To achieve a spawning potential ratio of 30%, fishing mortality must be reduced by 47% or a size limit of 40.6 cm applied. The necessary reduction in fishing mortality entails (approximately) curtailing the catch from 1.2 million individuals (508 mt) to about 640 thousand fish. A proposed twelve inch size limit results in an spawning potential ratio of only 0.14. A proposed 10 snapper aggregate limit will provide an as yet unmeasured reduction in fishing mortality for gray snapper. Where yellowtail and lane snapper are abundant the reduction in fishing mortality could be significant assuming that smaller fish are not discarded when a larger gray snapper is taken.

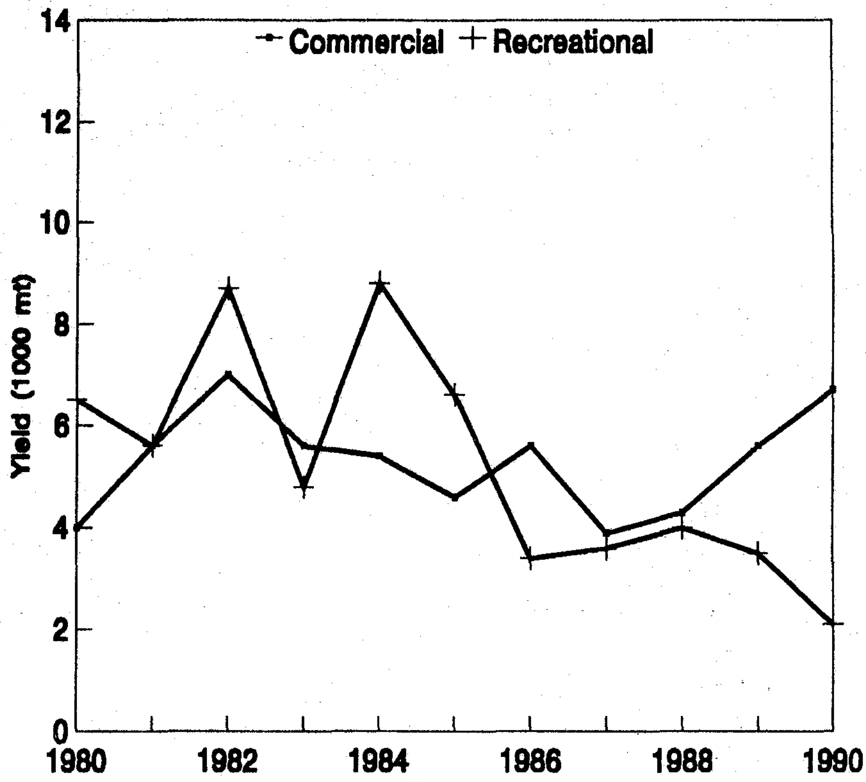


Figure 18. U.S. Atlantic reef fish yield.

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 important to commercial and recreational fisheries. Commercially the species is caught by hook and line, baited trap, trammel and gill nets, and beach seine. 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 mt in 1982 to 1,769 mt in 1989. The species is the most prized snapper in the U.S. Virgin Islands and Puerto Rico. 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.

It is also the most important species in the south Florida headboat fishery. South Florida headboat landings totalled 123 mt in 1981, rose to near 200 mt in 1982-1983, then declined to 127 mt in 1985 before rising to a peak of near 262 mt in 1988. Headboat landings of yellowtail snapper decreased 45%, to about 143 mt in 1989. 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 therefore imprecise. Landings ranged from over 110 mt in 1980 to over 838 mt in 1982, and then dropped to about 100 mt in 1986 before rising to near 437 mt in 1989.

Mean weight of headboat-caught yellowtail snapper has changed little over the last ten years, remaining between 0.55-0.65 kg since 1982. Mean weight of commercially caught fish has

Reef Fish

SCAMP
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Overexploited
Age at 50% maturity	5.08
Current spawning potential ratio	28%
Projected SPR at current fishing patterns	28%
Natural mortality rate	0.17
Fishing mortality rate at $F_{0.1}$	0.17
Fishing mortality rate at F_{max}	0.31
Fishing mortality rate in most recent year	0.18

YELLOWTAIL SNAPPER
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Not overexploited
Age at 50% maturity	2.1 years
Current spawning potential ratio	38%
Projected SPR at current fishing patterns	55%
Generation time	4.53 years
Natural mortality rate	0.20
Fishing mortality rate at $F_{0.1}$	0.37
Fishing mortality rate at F_{max}	0.50
Fishing mortality rate in most recent year	0.28

GRAY SNAPPER
(U.S. Atlantic)

Longterm potential yield	Unknown
Current potential yield	Unknown
Status of exploitation	Not overexploited
Age at 50% maturity	6.54 years
Current spawning potential ratio	12%
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

actually increased from 0.7 kg in 1986 to 1.0 kg in 1988.

Stock assessments for yellowtail snapper are based on Ricker yield-per-recruit and spawning potential ratio models and on 1988 data. As applied, these models assume equilibrium conditions over the fishery. Based on current recruitment age in the headboat fishery (1.8 years) no gains in yield per recruit are available by increasing minimum size while fishing mortality remains at present levels (0.28). Conditions existing under the south Florida headboat fishery in 1988 produced a spawning potential ratio of 0.38. The current 30.5 cm minimum size will provide a spawning potential ratio of 0.55 at present fishing mortality (0.28) and should maintain the spawning potential ratio at greater than 0.30 even if fishing mortality triples. The yellowtail snapper population in the south Florida area does not appear overexploited.

RED PORGY
(U.S. Atlantic)

The red porgy (*Pagrus pagrus*) is not a snapper or grouper but is an important reef fish resource. It ranks second only to black sea bass as the fish most frequently caught while bottom fishing offshore from Cape Hatteras to Cape Canaveral, Florida. 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. 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 are caught 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 on worms, snails, crabs, and sea urchins, which are crushed by the strong teeth and occasionally small fishes such as round scad and tomtate.

Bottom trawls, traps, and hook and line have been used to capture red porgy, but 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. 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 (45.7 cm) and bag limits (5 fish aggregate) exist for waters of Florida and the Gulf of Mexico.

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. However, it is clear from the recent increase in commercial landings (see above) that much greater attention is being paid to red porgy and many more vessels are entering the fleet. 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 to 1988 when the catch was about 50,000 fish. Weight caught diminished from 350,000 kg, in 1973 to less than 100,000 kg, in 1988.

Marine Recreational Fishery Statistics Survey data for 1980-1989 suggest a tremendous increase in landings from a low of 5.8 mt in 1986 to a high of 1,057 mt in 1982. Catches have generally increased for 1986-1989. But given the high variance attached to red porgy data in the Marine Recreational Fishery Survey Statistics, these estimates must be used with caution.

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

Mean weight of headboat-caught red porgy has diminished from values around 0.9 to 1.2 kg in the early 1970s to 0.6 kg in 1988. For the entire Carolina region, mean weight was 0.96 kg in 1983 and diminished through the late 1980s to 0.67 kg in 1989.

The present spawning potential ratio is only 0.11 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 51% 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 mt (from 535 mt).

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, long lines, bandit rigs, spears, and trammel and barrier nets. Commercial and recreational estimates of yield are shown in Figure 19. 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 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.

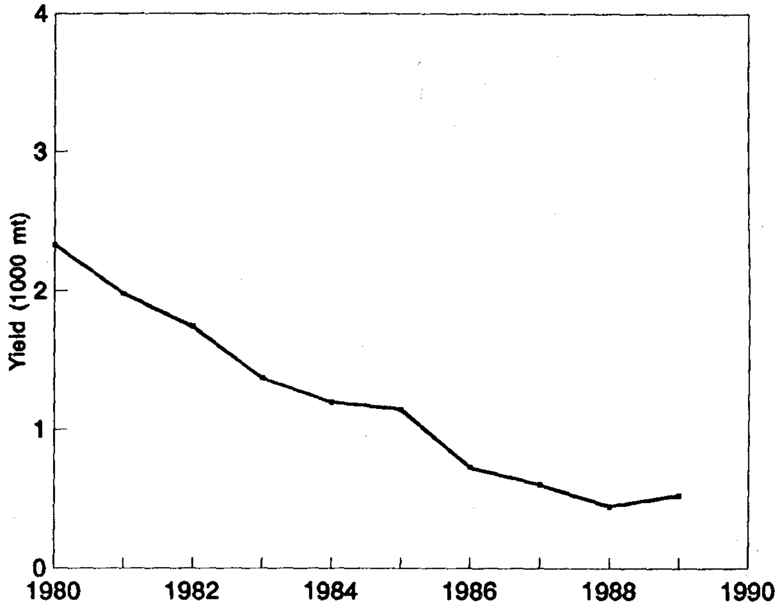


Figure 19. Reef fish yield in Puerto Rico.

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5. Sciaenids

Red drum investigation

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 seatrout. 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 (mt).

Large numbers of sciaenids are caught and killed as an incidental catch in the shrimp industry. 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 (mt) 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

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 Vera Cruz, 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 yields and an index of abundance are shown in Figure 20. 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 extreme 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 drum exceeded commercial landings by an estimated factor as high as 162.

Fishing mortality in most Gulf

estuarine areas is higher than natural mortality. 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.

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 percent maximum spawning potential is in excess of 30%.

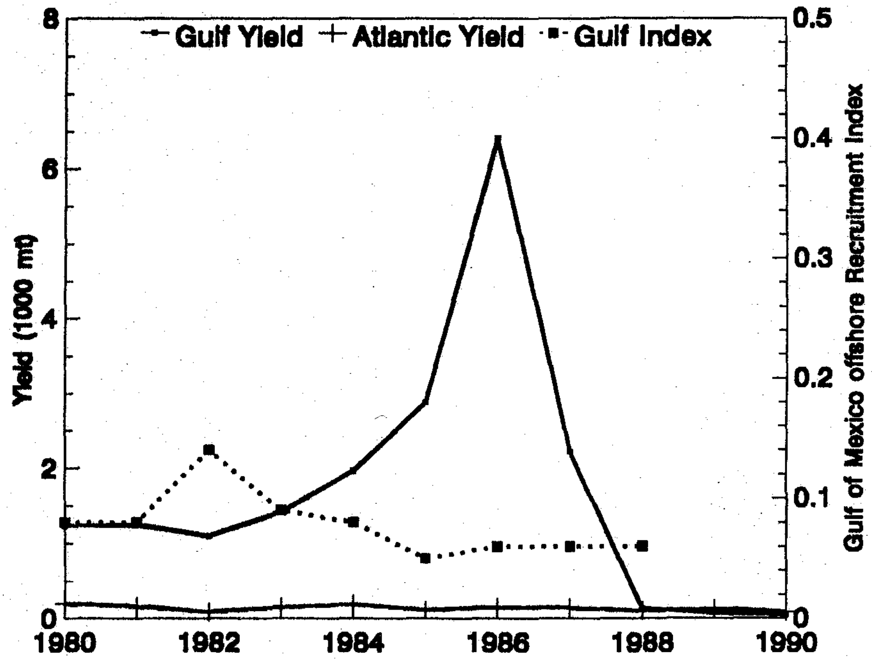

Figure 20. Commercial red drum yield and index of abundance.

Since 1980, coast-wide recreational catches ranged from 232 mt in 1990 to 988 mt in 1984, while commercial landings ranged from 85 mt in 1990 to 191 mt 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

Sciaenids

RED DRUM

	U.S. Gulf of Mexico	U.S. Atlantic
Longterm potential yield	7,900 mt	Unknown
Current potential yield	2,828 mt	Unknown
Recent average annual yield	2,828 mt	573 mt
Status of exploitation	Overexploited	Overexploited
Age at 50% maturity	4 years	3 years
Current spawning potential ratio	13%	0.3-1.9%
Projected SPR at current fishing patterns	20%	Not applicable
Natural mortality rate	0.21	0.1 - 0.5

WEAKFISH

	U.S. Atlantic
Longterm potential yield	Unknown
Current potential yield	Unknown
Recent average annual yield	8,700 mt
Status of exploration	Over exploited
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 mt
Current potential yield	Unknown
Recent average annual yield	4,946 mt
Status of exploitation	Overexploited

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 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 21. 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 is an issue with respect to finfish and shrimp trawl fisheries.

ATLANTIC CROAKER

The 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 for at least since 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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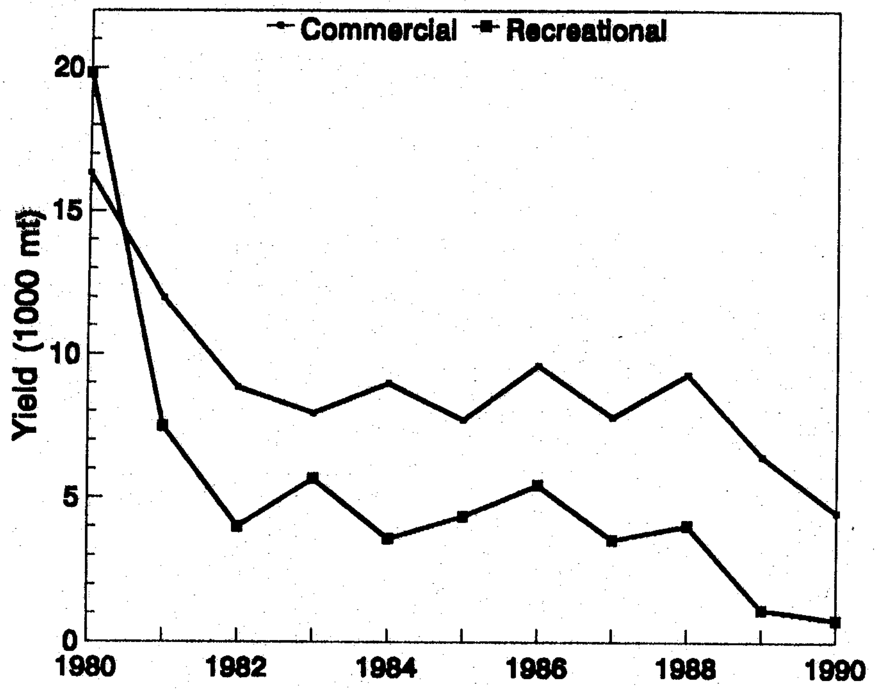

Figure 21. Commercial and recreational yields of Atlantic weakfish.

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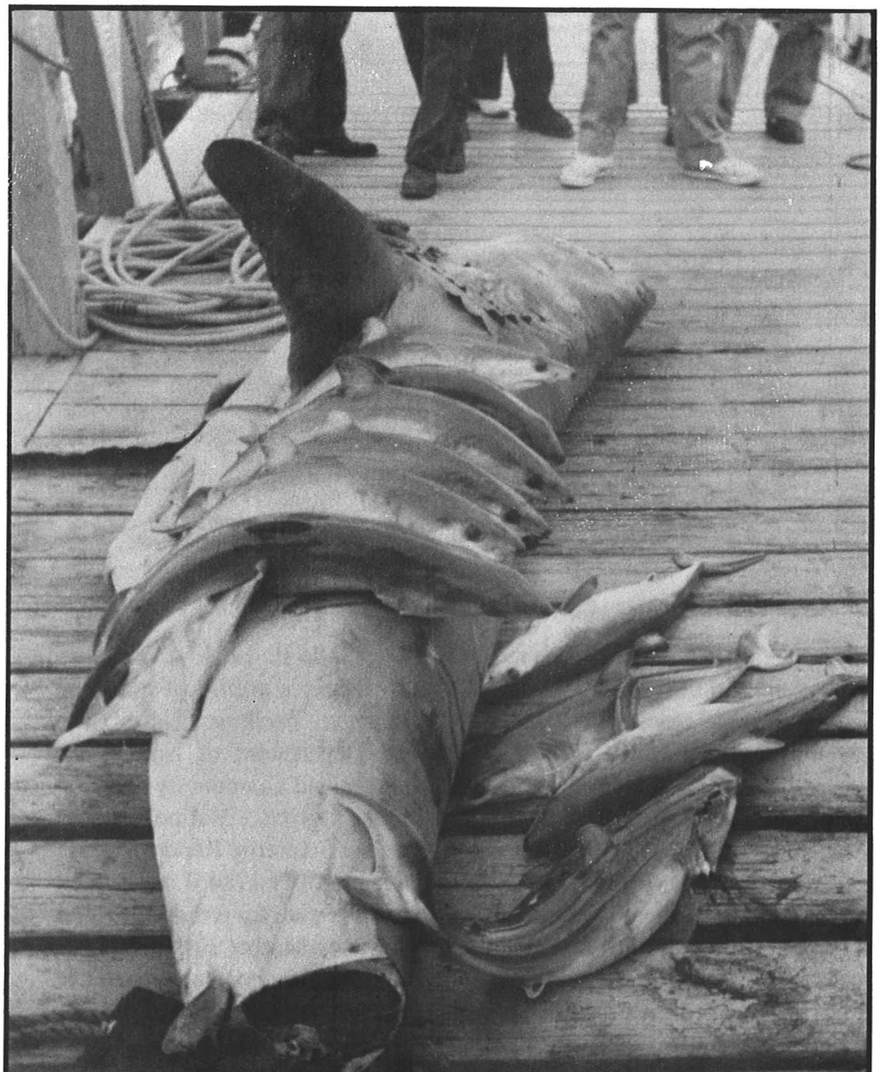
6. Sharks

Sharks belong to a diverse group of cartilaginous fishes that includes the rays, skates, and deep-water chimaeras (ratfishes). There are about 350 species of sharks, and of those, 72 species inhabit U.S. waters of the Atlantic, Gulf of Mexico, and Caribbean Sea.

Although many species of sharks live 30 to 40 years or longer, their slow rate of reproduction makes them vulnerable to overexploitation. They usually mature at older ages and have long intervals of gestation, protection of young within the mother's body, and a small number of pups.

In the United States, there was little consumption of shark meat prior to 1970, but in recent years shark meat has become a popular seafood. Much of the new demand for shark products is largely due to its low cost, an expanding Oriental market for dried shark fins, and improved shipboard handling to reduce urea content in the flesh.

A small longline fishery on large coastal sharks operated in Salerno, Florida from 1936 to 1950. The maximum number of shark-fishing boats operating from Salerno at any one time was 5, and the greatest number known to have operated off the southeastern coast at any one time in 1930-1950 was 16. Sharks were fished primarily for their livers and hides. The livers were processed into vitamin A, and the hides were processed into leather. Other minor products included fresh and salted meat, fins, and fish meal. The Salerno fishery ended in 1950 with the marketing of synthetic vitamin A which could be produced at a lower cost than the shark liver derivative.



Pregnant shortfin mako shark with her ten pups

Between World Wars I and II, the Norwegians and Danes pioneered fishing for porbeagles in the North Sea and in the region of the Shetland, Orkney, and Faroe Islands. In the late 1940s, these fishermen caught from 1,360 to 2,720 metric tons (mt) annually, with lesser amounts in the early 1950s. The subsequent scarcity of porbeagles forced the Norwegians to explore other grounds, and around 1960 they began fishing the Newfoundland Banks and waters east of New York. Between 1961 and 1964, their catches increased from 1,800 to 9,300 mt before declining to 200 mt, presumably due to stock depletion.

Significant catches of sharks in U.S. waters are made by recreational as well as commercial anglers (Figure 22). Non-tournament fishing predominates and the catch is usually small coastal sharks. Anglers fishing shark tournaments in the southern region target large coastal species. Many of these species migrate

Atlantic and Gulf Sharks

LARGE COASTAL SHARKS [a]

Long Term Potential Yield	3,400 mt
Current Potential Yield	1,900 mt
Recent Average Annual Yield	3,800 mt
Status of Exploration	Overexploited

SMALL COASTAL SHARKS [b]

Long Term Potential Yield	3,600
Current Potential Yield	3,000
Recent Average Annual Yield	3,000
Status of Exploration	Underexploited

PELAGIC SHARKS [c]

Long Term Potential Yield	--
Current Potential Yield	--
Recent Average Annual Yield	2,730 mt
Status of Exploration	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.

extensively along the continental shelf and into Caribbean Sea. In the central Atlantic states and southern New England, tournament anglers target the larger pelagic sharks such as the shortfin mako and blue shark. Many of these recreationally caught sharks are sold to the commercial market. In many years such catches were significant (it was estimated that in 1986 about 9% of the commercial landings were taken by rod and reel).

There is a directed commercial shark fishery that fishes large coastal sharks with specially constructed longlines. This fleet is mobile with some boats fishing both the U.S. Atlantic and Gulf of Mexico. There were about 130 boats in the directed fishery in 1990. Sharks are landed headless and gutted. Brokers prefer sharks from 7-23 kg dressed weight, thus the larger sharks are not as marketable. Their fins, however, are quite valuable and are commonly removed and the body discarded. This especially occurs when large hammerheads, dusky, tiger, and bull sharks are caught. Except for the hammerheads, if these species weigh about 27 kg or less, dressed weight, they are usually landed.

A seasonal gillnet fishery occurs. The gear includes drift gillnets directed at blacktip shark near shore in the late summer and early autumn. Some of these boats are less than 30 feet in length.

Pelagic sharks are a major bycatch of the tuna and swordfish longline fisheries. Many of the larger sharks are discarded at sea either because they are not marketable or worth very little. The most desirable species is the shortfin mako. Commercial swordfish bills of sale suggest that a large portion of the mako catch may have been discarded at sea before 1985, but now much of the mako is landed and sold to the fresh-fish market. Along with mako, other pelagic species are landed but not as often.

Both recreational and commercial fishermen have voiced concern regarding a downward trend in shark availability. In addition, the finning and discarding of live sharks has been a problem and a subject of criticism by the public in general. These problems were difficult to address in the past due to a lack of data from the fisheries. Newly developed assessment models were used to overcome data deficiencies. Information derived from the new techniques indicates that stocks of large coastal sharks are overfished and it is believed that harvest is exceeding surplus production. The small coastal sharks are believed to be underexploited, but their abundance would probably substantially increase if the bycatch mortality did not occur. The status of pelagic sharks is unknown, A fishery management plan for sharks is being developed partially based on this information.

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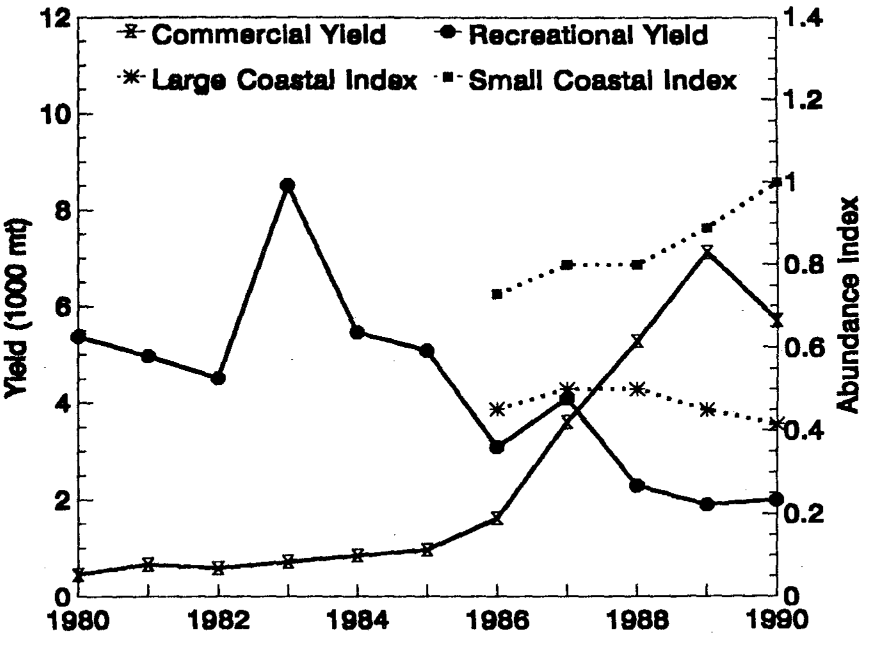
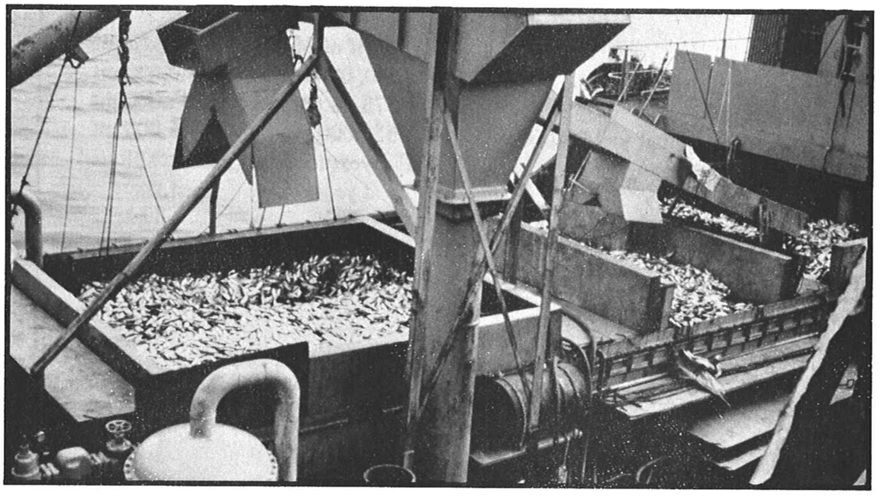


Figure 22. Yield and abundance of Atlantic and Gulf of Mexico Sharks.

7. Menhaden, Butterfish and Coastal Herrings



Menhaden vessel with catch

GULF MENHADEN

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, oil, and 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.

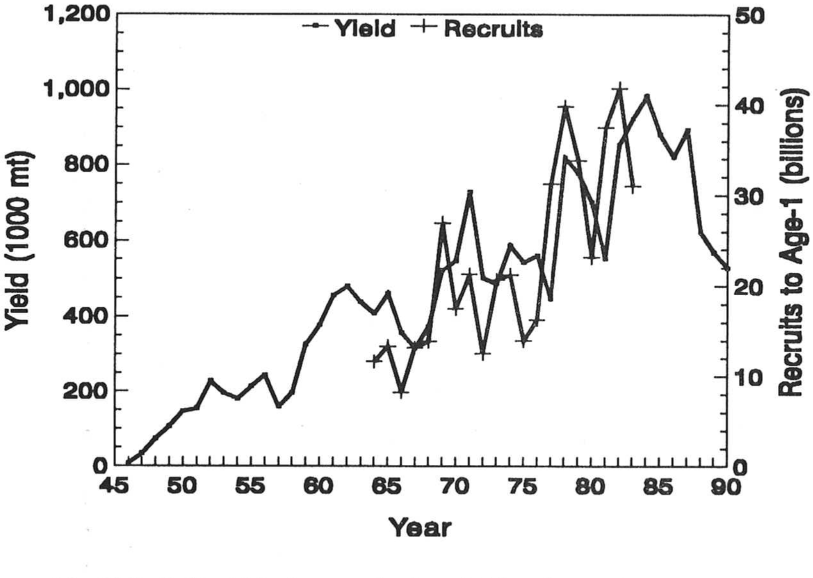


Figure 23. U.S. Gulf of Mexico menhaden yield and recruitment to age-1.

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. 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 1990 fishing season, 75 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 9 reduction plants (7 plants in Louisiana and 2 plants in Mississippi). Purse-seine

Menhaden

	U.S. Gulf of Mexico	U.S. Atlantic
Longterm potential yield	660, 000 mt	480,000 mt
Current potential yield	575,000 mt	345,000 mt
Recent average annual yield (1000 mt)	575,000 mt	345,000 mt
Status of exploitation	Fullyexploited	Overexploited
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]	2.0[a]	0.4[b]
Fishing mortality rate at F_{max}[c]	5.0[a,d]	0.7[b]
Fishing mortality rate in most recent year		
Age 0	0.0[a]	0.08[b]
Age 1	0.34[a]	0.15[b]
Age 2+	1.07[a]	1.15[b]

[a]Equilibrium, based on F's from 1983 fishing year.
[b]Equilibrium, based on F's from 1987 fishing year.
[c]Multiples of F_{recent}; 1983 for Gulf and 1987 for Atlantic menhaden.
[d]Maximum yield per recruit is at maximum F-multiplier (5.0) used in Y/R analysis.

landings of Gulf menhaden by the reduction fishery declined 7% in 1990 from 569,600 metric tons (mt) to 528,300 mt (Figure 23). Only limited data are available from bait fisheries for Gulf menhaden, and no data exist 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 mt). Landings were generally high during the mid-1980s (greater than 800,000 mt between 1982 and 1987), but have declined steeply between 1987 and 1990 (from 894,200 mt to 528,300 mt).

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 (65.8% and 31.7%, respectively in 1990), with the remaining 2.5% 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 1985. Estimates of annual instantaneous fishing mortality rates for 1983 (the most recent year that reliable estimates are available) are 0.34 for age-1, 1.06 for age-2, and 1.07 for age-3 and older, which are comparable to mean values of fishing mortality rates for the period 1978-83 (0.36, 0.95, and 1.17 respectively). 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.

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, oil, and 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 and publication expected in October 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 1990 fishing season, 35 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 4 shore-based reduction plants (1 in North Carolina, 2 in Virginia, and 1 in New Brunswick, Canada) and 1 internal waters processing operation in Maine (with a Soviet factory ship, *Riga*). Purse-seine landings of Atlantic menhaden by the reduction fishery increased 25% in 1990 from 322,000 mt in 1989 to 401,200 mt in 1990 (Figure 24). 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 mt 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 mt in 1969). Since 1970, landings have improved, but not to the levels of the late 1950s (recent peak of 418,600 mt 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.

Age composition data from the purse-seine fishery for reduction are dominated by age-0, age-1 and age-2 Atlantic menhaden (25.5%, 6.0% and 62.4%, respectively in 1990), with the remaining 6.1% 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 1988. Estimates of annual instantaneous fishing mortality rates for 1986 (the most recent year that reliable estimates are available) are 0.02 for age-0, 0.06 for age-1, 1.38 for age-2 and older, which are below the mean values of fishing mortality rates for the 1980s (0.10, 0.24, 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.

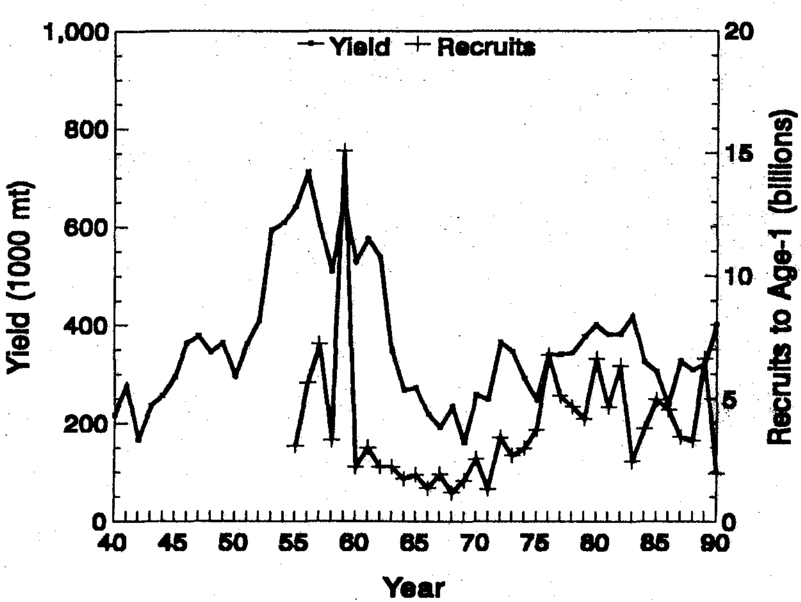


Figure 24. U.S. Atlantic menhaden yield and recruitment to age-1.

GULF BUTTERFISH

Gulf butterfish *(Peprilus burti)* is a semipelagic fish distributed in the Gulf of Mexico and along eastern 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 while larger/older fish are distributed in depths down to 365 m. The larval stages are associated with jellyfish and feed on jellyfish as they grow. As their size increases, butterfish move into deeper water, and their diet switches to include small shrimp, worms, and small fish. The largest Gulf butterfish captured measured 22.9 cm and weighed 200 g.

Gulf Butterfish

	U.S. Gulf of Mexico
Longterm potential yield	26,500 mt
Current potential yield	26,500 mt
Recent average annual yield	19,700 mt
Status of exploitation	Underexploited
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

Maximum age is 2+ years. Sexual maturity is reached at 10-16 cm 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 occurred in the catches of the industrial bottomfish and shrimp fisheries for many years. They were routinely discarded or processed for petfood or fish meal. In 1986, a directed bottom trawl fishery for Gulf butterfish began with the arrival of New England freezer trawlers. The New England vessels fished in the Gulf of Mexico during the spring months of 1986 and 1987, the spring and summer of 1988, and briefly during the spring of 1988. Also, in 1987 several Gulf vessels experimented with fishing for Gulf butterfish. Success in these early trips led to major conversions 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, and 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 the species.

Gulf butterfish are assessed as a single stock, but the fishery is not under management; a fishery management plan is being planned. Total catch in 1990 was 20,800 mt, about the average annual catch for the 1986-1990 period of 19,700 mt (Figure 25). 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 the annual catch is dominated by age-1 fish, with few age-0 and 2+ fish.

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

The Gulf butterfish stock is in good condition. The survey catch indices have been steady. NMFS research vessels only survey age-1+ butterfish since age-0 fish are found inshore. The 1990 catch-per-tow index was higher than the 1989 index. Research survey catch indices have fluctuated since 1972 but show no increasing or decreasing trend. 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), anchovies (engraulids), jacks (carangids) and one mackerel (scombrid). This complex is dominated by Spanish sardine, scaled sardine, 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 to 2 million mt.

Coastal herring are distributed along the U.S. Atlantic coast and throughout 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.

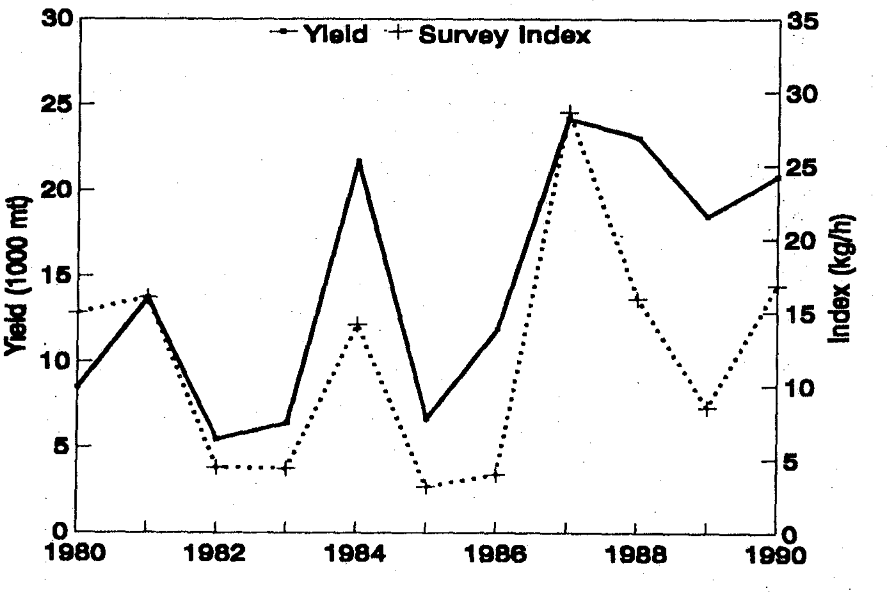


Figure 25. U.S. Gulf of Mexico butterfish yield and index of abundance.

These fish are found from the shoreline out to 70 m of depth. The offshore group contains round herring, scads, Atlantic bumper, and chub mackerel. These fish 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. During daylight, coastal herring form schools near the bottom. At night the schools break up and the fish scatter in 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 fishery along the Florida Atlantic and Gulf coasts. U.S. landings for all three species totaled 4,466 mt in 1989, and 2,596 mt in 1990. Anchovies are taken as bycatch by the menhaden fishery. 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 U.S. Atlantic or Gulf of Mexico, and no stock assessments have been made.

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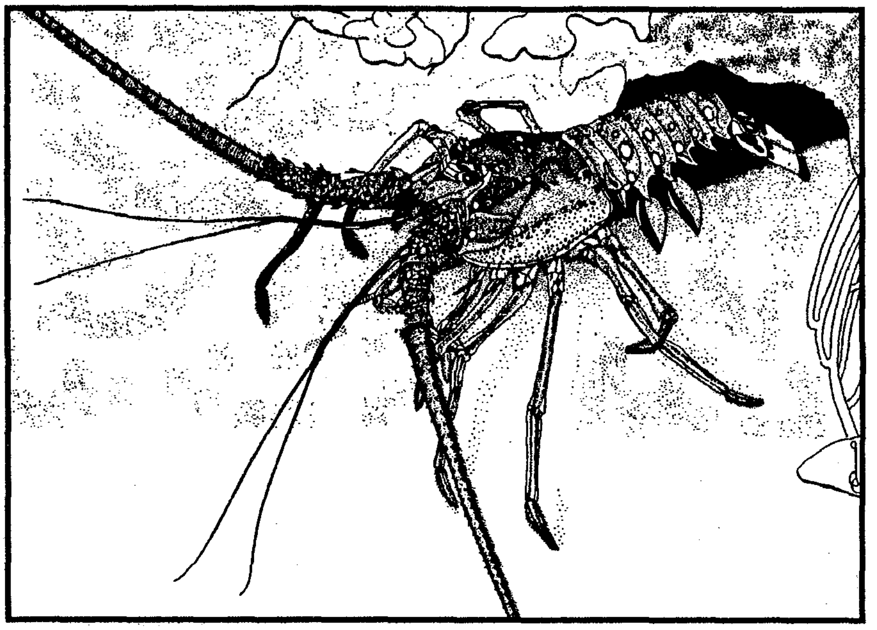
8. Reef Invertebrates



Spiny lobster

SPINY LOBSTER

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

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

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

In Florida spiny lobster are managed under a joint Gulf of Mexico and South Atlantic Council Fishery Management Plan which is coordinated in part 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 judgmental two day "sport" season occurs during the last full weekend 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 (mt) in the Gulf of Mexico. Record landings of 3,200 mt occurred in 1989 (Figure 26). In the U.S. Atlantic region, landings have averaged around 230 mt with a value of $2 million. The fishery is considered overcapitalized with approximately 500,000 traps in use. It is estimated that the same yield could be obtained with half the number of traps fished. 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 component of the fishery is large at the beginning of the season but the actual level of harvest is unknown. 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 could be of pan-Caribbean origin, and the amount of recruitment originating from local areas is unknown. Knowledge of the stock structure and sources of recruits is important for optimally managing the stock. Spiny lobster are very dependent on shallow water algal reef habitat flats for recruitment and feeding.

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 144 mt over 23 years. Landings increased from 108 mt in 1972 to 233 mt in 1979 and then declined to a low of 65 mt in 1988. Landings in the U.S. Virgin Islands during 1980-1988 remained relatively stable, averaging 19 mt.

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 overexploited in Puerto Rico.

Reef Invertebrates

SPINY LOBSTER

	Southeastern United States	U.S. Caribbean
Longterm potential yield	3,565 mt	376 mt
Current potential yield	2,400 mt	Unknown
Recent average annual yield	2,960 mt	91 mt
Status of exploitation	Overexploited	Overexploited
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 mt
Current potential yield	1,121 mt
Recent average annual yield	1,121mt
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

STONE CRAB

The range of the stone crab (*Menippe mercenaria*) is 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.

Females reach sexual maturity as small as 6.2 cm carapace width and bear egg masses containing 160 thousand to 350 thousand eggs. Even small female stone crabs have an annual egg production of about 500 thousand eggs. The average number of spawns between molts is 4.5.

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

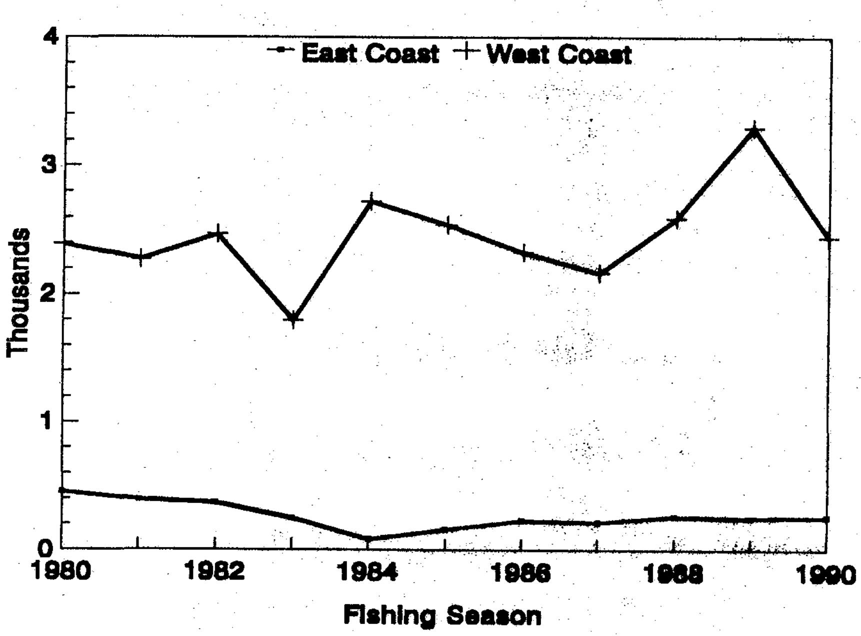


Figure 26. Florida spiny lobster commercial yield (fishing season is from July/August of year one through March 31 of year two).

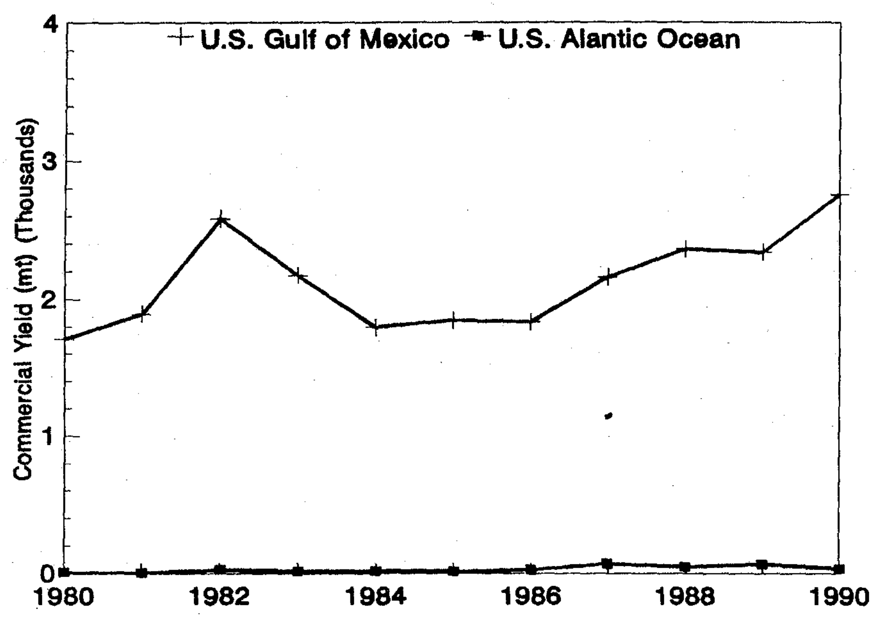


Figure 27. *Stone crab commercial yield.*

separate the two fisheries.

Annual catches (claw weight) have fluctuated around 2,000 mt in the Gulf of Mexico through the 1980s (Figure 27). Landings in the southern U.S. Atlantic region were much smaller, averaging around 34 mt. The number of traps increased from 295,000 in 1979-80 to a high of 567,000 in 1984-85 and has since been relatively stable. Although the number of traps has remained relatively stable during recent years, the estimated seasonal fishing effort increased from 3.6 million trap-hauls in 1985 to 4.8 million in 1987. The net result has been a greater proportion of the total landings being harvested earlier in the season and a shortening of the effective 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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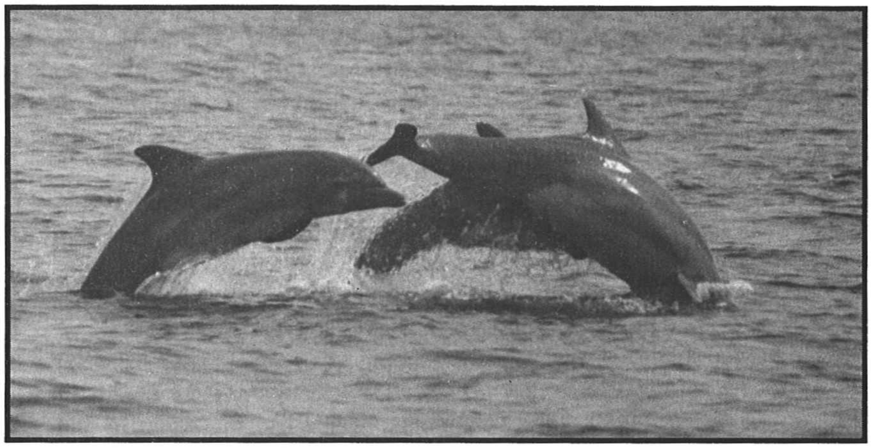
9. Marine Mammals

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.



Bottlenose dolphin

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 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.

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.

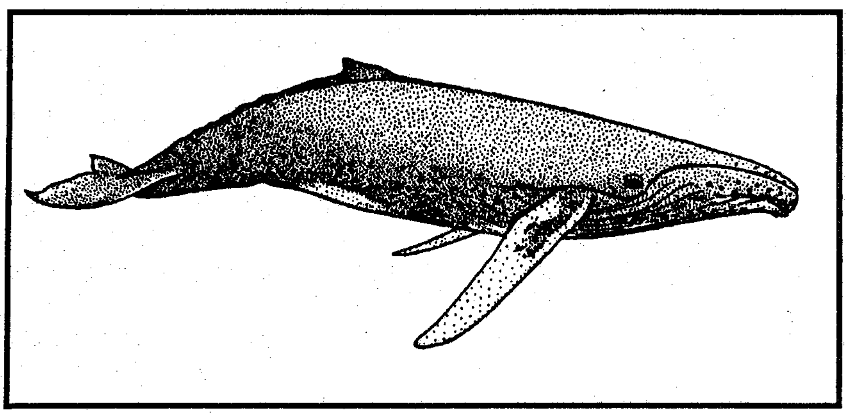
Bottlenose dolphins are known to live in the wild at least up to more than 40 years, although the average is probably about 25-30 years. Females become reproductively active at 5-8 years, producing a calf about every 2-5 years thereafter. Gestation lasts about 12 months. Males become sexually and socially 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, NC 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



Humpback whale

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. Both the 1987/88 increase in strandings along the eastern seaboard and the 1990 elevated number of strandings along the Gulf of Mexico coast have contributed to this concern. 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 baleen 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 whales and Bryde's whales. As in the Gulf of Mexico, pygmy and sperm whales are probably as common as sperm 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. 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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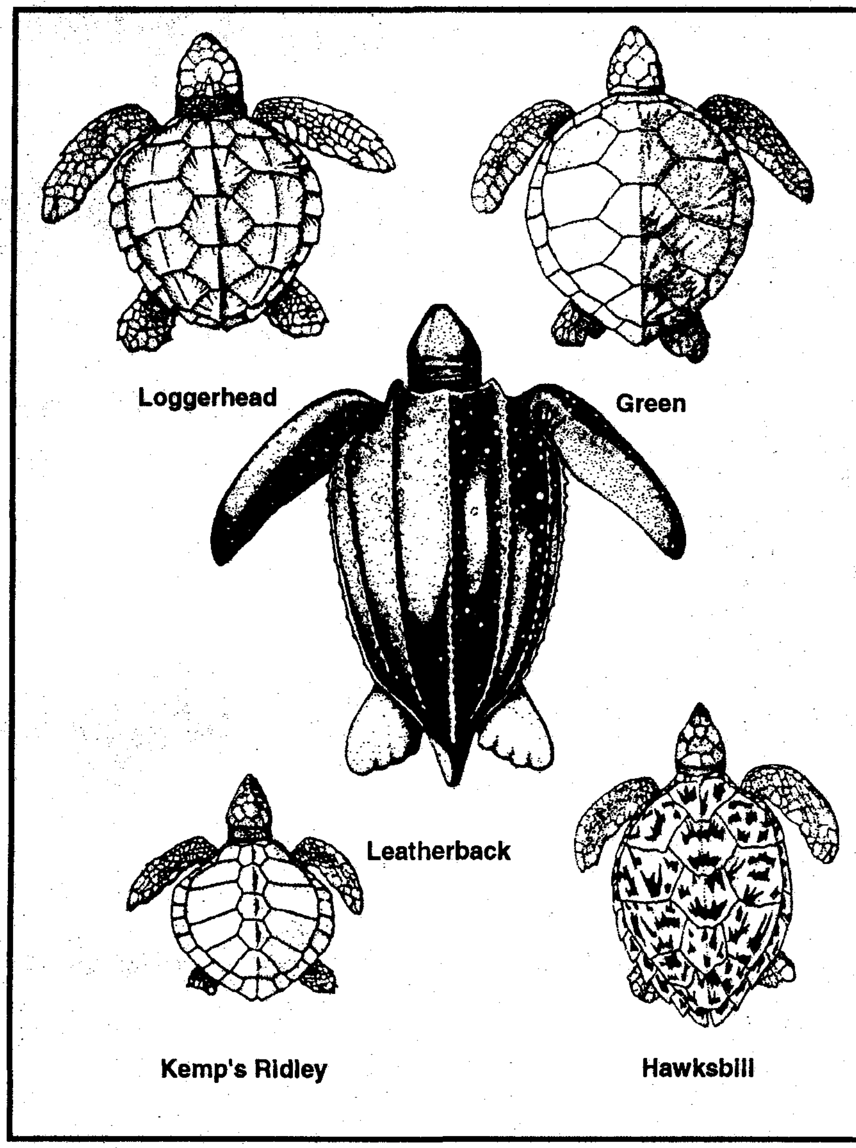
10 Sea Turtles

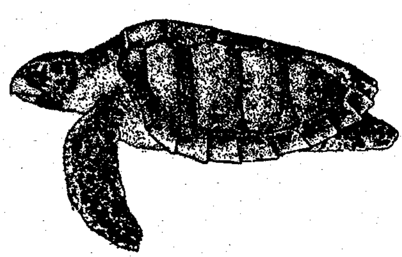
Marine turtles are highly migratory species that live in all oceans of the world. The loggerhead, green, Kemp's ridley, hawksbill, and leatherback are found in the U.S. Atlantic, Gulf of Mexico, and Caribbean Sea . Under the Endangered Species Act of 1973 and subsequent amendments, all U.S. marine turtles are listed as endangered or threatened. The National Marine Fisheries Service has jurisdiction to protect and conserve marine turtles in the water, while the U.S. Fish and Wildlife Service has jurisdiction when the turtles are on land.

The following is an overview of the distribution, abundance, and status of stocks for the loggerhead *(Caretta caretta)*, green *(Chelonia mydas)*, Kemp's ridley *(Lepidochelys kempi)*, hawksbill *(Eretmochelys imbricata)*, and leatherback *(Dermochelys coriacea)*.



The five species of sea turtles found in the eastern United States, Gulf of Mexico, and Caribbean Sea

LOGGERHEAD



In the United States, the loggerhead sea turtle is found along the Atlantic and Gulf coasts and in the Caribbean Sea. It is listed as a threatened species throughout its U.S. range.

Non-breeding adult and juvenile loggerheads occasionally occur as far north as the Gulf of Maine, but in the fall there is a net migration southward. In the spring the turtles concentrate along Florida's east coast from Brevard to Palm Beach Counties. During May-August, adult females emerge to nest on southeastern beaches.

During most of the year, loggerhead turtles on the Atlantic coast are distributed randomly. But during the winter, turtles from North Carolina to Key West, Florida, appear to aggregate within the western Gulf Stream which can be 5-6°C warmer than coastal waters. In the U.S. Gulf of Mexico, loggerhead turtles appear to concentrate along the central-west coast of Florida within 139 km of shore.

Aerial and ground surveys in the Southeastern United States of nests and nesting females for 1980, 1982, and 1983 resulted in an annual average estimate of 52,073 nests per year. Loggerheads also nest along Florida's west coast and sporadically along the entire coast of the Gulf of Mexico. Although, it is not known how many turtles nest there annually, it is likely that outside the North Carolina-Key Biscayne shoreline, there are no more than an additional 1,000 nests, or 400 turtles (at 2.5 nests per female). Thus, at least 98% of all nesting occurs between North Carolina and Key Biscayne, with a known concentration of nesting from Brevard to Palm Beach Counties.

Nine seasonal surveys were completed in 1982-84 from Cape Hatteras, North Carolina to Key West, Florida. The number of turtles sighted was significantly greater in the spring and summer than in the fall and winter. The estimated mean number of turtles present during the peak spring and summer survey, from North Carolina to Key West out to the Gulf Stream, was 387,594. This estimate includes all animals at and below the surface of the water and at least 60 cm carapace length (CL). Loggerhead turtles of 60 cm CL would include adults and sub-adults.

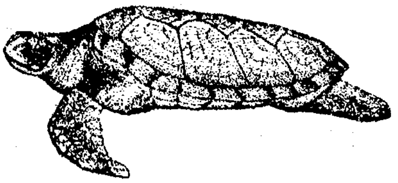
Comparable surveys have been completed from North Carolina to Maine up to 370 km offshore from 1979 to 1981. These surveys targeted marine mammals; turtle sightings were secondary. Their estimates are minimal values and do not include turtles below the surface of the water. The number of loggerhead turtles at the surface peaked in the summer and the average summer estimate over a 3-year survey period (1979-81) was 7,702.

In the Gulf of Mexico, similar estimates can be made using sighting and census data. The total number of sightings of loggerheads for the Gulf was 1,428. These sightings were made primarily off the west coast of Florida.

The survivorship requirements of the southeastern U.S. loggerhead population were examined using the assumptions that their abundance of about 387 thousand turtles represents the major reproductive component and can be considered a "unit stock." Analyses were also conducted assuming that fishing mortality was between 10 thousand and 23 thousand turtles annually. Between 0.8% and 5.2% of the hatchlings entering the water must survive to maintain the current population. These values are not contradicted by estimates from other populations of loggerheads and of other sea turtle species which average about 1% (i.e., 1% of hatchlings must survive to breed for the population to maintain stability).

Based on the best available information for the abundance of nesting females and the number of turtles in the water, it appears the loggerhead population since 1980 has remained stable. However, because turtles cannot be aged, it cannot be determined when conditions resulted in stability (i.e., whether this stability reflects conditions 5, 10, or 20 years ago). No long time series of data is available, thus, it is impossible to develop quantitative assessments on the status of this stock relative to levels prior to the Endangered Species Act of 1973, or to make predictions as to what will happen to the population beyond the next 10 years.

GREEN



The green turtle is listed as endangered in Florida and threatened elsewhere in its U.S. range. Historically, the green turtle was the primary target of U.S. turtle fishermen.

In the United States, green turtles now nest along Florida, Puerto Rico, and the U.S. Virgin Island beaches. In Florida they nest along the east coast from Brevard to Broward Counties, but historically the most significant nesting occurred in the Dry Tortugas. Unfortunately, the Dry Tortugas aggregation was extirpated by commercial exploitation early in the 20th century. North of Florida only sporadic nesting occurs to North Carolina.

Turtle fisheries were centered along the Texas coast and the Florida east and west coasts. Juveniles (less than 60 cm CL) and a few subadults (60-90 cm CL) were captured primarily in nearshore waters and in local estuaries. Landings were reported from Port Aransas, Texas; Cedar Key, Florida (west coast), and along the Indian River, Florida (east coast). Juveniles were also captured during the summer in the bays and inlets along the North Carolina coast. Historically and at present it appears that the majority of green turtles in U.S. waters are juveniles. It is likely that at least some turtles arrive seasonally from the Caribbean; therefore, it is unlikely that all immature turtles in U.S. waters are products of U.S. nesting females.

There are no historical estimates of abundance for nesting turtles within the United States. Notably, the only significant nesting assemblage was reported in the Dry Tortugas. It was estimated that in the 1800s up to 2,800 females nested per year in the Dry Tortugas, but this nesting population was extirpated through exploitation by the 1900s.

No current U.S. abundance estimate of nesting females is available. There is only one index of nesting activity and it is for a very restricted area within Brevard County, Florida. In that area, it was estimated that about 40 females nest annually. It is likely that nesting occurs on the many Florida islands and elsewhere along the Florida east coast. The minimum annual estimate of 300 females is a "best guess." figure.

Limited information is available for the species in the water. However, it is known that the majority of turtles within U.S. waters are immature. Historically, within the Indian River system on the Florida east coast the maximum green turtle catch was reported as 2,500 turtles in 1886. By 1895, the annual turtle catch was about 500 animals or a decrease of 80% from the 1886 level. This decrease is attributed to fishing and to an unusually cold winter in 1894-95, which ultimately caused the collapse of the fishery. Fishing resumed around 1970 and increased from 1,625 kg landed in 1970 to 4,152 kg in 1974. Using an average weight per turtle caught of about 8 kg yields a turtle catch of 203 for 1970 to 519 for 1974. It is estimated that about 1,500 green turtles now use this area, and within this area the number of turtles appears to be increasing.

There are no consistent current indices of abundance for green turtles within U.S. waters. It is estimated that there are about 600-800 nesting females from May-August or about 11 - 16 thousand total turtles within the southeastern United States throughout the year.

If the increase in the number of females nesting on continental U.S. beaches, and the increase in the numbers of non-adult turtles within the Indian River complex are real and not simply a result of improved sampling, then it appears that this population has been slowly increasing since at least 1980. Historical estimates are unavailable, but must have been considerable since several commercial fisheries for this species existed in the Gulf, Florida, and Caribbean and were supported for several decades. This species appears to be increasing in U.S. waters which suggests that existing and potential international conservation efforts may result in the recovery of this species throughout its U.S. and Caribbean range.

Before Turtle Excluder Trawl (TED) regulations, turtle mortality by shrimping was estimated at about 307 per year. Because green turtles are known as long-distance migrants, and no regional abundance estimates are available for the species throughout the southeastern United States, Gulf, and Caribbean, the impact of any fishing mortality on this species cannot be determined.

If the number of females nesting on U.S. beaches and the number of turtles in the Indian River provide adequate population indices, then it appears that this population has been increasing at least since about 1980. Management of this species within U.S. waters requires information on whether turtles nesting on U.S. beaches are residents or simply transients and whether juveniles in U.S. waters are products of resident females.

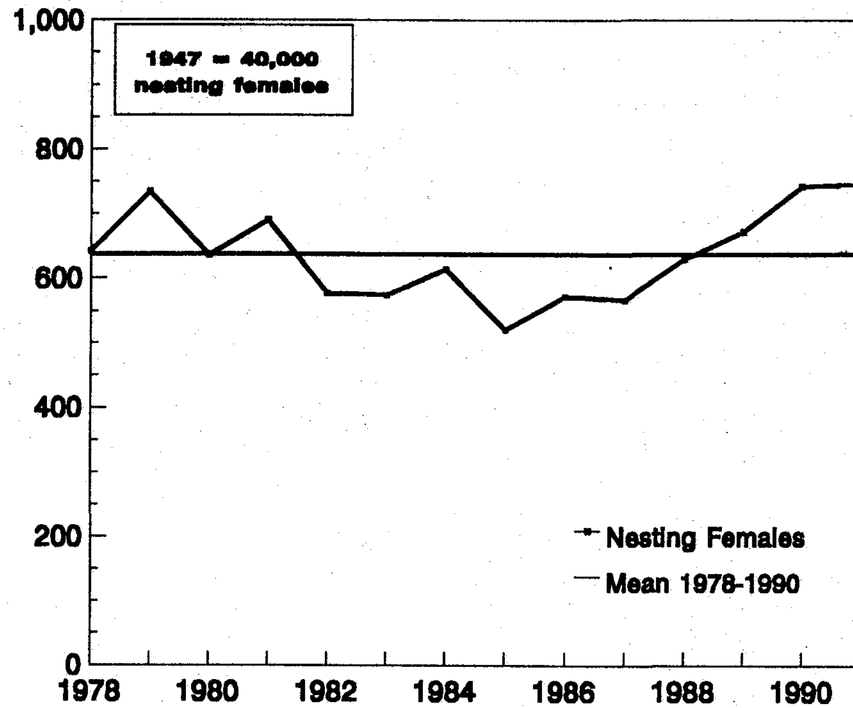
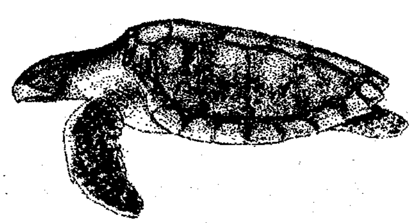


Figure 28. The number of nesting Kemp's ridley female turtles at Ranch Nuevo, Mexico.

KEMP'S RIDLEY



The Kemp's ridley sea turtle is listed as endangered throughout all of its range. It was so heavily exploited in Mexico during the 1950s and 1960s that the annual numbers of nesting females has dwindled from at least 47 thousand in 1947 to less than 600 today.

The Kemp's ridley is found from the Atlantic coast of South America throughout the Gulf of Mexico to New England. Its primary concentration appears to be within the Gulf of Mexico, and nesting is known primarily along 17 km of Mexican Gulf beach identified as "Rancho Nuevo," the name of a nearby fishing village.

Kemp's ridley turtles feed primarily on blue crabs and as a result concentrate in coastal waters of less than 100 m depth; thus, they are commonly observed in bays, sounds, and estuaries. While most turtles may spend their entire lives within the Gulf of Mexico, there are some which leave the Gulf probably via the Florida Straits and forage as far north as the Gulf of Maine during summer months before returning to Florida during the fall and winter. Whether these animals are ever recruited into the breeding population is not known. However, NMFS considers these turtles as potential recruits into the breeding population and therefore deserving of complete protection.

The only estimate of abundance available for this species is annual estimates of nesting females. This species is an aggregate nester (forming so-called "arribadas") and nests during the day along Rancho Nuevo beaches from May to August. Very little nesting is known to occur outside of Rancho Nuevo, and thus the Rancho Nuevo population is treated as a closed population. Beach surveys have concentrated on counting nests since 1978 and, using a value of 1.3 nests per female per year derived by Marquez et al. (1981) and Marquez (1990), provides one index for the annual number of nesting females.

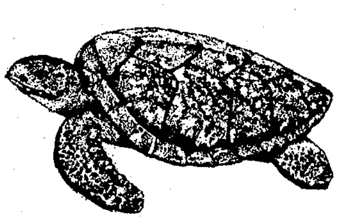
Using 1.3 nests per female, the average estimated number of nesting females for 1978 to 1991 was 637 turtles (range = 521-746, Figure 28). The available nesting data indicates that the remaining breeding population may be at least stabilizing in response to conservation efforts. From 1978 to 1988 the estimates of nesting females appeared to be declining, but from 1988 to 1991 the numbers of nesting females appeared to be increasing. However, since the current average number of nesting turtles (637) is only about 1.3% of the original 47,000 and, considering that it may take these animals many years to mature and reproduce, it is difficult to accurately interpret these figures and discern actual trends. Needless to say, the population level is still extremely depressed and is in danger of extinction.

Recovery of this population to the only available historical estimate of 47,000 (from 1947) depends upon the rate of recruitment into the breeding population. At this time it is unknown if the annual recruitment is actually greater or less than the annual mortality.

Annual Number of Female Sea Turtles on U.S. Beaches

	Current Level	Current Trend	Status in U.S.
Loggerhead	18,000-21,000	Stable	Threatened
Green	600-800	Increasing	Threatened In Florida, Endangered
Kemp's ridley	700	Declining 1978-1987; Stable but low 1988-1991	Endangered
Leatherback	--	--	Endangered
Hawksbill	--	Declining	Endangered

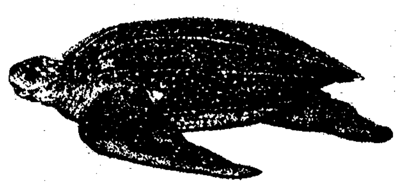
HAWKSBILL



The hawksbill turtle is listed as endangered throughout its range. Historically, the hawksbill has been heavily exploited for its "tortoiseshell" products, and continued international trade suggests that populations are likely to continue declining. It is unknown if the development habitat for hatchling hawksbills is predominantly pelagic, like other turtles, but there is some evidence that they may remain nearshore near tropical coral reefs. The sub-adult and adults feed on sponges and are therefore closely associated with tropical reef habitats. The hawksbill is a tropical species and is found primarily throughout the U.S. Caribbean. It prefers nesting on small, isolated, island beaches, with the largest nesting area in U.S. waters being the beaches of Mona Island, Puerto Rico. These beaches are listed as critical habitat for hawksbill nesting.

There is virtually no historic or current information available concerning the size of hawksbill populations in U.S. jurisdictional waters, except to say that they are rare and probably declining. Aerial surveys are generally ineffective due to the secretive and solitary nature of the species.

LEATHERBACK



This species is listed as endangered in U.S. jurisdictional waters. Leatherbacks exhibit the largest north-south range of any turtle species within U.S. waters. They are distributed from Maine southward through the Gulf of Mexico to South America. They are also found in U.S. Caribbean waters, especially in the Virgin Islands.

Very little is known about leatherback biology; however, it is assumed that the species undergoes a hatchling pelagic stage similar to other sea turtles. Adult leatherbacks tend to be more pelagic than other turtles, apparently feeding exclusively on large jellyfish.

There is occasional leatherback nesting on the east coast of Florida and on the offshore islands of Puerto Rico, but the majority of nesting in U.S. waters is in the Virgin Islands where St. Croix has been designated critical nesting habitat.

There is very little information concerning historic or current leatherback population sizes in U.S. jurisdictional waters. Nesting is sparse, scattered, and inconsistent. Although leatherbacks are occasionally seen during aerial surveys, population estimates are nonexistent.

MAJOR ISSUES

Although sea turtles are protected in U.S. waters under the Endangered Species Act, turtle habitat continues to be negatively impacted through human induced degradation. Continuing coastal development seriously reduces the quantity and quality of available nesting habitat. Turtles are also negatively impacted by commercial fishing gear and constitute a significant bycatch in various trawl fisheries. Additionally, the increasing presence of pollutants and debris in the pelagic habitat, such as tar balls and plastics, impacts turtles, particularly juveniles. The extent of all these negative impacts is not limited to the United States. These same adverse factors hinder recovery efforts throughout the entire sea turtle habitat around the world. Fortunately, there are increased efforts to promote international cooperation in turtle recovery through international and regional symposia and publications.

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