3.2 Status of the Stocks

The methods used to determine the status of Atlantic HMS are fully described in Chapter 3 of the 1999 Tunas, Swordfish, and Shark FMP and Amendment 1 to the Tunas, Swordfish, and Shark FMP and in a paper describing the technical guidance for implementing National Standard 1 of the Magnuson-Stevens Act (Restrepo et al., 1998). These methods will not change as a result of combining the FMPs. In summary, a species is considered overfished when the current biomass (B) is less than the minimum stock size threshold ($B < B_{MSY}$). The minimum stock size threshold is determined based on the natural mortality of the stock and the biomass at Maximum Sustainable Yield (B_{MSY}). The MSY is the maximum long-term average yield that can be produced by a stock on a continuing basis. Furthermore, overfishing may also be occurring on a species if the current fishing mortality (F) is greater than the fishing mortality at MSY (F_{MSY}) ($F > F_{MSY}$). If a species is declared overfished, action to rebuild the stock and/or prevent further overfishing is needed within one year. A species is considered rebuilt when B is greater than B_{MSY} and F is less than F_{MSY}. A species is considered healthy when B is greater than or equal to the biomass at optimum yield (B_{OY}) and F is less than or equal to the fishing mortality at optimum yield (F_{OY}).

3.2.1 Atlantic Swordfish

3.2.1.1 Life History/Species Biology

Swordfish are members of the family *Xiphiidae*, in the suborder *Scombroidei*. Atlantic swordfish (*Xiphias gladius*) are one of the largest and fastest predators in the Atlantic Ocean, reaching a maximum size of 530 kg (1165 lbs). Like other highly migratory species, they have developed a number of specialized anatomical, physiological, and behavioral adaptations (Helfman *et al*., 1997). Swordfish are distinguished by a long bill that grows forward from the upper jaw. This bill differs from that of marlins (family *Istiophoridae*) in that it is flattened rather than round in cross section, and smooth rather than rough. Swordfish capture prey by slashing this bill back and forth in schools of smaller fish or squid, stunning or injuring their prey in the process. They may also use the bill to spear prey, or as a defense during territorial encounters. Broken swordfish bills have been found embedded in vessel hulls and other objects (Helfman *et al.*, 1997).

Atlantic swordfish are usually found in surface waters but occasionally dive as deep as 650 meters. These large pelagic fishes feed throughout the water column on a wide variety of prey including groundfish, pelagics, deep-water fish, and invertebrate. Swordfish show extensive diel migrations and are typically caught on pelagic longlines at night when they feed in surface waters (SCRS, 2004). They are capable of migrating long distances to maximize prey availability and, as noted above, can prey upon various trophic levels during their daily vertical migrations (NMFS, 1999). As adults and juveniles, swordfish feed at the highest levels of the trophic food chain, implying that their prey species occur at low densities. The foraging behavior of swordfish reflects the broad distribution and scarcity of appropriate prey; they often aggregate in places where they are likely to encounter high densities of prey, including areas near current boundaries, convergence zones, and upwellings (Helfman *et al*., 1997).

Swordfish move thousands of kilometers annually and are distributed globally in tropical and subtropical marine waters. Their broad distribution, large spawning area, and prolific nature have contributed to the resilience of the species in spite of the heavy fishing pressure being exerted on it by many nations. During their annual migration, north Atlantic swordfish follow the major currents which circle the north Atlantic Ocean (including the Gulf Stream, Canary and North Equatorial Currents) and the currents of the Caribbean Sea and Gulf of Mexico. The primary habitat in the western north Atlantic is the Gulf Stream, which flows northeasterly along the U.S. coast, then turns eastward across the Grand Banks. North-south movement along the eastern seaboard of the United States and Canada is significant (NMFS, 2003). They are found in the colder waters during summer months and all year in the subtropical and tropical area (SCRS, 2003). Additional information on life history relating to habitat can be found in Section 3.3, Essential Fish Habitat, as well as the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks.

Like most large pelagic species, swordfish have adapted body contours that enable them to swim at high speeds. Their streamlined bodies are round or slightly compressed in cross section (fusiform), and their stiff, deeply forked tails minimize drag. This streamlined physical form is enhanced by depressions or grooves on the body surface into which the fins can fit during swimming. The extremely small second dorsal and anal fins of the swordfish may function like the finlets of tuna, reducing turbulence and enhancing swimming performance. Their method of respiration, known as ram gill ventilation, requires continuous swimming with the mouth open to keep water flowing across the gill surfaces, thereby maintaining an oxygen supply. This respiratory process is believed to conserve energy compared to the more common mechanism whereby water is actively pumped across the gills (Helfman *et al*., 1997). In addition to the benefits of speed and efficiency, their search for prey is aided by coloring that provides camouflage in pelagic waters. This shading is darker along the dorsal side and lighter underneath, enhanced by silvery tones.

Swordfish exhibit other physiological characteristics that enable them to extend their hunting range. For example, swordfish can maintain elevated body temperatures, conserving the heat generated by active swimming muscles. Swordfish have developed a heat exchange system that allows them to swim into colder, deep water in pursuit of prey. Because warm muscles contract faster than cool ones, heat conservation is believed to enable these predatory fishes to channel more energy into swimming speed. The internal temperatures of these fishes remains fairly stable even as they move from surface waters to deep waters. Swordfish have also adapted specialized eye muscles for deep water hunting. Because their eye muscles do not have the ability to contract, they produce heat when stimulated by the nervous system, locally warming both the brain and eye tissues (Helfman *et al*., 1997). With this modification, swordfish are able to hunt in the frigid temperatures of deep-water ocean environments without experiencing a decrease in brain and visual function that might be expected under such harsh conditions.

Juvenile swordfish are characterized as having exceptionally fast growth during the first year (NMFS, 1999). Swordfish exhibit dimorphic growth, where females show faster growth rates and attain larger sizes than males. Young swordfish grow very rapidly, reaching about 130 cm lower jaw-fork length (LJFL) by age two. Swordfish are difficult to age, but 53% of females are considered mature by age 5, at a length of about 130 cm LJFL (SCRS, 2003; SCRS, 2004). Approximately 50 percent of males attain maturity by 112 cm LJFL (Arocha, 1997). All males are mature by 145 to 160 cm LJFL (37 to 50 kg ww), approximately age five, and all females are mature by 195 to 220 cm LJFL (93 to 136 kg ww), approximately age nine. In general, swordfish reach 140 cm LJFL (33 kg ww) by age three and are considered mature by age five. Individual females may spawn numerous times throughout the year (NMFS,1999).

Swordfish stocks consist of several age classes, a condition that may serve as a buffer against adverse environmental conditions and confer some degree of stability on the stocks. Swordfish are also at a high trophic level which may make the species less vulnerable to short-term fluctuations in environmental conditions (NMFS, 1999).

When ICCAT's Standing Committee on Research and Statistics (SCRS) scientists assess the status of Atlantic swordfish, the stock is split between the North Atlantic, South Atlantic, and Mediterranean Sea. The SCRS continues to examine existing information, including spawning data, tagging information, genetic studies, and abundance indices to better define stock structure. For the purposes of domestic management, the swordfish population is considered to consist of two discrete stocks divided at 5 degrees N.

3.2.1.2 Effect of ICCAT Regulations

ICCAT Catch limits (all weights in this section are given in whole weight)

The total allowable catch in the North Atlantic in 2002 was 10,400 mt (10,200 mt retained and 200 mt discarded). The reported landings were about 9,000 mt and the estimated discards were about 600 mt. The total allowable catch in the North Atlantic in 2003 was 14,000 mt (13,900 mt retained and 100 mt discarded). The reported landings in 2003 were about 10,600 mt and the estimated discards were about 460 mt. Reports for year 2003 are considered provisional and subject to change. The total allowable catch in the South Atlantic in 2002 was 14,620 mt. The reported landings for 2002 were about 13,660 mt and reported discards were 1 mt. The total allowable catch in the South Atlantic in 2003 was 15,631 mt. The reported landings for 2003 were about 10,900 mt and reported discards were <1 mt. Reports for year 2003 are considered provisional and subject to change (SCRS, 2004).

ICCAT Minimum size limits (all weights in this section are given in whole weight)

There are two minimum size options that are applied to the entire Atlantic: 125 cm LJFL with a 15 percent tolerance for undersized fish, or 119 cm LJFL with zero tolerance and evaluation of the discards. In the absence of size data, these calculations could not be updated or examined for 2003. In 2000, the percentage of swordfish reported landed (throughout the Atlantic) less than 125 cm LJFL was about 21 percent (in number) overall for all nations fishing in the Atlantic. If this calculation is made using reported landings plus estimated discards, then the percentage less than 125 cm LJFL would be about 25 percent. The SCRS noted that this proportion of small fish did not increase very much even though recruitment in the North has been at a high level in recent years (SCRS, 2004).

3.2.1.3 Stock Status and SCRS Outlook

No new assessment was conducted in 2003 or 2004; the most recent assessment of North and South Atlantic swordfish stocks was conducted in 2002. In that assessment, updated CPUE and catch data through 2001 were examined. Sex and age-specific (North Atlantic) and biomass standardized catch rates (North and South Atlantic) from the various fleets were updated. The updated North Atlantic CPUE data showed similar trends to previous years, and also showed signs of improvement in stock status since 1998. In particular, the recruitment index (1997 - 2001) and the catch-at-age used in the 2002 North Atlantic assessment showed signs of substantially improved recruitment (age one), which has manifested in several age classes and the biomass index of some fisheries, and have allowed for increases in spawning biomass and a more optimistic outlook. The strong recruitments of the late 1990s promoted improvement in spawning stock biomass and should result in further improvement, if these year-classes are not heavily harvested. The CPUE patterns in the South Atlantic by fleet showed contradictory patterns. Lack of important CPUE information from some fleets fishing in the South Atlantic prevented the SCRS from reconciling these conflicts (SCRS, 2004).

North Atlantic Swordfish (all weights are given in whole weight)

An updated estimate of maximum sustainable yield from production model analyses is 14,340 mt (range 11,500 to 15,500 mt). Since 1997, North Atlantic swordfish catches have been below 14,340 mt; preliminary estimates (reported plus carried over) of catches in 2001, 2002, and 2003 were about 9,980, 9,550, and 11,020 mt, but the most recent years are provisional and probably underestimates. The biomass at the beginning of 2002 was estimated to be 94 percent (range: 75 to 124%) of the biomass needed to produce MSY. This estimate is up from an estimate of 65 percent of MSY in the 1998 assessment. The 2001 fishing mortality rate was estimated to be 0.75 times the fishing mortality rate at MSY (range: 0.54 to 1.06). The replacement yield for the year 2003 was estimated to be about the MSY level. As the TAC for North Atlantic swordfish for 2002 was 10,400 mt, it was considered likely that biomass would increase further under those catch levels. The TAC set for 2003 - 2005 is 14,000 mt (ICCAT Recommendation 02 - 02). Given recent fishing mortality patterns, the spawning biomass likely will increase largely owing to the very large recruitments estimated for 1997 - 2000. Further, given that recent (2002 - 2003) reported catch has been below estimated replacement yield, the North Atlantic swordfish biomass may have already achieved the B_{MSY} level. However, noting the uncertainties inherent in the assessment, the SCRS warned against large increases over the current TAC (SCRS, 2004). The next assessment is scheduled for 2006.

South Atlantic Swordfish

The SCRS noted that reported total catches have been reduced since 1995, as was recommended by the SCRS. SCRS had previously expressed serious concern about the trends in stock biomass of South Atlantic swordfish based on the pattern of rapid increases in catch before 1995 that could result in rapid stock depletion, and in declining CPUE trends of some by-catch fisheries. Standardized CPUE series were available for three fleets, the targeted fishery of European Community (EC)-Spain, and the bycatch fisheries of Chinese Taipei and Japan. There was considerable conflict in trends among the three CPUE series and it is unclear which, if any, of the series tracks total biomass. It was noted that there was little overlap in fishing area among the three fleets, and that the three CPUE trends could track different components (or cohorts) of the population. To address this possibility, an age-structured production model was run as a sensitivity test. For the base case production model, the Committee selected the bycatch CPUE series combined using a simple unweighted mean and the targeted CPUE series. Due to some inconsistencies in the available CPUE trends reliable stock assessment results could not be obtained (SCRS, 2004).

Reported catches of Atlantic swordfish, including discards for the period 1950 – 2003 can be found in Figure 3.1. Estimated fishing mortality rate relative to the F_{MSY} for the period 1959 – 2001 can be found in Figure 3.2. Annual yield for North Atlantic swordfish relative to the estimated MSY can be found in Figure 3.3. A summary of Atlantic swordfish stock status can be found in Table 3.3

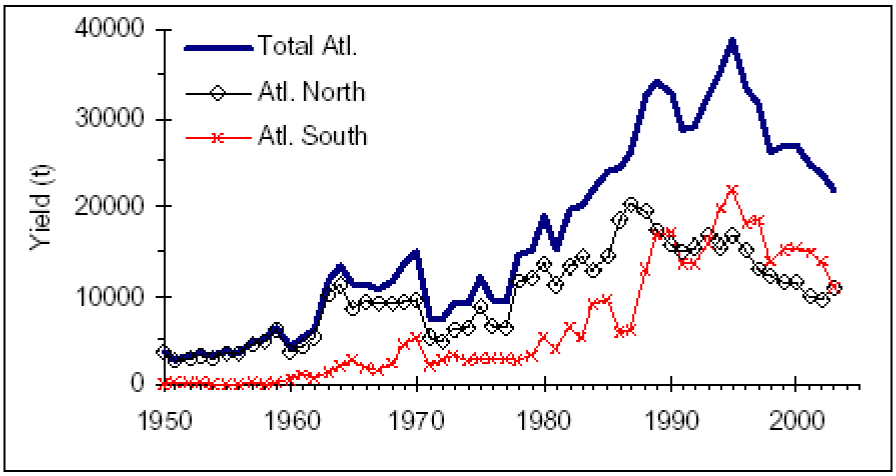

Figure 3.1 **Reported catches (mt whole weight) of Atlantic Swordfish, including discards for 1950 – 2003.** Source: SCRS, 2004.

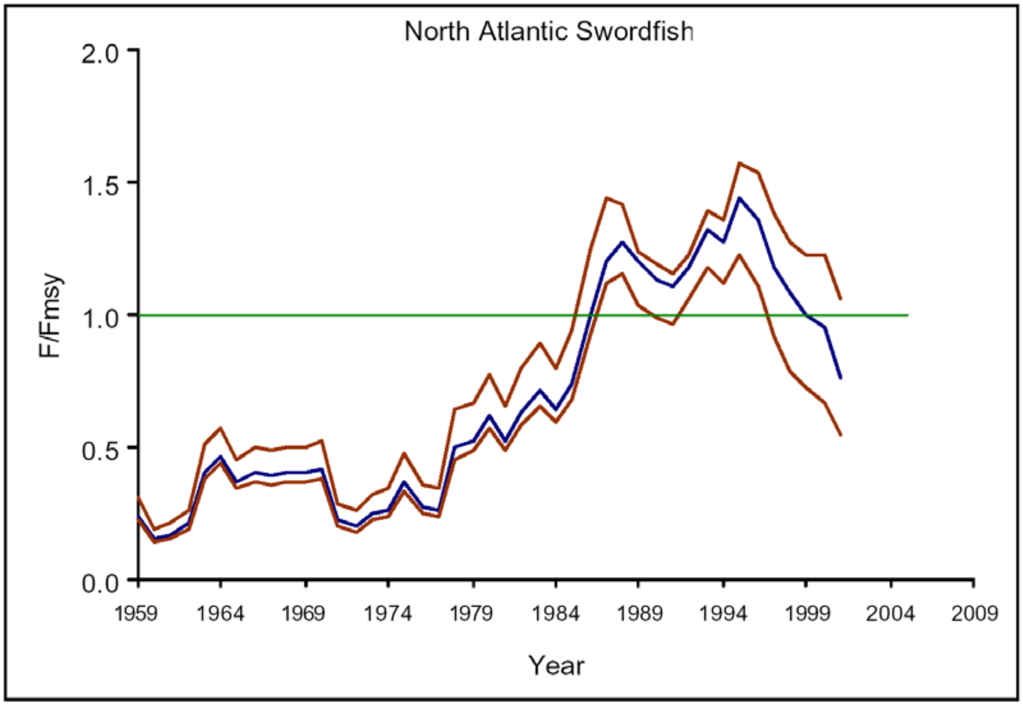

Figure 3.2 **Estimated fishing mortality rate relative to FMSY (F/FMSY) for the period 1959-2001 (median with 80% confidence bounds based on bootstrapping are shown).** Source: SCRS 2004.

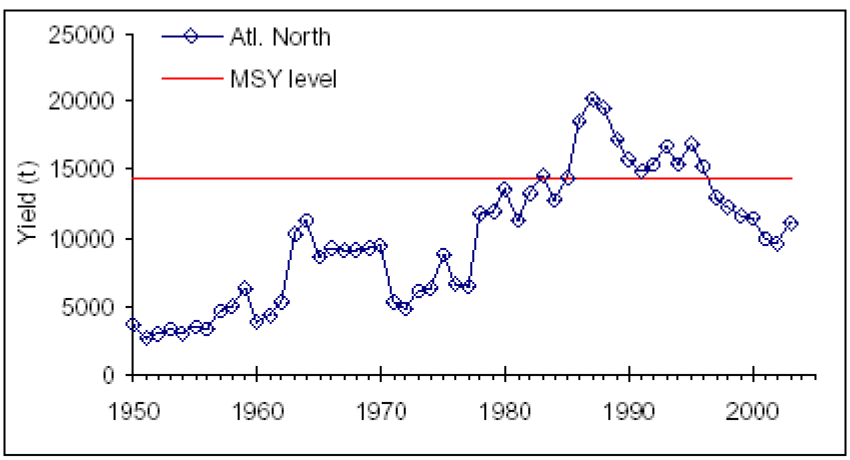

Figure 3.3 **Annual yield (mt) (whole weight) for North Atlantic swordfish relative to the estimated MSY level.** Source: SCRS 2004

Table 3.3 Atlantic Swordfish Stock Summary (weights given in mt ww). Source: SCRS, 2004.

ATLANTIC SWORDFISH SUMMARY		
	North Atlantic	**South Atlantic**
Maximum Sustainable Yield[1]	14,340 t (11,580-15,530)[4]	Not estimated
Current (2003) Yield[2]	11,028 t	10,919 t
Current (2002) Replacement Yield[3]	about MSY	Not estimated
Relative Biomass (B_{2002}/B_{MSY})	0.94 (0.75 - 1.24)	Not estimated
Relative Fishing Mortality		
F_{2001}/F_{MSY}[1]	0.75 (0.54 - 1.06)	Not estimated
F_{2000}/F_{max}	1.08	Not estimated
$F_{2000}/F_{0.1}$	2.05	Not estimated
$F_{2000}/F_{30\%SPR}$	2.01	Not estimated
Management Measures in Effect	Country-specific TACs [Ref. 02-02]; 125/119 cm LJFL minimum size [Ref. 99-02].	TAC target [Ref. 01-02]; 125/119 cm LJFL minimum size [Refs. 90-2 & 95-10].

1 Base Case production model results based on catch data 1950-2001.
2 Provisional and subject to revision, see footnote on SWO-ATL-Table 1.
3 For next fishing year.
4 80% confidence intervals are shown.

Table 3.4 Stock Assessment Summary Table. Source: SCRS 2004.

Species	Current Relative Biomass Level	Minimum Stock Size Threshold	Current Fishing Mortality Rate	Maximum Fishing Mortality Threshold	Outlook**
West Atlantic Bluefin Tuna	SSB_{01}/SSB_{MSY} = 0.31 (low recruitment); 0.06 (high recruitment) SSB_{01}/SSB_{75} = 0.13 (low recruitment); 0.13 (high recruitment)	*$0.86SSB_{MSY}$*	F_{01}/F_{MSY} = 2.35 (low recruitment scenario) F_{01}/F_{MSY} = 4.64 (high recruitment scenario)	F_{year}/F_{MSY} = 1.00	Overfished; overfishing is occurring.
East Atlantic Bluefin Tuna	SSB_{00}/SSB_{70} = 0.80	*Not estimated*	F_{00}/F_{max} = 2.4	*Not estimated*	Overfished; overfishing is occurring.*
Atlantic Bigeye Tuna	B_{03}/B_{MSY} = 0.85-1.07	*$0.6B_{MSY}$ (age 2+)*	F_{02}/F_{MSY} = 0.73-1.01	F_{year}/F_{MSY} = 1.00	Overfished; overfishing is occurring.
Atlantic Yellowfin Tuna	B_{01}/B_{MSY} = 0.73 - 1.10	*$0.5B_{MSY}$ (age 2+)*	F_{01}/F_{MSY} = 0.87-1.46	F_{year}/F_{MSY} = 1.00	Approaching an overfished condition.
North Atlantic Albacore Tuna	B_{00}/B_{MSY} = 0.68 (0.52-0.86)	*$0.7B_{MSY}$*	F_{00}/F_{MSY} = 1.10 (0.99 - 1.30)	F_{year}/F_{MSY} = 1.00	Overfished; overfishing is occurring.
South Atlantic Albacore Tuna	B_{02}/B_{MSY} = 1.66 (0.74-1.81)	*Not estimated*	F_{02}/F_{MSY} = 0.62 (0.46-1.48)	*Not estimated*	Not overfished; overfishing not occurring.*

Species	Current Relative Biomass Level	Minimum Stock Size Threshold	Current Fishing Mortality Rate	Maximum Fishing Mortality Threshold	Outlook**
West Atlantic Skipjack Tuna	*Unknown*	*Unknown*	*Unknown*	F_{year}/F_{MSY} = 1.00	Unknown

* South Atlantic albacore and East Atlantic bluefin tuna are not found in the U.S. EEZ.
** Based on "Sustaining and Rebuilding", National Marine Fisheries Service, 2003, - Report to Congress - The Status of U.S. Fisheries, May 2004.

3.2.2 Atlantic Bluefin Tuna

All text, figures and tables for this Section are from the SCRS 2004 Report and the United States National Report to ICCAT, 2004. All weights are reported as whole weights unless indicated as otherwise.

Life History/Species Biology

Atlantic bluefin tuna are distributed from the Gulf of Mexico to Newfoundland in the West Atlantic, from roughly the Canary Islands to south of Iceland in the East Atlantic, and throughout the Mediterranean Sea. Historically, catches of bluefin were made from a broad geographic range in the Atlantic and Mediterranean.

Atlantic bluefin tuna can grow to over 300 cm and reach more than 650 kg. The oldest age considered reliable is 20 years, based on an estimated age at tagging of two years and about 18 years at liberty, although it is believed that bluefin tuna may live to older ages. Bluefin tuna are, thus, characterized by a late age at maturity (thus, a large number of juvenile classes) and a long life span. These factors contribute to make Bluefin tuna well adapted to variations in recruitment success, but more vulnerable to fishing pressure than rapid growth species such as tropical tuna species. Bluefin tuna in the West Atlantic generally reach a larger maximum size compared to bluefin caught in the East Atlantic.

Bluefin in the west Atlantic are assumed to first spawn at age eight compared to ages four to five in the east Atlantic. Distribution expands with age; large bluefin are adapted for migration to colder waters. Bluefin tuna are opportunistic feeders, with fish, squid, and crustaceans common in their diet. In the West Atlantic, bluefin tuna are thought to spawn from mid-April into June in the Gulf of Mexico and in the Florida Straits. Juveniles are thought to occur in the summer over the continental shelf, primarily from about 35 N to 41 N and offshore of that area in the winter. In the East Atlantic, bluefin tuna generally spawn from late May to July depending on the spawning area, primarily in the Mediterranean, with highest concentrations of larvae around the Balearic Islands, Tyrrhenian Sea, and central and eastern Mediterranean where the sea-surface temperature of the water is about 24^0C. Sexually mature fishes have also been recently observed in May and June in the eastern Mediterranean (between Cyprus and Turkey).

Distribution and Migration

In 1982, ICCAT established a line for separating the eastern and western Atlantic management units based on discontinuities in the distribution of catches at that time in the Atlantic and supported by limited biological knowledge. The United States is allocated quota from the western Atlantic management unit where the U.S. fisheries primarily occur. However, the overall distribution of the catch in the 1990s is much more continuous across the North Atlantic than was seen in previous decades. Tagging evidence indicates that movement of bluefin across the current east/west management boundary in the Atlantic does occur, that movements can be extensive (including transatlantic) and complex, that there are areas of concentration of electronically tagged fish (released in the west) in the central North Atlantic just east of the management boundary, and that fisheries for bluefin tuna have developed in this area in the last decade. At least some of these fish have moved from west of the current boundary (see below for a brief summary of highlights of United States research).

Complementary studies, which might show east to west movement, are less advanced. The composition, and natal origin of these fish in the central North Atlantic area are not known. The SCRS emphasizes that “it is clear that the current boundary does not depict our present understanding of the biological distribution and biological stock structure of Atlantic bluefin tuna.” The SCRS also notes that “the current boundary is a *management* boundary and its effectiveness for management is a different issue.”

There has been an accumulation of evidence on bluefin tuna mixing in the last few years through the collection of tagging data and its examination through the modeling of mixing scenarios for evaluating their effect on management. However, the origin of fish older than one year still remains unknown. Mixing results were reviewed in 2001 by the Workshop on Bluefin Tuna Mixing. This research led to a long-term plan for modeling finer scale spatial mixing and to short-term strategies for assessment to assist the advice for management. The data and research were reviewed again in 2002.

ICCAT, at its 2002 Meeting in Bilbao, called for a *Working Group to Develop Integrated and Coordinated Atlantic Bluefin Tuna Management Strategies* which met in 2003 and again in 2004. In response to the recommendations from these meetings, the SCRS is developing a revised proposal for initiating a coordinated Bluefin Tuna Research Program, to address priority research and data needs for providing scientific advice to ICCAT related to revised management procedures for Bluefin tuna. Uncertainty exists regarding the importance and impacts of mixing on western stocks. The most important uncertainty regarding management advice by the SCRS for the eastern stock is the uncertainty in the catch data that is being taken.

Recent Updates on United States Bluefin Tuna Research

As part of its commitment to the Bluefin Program, research supported by the United States has concentrated on ichthyoplankton sampling, reproductive biology, methods to evaluate hypotheses about movement patterns, spawning area fidelity, stock structure investigations and population modeling analyses.

Ichthyoplankton surveys in the Gulf of Mexico during the bluefin spawning season were continued in 2003 and 2004. Data resulting from these surveys which began in 1977 are used to develop a fishery-independent abundance index of spawning west Atlantic bluefin tuna. This index has continued to provide one measure of bluefin abundance that is used in SCRS assessments of the status of the resource. During 2003 a U.S. scientist participated in the Spanish TUNIBAL project studying the relationships between bluefin larval and adult distributions and hydrography in waters near the Balaeric Islands in the Mediterranean Sea. During the 2004 U.S. ichthyoplankton survey, a plankton net of a type used in the Spanish surveys was fished in addition to the nets normally used to determine the impact of using a wider net mouth and larger mesh on the size and catch rates of bluefin in the Gulf of Mexico.

Scientists at Virginia Institute of Marine Science and Texas A&M University have used nuclear and mitochondrial DNA to investigate the population structure of bluefin tuna in the Mediterranean Sea (SCRS/2004/165). Young of the year bluefin were studied to reduce possible migratory effects. Their results indicate homogeneity within the western Mediterranean basin (Balaeric Islands and Tyrrhenian Sea) and differences between the eastern (Ionian Sea) and western basins. Samples collected for these studies were obtained by, or in cooperation with, European scientists from multiple locations including Spain and several locations in Italy; financial and logistical assistance was also provided by the ICCAT bluefin year program.

Since 1998, researchers from Texas A & M University and the University of Maryland with assistance of researchers from Canada, Europe, and Japan have studied the feasibility of using otolith chemical composition (microcontituents and isotopes) to distinguish bluefin stocks. Recent research has investigated the value of using additional microconstituent elements (transitional metals) to enhance classification success. By themselves the transitional metals provided little discriminatory power, but when combined with the other trace elements (for 13 elements in all), the classification success was improved to about 80-90 percent. Studies of classification success using oxygen isotopes continue.

Scientists at University of Maryland, Virginia Institute of Marine Science, and Texas A&M University have continued to sample specimens for genetic and otolith chemistry studies of stock structure. Roughly 10-20 young-of-the-year were collected in 2003. In addition, limited sampling of ages one and older continues. Efforts are also continuing to obtain samples from juveniles and mature bluefin from the Mediterranean Sea and adjacent waters.

In response to ICCAT's request for options for alternative approaches for managing mixed populations of Atlantic bluefin tuna, SCRS/2003/108 examined approaches to developing more complex models of bluefin population dynamics including detailed spatial information and methods for assessing the resources and examining management procedures. SCRS/2003/105 proposed the evaluation of possible age structured assessment using more complex geographic stratification and movement scenarios than have been used in recent assessments. Document SCRS/2004/166 further extends that work and shows that, under the proposed model structure, west Atlantic bluefin population trends from the conventional ICCAT assessments can be replicated while the most recent east Atlantic assessment trends cannot. It also corroborated earlier results that showed that estimated west Atlantic population trends are influenced by assumptions about movement rates and patterns.

In May 2004, scientists from (1) Stanford University and the Monterey Bay Aquarium and (2) the New England Aquarium and the University of New Hampshire made presentations on their research findings to the SCRS meeting on bluefin tuna management strategies held in France. Researchers at the Imperial College, London are working with the University of Miami, the University of New Hampshire, and NOAA/NMFS to develop methods to estimate bluefin movement and fishing mortality rate patterns (SCRS/2004/164). An operational model is being developed which will use conventional and electronic tagging data and fishing effort by management area. The operational model will be used to examine possible harvest control rules and the evaluation of possible management procedures.

A thorough review of recreational catch estimation procedures for HMS species, including but not limited to BFT, was conducted during 2004, focusing on a survey program covering the rod and reel fishery along the Atlantic Coast of the U.S. from Virginia northward. U.S. scientists also worked cooperatively with scientists in Brazil, instructing a course on CPUE standardization methods and applications to stock assessment (Recife, Brazil, June 7-12 2004).

SCRS Recent Stock Assessment Results

The last full stock assessments for western Atlantic Bluefin tuna were conducted in 2002 with the next scheduled for 2006. The assessment results are similar to those from previous assessments (see Figure 3.4). They indicate that the spawning stock biomass (SSB) declined steadily from 1970 (the first year in the assessment time series) through the late 1980s, before leveling off at about 20 percent of the level in 1975 (which has been a reference year used in previous assessments). A steady decline in SSB since 1997 is estimated and leaves SSB in 2001 at 13 percent of the 1975 level. The assessment also indicates that the fishing mortality rate during 2001 on the spawning stock biomass (SSB) is the highest level in the series.

Estimates of recruitment of age one fish have been generally lower since 1976. However, recruitment of age one fish in 1995 and 1998 is estimated to be comparable in size to some of the year-classes produced in the first half of the 1970s. While the large decline in SSB since the early 1970s is clear from the assessment, the potential for rebuilding is less clear. Key issues are the reasons for relatively poor recruitment since 1976, and the outlook for recruitment in the future. One school of thought is that recruitment has been poor because the SSB has been low. If so, recruitment should improve to historical levels if SSB is rebuilt. Another school of thought is that the ecosystem changed such that it is less favorable for recruitment and thus recruitment may not improve even if SSB increases. To address both schools of thought, the SCRS considered two recruitment scenarios as described below and summarized in Table 3.5. (East Atlantic Bluefin tuna summary data is also provided for comparison purposes). For both scenarios, the assessment indicates that the fishing mortality on the western Atlantic bluefin resource exceeds F_{MSY} and the SSB is below B_{MSY} (thus overfished according to ICCAT's objective of maintaining stocks at the MSY-biomass level and as indicated in the NMFS 2003).

Table 3.5 Summary Table for the Status of West Atlantic Bluefin Tuna

Age/size at Maturity	Age 8/~ 200 cm fork length
Spawning Sites	Primarily Gulf of Mexico and Florida Straits
Current Relative Biomass Level ***Minimum Stock Size Threshold***	SSB_{01}/SSB_{75} (low recruitment) = .13 (.07-.20) SSB_{01}/SSB_{75} (high recruitment) = .13 (.07-.20) SSB_{01}/SSB_{msy} (low recruitment) = .31 (.20-.47) SSB_{01}/SSB_{msy} (high recruitment) = .06 (.03-.10) $0.86B_{MSY}$
Current Relative Fishing Mortality Rate ***Maximum Fishing Mortality Threshold***	F_{01}/F_{MSY} (low recruitment) = 2.35 (1.72-3.24) F_{01}/F_{MSY} (high recruitment) = 4.64 (3.63-6.00) $F/F_{MSY} = 1.00$
Maximum Sustainable Yield	Low recruitment scenario: 3,500 mt (3,300-3,700) High recruitment scenario: 7,200 mt (5,900-9,500)
Catch (2003) including discards	2,146 mt
Short Term Sustainable Yield	Probably > 3,000 mt
Outlook	Overfished; overfishing continues to occur

Table 3.6 Summary Table for the Status of East Atlantic Bluefin Tuna

Age/size at Maturity	Age 4-5
Spawning Sites	Mediterranean Sea
Current Relative Biomass Level	SSB_{00}/SSB_{1970} = .80
Current Relative Fishing Mortality Rate	$F_{00}/F_{MAX} = 2.4$
Maximum Sustainable Yield	Not estimated
Current (2001) Yield	34,557 mt
Yield (long term)	23,543 to 24,649 mt
Outlook	Overfished; overfishing continues to occur.

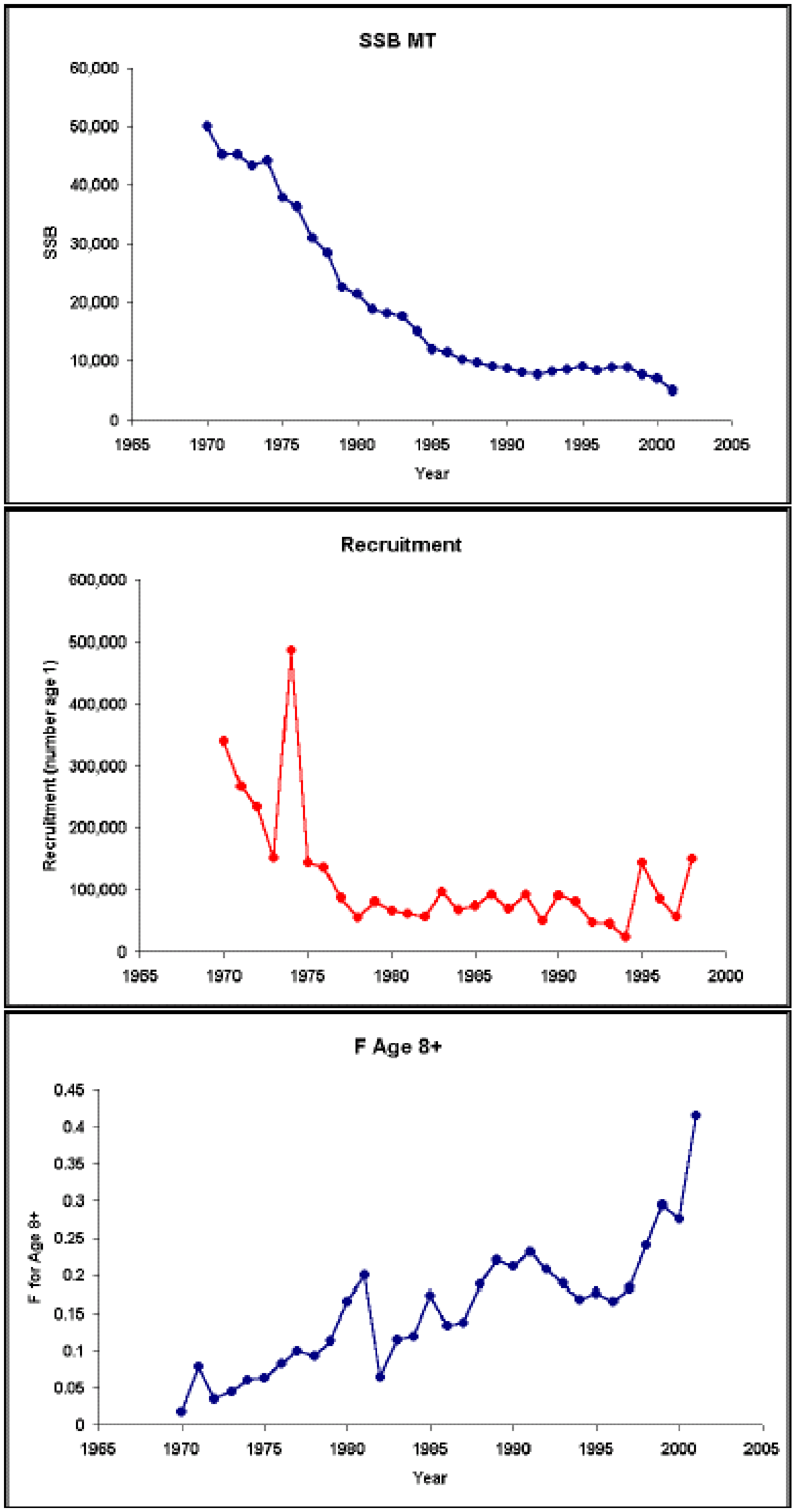

Figure 3.4 **West Atlantic bluefin tuna spawning biomass (t), recruitment (numbers) and fishing mortality rates for fish of age 8+ , estimated by the Base Case VPA run.**

SCRS Advice and Management Actions

The SCRS's management recommendation for the western Atlantic bluefin tuna management area is directed at the Rebuilding Program adopted by ICCAT in 1998. According to the Program, the MSY rebuilding target can be adjusted according to advice from SCRS. In 2002, ICCAT set the annual Total Allowable Catch (TAC), inclusive of dead discards, for the western Atlantic management area to 2,700 mt, effective beginning in 2003. The Program states that the TAC for the west would only be adjusted from the 2,500 mt level adopted for 2003-2004 if SCRS advises that (a) a catch of 2,700 mt or more has a 50 percent or greater probability of rebuilding or (b) a catch of 2,300 mt or less is necessary to have a 50 percent or greater probability of rebuilding.

The Program is designed with the intent to rebuild with 50 percent probability by 2018 to the spawning biomass level associated with MSY. In light of the uncertainty in the assessment, the choice between recruitment scenarios and rebuilding targets, and assumptions about mixing, the weight of scientific opinion within the SCRS favored no change from the current TAC of 2,500 mt per year. Projections based on the low recruitment scenario indicate that the TAC could be increased without violating the Rebuilding Program, assuming that relatively large recruitment estimates for some recent year-classes are realistic. The high levels of recruitment estimated for some recent year-classes are consistent with a higher biomass level as a rebuilding target. In previous assessment sessions, the spawning biomass level in 1975 was considered a useful rebuilding target. The 1975 biomass is more than twice the MSY spawning biomass level associated with the low recruitment scenario. The projections indicate a 35-60 percent probability of rebuilding to the 1975 spawning biomass level for a catch of 2,500 mt per year, depending on the recruitment scenario assumed. It seems likely that a recruitment scenario corresponding to a SSB_{MSY} equal to the level in 1975 would indicate a probability of rebuilding by 2018 for a catch of 2,500 mt per year within the range of 35-60 percent.

The MSY spawning biomass associated with the high recruitment scenario, which is nearly twice the 1975 level, is unlikely to be reached by 2018 if the recent level of catch (and TAC) is maintained. However, the SCRS does not recommend the sharp reduction in TAC that would be necessary to comply with the rebuilding Program based on the high recruitment scenario because of:

- Uncertainty about which recruitment scenario is most appropriate;
- Recognition that for the high recruitment scenario the spawning biomass associated with MSY is not well determined (because estimation leads to extrapolation beyond biomass levels included within the current assessment); and
- The generally positive outlook for the resource according to the current assessment regardless of the recruitment scenario assumed.

As emphasized in previous assessments, mixing across management unit boundaries of fish of western and eastern origin could be important for management of the resource in both areas. In particular, the condition of the eastern Atlantic stock and fishery could adversely affect recovery in the West Atlantic, which was also noted in the SCRS's 1998, 2000, and 2001 reports.

Therefore, the SCRS stressed the importance of continuing efforts to manage the fisheries in both the East and West Atlantic according to ICCAT's objectives.

SCRS Evaluation of Management Measures

The first regulatory measure for a scientific monitoring level was adopted for western Atlantic bluefin catches in 1981. Since then, monitoring levels have been changed in various years. Until 1987, both estimated catches and landings were below or equal to the level of the catch limits. However, from 1988 to 1997, estimated landings were very close to the level of the limits and, for some years, exceeded the limit by a maximum of 100 mt. Estimated catches (including discards) were higher than the limits every year during this period (by about 200 to 300 mt) with the exceptions of 1992 and 1997. The estimated catches exceeded the 2,500 mt limit in 2000 by 165 mt, by 218 mt in 2001, and by 715 mt in 2002. It should be pointed out that for compliance purposes, some countries (including the United States) are using fishing years that do not correspond to calendar years. Also, according to the ICCAT regulatory measure, the amount of catch that exceeded quota or was left over from the quota can be carried over to succeeding years. Hence, the catch limit set for each year could have been adjusted accordingly. The SCRS notes that the excess of the catch limits in most recent years is due to some new fisheries that operated without a quota.

For the West Atlantic, a size limit of 6.4 kg with 15 percent allowance, in number of fish, has been in effect since 1975. In addition, a prohibition on the taking and landing bluefin tuna less than 30 kg (or 115 cm) with an 8 percent tolerance, by weight on a national basis, became effective in 1992. The SCRS notes that, since 1992, the proportion of undersized fish for all catches combined has been below the allowance level (e.g., 1 percent and 3 percent <115cm in 2000 and 2001, respectively). In 2002, ICCAT set the annual TAC, inclusive of dead discards, for the western Atlantic management area to 2,700 mt, effective beginning in 2003. The reported 2003 catches were 2,146 mt.

SCRS Outlook

In general, the outlook for bluefin tuna in the West Atlantic is similar to the outlook reported based on the 2000 western Atlantic bluefin tuna assessment session. The assessment and projection results for the present assessment are somewhat less optimistic than in 2000 but the confidence in the strength of the 1994 year-class has increased. Therefore, the increases associated with different levels of future catch projected for the short-term are smaller but are estimated more confidently. It should be noted that the 1995 year-class was estimated to be strong in 2000, but it is now estimated to be only of average strength.

As noted by the previous assessment session, western Atlantic bluefin tuna catches have not varied very much since 1983 (the range over this period is 2,106 to 3,011 mt), and the estimated spawning stock size (Spawning Stock Biomass (SSB) measured as the biomass of fish age 8+) has been relatively stable, notwithstanding the indication of a decline in the most recent years. Thus, over an extended period of time, catches around recent levels have maintained stock size at about the same level, in spite of several past assessments that predicted the stock would either decline or grow if the current catch was maintained. This observation highlights the challenge of predicting the outlook for this stock.

In order to provide advice relative to rebuilding the western Atlantic bluefin resource, the SCRS conducted projections for two scenarios about future recruitment. One scenario assumed that future average recruitment will approximate the average estimated recruitment (at age one) since 1976, unless spawning stock size declines to low levels (such as the current level estimated in the assessment, but generally lower than estimates during most of the assessment history). The second scenario allowed average recruitment to increase with spawning stock size up to a maximum level no greater than the average estimated recruitment for 1970 to 1974. These scenarios are referred to as the low recruitment and high recruitment scenarios, respectively. The low and high recruitment scenarios implied that the B_{MSY} (expressed in SSB) is 42 percent and 183 percent of the biomass in 1975, respectively. With the current information the SCRS could not determine which recruitment scenario is more likely, but both are plausible, and recommended that management strategies should be chosen to be reasonably robust to this uncertainty.

Table 3.7below summarizes the results of projections of both scenarios at different catch levels. The projections for the low recruitment scenario estimated that a constant catch of 3,000 mt per year has an 83 percent probability of allowing rebuilding to the associated SSB_{MSY} by 2018. A constant catch of 2,500 mt per year has a 35 percent probability of allowing rebuilding to the 1975 SSB by 2018.

The results of projections based on the high recruitment scenario estimated that a constant catch of 2,500 mt per year has a 60 percent probability of allowing rebuilding to the 1975 level of SSB, and there is a 20 percent chance of rebuilding SSB to SSB_{MSY} by 2018. If the low recruitment scenario is valid, the TAC could be increased to at least 3000 mt without violating ICCAT's rebuilding plan. If the high recruitment scenario is valid, the TAC should be decreased to less than 1,500 mt to comply with the plan.

Table 3.7 Probability of western Atlantic bluefin tuna achieving rebuilding target by 2018.

Catch	**Low Recruitment Scenario**		**High Recruitment Scenario**	
(MT)	**SSB_{1975}**	**SSB_{MSY}**	**SSB_{1975}**	**SSB_{MSY}**
500	95 %	100 %	98 %	73 %
1,000	89 %	100 %	96 %	62 %
1,500	77 %	100 %	87 %	47 %
2,000	60 %	99 %	75 %	30 %
2,300	45 %	98 %	66 %	24 %
2,500	35 %	97 %	60 %	20 %
2,700	26 %	95 %	52 %	17 %
3,000	14 %	83 %	38 %	11 %
5,000	0 %	1 %	2 %	0 %

The estimate of SSB_{MSY} for the high recruitment scenario is critical to inferences regarding the probability of achieving rebuilding under different future levels of catch, and also less well determined by the data than SSB_{MSY} for the low recruitment scenario. In particular, the estimates of SSB_{MSY} based on the high recruitment scenario are substantially larger than the largest spawning stock size included in the assessment. This extrapolation considerably increases the uncertainty associated with these estimates of SSB_{MSY}. Previous meetings have used SSB_{1975} as a rebuilding target in the context of interpreting projections. Arguably SSB_{1975} is appropriate as a target level for interpreting the implications of projections based on the high recruitment scenario. Under such a target level for the high recruitment scenario, a TAC of 2,700 mt has an estimated probability of reaching the rebuilding level of about 50 percent.

The SCRS cautioned that these conclusions do not capture the full degree of uncertainty in the assessments and projections. An important factor contributing to uncertainty is mixing between fish of eastern and western origin. Furthermore, the projected increases in stock size are strongly dependent on estimates of recent recruitment, which are a particularly uncertain part of the assessment. A sensitivity test in which the estimates of the below average 1996 and the strong 1997 year-classes were excluded from the analysis gave somewhat less optimistic results in terms of the estimated probabilities of recovery by 2018. However, these projections still predicted increases in spawning biomass for both recruitment scenarios, except for extreme increases in catch.

3.2.3 Atlantic Bays Tuna

All text, figures and tables for this Section are from the SCRS 2004 Report and the United States National Report to ICCAT, 2004. All weights are reported as whole weights unless indicated as otherwise.

3.2.3.1 Atlantic Bigeye Tuna

Biology/Life History

The geographical distribution of bigeye tuna is very wide and covers almost the entire Atlantic Ocean between 50 N and 45 S. This species is able to dive deeper than other tuna species and exhibits extensive vertical movements. Similar to the results obtained in other oceans, pop-up tagging and sonic tracking studies conducted on adult fish in the Atlantic has revealed that they exhibit clear diurnal patterns being much deeper in the daytime than at night. Spawning takes place in tropical waters when the environment is favorable. From the nursery areas in tropical waters, juvenile fish tend to diffuse into temperate waters as they grow larger. Catch information from the surface gears indicate that the Gulf of Guinea is a major nursery ground for this species.

Dietary habits of bigeye tuna are varied such that various prey organisms like fish, mollusks, and crustaceans are found in stomach contents. A growth study based on otolith and tagging data resulted in the adoption by the SCRS of a new growth curve. The curve shows bigeye tuna exhibit relatively fast growth: about 105 cm in fork length at age three, 140 cm at age five and 163 cm at age seven. Bigeye tuna become mature at about age three and a half. Young fish form schools mostly mixed with other tunas such as yellowfin and skipjack. These schools are often associated with drifting objects, whale sharks and sea mounts. This association appears to weaken as bigeye tuna grow larger. An estimate of natural mortality (M) for juvenile fish was provided based on the results of a tagging program. According to this study, mortality for juvenile fish only is at a similar level of M as that currently used for the entire Atlantic stock as well as the level of M used for all other oceans. Various evidence including; a genetic study, the time-area distribution of fish, and movements of tagged fish, suggest an Atlantic-wide single stock for this species, which is currently accepted by the SCRS. However, the possibility of other scenarios, such as north and south stocks, should not be disregarded.

Recent Updates on United States Bigeye Tuna Research

During 2004, U.S. scientists participated in both the Bigeye Tuna Year Program (BETYP) Symposium (Madrid, Spain, March 8 – 9, 2004) and the Second World Bigeye Tuna Meeting (Madrid, Spain, March 10 - 13, 2004). Contributed papers included SCRS/2004/038, describing the simulated aggregation of bigeye tuna in free schools versus those associated with fish aggregating devices, and SCRS/2004/059, which reviewed published work on yellowfin tuna growth and compared parameter estimates in the context of potential impact on the catch-at-age matrices used for stock assessment. U.S. scientists took part in the 2004 ICCAT Bigeye Tuna Stock Assessment (Madrid, Spain, June 28 - July 3, 2004). For this meeting, relative abundance patterns based on U.S. pelagic longline data from 1982 to 2003 were presented in SCRS/2004/133.

SCRS Recent Stock Assessment Results

A new stock assessment was conducted for bigeye tuna in July 2004. Due to the early date of the meeting, the catch information for 2003 was incomplete and could not be incorporated in the assessment. The 2004 stock assessment was conducted using various types of models. However, there were considerable sources of uncertainty arising from the lack of information regarding (a) reliable indices of abundance for small bigeye from surface fisheries, (b) the species composition of Ghanaian fisheries that target tropical tunas, and (c) details on the historical catch and fishing activities of Illegal, Unregulated, Unreported (IUU) fleets (e.g., size, location and total catch).

Three indices of relative abundance were available to assess the status of the stock (Figure 3.5). All were from longline fisheries conducted by Japan, Chinese Taipei and United States. While the Japanese indices have the longest duration since 1961 and represent roughly 20-40 percent of the total catch, the other two indices are shorter and generally account for a smaller fraction of the catch than the Japanese fishery. These three indices primarily relate to medium and large-size fish.

Various types of production models were applied to the available data and the SCRS notes that the current year’s model fits to the data were better than in past assessments, although they required similar assumptions regarding stock productivity. The point estimates of MSY obtained from different production models ranged from 93,000 mt to 113,000 mt. The lower limit of this range is higher than the one estimated in the 2002 assessment, probably due to the revised indices and the addition of a new index. An estimate obtained from another age-aggregated model was 114,000 mt. The inclusion of estimation uncertainty would broaden this range considerably.

These analyses estimate that the total catch was larger than the upper limit of MSY estimates for most years between 1993 and 1999, causing the stock to decline considerably, and leveling off thereafter as total catches decreased. These results also indicate that the current biomass is slightly below or above (85 – 107 percent) the biomass at MSY (Figure 3.6), and that current fishing mortality is also in the range of 73 percent to 101 percent of the level that would allow production of MSY (Table 3.8). However, indications from the most targeted and wide-ranging fishery are of a more pessimistic status than implied by these model results. Several types of age-structured analyses were conducted using the above-mentioned longline indices from the central fishing grounds and catch-at-age data converted from the available catch-at-size data. In general, the trajectories of biomass and fishing mortality rates are in accordance with the production model analyses. Model fits appeared improved over those of past assessments, apparently as a result of using a new growth curve for the calculation of catch at age.

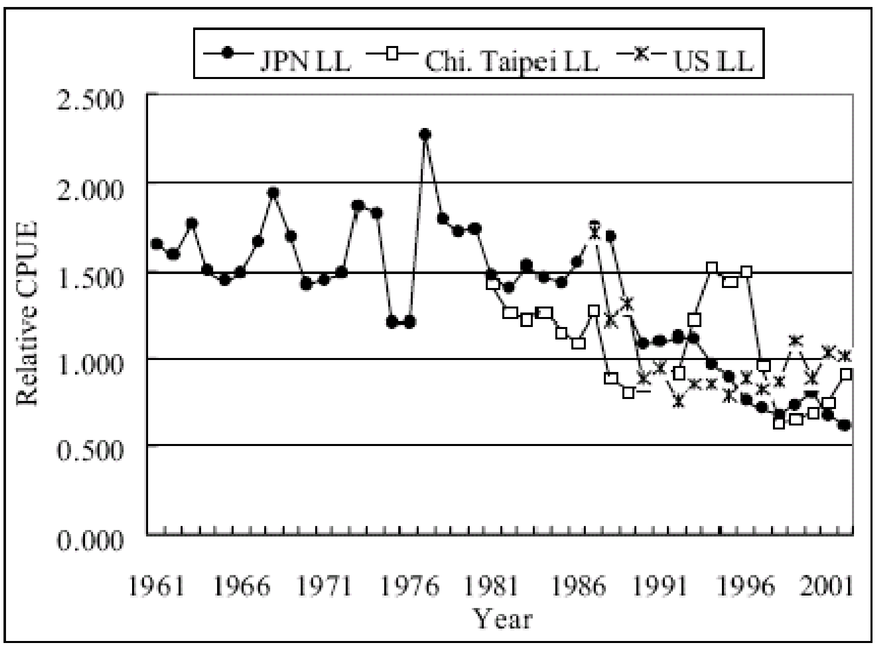

Figure 3.5 **Abundance indices in numbers of BET. All ages are aggregated**

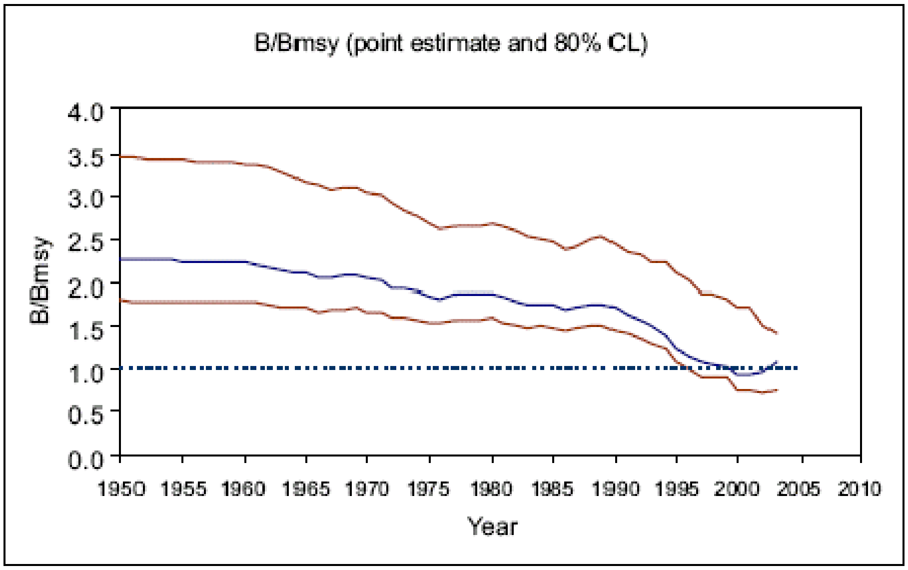

Figure 3.6 **Trajectory of the BET biomass modeled in production model analysis (middle line) bounded by upper and lower lines denoting 80 percent confidence intervals**

Table 3.8 **Summary Table for the Status of Atlantic Bigeye Tuna**

Age/size at Maturity	Age 3/~100 cm curved fork length
Spawning Sites	Tropical waters
Current Relative Biomass Level ***Minimum Stock Size Threshold***	B_{03}/B_{MSY} = 0.85 - 1.07 $0.6B_{MSY}$ (age 2+)
Current Relative Fishing Mortality Rate ***Maximum Fishing Mortality Threshold***	F_{02}/F_{MSY} = 0.73-1.01 F_{year}/F_{MSY} = 1.00
Maximum Sustainable Yield	93,000 - 114,000 mt
Current (2003) Yield	85,000 mt
Current (2003) Replacement Yield	89,000 - 103,000 mt
Outlook	Overfished; overfishing is occurring

SCRS Advice and Management Actions

Previous yield-per-recruit and spawner-per-recruit analyses highlighted the potential importance of reducing fishing mortality on small fish. However, the percentage of fish caught less than this minimum size (3.2 kg) is very high (46-62 percent of the total fish caught) since

1989. The SCRS, therefore, recommends the full implementation of the moratorium on Fish Aggregation Device (FAD) fishing by all surface fisheries in the Gulf of Guinea. This assessment indicated that the stock has declined due to the large catches made since the mid-1990s to around or below the level that produces the MSY, and that fishing mortality exceeded F_{MSY} for several years during that time period. Projections indicate that catches of more than 100,000 mt will result in continued stock decline. ICCAT should be aware that if major countries were to take the entire catch limit set under the ICCAT Recommendations and other countries were to maintain recent catch levels, then the total catch could exceed 100,000 mt. The SCRS highly recommended that catch levels of around 90,000 mt or lower be maintained at least for the near future for ICCAT to rebuild the stock.

The SCRS noted its appreciation for the effort made by ICCAT in establishing the Statistical Document Program for bigeye tuna and expressed hope that the data to be submitted to the Secretariat will be useful to improve estimates of unreported catches. The SCRS also stated its appreciation regarding the initiatives to reduce the IUU activities taken by several fishing authorities. These efforts are helpful in identifying and reducing the unreported catches in the Atlantic and will make the catch limit regulation more effective, and thus will contribute to reduce uncertainties in the bigeye stock assessment. As far as the IUU catches of BET are concerned, they are almost disappearing according to the available estimates. Nevertheless, the SCRS expressed concern that unreported catches may have been under-estimated.

SCRS evaluation of current regulations

ICCAT recommended a bigeye tuna minimum size regulation of 3.2 kg in 1980 to reinforce the same regulation for yellowfin tuna. It is clear that a large quantity of juvenile bigeye tuna smaller than 3.2 kg continues to be captured mostly from the equatorial surface fleets (baitboat and purse seine). The percentage and total number of fish smaller than the minimum size has increased since 1989 and was more than 45 percent of the total fish caught or more than six million fish thereafter, although the absolute number of undersized fish might have been reduced in some fisheries. According to previous yield-per-recruit analyses, a full implementation of this regulation could result in an increase in yield-per-recruit by almost 20 percent at F_{max}.

The moratorium on FAD fishing by surface gears in the Gulf of Guinea has been implemented by ICCAT since 1999. The full evaluation of this program is somewhat hindered by the multi-species nature of surface fisheries and the existence of other types of fisheries. The updated analysis indicated that this regulation appeared effective in reducing mortality for juvenile bigeye and increasing the spawning biomass per recruit. The full compliance with this regulation by all surface fisheries will greatly increase the effectiveness of this regulation. The SCRS was pleased to note that Ghana implemented this moratorium in the 2003/2004 season (SCRS/2004/027).

Limiting the annual catch to the average catch in two years of 1991 and 1992 entered into force for the major fishing countries whose 1999 catch reported to the 2000 SCRS was larger than 2,100 mt. The 2003 total reported catch for the major countries and fishing entities to which the catch limit applies (EC-Spain, EC-France, EC-Portugal, Japan, Ghana, China and Chinese Taipei) was 67,700 mt and 18,800 mt lower than the total catch limit (86,500 mt). As a whole, the total catch in 2003 for all countries is about 11,300 mt lower than the average total catch of 1991 and 1992.

SCRS Outlook

Stock projections were conducted based on the production model results, assuming a catch of 75,480 mt in 2003 and varying levels of constant catch thereafter. The projection results suggest that the biomass of the stock will likely decline further with constant catches of 100,000 mt or more. On average, increases in biomass are expected with catches of 90,000 mt or less. However, due to uncertainty, there is a non-negligible probability of further decline of the stock with a constant future catch of 100,000 mt or more.

3.2.3.2 Atlantic Yellowfin Tuna

Life History/Biology

Yellowfin tuna is a cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three oceans, where they form large schools. The sizes exploited range from 30 cm to 170 cm Fork Length (FL). Smaller fish (juveniles) form mixed schools with skipjack and juvenile bigeye, and are mainly limited to surface waters, while larger fish are found in surface and sub-surface waters. The majority of the long-term recoveries of tagged fish have been tagged in the West Atlantic and recovered in the East Atlantic, where several recaptures are recorded each year.

Sexual maturity occurs at about 100 cm FL. Reproductive output among females has been shown to be highly variable, although the extent of this is unknown. The main spawning ground is the equatorial zone of the Gulf of Guinea, with spawning occurring from January to April. Juveniles are generally found in coastal waters off Africa. In addition, spawning occurs in the Gulf of Mexico, in the southeastern Caribbean Sea, and off Cape Verde, although the relative importance of these spawning grounds is unknown.

Although such separate spawning areas might imply separate stocks or substantial heterogeneity in the distribution of yellowfin tuna, a single stock for the entire Atlantic is assumed as a working hypothesis (Atlantic Yellowfin Working Group, Tenerife, 1993), taking into account the transatlantic migration (from west to east) indicated by tagging, a 40-year time series of longline catch data that indicates yellowfin are distributed continuously throughout the entire tropical Atlantic Ocean, and other information (e.g., time-area size frequency distributions and locations of fishing grounds).

Growth patterns are variable with size, being relatively slow initially, and increasing at the time the fish leave the nursery grounds. Males are predominant in the catches of larger sized fish. Natural mortality is assumed to be higher for juveniles than for adults. This assumption is supported by tagging studies for Pacific yellowfin. New data on biology and catches obtained from the Brazilian longline fishery were presented in 2004.

Recent Updates on United States Yellowfin Tuna Research

During 2003, several collaborative studies were conducted by U.S. scientists in cooperation with scientists from other countries. Cooperative research by the U.S. NOAA Fisheries and Mexico continued and resulted in a joint analysis of United States and Mexican longline catch-per-unit-effort (CPUE) of yellowfin in the Gulf of Mexico (SCRS/2003/061). Cooperative research plans include further development of abundance indices for sharks and other tunas, as well as the refinement of the yellowfin tuna indices as additional data become available. Cooperative research on yellowfin tuna abundance indices, catch-at-age, and life-history studies is also continuing with Venezuelan scientists. One document on Venezuelan longline catch rate patterns resulted from this collaboration in 2003 (SCRS/2003/054) and additional working papers based on this collaboration are expected in future years.

U.S. scientists participated in the 2003 ICCAT Yellowfin Tuna Stock Assessment (Merida, Mexico, July 21-26, 2003), and submitted several other working papers. Two relative abundance patterns (one for the Gulf of Mexico and another for the Atlantic regions fished by U.S. longline vessels) based on U.S. pelagic longline data from 1981 to 2002 were presented in SCRS/2003/060. Additionally, a relative abundance index based on data collected through the Large Pelagic Survey from the Virginia-Massachusetts rod and reel fishery (1986-2002) was presented in SCRS/2003/062.

New information from a genetic study was presented in SCRS/2003/063. The phylogenetic analysis conducted on samples from the Gulf of Mexico and Gulf of Guinea by researchers at Texas A&M, Galveston, revealed the presence of siblings in several sampling tows for juvenile tuna. Given the high level of genetic diversity at both the mitochondrial and microsatellite loci, the probability of such sampling is extremely low and can best be explained by the unequal reproductive output of certain females. Increases in vulnerability of juvenile yellowfin tuna could be of concern in terms of genetic integrity of the population if levels of reproductive variance are confirmed to be large.

U.S. scientists also worked in cooperation with outside experts to study alternatives for improving the collection of catch statistics in the U.S. recreational yellowfin tuna fishery. A U.S. scientist attended the Tuna Statistics Meeting (Tema, Ghana, February 2-5, 2003) and collaborated with scientists from other nations (including Ghana) in the design of a pilot study to develop a sampling scheme for Ghana's tropical tuna fishery.

SCRS Recent Stock Assessment Results

A full assessment was conducted for yellowfin tuna in 2003 applying various age-structured and production models to the available catch data through 2001. Unfortunately, at the time of the assessment meeting, only 19 percent of the 2002 catch had been reported (calculated relative to the catch reports available at the time of the SCRS Plenary). The results from all models were considered in the formulation of the SCRS's advice.

The variability in overall catch-at-age is primarily due to variability in catches of ages zero and one (note that the catches in numbers of ages zero and especially one were particularly high during the period 1998-2001). Both equilibrium and non-equilibrium production models were examined in 2003 and the results are summarized in Table 3.9. The estimate of MSY based upon the equilibrium models ranged from 151,300 to 161,300 t; the estimates of F_{2001}/F_{MSY} ranged from 0.87 to 1.29. The point estimate of MSY based upon the non-equilibrium models ranged from 147,200-148,300 mt. The point estimates for F_{2001}/F_{MSY} ranged from 1.02 to 1.46. The main differences in the results were related to the assumptions of each model. The SCRS was unable to estimate the level of uncertainty associated with these point estimates. An age-structured virtual population analysis (VPA) was made using eight indices of abundance. The results from this model were more comparable to production model results than in previous assessments, owing in part to a greater consistency between several of the indices used. The VPA results compare well to the trends in fishing mortality and biomass estimated from production models. The VPA estimates that the spawning biomass (Figure 3.7) and the levels of fishing mortality (Figure 3.8) in recent years have been very close to MSY levels. The estimate of MSY derived from these analyses was 148,200 mt.

In summary, the age-structured and production model analyses implied that although the 2001 catches of 159,000 mt were slightly higher than MSY levels, effective effort may have been either slightly below or above (up to 46 percent) the MSY level, depending on the assumptions. Consistent with these model results, yield-per-recruit analyses also indicated that 2001 fishing mortality rates could have been either above or about the level which could produce MSY. Yield-per-recruit analyses further indicated that an increase in effort is likely to decrease the yield-per-recruit, while reductions in fishing mortality on fish less than 3.2 kg could result in substantial gains in yield-per-recruit and modest gains in spawning biomass-per-recruit.

Table 3.9 Summary Table for the Status of Atlantic Yellowfin Tuna

Age/size at Maturity	Age 3/~110 cm curved fork length
Spawning Sites	Tropical waters
Relative Biomass Level ***Minimum Stock Size Threshold***	B_{01}/B_{MSY} = 0.73 - 1.10 $0.5B_{MSY}$ (age 2+)
Relative Fishing Mortality Rate ***Maximum Fishing Mortality Threshold***	F_{01}/F_{MSY} = 0.87 - 1.46 F_{year}/F_{MSY} = 1.00
Maximum Sustainable Yield	147,200 - 161,300 mt
Current (2003) Yield	124,000 mt
Replacement Yield (2001)	May be somewhat below the 2001 yield (159,000 mt)
Outlook	Approaching an overfished condition

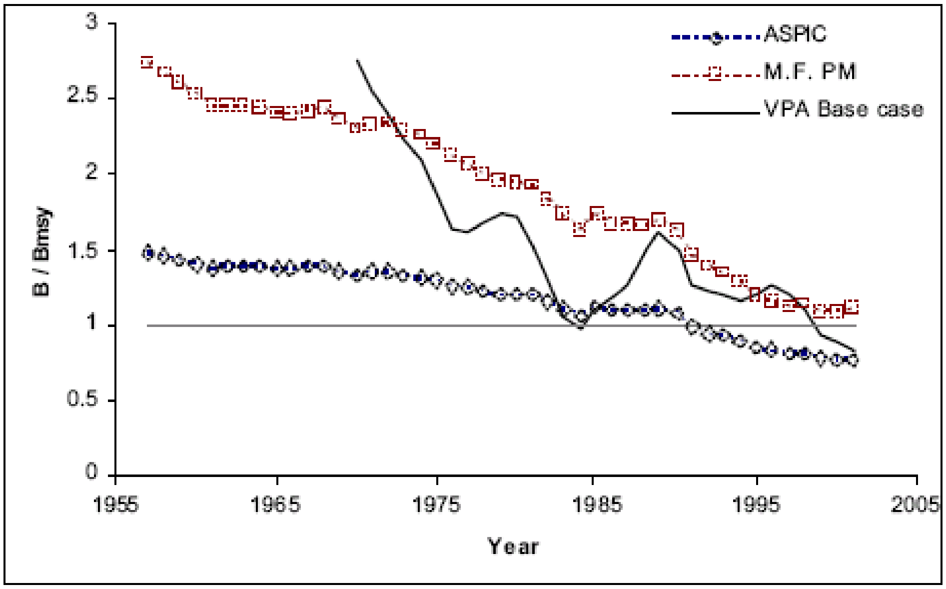

Figure 3.7 **Comparison of relative biomass trends calculated using VPA and non-equilibrium production models.**

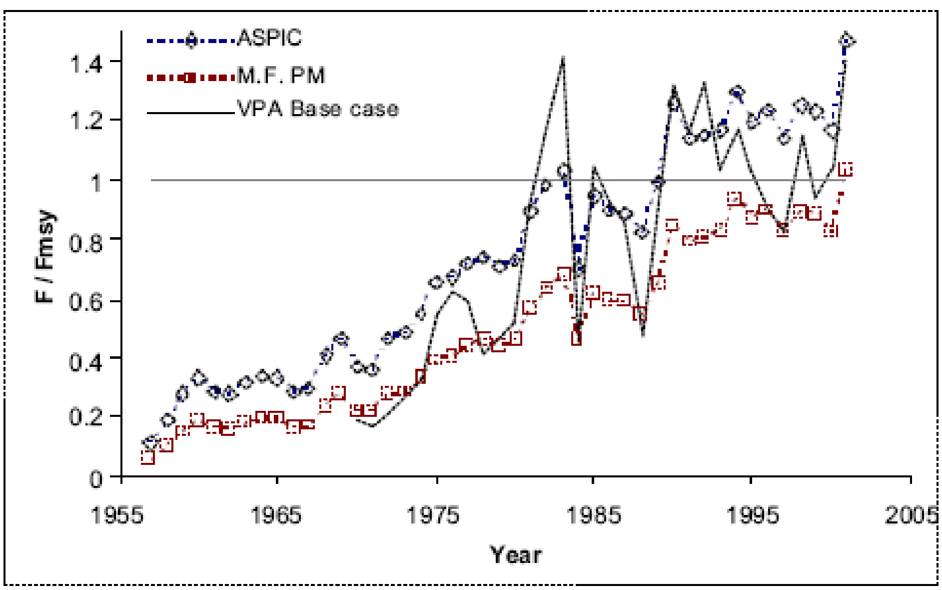

Figure 3.8 Comparison of relative fishing mortality trends calculated using VPA and non-equilibrium production models.

SCRS Advice and Management Recommendations

Estimated catches of yellowfin tuna have averaged 141,000 mt over the past three years. This average falls near the lower estimate of the range of MSY from the age-structured and production model analyses conducted during the 2003 assessment. The SCRS considers that the yield of 159,000 mt in 2001 is likely somewhat above the replacement yield, and that levels of fishing effort and fishing mortality may have been near MSY. Total catches since 2001 have been declining, but without a new assessment it is not clear whether or not this reflects decreases in fishing effort and fishing mortality. Therefore the SCRS reaffirms its support for ICCAT's 1993 recommendation "that there be no increase in the level of effective fishing effort exerted on Atlantic yellowfin tuna, over the level observed in 1992." During the 2003 assessment, the SCRS's estimates of effective fishing effort for recent years fell near the estimate for 1992.

A number of management measures have been implemented in the United States, consistent with this advice, to prevent overfishing. In 1999, NOAA Fisheries implemented limited access in the pelagic longline fishery for Atlantic tunas, as well as a recreational retention limit for yellowfin tuna. The United States has also implemented a larger minimum size than that required by ICCAT. This species is listed as approaching an overfished condition by the United States.

The SCRS also continues to recommend that effective measures be found to reduce fishing mortality of small yellowfin, based on previous results of yield-per-recruit analysis. In 2003, the SCRS evaluated the effects of the moratorium on fishing on floating objects (and other measures to reduce catches of small fish) begun in late 1997, but there were insufficient data to fully evaluate the impact on yellowfin tuna. In general, the approach was intended to benefit bigeye tuna and is not expected to reduce the mortality of juvenile yellowfin tuna. In fact, the fishing mortality on juvenile yellowfin tuna appears to have increased substantially during the moratorium years, although it is unclear that this is related to the moratorium.

SCRS Evaluation of Management Measures

In 1973, ICCAT adopted a regulation that imposed a minimum size of 3.2 kg for yellowfin tuna, with a 15 percent tolerance in the number of undersized fish per landing. This regulation has not been adhered to internationally, as the proportion of landings of yellowfin tuna less than 3.2 kg has been far in excess of 15 percent per year for the purse seine and baitboat fisheries. Based on the catch species composition and catch-at-size data available during the 2003 assessment, yearly catches in number ranged between 54 percent and 72 percent undersized yellowfin tuna by purse seiners, from 63 percent to 82 percent undersized fish for baitboats over the period 1997-2001. Landings of undersized fish occur primarily in the equatorial fisheries. Unfortunately, it is difficult to realize substantial reductions in catches of undersized fish in these fisheries because small yellowfin tuna are mostly associated with skipjack tuna, especially when fishing occurs on floating objects; thus it is difficult to avoid catching small yellowfin when catching skipjack, the latter being an important component of eastern Atlantic (equatorial) purse seine fleet catches. The SCRS plans further investigations of the utility of minimum size regulations and alternative measures to reduce juvenile mortality in this multi-species fishery.

In 1993, ICCAT recommended "that there be no increase in the level of effective fishing effort exerted on Atlantic yellowfin tuna, over the level observed in 1992." As measured by fishing mortality estimates from the 2003 assessment, effective effort in 2001 appeared to be approaching or exceeding the 1992 levels.

SCRS Outlook

Since reported yellowfin tuna landings in 2001 appeared to be somewhat above the MSY level estimated during the 2003 assessment and fishing effort and fishing mortality may have been in excess of the levels associated with MSY, it is important to ensure that effective effort does not increase beyond the 2001 level. Projections indicate that stock biomass is likely to decrease if fishing mortality increases to the level estimated for 1992, which is currently being approached or exceeded. Thus the possibility that the fishing power of the purse seiners and other fleets may further increase, even if the total capacity of the fleet were to remain constant, is also cause for concern. It should be noted that the current estimates of total yellowfin landings in 2002 and 2003, which were not available at the time of the assessment, are 139,000 mt and 124,000 t, respectively.

3.2.3.3 Atlantic Albacore Tuna

Life History / Species Biology

Albacore is a temperate tuna widely distributed throughout the Atlantic Ocean and Mediterranean Sea. For assessment purposes, the existence of three stocks is assumed based on available biological information: northern and southern Atlantic stocks (separated at 5ºN), and a Mediterranean stock. Albacore spawning areas in the Atlantic are found in subtropical western areas of both hemispheres and throughout the Mediterranean Sea. Spawning takes place during austral and boreal spring-summer. Sexual maturity is considered to occur at about 90 cm FL (age five) in the Atlantic, and at smaller size (62 cm, age two) in the Mediterranean. Until this age they are mainly found in surface waters, where they are targeted by surface gears. Some adult albacore are also caught using surface gears but, as a result of their deeper distribution, they are mainly caught using longlines. Young albacore tuna are also caught by longline in temperate waters.

Recent Updates on United States Albacore Tuna Research

In 2003, an analysis of U.S. longline CPUE (SCRS/03/086) was prepared in support of the ICCAT assessment of northern and southern Atlantic albacore tuna.

SCRS Stock Assessment Results

The last assessment of the North stock was conducted in 2000 (1975-1999) and that of the South stock in 2003; no assessment of the Mediterranean stock has ever been carried out. To coordinate the timing of the assessments of northern and southern albacore tuna, the stock assessment for northern albacore was postponed at the 2004 ICCAT meeting from 2006 to 2007 (note the management measures for northern albacore expire at the end of 2006). The SCRS noted the considerable uncertainty that continues to remain in the catch-at-size data for the North and South stocks, and the profound impact this has had on attempts to complete a satisfactory assessment of northern albacore tuna.

North Atlantic

The SCRS carried out an initial analysis of the state of the northern stock using a model essentially the same as that used in previous assessments. However, revisions to catch-at-size data, provided to the Secretariat during and shortly before the assessment, altered the historical data series. The impacts of these revisions are such that the SCRS concluded that it was not appropriate to proceed with an assessment based on the 2003 catch-at-age. Consequently, the SCRS's opinion of the current state of the northern albacore tuna stock is based primarily on the last assessment conducted in 2000 together with observations of CPUE and catch data provided to the SCRS since then. The results, obtained in 2000, showed consistency with those from previous assessments (Table 3.10).

The SCRS noted that CPUE trends have varied since the last assessment in 2000, and in particular differed between those representative of the surface fleets (Spain Troll age two and Spain Troll age three) and those of the longline fleets of Japan, Chinese Taipei and the United States. The Spanish age two troll series, while displaying an upward trend since the last assessment, none the less declines over the last ten years. For the Spanish age three troll series the trend in the years since the last assessment is down, however, the trend for the remainder of the last decade is generally unchanged. For the longline fleets, the trend in CPUE indices is either upwards (Chinese Taipei and United States) or unchanged (Japan) in the period since the last assessment. However, variability associated with all of these catch rate estimates prevented definitive conclusions about recent trends of albacore catch rates.

Equilibrium yield analyses, carried out in 2000 and made on the basis of an estimated relationship between stock size and recruitment, indicate that spawning stock biomass was about 30 percent below that associated with MSY. However, the SCRS noted considerable uncertainties in these estimates of current biomass relative to the biomass associated with MSY (B_{MSY}), owing to the difficulty of estimating how recruitment might decline below historical levels of stock biomass. Thus, the SCRS concluded that the northern stock is probably below B_{MSY}, but the possibility that it is above it should not be dismissed (Figure 3.9). However, equilibrium yield-per-recruit analyses made by the SCRS in 2000 indicate that the northern stock is not being growth overfished ($F < Fmax$).

South Atlantic

In 2003, an age-structured production model, using the same specifications as in 2000, was used to provide a Base Case assessment for South Atlantic albacore. Results were similar to those obtained in 2000, but the confidence intervals were substantially narrower in 2003 than in 2000 (Table 3.11). In part, this may be a consequence of additional data now available, but the underlying causes need to be investigated further. The estimated MSY and replacement yield from the 2003 Base Case (30,915 mt and 29,256 mt, respectively) were similar to those estimated in 2000 (30,274 mt and 29,165 mt). In both 2003 and 2000 the fishing mortality rate was estimated to be about 60 percent of F_{MSY}. Spawning stock biomass has declined substantially relative to the late 1980s, but the decline appears to have leveled off in recent years and the estimate for 2002 remains well above the spawning stock biomass corresponding to MSY.

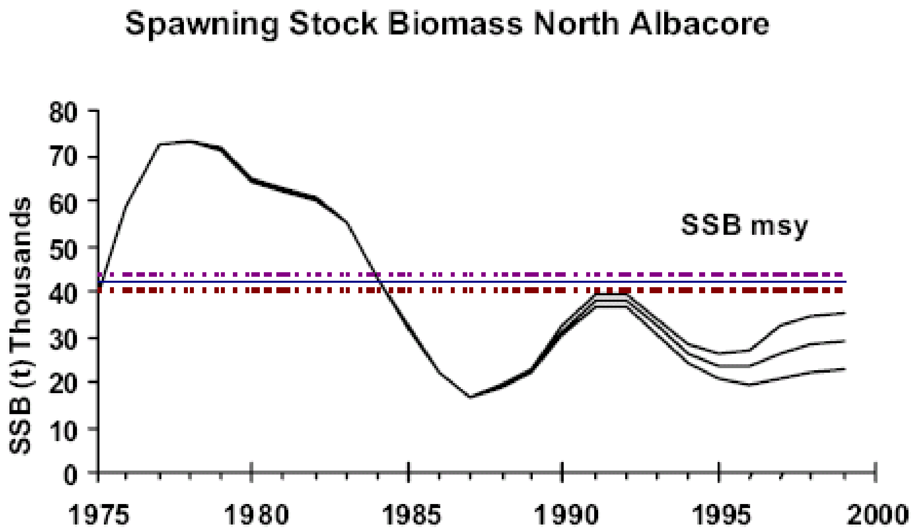

Figure 3.9 North Atlantic albacore spawning stock biomass and recruits with 80 percent confidence limits.

Table 3.10 Summary Table for the Status of North Atlantic Albacore Tuna

Age/size at Maturity	Age 5/~90 cm curved fork length
Spawning Sites	Subtropical western waters of the northern Hemisphere
Current Relative Biomass Level ***Minimum Stock Size Threshold***	B_{99}/B_{MSY} = 0.68 (0.52 - 0.86) *0.7B_{MSY}*
Current Relative Fishing Mortality Rate ***Maximum Fishing Mortality Threshold***	F_{99}/F_{MSY} = 1.10 (0.99 - 1.30) F_{year}/F_{MSY} = 1.00
Maximum Sustainable Yield	32,600 mt [32,400 - 33,100 mt]
Current (2003) Yield	25,516 mt
Current (2003) Replacement Yield	not estimated
Outlook	Overfished; overfishing is occurring

Table 3.11 Summary Table for the Status of South Atlantic Albacore Tuna

Age/size at Maturity	Age 5/~90 cm curved fork length
Spawning Sites	Subtropical western waters of the southern Hemisphere
Current Relative Biomass Level	B_{02}/B_{MSY} = 1.66 (0.74 - 1.81)
Current Relative Fishing Mortality Rate	F_{02}/F_{MSY} = 0.62 (0.46 - 1.48)

Maximum Sustainable Yield	30,915 mt (26,333 - 30,915)
Current (2003) Yield	27,811 mt
Current (2003) Replacement Yield	29,256 mt (24,530 - 32,277)
Outlook	Not overfished; overfishing is not occurring

SCRS Advice and Management Recommendations

North Atlantic

No assessment of the North Atlantic albacore stock was possible in 2003 because of uncertainties associated with the catch-at-age. In 2000, the SCRS recommended that in order to maintain a stable Spawning Stock Biomass in the near future the catch should not exceed 34,500 mt (the 1999 catch level) in the period 2001-2002. The SCRS further noted that should ICCAT wish the Spawning Stock Biomass to begin increasing towards the level estimated to support MSY, then catches in 2001 and 2002 should not exceed 31,000 mt. In 2003, the SCRS reiterated its previous advice and extended it until the next assessment.

South Atlantic

Recent catches of albacore tuna in the South Atlantic are in the vicinity of the current and recent estimates of MSY (30,915 mt). Both the 2000 and the 2003 albacore assessments estimated that the stock is above B_{MSY} (2003 estimates $B_{current}/B_{MSY} = 1.66$, $F_{current}/F_{MSY} = 0.62$). The SCRS recommends that in order to maintain SSB in the near future the catch should not exceed 31,000 mt for the next three to five years.

Mediterranean

There are no ICCAT management recommendations for the Mediterranean stock. However, the SCRS recommended to ICCAT that reliable data be provided on catch, effort and size for Mediterranean albacore tuna. The SCRS also recommended that an effort be made to recover historical data. Improvements to these basic inputs are essential before a stock assessment of Mediterranean albacore tuna can be attempted.

SCRS Evaluation of Management Recommendations

North Atlantic

Since 2001, ICCAT established a TAC of 34,500 mt for this stock. In 2003, ICCAT extended this TAC up to 2006. The SCRS noted that reported catches for 2001, 2002, and 2003 have been below the TAC. A 1998 recommendation that limits fishing capacity to the average of 1993-1995 also remains in force. The SCRS is unable to assess whether or not these recommendations have had a direct effect on the stock.

South Atlantic

Since 1999, ICCAT established the TAC for this stock (in 2001-2003 the TAC has been set to 29,200 mt). In 2003, ICCAT extended this TAC to 2004. The SCRS noted that reported catches have not exceeded the TAC in 2003. Also the total catch by Chinese Taipei, South Africa, Brazil and Namibia (26,620 mt) did not exceed the 27,500 mt catch limit of parties actively fishing for southern albacore, as stipulated by resolution 02-06. It should be noted that sufficient capacity exists within the fisheries to exceed the TAC as was done in 2000, 2001, and 2002. Japan adhered to its by-catch limit of four percent of the total catch of bigeye tuna in the Atlantic Ocean. However, the SCRS is unable to assess whether or not these catch limits have had a direct effect on the stock.

SCRS Outlook

North Atlantic

In terms of yield per recruit, the assessment carried out in 2000 indicates that the fishing intensity is at, or below, the fully exploited level. Concerning MSY-related quantities, the SCRS recalls that they are highly dependent on the specific choice of stock-recruitment relationship. The SCRS believed that using a particular form of stock-recruitment relationship that allows recruitment to increase with spawning stock size provided a reasonable view of reality. This hypothesis together with the results of the assessment conducted in 2000 indicate that the spawning stock biomass (B_{1999}) for the northern stock (29,000 mt) was about 30 percent below the biomass associated with MSY (42,300 mt) and that current F (2000) was about 10 percent above F_{MSY}. However, an alternative model allowing for more stable recruitment values in the range of observed SSB values would provide a lower estimate of SSB at MSY, below the current value.

South Atlantic

Catches of albacore in the South Atlantic in 2001 and 2002 were above replacement yield, and were below estimates of MSY in 2003. Nevertheless, both the 2000 and 2003 albacore assessments estimated that the stock is above B_{MSY}. There is now greater confidence in these estimates of MSY and therefore there is justification to base a TAC recommendation on MSY instead of replacement yield estimates from the model as in 2000. This results from the SCRS's view that current stock status is somewhat above B_{MSY} and catch of this level, on average, would be expected to reduce the stock further towards B_{MSY}. Recent estimates of high recruitment could allow for some temporary increase in adult stock abundance under a 31,000 mt catch, but this result is uncertain.

Mediterranean

Given the lack of an assessment, the implications of the rapid increase in landings in unknown.

3.2.3.4 Atlantic Skipjack Tuna

Life History / Species Biology

Skipjack tuna is a cosmopolitan species forming schools in the tropical and subtropical waters of the three oceans. Skipjack spawn opportunistically throughout the year in vast areas of the Atlantic Ocean. The size at first maturity is about 45 cm for males and about 42 cm for females in the East Atlantic, while in the West Atlantic sexual maturity is reached at around 51 cm for females and 52 cm for males. Skipjack growth is seasonal, with substantial differences according to the latitude. There remains considerable uncertainty about the variability of the growth parameters between areas. It is, therefore, a priority to gain more knowledge on the growth schemes of this species.

Skipjack is a species that is often associated with floating objects, both natural objects or fish aggregating devices (FADs) that have been used extensively since the early 1990s by purse seiners and baitboats (during the 1991 to 2003 period, about 55 percent of skipjack were caught with FADs). The concept of viscosity (low interchange between areas) could be appropriate for the skipjack stocks. A stock qualified as "viscous"can have the following characteristics:

- It may be possible to observe a decline in abundance for a local segment of the stock;
- Overfishing of that component may have little, if any, repercussion on the abundance of the stock in other areas; and,
- Only a minor proportion of fish may make large-scale migrations.

The increasing use of FADs could have changed the behavior of the schools and the migrations of this species. It is noted that, in effect, the free schools of mixed species were much more common prior to the introduction of FADs than now. These possible behavioral changes ("ecological trap" concept) may lead to changes in the biological parameters of this species as a result of the changes in the availability of food, predation and fishing mortality. Skipjack caught with FADs are usually found associated with other species. The typical catch with floating objects is comprised of about 63 percent skipjack, 20 percent small yellowfin, and 17 percent juvenile bigeye and other small tunas. A comparison of size distributions of skipjack between periods prior to and after the introduction of FADs show that, in the East Atlantic, there has been an increase in the proportion of small fish in the catches, as well as a decline in the total catch in recent years in some areas.

The SCRS reviewed the current stock structure hypothesis that consists of two separate management units, one in the East Atlantic and another in the West Atlantic, separated at 30^{o}W. The boundary of 30^{o}W was established when the fisheries were coastal, whereas in recent years the East Atlantic fisheries have extended towards the west, surpassing this longitude, and showing the presence of juvenile skipjack tuna along the Equator, west of 30^{o}W, following the drift of the FADs. This implies the potential existence of a certain degree of mixing. Nevertheless, taking into account the large distances between the east and west areas of the ocean, various environmental constraints, the existence of a spawning area in the East Atlantic as well as in the northern zone of the Brazilian fishery, and the lack of additional evidence (e.g. transatlantic migrations in the tagging data), the hypothesis of separate East and West Atlantic stock is maintained as the most plausible alternative. On the other hand, in taking into account the biological characteristics of the species and the different fishing areas, smaller management units could be considered.

SCRS Recent Stock Assessment Results

The last assessment on Atlantic skipjack tuna was carried out in 1999 (Table 3.12). The state of the Atlantic skipjack stock(s), as well as the stocks of this species in other oceans, show a series of characteristics that make it extremely difficult to conduct an assessment using current models. Among these characteristics, the most noteworthy are:

- The continuous recruitment throughout the year, but heterogeneous in time and area, making it impossible to identify and monitor the individual cohorts;
- Apparent variable growth between areas, which makes it difficult to interpret the size distributions and their conversion to ages; and,
- Exploitation by many and diverse fishing fleets (baitboat, purse seine), having distinct and changing catchabilities, which makes it difficult to estimate the effective effort exerted on the stock in the East Atlantic.

For these reasons, no standardized assessments have been able to be carried out on the Atlantic skipjack stocks. Notwithstanding, some estimates were made, by means of different indices of the fishery and some exploratory runs were conducted using a new development of the generalized production model.

Eastern stock

Standardized catch rates are not available. However, an analysis was made, for the 1969-2002 period, of the different indices of the purse seine fishery that could provide valuable information on the state of the stock. For the majority of the indices, the trends were divergent, depending on the area, which may indicate the viscosity of the skipjack stock, with limited mixing rates between areas. Because of the difficulties in assigning ages to the skipjack catches, the estimates of the values of natural mortality by age and obtaining indices of abundance (especially for the eastern stock), no catch-by-age matrices were developed and, consequently, no analytical assessment methods were applied.

Western stock

Standardized abundance indices up to 1998 were available from the Brazilian baitboat fishery and the Venezuelan purse seine fishery, and in both cases the indices seem to show a stable stock status. Uncertainties in the underlying assumptions for the analyses prevent the extracting of definitive conclusions regarding the state of the stock. However, the results suggest that there may be over-exploitation within the FAD fisheries, although it was not clear to what extent this applies to the entire stock. The SCRS could not determine if the effect of the FADs on the resource is only at the local level or if it had a broader impact, affecting the biology and behavior of the species. Under this supposition, maintaining high concentrations of FADs would reduce the productivity of the overall stock. However, since 1997, and due to the implementation of a voluntary Protection Plan for Atlantic tunas, agreed upon by the Spanish and French boat owners in the usual areas of fishing with objects, which later resulted in a

Commission regulation on the surface fleets that practice this type of fishing, there has been a reduction in the skipjack tuna catches associated with FADs. Maintaining this closure could have a positive effect on the resource.

Table 3.12 Summary Table for the Status of West Atlantic Skipjack Tuna

Age/size at Maturity	Age 1 to 2/~50 cm curved fork length
Spawning Sites	Opportunistically in tropical and subtropical waters
Current Relative Biomass Level ***Minimum Stock Size Threshold***	*Unknown* *Unknown*
Current Relative Fishing Mortality Rate F_{2003}/F_{MSY} ***Maximum Fishing Mortality Threshold***	*Unknown* F_{year}/F_{MSY} = 1.00
Maximum Sustainable Yield	*Not Estimated*
Current (2003) Yield	24,053 mt
Current Replacement Yield	*Not Estimated*
Outlook	*Unknown*

SCRS Advice and Management Recommendations

There is currently no specific regulation in effect for skipjack tuna. However, the French and Spanish boat owners voluntarily applied a moratorium for the period of November 1997 through January 1998, and November 1998 through January 1999. The moratorium, which was implemented in order to protect juvenile bigeye tuna, has had an influence on the skipjack catches made with FADs. Since 1999, a similar moratorium was applied, recommended by ICCAT, and is still in force. The average purse seine skipjack catches during the months from November to January by the fleets that applied the moratoria were reduced by 64 percent compared to the average catches between the 1993-1996 period (before the moratoria) and those corresponding to the 1998-2002 period. For the entire period in which the moratoria have been in effect (1998-2002), the average annual skipjack catches by the purse seine fleets that applied the moratoria decreased by 41 percent, which is equivalent to 42,000 mt per year. However, this decrease is likely a combined result of the decrease in effort and the moratorium impact; this is supported by the observation that the mean annual catch by boats has decreased only 18 percent between the two periods.

3.2.4 Atlantic Billfish

3.2.4.1 Blue Marlin

Life History/Species Biology

Blue marlin (*Makaira nigricans*) range from Canada to Argentina in the western Atlantic, and from the Azores to South Africa in the eastern Atlantic. Blue marlin are large apex predators with an average weight of 100-175 kg (220-385 lb). Female blue marlin grow faster and reach a larger maximum size than males. Young blue marlin are one of the fastest growing teleosts, reaching 30-45 kg (66-99 lb) after the first year. The maximum growth rate of these fish is 1.66 cm/day (0.65 inches/day) which occurs at 39 cm LJFL (15.3 inches) (NOAA Fsiheries, 1999). Life expectancy for blue marlin is between 20-30 years based on analysis of dorsal spines.

Estimates of natural mortality rates for billfish would be expected to be relatively low, generally in the range of 0.15 to 0.30, based on body size, behavior and physiology (N, 1999). Sagitta otolith weight is suggested to be proportional to age, indicating that both sexes are equally long-lived, based on the maximum otolith weight observed for each sex. Additionally, predicting age from length or weight is imprecise due to many age classes in the fishery.

Blue marlin have an extensive geographical range, migratory patterns that include trans-Atlantic as well as trans-equatorial movements, and are generally considered to be a rare and solitary species relative to the schooling Scombrids (tunas). Graves et al. (2002) captured eight blue marlin with recreational fishing gear and then implanted fish with satellite pop-up tags. These fish moved 74-248 km (40-134 nautical miles (nm)) over five days, with a mean displacement of 166 km (90 nm). Fish spent the vast majority of their time in waters with temperatures between 22 and 26 °C (71–78 °F) and at depths less than 10 m. The maximum time at liberty recorded of a tagged individual was 4,024 days (about 11 years) for a blue marlin that was estimated to weigh 29.5 kg (65 lb) at the time of release. Junior et al. (2004) found the depth of capture for blue marlin, with pelagic longline gear ranged from 50-190 m (164-623 feet), with most individuals captured at 90 m (295 feet).

The Cooperative Tagging Center (CTC) program has tagged and recaptured over 147 blue marlin and found that these fish moved an average of 903 km (488 nm) (NMFS, 1999). Some individuals have exhibited extended movement patterns, and strong seasonal patterns of movement of individuals between the United States and Venezuela are evident. A blue marlin released off Delaware and recovered off the island of Mauritius in the Indian Ocean represents the only documented inter-ocean movement of a highly migratory species in the history of the CTC. The minimum straight-line distance traveled for this fish was 16,853 km (9,100 nm) in 1,108 days-at-large (roughly three years).

Adults are found primarily in the tropics within the 24°C (75 °F) isotherm, and make seasonal movements related to changes in sea surface temperatures. In the northern Gulf of Mexico they are associated with the Loop Current, and are found in blue waters of low productivity rather than in more productive green waters. Off Puerto Rico, the largest numbers of blue marlin are caught during August, September, and October. Equal numbers of both sexes occur off northwest Puerto Rico in July and August, with larger males found there in May and smaller males in September. Very large individuals, probably females, are found off the southern coast of Jamaica in the summer and off the northern coast in winter, where males are caught in December and January.

There has not been an Atlantic wide survey of spawning activity for blue marlin, however, these fish generally reproduce between the ages of two and four, at 220-230 cm (86-90 inches) in length, and weigh approximately 120 kg (264 lb). Female blue marlin begin to mature at approximately 47-60 kg (104-134 lb), while males mature at smaller weights, generally from 35-44 kg (77-97 lb). There are likely two separate spawning events that occur at different times in the North and South Atlantic. South Atlantic spawning takes place between February and March (NMFS, 1999). Peak spawning activity in the North Atlantic Ocean occurs between July and October, with females capable of spawning up to four times per reproductive season (de Sylva and Breder, 1997).

During the spawning season, blue marlin release between one and eleven million small (1-2 mm), transparent pelagic planktonic eggs. The number of eggs has been correlated to interspecific sizes among billfish and the size of individuals within the same species. Ovaries from a 147 kg (324 lb) female blue marlin from the northwest Atlantic Ocean were estimated to contain 10.9 million eggs, while ovaries of a 125 kg (275 lb) female were estimated to contain seven million eggs. Males are capable of spawning at any time.

Blue marlin are generalist predators feeding primarily on epipelagic fish and cephalopods in coastal and oceanic waters, however, mesopelagic fish and crustaceans associated with rocky, sandy, and reef bottoms are also important components of the diet. Feeding in mesopelagic areas probably takes place at night (Rosas-Alayola et al., 2002). Diet studies of blue marlin off the northeastern coast of Brazil indicate that oceanic pomfret (*Brama brama*) and squid (*Ornithoteuthis antillarum*) were the main prey items and present in at least 50 percent of stomachs. Other important prey species vary by location and include dolphin fishes, bullet tuna (*Auxis. spp*) around the Bahamas, Puerto Rico, and Jamaica, and dolphin fishes and scombrids in the Gulf of Mexico. Stomach contents have also included deep-sea fishes such as chiasmodontids.

Constant ingestion of small quantities of food is necessary. Blue marlin have relatively small stomachs, reducing the proportion of the body allocated for visceral mass, and allocating more volume to musculature for swimming speed and endurance (Junior et al., 2004). In the Pacific Ocean, changes in the diet observed are related more with abundance and distribution of prey than preferences in food items, with *Auxis spp*. (bullet and frigate tunas) well represented in all locations. Predators of blue marlin are relatively unknown. Sharks will attack hooked blue marlin, but it is not known if they attach free-swimming, healthy individuals.

Effect of ICCAT Management Regulations

Since 1995, blue marlin have been managed under a single stock hypothesis because of tagging data and mitochondrial DNA evidence that are consistent with one Atlantic-wide stock. The participants in this fishery are varied. Most landings of blue marlin are incidental to offshore longline fisheries targeting tuna and/or swordfish near the surface. However, significant bycatch landings are also made using gear intended to fish deeper in the water column. The United States, Brazil, Venezuela, and Bahamas have significant, directed recreational fisheries for blue marlin (SCRS, 2004). Purse-seiners incidentally catch blue marlin. These harvests are more significant in the tropics where nets are set on floating Fish Aggregation Devices (FADs), than in the European Union (EU) where blue marlin comprise only 0.021percent of the total tuna catches, and less than 10 percent of the total billfish catches reported. The temporary ban on FADs adopted by the EU produced a 300-400 mt ww (661,386 – 881,849 lb) decrease in incidental catches of marlins (Gaertner et al., 2002).

ICCAT Recommendation 97-09 required Contracting Parties to reduce, starting in 1998, blue marlin and white marlin landings by at least 25 percent for each species from 1996 landings, by the end of 1999. Recommendations 00-13, 01-10, and 02-13 imposed or extended additional catch restrictions for blue marlin. These included limiting the annual amount of blue marlin that can be harvested by pelagic longline and purse seine vessels and retained for landing to no more than 50 percent of the 1996 or 1999 landing levels, whichever is greater, as well as requiring that all blue marlin and white marlin brought to pelagic longline and purse seine vessels alive be released in a manner that maximizes their survival. The live release provision does not apply to marlins that are dead when brought along the side of the vessel or that are not sold or entered into commerce (SCRS, 2004). In addition, these recommendations limited recreational landings in the United States to 250 blue and white marlin combined, on an annual basis. Also in 2000, ICCAT recommended that a blue marlin minimum size be established for recreational fisheries (251 cm (98.8 inches) LJFL). In November 2004, ICCAT extended phase one of the ICCAT mortality reduction plan, as established and modified by recommendations 00-13, 01-10, 02-13, through 2006 and postponed the next scheduled assessment of Atlantic blue marlin until 2006. The SCRS noted that it does not expect to have enough new information to provide an assessment of these recent regulations until 2006.

In the United States, blue marlin are managed exclusively for recreational fisheries. This fishery is subject to the ICCAT imposed 250-fish limit for both blue and white marlin combined, annually. There is also a domestic minimum size of 251 cm (99 inches) and 167 cm (66 inches) inches for blue and white marlin, respectively. In 2003, 131 blue and white marlin were reported landed in tournaments (108 blue marlin).

Status of the Stock and SCRS Outlook

The last stock assessment for blue marlin was in 2000 using similar methods to the previous assessment (1996), however, data was revised in response to concerns raised since the 1996 assessment. The assessment might reflect a retrospective pattern wherein improvement in estimated biomass ratios result in estimated lower productivity. The 2000 assessment was slightly more optimistic than the 1996 assessment. Atlantic blue marlin are at approximately 40 percent of B_{MSY} and over-fishing has taken place for the last 10-15 years. B_{MSY} is estimated at 2,000 mt (4,409,245 lb) and current fishing mortality is approximately four times higher than F_{MSY} (Table 3.13) (SCRS, 2004). There is uncertainty in the assessment because the historical data that is not well quantified. The 2000 assessment estimated that over-fishing was still occurring and that productivity (MSY and a stock's capacity to replenish) was lower than previously estimated, it is expected that landings in excess of estimated replacement yield would result in further stock decline (SCRS, 2004).

No additional assessment information became available in 2004 to modify recommendations currently in force. The current assessment indicates that the stock is unlikely to recover if the landings contemplated by the 1996 ICCAT recommendation continue into the future. While there is additional uncertainty in stock status and replacement yield estimates do not reflected in bootstrap results, these uncertainties can only be addressed through substantial investment in research into habitat requirements of blue marlin and further verification of historical data. The SCRS recommended that the ICCAT take steps to reduce the catch of blue marlin as much as possible, including: reductions in fleet-wide effort, a better estimation of dead discards, establishment of time area closures, and scientific observer sampling for verification of logbook data. The SCRS noted that future evaluation of management measures relative to the recovery of the blue marlin stock are unlikely to be productive unless new quantitative information on the biology and catch statistics of blue marlin, and additional years of data are available (SCRS, 2004).

A summary of Atlantic blue marlin stock assessment data can be found in Table 3.13. Estimated catches of Atlantic blue marlin by region for the period 1956 – 2001 can be found in Figure 3.10. A composite CPUE series for blue marlin for the period 1955 – 2000 can be found in Figure 3.11. The estimated median relative fishing mortality trajectory for Atlantic blue marlin can be found in Figure 3.12.

Table 3.13 Summary of Atlantic Blue Marlin Stock Assessment data. Weights are in metric tons, whole weight.

ATLANTIC BLUE MARLIN SUMMARY[1]	
	Total Atlantic
Maximum Sustainable Yield (MSY)	~ 2,000 t (~ 1,000 ~ 2,400 t)[2]
2002 Yield	2,494 t
2003 Yield[4]	1,951 t
1999 Replacement Yield	~ 1,200 t (~ 840 - 1,600 t)[2]
Relative Biomass (B_{2000}/B_{MSY})	~ 0.4 (~ 0.25 - 0.6)[2]
Relative Fishing Mortality (F_{1999}/F_{MSY})	4.0 (~ 2.5 - 6.0)[2]
Management Measures in Effect	- Reduced pelagic longline and purse seine landings to 50% of 1996 or 1999 levels, whichever is greater [Refs. 00-13[3], 01-10[3] and 02-13].

[1] Assessment results are uncertain. Uncertainty in these estimates is not fully quantified by bootstrapping.
[2] Approximate 80% CI from bootstrap for ASPIC model.
[3] These measures did not take effect until mid-2001.
[4] Reported Task I value, which is likely to be a substantial underestimate of the total catch.

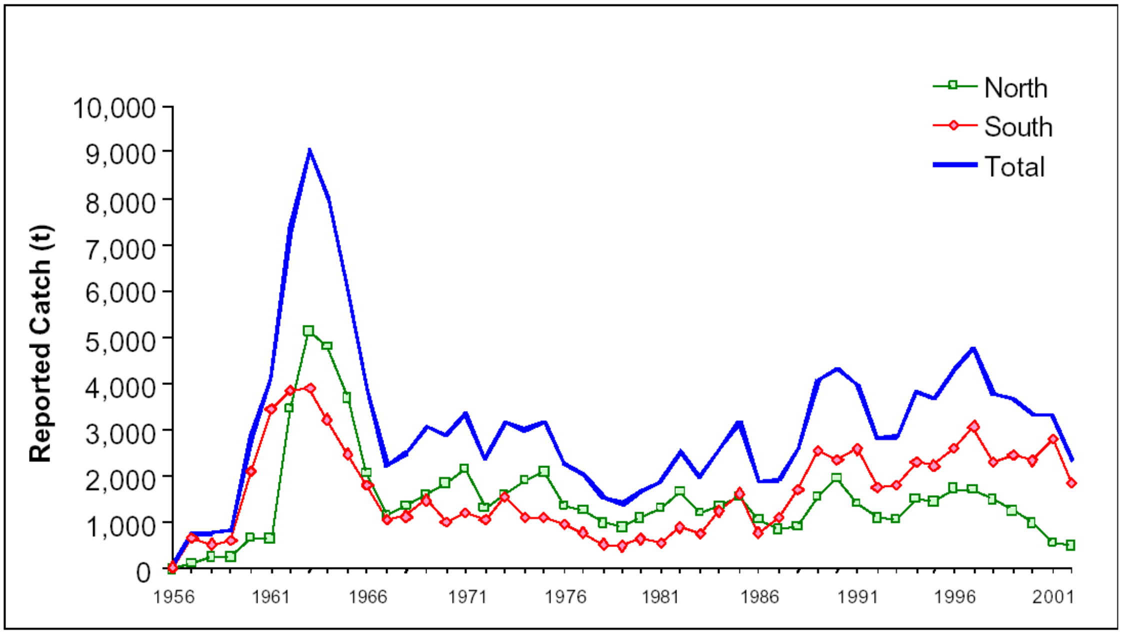

Figure 3.10 Estimated catches (including landings and dead discards in mt) of blue marlin in the Atlantic by region. The 2003 catch reported to ICCAT is preliminary and is not included in this figure. Weights are in metric tones, whole weight.

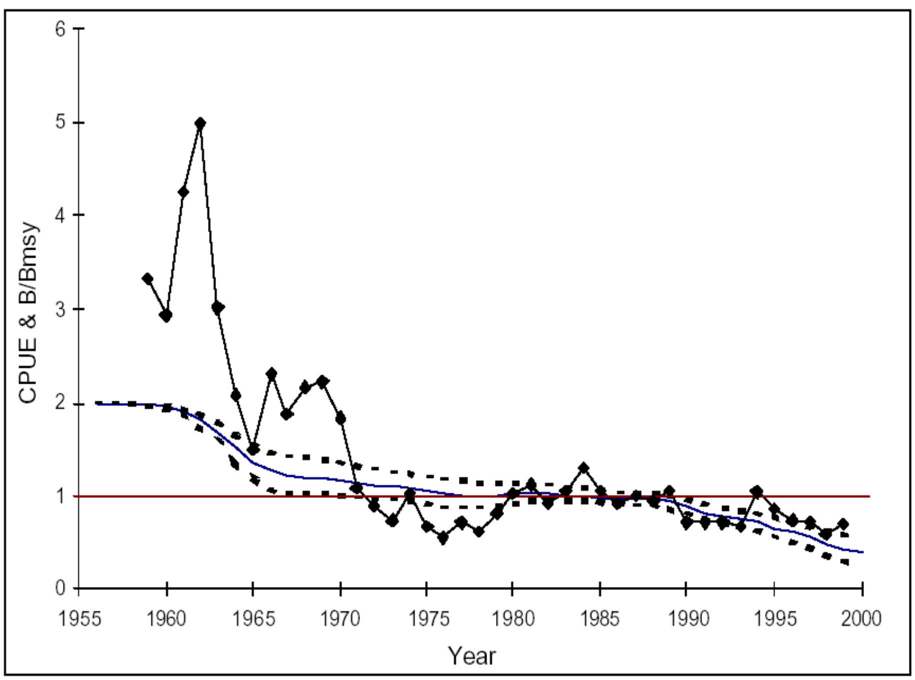

Figure 3.11 Composite CPUE series (symbols) used in the blue marlin assessment compared to model estimated median relative biomass (solid lines) from bootstrap results (80 percent confidence bounds shown by dotted lines)

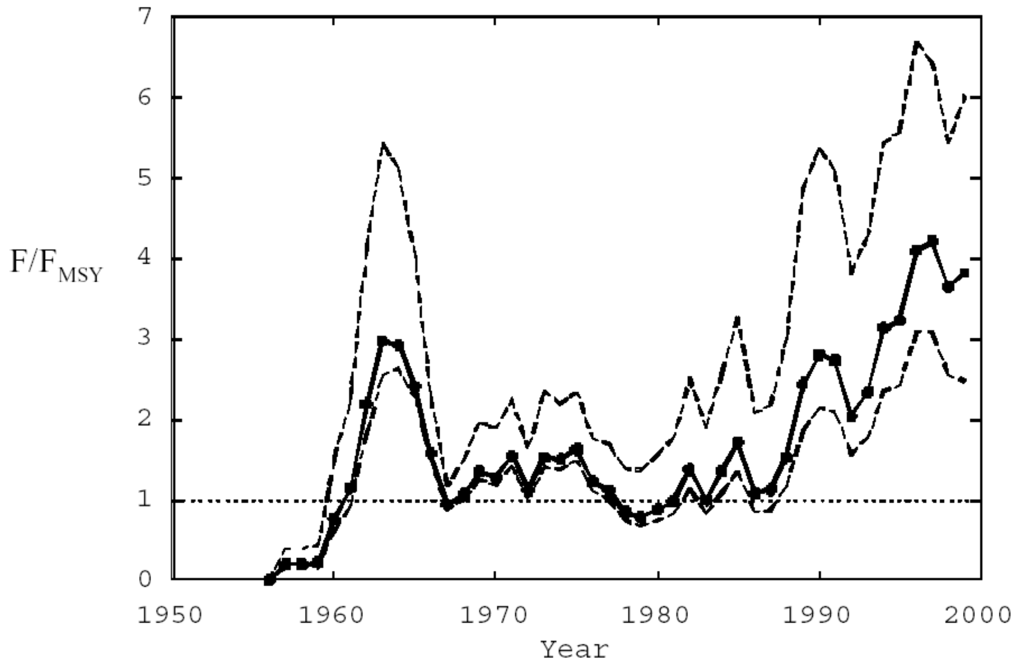

Figure 3.12 **Estimated median relative fishing mortality trajectory for Atlantic blue marlin (center, dark line) with approximate 80 percent confidence range (light lines) obtained from bootstrapping.**

3.2.4.2 White Marlin

Life History/Species Biology

White marlin (*Tetrapturus albidus*) are found exclusively in tropical and temperate waters of the Atlantic Ocean and adjacent seas, unlike sailfish and blue marlin, which are also found in the Pacific Ocean. White marlin are found at the higher latitudes of their range only in the warmer months. Junior et al. (2004) captured white marlin with pelagic longline gear off northeastern Brazil in depths ranging from 50-230 m (164-754 feet), with no obvious depth layer preference. White marlin generally prefer water temperatures above 22°C (71° F) with salinities between 35-37 ppt (NMFS, 1999). They may occur in small, same-age schools, however, are generally solitary compared to the Scombrids (tunas). Catches in some areas may include a rare species (*Tetrapturus georgei*) which is superficially similar to white marlin. The so-called “hatchet marlin” may also represent (*T. georgei)*, and has been caught occasionally in the Gulf of Mexico (NMFS, 1999).

White marlin are generally 20-30 kg (44-66 lb) at harvest. These fish grow quickly, with females attaining a larger maximum size than males, and have a life span of 18 years (SCRS 2004). Adult white marlin grow to over 280 cm (110 inches) TL and 82 kg (180 lb). White marlin exhibit sexually dimorphic growth patterns; females grow larger than males, but the dimorphic growth differences are not as extreme as noted for blue marlin. The longest time at liberty for a tagged white marlin, 4,305 days (11.8 years).

This species undergoes extensive movements, although not as extreme as those of the bluefin tuna and albacore. Trans-equatorial movements have not been documented for the species. There have been 29,751 white marlin tagged and released by the CTC program, with 540 reported recaptures (1.8 percent of all releases). The majority of releases took place in the months of July through September, in the western Atlantic off the east coast of the United States. Releases of tagged white marlin also occurred off Venezuela, in the Gulf of Mexico, and in the central west Atlantic. The mean straight line distance of recaptured white marlin is 842 km (455 nm). A substantial number of individuals moved between the mid-Atlantic coast of the United States and the northeast coast of South America. Overall, 1.1 percent of documented white marlin recaptures have made trans-Atlantic movements. The longest movement was for a white marlin tagged during July 1995 off the east coast near Cape May, NJ and recaptured off Sierra Leone, West Africa, in November, 1996. The fish traveled a distance of at least 6,517 km (3,519 nm) over 476 days (NMFS, 1999).

White marlin spawn in the spring (March through June) in the northwestern Atlantic Ocean and females are generally 20 kg (44 lb) in mass and 130 cm (51.2 inches) in length at sexual maturity. White marlin spawn in tropical and sub-tropical waters with relatively high surface temperatures and salinities (20 to 29°C (68-84°F) and over 35 ppt) and move to higher latitudes during the summer. There has not been an Atlantic-wide study of the spawning behavior of white marlin. Spawning seems to take place in more offshore areas than for sailfish, although larvae are not found as far offshore as blue marlin. Females may spawn up to four times per spawning season (de Sylva and Breder, 1997). It is believed there are at least three spawning areas in the western north Atlantic: northeast of Little Bahama Bank off the Abaco Islands, northwest of Grand Bahama Island, and southwest of Bermuda. Larvae have also been collected from November to April, but these may have been sailfish larvae (*Istiophorus platypterus*), as the two can not readily be distinguished (NMFS, 1999). Spawning concentrations occur off the Bahamas, Cuba, and the Greater Antilles, probably beyond the U.S. EEZ, although the locations are unconfirmed. Concentrations of white marlin in the northern Gulf of Mexico and from Cape Hatteras, NC to Cape Cod, MA are probably related to feeding rather than spawning (NMFS, 1999).

White marlin are primarily piscivorous. Oceanic pomfret and squid were the most important food items in a study that sampled sailfish stomachs collected off the coast of Brazil in the southwestern Atlantic Ocean (Junior et al., 2004). The number of food items per stomach ranged from 1-12 individuals. The largest prey observed in white marlin stomachs were snake mackerel (*Gempylus serpens*), that were 40-73 cm (15.7-28.7 inches) in length (Junior et al., 2004). Squid, dolphin, hardtail jack, flying fish, bonitos, mackerels, barracuda, and puffer fish are the most important prey items in the Gulf of Mexico.

The world's largest sport fishery for white marlin occurs in the summer from Cape Hatteras, NC to Cape Cod, MA especially between Oregon Inlet, NC and Atlantic City, NJ. Successful fishing occurs up to 148 km (80 nm) offshore at submarine canyons, extending from Norfolk Canyon in the mid-Atlantic to Block Canyon off eastern Long Island. Concentrations are associated with rip currents and weed lines (fronts), and with bottom features such as steep drop-offs, submarine canyons, and shoals. The spring peak season for white marlin sport fishing occurs in the Straits of Florida, southeast Florida, the Bahamas, and off the north coasts of Puerto

Rico and the Virgin Islands. In the Gulf of Mexico summer concentrations are found off the Mississippi River Delta, at DeSoto Canyon, at the edge of the continental shelf off Port Aransas, TX, with a peak off the Delta in July, and in the vicinity of DeSoto Canyon in August. In the Gulf of Mexico, adults appear to be associated with blue waters of low productivity, being found with less frequency in more productive green waters. While this is also true of the blue marlin, there appears to be a contrast between the factors controlling blue and white marlin abundance, as higher numbers of blue marlin are generally caught when catches of white marlin are low, and vice versa. It is believed that white marlin prefer slightly cooler temperatures than blue marlin.

Effect of ICCAT Management Regulations

Recommendation 97-09 required ICCAT Contracting Parties to reduce, starting in 1998, blue marlin and white marlin landings by at least 25 percent for each species from 1996 landings, such reduction to be accomplished by the end of 1999. ICCAT Recommendations 00-13, 01-10, and 02-13 imposed or extended additional catch restrictions for white marlin. These included reductions of 33 percent from the 1996 or 1999 landing levels, whichever is greater, in the annual amount of white marlin that can be harvested by pelagic longline and purse seine vessels and retained for landing. Further, all blue marlin and white marlin brought to pelagic longline and purse seine vessels alive are required to be released in a manner that maximizes their survival (SCRS, 2004). The live release provision does not apply to marlins that are dead when brought along the side of the vessel or that are not sold or entered into commerce. While the stock status evaluations are uncertain, projections indicated that the apparent intent of the ICCAT Billfish recommendations has, in the short term, some potential for stabilizing the stock biomass near current levels.

In the United States, white marlin are managed exclusively for recreational fisheries. The sport fishery for the species is concentrated between Cape Hatteras, NC and Cape Cod, MA during the summer months (NMFS, 1999). This fishery is subject to an ICCAT imposed, 250-fish limit, annually for both blue and white marlin combined. In 2001, time area closures were established in the United States to reduce interactions between longline fisheries and white marlin. In 2003, 131 blue and white marlin were reported landed in tournaments (23 white marlin). Purse seine fisheries have incidental catches of white marlin, especially those that set on FADs. A temporary ban on FADs implemented by the EU resulted in a 300-400 mt (661,386 – 881,849 lb) decrease in incidental purse seine catches of all marlins (Gaertner et al., 2002).

Status of the Stock and SCRS Outlook

White marlin have been managed under a single stock hypothesis by ICCAT since 2000. The most recent stock assessments for white marlin (1996, 2000, and 2002) all indicated that biomass of white marlin has been below B_{MSY} for more than two decades and the stock is overfished. In 2004, the SCRS indicated that in spite of significant improvements in the relative abundance estimates made available during the last three assessments, they are still not informative enough to provide an accurate estimate of stock status (SCRS, 2004). The 2002 assessment indicated that the relative fishing mortality is 8.28 times that permissible at F_{MSY} (Table 3.14). Given that the stock is severely depressed, the SCRS concluded that ICCAT should take steps to reduce the catch of white marlin by as much as possible, first by increasing observer coverage to improve estimates of catch and dead discards of white marlin.

Furthermore, SCRS recommended that Contracting Parties conduct research into habitat requirements and post-release survival of white marlin and take steps to verify historical fishery data.

The SCRS suggested that ICCAT take steps to make sure that the intended reductions in catch are complied with, and monitored, so that proper evaluation can be carried out in the future. The SCRS recommended improving observer programs so that better estimates of catch and dead discards of white marlin are obtained. The SCRS further recommended that, in the absence of observing a change in population status resulting from the most recent management measures, the potential for increasing stock size of white marlin may require future catches to be reduced beyond the level apparently intended by its most recent recommendations. However, the SCRS also stated that more definitive advice should be available after several years of data become available. The SCRS also noted that future evaluation of management measures relative to the recovery of the white marlin stock are unlikely to be productive unless new quantitative information on the biology and catch statistics of white marlin, and additional years of data, are available (SCRS, 2004). As such, ICCAT postponed the next white marlin assessment until 2006 or later. A summary of Atlantic white marlin stock assessment data can be found Table 3.14 and Figure 3.13.

Table 3.14 **Summary of Atlantic White Marlin Stock Assessment data. Weights are in metric tons, whole weight.** Source: SCRS, 2004.

ATLANTIC WHITE MARLIN SUMMARY[1]				
	Likely value	*Continuity case[2] estimate (80% conf. limit)*	*Retrospective adjusted estimate[3]*	*Range of sensitivity[4] estimates*
Maximum Sustainable Yield	Below 2000 Yield	964 t (849-1070)		323-1,320 t
2002 Yield	822 t	--		--
2003 Yield[5]	571 t	--		--
2001 Replacement Yield	Below 2000 Yield	222 t (101-416)	371 t	102-602 t
Relative Biomass (B_{2001}/B_{MSY})	<1 (Over-fished)	0.12 (0.06-0.25)	0.22	0.12-1.76
Relative Fishing Mortality (F_{2000}/F_{MSY})	>1 (Over-fishing)	8.28 (4.5-15.8)	5.05	0.80-10.30
Management Measures in Effect:	- In 2001 and 2002, PS and LL fisheries limit landings to 33% of max (1996, 1999) level. [Ref. 00-13], [Ref. 01-10] and [Ref. 02-13].			

1 Assessment results are highly uncertain.
2 The data used are not sufficiently informative to choose a "best case". For consistency, the continuity case presented here is based on data and assumptions that closely resemble the analyses made in 2000. Confidence limits from bootstrapping are conditional on this model-data set and thus may underestimate the real uncertainty.
3 These results are for the continuity case except that they were adjusted for retrospective biases.
4 The sensitivity analyses made were not chosen in a systematic way; the range is presented only for qualitative guidance.
5 Reported Task I value for 2003, which is likely an underestimate of total catch.

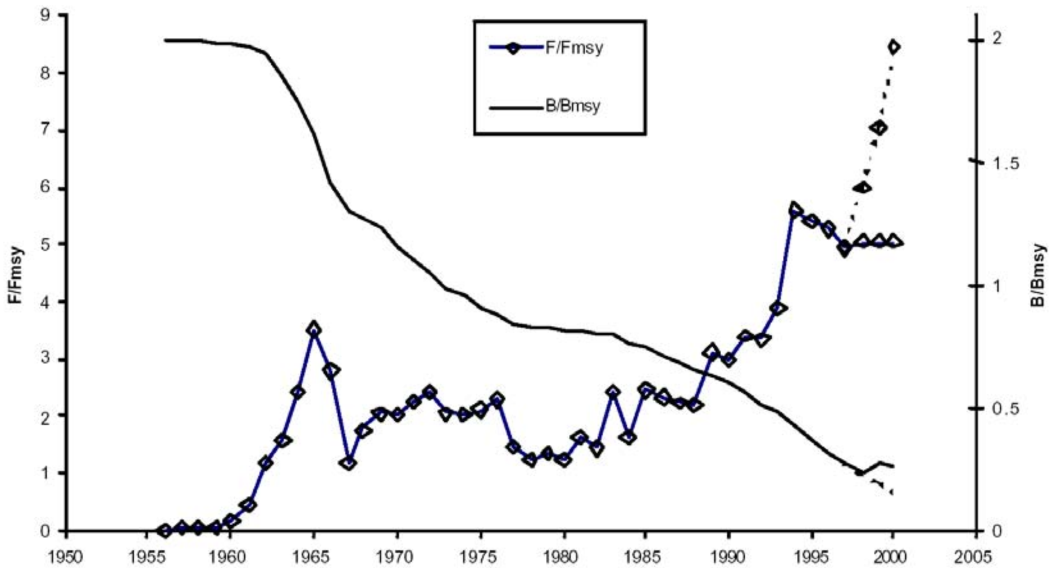

Figure 3.13 **Estimated biomass ratio B2000/ BMSY (solid line, no symbols) and fishing mortality ratio F2000/FMSY (solid line with symbols) from the production model fitted to the continuity case for white marlin. Ratios of last three yearshave been adjusted for retrospective pattern. Broken lines show unadjusted ratios. Note that scales are different for each ratio.** Source: SCRS, 2004.

3.2.4.3 Sailfish

Life History/Species Biology

Sailfish have a pan-tropical distribution and prefer water temperatures between 21 and 28°C (69-82°F). Although sailfish are the least oceanic of the Atlantic billfish and have higher concentrations in coastal waters (more than any other Istiophorid), they are also found in offshore waters. They range from 40°N to 40°S in the western Atlantic and 50°N to 32°S in the eastern Atlantic. No trans-Atlantic movements have been recorded, suggesting a lack of mixing between east and west. Although sailfish are generally considered to be rare and solitary species relative to the schooling Scombrids, sailfish are known to occur along tropical coastal waters in small groups consisting of at least a dozen individuals. Junior et al. (2004) captured sailfish in the southwestern Atlantic Ocean with pelagic longline gear at depths between 50-210 m (164-688 feet), with most individuals captured at 50 m. Sailfish are the most common representative of the Atlantic Istiophorid*s* in U.S. waters (SCRS, 2004). Female sailfish grow faster, and attain a larger maximum size, than males while both sexes have a life expectancy of 15 years (NMFS, 1999).

In the winter, sailfish are found in schools around the Florida Keys and eastern Florida, in the Caribbean, and in offshore waters throughout the Gulf of Mexico. In the summer they appear to diffuse northward along the U.S. coast as far north as the coast of Maine, although there is a population off the east coast of Florida all year long. During the summer, some of these fish move north along the inside edge of the Gulf Stream. After the arrival of northerlies in the winter, they regroup off the east coast of Florida. Sailfish appear to spend most of their time above the thermocline, which occurs at depths of 10 - 20 m (32.8 – 65.6 feet) and 200 - 250 m (656 – 820 feet), depending on location. The 28°C (82°F) isotherm appears to be the optimal temperature for this species. Sailfish are mainly oceanic but migrate into shallow coastal waters. Larvae are associated with the warm waters of the Gulf Stream (NMFS, 1999).

A total of 62,740 sailfish have been tagged and released through the efforts of the CTC program, with reported recapture of 1,090 sailfish (1.7 percent of all releases). Most releases occurred off southeast Florida, from north Florida to the Carolinas, the Gulf of Mexico, Venezuela, Mexico, the northern Bahamas and the U.S. Virgin Islands. One tagged and recaptured specimen traveled from Juno, FL to the mid-Atlantic, a distance of 2,972 km (1,745 miles). The longest movement tracked by tagging was 3,509 km (2,193 miles), with this specimen at-large for 1.4 years. During the winter sailfish are restricted to the warmer parts of their range and move farther from the tropics during the summer. The summer distribution of sailfish does not extend as far north as for marlins. Tag-and-recapture efforts have recovered specimens only as far north as Cape Hatteras, NC. Few trans-Atlantic or trans-equatorial movements have been documented using tag-recapture methods (NMFS, 1999).

Most sailfish examined that have been caught off Florida are under three years of age. Mortality is estimated to be high in this area, as most of the population consists of only two year classes. The longest period a recaptured-tagged animal was found to be at-large was 16.1 years. Unfortunately, the size at release is not available for this fish. Growth rate in older individuals is very slow (0.59 kg/yr (1.3 lb/year). Sailfish are probably the slowest growing of the Atlantic istiophorids. Sexual dimorphic growth is found in sailfish, but it is not as extreme as with blue marlin (NMFS, 1999).

Female sailfish spawn at age three and are generally 13-18 kg and 157 cm (28.6-39.6 lb and 61.8 inches), whereas males generally mature earlier at 10 kg and 140 cm (22 lb and 55.1 inches). Spawning takes place between April and October (de Sylva and Breder, 1997). Spawning has been reported to occur in shallow waters 9-12 m (30-40 ft) around Florida, from the Florida Keys to the region off Palm Beach on the east coast. Spawning is also assumed to occur, based on presence of larvae, offshore beyond the 100 m (328 feet) isobath from Cuba to the Carolinas, from April to September. However, these spawning activities have not been observed. Sailfish can spawn multiple times in one year, with spawning activity-moving northward in the western Atlantic as the summer progresses. Larvae are found in Gulf Stream waters in the western Atlantic, and in offshore waters throughout the Gulf of Mexico from March to October (NMFS, 1999). In the Pacific Ocean, sailfish spawn in waters between 27-30°C (Hernandez-H and Ramirez-H, 1998).

Sailfish are generally piscivorous, but also consume squid. Larvae eat copepods early in life then switch to fish at 6.0 mm (0.2 inches) in length (NMFS, 1999). The diet of adult sailfish caught around Florida consists mainly of pelagic fishes such as little tunny (*Euthynnus alletteratus*), halfbeaks (*Hemiramphus* spp.), cutlassfish (*Trichiurus lepturus*), rudderfish (*Strongylura notatus*), jacks (*Caranx spp.*), pinfish (*Lagodon rhomboides*), and squids (*Argonauta argo* and *Ommastrephes bartrami)*. Sailfish are opportunistic feeders and there is evidence that they may feed on demersal species such as sea robin (*Triglidae*), cephalopods and gastropods found in deep water.

Sailfish collected in the western Gulf of Mexico contained a large proportion of shrimp in their stomachs in addition to little tunny, bullet tuna (*Auxis* sp.), squid, and Atlantic moonfish (*Vomer setapinnis*). Adult sailfish are probably not preyed upon often, but predators include killer whales (*Orcinus orca*), bottlenose dolphin (*Tursiops turncatus*), and sharks. Junior et al. (2004) determined that squid were actually the second most important food item in the southwestern Atlantic off the coast of Brazil. Number of food items per stomach ranged from 1-14, and 6 percent of the stomachs were empty upon collection (Junior et al., 2004).

Participants from many nations characterize fisheries in both the western and eastern Atlantic Ocean. Sailfish are found predominantly in the upper reaches of the water column and are caught in directed sport fisheries (recreational) and as bycatch in the offshore longline fisheries for swordfish and tunas and as a directed catch in coastal fisheries. The reported catches of sailfish/spearfish (Task I) for 2003 were 1,310 and 416 mt (2,888,055 and 917,123 lb) for the west and east Atlantic, respectively. In coastal waters, artisanal fisheries use many types of shallow water gear to target sailfish (NMFS, 2003).

Effect of ICCAT Management Regulations

There are currently no specific ICCAT regulations for sailfish. Sailfish are managed as distinct eastern and western Atlantic stocks. This separation into two management units is based on life history information.

Status of the Stock and SCRS Outlook

Sailfish and Longbill spearfish landings have historically been reported together in annual ICCAT landing statistics. An assessment was conducted in 2001 for the western Atlantic sailfish stock based on sailfish/spearfish composite catches and sailfish “only” catches. The assessment tried to address shortcomings of previous assessments by improving abundance indices and separating the catch of sailfish from that of spearfish in the offshore longline fleets. The 2001 assessment looked at catches reported between 1956-2000 and all the quantitative assessment models used produced unsatisfactory fits, therefore the SCRS recommended applying population models that better accounted for these dynamics in order to provide improved assessment advice. For the western Atlantic stock, annual sailfish catches have averaged about 700 mt ww (1,543,235 lb) over the past two decades and the abundance indices have remained relatively stable. The 2000 yield was 506 mt ww (1,115,539 lb) (Table 3.15). Recent analyses did not provide any information on the MSY or other stock benchmarks for the ‘sailfish only’ stock. In the eastern Atlantic, abundance indices based on coastal/inshore fisheries for sailfish have decreased in recent years, while those attained from the Japanese longline fishery indicate constant estimates of abundance since the mid-1970s (SCRS, 2004).

Based on the 2001 assessment, it is unknown if the western or eastern sailfish stocks are undergoing overfishing or if the stocks are currently overfished. Therefore SCRS recommended that Contracting Parties consider methods to reduce fishing mortality rates, overall, and that western Atlantic catches should not be increased above current levels. Furthermore, the SCRS expressed concerned about the incomplete reporting of catches, particularly in recent years.

Management recommendations made by the SCRS in 2004 were the same as those made in 2003. These management recommendations indicated that ICCAT should consider methods for reducing fishing mortality rates. The current western Atlantic assessment led the SCRS to recommend that the West Atlantic sailfish “only” catches should not exceed current levels. For the East Atlantic, the SCRS recommended that sailfish “only” catches should not exceed current levels and that ICCAT should consider practical and alternative methods to reduce fishing mortality and assure data collection systems. SCRS expressed concern about the incomplete reporting of catches, particularly for the most recent years, the lack of sufficient reports by species, and evaluations of the new methods used to split the sailfish and spearfish catch and to index abundance. The SCRS recommended all countries landing sailfish/spearfish or having dead discards, report these data to the ICCAT Secretariat and that the SCRS should consider the possibility of a spearfish “only” assessment in the future (SCRS, 2004).

A summary of Atlantic sailfish stock assessment data is given in Table 3.15. The evolution of estimated sailfish/spearfish catches in the Atlantic during the period 1956–2002 for both east and west stocks in Figure 3.14. Available CPUE for western Atlantic sailfish/spearfish for the period 1967-2000 is shown in Figure 3.15. Estimated sailfish only catches from 1956-2000 is shown in Figure 3.16.

Table 3.15 Summary of Atlantic Sailfish Stock Assessment data. Weights are in metric tons, whole weight. Source: SCRS, 2004.

ATLANTIC SAILFISH “ONLY” SUMMARY		
	West Atlantic	**East Atlantic**
Maximum Sustainable Yield (MSY)	Not estimated	Not estimated
Recent Yield (2000)[1]	506 t[2]	969 t[2]
2000 Replacement Yield	~ 600 t	Not estimated
Management Measures in Effect	None	None

[1] Estimated yield includes that carried over from previous years.
[2] Recent yield (2000) was estimated during the 2001 sailfish assessment. To estimate the 2001, 2002 and 2003 yield, catches of sailfish and spearfish would have to be separated. A separation similar to the one conducted in the 2001 assessment has not yet been conducted.

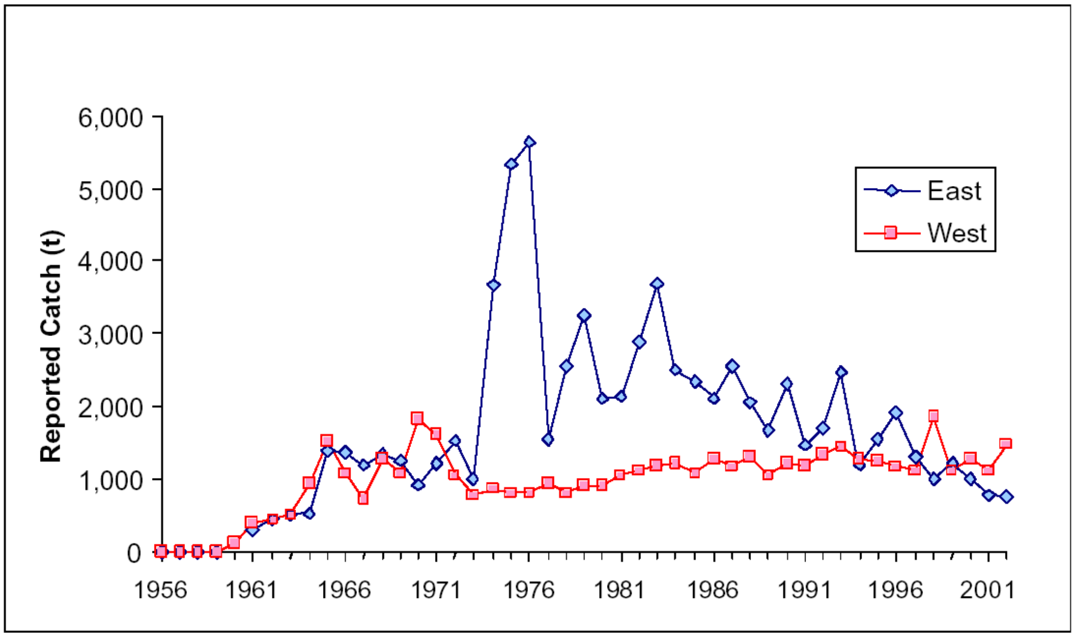

Figure 3.14 **Evolution of estimated sailfish/spearfish catches in the Atlantic (landings and dead discards, reported and carried over) in the ICCAT Task I database during 1956-2002 for the east and west stocks. The 2003 catch reported to ICCAT is preliminary and is not included in this figure. Weights are in metric tons, whole weight.**

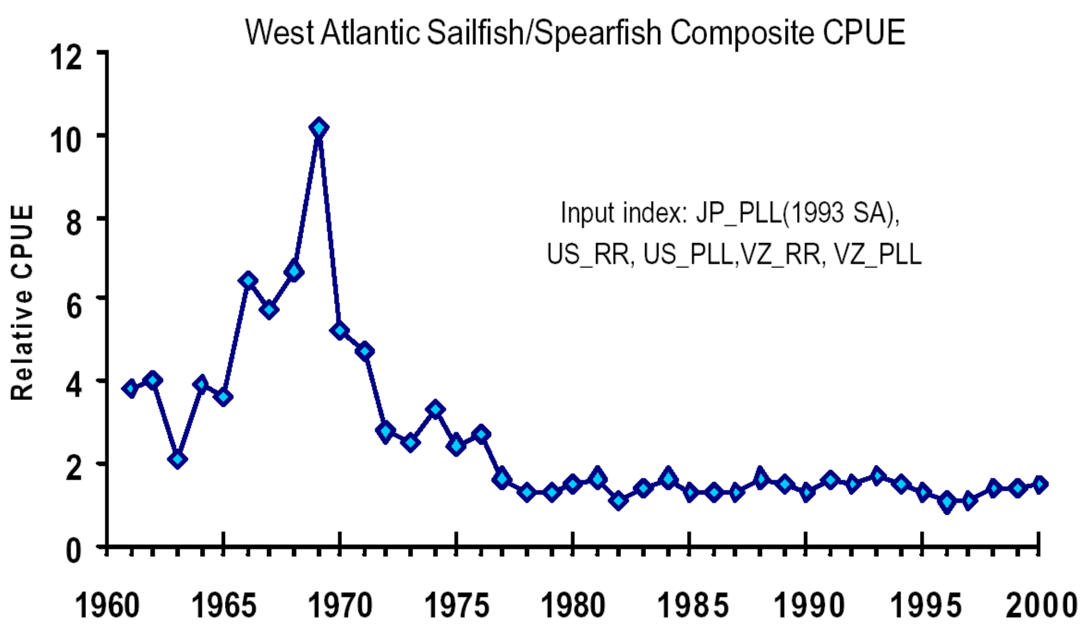

Figure 3.15 **Available standardized CPUE for western Atlantic sailfish/spearfish for the period 1967-2000, including Japanese, U.S., and Venezuelan time series data.**

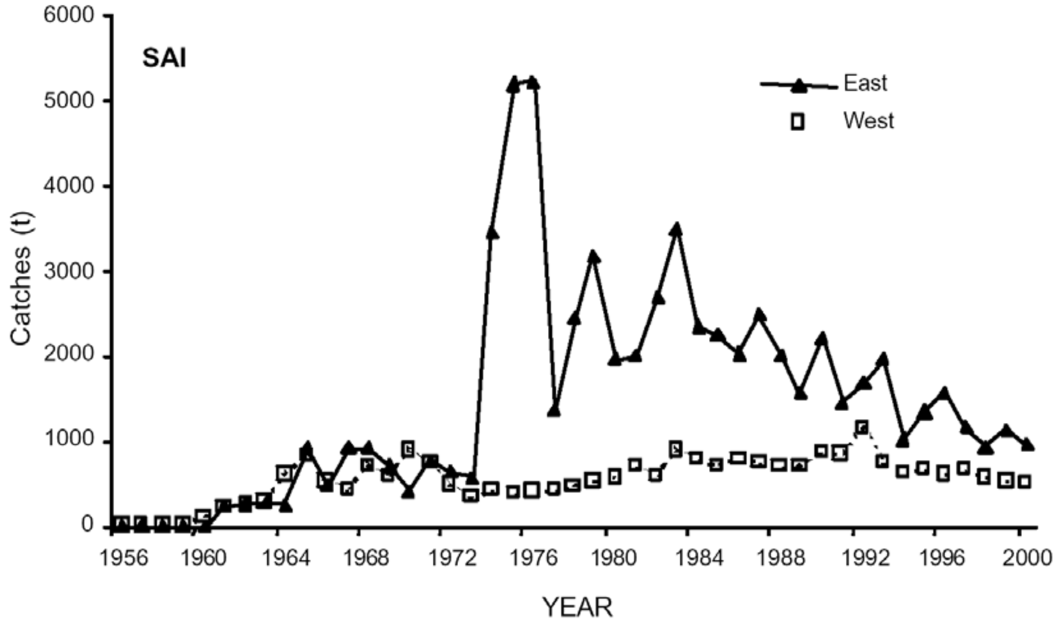

Figure 3.16 **Estimated sailfish "only" catches based on the new procedure for splitting combined sailfish and longbill spearfish catches from 1956-2000. Weights are in metric tons, whole weight.**

3.2.4.4 Longbill Spearfish

The longbill spearfish (*Tetrapturus pfluegeri*) are the most rare of the Atlantic istiophorids, and were identified as a distinct species in 1963. There is relatively little information available on spearfish life history. A related istiophorid, the Mediterranean spearfish (*Tetrapturus belone*), is the most common representative of this family in the Mediterranean Sea. Longbill spearfish are known to occur in epipelagic waters above the thermocline, off the east-coast of Florida, the Bahamas, the Gulf of Mexico, and from Georges Bank to Puerto Rico. Junior et al. (2004) captured spearfish off the coast of Brazil at depths ranging from 50-190 m (164 – 623 feet). The geographic range for this species is from 40°N to 35° S.

Spearfish spawn from November to May and females are generally 17-19 kg (37.4-41.8 lb) and 160-170 cm (63-66 inches) at first maturity. These fish are unique among istiophorids in that they are winter spawners. Larval spearfish have been identified from the vicinity of the mid-Atlantic ridge from December to February, indicating that this species spawns in offshore waters (de Sylva and Breder, 1997).

Common prey items include fish and squid. Specifically, Junior et al. (2004) observed 37 stomachs and found that oceanic pomfret and squid comprised 63 percent of the items identified in stomachs. Most prey items were between 1-10 cm (0.39-3.9 inches) in length, with a mean length of 6.7 cm (2.63 inches). The maximum number of prey items found in any individual stomach was 33.

Similar to sailfish, spearfish are caught incidentally or as bycatch, in offshore longline fisheries by many nations. There are also artisinal fisheries that take place in the Caribbean Sea and in the Gulf of Guinea. Directed recreational fisheries for spearfish are limited due to the fact that the fish are generally located further offshore than other istiophorids. The reported catches of sailfish/spearfish (Task I) for 2003 are 1,310 and 416 mt ww (2,888,055 and 917,123 lb) for the west and east Atlantic, respectively. The 2001-2003 reported catch of unclassified billfish was 12 percent of the reported catch for all billfish and for some fisheries this proportion is much greater. This is a problem for species like spearfish for which there is already a paucity of data (SCRS, 2004).

Effect of ICCAT Management Regulations

There are currently no specific ICCAT regulations for longbill spearfish in effect.

State of the Stock and SCRS Outlook

Initial stock assessments conducted on spearfish aggregated these landings with sailfish. As mentioned in the Sailfish section, the 2001 assessment included a 'sailfish only' in addition to an aggregate sailfish/spearfish assessment. West Atlantic catch levels for sailfish/spearfish combined seem sustainable because over the past two decades CPUE and catch levels have remained constant, however, MSY is unknown. As a result, it is unknown whether or not spearfish are experiencing overfishing or are overfished. Spearfish catch levels are shown in Figure 3.17.. The SCRS recommends implementing measures to reduce, or keep fishing mortality levels constant and evaluations of new methods to split sailfish and spearfish indices of abundance (SCRS, 2004).

Management recommendations are similar to those listed for sailfish, including: consider methods for Contracting Parties to reduce mortality rates, encourage Contracting Parties to provide complete reporting of spearfish catches, evaluate new methods to split the sailfish and spearfish catch/index abundance, and assess sailfish independently of spearfish.

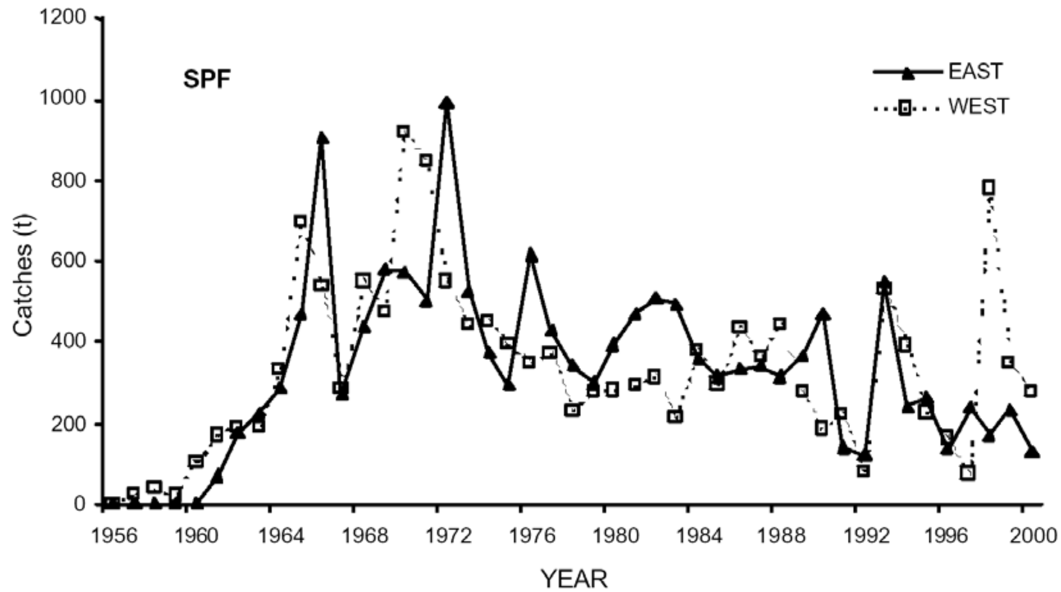

Figure 3.17 **Estimated spearfish "only" catches in the Atlantic based on the new procedure for splitting combined sailfish and spearfish catches from 1956-2000. Weights are in metric tons, whole weight.**

3.2.5 Atlantic Sharks

3.2.5.1 Life History/Species Biology

Sharks belong to the class Chondrichthyes (cartilaginous fishes) that also includes rays, skates, and deepwater chimaeras (ratfishes). From an evolutionary perspective, sharks are an old group of fishes characterized by skeletons lacking true bones. The earliest known sharks have been identified from fossils from the Devonian period, over 400 million years ago. These primitive sharks were small creatures, about 60 to 100 cm long, that were preyed upon by larger armored fishes that dominated the seas. Sharks have survived competition for eons, evolving into the large and aggressive predators that dominate the seas today. The life span of sharks in the wild is not known, but it is believed that many species may live 30 to 40 years or longer.

Relative to other marine fish, sharks have a very low reproductive potential. Several important commercial species, including large coastal carcharhinids such as sandbar (*Carcharhinus plumbeus)* (Casey and Hoey, 1985; Sminkey and Musick, 1995; Heist *et al*., 1995), lemon (*Negaprion brevirostris)* (Brown and Gruber, 1988), and bull sharks (Branstetter and Stiles, 1987), do not reach maturity until 12 to 18 years of age. Various factors determine this low reproductive rate: slow growth, late sexual maturity, one- to two-year reproductive cycles, a small number of young per brood, and specific requirements for nursery areas. These biological factors leave many species of sharks vulnerable to overfishing.

There is extreme diversity among the 350 species of sharks, ranging from tiny pygmy sharks of only 20 cm in length to the giant whale sharks, over 12 meters in length. There are fast-moving, streamlined species such as mako (*Isurus spp).* and thresher sharks (*Alopias spp*.), and sharks with flattened, ray-like bodies, such as angel sharks (*Squatina dumerili)*. The most commonly known sharks are large apex predators including the white (*Carchardodn carcharias*), mako, tiger (*Galeocerdo cuvier*), bull (*Carcharhinus leucas)*, and great hammerhead (*Sphyrna modarran*). Some shark species reproduce by laying eggs, others nourish their embryos through a placenta. Despite their diversity in size, feeding habits, behavior and reproduction, many of these adaptations have contributed greatly to the evolutionary success of sharks.

The most significant reproductive adaptations of sharks are internal fertilization and the production of fully developed young or "pups." These pups are large at birth, effectively reducing the number of potential predators and enhancing their chances of survival. During mating, the male shark inseminates the female with copulatory organs, known as claspers, that develop on the pelvic fins. In most species, the embryos spend their entire developmental period protected within their mother's body, although some species lay eggs. The number of young produced by most shark species in each litter is small, usually ranging from two to 25, although large females of some species can produce litters of 100 or more pups. The production of fully-developed pups requires great amounts of nutrients to nourish the developing embryo. Traditionally, these adaptations have been grouped into three modes of reproduction: oviparity, ovoviviparity, and viviparity.

Adults usually congregate in specific areas to mate and females travel to specific nursery areas to pup. These nurseries are discrete geographic areas, usually in waters shallower than those inhabited by the adults. Frequently the nursery areas are in highly productive coastal or estuarine waters where abundant small fishes and crustaceans provide food for the growing pups. These areas also may have fewer large predators, thus enhancing the chances of survival of the young sharks. In temperate zones, the young leave the nursery with the onset of winter; in tropical areas, young sharks may stay in the nursery area for a few years.

Shark habitat can be described in four broad categories: (1) coastal, (2) pelagic, (3) coastal- pelagic, and (4) deep-dwelling. Coastal species inhabit estuaries, the nearshore and waters of the continental shelves, e.g., blacktip (*Carcharhinus limbatus*), finetooth, bull, lemon, and sharpnose sharks (*Rhizoprinondon terraenaovae*). Pelagic species, on the other hand, range widely in the upper zones of the oceans, often traveling over entire ocean basins. Examples include shortfin mako (*Isurus oxyrinchus*), blue (*Prionace glauca*), and oceanic whitetip (*Carcharhinus longimanus*) sharks. Coastal-pelagic species are intermediate in that they occur both inshore and beyond the continental shelves, but have not demonstrated mid-ocean or transoceanic movements. Sandbar, scalloped hammerhead (*Sphyrna lewini*), and dusky sharks (*Carcharhinus obscurus*) are examples of coastal-pelagic species. Deep-dwelling species, e.g., most cat sharks (*Apristurus spp*.) and gulper sharks (*Centrophorus spp*.), inhabit the dark, cold waters of the continental slopes and deeper waters of the ocean basins.

Seventy-three species of sharks are known to inhabit the waters along the U.S. Atlantic coast, including the Gulf of Mexico and the waters around Puerto Rico and the U.S. Virgin Islands. Seventy-two species are managed by HMS; spiny dogfish also occur along the U.S. coast, however management for this species is under the authority of the Atlantic States Marine Fisheries Commission as well as the New England and Mid-Atlantic Fishery Management Councils. Based on a combination of ecology and fishery dynamics the sharks in the management unit have been divided into four species groups for management: (1) large coastal species, (2) small coastal species, (3) pelagic species, and (4) prohibited species (Table 3.16).

Table 3.16 Common names of shark species included within the four species management units under the purview of the HMS management division.

Management Unit	Shark Species Included
Large Coastal Sharks (11)	Sandbar, silky, tiger, blacktip, bull, spinner, lemon, nurse, smooth hammerhead, scalloped hammerhead, and great hammerhead sharks
Small Coastal Sharks (4)	Atlantic sharpnose, blacknose, finetooth, and bonnethead sharks
Pelagic Sharks (5)	Shortfin mako, thresher, oceanic whitetip, porbeagle, and blue sharks
Prohibited Species (19)	Whale, basking, sandtiger, bigeye sandtiger, white, dusky, night, bignose, Galapagos, Caribbean reef, narrowtooth, longfin mako, bigeye thresher, sevengill, sixgill, bigeye sixgill, Caribbean sharpnose, smalltail, and Atlantic angel sharks.

3.2.5.2 Status of the Stocks

NMFS is responsible for conducting stock assessments for the Large and Small Coastal Shark complexes (LCS and SCS) (Cortes, 2002; Cortes et al., 2002). ICCAT and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) have recently conducted assessments of three pelagic species. Stock assessments were conducted for the Large and Small Coastal Shark complexes (LCS and SCS) in 2002. Species-specific assessments for blacktip and sandbar sharks within the LCS complex and finetooth sharks, Atlantic sharpnose sharks, blacknose sharks (*Carcharhinus acronotus*), and bonnethead sharks (*Sphyrna tiburo*) within the SCS complex, were also conducted in 2002. The conclusions of these assessments are summarized in Table 3.17 and Table 3.18 and are fully described in Amendment 1 to the 1999 Atlantic Tunas, Swordfish, and Sharks FMP. Summaries of recent stock assessments and reports on several species of pelagic sharks (blue sharks, shortfin mako sharks, and porbeagle sharks (*Lamna nasus*) by COSEWIC and ICCAT are also included in this section.

3.2.5.3 Finetooth Sharks

Finetooth sharks inhabit shallow coastal waters to depths of 10 m (32.8 feet) near river mouths in the Gulf of Mexico and South Atlantic Ocean between Texas and North Carolina. These fish often form large schools and migrate to warmer waters when water temperatures drop below 20°C (68°F). Finetooth sharks are relatively productive compared to other sharks as fish are sexually mature at 3.9 (TL = 118 cm (46 inches)) and 4.3 (TL = 123 cm (48 inches)) years for males and females, respectively (Carlson et al. 2003). Reproduction in finetooth sharks is viviparous with yolksac placenta and embryos nourished through a placental connection. Females move into the nursery areas in late May and gestation is approximately 12 months. Each litter can have 1-6 pups with individuals measuring 51-64 cm (20-25 inches) in length. The finetooth shark feeds primarily on mullet, Spanish mackerel, spot, Atlantic menhaden, cephalopods, and crustacean (Bester and Burgess, 2004).

In a 2002 stock assessment, NMFS determined that finetooth sharks are not overfished ($B<B_{MSY}$), but that overfishing is occurring ($F>F_{MSY}$) (Table 3.17). Under National Standard 1 of the Magnuson-Stevens Act, NMFS is required to take measures to reduce fishing mortality. In general, more catch series data were available for the other species of SCS which were assessed simultaneously in 2002, than for finetooth sharks. It was determined that other species in the complex, and the complex as a whole, were not overfished and were not experiencing overfishing. Another limitation of the 2002 finetooth shark stock assessment was that bycatch data from the shrimp fishery was not included. Alternatives for reducing fishing mortality of finetooth sharks are explored in greater detail in Section 2.3.2 - Reducing Fishing Mortality of Finetooth Sharks.

Table 3.17 **Summary Table of Biomass and Fishing Mortality for Small Coastal Sharks SCS)** Source: Cortes, 2002.

Species/ Complex	**MSY (B_{MSY}) million lb dw**	**2001 Relative Biomass Level (B_{2001}/ B_{MSY})**	**Minimum Stock Size Threshold MSST = (0.5)B_{MSY} if M>=0.5 MSST = (1-M)Bmsy if M<0.5**	**Fishing Mortality Rate (F_{2000})**	**Maximum Fishing Mortality Threshold (F_{MSY})**	**Outlook**
Small Coastal Sharks (SCS)	7.0-2.2	1.38-2.39	16.2-50.2	0.03-0.24	0.04-0.78	Not overfished; No overfishing occuring
Finetooth Sharks	0.26-0.05	1.39-2.37	0.4-1.4	0.13-1.50	0.03-0.44	Not overfished; Overfishing is occuring
Bonnethead Sharks	1.8-0.5	1.46-2.78	2.3-7.3	0.03-0.18	0.05-0.53	Not overfished; No overfishing occuring
Atlantic Sharpnose Sharks	7.8-1.9	1.69-3.16	11.5-33.4	0.02-0.06	0.04-0.42	Not overfished; No overfishing occuring
Blacknose Sharks	0.8-0.2	1.92-3.15	1.6-4.5	0.02-0.19	0.03-0.44	Not overfished; No overfishing occuring

Table 3.18 **Summary Table of Biomass and Fishing Mortality for Large Coastal Sharks (LCS).** Source: Cortes et al., 2002

Species/ *Complex*	**2001 Biomass (N_{2001})**	**2001 Relative Biomass (N_{2001}/N_{MSY})**	**Fishing Mortality Rate (F_{2001})**	**Maximum Fishing Mortality Threshold (F_{MSY})**	**Outlook**
Large Coastal Complex	2,940-10,156	0.46-1.18	0.07-0.21	0.05-0.10	Overfished; Overfishing is occurring
Sandbar Sharks	1,027-4.86 E8	3.25E4-2.22	0.0001-0.70	0.05-0.46	Not overfished; Overfishing is occurring
Blacktip Sharks	5,587-3.16 E7	0.79-1.66	0.01-0.21	0.06-0.18	Not overfished; No overfishing occurring

ICCAT Stock Assessment on Blue and Shortfin Mako Sharks

At the 2004 ICCAT annual meeting in New Orleans the commission adopted a recommendation concerning the conservation of sharks caught in association with fisheries managed by ICCAT. This is the first binding measure passed by ICCAT dealing specifically with sharks. This recommendation includes, among other measures: reporting of shark catch data by Contracting Parties, a ban on shark finning, a request for Contracting Parties to live-release sharks that are caught incidentally, a review of management alternatives from the 2004 assessment on blue and shortfin mako sharks, and a commitment to conduct another stock assessment of selected pelagic shark species no later than 2007.

At the 2004 Inter-Sessional Meeting of the ICCAT Sub-Committee on bycatch, stock assessments for Atlantic blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) were conducted. This work included a review of their biology, a description of the fisheries, analyses of the state of the stocks and outlook, analyses of the effects of current regulations, and recommendations for statistics and research. The assessment indicated that the current biomass of North and South Atlantic blue shark seems to be above MSY ($B>B_{MSY}$), however, these results are conditional and based on assumptions that were made by the committee. These assumptions indicate that blue sharks are not currently overfished, again, this conclusion is conditional and based on limited landings data. The committee estimates that between 82,000 and 114,000 mt ww (180,779,054 - 251,326,978 lb) of blue shark are harvested from the Atlantic Ocean each year.

The North Atlantic shortfin mako population has experienced some level of stock depletion as suggested by the historical CPUE trend and model outputs. The current stock may be below MSY ($B<B_{MSY}$), suggesting that the species may be overfished. Overfishing may also be occurring as between 13,000 and 18,000 mt ww (28,660,094 – 39,683,207 lb) of shortfin mako are harvested in the Atlantic Ocean annually. South Atlantic stocks of shortfin mako shark are likely fully exploited as well, but depletion rates are less severe than in the North Atlantic.

The results of both of these assessments should be considered preliminary in nature due to limitations on quality and quantity of catch data available (SCRS, 2004). The sub-committee stated that catch data currently being reported to ICCAT does not represent the total catch actually landed, and are very limited with regard to size, age, and sex of shark harvested or caught incidentally. In order to attain a more accurate estimate of total landings, and improve future stock assessments, the committee made several recommendations, including: increase the infrastructure investment for monitoring the overall catch composition of sharks, standardize catch per unit effort (CPUE) from major fishing fleets, expand use of trade statitistics (fins) to extend historical time series, and include scientists from all Contracting Parties with significant blue and shortfin mako catches in future assessments (SCRS, 2004).

COSEWIC Stock Assessment on Porbeagle

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) conducted a species report and assessment for porbeagle in 2004. They suggest that significant declines in porbeagle abundance have occurred as a result of overexploitation in fisheries. In 2001, porbeagle biomass was estimated at 4,409 mt ww (9,720,181 lb), a decline of 89% from the prefishing biomass in 1961 (COSEWIC, 2004). The model employed predicts that populations declined precipitously after the fishery was developed in 1961, recovered slightly in the 1980s, and then declined again to the current level. Porbeagle quotas have been reduced significantly for Canadian fisheries. NMFS is interested in working with the Canadian government to address concerns raised by the COSEWIC report. Currently, NMFS has a species-specific quota of 46 mt dw (101,412 lb) for porbeagle. These fish are generally harvested incidentally in the pelagic longline fisheries. Between 2000 and 2003, landings of porbeagle were approximately 3.4 mt dw for the four fishing years combined.

3.2.5.4 Ongoing Research

Northeast Fisheries Science Center

Fishery Independent Survey for Coastal Sharks

The bi-annual fishery independent survey of Atlantic large and small coastal sharks in US waters from Florida to Delaware was conducted from April 19 to June 1, 2004. The goals of this survey are to: 1) monitor the species composition, distribution, and abundance of sharks in the coastal Atlantic; 2) tag sharks for migration and age validation studies; 3) collect biological samples for age and growth, feeding ecology, and reproductive studies; and 4) collect morphometric data for other studies. Results from this 2004 survey included 557 sharks representing eight species caught on 69 longline sets. The time series of abundance indices from this survey are critical to the evaluation of coastal Atlantic shark species.

Age and Growth of Coastal and Pelagic Sharks

A comprehensive aging and validation study for the shortfin mako (*Isurus oxyrinchus)*, continued in conjunction with scientists at Moss Landing Marine Laboratories, California using bomb carbon techniques. Additional validation studies have begun on the sandbar shark, (*Carcharhinus plumbeus)*, dusky shark, (*Carcharhinus obscurus)*, tiger shark, (*Galeocerdo cuvieri)*, and white shark, (*Carcharodon carcharias)*. Age and growth studies on the tiger shark (with scientists at the University of New Hampshire), thresher shark, (*Alopias vulpinus)* (with scientists at the University of Rhode Island), night shark, (*Carcharhinus signatus)* (with NMFS scientists at the SEFSC Panama City Laboratory), and the bull shark, (*Carcharhinus leucas)* (with scientists with the Florida Division of Natural Resources) are underway. Collection, processing, photographing, and reading of samples are in various stages for these species including intercalibration of techniques, criteria, and band readings. This intercalibration process involves sharing samples and comparing counts between researchers including a researcher from the Natal Sharks Board, South Africa for joint work on shortfin mako, blue, and basking shark band periodicity. Collections of vertebra took place at tournaments and on the biannual research cruise with 285 sharks injected with OTC for validation. Night and dusky sharks were prepared with gross sectioning to determine the best method for reading and all processing was initiated using histology. Readings were completed on the thresher and tiger sharks towards intercalibration to generate bias graphs. Vertebrae, length-frequency data, and tag/recapture data collected from 1962 to present are being analyzed on each of these species to obtain growth parameters.

Biology of the Thresher Shark

Life history studies of the thresher shark continued. Data collection was augmented to include reproductive and food habits, in addition to age and growth information.

Biology of the Porbeagle Shark

A cooperative U.S./Canada research program continued on the life history of the porbeagle shark, (*Lamna nasus)* with preliminary analysis of porbeagle tagging and recapture data using information from U.S., Canadian, and Norwegian sources.

Collection of Recreational Shark Fishing Data and Samples

Biological samples for age and growth, feeding ecology, and reproductive studies and catch data for pelagic sharks were collected at recreational fishing tournaments in the Northeast. Analysis of these tournament landings data was initiated by creating a database of historic information (1961-2004) and producing preliminary summaries of one long term tournament. The collection and analysis of these data are critical for input into species and age specific population and demographic models for shark management

Cooperative Shark Tagging Program (CSTP)

The Cooperative Shark Tagging Program involving over 6,500 volunteer recreational and commercial fishermen, scientists, and fisheries observers conducted since 1962, continued to tag large coastal and pelagic sharks and provide information to define essential fish habitat for shark species in U.S. Atlantic and Gulf of Mexico waters. Since its inception, the CSTP has tagged over 128,000 sharks representing 40 species.

Atlantic Blue Shark Life History and Assessment Studies

A collaborative program to examine the biology and population dynamics of the blue shark, *Prionace glauca,* in the North Atlantic is ongoing. Research on the food and feeding ecology of the blue shark is being conducted cooperatively with University of Rhode Island staff with additional samples collected and a manuscript under revision. A detailed reexamination of the reproductive parameters of the blue shark continued with collection of additional biological samples to determine if any changes have occurred since the 1970s. A manuscript on blue shark stock structure based on tagging data was completed detailing size composition and movements between Atlantic regions. Additionally, a research focus on the population dynamics in the North Atlantic with the objectives of constructing a time series of blue shark catch rates (CPUE) from research surveys, estimation of blue shark migration and survival rates, and the development of an integrated tagging and population dynamics model for the North Atlantic for use in stock assessment continued in collaboration between NEFSC scientists and scientists at the School of Aquatic and Fishery Sciences, University of Washington. Progress to date includes the preliminary recovery of historical research survey catch data, size composition, and biological sampling data on pelagic sharks and preliminary analysis of survival and movement rates for blue sharks based on tag and release data from the NMFS CSTP. Preparation of standardized catch rate and size composition data compatible with pelagic longline observer data continued with a resulting ICCAT submission. As part of this comprehensive program, cooperative research continued with the Irish Marine Institute and Central Fisheries Board on mark-recapture databases including coordination of formats and programs with the NMFS CSTP for joint data analyses.

Atlantic Shortfin Mako Life History and Assessment Studies

A collaborative program with students and scientists at the University of Rhode Island to examine the biology and population dynamics of the shortfin mako in the North Atlantic was continued. Ongoing research included an update on age and growth and reproductive parameters and an examination of the predator-prey relationships between the shortfin mako and its primary prey, bluefish (*Pomatomus saltatrix).* A manuscript was completed comparing contemporary and historic levels of bluefish predation. Future research includes the estimation of shortfin mako migration rates and patterns and survival rates using CSTP mark/recapture data and satellite tags with movements correlated with Advanced Very High Resolution Radiometer

(AVHRR) sea surface temperature data. Toward these goals, two shortfin mako sharks were tagged with pop-up archival transmitting tags.

Blacktip Shark Migrations

Analysis of movements of the blacktip shark (*Carcharhinus limbatus)* in the western North Atlantic and Gulf of Mexico based on release and recapture data is ongoing with the examination of general migration patterns and exchange between and within regions of U.S. and Mexican waters. Release and recapture data were analyzed for evidence of Atlantic and Gulf primary and secondary blacktip nursery grounds.

Cooperative Atlantic States Shark Pupping and Nursery Survey (COASTSPAN)

NEFSC Apex Predators Program staff manage and coordinate this project that uses researchers in major coastal Atlantic states from Florida to Delaware to conduct a cooperative, comprehensive, and standardized investigation of valuable shark nursery areas. This research identifies which shark species utilize coastal zones as pupping and nursery grounds, gauges the relative importance of these areas, and determines migration and distribution patterns of neonate and juvenile sharks. This program is described in further detail in Section 3.3 of this document.

Juvenile Shark Survey for Monitoring and Assessing Delaware Bay Sandbar Sharks

NEFSC staff conduct this part of the COASTSPAN monitor and assessment project for the juvenile sandbar shark population in the Delaware Bay nursery grounds using monthly longline surveys from June to September each year. A random stratified sampling plan based on depth and geographic location is ongoing to assess and monitor the juvenile sandbar shark population during the nursery season. In addition, the tagging and recapture data from this project are being used to examine the temporal and spatial relative abundance and distribution of sandbar sharks in Delaware Bay.

Habitat Utilization, Food Habits, and Essential Fish Habitat of Delaware Bay Sandbar and Smooth Dogfish Sharks

The food habits portion of the study characterizes the diet, feeding periodicity, and foraging habits of the sandbar shark as well as examine the overlap in diet and distribution with the smooth dogfish shark (*Mustelus canis)*. Stomachs from over 800 sandbar sharks and over 200 smooth dogfish sharks have been sampled for contents through a non-lethal lavage method. Acquired data will be coupled with environmental data, providing information on preferred habitat. This information is an important contribution towards understanding essential fish habitat and provides information necessary for nursery ground management and rebuilding of depleted shark populations.

Ecosystems Modeling

Ecosystem modeling, focusing on the role of sharks as top predators, will be conducted using ECOPATH - ECOSIM models, using the sandbar shark as a model species and examining the ecological interactions between sandbar and smooth dogfish sharks in Delaware Bay.

Overview of Gulf and Atlantic Shark Nurseries

Due to the requirement for a better understanding of shark nursery habitat in U.S. coastal waters, NEFSC staff are editors for an American Fisheries Society symposium proceedings volume on U.S. Atlantic and Gulf of Mexico coastal shark nursery ground and habitat studies.

Post-Release Recovery and Survivorship Studies in Sharks -- Physiological Effects of Capture Stress

This ongoing research is directed towards the sandbar shark (*Carcharhinus plumbeus)*, and is being conducted cooperatively with Massachusetts Division of Marine Fisheries biologists. The study utilizes blood and muscle sampling methods in addition to acoustic tracking to obtain physiological profiles of individual sharks to characterize stamina and to determine ultimate post release survival. These analyses are requisite in view of the extensive current and proposed catch and release management strategies for coastal and pelagic shark species.

Southeast Fisheries Science Center

Stock Assessments of Pelagic, Large Coastal, and Prohibited Sharks

The ICCAT Sub-Committee on Bycatches conducted a stock assessment of blue sharks and shortfin makos in Tokyo, Japan, in June 2004. All information available on biology, fisheries, stock identity, catch, CPUE, and size of these species was reviewed and an evaluation of the status of stocks conducted using surplus production, age-structured, and catch-free stock assessment models. U.S. scientists contributed eight working documents for this meeting on various aspects of shark biology and methods to assess stock status; SEFSC scientists participated in the assessment process and authored or co-authored six of those documents. A stock assessment of dusky shark, a prohibited species under the shark FMP and candidate for listing under the ESA, is under way with expected completion in late 2004. Biological and fishery information available for this species is being synthesized and stock status will be evaluated using multiple stock assessment methodologies. The next assessment of large coastal sharks is planned for FY06, but data collection, synthesis, analysis, and preliminary stock evaluations will begin well in advance during FY05.

Update on Catches of Atlantic Sharks:

An update on catches of large and small coastal and pelagic sharks in U.S. Atlantic, Gulf of Mexico, and Caribbean waters was generated in FY04 for inclusion in the 2004 SAFE Annual Report and future shark stock assessments. Time series of commercial and recreational landings and discard estimates from several sources were compiled for the large coastal shark complex and sandbar and blacktip sharks. Additionally, recent species-specific commercial and recreational landings were provided for sharks in the large coastal, small coastal, and pelagic groups. Species-specific information on the geographical distribution of commercial landings by gear type and geographical distribution of the recreational catches was also provided. Trends in length-frequency distributions and average weights and lengths of selected species reported from three separate recreational surveys and in the directed shark bottom-longline observer program were also included. Another update on catches of Atlantic sharks will be generated in FY05.

Ecosystem Modeling

A dynamic mass-balance ecosystem model was used to investigate how relative changes in fishing mortality on sharks can affect the structure and function of Apalachicola Bay, Florida, a coastal marine ecosystem. Simulations were run for 25 years wherein fishing mortality rates from recreational and trawl fisheries were doubled for 10 years and then decreased to initial levels. Effect of time/area closures on ecosystem components were also tested by eliminating recreational fishing mortality on juvenile blacktip sharks. Simulations indicated biomass of sharks declined up to 57 percent when recreational fishing mortality was doubled. Simulating a time/area closure for juvenile blacktip sharks caused increases in their biomass but decreases in juvenile coastal shark biomass, a competing multi-species assemblage that is the apparent competitor. In general, reduction of targeted sharks did not cause strong top-down cascades. A manuscript from this study is currently in press.

Elasmobranch Feeding Ecology and Shark Diet Database

The current Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks gives little consideration to ecosystem function because there is little quantitative species-specific data on diet, competition, predator-prey interactions, and habitat requirements of sharks. Given this, several studies are currently underway describing the diet and foraging ecology, habitat use, and predator-prey interactions of elasmobranchs in various communities. In 2004, the diet of Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) was compared in two marine embayments of the northeast Gulf of Mexico. Results indicate that variations in diet composition between areas and ontogenetic diet shifts within each location are likely due to differences in overall habitat structure and availability of potential prey species. A manuscript is currently in review. A database containing information on quantitative food and feeding studies of sharks conducted around the world has been in development for several years and presently includes over 200 studies. This fully searchable database will continue to be updated and fine-tuned in FY05. The goal is to make this tool available to researchers in the relatively near future.

Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey (GULFSPAN)

The SEFSC Panama City Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries between the Panhandle of Florida and Texas. Surveys identify the presence/absence of neonate and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to essential fish habitat requirements for sharks. The SEFSC Panama City Shark Population Assessment Group also initiated a juvenile shark abundance index survey in 1996. The index is based on random, depth-stratified gillnet sets conducted throughout coastal bays and estuaries in northwest Florida monthly from April to October. The species targeted for the index of abundance are juvenile sharks in the large and small coastal management groups. More information on this program can be found in Section 3.3 of this document.

Angel Shark Life History

The Atlantic Angel Shark is a benthic species inhabiting deep waters of the Gulf of Mexico and the Atlantic Ocean. This species is listed as prohibited by the Fisheries Management Plan for Atlantic Tunas, Swordfish, and Sharks due to the lack of biological data and a precautionary approach for species thought to be highly susceptible to exploitation. Life history studies began in 2003. Samples are obtained from commercial fishers and fishery-independent surveys. Preliminary reproductive parameters were determined in 2004 and results presented at the annual American Elasmobranch Society meeting held in Norman, Oklahoma, in May 2004.

Life History Studies of Elasmobranchs

Biological samples are obtained through research surveys and cruises, recreational fishers, and through collection by onboard observers on commercial fishing vessels. Age and growth rates and other life history aspects of selected species are processed and data analyzed following standard methodology. This information is vital as input to population models incorporating variation and uncertainty in estimates of life-history traits to predict the productivity of the stocks and ensure that they are harvested at sustainable levels. The age and growth parameters of bull shark (*Carcharhinus leucas*) and spinner shark (*C. brevipinna*) were completed and submitted for publication in 2004.

Cooperative Research-Definition of Winter Habitats for Blacktip Sharks in the Eastern Gulf of Mexico

A collaborative effort between SEFSC Panama City Shark Population Assessment Group and Mote Marine Laboratory is underway to define essential winter habitats for blacktip sharks (*Carcharhinus limbatus*). Deployment of archival Pop-up Archival Transmitting (PAT) tags on sharks during January-February of FY05 in the Florida Keys and north Florida will be executed with the cooperation of the charter boat industry. PAT tags will be programmed to detach from individuals during late spring and early summer when sharks have recruited to coastal areas.

Cooperative Research-Habitat Utilization among Coastal Sharks

Through a collaborative effort between SEFSC Panama City Shark Population Assessment Group and Mote Marine Laboratory, the utilization of coastal habitats by neonate and young-of-the-year blacktip and Atlantic sharpnose sharks will be monitored through an array of underwater acoustic receivers (VR2, Vemco Ltd.) placed throughout each study site. Movement patterns, home ranges, activity space, survival, and length of residence of individuals will be compared by species and area to provide information to better manage critical species and essential fish habitats.

Cooperative Research-Characterization of Bycatch in the Gulf Butterfish, (*Peprilus burti*), Trawl Fishery, with an Emphasis on Identification of Life History Parameters for several Potentially High-Risk Species

A proposal with the SEFSC Panama City Shark Population Assessment Group and the University of Florida was submitted to MARFIN to quantify and qualify the elasmobranch bycatch in the butterfish, (*Peprilus triacanthus)*, trawl fishery in the Gulf of Mexico. Determination of life history parameters for the roundel skate, (*R. texana)*, the clearnose skate, (*R. eglanteria)*, the spreadfin skate (*Dipturus olseni)*, and the Atlantic angel shark, (*Squatina dumerili)* will be developed ultimately for the estimation of vital rates. Vital rate information will be used to determine the productivity of the stocks and ensure that they are harvested at sustainable levels.

Coastal Shark Assessment Research Surveys

The SEFSC Mississippi Laboratories in Pascagoula have been operating annual research cruises aboard NOAA vessels since 1995. The objectives of this program are to conduct bottom longline surveys to assess the distribution and relative abundance of coastal sharks along U.S. and Mexican waters of the Gulf of Mexico and the U.S. eastern seaboard. This is the only long-term, nearly stock-wide, fishery-independent survey of Atlantic sharks conducted in U.S. and neighboring waters. Ancillary objectives are to collect biological and environmental data, and to tag-and-release sharks. Starting in 2001 and under the auspices of the Mex-US Gulf Program, the Pascagoula Laboratories have provided logistical and technical support to Mexico's Instituto Nacional de la Pesca to conduct a cooperative research cruise aboard the Mexican research vessel Onjuku in Mexican waters of the Gulf of Mexico. The cruise also took place in 2002, but was suspended in 2003 and 2004 because of mechanical problems with the research vessel and other issues.

Cooperative Research--The capture depth, time, and hooked survival rate for bottom longline-caught large coastal sharks

A collaborative effort between SEFSC Panama City Shark Population Assessment Group and the University of Florida to examine alternative measures in the shark bottom longline fishery to reduce mortality on prohibited sharks such as reduced soak time, restrictions on the length of gear, and fishing depth restrictions will be tested using hook timers. Funding is being sought through the NMFS Cooperative Research Program.