## 2.0 STATUS OF THE STOCKS

The thresholds 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 Billfish FMP, and are presented in Figure 2.1. These thresholds were carried over in full in the 2006 Consolidated HMS FMP. These thresholds are based on the thresholds described in a paper describing the technical guidance for implementing National Standard 1 of the Magnuson-Stevens Act (Restrepo *et al.*, 1998).

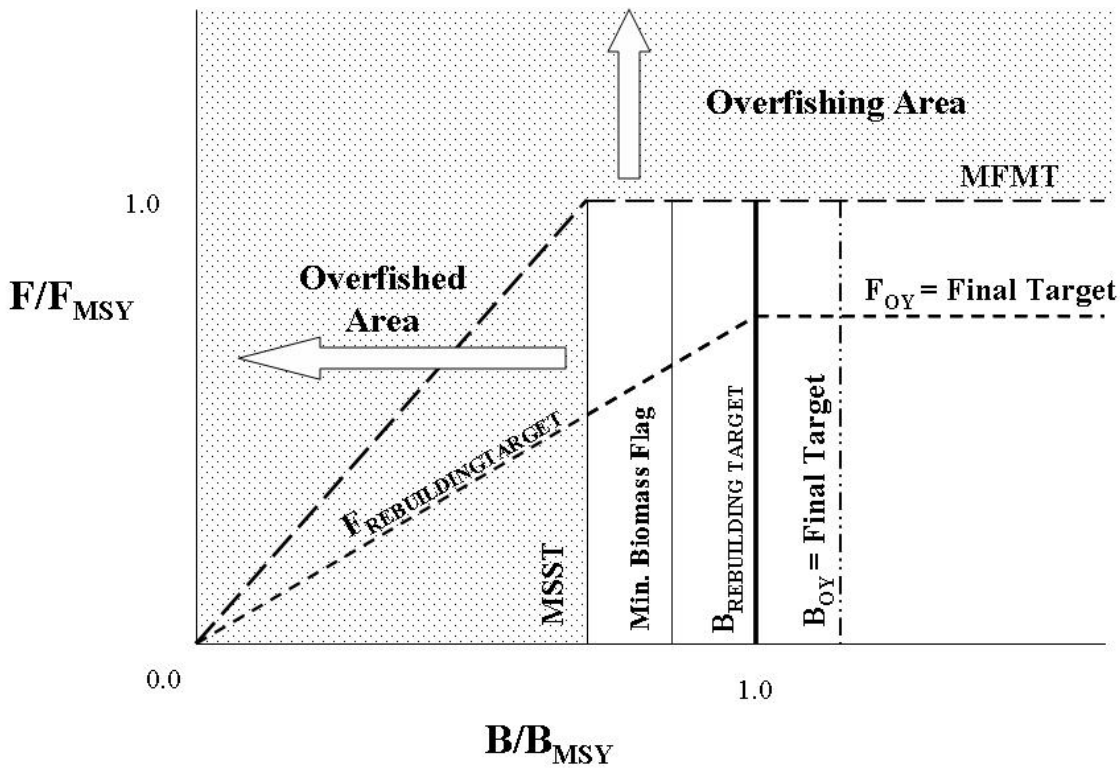


**Figure 2.1 Illustration of the status determination criteria and rebuilding terms.**

In summary, a species is considered overfished when the current biomass (B) is less than the minimum stock size threshold ($B < B_{MSST}$). The minimum stock size threshold (MSST) is determined based on the natural mortality of the stock and the biomass at maximum sustainable yield ($B_{MSY}$). Maximum sustainable yield (MSY) is the maximum long-term average yield that can be produced by a stock on a continuing basis. The biomass can be lower than $B_{MSY}$, and the stock not be declared overfished as long as the biomass is above $B_{MSST}$.

Overfishing may be occurring on a species if the current fishing mortality (F) is greater than the fishing mortality at MSY ($F_{MSY}$) ($F > F_{MSY}$). In the case of F, the maximum fishing mortality threshold is $F_{MSY}$. Thus, if F exceeds $F_{MSY}$, the stock is experiencing overfishing.

If a species is declared overfished or has overfishing occurring, action to rebuild the stock and/or prevent further overfishing is required by law. 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 ($F_{OY}$).

In summary, the thresholds used to calculate the status of Atlantic HMS, as described in the 1999 FMP and Amendment 1 to the Billfish FMP, are:

- Maximum Fishing Mortality Threshold (MFMT) = $F_{limit}$ = $F_{MSY}$;
- Overfishing is occurring when $F_{year} > F_{MSY}$;
- Minimum Stock Size Threshold (MSST) = $B_{limit}$ = $(1\text{-}M)B_{MSY}$ when $M < 0.5 = 0.5B_{MSY}$ when $M >= 0.5$ (for billfish, the specific MSST values are: blue marlin = $0.9B_{MSY}$; white marlin = $0.85B_{MSY}$; west Atlantic sailfish = $0.75B_{MSY}$);
- Overfished when $B_{year}/B_{MSY} <$ MSST;
- Biomass target during rebuilding = $B_{MSY}$;
- Fishing mortality during rebuilding < $F_{MSY}$;
- Fishing mortality for healthy stocks = $0.75F_{MSY}$;
- Biomass for healthy stocks = $B_{OY}$ = ~1.25 to $1.30B_{MSY}$;
- Minimum biomass flag = $(1\text{-}M)B_{OY}$; and
- Level of certainty of *at least* 50 percent but depends on species and circumstances.
- For bluefin tuna, spawning stock biomass (SSB) is used as a proxy for biomass
- For sharks, in some cases, spawning stock fecundity (SSF) or spawning stock number (SSN) was used as a proxy for biomass since biomass does not influence pup production in sharks.

With the exception of Atlantic sharks, stock assessments for Atlantic HMS are conducted by ICCAT's SCRS. In 2007, SCRS completed several stock assessments for Atlantic HMS: Atlantic bigeye tuna, albacore, and Mediterranean swordfish (not considered in the HMS management unit), and provided an update to the 2006 Atlantic bluefin tuna and 1999 skipjack tuna stock assessments. In 2008, SCRS completed stock assessments for western and eastern Atlantic bluefin tuna, yellowfin tuna, skipjack tuna, shortfin mako and blue sharks. Additionally, ecological risk assessments were conducted for several other shark species. All SCRS final stock assessment reports can be found at www.iccat.int/assess.htm.

Atlantic shark stock assessments for LCS and small coastal sharks (SCS) are completed by the NMFS Southeast Data, Assessment, and Review (SEDAR) process. The LCS complex, blacktip, and sandbar sharks were evaluated in 2006 (July 24, 2006, 71 FR 41774). The 2006 LCS assessment assessed blacktip sharks for the first time as two separate populations - Gulf of Mexico and Atlantic – and also assessed the status of sandbar sharks separately. In addition, the first dusky-specific shark assessment was released on May 25, 2006 (71 FR 30123). In 2007, NMFS released a stock assessment for SCS, including individual assessments for Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks (November 13, 2007, 72 FR 63888).

For porbeagle sharks, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) conducted a species report and assessment in 2004 (COSEWIC, 2004) and recommended to the Canadian Minister of Fisheries that porbeagle sharks be listed as endangered under the Species at Risk Act (SARA). The Canadian Department of Fisheries and Oceans conducted the latest assessment on porbeagle sharks in 2005, and NMFS has deemed this assessment the best available science and appropriate to use for U.S. domestic management measures (November 7, 2006, 71 FR 65086).

Table 2.1and Table 2.2 summarize stock assessment information and the current status of Atlantic HMS as of October 2008.

**Table 2.1** **Stock Assessment Summary Table for Atlantic tunas, swordfish, and marlin.** Source: SCRS, 2008.

| Species | Current Relative Biomass Level | Minimum Stock Size Threshold | Current Relative Fishing Mortality Rate | Maximum Fishing Mortality Threshold | Outlook – From Status of Stocks for U.S. managed species |
|---|---|---|---|---|---|
| **West Atlantic Bluefin Tuna** | $SSB_{07}/SSB_{MSY}$ = 0.57 (0.46-0.70) (low recruitment)<br>$SSB_{07}/SSB_{MSY}$ = 0.14 (0.08-0.21) (high recruitment)<br><br>$SSB_{07}/SSB_{75}$ = 0.25 | $0.86SSB_{MSY}$ | $F_{04\text{-}06}/F_{MSY}$ = 1.27 (1.04-1.53) (low recruitment)<br>$F_{04\text{-}06}/F_{MSY}$ =2.18 (1.74-2.64) (high recruitment) | $F_{year}/F_{MSY}$ = 1.00 | Overfished; overfishing is occurring. |
| **Atlantic Bigeye Tuna** | $B_{06}/B_{MSY}$ = 0.92 (0.85-1.07) | $0.6B_{MSY}$ (age 2+) | $F_{05}/F_{MSY}$ = 0.87 (0.70-1.24) | $F_{year}/F_{MSY}$ = 1.00 | Rebuilding; overfishing not occurring. |
| **Atlantic Yellowfin Tuna** | $B_{06}/B_{MSY}$ = 0.96 (0.72-1.22) | $0.5B_{MSY}$ (age 2+) | $F_{current}/F_{MSY}$=0.86 (0.71-1.05)* | $F_{year}/F_{MSY}$ = 1.00 | Not overfished ; overfishing not occurring. |
| **North Atlantic Albacore Tuna** | $B_{05}/B_{MSY}$ = 0.81 (0.68-0.97) | $0.7B_{MSY}$ | $F_{05}/F_{MSY}$ = 1.5 (1.3-1.7) | $F_{year}/F_{MSY}$ = 1.00 | Overfished; overfishing is occurring. |
| **West Atlantic Skipjack Tuna** | $B_{06}/B_{MSY}$: most likely>1 | *Unknown* | $F_{06}/F_{MSY}$: most likely<1 | $F_{year}/F_{MSY}$ = 1.00 | Unknown |
| **North Atlantic Swordfish** | $B_{06}/B_{MSY}$ = 0.99 (0.87-1.27) | *Unknown* | $F_{05}/F_{MSY}$ = 0.86 (0.87-1.27) | $F_{year}/F_{MSY}$ = 1.00 | Rebuilding; overfishing not occurring |
| **South Atlantic Swordfish** | Likely >1 | *Unknown* | Likely <1 | $F_{year}/F_{MSY}$ = 1.00 | Unknown |

| Species | Current Relative Biomass Level | Minimum Stock Size Threshold | Current Relative Fishing Mortality Rate | Maximum Fishing Mortality Threshold | Outlook – From Status of Stocks for U.S. managed species |
|---|---|---|---|---|---|
| **Blue Marlin** | $B_{04}$<$B_{MSY}$: yes | 0.9$B_{MSY}$ | $F_{04}$>$F_{MSY}$: Yes | $F_{year}/F_{MSY}$ = 1.00 | Overfished: overfishing is occurring |
| **White Marlin** | $B_{04}$<$B_{MSY}$: yes | 0.85$B_{MSY}$ | $F_{04}$>$F_{MSY}$: Possibly | $F_{year}/F_{MSY}$ = 1.00 | Overfished: overfishing is occurring |
| **West Atlantic Sailfish** | *Unknown* | 0.75$B_{MSY}$ | *Unknown* | *Not estimated* | Overfished; overfishing is occurring |
| **Spearfish** | *Unknown* | *Unknown* | *Unknown* | *Not estimated* | *Unknown* |

*$F_{current}$ refers to F2006 in the case of ASPIC, and the geometric mean of F across 2003-2006 in the case of VPA.

**Table 2.2** **Stock Assessment Summary Table for Atlantic sharks.** Sources: SCRS, 2007; Gibson and Campana, 2005; Cortés *et al*., 2006; NMFS, 2006; NMFS, 2007.

| Species | Current Relative Biomass Level | Minimum Stock Size Threshold | Current Relative Fishing Mortality Rate | Maximum Fishing Mortality Threshold | Outlook |
|---|---|---|---|---|---|
| **LCS Complex** | *Unknown* | *Unknown* | *Unknown* | *Unknown* | *Unknown* |
| **Sandbar** | $SSF_{04}/SSF_{MSY}$ = 0.72 | 4.75-5.35E+05 | $F_{04}/F_{MSY}$ = 3.72 | 0.015 | Overfished; overfishing is occurring |
| **Gulf of Mexico Blacktip** | $SSF_{04}/SSF_{MSY}$ = 2.54-2.56 | 0.99-1.07E+07 | $F_{04}/F_{MSY}$ = 0.03–0.04 | 0.20 | Not overfished; overfishing not occurring |
| **Atlantic Blacktip** | *Unknown* | *Unknown* | *Unknown* | *Unknown* | *Unknown* |
| **Dusky Sharks** | $B_{03}/B_{MSY}$ = 0.15-0.47 | *Unknown* | $F_{03}/F_{MSY}$ = 1.68-1,810 | 0.00005-0.0115 | Overfished; overfishing is occurring |
| **SCS Complex** | $N_{05}/N_{MSY}$ = 1.69 | 2.1E+07 | $F_{05}/F_{MSY}$ = 0.25 | $F_{MSY}$ = 0.091 | Not overfished; overfishing not occurring |
| **Bonnethead Sharks** | $SSF_{05}/SSF_{MSY}$ = 1.13 | 1.4 E+06 | $F_{05}/F_{MSY}$ = 0.6 | $F_{MSY}$ = 0.31 | Not overfished; overfishing not occurring |
| **Atlantic Sharpnose Sharks** | $SSF_{05}/SSF_{MSY}$ = 1.47 | 4.09 E+06 | $F_{05}/F_{MSY}$ = 0.74 | $F_{MSY}$ = 0.19 | Not overfished; overfishing not occurring |
| **Blacknose Sharks** | $SSF_{05}/SSF_{MSY}$ = 0.48 | 4.3 E+05 | $F_{05}/F_{MSY}$ = 3.77 | $F_{MSY}$ = 0.07 | Overfished; overfishing is occurring |

| Species | Current Relative Biomass Level | Minimum Stock Size Threshold | Current Relative Fishing Mortality Rate | Maximum Fishing Mortality Threshold | Outlook |
|---|---|---|---|---|---|
| **Finetooth Sharks** | $N_{05}/N_{MSY} = 1.80$ | 2.4E+06 | $F_{05}/F_{MSY} = 0.17$ | $F_{MSY} = 0.03$ | Not overfished; overfishing not occurring |
| **Pelagic sharks** | *Unknown* | *Unknown* | *Unknown* | *Unknown* | *Unknown* |
| **Porbeagle Sharks** | $SSN_{04}/SSF_{MSY} = 0.15\text{-}0.32$ | *Unknown* | $F_{04}/F_{MSY} = 0.83$ | 0.033-0.065 | Overfished; overfishing is not occurring |

## 2.1 Atlantic Swordfish

### 2.1.1 Life History and Species Biology

Swordfish are one of the fastest and largest predators of the Atlantic Ocean, reaching maximum size at 530 kg. Highly migratory in nature, swordfish exhibit a long bill that is used for both foraging and defense of territory. Swordfish are also pelagic in nature, but have been known to feed throughout the water column on ground fish, pelagic, deep-water fish, and invertebrates. A fusiform body and stiff, deeply forked tail allow them to swim at high speeds.

In 2006, a SCRS workshop examined both the swordfish stock structure and the boundaries of the North and South Atlantic and Mediterranean stocks. This workshop, held in Crete, was conducted to satisfy ICCAT's resolution 99-03, *Resolution by ICCAT on the Clarification of the Stock Structure and Boundaries Between the Swordfish Stocks in the Atlantic*. In this resolution, ICCAT noted that there were considerable uncertainties about the structure, mixing and boundaries of the swordfish stocks, and called for national and international research programs on swordfish stock structure. The stock structure data presented at the 2006workshop were consistent with current theories about Atlantic and Mediterranean swordfish stock structure. Researchers at the workshop found that without intensified collaborative and multi-disciplinary research, different swordfish stock boundaries could not be improved upon. However, the workshop confirmed that some mixing of stocks between the Atlantic and Mediterranean occur, and fish from the Mediterranean stock are genetically different from swordfish in other oceans. The next stock assessment scheduled by ICCAT is to take place in 2009.

### 2.1.2 Stock Status and Outlook

*North Atlantic*

The biomass of North Atlantic swordfish has improved, reaching 99 percent of the level necessary to support MSY in 2006. Several strong year classes in the late 1990s, and a reduction in the overall catch since 1987, has allowed the rebound of swordfish in the North Atlantic. In 2005, the fishing mortality for North Atlantic swordfish was 14 percent below the level needed to maintain MSY. The $F_{2005}$ was less than $F_{MSY,}$ but the SCRS has shown some uncertainty in the estimates of $F_{2005}$. The replacement yield for 2006 (14,438 t) was slightly above MSY, and the TAC set by ICCAT in 2005 was 14,000 t assuming that North Atlantic swordfish biomass would continue to reach $B_{MSY}$ with those catch levels (Table 2.3).

**Table 2.3 Summary Table for the Status of North Atlantic Swordfish.** Source: SCRS 2006

| | |
|---|---|
| **Age/size at Maturity** | Females: 180 cm lower jaw fork length (LJFL)<br>Male: 129 cm LJFL |
| **Spawning Sites** | Warm tropical and subtropical waters throughout the year |
| **Current Relative Biomass Level** | $B_{06}/B_{MSY}$ = .99 (0.87-1.27) |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{05}/F_{MSY}$ = 0.86 (0.65-1.04)<br>$F_{year}/F_{MSY}$ = 1.00 |
| **Maximum Sustainable Yield** | 14,133 t (12,800-14,790) |
| **Current (2007) Yield** | 11,938 t |
| **Current (2006) Replacement Yield** | 14,438 t |
| **Outlook** | Stock is nearly rebuilt; overfishing is not occurring |

*South Atlantic*

The SCRS used a simple production model using catch per unit effort (CPUE) data to estimate the biomass of South Atlantic swordfish. Depending on the use of bycatch fishery data or target fishery data, two different outcomes are reached. When using bycatch CPUE the conclusion is a relatively low abundance. In contrast, using target CPUE data leads to a positive outlook. The SCRS believes that the bycatch CPUE data could not be supported as an indicator of abundance. In addition, the use of target fishery data cannot be used because it is believed that increased catchablity of South Atlantic swordfish and not abundance was the reason for high CPUE. The SCRS chose to use a composite CPUE for both fisheries data for the base case estimate. Though more research is needed, results from the analyses using data from both fisheries show that current fishing mortality is less than that needed to maintain MSY, and biomass levels are above that which would occur when fishing at $F_{MSY}$ for a long period of time. The estimated MSY (about 17,000 t) is 33 percent higher than current reported landings (Table 2.4).

**Table 2.4 Summary Table for the Status of South Atlantic Swordfish.** Source: SCRS, 2006

| | |
|---|---|
| **Age/size at Maturity** | Females: 180 cm lower jaw fork length (LJFL)<br>Male: 129 cm LJFL |
| **Spawning Sites** | Warm tropical and subtropical waters throughout the year |
| **Current Relative Biomass Level** | Likely >1 |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | Likely <1<br>$F_{year}/F_{MSY}$ = 1.00 |
| **Maximum Sustainable Yield** | ~17,000 t |
| **Current (2007) Yield** | 15,416 t |
| **Current (2006) Replacement Yield** | *not estimated* |
| **Outlook** | *unknown* |

### 2.1.3 Management Recommendations

*North Atlantic*

The SCRS noted in the 2006 stock assessment summary that in order to maintain the northern Atlantic swordfish stock close to a level that would produce MSY, the SCRS continues to recommend continuing the present TAC (14,000 t). Given the estimated stock productivity (r=0.49) and MSY (14,100 t), this TAC should be sustainable into the future, and reflects the maximum yield that could be harvested from the population under existing environmental and fishery conditions.

*South Atlantic*

The SCRS recommends that until sufficiently more research can been conducted to reduce the high uncertainty in stock status evaluations for the southern Atlantic swordfish stock, the SCRS recommends that annual catch should not exceed the provisionally estimated MSY (about 17,000 t).

### 2.1.4 Recent and Ongoing Research

In late 2007, NMFS issued an Exempted Fishing Permit to three U.S. vessels in order to allow them to fish in portions of areas currently closed to pelagic longline fishing off the coast of the Southeastern U.S. NMFS contracted with Nova Southeastern University to conduct a study on these vessels in order to evaluate the catch rates of target and bycatch species inside the closed areas relative to open fishing areas. The research may also evaluate bycatch reduction and immediate mortality reduction using 18/0 non-offset circle hooks on various species (particularly undersize swordfish). The vessels began conducting the study in February 2008 and are expected to continue through 2009.

NMFS also continues to tag swordfish with pop-up satellite archival tags to better understand behavior. Ten and three swordfish were released with these tags in 2007 and 2008, respectively. In addition, 172 swordfish have been released with conventional tags in 2007 and 2008.

## 2.2 Atlantic Bluefin Tuna

Information for the text, figures and tables for this section are from the SCRS 2008 Report, as well as the U.S. National Report to ICCAT, 2008. All weights are reported as whole weights unless indicated otherwise.

### 2.2.1 Life History and Species Biology

The Atlantic bluefin tuna is one of the only large pelagic fish living permanently in temperate Atlantic waters. They 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 tuna were made from a broad geographic range in the Atlantic and Mediterranean.

Archival tagging and tracking information confirmed that bluefin tuna can sustain cold as well as warm temperatures while maintaining stable internal body temperature. Until recently, it was assumed that bluefin tuna preferentially occupied the surface and subsurface waters of the coastal and open-sea areas, but archival tagging and ultrasonic telemetry data indicate that bluefin tuna frequently dive to depths of 500 m to 1,000 m (1,640 to 3,280 ft). Bluefin tuna appears to display homing behavior and spawning site fidelity in both the Mediterranean Sea and Gulf of Mexico, which constitute the two main spawning areas being clearly identified today. Less is known about feeding migrations within the Mediterranean and the North Atlantic, but results from electronic tagging indicated that bluefin tuna movement patterns vary considerably between individuals, years and areas. The appearance and disappearance of important past fisheries further suggest that important changes in the spatial dynamics of bluefin tuna may also have resulted from interactions between biological factors, environmental variations and fishing. Although the Atlantic bluefin tuna population is managed as two stocks, separated at 45° W latitude, its population structure remains poorly understood and needs to be further investigated. Recent genetic and microchemistry studies as well as work based on historical fisheries tend to indicate that the bluefin tuna population structure is complex.

Bluefin tuna are assumed to mature at 4 years of age (approximately 25 kg or 55 lb) in the Mediterranean and at approximately 8 to 10 years of age (approximately 140 kg-150 kg or 300 lb to 330 lb) in the Gulf of Mexico. Juvenile and adult bluefin tuna are opportunistic feeders (as are most predators) and their diet can include jellyfish and salps, as well as demersal and sessile species such as, octopus, crabs and sponges. However, in general, juveniles feed on crustaceans, fish and cephalopods, while adults primarily feed on fish such as herring, anchovy, sand lance, sardine, sprat, bluefish, and mackerel. Juvenile growth is rapid for a teleost fish (about 76 cm or 30 inches/year), but slower than other tuna and billfish species. Fish born in June attain a length of about 76-102cm (30-40 inches) long and a weight of about 1 kg (2.3 lb) by October. After one year, fish reach about 4 kg (8.8 lb) and 60 cm (24 inches) long. Growth in length tends to be lower for adults than juveniles, but growth in weight increases. At 10 years old, a bluefin tuna is about 200 cm (79 inches) and 150 kg (331 lb) and reaches about 300 cm (118 inches) and 400 kg (882 lb) at 20 years. However, there remain large uncertainties about bluefin tuna growth curves, and bluefin tuna in the West Atlantic generally reach a larger maximum size compared to bluefin tuna caught in the East Atlantic. Bluefin tuna is a long lived species, with a lifespan of 20 years or more, as indicated by recent studies from radiocarbon deposition.

In the 2006 stock assessment, a need to integrate recent and anticipated advances in otolith microconstituent analyses, age determination, archival tagging and genetics into the next assessment and management evaluation processes was noted. While more work needs to be completed, SCRS has achieved important progress towards that goal. Concerning age determination, SCRS received new information that presented a novel approach for determining age and area of natal origin from the same otolith, allowing construction of area-specific growth curves. The preliminary results diverge considerably from the age-length relationship used by

SCRS for the western stock, and could have significant impacts for estimates of stock productivity.

In 2008, SCRS continued to be concerned with the effects of mixing and management measures on the eastern stock. Bluefin tuna are known to be highly migratory and the nature and extent of their ability to conduct transoceanic migrations are the subject of significant research (see section on Research below). Movements between the east and west are complex and it is difficult to quantify the amount of mixing that occurs. A positive correlation between age and migration distances exists with all Atlantic bluefin tuna. The information on natal origin derived from otolith microchemistry received by SCRS indicated that there is an increasing contribution of eastern origin fish to the western fisheries with decreasing average size of the fish in the catch (*i.e,*. up to 62% for fish in the 69-119 cm or 27-47 inch size class, i.e., school bluefin tuna). In contrast, other western fisheries supported by the largest size classes had minimal or no eastern component in the catch. However, there remains considerable uncertainty and therefore additional samples are needed to improve understanding about the relative contribution of the two populations to the different fisheries over time.

Other recent research activities for bluefin tuna can be found in the 2008 Annual Report of the United States to ICCAT (NMFS, 2008), available by calling the HMS Management Division at 301-713-2347 or at www.nmfs.noaa.gov/sfa/hms/hmsdocument_files/ICCAT.htm.

### 2.2.2 Stock Status and Outlook

The last full stock assessment for western Atlantic bluefin tuna was conducted in 2008 by SCRS with the next scheduled for 2010. Summarized information for western Atlantic bluefin tuna and eastern Atlantic/Mediterranean bluefin tuna are shown in Table 2.5 and Table 2.6, respectively. This section summarizes the findings of SCRS.

The 2008 western bluefin tuna assessment, which included information up to 2007, showed results consistent with previous year evaluations, in that spawning stock biomass (SSB) declined steadily between the early 1970s and 1992. Since then, SSB has fluctuated between 18 percent and 27 percent of the 1975 level (Figure 2.2). The stock has experienced different levels of fishing mortality (F) over time, depending on the size of fish targeted by various fleets. F for spawners (age 8+) declined markedly between 2002 and 2007.

Estimates of recruitment were very high in the early 1970's, and additional analyses involving longer catch and index series suggest that recruitment was also high during the 1960s. Since 1977, recruitment has varied from year to year without trend. SCRS noted that a key factor in estimating MSY-related benchmarks is the highest level of recruitment that can be achieved in the long term. Assuming that average recruitment cannot reach the high levels from the early 1970s, recent F (2004-2006) is about 30 percent higher than the MSY level and SSB is about half of the MSY level (Figure 2.3). Estimates of stock status are more pessimistic if a high recruitment scenario is considered ($F/F_{MSY}$=2.1, $B/B_{MSY}$=0.14).

One important factor in the recent decline of fishing mortality on large bluefin tuna is that the TAC has not been taken during this time period, due primarily to a shortfall by U.S. fisheries that target large bluefin tuna. Two plausible explanations for the shortfall were put forward previously by SCRS: (1) that availability of fish to the U.S. fishery has been abnormally low, and/or (2) the overall size of the population in the Western Atlantic declined substantially from the level of recent years. SCRS noted that while there is no overwhelming evidence to favor either explanation over the other, the base case assessment [which excluded the Canadian Gulf of St. Lawrence catch per unit effort (CPUE) index since inclusion might produce overly optimistic results] implicitly favors the first hypothesis (regional changes in availability) because a large recent reduction in SSB is not estimated. Nevertheless, SCRS noted that substantial uncertainty remains on this issue and more research needs to be done. SCRS also cautioned that the conclusions of the 2008 assessment do not capture the full degree of uncertainty in the assessments and projections, due to: (1) mixing between fish of eastern and western origin, (2) recruitment, both in terms of recent levels (which are estimated with low precision in the assessment), and potential future levels (the "low" vs. "high" recruitment hypotheses which affect management benchmarks), and (3) the assumed growth curve, which may be revised based on new information that is being collected. If the growth curve changes substantially, it may impact the assessment results as well as management benchmarks.

To determine the outlook, SCRS conducted a medium-term (12-year) evaluation of changes in spawning stock size and yield over the remaining rebuilding period under various management options. In order to provide advice relative to rebuilding the western Atlantic bluefin tuna resource, SCRS conducted projections for two scenarios about future recruitment. The “low recruitment” scenario assumed that future average recruitment will approximate the average of recruitment (at age one) levels observed from 1976 through 2004 (70,000 recruits). The “high recruitment” scenario assumed average recruitment levels would increase as the stock rebuilds (an MSY level of 160,000 recruits). SCRS had no strong evidence to favor one scenario over the other and noted that both are reasonable (but not extreme) lower and upper bounds on rebuilding potential. The outlook for bluefin tuna in the West Atlantic with the low recruitment scenario (Figure 2.4) is similar to that from the 2006 assessment. A total catch of 2,100 mt is predicted to have at least a 50 percent chance of achieving the convention objectives of preventing overfishing and rebuilding the stock to MSY levels by 2019, the target rebuilding time. The outlook under the high recruitment scenario is more pessimistic since the rebuilding target would be higher; a total catch of less than 1,500 mt is predicted to stop overfishing in 2009, but the stock would not be expected to rebuild by 2019 even with no fishing.

Table 2.7 below summarizes the results of projections of both scenarios at different catch levels. The projections for the low recruitment scenario suggests that catch levels of 2,400 mt will have about a 50 percent chance of rebuilding the stock by 2019 and catches of 2,000 mt or lower will have greater than a 75 percent chance of rebuilding. If the high recruitment scenario is correct, then the western stock will not rebuild by 2019 even with no catch, although catches of 1,500 mt or less are expected to immediately end overfishing and initiate rebuilding (Table 2.8). SCRS also examined an alternative model that excluded the Canadian Gulf of St. Lawrence CPUE index, noting considerations of possible resource re-distribution, and the observation that the recent high values were difficult to reconcile with other available fisheries data, and could reflect the impact of a single or a limited number of strong year-classes. The levels of catch that lead to rebuilding with that alternative model are lower; 1,800 mt will have about a 50 percent chance and 1,500 mt will have a 75 percent chance.

**Table 2.5** **Summary Table for the Status of West Atlantic Bluefin Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Age 8/~ 200 cm fork length |
| **Spawning Sites** | Gulf of Mexico and Florida Straits |
| **Current Relative Biomass Level**<br><br><br><br>*Minimum Stock Size Threshold* | $SSB_{07}/SSB_{75}$ (low recruitment) = .25 (.16-.38)<br>$SSB_{07}/SSB_{75}$ (high recruitment) = .25 (.16-.38)<br>$SSB_{07}/SSB_{msy}$ (low recruitment) = .57 (.46-.70)<br>$SSB_{07}/SSB_{msy}$ (high recruitment) = .14 (.08-.21)<br>$0.86B_{MSY}$ |
| **Current Relative Fishing Mortality Rate**<br><br>*Maximum Fishing Mortality Threshold* | $F_{04\text{-}06}/F_{MSY}$ (low recruitment) = 1.27 (1.04-1.53)<br>$F_{04\text{-}06}/F_{MSY}$ (high recruitment) = 2.18 (1.74-2.64)<br>$F/F_{MSY} = 1.00$ |
| **Maximum Sustainable Yield** | Low recruitment scenario: 2,852 mt (2,680-3,032)<br>High recruitment scenario: 6,201 mt (4,887-9,142) |
| **Catch (2007) including discards** | ~1,624 mt |
| **Short Term Sustainable Yield** | (not provided) |
| ***(Outlook – Status of Stocks, NMFS, 2008)*** | ***(Overfished; overfishing continues to occur)*** |

**Table 2.6** **Summary Table for the Status of East Atlantic Bluefin Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Age 4-5 |
| **Spawning Sites** | Mediterranean Sea |
| **Current Relative Biomass Level** | $SSB_{07}/SSB_{FMAX}$ (low recruitment) = .35<br>$SSB_{07}/SSB_{FMAX}$ (high recruitment) = .14 |
| **Current Relative Fishing Mortality Rate** | $F_{07}/F_{MAX}$ =3.04 (reported catches)<br>$F_{07}/F_{MAX}$ =3.42 (adjusted catches) |
| **Short-term Sustainable Yield** | $F_{MAX}$: 15,000 mt or less |
| **Long-term Potential Yield** | $\simeq$ 50,000 mt |
| **Current (2007) Yield** | 32,398 mt reported; 61,000 mt (SCRS estimate) |
| **Outlook** | Overfished; overfishing continues to occur |

**Table 2.7 Estimated chance of recovery under the high and low recruitment scenarios and various levels of future catch. No shading indicates the chance of recovery by the given year is greater than or equal to the reference probability level (50 or 75 percent). Gray shading indicates the chance of recovering by 2019 is less than the reference probability level.** Source: SCRS, 2008.

| Projected Catch Level | 50% Probability | | 75% Probability | |
|---|---|---|---|---|
| (mt) | Low | High | Low | High |
| 0 | 2012 | No | 2013 | No |
| 500 | 2012 | No | 2013 | No |
| 1,000 | 2013 | No | 2014 | No |
| 1,500 | 2014 | No | 2015 | No |
| 1,600 | 2014 | No | 2016 | No |
| 1,700 | 2015 | No | 2016 | No |
| 1,800 | 2015 | No | 2017 | No |
| 1,900 | 2015 | No | 2018 | No |
| 2,000 | 2016 | No | 2019 | No |
| 2,100 | 2017 | No | No | No |
| 2,200 | 2017 | No | No | No |
| 2,300 | 2018 | No | No | No |
| 2,400 | 2019 | No | No | No |
| 2,500 | No | No | No | No |
| 2,600 | No | No | No | No |
| 2,700 | No | No | No | No |
| 3,000 | No | No | No | No |
| 5,000 | No | No | No | No |

**Table 2.8** **Estimated chance of ending overfishing under the high and low recruitment scenarios and various levels of future catch. Entries are year overfishing ends or "no" if overfishing has less than the given probability of success by 2019.** Source: SCRS, 2008.

| Projected Catch Level | 50% Probability | | 75% Probability | |
|---|---|---|---|---|
| (mt) | Low | High | Low | High |
| 0 | 2009 | 2009 | 2009 | 2019 |
| 500 | 2009 | 2009 | 2009 | 2009 |
| 1,000 | 2009 | 2009 | 2009 | 2010 |
| 1,500 | 2009 | 2009 | 2009 | 2015 |
| 1,600 | 2009 | 2010 | 2009 | 2016 |
| 1,700 | 2009 | 2011 | 2009 | 2018 |
| 1,800 | 2009 | 2012 | 2011 | 2019 |
| 1,900 | 2009 | 2013 | 2012 | No |
| 2,000 | 2010 | 2014 | 2013 | No |
| 2,100 | 2011 | 2015 | 2014 | No |
| 2,200 | 2012 | 2016 | 2016 | No |
| 2,300 | 2014 | 2017 | 2019 | No |
| 2,400 | 2015 | 2018 | No | No |
| 2,500 | 2017 | No | No | No |
| 2,600 | No | No | No | No |
| 2,700 | No | No | No | No |
| 3,000 | No | No | No | No |
| 5,000 | No | No | No | No |

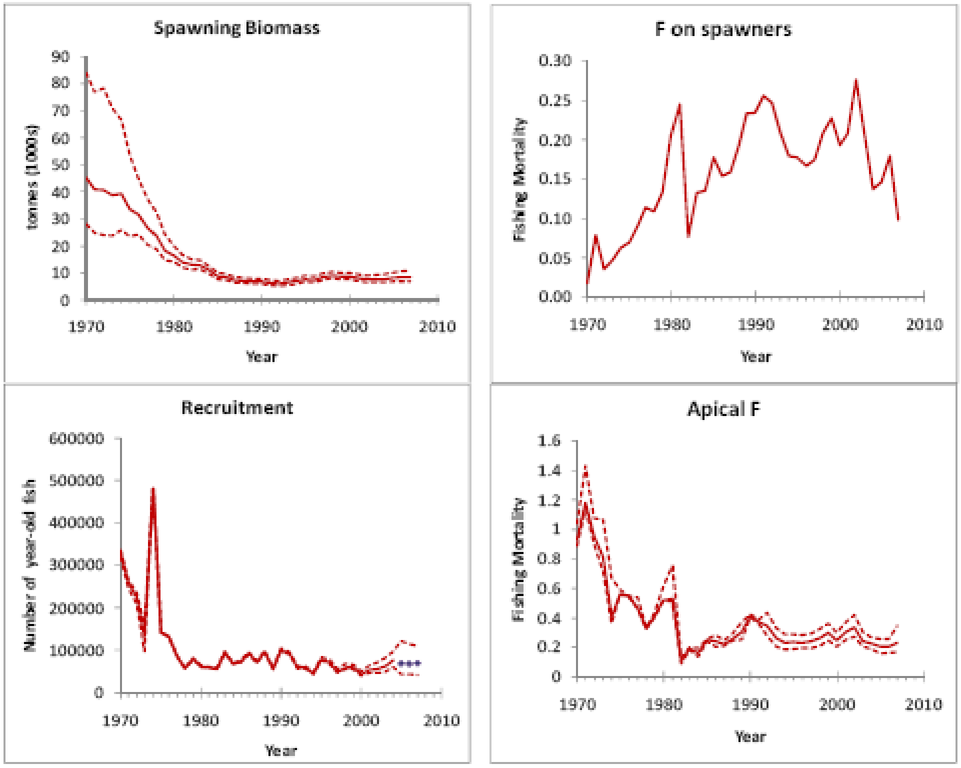


**Figure 2.2** **Median estimates of spawning biomass (mt) and fishing mortality on spawners, (age 8+), apical fishing mortality (F on the most vulnerable age class), and recruitment (numbers) for the base VPA model. Source: SCRS, 2008.**

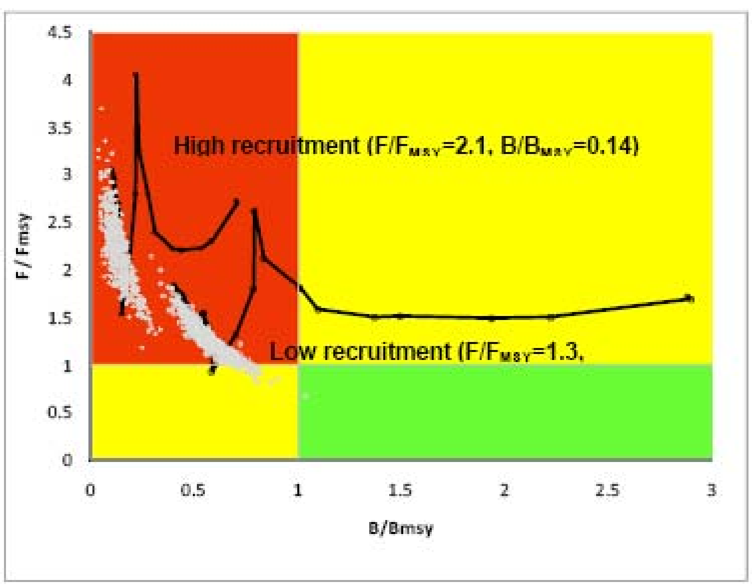


**Figure 2.3** **Estimated status of stock relative to the Convention objectives (MSY) by year (1970 to 2007). The lines give the time series of point estimates for each recruitment scenario and the clouds of white symbols depict the corresponding bootstrap estimates of uncertainty for the most recent year. Source: SCRS, 2008.**

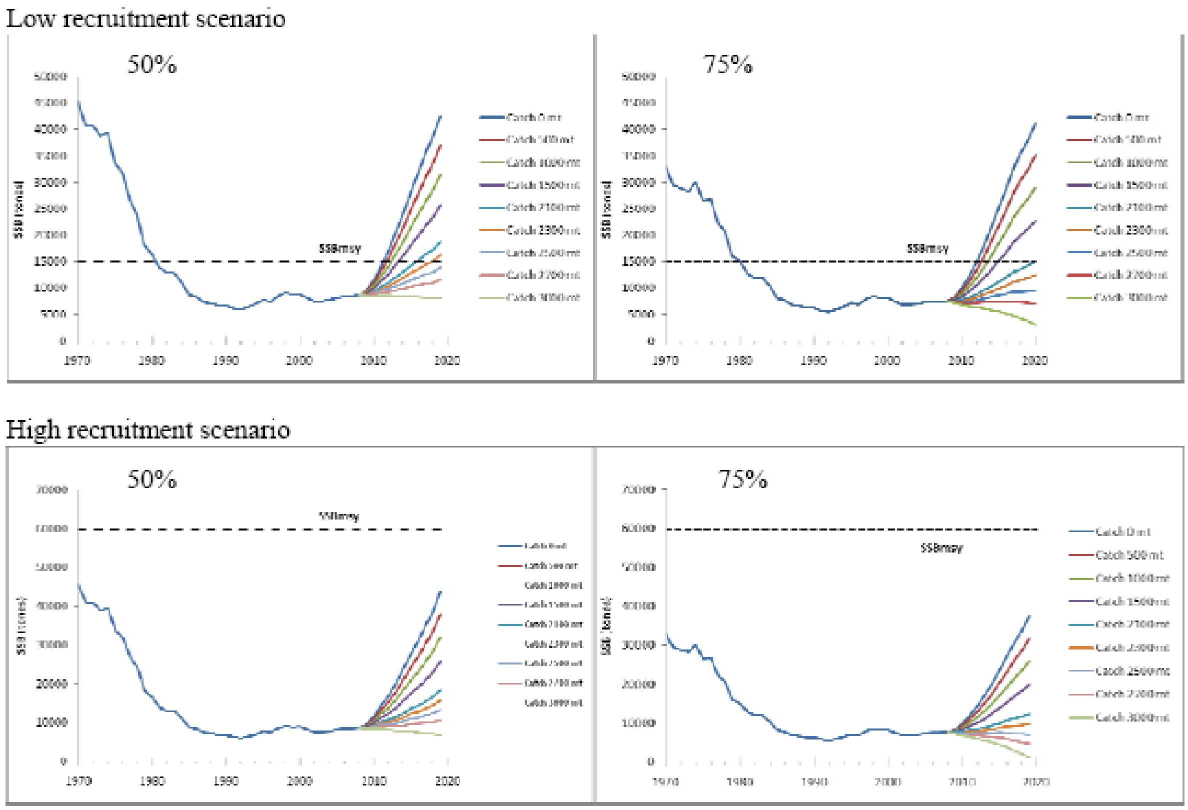


**Figure 2.4** **Projections of spawning stock biomass (SSB) for the Base Case assessment under low recruitment (top panels) and high recruitment (bottom panels) and various levels of constant catch. The labels "50%" and "75%" refer to the probability that the SSB will be greater than or equal to the values indicated by each curve. Note that curves are arranged sequentially in the same order as the legends. The dashed horizontal lines represent the median (50%) level of SSB at MSY. Source: SCRS, 2008.**

### 2.2.3 Effects of Regulations

**ICCAT Management Recommendations**

The first ICCAT recommendation for a scientific monitoring level was adopted for western Atlantic bluefin tuna catches in 1981. Since then, the total allowable catch has varied from a high of 2,700 mt to the recent 1,900-mt TAC, inclusive of dead discards, set in 2008 and effective beginning in 2009. SCRS noted that catches of western bluefin tuna have been below the TAC since 2003, although that was not always the case prior to then (Figure 2.5).

For the West Atlantic, the ICCAT-recommended 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 eight percent tolerance, by weight on a national basis, became effective in 1992. The tolerance was increased to ten percent in 2006. SCRS noted that the estimated percentage of fish less than 47 inches (school bluefin tuna) in the catch has been less than 8 percent of the TAC from 1992 to 2006, although this percentage increased in 2007 to about 11 percent of TAC.

The western Atlantic bluefin tuna recommendation historically has included a provision to subtract overharvest from a country's allocation the following year and, conversely, to allow carryforward of underharvest of an allocation in a given year to the following year. In 2006, the carryforward of underharvest to the next year was limited to 50% of the country's initial allocation.

SCRS noted in its 2007 and 2008 reports that the 2006 western Atlantic bluefin tuna recommendation was expected to result in a rebuilding of the stock by 2019 with fishing mortality rates at about the estimated MSY level, but also noted that more conservative management measures may be necessary.

**Domestic Regulations**

The U.S. bluefin tuna fishery continues to be limited by quotas, seasons, gear restrictions, limits on catches per trip, and size limits, consistent with ICCAT recommendations. U.S. 2008 provisional estimated landings and discards from the northwest Atlantic (including the Gulf of Mexico), as reported by the United States to ICCAT in its annual National Report (NMFS, 2008), were 758 mt and 91 mt, respectively. Those estimated landings and discards represent an increase of 234 mt from the 2006 estimates. (Out of a total western Atlantic management area TAC of 2,100 mt, total reported catches were 1,811 mt in 2006 and 1,632 mt in 2007). The 2007 U.S. landings by gear were: 28 mt by purse seine, 23 mt by harpoon, 634 mt by rod and reel, and 151 mt by longline (including discards) of which 81 mt were from the Gulf of Mexico.

To properly implement 1992 regulations limiting the allowable catch of small fish by U.S. fishermen, in conformity with ICCAT agreements, enhanced monitoring of the rod and reel fishery was implemented in 1993 for the purpose of providing near real-time advice on catch levels by this fishery. This monitoring activity has continued and has included estimation of catches by finer scale size categories than reported above. The preliminary estimates for the 2007 rod and reel fishery off the northeastern United States (including the North Carolina winter fishery) for landings in several size categories were 52 fish < 66 cm; 6,100 fish 66-114 cm; 6,565 fish 115-144 cm, and 1,549 fish 145-177 cm (an estimated 0.2, 155, 239, and 112 mt, respectively) (NMFS, 2008).

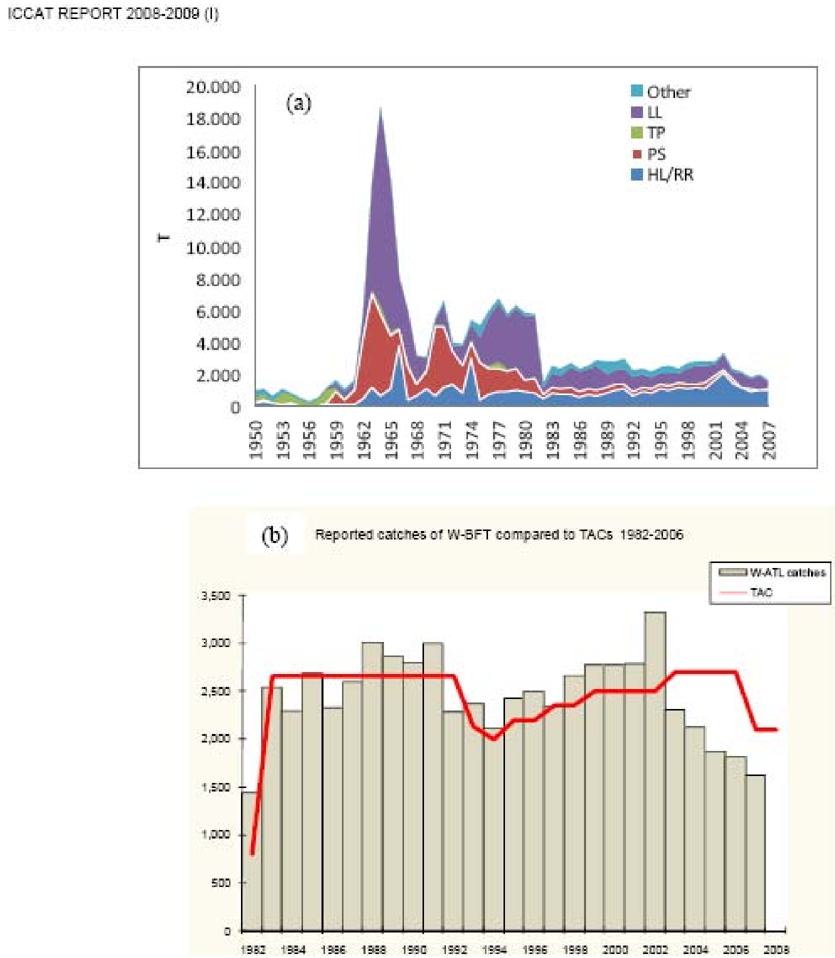


**Figure 2.5** **Historical catches of western bluefin tuna: (a) by gear type (LL=longline, TP=trap, PS=purse seine, HL/RR= hand line/rod and reel) and (b) in comparison to TAC levels agreed by ICCAT. Source: SCRS, 2008.**

### 2.2.4 Management Recommendations

SCRS' management recommendations for the western Atlantic bluefin tuna management area are directed at the Rebuilding Program adopted by ICCAT in 1998. According to the Program, the MSY rebuilding target can be adjusted based on advice from SCRS. Specifically, the TAC for the west would be adjusted from the 2,100 mt level only if the TAC under consideration will allow the MSY target to be achieved within the rebuilding period with a 50 percent or greater probability. In 2008, SCRS determined that the stock has not yet rebuilt as projected under the plan initially, and that the 2007 SSB was estimated to be 7 percent below the level of the Plan's first year.

Based on a strict interpretation of the base case projections and the rebuilding program, SCRS found itself facing TAC options that range between 2,400 mt and 0 mt depending on its choice of recruitment scenarios and choice of the probability of rebuilding. SCRS notes that making decisions based on the low recruitment scenario when in fact the high recruitment scenario is true, could be riskier in terms of stock rebuilding. In light of the uncertainty about recruitment and other uncertainties not taken into account in the projections, SCRS strongly advised against an increase in TAC. Recent analyses suggested that the projections made during past assessments were too optimistic. This is reinforced by the observation that, halfway through the rebuilding program, biomass is still below what it was at the beginning. Noting that the rebuilding plan calls for ICCAT to adopt harvest levels that provide a 50% *or greater* chance of meeting rebuilding targets, and the lack of progress on rebuilding, SCRS recommended that ICCAT adopt more conservative catch levels that will result in a higher probability (for example, 75% chance) that $B_{MSY}$ is achieved by the beginning of 2019. Under the more optimistic "low recruitment" scenario, this target could be achieved with a TAC of 2,000 mt. However, if the assessment and estimates of future yield are positively biased or if there is implementation error (both of which have occurred in the past), the TAC should be lower (for instance, based on the assessment results without the Gulf of St. Lawrence CPUE index, the TAC would need to be reduced to less than 1,500 mt in order to achieve $B_{MSY}$ by 2019 with 75% probability).

In 2008, SCRS again noted that both the productivity of western Atlantic bluefin tuna and western Atlantic bluefin tuna fisheries are linked to the eastern Atlantic and Mediterranean stock. Therefore, management actions taken in the eastern Atlantic and Mediterranean are likely to influence the recovery in the western Atlantic, because even small rates of mixing from East to West can have significant effects on the West due to the fact that the Eastern plus Mediterranean resource is much larger than that of the West.

### 2.2.5 Recent and Ongoing Research

As part of its commitment to the Bluefin Year Program (the SCRS Atlantic bluefin tuna research program), research supported by the United States has concentrated on ichthyoplankton sampling, growth and reproductive biology, methods to evaluate hypotheses about mixing and movement patterns, spawning area fidelity, stock structure investigations and population modeling analyses.

Ichthyoplankton surveys in the Gulf of Mexico during the bluefin tuna spawning season were continued in 2007 and 2008. Data resulting from these surveys, which began in 1977, are used to develop a fishery-independent abundance index of spawning for western Atlantic bluefin tuna. This index has continued to provide one measure of bluefin tuna abundance that is used in SCRS assessments of the status of the resource (SCRS/2008/086). In addition to the regular survey which occurs over a fixed spatial grid, adaptive sampling was carried out in 2008 to better understand larval distribution in relation to oceanographic features. Neuston and bongo samples were taken across the Loop Current and adjacent mesoscale structures to sample for larval bluefin tuna during the time period 1-8 May, 2008. Transects were selected to provide high resolution physical and biological mapping of larval scombrids in relation to rapidly changing current flows and gyre movement. The larvae are being sorted and preliminary results are expected to be made available to SCRS in 2009.

Scientists from the Virginia Institute of Marine Science continue to investigate the stock composition of small bluefin tuna caught off the northeastern U.S. and larger bluefin tuna caught in the Gulf of Mexico and off Canada. Genetic markers derived from young-of-the-year bluefin tuna caught in the Mediterranean Sea and the Gulf of Mexico are being used to assign origin.

Scientists from the University of Maryland initiated a study to age bluefin tuna sampled from the Gulf of Mexico and elsewhere. Part of this research was conducted jointly with Canadian scientists who have developed validated age readings. A new growth model was fit for recent year-classes (after 1970) for western captured, western-origin Atlantic bluefin tuna, which results in expected lengths that differ substantially from the model adopted by SCRS for fish ages 12 and older (SCRS/2008/084). Future priority on age determinations may be given to samples from the Mediterranean population and historical samples from the Gulf of Mexico population.

Scientists from Texas A & M University and the University of Maryland continue to study the stock structure of bluefin tuna using otolith chemistry particularly focusing on large bluefin tuna from the Gulf of Mexico and the Mediterranean Sea. This research is greatly facilitated through continued collaboration with Canadian, Italian, and Spanish scientists. Results from stable isotope analysis of otoliths provide strong evidence for natal homing by two populations of Atlantic bluefin tuna each with discrete centers of origin (Mediterranean Sea and Western Atlantic). As more samples are analyzed, it is possible that this type of information will feed directly into stock assessments.

Scientists at Stanford University and the TAG-A-Giant research team continued to deploy electronic tags in the western Atlantic in 2007 and 2008 (n=67 deployments). Three additional bluefin tuna also were fitted with pop-up satellite archival tags in the Mediterranean Sea off the coast of France. These efforts brought the total number of electronic tags deployed on Atlantic bluefin tuna by the TAG team to nearly 1,000. Tagging in the Gulf of St. Lawrence revealed a strong linkage between fish there and the Gulf of Mexico spawning grounds (SCRS/2008/092), corroborating findings from otolith studies. In collaboration with scientists from the University of British Columbia, a new stock assessment model is being developed (Multi-Stock Age-Structured Tag-Integrated stock assessment model, or MAST) that models eastern and western Atlantic bluefin tuna stocks simultaneously but includes different growth, movement, maturity and natural mortality parameters for each stock, season and age group. The model includes four areas and quarterly time steps (SCRS/2008/097). Model revision and simulation testing are now underway.

Researchers at the University of New Hampshire continue to engage in ecological analyses seeking to identify the underlying dynamics of Atlantic bluefin tuna migration, maturity schedules and reproduction, age and growth, and forage relationships. In 2006, the UNH-DFO electronic tagging program included release of 26 PSATs on giant bluefin tuna (24 in Canadian waters, 2 by U.S. longliners), and 10 in 2007 (all in Canadian waters), and continuation of the Tag-a-Tiny juvenile tagging program in 2007, when over 25 miniature PSATs, or X-tags, were deployed on juvenile bluefin tuna in the New England region, and implanted archival tagging of school bluefin tuna continues. A study is also underway on shifts in oceanographic regimes and possible impacts on bluefin tuna and their prey.

NMFS scientists have developed a virtual population analysis (VPA) model to estimate the degree of mixing between two stocks based on conventional tagging data, electronic tagging data, and new data on the proportion of the catch that comes from each stock (as deduced from genetic and otolith microconstituent analyses). The new model was applied to bluefin tuna stocks in collaboration with scientists from other ICCAT nations during the 2008 assessment meeting.

From early March through mid-June 2008, NMFS conducted extensive observations of the pelagic longline fishery in the Gulf of Mexico, as a continuation of a similar effort undertaken in 2007. Roughly 75 percent of known fishing trips and a higher percentage of total effort was observed. During that sampling, more than 3,305 yellowfin tuna, about 3,774 swordfish, 347 bluefin tuna, 97 shortfin mako and 32 bigeye tuna were observed. Fifty of the bluefin tuna were landed, 201 were released dead, 72 were released alive and 24 broke off. Various tissues were taken from the bluefin tuna including otoliths, gonads and muscle. Contracts were awarded to conduct research on bluefin tuna stock structure, growth, gender determination and reproduction.

At the same time as the extended coverage observer program, NMFS has been assessing the efficacy of new technologies and changes in fishing practices in reducing the bycatch mortality of bluefin tuna in the directed yellowfin tuna fishery in the Gulf of Mexico. The 2008 pilot study was a continuation of research conducted in April 2007 to examine “weak link” concepts which would allow bluefin tuna to escape capture on pelagic longlines, while retaining yellowfin tuna. Results to date are encouraging, suggesting that retention of yellowfin tuna is not reduced. There are plans to continue this research in 2009.

## 2.3 Atlantic Bigeye Tuna, Albacore, Yellowfin Tuna, and Skipjack Tuna

All text, figures and tables for this section are from the SCRS 2008 Report and the U.S. National Report to ICCAT, 2008. All weights are reported as whole weights unless otherwise indicated.

### 2.3.1 Atlantic Bigeye Tuna

#### 2.3.1.1 Life History and Species Biology

Bigeye tuna are distributed throughout the Atlantic Ocean between 50ºN and 45ºS, but not in the Mediterranean Sea. This species swims at deeper depths than other tropical 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 have revealed that they exhibit clear diurnal patterns: they are found much deeper during the daytime than at night. Spawning takes place in tropical waters when the environment is favorable. From nursery areas in tropical waters, juvenile fish tend to diffuse into temperate waters as they grow larger. Catch information from surface gears indicate that the Gulf of Guinea is a major nursery ground for this species.

Bigeye tuna feed on a variety of prey organisms including fish, mollusks, and crustaceans. Bigeye tuna exhibit relatively fast growth: about 105 cm fork length at age 3; 140 cm at age of 5; and, 163 cm at age 7. Bigeye tuna over 200 cm are relatively rare, but do occur with some frequency. Bigeye tuna mature at about 3-5 years of age. Young fish form schools mostly mixed with other tunas such as yellowfin and skipjack tuna. These schools are often associated with drifting objects, whale sharks, and sea mounts. This association appears to weaken as bigeye tuna grow larger. Estimated natural mortality rates (M) for juvenile fish, obtained from tagging data, were of a similar range as those applied in other oceans. Various pieces of evidence, such as a lack of identified genetic heterogeneity, 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 SCRS. However, the possibility of other scenarios, such as the existence of north and south stocks, should not be disregarded.

#### 2.3.1.2 Stock Status and Outlook

The most recent stock assessment for bigeye tuna was conducted in 2007. Due to the early date of the assessment, the last year for which catch data was available was 2005 (71,000 mt at the time of the assessment). The 2007 stock assessment used various types of models. In general, data availability has improved but there is still a lack of information regarding detailed fishing and size data from certain fleets, in addition to the past catch and fishing activities of IUU fleets (e.g., size, location and total catch), leading to the need to assume catch-at-size for an important part of the overall catch. Species composition of Ghanaian fisheries catch was reconstructed for 1997 based on improved sampling and catch-at-size estimated in recent years as part of the data improvement projects of ICCAT.

Two new indices of relative abundance and updated indices of those previously used were made available to SCRS for the 2007 assessment. In total, six indices were provided, of which four were from longline fisheries from Japan, Chinese Taipei, United States, and Brazil. The other two indices were from a purse seine fishery operated by the EC, and from a baitboat fishery located in the Azores. The Japanese indices are the longest in duration and represent about 20-40% of the total catch. The other indices are shorter and account for smaller fractions of the catch than the Japanese fishery, except for Chinese Taipei's longline index which is based on catch as high as Japan's. These longline indices primarily relate to medium and large-size fish. The purse seine index was developed from fish aggregating device (FAD) fishing operations, and represents the stock trend in recruitment. The Azorean baitboat index represents various size components.

Several types of assessment models, including production models, VPA, and a statistical integrated model (Multifan-CL) were applied to the available data. A range of stock status evaluations were obtained from the various model formulations applied, but not all were judged to be equally likely.

Consistent with previous assessments of Atlantic bigeye tuna, the results from non-equilibrium production models were used to provide the best characterization of the status of the resource. The current MSY estimated using two types of production models was around 90,000 mt and 93,000 mt, although uncertainty in the estimates broadens the range. In addition, the estimates reflect the current relative mixture of fisheries that capture small or large bigeye tuna. MSY can change considerably with changes in the relative fishing effort exerted on the stock by surface and longline fisheries.

The 2007 assessment results indicated that the bigeye tuna stock declined rapidly during the 1990s due to the large catches taken in that period, and it has recently stabilized at around or below the level that produces MSY in response to a large reduction in reported catches. Estimated fishing mortality exceeded $F_{MSY}$ for several years in the period of the mid-1990s and has rapidly been reduced since 1999. A summary of the 2007 stock assessment is provided in Table 2.9.

The estimated stock trajectory is shown in Figure 2.6. The biomass at the beginning of 2006 was estimated to be nearly 92% of the biomass at MSY, and the 2005 fishing mortality rate was estimated to be about 13% below the fishing mortality rate at MSY. The replacement yield for 2006 was estimated to be slightly below MSY. Projections indicate that catches reaching 85,000 mt or less will permit the stock to rebuild in the future. SCRS indicated that this overall characterization best represents the current status of bigeye tuna in the Atlantic, however, it was also noted that there are other models showing both more optimistic and more pessimistic stock status evaluations.

SCRS suggested that the biomass would possibly decline further with constant catches of 90,000 mt or more, and recommended that the total catch not exceed 85,000 mt. The Committee indicated that if major countries were to take the entire bigeye tuna catch limit set under Recommendation 04-01 and other countries were to maintain recent catch levels, then the total catch could well exceed 100,000 mt.

**Table 2.9 Summary Table for the Status of Atlantic Bigeye Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Age 3/~100 cm curved fork length |
| **Spawning Sites** | Tropical waters |
| **Current Relative Biomass Level**<br>*Minimum Stock Size Threshold* | $B_{06}/B_{MSY}$ = 0.92 (0.85-1.07)<br>*$0.6B_{MSY}$ (age 2+)* |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{05}/F_{MSY}$ = 0.87 (0.70-1.24)<br>*$F_{year}/F_{MSY}$ = 1.00* |
| **Maximum Sustainable Yield** | 90,000 - 93,000 mt |
| **Current (2007) Yield** | 67,172 mt |
| **Current (2006) Replacement Yield** | Slightly below MSY |
| ***(Outlook – Status of Stocks, NMFS, 2008)*** | ***Rebuilding; Overfishing not occurring)*** |

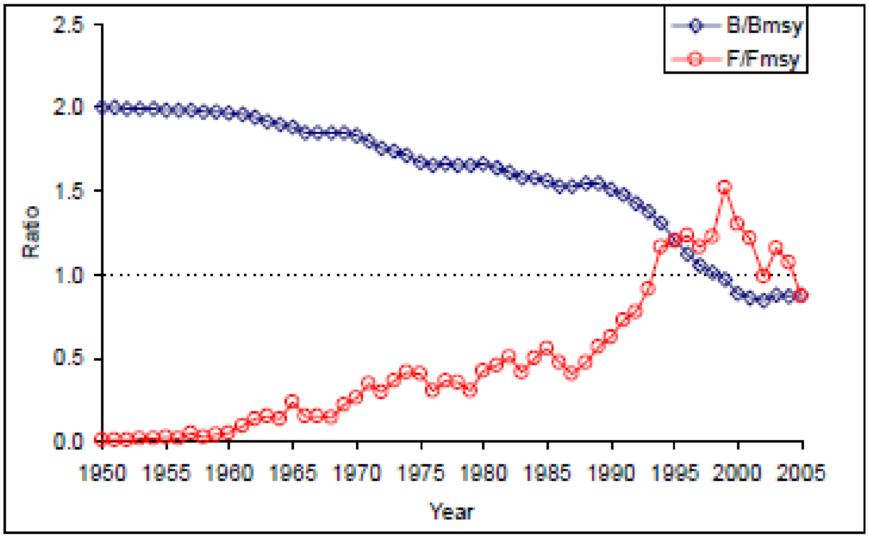


**Figure 2.6** **Trajectories of B/Bmsy and F/Fmsy estimated for the 2007 assessment.** Source: SCRS, 2008.

### 2.3.1.3 Effects of Regulations

**ICCAT Management Recommendations**

ICCAT Recommendation 04-01 established a multi-year conservation and management program for bigeye tuna and specified a number of regulations for 2005-2008 including an overall TAC for major harvesting countries set at 90,000 mt as well as capacity limitations. The overall estimated catch in 2007 (67,172 mt) was well below the TAC.

Recommendation 04-01 also implemented a new, smaller closure for surface fishing in the area 0º - 5º N, 10º W - 20º W during November in the Gulf of Guinea. SCRS examined the percentages of the small bigeye tuna (<53 cm or 21 inches) based on the catch-at-size information created at the time of 2007 assessment. Based on that information, the percentage of small bigeye tuna is at about 70% in number of fish and there is a general increasing trend. Considering that the new closed area is much smaller in time and area than the previous moratorium time/area, and is located in an area which historically has lower effort anyway, this regulation is likely to be less effective in reducing the overall catches of small bigeye tuna by the surface fishery. This expectation is supported by an analysis of 1994 - 2007 purse seine catches which was presented to SCRS, confirming that the new closure has been less effective than previous moratoria in reducing the proportional catch of small bigeye tuna. SCRS stressed that, if time/area closures are to be effective in reducing small fish harvests and growth overfishing, such a closure should be expanded in time and space and focused in locations with optimal potential benefit.

**Domestic Regulations**

The United States considers the status of the bigeye tuna stock to be not overfished (rebuilding). Several management measures have been implemented in the United States, consistent with ICCAT advice to limit fishing effort and to prevent overfishing. In 1999, NMFS implemented limited access in the pelagic longline fishery for Atlantic tunas. The United States has also maintained its minimum size limit for bigeye tuna of 27". An ICCAT recommendation recommending a smaller size was ultimately repealed because it was not feasible to sort the undersized bigeye and yellowfin tuna from purse seine and bait-boat catch mixed with regulation sized small skipjack tuna without large quantities of dead discards of small bigeye and yellowfin tuna.

Total reported U.S. bigeye tuna catches and landings (preliminary) for 2007 decreased by approximately 468 mt from 991 mt in 2006 to 523 mt. Like yellowfin tuna, the estimates of rod and reel catch are considered provisional and may be revised based on results of a future review of recreational harvest estimates.

*Management Recommendations*

The assessment results indicated that the stock declined rapidly during the 1990s due to the large catches taken in that period, and recently it has stabilized at or below the level that produces MSY in response to a large reduction in reported catches. Estimated fishing mortality exceeded $F_{MSY}$ for several years in the period of the mid-1990s and rapidly declined since 1999. Projections indicate that catches reaching 85,000 mt or less will permit the stock to rebuild in the future. SCRS advised ICCAT to be aware that if major countries were to take the entire catch limit set under Recommendation 04-01 and other countries were to maintain recent catch levels, then the total catch could well exceed 100,000 mt. SCRS recommended that the total catch not exceed 85,000 mt. The assessment and subsequent management recommendations are conditional on the reported and estimated history of catch for bigeye tuna in the Atlantic. SCRS reiterated its concern that unreported catches from the Atlantic might have been and may continue to be poorly estimated, but available statistical data collection mechanisms are insufficient to fully investigate this possibility. It also suggested that coordination amongst the tuna RFMOs be encouraged, among other objectives, to examine the possibility of 'fish laundering' for bigeye tuna and other species.

*Recent and Ongoing Research*

In addition to monitoring catch and effort statistics for tropical tunas that include bigeye tuna, U.S. scientists participated in the 2007 ICCAT SCRS bigeye tuna stock assessment session of the Tropical Species Group, held in Madrid, Spain, June, 5-12 2007. U.S. scientists also participated in the Tropical Species Group meeting (Madrid, Spain, Sept. 24-26, 2008) where the recent work of the Group in evaluating alternative measures to protect juvenile tropical tunas was continued.

In 2008, U.S. scientists pursued research to develop demographically-based prior distributions for the intrinsic rate of population increase for tropical tunas. Also, U.S. scientists from the University of Miami's Rosenstiel School of Marine and Atmospheric Science collaborated with EC scientists on an EC-funded FEMS project regarding management strategy evaluations related to tropical tuna fisheries. U.S. scientists have continued to conduct cooperative research with scientists from Mexico, combining observer data collected from each nation's longline fleets in the Gulf of Mexico, pursuing the development of indices of abundance for species of concern to ICCAT as well as descriptive analyses of that fishery.

### 2.3.2 Atlantic Yellowfin Tuna

#### 2.3.2.1 Life History and Species Biology

Yellowfin tuna is a cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three oceans. The size of yellowfin tuna exploited by fisheries ranges from 30 cm to 170 cm fork length; and maturity occurs at about 100 cm fork length. Smaller fish (juveniles) form mixed schools with skipjack and juvenile bigeye tuna, and are mainly limited to surface waters, while larger fish form schools in surface and sub-surface waters.

Reproductive output among females has been shown to be highly variable. The main spawning ground is the equatorial zone of the Gulf of Guinea, with spawning primarily 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, taking into account the trans-Atlantic migration (from west to east) indicated by tagging, a 40-year time series of longline catch data that indicates yellowfin tuna are distributed continuously throughout the entire tropical Atlantic Ocean, and other information (*e.g*., time-area size frequency distributions and locations of fishing grounds). Males are predominant in the catches of larger sized fish. Natural mortality is assumed to be higher for juveniles than for adults; this is supported by tagging studies for Pacific yellowfin tuna.

Growth rates have been described as relatively slow initially, increasing at the time the fish leave the nursery grounds. Nevertheless, questions remain concerning the most appropriate growth model for Atlantic yellowfin tuna. A recent study (SCRS/2006/146) developed a new growth curve using daily growth increment counts from otoliths. The results of this study, as well as other recent hard part analyses, do not support the concept of the two-stanza growth model (initial slow growth) which is currently used for ICCAT (as well as other management bodies) yellowfin tuna stock assessments and was developed from length frequency and tagging data. This discrepancy in growth models could have implications for stock assessments and is being investigated. The younger age classes of yellowfin tuna exhibit a strong association with FADs (fish aggregating devices/floating objects, which can be natural or artificial). SCRS noted that this association with FADs, which increases the vulnerability of these smaller fish to surface fishing gears, may also have a negative impact on the biology and on the ecology of yellowfin tuna due to changes in feeding and migratory behaviors.

### 2.3.2.2 Stock Status and Outlook

A full stock assessment was conducted for yellowfin tuna in 2008, applying both an age-structured model and a non-equilibrium production model to the available catch data through 2006. Catch data for 2007 were provided soon after the assessment and available in the 2008 SCRS report. Information from the assessment is summarized in Table 2.9.

Since the relatively high catch levels of 2001 (164,650 t), catches have declined each year to a level of 108,160 t, a reduction of 34%. Catches in 2005 and 2006 represented the lowest level of catches since 1974. The catch estimate in 2007 (96,580 t) is preliminary, but may be even lower. A potential explanation for this decline is the reduction in eastern Atlantic purse seine effort, but that alone does not explain the reduction of baitboat and purse seine catches in the western Atlantic, nor the more recent declines of longline catches in both the western and eastern Atlantic.

An age-structured virtual population analysis (VPA) was conducted using fifteen indices of abundance. The VPA, using results from the base case runs, estimates that the levels of fishing mortality and spawning biomass in recent years have been very close to MSY levels. The estimate of MSY derived from these analyses was 130,600 mt. This estimate may be below what was achieved in past decades because overall selectivity has shifted to smaller fish; the impact of this change in selectivity on estimates of MSY is clearly seen in the results from VPA. The estimate of relative fishing mortality ($F_{06}/F_{MSY}$) was 0.84, and for relative biomass ($B_{06}/B_{MSY}$) was 1.09.

The stock was also assessed with a production model (ASPIC). Analyses were conducted using either nine separate indices or using a combined index created from all available abundance indices by fleet and gear, and weighting each index by the area covered by that fishery. The estimate of MSY derived using the basic case runs of ASPIC was 146,600 mt. Although the estimate of MSY was somewhat higher than that from the age structured model, the stock status results are slightly more pessimistic. The estimate of relative fishing mortality ($F_{06}/F_{MSY}$) was 0.89, and for relative biomass ($B_{06}/B_{MSY}$) was 0.83.

Trajectories of $B/B_{MSY}$ and $F/F_{MSY}$ from both age structured (VPA) and the production model (ASPIC) analyses are shown in Figure 2.7. The trend estimated from VPA indicates that overfishing ($F>F_{MSY}$) has occurred in recent years, but that the current status is neither overfished ($B<B_{MSY}$) nor is there over fishing. The more pessimistic ASPIC estimates indicate that there has been both overfishing and an overfished status in recent years, but that overfishing was not occurring in 2006. Bootstrapped estimates of the current status of yellowfin tuna based on each model, which reflect the variability of the point estimates given assumptions about uncertainty in the inputs, are shown in Figure 2.8. Examination of the distribution of these estimates from both models shows that about 40% indicate a sustainable situation, in which the stock is not overfished and overfishing is not occurring.

In summary, 2006 catches are estimated to be well below MSY levels, stock biomass is estimated to be near the ICCAT Convention Objective and recent fishing mortality rates somewhat below $F_{MSY}$. The recent trends indicate declining effective effort and some recovery of stock levels. However, when the uncertainty around the point estimates from both models is taken into account, there is still about a 60% chance that stock status is not consistent with Convention Objective.

Projections were made considering a number of constant catch scenarios. These indicate that catches of 130,000 t or less are sustainable during the projection interval, while catches in excess of 130,000 t can lead to overfishing. Maintaining current catch levels (110,000 t) is expected to lead to a biomass somewhat above $B_{MSY}$. In terms of equilibrium conditions, the various assessment model results show that increasing fishing mortality in the long term by up to 10% (depending on the model) to reach $F_{MSY}$ would only result in equilibrium yield gains of 1% to 4% over the expected yields at current fishing mortality levels. Yearly catches of small (less than 3.2 kg) yellowfin tuna in numbers have ranged around 60-75% of purse seine catches and about 40-80% of baitboat catches since 2000, occurring primarily in the equatorial fisheries. The generally declining trends in average weight may still be a cause for concern. Minimum size limits for yellowfin tuna have been shown to be ineffective by themselves, due to difficulties related to the multi-species nature of the fishery. Previously conducted yield-per-recruit analyses have indicated that reductions in fishing mortality on fish less than 3.2 kg could result in gains in yield-per-recruit and modest gains in spawning biomass-per-recruit. The protection of juvenile tunas may therefore be important and alternative approaches to minimum size regulations to accomplish this should be studied. In accordance with concerns expressed at ICCAT that alternatives be examined, a limited evaluation was conducted on the relative impact of effective effort restrictions on individual fisheries in terms of yield per recruit and spawning biomass per recruit. This evaluation is presented in a separate report.

**Table 2.10 Summary Table for the Status of Atlantic Yellowfin Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Assumed to be knife-edge at the beginning of Age 3<br>~100 cm curved fork length |
| **Spawning Sites** | Tropical waters |
| **Relative Biomass Level**<br>*Minimum Stock Size Threshold* | $B_{06}/B_{MSY}$ = 0.96 (0.72 - 1.22)<br>$0.5B_{MSY}$ (age 2+) |
| **Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{current}/F_{MSY}$ = 0.86 (0.71-1.05)*<br>$F_{year}/F_{MSY}$ = 1.00 |
| **Maximum Sustainable Yield** | ~ 130,600 mt (120,100-136,500 mt) (VPA)<br>~ 146,600 mt (128,200-152,500 mt) (ASPIC) |
| **Current (2006) Yield** | 108,160 mt |
| **Replacement Yield (2006)** | ~ 130,000 mt |
| ***(Outlook – Status of Stocks, NMFS, 2008)*** | *(Not Overfished; overfishing not occurring)* |

*$F_{current}$ refers to F2006 in the case of ASPIC, and the geometric mean of F across 2003-2006 in the case of VPA.

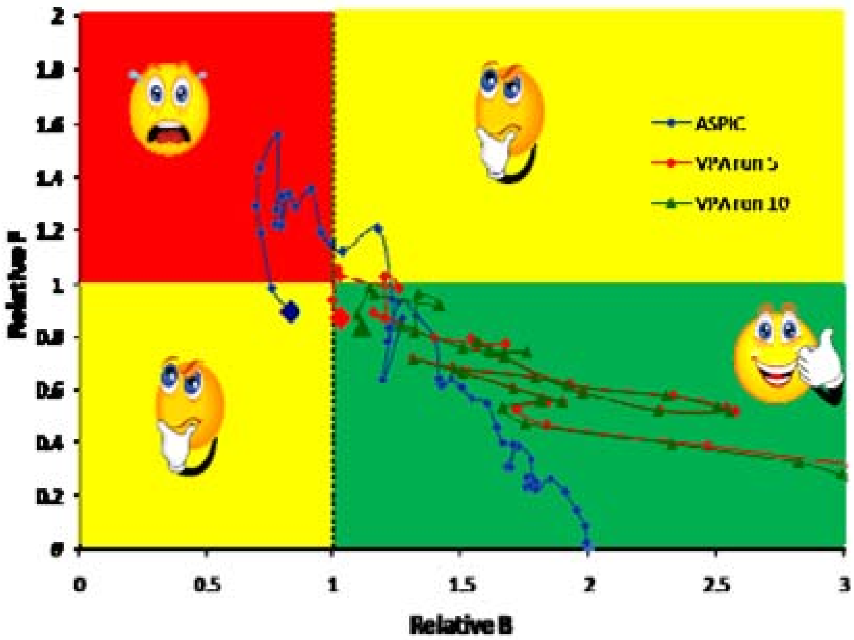


**Figure 2.7** **Stock status trajectories of B/BMSY and F/FMSY from age-structured (VPA) and production model (ASPIC) analyses. The age structured analysis started in 1970 and the production model in 1950. Current status is indicated by the large point at the end of each time-series.** Source: SCRS, 2008.

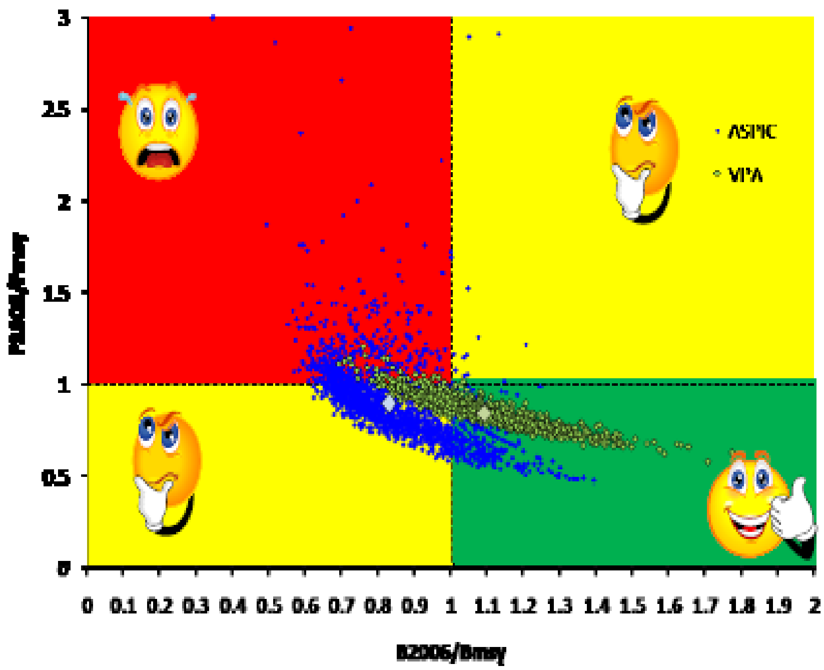


**Figure 2.8** **Current status of yellowfin tuna based on age structured and production models. The median point estimate for each model is shown as a large diamond and the clouds of symbols depict the bootstrap estimates of uncertainty for the most recent year.** Source: SCRS, 2008.

### 2.3.2.3 Effects of Regulations

**ICCAT Management Recommendations**

Recommendation 04-01 implemented a small closure for surface fishing in the area 0º-5ºN, 10ºW-20ºW during November in the Gulf of Guinea. Although this regulation is intended to reduce small bigeye tuna catches, SCRS recognizes that its implementation and the change from the previous moratorium to the current regulation will potentially impact yellowfin tuna catches. Given the relatively small time-area coverage of the closure, any reduction in juvenile mortality is expected to be minimal. Although there are as yet insufficient data to conduct a thorough evaluation of the impact of Rec. 04-01, an analysis of 1994-2007 purse seine catches presented to SCRS confirms that the new closure has been less effective than previous moratoria in reducing small fish harvests and avoiding growth overfishing.

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 VPA, during the 2008 assessment, effective effort in 2006 appeared to be well below (about 25-30% below) the 1992 levels, and there has been a declining trend in recent years.

**Domestic Regulations**

Yellowfin tuna is listed as approaching an overfished condition by the United States. Several management measures have been implemented in the United States, consistent with ICCAT recommendations to limit fishing effort and to prevent overfishing. In 1999, NMFS 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 maintained its minimum size limit for YFT of 27" which was greater (i.e., more restrictive) than an intial recommendation by ICCAT that was ultimately repealed by ICCAT because of implementation problems.

Yellowfin tuna is the principal species of tropical tuna landed by U.S. fisheries in the western North Atlantic. Total estimated landings decreased to 5,559 mt in 2007, from the 2006 landings estimate of 7,090 mt. The 2007 estimate is considered provisional and may change owing to incorporation of late reports of commercial catches as they become available and to possible revisions in estimates of rod and reel catches made by recreational anglers. A high proportion of the estimated landings were due to rod and reel catches of recreational anglers in the Northwest Atlantic (2,756 mt). Estimates of U.S. recreational harvests for tuna and tuna-like species continue to be reviewed and this may result in the need to report additional revisions to the available estimates in the future (NMFS, 2008).

*Management Recommendations*

The status of yellowfin tuna has shown some improvement since the last assessment, which is not surprising in that catches and fishing effort have generally declined and there have been small increases in catch rates observed for some longline fisheries over the past few years. Currently, stock biomass is estimated to be near the ICCAT Convention Objective and recent fishing mortality rates somewhat below $F_{MSY}$. Continuation of current catch levels is expected to lead to a healthy biomass, somewhat above $B_{MSY}$, which should provide adequate safeguard against biomass falling below the Convention Objective as long as fishing effort does not substantially increase. Effort increases on the order of about 10% above current levels (in order to achieve MSY) would be expected in the long run to increase yield by only about 1-4% over what could be achieved at current effective effort levels, but with substantially increased risk of biomass falling below the Convention Objective. In addition, SCRS indicated that ICCAT should be aware that increased harvest of yellowfin tuna could have negative consequences for bigeye tuna in particular, and other species caught together with yellowfin tuna in fishing operations taking more than one species. SCRS also continued to recommend that effective measures be found to reduce fishing mortality of small yellowfin tuna, if ICCAT wishes to increase long-term sustainable yield.

*Recent and Ongoing Research*

U.S. scientists participated in the ICCAT SCRS yellowfin tuna and skipjack tuna stock assessment session of the Tropical Species Group, held in Florianopolis, Brazil, 21-29 July, 2008. U.S. scientists also participated in the Tropical Species Group meeting (Madrid, Spain Sept. 24-26, 2008) where the recent work of the Group in evaluating alternative measures to protect juvenile tropical tunas was continued.

In 2008, U.S. scientists have presented several papers to SCRS consisting of indices of abundance and length-frequencies of yellowfin and skipjack tuna from U.S. fisheries. U.S. scientists have also pursued research to develop demographically-based prior distributions for the intrinsic rate of population increase for tropical tunas. These prior distributions were essential input into Bayesian and non-Bayesian surplus production modeling conducted during the 2008 skipjack tuna assessment.

U.S. scientists from the University of Miami's Rosenstiel School of Marine and Atmospheric Science collaborated with EC scientists on an EC-funded FEMS project regarding management strategy evaluations related to tropical tuna fisheries. U.S. scientists have continued to conduct cooperative research with scientists from Mexico, combining observer data collected from each nation's longline fleets in the Gulf of Mexico, pursuing the development of indices of abundance for species of concern to ICCAT as well as descriptive analyses of that fishery. U.S. and Mexican scientists collaboratively calculated abundance indices for the 2008 yellowfin tuna stock assessment using the combined database. U.S. scientists also collaborated with EC scientists to calculate skipjack tuna abundance indices from the Azorean baitboat fishery as well as in the estimation of potential trends in catchability in the European purse seine fleet.

### 2.3.3 Atlantic Albacore Tuna

#### 2.3.3.1 Life History and Species Biology

Albacore is a temperate tuna widely distributed throughout the Atlantic Ocean and Mediterranean Sea. On the basis of the biological information available for assessment purposes, the existence of three stocks is assumed: northern and southern Atlantic stocks (separated at 5ºN) and a Mediterranean stock. Nevertheless, there is likely intermingling of Indian Ocean and South Atlantic immature albacore which needs further research. Present available knowledge about habitat distribution according to size, spawning areas and maturity estimates are based on limited studies.

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 longlines in temperate waters.

#### 2.3.3.2 Stock Status and Outlook

The most recent stock assessment for northern and southern albacore tuna was conducted in 2007. The Mediterranean stock has never been assessed. A thorough revision of North and South Atlantic Task I and Task II (catch and effort) data was conducted for the 2007 assessment, and a more robust method for catch-at-size analyses was utilized. In addition, catch rate analyses were improved and updated with new information for the northern and southern albacore fisheries and a substantial effort was undertaken to implement assessment methods which did not assume that catch-at-age is perfectly known. The analyses were also conducted to incorporate longer time-series of catch, effort and size information into the assessment. This approach provided an opportunity to evaluate a range of hypotheses about how albacore fisheries have operated over time, and their impact on the population. The results of these efforts are reflected in the following summaries of stock status, which analyzed data through 2005.

North Atlantic

SCRS noted that the most recent CPUE trends showed somewhat different patterns for the surface fleets (which catch mostly immature fish) and the longline fleets (which catch mostly mature fish). The Spanish age 2 troll series, showed evidence of a relatively strong 2003 year class entering the fishery. For the Spanish age 3 troll series, the age-two signal is not yet fully reflected, leading to uncertainty about the possibility of a good year class. For the longline fleets, the general CPUE trend shows a decline over time, with varying rates. Given the variability associated with these catch rate estimates, definitive conclusions about recent trends could not be reached by examining CPUE alone which represent different parts of the population.

Based on the 2007 assessment which considered catch, size and effort since the 1930s, SCRS stated that the northern albacore spawning stock biomass has declined. In 2005, the spawning stock biomass was about one quarter of the peak levels estimated for the late 1940s. Estimates of recruitment to the fishery, although variable, have shown generally higher levels in the 1960s and earlier periods, with a declining trend thereafter. However, the most recent recruitment is estimated to be large, but uncertain.

Table 2.11 provides a summary of the stock assessment results for northern albacore. The 2007 northern albacore stock assessment indicates that the stock has recently rebuilt to levels near $B_{MSY}$ (current SSB is approximately 20% below the MSY level, compared to 2000 when it was 50% below). Recent fishing mortality rates have generally been above $F_{MSY}$ (current F is approximately 50% larger than $F_{MSY}$) (Figure 2.9).

While estimates of MSY varied over time as the relative combination of fisheries taking juvenile and mature albacore varies, which results in different overall selectivity patterns across time, the biomass that supports that MSY has little variation. For the three most recent years, the estimate of MSY is about 30,000 t, but over time the estimates have ranged from about 26,000 mt to 34,000 t, depending on the relative importance of the surface and longline fisheries catch levels. If recruitment were at the levels estimated in the 1960s, then MSY would be higher. For example, the total annual albacore average catch was about 50,000 mt during the 30 years from 1956-1986, which is much higher than the 2005 MSY estimate of about 30,200 mt. This decline in MSY may partially be due to environmental factors affecting the productivity of the stock and also possibly due to economic variables. Thus, further studies need to be conducted to achieve an improved condition of the stock. There is some uncertainty around the 2005 estimates of biomass and fishing mortality ratios.

The assessment indicated that the spawning stock will decline from the levels estimated in 2005 over the next few years, particularly given the fact that the 2006 catch was higher than the 2005 level. The spawning stock response to different catch levels after the next few years depends upon the real strength of the 2003 year class, which could be relatively strong (although SCRS did not have confidence in the overall level).

**Table 2.11 Summary Table for the Status of Northern Atlantic Albacore Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Age 5/~90 cm curved fork length |
| **Spawning Sites** | Subtropical western waters of the northern Hemisphere |
| **Current Relative Biomass Level**<br>*Minimum Stock Size Threshold* | $B_{05}/B_{MSY}$ = 0.81 (0.68-0.97)<br>*0.7$B_{MSY}$* |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{05}/F_{MSY}$ = 1.5 (1.3-1.7)<br>$F_{year}/F_{MSY}$ = 1.00 |
| **Maximum Sustainable Yield** | 30,200 mt [26,800 - 34,100 mt] |
| **Current (2007) Yield** | 21,549 mt |
| **Current (2006) Replacement Yield** | ~32,000 |
| ***(Outlook – Status of Stocks, NMFS, 2008)*** | ***(Overfished; overfishing is occurring)*** |

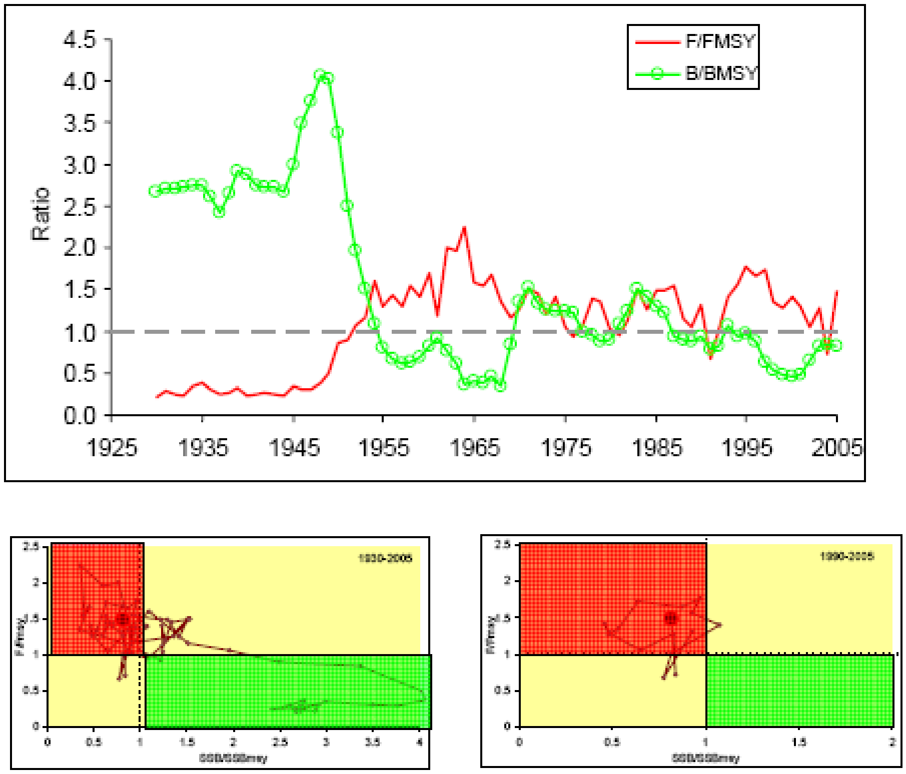


**Figure 2.9** **Stock status of northern albacore, estimated with Multifan-CL. Top: Relative biomass (B/BMSY) and relative fishing mortality (F/FMSY) trajectories over time. Bottom: joint trajectories of B/BMSY and F/FMSY. The large closed circle in the lower panels represents the stock status in 2005.** Source: SCRS, 2008.

<u>South Atlantic</u>

In 2003, SCRS assessed the status of the Southern Atlantic albacore stock using the same specifications as were used in 2000, but with updated data. Because of the detailed review, revisions, and updates of the data since that time, SCRS incorporated additional information into the model used for assessing the Southern Albacore stock, and incorporated an assessment methodology in 2007 that more objectively brought information about fishery selectivity into the evaluation. Table 2.12 provides a summary of the stock assessment results for southern albacore.

**Table 2.12 Summary Table for the Status of Southern Atlantic Albacore Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Age/size at Maturity** | Age 5/~90 cm curved fork length |
| **Spawning Sites** | Subtropical western waters of the Southern Hemisphere |
| **Current Relative Biomass Level** | $B_{05}/B_{MSY}$ = 0.91 (0.71-1.16) |
| **Current Relative Fishing Mortality Rate** | $F_{05}/F_{MSY}$ = 0.63 (0.47-0.9) |
| **Maximum Sustainable Yield** | 33,200 mt [29,900 – 36,700 mt] |
| **Current (2007) Yield** | 20,032 mt |
| **Current (2006) Replacement Yield** | 28,800 mt (25,800-29,300 mt) |
| **Outlook** | Overfished; overfishing is not occurring |

Regarding southern albacore CPUE trends, trends in the longline fisheries harvesting mostly mature albacore showed a strong declining trend in CPUE in the early part of the time series, and a less steep decline over the past decade. CPUE trends from the surface fishery, harvesting mostly juvenile albacore, are more recent and show no apparent trend.

Based on the 2007 stock assessment which considered catch, size and effort since the 1950s, SCRS stated that the southern albacore spawning stock biomass has declined to about 25% of its unfished level. SCRS concluded that the stock is below the maximum sustainable yield (MSY) level at about 90% of $B_{MSY}$ in 2005. The fishing mortality rate in 2005 was about 60% of $F_{MSY}$. MSY was estimated to be around 33,300 mt, whereas the replacement yield, averaged over the last 10 years, is estimated to be approximately 29,000 mt.

The assessment indicates that the spawning stock will increase from the levels estimated in 2005 over the next few years, assuming that catches in 2006 and 2007 remain at about the 2005 level, which is below the estimated replacement yield of about 29,000 mt.

Mediterranean

Due to the lack of adequate data, an assessment of the Mediterranean stock has never been conducted by SCRS.

#### 2.3.3.3 Effects of Regulations

North Atlantic

**ICCAT Management Recommendations**

In 2001, ICCAT established a total allowable catch (TAC) of 34,500 mt for northern albacore and, in 2003, extended the TAC to 2007. Furthermore, a 1998 recommendation limiting fishing capacity to the average of 1993 – 1995 remains in force. SCRS found that reported northern albacore catches for the period 2001-2004 had been below the TAC, but 2005 and 2006 catches were above TAC. The reported catch of 21,549 mt in 2007 was well below the established northern albacore TAC.

**Domestic Regulations**

Historically, albacore has not been a main focus of the U.S. commercial tuna fisheries operating in the North Atlantic. Reported commercial catches were relatively low prior to 1986; however, these catches increased substantially and have remained at higher levels throughout the 1990s, with nearly all of the production coming from the northeastern U.S. coast. The U.S. landings from the Caribbean increased in 1995 to make up over 14% of the total U.S. harvest of albacore, but have since remained below 4% of the total. Estimated total catches of albacore were 532 MT in 2007, an increase of 132 MT from 2006.

South Atlantic

**ICCAT Management Recommendations**

Since 1999, ICCAT has established a total allowable catch (TAC) for this stock. For 2001 - 2007 the TAC was set at 29,200 mt. SCRS noted that reported catches in 2007 were well below the established TAC.

Mediterranean

There are no ICCAT recommendations that specifically address the Mediterranean stock.

*Management Recommendations*

North Atlantic

The TAC for the northern albacore stock until 2007 was 34,500 mt. SCRS noted that the reported catches in 2005 and 2006 were over the TAC, and that the 2007 catch was well below the TAC. Furthermore, stock projections indicate that the northern stock will not recover from the overfished conditions if catch levels remain over 30,000 mt. If strong year classes enter the fishery, which is uncertain but suggested by some CPUE series, the stock will recover faster. In 2007, the ICCAT implemented Recommendation 07-02, intended to reduce the TAC to 30,200 mt in 2008 and 2009 and allow rebuilding of the northern albacore stock from an overfished condition. However, it was noted that fishing opportunities provided in Recommendation 07-02 allow the potential catch to exceed the TAC.

South Atlantic

In the case of the southern stock, the TAC from 2001 – 2007 was set at 29,200 mt. Recent catches have been below this level. The SCRS assessment showed that the southern stock is overfished. Current model projections indicate that catches at about the 2006 level will recover the stock. The observed 2007 catch was, however, even lower. SCRS considered that the current management regulations in effect are sufficient for the recovery of the southern stock. In 2007, the Commission adopted Recommendation 07-03 which establishes a catch limit of 29,900 mt (the lowest estimate of MSY) until 2011.

*Recent and Ongoing Research*

NMFS scientists continue to be involved in the development of alternative, more detailed statistical-based models, in efforts to evaluate more fully the relationship between this species' population dynamics and associated fishery operations (i.e., areas of uncertainty in an overall stock assessment). In addition, research is being conducted to improve the implementation of the stochastic approach being used currently to estimate catch-at-age for northern albacore. It is envisioned that these analyses will be completed in time for the 2009 albacore assessment.

### 2.3.4 Atlantic Skipjack Tuna

#### 2.3.4.1 Life History and Species Biology

Skipjack tuna is a gregarious species that is found in schools in the tropical and subtropical waters of the three oceans. It is the predominant species found under fish aggregating devices (FADs) where it is caught in association with juvenile yellowfin tuna, bigeye tuna and with other species of epipelagic fauna. Skipjack tuna show an early maturity (around first or second year of life), high fecundity and spawn opportunistically throughout the year in warm waters above 25º C. Skipjack tuna are also thought to be a faster-maturing and shorter lived species than yellowfin tuna. One of the characteristics of skipjack tuna is that from its first year of life it spawns opportunistically throughout the year and in vast sectors of the ocean. A recent analysis of tagging data from the eastern Atlantic confirmed that the growth of skipjack tuna varies according to the latitude. However, this variation is not as great as had been previously thought. For example, the growth curve parameters obtained recently for the 10° N latitude region were closer to the estimates made in the Gulf of Guinea or in other oceans than those that had been estimated in Senegal in the early 1980s. The increasing use of FADs since the early 1990s, have changed the species composition of free swimming schools. It is noted that, in effect, the free schools of mixed species were considerably more common prior to the introduction of FADs. Furthermore, the association with FADs may also have an impact on the biology (food intake, growth rate, plumpness of the fish) and on the ecology (displacement rate, movement orientation) of skipjack and yellowfin tuna (ecological trap concept).

#### 2.3.4.2 Stock Status and Outlook

The last full stock assessment for skipjack tuna was conducted in 2008. Summarized information for west Atlantic skipjack tuna and east Atlantic skipjack tuna are shown in Table 2.13 and Table 2.14, respectively.

Traditional stock assessment models have been difficult to apply to skipjack tuna because of their particular biological (continuous spawning, areal variation in growth) and fishery characteristics (non-directed effort, weak cohorts identified). In order to overcome these difficulties, several different assessment methods which accommodate expert opinion and prior knowledge of the fishery and biological characteristics of skipjack tuna have been carried out on the two stocks of Atlantic skipjack tuna. Additionally, several fishery indicators were analyzed for evidence of changes in the state of the stock over time. Although the fisheries operating in the east have extended toward the west beyond 30º W longitude, SCRS decided to maintain the hypothesis in favor of two distinct stock units, based on available scientific studies. However, taking into account the state of current knowledge of skipjack tuna migrations and the geographic distances between the various fishing areas, the use of smaller stock units continues to be the envisaged hypothesis.

**Table 2.13 Summary Table for the Status of West Atlantic Skipjack Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Maturity schedule** | Assumed to be knife-edge at the beginning of Age 2 |
| **Spawning Sites** | Spawn opportunistically in tropical and subtropical waters |
| **Current Relative Biomass Level**<br>*Minimum Stock Size Threshold* | $B_{06}/B_{MSY}$: most likely >1<br>*Unknown* |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{06}/F_{MSY}$: most likely <1<br>$F/F_{MSY}$ = 1.00 |
| **Maximum Sustainable Yield** | Around 30,000-36,000 mt |
| **Current (2007) Yield** | 25,400 t |
| **Current Replacement Yield** | Somewhat higher than 25,400 mt |
| ***(Outlook – Status of Stocks, NMFS, 2008)*** | ***(Unknown)*** |

**Table 2.14 Summary Table for the Status of East Atlantic Skipjack Tuna.** Source: SCRS, 2008.

| | |
|---|---|
| **Maturity schedule** | Assumed to be knife-edge at the beginning of Age 2 |
| **Spawning Sites** | Spawn opportunistically in tropical and subtropical waters |
| **Current Relative Biomass Level**<br>*Minimum Stock Size Threshold* | $B_{06}/B_{MSY}$: most likely >1<br>*N/A (no U.S. fishing)?* |
| **Current Relative Fishing Mortality Rate**<br>*Maximum Fishing Mortality Threshold* | $F_{06}/F_{MSY}$: most likely <1<br>*N/A (no U.S. fishing)?* |
| **Maximum Sustainable Yield** | Around 143,000-170,000 mt |
| **Current (2007) Yield** | 125,400 mt |
| **Current Replacement Yield** | Somewhat higher than 125,400 mt |
| **Outlook** | Not overfished; overfishing not occurring. |

Western stock

The standardized CPUEs of Brazilian baitboats remain stable while those of Venezuelan purse seiners and U.S. rod and reel decreased in recent years. This decrease, also observed in the yellowfin tuna CPUE time series of Venezuela, could be linked to specific environmental conditions (high surface temperatures, lesser accessibility of prey). The average weight of skipjack tuna caught in the western Atlantic is higher than in the east (3 to 4.5 kg vs. 2 to 2.5 kg), at least for the Brazilian baitboat fishery. The catch only model estimated MSY at around 30,000 t and the Bayesian surplus model (Schaefer formulation) at 34,000 mt. SCRS attempted several analyses, specifically sensitivity runs using different values of natural mortality. For this stock, only the three fisheries mentioned above were considered. The final estimate of MSY converges also at about: 31,000-36,000 mt. It must be stressed that all of these analyses correspond to the current geographic coverage of this fishery (i.e., relatively coastal fishing grounds due to the deepening of the thermocline and of the oxycline to the East). For the western Atlantic stock, it is unlikely that the current catch is larger than the current replacement yield as shown by the trajectories of $B/B_{MSY}$ and $F/F_{MSY}$ (Figure 2.10).

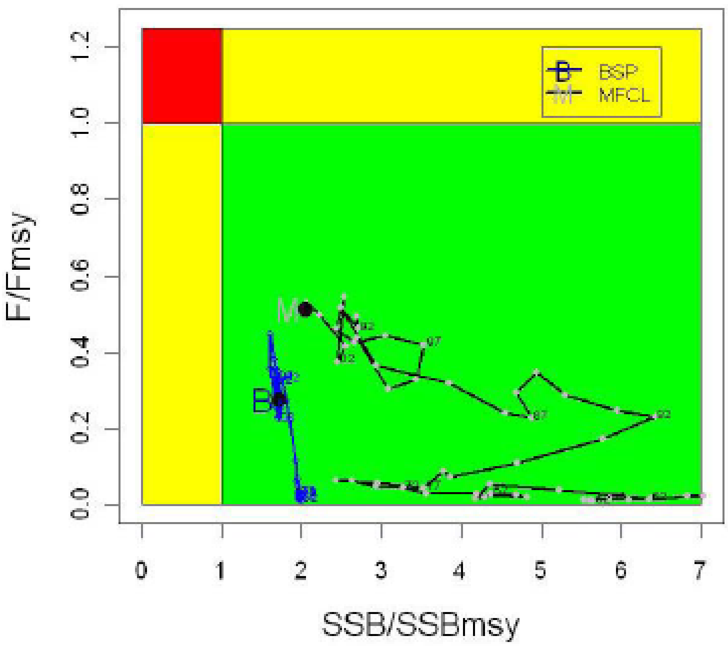


**Figure 2.10** **2007 stock status for western skipjack tuna. Trajectories of B/BMSY and F/FMSY from the Bayesian surplus production model (Schaefer type) and from the generalized multi-fleets dynamic model and from MULTIFAN-CL.** Source: SCRS, 2008.

<u>Eastern stock</u>

SCRS analyzed two standardized indices from the EC-purse seine fishery: The first index depicting skipjack tuna caught in free school in the Senegalese area during the 2nd quarter of the year and the second index characterizing small fish captured under FADs in the equatorial area. In previous meetings of the Tropical Tunas Species Group it was confirmed that the increase in CPUE of the European purse seiners in the late 1990s was due, mainly, to the increase in the catches of positive sets under FADs. Furthermore, the regular increase in the skipjack tuna yields of the baitboats based in Senegal (contrary to the other two tropical tuna species) may only have been the result of an increase in catchability linked to the adoption of the so-called "baitboat associated school" fishing towards the mid-1980s. Furthermore, no marked trend has been observed for the Canary Islands baitboats as well as for a peripheral fishery such as the Azorean baitboat fishery. The fact that a reduction in abundance for a local segment of the stock would have little repercussion on abundance in other areas, leads to suppose that only a minor proportion of skipjack tuna carry out extensive migrations between areas. This assumption was reinforced by a recent tagging study on growth variability of skipjack tuna between two eastern Atlantic regions divided by 10° N latitude, which were established on the basis of their low amount of mixing (only 0.9% of the tagged fish crossed this limit).

A new Bayesian method, using only catch information, estimated the MSY (under a Schaefer-type model parameterization) at 143,000-156,000 t, a result which agrees with the estimate obtained by the modified Grainger and Garcia approach: 149,000 mt. In addition, two surplus biomass production models (a multi-fleets generalized dynamic model and a Schaeferbased dynamic model) were applied for 8 time series of CPUEs, and for a combined index weighted by fishing areas. To account for the increase in catchability of purse seine fisheries, a correction factor of 3% per year was applied. As for the catch only model, different working hypothesis on the distribution of the priors of the parameters of the surplus production model (i.e., growth rate, carrying capacity, catchability coefficient of each fleet, etc.) were tested. In general, the range of plausible MSY values estimated from these models (155,000-170,000 mt) were larger than in the catch only model. SCRS stated the difficulty of estimating MSY due to the one-way trip trend depicted by this fishery and, as the result, the needs to constraint the range distribution of some priors (e.g., for growth rate, or for the shape parameter of the generalized model). Although some caution is needed as regards to the generalization of the status to the overall stocks in the East Atlantic, due to the moderate mixing rates that seem to occur among the different sectors of this region, it is unlikely that skipjack tuna be exploited in the eastern Atlantic (Figure 2.11).

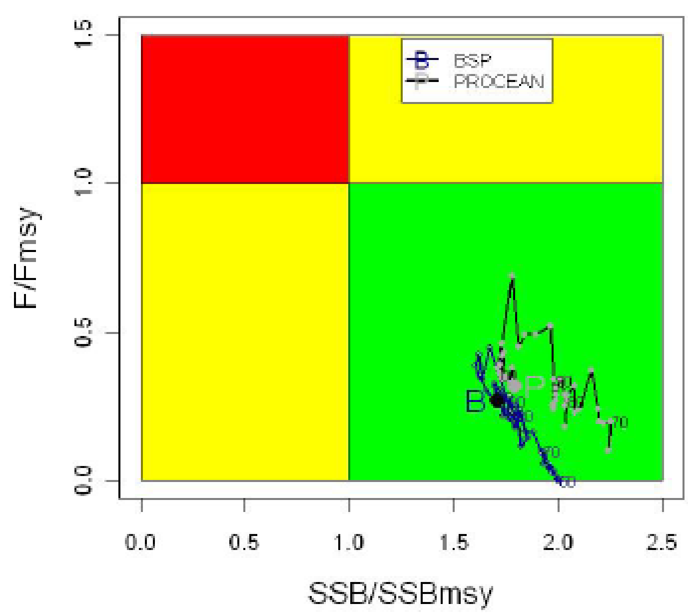


**Figure 2.11** **2007 stock status for eastern skipjack tuna. Trajectories of B/BMSY and F/FMSY from the Bayesian surplus production model (Schaefer type) and from the generalized multi-fleets dynamic model and from MULTIFAN-CL.** Source: SCRS, 2008.

### 2.3.4.3 Effects of Regulations

**ICCAT Management Recommendations**

There is currently no specific regulation in effect for skipjack tuna. However, with the aim of protecting juvenile bigeye tuna, the French and the Spanish boat owners voluntarily decided to apply a moratorium for fishing under floating objects between November and the end of January for the 1997-1998 and 1998-1999 periods. ICCAT implemented a similar moratorium from 1999 to January 2005. This moratorium has had an effect on skipjack tuna catches made with FADs. On the basis of a comparison of average catches between 1993-1996, prior to the moratoria, and those between the 1998-2002 period, the average skipjack tuna catches between November and January for the purse seine fleets that applied the moratoria, were reduced by 64%. During that period (1998-2002), the average annual skipjack tuna catches by purse seine fleets that applied the moratoria decreased by 41% (42,000 t per year). However, this decrease is possibly a combined result of the decrease in effort and the impact of the moratoria (the average annual catch per boat decreased only 18% between these two periods). The repealing in 2006 of Recommendation [Rec. 05-01] on the 3.2 kg minimum size limit on yellowfin tuna [Rec. 72-01] and the establishment of a time/area closure of the surface fishery [Rec. 04-01], which replaces the old strata relative to the moratorium on catches under floating objects, are regulatory measures whose effects were analyzed during the species Group meeting. Considering that the new closed area is much smaller in time and surface than the previous moratorium time/area, and is located in an area which historically has lower effort anyway, this regulation is likely to be less effective in reducing the overall catches of small bigeye tuna (the species for which the regulation was applied) by the surface fishery. When the fishing effort for the EC purse seine fleet was at its maximum value (period 1994-1996, i.e., before the implementation of the first moratorium), the skipjack tuna catch from this fleet within the time and area limits defined by Rec. 04-01, was only on average at 7,180 t (i.e., 7.5% of the total skipjack tuna catch from the EC purse seiners).

**Domestic Regulations**

Skipjack tuna are caught by U.S. vessels in the western North Atlantic. Total reported skipjack tuna landings (preliminary) increased from 61 mt in 2006 to 66.4 mt in 2007. Over 75 percent of U.S. landings are from recreational rod and reel catches and landings from the Northwest Atlantic, Gulf of Mexico, and Caribbean areas, based on LPS statistical surveys of the U.S. recreational harvesting sector. Estimates of recreational harvests of skipjack tuna continue to be reviewed and could be revised again in the future (NMFS, 2008).

*Management Recommendations*

Although SCRS did not make specific management recommendations in 2008, it indicated that catches should not be allowed to exceed MSY, and that ICCAT should be aware that increasing harvests and fishing effort for skipjack tuna could lead to unintended consequences for other species that are harvested in combination with skipjack tuna in certain fisheries.

*Recent and Ongoing Research*

U.S. scientists participated in the ICCAT SCRS yellowfin tuna and skipjack tuna stock assessment session of the Tropical Species Group, held in Florianopolis, Brazil, 21-29 July, 2008. U.S. scientists also participated in the Tropical Species Group meeting (Madrid, Spain Sept. 24-26, 2008) where the recent work of the Group in evaluating alternative measures to protect juvenile tropical tunas was continued.

In 2008, U.S. scientists presented several papers to SCRS consisting of indices of abundance and length-frequencies of yellowfin and skipjack tuna from U.S. fisheries. U.S. scientists have also pursued research to develop demographically-based prior distributions for the intrinsic rate of population increase for tropical tunas. These prior distributions were essential input into Bayesian and non-Bayesian surplus production modeling conducted during the 2008 skipjack tuna assessment.

U.S. scientists from the University of Miami's Rosenstiel School of Marine and Atmospheric Science collaborated with EC scientists on an EC-funded FEMS project regarding management strategy evaluations related to tropical tuna fisheries. U.S. scientists have continued to conduct cooperative research with scientists from Mexico, combining observer data collected from each nation's longline fleets in the Gulf of Mexico, pursuing the development of indices of abundance for species of concern to ICCAT as well as descriptive analyses of that fishery. U.S. and Mexican scientists collaboratively calculated abundance indices for the 2008 yellowfin tuna stock assessment using the combined database. U.S. scientists also collaborated with EC scientists to calculate skipjack tuna abundance indices from the Azorean baitboat fishery as well as in the estimation of potential trends in catchability in the European purse seine fleet.

## 2.4 Atlantic Billfish

### 2.4.1 Blue Marlin

#### 2.4.1.1 Life History and 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) (NMFS, 1999). Life expectancy for blue marlin is between 20 – 30 years based on age and growth analyses of dorsal spines.

Estimates of natural mortality rates for juvenile and adult 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 (NMFS, 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. Predicting age from length or weight is imprecise due to many age classes in the fishery, and otoliths may provide a more accurate measure of age.

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 pop-up satellite 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. Prince et al. (2005) tagged one blue marlin with a PSAT tag off the coast of Punta Cana, Dominican Republic and found that the fish moved 406.2 km (219.3 nm) during a 40-day deployment (10.15 km/day (5.48 nm/day)). 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).

Temperature-depth vertical habitat utilization for Atlantic blue marlin has been recently studied using data collected by 51 electronic pop-up satellite archival tags (PSATs) attached to fish released by recreational and commercial fishers (Goodyear, et. al., 2008). The average maximum depth observed was 319 m. A few of the monitored animals confined their vertical excursions to less than 100 m but dives below 800 m were also observed. The mean of the lowest temperatures explored was 17°C, with a range from just less than 10°C to just over 24°C. The distributions of times at depth were significantly different between day and night. At night, the fish spent most of their time at or very close to the surface. During daylight hours, they were typically below the surface, often at 40 to 100+ m. The blue marlin sometimes remained below the near-surface layer throughout the daylight hours, but they often returned briefly to the surface. This pattern of behavior also meant the distributions of time at temperature were significantly different between day and night, with the fish occupying warmer strata during darkness. Frequency distributions of the time blue marlin spend at temperatures relative to the temperature of the surface mixed layer, a key issue in some CPUE analyses, were determined for periods of darkness, daylight and, twilight. Results were highly variable within the time series for individual fish, and among individuals (SCRS, 2008).

The Cooperative Tagging Center (CTC) program has tagged 24,108 blue marlin and recaptured over 220 of these fish and found that they moved an average of 903 km (488 nm) (Ortiz et al., 2003). Some individuals have exhibited extended movement patterns, and strong seasonal patterns of movement of individuals between the United States and Venezuela are evident. The greatest straight-line distance traveled for a blue marlin was 14,893 km (8,041 nm) and the maximum number of days at large was 4,024 days.

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 of 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. Coastal areas off West Africa have strong seasonal upwelling, and may be feeding areas for blue marlin. 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. Prince and Goodyear (2006) reported evidence of habitat compression in areas where there is a distinct band of cold, hypoxic water close to the surface in the eastern Atlantic and Pacific Oceans. This restricts the acceptable habitat of billfish to shallower water in these areas, making them more vulnerable to surface gear, but also increases their access to prey items, possibly increasing growth rates. Figure 2.12 shows blue marlin catches by major gear from 2000 - 2006.

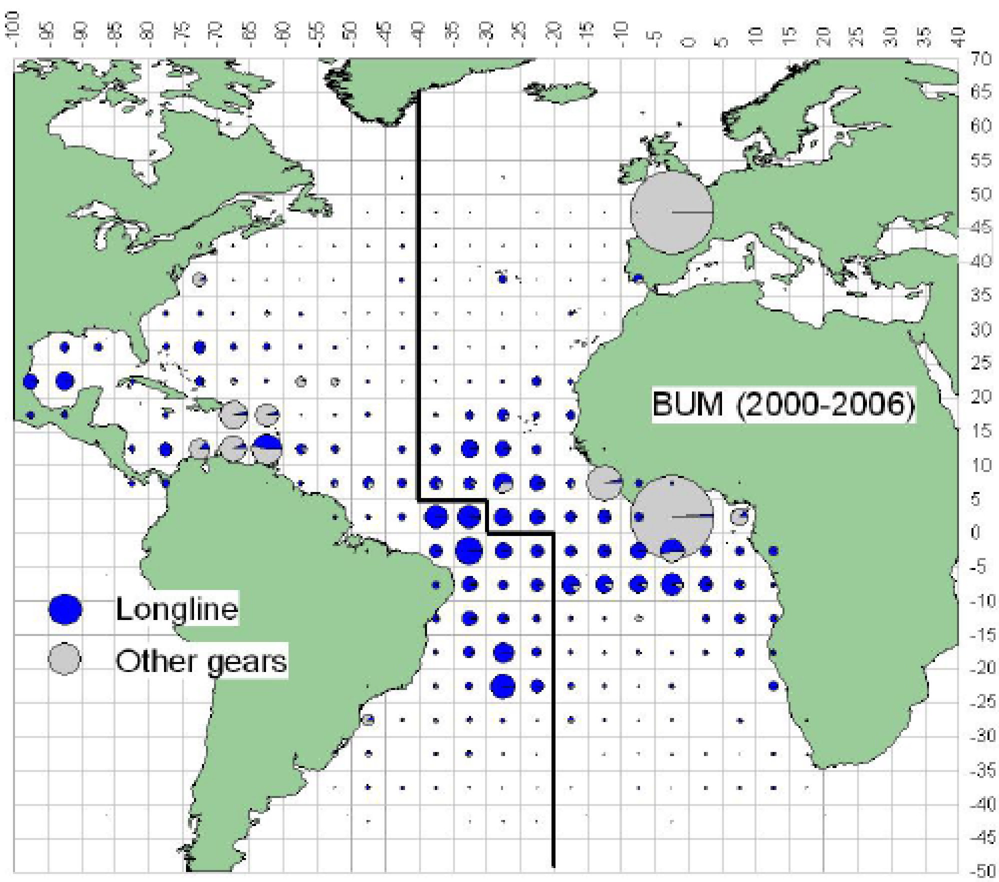


**Figure 2.12 Geographic distribution of mean blue marlin catch for the period 2000 – 2006 by major gears. Largest circle corresponds to catch of 789 mt.** Source: SCRS 2008.

Information on the timing and location of spawning, as well as size at first maturity and fecundity can help identify critical areas and size classes for protection. 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). A female specimen weighing over 1,000 lb. was found to be in spawning condition, indicating that even the largest females are capable of spawning (Luckhurst et.al. 2006).

The central and northern Caribbean Sea and northern Bahamas have historically been known as the primary spawning area for blue marlin in the western North Atlantic. Recent reports show that blue marlin spawning can also occur north of the Bahamas in an offshore area near Bermuda at about 32º-34º N. lat. New information on the reproduction of blue marlin from West Africa reported no evidence of spawning events from female blue marlin caught by artisanal vessel in Ivory Coast. Pre-spawning and post-spawning females are present in larger numbers than males (4:1 female/male ratio) in this area (SCRS, 2008).

There are likely two separate spawning events that occur at different times in the North and South Atlantic. In the South Atlantic, offshore from southeast Brazil (17º to 18º S lat. and 37º to 38ºW long.) blue marlin spawn from March to April. 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). Prince et al. (2005) conducted 23 neuston tows in the vicinity of Punta Cana, Dominican Republic between 23 April and 17 May and successfully identified four larval blue marlin; the size of the larvae indicated that spawning activity was taking place in the same general area where these samples were conducted. Serafy et al. (2003) identified 90 blue marlin larvae in the vicinity of Exuma Sound, Bahamas in the month of July, indicating that spawning activity had taken place 18 days prior to sampling. Luckhurst (2006) described evidence of spawning in blue marlin during July in the waters of Bermuda. This represents a northern extension (32°N) of the known spawning area in the northwest Atlantic for blue marlin.

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.

Larval blue marlin are voracious predators and feed on copepods and cladocerans in their first feeding stages but soon switch to a piscivourous diet (SCRS, 2008). 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 their 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 attack free-swimming, healthy individuals.

#### 2.4.1.2 Stock Status and Outlook

Since 1995, blue marlin have been managed internationally under a single stock hypothesis because of tagging data and mitochondrial DNA evidence that are consistent with one Atlantic-wide stock. The most recent stock assessment for blue marlin was conducted in 2006. However, large catches of billfish continue to be reported to ICCAT as unclassified and reporting gaps remain for some important fleets, which introduced significant uncertainty into the 2006 SCRS stock assessment. As a result, specific quantitative reference points normally associated with stock assessments could not be produced with reasonable confidence levels, and the 2006 assessment focused instead on recent trends in abundance. It should be noted that these trends are based only on a few years of observations. Confirmation of these recent apparent changes in abundance trends will require at least an additional four or five years of data (SCRS, 2006).

The October 2008 SCRS Report indicated that no new information on blue marlin stock status has become available since the 2006 assessment, which found that blue marlin remain overfished (Table 2.15), and that the biomass level most likely remains well below the $B_{msy}$ estimated in 2000. However, over the period 2001-2005, several indicators suggest that a decline in abundance has been at least partially arrested, although some other indicators suggest that abundance has continued to decline. While the 2006 assessment includes significant uncertainty, it appears that recent abundance trends (2001-2004) have possibly stabilized for blue marlin (Table 2.15, and Figure 2.13). Current and provisional mortality estimates suggest that F has recently declined during 2000 – 2004 and is possibly smaller than $F_{replacement}$, but larger than the $F_{msy}$ estimated in the 2000 assessment. The SCRS reported that blue marlin have the potential to rebuild under the current ICCAT management plan but this potential needs verification with an additional 4-5 years of data collection, especially since the reliability of recent information has diminished and may continue to do so (SCRS, 2006). Recent analyses suggest that the recovery of blue marlin stock might proceed faster than would have been estimated at the 2000 assessment, provided catches remain at the level estimated for 2004. Some signs of stabilization in the abundance trend are apparent in the most recent catch per unit of effort data of blue marlin (2000-2004). Despite more positive results in the 2006 SCRS blue marlin stock assessment than existed in the 2002 assessment, the overfished status of blue marlin remains unchanged.

To increase the likelihood of success of the blue marlin rebuilding plan, the SCRS indicated that further reductions in mortality would be needed, for example by improving compliance with current regulations, encouraging the use of circle hooks, and/or broader application of time/area catch restrictions. The SCRS also recommended that additional steps be taken to ensure that the reliability of recent fishery information improves. Improvements are needed in monitoring the fate and amount of dead and live releases, with verification from scientific observer programs. Additionally, verification of current and historical landings from some artisanal and industrial fleets needs to be conducted. Further, the results of habitat research are not yet sufficient to allow the SCRS to reach consensus on the best method to directly estimate MSY benchmarks for marlins based on a complete time series of data. Continued research is needed on the development of methods to incorporate habitat data into stock assessments to provide a basis for increasing the certainty with which management advice can be provided (SCRS 2006).

Recent trends in blue marlin abundance are contained in Figure 2.13. A summary of both Atlantic blue and white marlin stock assessment data may be found in Table 2.15.

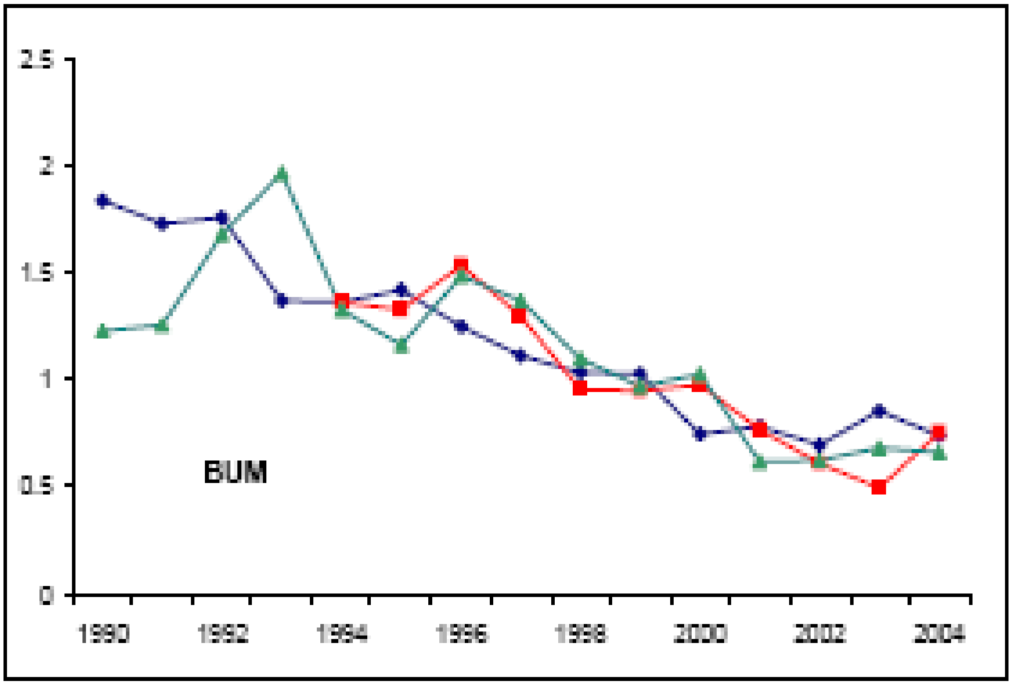


**Figure 2.13** **Relative abundance indices for blue marlin estimated by combining data for four longline fleets. Three different statistical models are shown for comparison.** Source: SCRS, 2006.

**Table 2.15 Summary of Atlantic Blue and White Marlin Stock Assessment Data.** Source SCRS, 2008.

| Atlantic blue marlin and Atlantic white marlin summary | | |
|---|---|---|
| | WHM | BUM |
| $B_{2004} < {}^{1}B_{MSY}$ | Yes | Yes |
| Recent Abundance Trend (2001-2004) | Slightly upward | Possibly stabilizing |
| $F_{2004} > F_{replacement}$ | No | Possibly |
| $F_{2004} > {}^{1}F_{MSY}$ | Possibly | Yes |
| ${}^{2}Catch_{recent}/Catch_{1996}$ Longline and Purse seine | 0.47 | 0.52 |
| ${}^{3}Catch_{2004}$ | 610 t | 2,916 t |
| Rebuilding to $B_{MSY}$ | Potential to rebuild under current management plan but needs verification. | Potential to rebuild under current management plan but needs verification. |
| [1]MSY | [4] 600-1,320 t | ~ 2,000 t (1,000 ~ 2,400 t) |

[1] As estimated during the 2000 (Anon. 2001) and 2002 (Anon. 2003a) assessments.
[2] Catch recent is the average longline catch for 2000-2004.
[3] Estimate of total removals obtained by the Committee. The Task I catch reported for 2006 is 2,182 t for blue marlin and 387 t for white marlin. The preliminary Task I catch reported for 2007 is 2,303 t for blue marlin and 302 t for white marlin. Final estimates for 2005-2007 are likely to be greater.
[4] Range of estimates were obtained in the previous assessments, but recent analyses suggest that the lower bound for white marlin should be at least 600.

#### 2.4.1.3 Effects of Regulations

**ICCAT Management Recommendations**

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. In 2000, ICCAT recommended that a blue marlin minimum size be established for recreational fisheries (251 cm (98.8 inches) LJFL). Recommendations 00-13, 01-10, 02-13, and 04-09 also 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 alongside 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. Most recently, ICCAT recommendation 06-09 consolidated all previous recommendations, extended phase one of the ICCAT mortality reduction plan through 2010, and scheduled the next assessment of Atlantic blue marlin for 2010.

Most countries started reporting live releases in 2006. Additionally, more information has become available, for some fleets, on the potential for using gear modifications to reduce bycatch and increase the survival rate of marlins. Such studies have also provided information on the rates of live releases for those fleets. However there is not enough information on the proportion of fish being released alive for all fleets to evaluate the effectiveness of the ICCAT recommendation relating to the live release of marlins. While the stock status evaluations are uncertain, the SCRS noted that the ICCAT billfish recommendations have the potential to rebuild these stocks, although verification is necessary.

Globally, catches of blue marlin appear to have been reduced as a result of ICCAT recommendations, which tied reductions in blue marlin landings to 1996 or 1999 levels, whichever is greater. During the 2006 marlin assessment, it was noted that catches of blue marlin had continued to decline through 2004 (Figure 2.14). Task 1 catches of blue marlin in 2005 were 3,436 t, including large catches that were newly reported from Caribbean FAD fleets. In 2006, Task 1 catches of blue marlin were 2,060 t. Task I catches of blue marlin in 2006 and 2007 were 2,182 t. and 2,303 t., respectively. The 2007 estimate is considered preliminary. Historical reports of unclassified billfish remain an important issue in the estimation of historical removals from marlin stocks.

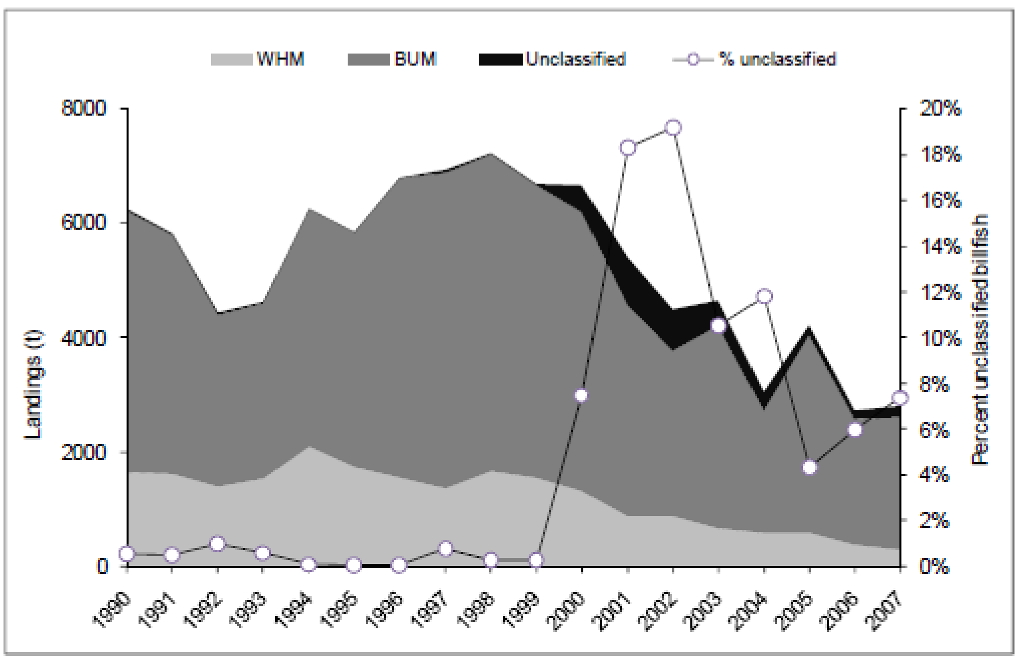


**Figure 2.14** **Total catch of Blue Marlin, White Marlin, and Unclassified Billfish for 1990 – 2007, and Percentage of the Ratio of Unclassified Billfish (line with symbols) with Respect to the Total Blue Marlin and White Marlin Catch.** Source SCRS, 2008.

## Domestic Regulations

The U.S. Atlantic billfish fishery, including blue marlin, white marlin, sailfish, and spearfish, has been managed as a recreational fishery through domestic regulation since 1988. Possession of Atlantic billfish is prohibited by U.S. pelagic longline vessels and no sale of

Atlantic billfish is allowed. The recreational fishery is an open access fishery. Anglers must possess either a HMS Angling category permit or a CHB category permit to possess billfish. General category tuna permit holders may possess Atlantic billfish only when participating in a registered HMS tournament. Details of the permitting program, including the number of permit holders can be found in Section 0 of this document. Data on domestic recreational catches of Atlantic billfish are obtained from a combination of sources, including: the Recreational Billfish Survey; the HMS swordfish and billfish non-tournament reporting line; MRFSS, LPS, and some state catch card programs (MD and NC). U.S. recreational billfish landings can be seen in Section 4.4.2 of this document. The U.S. implemented a minimum legal size of 251 cm (99 inches), 167 cm (66 inches), 160 cm (63 inches) for blue marlin, white marlin, and sailfish respectively, in 1999. Possession of Atlantic longbill spearfish has been prohibited since 1988. Rod and reel is the only type of gear authorized in the domestic billfish fishery.

***Recent and Ongoing Research***

The NMFS SEFSC has played a substantial role in the ICCAT Enhanced Research Program for Billfish which began in 1987 and has continued through 2007, with SEFSC scientists acting as the coordinator for research in the western Atlantic Ocean. Major accomplishments in the western Atlantic in 2007 are documented in SCRS/2007/144. Highlights include four at-sea sampling trips with observers on Venezuelan industrial longline vessels in 2007. Although this represents less than half of what had been planned for 2007, the activity provides uninterrupted continuation of the biological sampling of this fleet that was initiated in 1991. Sampling of Venezuelan artisanal catches also continued in Margarita Island and in the central coast of Venezuela. Biological samples from the pelagic longline and artisanal Venezuelan fisheries have provided large numbers of spines and gonads for age, growth and reproductive studies of blue and white marlin. Notably, this program recovered 70 tagged billfish in the first six months of 2007. Finally, participants in the U.S. Southeast Fisheries Science Center's Cooperative Tagging Center (CTC) and the Billfish Foundation Tagging Program (TBF) tagged and released 3,647 billfishes (including swordfish) in 2007 (SCRS, 2008).

Internationally, Brazil continued its collaborative program with U.S. institutions that started in 2005. During 2007, the program focused on testing the performance of circle hooks on board commercial vessels, tagging with PSATs, and collection of spine samples for age and growth studies. Additional research in Brazil will also focus on PSAT tagging of billfish and the collection of biological materials for ageing and molecular genetic analyses. In Bermuda, the ICCAT Enhanced Research Program for Billfishes program continued to support collaborative activities to collect biological materials from billfish tournaments. A review of billfish statistics in Ghana, Senegal, and Ivory Coast, initiated in 2006, has not been completed. However, improvements on catch records from these countries are reflected in recent ICCAT Task I tables for billfish.

The highest priority for the ICCAT Enhanced Research Program for Billfish in 2008 is to support improvement in the collection of statistics on artisanal Atlantic billfish fisheries. Other important activities include support for the continuation of the monitoring of the Venezuelan and Brazilian longline fleets through an observer program, collection of conventional tags, and the collection of biological samples. Shore-based samples will be conducted on billfish tournaments in Bermuda and Brazil; longline fleets in Venezuela, Uruguay, and Brazil; the gillnet fleet in central Venezuela, Ghana, Ivory Coast, and Senegal; and the recreational fishery in Senegal. Continued at-sea sampling will be conducted onboard Venezuelan and Brazilian vessels. Several on-going projects will be evaluating habitat use and critical habitat needs of blue and white marlin using pop-up satellite archival tag technology. Additionally, ICCAT continues to support a conventional tagging and recovery program for billfishes.

Several studies by researchers at the Virginia Institute of Marine Science (VIMS) and elsewhere have recently been published, or are in press, that analyze the genetic structure of blue and white marlin; post release survival and habitat use from the recreational fishery for Atlantic white marlin using PSATs; the effects of circle hooks and J-hooks on target and non-target species in the pelagic longline fishery; and the survival of white marlin released from commercial and recreational fisheries.

In addition to the ongoing cooperative billfish research program between the U.S. and Brazil, the SEFSC has also completed several billfish studies since 2006. These include an examination of vertical habitat utilization by large pelagic animals; evidence of blue marlin spawning in Bermuda waters; characterization of the white marlin recreational fishery off Maryland and New Jersey; the identification, and distribution of roundscale spearfish; and, a hook performance study of the south Florida recreational live-bait fishery for sailfish.

The Fishery Management Group of the University of Miami is continuing to conduct research on Atlantic billfish in three areas: population parameter estimation; population modeling; and, development of socio-economic indicators. Others at the University of Miami's Rosenstiel School and elsewhere are conducting research on early life history, reproductive biology and ecology of billfishes, as well as age and growth estimation.

Numerous papers on billfish research were submitted to ICCAT in preparation for the 2006 billfish stock assessment. These included: An evaluation of the importance of discards and other uses of billfish in the Spanish surface longline fishery (SCRS/2006/060); an analysis of the billfish fishery off Rio de Janeiro (SCRS/2006/139); post-release survival of sailfish captured on commercial pelagic longline gear in the southern Gulf of Mexico (SCRS/2006/149); estimates of biological benchmarks using simulated blue marlin data (SCRS/2006/153); analysis of recent catch data of blue marlin caught by Japanese longliners in the Atlantic using logbook information (SCRS/2006/ 100); preliminary results on the reproductive biology of blue marlin in the tropical western Atlantic Ocean (SCRS/2006/104); application of a bayesian surplus production model to Atlantic white marlin (SCRS/2006/064); catch rates of white marlin and blue marlin from the U.S. pelagic longline in the northwest Atlantic and Gulf of Mexico (SCRS/2006/066); catch rates of white marlin and blue marlin from the U.S. recreational tournament fishery in the Northwest Atlantic, Gulf of Mexico, Bahamas and U.S. Caribbean (SCRS/2006/067); white marlin and blue marlin catch rates from the Taiwanese longline fishery in the Atlantic (SCRS/2006/102); an estimation of the relative abundance of Atlantic billfish (SCRS/2006/105); the ratio of live Atlantic blue marlin and white marlin caught by Japanese longliners using data obtained from the observer program in the Atlantic Ocean (SCRS/2006/ 106); ring counts and timing of ring formation in fin spines of white marlin from Venezuelan longline and artisanal fisheries (SCRS/2006/ 068); recent catch data of white marlin caught by Japanese longliners in the Atlantic using logbooks (SCRS/2006/101); the reproductive biology of the white marlin in the western equatorial Atlantic Ocean (SCRS/2006/103); and, spatial-temporal distribution, sex ratio at size and gonad index of white marlin and longbill spearfish in the western central Atlantic from 2002-2005 (SCRS/2006/061). Please see http://www.iccat.int/Documents/CVSP/CV060_2007/colvol60.htm for more information.

### 2.4.2 White Marlin

#### 2.4.2.1 Life History and 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 movements extend to the higher temperate latitudes of their range only during the warmer months of the year. They may occur in small, same-age schools, however they are generally solitary compared to the Scombrids (tunas). Catches in some areas may include a rare species, the so-called "hatchet marlin" (*Tetrapturus georgei*), which is superficially similar to white marlin. The "hatchet marlin" has been caught occasionally in the Gulf of Mexico and South Atlantic (NMFS, 1999).

Large post-spawning aggregations of white marlin are reported off the Mid-Atlantic states during the summer period. A large, mostly catch and release, sport fishery for white marlin occurs during the summer between Cape Hatteras, NC and Cape Cod, MA, and indicates that white marlin inhabit offshore (148 km (80 nm)) submarine canyons, extending from Norfolk Canyon in the Mid-Atlantic to Block Canyon off eastern Long Island. White marlin usually can be found where large numbers of prey items are available. Concentrations of white marlin are associated with rip currents and weed lines (fronts), and with bottom features such as steep drop-offs, submarine canyons, and shoals. Recreational fishing for white marlin also occurs in the Straits of Florida, southeast Florida, the Bahamas, and off the north coasts of Puerto Rico and USVI, and in the Mona Passage east of the Dominican Republic. Summer concentrations in the Gulf of Mexico are found off the Mississippi River Delta and at DeSoto Canyon, with a peak off the delta in July, and in the vicinity of DeSoto Canyon in August. In the Gulf of Mexico, adult white marlin 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. White marlins generally prefer water temperatures above 22°C (71° F) with salinities between 35 – 37 ppt (NMFS, 1999).

White marlin undergo extensive movements, although not as extreme as those of bluefin tuna and albacore. Conventional mark-recapture data collected by the Cooperative Tagging Center (CTC) constituent-based tagging program (NOAA/Southeast Fisheries Science Center, Miami, Fl) has revealed spatial and temporal characteristics of white marlin movement (Ortiz et al. 2003). From 1954 through 2005, a total of 49,543 white marlin were marked and released in the Atlantic basin, resulting in 961 recaptures (1.94%) (Orbesen *et al*., 2005). The majority of releases took place in the months of July through September, in the western North Atlantic off the eastern coast of the United States; and, to a lesser extent, off Venezuela, the Gulf of Mexico, and the western central Atlantic. The longest distance traveled was 6,523 km (4,053 miles), while the maximum number of days at-liberty was 5,488 (15 yrs). Trans-Atlantic crossing have been recorded for several individuals. However, only two reports of trans-equatorial crossings have been documented (Orbesen et al., 2005). Recaptures indicate a substantial number of individuals moving between the Mid-Atlantic coast of the United States and the northeast coast of South America. Figure 2.15 shows the location of worldwide white marlin catches.

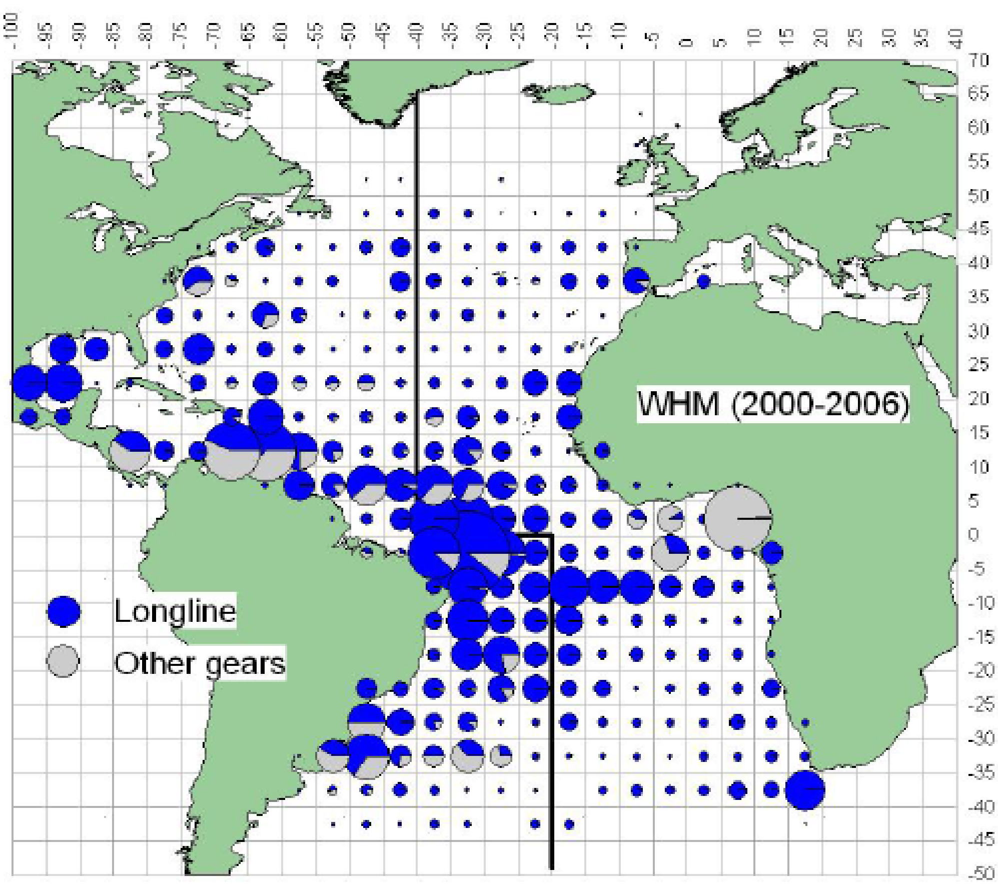


**Figure 2.15** **Geographic distribution of mean white marlin catch by major gears (all fleets) for the period 2000 – 2006. Largest circle corresponds to a catch of 52 t.** Source: SCRS 2008.

Prince et al. (2005) monitored movement and behavior of six white marlin released with PSATs off the coast of Punta Cana, Dominican Republic. These individuals were at-liberty for periods ranging from 28 to 37 days. Net displacement between points of release and first transmission ranged from 76 to 496 km, with a mean daily displacement of 6.2 km. The daily displacements are low compared to other marlin PSAT tagging studies. The Punta Cana area is an active white marlin spawning ground during the period these PSATs were monitored. The low displacement rates suggest site affinity that may be associated with spawning behavior. These six white marlin spent more than 50% of their time above 25 m, and about 70% of time in water ranging from 28 to 30 °C. Although most time was spent near the surface, active short-duration vertical movements were made daily; extending as deep as 368 m in one case.

Horodysky et al. (2007) examined vertical movement and habitat use via 47 PSATs attached to white marlin released from recreational and commercial vessels. Most of these PSATs were high resolution tags, collecting data points every 90 seconds. During at-liberty periods ranging from five to ten days, these white marlin spent nearly half their time near the surface (< 10 m). All made frequent short duration dives to depths averaging 51 m, suggesting that a great deal of foraging effort takes place well below the surface waters. Horodysky et al. (2007) suggest that this behavior may explain the relatively high catch rates of white marlin on some deep-set pelagic longline gears. In a study supporting this suggestion, Junior et al. (2004) reported a preference for depths ranging from 50 – 230 m (164-754 feet), with no obvious preference for surface waters for white marlin captured with pelagic longline gear off northeastern Brazil. An analysis of high resolution (≤ 60 s) archival data from two white marlin PSATs showed time engaged in vertical movement ranged from 29.4% to 54.4%, with most of the activity taking place during daylight hours (Hoolihan et al. in prep.). Maximum depths recorded for these individuals were 188 m and 260 m. While dive events were frequent, the majority of time (55.9 and 86.1%) was spent at depths less than 75 m. Prince and Goodyear (2006) used PSAT data from sailfish and blue marlin to show how vertical movement could be restricted by a hypoxic barrier formed during upwelling. One implication of this condition is that billfish movements are constrained to near-surface depths where adequate levels of dissolved oxygen are available. Another is that their susceptibility to capture by surface fishing gears would increase. Given the same conditions, white marlin could be expected to behave similarly.

White marlin exhibit sexually dimorphic growth patterns with females growing larger than males. Size at harvest generally ranges from 20 to 30 kg (44-66 lb). They grow quickly and can reach an age of at least 18 years, based on tag recapture data (SCRS, 2004). Adult white marlin can grow to over 280 cm (110 inches) TL and 82 kg (184 lb).

White marlin are primarily general piscivores, but also feed on squid and other prey items. In the Gulf of Mexico and along the U.S. Atlantic coast important prey items for adult white marlin include herring, dolphinfish (*Coryphaena*), hardtail jacks *Caranx crysos*, and squid (Nakamura 1985). In the northeastern Gulf of Mexico, off the coasts of Florida and Mississippi, Davies and Bortone (1976) found the most common prey items were Scombrids (*Euthynnus* sp. and *Auxis* sp.), squid, and moonfish (*Selene setapinnis)*. In turn, oceanic pomfret (*Brama brama*) and squid (*Ornithoteuthis antillarum*) were the most abundant food items in a study that sampled 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, while the largest sized prey items were snake mackerel (*Gempylus serpens*), ranging in length from 40 – 73 cm (15.7 – 28.7 inches) (Junior et al., 2004). Likely predators of adult white marlin include sharks and killer whales (Mather et al., 1975).

Female white marlin are about 20 kg (44 lb) in mass and 130 cm (51.2 inches) in length at sexual maturity. Spawning activity occurs during the spring (March through June) in northwestern Atlantic tropical and sub-tropical waters marked by relatively high surface temperatures (20-29°C) and salinities (> 35 ppt). White marlin move to higher latitudes during summer, as waters warm. White marlin sampled during the summer at these higher latitudes (Mid-Atlantic states) were in a post-spawning state (deSylva and Davis 1963). Arocha et al.

(2006) reported females exhibiting high gonad index values (associated with mature gonads) present in the western North Atlantic from April to July between 18° N. lat. and 22° N. lat. Spawning seems to take place further offshore than sailfish, although larvae are not found as far offshore as blue marlin. Females may spawn up to four times per spawning season (deSylva and Breder 1997). It is believed there are at least five spawning areas in the western north Atlantic: northeast of Little Bahama Bank off the Abaco Islands; northwest of Grand Bahama Island; southwest of Bermuda; the Mona Passage, east of the Dominican Republic; and the Gulf of Mexico. Prince et al. (2005) collected eight white marlin larvae in neuston tows in April/May off the coast of Punta Cana, Dominican Republic indicating that there had been recent spawning activity in this general area. More recently, white marlin larvae were collected during March and April in Bahamian waters, and from May-June in the Florida Straits (D.E. Richardson and S.A. Luthy, unpubl. data). White marlin larvae (n = 15) have also been genetically identified from the Gulf of Mexico, confirming spawning activity in that region (J. Rooker, unpubl. data).

In the south Atlantic, previous reports have mentioned spawning of white marlin off southeast Brazil in the same area where blue marlin spawn, but later in the year from April to June. Off southern Brazil (25º to 26º S. lat., and 45º to 45º W. long.), white marlin spawn from December to March (SCRS, 2008).

There is a paucity of information regarding the age and growth of white marlin. Efforts to accurately determine the incremental growth annuli from fin spines have been hindered by enlargement of the spine's vascular core. This enlargement results in erosion (i.e. obliteration) of early annuli. This problem has been well documented for other istiophorid billfishes (Jolley 1974; Jolley 1977; Hedgepeth and Jolley 1983; Hill et al. 1989; Freire et al. 1998; Hoolihan 2006). Comparing fin spine radius with incremental growth of annuli has allowed some researchers to back-calculate the number of annuli eroded in sailfish fin spines (Alvarado-Castillo and Félix-Uraga 1996; Chiang et al. 2004). A preliminary study has been undertaken to age white marlin using anal fin spines. These researchers reported a value of two annuli for both the median and mode from white marlin anal fin spines collected from two Venezuelan fisheries. However, these counts still require correction for annuli loss due to vascularization (Drew et al. 2006). Validation of annuli counts is necessary prior to interpreting ages. Preliminary analysis of the marginal increment growth suggested one annulus was formed each year. Unfortunately, sample specimens did not include the full size range of white marlin, lacking both very small and very large individuals. In addition, samples were absent from several months (April-June), hindering the validation of this ageing technique (Drew et al. 2006); spawning may influence annuli formation, so obtaining additional samples from these months is necessary.

#### 2.4.2.2 Stock Status and Outlook

White marlin have been managed under a single stock hypothesis by ICCAT since 2000. The most recent stock assessment for white marlin was conducted in 2006. No new information has been provided on stock status since then. Large catches of billfish continue to be reported to ICCAT as unclassified and reporting gaps remain for some important fleets, which introduced significant uncertainty into the 2006 SCRS stock assessment. A special effort was made by ICCAT prior to the 2006 meeting to obtain catches from countries not previously reporting. Controversy continued about interpretation and standardization of Catch per Unit Effort (CPUE) time series, attracting a considerable amount of analysis and simulation effort by the ICCAT participants. Those efforts were largely unsuccessful in making new progress toward international consensus on CPUE. As a result, the assessment working group elected not to reevaluate population benchmarks from the previous assessment. Instead, the 2006 assessment concentrated on evaluating recent population trends, and looking for possible impacts of the new ICCAT catch restrictions.

The 2006 stock assessment for white marlin indicated that the biomass of white marlin for 2000 – 2004 most likely remained well below the $B_{MSY}$ estimated in the 2002 assessment (Table 2.15). The 2006 assessment estimated that $F_{2004}$ was probably smaller than $F_{replacement}$ and probably also larger than $F_{MSY}$ estimated in the 2002 assessment. Over the period 2001 – 2004, combined longline indices and some individual fleet indices suggest that the decline in abundance has been at least partially reversed, but some other individual fleet indices suggest that abundance has continued to decline (Figure 2.16). Overall, the SCRS noted that some signs of a recovery trend are apparent, and that white marlin have the potential to rebuild to the $B_{MSY}$ level under the current ICCAT management plan, but reports of recent increases in artisanal fisheries could negate this potential (SCRS, 2006). Despite more positive results in the 2006 SCRS white marlin stock assessment than existed in the 2002 assessment, the overfished status of white marlin remains unchanged. It should be noted that the abundance trends are based only on a few years of observations. Confirmation of these recent apparent changes in trends will require at least an additional four or five years of data (SCRS, 2006).

Recent trends in white marlin abundance are contained in Figure 2.16. A summary of both Atlantic blue and white marlin stock assessment data may be found in (Table 2.15).

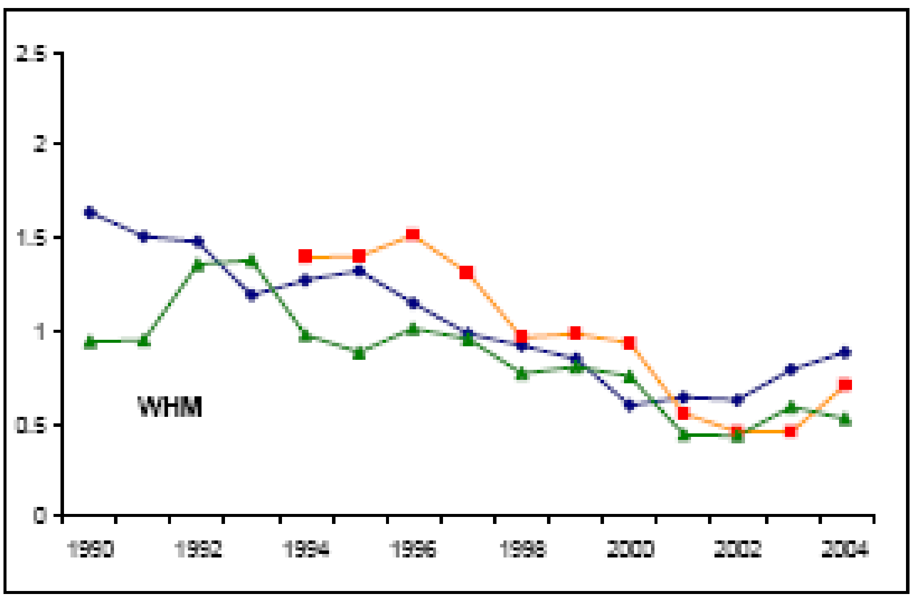


**Figure 2.16** **Relative abundance indices for white marlin estimated by combining data for four longline fleets. Three different statistical models are shown for comparison.** Source: SCRS, 2006.

The SCRS recommended that ICCAT should, at a minimum, continue the management measures already in place because marlins have not yet recovered. To increase the likelihood of success of the white marlin rebuilding plan, the SCRS indicated that further reductions in mortality would be needed, for example by improving compliance with current regulations, encouraging the use of circle hooks, and/or broader application of time/area catch restrictions. The SCRS also recommended that additional steps be taken to ensure that the reliability of recent fishery information improves. Improvements are needed in monitoring the fate and amount of dead and live releases, with verification from scientific observer programs. Additionally, verification of current and historical landings from some artisanal and industrial fleets needs to be conducted. Further, the results of habitat research are not yet sufficient to allow the SCRS to reach consensus on the best method for directly estimating MSY benchmarks for marlins based on a complete time series of data. Continued research on the development of methods to incorporate habitat data into stock assessments is needed to provide a basis for increasing the certainty with which management advice can be provided (SCRS 2006).

#### 2.4.2.3 Effects of Regulations

**ICCAT Management Recommendations**

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, 02-13, and 04-09 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). Recommendation 06-09 consolidated the previous recommendations and extended Phase 1 of the rebuilding plan through 2010.

Most countries started reporting live releases in 2006. Additionally, more information has become available, for some fleets, on the potential for using gear modifications to reduce the bycatch and increase the survival of marlins. Such studies have also provided information on the rates of live releases for those fleets. However there is not enough information on the proportion of fish being released alive for all fleets to evaluate the effectiveness of the ICCAT recommendation relating to the live release of marlins. While the stock status evaluations are uncertain, the SCRS noted that the ICCAT billfish recommendations have the potential to rebuild these stocks although verification is necessary. For white marlin, there has been a slight upward abundance trend.

Globally, catches of white marlin appear to have been reduced as a result of ICCAT recommendations to less than 1,000 mt since 2000. Total Atlantic-wide catches of white marlin, as reported to ICCAT, decreased by approximately 81 percent from 1,556 mt in 1999 to 302 mt in 2007. Task 1 catches of white marlin in 2006 were 387 mt. In 2007, Task 1 catches of white marlin were 302 mt, but this estimate is considered preliminary. Historical reports of unclassified billfish remain an important issue in the estimation of historic removals from marlin stocks. In the United States, white marlin are managed exclusively for recreational fisheries.

The 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 and other billfish.

**<u>Domestic Regulations</u>**

Please see the discussion of domestic regulations contained in Section 2.4.1.3 above.

***Recent and Ongoing Research***

Please see the discussion of recent and ongoing research contained in section under blue marlin.

### 2.4.3 Sailfish

#### 2.4.3.1 Life History and Species Biology

Sailfish have a pan-tropical distribution and prefer water temperatures between 25°C and 28°C (77°F – 82°F). Sailfish are the most coastal of all billfish species and conventional tagging data suggest that they move shorter distances than other billfishes. Although sailfish are the least oceanic of the Atlantic billfish and have higher concentrations in coastal waters (more than any other Istiophorid), they are occasionally 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. Few 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. A study in the southern Gulf of Mexico indicated that habitat preferences for sailfish were primarily within the upper 20 m of the water column (SCRS 2008). Sailfish are the most common representative of the Atlantic Istiophorids in U.S. waters (SCRS, 2005). Female sailfish grow faster, and attain a larger maximum size, than males. Sailfish have a maximum age of at least 17 years (SCRS 2008).

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 migrate 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 year-round. During the summer, some of these fish move north along the inside edge of the Gulf Stream. 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 28EC (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 102,689 sailfish had been tagged and released as of 2001 through the efforts of the CTC program, with the reported recapture of 1,704 sailfish (1.65 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. Although the majority of sailfish recaptures were in the vicinity of release, there were a number of movements in excess of 2,000 km. 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 3,861 km (2,084 miles) and the longest time at large was 6,658 days (18.2 years) (Ortiz et al., 2003). This demonstrates that sailfish have the ability to undertake extensive movements. 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 does not extend as far north as for marlins, especially white marlin, as sailfish specimens have been recovered only as far north as Cape Hatteras, NC.

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 or 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).

Sailfish spawn year-round over a wide area. The timing of spawning can differ, and occurs from late spring to early summer in the higher latitudes (Florida, southern Brazil) and in the winter months in the lower latitudes (Caribbean Sea, western Africa) (SCRS 2008). 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 in U.S. waters 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). Serafy et al. (2003) found three larval sailfish in Exuma Sound, Bahamas, in the month of July indicating that there had been recent spawning activity in this vicinity. 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. 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* spp.), squid, and Atlantic moonfish (*Vomer setapinnis*). Junior et al. (2004) determined that squid were actually the second most important food item in the southwestern Atlantic off the coast of Brazil. The number of food items per stomach ranged from 1-14, and 6 percent of the stomachs were empty upon collection (Junior et al., 2004). Adult sailfish are probably not preyed upon often, but predators include bottlenose dolphin (*Tursiops turncatus*), and sharks.

Participants from many nations target sailfish 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), coastal artisanal fisheries, and as bycatch in the offshore longline fisheries for swordfish and tunas. In coastal waters, artisanal fisheries use many types of shallow water gear to target sailfish (NMFS, 2003). Kerstetter & Graves (2007) found that sailfish released from pelagic longline vessels in the southern Gulf of Mexico can survive the trauma resulting from interaction with pelagic longline gear, and that management measures promoting the live release of sailfish will reduce fishing mortality on the stocks.

#### 2.4.3.2 Stock Status and Outlook

Sailfish and longbill spearfish landings have historically been reported together in annual ICCAT landing statistics. At present it is not possible to separate the catches of these two species. The most recent stock assessment was conducted in 2001 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 and 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 (1,543,235 lb) over the past two decades and the abundance indices have remained relatively stable. The 2000 yield was 572 mt (1,261,044 lb). The reported catches of sailfish/spearfish combined (Task I) for 2007 were 920 mt (2,028,252 lb) and 1,060 mt (2,336,899 lb) for the west and east Atlantic, respectively. Recent analyses did not provide any information on the MSY or other stock benchmarks for the 'sailfish only' stock.

Although the 2001 attempts at quantitatively assessing the status of these two stocks (eastern and western sailfish) proved to be unsatisfactory, there were indications of early decreases in biomass for these two stocks. These decreases probably lowered the biomass of the stocks to levels that may be producing sustainable catches, but it is unknown whether biomass levels are below those that could produce MSY. There is no new information available to change the outlook presented in the 2001 assessment. It is still unknown if the western or eastern sailfish stocks are undergoing overfishing or if the stocks are currently overfished. Because no assessment has been conducted since 2001, no relative abundance indices are available after 2000. The SCRS stated that trends in abundance, catch, and CPUE are not very informative, and the outlook for both the eastern and western stock is uncertain. During a 2008 intercessional data preparatory meeting, the SCRS found that the available data had improved. The next sailfish assessment is scheduled for 2009.

Reports to ICCAT estimate that the Task I catch for 2007 was 1,060 t and 920 t, respectively for the east and west region. Task I catches of sailfish for 2007 are preliminary because they do not include reports from some important fleets.

A summary of Atlantic sailfish stock assessment data is given in Table 2.16. The reported Task I catches of sailfish/spearfish combined in the Atlantic from 1956 – 2006 for both east and west stocks is presented in Figure 2.17. The worldwide geographic distribution of sailfish catches by major gears from the period 2000 – 2006 is provided in Figure 2.18.

**Table 2.16 Summary of Atlantic Sailfish Stock Assessment Data. Weights are in metric tons, whole weight.** Source: SCRS, 2008.

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

[1]As estimated in 2001.

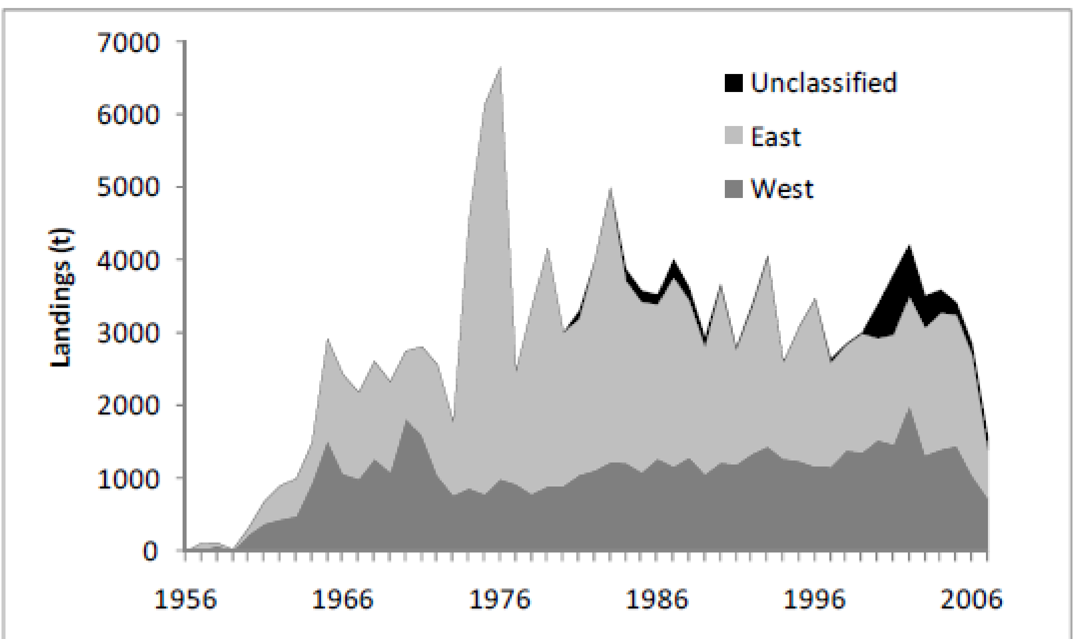


**Figure 2.17 Reported Task I catches of sailfish and spearfish combined in the Atlantic from 1956 to 2006 for the east and west stocks. Weights are in metric tons, whole weight.** Source: SCRS, 2008.

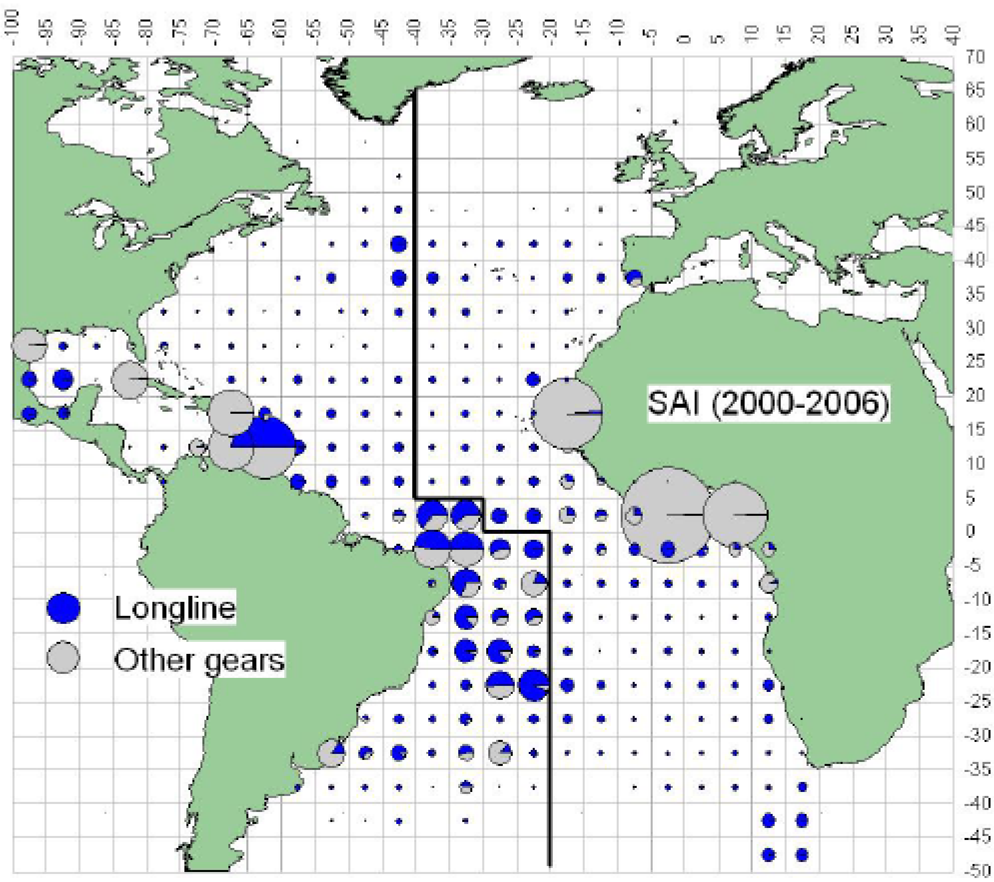


**Figure 2.18** **Geographical distribution of the mean sailfish catches by major gears (all fleets) from 2000 - 2006.** Source: SCRS, 2008.

### 2.4.3.3 Effects of Regulations

**ICCAT Management Recommendations**

No ICCAT management regulations are currently in effect for Atlantic sailfish. Sailfish are managed as distinct eastern and western Atlantic stocks. This separation into two management units is based on life history information. General management recommendations made by the SCRS to ICCAT have remained consistent in recent years. These management recommendations indicated that ICCAT should consider methods for reducing fishing mortality rates, and that western Atlantic catches should not be increased above 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. Furthermore, the SCRS expressed concern about the incomplete reporting of catches, particularly in recent years. Historical catches of unclassified billfish continue to be reported to ICCAT, thus making the estimation of sailfish catch difficult. The SCRS recommended that all countries landing sailfish/spearfish, or having dead discards, report these data to ICCAT. At an intercessional data workshop, the SCRS reviewed catch and CPUE data during 2008 in preparation for the next assessment in 2009. It found improved data available from West Africa, although there is still a need for further analysis of CPUE data particularly for some of the longline fleets, and separation of spearfish/sailfish catches prior to the assessment. This data is expected to be available for the 2009 assessment (SCRS 2008).

**Domestic Regulations**

Please see the discussion of domestic regulations contained in Section 2.4.1.3 above.

***Recent and Ongoing Research***

Several papers were prepared for the 2001 sailfish/spearfish SCRS stock assessment. Document SCRS/01/97 presented updates of the catch data for sailfish caught by artisanal fisheries of the Ivory Coast. SCRS/01/102 described and estimated the bycatch of billfish (including sailfish and spearfish) in the Spanish swordfish longline fisheries. SCRS/01/138 presented new estimates of sailfish harvested by U.S. recreational fishermen, with various new sources of information (including the RBS, LPS, and MRFSS). SCRS/01/145 presented recent developments on billfish fishing in Venezuela. In 2001, many national reports updated their catch statistics, including the landing of sailfish and spearfish. Some of the updates were accepted with justifications as the improved Task I data. However, other data were not accepted, in many cases because of the inability to separate catches of sailfish and spearfish.

As the total catches of respective species are relatively small, unclassified catches can be an important part of total yield and could not be ignored. The SCRS agreed that it was imperative to develop a procedure to estimate catches and abundance estimates for sailfish only from offshore longline fleets so that the data could be incorporated into stock assessments. A procedure was adopted to provide a basis for the sailfish-only catch used in the 2001 assessment. The SCRS felt that a good achievement was obtained in 2001 by separating catches of sailfish and spearfish. However, the work was carried out during the ICCAT species group session, without any advance preparations and with little available time. Consequently, the group was not able to evaluate the assumptions used in the separation procedure. Items that needed to be re-examined include the east-west break, including the feasibility of division lines, and species separation.

The SCRS has stated that the procedures used in the 2001 assessment should be fully documented and reviewed in the future, as a priority, before another assessment is conducted. A Sailfish Data Preparatory Meeting was held in Madrid, May 19 to 24, 2008 to review the biological information, catch reports and relative abundance indices for Atlantic sailfish. New information on depth and temperature preferences of adult sailfish was presented. Biological samples conducted from some longline and artisanal fleets provide sex ratios in the catch and information on the spawning locations and the timing of spawning. Furthermore, recent research provides a description of the physical and biological characteristics of sailfish spawning habitat. New information was also provided on the survival of sailfish after release from longline gear. Analysis of reported catches generated new estimates of total catch for the eastern and western stocks. These analyses included disaggregation of catches reported as unclassified billfish and filling the gaps of the time series for fleets that had incomplete historical reports. Work on the separation of sailfish and spearfish catches of selected longline fleets was initiated by developing a preliminary matrix of ratios of sailfish/spearfish by 5 degree grids. A number of relative abundance indices were presented at the meeting including updates of the U.S. recreational and longline, Venezuelan gillnet and longline and new indices for the Brazilian longline and recreational, and the artisanal Senegalese fleets. This review provided enough information to support the SCRS goal of assessing sailfish during a meeting in 2009.

### 2.4.4 Longbill Spearfish

#### 2.4.4.1 Life History and Species Biology

Longbill spearfish (*Tetrapturus pfluegeri*) are the rarest 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. There are seasonal variations and in general, spearfish are distributed mostly in the offshore area while sailfish are more coastal and hence the sailfish proportion is much higher in the coastal waters (SCRS 2007).

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 artisanal 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. For the western Atlantic stock, annual spearfish catches have averaged about 320 mt (705,479 lb) from 1981 – 2000. The estimated 2000 yield for western Atlantic spearfish was 367 mt (809,096 lb). The reported catches of sailfish/spearfish combined (Task I) for 2007 were 920 mt (2,028,252 lb) and 1,060 mt (2,336,899 lb) for the west and east Atlantic, respectively. Recent analyses did not provide any information on the MSY or other stock benchmarks for the 'spearfish only' stock. 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).

### 2.4.4.2 Stock Status and Outlook

Initial stock assessments conducted on spearfish aggregated these landings with sailfish. As mentioned in the sailfish section (Section 2.4.3), the 2001 assessment included a 'sailfish only' assessment in addition to an aggregate sailfish/spearfish assessment. There is no new information available to change the outlook presented in the 2001 assessment. It is still unknown if the western or eastern spearfish stocks are undergoing overfishing or if the stocks are currently overfished. Because no assessment has been conducted since 2001, no relative abundance indices are available after 2000. The SCRS has recommended that Contracting Parties consider methods to reduce fishing mortality rates, overall, and that western Atlantic catches should not be increased above current levels. The SCRS recommends evaluating new methods to split sailfish and spearfish indices of abundance (SCRS, 2004). Spearfish catch levels through 2000 are shown in Figure 2.19.

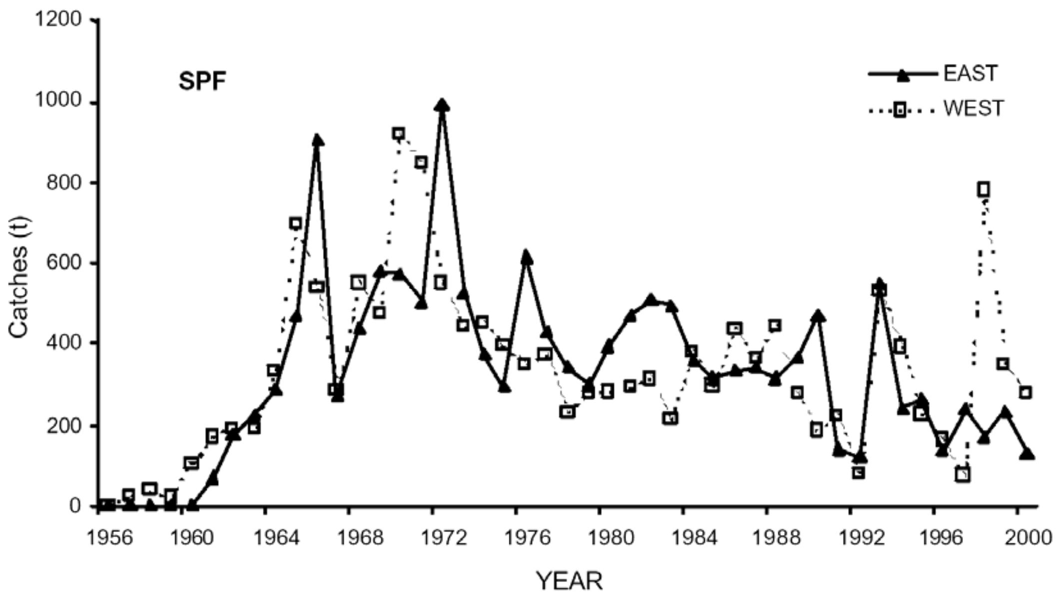


**Figure 2.19** **Estimated spearfish "only" catches in the Atlantic based on the new procedure for splitting combined sailfish and spearfish catches from 1956-2000. Weights are in metric tons, whole weight.** Source: SCRS, 2005.

### 2.4.4.3 Effects of Regulations

**ICCAT Management Recommendations**

No ICCAT management regulations are currently in effect for Atlantic longbill spearfish. 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.

**Domestic Regulations**

Please see the discussion of domestic regulations contained in Section 2.4.1.3 above.

***Recent and Ongoing Research***

Please see the discussion of recent and ongoing research contained in Section 2.4.1.3 above.

## 2.5 Atlantic Sharks

### 2.5.1 Life History and 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. The life span of all shark species 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 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 (*Carcharhinus leucas)* (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 approximately 350 species of sharks, ranging from tiny pygmy sharks of only 20 cm (7.8 in) in length to the giant whale sharks, over 12 meters (39 feet) 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 (*Carcharadon carcharias*), mako, tiger (*Galeocerdo cuvier*), bull, and great hammerhead (*Sphyrna mokarran*). Some shark species reproduce by laying eggs, while 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 2 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 (eggs hatch outside body), ovoviviparity (eggs hatch inside body), and viviparity (live birth).

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 (*Carcharhinus isodon)*, bull, lemon, and Atlantic sharpnose sharks (*Rhizoprionondon terraenovae*). 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 sharks are examples of a 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. Thirty-nine species are managed by HMS; spiny dogfish (*Squalus acanthias*) also occur along the U.S. coast, however management for this species is under the authority of the ASMFC as well as the New England and Mid-Atlantic Fishery Management Councils. Deep-water sharks and smooth dogfish were removed from the management unit in 2003. Based on the ecology and fishery dynamics, the sharks have previously been divided into four species groups for management: (1) LCS, (2) SCS, (3) pelagic sharks, and (4) prohibited species (Table 2.17). As a result of Amendment 2 to the HMS FMP, sandbar sharks can only be taken commercially within a shark research fishery. In addition, sandbar and silky sharks can not be retained by recreational anglers.

**Table 2.17 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 |

*sandbar sharks can only be retained commercially within a shark research fishery, and cannot be retained by recreational anglers
**silky sharks cannot be retained by recreational anglers

### 2.5.2 Stock Status and Outlook

NMFS is responsible for conducting stock assessments for the LCS and SCS complexes (Cortés, 2002; Cortés *et al*., 2002). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recently conducted assessments of three pelagic shark species. ICCAT's SCRS conducted stocks assessments for blue sharks (*Prionance glauca*) and shortfin mako (*Isurus oxyrinchus*) in 2008. Ecological risk assessements were also conducted by the SCRS for nine additional priority species of pelagic elasmobranchs. (Isurus paucus; Alopias superciliosus; Alopias vulpinus; Carcharhinus longimanus; C.falciformis; Lamna nasus; Sphyrna lewini; Sphyrna zygaena; and Pteroplatytrygon violacea). Stock assessments were conducted for the LCS complex, sandbar sharks (*Carcharhinus plumbeus*), and blacktip sharks in 2006 (NMFS, 2006a), and the SCS stock assessment was finalized during the summer of 2007 (NMFS, 2007a), which also assessed finetooth, Atlantic sharpnose, blacknose (*Carcharhinus acronotus*), and bonnethead sharks (*Sphyrna tiburo*) separately. NMFS also recently released a stock assessment for dusky sharks (*Carcharhinus obscurus)* (May 25, 2006, 71 FR 30123) (Cortés *et al*., 2006). 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.

A number of new shark stock assessments were conducted in 2005 - 2007 (see descriptions below) (Gibson and Campana, 2005; Cortés *et al*., 2006; NMFS, 2006a; NMFS, 2007a). Based on those assessments, NMFS has determined that sandbar, dusky, and porbeagle sharks are overfished; sandbar and dusky sharks have overfishing occurring; the status of the Atlantic blacktip shark population and the LCS complex is unknown; and the Gulf of Mexico blacktip shark population is healthy (November 7, 2006, 71 FR 65086). Based on the 2005 and

2006 stock assessments and these stock status determinations, NMFS has developed new management measures to rebuild sandbar, dusky, and porbeagle sharks while providing an opportunity for the sustainable harvest of blacktip and other sharks in the Gulf of Mexico. In addition, based on the 2007 SCS assessment, NMFS has determined that blacknose sharks are overfished with overfishing occurring (May 7, 2008, 73 FR 25665). NMFS is currently working on a new amendment to rebuild blacknose sharks and end overfishing.

### 2.5.3 Large Coastal Sharks

The 2005/2006 stock assessment for LCS followed the Southeast Data, Assessment, and Review (SEDAR) process. This process is a cooperative program designed to improve the quality and reliability of stock assessments. The SEDAR process emphasizes constituent and stakeholder participation in the assessment development, transparency in the assessment process, and a rigorous and independent scientific review of the completed stock assessment. The Data Workshop for the stock assessment, which documented, analyzed, reviewed, and compiled the data for conducting the assessment, was held from October 31 to November 4, 2005, in Panama City, FL (September 15, 2005, 70 FR 54537; correction October 5, 2005, 70 FR 58190). The Assessment Workshop, which developed and refined the population analyses and parameter estimates, was held from February 6 to February 10, 2006, in Miami, FL (December 22, 2005, 70 FR 76031). At the Review Workshop held on June 5 to June 9, 2006, in Panama City, FL (March 9, 2006, 71 FR 12185), independent scientists reviewed the assessment and data used in the stock assessment.

The latest 2005/2006 stock assessments for LCS in the Gulf of Mexico and Atlantic Ocean became available on July 24, 2006 (71 FR 41774). Unlike past assessments, the 2005/2006 LCS stock assessment determined that it is inappropriate to assess the LCS complex as a whole due to the variation in life history parameters, different intrinsic rates of increase, and different catch and abundance data for all species included in the LCS complex. Based on these results, NMFS changed the status of the LCS complex from overfished to unknown and is continuing to examine viable options to assess shark populations (November 7, 2006; 71 FR 65086) (Table 2.18).

*Sandbar Sharks*

According to 2005/2006 sandbar shark stock assessment, sandbar sharks are overfished ($SSF_{2004}/SSF_{MSY} = 0.72$; SSF is spawning stock fecundity and was used a proxy for biomass), and overfishing is occurring ($F_{2004} / F_{MSY} = 3.72$). The assessment recommends that rebuilding could be achieved with 70 percent probability by 2070 with a total allowable catch across all fisheries of 220 metric tons (mt) whole weight (ww) each year and fishing pressure (F) between 0.0009 and 0.011.

*Blacktip Sharks*

The 2005/2006 stock assessment assessed blacktip sharks for the first time as two separate populations: a Gulf of Mexico and Atlantic population. The results indicate that the Gulf of Mexico stock is not overfished and overfishing is not taking place (November 7, 2006, 71 FR 65086), but the assessment Panel did not accept the absolute estimates of the stock status. The three abundance indices believed to be most representative of the stock were consistent with each other, suggesting that stock abundance has been increasing over a period of declining catch during the past 10 years. Based on life history characteristics, blacktip sharks are a relatively productive shark species, and a combination of these characteristics and recent increases in the most representative abundance indices, suggested that the blacktip stock is relatively healthy. There was no scientific basis, however, to consider increasing the catch or quota.

This assessment also indicated that the current status of the blacktip shark population in the South Atlantic region is unknown. The assessment scientists were unable to provide estimates of stock status or reliable population projections, but indicated that current catch levels should not change. Based on this, NMFS has declared the status of the South Atlantic blacktip shark population to be unknown (November 7, 2006, 71 FR 65086).

*Dusky Sharks*

The first dusky-specific shark assessment was released on May 25, 2006 (71 FR 30123) (Cortés *et al*., 2006). The 2006 dusky shark stock assessment included data through 2003 and indicated that dusky sharks are overfished ($B_{2003}/B_{MSY}$ = 0.15 – 0.47) with overfishing occurring ($F_{2004}/F_{MSY}$ = 1.68 – 1,810). The assessment concluded that rebuilding for dusky sharks could require 100 to 400 years. Based on these results, NMFS declared the status of dusky sharks as overfished with overfishing occurring (November 7, 2006, 71 FR 65086).

### 2.5.4 Small Coastal Sharks

On November 13, 2007, NMFS completed a SCS stock assessment following the SEDAR process (72 FR 63888). The SCS Data Workshop was held February 5-9, 2007 (December 7, 2006, 71 FR 70965). The SCS Assessment workshop was held May 7-11, 2007 (April 19, 2007, 72 FR 19701), and the SCS Review workshop was held on August 6-10, 2007 (July 19, 2007, 72 FR 39606). The assessment reviewed data and models for the SCS complex and for each individual species within the SCS complex, per recommendations in previous assessments. This allowed individual analyses, discussions, and stock status determinations for five separate assessments: 1) SCS complex, 2) Atlantic sharpnose shark, 3) bonnethead shark, 4) blacknose shark, and 5) finetooth sharks. These assessments are included in one report as many of the indices, data, and issues overlap among assessments. The Review Panel found that the data and methods used were appropriate and the best available; however, the panel recommended using the individual assessments for each species rather than the assessment on the SCS complex as a whole. The Review Panel also endorsed recommendations for future research contained in the Data Assessment workshop reports, added additional recommendations, and provided comments on the SEDAR process to consider in the future. Based on these assessments, NMFS determined that blacknose sharks are overfished with overfishing occurring; however, Atlantic sharpnose, bonnethead, and finetooth sharks are not overfished and overfishing is not occurring (May 7, 2008, 73 FR 25665) (Table 2.19).

*SCS complex*

According to the 2007 the SCS stock assessment, the SCS complex is not overfished and overfishing is not taking place (May 7, 2008, 73 FR 25665). The peer reviewed assessment provides an update from the 2002 stock assessment on the status of SCS stocks and projects future abundance under a variety of catch levels in the U.S. Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. Because the species were individually assessed, the peer reviewers recommended using species-specific results rather than on the aggregrated SCS complex results. As a result of this recommendation, and because the stock assessment covered all SCS species, NMFS will no longer provide status updates or determinations on the SCS complex as a whole.

*Atlantic sharponse*

The 2002 SCS stock assessment found that Atlantic sharpnose sharks were not overfished and overfishing was not occurring. The 2007 assessment for Atlantic sharpnose sharks also indicated that the stock is not overfished ($SSF_{2005}/SSF_{MSY} = 1.47$) and that no overfishing is occurring ($F_{2005} / F_{MSY} = 0.74$) (Table 2.19). Based on these results, NMFS has determined that the Atlantic sharpnose sharks are not overfished with no overfishing occurring (May 7, 2008, 73 FR 25665). However, because estimates of fishing mortality from the assessment indicate that fishing mortality is close to, but presently below, $F_{MSY}$ (*i.e.*, overfishing is not occurring), the peer reviewers suggest setting a threshold for fishing mortality to keep it below the $F_{MSY}$ threshold to prevent overfishing in the future.

*Bonnethead Sharks*

Based on the bonnethead stock assessment, the peer reviewers determined that bonnethead sharks are not overfished ($SSF_{2005}/SSF_{MSY} = 1.13$). In addition, the estimate of fishing mortality rate in 2005 was less than FMSY, ($F_{2005} / F_{MSY} = 0.61$) (Table 2.19), thus overfishing was not occurring. As a result, NMFS has determined that bonnethead sharks are not overfished and no overfishing is occurring (May 7, 2008, 73 FR 25665). In addition, the assessment showed that there had been years of overfishing, and the main contributor of population mortality is the recreational fleet and the commercial gillnet fleet.

*Blacknose Sharks*

The 2002 assesment found blacknose sharks were not overfished and overfishing was not occurring. However, the 2007 assessment for blacknose shark indicates that spawning stock fecundity (SSF; *i.e.*, the number of reproductive-age individuals in a population) in 2005 and during 2001-2005 was smaller than $SSF_{MSY}$ ($SSF_{2005}/SSF_{MSY} = 0.48$). Therefore, NMFS has determined that blacknose sharks are overfished. In addition, the estimate of fishing mortality in 2005 and the average from 2001-2005 was greater than $F_{MSY,}$ and the ratio was substantially greater than 1 in both cases ($F_{2005} / F_{MSY} = 3.77$). Based on these results, NMFS has determined that blacknose sharks are experiencing overfishing (May 7, 2008, 73 FR 25665). The assessment recommended a rebuilding plan with 70 percent probability of recovering to $SSF_{MSY}$ by 2019. This recommended rebuilding time is 11 years from 2009. A constant TAC of 19,200 individuals would lead to rebuilding with 70 percent probability by 2027. The constant TAC also allows for rebuilding with 50 percent confidence by 2024. The assessment found that the majority of the mortality for blacknose sharks was occurring as bycatch in the Gulf of Mexico shrimp trawl fishery. In addition, the majority of mortality was occurring on juvenile and neonate blacknose sharks. Blacknose sharks mature around 91 cm total length and around 4.5 years of age.

*Finetooth Sharks*

According to the 2007 finetooth shark stock assessment, finetooth sharks are not overfished ($N_{2005}/N_{MSY}$ = 1.80) and overfishing is not occurring ($F_{2005}/F_{MSY}$ = 0.17) (May 7, 2008, 73 FR 25665). This is a change from the 2002 assessment in which finetooth sharks were determined to be experiencing overfishing. However, NMFS also notes that while the peer reviewers agreed that it is reasonable to conclude that the stock is not currently overfished, they also indicated that given the limited data available on the population dynamics for finetooth, management should be cautious. Unlike the other SCS, where the bulk of the mortality occurs in shrimp trawl gear, the majority of the mortality for finetooth sharks occur in gillnets.

**Table 2.18 Summary Table of Biomass and Fishing Mortality for Large Coastal Sharks (LCS).** Source: NMFS, 2006a.

| Species | Current Relative Biomass Level | Current Biomass $B_{YEAR}$ | $N_{MSY}$ | Minimum Stock Size Threshold (MSST) | Current Relative Fishing Mortality Rate | Maximum Fishing Mortality Threshold ($F_{MSY}$) | Outlook |
|---|---|---|---|---|---|---|---|
| **Sandbar Sharks** | *$SSF_{2004}/SSF_{MSY}$ = 0.72 | 3.06E+07 | 5.94E+05 | 4.75 - 5.35E+05 | $F_{2004}/F_{MSY}$ = 3.72 | 0.015 | Overfished; Overfishing is occurring |
| **Gulf of Mexico Blacktip Sharks**** | *$SSF_{2004}/SSF_{MSY}$ = 2.54 - 2.56 | 1.33E+08 – 1.93E+09 | 1.23 – 1.78E+07 | 0.99 - 1.07E+07 | $F_{2004}/F_{MSY}$ = 0.03-0.04 | 0.20 | Not overfished; No overfishing is occurring |
| **Atlantic Blacktip Sharks** | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* |
| **Dusky Sharks**** | $B_{2003}/B_{MSY}$= 0.15 - 0.47 | 687,290 | 4,409,144 | unknown | $F_{2003}/F_{MSY}$=1.68 -1,810 | 0.00005 – 0.0115 | Overfished; Overfishing is occurring |
| **LCS Complex** | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* | *unknown* |
| **Porbeagle Sharks** | *$SSN_{2004}/SSN_{MSY}$ = 0.15 – 0.32 | 5,520-12,945 | 29,382 – 40,670 | *unknown* | $F_{2004}/F_{MSY}$ = 0.83 | 0.033 – 0.065 | Overfished; overfishing is not occurring |

*Spawning stock fecundity (SSF) or spawning stock number (SSN) was used as a proxy of biomass since biomass (B) does not influence pup production in sharks.
** Ranges of values are provided for these species because the assessment did not recommend a specific value for that parameter, rather the ranges reflect high and low estimates of different outputs achieved from numerous models that were employed.

**Table 2.19 Summary Table of Biomass and Fishing Mortality for Small Coastal Sharks (SCS)** Source: NMFS, 2007a.

| **Species** | **Current Relative Biomass Level** | **Current Biomass $N_{2005}$** | **Stock Abundance $N_{MSY}$** | **Minimum Stock Size Threshold (MSST)** | **Current Relative Fishing Mortality Rate ($F_{2005}/F_{MSY}$)** | **Maximum Fishing Mortality Threshold ($F_{MSY}$)** | **Outlook** |
|---|---|---|---|---|---|---|---|
| Small Coastal Sharks (SCS) | 1.69 ($N_{2005}/N_{MSY}$) | 5.16E+07 | 2.98E+07 | 2.1E+07 | 0.25 | 0.09 | Not overfished; No overfishing is occurring |
| Bonnethead Sharks | 1.13 ($SSF_{2005}/SSF_{MSY}$) | 1.59E+06 | 1.92E+06 | 1.4E+06 | 0.61 | 0.31 | Not overfished; No overfishing is occurring |
| Atlantic Sharpnose Sharks | 1.47 ($SSF_{2005}/SSF_{MSY}$) | 5.96E+06 | 4.45E+06 | 4.09E+06 | 0.74 | 0.19 | Not overfished; No overfishing is occurring |
| Blacknose Sharks | 0.48 ($SSF_{2005}/SSF_{MSY}$) | 3.49E+05 | 5.7E+05 | 4.3E+05 | 3.77 | 0.07 | Overfished; Overfishing is occurring |
| Finetooth Sharks | 1.80 ($N_{2005}/N_{MSY}$) | 6.00E+06 | 3.20E+06 | 2.4E+06 | 0.17 | 0.03 | Not overfished; No overfishing is occurring |

### 2.5.5 Pelagic Sharks

Pelagic sharks are subject to exploitation by many different nations and exhibit trans-oceanic migration patterns. As a result, ICCAT's SCRS Subcommittee on Bycatch has recommended that ICCAT take the lead in conducting stock assessments for pelagic sharks.

An ICCAT meeting was held in September 2001 to review available statistics for Atlantic and Mediterranean pelagic sharks. Newly available biological and fishery information presented for review included age and growth, length/weight relationships, species identification, species composition of catch, catch per unit effort, mortality (both natural and fishing estimates for blue sharks), bycatch, and tagging and migration studies. Landings estimates, which incorporated data for both the Atlantic and Mediterranean populations of blue shark, suggested that landings declined in 2000 (3,652 mt) following a peak of 32,654 mt in 1999. Landings of porbeagles peaked in 1997, with an estimated total of 1,450 mt, and have slowly declined each year since that time period (1998 – 2000). Similarly, landing estimates for shortfin mako also peaked in 1997 (5,057 mt) and have declined by 83 percent (863 mt in 2000) since that time. Meeting participants expressed concern regarding the lack of information pertaining to the number of fleets catching sharks, landing statistics, and dead discards of sharks.

The SCRS decided to conduct an assessment of Atlantic pelagic sharks beginning in 2004. Emphasis was placed on blue sharks and shortfin mako sharks. Several models such as non-equilibrium production and statistical age/length-structured models were considered to analyze the population dynamics of pelagic shark species. The SCRS plans to conduct another assessment of Atlantic pelagic sharks in 2008. All SCRS stock assessments can be found at http://www.iccat.es/assess.htm.

*2008 ICCAT Shark Stock Assessment*

In response to the Supplementary Recommendation by ICCAT Concerning the Conservation of Sharks caught in Association with Fisheries Managed by ICCAT [Rec. 06-10], an updated assessment of the stocks of blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) was conducted in 2008. Ecological risk assessments (ERA) were also conducted for nine additional priority species of pelagic elasmobranchs, for which available data are very limited (*Isurus paucus; Alopias superciliosus; Alopias vulpinus; Carcharhinus longimanus; C.falciformis; Lamna nasus; Sphyrna lewini; Sphyrna zygaena;* and *Pteroplatytrygon violacea*).

SCRS concluded that for both North and South Atlantic blue shark stocks, although the results are highly uncertain, biomass is believed to be above the biomass that would support MSY and current harvest levels below FMSY. Results from all models used were conditional on the assumptions made (*e.g.*, estimates of historical catches and effort, the relationship between catch rates and abundance, the initial state of the stock in the 1950s, and various life-history parameters), and a full evaluation of the sensitivity of results to these assumptions was not possible during the assessment. Nonetheless, as for the 2004 stock assessment, the weight of available evidence does not support hypotheses that fishing has yet resulted in depletion to levels below the Convention objective (SCRS 2004).

Estimates of stock status for the North Atlantic shortfin mako obtained with the different modeling approaches were much more variable than for blue shark. For the North Atlantic, most model outcomes indicated stock depletion to about 50% of biomass estimated for the 1950s. Some model outcomes indicated that the stock biomass was near or below the biomass that would support MSY with current harvest levels above FMSY, whereas others estimated considerably lower levels of depletion and no overfishing. In light of the biological information that indicates the point at which BMSY is reached with respect of the carrying capacity which occurs at levels higher than for blue sharks and many teleost stocks. There is a non-negligible probability that the North Atlantic shortfin mako stock could be below the biomass that could support MSY. A similar conclusion was reached by the Committee in 2004, and recent biological data show decreased productivity for this species. Only one modeling approach could be applied to the South Atlantic shortfin mako stock, which resulted in an estimate of unfished biomass which was biologically implausible, and thus the Committee can draw no conclusions about the status of the South stock.

The ecological risk assessments (ERA) conducted by the SCSR, for eleven priority species of sharks (including blue shark and shortfin mako) caught in ICCAT fisheries, demonstrated that most Atlantic pelagic sharks have exceptionally limited biological productivity and, as such, can be overfished even at very low levels of fishing mortality. Specifically, the analyses indicated that bigeye threshers, longfin makos, and shortfin makos have the highest vulnerability (and lowest biological productivity) of the shark species examined (with bigeye thresher being substantially less productive than the other species). All species considered in the ERA, particularly smooth hammerhead, longfin mako, bigeye thresher and crocodile sharks, are in need of improved biological data to evaluate their biological productivity more accurately and thus specific research projects should be supported to that end. The SCRS recommended that ERAs be updated with improved information on the productivity and susceptibility of these species.

*COSEWIC Stock Assessment on Porbeagle*

COSEWIC conducted a species report and assessment for porbeagle in 2004 (COSEWIC, 2004). They suggest that significant declines in porbeagle abundance have occurred as a result of overexploitation in fisheries. In May 2004, the COSEWIC recommended to the Canadian Minister of Fisheries that porbeagles be listed as endangered under the Species at Risk Act (SARA). In 2006, the Canadian government decided not to list the porbeagle shark under SARA due to the economic impact of a listing, both on the commercial fishing industry and on the government who would have to expend over $50,000 annually in monitoring funds (Canada Gazette 2006; http://canadagazette.gc.ca/partII/2006/20060906/html/si110-e.html).

The Canadian Department of Fisheries and Oceans has conducted stock assessments on porbeagle sharks in 1999, 2001, 2003, and 2005. Reduced Canadian porbeagle quotas in 2002 brought the 2004 exploitation rate to a sustainable level. According to the 2005 recovery assessment report conducted by Canada (Canadian Science Advisory Secretariat, 2005), the North Atlantic porbeagle stock has a 70 percent probability of recovery in approximately 100 years if F is less than or equal to 0.04. To date, the United States has not conducted a stock assessment on porbeagle sharks. NMFS has reviewed the Canadian stock assessment and deems it to be the best available science and appropriate to use for U.S. domestic management purposes (NMFS, 2006b). The Canadian assessment indicates that porbeagle sharks are overfished ($SSN_{2004}/SSN_{MSY}$ = 0.15 – 0.32; SSN is spawning stock number and used as a proxy for biomass) (Gibson and Campana, 2005). However, the Canadian assessment indicates that overfishing is not occurring ($F_{2004}/F_{MSY}$ = 0.83) (Gibson and Campana, 2005). Based on these results, NMFS declared the status of porbeagle sharks as overfished, but overfishing is not occurring (71 FR 65086).

#### 2.5.5.1 Effects of Regulations

*ICCAT Management Recommendations*

Internationally, sharks management measures are established through ICCAT. At the 2004 ICCAT annual meeting in New Orleans, ICCAT adopted *Recommendation 04-10 Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT*. This was the first binding measure passed by ICCAT dealing specifically with sharks. This recommendation included, 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. In 2005, additional measures pertaining to pelagic sharks were added to the 2004 ICCAT recommendation. Measures included a requirement for Contracting Parties that have not yet implemented the 2004 recommendation, to reduce shortfin mako mortality, and annually report on their efforts to the Commission.

At the 2006 ICCAT annual meeting in Dubrovnik, Croatia, ICCAT adopted Recommendation 06-10 which amended Paragraph 7 of *Recommendation 04-10 Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT*. The new paragraph called for SCRS to conduct stock assessments and recommended management alternatives for Atlantic blue sharks and shortfin mako sharks in time for consideration at the 2008 annual ICCAT meeting. It also required a data prepatory meeting to be held in 2007 to review all relevant data on biological parameters, catch, effort, discards, trade, and historical data.

At the 2007 ICCAT annual meeting in Antalya, Turkey, ICCAT adopted a recommendation (07-06) concerning pelagic sharks. The new operative paragraphs called for SCRS to conduct stock assessments and recommended management alternatives for porbeagle sharks (*Lamna nasus*), to take appropriate measures to reduce fishing mortality in porbeagles (*Lamna nasus*) and North Atlantic shortfin mako sharks (*Isurus oxyrinchus*), and to implement research on pelagic shark species caught in the Convention area in order to identify potential nursery areas. It also required that Contracting Parties, Cooperating non-Contracting Parties, Entities and Fishing Entities submit Task I and II data for sharks in advance of the next SCRS assessment.

At the 2008 ICCAT annual meeting in Marrakech, Morocco, ICCAT adopted recommendation (08-07) concerning bigeye thresher sharks and recommendation (08-08) concerning porbeagle sharks. *Recommendation (08-07) by ICCAT on the Conservation of Big Eye Thresher Sharks (Alopias superciliosus) Caught in Association with Fisheries Managed by ICCAT* would require the live release of bigeye thresher sharks, a species that is the most vulnerable of the top 10 species of concern that were evaluated by the international commission's science committee. U.S. fisheries are already subject to this requirement under domestic regulations. In addition, all CPCs would be required to report incidental catches as well as live releases of bigeye thresher sharks in accordance with ICCAT data reporting requirements. *Recommendation (08-08) Resolution by ICCAT on Porbeagle Shark (Lamna nasus)* calls for a joint ICCAT-ICES Inter-sessional meeting in 2009 to further assess porbeagle (*Lamna nasus*) in accordance with recommendation (07-06).

*Domestic Regulations*

Domestically, Atlantic sharks have been managed by NMFS since the 1993 FMP for Atlantic Sharks. The 1999 FMP for Atlantic Tunas, Swordfish, and Sharks addressed numerous shark management measures, including: reducing commercial LCS and SCS quotas; establishing a commercial quota for blue sharks and a species-specific quota for porbeagle sharks; expanding the list of prohibited shark species; implementing a LAP system in commercial fisheries; and establishing season-specific over- and underharvest adjustment procedures. The 1999 FMP also partitioned the LCS complex into ridgeback and non-ridgeback categories but did not include regional quota measures. Due to litigation, many management measures in the 1999 FMP were not implemented.

The regulations governing the recreational and commercial shark fisheries allow opportunities for participants to pursue sharks for leisure, subsistence, and/or commercial gain while maintaining compliance with statutes that include, but are not limited to, the MSA, ESA, MMPA, and NEPA. These regulations seek to minimize bycatch of non-target, prohibited shark species, and protected resources by a variety of measures, including, but not limited to: mandating the use of corrodible, non-stainless steel hooks; requiring possession of handling and release equipment for protected resources; conducting gillnet checks every two hours; mandatory observer coverage for commercial fisheries (if selected); limits on the deployment and operation of authorized gears; and, maintaining 19 species of shark on the prohibited species list (possession not authorized). Rebuilding overfished stocks is another objective of shark fishery regulations, and is accomplished through numerous measures, including, but not limited to: regional fishing quotas based on MSY; regional fishing seasons; commercial trip limits (4,000 lbs dw for LCS); recreational bag limits (1 shark/vessel/day for all authorized species except Atlantic sharpnose and bonnethead sharks (1 shark/person/day); and, recreational minimum size limits (>54" FL for all authorized species except Atlantic sharpnose and bonnethead sharks). Controlling fishing effort is accomplished by the requirement to possess a LAP for commercial shark fisheries and upgrading restrictions for transferred permits. Reducing fishing mortality of prohibited dusky sharks and juvenile sandbar sharks is achieved by the Mid-Atlantic time area closure (January 1 – July 31) and the requirement to use VMS when BLL gear is onboard during this time period.

The final rule implementing Amendment 1 to the 1999 FMP was published in the Federal Register on December 23, 2003. This final rule revised the shark regulations based on the results of the 2002 stock assessments for SCS and LCS. In Amendment 1 to the 1999 FMP, NMFS revised the rebuilding timeframe for LCS to 26 years from 2004, and implemented several new regulatory changes. Management measures enacted in the amendment included, among other things: using MSY as a basis for setting commercial quotas; eliminating the commercial minimum size restrictions; implementing a commercial trip limit for LCS and SCS; imposing gear restrictions to reduce bycatch; and implementing a time/area closure off the coast of North Carolina effective January 1, 2005. Annual quotas established under Amendment 1 to the 1999 FMP were as follows: 1,017 metric tons (mt) dressed weight (dw) (2.24 million lbs dw) for LCS; 454 mt dw per year for SCS; 273 mt dw for blue sharks, 92 mt dw for porbeagle sharks, and 488 mt dw for pelagic sharks other than porbeagle and blue sharks.

An updated LCS stock assessment became available in 2006 and data workshops for an updated SCS stock assessment began in early 2007. Based on the 2006 LCS stock assessment, NMFS implemememented Amendment 2 to the 2006 Consolidated HMS FMP to rebuild overfished sandbar, dusky, and porbeagle shark stocks and to end overfishing. The final rule for Amendment 2 published on June 24, 2008 (73 FR 35778) with a correction published on July 15, 2008 (73 FR 40658). The final rule became effective on July 24, 2008. In the final rule, NMFS focused on additional shark management measures. These included, but were not limited to, removing sandbar sharks from the LCS complex and establishing a non-sandbar LCS complex; setting new annual quotas for sandbar sharks (87.9 mt dw), non-sandbar LCS (Atlantic: 187.7 mt dw; Gulf of Mexico: 390.5 mt dw), and porbeagle sharks (1.7 mt dw); maintaining the annual SCS quota (454 mt dw), pelagic sharks quota (273 mt dw for blue sharks), and quota for pelagic sharks other than porbeagle and blue sharks (488 mt dw); establishing a sandbar shark research fishery with prohibition on the retention of sandbar sharks outside the shark research fishery; creating one region for SCS, sandbar, and pelagic sharks and two regions for non-sandbar LCS (Gulf of Mexico and Atlantic regions); creating eight marine protected areas as requested by the South Atlantic Fishery Management Council to prohibit the use of bottom longline gear in those areas; establishing new non-sandbar LCS retention limits for directed and incidental shark permit holders (33 non-sandbar LCS per vessel per trip for directed permit holders and 3 non-sandbar LCS per vessel per trip for incidental permit holders); establishing a fishing year for sharks that begins on January 1 of each year; limiting the carry over of underharvest to 50 percent of the base quota for shark stocks whose status are healthy and prohibiting the carry over of underharvest for shark stocks whose status are overfished, experiencing overfishing, or are determined to be unknown; deducting overharvests from the following fishing year, or multiple years (up to five year maximum), based on the level of overharvest; requiring HMS dealer reports to be received by NMFS within 10 days of the end of a reporting period; requiring sharks to landed with fins on; and, proportioning unclassified sharks out among each shark species/complex based on observer and dealer reports. Regulations are subject to change based on stock assessments, international obligations, litigation, and public sentiment.

#### 2.5.5.2 Recent and Ongoing Research

*Northeast Fisheries Science Center*

Fishery Independent Survey for Coastal Sharks

The biannual fishery-independent survey of Atlantic LCS and SCS in U.S. waters from Florida to Delaware was conducted from April 19 to June 1, 2004. The goals of this survey were to: (1) monitor the species composition, distribution, and abundance of sharks in the coastal Atlantic; (2) tag sharks for migration studies; (3) collect biological samples for age and growth, feeding ecology, and reproductive studies; (4) tag sharks whenever feasible for age validation studies; and (5) collect morphometric data for other studies. Results from the 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 continued in conjunction with scientists at Moss Landing Marine Laboratories, California, using bomb carbon techniques. Additional validation studies were begun on the sandbar shark, dusky shark, tiger shark, 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 bull shark (with scientists with the Florida Division of Natural Resources) are under way. 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 vertebrae took place at tournaments and on the biannual research cruise, with 285 sharks injected with oxytetracycline for age validation. Night and dusky sharks were prepared with cross sectioning to determine the best method for reading, and all processing was initiated using histology. Readings were completed on the thresher and tiger sharks toward 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.

Using the standard age and growth techniques, the Narragansett Laboratory is currently processing samples from mako and thresher sharks obtained from sportfishing tournaments, research cruises, and cooperating scientists and commercial fishermen in the Northeast. Additionally, a comprehensive validation study using bomb carbon techniques is being undertaken in cooperation with Dr. Greg Cailliet, Lisa Kerr, and graduate student Daniele Ardizzone of the Moss Landing Marine Laboratories. This study will attempt to validate the periodicity of band formation in the shortfin mako for both the Atlantic and Pacific Oceans, and perhaps elsewhere in the world.

Biology of the Thresher Shark

Life history studies of the thresher shark (*Alopias vulpinus*) continue. Reproductive organs from over 200 thresher sharks, ranging in size from 62 to 263 cm fork length (FL), caught in the western North Atlantic Ocean are being examined to determine size at maturity and reproductive cycle. Preliminary evidence indicates that maturity in males is best indicated by an inflection in the relationship of clasper length to fork length when combined with clasper calcification. In females, all reproductive organ measurements related to body length show a strong inflection around the size of maturity. As in other lamnids, young are nourished through oophagy. Histological processing of a variety of reproductive organs is currently underway and will provide more detailed information on reproductive condition.

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.

Essential Fish Habitat and Shark Identification Updates

Through the cooperation of NMFS staff in the HMS Management Division and the Northeast and Southeast Fisheries Science Centers, NMFS has updated EFH maps for sharks and other HMS using information from observer and tagging databases. NMFS is currently working on a new EFH amendment. In addition, a guide was published to aid in identification of sharks and other HMS.

Cooperative Shark Tagging Program (CSTP)

The CSTP, involving over 6,500 volunteer recreational and commercial fishermen, scientists, and fisheries observers since 1962, continued to tag large coastal and pelagic sharks and provide information to define EFH for shark species in U.S. Atlantic and Gulf of Mexico waters. Research is being conducted on shortfin mako migration 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. Data from tagging programs, such as the NMFS CSTP, provide valuable information on migration and the extent of fish movements. The need for international cooperation in such work is underscored by the fact that many shark species have wide ranging distributions, frequently traverse national boundaries, and are exploited by multinational fisheries. The CSTP is also an important means to increase biological understanding of sharks and to obtain information for rational resource management. The tagging of sharks (and other aquatic animals) provides information on stock identity, movements and migration (including rates and routes), abundance, age and growth (including verification/validation of age-determination methods), mortality, and behavior.

Atlantic Blue Shark Life History and Assessment Studies

A collaborative program to examine the biology and population dynamics of the blue shark 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. In addition, research focused 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 with 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 PLL 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, the bluefish (*Pomatomus saltatrix*). A manuscript was completed comparing contemporary and historic levels of bluefish predation.

Currently, 290 shortfin mako shark samples are being reprocessed and new counts generated using the standard age and growth techniques of the Narragansett Laboratory. To date, the total number of sharks sampled is 188, and 118 of these sharks had prey in their stomachs. The Narrgansett laboratory counted 235 prey items, 168 of which were bluefish. Some of the other prey items included mackerel, menhaden, tuna, triggerfish, and both long and short finned squid. In stomachs containing bluefish, 1 or 2 prey fish was the most common. In the first year of this study, bluefish made up 94.1 percent of the overall diet of inshore sharks by volume, compared to previous studies 20 years ago where bluefish made up 85 percent of the weight. Although this comparison is preliminary, it could elude to increased predation by makos on bluefish compared to 20 years ago.

Two shortfin mako sharks were tagged with pop-up archival transmitting tags off Martha's Vineyard and had moved south off the Delaware coastline when the transmitters popped up and began transmitting data. These data represent the first long-term and detailed record of the movements of mako sharks in the Atlantic. Currently, three more transmitters are scheduled to be deployed on mako sharks.

Blacktip Shark Migrations

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

Cooperative Atlantic States Shark Pupping and Nursery Survey (COASTSPAN)

NEFSC Apex Predators Program staff manages and coordinates this project, using researchers in major coastal Atlantic and Gulf of Mexico states from Massachusetts to Texas 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. The COASTSPAN participants published a special volume of an American Fisheries Society publication entitled Shark Nursery Grounds of the Gulf of Mexico and the East Coast Waters of the United States in December, 2007 (McCandless et al., 2007).

Juvenile Shark Survey for Monitoring and Assessing Delaware Bay Sandbar Sharks

NEFSC staff conducts this part of the COASTSPAN monitoring 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, and examines the overlap in diet and distribution with the smooth dogfish shark (*Mustelus canis*). Over the past four years over 1,150 sandbar sharks have been sampled, with approximately 55 percent of those sharks containing food. Preliminary analysis indicates a diet dominated by teleosts, but strong trends in ontogeny are evident. Gastric evacuation data has been collected, but only very preliminary analysis has been conducted.

However, gastric evacuation estimates for the digestion of menhaden appear to be shorter than those reported previously.

During this same period, over 350 dogfish stomachs have been sampled with nearly all of them containing food. The diet is composed of predominately crustaceans with some bivalves, annelids, mollusks, and fish. Some ontogeny is evident with bivalves, shrimp, annelids and other small invertebrates of importance to smaller sharks, with more and larger crabs becoming important to large juveniles and adults, which also begin to consume small quantities of fish.

Preliminary work has begun on a dietary and habitat study of smooth dogfish in coastal New England waters. This study will characterize the diet of the species in these waters, especially in relation to predation on large commercially important crustaceans. Habitat, geographic, seasonal, and ontogenetic aspects of the diet will be examined in detail, and related to previous research in other locales. Acquired data will be coupled with environmental data, providing information on preferred habitat. This information is an important contribution toward understanding EFH 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.

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*Southeast Fisheries Science Center*

Stock Assessments of LCS, SCS, and Prohibited Sharks

The 2005/2006 assessment for the LCS Complex was run according to the SEDAR process. The SEDAR 11 Stock Assessment Report (NMFS, 2006a) compiles the new data used in the assessments, the report from the Assessment Workshop, and the final report by the peer reviewers (the Consensus Summary Report). This Stock Assessment Report constitutes the best available science.  The results of the assessment were released on July 24, 2006 (71 FR 41774). A stock assessment of dusky shark, a prohibited species and candidate for listing under the ESA, was also almost completed and was to be released on May 25, 2006 (71 FR 30123).

In 2007 a stock assessment for SCS following the SEDAR process was completed on November 13, 2007 (72 FR 63888).  Based on these assessments, NMFS determined blacknose sharks to be overfished with overfishing occurring; however, Atlantic sharpnose, bonnethead, and finetooth sharks were not found to be overfished with no overfishing occurring (May 7, 2008, 73 FR 25665).  NMFS is currently working on a new amendment to rebuild blacknose sharks and end overfishing.

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 October 2006 (Cortés and Neer, 2005; LCS05/06-DW-16) and formed the basis of the catch scenarios included in the SEDAR Data Workshop report described above.  Time series of commercial and recreational landings and discard estimates from several sources were compiled for the LCS complex and sandbar and blacktip sharks.  In addition, 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 was generated in 2007 for the SCS assessment (Cortés and Neer, 2007; SEDAR 13-DW-15).  This document presented updated commercial and recreational landings of Atlantic SCS up to 2005.  Species-specific information on the geographical distribution of commercial landings and recreational catches was presented along with the different gear types used in the commercial fisheries.  Length-frequency information and average weights of the catches in three separate recreational surveys and in the directed shark bottom-longline observer program were also included.

Observer Programs: Shark Longline Program

From 1994 to 2004, the southeastern United States commercial shark BLL fishery was monitored by the University of Florida Commercial Shark Fishery Observer Program.  In 2005, the responsibilities of the program were moved to the NOAA Fisheries Service Panama City Laboratory Shark Population Assessment Group in Panama City, FL.  This program is designed to meet the intent of the ESA and the FMP for HMS.  It was created to obtain better data on catch, bycatch, and discards in the shark BLL fishery.  All observers are required to attend a 1-week safety training and species identification course prior to being dispatched to the fishery.  While onboard the vessel, the observer records information on gear characteristics and all species caught, condition of the catch (*e.g.*, alive, dead, damaged, or unknown), and the final disposition of the catch (*e.g.*, kept, released, *etc.*).  As of 2007, the target coverage level is 4-6 percent of the total fishing effort.  This level is estimated to attain a sample size needed to provide estimates of protected resource interaction with an expected coefficient of variation of 0.3.

Observer Programs: Shark Gillnet Program

Since 1993, an observer program has been underway to estimate catch and bycatch in the directed shark gillnet fisheries along the southeastern U.S. Atlantic coast. This program was designed to meet the intent of the MMPA, ESA, and the 1999 revised FMP for HMS. It was also created to obtain better data on catch, bycatch, and discards in the shark fishery. The ALWTRP and the BiOp issued under Section 7 of ESA mandate 100 percent observer coverage during the right whale calving season (15 November - 1 April). Outside the right whale calving season (1 April - 14 November), observer coverage equivalent to 38 percent of all trips is maintained. Based on June 25, 2007 rule (72 FR 34632) shark gillnet vessels fishing between 29° 00' N and 26° 46.5' N have certain requirements as outlined 50 CFR § 229.32 from December 1 through March 31 of each year. These include vessel operators contacting the SEFSC Panama City Laboratory at least 48 hours prior to departure of a fishing trip in order to arrange for an observer. In addition, a recent rule (October 5, 2007, 72 FR 57104) amends restriction in the Southeast U.S. Monitoring Area from December 1 through March 31. In that area the 100 percent observer coverage has been replaced with VMS requirements found in 50 CFR 635.69. Similar to the shark longline observer program, all observers are required to attend a 1-week safety training and species identification course and while onboard the vessel record information on gear characteristics and all species caught, condition of the catch and the final disposition of the catch.

Ecosystem Modeling: Reconstructing ecosystem dynamics in the Gulf of Mexico. An assessment of the trophic impacts of fishing and its effects on keystone predator dynamics

Keystone species, such as sharks, can play a central role in the structure and function of marine communities. There are conflicting views surrounding the ecological interactions between sharks and fisheries. One view suggests that removals of keystone species are thought to cause a cascading trophic effect within the remaining community. These effects may involve changes in species composition among the prey or changes in the preferred prey of the predator. An alternate view has been suggested that the high diversity of oceanic systems may oppose strong "top-down" effects. In light of the recent revelations on the reductions of higher trophic levels species and fishing down food webs, an improved understanding of the role of keystone predators in the Gulf of Mexico would be useful in evaluating the impacts of fishing on the marine ecosystem. An Ecopath with Ecosim model has been developed to model the Gulf of Mexico ecosystem dynamics (Carlson, 2007). Hypotheses regarding the depletion of apex predators, and their impact on predation mortality of major prey groups were examined. Further, hypotheses regarding the role of complementary niches among sharks were explored.

Elasmobranch Feeding Ecology and Shark Diet Database

Because there is little quantitative species-specific data on diet, competition, predator-prey interactions, and habitat requirements of sharks, several studies are currently under way describing the diet and foraging ecology, habitat use, and predator–prey interactions of elasmobranchs in various communities. Atlantic angel sharks (*Squatina dumerili*) have been collected for stomach content analysis from a trawl fishery in northeastern Florida since 2004.

Evidence suggests angel sharks consumed mostly teleost fishes, with Atlantic croaker (*Micropogonias undulatus*) being the most common fish species (Baremore *et al*., 2006). The diet of the roundel skate *Raja texana* from the northern Gulf of Mexico is also being examined (Bethea and Hale, 2006). 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 FY 2007 and will be used as part of a collaborative study with researchers from the University of Washington, University of Wisconsin, and the Inter-American Tropical Tuna Commission, aimed at characterizing intra-guild predation and cannibalism in pelagic predators and evaluate the implications for the dynamics, assessment and management of Pacific tuna populations.

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 northwest Florida (Cedar Key-Pensacola) 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 EFH 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. This index has been utilized as an input to various stock assessment models.

Essential Fish Habitat

Conventional theory assumes that shark nursery areas are habitats where female sharks give birth to young or lay eggs, or where juvenile sharks spend their first weeks, months, or years of life. The SEFSC Panama City Shark Population Assessment Group is currently testing a number of hypotheses regarding juvenile sharks and EFH that challenge this assumption. There are many bays and inlets along the Gulf of Mexico coastline which may serve as EFH for sharks. These habitats vary from near-oceanic conditions to shallow, enclosed estuarine areas. Following Beck *et al*. (2001), the SEFSC Panama City Shark Population Assessment Group is determining which habitats provide a greater “nursery value” for a given species. A study using diet and bioenergetics published in 2006 by the Panama City Laboratory (Bethea *et al*., 2006) concluded that Crooked Island Sound provided a greater “nursery value” than Apalachicola Bay, FL.

Determining differences in the ratios of fin to carcass weight among sharks

Although many different species are harvested for their fins, the “5 percent rule” was established using data from only sandbar sharks due to a lack of data for other shark species. Using standardized data collated from state and federal databases, additional fin weight ratios were calculated for several commercially valuable shark species from coastal waters of the U.S. Atlantic Ocean and Gulf of Mexico. The wet fin to dressed carcass weight ratio of the sandbar shark (5.3 percent) was the largest of the 14 species examined, while the silky shark exhibited the lowest ratio at 2.5 percent. The fin-to-dressed weight ratio of the sandbar shark was significantly higher than most of the other large coastal species examined, and the bonnethead shark had a fin weight ratio (4.9 percent) significantly higher than other small coastal species examined.

Life History Studies of Elasmobranchs

Biological samples are obtained through research surveys and cruises, recreational fishers, and 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 they are harvested at sustainable levels. Samples are obtained from commercial fishers and fishery-independent surveys. Samples and preliminary analysis continue on determining life history parameters for skates in the Gulf of Mexico, a group of elasmobranchs often ignored despite being harvested as catch and bycatch in commercial fisheries. In 2006, the age and growth parameters of blacktip sharks (Carlson *et al.*, 2006) and scalloped hammerhead shark (Piercy *et al.*, 2007) from the Gulf of Mexico and southeast United States were published. In addition, a study was published on the reproductive cycle of blacknose sharks in the Gulf of Mexico, which concluded that not all carcharhinid sharks exhibit a biennial reproductive cycle (Sulikowski *et al.*, 2007). Along this line, new studies began in 2006 on the reproductive cycle of blacktip sharks in the Gulf of Mexico and sandbar sharks in the Atlantic Ocean.

Elemental chemistry of elasmobranch vertebrae

Although numerous studies have utilized elemental analysis techniques for age determination in bony fishes, little work has been conducted utilizing these procedures to verify age assessments or temporal periodicity of growth band formation in elasmobranchs. A study was completed in 2006 to determine the potential of laser ablation inductively coupled plasma-mass spectrometry (LA-ICP-MS) to provide information on the seasonal deposition of elements in the vertebrae of the round stingray. Spatially resolved time scans for elements across the round stingray vertebrae showed peaks in calcium intensity that aligned with and corresponded to the number of seasonal growth bands identified using standard light microscopy. Higher signals of calcium were associated with the wide opaque bands while lower signals of calcium corresponded to the narrow translucent bands. While a close alignment between the numbers of calcium peaks and annual growth bands was observed in round stingray samples aged five years or younger, this relationship was less well defined in vertebral samples from round stingrays over 11 years old. To the best of our knowledge, this is the first study of its kind to utilize ICP-MS to verify age assessments and seasonal band formation in an elasmobranch. The results of this research were published in 2006 (Hale *et al.*, 2006).

Cooperative Research—Habitat Utilization among Coastal Sharks

Through a collaborative effort between the 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 for better management of critical species and EFH.

Cooperative Research—Definition of Summer Habitats and Migration Patterns for Bull Sharks in the Eastern Gulf of Mexico

A collaborative effort between the SEFSC Panama City Shark Population Assessment Group, University of Florida, and Mote Marine Laboratory is under way to determine summer habitat use and short-term migration patterns of bull sharks. Sharks are being outfitted with pop-off satellite archival tags (PAT) during July and August and scheduled to deploy in autumn. Preliminary results indicate sharks, while occupying summer habitats, do not travel extensive distances. This project is driven by the lack of data for this species and its current prominence within the Florida coastal community. A better understanding of this species is required to effectively manage this species for both commercial and recreational fishers as well as the general public. Concerns regarding this species will continue to be an issue as fishers and the public demand that state and federal governments provide better information concerning the presence and movements of these sharks.

Shark Assessment Research Surveys

The SEFSC Mississippi Laboratories (MSL) has conducted BLL surveys in the Gulf of Mexico, Caribbean, and Southern North Atlantic since 1995 (21 surveys completed through 2005). The primary objective was assessment of the distribution and abundance of large and SCS across their known ranges to develop a time series for trend analysis. The surveys were designed to satisfy five important assessment principles: stockwide survey, synopticity, well-defined universe, controlling biases, and useful precision. The BLL surveys are the only long-term, nearly stock-wide, fishery-independent surveys of Western North Atlantic Ocean sharks conducted in U.S. and neighboring waters. Ancillary objectives were to collect biological and environmental data, and to tag-and-release sharks. Starting in 1997 and under the auspices of the MEXUS Gulf Program, MSL have provided logistical and technical support to Mexico's Instituto Nacional de la Pesca to conduct a cooperative research cruise aboard both the NOAA Ship OREGON II (1997 and 1998) and the Mexican research vessel Onjuku (2001 and 2002) in Mexican waters of the Gulf of Mexico. The circumference of Cuba was surveyed with the NOAA Ship OREGON II during 1998. One of the most noteworthy changes in the surveys was a shift from the standard "J" hook used in all the earlier surveys to a circle "C" hook (gear testing surveys conducted in 2000), which is much more efficient for capturing teleosts and slightly more efficient for elasmobranchs. Current surveys continue to address expanding fisheries management requirements for both elasmobranchs and teleosts and annual surveys include the U.S. Atlantic coast from Cape Hatteras to southern Florida and the U.S. Gulf of Mexico

Shark Research Fishery

Amendment 2 to the Consolidated HMS FMP established a shark research fishery to maintain time series data for stock assessments and to help meet NMFS' shark research objectives. Each year, NMFS determines the research objectives for the upcoming shark research fishery.  The research objectives are developed by a shark board, which is comprised of representatives within NMFS including representatives from the Southeast Fisheries Science Center (SEFSC) Panama City Laboratory, Northeast Fisheries Science Center (NEFSC) Narragansett Laboratory, the Southeast Regional Office of Protected Resources Division (SERO\PRD), and the HMS Management Division.  The research objectives of the shark research fishery are primarily based on the research needs identified in shark stock assessments. Many of the research objectives for 2008 and 2009 came from the SEDAR 11, 2005/2006 LCS stock assessment.  These objectives were developed with input from non-governmental organizations, industry representatives, fishery managers, and academics present during the stock assessment workshops.  In addition, the shark board identified additional needs for tagging studies, collection of genetic material, and controlled bottom longline (BLL) experiments to assess the impact of different hook types.

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