Scup:
Stock Assessment and
Biological Reference Points for 2008

by

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Executive Summary

The current biomass reference point for scup relies on the index of Spawning Stock Biomass (SSB) from the NEFSC spring trawl survey. Previous reviews of the stock assessment have indicated that while this index may be the most reliable fishery independent index of scup SSB, it is subject to a relatively high degree of inter-annual variability that reduces its utility as an indicator of stock status. Managers, scientists, and other stakeholders indicated a desire for a more reliable way to monitor the status of scup and support the annual specification of fishery regulations. The December 2008 Northeast Data Poor Stocks Peer Review Panel accepted a revised stock assessment using a statistical catch at age model (ASAP) as the basis for biological reference points and status determination for scup. The new model of scup population dynamics and the recommended reference points represent a more stable approach for monitoring stock status and specifying annual fishery regulations, compared with the current single index-based model. The new model integrates a broad array of fishery and survey input data and should be less sensitive to inter-annual changes in any single data component than the current model.

The Peer Review Panel recommended $F_{40\%}$ as the proxy for F_{MSY}, and the corresponding $SSB_{F40\%}$ as the proxy for SSB_{MSY}. The $F_{40\%}$ proxy for F_{MSY} = 0.177, the proxy estimate for SSB_{MSY} = 92,044 mt, and the proxy estimate for MSY = 16,161 mt (13,134 mt of landings, 3,027 mt of discards). The stock biomass threshold of ½ SSB_{MSY} = ½ $SSB_{F40\%}$ = 46,022 mt = 101.461 million lbs.

The 2007 SSB estimate of 119,343 mt is 30% above SSB_{MSY} = 92,044 mt, indicating the stock was not overfished. The F_{2007} estimate of 0.054 is 31% of F_{MSY} = 0.177, indicating overfishing was not occurring. Total catch (landings plus discards) was 7,867 mt in 2007, about 49% of MSY. The revised status determination represents a significant change from the recent biomass status update conducted in July 2008, which indicated that the stock was overfished in 2007, although not experiencing overfishing. While the accepted long-term MSY estimate appears feasible given historical evidence from the fishery, managers may wish to take an adaptive approach to the specification of fishery quotas in the short-term. Total fishery landings over the last five years (2003-2007) have averaged 6,214 mt (13.7 million lbs). If the stock is fished at $F_{40\%}$ = 0.177 over the long-term, the corresponding annual total MSY landings would be 13,134 mt (29.0 million lbs), more than double the recent five year average. The Peer Review Panel recommended that "…rapid increases in quota to meet the revised MSY would be unwarranted given uncertainties in recruitments. A more gradual increase in quotas is a preferred approach reflective of the uncertainty in the model estimates and stock status."

Term of Reference

The following components of the Terms of Reference for the Northeast Data Poor Stocks Working Group are relevant for scup:

1. Constitute and convene a Working Group comprising NEFSC assessment scientists, and staff from NERO, NEFMC, MAFMC, and ASMFC to:

    a. Recommend biological reference points (BRPs) and measurable BRP and maximum sustainable yield (MSY) proxies for Scup.

b. Provide advice about scientific uncertainty and risk for Scientific and Statistical Committees (SSCs) to consider when they develop allowable biological catches (ABCs) for these stocks.
c. Comment on what can be done to improve the information, proxies or assessments for each species.

Introduction

Scup (*Stenotomus chrysops*) is a schooling continental shelf species of the Northwest Atlantic that is distributed primarily between Cape Cod and Cape Hatteras (Morse 1978). Scup undertake extensive migrations between coastal waters in summer and offshore waters in winter. Scup migrate north and inshore to spawn in spring, with larger scup (age 2 and older) tending to arrive in spring first, followed by smaller scup (Neville and Talbot 1964; Sisson 1974). Larger scup are found during the summer near the mouth of larger bays and in the ocean within 20-fathoms, and often inhabit rough bottom areas. Smaller scup are more likely to be found in shallow, smooth bottom areas of bays during summer (Morse 1978). Scup migrate south and offshore in autumn as the water temperature decreases, arriving in offshore wintering areas by December (Hamer 1970; Morse 1978). Spawning occurs from May through August and peaks in June. About 50% of age-2 scup are sexually mature (about 17 cm total length; Morse 1978), while nearly all scup of age 3 and older are mature. Scup reach a maximum fork length of at least 41 cm and a maximum age of at least 14 years, with a likely maximum of 20 years (Dery and Rearden 1979). Tagging studies (e.g., Neville and Talbot 1964; Cogswell 1960, 1961; Hamer 1970, 1979) have indicated the possibility of two stocks of scup, one in Southern New England waters and another extending south from New Jersey waters. However, the lack of definitive locations for tag return data coupled with distributional data from the NEFSC bottom trawl surveys support the concept of a single unit stock extending from Cape Hatteras north to New England (Mayo 1982).

Overfished and Overfishing Definitions

The Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC) manage scup under Amendment 8 (1997) to the Summer Flounder, Scup, and Black Sea Bass (SFSCBSB) Fishery Management Plan (FMP). The FMP management unit includes all scup from Cape Hatteras, NC northward to the US-Canada border.

Amendment 8 also established a recovery plan for scup under which exploitation rates were to be reduced to 47% (F=0.72) during 1997-1999, to 33% (F=0.45) during 2000-2001, and to 21% (F=0.26) during 2002-2007. These goals were to be attained through implementation of a Total Allowable Catch (TAC) that included a commercial quota and recreational harvest limit, and other regulations including commercial fishery minimum net mesh, trap vent and fish sizes, closed areas, and recreational fishery minimum fish sizes, possession limits, and open seasons.
Amendment 12 (1998) to the FMP established a biomass threshold (a proxy for one-half BMSY) for scup based on the three-year moving average of the NEFSC spring bottom trawl survey index of Spawning Stock Biomass (SSB) during 1977-1979, which was perceived to be a period when the stock was near one-half BMSY (2.77 SSB kg per tow). The scup stock is overfished when the spawning stock biomass index falls below this value. Amendment 12 defined overfishing for

scup to occur when the fishing mortality rate exceeds the threshold fishing mortality of Fmax = 0.26 (proxy for FMSY).

Broad scale Gear Restricted Areas (GRAs) for scup were implemented in November 2000 under the framework provisions of the FMP as a measure to reduce discards of scup in the small mesh fisheries for *Loligo* squid and silver hake. The regulations restricted the use of small mesh trawl gear in areas with high concentrations of small scup during the late fall and winter months. Two Northern Areas off Long Island were implemented for November through January, while a Southern Area off the mid-Atlantic coast was implemented for January through April. The size and boundaries of the GRAs were modified in December 2000 and again in 2005 in response to commercial fishing industry recommendations.

Amendment 14 (July 2007) to the FMP defined the biomass target and implemented a stock rebuilding plan for scup. The stock must be fully rebuilt to the biomass target by January 1, 2015. The proxy for BMSY is two times the 3-year moving average of the NEFSC spring index of SSB during 1977-1979, or 2*2.77 = 5.54 SSB kg per tow. A constant fishing mortality rate (F) of 0.10 (9% exploitation rate) is to be applied in each year of a 7 year rebuilding period; 2008 was year 1 of rebuilding and F=0.10 was applied as the target F. Total Allowable Catch (TAC) of 4,491 mt (9.90 million lbs) and corresponding Total Allowable Landings (TAL) of 3,329 mt (7.34 million lbs) were established for 2008 to achieve the target F.

The current overfished and overfishing definitions are based on revisions to the SFSCBSB FMP through Framework 7 (October 2007), currently use the values established in Amendments 12 (1998) and 14 (July 2007), and are as follows:

AThe maximum fishing mortality threshold for each of the species under the FMP is defined as FMSY (or a reasonable proxy thereof) as a function of productive capacity, and based upon the best scientific information consistent with National Standards 1 and 2. Specifically, FMSY is the fishing mortality rate associated with MSY. The maximum fishing mortality threshold (FMSY) or a reasonable proxy may be defined as a function of (but not limited to): total stock biomass, spawning stock biomass, total egg production, and may include males, females, both, or combinations and ratios thereof which provide the best measure of productive capacity for each of the species managed under the FMP. Exceeding the established fishing mortality threshold constitutes overfishing as defined by the Magnuson-Stevens Act.@

AThe minimum stock size threshold for each of the species under the FMP is defined as one-half BMSY (or a reasonable proxy thereof) as a function of productive capacity, and based upon the best scientific information consistent with National Standards 1 and 2. The minimum stock size threshold (one-half BMSY) or a reasonable proxy may be defined as a function of (but not limited to): total stock biomass, spawning stock biomass, total egg production, and may include males, females, both, or combinations and ratios thereof which provide the best measure of productive capacity for each of the species managed under the FMP. The minimum stock size threshold is the level of productive capacity associated with the relevant one-half MSY level. Should the measure of productive capacity for the stock or stock complex fall below this minimum threshold, the stock or stock complex is considered overfished. The target for rebuilding is specified as BMSY (or reasonable proxy thereof) at the level of productive capacity associated with the relevant MSY level, under the same definition of productive capacity as specified for the minimum stock size threshold.@

Current Biological Reference Points

The current Biological Reference Points for scup are defined as follows in SFSCBSB FMP Amendment 12:

AOverfishing for scup is defined to occur when the fishing mortality rate exceeds the threshold fishing mortality rate of FMSY. Because FMSY cannot be reliably estimated, Fmax is used as a proxy for FMSY. Fmax is 0.26 under current stock conditions. The maximum value of the spring survey index based on a three year moving average (2.77 kg/tow) would serve as a biomass threshold. BMSY cannot be reliably estimated for scup.@ The original definition under Amendment 12 did not explicitly provide the time frame for the biomass threshold calculation. However, the specifics of the definition were provided in the discussion of the National Standards in another section of Amendment 12 as follows: AY 3-year moving average of the NEFSC spring survey catch per tow of spawning stock biomass (1977-1979 average = 2.77 kg/tow).@

Amendment 14 to the SFSCBSB FMP defined a proxy for BMSY for scup as follows:
AThe current minimum biomass threshold is the NEFSC spring SSB 3-year index value (1977-1979) of 2.77 kg/tow. Assuming the minimum biomass threshold is a proxy for 2 BMSY, doubling that index value would be a proxy for BMSY. Specifically, NEFSC spring 3-year index value of 5.54 kg/tow would be a proxy for BMSY. A

Background and Justification for Current Biological Reference Points

The last peer-reviewed assessment to include an analytical model was accepted in 1995 by SAW 19 (NEFSC 1995). The assessment featured a Virtual Population Analysis (VPA) modeled in the ADAPT framework (Conser and Powers 1990), included commercial and recreational landings and discards at age estimates, and used state and NEFSC abundance indices for calibration. The 1995 SAW 19 assessment indicated that the instantaneous fishing mortality rate (F) in 1993 was 1.3, and spawning stock biomass was 4,600 mt. A yield per recruit (YPR) analysis indicated that Fmax = 0.236.

The VPA was updated through 1996 and reviewed by SAW 25 (NEFSC 1997), but due to concerns over the low intensity of fishery sampling in the 1990s, uncertainty about the magnitude of commercial discards in the late 1990s, and the ongoing variability of survey indices, the VPA was not accepted as a basis for management decisions. Assessment conclusions were therefore based primarily on trends in NEFSC and state agency survey indices and catch curve analyses using those survey data. The 1997 SAW 25 was able to conclude that in 1996 scup were Aover-exploited and near record low abundance levels.@

The scup assessment was next updated through 1997 and reviewed by SAW 27 (NEFSC 1998). Several configurations of a surplus production model (ASPIC; Prager 1994) were reviewed in addition to an updated VPA, but like the VPA, the ASPIC model results were not accepted due to concerns over the validity of the input fishery and survey data. An updated YPR analysis was accepted and indicated that F_{max} = 0.26. SAW 27 concluded that AA VPA or other analytical model formulation for scup will not be feasible until the quality of the input data, particularly the precision of discard estimates, is significantly improved.@ The 1998 SAW 27 also concluded the scup was Aover exploited and at a low biomass level.@

The 1998 SAW27 Panel recommended the scup assessment be based on the long-term time series of NEFSC trawl survey indices and fishery catches. The Panel noted that commercial landings were sustained near 19,000 mt annually during the mid-1950s to mid-1960s, and concluded that the stock was likely near BMSY during that period (Figure 1). The nearest subsequent peak in NEFSC survey indices occurred in the late 1970s. Commercial and total fishery catches in the late 1970s were about one-half of those in the 1950s to 1960s, and so the late 1970s were identified as a period when the stock was likely to be near one-half of BMSY (Figures 1-2). The Panel considered the NEFSC spring survey series to be most representative of spawning stock biomass, since older ages were better represented in the age structure than in the NEFSC fall survey or other state agency surveys. The 1998 SAW27 Panel recommended that the three-year moving average of the NEFSC spring bottom trawl survey index of Spawning Stock Biomass (SSB) during 1977-1979 (2.77 SSB kg per tow) be used as the proxy biomass threshold (one-half BMSY) and that Fmax = 0.26 be used as the proxy fishing mortality threshold (FMSY). Those recommendations were subsequently adopted for the BRPs in FMP Amendment 12.

The scup assessment was next updated through 1999 and reviewed by SAW 31 (NEFSC 2000). The assessment continued to be based on trends in research survey indices and fishery catches and indicated that the stock was Aoverfished@ (the NEFSC spring SSB index was much lower than the biomass threshold specified in FMP Amendment 12) and that Aoverfishing@ was occurring (catch curve analyses indicated that F exceeded 1.0, much greater than the FMP Amendment 12 threshold of Fmax = 0.26).

The most recent peer-reviewed assessment of scup included fishery data through 2001 and was reviewed by SAW 35 (NEFSC 2002). The assessment was again based on trends in research survey indices and fishery catches, but indicated that the stock was no longer Aoverfished@ (the NEFSC spring SSB index was above the biomass threshold specified in FMP Amendment 12), although the SAW 35 Panel concluded that Astock status with respect to the overfishing definition cannot currently be evaluated,@ due to the uncertainty of F estimates derived from research survey catch curve calculations. The 2002 SAW 35 Panel found sufficient evidence to conclude that AThe relative exploitation rates have declined in recent years...@ and that ASurvey observations indicated strong recruitment and some rebuilding of age structure.@

Since 2002, the status of the stock has been monitored by the MAFMC Monitoring Committee using trends in research survey indices and fishery catches. A Relative Exploitation Index (REI) based on the annual total fishery landings and the NEFSC spring three-year average SSB index has been used as a proxy for F to monitor status with respect to overfishing and provide guidance to the specification of annual TACs. A projection of the NEFSC spring survey SSB index using assumptions about maturity, partial recruitment to the survey, and the level of future recruitment as indexed by the NEFSC spring survey at age 1 was used in FMP Amendment 14 to forecast stock rebuilding and set the Frebuild target for 2008-2105.

An update to the status monitoring metrics was completed in July 2008 to aid in the specification of fishery regulations for 2009. The update indicated that while the stock was overfished in 2007 (NEFSC spring SSB three-year average index = 1.16 kg per tow, 21% of the biomass target of 5.54 kg per tow), the exploitation rate was at the rebuilding target rate (9%, or about F = 0.10), suggesting that overfishing was not occurring in 2007. However, the stock rebuilding rate was slower than indicated by the Amendment 14 projection, with the NEFSC spring 2007 SSB index (three-year average = 1.16 kg per tow) at only 56% of the forecast 2007 index (2.08 kg per tow).

Need for Revision of the Current Biological Reference Points

The current stock biomass reference point relies on the index of SSB from the NEFSC spring trawl survey. Previous reviews of the scup stock assessment have indicated that while this index may be the most reliable fishery independent metric of scup SSB, it is subject to a relatively high degree of inter-annual variability and the possibility that positive and negative Aavailability@ events will reduce the utility of the index in monitoring the status of the stock for any given year, in spite of the three-year smoothing protocol (Figure 2). An example of this phenomenon took place in 2002, when an unusually high value of the NEFSC spring SSB index was recorded that did not seem to result from high abundance in 2001, nor translate into a correspondingly high value in 2003. Subsequent reviews concluded that the high 2002 index resulted mainly from an increased availability of fish to the survey, rather than due to a true increase in abundance of the recorded magnitude. However, the high 2002 index lead to a change in official stock status to Anot overfished@ when incorporated into the three-year average SSB index calculation, and then a change back to Aoverfished@ when the 2002 index passed out of the three-year average in 2005 (Figure 2), with accompanying volatility in the annual specification of fishery regulations.

The last four peer reviews of the assessment have rejected analytical models for scup, and indicated that estimates of F based on research survey catch curve analyses are not valid. The Relative Exploitation Index (REI; total fishery landings divided by the NEFSC spring three-year SSB index) used as a proxy for F is also volatile and potentially unreliable if inter-annual changes in the SSB index are suspected to be biologically unrealistic. Finally, the NEFSC survey series using NOAA Ship *Albatross IV* sampling, on which the stock status monitoring is based, ended in November 2008. While efforts are underway to calibrate the *Albatross IV* indices to new indices collected by the NOAA Ship *Henry B. Bigelow*, those efforts may not provide a reliable basis for stock monitoring in the short term. Managers, scientists, and other stakeholders have therefore indicated a desire for a more reliable way to monitor the status of the scup stock and support the annual specification of fishery regulations.

Proposed Biological Reference Points

The following section details the sequence of work that was performed in the series of Data Poor Stocks Working Group meetings during the fall of 2008 to develop the analytical model that is the basis for the accepted BRPs. The section details the two analytical modeling approaches for scup that were pursued. The first was a relatively simple approach, the AIM model, which fits relationships between single abundance index time series and fishery catch time series. The second was a statistical catch at age model incorporating many data components, ASAP. Because the accepted model requires the use of significantly more complex input fishery and research survey data than the current BRPs, a description of those data precedes the model descriptions.

Commercial Landings

US commercial landings averaged over 18,000 mt per year from 1950 to 1965 (peaking at over 22,000 mt in 1960) and declined to less than 10,000 mt per year in the late 1960s. Landings fluctuated between about 5,000 and 10,000 mt from 1970 to the early 1990s and then declined to about 1,200 mt in 2000, less than 6% of the peak observed in 1960. Commercial landings have since increased to average about 4,200 mt during 2003-2007 (Figure 1).

About eighty percent of the commercial landings of scup for the period 1979-2007 were in Rhode Island (38%), New Jersey (26%), and New York (16%; Table 1). The otter trawl is the principal commercial fishing gear, accounting for about 75% of the total catch during 1979-2007 (Table 2). The remainder of the commercial landings is taken by floating trap (11%) and hand lines (7%), with paired trawl, pound nets, and pots and traps each contributing between 1 and 4%.

Commercial Discards

The NEFSC Observer Program has collected information on landings and discards in the commercial fishery for 1989-2007. Northeast Region (ME-VA) discard estimates were raised to account for North Carolina landings. A discard mortality rate of 100% was assumed because there are no published estimates of scup discard mortality rates. This assumption is based on limited observations and is an important element of uncertainty in the assessment. Past SAW panels have recommended that research be conducted to better characterize the discard mortality rate of scup in different gear types in order to more accurately quantify the absolute magnitude of scup discard mortality (NEFSC 1995, 1997, 1998, 2000, 2002; see also Section 7 of this report AResearch Recommendations@).

Quantifying discards from the commercial fishery is necessary for a reliable scup assessment, but low sample sizes in the past have resulted in uncertain estimates. Concern regarding the uncertainty of discard estimates due to inadequate observer sampling has been expressed in at least five previous SAW reviews of the scup assessment, and those reviews have recommended increases in sampling intensity to increase the accuracy and precision of discard estimates (NEFSC 1995, 1997, 1998, 2000, 2002). Despite the uncertainty of the discard data, recent SAW panels have concluded that commercial discarding of scup has been high during most of the last 20 years, generally approaching or exceeding commercial landings (i.e., about 50% or more of the total commercial catch). Since the implementation of GRAs in 2000, estimated discards as a proportion of the total commercial catch have decreased, averaging about 35%.

Given the uncertainty associated with estimating commercial discards for scup, three different methods for calculating discard estimates have been considered in assessments since 1998:

1) Geometric Mean Discards-to-Landings Ratio (GMDL): Ratios of discards to landings by trip landings level (for trip landings < 300 kg [661 lbs], the Abycatch fishery@; or => 300 kg, the Adirected fishery@) and half year period were calculated and multiplied by the corresponding observed landings from the NEFSC Dealer Report database to provide estimates of discards. Geometric mean rates (re-transformed, uncorrected, mean ln-transformed Discards to Landings [D/L] per trip) were used because the distributions of landings and discards and the ratio of discards to landings on a per-trip basis in the scup fishery are highly variable and positively skewed. Observed trips with both scup landings and discard were used to calculate the per trip discard to landings ratios. Only trips with both non-zero landings and discards could be used for this approach to avoid division by zero. The number of trawl gear trips used to calculate geometric mean discard-to-landings ratios (GMDL) by half year for 1997-2007 ranged from 1 to 104 for trips < 300 kg and from 1 to 35 for trips =>300 kg, with the best sampling occurring since 2003. No trawl gear trips were available for half year two in 1997 and 1999 for trips < 300 kg and for half year two in 1997-2001 for trips => 300 kg. The GMDL calculated for half year one was used to estimate discards for half year two when no trawl gear trips were available in half year two. The GMDL ratios ranged from 0.03 in 2004 (half year two, trips => 300 kg) to 121.71 in 1998 (half year one, trips => 300 kg; Table 3).

The large 1998 Adirected fishery@ discard ratio and subsequent very high annual discard estimate (111,973 mt) was based on one trawl gear trip. About 93% of the discard from that trip was attributable to a single tow in which an estimated 68.2 mt (150,000 lbs) of scup were captured. This tow was not lifted from the water and the captain of the vessel estimated the weight of the catch. There has been debate concerning the validity of the catch weight estimate and whether or not it was representative of other vessels or trips in the fishery. However, the observation was reported by a trained NEFSC observer and was therefore included in the initial calculation of the GMDL estimate of scup discards (Tables 3-4).

2) Aggregate Discards-to-Landings Ratio (AGDL): The second approach for estimating discards considered aggregate discards to landings ratios (summed D/summed L for all trips catching scup in stratum). As in the GMDL method, trips are stratified by trip landings level and half year period. The number of trawl gear trips used to calculate AGDL by half year for 1997-2007 ranged from 14 to 254 for trips < 300 kg and from 1 to 35 for trips => 300 kg, with the best sampling occurring since 2003. There are more trips available for the AGDL calculation for trips < 300 kg than in the GMDL approach, since trips with zero landings can be used. The lowest AGDL ratio calculated was 0.00 in 2001 (no discard observed in 4 trips, half year two, trips => 300 kg). The highest AGDL was 121.71 in 1998 (half year one, trips => 300 kg), the same as that calculated in the GMDL method. The AGDL approach generally provides higher annual estimates of scup discards, with greater inter-annual variability, than the GMDL approach.

3) Mean Differences between Landings and Discards (DELTA): Mean differences (kg) between landings and discard (D = landings - discard, per trip) were also calculated using the same strata as for the other methods. Observed trips in the stratum were used to calculate the mean difference in stratum, which was then applied to the scup landings of trips in the NEFSC Dealer Report database to calculate a discard for each trip (discard = landings -(D)). Calculating differences allows use of trips that had discards but no landings, whereas D/L ratios cannot be calculated in these situations (i.e. zero in the denominator). When discards exceed landings, the difference (D) is negative. As the magnitude of discards is of primary interest, the absolute values of D are used. The number of trawl gear trips used in the DELTA method calculations ranged from 6 to 254 for trips < 300 kg and from 1 to 35 for trips => 300 kg, with the best sampling occurring since 2003. The magnitude of the DELTA values ranged from 10.7 in 2001 (half year two, trips < 300 kg) to 72707 in 1998 (half year one, trips => 300 kg). As before, this large discard estimate is the result of one large discarding event in the Adirected fishery@ that was discussed above. The DELTA approach generally provides lower estimates of scup discards for the Adirected fishery @ but slightly higher estimates for the Abycatch fishery@ compared to the GMDL approach.

Since 2002 the GMDL approach discard estimates have been adopted by the MAFMC Monitoring Committee to monitor trends in fishery catch and evaluate the status of the stock, since the year-to-year trends among the three approaches differed in magnitude but followed similar trends. The large discard event in 1998 affected calculations from each method, resulting in extremely high D/L rates and subsequent discard estimates in 1998 for each approach. The DELTA method yielded estimates that were fairly consistent with the GMDL rates, while the AGDL estimates exhibited generally higher discard estimates with more variability. Previous SAW Working Groups and review panels have expressed most confidence in the estimates produced using the GMDL approach and considered the estimates to be supported by the DELTA rates. The GMDL estimates were used for all subsequent modeling approaches considered in the assessment. The 1998 estimates from all 3 computational methods was considered infeasible, and replaced by the mean of the 1997 and 1999 GMDL estimates (3,331 mt) in subsequent tabulations of catch and in subsequent modeling (Tables 3-5, and 9).

Recreational Catch

Scup is an important recreational species, with the greatest proportion of catches taken in the states of Massachusetts, Rhode Island, Connecticut and New York. Estimates of the recreational catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1981-2007. These estimates were available for three categories: type A - fish landed and available for sampling, type B1 - fish landed but not available for sampling, and type B2 - fish caught and released alive. The estimated recreational landings (types A and B1) in weight during 1981-2007 averaged about 2,000 mt per year (Table 5). Since 1981, the MRFSS data indicate that the recreational landings have averaged 29% of the commercial and recreational landings total.

The estimated recreational discard in weight during 1984-2007 ranged from 6 mt in 1999 to a high of 185 mt in 2006, while averaging about 72 mt per year (Table 5). The weight of discards has been directly calculated only for those years (1984 and later) for which recreational catch at age has been compiled. In compilations of total fishery catch for earlier years, the recreational discards was assumed to be approximately 2% of the estimated recreational landings, based on the mean discard percentage for 1984-1996 (directly calculated discard weights for years prior to implementation of FMP regulations). No length frequency samples of the scup discard were collected under the MRFSS program before 2005, so recreational discards were assumed to be fish aged 0 and 1, in the same relative proportions and with the same mean weight as the landed catch less than state regulated minimum fish sizes. An inspection of discard length frequency samples from the New York recreational fishery for 1989-1991 indicated that this assumption was reasonable. Since 2005, length samples of the recreational fishery discard have been collected in the MRFSS For Hire Survey sampling. The mortality rate due to discarding in the recreational fishery has been reported to range from 0-15% (Howell and Simpson 1985) and from 0-13.8% (Williams, pers. comm.). Howell and Simpson (1985) found mortality rates were positively correlated with size, due mainly to the tendency for larger fish to take the hook deep in the esophagus or gills. Williams more clearly demonstrated increased mortality with depth of hook location, as well as handling time, but found no association with fish size. Based on these studies, a discard mortality rate in the recreational fishery of 15% appears reasonable and has been used in previous and the current assessments.

Commercial Fishery Landings at Length and Age

The intensity of commercial fishery biological sampling is summarized in Table 6. Annual sampling intensity varied from 27 to 687 mt per 100 lengths, with sampling exceeding the informal threshold criterion of 200 mt per 100 lengths sampled since 1994. For this assessment, commercial fishery landings at age beginning in 1984 have been updated through 2007, with samples generally pooled by market category (pins/small, medium, large/mix, jumbo, and unclassified) and half year period (January-June, July-December), with market category samples pooled on a quarterly basis for 2004-2007. Estimates of commercial fishery landings at age (Figure 3) and mean weights at age are presented in Tables 7-8.

Commercial Fishery Discards at Length and Age

The intensity of length frequency sampling of discarded scup from the NEFSC Observer Program declined in 1992-1995 relative to 1989-1991 (Table 9). Sampling intensity ranged from 489 to 335 mt per 100 lengths sampled in 1992-1995, failing to meet the informal criterion of 200 mt per100 lengths sampled. Sampling intensity improved to 100 mt per 100 lengths in 1996, but then declined to over 200 mt per 100 lengths in 1997-1999. Sampling intensity has generally met the 200 mt per 100 length threshold since 1999. The mean weight of the discard was estimated from length frequency data and a length-weight equation, with the total numbers discarded then estimated by dividing total discard weight by mean fish weight, and the numbers at length then calculated from the length-frequency distribution. Discards at length were aged using a combination of commercial and survey age-length keys, with discards at age dominated by fish aged 0, 1, or 2, depending on the year under consideration. Estimates of commercial fishery discards at age (Figure 4) and mean weights at age are presented in Tables 10-11.

Recreational Fishery Landings at Length and Age

In the recreational fishery, landings sampling intensity varied from 45 to 471 mt per 100 lengths. Sampling in all years except one (1984) during 1981-1987 failed to satisfy the above criterion, but since 1987 the criterion has been met except for 1999-2000 (Table 12). Numbers at length for recreational landings were determined based on available recreational fishery length frequency samples pooled by half year period over all regions and fishing modes, and were converted to numbers at age by applying half year period age-length keys constructed from NEFSC commercial and survey samples. Age-length keys from spring surveys and first and second quarter commercial samples were applied to numbers at length from the first half of the year, while age-length keys from fall surveys and third and fourth quarter commercial samples were applied to numbers at length from the second half of the year. Estimates of recreational fishery landings at age (Figure 5) and mean weights at age are presented in Tables 13-14.

Recreational Fishery Discards at Length and Age

As noted earlier, no length frequency distribution data on scup discard are routinely collected under the MRFSS program prior to 2005, so recreational discards were assumed to be fish less than state minimum sizes, in the same relative proportions at age as the landed catch less than the respective state minimum sizes (i.e., sub-legal fish of ages 0 and 1). This assumption for the coastwide fishery is supported by discard length frequency samples from the New York recreational fishery (1989-1991) and samples collected since 2005 by the MRFSS For-Hire Survey. Since 2005, the MRFSS For-Hire Survey discard samples have been used in concert with the MRFSS sub-legal landed lengths to directly characterize the length frequency of the recreational discard. As noted earlier, a 15% discard mortality rate is assumed. Estimates of recreational fishery discards at age (Figure 6) and mean weights at age are presented in Tables 15-16.

Total Fishery Catch

Estimates of the total fishery catch at age and mean weights at age for 1984-2004 (the time series is limited by the availability of sampled fishery ages) are presented in Tables 17-18.

An extended time series of the total catch of scup has been estimated to provide an historical perspective of the exploitation of scup in the years before fishery aging data were available (Table 19). These estimates include commercial and recreational landings and discards. The catches before 1981 are the least reliable due to uncertainty about a) the level of domestic commercial fishery discards, b) distant water fleet (DWF) catch, and c) assumptions to estimate the recreational catch (50% reduction from interpolations made in Mayo 1982 for 1960-1978; recreational discards assumed to be 2% of the adjusted recreational landings). For years in which no observer data were collected (prior to 1989), commercial discards were estimated using the mean of GMDL approach ratios for 1989-2001.

Research Vessel Survey Indices

NEFSC

The NEFSC spring and fall surveys provide long time series of fishery-independent indices for scup. The NEFSC spring and fall surveys are conducted annually during March-May and September-November, ranging from just south of Cape Hatteras, NC to Canadian waters. NEFSC spring and fall abundance and biomass indices for scup exhibit considerable inter-annual variability (Table 20). The 2002 spring SSB index (9.24 kg/tow) was about twice the second highest spring SSB index, which was observed in 1977 (4.35 kg/tow)(Figure 7). The spring numeric abundance indices are similar; in 2002, the estimated index of spring abundance is the highest observed in the series (154.86 fish/tow) and about twice the 1970 index (78.50 fish/tow). These dramatic increases were evident across all ages in the estimated 2002 spring numbers at age (Table 21; Figure 8). Fall survey estimates of numbers at age in 2001 did not reflect relatively large values from which corresponding 2002 spring numbers at age might be expected to derive (Table 22, Figure 9) , nor did they translate to exceptional indices of biomass or SSB in fall 2002 or spring 2003. Spring survey SSB and abundance indices decreased subsequent to 2002, but are still above the low values of the late 1990s. Fall survey abundance and biomass have been highly variable since 2002.

The NEFSC winter survey was started in 1992 primarily as a flatfish survey (used a different trawl net than the spring and fall surveys), was conducted during February, and ranged from Cape Hatteras, NC to the southwestern part of Georges Bank. The winter survey 2002 abundance and biomass indices were, like the spring survey, the largest of the time series (Table 23). Similar to the spring estimates, numbers at age estimated for the 2002 winter survey were also exceptionally large (Table 24, Figure 10). Winter survey abundance and biomass decreased subsequent to 2002, but were still above the low values of the late 1990s. The winter trawl series ended in 2007.

As noted in Sections 1-4, indices of scup SSB per tow were developed from the NEFSC spring offshore strata series for use as proxy biomass reference points. The 1998 SAW 27 panel (NEFSC 1998) selected a three-year moving average of the NEFSC spring SSB index as a representative measure of scup SSB, based on the characteristics of the survey age structure, the magnitude of the survey catch, and the trend in the extended series of commercial and total fishery catch estimated back to 1960 (Table 19, Figures 1-2). FMP Amendment 12 defined the biomass threshold reference point as the maximum (at the time) observed value of this three-year moving average: the 1978 value (mean of 1977-1979) of 2.77 SSB kg/tow (Table 20, Figure 2). FMP Amendment 14 defined the target biomass BRP as twice the threshold value of this three-year moving average, or 2 times 2.77 = 5.54 SSB kg/tow.

Massachusetts DMF

The Massachusetts Division of Marine Fisheries (MADMF) has conducted a semi-annual bottom trawl survey of Massachusetts territorial waters in May and September since 1978. Survey coverage extends from the New Hampshire to Rhode Island boundaries and seaward to three nautical miles including Cape Cod Bay and Nantucket Sound. The study area is stratified into geographic zones based on depth and area. Trawl stations are allocated in proportion to stratum area and are chosen randomly within each stratum. A 20 minute tow at 2.5 knots is made at each station with a 3/4-size North Atlantic two- seam otter trawl (11.9 m headrope, 15.5 m footrope) rigged with a 19.2 m chain sweep with 7.6 cm rubber discs. The net contains a 6.4 mm mesh codend liner to retain small fish. Approximately 95 stations are sampled during each survey. Standard bottom trawl survey techniques are used to process the catch of each species. Generally, the total weight (nearest 0.1 kg) and length frequency (nearest cm) are recorded for each species on standard trawl logs. Collections of age and growth structures, maturity observations, and pathology observations are taken. The MADMF spring survey catches are characterized mainly by scup of ages 1 and 2, while the fall survey often captures large numbers of age 0 fish. The spring biomass and abundance indices dropped sharply from a high in the early 1980s to relatively low levels through the remainder of the time series, with the exception of spikes in 1990, 2000, and 2002, the latter event in common with the NEFSC spring trawl survey (Table 25, Figure 11). The MADMF fall indices can include large numbers of age 0 fish, and on a numeric basis are more variable than the spring indices. The fall biomass index is less variable than the spring, however, and exhibits an increasing trend since the mid 1990s (Figure 12).

Rhode Island DFW

The Rhode Island Division of Fish and Wildlife (RIDFW) has conducted autumn and spring surveys since 1979 based on a stratified random sampling design. Three major fishing grounds are considered in the spatial stratification, including Narragansett Bay, Rhode Island Sound, and Block Island Sound. Stations are either fixed or randomly selected for each stratum. To maintain continuity in the number of stations sampled per stratum each season, an alternate list is generated for substitution in the event of an unexpected hang-up or questionable bottom type. At each station, a 3/4-scale High Rise bottom trawl is towed for 20 minutes at an average speed of 2.5 knots. The net average vertical opening is estimated at 10 feet. The otter trawl doors are 2 ft by 4 ft in dimension, set 7.5 fathoms ahead of the wings of the net. The RIDFW spring survey mainly catches scup of ages 1 and 2. The spring indices show relatively levels of scup abundance and biomass through 1999 followed by a steep increase during 2000-2002, in common with the NEFSC and MADMF indices. No scup were caught in the spring 2003 survey, but the index has since rebounded to pre-2000 levels (Table 26; Figure 11). The RIDFW fall survey is dominated by age 0 scup. Fall abundance indices show a general increase to its 1993 peak, followed by a steep decline until 1998, and a general increase since then, reaching a time series peak in 2007 (Figure 12).

Connecticut DEP

The Connecticut Department of Environmental Protection (CTDEP) trawl survey program was initiated in May 1984 and encompasses both New York and Connecticut waters of Long Island Sound. The stratified random design survey is conducted in the spring (April-June) and fall (September-October). Each survey consists of three cruises, with 40 stations sampled during each cruise, providing a sampling density of one station per 20 square nautical miles per cruise. Prior to 1990, the survey was conducted monthly from April to November. The CTDEP spring indices exhibit relatively low levels through most of the survey period, but have increased substantially since 1999 (Table 27, Figures 11 & 13). The CTDEP fall survey, which often catches large numbers of age-0 scup, indicates that recruitment was relatively stable during most of the survey period, but fall indices have also increased substantially since 1999 (Table 28, Figures 12 & 14). The age compositions of the CTDEP spring and fall surveys generally include a higher proportion of age 2 and older fish than the other state or NEFSC surveys (Figures 13-14).

New York DEC

The New York Department of Environmental Conservation (NYDEC) initiated a small mesh trawl survey in 1985 to collect fisheries-independent data on the age and size composition of scup in local waters. This survey is conducted in the Peconic Bays, the estuarine waters which lie between the north and south forks of eastern Long Island. Tows are 20 min in duration. The net used has a 16 ft headrope and a 19 ft footrope and is constructed of polypropylene netting with 1.5 in stretch mesh in the body and 1.25 in stretch mesh in the codend. No survey data are available for 2005. The NYDEC survey provides age 0, 1, and 2+ indices of scup abundance. The age 0 indices are generally low over the survey period, with peaks in 2000, 2002, 2003, 2006, and 2007 that may indicate recruitment of strong cohorts in those years (Table 29). In the early years of the survey there often has not been a strong correspondence between the age 0 indices and age 1 and 2+ indices in the following years (Figure 15).

New Jersey BMF

The New Jersey Bureau of Marine Fisheries (NJBMF) conducts a stratified random bottom trawl survey of New Jersey coastal waters from Ambrose Channel south to Cape Henlopen Channel. Latitudinal strata boundaries correspond to those in the NEFSC trawl survey; longitudinal boundaries correspond to the 30, 60, and 90 foot isobaths. Each survey includes two tows per stratum plus one additional tow in each of nine larger strata for a total of 39 tows. A three-in-one trawl with a 100 ft footrope, an 82 ft headrope, 3- 4.7 in mesh throughout most of the body and a 0.25 in mesh codend liner is used. From 1991 to present, the area has been surveyed in January, April, June, August, and October; from 1988-1990, February and December surveys were incorporated instead of the January survey. The NJBMF abundance and biomass indices exhibit variable patterns over the early part of the time series. The index reached a minimum in 1996, and has generally increased since then, reaching time series highs in numbers and biomass in 2007 (Table 29; Figure 11).

Virginia Institute of Marine Science (VIMS)

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile scup survey in lower Chesapeake Bay during June-September since 1988. The VIMS age-0 scup survey shows a general decline in recruitment from relatively high levels with peaks in 1990 and 1993 to relatively low levels from 1994 to 2004, and the indication of stronger year classes in 2006 and 2007 (Table 29).

University of Rhode Island Graduate School of Oceanography (URIGSO)

University of Rhode Island Graduate School of Oceanography (URIGSO) has conducted a standardized, two-station trawl survey in Narragansett Bay and Rhode Island Sound since the 1950s, with consistent sampling since 1963. Irregular length-frequency samples for scup indicate that most of the survey catch is of fish from ages 0 to 2. The aggregate numbers-based index reached a peak in the late 1970s, was relatively low during the late 1990s, reached a second peak in 2002 in common with the NEFSC, MADMF, RIDFW spring biomass indices, and has since been variable at relatively high level (Table 30, Figure 11).

Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP)

The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) trawl survey is designed to support bay-specific stock assessment activities at both a single and multispecies scale. While no single gear or monitoring program can collect all of the data necessary for quantitative assessments, ChesMMAP was designed to fulfill data gaps by maximizing the biological and ecological data collected for several recreationally and commercially important species in the bay. Total abundance and biomass indices for scup mainly of age 0 and 1 are available since 2002, and indicate strong recruitment in 2005 and 2006 (Table 31).

Natural Mortality

Instantaneous natural mortality (M) for scup was assumed to be 0.20 (Crecco *et al.* 1981, Simpson *et al.* 1990). The largest/oldest scup sampled in NEFSC surveys (1973, 1978) were fish 38-41 cm (fork length) and 14 years old. The largest/oldest scup in NEFSC commercial fishery samples (1974) was 40 cm (fork length) and 14 years old.

Models of Fishing Mortality and Stock Size

Background Information

The 1998 SAW 27 Panel (NEFSC 1998) rejected an ADAPT VPA for scup as the basis for assessing stock status or as the basis for projections. The panel indicated that the amount of variance in the scup catch at age, particularly for the commercial discards, was unreasonably large. The Panel concluded that the precision of estimates of fishing mortality and stock size from the VPA was unacceptably low and would provide an unreliable basis for any estimates of stock size and fishing mortality rates (NEFSC 1998). The SAW 27 Panel also reviewed a surplus production model for scup developed in the ASPIC framework. The Panel noted that the inability to directly estimate historical commercial fishery discards (1968-1988) and recreational catch (1968-1978) cast uncertainty on the validity of the ASPIC absolute estimates of stock biomass, fishing mortality rates, and biological reference points. Since the ASPIC analysis suffered from many of the same input data inadequacies as the VPA, the SAW 27 Panel rejected the ASPIC analysis as a basis for stock status, projections, or reference points (NEFSC 1998).

State and NEFSC survey indices at age for scup are highly variable. The patterns in proportions at age in survey indices and survey catchability coefficients at age estimated in the VPA suggested that all ages of scup may not be equally available or susceptible to capture by survey trawl gear. As a result, the SAW 27 Panel noted that mortality estimates derived from survey catch at age indices are highly variable and may be positively biased, and are probably not a reliable basis for evaluating fishing mortality rates (NEFSC 1998). These conclusions about the lack of reliability of surplus production, VPA, or catch curve analyses for scup, due mainly to an inability to evaluate the uncertainty of results, have been supported by subsequent SAW Panel reviews of the scup assessment (NEFSC 2000, 2002).

In the absence of reliable analytical model results for scup, the 2000 SAW 31 Panel (NEFSC 2000) developed and the MAFMC Monitoring Committee has subsequently used a Relative Exploitation Index (REI) as a metric for the instantaneous fishing mortality rate (F). The scup REI is computed as the ratio of total fishery landings to the NEFSC spring trawl survey

SSB three year average index. Landings, rather than total catch, are used in the REI because of the relatively high uncertainty of commercial fishery discard estimates. The REI is therefore assumed to reflect the fishing mortality on age 2 and older scup because fishery landings and survey catch in the NEFSC spring SSB index are generally scup of ages 2 and older. The low REI values in the early 1980s were consistent with the Mayo (1982) assessment of scup (Figure 16; note that the REI is plotted on a log scale). There was a general increasing trend in the REI through the mid-1990s followed by a steady decline through 2001, with an increasing trend since 2001.

The 2000 SAW 31 Panel (NEFSC 2000) concluded that A ...catch curve analyses of survey indices indicate that F for ages 0-3 exceeds 1.0...for the 1994-1998 year classes.@ The 2002 SAW 35 Panel (NEFSC 2002) concluded, however, that AThough the relative exploitation rates have declined in recent years, the absolute value of F cannot be determined.@ In recent years, the MAFMC Monitoring Committee has used the REI as part of the assessment information used to recommend an annual Total Allowable Landings (TAL) for the stock. The MAFMC Monitoring Committee has assumed that F in 1999 was equal to 1.0 (NEFSC 2000), equating to an annual exploitation rate of 58%, which in turn equates to the 1999 REI = 62.4. An estimate of the current year exploitation rate has then been developed by assuming the same ratio between the current REI and exploitation rate, to provide advice on an appropriate level for the next year TAL.

The SAW 35 Panel (NEFSC 2002) reviewed an application of the NOAA Fisheries Toolbox model called AAn Index Method,@ or AIM, to scup fishery and survey catch data. That work used the extended total catch series noted earlier, and found that the NEFSC fall survey series provided a better model fit than the NEFSC spring series used as the basis for the biomass reference point and as input to the REI described earlier. The SAW 35 Panel (NEFSC 2002) noted that for scup, the AIM approach had A...considerable promise as a monitoring tool to evaluate stock trajectories and provide valuable information in interim years between analytical assessments@ and A...utility in presenting an integrated picture of stock dynamics for resources where only catch statistics and survey trends are available.@ While this approach was not adopted by the 2002 SAW 35 Panel to monitor the status of the stock, further research using the AIM model was recommended.

As noted earlier, the most recent update of the current stock assessment approach was completed in July 2008 to support the specification of fishery regulations for 2009. The update indicated that while the stock was overfished in 2007 (1.16 kg per tow, 21% of the biomass target of 5.54 kg per tow; Figure 16), the exploitation rate was at about the rebuilding target rate (9%; F = 0.10), suggesting that overfishing was not occurring in 2007. However, the stock rebuilding rate was slower than indicated by the FMP Amendment 14 projection, with the actual 2007 index (2006-2008 three-year average = 1.16 kg per tow) at only 56% of the forecast 2007 index (2.08 kg per tow).

An Index Method (AIM)

The AIM model (NFT 2008a) fits a relationship between time series of relative stock abundance, such as survey indices of abundance or biomass, and fishery catch data that might include landings and discards. Underlying the approach is a linear model of population growth, which characterizes the population response to varying levels of fishing mortality. If the underlying model is valid over the range of densities observed, AIM can be used to estimate the level of relative fishing mortality at which the population is likely to be stable (e.g., a proxy for

FMSY). The approach can be used to construct reference points based on relative abundance indices and catches, and to perform deterministic and stochastic projections to achieve a target stock size.

The basic calculations of the AIM model are two derived quantities, the Replacement Ratio (RR) and Relative F (RF). Replacement ratio is the ratio between the current year observed index and a smoothed value of the index over a given number of the current and previous years (typically 3 to 5), and is a measure of the trend in abundance or biomass of the population. Relative F is the ratio of the observed catch to a centered average index over a given number of years (typically 2 to 3). It should be noted that the application of any smoothing technique reflects a choice between signal and noise, with a greater degree of smoothing eliminating noise but possibly failing to detect a true change in signal (Rago 2001).

When fishing mortality rates exceed to capacity of a population to replace itself the population is expected to decline over time; likewise the population is expected to increase if fishing mortality rates are less than the capacity of a population to replace. In the AIM approach, the RR will have a stable point = 1 when the fishing mortality rate is in balance with recruitment and growth, resulting in a stable population. Robust regression techniques are used in AIM to estimate the RF ($RF_{threshold}$) corresponding to RR = 1. Values of RF in excess of $RF_{threshold}$ are therefore expected to lead to stock decline (i.e., fishing mortality exceeds FMSY), while RF values less than $RF_{threshold}$ would be expected to allow populations to increase. Randomization tests are used to test the null hypothesis that the input fishery catch and survey index time series represent a random ordering of observations with no underlying association, and that in turn the relationship between RR and RF is not spurious.

The AIM approach was tested with data for scup in the 2002 SAW 35 review (NEFSC 2002). An extended series of total catch beginning in 1963 and the NEFSC spring and fall biomass indices through 2001 were used as inputs. In the SAW 35 work, only the NEFSC fall series provided a statistically significant regression between the RR and RF, and results indicated that the RR first increased above 1.0 in 1996, and that the RF during 2000 was lowest of the time series. The SAW 35 work also indicted that re-examination of the reliance on the NEFSC spring survey series as the primary signal of stock abundance was warranted (NEFSC 2002).

The current AIM implementation for scup was tested over a range of degree of smoothing of both the RR and RF to explore the sensitivity of results to those inputs. Also, three different lengths of the extended catch time series (Table 19) were tested: beginning in 1963 (advent of the NEFSC trawl surveys), beginning in 1974 (to include the peak in NEFSC Surveys used as the basis for the current biomass reference point), and beginning in 1981 (to include the least number of assumptions for catch estimates). All of the available NEFSC and state agency survey series of stock biomass and abundance were initially tested for their utility in the AIM approach.

The best (i.e., a significant model at the p = 0.10 level) simple regression fits in AIM were provided by the NEFSC fall, URIGSO, NJBMF annual, and MADMF spring survey series (Figures 17-20). The MADMF and NJBMF series are too short to serve as the sole stock index for scup in the AIM model - neither series captures the historical peaks and trends in biomass. The 1974 and 1981 AIM run configurations suffer from the same shortcoming. The URIGSO, MADMF and NJBMF series also failed to satisfy the randomization test at the p = 0.10 level. These initial results indicated that only the NEFSC fall survey biomass index (Figures 17 and 19) provided acceptable fit statistics and other diagnostics within the AIM model framework.

In an attempt to include the recent information content of the multitude of state agency surveys as well as the historical perspective provided by the long-term NEFSC and URIGSO series, a model-based index including all of the index series in a GLM framework was developed. Alternative configurations included lognormal, Poisson, and negative binomial error distribution assumptions; Asurvey@ was used as the classification variable, with the Ayear@ classification variable coefficient acting as the index of abundance. The Working Group adopted the GLMALL index with Poisson error (Figure 21) for input to AIM based on the GLM model fit statistics and diagnostics. AIM results for the GLMALL index with Poisson error showed a significant regression model ($p < 0.10$) and feasible Relative F and Replacement Ratio results (Figure 22), but a failed randomization test.

These results suggest that the most appropriate AIM model would include only the NEFSC fall survey biomass index. However, the NEFSC spring and fall *Albatross IV* time series have ended, and even if reliably calibrated indices from the *Henry B. Bigelow* series can be developed (Figure 23), they will likely not be available for at least a few years. Thus, the Working Group concluded that the AIM results provided the impetus to explore a more complex statistical catch at age model (such as ASAP) that is better able to accommodate the numerous sources and relatively high uncertainty of both fishery and survey data for scup.

Age Structured Assessment Program (ASAP) Model

The fishery and research survey data for scup described earlier were used as input for the Age Structured Assessment Program (ASAP) statistical catch at age model in NFT version 2.0.17 (NFT 2008b). NEAMAP survey data were considered by the Data Poor Working Group but were not used to calibrate the scup population model. It was not clear that the NEAMAP data could serve as an abundance index yet given the very short survey time series and the high variance between seasons.

The ASAP model is able to estimate residuals (error) for the fishery catch components as well as for the survey indices used for calibration. The ASAP model also allows control in specifying the selection (partial recruitment) characteristics for both the fisheries and the surveys, in specifying the underlying stock-recruitment relationship, and in the relative emphasis of the different likelihood components that influence the model estimation results.

Initial Runs

The fishery catch data (aggregate catches in weight for 1963-2007; catches at age in number for 1984-2004) were input as four component fisheries (commercial landings, commercial discards, recreational landings, recreational discards; in aggregate weight and as number at age) and associated mean weights at age. Natural mortality (M) was set equal to 0.2, and maturity at age was set as in the SAW 27 assessment (NEFSC 1998) with proportions mature as follows: age 0 = 0.00, age 1 = 0.13, age 2 = 0.75, age 3 = 0.99, and age 4 and older = 1.00. In the initial ALL configuration, the following research survey abundance indices at age were used: NEFSC spring ages 1-4, NEFSC fall ages 0-4, NEFSC winter ages 1-4, CTDEP spring ages 1-6+, CTDEP fall ages 0-5+, NYDEC ages 0-1, and VIMS age 0. Aggregate biomass or abundance indices from the NEFSC winter, spring, and fall, MADMF spring and fall, RIDFW spring and fall, CTDEP spring and fall, NJBMF annual, and VIMS surveys were also used as input in initial runs. Fishery selectivity was estimated for two time periods: 1984-1996 and 1997-2007, with the break roughly coinciding with the advent of substantial regulatory changes in the fisheries (Amendment 8 in 1997 and Amendment 12 in 1998). Other model options (survey CVs, stock-recruit function CVs and lambdas, etc.) were configured to provide stable and feasible results. Alternative input data model configurations tested included a) only NEFSC surveys, b) only STATE surveys, and c) only NEFSC and URIGSO (NEC-URI) surveys.

The four initial model configurations (ALL, NEFSC, STATE, and NEC-URI) provided comparable time series trends in SSB and F through the late 1990s: high abundance and low F in the early 1960s, a decline and then rebuilding to a period of abundance in the late 1970s, and then a decline in abundance under high Fs in the mid-1980s to mid-1990s resulting in a period of low abundance in the late 1990s. The alternatives differed substantially in the development of the stock since 2000, and in the estimate of current abundance with respect to the previous peak in the late 1970s, mainly as a result of differing estimates of recruitment since the late 1990s (Figures 24-26). The STATE run provided the highest recent estimates of SSB, due to the scaling of recent large year classes (with the notable exception of 2006) about 50% higher than the ALL run and 100% higher than the NEFSC and NEC-URI runs. Comparison of the alternative estimates of SSB and F with ASAP internally calculated BRPs indicates that the stock in 2007 was about two to four times SSBMSY, with Fs at about 20-50% of FMSY (Figure 27).

Modifications to Survey Input Data

The initial runs indicated that the stock should be considered to be fully rebuilt with no overfishing. With a stock at that level of abundance, there is an expectation that both fishery and survey catches would reflect a robust age structure with significant numbers of older fish. There is evidence of expansion of the age structure of the fishery catch since about 2000 (Figures 3-6), likely reflecting the combined effects of a) increasing minimum retention sizes b) more restrictive trip limits in the fisheries, c) recent decreases in quotas/harvest limits and d) real increases in recruitment and subsequently SSB.

However, there is little evidence of substantial expansion of the age structure of the stock in the survey catches (Figures 8-10, 15), except for the CTDEP survey catches (Figures 13-14). Previous and current reviews of the scup research trawl survey data have noted that the catchability and/or availability of age 3 and older fish is likely reduced compared to age 0-2 fish. The NEFSC survey catches likely reflect this higher catchability of ages 0-2 relative to older fish (ages 3 and older), and so the aggregate biomass indices likely reflect mainly the abundance of ages 0-2, but not of ages 3 and older. Examination of the available length and age frequencies suggests the same properties likely apply to the MADMF, RIDFW, URIGSO, NYDEC, and ChesMMAP indices for scup. The CTDEP survey catches, however, are distributed across ages more in line with realistic total mortality rates, suggesting that the CTDEP survey older age indices (ages 3 and older) may be reflective of true abundance, with aggregate indices in turn more reflective of total stock biomass (Figures 13-14).

In an attempt to resolve the inconsistent signals provided by the fishery and survey catches, a number of modifications were made to the input survey data and to the manner in which the survey data are modeled in ASAP. For the NEFSC survey indices at age, input data were limited to the age 0-2 indices. The NEFSC long-term aggregate biomass indices were recompiled with a length cut-off at age 2 (winter = 22 cm; spring = 20 cm; fall = 23 cm; Figures 28-30), and selectivity (selex) within the ASAP model limited to ages 0/1 to 2. The consistency of rank order and trends between the original and modified NEFSC aggregate indices indicates that those series best index the abundance and biomass of ages 0/1 to 2.

For the MADMF, RIDFW, NJBMF, and URIGSO aggregate indices, selectivity within the ASAP model was also limited to ages 0/1 to 2. Alternative runs were made with different inputs and assumptions for the CTDEP indices, to test the inclusion of age 3 and older indices and aggregate indices, and correspondingly varying the selectivity of the aggregate indices. The newly modified runs are identified as:

Sep08_ALL:	All indices, all ages, aggregate index selex for ages 0/1 to 7+
SV0to2:	Use only age 0-2 indices, no aggregate indices
SV0to2_AGG0to2	Use only age 0-2 indices, aggregate indices selex for age 0/1 to 2
SV0to2_AGG0to2_CTALL:	Use all CT indices, CT aggregate indices selex for ages 0/1 to 7+

The modified runs generally provided a different recent pattern of stock biomass in relation to the early 1960s and late 1970s peaks compared to the four initial runs, and also higher recent biomass in absolute terms. The four initial run estimates of SSB in 2007 ranged from 55,000 mt to 140,000 mt (Figure 24); the four modified run estimates ranged from 90,000 mt to 180,000 mt (Figure 31). The Sep08_ALL run, which includes some additional input data series (URIGSO, ChesMMAP and updated NYDEC) and some modifications to initial settings, provided results closest to the initial ALL run.

The two modified runs with older ages excluded from both the at-age and aggregate indices (SV0to2 and SV0to2_AGG0to2) estimated higher recent recruitment and thus lower recent F and higher recent SSB than the Sept08_ALL run (Figures 31-33). The run including all ages in the CTDEP indices (SV0to2_AGG0to2_CTALL) estimated extremely high recent recruitments (three year classes > 300 million age 0 fish) and correspondingly low F and high SSB. The SV0to2_AGG0to2_CTALL run had the poorest diagnostics of the four runs, in terms of a) large residuals for many of the survey indices, b) relatively poor fits to the estimated commercial and recreational fishery aggregate discards, and c) relatively poor fits to the estimated commercial and recreational fishery discards at age. For those reasons, the SV0to2_AGG0to2_CTALL configuration was not considered further.

The other three runs had comparable residual patterns and fits to the estimated catches. Four objective function components, a) fishery total catch, b) fishery age compositions, c) survey indices (age compositions plus aggregate indices), and d) recruitment deviations, account for 99% of the total objective function for all four modified runs. With the SV0to2_AGG0to2_CTALL excluded, the remaining three runs had comparable objective function distribution and fit diagnostics. Figure 34 shows that restricting the input survey data to only the age 0-2 indices (run SV0to2) shifts more of the influence on the model solution to the fishery catch (total and age composition) components, compared to the other runs that also include aggregate indices (whether restricted to ages 0-2 or allowed to include older ages). The SV0to2 run does not include the long-term aggregate indices that are included in the Sep08_ALL and SV0to2_AGG0to2 runs, fishery independent data that increases the precision of historical stock size estimates in those runs. However, run Sep08_ALL includes indices at age 3 and older that are less likely to be reflective of true abundance than indices for ages 0-2. Therefore, by elimination of configurations with diagnostic or data fit concerns, the SV0to2_AGG0to2 run was carried forward for further examination of the sensitivity of the model to changes in configuration.

The next step was to examine the retrospective performance of the SV0t2_AGG0to2 run to judge its= potential utility to reliably monitor the stock. Six retrospective peels (a seventh, terminal year 2001 retrospective peel did not converge) indicated that the SV0to2_AGG0to2 run was stable with little retrospective pattern evident in SSB, F, or R (Figure 35).

Sensitivity to Fishery Catch Lambdas (Weighting Factors) and Time Series Length

Next, model sensitivity to fishery catch lambdas (the weighting or emphasis factors on the four aggregate fishery catch components) was examined. The initial and modified runs described earlier were made with lambdas set at 0.10 (i.e., CV = 10%) for all four aggregate fishery catch components. Further sensitivity runs were made with lambda set at 0.10 for commercial landings and 0.20 for the commercial discards, recreational landings, and recreational discards (run CAT20); with 0.10 for commercial landings and 0.30 for the commercial discards, recreational landings, and recreational discards (run CAT30); with 0.10 for commercial landings and 0.60 for the commercial discards, recreational landings, and recreational discards (run CAT60); with 0.10 for commercial landings and lambda changing from 0.30 to 0.10 in 1981 for the commercial discards, recreational landings, and recreational discards (run CAT30to10); and with 0.10 for commercial landings and lambda changing from 0.60 to 0.30 in 1981 for the commercial discards, recreational landings, and recreational discards (run CAT60to30). The 1980/1981 time split coincides with the more reliable estimation of recreational catches.

The results of the SV0to2_AGG0to2 run configuration were sensitive to the catch lambda specifications. The 1980/1981 time split in the CAT30to10 and CAT60to30 runs did not have an important effect on the results. However, the change from lambdas of 0.10 to lambdas of 0.20 and higher did have an important effect on SSB results, as reflected by the Ashift@ from the initial SV0to2_AGG0to2 and CAT30to10 runs (all recent catch lambdas set at 0.10) to the runs with recent commercial discards, recreational landings, and recreational discards lambdas set at 0.20 or higher. Results for F and R were less strongly affected. Lambdas reflecting greater uncertainty of the magnitude of commercial discards and recreational catch resulted in lower recent estimates of SSB and a different relationship between current estimates and previous peaks in SSB in the 1960s and late 1970s (Figure 36-38). This result occurs because the influence of the survey indices in these run configurations is mainly restricted to ages 0-2, and so the magnitude and uncertainty of the input fishery catches has the strongest influence on estimates of recent SSB.

The input assumptions for the age range for which the survey indices can be considered reliable, and the estimate or assumption for the uncertainty of the input fishery catch, both have strong influence on the model results. Based on the work presented earlier, an assumption that most survey indices are likely to be reflective of true abundance only for ages 0 to 2 is appropriate - hence the subsequent work using run SV0to2_AGG0to2 as a basis. Further investigation of the empirical precision of the commercial fishery discards and recreational catches indicated that the precision of commercial fishery discards averaged (unweighted average of annual PSE) 39% for 1997-2007 (Table 4) and 32% for the entire NEFSC Observer Program sample period (1989-2007). The precision of recreational fishery landings (catch types A+B1 numbers) during 1981-2007 averaged 10%; the precision of recreational fishery discards (catch type B2 numbers) during 1981-2007 averaged 12%. A new run, BASE_Nov08, was configured to reflect this empirical information about the uncertainty of the fishery catch for scup, with commercial landings lambda assumed to be 0.10, commercial discards lambda set at 0.32, recreational landings lambda set at 0.10, and recreational discards lambda set at 0.12; for all years 1963-2007. The results of the BASE_Nov08 run were similar to the sensitivity runs with commercial discard and recreational catch lambdas of 0.20 and greater, indicating that the current magnitude of SSB is about the same as in the 1960s and higher than in the late 1970s, with very low current F and several very large year classes recruiting to the stock since 2000 (Figure 39-41).

A sensitivity exercise was conducted to test the influence of the length of the catch time series modeled. The BASE_Nov08 time series includes a time series of fishery catches extended back to 1963, using ratios to extend the commercial discards (1963-1988) and recreational landings and discards (1963-1980; Table 19). The BASE81_Nov08 run was configured to include only fishery and survey data from 1981-2007, the time period for which most of the fishery catches are reported or estimated from sampling, rather than extrapolated from ratios. The shorter time series provided 10-30% lower estimates of SSB during the early 1980s, and 10-20% higher estimated of SSB since 2003, when compared to the 1963-2007 BASE_Nov08 run (Figure 42). Patterns and levels of F and R were very similar, however (Figures 43-44). The BASE_Nov08 run SSB varied from about 103,000 mt in 1963 to a time-series low of 4,100 mt in 1995 to a time-series high of 107,100 mt in 2007; Fs varied from a high of 1.13 in 1993 to a low of 0.06 in 2007; recruitment varied from a low of 32 million age 0 fish in 1996 to a high 367 million in 2007. The BASE81_Nov08 run SSB varied from a low of 4,200 mt in 1995 to a high of 122,700 mt in 2007; Fs varied from a high of 1.14 in 1994 to a low of 0.06 in 2007; recruitment varied from a low of 35 million age 0 fish in 1996 to 308 million in 2007. Biological Reference Points calculated from the BASE_Nov08 and BASE81_Nov08 runs are presented in Figure 45. Given the similarity of the results, the November 2008 Working Group decided to use to the BASE_Nov08 runs with the full 1963-2007 time series as the basis for further model development.

Sensitivity to 2002 Survey and Commercial Discard Estimates

The next step in model development was to add preliminary fishery catch at age estimates for the four fishery fleets for 2004-2006, which provided model run configuration BASE_C2006. The November 2008 Working Group reviewed the diagnostics of the BASE_C2006 run in detail, and noted that some components of the calendar year 2002 survey data and the 2002 commercial fishery discard aggregate estimate provided large residuals (Figure 46-48). The unusually high values for many survey indices in 2002 has been noted previously, and is presumed to result mainly from increased availability of fish to the surveys, especially during the first half of 2002, rather than true increases in abundance (e.g., Figures 7-8, 11). The same type of availability event may have affected the 2002 commercial fishery discard sampling, resulting in higher than usual discard rates and increased estimated discards at age in 2002 (Figure 4). To explore the sensitivity of the ASAP model for scup to these data, two new runs were configured. The first, BASE_C2006_No02SV, dropped all the calendar year 2002 survey indices (at age and aggregate) from the model fit. The second, BASE_C2006_No02SV_NoCD02, also dropped the 2002 commercial fishery discard estimates at age and used the average of the 2001 and 2003 estimates as a substitute for the 2002 aggregate discard weight.

Figures 49-51 summarize the results of these BASE_C2006 runs. The BASE_C2006 run with fishery catch at age through 2006 provided results very similar to the BASE_Nov08 run with fishery catch at age through 2004, with SSB in 2007 estimated at just over 100,000 mt, F in 2007 estimated at about 0.05, and the large recent recruitments in 2000 and 2007 estimated at 300-400 million fish. Dropping the 2002 survey indices in the BASE_C2006_No02SV run increased the SSB in 2007 to about 125,000 mt, substantially reduced the 2002 recruitment estimate from about 296 million to 156 million fish, changed the pattern of recruitment so that the 1999 year class (212 million) was larger than the new estimate of the 2000 year class, and increased the estimated of recruitment in 2007 to about 376 million fish. Dropping the 2002 Commercial Discards at age and substituting for the high 2002 aggregate discard in weight in the BASE_C2006_No02SV_No02CD run had relatively little additional effect on results, other than eliminating the large residual for the 2002 estimate, and so the November 2008 Working Group decided to retain the original 2002 commercial fishery discard estimates in subsequent model runs.

The November 2008 Working Group extensively debated whether it was appropriate to exclude the 2002 survey data in a BASE case run for subsequent development. It was noted that the model Acompensated@ for the missing data, changing the rank order of recruitments over the last decade, and increasing the size of the 2007 year class. It was also noted that there may have been other abrupt, but substantial Apositive availability@ events that have occurred in the past (e.g., NEFSC spring survey in 1977, NEFSC fall survey in 1976, 1989, and 1999; Table 20, Figure 7), that were not being considered for exclusion from the analysis. Likewise, there may have been several abrupt, but substantial Anegative availability@ events that have occurred (e.g., NEFSC spring 2003, 2005, and 2007, NEFSC fall 2005), and no exclusion was being considered for those possible events. The November 2008 Working Group found it difficult to develop an objective justification for the exclusion of the 2002 survey data, and so they were retained in subsequent model runs.

Alternative Assumptions for Natural Mortality (M)

A range of alternative assumptions for the instantaneous natural mortality rate (M) was tested in a series of runs derived from the BASE_C2006 run. The values ranged from 0.10 to 0.40, in runs BASE_C2006_M10 to BASE_C2006_M40. A sensitivity profile indicated that the ASAP model for scup fit best (lowest total likelihood value) at M = 0.10 (Figure 52). This was considered a counter-intuitive result, as most members of the November 2008 Working Group expected a higher value of M (e.g., in the 0.3-0.4 range) to perform better, given the maximum observed age in survey and fishery samples of 14 years, and configuration of the model with an oldest age group of 7-plus. Those expectations were not born out by the results, however, and so the November 2008 Working Group retained the initial assumption of M = 0.2 for all ages in subsequent model runs.

Update with final 2004-2007 Catches: BASE_C2007 runs

Final fishery catch at age estimates for 2004-2007 became available in mid-November 2008, after the November 2008 Working Group meeting, and model runs including these data were called BASE_C2007 runs. In the BASE_C2007 and all previous runs, the same mid-year mean weights at age were used for the total catch, January 1 total stock biomass, and June 1 SSB mean weights at age. Once the fishery catches at age were finalized through 2007, mean weights for the January 1 and SSB biomass were re-calculated using the Rivard method (NFT 2008c), to provide run BASE_C2007_RIV. As a final model tuning step, the ratio of the estimated Effective Sample Sizes (ESS) to the input ESS was calculated for the four fishery fleets, and the ratio used to adjust the ESS for the final run, BASE_C2007_T1.

Figures 53-55 summarize comparative results for the runs configured during and since the November 2008 Working Group meeting. The addition of the preliminary 2004-2006 fishery catches at age to the BASE_Nov08 run to create the BASE_C2006 run had a very minor effect on the results. The addition of the final 2004-2007 catches at age to create the BASE_C2007 run had a slightly larger effect on recent trends, increasing the SSB in 2007 from 103,000 mt to about 113,000 mt, and increasing recruitment in 2000 (from 297 million to 302 million) while decreasing recruitment in 2007 (from 364 million to 305 million). Re-calculation of the mean weights at age in the BASE_C2007_RIV run affected only the SSB estimates by increasing the recent estimates by a few percent, with the SSB in 2007 increasing from 113,000 mt to 121,000 mt. The final tuning of the ESS created the final run BASE_C2007_T1, with a slight decrease in SSB and R in recent years compared to the previous run, and an estimate of SSB in 2007 of 119,000 mt, F of 0.054, and recruitment in 2007 of 308 million fish. The December 2008 Northeast Data Poor Stocks Peer Review Panel accepted the BASE_C2007_T1 ASAP run as the basis for subsequent calculation of biological reference points and status evaluation. Run BASE_C2007_T1 did not exhibit substantial retrospective patterns in SSB, F, or R (Figures 56-58).

Summary estimates, estimated January 1 stock size at age in numbers, and estimated fishing mortality (F) at age from the accepted BASE_C2007_T1 run for 1984-2007 (the years with input fishery catches at age) are provided in Tables 32-34. Spawning stock biomass (SSB) decreased from about 102,000 mt in 1963 to about 50,000 mt in 1969, then increased to about 75,000 mt during the late 1970s (Figure 53). SSB declined through the 1980s and early 1990s to only 4,000 mt in 1995. With greatly improved recruitment and low fishing mortality rates since 2000, SSB has steadily increased since to about 113,000 mt in 2007 (Table 32, Figure 53). There is an 80% chance that SSB in 2007 was between 111,204 and 130,120 mt (Figure 59). Fishing mortality varied between F = 0.100 and F = 0.274 during the 1960s and 1970s (Figure 54). Fishing mortality increased steadily during the 1980s and early 1990s, peaking at F = 1.120 in 1994. Fishing mortality decreased rapidly after 1994, falling to less than F = 0.100 since 2004, with F in 2007 = 0.054 (Table 32, Figure 54). There is an 80% chance that F in 2007 was between 0.048 and 0.060 (Figure 60). Recruitment at age 0 averaged 91.4 million fish during 1963-1983, the period during which recruitment estimates are influenced mainly by the internal ASAP stock-recruitment relationship (Figure 55). Since 1984, recruitment estimates are influenced mainly by the fishery and survey catches at age, and recruitment at age 0 averaged 119.6 million fish during 1984-2007, with the 2000 and 2007 year classes estimated to be the largest of the time series, at 311.2 and 307.9 million age 0 fish (Table 32, Figures 55 and 61).

Recommended Biological Reference Points and Status Determination

The December 2008 Northeast Data Poor Stocks Peer Review Panel accepted the BASE_C2007_T1 ASAP run as the basis for biological reference points and status determination for scup. Biological reference points were calculated using the non-parametric yield and SSB per recruit/long-term projection approach recently adopted for summer flounder (NEFSC 2008a) and New England groundfish stocks (NEFSC 2008b). In the yield and SSB per recruit calculations, the most recent five year averages were used for mean weights and fishery partial recruitment pattern (Table 35). For the projections, the cumulative distribution function of the 1984-2007 recruitments (corresponding to the period of input fishery catches at age) was re-sampled to provide future recruitment estimates (mean = 117.2 million age 0 fish).

The Peer Review Panel recommended $F_{40\%}$ as the proxy for F_{MSY}, and the corresponding $SSB_{F40\%}$ as the proxy for SSB_{MSY}. The F40% proxy for F_{MSY} = 0.177, the proxy estimate for SSB_{MSY} = 92,044 mt, and the proxy estimate for MSY = 16,161 mt (13,134 mt of landings, 3,027

mt of discards). The stock biomass threshold of ½ SSB_{MSY} = ½ $SSB_{40\%}$ = 46,022 mt = 101.461 million lbs.
The 2007 F estimate of 0.054 is 31% of F_{MSY} = 0.177, indicating no overfishing was occurring. The 2007 SSB estimate of 119,343 mt is 30% above SSB_{MSY} = 92,044 mt, indicating the stock was not overfished. Total catch (landings + discards) was 7,867 mt in 2007, about 49% of MSY (Table 36). Estimates of biomass and catch reference points corresponding to F_{MAX} and $F_{35\%}$ are also listed in Table 36 for comparison.

Uncertainty and Risk for Scientific and Statistical Committees (SSCs) to Consider
The accepted ASAP model of scup population dynamics and recommended BRPs provides a more stable tool for monitoring stock status and specifying annual fishery regulations than the current single index-based model. The ASAP model integrates a broad array of fishery and survey input data and should be less sensitive to inter-annual changes in any single data component than the current model. The accepted model results and recommended BRPs indicate that the stock was above the SSB_{MSY} proxy and being fished at below the F_{MSY} proxy in 2007. This status represents a significant change from the July 2008 biomass status update, which indicated that the stock was overfished in 2007 (NEFSC spring SSB three-year average index = 1.16 kg per tow, 21% of the biomass target of 5.54 kg per tow) and rebuilding more slowly than indicated by the Amendment 14 projection (see Section 3). The current REI proxy for F did indicate that F in 2007 was low (about 0.10) and therefore was not experiencing overfishing, in accord with the accepted ASAP model.

The 2007 stock abundance indicated by the accepted model is the result of historically low fishing mortality rates and historically high levels of recruitment since about 2000 (Figures 53-55). Age 0 fish accounted for about 40% of the stock size in 2007 due to the large size of the 2007 year class, but the relative percentages of the age 1 and older fish are within of few percent of what might be expected in the stock if it was fished at Fmax = 0.283 over the long-term (Figure 62). The age 7+ fish accounted for about 6% of the stock size in 2007. The model results indicate that stock has not been fished at low levels of F long enough to accumulate as high a percentage in the age 7+ group (16%) as would be expected if fished at F = 0.05 over the long-term (Figure 62). Since 2000, a high proportion of the SSB has accumulated at ages 3 and older (those expected to be fully mature). The percentage of SSB in 2007 at fully mature ages 3-6 (56%) is near what would be expected if the stock were fished at F = 0.050 over the long-term (46%), while the age 7+ fish accounted for about 35% of the SSB in 2007 (Figure 63).

A retrospective look at historical stock assessments for scup shows that the accepted ASAP model estimates of SSB and R are comparable to those previously estimated for the same time period in the 1995, 1997 and 1998 assessments using ADAPT VPA; estimates of F are somewhat higher in the VPA assessments (NEFSC 1995, 1997, 1998) (Figures 64-66). The 1995 SAW19 assessment was the last accepted peer-reviewed analytical assessment. The analytical components of the 1997 and 1998 assessments were not accepted as valid bases for assessing the stock. The historical analyses used input fishery and research survey data time series beginning in 1984.

The recommended MSY proxy for scup in terms of total catch is 16,161 mt (35.6 million lbs), with total landings of 13,134 mt (29.0 million lbs) and total discards of 3,027 mt (6.7 million lbs). The extended catch series estimated for scup (Table 19) indicates that this MSY proxy is a feasible estimate. Total fishery catch is estimated to have averaged about 34,000 mt

(75.0 million lbs) during 1960-1965, while reported commercial landings alone averaged about 19,000 mt (41.9 million lbs) in that period (Table 19 and Figure 1).

While the accepted long-term MSY estimate appears feasible given historical evidence from the fishery, managers may wish to take an adaptive approach to the specification of fishery quotas in the short-term. Total fishery landings over the last five years (2003-2007) have averaged 6,214 mt (13.7 million lbs). If the stock is fished at F40% = 0.177 over the long-term, the corresponding annual total MSY landings would be 13,134 mt (29.0 million lbs), more than double the recent five year average. The Peer Review Panel recommended that "…rapid increases in quota to meet the revised MSY would be unwarranted given uncertainties in recruitments. A more gradual increase in quotas is a preferred approach reflective of the uncertainty in the model estimates and stock status."

Research Recommendations

Short term analytical tasks

a) Evaluation of indicators of potential changes in stock status that could provide signs to management of potential reductions of stock productivity in the future would be helpful.
b) A management strategy evaluation of alternative approaches to setting quotas would be helpful.

Long term data and analytical needs

a) Current research trawl surveys are likely adequate to index the abundance of scup at ages 0 to2. However, the implementation of new standardized research surveys that focus on accurately indexing the abundance of older scup (ages 3 and older) would likely improve the accuracy of the stock assessment.
b) Continuation of at least the current levels of at-sea and port sampling of the commercial and recreational fisheries in which scup are landed and discarded is critical to adequately characterize the quantity, length and age composition of the fishery catches.
c) Quantification of the biases in the catch and discards, including non-compliance, would help confirm the weightings used in the model. Additional studies would be required to address this issue.
d) The commercial discard mortality rate was assumed to be 100% in this assessment. Experimental work to better characterize the discard mortality rate of scup captured by different commercial gear types should be conducted to more accurately quantify the magnitude of scup discard mortality.

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