

**A. SUMMER FLOUNDER
Stock Assessment Update
And Biological Reference Point Estimation**

**A report of the
SAW Southern Demersal Working Group (SDWG), SAW-41**

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EXECUTIVE SUMMARY

The Terms of Reference (ToR) for SAW 41 were completed as summarized below:

- 1) Update the summer flounder assessment models (i.e. ADAPT VPA and AGEPRO projection) using the same configurations as those used in the 2004 SAW Southern Demersal Working Group (WG) assessment update.

The assessment was updated using fishery catches through 2004, survey indices through 2004/2005, and the same ADAPT VPA and AGEPRO model configurations as in the 2004 update. Fully recruited fishing mortality (ages 3-5) was estimated by ADAPT VPA to be 0.40 in 2004, above the current overfishing definition reference point ($F_{threshold} = F_{max} = 0.26$) and above the updated estimate of $F_{threshold} = 0.276$. Total stock biomass on Jan. 1, 2005 was estimated to be 54,900 mt, slightly above the biomass threshold (53,200 mt). Forecasts indicate that the currently specified TAL of 13,744 mt (30.3 million lbs) in 2005 will result in a median F in 2005 = 0.40, and the currently specified TAL of 14,969 mt (33.0 million lbs) in 2006 will result in a median F in 2006 = 0.41.

- 2) Estimate biological reference points derived by yield and SSB per recruit analysis and by stock-recruitment modeling, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.
- 3) Consider the recommendations of the MAFMC Science and Statistical Committee (SSC) 2001 peer review of the summer flounder Overfishing Definition in developing the analyses described in ToR 2. The major recommendations were to explore other proxies (besides F_{max}) to F_{MSY} , to continue stock-recruitment model development as additional stock-recruit estimates become available, and to monitor and utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) as they become available.

The SDWG updated the biological reference points for summer flounder using both parametric and empirical non-parametric approaches to derive F_{MSY} and B_{MSY} or their

proxies, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. The SDWG also followed the recommendations of the MAFMC SSC 2001 Overfishing Definition review to utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) in estimating the biological reference points. The mean weights in the catch and stock, maturity schedule, and partial recruitment pattern have been updated and broadened to include data from 1992-2004. This covers the year range for individually measured and weighed fish sampled in NEFSC research surveys, and includes the latest fishery data available. Also in line with the SSC 2001 recommendations, stock-recruitment estimates were updated to include the results of the current assessment update.

*The SDWG recommended adoption of biological reference points from the empirical non-parametric approach for summer flounder. Updated FMP biological reference points would be $F_{MSY} = F_{max} = 0.276$, $MSY = 19,072$ mt (42.0 million lbs), and $TSB_{MSY} = 92,645$ mt (204.2 million lbs; Table 3-4). The biomass threshold of $0.5 * TSB_{MSY} = 46,323$ mt (102.1 million lbs).*

- 4) Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in previous SARC and WG reviewed assessments.

Of the thirteen Research Recommendations (RR) listed in the 2003 assessment, significant progress or completion has been achieved for seven items (RRs # 1, 2, 6, 7, 8, 9, & 10). There has been little or no progress made for the remaining six research recommendations (RRs # 3, 4, 5, 11, 12, & 13). Five new research recommendations were developed during the 2005 SDWG meeting.

1.0 INTRODUCTION

The following Terms of Reference were addressed for summer flounder:

- 1) Update the summer flounder assessment models (i.e. ADAPT VPA and AGEPRO projection) using the same configurations as those used in the 2004 SAW Southern Demersal Working Group (WG) assessment update.

WG Response: This ToR was completed; see Section 2) Summer Flounder Assessment Summary for 2005. The updated assessment results were used as inputs for the models used in responding to ToR 2 & 3.

- 2) Estimate biological reference points derived by yield and SSB per recruit analysis and by stock-recruitment modeling, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.

WG Response: This ToR was completed, and the results were used in formulating WG recommendations for updated values in Section 3) Biological Reference Points for Summer Flounder.

- 3) Consider the recommendations of the MAFMC Science and Statistical Committee (SSC) 2001 peer review of the summer flounder Overfishing Definition in developing the analyses described in ToR 2. The major recommendations were to explore other proxies (besides F_{\max}) to F_{MSY} , to continue stock-recruitment model development as additional stock-recruit estimates become available, and to monitor and utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) as they become available.

WG Response: This ToR was completed, as direct estimates of F_{MSY} were calculated from stock-recruitment models, and updated information on the population dynamics of summer flounder (1992-2004) were included as inputs to the models presented in Section 3) Biological Reference Points for Summer Flounder.

- 4) Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in previous SARC and WG reviewed assessments.

WG Response: This ToR was completed; see Section 4) Research Recommendations for Summer Flounder.

2.0 SUMMER FLOUNDER ASSESSMENT SUMMARY FOR 2005

State of Stock: The summer flounder stock is not overfished, but overfishing is occurring relative to the biological reference points. The fishing mortality rate has declined from 1.32 in 1994 to 0.40 in 2004 (Figure 2-1). The 80% confidence interval for F in 2004 ranges from 0.34 to 0.49. Retrospective analysis shows that the current assessment method tends to underestimate recent fishing mortality rates (Figure 2-4). The overfishing reference point $F_{\text{threshold}} (= F_{\text{max}})$ was previously estimated to be 0.263 (Terceiro 1999; MAFMC 1999) (Figures 2-1, 2-3). For the present assessment, the updated estimate of $F_{\text{threshold}} (= F_{\text{max}})$ is 0.276 (Figures 2-1, 2-3).

Total stock biomass (TSB) has increased substantially since 1989, and was estimated to be 54,900 mt on January 1, 2005. The 80% confidence interval for total stock biomass on January 1, 2005 ranged from 49,300 to 62,100 mt. The biomass threshold reference point ($\frac{1}{2}TSB_{\text{MSY}}$) was previously estimated to be 53,200 mt (Terceiro 1999; MAFMC 1999) (Figures 2-2, 2-3). For the present assessment, the updated estimate of the biomass threshold ($\frac{1}{2}TSB_{\text{MSY}}$) is 46,323 mt (Figures 2-2, 2-3).

Spawning stock biomass (SSB; Age 0+) declined 72% from 1983 to 1989 (18,800 mt to 5,200 mt), but with improved recruitment and decreased fishing mortality has increased to 38,600 mt in 2004 (Figure 2-2). Retrospective analysis shows a tendency to overestimate the SSB in the most recent years (Figure 2-4). The age structure of the spawning stock has expanded, with 75% at ages 2 and older, and 16% at ages 5 and older (Figure 2-5).

The arithmetic average recruitment from 1982 to 2004 is 38 million fish at age 0, with a median of 33 million fish. The 2004 year class is currently estimated to be at the median of 33 million fish (Figure 2-2, 2-6). Retrospective analysis shows that the current assessment method tends to overestimate the abundance of age 0 fish in the most recent years (Figure 2-4).

Forecasts for 2005-2006: Stochastic forecasts were conducted, incorporated uncertainty in 2005 stock sizes from survey variability, and assumed current discard to landings proportions. If landings in 2005 are 13,744 mt (30.2 million lbs) and discards are 1,269 mt (2.8 million lbs), the forecasts estimate a median F in 2005 = 0.40 and a median total stock biomass on January 1, 2006 of 59,900 mt, above the biomass threshold of $\frac{1}{2}TSB_{\text{MSY}} = 53,200$ mt. (Figure 2-3). Landings of 14,969 mt (33.0 million lbs) and discards of 1,400 mt (3.1 million lbs) in 2006 provide a median F in 2006 = 0.41 and a median total stock biomass level on January 1, 2007 of 63,800 mt (Figure 2-3). A subsequent reduction in fishing mortality in 2007 to $F = 0.263$, the reference point, is forecast to yield landings of 10,853 mt (23.9 million lbs).

**Forecast Table: 2005 Landings = 13,744 mt
2005-2007 median recruitment from 1982-2004 VPA estimates (33.1million)**

Forecast medians (landings, discards, and total stock biomass (TSB) in '000 mt)

2005				2006				2007			
TSB	F	Land	Disc	TSB	F	Land	Disc	TSB	F	Land	Disc
54.9	0.40	13.7	1.3	59.9	0.41	15.0	1.4	63.8	0.26	10.9	1.0

Catch and Status Table (weights in '000 mt, recruitment in millions, arithmetic means): Summer Flounder

Year	1998	1999	2000	2001	2002	2003	2004	Max ²	Min ²	Mean ²
Commercial landings	5.1	4.8	5.1	5.0	6.6	6.5	7.8	17.1	4.0	8.3
Commercial discards	0.4	1.5	0.7	0.5	0.4	0.5	0.2	1.5	0.2	0.7
Recreational landings	5.7	3.8	7.1	5.3	3.6	5.3	4.8	12.7	1.4	5.3
Recreational discards	0.5	0.7	0.9	1.2	0.7	0.7	1.0	1.2	0.1	0.5
Catch used in assessment	11.7	10.8	13.8	12.0	11.3	13.0	13.8	26.5	8.0	14.6
Commercial quota	4.9	4.9	4.9	4.6	6.6	6.3	7.6			
Recreational harvest limit	3.4	3.4	3.4	3.3	4.4	4.2	5.1			
Spawning stock biomass ¹	17.8	16.5	19.4	25.5	29.4	36.4	38.6	38.6	5.2	16.5
Recruitment (age 0)	31.0	29.4	35.9	32.8	38.1	27.5	33.1	80.3	13.0	38.0
Total stock biomass ³	32.0	29.1	27.9	31.4	39.5	46.4	53.1	53.1	16.1	32.7
F (ages 3-5)	0.97	0.99	0.86	0.65	0.46	0.43	0.40	2.07	0.40	1.32
Exploitation rate	57%	58%	53%	44%	34%	33%	30%	82%	23%	68%

¹At the peak of the spawning season (i.e., on November 1), ages 0-7+ . ²Over period 1982-2004 ³On January 1

Stock Distribution and Identification: The Mid-Atlantic Fishery Management Council (MAFMC) and Atlantic States Marine Fisheries Commission (ASMFC) Fishery Management Plan for summer flounder defines the management unit as all summer flounder from the southern border of North Carolina northeast to the US-Canada border. For assessment purposes, the definition of Wilk et al. (1980) of a unit stock extending from Cape Hatteras north to New England has been accepted in this and previous assessments (NEFSC 2002a). A recent summer flounder genetics study, which revealed no population subdivision at Cape Hatteras (Jones and Quattro 1999), is consistent with the definition of the current management unit. A recent consideration of summer flounder stock structure incorporating new tagging data concluded that evidence supported the existence of stocks north and south of Cape Hatteras, with the stock north of Cape Hatteras possibly composed of two distinct spawning aggregations, off New Jersey and Virginia-North Carolina (Kraus and Musick, 2003). The conclusions of Kraus and Musick (2003) are consistent with the current assessment unit.

Catches: Total landings peaked in 1983 at 26,100 mt. During the late 1980s and into 1990, landings declined markedly, reaching 4,200 mt in the commercial fishery in 1990 and 1,400 mt in the recreational fishery in 1989. Total landings were only 6,500 mt in 1990. Reported 2004 landings in the commercial fishery were 7,748 mt, about 2% over the adjusted commercial quota.

Commercial discard losses are estimated from fishery observer data and have recently constituted 5%-10% of the total commercial catch, assuming a discard mortality rate of 80%. Estimated 2004 landings in the recreational fishery were 4,841 mt, about 5% under the recreational harvest limit. Recreational discard losses have recently comprised 10%-15% of the total recreational catch, assuming a discard mortality rate of 10%. Total commercial and recreational landings in 2004 were 12,589 mt, and total catch was estimated at 13,832 mt (Figure 2-1).

Data and Assessment: An analytical assessment (VPA) of commercial and recreational total catch at age (landings plus discards) was conducted. The natural mortality rate (M) was assumed to be 0.2. Indices of recruitment and stock abundance from NEFSC winter, spring, and autumn; Massachusetts spring and autumn; Rhode Island; Connecticut spring and autumn; Delaware; and New Jersey trawl surveys were used in VPA tuning in an ADAPT framework (NFT 2005). Recruitment indices from surveys conducted by the states of North Carolina, Virginia, and Maryland were also used in the VPA tuning. The current VPA tuning configuration is the same as that in the 2002 SAW 35 (NEFSC 2002a) and in the 2003 and 2004 SAW Southern Demersal Working Group assessments (Terceiro 2003, SDWG 2004).

Biological Reference Points: Biological reference points for summer flounder are based on a yield per recruit model (Thompson and Bell 1934). The yield per recruit analysis conducted for the 1999 assessment (Terceiro 1999) indicated that $F_{\max} = 0.263$, which was used as a proxy for $F_{\text{threshold}}$ (Figure 2-3). No value for F_{target} has been defined for summer flounder. The current Fishery Management Plan (FMP) Amendment 12 stock biomass reference points were estimated as the product of yield per recruit (0.552 kg per recruit) and total stock biomass per recruit (2.813 kg per recruit) at $F_{\max} = 0.263$, and median recruitment of 37.8 million fish per year (1982-1998; from Terceiro (1999)). Yield at F_{\max} , used as a proxy for MSY , was estimated to be 20,900 mt (46 million lbs), and the corresponding stock biomass, used as a proxy for B_{MSY} , was estimated to be 106,400 mt (235 million lbs; Figure 2-3). In the review of the 2002 stock assessment, SARC 35 concluded that updating these reference points was not warranted at that time (NEFSC 2002a).

For present assessment, updated input data (1992-2004 average mean weights, maturities, and partial recruitment) were used to revise the yield and biomass per recruit analysis. The updated 1982-2004 VPA provided an estimate of median recruitment for summer flounder of 33.1 million age 0 fish. The revised estimates of the biological reference points are $F_{MSY} = F_{\max} = 0.276$, $MSY = 19,072$ mt (42.0 million lbs), and $TSB_{MSY} = 92,645$ mt (204.2 million lbs). The revised estimate of the biomass threshold, $\frac{1}{2}TSB_{MSY}$, is 46,323 mt (102.1 million lbs).

Fishing Mortality: Fishing mortality calculated from the average of the currently fully recruited ages (3-5) was high during 1982-1997, varying between 0.9 and 2.2 (55%-83% exploitation), far in excess of the Amendment 12 overfishing definition, $F_{\text{threshold}} = F_{\max} = 0.26$ (21% exploitation; Figure 2-1). The fishing mortality rate has declined substantially since 1997 and was estimated to be 0.40 (30% exploitation) in 2004. The 80% confidence interval for F in 2004 ranged from 0.34 to 0.49. Retrospective analysis shows that the current assessment method tends to underestimate recent fishing mortality rates (Figure 2-4).

Total Stock Biomass: Total stock biomass has increased substantially since 1989, and in 2005 total stock biomass was estimated to be 54,900 mt, slightly above the Amendment 12 biomass threshold (Figures 2-2, 2-3). The 80% confidence interval for total stock biomass in 2005 ranged from 49,300 to 62,100 mt.

Recruitment: The arithmetic average recruitment from 1982 to 2004 is 38 million fish at age 0, with a median of 33 million fish. The 1982 and 1983 year classes are the largest in the VPA time series, at 74 and 80 million fish. Recruitment declined from 1983 to 1988, with the 1988 year class the weakest at only 13 million fish. Recruitment since 1988 has generally improved. The 2003 year class is currently estimated to be below average at 27 million fish. The 2004 year class is currently estimated to be at the median of 33 million fish (Figures 2-2, 2-6). Retrospective analysis shows that the current assessment method tends to overestimate the abundance of age 0 fish in the most recent years (Figure 2-4).

Spawning Stock Biomass: Spawning stock biomass (SSB; Age 0+) declined 72% from 1983 to 1989 (18,800 mt to 5,200 mt), but with improved recruitment and decreased fishing mortality has increased to 38,600 mt in 2004 (Figure 2-2). Retrospective analysis shows a tendency to overestimate the SSB in the most recent years (Figure 2-4). The age structure of the spawning stock has expanded, with 75% at ages 2 and older, and 16% at ages 5 and older (Figure 2-5). Under equilibrium conditions and at $F_{\max} = 0.263$ from Amendment 12, about 85% of the spawning stock biomass would be expected to be ages 2 and older, with 50% at ages 5 and older (Figure 2-5). Similar results for the long-term population structure are derived using the updated $F_{\max} = 0.276$.

Special comments: Major sources of assessment uncertainty

- 1) There is persistent retrospective underestimation of fishing mortality in the assessment.
- 2) The landings from the commercial fisheries used in this assessment assume no under reporting of summer flounder landings. Therefore, reported landings from the commercial fisheries should be considered minimal estimates.
- 3) The recreational fishery landings and discards used in the assessment are estimates developed from the Marine Recreational Fishery Statistics Survey (MRFSS). While the estimates of summer flounder catch are among the most precise produced by the MRFSS, they are subject to possible error. The proportional standard error (PSE) of estimates of summer flounder total landings in numbers has averaged 7%, ranging from 26% in 1982 to 3% in 1996, during 1982-2004.
- 4) The length and age composition of the recreational discards are based on data from a limited geographic area (Long Island, New York, 1988-1992; Connecticut, 1997-2004, New York party boats 2000-2004, ALS releases focused in New York and New Jersey, 1999-2004). Sampling of recreational fishery discards on an annual, synoptic basis is needed.

5) The allocation of commercial landings to water area and the measure of commercial fishing effort used in the estimate of discards both rely on information self-reported by commercial fishermen in Vessel Trip Reports (VTR), which are subject to possible error.

3.0 BIOLOGICAL REFERENCE POINTS FOR SUMMER FLOUNDER

Introduction

The calculation of biological reference points for summer flounder based on yield per recruit analysis using the Thompson and Bell (1934) model was first detailed in the 1990 Stock Assessment Workshop (SAW) 11 assessment (NEFC 1990). The 1990 analysis estimated that $F_{\max} = 0.23$. In the 1997 SAW 25 assessment (NEFSC 1997), an updated yield per recruit analysis reflecting the partial recruitment pattern and mean weights at age for 1995-1996 estimated that $F_{\max} = 0.24$. The analysis in the Terceiro (1999) assessment, reflecting partial recruitment and mean weights at age for 1997-1998, estimated that $F_{\max} = 0.263$.

The Overfishing Definition Review Panel (Applegate *et al.* 1998) recommended that the Mid-Atlantic Fishery Management Council (MAFMC) base MSY proxy reference points on yield per recruit analysis, and this recommendation was adopted in formulating the FMP Amendment 12 Overfishing Definition (MAFMC 1999). These reference points were based on the 1999 assessment (Terceiro 1999) and followed what would later be described as the “empirical non-parametric approach,” detailed below (NEFSC 2002b). The 1999 assessment yield per recruit analysis indicated that $F_{\text{threshold}} = F_{\max} = 0.263$, yield per recruit (YPR) at F_{\max} was 0.55219 kg/recruit, and January 1 biomass per recruit (BPR) at F_{\max} was 2.8127 kg/recruit. The median number of summer flounder recruits estimated from the 1999 Virtual Population Analysis (VPA) for 1982-1998 was 37.844 million age-0 fish. Based on this median recruitment level, maximum sustainable yield (MSY) was estimated to be 20,897 mt (46 million lbs) at a total stock biomass (B_{MSY}) of 106,444 mt (235 million lbs). The biomass threshold, one-half B_{MSY} , was therefore estimated to be 53,222 mt (118 million lbs). The Terceiro (1999) reference points were retained in the 2000 SAW 31 assessment (NEFSC 2000) because of the stability of the input data and resulting biological reference point estimates.

The MAFMC Science and Statistical Committee (SSC) conducted a peer review of the summer flounder Overfishing Definition in concert with the 2001 assessment update (MAFMC 2001a, b). The SSC reviewed six analyses to estimate biological reference points for summer flounder conducted by members of the Atlantic States Marine Fisheries Commission (ASMFC) Summer Flounder Biological Reference Point Working Group. After considerable discussion, the SSC decided that although the new analyses conducted by the ASMFC Working Group had resulted in a wide range of estimates, they did not provide a reliable alternative set of reference points for summer flounder. The SSC therefore recommended that F_{target} remain $F_{\max} = 0.263$ because a better estimate had not been established by any of the new analyses. The SSC also reviewed the biomass target (B_{MSY}) and threshold (one-half B_{MSY}) components of the Overfishing Definition and concluded that the new analyses did not justify an alternative estimate of B_{MSY} .

The SSC endorsed the recommendations of SAW 31 which stated that “the use of F_{\max} as a proxy for F_{MSY} should be reconsidered as more information on the dynamics of growth in relation to

biomass and the shape of the stock recruitment function become available” (NEFSC 2000). The SSC agreed that additional years of stock and recruitment data should be collected and encouraged further model development, including model evaluation through simulation studies. They also encouraged the evaluation of alternative proxies for biological reference points that might be more appropriate for an early maturing species like summer flounder and the development and evaluation of management strategies for fisheries where B_{MSY} is unknown. The SSC indicated that as the stock size increases, population dynamic processes that could reflect density dependent mechanisms should be more closely monitored and corresponding analyses should be expanded, i.e., rates of size and age, maturity, fecundity, and egg viability should be closely monitored as potential indicators of compensation at higher stock sizes. Finally, the committee recommended that potential environmental influences on recruitment, including oceanographic changes and predation mortality, should be reevaluated as additional recruitment data become available.

As a result of the SSC peer review (MAFMC 2001a) the Terceiro (1999) reference points were retained in the 2001 stock assessment (MAFMC 2001b). In the review of the 2002 stock assessment (NEFSC 2002a), SAW 35 concluded that revision of the reference points was not warranted at that time due to the continuing stability of the input data and resulting reference point estimates. The Terceiro (1999) reference points were retained in the 2003 (Terceiro 2003) and 2004 (SDWG 2004) assessment updates.

The SAW Southern Demersal Working Group (SDWG), the scientific body responsible for the summer flounder assessment, has continued to monitor the biological characteristics of the stock in accordance with SARC and SSC recommendations. This work updates the biological reference points for summer flounder based on the 2005 assessment update using fishery data through 2004 and research survey data through 2004/2005.

Estimation Methodology

The SDWG updated the biological reference points for summer flounder using both parametric and empirical non-parametric approaches to derive F_{MSY} and B_{MSY} or their proxies, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (BRPWG; NEFSC 2002b). Note that the remainder of this **Estimation Methodology** section closely paraphrases pages 14-26 of the 2002 BRPWG report, with interspersed references specific to summer flounder.

The two approaches were applied so as to be potentially complimentary and supportive and because using both should build confidence in the results. Where results differ appreciably, the results of the empirical approach were used as a component in final model selection. Automatic objective application of these techniques is often compromised by lack of sufficient observation on stock and recruitment over a range of biomass to provide suitable contrast. Thus it is often necessary to extrapolate beyond the range of observation and to infer the shape of the stock recruit relationship from limited and variable observations. The 2001 MAFMC SSC review of summer flounder reference points also noted this concern (MAFMC 2001a).

The empirical non-parametric approach was to evaluate various statistical moments (mean, variance, percentiles) of the observed series of recruitment data and apply the estimated biomass or yield per recruit associated with common F reference points to derive the implied spawning or total biomass and equilibrium yield. The yield and biomass per recruit models were fit using the NOAA Fisheries Toolbox (NFT) YPR version 2.6 software (NFT 2004a). A loess smoother (tension = 0.5) was fit to the scatter plot of stock-recruitment estimates as a visual guide to any trend in the relationship. If the trend was flat (implying that the observed recruitment variation was density independent), then the mean or median recruitment was chosen for the biomass and yield calculations. For summer flounder the median recruitment estimated by ADAPT VPA was used in the biomass calculations at fishing mortality reference points for consistency with the method used to calculate the FMP Amendment 12 reference points. In addition to performing the calculation at F_{max} , this work for summer flounder also followed the 2002 BRPWG guideline (NEFSC 2002b) to use a B_{MSY} proxy calculated from the spawning biomass per recruit at $F_{40\%}$. The empirical, non-parametric approach assumes that compensatory mechanisms such as impaired growth, maturity, or recruit survival are negligible over the range of biomass considered.

The parametric approach used fitted parametric stock-recruitment models along with yield and spawning biomass per recruit information to calculate MSY-based reference points following the procedure of Sissenwine and Shepherd (1987). Stock-recruitment models were fit using the NFT SRFIT version 6.0.3 software (NFT 2004b) and evaluated using the approach described in Brodziak et al. (2001) and Brodziak and Legault (2005). For summer flounder, both compensatory Beverton-Holt (Beverton and Holt 1957, Mace and Doohan 1988) and over-compensatory Ricker stock-recruit models (Ricker 1954) were fit using maximum likelihood estimation. The stochastic component of the models was represented by a multiplicative lognormal or an autoregressive, multiplicative lognormal error structure with a lag of one year. The autoregressive term was included to model serial correlation in random environmental variation, because this allowed successive recruitments to be correlated when the potential effects of environmental forcing were indicated (e.g., periods of good recruitment followed by periods of poor recruitment, regardless of the influence of the stock). Finally, the modeling framework allowed Bayesian priors on Beverton-Holt curve steepness (z_{max} , the ratio of recruitment (R) at 20% of the maximum observed SSB (S_{max}) to the R at S_{max} ; Myers et al. 1999), Ricker slope at the curve origin, and unfished recruitment (Brodziak et al. 2001; NEFSC 2002b, Brodziak and Legault 2005).

For each of the candidate stock-recruit models, a hierarchy of criteria was applied to determine whether the maximum likelihood mode fits were consistent with auxiliary information and with respect to model goodness of fit measures. A priori, it was required that the estimated MLE from the model fit satisfied the first- and second- order derivative conditions required for a strict maximum (i.e., the gradient of the log likelihood is identically zero at the MLE; Hessian matrix of the second derivatives of the negative log likelihood is positive definite). In addition to satisfying these derivative conditions, each model was required to satisfy the following six criteria to be considered credible:

- 1) Parameter estimates must not lie on the boundary of their feasible range of values
- 2) The estimate of MSY lies within the range of observed landings
- 3) The estimate of S_{MSY} is not substantially greater than the nonparametric proxy estimate
- 4) The estimate of F_{MSY} is not substantially greater than the value of F_{max}
- 5) The dominant frequencies for the autoregressive parameter, if applicable, lie within the range of one-half of the length of the stock-recruitment time series (implying the influence of environmental forcing within the length of the observed stock-recruitment time series)
- 6) The estimate of recruitment at S_{MAX} , the maximum spawning stock size proxy input to the stock-recruitment model, is consistent with the value of recruitment used to compute the nonparametric proxy estimate of S_{MSY}

Next, for the subset of parametric models that satisfied these criteria, Akaike's Information Criteria (AIC) was used to assign relative probabilities to each model based on likelihood values, and the resulting model likelihood ratios calculated and compared using Bayes Theorem to judge the most likely model (odds ratio test; the posterior probability that each model represents the true state of nature). In the absence of any prior information on the credibility of candidate models, equal prior probability was assumed. Models that did not satisfy derivative condition or one or more of the hierarchical criteria were assigned a prior probability of zero and eliminated from further consideration (Brodziak et al., 2001, NEFSC 2002b).

Fishery and research survey input data for summer flounder

In the 1990 SAW 11 yield and biomass per recruit analysis (NEFC 1990), mean weights at age in the catch and stock were based on fishery mean weights at age (catch number weighted average of commercial and recreational landed weights at age) for ages 0-8, 1982-1988. The 1990 analysis assumed a natural mortality rate of $M = 0.2$, based on an assumed maximum age of about 15 years (Anthony 1982; Penttila et al. 1989). No commercial or research survey estimates for ages 9-15 were available, so a Gompertz model relating age and weight was fit to the age 0-8 mean weight age estimates to develop mean weights for ages 9-15 ($W_t = W_0 * \exp(G(1-\exp(-gt)))$) (Table 3-1). Maturity at age was estimated from NEFSC Autumn survey data for 1978-1989. Peak spawning was estimated to occur on November 1 (0.83 years). Combined maturities indicated the following estimated percentages mature at age: 38% for age 0, 72% for age 1, 90% for age 2, 97% for age 3, 99% for age 4, and 100% for ages 5 and older. The partial recruitment vector for the 1990 SAW 11 analysis was developed from a separable virtual population analysis (SVPA) employing catch at age data for 1982-1988, with the reference age set at age 2 and selection at age 4 set at 1.0. The analysis indicated the following selection percentages at age: 5% at age 0, 50% at age 1, and 100% at ages 2 and older (Table 3-2). As noted in the **Introduction**, the yield and biomass per recruit analysis was updated in the 1999 assessment (Terceiro 1999) using the mean weights at age in the catch and partial recruitment pattern for 1997-1998. Mean weights from the catch and spawning biomass were recalculated for ages 0-8 only; the mean weights from the 1990 analysis were retained for ages 9-15. Mean weights at age on January 1 were estimated from the mid-year catch weights using the Rivard equations (Rivard 1982) to provide input for the calculation of total stock biomass per recruit. Maturities at ages 0-2 were the same as in the 1990 SAW 11 analysis, while maturities at ages 3 and 4 were rounded up to 100% (Tables 3-1, 3-2). The 1999 analysis was reviewed in the subsequent assessments (NEFSC 2000; MAFMC 2001b; NEFSC 2002a; Terceiro 2003, SDWG 2004) and the results

retained as the basis for biological reference points due to the continuing stability of the input data and resulting parameter estimates (Tables 3-3, 3-4).

In this work, the mean weights at age in the catch and stock, maturity schedule, and partial recruitment pattern have been updated and broadened to include data from 1992-2004. This covers the year range for individually measured and weighed fish sampled in NEFSC research surveys. These NEFSC research survey data have been used to develop estimates of mean weights at age for fish in the total (January 1) and spawning (November 1) biomass and for the maturity schedule. Summer flounder spawning takes place during the annual southern and offshore migration during the autumn and winter months, with peak activity occurring in October and November (O'Brien et al. 1993). Spawning stock biomass mean weights at age and observed proportions mature at age were therefore estimated from NEFSC autumn survey (1992-2004; September-October) individual fish samples (Tables 3-1, 3-2; Figures 3-1, 3-2). Total stock biomass (January 1) mean weights at age were estimated from the NEFSC winter survey (1993-2004; February) individual fish samples (Table 3-2; Figures 3-1, 3-3). Cumulative sample sizes at age for the 1992/1993-2004 period were as follows:

	Age								
	0	1	2	3	4	5	6	7+	Total
Autumn weights and maturities	696	2,150	1,467	489	132	64	29	14	5,041
Winter Weights	0	2,250	4,428	2,421	1,270	527	225	172	11,293

Estimates of the mean weights in the catch have been developed as in previous assessments, using samples from the commercial and recreational fishery landings and discards at length and age and quarterly length-weight relationships from Lux and Porter (1966), for the 1992-2004 period (Tables 3-1, 3-2; Figures 3-1, 3-4). Annual commercial landings length sample sizes averaged 7,398 fish per year in NEFSC samples (88,776 total) and 17,823 fish per year (213,887 total) in NCDMF samples. Annual commercial discard length sample sizes averaged 3,688 fish per year in NEFSC (44,259 total). Annual recreational landings length samples sizes averaged 4,335 fish per year (52,024 total) in NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) samples and 764 fish per year (3,054 total) in New York Department of Environmental Conservation (NYDEC) samples (2000-2003). Annual recreational discard length samples sizes averaged 1,354 fish per year (5,416 total) in NYDEC samples (2000-2003). Annual commercial landings age sample sizes averaged 1,922 fish per year in NEFSC samples (23,064 total) and 490 fish per year (5,880 total) in NCDMF samples; while recreational fishery age sample sizes averaged 1,093 fish per year (2,185 total) in NYDEC samples (2002-2003). With all data sources combined, the mean weights at age in the catch (landings and discards) for the period 1992-2004 were derived from a cumulative length sample total of 407,297 fish and cumulative age sample total of 31,129 fish.

As in previous work for older aged fish with very limited or missing samples, Gompertz functions based on younger ages were used to estimate mean weights for the older ages (NEFSC Winter survey ages 1-11 for Jan1 Bio ages 12-15; $n = 11,293$ fish, $W_0 = 0.0926$, $G = 4.0758$, $g = 0.2929$, $p < 0.0001$; NEFSC Autumn survey ages 0-8 for catch and Nov 1 SSB ages 9-15, $n = 4601$ fish, $W_0 = 0.1959$, $G = 3.5480$, $g = 0.2662$, $p < 0.0001$). Also, for the 2005 SAW 41 catch at age 8, the Nov 1 SSB weight (NEFSC Autumn Survey) was substituted due to low sample numbers from the fisheries. For the 2005 SAW 41 Jan 1 Bio at age 0, the Nov 1 SSB weight at age 0 was substituted since no age 0 fish are taken in the NEFSC Winter survey (Table 3-1).

The partial recruitment pattern has been calculated from fishing mortality rate estimates from the SDWG 2005 assessment NFT ADAPT VPA for 1992-2004 (See Section 2: Assessment Update and Table 3-2). The SDWG considered shorter time periods over which to calculate the partial recruitment pattern, in order to reflect the most recent changes in regulations that might impact partial recruitment. However, the average partial recruitment, and thus the estimated yield and biomass per recruit, was not very sensitive to the period of years included in the averaging. There was practically no change in partial recruitment for ages 0, 1, and 3 and older for the three periods examined (1992-2004 as compared to 1997-2004 or 2002-2004). The partial selection for age 2 fish varied from ~60% to ~80%, depending on the year range selected. Further, the partial recruitment pattern (partial fishing mortality at age) in the most recent years of the summer flounder VPA often change and eventually stabilize at higher values as those estimates pass into the converged portion of the VPA, a function of VPA convergence properties and the current pattern of retrospective bias in the assessment. Thus, the SDWG used the same time periods for the partial recruitment as for the mean weights and maturities at age.

The 2002 BRPWG (NEFSC 2002b) fit stock-recruitment models to data sets for some of the New England groundfish stocks which included “hindcast” estimates of spawning stock and recruitment – estimates derived from NEFSC survey data for years before the start of the respective VPA time series. These “hindcast” estimates were developed in an attempt to enlarge the stock-recruit data sets and include estimates beyond the range of the VPA estimates, thus providing greater contrast in the data used to fit stock-recruitment models. In the 2001 SSC peer review for summer flounder (MAFMC 2001a), “hindcast” estimates for summer flounder were also developed for stock-recruitment model work. The “hindcast” estimates were of limited utility in the 2001 modeling work because the longest available series of research survey indices of spawning stock (NEFSC Spring survey biomass per tow: 1969-2000) and recruitment (MD DNR index of age-0 summer flounder: 1972-2000) did not provide estimates outside the range of the VPA estimates and so failed to increase the contrast in the stock-recruitment data, therefore providing essentially the same stock-recruitment model results. The “hindcast” exercise was attempted again in the preliminary stages of this work, by incorporating the updated VPA estimates and most recent survey indices. While the relationships between the survey indices and VPA estimates continue to be statistically significant (NEFSC biomass: VPA SSB, $r^2 = 0.70$, $p < 0.01$; MDDNR age-0: VPA age-0; $r^2 = 0.41$, $p < 0.05$), the pre-VPA “hindcast” estimates of spawning stock and recruitment remain within the range of the VPA estimates and therefore provide similar stock-recruitment model results, and so use of “hindcast” estimates was not continued in developing the current suite of parametric model comparisons. Therefore, the SDWG 2005 assessment NFT ADAPT VPA 1982-2004 time series of stock-recruit estimates

was used as input in fitting parametric stock-recruit models (See Section 2: Assessment Update; Table 3-5; Figure 3-5).

For the Bayesian priors, the Beverton-Holt model steepness (and Ricker model slope starting values were set at mean = 0.8 and standard error = 0.1, reflecting the values reported in Myers et al. (1999) for Pleuronectid flounders (Beverton-Holt steepness mean = 0.8, standard error = 0.09; Ricker slope mean = 0.79, standard error = 0.18). Recruitment priors approximated the 1982-2004 ADAPT VPA time series of stock-recruit estimates, with mean of 40 million fish and standard error of 10 million fish.

Results: Empirical Non-parametric Approach

The yield per recruit analysis indicated that $F_{max} = 0.276$ (the FMP Amendment 12 proxy for F_{MSY}), and $F_{40\%} = 0.181$ (the 2002 BRPWG [NEFSC 2002b] recommended proxy for F_{MSY}). Yield per Recruit (Y/R) at F_{max} was estimated to be 0.576 kg, Spawning Stock Biomass per Recruit (SSB/R) at F_{max} was estimated to be 2.466 kg, and Total Stock Biomass per Recruit (TSB/R) at F_{max} was estimated to be 2.798 kg. Yield per Recruit at $F_{40\%}$ was estimated to be 0.553 kg, SSB/R at $F_{40\%}$ was estimated to be 3.477 kg, and TSB/R at $F_{40\%}$ was estimated to be 3.748 kg (Table 3-3).

Given that the loess smoother (tension = 0.5) indicted no trend in recruitment with spawning stock size, the recruitment at age 0 estimates from the 2005 ADAPT VPA for the entire time series (1982-2004) were used to calculate the equilibrium biomass (SSB_{MSY} , B_{MSY}) and yields (MSY) in the empirical non-parametric approach (Figure 3-5). Median recruitment was estimated to be 33.111 million fish (mean of 37.951 million fish). The product of the median recruitment and Y/R at F_{max} was 19,072 mt (current FMP Amendment 12 proxy for MSY), SSB at F_{max} was calculated at 81,652 mt, and TSB at F_{max} was calculated at 92,645 mt (current FMP Amendment 12 proxy for B_{MSY}). The product of the median recruitment and Y/R at $F_{40\%}$ was 18,310 mt, SSB at $F_{40\%}$ was calculated at 115,127 mt, and Total Biomass at $F_{40\%}$ was calculated at 124,100 mt.

New FMP biological reference points derived from the empirical non-parametric approach would be $F_{MSY} = F_{max} = 0.276$, $MSY = 19,072$ mt (42.0 million lbs), and $TSB_{MSY} = 92,645$ mt (204.2 million lbs), where the estimate of MSY includes commercial and recreational landings and discards. The biomass threshold of $0.5 * TSB_{MSY} = 46,323$ mt (102.1 million lbs). A comparison with the biological reference points from the 1990 SAW 11 assessment (NEFC 1990) and 1999 Assessment/FMP Amendment 12 (Terceiro 1999; MAFMC 1999) is provided in Table 3-4.

Results: Parametric Model Approach

Maximum likelihood fits of 12 parametric stock-recruitment models to the summer flounder VPA estimates for 1982-2004 are listed in Table 3-6. The model acronyms are: BH = Beverton-Holt, ABH = Beverton-Holt with autoregressive errors, RBH = Beverton-Holt with recruitment prior, SBH = Beverton-Holt with steepness prior, ARBH = Beverton-Holt with autoregressive errors and recruitment prior, ASBH = Beverton-Holt with autoregressive errors and steepness prior, RSBH = Beverton-Holt with recruitment and steepness priors, ARSBH = Beverton-Holt

with autoregressive errors and both recruitment and steepness priors, RK = Ricker model, ARK = Ricker model with autoregressive errors, SRK = Ricker model with slope prior, ASRK = Ricker model with autoregressive errors and slope prior. The six hierarchical criteria were applied to each of the models to determine the set of candidate models.

The first criterion (i.e., feasible parameter estimates) was not satisfied by any of the Ricker model configurations, which either provided estimates of F_{MSY} (> 1.0) that greatly exceed F_{max} (0.27) or infeasible estimates of S_{MSY} (either very large or very small). All of the Beverton-Holt models satisfied the first through fourth criteria, with estimates of MSY within the range of observed landings (i.e., 20,000-30,000 mt), estimates of S_{MSY} comparable to the empirical non-parametric approach estimate (95,000-105,000 mt), estimates of F_{MSY} (~0.25-0.26) comparable to the values of F_{max} (0.23-0.27), and estimates of the Beverton-Holt steepness parameter (~0.98-1.00) that were similar to the Bayesian prior (mean = 0.8, standard error = 0.1) for other flatfish stocks, although outside the ± 1 standard error interval.

The four Beverton-Holt models incorporating autoregressive errors all provided dominant power spectrum frequencies greater (~25 years or more) than one-half the length of the relatively short stock-recruitment time series for summer flounder (one-half of 22 years = 11 years), and so failed to satisfy the fifth criterion since this result implies a period of environmental forcing greater than the length of the stock-recruitment time series (Figure 3-6). The four remaining Beverton-Holt models (BH, RBH, SBH, and RSBH) all satisfied the sixth criteria, providing estimates of recruitment at S_{max} (R_{max} , ~ 40 million fish) consistent with the value of recruitment (~33 million fish) used to compute the empirical non-parametric estimate of S_{MSY} . The four remaining models also had very similar corrected AIC values and parameter estimates. To aid in the selection of the most likely model, the four models were assigned equal prior probability (i.e., 0.250), and the model likelihood ratios compared using Bayes Theorem to compute the posterior probability that each model represents the true state of nature (Brodziak et al. 2001, NEFSC 2002b). Since the AIC value for the BH model (Beverton-Holt without priors) was very slightly lower than the other models, the odds ratio of the BH model being true compared to the others was also slightly better (i.e., 0.1% more likely than the RBH, 4% more likely than the RSBH, and 7% more likely than the SBH), and so the BH configuration was selected as the most likely model (Table 3-7).

The standardized residual plot of the fit of the BH model to the summer flounder stock-recruitment data shows that the residuals lie within \pm two standard deviations of zero, with the exception of the 1983 and 1988 year classes, which are the largest and smallest recruitments of the time series (Figure 3-7). The BH model stock-recruitment plot shows that recruitment values near SSB_{MSY} are about 40 million fish, about 20% higher than the median of 33 million fish from the observed VPA recruitment series (Figure 3-8). Parameter uncertainty plots show 5000 Markov Chain Monte Carlo (MCMC) sample estimates of MSY, S_{MSY} , and F_{MSY} drawn from the posterior distribution of the MLE for the BH model (Figure 3-9). Overall, the point estimates of MSY and S_{MSY} were slightly lower, and F_{MSY} slightly higher, than the medians of the MCMC samples. New FMP biological reference points from the BH model would be $F_{MSY} = 0.254$, $MSY = 23,193$ mt (51.1 million lbs), and $SSB_{MSY} = 106,435$ mt (234.6 million lbs), where the estimate of MSY includes commercial and recreational landings and discards (Table 3-6; Figure

3-10). If expressed in terms of SSB, the biomass threshold of $0.5 * SSB_{MSY}$ would be 53,218 mt (117.3 million lbs).

SDWG Reference Point Advice

The BH model fits the observed stock-recruitment data well, and reference points are comparable to those derived from the empirical non-parametric approach. However, the quantity of observed stock-recruitment data is limited (22 years), and the data during the early part of the time series, when the SSB was at the lowest observed levels, indicates a level of recruitment near the estimated R_{max} , and exerts a high degree of leverage on the estimation of the model parameters (Figure 3-8). This leverage results in a high value (0.984) for the subsequently calculated steepness of the BH curve, which is outside of the \pm one standard interval of Myers et al. (1999) estimate for Pleuronectid flatfish (0.8 ± 0.1). The BH model results suggest that summer flounder SSB could fall to very low levels (<2,000 mt) and still produce recruitment near that produced at SSB_{MSY} . This may not be a reasonable assumption for the long term, given the recent stock-recruitment history of the stock (i.e., production of a very poor year class in 1988). The BH model estimated parameters may prove to be sensitive to subsequent additional years of S-R data, especially if they accumulate at higher levels of SSB and recruitment in the near term. The BH model fit may also be sensitive to the magnitude of recently estimated spawning stock and recruitment, given the recent retrospective pattern of overestimation of stock size evident in the assessment. The SDWG recognizes that the limited time series of observed stock-recruitment data impacts both reference point estimation approaches (empirical non-parametric and parametric stock-recruitment model) in terms of the potential spawning stock biomass and recruitment levels that might be realized from the stock if fished at fishing mortality rates in the 0.2-0.3 range over the long term. Given these concerns, the SDWG advises that the current BH model estimates are not suitable for use as biological reference points for summer flounder.

The SDWG updated the input data (1992-2004 averages of mean weights, maturities, and partial recruitment) for yield and biomass per recruit analysis. The updated 1982-2004 VPA provided an estimate of median recruitment for summer flounder of 33.111 million age 0 fish. The SDWG recommends adoption of biological reference points from the empirical non-parametric approach for summer flounder. Updated FMP biological reference points would be $F_{MSY} = F_{max} = 0.276$, $MSY = 19,072$ mt (42.0 million lbs), and $TSB_{MSY} = 92,645$ mt (204.2 million lbs; Table 3-4). The biomass threshold of $0.5 * TSB_{MSY} = 46,323$ mt (102.1 million lbs).

4.0 RESEARCH RECOMMENDATIONS FOR SUMMER FLOUNDER

The following major data and analytic needs for future assessments were identified in the SARC 35 review of the 2002 assessment (NEFSC 2002a) and in the SDWG assessment updates for 2003 and 2004 (Terceiro 2003; SDWG 2004):

- 1) Expand the NEFSC fishery observer program for summer flounder, with special emphasis on a) comprehensive areal and temporal coverage, b) adequate length and age sampling, and c) continued sampling after commercial fishery areal and seasonal quotas are reached and fisheries are limited or closed, and d) sampling of summer flounder discard in the scallop dredge fishery. Maintaining adequate observer coverage will be especially important in order to monitor a) the effects of implementation of gear and closed/exempted area regulations, both in terms of the response of the stock and the fishermen, b) potential continuing changes in "directivity" in the summer flounder fishery, as a results of changes in stock levels and regulations, and c) discards of summer flounder in the commercial fishery once quota levels have been attained and the summer flounder fishery is closed or restricted by trip limits.

WG Response: Observer sampling intensity has improved since 2001. Attempts are made to maintain coverage of otter trawl fishing even after summer flounder quotas have been filled.

- 2) Evaluate the amount of observer data needed to reliably estimate discards of summer flounder in all components of the fishery

WG Response: The NEFSC Population Dynamics Branch has developed an optimization algorithm to calculate sampling levels adequate to reliably estimate summer flounder discards and then allocate observer sea days across gear types, mesh sizes, regions, and trip lengths to define trips participating in various fisheries. This tool has been used to allocate Observer sea days since May 2004. Sea days are allocated across three gear types (otter trawl, gillnet and scallop dredge). Otter trawl and gillnet trips have been classified into four mesh size categories: Small (less than 3.99 inch mesh); Medium (between 3.99 and 5.49 inch mesh); Large (between 5.5 and 7.99 inch mesh) and XLarge (8.0 inch mesh or greater). Additionally, trips have been classified into six geographical regions: vessel leaving from ports located within Maine and New Hampshire (ME_NH); Massachusetts (N_MA, excluding Bristol county); Connecticut, RI, and Bristol county, MA (SNE); New Jersey - New York (NJ/NY); Maryland and Delaware (MD/DE); Virginia and North Carolina (VA/NC).

- 3) Conduct further research to better determine the discard mortality rate of recreational and commercial fishery summer flounder discards.

WG Response: the assessment continues to rely on commercial industry advisors for an assumption of the commercial fishery discard mortality rate (80%). The results of three research programs completed in the late 1990s are averaged to provide the recreational fishery discard mortality rate (10%). Clearly, further research is needed to improve the commercial rate assumption.

- 4) Develop a program to annually sample the length and age frequency of summer flounder discards from the recreational fishery.

WG Response: To date, programs are in place only in New York (NYDEC Party Boat Survey) and Connecticut (CTDEP Volunteer Anglers) to sample the biological characteristics recreational discards. So, progress has been made, but more synoptic data are needed.

- 5) RIDFW monthly fixed station survey length frequencies are currently converted to age using length cut-offs points. Investigate the utility of applying the appropriate NEFSC or MADMF age-length keys to convert the RIDFW monthly fixed station survey lengths to age.

WG Response: This recommendation has not yet been addressed by the RIDFW.

- 6) Explore the possibility of weighting survey indices used in VPA calibration by the areal coverage (e.g., in square kilometers) of the respective seasonal surveys.

WG Response: This recommendation was addressed in the 2004 assessment update (SDWG 2004), and the SDWG found that results from two areal weighted runs were nearly identical (due to the large NEFSC areal weights) and very similar to their respective unweighted runs. The SDWG therefore recommended retention of the 2003 tuning index selection process and configuration, which essentially gives greatest weight to the initially best fitting indices, in the 2004 assessment update (SDWG 2004). That recommendation was also implemented in the 2005 assessment update.

- 7) Explore the sensitivity of the VPA calibration to the addition of 1 and/or a small constant to values of survey series with “true zeros.”

WG Response: This recommendation was addressed in the 2004 assessment update (SDWG 2004). This recommendation stems from the nature of the ADAPT VPA tuning (calibration) algorithm, which includes natural logarithm (ln) transformation (i.e., assumption of a lognormal error distribution) of the input survey abundance indices prior to calibration. Some of the tuning series in the assessment include several “true zero” observations (as contrasted with years for which no sampling was performed) in their time series. Since “zeros” are treated as missing values in the ADAPT computations, a constant value of 1 was added to every value in these series to enable use of these “true zeros” as observations. The choice of the value of 1 as the additive constant was made by the previous WGs based on recommendations from traditional statistical texts for ln-transformation of data. However, more recent statistical literature provides guidance on the objective selection of the appropriate value of the additive constant based on the statistical properties (skew and kurtosis) of the series to be ln-transformed. Briefly, the method consists of 1) addition of a range of constants from very large (e.g., 1,000) to very small (e.g., 0.0001) to the original values in the series, 2) ln-transformation of the modified series, 3) calculation of the skewness and kurtosis of the modified series, and 4) summation of the absolute value of the skewness and kurtosis (providing the statistic “g”) of the modified series. The additive constant that minimizes the statistic “g” for a given series of data is the one that best minimizes the effect of outliers and normalizes residuals from the lognormal error distribution, hence best adhering to the assumption of the lognormal distribution. Studies using both empirical and simulated indices of abundance indicate that for “small value” (e.g. < 1.0 fish per tow) summer flounder survey time series, the value of “g” appears on average to be best minimized by the additive constant value equal to 0.10. Thus, use of 0.10 as the additive constant for those “small value” series provides a transformation of the calibration data that best matches the assumed error distribution. The SDWG

therefore recommended use of the revised, varying additive constants in the 2004 assessment update (SDWG 2004). That recommendation was also implemented in the 2005 assessment update.

- 8) Statistically analyze changes in mean weights at age in the catch and NEFSC surveys. Determine if using mean weights at age in the survey are more appropriate for estimating the B_{MSY} proxy. Explore the sensitivity of the mean weights of the catch and partial recruitment pattern from a longer time series (1997 to 2001) to the re-estimated B_{MSY} proxy. As the NEFSC fall survey age structure expands, investigate the use of survey mean weights at age for stock weights at age in yield per recruit, VPA, and projection analyses.

WG Response: This recommendation has been addressed in the 2005 SDWG Response to SAW 41 ToRs 2 and 3.

- 9) Monitor changes in life history (growth and maturity) as the stock rebuilds.

WG Response: This recommendation has been addressed in the 2005 SDWG Response to SAW 41 ToRs 2 and 3.

- 10) Evaluate use of a forward calculating age-structured model for comparison with VPA. Forward models would facilitate use of expanding age/sex structure and allow inclusion of historical data. If sex-specific assessments are explored, the implications on YPR should also be investigated.

WG Response: Work to address this recommendation is underway (use of ASAP model), and will be a component of the next benchmark assessment.

- 11) Explore the sensitivity of the VPA results to separating the summer flounder stock into multiple components.

WG Response: This recommendation has not yet been addressed by the SDWG.

- 12) Evaluate trends in the regional components of the NEFSC surveys and contrast with the state surveys that potentially index components of the stock.

WG Response: This recommendation has not yet been addressed by the SDWG.

- 13) Use NEFSC fishery observer age-length keys for 1994 and later years (as they become available) to supplement NEFSC survey data in aging the commercial fishery discard.

WG Response: This recommendation has not been addressed by the SDWG, as the age data are not yet available.

The following major data and analytic needs for future assessments were identified by the SDWG in completing the 2005 assessment update:

- 1) Initiate an age structure exchange between the NEFSC and all interested state agencies and academic institutions, with a goal of completing the laboratory work and a summary report by May 1, 2006.
- 2) Complete the NEFSC comparison study between scales and otoliths as aging structures for summer flounder, and prepare a summary report by May 1, 2006.
- 3) Develop a long term protocol to sample otoliths from summer flounder caught in the recreational and commercial fisheries (e.g., purchase samples; as a component of Research Set-Aside projects; as Cooperative Research with industry).
- 4) Develop a long term protocol to correct summer flounder scale ages using a more limited sample of otolith ages.
- 5) Explore statistical methods to develop “combined” survey abundance indices (by age if possible) from state agency survey data, for use in calibration of analytical assessment models.

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SUMMER FLOUNDER TABLES

Table 3-1. Input data for summer flounder yield per recruit analyses: mean weights at age. Weights in italics estimated from Gompertz function and/or Rivard equations. For 2005 SAW 41 catch at age 8, the Nov 1 SSB weight (NEFSC Autumn Survey) was substituted due to low sample numbers from the fisheries. For 2005 SAW 41 Jan 1 Bio at age 0, the Nov 1 SSB weight at age 0 was substituted since no age 0 fish are taken in the Winter survey.

Age	1990 SAW 11		1999 Assessment			2005 SAW 41		
	Catch	Nov 1 SSB	Jan 1 Bio	Catch	Nov 1 SSB	Jan 1 Bio	Catch	Nov 1 SSB
0	0.237	0.237	0.170	0.234	0.234	0.184	0.221	0.184
1	0.432	0.432	0.353	0.471	0.471	0.241	0.499	0.469
2	0.642	0.642	0.556	0.643	0.643	0.577	0.684	0.817
3	1.164	1.164	0.722	0.862	0.862	0.980	1.049	1.402
4	1.811	1.811	1.111	1.277	1.277	1.539	1.489	1.953
5	2.449	2.449	1.860	2.330	2.330	2.136	2.217	2.946
6	3.074	3.074	2.337	2.565	2.565	2.680	2.745	3.073
7	3.434	3.434	3.130	3.537	3.537	3.245	3.515	3.630
8	4.380	4.380	4.120	4.592	4.592	3.576	4.515	4.515
9	<i>4.841</i>	<i>4.841</i>	<i>4.671</i>	<i>4.841</i>	<i>4.841</i>	3.780	<i>4.926</i>	<i>4.926</i>
10	<i>5.336</i>	<i>5.336</i>	<i>5.162</i>	<i>5.336</i>	<i>5.336</i>	4.672	<i>5.313</i>	<i>5.313</i>
11	<i>5.767</i>	<i>5.767</i>	<i>5.590</i>	<i>5.767</i>	<i>5.767</i>	5.020	<i>5.630</i>	<i>5.630</i>
12	<i>6.135</i>	<i>6.135</i>	<i>5.957</i>	<i>6.135</i>	<i>6.135</i>	5.360	<i>5.885</i>	<i>5.885</i>
13	<i>6.445</i>	<i>6.445</i>	<i>6.266</i>	<i>6.445</i>	<i>6.445</i>	5.553	<i>6.089</i>	<i>6.089</i>
14	<i>6.704</i>	<i>6.704</i>	<i>6.525</i>	<i>6.704</i>	<i>6.704</i>	5.674	<i>6.249</i>	<i>6.249</i>
15	<i>6.917</i>	<i>6.917</i>	<i>6.738</i>	<i>6.917</i>	<i>6.917</i>	5.765	<i>6.375</i>	<i>6.375</i>

Table 3-2. Input data for summer flounder yield per recruit analyses: percent mature and partial recruitment (percent selection) at age.

Age	1990 SAW 11		1999 Assessment		2005 SAW 41	
	Percent Mature	Partial Recruit.	Percent Mature	Partial Recruit.	Percent Mature	Partial Recruit.
0	38	5	38	1	38	1
1	72	50	72	18	91	19
2	90	100	90	62	98	77
3	97	100	100	100	100	100
4	99	100	100	100	100	100
5	100	100	100	100	100	100
6	100	100	100	100	100	100
7	100	100	100	100	100	100
8	100	100	100	100	100	100
9	100	100	100	100	100	100
10	100	100	100	100	100	100
11	100	100	100	100	100	100
12	100	100	100	100	100	100
13	100	100	100	100	100	100
14	100	100	100	100	100	100
15	100	100	100	100	100	100

Table 3-3. Summary results for summer flounder yield per recruit analyses. Yield per Recruit (Y/R), Spawning Biomass per Recruit (SSB/R) and Total Stock Biomass per Recruit (TSB/R) in kilograms.

	1990 SAW 11	1999 Assessment	2005 SAW 41
Fmax	0.232	0.263	0.276
F40%	0.150	0.167	0.181
Y/R @ Fmax	0.574	0.552	0.576
SSB/R @ Fmax	2.107	2.139	2.466
TSB/R @ Fmax	not calculated	2.813	2.798
Y/R@ F40%	0.540	0.524	0.553
SSB/R @ F40%	3.275	3.111	3.477
TSB/R @ F40%	not calculated	3.853	3.748

Table 3-4. Summary results for summer flounder empirical non-parametric biological reference point calculations. Maximum Sustainable Yield (MSY), Spawning Stock Biomass at MSY (SSB_{MSY}), and Total Stock Biomass at MSY (TSB_{MSY}) in metric tons.

	1990 SAW 11	1999 Assessment	2005 SAW 41
Recruitment Year Range	1982-1987	1982-1998	1982-2004
Median Recruitment (000s)	58,440	37,844	33,111
Y @ Fmax (MSY)	33,545	20,897	19,072
SSB @ Fmax (SSB_{MSY})	123,133	80,948	81,652
TSB @ Fmax (TSB_{MSY})	not calculated	106,444	92,645
Y @ F40% (MSY)	31,558	19,830	18,310
SSB @ F40% (SSB_{MSY})	191,391	117,733	115,127
TSB @ F40% (TSB_{MSY})	not calculated	145,813	124,100

Table 3-5. Input spawning stock biomass (metric tons; ages 0-7+) and recruitment (millions of age 0 fish) data for summer flounder parametric stock-recruitment models._

Year Class	Spawning Stock Biomass	Recruitment
1983	17,501	80,323
1984	18,837	48,380
1985	16,087	48,579
1986	14,972	53,444
1987	13,934	43,921
1988	14,424	13,033
1989	8,130	27,270
1990	5,217	30,352
1991	7,453	28,686
1992	6,007	32,315
1993	7,303	33,158
1994	9,249	35,251
1995	11,960	38,679
1996	15,611	28,244
1997	15,886	29,089
1998	15,669	31,046
1999	17,794	29,417
2000	16,497	35,871
2001	19,381	33,831
2002	25,544	38,133
2003	29,415	27,478
2004	36,696	33,111

Table 3-6. Stock-recruitment model comparisons for summer flounder. MSY and S_{MSY} in 000s metric tons.

Model	BH	ABH	RBH	SBH	ARBH	ASBH	RSBH	ARSB	RK	ARK	SRK	ASRK
Number of data points	22	22	22	22	22	22	22	22	22	22	22	22
Number of parameters	3	4	3	3	4	4	3	4	3	4	3	4
Negative log likelihood	84.520	83.379	87.742	84.751	86.636	83.849	87.997	87.072	85.015	84.483	122.85	90.690
Bias corrected AIC	176.37	177.11	176.37	176.51	177.13	177.42	176.44	177.39	177.36	179.31	246.66	190.49
Parameter estimates												
F _{MSY}	0.254	0.262	0.254	0.252	0.260	0.256	0.252	0.256	1.360	1.414	0.272	0.252
S _{MSY}	106.4	95.5	106.1	112.7	98.1	106.2	110.4	105.6	20.7	20.3	101.45	10.7
MSY	23.2	21.4	23.1	24.4	21.9	23.3	23.9	23.2	17.8	17.9	23.488	2.3
Alpha	40.6	36.9	40.5	43.0	37.9	40.8	42.0	40.5	1.876	1.906	0.098	4.54e-
Beta	1.506	5.09e-	1.467	2.375	0.238	1.445	2.094	1.376	-0.059	-0.060	-9.99e-	-0.092
steepness	0.984	1.000	0.984	0.976	0.997	0.984	0.978	0.985	n/a	n/a	n/a	n/a
R _{max}	39.4	36.9	39.3	41.1	37.7	39.6	40.4	39.4	17.3	16.8	55.1	0.5
Prior mean steepness;	n/a	n/a	n/a	0.8	n/a	0.8	0.8	0.8	n/a	n/a	0.8	0.8
Prior se steepness; slope	n/a	n/a	n/a	0.1	n/a	0.1	0.1	0.1	n/a	n/a	0.1	0.1
Prior mean recruitment	n/a	n/a	40	n/a	40	n/a	40	40	n/a	n/a	n/a	n/a
Prior se recruitment	n/a	n/a	10	n/a	10	n/a	10	10	n/a	n/a	n/a	n/a
Sigma	n/a	0.340	0.328	0.329	0.339	0.332	0.328	0.332	0.336	0.338	0.890	3.153
Phi	n/a	0.408	n/a	n/a	0.397	0.336	n/a	0.339	n/a	0.247	n/a	0.993
Sigmaw	n/a	0.311	n/a	n/a	0.311	0.313	n/a	0.313	n/a	0.327	n/a	0.384
last log-residual R	n/a	-0.109	n/a	n/a	-4.563	-0.169	n/a	-0.165	n/a	5.497	n/a	3.239
expected lognormal error	1.055	1.060	1.055	1.056	1.059	1.057	1.055	1.057	1.058	1.059	1.486	144.58

Table 3-7. Posterior probability and odds ratio tests for the most likely stock-recruitment models for summer flounder.

S-R Model	BH	RBH	SBH	RSBH
Number of data points	22	22	22	22
Number of parameters	3	3	3	3
Bias-corrected AIC	175.373	176.374	176.512	176.446
Prior Probability	0.250	0.250	0.250	0.250
Model AIC Ratio	1.072	1.071	1.000	1.034
Normalized (Unity) Likelihood	0.257	0.257	0.239	0.247
Posterior Probability	0.257	0.257	0.239	0.247
Odds Ratio for Most Likely Model	1.000	1.001	1.072	1.037
	Most Likely Model			

SUMMER FLOUNDER FIGURES

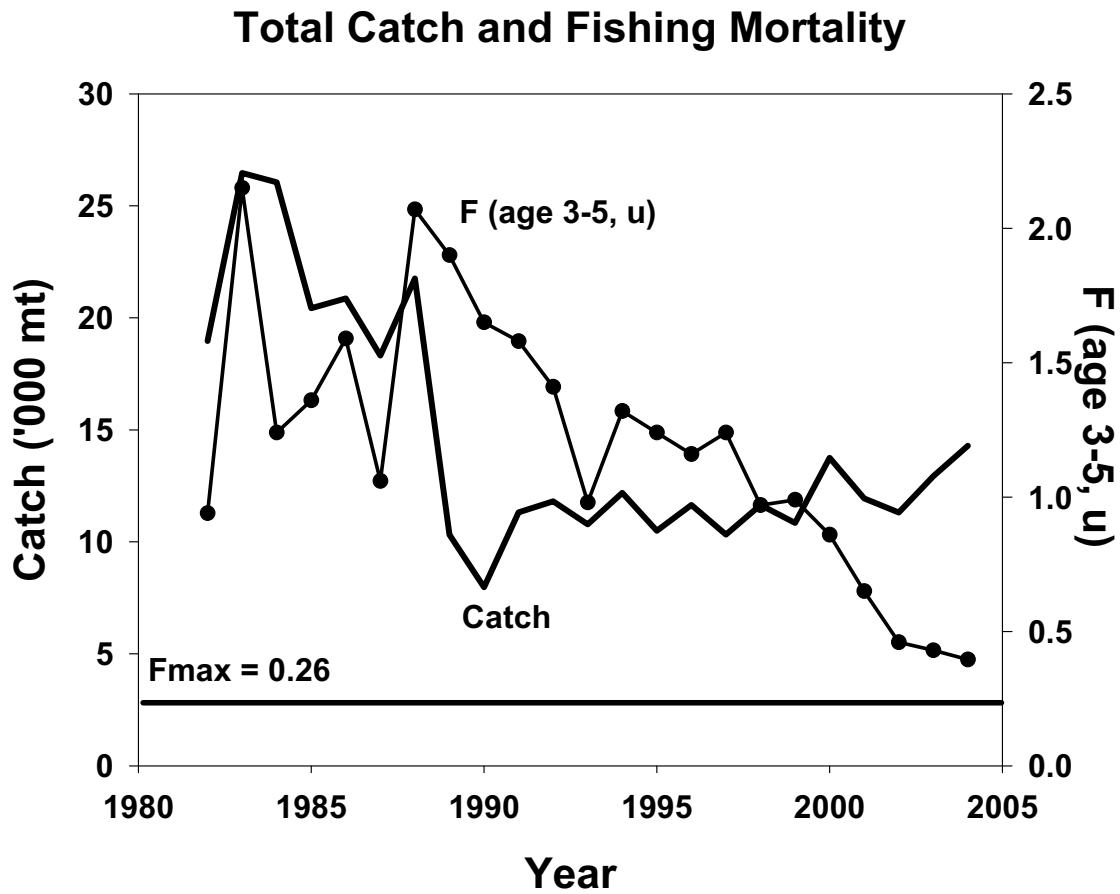


Figure 2-1. Total catch (landings and discards, thousands of metric tons) and fishing mortality rate (F, ages 3-5, unweighted) for summer flounder.

Total Biomass, SSB, and Recruitment (R)

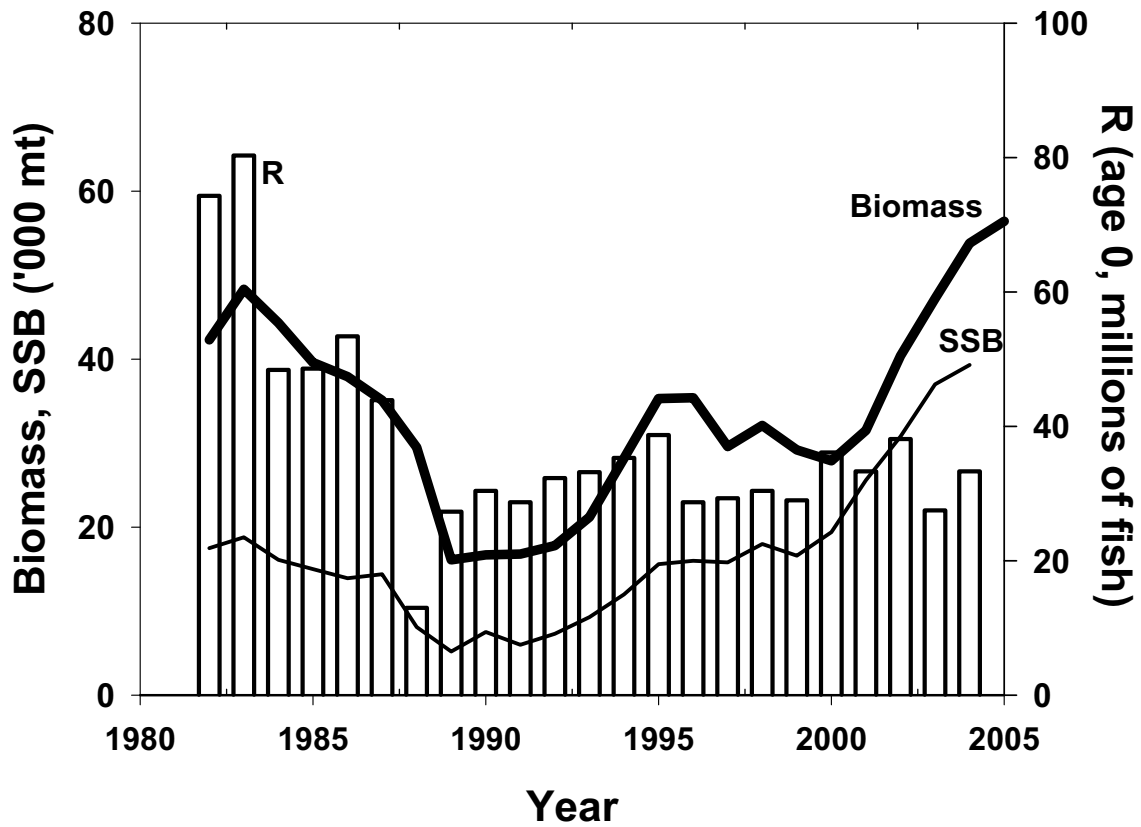


Figure 2-2. Total stock biomass ('000 mt; thick line), spawning stock biomass (SSB, '000 mt; thin line), and recruitment (millions of fish at age-0; bars) for summer flounder.

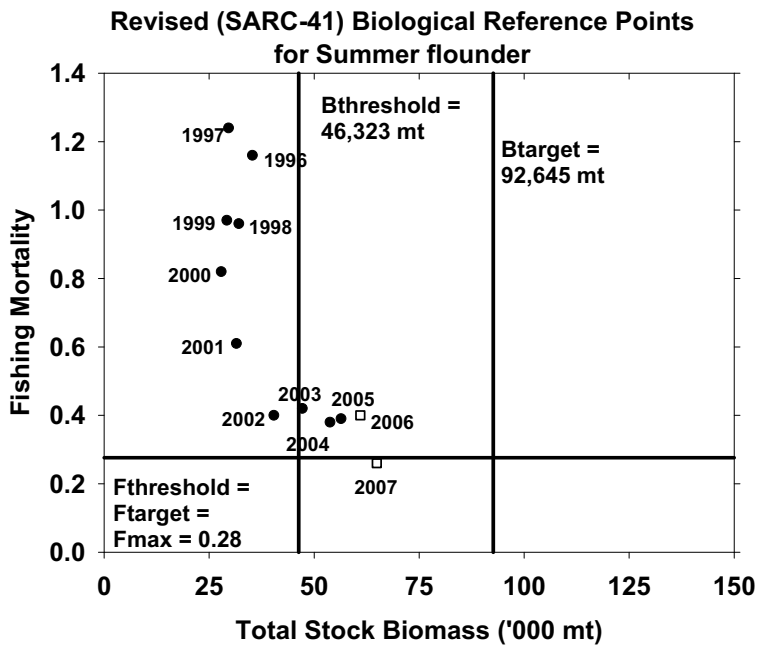
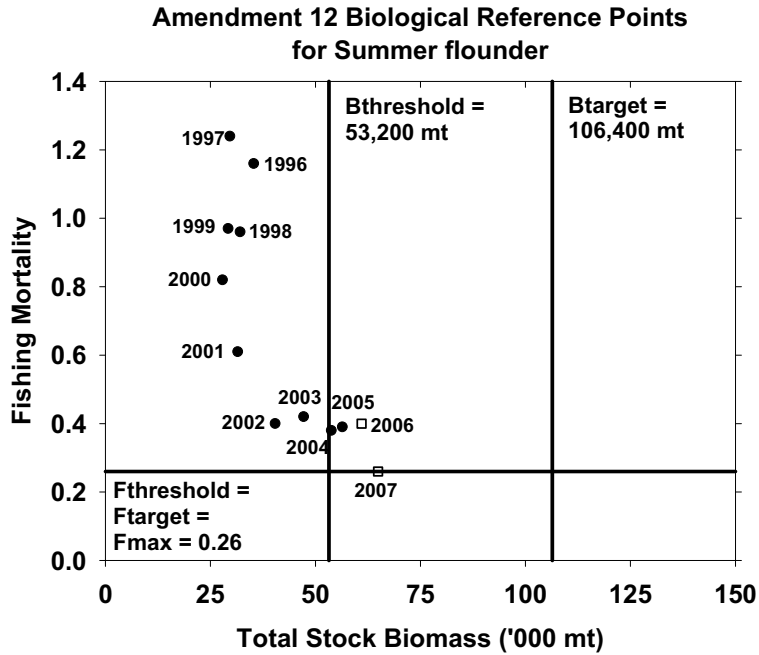


Figure 2-3. Estimates of Biological Reference Points, biomass and F.

Summer flounder Retrospective VPAs

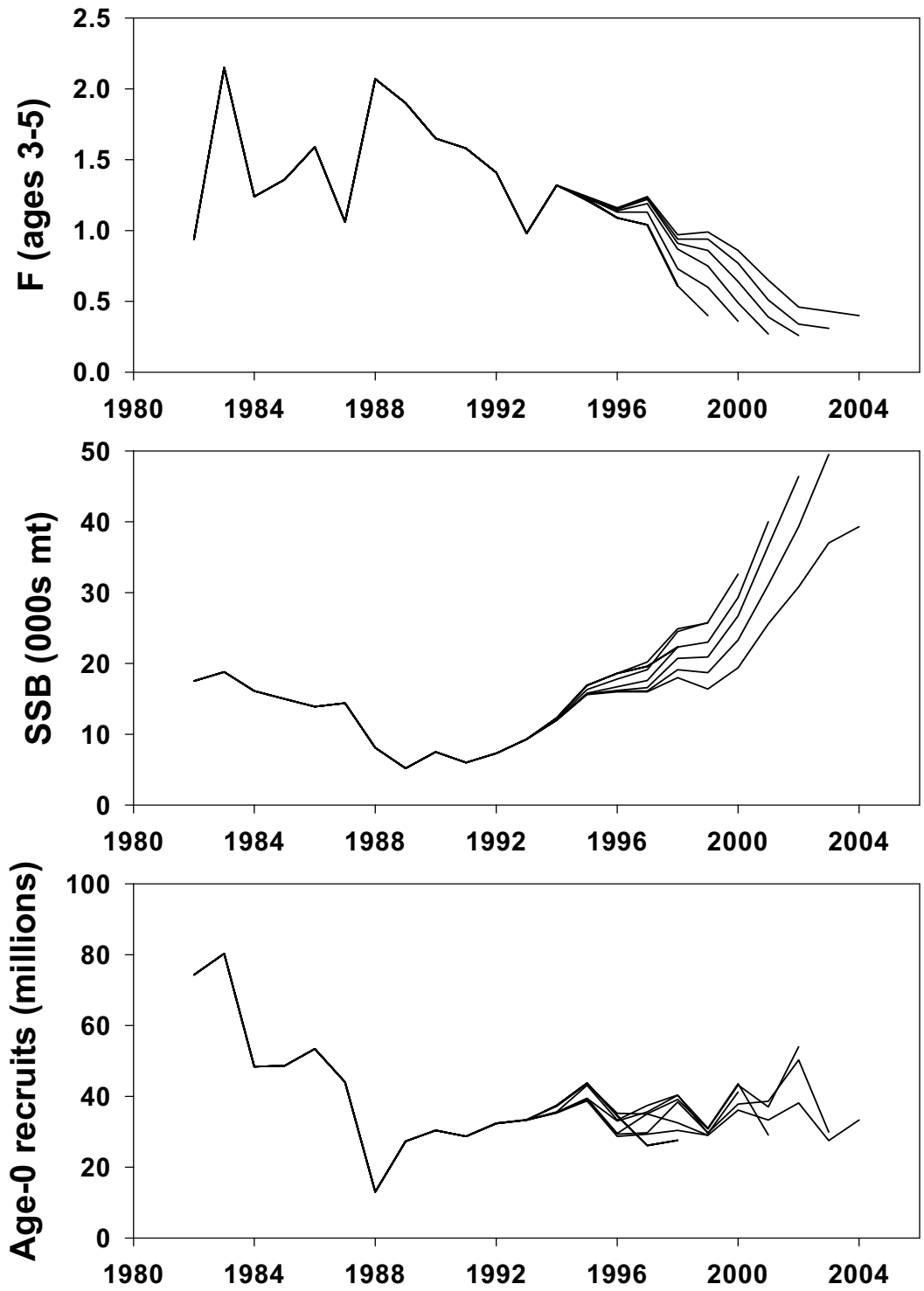


Figure 2-4. Retrospective VPAs for summer flounder.

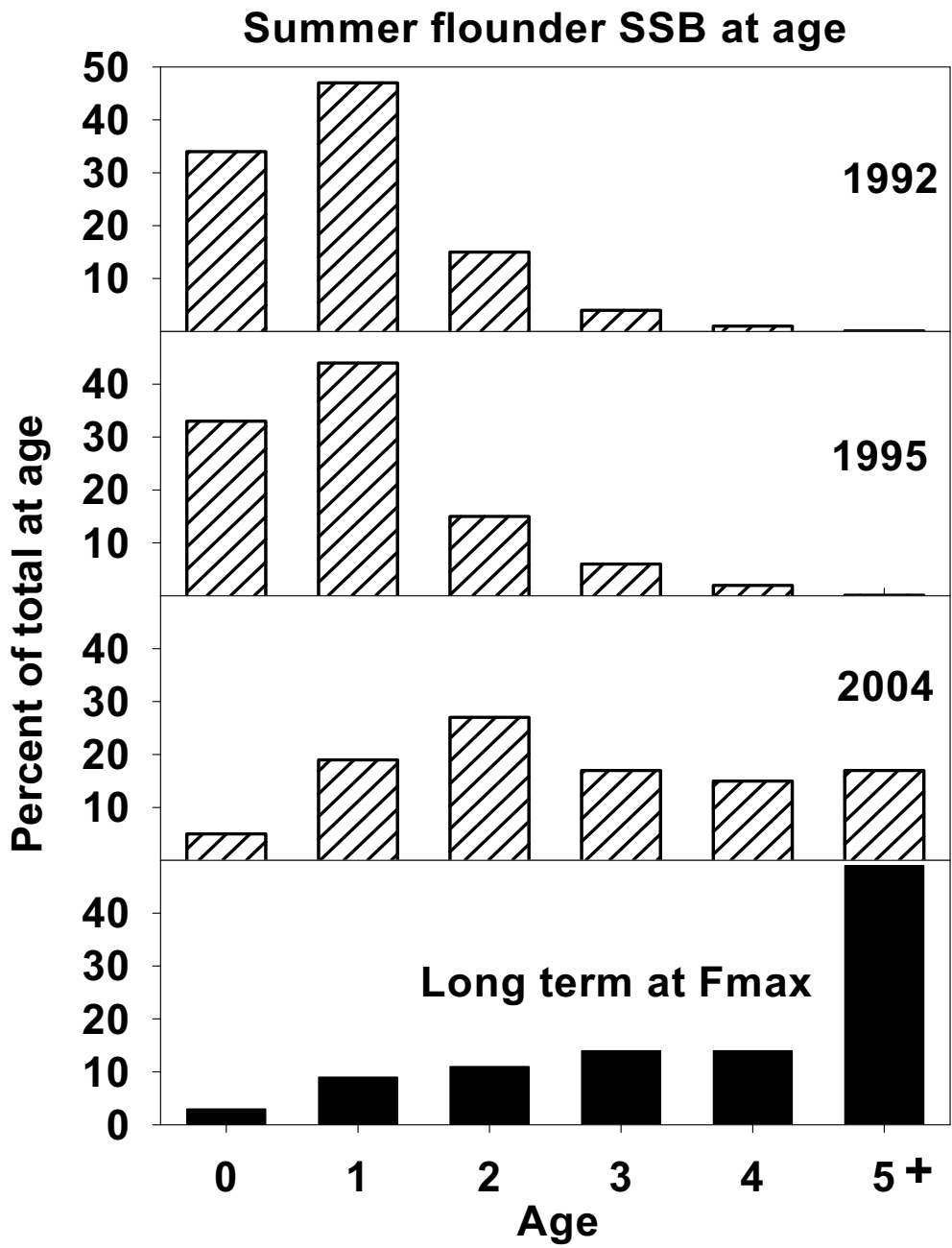


Figure 2-5. Percent of summer flounder spawning stock biomass (SSB) at age in 1992, 1995, 2004 and long-term at $F_{max} = 0.263$. Similar long-term results are derived using updated $F_{max} = 0.276$.

SSB - RECRUIT DATA FOR 1983-2004 YEAR CLASSES

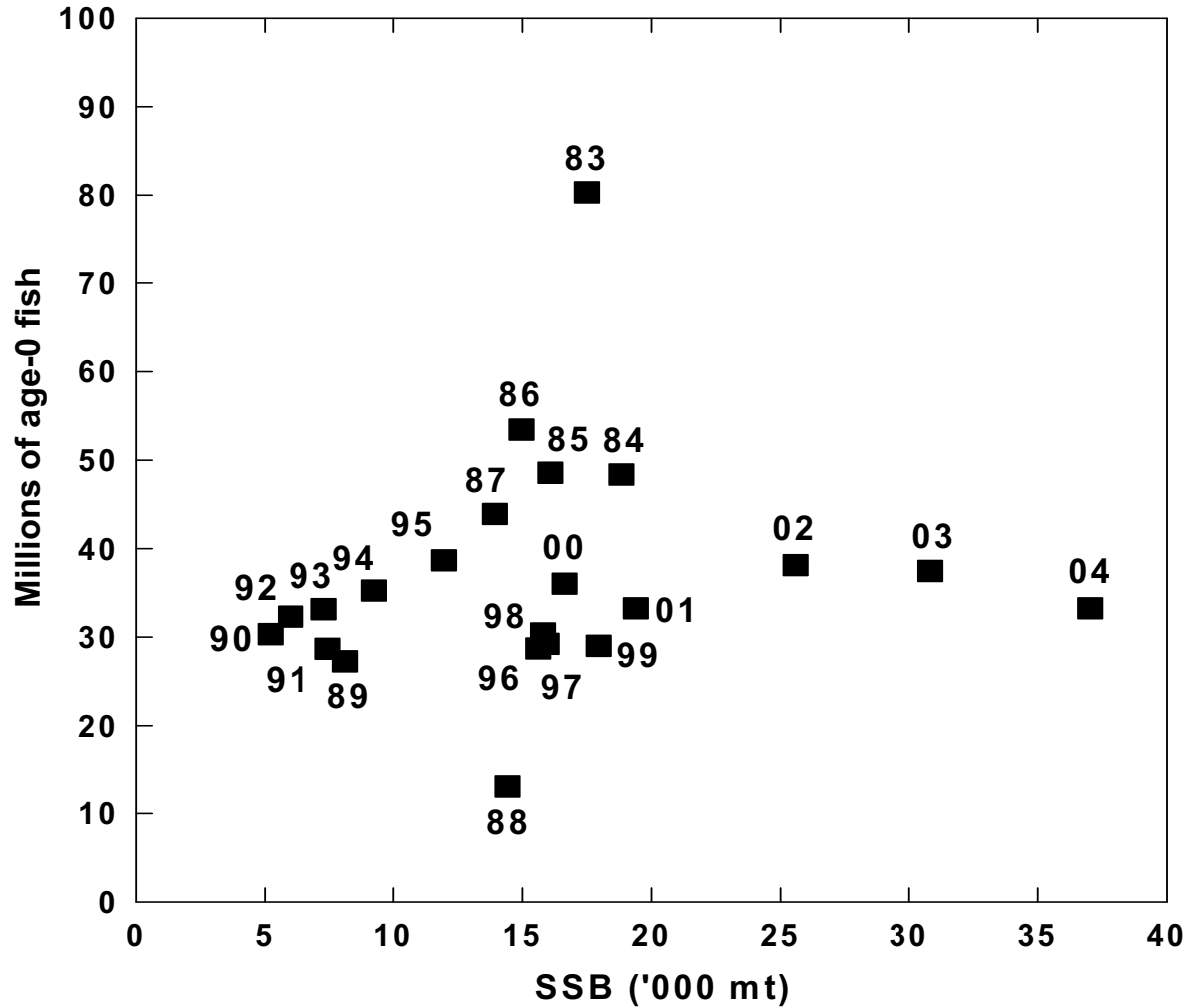


Figure 2-6. VPA spawning stock biomass and recruitment estimates for summer flounder.

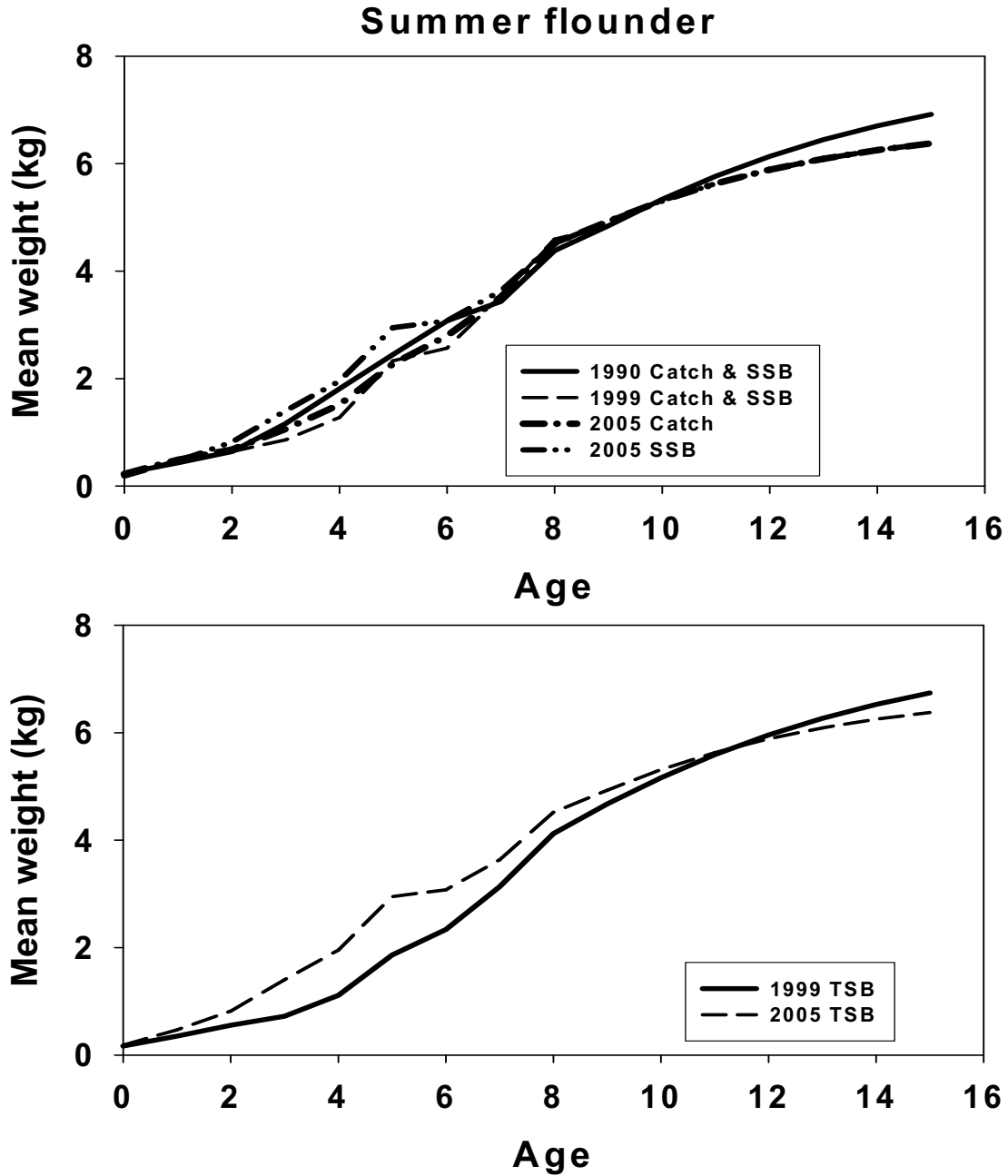


Figure 3-1. Mean weights at age for summer flounder yield and biomass per recruit analyses.

Summer flounder SSB mean weights at age

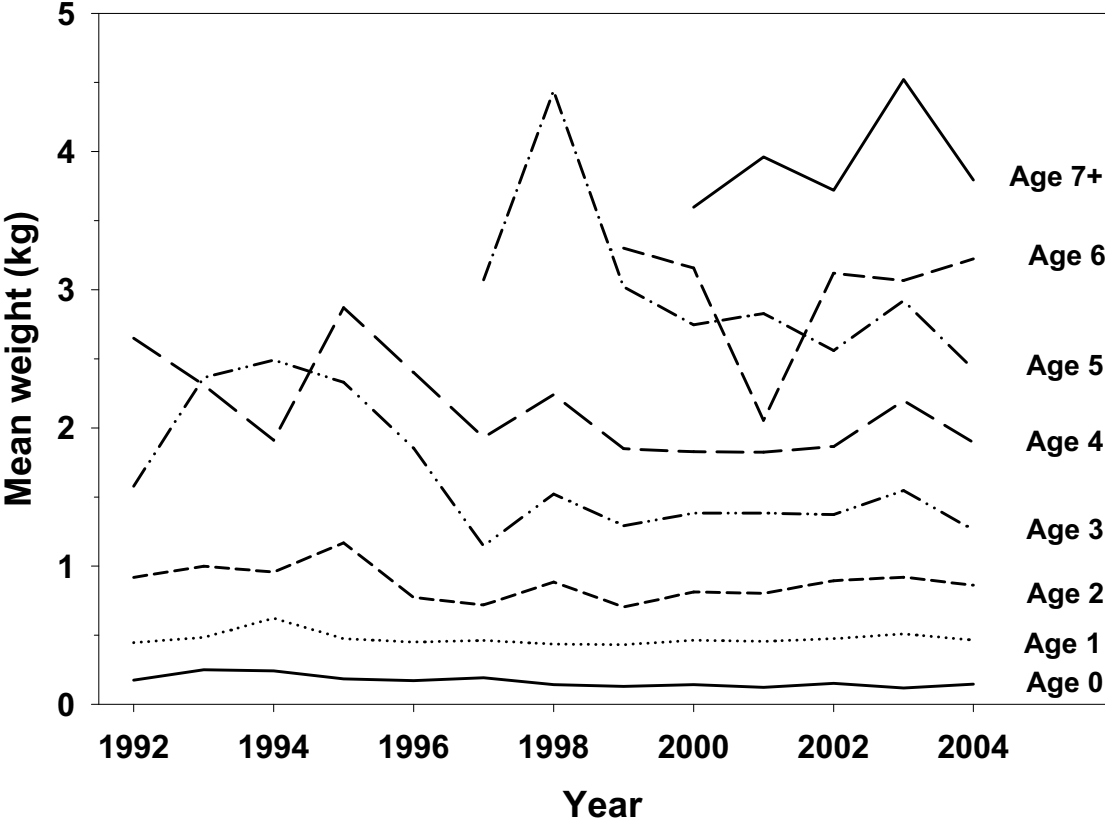


Figure 3-2. Trends in mean weight at age in the spawning stock of summer flounder: NEFSC Autumn survey 1992-2004.

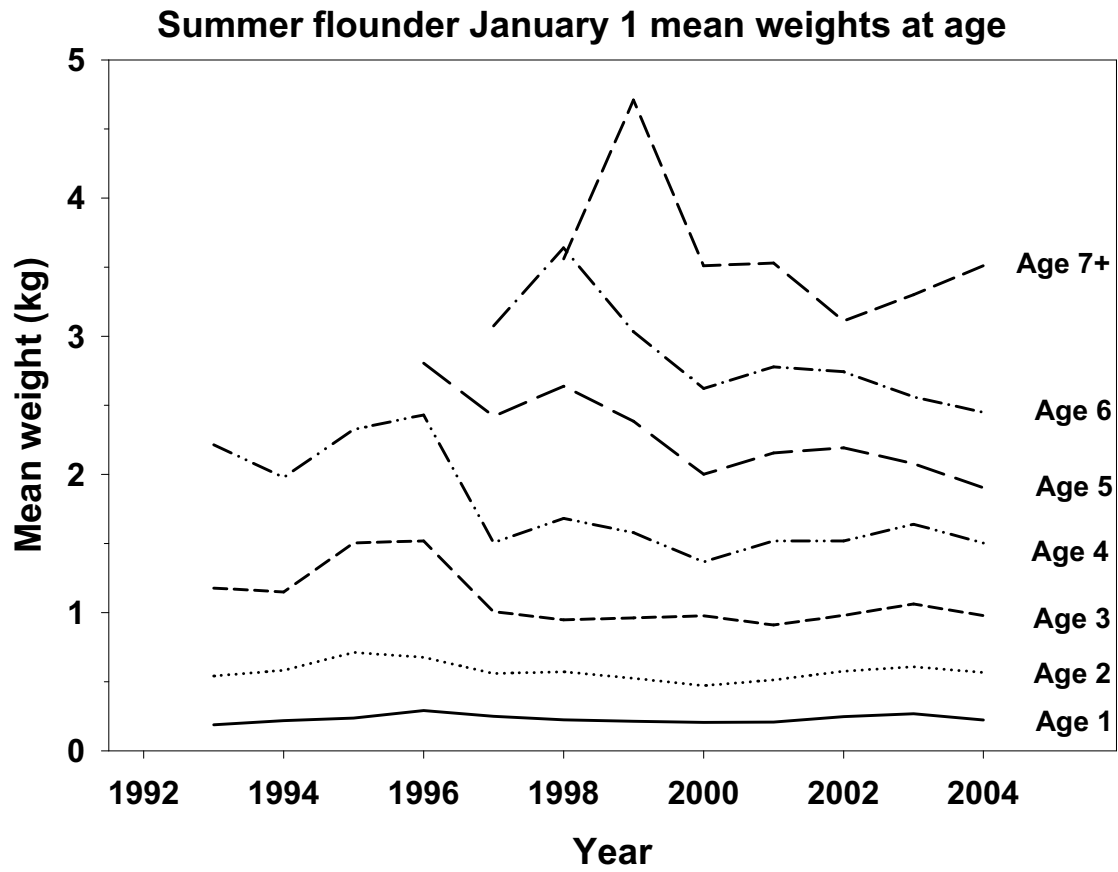


Figure 3-3. Trends in mean weight at age on January 1 for summer flounder: NEFSC Winter survey 1993-2004.

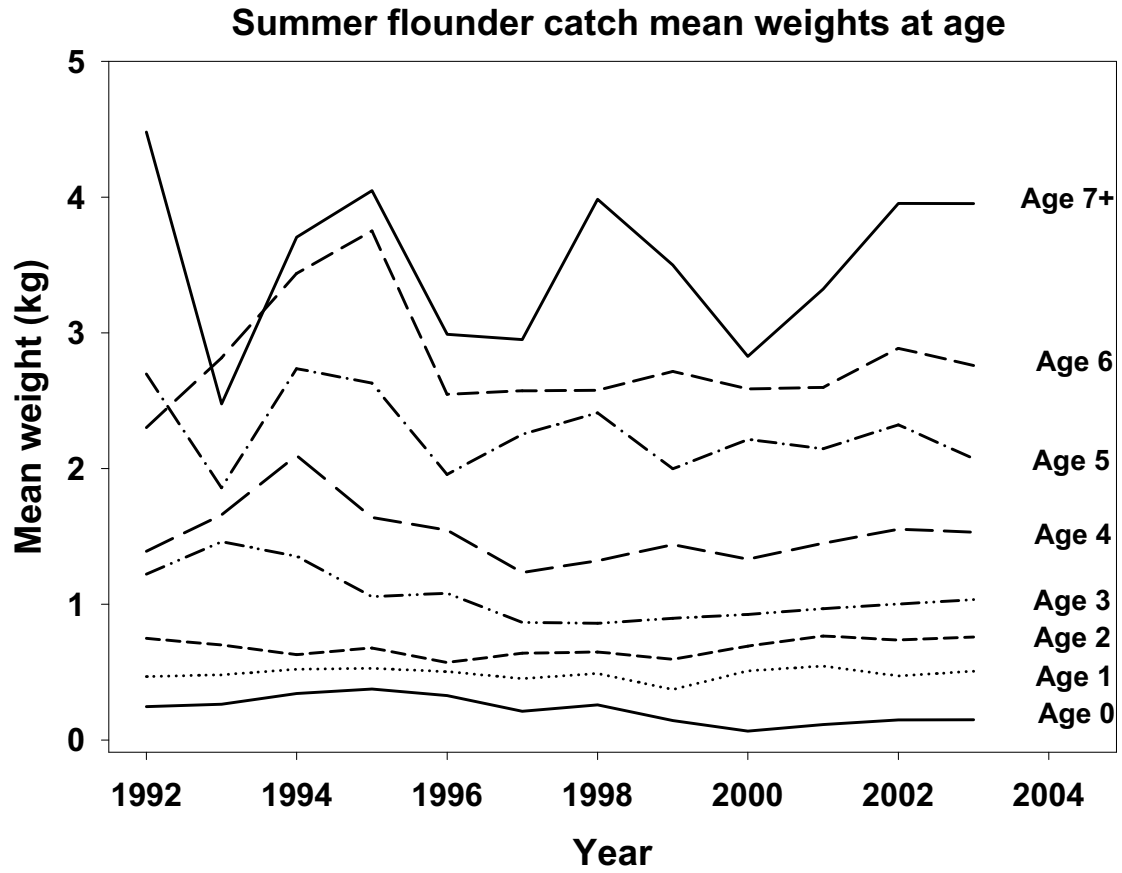


Figure 3-4. Trends in mean weight at age in the total catch of summer flounder.

SSB - RECRUIT DATA FOR 1983-2004 YEAR CLASSES

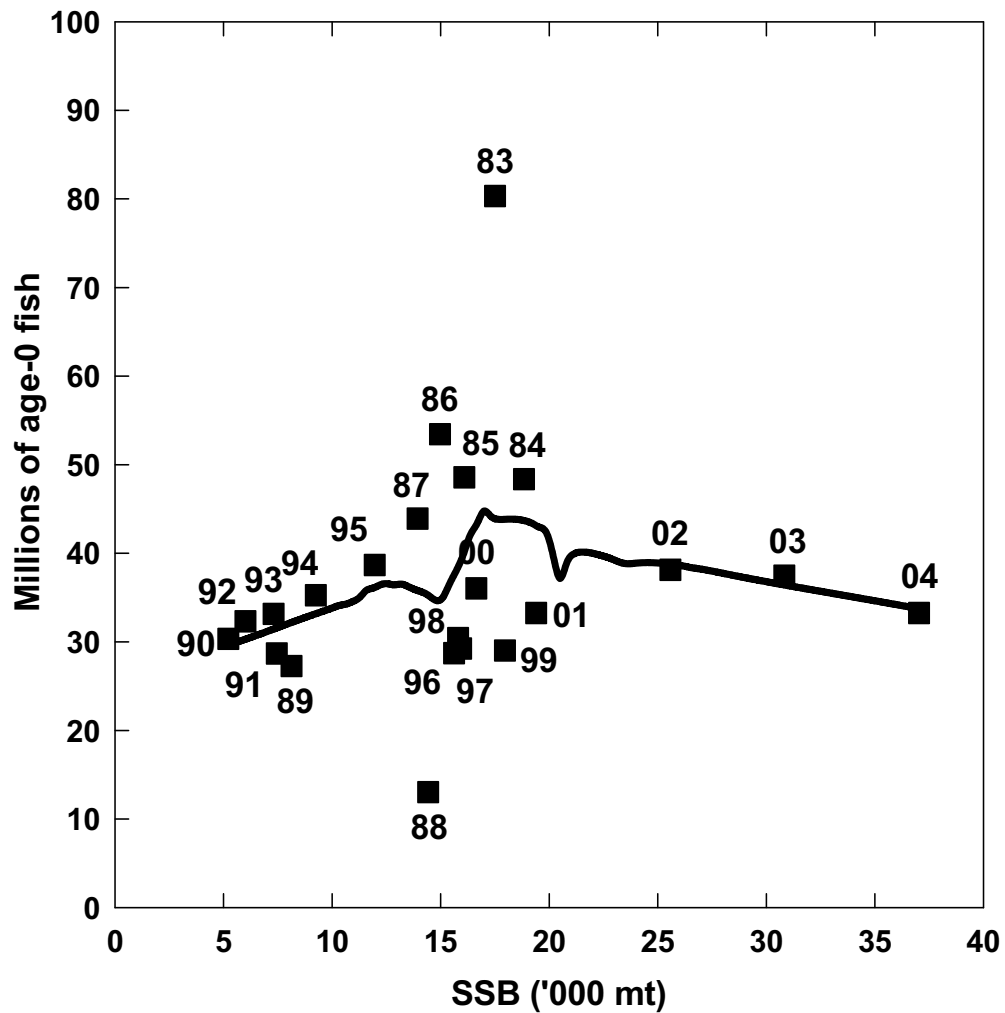


Figure 3-5. VPA spawning stock biomass and recruitment estimates for summer flounder. Smoother in the plot is loess with tension = 0.5.

Summer flounder BH models

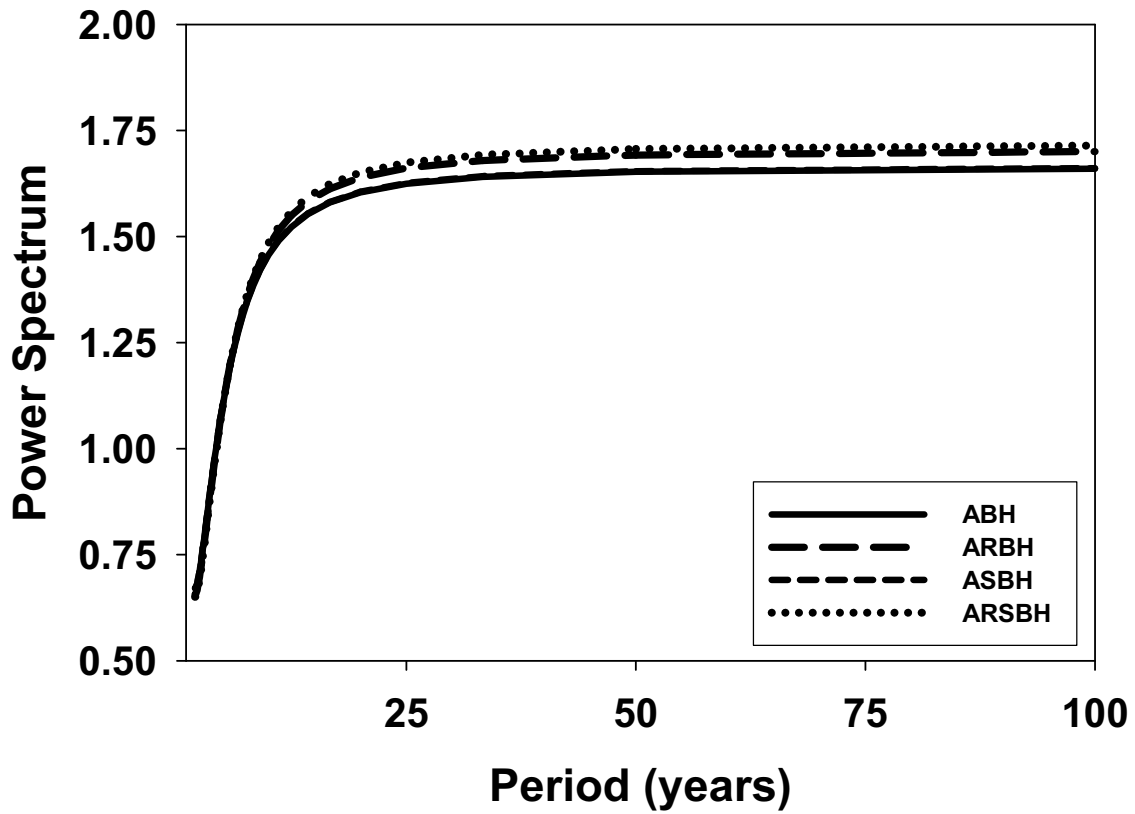


Figure 3-6. Summer flounder periodicity of environmental forcing for autoregressive BH stock-recruitment models.

Summer flounder BH model

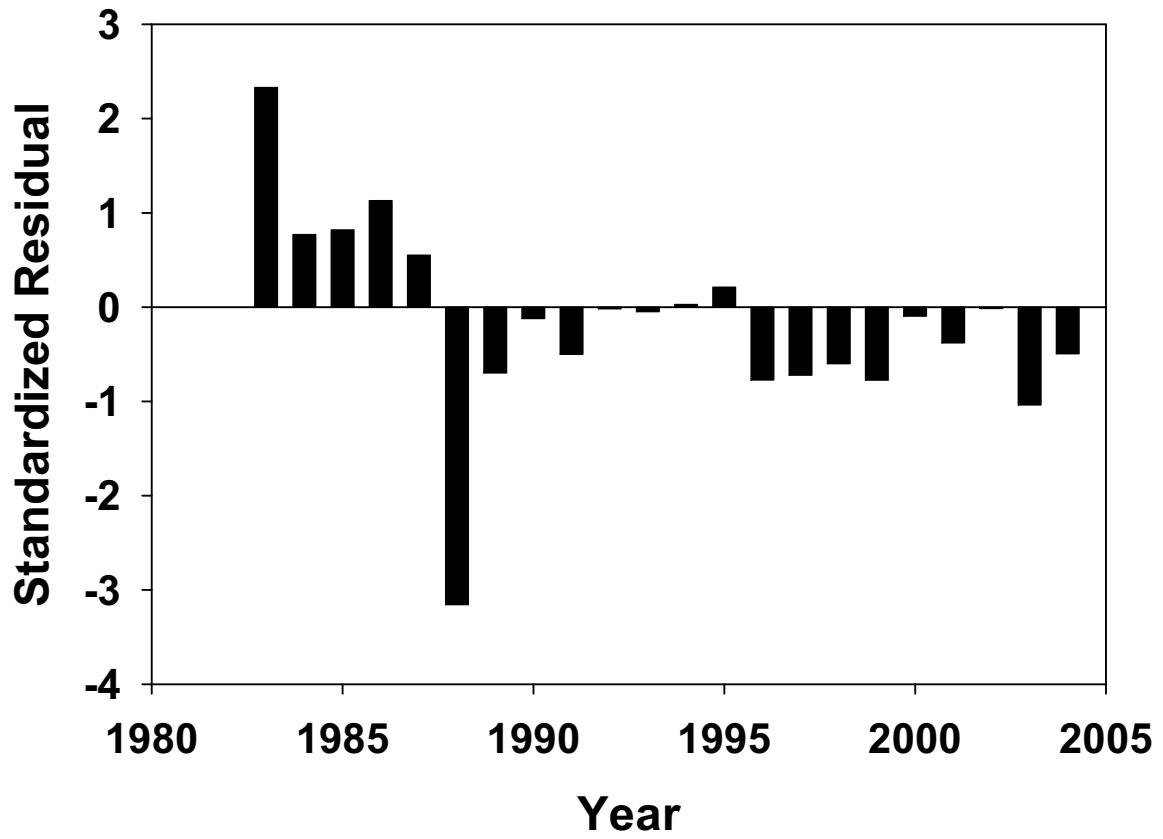


Figure 3-7. Summer flounder standardized residuals for the BH stock-recruitment model.

Summer flounder BH model

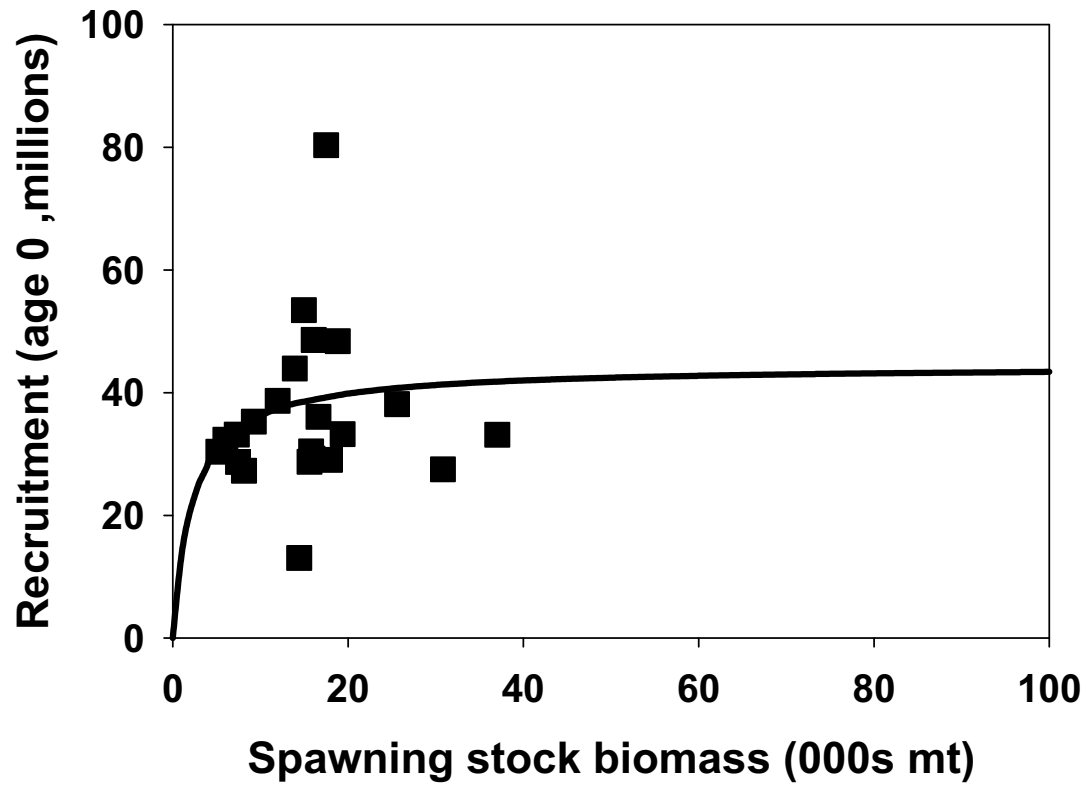


Figure 3-8. Summer flounder stock-recruitment relationship for the BH model.

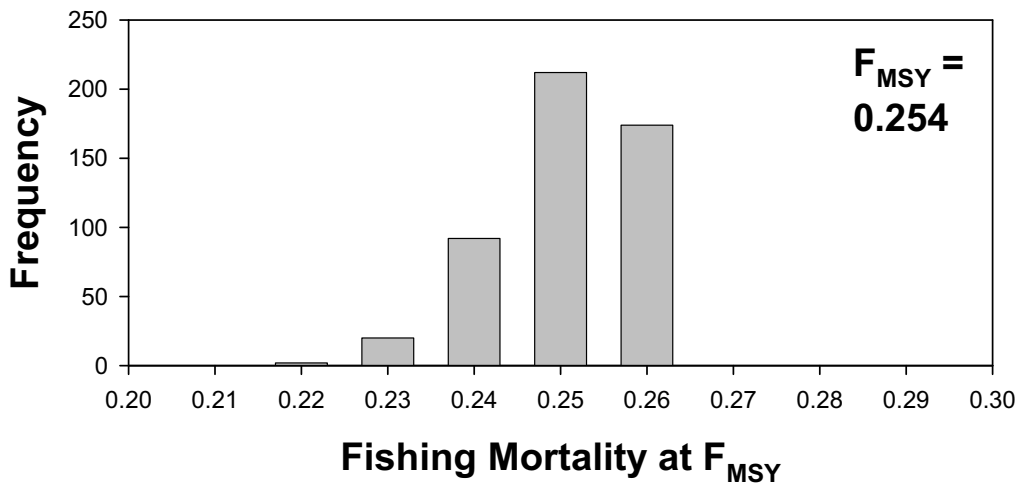
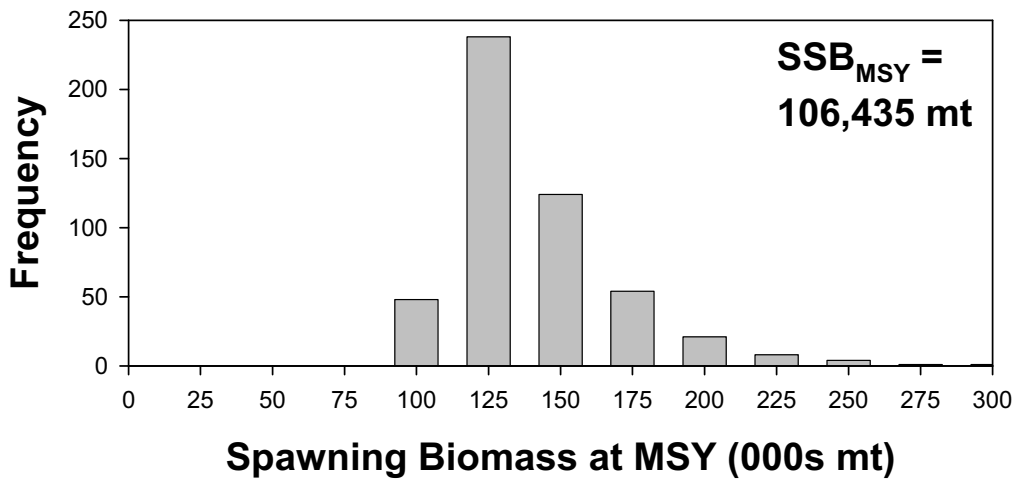
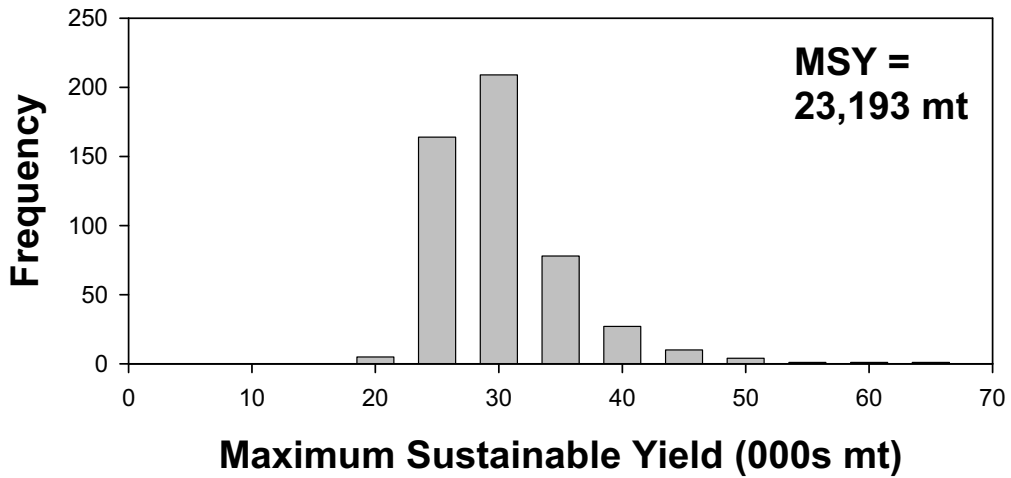


Figure 3-9. Summer flounder posterior distribution of MSY, SSB_{MSY}, and F_{MSY} for the most likley parametric BH stock-recruitment model fit.

Summer flounder BH model

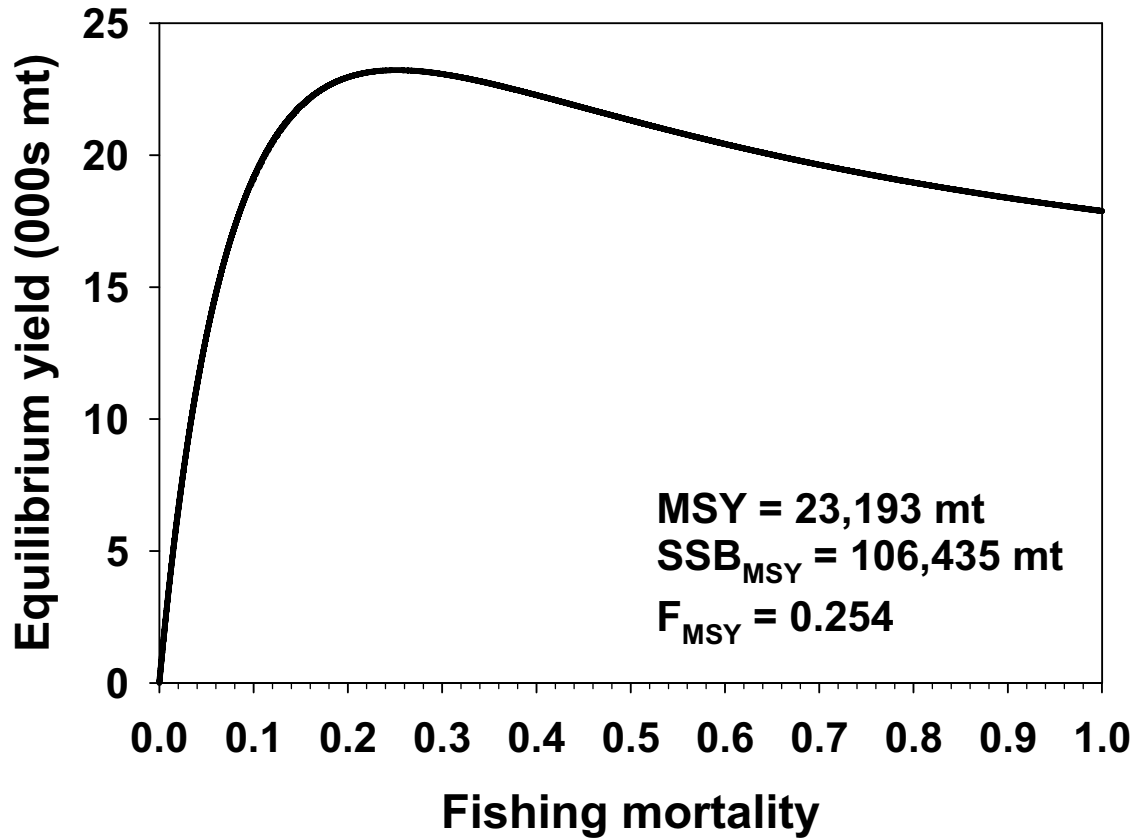


Figure 3-10. Summer flounder equilibrium yield versus F for the BH stock-recruitment model.