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Summer Flounder Biological Reference Point Update for 2006

by

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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" (i.e., biomass reference points calculated as the product of biomass per recruit and a reference period recruitment level; NEFSC 2002b). The 1999 assessment yield per recruit analysis indicated that $F_{threshold} = F_{target} = F_{max}$ = 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 biological reference points for summer flounder were next peer-reviewed by the 2005 SAW 41, based on the 2005 assessment update using fishery data through 2004 and research survey data through 2004/2005 (NEFSC 2005). The SAW 41 Review Panel noted that the Beverton-Holt (Beverton and Holt, 1957; BH) model fit the observed stock-recruitment data well, and provided reference points comparable to those derived from an empirical non-parametric (yield-per recruit) approach. The SAW 41 Panel noted, however, that the quantity of observed stock-recruitment data was limited (22 years), and the data during the early part of the time series, when the SSB was at the lowest observed levels, indicated a level of recruitment near the estimated R_{max}, and exerted a high degree of leverage on the estimation of the model parameters. This leverage resulted 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 (1999) estimate for Pleuronectid flatfish (0.8 $\pm$ 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 result may not be reasonable 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 SAW 41 Panel recognized 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 SAW 41 Panel advised that the BH model estimates were not suitable for use as biological reference points for summer flounder, and recommended continued use of reference points developed using the non-parametric model approach. The 2005 assessment update (NEFSC 2005) included updated the input data (1992-2004 averages of mean weights, maturities, and partial recruitment) for use in the yield and biomass per recruit component of the non-parametric approach. The updated 1982-2004 VPA provided an estimate of median recruitment for summer flounder of 33.111 million age 0 fish. FMP biological reference points from the 2005 assessment were $F_{MSY} = F_{max} = 0.276$, MSY = 19,072 mt (42.0 million lbs), and TSB_{MSY} = 92,645 mt (204.2 million lbs). The biomass threshold of $0.5*TSB_{MSY}$ = 46,323 mt (102.1 million lbs).

UPDATE OF BIOLOGICAL REFERENCE POINTS FOR 2006

Estimation Methodology

Two approaches were applied so as to be potentially complementary 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 (NEFSC 2002a). 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). For summer flounder the median recruitment estimated by the 2006 NFT ADAPT VPA (NFT 2005, SDWG 2006) over different time periods 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. 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 (NEFSC 2002a).

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). Since a wide range of models (Beverton-Holt and Ricker (1954) models, incorporating autoregressive error, and Bayesian priors for various parameters) had been tested in the 2005 SAW 41 work, the current parametric model exercise was limited to an update of the most-likely modeling result from the 2005 work, the simple Beverton-Holt model (BH; Beverton and Holt 1957, Mace and Doohan 1988).

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 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 ($W_t = W_0 * \exp(G(1-\exp(-gt)))$). 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. 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%. 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.

In the 2005 SAW 41 work (NEFSC 2005), the mean weights at age in the catch and stock, maturity schedule, and partial recruitment pattern were updated and broadened to include data from 1992-2004, covering the year range for individually measured and weighed fish sampled in NEFSC research surveys. The NEFSC research survey data were 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. Total stock biomass (January 1) mean weights at age were estimated from the NEFSC winter survey (1993-2004; February) individual fish samples. Estimates of the mean weights in the catch were 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 the1992-2004 period. 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 January 1 biomass 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 November 1 SSB ages 9-15, n = 4601 fish, $W_0 = 0.1959$, $G = 3.5480$, $g = 0.2662$, $p < 0.0001$). The partial recruitment pattern was calculated from fishing mortality rate estimates from the 2005 SAW 41 assessment NFT ADAPT VPA for 1992-2004 (NEFSC 2005). Shorter time periods over which to calculate the partial recruitment pattern were considered 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 2005 SAW 41 analyses used the same time periods for the partial recruitment as for the mean weights and maturities at age.

The 2002 BRPWG (NEFSC 2002a) fit stock-recruitment models to data sets for some 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 provides 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 2005 SAW 41 NFT ADAPT VPA 1982-2004 time series of stock-recruit estimates was used as input in fitting parametric stock-recruit models (NEFSC 2005).

In the current work, a consistent set of recent averages of mean weights at age in the catch, SSB, and biomass, and partial recruitment to the fisheries were used in all models to ensure consistency in results among the empirical non-parametric reference point estimation, parametric reference point estimation, VPA stock size and fishing mortality rate estimation, and projection model results, Mean weights at age in the catch as used in the VPA served as the basis for mean weights at age for the 1 January biomass (Rivard (1982) method calculated weights) and 1 November SSB weights (same as the catch). Mean weights at age and partial recruitment at age averaged over the 2003-2005 period were used as input to the yield and biomass per recruit analyses and in projections. Maturity at age remained the same as in the 2005 SAW 41 analyses (Tables 1-2). Estimates of SSB and recruitment for both modeling approaches were taken from the 2006 VPA update (Table 3, Figure 1; SDWG 2006).

Results for 2006: Empirical Non-parametric Approach

The updated yield per recruit analysis indicated that Fmax = 0.277 (the FMP Amendment 12 proxy for F_{MSY}). Yield per Recruit (Y/R) at F_{max} was estimated to be 0.548 kg, Spawning Stock Biomass per Recruit (SSB/R) at F_{max} was estimated to be 2.099 kg, and Total Stock Biomass per Recruit (TSB/R) at F_{max} was estimated to be 2.527 kg (Table 3).

Median recruitment for the 1982-2005 period was estimated to be 32.736 million fish (mean of 36.492 million fish). The product of the median recruitment and Y/R at F_{max} was 17,939 mt = 39.549 million lbs (current FMP Amendment 12 proxy for MSY), SSB at F_{max} was calculated at 68,713 mt = 151.486 million lbs and TSB at F_{max} was calculated at 82,724 mt = 182.375 million lbs (current FMP Amendment 12 proxy for $B_{MSY;}$ Table 3).

Median recruitment for the 1996-2005 period, during which R/SSB ratios have been lower than in earlier years (Figure 2), was estimated to be 28.969 million fish (mean of 28.818 million fish). The product of the 1996-2005 median recruitment and Y/R at F_{max} was 15,875 mt = 34.998 million lbs (current FMP Amendment 12 proxy for MSY), SSB at F_{max} was calculated at 60,806 mt = 134.054 million lbs and TSB at F_{max} was calculated at 73,205 mt = 161.389 million lbs (current FMP Amendment 12 proxy for B_{MSY}; Table 3).

Results for 2006: Parametric Model Approach

The standardized residual plot of the fit of the BH model to the summer flounder stock-recruitment data shows that the residuals lie within ±two standard deviations of zero, with the exception of the 1983, 1988, and 2005 year classes, which are the largest and smallest recruitments of the time series (Figure 3). The BH model stock-recruitment plot shows that recruitment values near SSB_{MSY} are about 35 million fish, about 6% higher than the median of 33 million fish from the observed VPA 1982-2005 recruitment series (Figure 4). FMP biological reference points from the BH model would be F_{MSY} = 0.264, MSY = 19,094 mt (42.1 million lbs), and SSB_{MSY} = 92,831 mt (204.7 million lbs), where the estimate of MSY includes commercial and recreational landings and discards. If expressed in terms of SSB, the biomass threshold of 0.5*SSB_{MSY} would be 46,416 mt (102.3 million lbs).

PROJECTIONS

Previous peer-reviews of summer flounder biological reference points endorsed use of those estimated by the empirical non-parametric approach (Fmax as a proxy for FMSY; Bmax as a proxy for BMSY, estimated as the product of biomass per recruit and an historic, median level of recruitment) (MAFMC 2001a, NEFSC 2000, 2002b, 2005). In the current work, that endorsement has been continued (i.e., use of either the 1982-2005 or the 1996-2005 recruitment series, and the subsequently estimated proxies for BMSY), and projections made to determine the associated TALs for 2007 and trajectories of the total stock biomass toward BMSY.

Projections of stock biomass and associated TALs for 2007 are presented in Table 6 for both recruitment scenarios and BMSY estimates, including scenarios (A3 and B3) with a 33% downward adjustment of the fishing mortality rate to account the retrospective pattern in fishing mortality apparent in the 2006 assessment (Figure 5). The adjustment in these short-term projections are made in the same manner as those used by the MAFMC Monitoring Committee in developing TAL recommendations for the MAFMC and NMFS.

Deterministic long-term projections were made for both recruitment and reference point alternatives, with one beginning in 2000 and another beginning in 2006, in order to demonstrate that both candidate reference points would have been (i.e., the projection from 2001) and will be (i.e., the projection from 2006) attainable if the stock is fished at the updated F_{max} = 0.277 over the long term (Figure 6; due to software limitations and to maintain consistency between the from-2001 and from-2006 projections, stochastic projections could not be made). The plots show total stock biomass (1 January) trajectories from two starting points toward estimates of BMSY for two recruitment assumptions (1982-2005 distribution with median = 32.7 million and 1996-2005 distribution with median = 29.0 million). The top panel of Figure 6 shows the trajectory from 2001 stock sizes at age as estimated in the 2006 assessment. By starting in 2001 (terminal catch year 2000), large changes in stock size estimates due to VPA convergence and the retrospective pattern have ceased. The bottom panel of Figure 6 shows the trajectory from 2006 stock sizes as estimated in the 2006 assessment, adjusted for the retrospective pattern (recruitment [age 0] reduced by 10%, age 1+ reduced by 17%).

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Table 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. Bold italic values for the 2006 update remained unchanged from the 2005 SAW 41 work, due to sample size considerations.

	1990 SAW 11		1999 Assessment			2005 SAW 41			2006 Update		
Age	Catch	Nov 1 SSB	Jan 1 Bio	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	0.118	0.188	0.188
1	0.432	0.432	0.353	0.471	0.471	0.241	0.499	0.469	0.287	0.487	0.487
2	0.642	0.642	0.556	0.643	0.643	0.577	0.684	0.817	0.609	0.728	0.728
3	1.164	1.164	0.722	0.862	0.862	0.980	1.049	1.402	0.852	0.975	0.975
4	1.811	1.811	1.111	1.277	1.277	1.539	1.489	1.953	1.152	1.347	1.347
5	2.449	2.449	1.860	2.330	2.330	2.136	2.217	2.946	1.577	1.760	1.760
6	3.074	3.074	2.337	2.565	2.565	2.680	2.745	3.073	2.130	2.307	2.307
7	3.434	3.434	3.130	3.537	3.537	3.245	3.515	3.630	2.769	3.769	3.769
8	4.380	4.380	4.120	4.592	4.592	3.576	4.515	4.515	***3.576***	***4.515***	***4.515***
9	*4.841*	*4.841*	*4.671*	*4.841*	*4.841*	3.780	*4.926*	*4.926*	***3.780***	***4.926***	***4.926***
10	*5.336*	*5.336*	*5.162*	*5.336*	*5.336*	4.672	*5.313*	*5.313*	***4.672***	***5.313***	***5.313***
11	*5.767*	*5.767*	*5.590*	*5.767*	*5.767*	5.020	*5.630*	*5.630*	***5.020***	***5.630***	***5.630***
12	*6.135*	*6.135*	*5.957*	*6.135*	*6.135*	5.360	*5.885*	*5.885*	***5.360***	***5.885***	***5.885***
13	*6.445*	*6.445*	*6.266*	*6.445*	*6.445*	*5.553*	*6.089*	*6.089*	***5.553***	***6.089***	***6.089***
14	*6.704*	*6.704*	*6.525*	*6.704*	*6.704*	*5.674*	*6.249*	*6.249*	***5.674***	***6.249***	***6.249***
15	*6.917*	*6.917*	*6.738*	*6.917*	*6.917*	*5.765*	*6.375*	*6.375*	***5.765***	***6.375***	***6.375***

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

	1990 SAW 11		1999 Assessment		2005 SAW 41		2006 Update	
Age	Percent Mature	Partial Recruit.	Percent Mature	Partial Recruit.	Percent Mature	Partial Recruit	Percent Mature	Partial Recruit.
0	38	5	38	1	38	1	38	2
1	72	50	72	18	91	19	91	13
2	90	100	90	62	98	77	98	67
3	97	100	100	100	100	100	100	100
4	99	100	100	100	100	100	100	100
5	100	100	100	100	100	100	100	100
6	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100
11	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100
13	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100

Table 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	2006 Update
Fmax	0.232	0.263	0.276	0.277
Y/R @ Fmax	0.574	0.552	0.576	0.548
SSB/R @ Fmax	2.107	2.139	2.466	2.099
TSB/R @ Fmax	not calculated	2.813	2.798	2.527

Table 4. Input spawning stock biomass (metric tons; ages 0-7+) and recruitment (millions of age 0 fish) data for summer flounder parametric stock-recruitment models: 2006 assessment update.

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	32,316
1993	7,303	33,156
1994	9,249	35,248
1995	11,960	38,660
1996	15,608	28,194
1997	15,874	28,973
1998	15,641	30,716
1999	17,710	28,643
2000	16,328	35,050
2001	18,951	28,965
2002	24,603	34,080
2003	27,314	24,517
2004	32,493	34,543
2005	32,608	14,496

Table 5. 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	2006 Update	2006 Update
Recruitment Year Range	1982-1987	1982-1998	1982-2004	1982-2005	1996-2005
Median Recruitment (000s)	58,440	37,844	33,111	32,736	28,969
Y @ Fmax (MSY)	33,545	20,897	19,072	17,939	15,875
SSB @ Fmax (SSB_{MSY})	123,133	80,948	81,652	68,713	60,806
TSB @ Fmax (TSB_{MSY})	not calculated	106,444	92,645	82,724	73,205

Table 6. Summary summer flounder projection results incorporating updated biological reference points and alternative recruitment assumptions.

Projection Run Descriptions:

A1: Recruitment distribution with median = 32.736 million fish, fishing during 2007-2009 at updated F_{max} = 0.277.

A2: Recruitment distribution with median = 32.736 million fish, fishing during 2007-2009 at F = 0.170 to reach B_{MSY} target in 2010 .

A3: Recruitment distribution with median = 32.736 million fish, fishing during 2007-2009 at adjusted F = 0.114 (A2 F reduced 33% to account for retrospective pattern).

B1: Recruitment distribution with median = 28.969 million fish, fishing during 2007-2009 at updated F_{max} = 0.277.

B2: Recruitment distribution with median = 28.969 million fish, fishing during 2007-2009 at F = 0.201 to reach B_{MSY} target in 2010.

B3: Recruitment distribution with median = 28.969 million fish, fishing during 2007-2009 at adjusted F = 0.135 (B2 F reduced 33% to account for retrospective pattern).

Projection Run	Median Recruitment (millions)	F2007-2009	Median 2010 Total Stock Biomass 000s mt (m lbs)	B_{MSY} target for 2010 000s mt (m lbs)	Percent B_{MSY} target	Median TAL for 2007 000s mt (m lbs)
A1	32.736	0.277	70,896 (156.3)	82,724 (182.4)	86	9,054 (20.0)
A2	32.736	0.170	82,724 (182.4)	82,724 (182.4)	100	5,838 (12.9)
A3	32.736	0.114	90,383 (199.2)	82,724 (182.4)	109	4,005 (8.8)
B1	28.969	0.277	65,377 (144.1)	73,205 (161.4)	89	9,053 (20.0)
B2	28.969	0.201	73,205 (161.4)	73,205 (161.4)	100	6,800 (15.0)
B3	28.969	0.135	81,400 (179.5)	73,205 (161.4)	112	4,697 (10.4)

Figure 1.

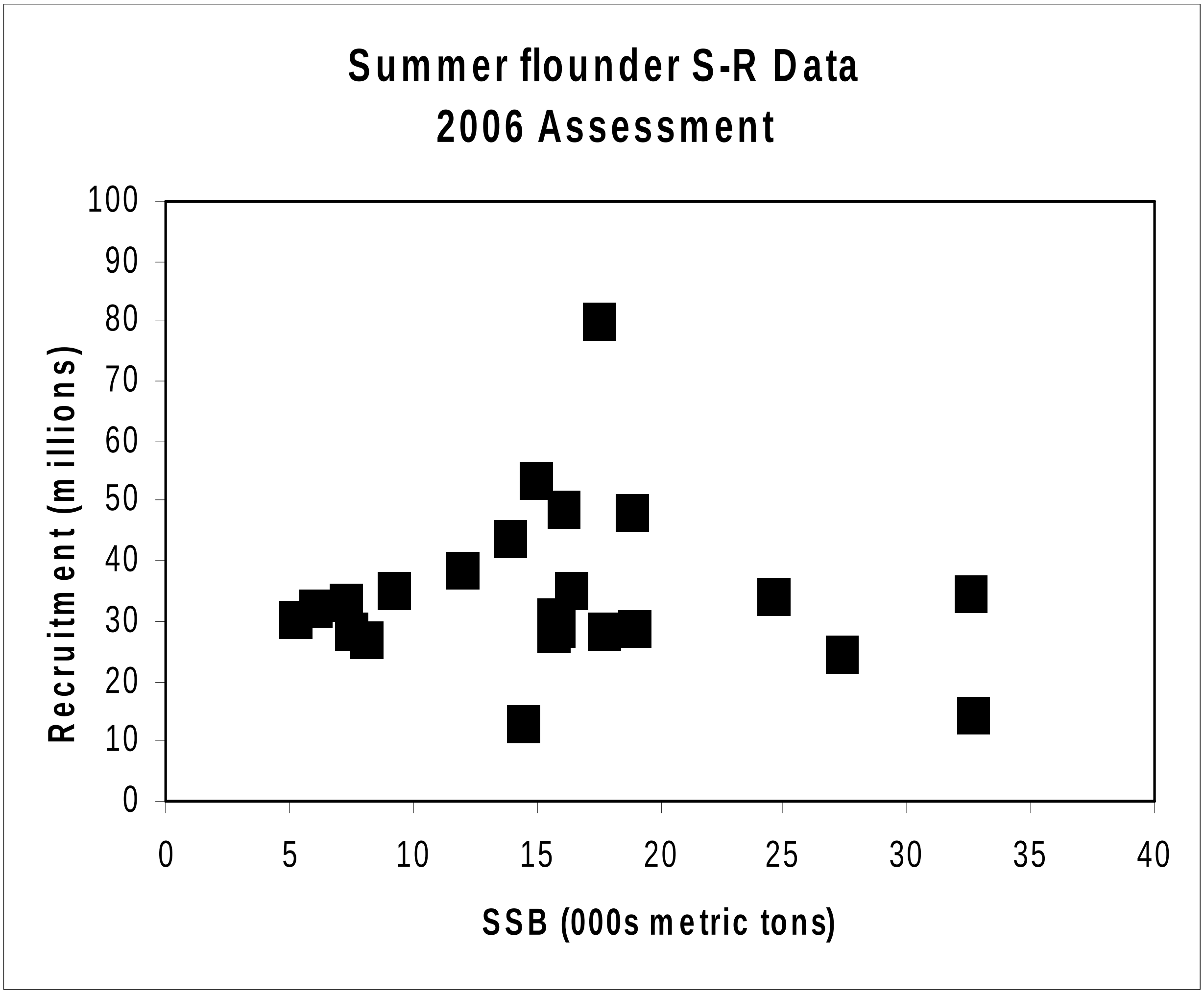
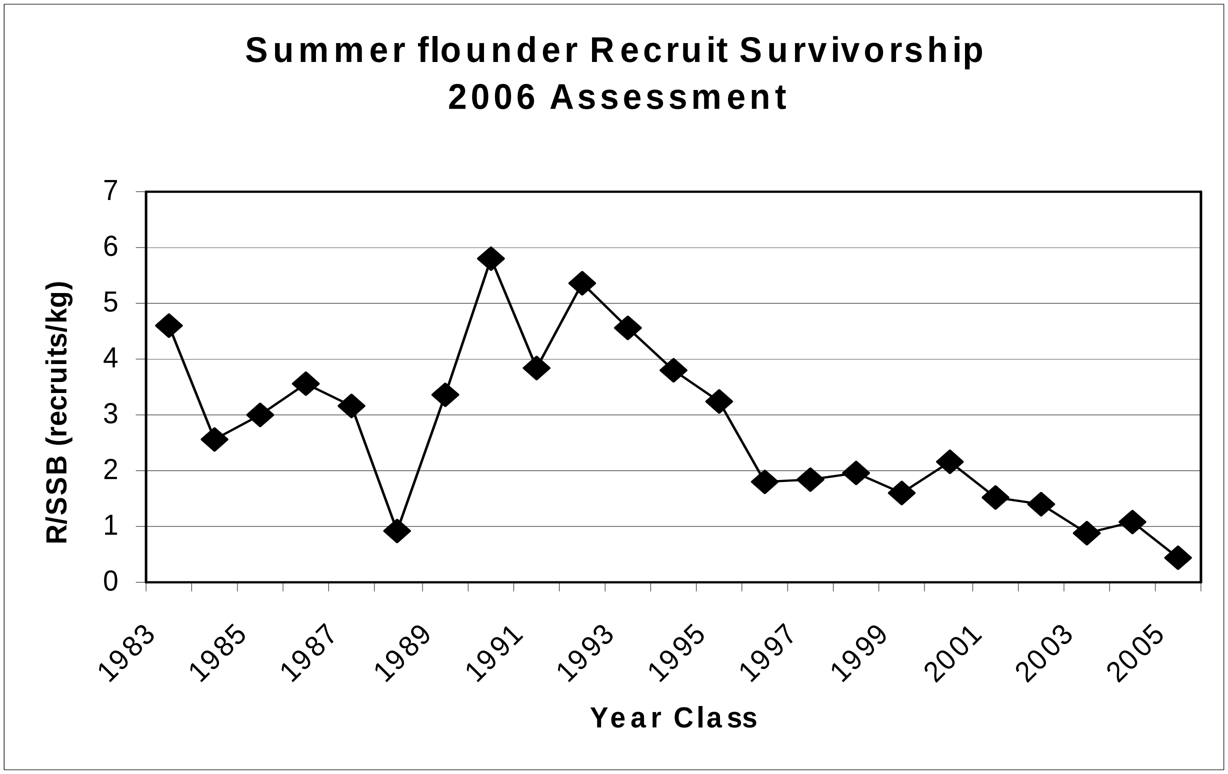

Summer flounder S-R Data
2006 Assessment
100
90
80
70
60
50
40
30
20
10
0
Recruitment (millions)
0
5
10
15
20
25
30
35
40
SSB (000s metric tons)

Figure 2.



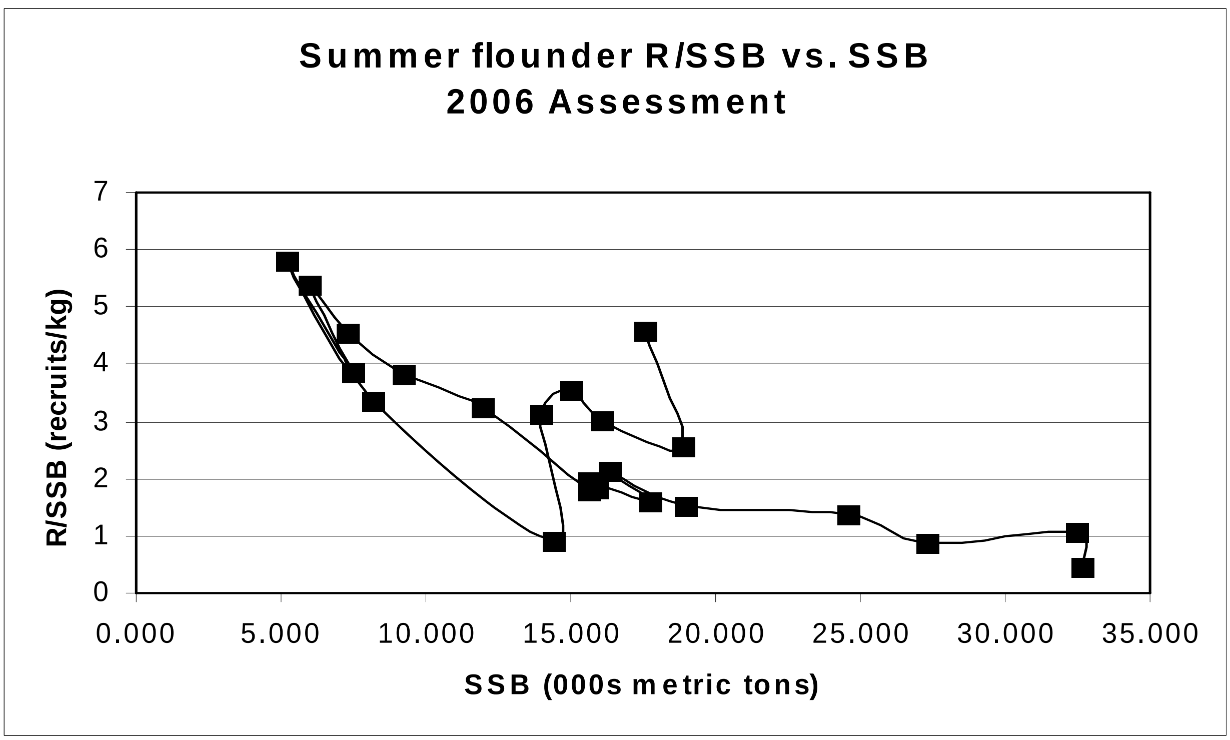


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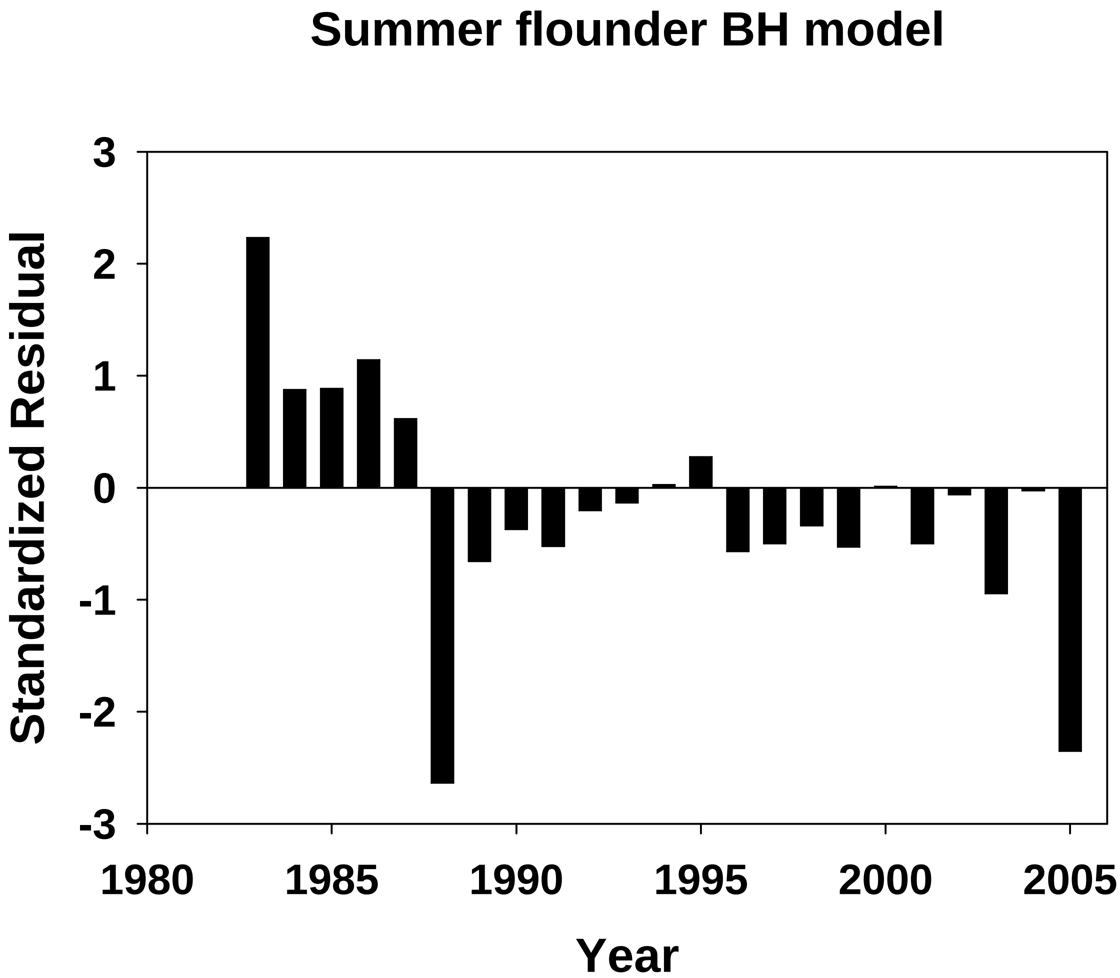
Figure 3.



Summer flounder BH model
Standardized Residual
3
2
1
0
-1
-2
-3
1980
1985
1990
1995
2000
2005
Year

Figure 4.

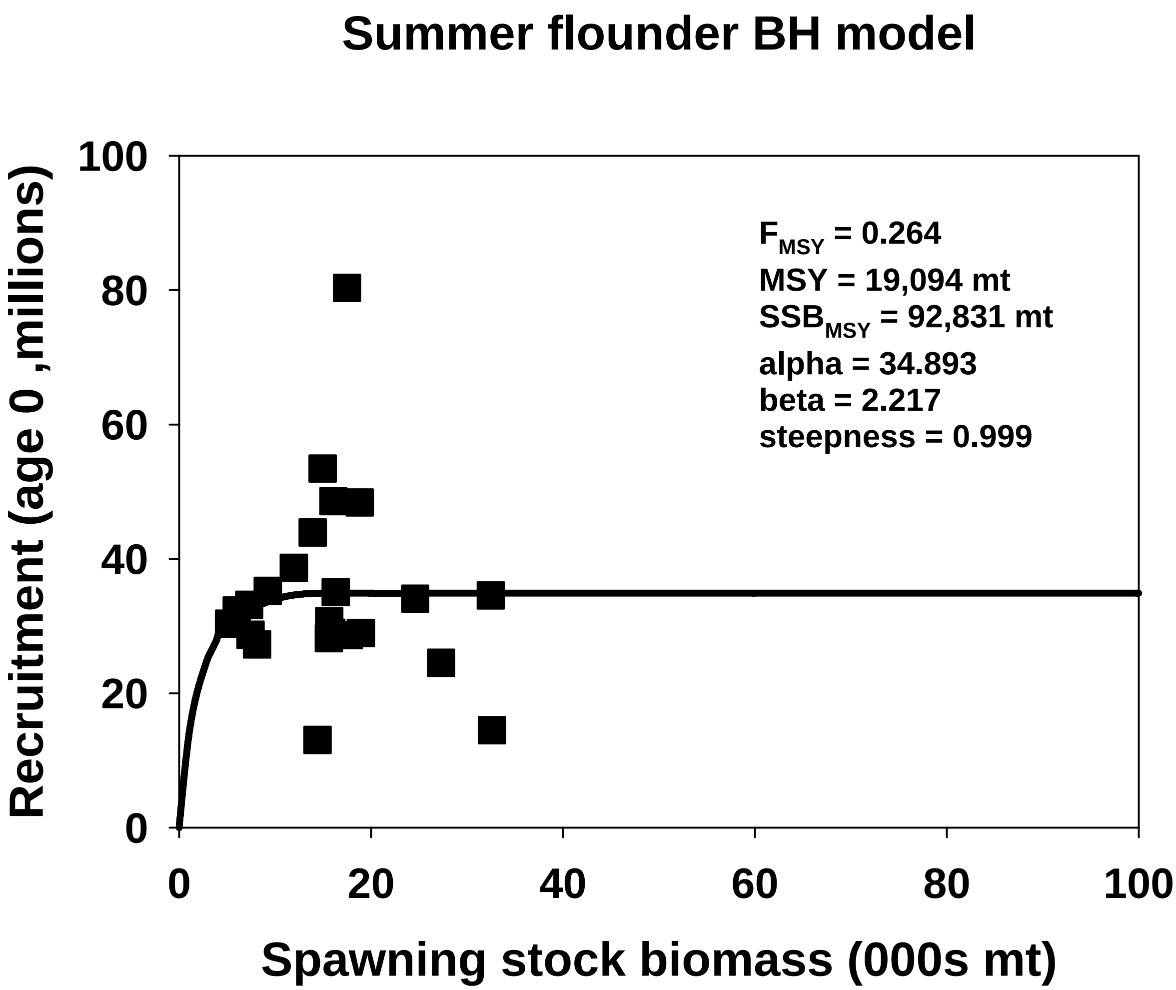
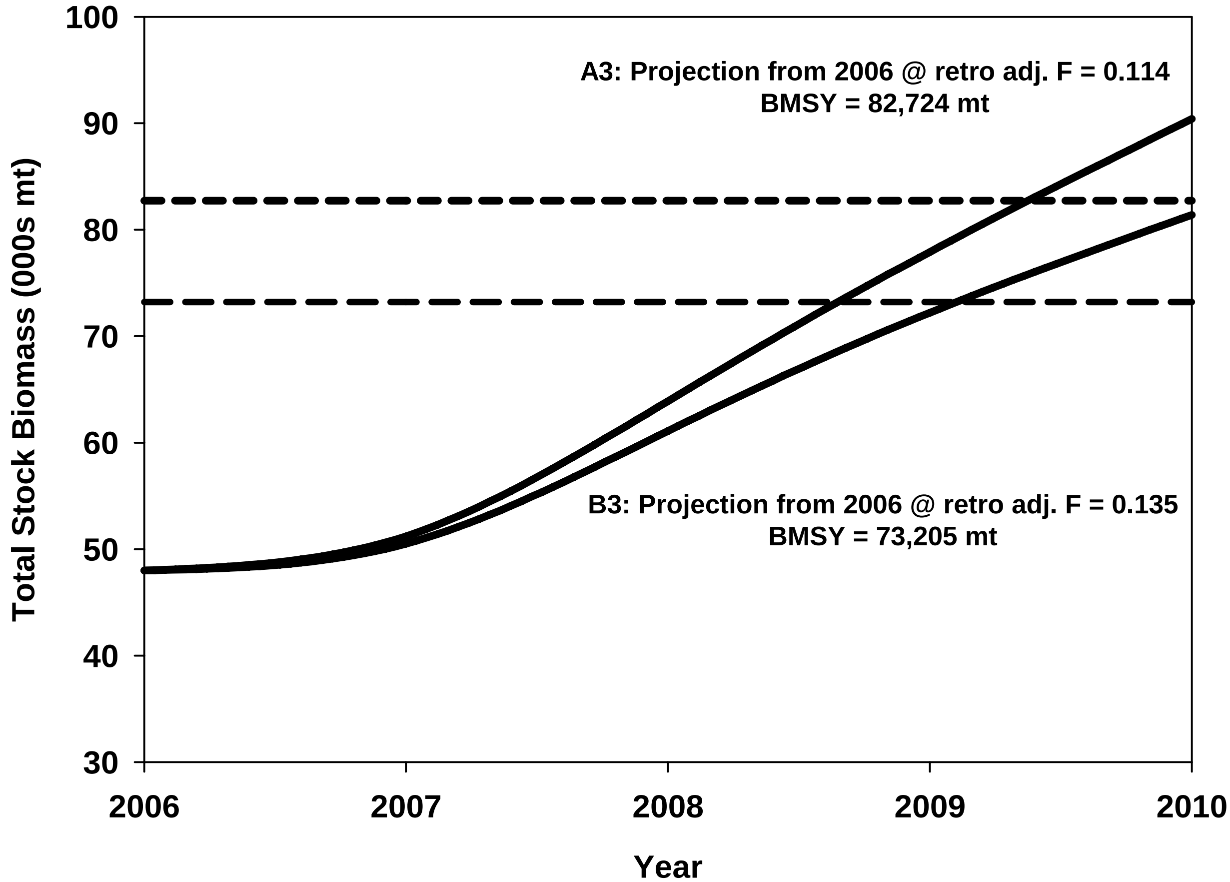
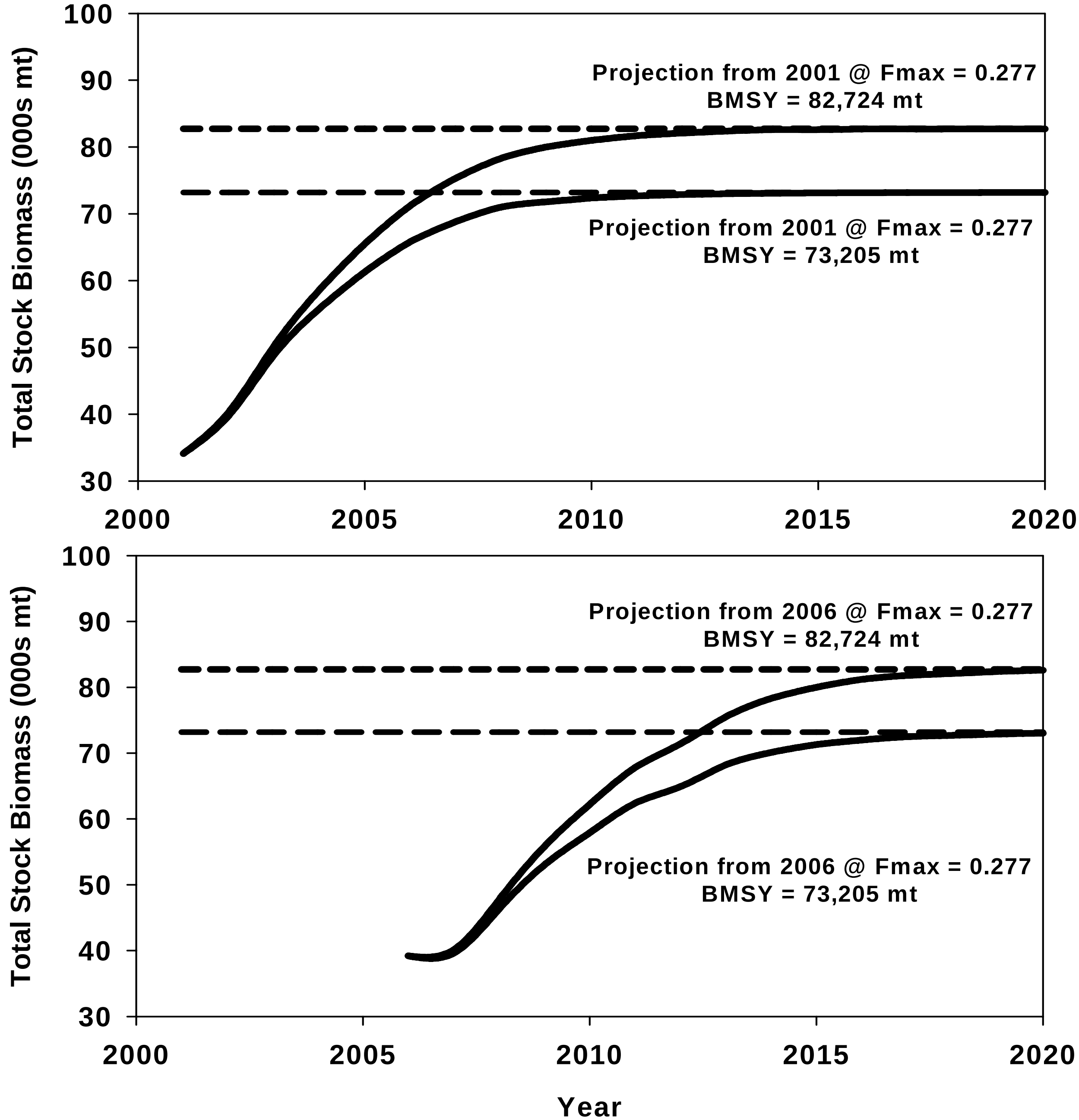

Summer flounder BH model
Recruitment (age 0 ,millions)
Spawning stock biomass (000s mt)
0
20
40
60
80
100
F_{MSY} = 0.264
MSY = 19,094 mt
SSB_{MSY} = 92,831 mt
alpha = 34.893
beta = 2.217
steepness = 0.999

Figure 5.



A3: Projection from 2006 @ retro adj. F = 0.114
BMSY = 82,724 mt
B3: Projection from 2006 @ retro adj. F = 0.135
BMSY = 73,205 mt
Total Stock Biomass (000s mt)
100
90
80
70
60
50
40
30
2006
2007
2008
2009
2010
Year

Figure 6.



Total Stock Biomass (000s mt)
100
90
80
70
60
50
40
30
2000
2005
2010
2015
2020
Projection from 2001 @ Fmax = 0.277
BMSY = 82,724 mt
Projection from 2001 @ Fmax = 0.277
BMSY = 73,205 mt
Total Stock Biomass (000s mt)
100
90
80
70
60
50
40
30
2000
2005
2010
2015
2020
Year
Projection from 2006 @ Fmax = 0.277
BMSY = 82,724 mt
Projection from 2006 @ Fmax = 0.277
BMSY = 73,205 mt