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GARM3
Georges Bank Haddock (*Melanogrammus aegelfinus*)

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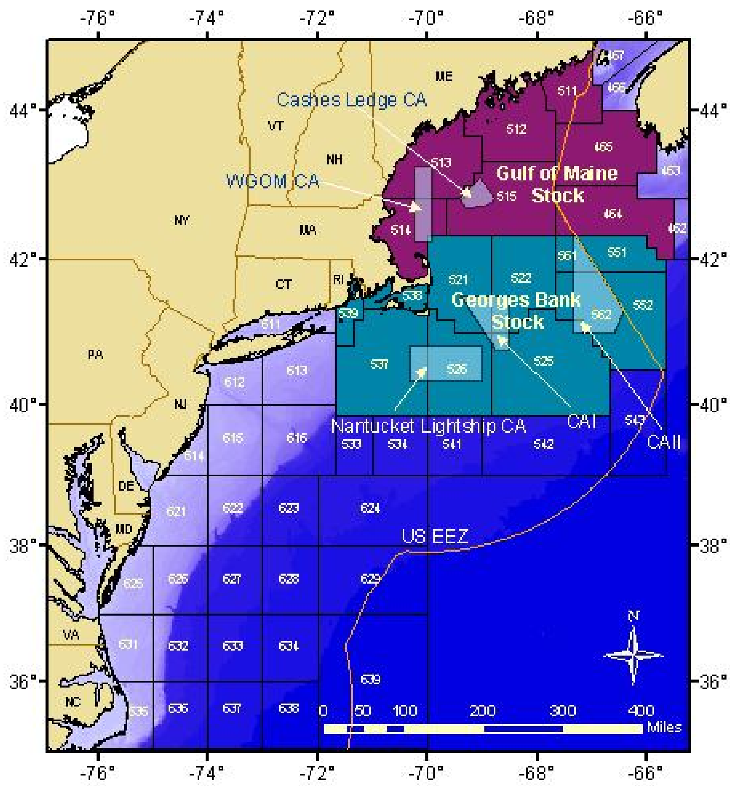
NEFSC



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B. Georges Bank Haddock

1.0 Background

The Georges Bank haddock stock was last assessed as part of the GARM2 (Brodziak et al. 2006). That assessment, which was an update rather than a benchmark, included landings and discards through 2004, and abundance indices through 2005. The model applied was the NMFS Toolbox implementation of VPA, with catch at age extending back to 1963. Reference points had been examined as part of the 2002 working group on biological reference points (NEFSC 2002). Although it was determined that stock size had an effect on recruitment, the parametric fits of stock recruit curves had poor residual diagnostics; a nonparametric approach was taken, with $F_{40\%}$ serving as a proxy for F_{MSY} (Brodziak and Legault 2005). The value of $F_{40\%}$ was 0.26, and the corresponding levels of SSB_{MSY} and MSY were 250,300 mt and 52,900 mt, respectively. These values were derived by taking SSB/R and YPR and multiplying by the mean recruitment for years in the period (1931-1960) where SSB was above its median (75,000 mt). Based on the SSB median criterion, mean recruitment was 75.23 million age-1 recruits (NEFSC 2002).

The current overfished threshold is $SSB_{threshold}$=0.5*SSB_{MSY}=125,150 mt, while the current overfishing threshold is $F_{threshold}$=F_{MSY}. VPA estimated spawning stock biomass in 2004 was 116,800 mt, or 93% of the $SSB_{threshold}$, and the estimate of F_{2004} was 0.24. Therefore, the stock was slightly overfished, but overfishing was not occurring. Catch in 2004 was estimated to be 16,924 mt—well below the estimated 52,900 mt at MSY.

2.0 Assessment for 2008

<u>The Fishery</u>

US haddock commercial landings and discards were re-estimated for the period 1989-2006. Commercial landings were apportioned among statistical areas following a landings allocation algorithm (Wigley et al. 2007), and between Gulf of Maine and Georges Banks stocks following a general algorithm developed by Palmer (2008). Total catches of Georges Bank haddock increased from a low of 2,492 mt in 1995 to 21,388 mt in 2005, but decreased to 15,495 mt in 2006 (Table B1, Figure B1). Total discards were estimated using a ratio of discarded haddock to kept of all species following the methodology in Wigley et al. (2007). Estimates were made for years 1989-2006 because these are the years where at-sea observer sampling was available. No attempt was made to hindcast discards prior to 1989, thus it is assumed that appropriate estimates of discard were incorporated into the catch at age matrix for earlier years. From the previous assessment, the difference between total US catches and total US landings was used to infer the magnitude of discards for the years 1989-2004 (Tables 1.2 and 2 in Brodziak et al. 2006). Inferred discards are compared to the current discards in Table B2 of this report. Inferred discards are 0 for the years 1989-2000, suggesting that either there is a mislabeling of Tables or that no discards were estimated for that period in the previous assessments. For this assessment, discards are at fairly low levels compared to landings for 1989-2003, and then increase sharply in 2004-2006 following the enormous 2003 year class (Table B3). Discards in year 2004 seem rather large, however, the CVs on annual discard estimates are rather high (0.4 to >2.0 in most years). US landings at age, on the other hand, are fairly well estimated with CVs generally <15% for the ages that make up the bulk of annual US landings from about 1999 onwards (Table B4, B5). Prior to 1999, CVs on US landings at age were somewhat larger, ranging from about 20% to >40%.

The Canadian catch at age of eastern Georges Bank haddock during 1972-2006 was taken from the most recent TRAC assessment of this substock (Van Eeckhaute et al. 2007).

Survey Indices

NEFSC spring survey and autumn survey indices in total number and kg per tow (Table B6, Figure B2) were computed using standardized research survey data. Mean number per tow increased sharply with the enormous 2003 yearclass, but has since decreased as that cohort experiences natural and fishing mortality. Mean kg/tow has been increasing in an oscillating fashion since about 1999. Number per tow at age indices for the NEFSC spring (Table B7a) and autumn (Table B7b) surveys were computed using survey-specific age-length keys using the NMFS Toolbox program SAGA, both with and without conversion factors (Table B8). The NEFSC indices used in the assessment were calculated with the conversion factors.

Canadian winter survey indices (Table B9) were taken from the most recent TRAC assessment (Van Eeckhaute et al. 2007).

Maturity

Maturity samples are available for haddock beginning in 1969. Most haddock are immature at age 1 and almost fully mature by age 3. Previous assessments used time-varying stanzas of maturity at age in VPA analyses. In preparation for the 2008 assessment, the estimation of maturity at age was revisited. A series of analyses were performed to estimate maturity at age with a "moving average" type of approach using windows of 3 or 5 years, as well as a single maturity ogive using all years (O'Brien 2008). The model estimate of the age at 50% maturity did not appear to differ significantly across years for the 3 or 5 year window (Figure B3). Although the estimated proportion mature at age appeared to differ over time, the trends between ages was not always consistent, nor did it fit entirely within a hypothesized density dependent response (Figure B4). In some years, maturity at age increased when the stock size was low, but in other years, maturity at age increased with stock size. It may be that maturity is better understood as a length based process, or there may be lags associated with large changes in population abundance. Ultimately, this question deserves further (future) study. A "continuity" VPA run was made using the previous maturity at age stanzas, however the proposed 2008 VPA base run uses a single maturity ogive for all years.

Natural Mortality

As in previous assessments for this stock, M=0.2 was assumed for all ages (1-9+) and all years. No alternatives were explored.

3.0 Assessment Results

VPA Analyses

Several different decisions regarding data treatment were made between GARM2 and GARM3. A standard allocation algorithm to apportion landings to statistical area was adopted as an improvement over individually determined proration schemes. The methodology to estimate discards formerly was based on a discard to kept ratio of haddock only, whereas currently the ratio is based on discarded haddock to kept of all species. Finally, the previous assessment used time-varying stanzas of maturity at age, whereas the current assessment proposes to use a single maturity ogive for all years. Any or all of these differences can influence model results outside of the dynamics that are actually driving the stock. To delineate changes in stock abundance from changes in methodology and the addition of 2 years of data, three VPAs were conducted.

VPA Model-1: This is as close to a continuity scenario as possible, with the same maturity stanzas, and only two years of additional landings and discards added to the model.

VPA Model-2: The same CAA matrix as in VPA-1, but a single maturity ogive for all years was used.

VPA Model-3: The CAA matrix was updated for years 1989-2006 according to the new landings allocation algorithm and the new ratio method for estimating discards, and a single maturity ogive was used for all years.

VPA Results

All three VPA runs were performed with the NOAA Fisheries Toolbox (NFT) ADAPT VPA version 2.7.7. There was very little difference between VPA models 1 and 2 (maturity stanzas versus time invariant maturity). The estimates of F_{2006}, N_{2007}, B_{2007} were identical, and SSB_{2006} differed by only 8 mt (Table B10). Comparing VPA models 2 and 3, all abundance measures were greater in model 3 by about 10%, because the annual catch totals (landings+discards) were greater in model 3. The proposed 2008 VPA base model is Model-3, because it implements decisions made at GARM3 data and model meetings regarding treatment of landings and discards.

Bootstrapping and retrospective analyses were conducted for all three models, with 1000 bootstraps for each year from 1995-2006. Bootstrapped distributions of estimated F, SSB, and N were examined for years 1995, 2000, and 2004 and are plotted for VPA models 1 and 3 (Figures 5, 6). The year 1995 was selected for detailed examination because several stocks assessed by NEFSC show a retrospective pattern around the years 1994-1995. The years 2000 and 2004 were also examined because year 2000 was the last data year considered in the estimate of current BRPs (NEFSC 2002), and because 2004 was the last year of data considered at the GARM2 (Brodziak et al. 2006).

There was substantial overlap in the distributions by year in 1995 and 2004, although the plots for year 2000 showed a trend. Specifically, the distribution of F_{2000} spanned a consistently smaller range of values in retrospective runs for years 2000-2006, while the distribution of SSB_{2000} spanned a consistently larger range of values for the same years. Model-3 revealed the same pattern in bootstrapped distributions for F, SSB, and N for the three years that were examined (1995, 2000, and 2004).

For VPA Model-3, the estimated stock status in 2006 is that the stock is not overfished (SSB_{2006}=336,989 mt > SSB_{MSY} = 250,300 mt) and overfishing is not occurring (F_{2006}=0.20 < F_{MSY} = 0.26). Note that the conclusion regarding stock status is not dependent on the VPA model selected (Table B10). The rapidity with which the stock has rebuilt is attributable to the very large 2003 year class. However, as can seen in population trajectories, the total stock numbers are declining as that cohort ages; spawning biomass is still increasing, a direct consequence of that year class reaching maturity (Figure B7). Without further production of strong year classes, the stock will likely decline to lower levels as the 2003 yearclass progresses through the catch at age matrix.

Alternative model: ASAP

A sensitivity model run was made using the NMFS Toolbox model ASAP.v2, a forward projecting statistical catch at age model. When proposed as an alternative model at the GARM3 model meeting, the main comments and caveats focused on treating the strong 1963 and 2003 year classes, and exploring the use of multiple sensitivity blocks to capture effects due to development of the fishery, management action, and apparent changes in average size of fish at age over the time period.

The VPA data (1963-2006) were converted to a format amenable to ASAP via a NMFS Toolbox utility. ASAP has many options for tuning, and those options were explored parsimoniously and in a step-wise fashion. At first, a single logistic selectivity was applied to all model years. The CV on recruitment deviations was set at 0.5 for all years, and the CV on indices was set to 0.3 in all years. This configuration fit poorly, and the estimated unexploited population size was on the order of 10^{25}. Increasing the CV on recruitment deviations on the enormous year classes in 1963 and 2003 to 1.0 brought the Beverton-Holt spawner recruit estimates into a reasonable range. Fits to the age composition were still poor, and additional selectivity blocks were defined until the fits to age composition and total catch in all years were acceptable (Fig. B8). The final model configuration for ASAP had 6 time blocks of selectivity: 1) 1963-1981; 2) 1982-1984; 3) 1985-1989; 4) 1990-1998; 5) 1999-2002; 6) 2003-2006 (Fig. B8). The last three selectivity blocks are shifted to consecutively older ages, which seems reasonable, and consistent with management regulations intended to reduce catch of smaller (younger) fish. It is also consistent with the recently observed phenomenon of fish being smaller at age.

ASAP Results

ASAP fits to total catch (Fig. B9) and to annual age composition of the catch (Fig. B10) were fairly good, although there were a few years with large residuals. Annual estimates of spawning biomass and recruitment were very similar between ASAP and the VPA Model-3 (Figure B11). However, the unweighted average F in ASAP showed far greater interannual variability than the VPA, albeit with a somewhat similar trend, and the estimate of F_{2006} is nearly identical between the two models. The estimated stock status from this implementation of ASAP is that the stock is not overfished (SSB_{2006}= 253,297 mt > SSB_{MSY} = 250,300 mt) and overfishing is not occurring (F_{2006}=0.23 < F_{MSY} = 0.26). Note, however, that these ASAP results imply that overfishing was occurring for the last three years, and that the stock has been in an overfished condition for almost the entire time period from 1963-2006. The long-term condition of being overfished is consistent with the VPA result, however the VPA result suggests that overfishing has not been occurring since 1995. One potential reason for this difference is the shape of partial recruitment estimated in the VPA (Fig. B12), which tends to show that ages 7-9 are less vulnerable than ages 4-6—a different pattern than the logistic selectivity that was fit in ASAP (Figure B8).

4.0 Biological reference points (BRPs)

Nonparametric

The NMFS Toolbox program for calculating yield per recruit was used to estimate $F_{40\%}$ (the current proxy for F_{MSY}). An average of the last 5 years selectivity at age was examined to determine the fully selected age; ages beyond that were assumed to be fully selected as well. The stock weight, catch weight, SSB weights, and maturity were also based on an average of the last 5 years from VPA-Model 3 (2002-2006; Table B11). Compared to the selectivity at age that was used to derive the current BRPs, the selectivity ogive in this assessment is shifted towards older ages by almost two years (Table B11). The shift of selectivity towards older fish leads to a higher estimate of $F_{40\%}$ (Table B12).

Parametric, External

Estimates of annual recruitment and spawning stock biomass from an extended VPA run combining VPA Model-3 with historic catch at age as summarized in Clark et al. (1982) were used in an attempt to estimate a spawner recruit curve with the NMFS Toolbox program SRFit (v6.3). A Beverton-Holt functional form was assumed, and fits were attempted with no priors on the stock-recruit parameters, and with priors on one or both parameters. Residual patterns from fitting all model configurations (with and without priors) were unacceptable, as there was a substantial time trend (Figure B13). Although the steepness estimate was reasonable (0.65), the unexploited stock biomass and recruitment were somewhat large (881.6 million recruits, and 6.26 mt of spawning stock biomass). The same fitting exercise was attempted using just the SSB and recruit estimates from VPA Model-3, but the fit remained poor. The same result in terms of residual patterns was observed in 2002 (NEFSC 2002).

Parametric, Internal

Within the ASAP model runs, a Beverton-Holt stock recruit function was specified, with a minor penalty on steepness (λ=1, CV=0.15) and unexploited spawning biomass (λ=0.5, CV=0.3). For the model presented herein, steepness was estimated to be 0.68; unexploited recruitment and spawning stock biomass were 17.9 million and 135 mt, respectively. The steepness estimate is very similar to the estimate from applying SRFit to the VPA data, however the unexploited levels are much lower. One possible reason for the lower scaling is that the SRFit model was applied to data from 1931 to 2006, whereas the data in ASAP was only from years 1963-2006. As with the attempts to fit the VPA trajectories of recruitment and SSB in SRFit, the internally estimated stock recruit function in ASAP also showed some temporal trends in the residuals, particularly the series of positive residuals throughout the 1990s (Fig. B14).

5.0 Projections to obtain SSB_{MSY} and MSY

Following the recommendation in WP4.2 (Legault 2008), the NMFS Toolbox program AGEPRO was used to determine equilibrium, median values for SSB_{MSY} and MSY under the $F_{40\%}$ from the YPR analysis. The selectivity ogive and weights used in the determination of $F_{40\%}$ (see Table B11) were applied to the population for 100 years and the median, 10^{th}, and 90^{th} percentiles of 1000 bootstraps are reported for SSB, Recruits, and Landings (Table B13). The recruitment option employed was to sample from the empirical cdf (Model 14), and the recruitment estimates from the VPA run combining Model-3 with historic catch (1931-2006) were used. Bootstrapped numbers at age from 1000 bootstraps of this VPA run were also provided to the AGEPRO software. As the stock was in an overfished state for many of the years modeled, the recruitment levels are less than one would expect from a stock that is at the point of producing maximum surplus. Consequently, the estimates of equilibrium SSB_{MSY} and MSY are very low compared to the current reference points (Table B13).

6.0 Stock Status Summary and Recommendation for Reference Points

Given the poor diagnostics of parametric approaches for deriving the reference points, the recommended proxy for F_{MSY} is $F_{40\%}$=0.34 from the non-parametric YPR analysis. While this value is larger than the current F_{MSY} (0.26), it is consistent with the apparent shift in selectivity in recent years to older ages. The resultant YPR and SSB/R are less than the values in NEFSC (2002) because the weights at age are lower in recent years for both the stock and the catch (Figure B15). Multiplying YPR and SSB/R by the updated mean recruitment (74.87 million, Table B12) produces the following estimates: SSB_{MSY} = 211,352 mt, and MSY= 45,519 mt. Re-calculating YPR and SSB/R with the same weights used in NEFSC (2002) and multiplying by mean recruitment produces values very similar to the current reference points (Table B12). Considering that the stock was overfished when the reference points were last estimated (SSB_{2000}/SSB_{MSY} = 64100/250300= 0.25), and that the stock is currently rebuilt to a level that is 35% above SSB_{MSY}, it is likely that the weights at age for a stock at equilibrium at MSY would be somewhere in between the weight at age vectors for the two assessments (Table B11). Therefore, it is reasonable to assume that the reference points from NEFSC (2002) and those recommended in this assessment (Table B12) provide appropriate bounds for management of Georges Bank haddock.

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Table B1. Total catches (mt) of Georges Bank Haddock, 1963-2006. Landings and discards for years 1989-2004 were re-estimated, and years 2005-2006 were estimated, following methods described in Palmer (2008) and Wigley et al. (2007).

Year	Total mt
1963	57731
1964	67823
1965	181774
1966	140715
1967	52065
1968	40995
1969	22336
1970	12376
1971	11999
1972	6614
1973	6934
1974	7567
1975	5735
1976	4446
1977	26342
1978	27237
1979	21302
1980	49156
1981	28310
1982	17638
1983	12000
1984	10385
1985	7948
1986	6829
1987	6917
1988	6713
1989	4616
1990	5493
1991	6980
1992	6251
1993	4567
1994	3297
1995	2492
1996	4080
1997	4175
1998	5584
1999	6504
2000	8792
2001	11616
2002	13146
2003	12620
2004	17802
2005	21388
2006	15495

Table B2. Comparison of estimated discards (this assessment) and inferred discards (previous assessments). Inferred discards were calculated by subtracting total US catch from total US landings (Tables 1.2 and 2, respectively, in Brodziak et al. 2006).

Year	Garm 3 (estimated)	Garm 2 (inferred)
1989	348	0
1990	105	0
1991	53	0
1992	79	0
1993	161	0
1994	2848	0
1995	134	0
1996	261	0
1997	347	0
1998	433	0
1999	95	0
2000	121	591
2001	343	1979.13
2002	355	3110.85
2003	259	1072.6
2004	2279	1415.89
2005	1121	
2006	2196	

Table B3. US landings, discards, and ratio of discards to landings for years 1989-2006 for Georges Bank Haddock.

Year	Discards (mt)	Landings (mt)	Discards:Landings	CV for Discards
1989	348	1430	0.24	0.7
1990	105	2005	0.05	1.3
1991	53	1395	0.04	2.9
1992	79	2005	0.04	1.2
1993	161	687	0.23	0.9
1994	2848	206	13.82	1.2
1995	134	231	0.58	1
1996	261	320	0.81	2.2
1997	347	880	0.39	1.7
1998	433	1914	0.23	1.8
1999	95	2572	0.04	1.2
2000	121	3203	0.04	0.6
2001	343	4820	0.07	0.6
2002	355	6532	0.05	0.4
2003	259	5760	0.05	0.4
2004	2279	7375	0.31	1.4
2005	1121	6604	0.17	0.2
2006	2196	2643	0.83	0.3

Table B4. Coefficient of Variation (CV) for US landings at age of Georges Bank Haddock in years 1989-2006.

	Age								
Year	1	2	3	4	5	6	7	8	9
1989		0.12	0.40	0.20	0.19	0.19	0.26	0.36	0.58
1990		0.64	0.19	0.18	0.10	0.21	0.24	0.28	0.62
1991		0.39	0.43	0.08	0.31	0.29	0.36	0.46	0.79
1992		0.54	0.19	0.28	0.07	0.15	0.13	0.30	0.43
1993		0.04	0.26	0.22	0.26	0.15	0.23	0.28	0.50
1994		0.50	0.09	0.28	0.41	0.37	0.14	0.47	0.48
1995		0.46	0.11	0.13	0.51	0.48	0.37	0.26	-----
1996		0.32	0.17	0.35	0.43	0.86	0.69	0.65	0.86
1997		0.56	0.09	0.18	0.15	0.35	0.72	0.71	0.72
1998		0.40	0.19	0.11	0.14	0.23	0.32	0.51	0.75
1999		1.32	0.25	0.15	0.12	0.13	0.23	0.32	0.39
2000		0.26	0.13	0.13	0.10	0.11	0.15	0.22	0.38
2001		0.35	0.10	0.11	0.10	0.08	0.10	0.14	0.18
2002		1.31	0.29	0.09	0.10	0.12	0.13	0.15	0.19
2003		1.34	0.25	0.17	0.05	0.13	0.09	0.13	0.12
2004		-----	0.54	0.11	0.17	0.07	0.15	0.14	0.12
2005		0.76	0.60	0.21	0.07	0.15	0.09	0.16	0.13
2006		-----	0.14	0.38	0.14	0.04	0.12	0.11	0.14

Table B5. US landings at age, and proportion at age, of Georges Bank haddock for years 1989-2006.

Year	Age 1	2	3	4	5	6	7	8	9+	**Total**
1989	0	168975	19234	262332	85856	145758	29039	15940	11673	**738,807**
1990	0	4356	383504	137658	376383	85290	53011	13243	7343	**1,060,788**
1991	0	23251	30267	325679	55705	127289	55360	25843	4391	**647,785**
1992	0	19760	93635	69376	506805	92110	110493	20873	9521	**922,573**
1993	0	48612	32621	59618	33135	104609	28567	15953	7838	**330,953**
1994	0	5866	56019	13512	6956	7628	14527	1749	688	**106,945**
1995	0	9074	66917	45120	4199	2749	3516	6847	0	**138,422**
1996	0	10604	69054	37221	16008	4552	3914	3673	922	**145,948**
1997	0	11227	138150	152797	51099	13240	3461	8127	9307	**387,408**
1998	0	21629	172480	268926	198833	109035	52921	11713	9234	**844,771**
1999	0	789	147030	220806	356767	218002	128758	63175	20716	**1,156,043**
2000	0	82161	170698	317138	334261	323931	165030	74452	31536	**1,499,207**
2001	0	69998	643652	425153	462090	372423	226394	136037	88982	**2,424,729**
2002	0	2020	93849	1282792	543841	441817	285768	199080	271055	**3,120,222**
2003	0	1277	173813	218439	1491398	258223	348704	147487	251083	**2,890,424**
2004	0	0	29914	1490359	261708	1645837	273457	223550	214019	**4,138,844**
2005	0	2729	6204	109158	1866942	286340	988479	200435	206040	**3,666,327**
2006	0	0	104257	5770	63535	911094	81184	267505	63739	**1,497,084**

Year	Age 1	2	3	4	5	6	7	8	9+
1989	0.00	0.23	0.03	0.36	0.12	0.20	0.04	0.02	0.02
1990	0.00	0.00	0.36	0.13	0.35	0.08	0.05	0.01	0.01
1991	0.00	0.04	0.05	0.50	0.09	0.20	0.09	0.04	0.01
1992	0.00	0.02	0.10	0.08	0.55	0.10	0.12	0.02	0.01
1993	0.00	0.15	0.10	0.18	0.10	0.32	0.09	0.05	0.02
1994	0.00	0.05	0.52	0.13	0.07	0.07	0.14	0.02	0.01
1995	0.00	0.07	0.48	0.33	0.03	0.02	0.03	0.05	0.00
1996	0.00	0.07	0.47	0.26	0.11	0.03	0.03	0.03	0.01
1997	0.00	0.03	0.36	0.39	0.13	0.03	0.01	0.02	0.02
1998	0.00	0.03	0.20	0.32	0.24	0.13	0.06	0.01	0.01
1999	0.00	0.00	0.13	0.19	0.31	0.19	0.11	0.05	0.02
2000	0.00	0.05	0.11	0.21	0.22	0.22	0.11	0.05	0.02
2001	0.00	0.03	0.27	0.18	0.19	0.15	0.09	0.06	0.04
2002	0.00	0.00	0.03	0.41	0.17	0.14	0.09	0.06	0.09
2003	0.00	0.00	0.06	0.08	0.52	0.09	0.12	0.05	0.09
2004	0.00	0.00	0.01	0.36	0.06	0.40	0.07	0.05	0.05
2005	0.00	0.00	0.00	0.03	0.51	0.08	0.27	0.05	0.06
2006	0.00	0.00	0.07	0.00	0.04	0.61	0.05	0.18	0.04

Table B6a. Georges Bank haddock NEFSC spring survey indices (number and weight). Years where CV=NA reflect years where one or more strata had zero or one tow.

	With conversion factors				Without conversion factors			
	Spring Survey				Spring Survey			
Year	Number/ Tow	CV	Weight (kg)/ Tow	CV	Number/ Tow	CV	Weight (kg)/ Tow	CV
1968	13.8	0.3	20.6	0.2	9.2	0.3	13.6	0.2
1969	7.3	0.2	16.9	0.3	4.9	0.2	11.2	0.3
1970	6	0.5	17.1	0.7	4	0.5	11.3	0.7
1971	2.8	0.3	5	0.2	1.9	0.3	3.3	0.2
1972	6.4	0.4	7.4	0.2	4.5	0.4	5	0.2
1973	37.6	0.7	15.4	0.3	25.2	0.7	10.2	0.3
1974	19	0.4	17.7	0.3	12.8	0.4	11.7	0.3
1975	6.2	0.4	8.2	0.4	4.2	0.4	5.4	0.4
1976	83.2	0.5	15.7	0.3	55.8	0.5	10.4	0.3
1977	36.9	0.4	26.6	0.4	24.7	0.4	17.5	0.4
1978	19.4	0.3	31.3	0.3	13	0.3	20.7	0.3
1979	45.5	0.3	19.8	0.2	30.5	0.3	13.1	0.2
1980	60.1	0.4	53.9	0.3	40.3	0.4	35.7	0.3
1981	31.2	0.2	38	0.2	25.5	0.2	31.9	0.2
1982	8.6	0.2	13.1	0.2	7.3	0.2	11	0.2
1983	5.6	0.2	13.2	0.3	3.8	0.2	8.8	0.3
1984	6.2	0.3	7.5	0.3	4.2	0.3	4.9	0.3
1985	8.9	0.3	11.1	0.3	8.9	0.3	11.1	0.3
1986	5.9	0.2	5.9	0.3	5.9	0.2	5.9	0.3
1987	5	0.5	5.6	0.5	5	0.5	5.6	0.5
1988	3.4	NA	3.4	NA	3.4	NA	3.4	NA
1989	5.4	NA	4.7	NA	6.5	NA	5.9	NA
1990	7.7	NA	7.6	NA	9.4	NA	9.6	NA
1991	4	NA	4.4	NA	4.9	NA	5.6	NA
1992	1.2	NA	1.4	NA	1.2	NA	1.4	NA
1993	2.8	NA	2.5	NA	2.7	NA	2.5	NA
1994	5	NA	3.6	NA	6.1	NA	4.6	NA
1995	5.6	NA	5.7	NA	5.6	NA	5.7	NA
1996	23.4	NA	25.7	NA	23.4	NA	25.7	NA
1997	13	NA	18.5	NA	12.9	NA	18.5	NA
1998	7.3	NA	6.1	NA	7.3	NA	6.1	NA
1999	16.7	NA	7.7	NA	16.7	NA	7.7	NA
2000	14.3	NA	17.9	NA	14.3	NA	17.9	NA
2001	14.9	NA	6.1	NA	14.9	NA	6.1	NA
2002	32.3	NA	22.3	NA	32.2	NA	22.3	NA
2003	14.8	NA	15.6	NA	18	NA	19.8	NA
2004	140.5	NA	41.4	NA	140.5	NA	41.4	NA
2005	59.8	NA	17.7	NA	59.8	NA	17.7	NA
2006	37.3	NA	17.3	NA	37.3	NA	17.3	NA
2007	57.3	NA	34.6	NA	57.3	NA	34.6	NA

Table B6b. Georges Bank haddock NEFSC Fall survey indices (number and weight). Years where CV=NA reflect years where one or more strata had zero tows or only one tow.

	With conversion factors				Without conversion factors			
	Autumn Survey				Autumn Survey			
Year	Number/ Tow	CV	Weight (kg)/ Tow	CV	Number/ Tow	CV	Weight (kg)/ Tow	CV
1963	145	NA	79.8	NA	97.3	NA	52.8	NA
1964	193.2	0.2	96.8	0.2	129.7	0.2	64	0.2
1965	101.7	0.2	72.8	0.2	68.3	0.2	48.2	0.2
1966	33.3	0.2	29.9	0.2	22.9	0.2	20.1	0.2
1967	17.7	0.3	25.5	0.2	11.4	0.3	16.5	0.2
1968	7.5	0.3	15.4	0.3	5.1	0.3	11.1	0.3
1969	3.4	0.2	8.4	0.3	2.2	0.2	5.7	0.3
1970	7.7	0.5	13.5	0.4	5.1	0.5	8.8	0.4
1971	4.2	0.2	5.6	0.3	2.8	0.2	3.7	0.3
1972	11.4	0.2	8.5	0.2	7.6	0.2	5.6	0.2
1973	14.9	0.3	9.8	0.3	10	0.3	6.5	0.3
1974	4.1	0.2	4	0.3	2.7	0.2	2.6	0.3
1975	31	0.2	15.1	0.5	20.8	0.2	10	0.5
1976	71.1	0.5	35.8	0.4	47.7	0.5	23.7	0.4
1977	23.3	NA	27.5	NA	19	NA	23.1	NA
1978	25.3	0.2	18.1	0.2	20.7	0.2	15.2	0.2
1979	52.2	0.6	32	0.5	42.7	0.6	26.9	0.5
1980	30.5	0.2	22	0.2	25	0.2	18.5	0.2
1981	13.5	0.3	14	0.2	11	0.3	11.8	0.2
1982	5	NA	7.3	NA	3.7	NA	4.8	NA
1983	8	0.4	5.8	0.2	5.4	0.4	3.8	0.2
1984	5.4	0.4	4.5	0.3	3.6	0.4	3	0.3
1985	14.2	0.3	3.9	0.2	14.2	0.3	3.7	0.2
1986	6.8	0.5	5.1	0.3	6.8	0.5	5.1	0.3
1987	3.6	NA	2.6	NA	3.6	NA	2.6	NA
1988	5.4	NA	5.6	NA	5.3	NA	5.6	NA
1989	4.3	NA	4.7	NA	5.3	NA	5.6	NA
1990	2.9	NA	2.6	NA	3.6	NA	3.3	NA
1991	2.9	NA	0.9	NA	3.6	NA	1.2	NA
1992	6.1	NA	3.2	NA	6.1	NA	3.2	NA
1993	8.1	NA	4.3	NA	9.9	NA	5.5	NA
1994	3.6	NA	2.9	NA	3.6	NA	2.9	NA
1995	17.1	NA	10.7	NA	17.1	NA	10.7	NA
1996	4.5	NA	4.1	NA	4.5	NA	4.1	NA
1997	6.2	NA	6.5	NA	6.2	NA	6.5	NA
1998	11.1	NA	5.8	NA	11.1	NA	5.8	NA
1999	23.1	NA	33.1	NA	23.1	NA	33.1	NA
2000	18	NA	15.4	NA	18	NA	15.4	NA
2001	22.7	NA	20	NA	22.7	NA	20	NA
2002	42.1	NA	36.3	NA	42.1	NA	36.3	NA
2003	169.5	NA	23	NA	169.5	NA	23	NA
2004	187	NA	55.8	NA	187	NA	55.8	NA
2005	90.5	NA	39.4	NA	90.5	NA	39.4	NA
2006	57	NA	37.4	NA	57	NA	37.4	NA
2007	53.9	NA	43.9	NA	53.9	NA	43.9	NA

Table B7a. Georges Bank haddock NEFSC spring survey stratified mean number per tow at age indices (ages 1 through 8), 1963-2007.

Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9+
1968	0.40	2.83	0.46	0.70	6.72	1.68	0.25	0.45	0.34
1969	0.00	0.07	0.58	0.25	0.42	4.23	1.03	0.28	0.46
1970	0.67	0.25	0.00	0.33	0.46	0.46	2.00	0.98	0.85
1971	0.00	1.16	0.25	0.00	0.12	0.12	0.09	0.82	0.22
1972	4.02	0.09	0.61	0.12	0.03	0.04	0.13	0.03	1.30
1973	30.68	4.84	0.00	0.54	0.09	0.00	0.18	0.01	1.28
1974	2.13	13.29	2.86	0.00	0.24	0.00	0.01	0.10	0.37
1975	0.94	0.97	3.32	0.63	0.00	0.13	0.09	0.01	0.15
1976	80.79	0.30	0.60	0.92	0.43	0.00	0.04	0.00	0.10
1977	0.61	33.41	0.42	1.22	0.60	0.45	0.00	0.04	0.12
1978	0.07	0.97	15.93	0.36	0.94	0.82	0.16	0.06	0.10
1979	36.12	1.58	1.13	5.71	0.33	0.16	0.37	0.06	0.04
1980	5.20	46.70	0.51	1.04	4.87	0.67	0.37	0.46	0.24
1981	3.30	3.29	19.49	2.19	0.76	1.78	0.24	0.11	0.05
1982	0.76	1.53	0.94	4.07	0.42	0.28	0.61	0.00	0.00
1983	0.43	0.55	0.58	0.22	2.41	0.01	0.04	1.16	0.18
1984	2.09	1.18	0.64	0.63	0.58	0.72	0.07	0.04	0.30
1985	0.00	4.96	0.76	0.40	0.87	0.34	1.17	0.10	0.25
1986	2.49	0.18	2.06	0.24	0.11	0.21	0.12	0.33	0.11
1987	0.00	3.62	0.06	0.81	0.08	0.10	0.05	0.22	0.01
1988	1.55	0.04	0.99	0.13	0.32	0.12	0.11	0.12	0.00
1989	0.02	3.49	0.45	0.71	0.14	0.41	0.06	0.05	0.01
1990	0.86	0.00	5.72	0.33	0.58	0.06	0.13	0.00	0.01
1991	0.54	1.07	0.24	1.85	0.09	0.10	0.02	0.04	0.02
1992	0.40	0.18	0.11	0.07	0.33	0.03	0.03	0.03	0.00
1993	1.17	0.65	0.18	0.14	0.12	0.37	0.06	0.02	0.02
1994	0.70	2.68	1.00	0.15	0.10	0.07	0.16	0.02	0.05
1995	0.50	1.29	2.32	0.91	0.17	0.11	0.03	0.18	0.11
1996	1.09	4.59	8.86	5.21	2.62	0.35	0.07	0.07	0.00
1997	1.79	1.02	3.35	3.66	2.01	0.89	0.13	0.07	0.00
1998	0.82	2.95	1.25	1.06	0.85	0.21	0.06	0.01	0.06
1999	10.21	2.03	2.14	0.72	0.64	0.51	0.20	0.20	0.02
2000	1.83	2.37	4.10	2.01	1.11	1.11	1.01	0.48	0.13
2001	10.01	0.86	2.44	0.83	0.30	0.21	0.12	0.08	0.07
2002	0.18	19.25	6.72	3.22	1.09	0.48	0.61	0.17	0.53
2003	0.01	0.25	5.45	1.21	4.85	0.96	1.14	0.86	0.89
2004	112.14	1.85	1.20	9.06	2.18	2.67	0.43	0.96	0.42
2005	0.80	53.34	0.16	0.38	3.35	0.45	1.01	0.19	0.08
2006	2.01	0.57	28.73	0.51	0.63	3.70	0.52	0.47	0.11
2007	0.86	7.01	1.83	45.19	0.34	0.24	1.40	0.13	0.25

Table B7b. Georges Bank haddock NEFSC autumn survey stratified mean number per tow at age indices (ages 1 through 5), 1963-2007.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9+
1963	83.93	25.39	9.22	6.81	8.34	5.95	2.04	1.68	1.18	0.46
1964	2.37	112.87	63.74	5.83	1.79	3.81	1.56	0.69	0.25	0.33
1965	0.33	10.16	77.39	9.70	1.07	0.80	0.91	0.80	0.25	0.27
1966	6.14	0.95	2.89	18.39	3.35	0.52	0.49	0.33	0.12	0.07
1967	0.03	6.72	0.36	1.00	6.76	1.62	0.49	0.21	0.33	0.18
1968	0.09	0.06	0.95	0.13	0.33	3.86	1.27	0.27	0.16	0.39
1969	0.39	0.03	0.00	0.28	0.13	0.16	1.52	0.51	0.09	0.27
1970	0.04	4.13	0.21	0.01	0.28	0.27	0.51	1.37	0.48	0.40
1971	2.43	0.00	0.31	0.07	0.01	0.22	0.03	0.09	0.75	0.28
1972	6.75	2.52	0.00	0.52	0.09	0.00	0.09	0.06	0.03	1.30
1973	3.23	9.00	1.61	0.00	0.19	0.04	0.00	0.07	0.01	0.72
1974	0.75	1.77	0.98	0.31	0.00	0.01	0.00	0.00	0.00	0.22
1975	23.48	0.63	0.72	4.86	0.92	0.00	0.03	0.00	0.01	0.30
1976	4.32	64.17	0.52	0.54	0.82	0.30	0.00	0.04	0.10	0.25
1977	0.13	2.14	18.73	0.56	0.57	0.64	0.34	0.04	0.01	0.09
1978	13.22	0.84	1.04	9.27	0.18	0.26	0.45	0.01	0.00	0.01
1979	1.32	45.57	0.04	0.90	3.81	0.26	0.28	0.05	0.01	0.00
1980	11.68	2.71	12.72	0.45	0.18	1.70	0.48	0.46	0.09	0.06
1981	0.38	6.13	2.08	3.70	0.21	0.42	0.53	0.00	0.00	0.01
1982	1.36	0.00	1.33	0.34	1.40	0.13	0.07	0.21	0.01	0.10
1983	5.80	0.24	0.21	0.27	0.30	0.94	0.12	0.00	0.10	0.01
1984	0.03	3.32	0.88	0.24	0.28	0.06	0.45	0.00	0.00	0.12
1985	11.35	0.65	1.53	0.22	0.05	0.10	0.07	0.17	0.00	0.05
1986	0.00	5.11	0.09	1.21	0.06	0.13	0.13	0.02	0.03	0.03
1987	1.80	0.00	0.79	0.10	0.77	0.06	0.06	0.02	0.02	0.00
1988	0.07	3.02	0.18	1.30	0.12	0.40	0.12	0.11	0.00	0.03
1989	0.47	0.05	2.71	0.20	0.66	0.09	0.13	0.02	0.02	0.00
1990	0.77	0.67	0.02	1.19	0.05	0.17	0.04	0.00	0.00	0.00
1991	2.16	0.21	0.24	0.05	0.22	0.02	0.02	0.00	0.00	0.02
1992	2.85	2.08	0.23	0.24	0.00	0.47	0.02	0.08	0.03	0.06
1993	1.52	4.04	2.01	0.30	0.00	0.06	0.15	0.02	0.00	0.00
1994	0.91	0.77	0.81	0.67	0.12	0.05	0.02	0.17	0.06	0.00
1995	2.27	7.14	4.90	2.32	0.38	0.01	0.00	0.07	0.02	0.00
1996	1.31	0.54	0.93	1.04	0.49	0.14	0.01	0.01	0.00	0.01
1997	0.32	2.47	1.47	0.75	0.55	0.33	0.13	0.00	0.07	0.08
1998	4.32	2.79	2.47	0.72	0.41	0.18	0.16	0.02	0.00	0.01
1999	1.82	0.84	3.37	8.05	3.52	2.32	0.82	1.32	0.75	0.31
2000	4.14	2.82	5.48	3.10	1.10	0.66	0.13	0.27	0.09	0.19
2001	0.85	8.77	1.68	7.44	2.12	1.16	0.36	0.22	0.13	0.01
2002	0.12	1.91	22.27	5.45	8.54	1.87	0.62	0.53	0.68	0.10
2003	154.54	0.07	0.45	8.55	1.77	3.36	0.29	0.28	0.00	0.22
2004	1.63	163.65	0.22	0.84	13.62	1.18	4.54	0.50	0.67	0.15
2005	4.23	1.77	77.24	0.28	0.70	4.74	0.48	0.84	0.11	0.10
2006	0.94	4.54	0.73	48.36	0.40	0.43	1.28	0.10	0.21	0.02
2007	0.84	1.24	7.01	1.19	42.31	0.35	0.23	0.53	0.13	0.07

Table B8. Conversion factors used to adjust for changes in door type and survey vessel in the NMFS surveys during 1968-2005.

		Spring		Fall	
Year	Door	Vessel	Conversion	Vessel	Conversion
1968	BMV	Albatross IV	1.49	Albatross IV	1.49
1969	BMV	Albatross IV	1.49	Albatross IV	1.49
1970	BMV	Albatross IV	1.49	Albatross IV	1.49
1971	BMV	Albatross IV	1.49	Albatross IV	1.49
1972	BMV	Albatross IV	1.49	Albatross IV	1.49
1973	BMV	Albatross IV	1.49	Albatross IV	1.49
1974	BMV	Albatross IV	1.49	Albatross IV	1.49
1975	BMV	Albatross IV	1.49	Albatross IV	1.49
1976	BMV	Albatross IV	1.49	Albatross IV	1.49
1977	BMV	Albatross IV	1.49	Delaware II	1.2218
1978	BMV	Albatross IV	1.49	Delaware II	1.2218
1979	BMV	Albatross IV	1.49	Delaware II	1.2218
1980	BMV	Albatross IV	1.49	Delaware II	1.2218
1981	BMV	Delaware II	1.2218	Delaware II	1.2218
1982	BMV	Delaware II	1.2218	Albatross IV	1.49
1983	BMV	Albatross IV	1.49	Albatross IV	1.49
1984	BMV	Albatross IV	1.49	Albatross IV	1.49
1985	Polyvalent	Albatross IV	1	Albatross IV	1
1986	Polyvalent	Albatross IV	1	Albatross IV	1
1987	Polyvalent	Albatross IV	1	Albatross IV	1
1988	Polyvalent	Albatross IV	1	Albatross IV	1
1989	Polyvalent	Delaware II	0.82	Delaware II	0.82
1990	Polyvalent	Delaware II	0.82	Delaware II	0.82
1991	Polyvalent	Delaware II	0.82	Delaware II	0.82
1992	Polyvalent	Albatross IV	1	Albatross IV	1
1993	Polyvalent	Albatross IV	1	Delaware II	0.82
1994	Polyvalent	Delaware II	0.82	Albatross IV	1
1995	Polyvalent	Albatross IV	1	Albatross IV	1
1996	Polyvalent	Albatross IV	1	Albatross IV	1
1997	Polyvalent	Albatross IV	1	Albatross IV	1
1998	Polyvalent	Albatross IV	1	Albatross IV	1
1999	Polyvalent	Albatross IV	1	Albatross IV	1
2000	Polyvalent	Albatross IV	1	Albatross IV	1
2001	Polyvalent	Albatross IV	1	Albatross IV	1
2002	Polyvalent	Albatross IV	1	Albatross IV	1
2003	Polyvalent	Delaware II	0.82	Delaware II	0.82
2004	Polyvalent	Albatross IV	1	Albatross IV	1
2005	Polyvalent	Albatross IV	1	Albatross IV	1
2006	Polyvalent	Albatross IV	1	Albatross IV	1

Table B9. Canadian spring survey indices.

YEAR	Can_Sp 1 number	Can_Sp 2 number	Can_Sp 3 number	Can_Sp 4 number	Can_Sp 5 number	Can_Sp 6 number	Can_Sp 7 number	Can_Sp 8 number
1986	4.06	0.22	6.05	1.07	0.19	0.29	0.34	0.37
1987	0.03	3.04	0.69	2.51	0.67	0.08	0.3	0.1
1988	1.47	0.05	8.53	0.17	2.85	0.18	0.17	0.11
1989	0.03	5.34	0.72	2.12	0.19	0.42	0.03	0.03
1990	0.93	0.11	9.87	0.13	3.36	0.23	1.09	0.13
1991	0.75	1.67	0.14	8.99	0.11	1.6	0.09	0.44
1992	3.3	2.95	1.13	0.17	3.82	0.03	1.06	0.04
1993	3.96	2.16	0.55	0.45	0.04	1.28	0.02	0.32
1994	3.32	11.52	4.08	0.42	0.24	0.02	0.7	0.01
1995	1.94	2.62	4.3	2.22	0.56	0.03	0	0.48
1996	6.11	2.89	4.84	5.04	2.92	0.26	0.24	0.04
1997	1.74	1.16	0.99	2.34	2.37	1.7	0.23	0.09
1998	2.41	8.18	3.08	2.57	3.76	3.67	1.98	0.24
1999	19.75	3.41	7.16	2.21	1.4	1.35	1.26	0.33
2000	18.33	68.6	9.32	8.91	2.11	1.55	1.94	1.14
2001	22.28	2.83	10.88	3.09	4.13	1.29	1.15	1.41
2002	1.98	31.7	6.65	15.36	4.32	5.32	1.59	1.32
2003	1.37	2.55	69.32	5.14	13.24	2.94	2.69	1.21
2004	147.70	0.41	1.99	39.57	3.94	7.38	1.24	0.73
2005	2.91	38.78	0.92	2.62	42.34	5.69	8.16	1.87
2006	12.68	7.38	261.51	4.03	3.07	20.55	0.98	2.31
2007	3.00	10.66	3.14	57.17	0.80	0.13	2.97	0.21

Table B10. Comparison between VPA model estimates. Model 1 is a "continuity" run; Model 2 introduces a single maturity ogive; Model 3 uses the single maturity ogive and updated US landings and discard estimates. 10th and 90th percentiles from 1000 VPA bootstraps are given for each point estimate (rows in italics).

Model	**$Catch_{2006}$**	**F_{2006}**	**SSB_{2006}**	**N_{2007}**	**B_{2007}**
VPA-1	15,493	0.1979	313,299	369,960	431,745
10th-90th		*[0.1633--0.2578]*	*[234,951--420,638]*	*[278,456--508,297]*	*[315,581--593595]*
VPA-2	15,493	0.1979	305,066	369,960	431,745
10th-90th		*[0.1633--0.2578]*	*[229,512--409,284]*	*[278,456--508,297]*	*[315,581--593595]*
VPA-3	17,312	0.1995	336,989	411,743	481,419
10th-90th		*[0.1676--0.2558]*	*[251,931--457,234]*	*[305,158--575,448]*	*[345,990--669,872]*

Table B11. Inputs to the NMFS Toolbox program YPR from the GARM3 VPA Model-3. Inputs from NEFSC 2002 are shown for comparison.

	GARM3 VPA Model-3					
Age	**Selectivity**	**M Scalar**	**Stock wt**	**Catch wt**	**SSB wt**	**Maturity**
1	0.013	1	0.157	0.230	0.157	0.063
2	0.073	1	0.395	0.599	0.395	0.469
3	0.133	1	0.909	1.140	0.909	0.920
4	0.510	1	1.350	1.473	1.350	0.993
5	0.831	1	1.678	1.750	1.678	0.999
6	1.000	1	1.936	2.017	1.936	1.000
7	1.000	1	2.243	2.327	2.243	1.000
8	1.000	1	2.518	2.565	2.518	1.000
9	1.000	1	2.871	2.871	2.871	1.000

	NEFSC 2002 assmt					
Age	**Selectivity**	**M Scalar**	**Stock wt**	**Catch wt**	**SSB wt**	**Maturity**
1	0.003	1	0.257	0.359	0.257	0.012
2	0.088	1	0.619	0.851	0.619	0.548
3	0.471	1	1.145	1.324	1.145	0.948
4	0.920	1	1.558	1.699	1.558	0.992
5	1.000	1	1.867	1.976	1.867	1.000
6	1.000	1	2.167	2.274	2.167	1.000
7	1.000	1	2.478	2.615	2.478	1.000
8	1.000	1	2.802	2.869	2.802	1.000
9	1.000	1	3.225	3.225	3.225	1.000

Table B12. Estimated quantities from two runs of the NMFS Toolbox program YPR, and the outputs upon which current reference points are based (NEFSC 2002). $F_{40\%}$ is a proxy for F_{MSY}.

	GARM3 VPA Model-3	GARM3-NEFSC 2002 weights	NEFSC 2002
F40%	0.340	0.360	0.260
YPR	0.608	0.700	0.769
SSB/R	2.823	3.220	3.634
ave (R)	74,870,000	74,870,000	75,230,000
MSY	45,519	52,409	52,900
SSBmsy	211,352	241,081	250,300

GARM3 (1931-1960) ave Recr

74.87 million 75.23 million for NEFSC 2002

GARM3 (SSB median)

84,384 mt 75,000 mt for NEFSC 2002

GARM3 (Recruitment in years where SSB>SSB median)

61.15 million 68.87 million for NEFSC 2002

Table B13. AGEPRO estimates of equilibrium SSB_{MSY}, MSY, and R_{MSY}.

	AGEPRO estimate	NEFSC 2002	AGEPRO/(NEFSC 2002)
SSB_{MSY}	76,396	250,300	0.31
MSY	15,496	52,900	0.29
R_{MSY}	13,655,778	75,000,000	0.18

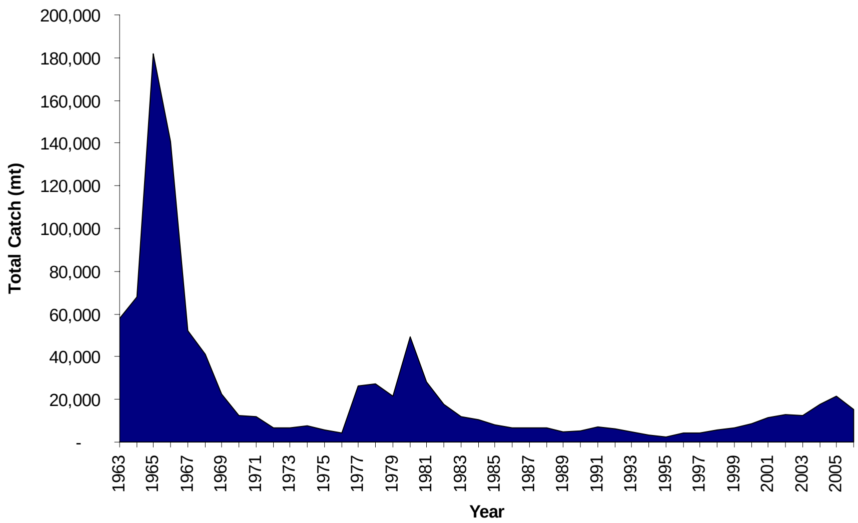


Figure B1. Total catch of Georges Bank haddock (1963-2006).

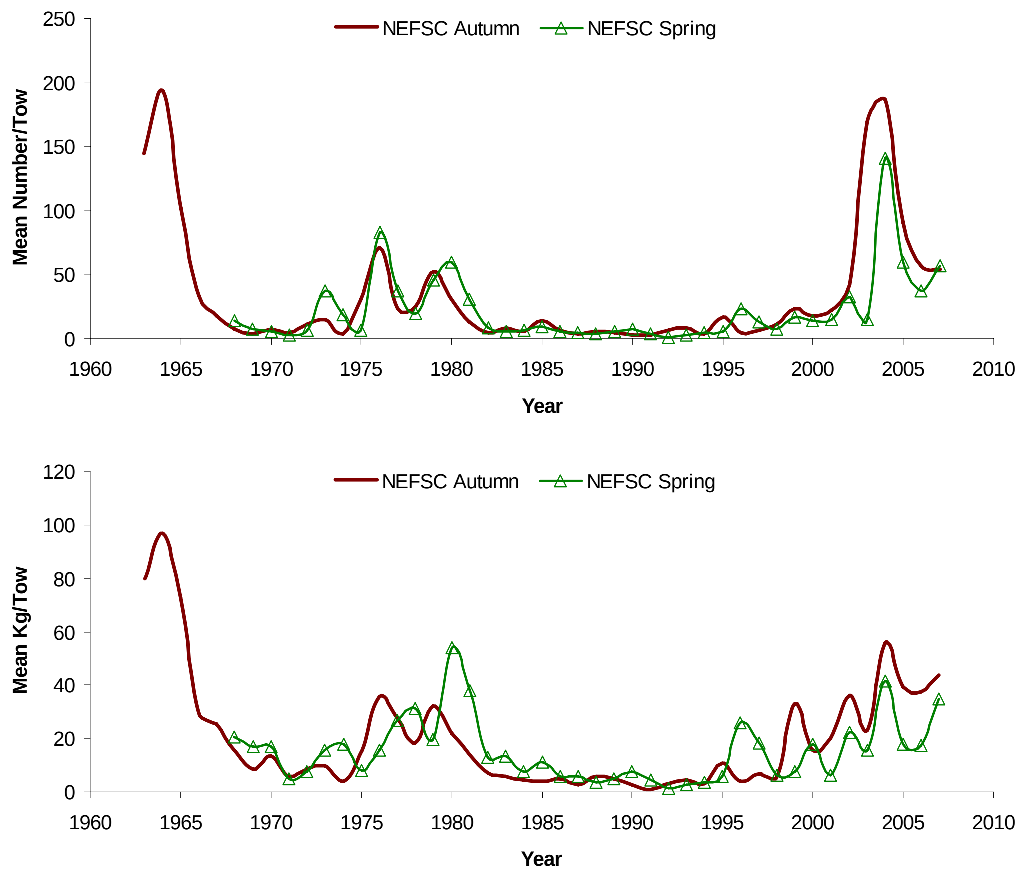


Figure B2. NEFSC mean number per tow (top) and mean weight per tow (bottom) from spring and autumn bottom trawl surveys.

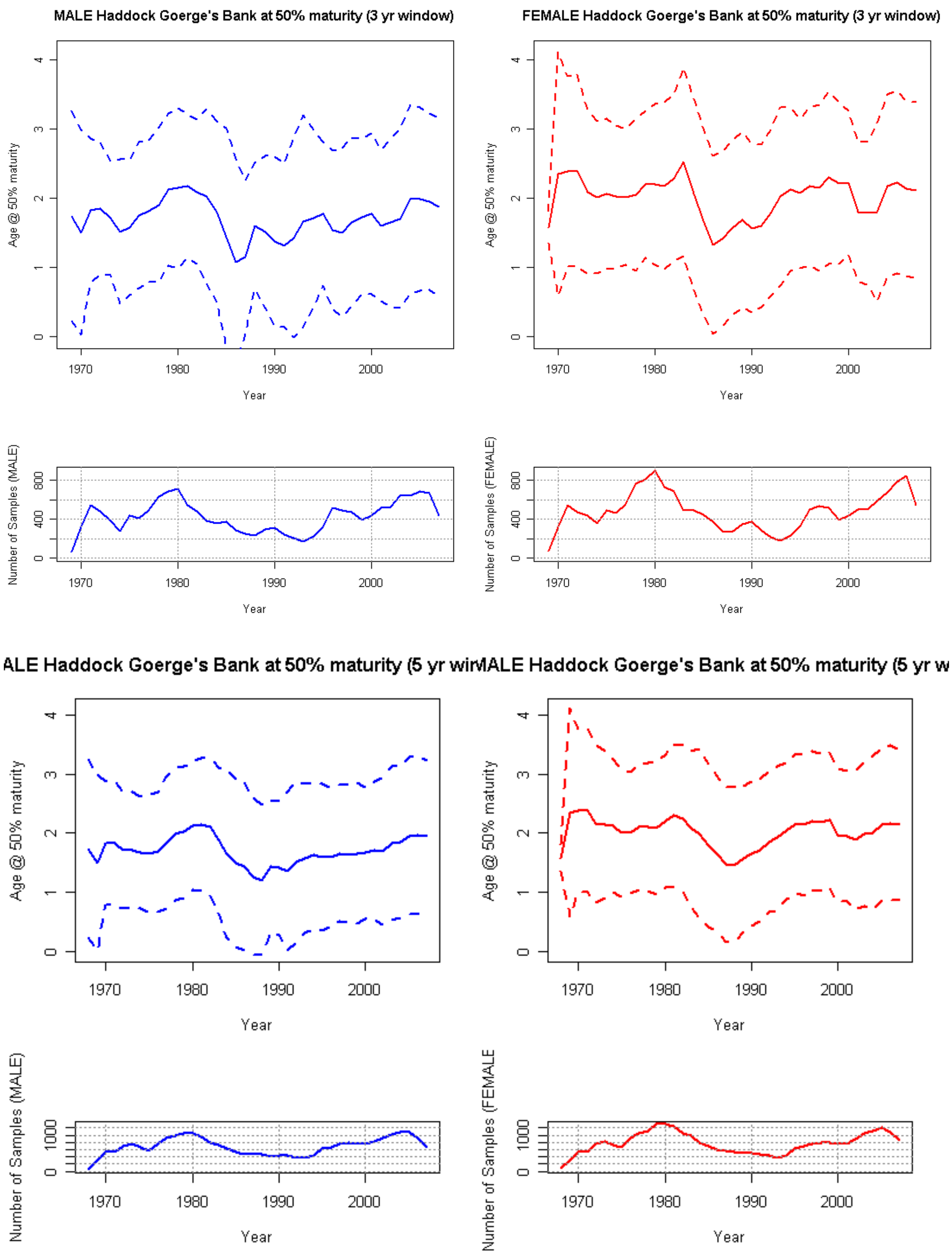
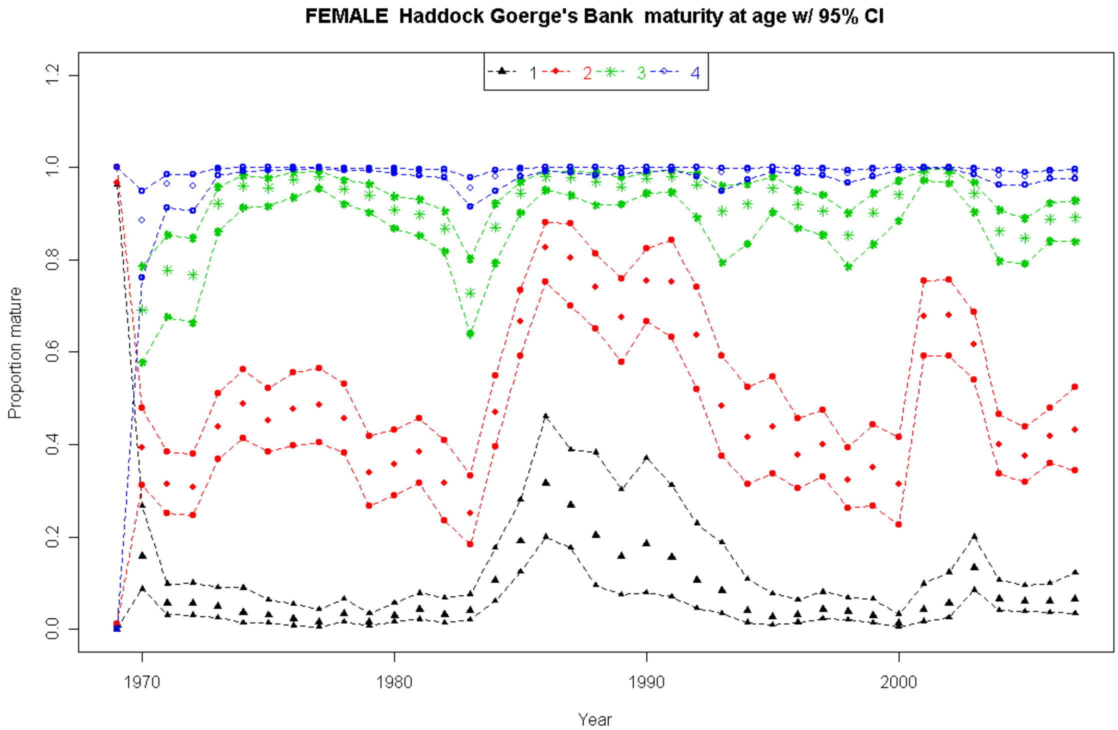


Figure B3. Estimates of the age at 50% maturity, and the number of pooled samples, from a 3 year (top) and a 5 year (bottom) “moving average” method.



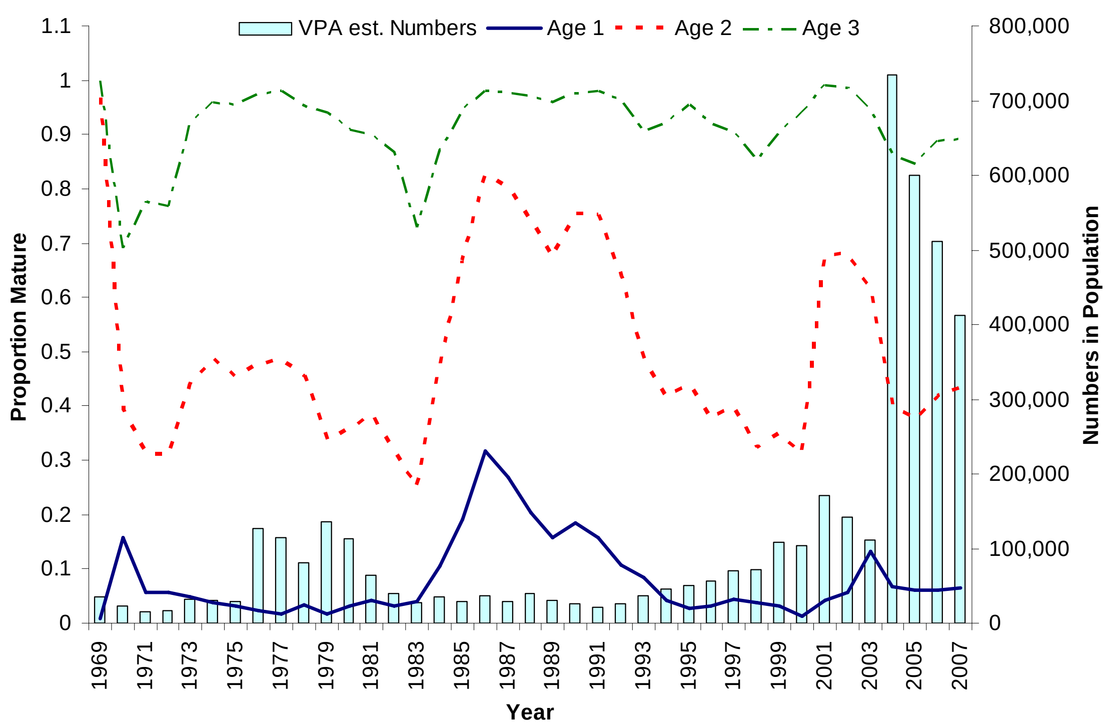
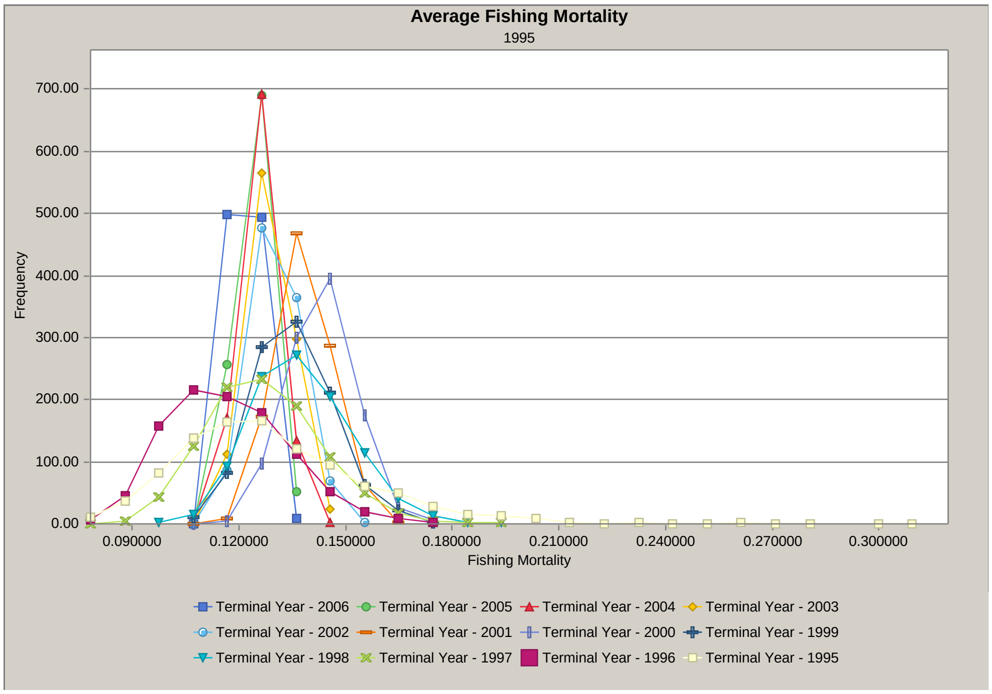


Figure B4. Proportion mature at age with 95% confidence intervals (top) using a 3 year "moving average" approach. The same maturity at age is plotted with total population number in thousands (bottom).



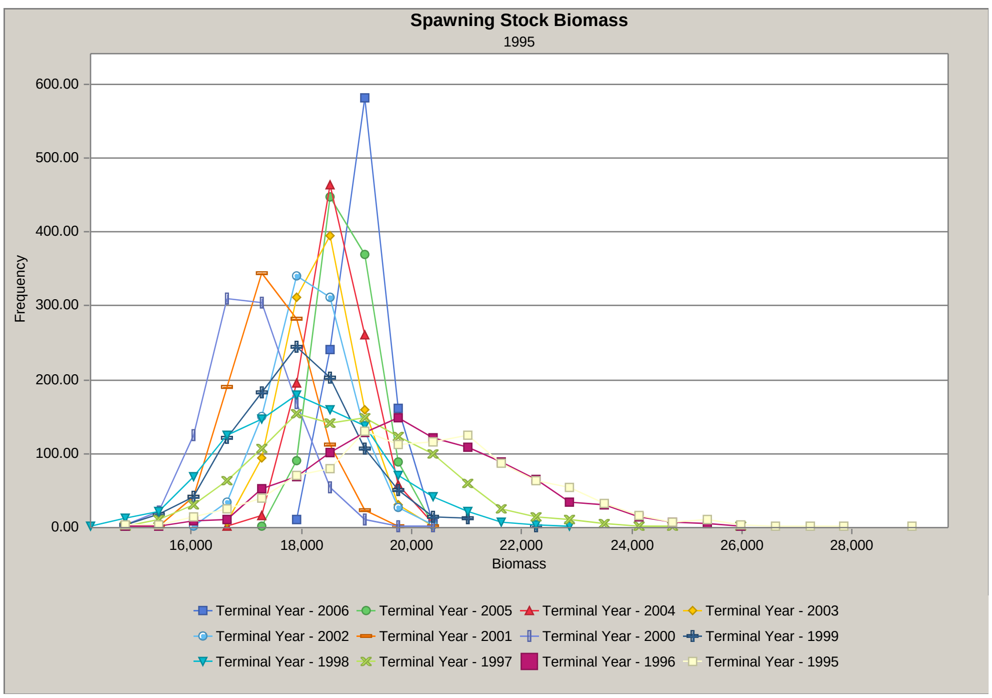
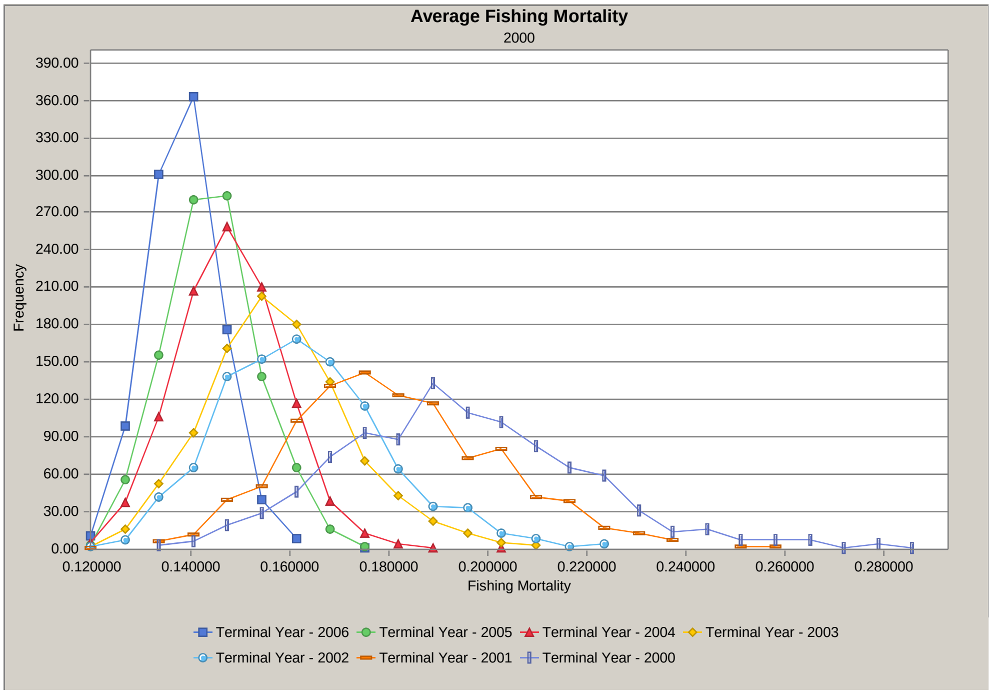


Figure B5a: VPA Model-1 bootstrapped retrospective for year 1995.



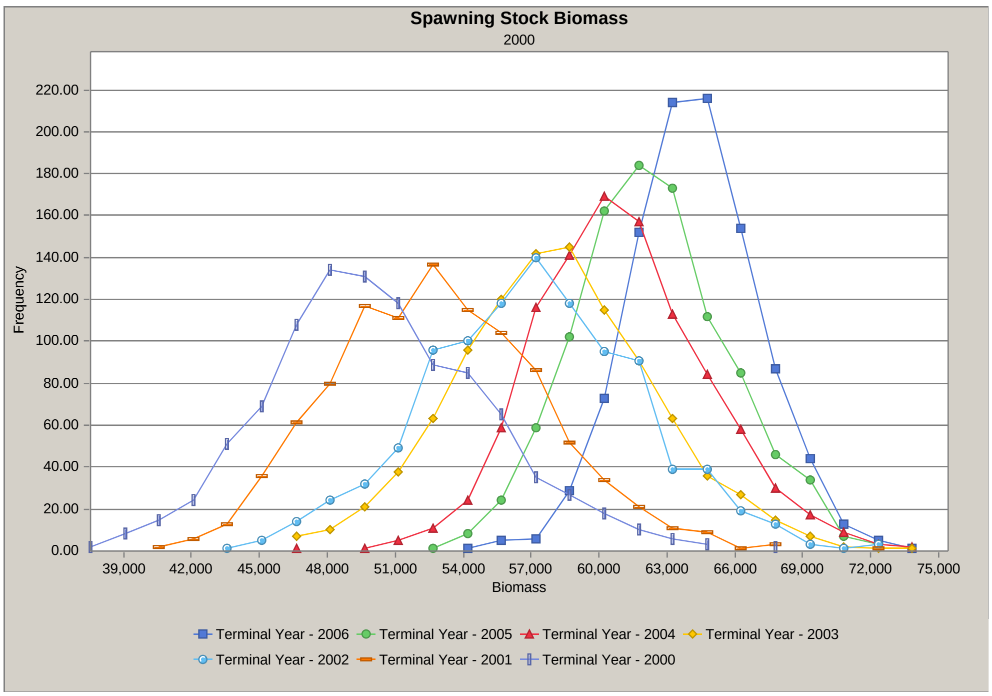


Figure B5b: VPA Model-1 bootstrapped retrospective for year 2000.

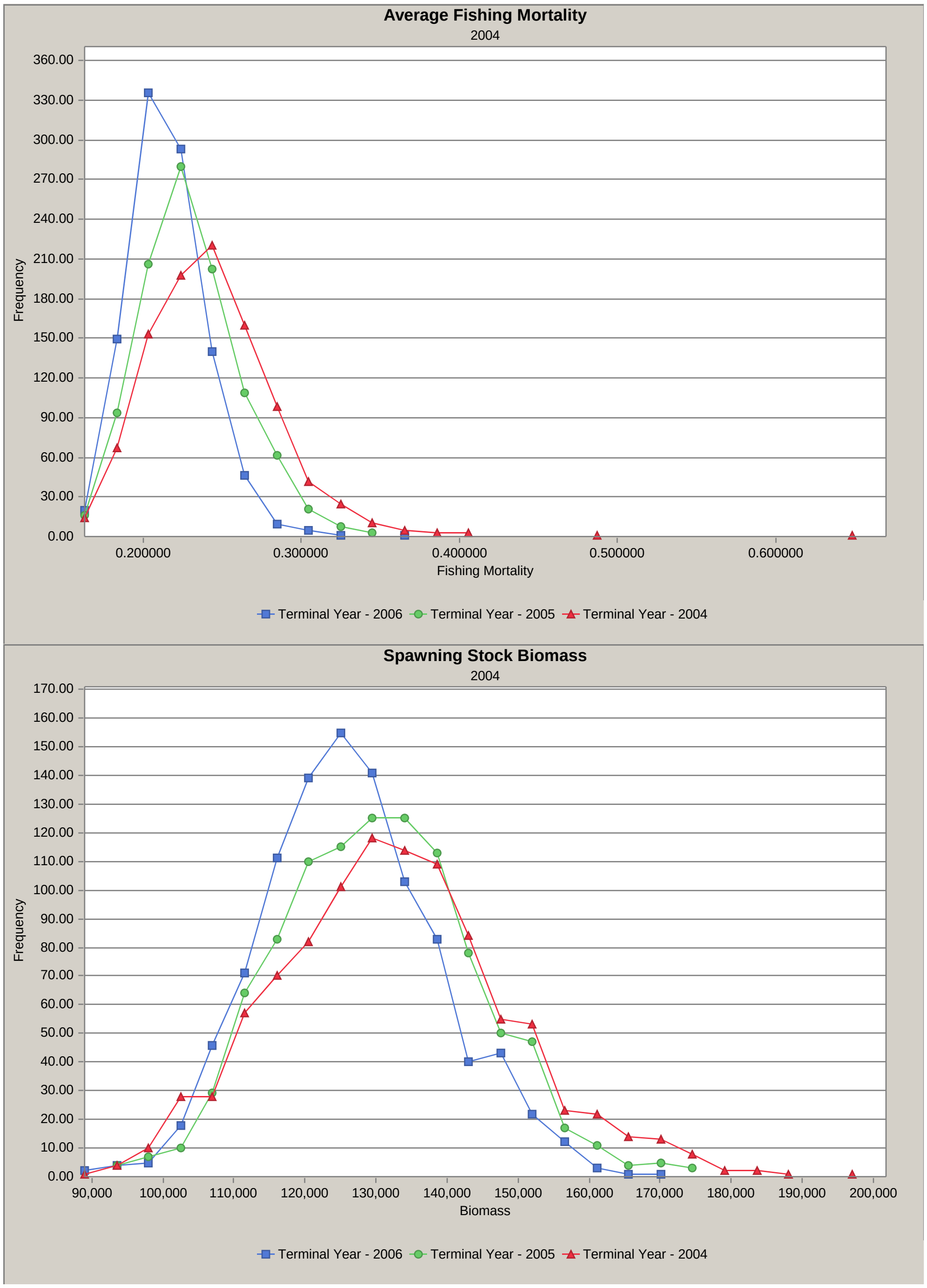
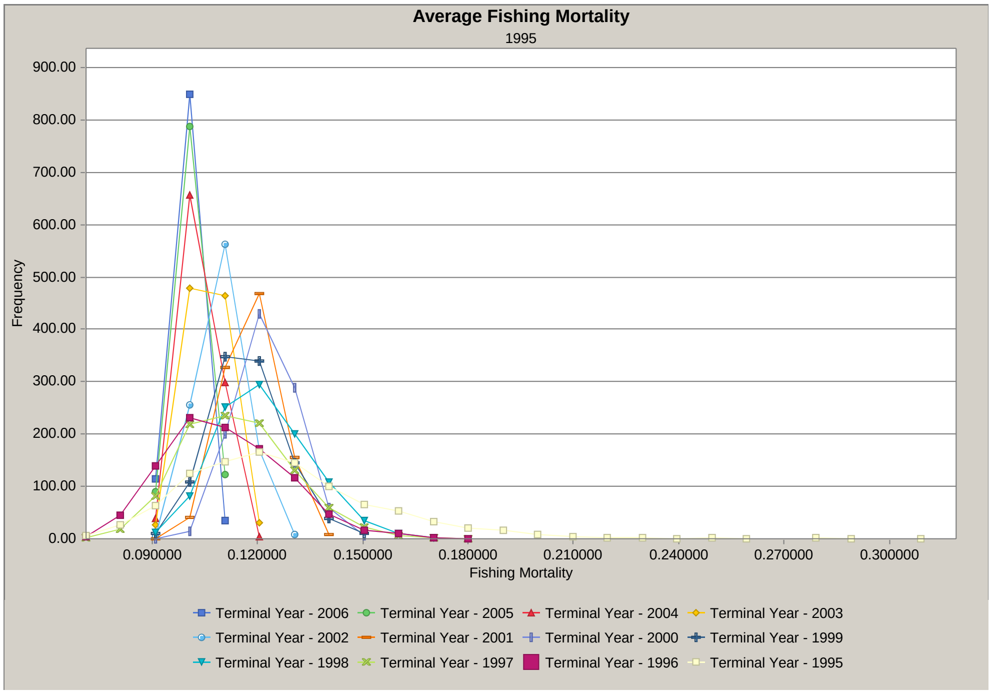


Figure B5c: VPA Model-1 bootstrapped retrospective for year 2004.



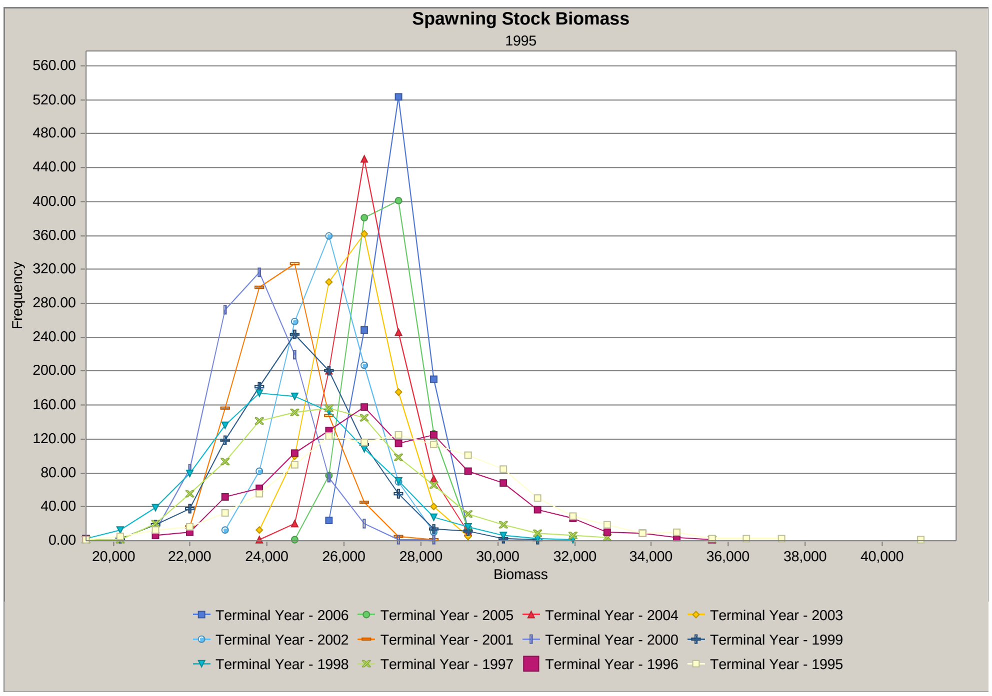
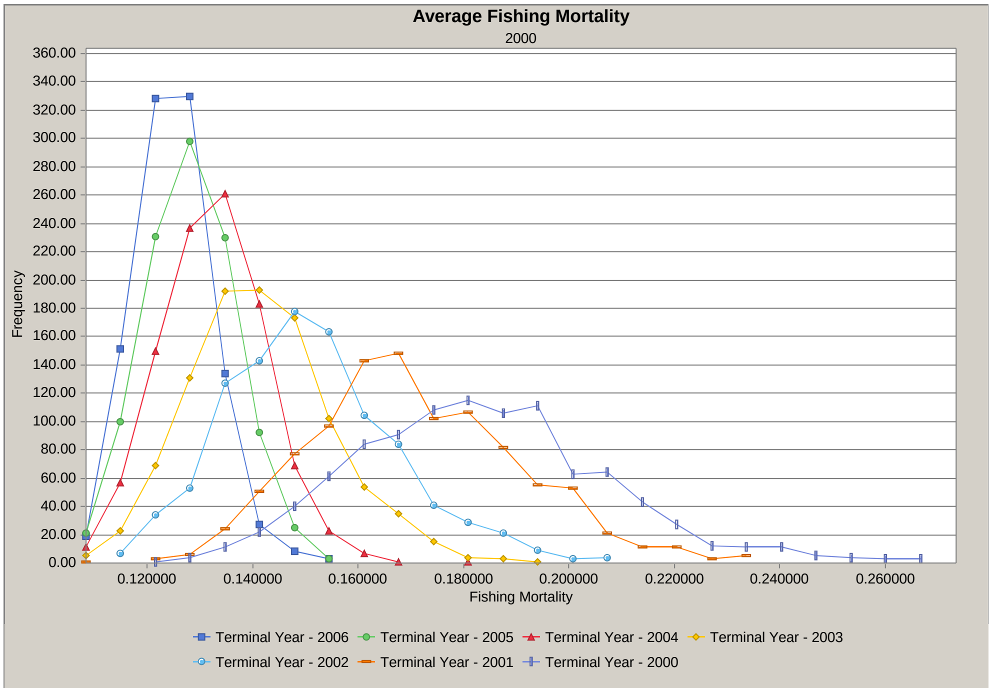


Figure B6a. VPA Model-3 bootstrapped retrospective for year 1995.



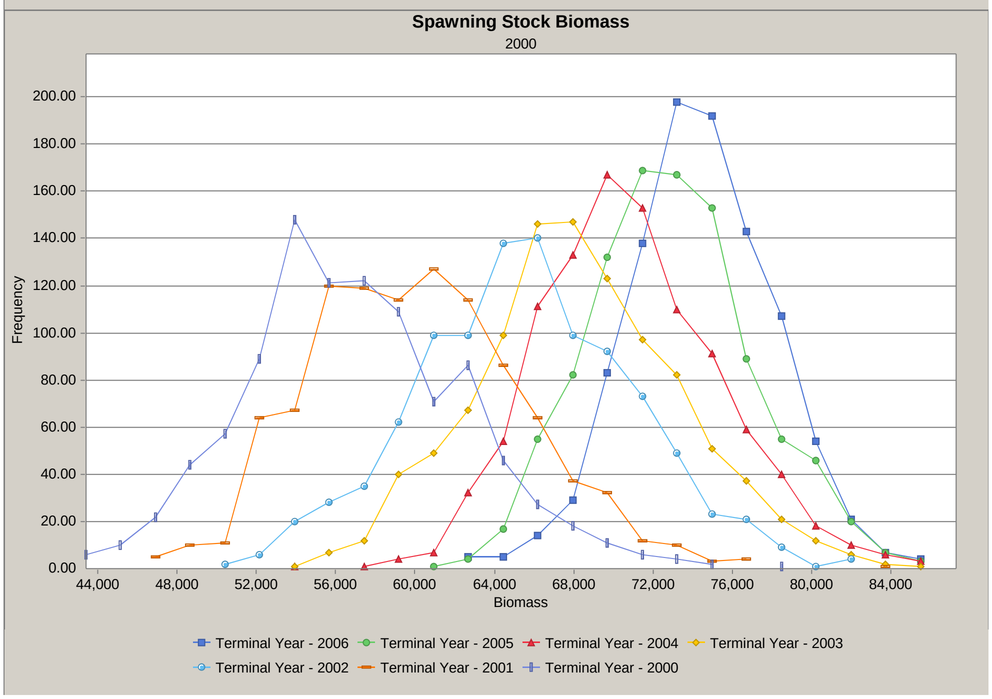


Figure B6b. VPA Model-3 bootstrapped retrospective for year 2000.

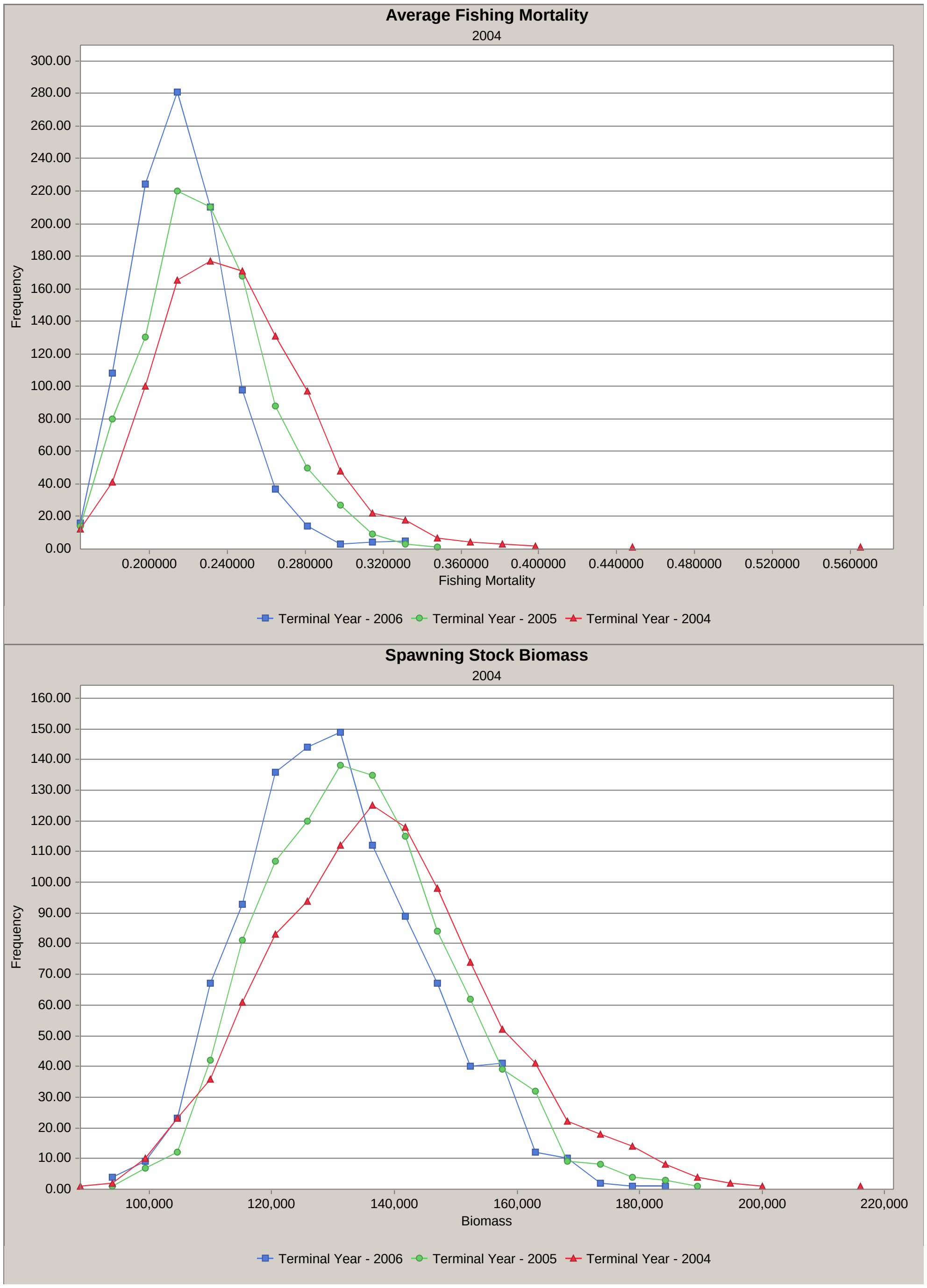


Figure B6c. VPA Model-3 bootstrapped retrospective for year 2004.

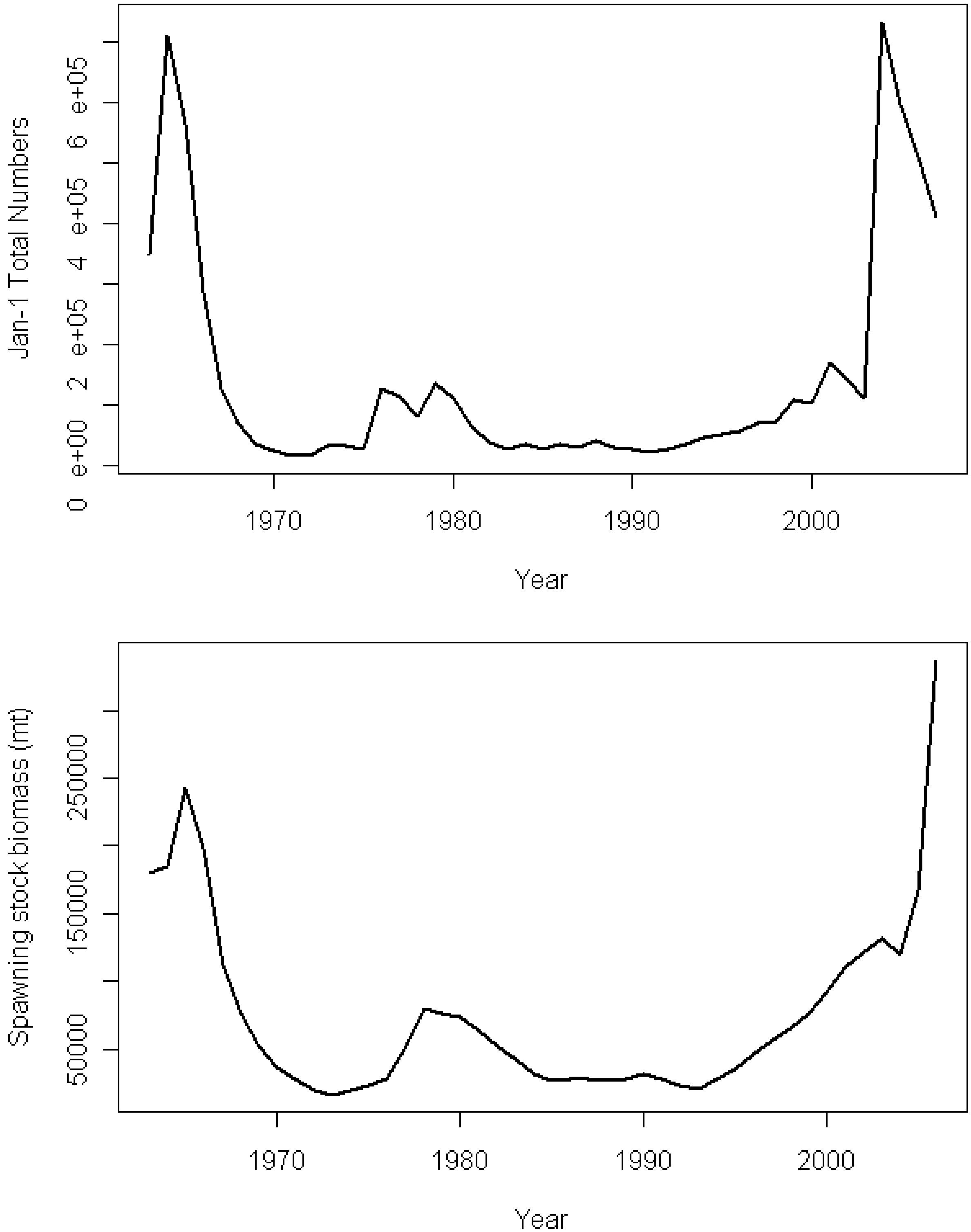


Figure B7.Trajectories of SSB and total population numbers from VPA Model-3.

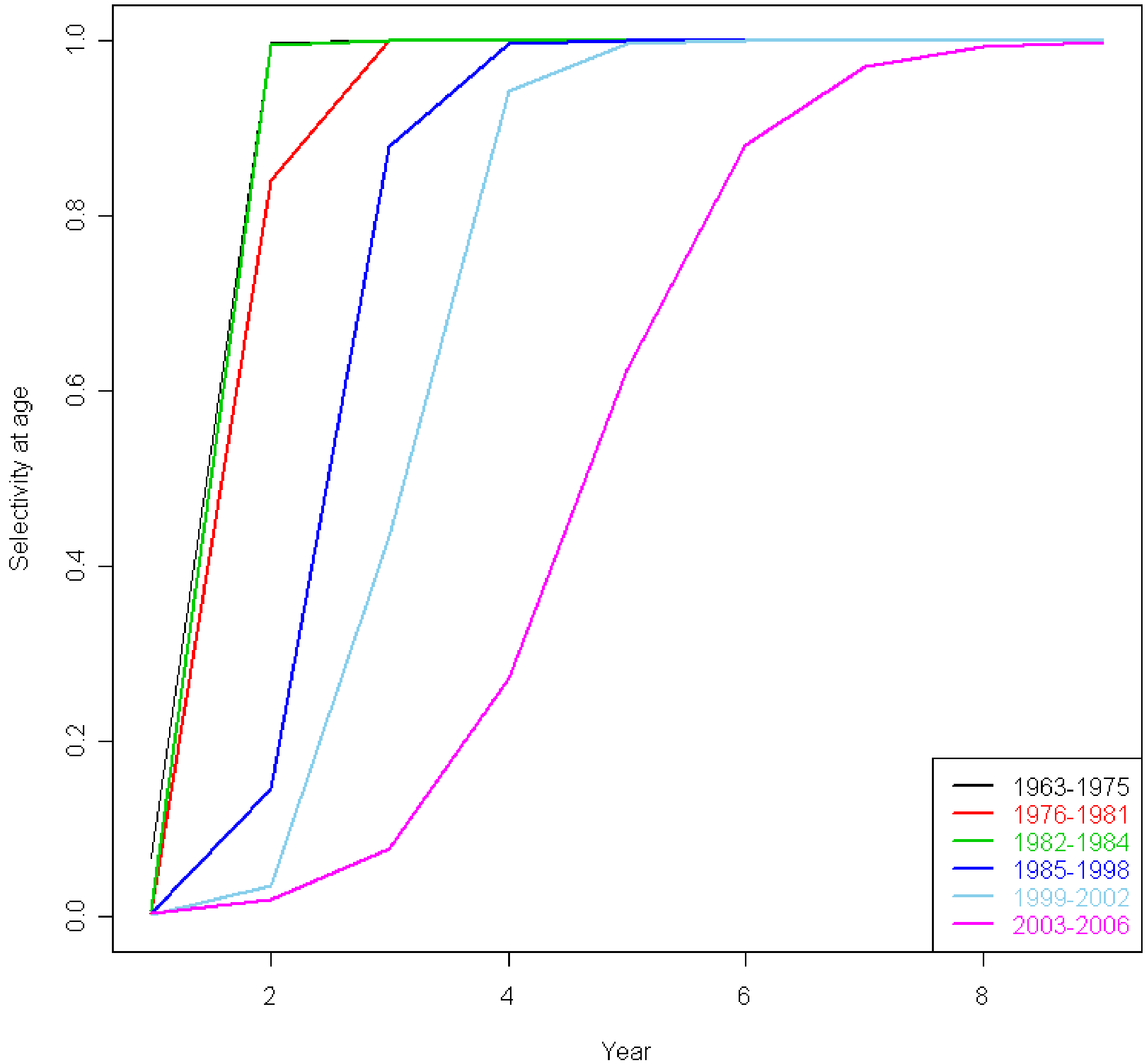


Figure B8. Logistic selectivity estimated in the ASAP sensitivity model.

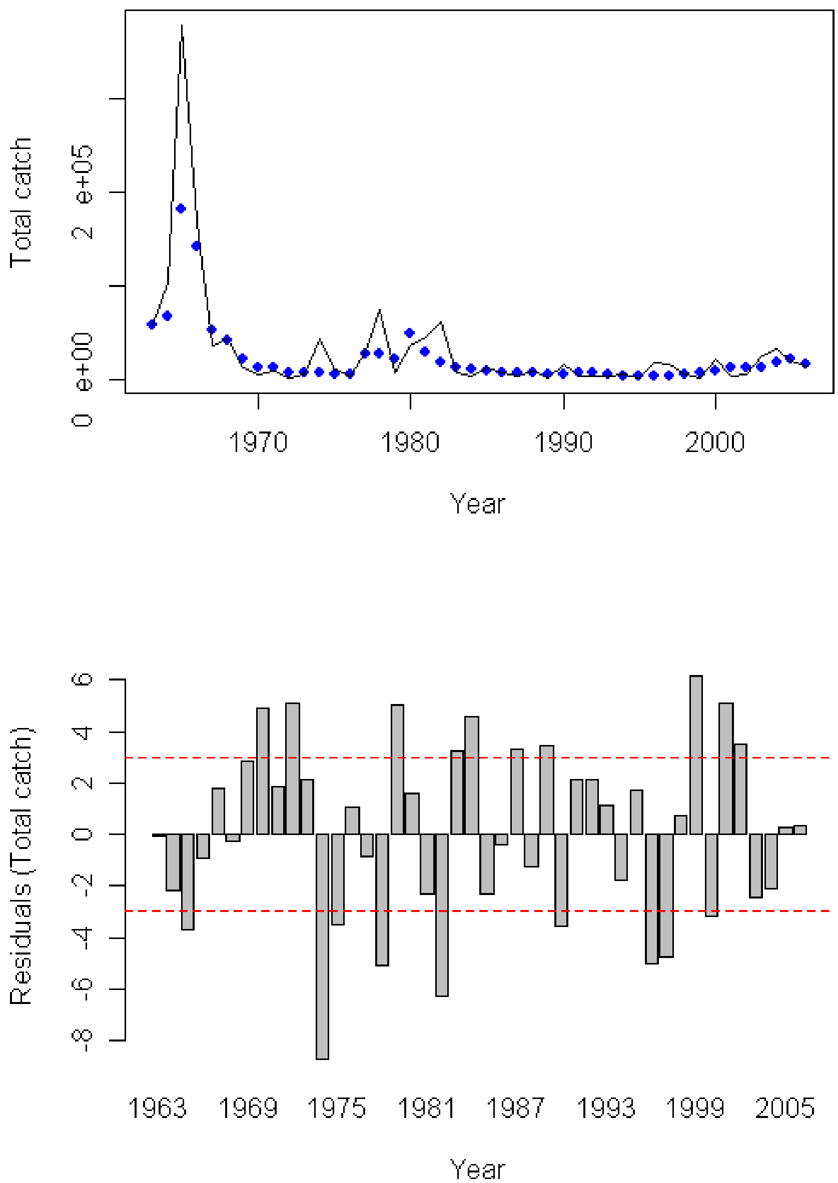


Figure B9. ASAP fits to total catch, and standardized residuals of the fit to total catch.

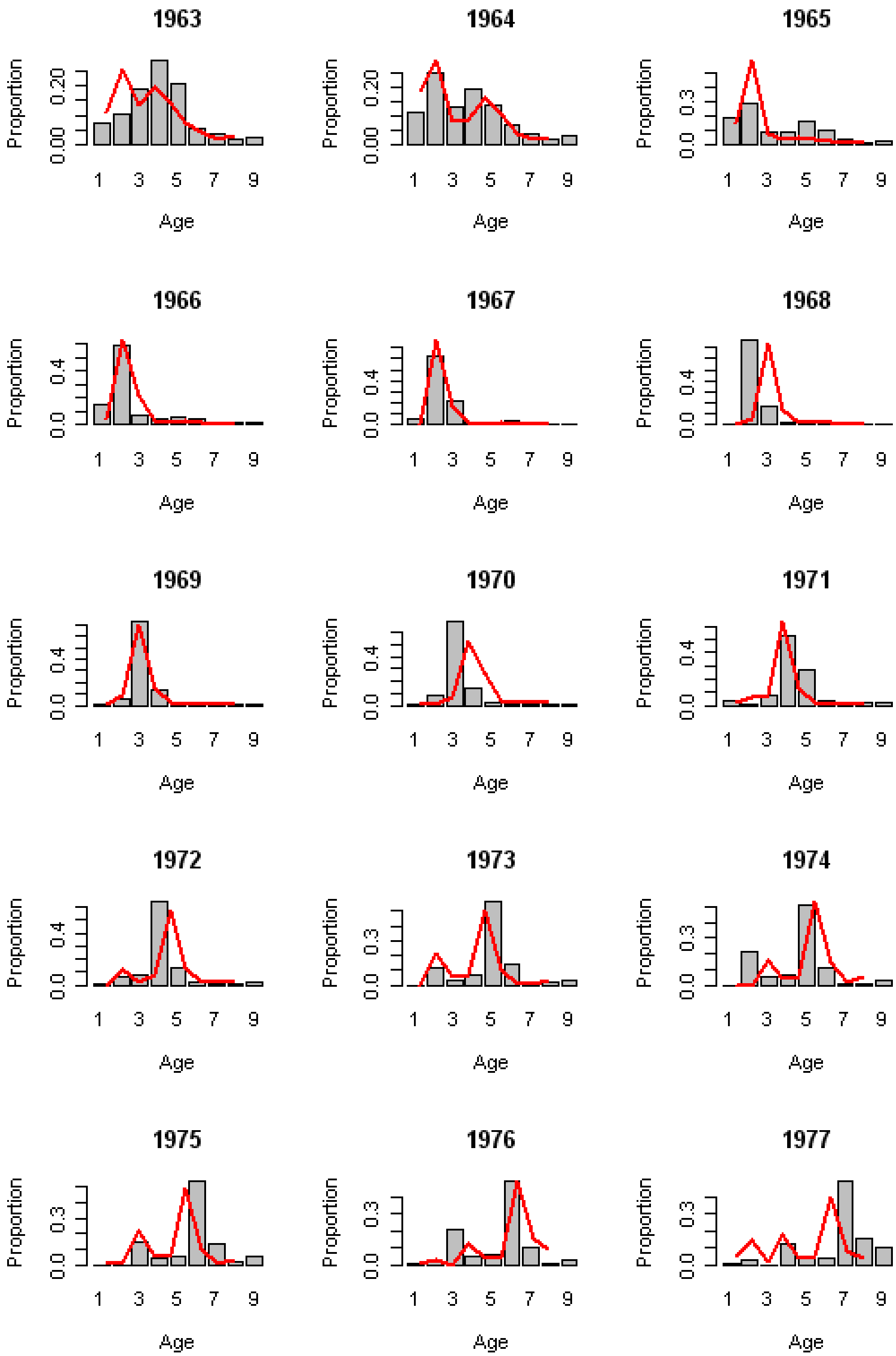


Figure B10a. ASAP fits to age composition.

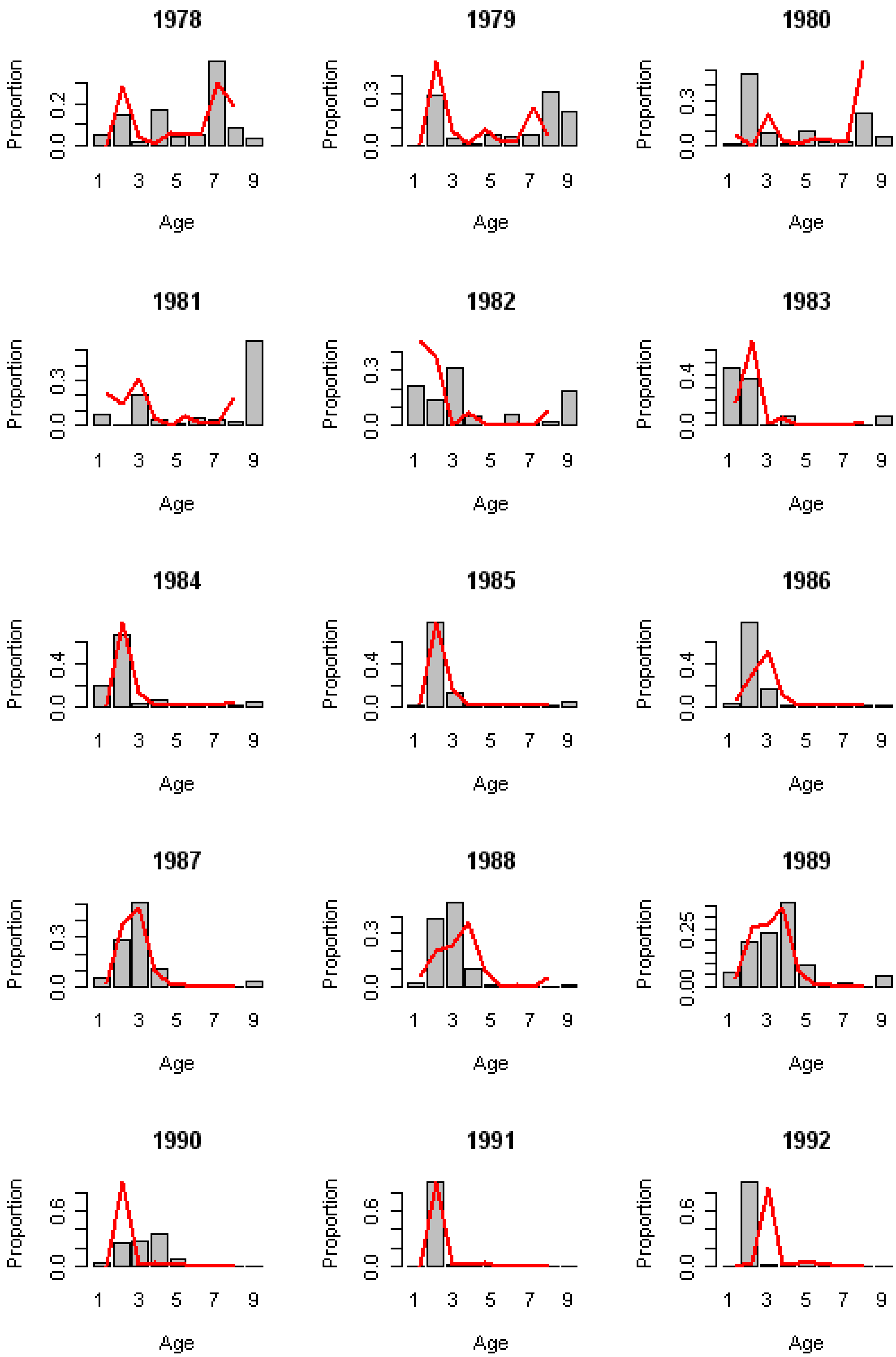


Figure B10b. ASAP fits to age composition.

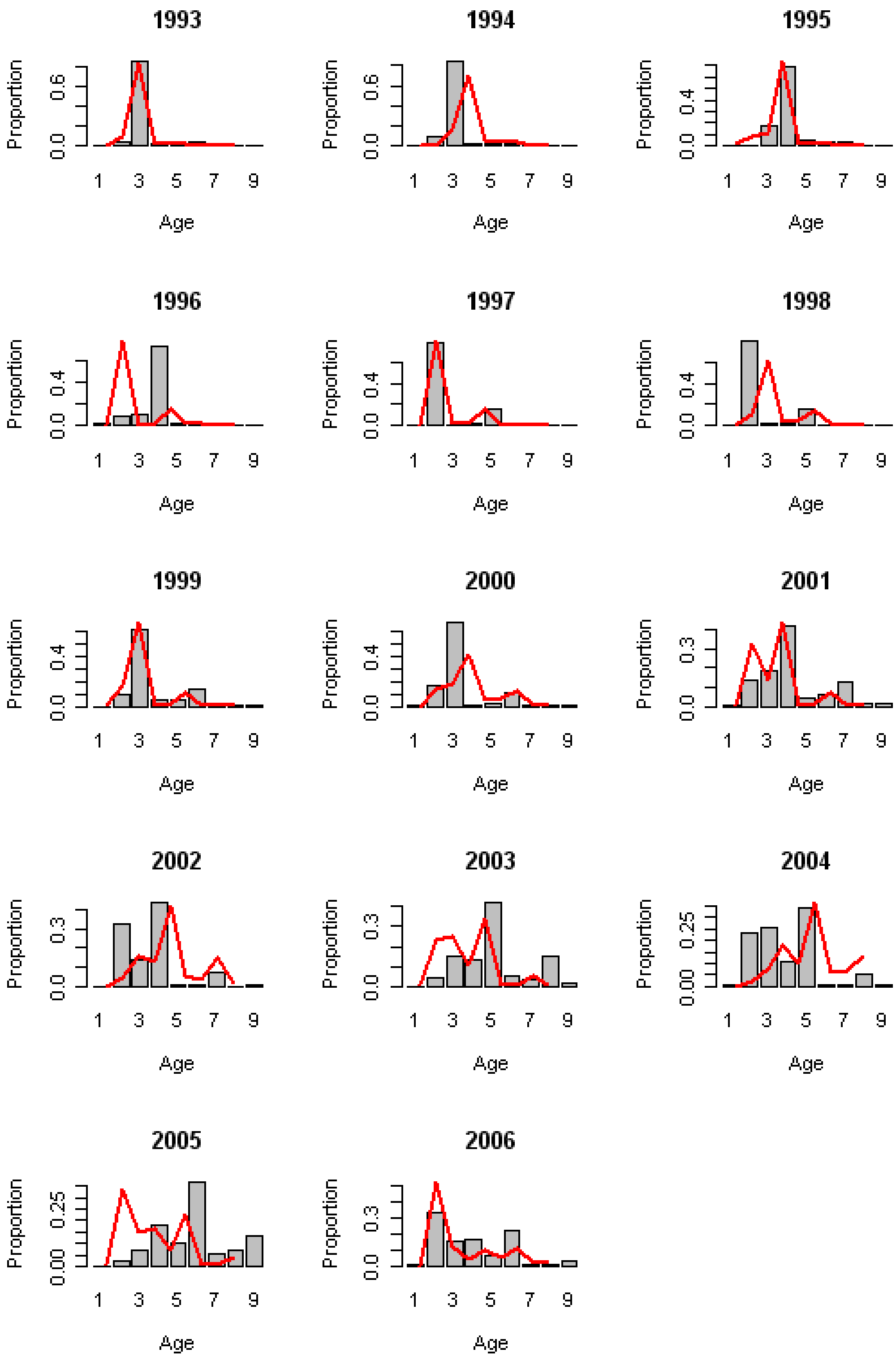


Figure B10c. ASAP fits to age composition.

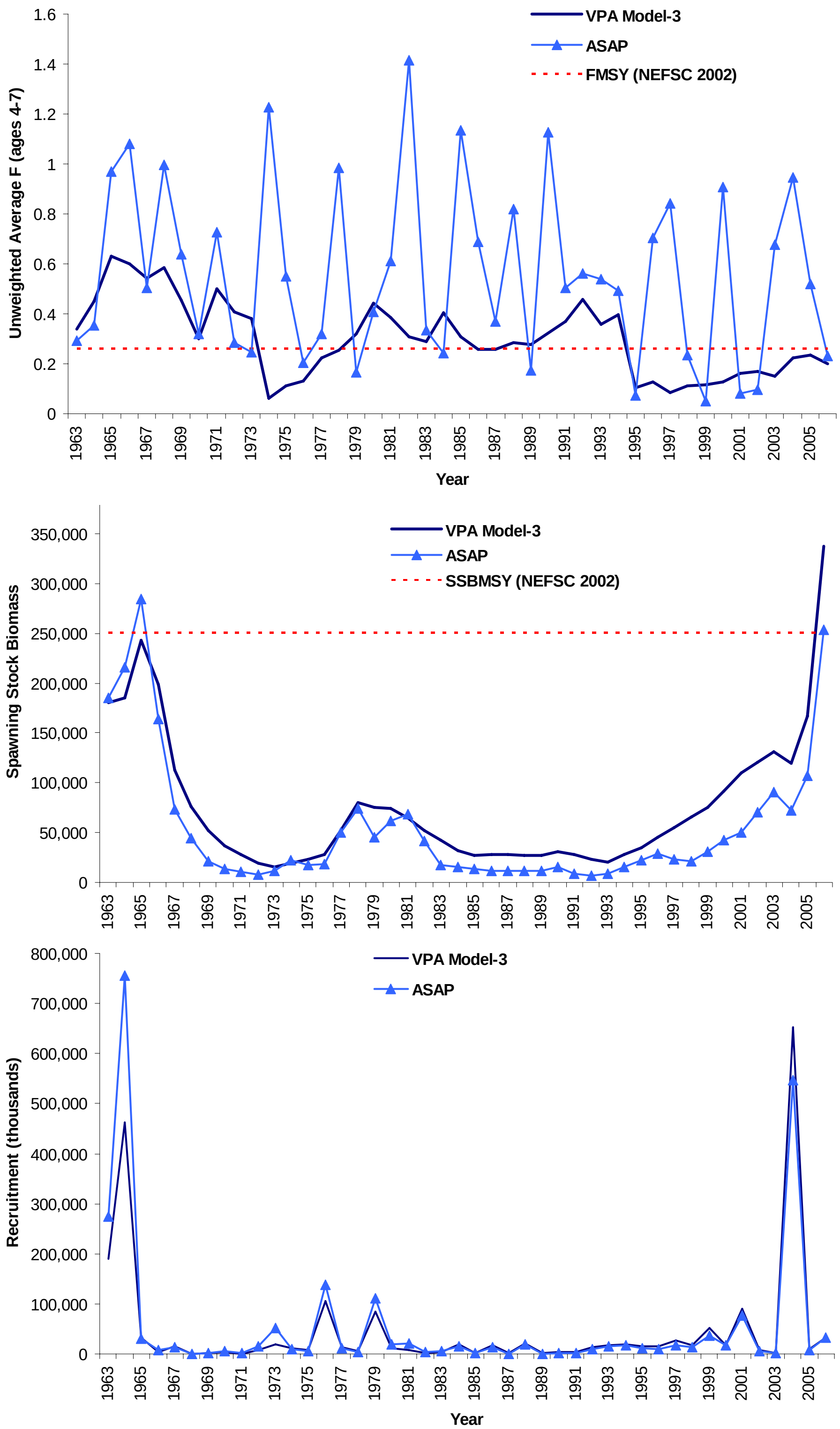


Figure B11. Comparison between VPA Model-3 results and ASAP.

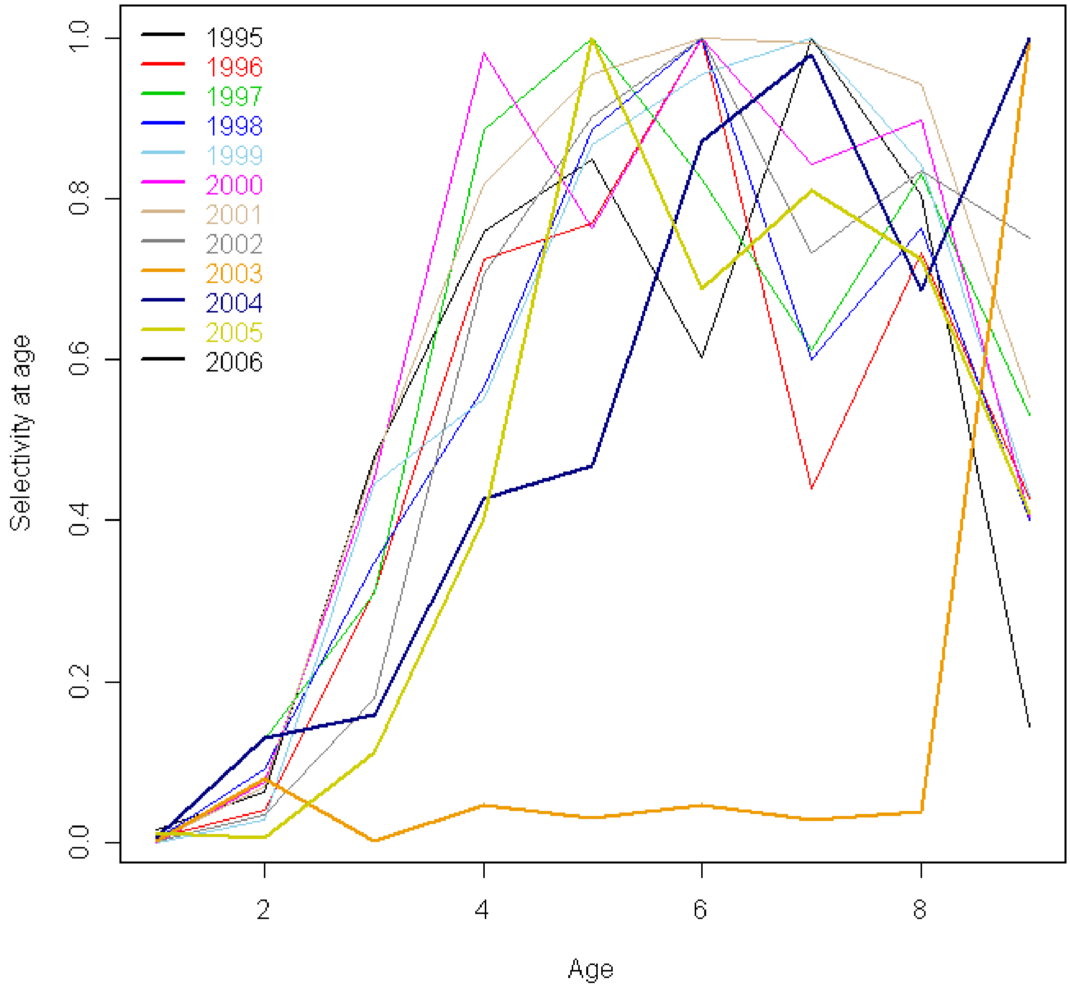


Figure B12. Partial recruitment in the VPA Model-3 (compare with ASAP selectivity in Fig. B8).

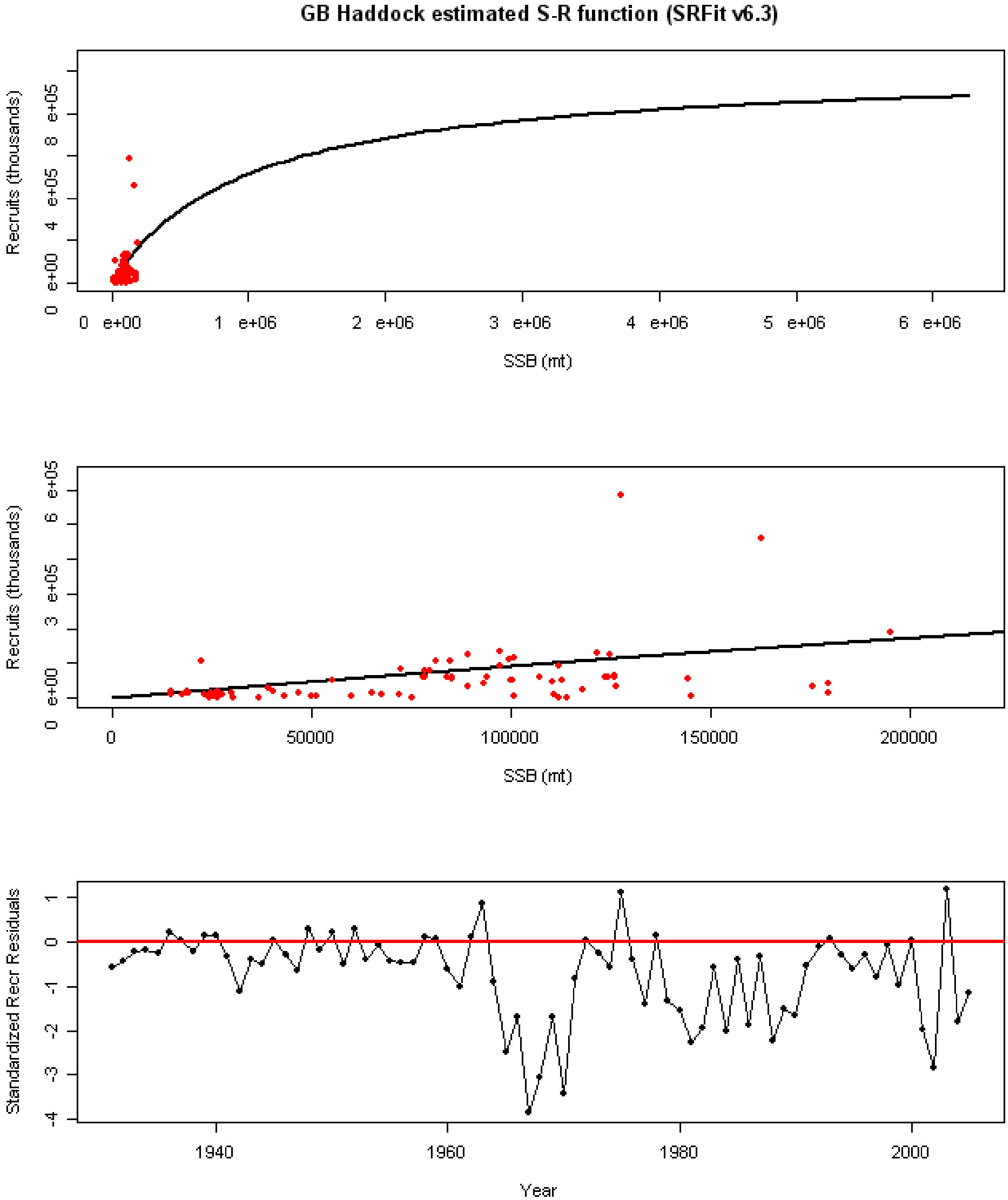


Figure B13. SRFit estimated stock recruitment curve from VPA Model-3 configuration, using catch at age from 1931-2006 (top), and the same plot with axes truncated to the range of observed SSB and recruitment (middle). Standardized residuals are plotted in the bottom panel.

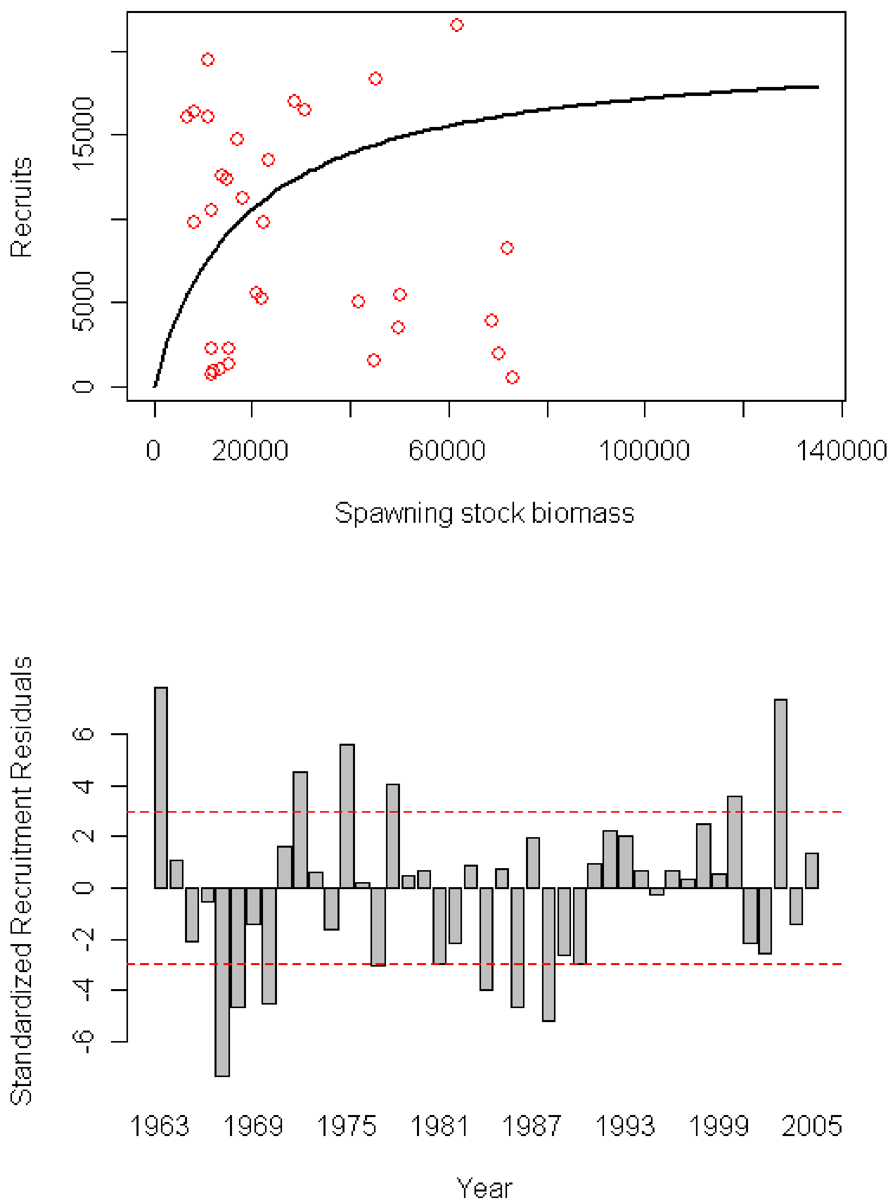
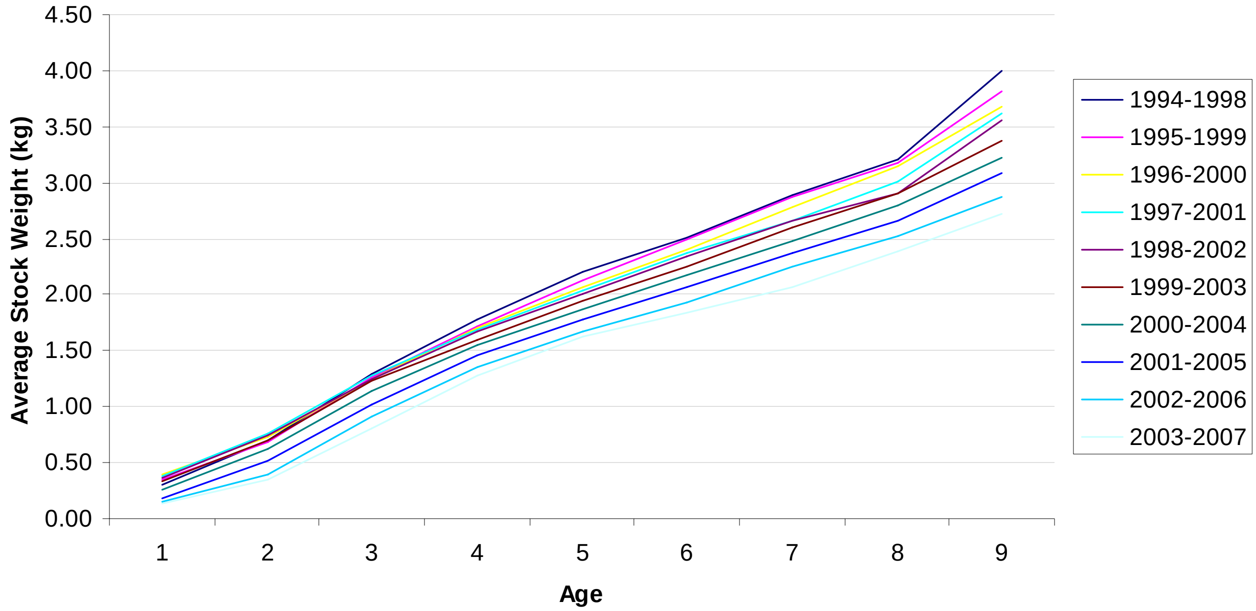


Figure B14. ASAP predicted Beverton-Holt relationship with observed spawning biomass and recruitment (top, open circles) and standardized residuals (bottom).



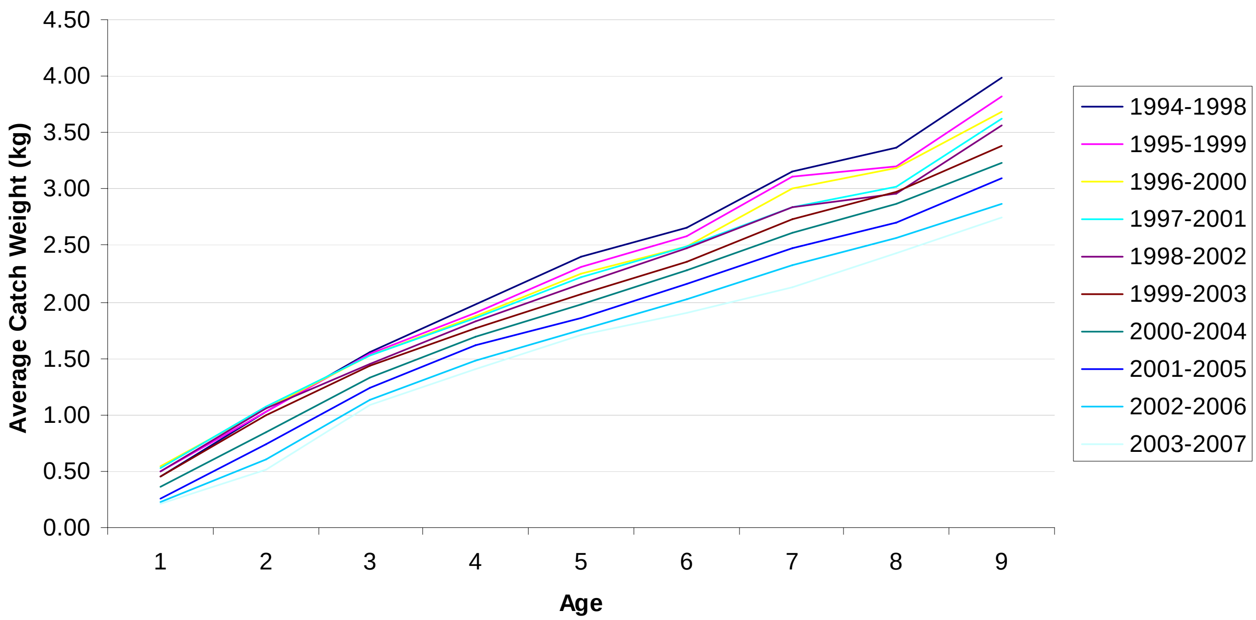


Figure B15. Trends in 5-year average stock weights (top) and catch weights at age (bottom).