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Population estimates of Greenland Halibut in NAFO Sub-area 2 & Divisions 3KLMNO using ADAPT

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Abstract

Estimates of stock size using ADAPT (Gavaris, 1988) are presented to assist the WG in addressing the FC request on evaluation of alternate assessment models as applied to this stock. We present and compare two series of analyses; each produced using the two F-constraint options available when using a catch-at-age matrix having a plus-group. We also explore the sensitivity of the model output to variations in the F-constraints considered and provide results of two separate retrospective analyses.

Introduction

Previous assessments of this stock have included comparisons of ADAPT estimates against those from the XSA results, which have been used for producing management advice. Exploratory ADAPT analyses were conducted during the 2000, the 2004 and the 2005 assessments of this stock (for more detail, refer to Healey, 2009). We focus upon comparisons of ADAPT analyses produced from the two options available for applying F-constraints when a plus-group is used. All ADAPT results were produced using ADAPT version 3.1.

Methods

The catch-at-age and RV surveys-at-age data used to estimate population size were taken from the agreed SC assessment data set from the 2008 assessment (see Healey and Mahé, 2008). Further, in the analyses presented here, all survey data are equally weighted. Additional preliminary analyses giving common weight to each survey were explored. The weighted estimates were generally indistinguishable from the unweighted results.

Within the ADAPT software, there are two methods used to handle analyses which include a plus group. The **FIRST** and **FRATIO** methods are the two methods used to construct the fishing mortality constraints to determine the cohorts for which survivors are not estimated.

When using the FIRST plus-group method of ADAPT, the fishing mortality (or population abundance) of the plus group (ages 14 and older) is specified in the initial year only (i.e. 1975). For all subsequent cohorts, an F-constraint on the oldest true age (age 13) is applied. From this, the plus group abundance for this cohort can be computed.

Using the FRATIO method, the population abundance of the plus-group in the terminal year must be estimated. For all years prior to the terminal year, the plus-group fishing mortality is derived as a ratio of the last true age F, which can be either assigned or estimated. In this method, the catch data in the last true age and in the plus group is used in the estimation of the last true age F.

Unless otherwise specified, analyses using the FIRST option employed the following F-constraints:

$F_{13,y}=F_{12,y}$, for y in 1975-2007, and

$F_{14+,\,1975}=F_{13,1975}$ (i.e. $F_{14+,\,1975}=F_{12,\,1975}$).

Similarly, unless otherwise specified, the FRATIO analyses have the following structure imposed:

$F_{14+,\,y}=F_{13,\,y}$ for y in 1975-2007.

In all analyses, natural mortality was assumed to be 0.2 throughout.

Results and Discussion

Estimated survivors from the ADAPT analyses using both the FIRST and FRATIO plus-group methods (Table 1) indicate similarities in both magnitude and with respect to the associated standard errors and biases. (Note that survivors in the plus-group are only estimated in the FRATIO analysis). Comparisons of the estimated 5+ biomass, average fishing mortality, and recruitment (Fig. 1) reveal common trends, although there are differences in the earliest portion of the time-series. An examination of the percentage of the total biomass (i.e. 5+ biomass) associated with the plus-group indicates some difference in the structure of the estimated population, with a much larger plus-group biomass in the FIRST-method estimates.

The overall mean squared residual for the FIRST and FRATIO runs are 0.459 and 0.460, respectively. Residual graphics for the FIRST and FRATIO runs (Fig. 2) reveal, in general, slight differences though the mean squared error for age 13 in the Canadian fall survey and age 12 in the EU summer survey are increased in the FRATIO analysis. In addition, there are cohort patterns evident in bubble plots of residuals by survey in each analysis (not shown).

Estimates of catchability for each survey from the FRATIO and FIRST analyses, as well as the relative differences of these estimates are given in Figure 3. It is evident that the FRATIO method estimates higher catchability coefficients for older ages, which in turn results in lower estimates of biomass, most particularly the biomass at the older ages and in the plus group. This is consistent with the differences previously noted when discussing the percentage of total biomass in the plus-group from the FIRST and FRATIO results.

Trends in the estimated commercial selection patterns over 2003-2007 using the FIRST and FRATIO methods show insignificant differences over ages 1-9 (Fig. 4). However, for age 10 through to the plus-group, there are significant departures in selection, again reflective of the differing estimates of abundance at older ages and within the plus group. Both results suggest large decreases in selection after beyond age 9; however, fish older than this comprise only 5% of total numbers removed over 2003-2007 (prior to 2003 it varies from 5-20%, averaging 10%).

Three year retrospective analyses under both plus-group options (Figs. 5 and 6 for FIRST and FRATIO respectively) indicate large revisions to the estimates of exploitable biomass, average fishing mortality, and age 1 recruitment. The patterns of these revisions are consistent between the FIRST vs. FRATIO methods. An examination of the structure of the one-year retrospective was conducted by computing the percent relative difference in the estimates of population abundance at each year and age from the terminal year assessment compared to the first retrospective year assessment (i.e. ADAPT analysis excluding the final year of catch and survey data). Given differences noted previously regarding both the catchability coefficients for the older ages and the plus-group biomass, the nature of the one year retrospective differences in FIRST and FRATIO analyses (Tables 3 and 4) are not surprising. The retrospective revisions are practically identical for most age groups, but are quite different at the oldest ages, at which catchability estimates substantially differ between the two analyses.

For the FIRST plus-group method, the sensitivity of the estimates to the relationship between the commercial selectivity at the oldest ages was explored. Considering that the F-constraints applied are:

$F_{13,y}=\alpha F_{12,y}$, for y in 1976-2007, with

$F_{14+,\,1975}=\alpha F_{13,1975}$ and $F_{14+,\,1975}=\alpha F_{12,\,1975}$,

we repeated the analysis for α values of 0.5, 0.75, and 1.5 to compare to the α=1 analysis presented in Figure 1.

The results (Fig. 7) are highly volatile, with large increases in biomass at the beginning of the time-series for both α=0.75, and α=0.5 (not plotted). Lower estimates of exploitable biomass were obtained when assuming α=1.5. For the α=0.5 case, the 1975 estimate of exploitable biomass is approximately 22 *billion* tons, though the MSE (0.84) is considerably larger than that for any of the α=0.75, 1 or 1.5 cases (0.47, 0.46, 0.46, respectively).

A similar exercise was conducted for the FRATIO analyses. Recall that in this method the ratio between the plus-group fishing mortality and oldest true age can be either fixed or estimated. The F-constraints applied in this analysis are thus:

$F_{14+,y} = \alpha F_{13,y}$, for y in 1975-2007.

The results of these analyses (Fig. 8) suggest that the estimates are robust to varied choices for the ratio of fishing mortality in the 14 + group and at age 13. There are however, some small differences in the plus-group contribution to the total biomass. The magnitude of these variations (approximately 1-6%) pale in contrast to those from the FIRST analysis (ranging from 2-70%). Although there was a trend for decreasing overall MSE for models assuming increasing commercial selectivity at the oldest ages there was really very little difference between model errors with the MSE being 0.466, 0.462, 0.460, 0.459 for α=0.5, 0.75, 1.0 and 1.5 respectively.

As described in the Methods section, all analyses considered assign equal weighting to all survey data. Arriving at the appropriate weightings and making comparisons between various weighted fits are not trivial undertakings. Further, weighted analyses may be sensitive to influential series (S. Gavaris, DFO, pers. comm.).

As noted by Healey (2009) for XSA assessments of this stock, the high degree consistency amongst many of these results is aided by the backwards-convergence property of ADAPT. Hence, it can generally be concluded that the ADAPT results are robust over most of the options explored, conditioned on the catch history being exact. For this stock, catch has been at times estimated with varying degrees of precision. Hence, any modeling of population dynamics including catches may result in a biased solution.

Conclusion

Estimates of the population dynamics of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO using ADAPT based upon the two plus group options are highly consistent, with trends in biomass and F being very similar. There are minor differences in the absolute quantities estimated from the FIRST and FRATIO analyses, with (in general) common residual patterns. Larger differences are evident when focusing upon the dynamics of the older ages and the plus-group. These differences are explained due to relatively higher survey catchability parameters being estimated in the FRATIO analysis. Both analyses indicate similar retrospective patterns, with large revisions to exploitable biomass, average fishing mortality, and recruitment. The sensitivity of the FIRST and FRATIO methods to the fixed multipliers used to construct the F-constraints was explored. Results of the FIRST analysis were highly dependent upon the constant chosen. This instability was not present in the companion FRATIO analyses. Trends in all model formulations explored, except for α=0.5 and 0.75 in the FIRST method were similar to those in the accepted XSA model for most of the time series. The main difference is that the ADAPT runs are slightly more optimistic in the recent period showing stability in 5+ biomass the last few years while the XSA (which includes F-shrinkage) shows a decline. This is in contrast to a comparison of ADAPT and XSA during the June 2004 SC meeting (Darby et al., 2004). At that time, ADAPT estimates of 5+ biomass were more pessimistic compared than those of XSA, as the XSA shrinkage estimated a lower terminal F.

References

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Table 1. Parameter Estimates for ADAPT analysis using "FIRST" plus-group method.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[2008 2]	60822.17	25098.02	41%	5443.404	9%
N[2008 3]	24707.21	7917.533	32%	1371.274	6%
N[2008 4]	25942.17	6607.223	25%	946.5475	4%
N[2008 5]	26002.44	5677.829	22%	720.7112	3%
N[2008 6]	39223.13	7687.713	20%	893.996	2%
N[2008 7]	35510.13	6944.882	20%	756.2324	2%
N[2008 8]	17561.5	4800.288	27%	534.0554	3%
N[2008 9]	8459.506	2800.571	33%	357.7806	4%
N[2008 10]	2309.739	966.2477	42%	163.7439	7%
N[2008 11]	1277.961	489.6897	38%	76.67429	6%
N[2008 12]	857.1193	297.6287	35%	44.13724	5%
N[2008 13]	694.7147	166.4011	24%	16.76488	2%
q Cdn_Spr_1	7E-06	1.51E-06	22%	1.31E-07	2%
q Cdn_Spr_2	1.16E-05	2.46E-06	21%	2.11E-07	2%
q Cdn_Spr_3	2E-05	4.17E-06	21%	3.59E-07	2%
q Cdn_Spr_4	2.27E-05	4.7E-06	21%	4.06E-07	2%
q Cdn_Spr_5	2.9E-05	5.98E-06	21%	5.22E-07	2%
q Cdn_Spr_6	1.75E-05	3.6E-06	21%	3.18E-07	2%
q Cdn_Spr_7	9.07E-06	1.87E-06	21%	1.66E-07	2%
q Cdn_Spr_8	2.81E-06	5.84E-07	21%	5.22E-08	2%
q Cdn_Fall_1	0.000419	8.71E-05	21%	7.19E-06	2%
q Cdn_Fall_2	0.000377	7.68E-05	20%	6.27E-06	2%
q Cdn_Fall_3	0.000265	5.33E-05	20%	4.34E-06	2%
q Cdn_Fall_4	0.000273	5.44E-05	20%	4.45E-06	2%
q Cdn_Fall_5	0.000229	4.53E-05	20%	3.73E-06	2%
q Cdn_Fall_6	0.000175	3.46E-05	20%	2.85E-06	2%
q Cdn_Fall_7	0.000183	3.64E-05	20%	3.01E-06	2%
q Cdn_Fall_8	0.000117	2.38E-05	20%	2.04E-06	2%
q Cdn_Fall_9	5.09E-05	1.06E-05	21%	9.98E-07	2%
q Cdn_Fall_10	2.7E-05	5.66E-06	21%	5.62E-07	2%
q Cdn_Fall_11	2.23E-05	4.75E-06	21%	4.78E-07	2%
q Cdn_Fall_12	1.93E-05	4.35E-06	23%	4.65E-07	2%
q Cdn_Fall_13	3.45E-05	7.98E-06	23%	8.63E-07	2%
q EU_Summ_1	2.66E-05	5.29E-06	20%	4.15E-07	2%
q EU_Summ_2	1.61E-05	3.14E-06	20%	2.44E-07	2%
q EU_Summ_3	2.98E-05	5.75E-06	19%	4.46E-07	1%
q EU_Summ_4	4.09E-05	7.83E-06	19%	6.12E-07	1%
q EU_Summ_5	0.000116	2.2E-05	19%	1.74E-06	2%
q EU_Summ_6	0.000238	4.52E-05	19%	3.58E-06	2%
q EU_Summ_7	0.000288	5.48E-05	19%	4.33E-06	2%
q EU_Summ_8	0.000239	4.61E-05	19%	3.66E-06	2%
q EU_Summ_9	0.000117	2.29E-05	20%	1.96E-06	2%
q EU_Summ_10	8.17E-05	1.62E-05	20%	1.47E-06	2%
q EU_Summ_11	3.73E-05	7.51E-06	20%	7.02E-07	2%
q EU_Summ_12	3.19E-05	7.12E-06	22%	7.51E-07	2%

Table 2. Parameter Estimates for ADAPT analysis using “FRATIO” plus-group method.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[2008 2]	60211.16	24869.46	41%	5400.924	9%
N[2008 3]	24459.3	7844.769	32%	1360.627	6%
N[2008 4]	25672.75	6543.195	25%	938.6248	4%
N[2008 5]	25726.06	5620.792	22%	714.326	3%
N[2008 6]	38788.66	7606.976	20%	885.3957	2%
N[2008 7]	35056.58	6866.896	20%	748.1526	2%
N[2008 8]	17166.72	4728.471	28%	527.8808	3%
N[2008 9]	8083.728	2715.206	34%	352.3421	4%
N[2008 10]	2120.41	903.8715	43%	157.2713	7%
N[2008 11]	1127.892	442.822	39%	71.12434	6%
N[2008 12]	715.6945	255.2852	36%	38.56585	5%
N[2008 13]	654.3337	203.1699	31%	27.51824	4%
N[2008 14+]	479.915	151.0263	31%	17.31856	4%
q Cdn_Spr_1	7.08E-06	1.52E-06	22%	1.32E-07	2%
q Cdn_Spr_2	1.17E-05	2.48E-06	21%	2.13E-07	2%
q Cdn_Spr_3	2.02E-05	4.22E-06	21%	3.63E-07	2%
q Cdn_Spr_4	2.29E-05	4.76E-06	21%	4.12E-07	2%
q Cdn_Spr_5	2.94E-05	6.06E-06	21%	5.30E-07	2%
q Cdn_Spr_6	1.77E-05	3.65E-06	21%	3.23E-07	2%
q Cdn_Spr_7	9.26E-06	1.91E-06	21%	1.70E-07	2%
q Cdn_Spr_8	2.95E-06	6.11E-07	21%	5.42E-08	2%
q Cdn_Fall_1	0.000423	8.8E-05	21%	7.25E-06	2%
q Cdn_Fall_2	0.000381	7.76E-05	20%	6.32E-06	2%
q Cdn_Fall_3	0.000268	5.39E-05	20%	4.38E-06	2%
q Cdn_Fall_4	0.000276	5.51E-05	20%	4.51E-06	2%
q Cdn_Fall_5	0.000231	4.59E-05	20%	3.79E-06	2%
q Cdn_Fall_6	0.000178	3.52E-05	20%	2.9E-06	2%
q Cdn_Fall_7	0.000188	3.75E-05	20%	3.08E-06	2%
q Cdn_Fall_8	0.000125	2.52E-05	20%	2.1E-06	2%
q Cdn_Fall_9	5.7E-05	1.17E-05	20%	1.07E-06	2%
q Cdn_Fall_10	3.2E-05	6.59E-06	21%	6.39E-07	2%
q Cdn_Fall_11	2.87E-05	5.96E-06	21%	5.93E-07	2%
q Cdn_Fall_12	2.85E-05	6.27E-06	22%	6.76E-07	2%
q Cdn_Fall_13	6.13E-05	1.41E-05	23%	1.58E-06	3%
q EU_Summ_1	2.68E-05	5.34E-06	20%	4.19E-07	2%
q EU_Summ_2	1.63E-05	3.18E-06	20%	2.47E-07	2%
q EU_Summ_3	3.01E-05	5.82E-06	19%	4.52E-07	1%
q EU_Summ_4	4.14E-05	7.93E-06	19%	6.21E-07	1%
q EU_Summ_5	0.000117	2.23E-05	19%	1.76E-06	2%
q EU_Summ_6	0.000242	4.59E-05	19%	3.64E-06	2%
q EU_Summ_7	0.000296	5.63E-05	19%	4.45E-06	2%
q EU_Summ_8	0.000254	4.88E-05	19%	3.8E-06	1%
q EU_Summ_9	0.00013	2.52E-05	19%	2.09E-06	2%
q EU_Summ_10	9.5E-05	1.86E-05	20%	1.65E-06	2%
q EU_Summ_11	4.68E-05	9.21E-06	20%	8.51E-07	2%
q EU_Summ_12	4.67E-05	1.02E-05	22%	1.07E-06	2%

Table 3. Retrospective comparison (one year) of numbers at age as estimated from ADAPT using the FIRST plus-group method. Table entries provide the ratio of the estimated numbers from the current assessment to those estimated in the previous assessment (model formulation unchanged). Shaded entries highlight changes in excess of +/- 10%.

N[a,y] Ratio Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1976	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1977	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1978	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1979	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1980	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1981	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1982	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1983	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1984	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1985	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1986	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1987	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1988	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1989	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1990	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1992	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1993	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1994	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1995	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1996	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1997	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1998	4%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1999	8%	4%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2000	**24%**	8%	4%	3%	0%	0%	0%	1%	1%	1%	1%	1%	1%	0%
2001	**28%**	**24%**	8%	4%	3%	0%	0%	1%	1%	1%	1%	1%	1%	0%
2002	**17%**	**28%**	**24%**	8%	4%	3%	0%	1%	1%	1%	1%	1%	1%	1%
2003	6%	**17%**	**28%**	**24%**	8%	5%	4%	0%	2%	2%	2%	2%	2%	1%
2004	-1%	6%	**17%**	**28%**	**25%**	9%	7%	10%	1%	3%	3%	3%	3%	1%
2005	**25%**	-1%	6%	**17%**	**29%**	**27%**	**12%**	**15%**	**21%**	1%	4%	4%	4%	2%
2006	**-14%**	**25%**	-1%	6%	**17%**	**30%**	**33%**	**25%**	**35%**	**40%**	2%	5%	5%	3%
2007		**-14%**	**25%**	-1%	6%	**18%**	**37%**	**72%**	**69%**	**62%**	**58%**	2%	6%	4%

Table 4. Retrospective comparison (one year) of numbers at age as estimated from ADAPT using the FRATIO plus-group method. Table entries provide the ratio of the estimated numbers from the current assessment to those estimated in the previous assessment (model formulation unchanged). Shaded entries highlight changes in excess of +/- 10%.

N[a,y] Ratio Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1975	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1976	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1977	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1978	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1979	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1980	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1981	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1982	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1983	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1984	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1985	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1986	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1987	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1988	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1989	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1990	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1992	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1993	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1994	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1995	-1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1996	1%	-1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1997	2%	1%	-1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1998	4%	2%	1%	-1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
1999	7%	4%	2%	1%	-1%	0%	1%	1%	1%	1%	1%	0%	0%	0%
2000	**24%**	7%	4%	2%	1%	-1%	0%	1%	1%	1%	1%	1%	1%	1%
2001	**28%**	**24%**	7%	4%	2%	1%	-1%	1%	3%	2%	1%	2%	1%	1%
2002	**17%**	**28%**	**24%**	7%	4%	3%	1%	-2%	3%	4%	3%	3%	3%	3%
2003	6%	**17%**	**28%**	**24%**	7%	4%	3%	2%	-5%	6%	7%	6%	5%	5%
2004	-1%	6%	**17%**	**28%**	**24%**	8%	6%	9%	6%	-9%	10%	**11%**	**10%**	**10%**
2005	**24%**	-1%	6%	**17%**	**29%**	**27%**	**11%**	**14%**	**19%**	**10%**	**-13%**	**19%**	**21%**	**21%**
2006	**-14%**	**24%**	-1%	6%	**17%**	**30%**	**33%**	**24%**	**34%**	**39%**	**14%**	**-18%**	**32%**	**32%**
2007		**-14%**	**24%**	-1%	6%	**17%**	**37%**	**71%**	**70%**	**63%**	**60%**	**17%**	**-20%**	**44%**

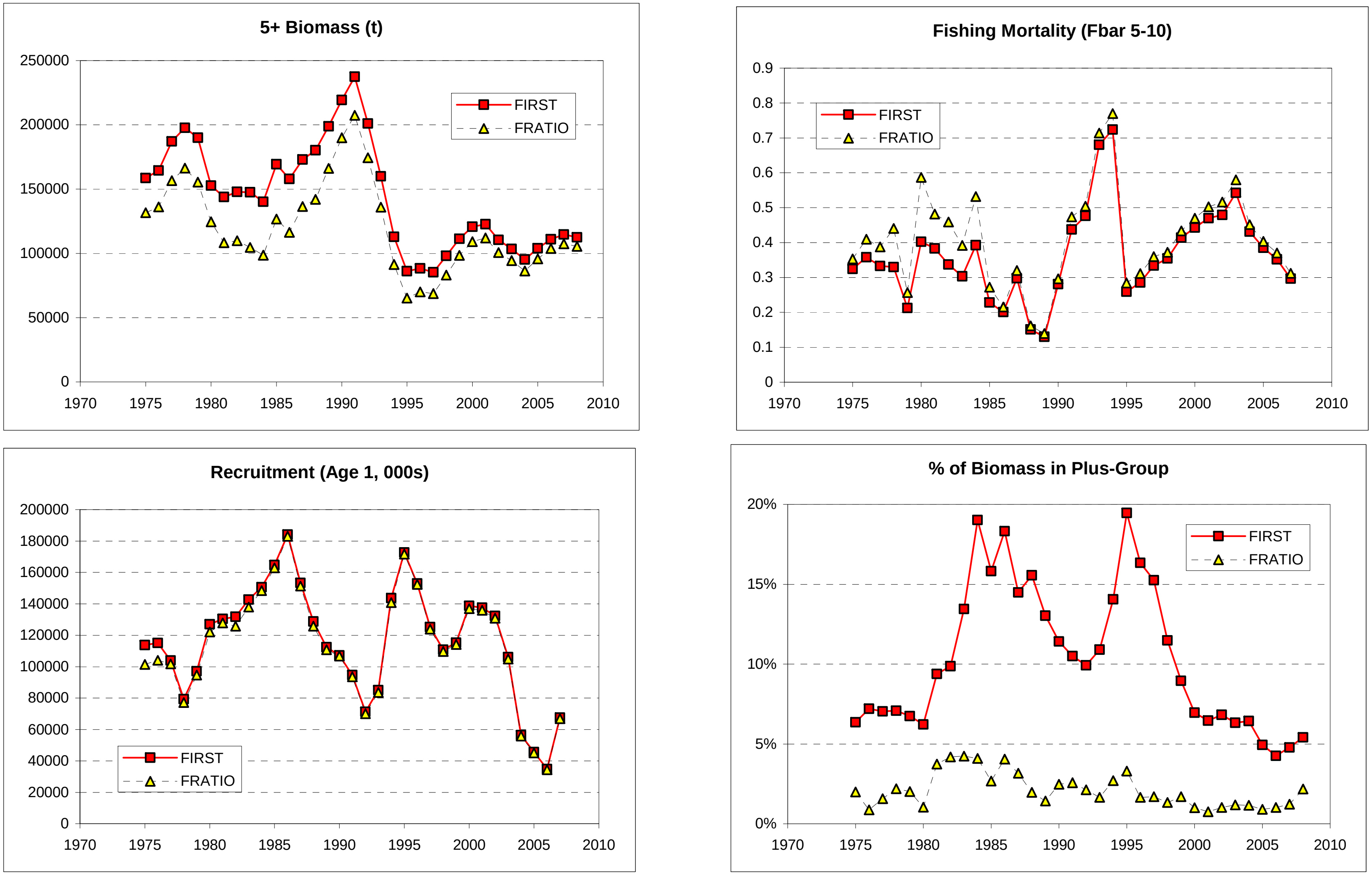

Figure 1. Comparison of ADAPT results using the FIRST and FRATIO plus-group options.

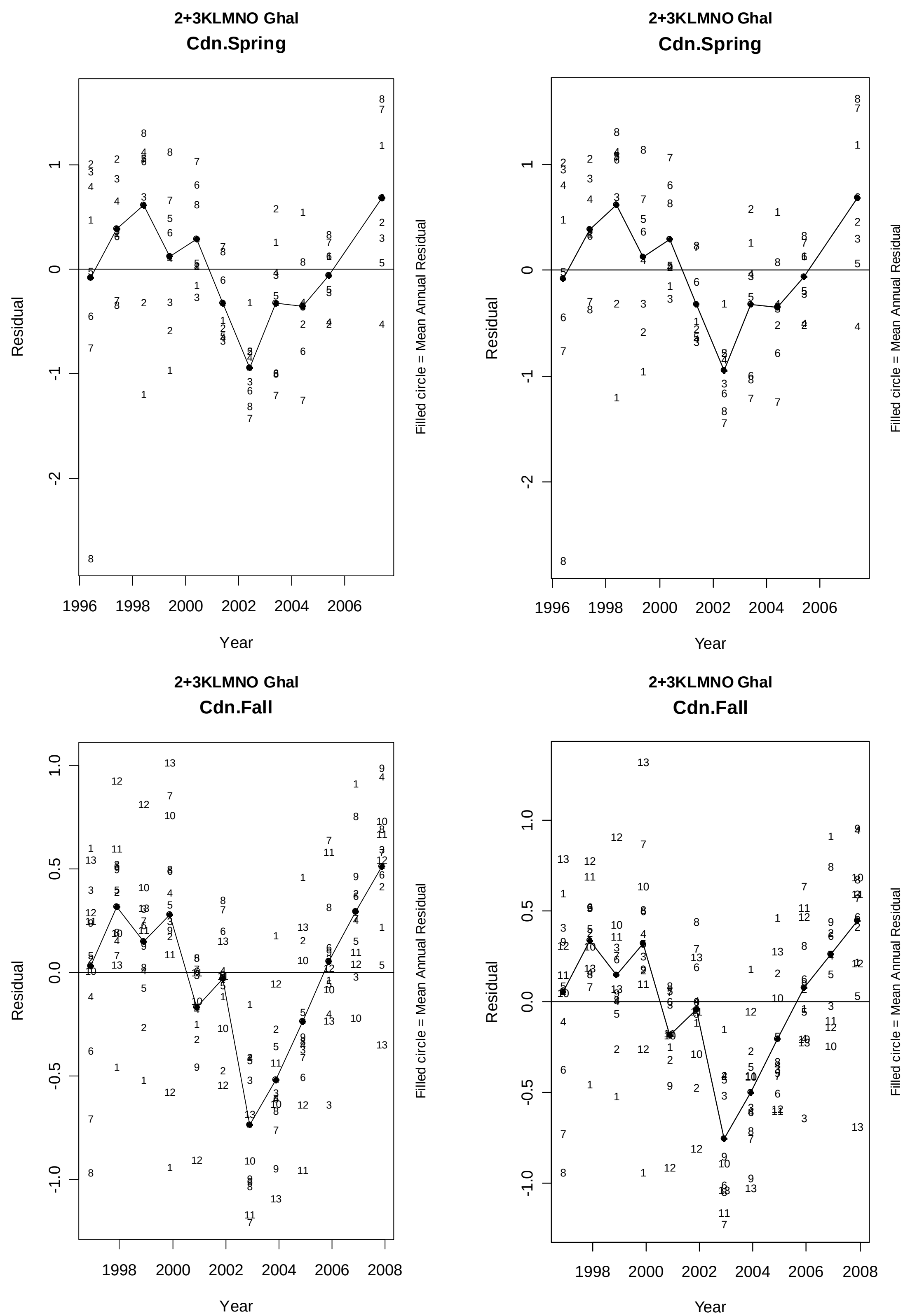

Figure 2. Comparison of residuals from ADAPT analyses using the FIRST (left column) and FRATIO (right column) plus-group options.

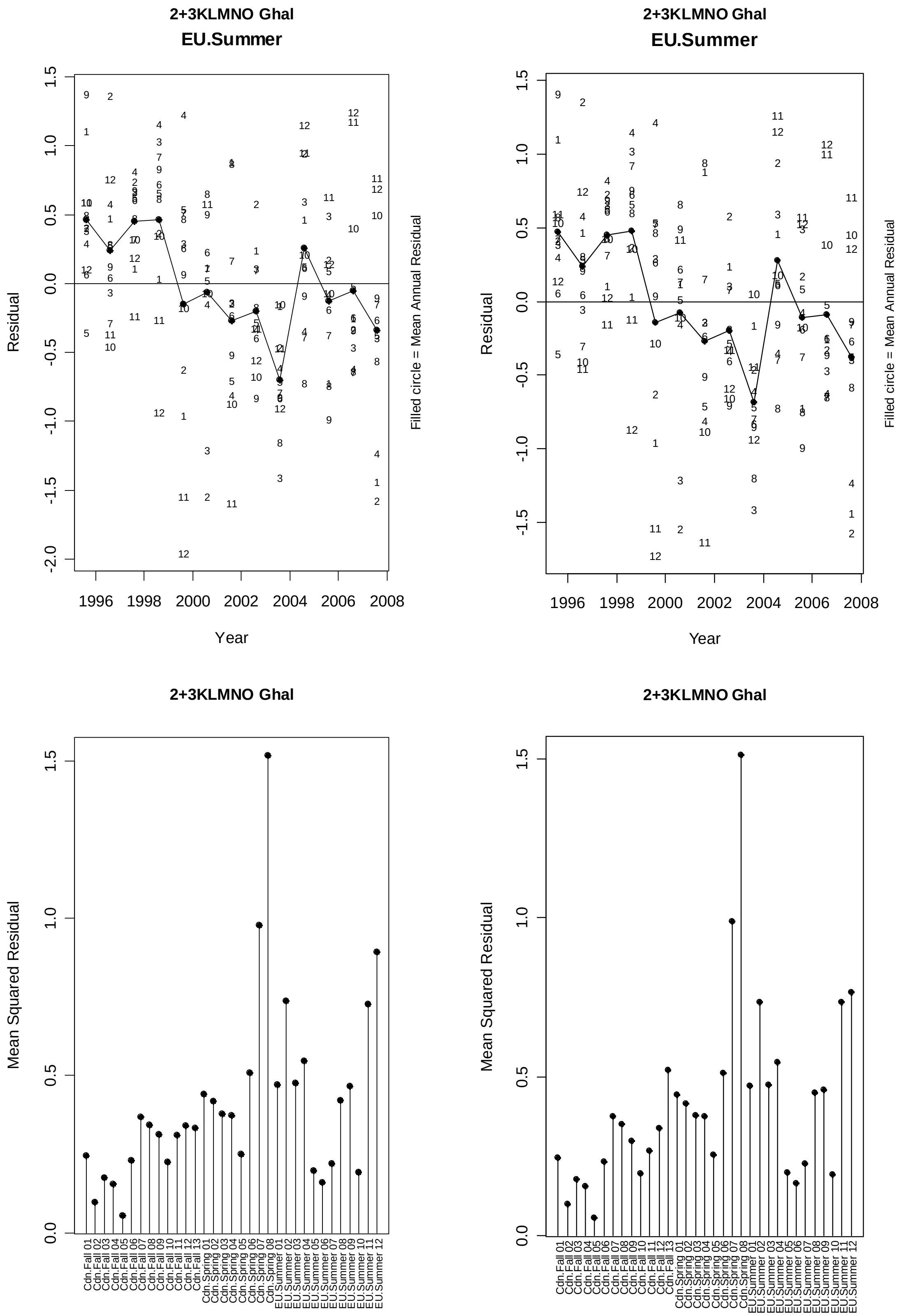

Figure 2 (cont.). Comparison of residuals from ADAPT analyses using the FIRST (left column) and FRATIO (right column) plus-group options.

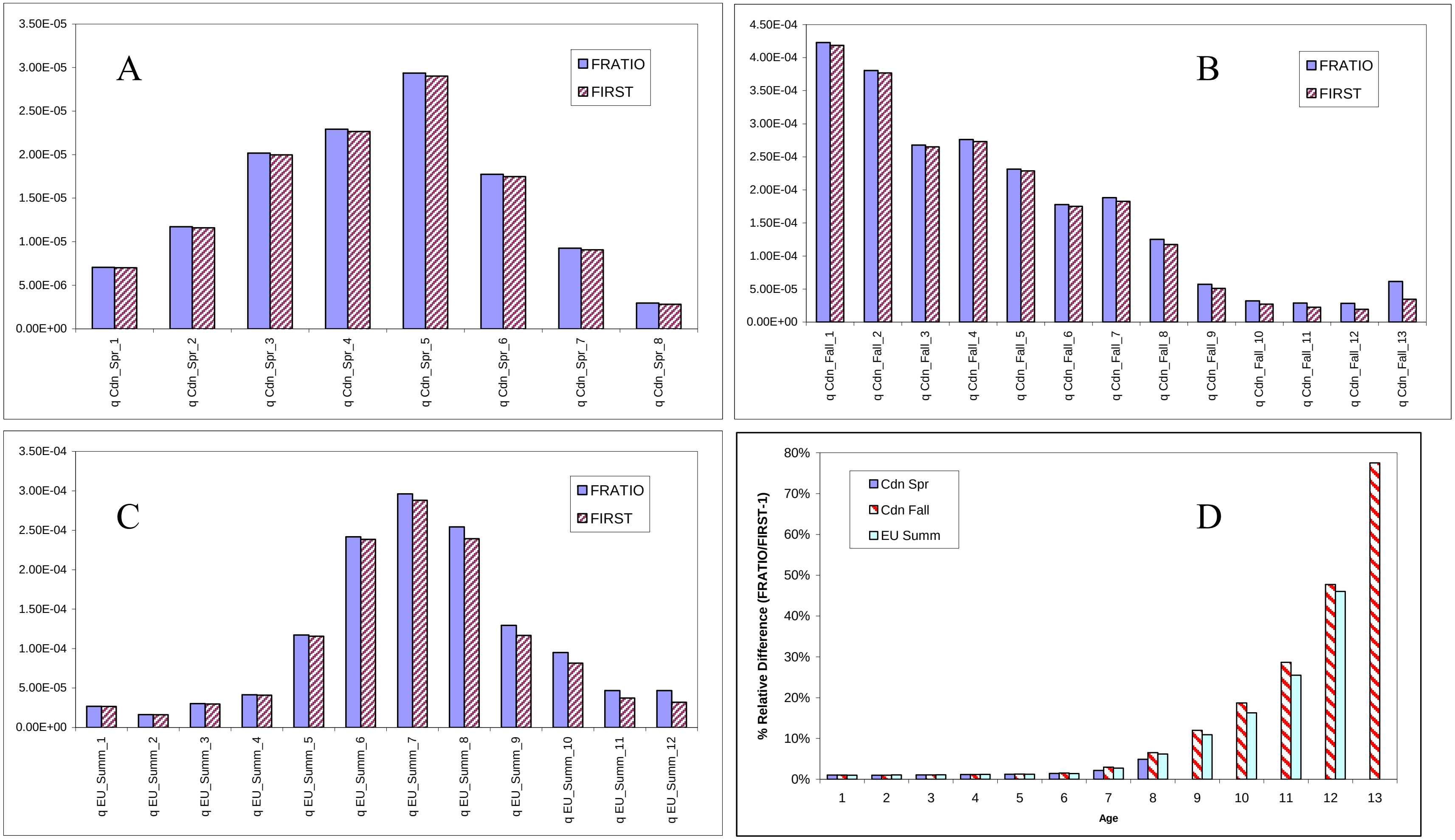

Figure 3. Comparison of catchability parameters from ADAPT analyses using the FIRST and FRATIO plus-group options. Panels A, B & C illustrate estimated catchability parameters from each analysis; panel D illustrates the percent relative difference in these estimates.

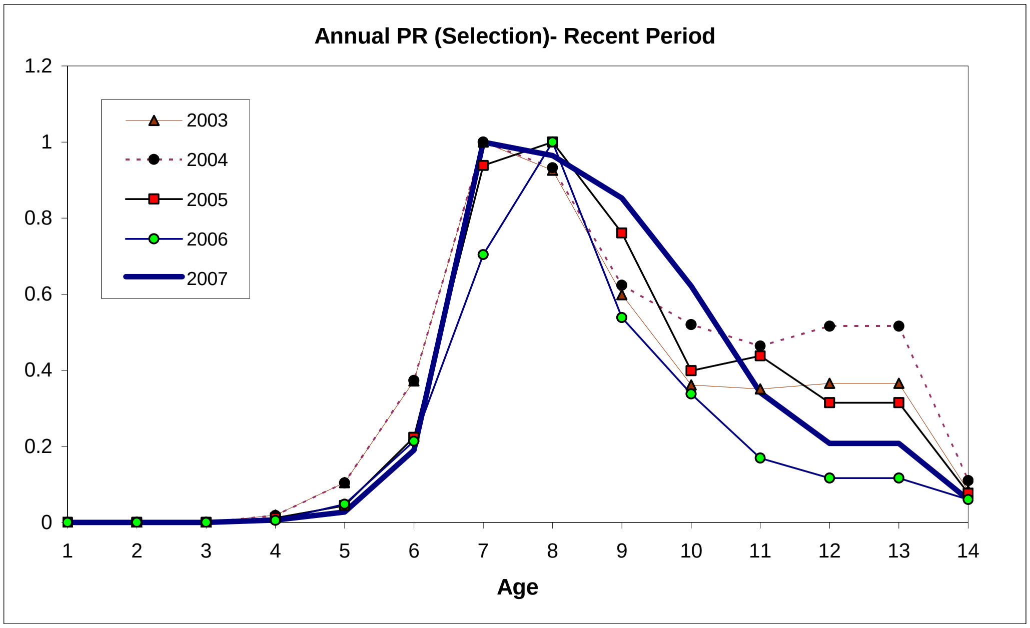

Figure 4a. Estimated selection over 2003-2007 from ADAPT analysis using the FIRST plus-group method.

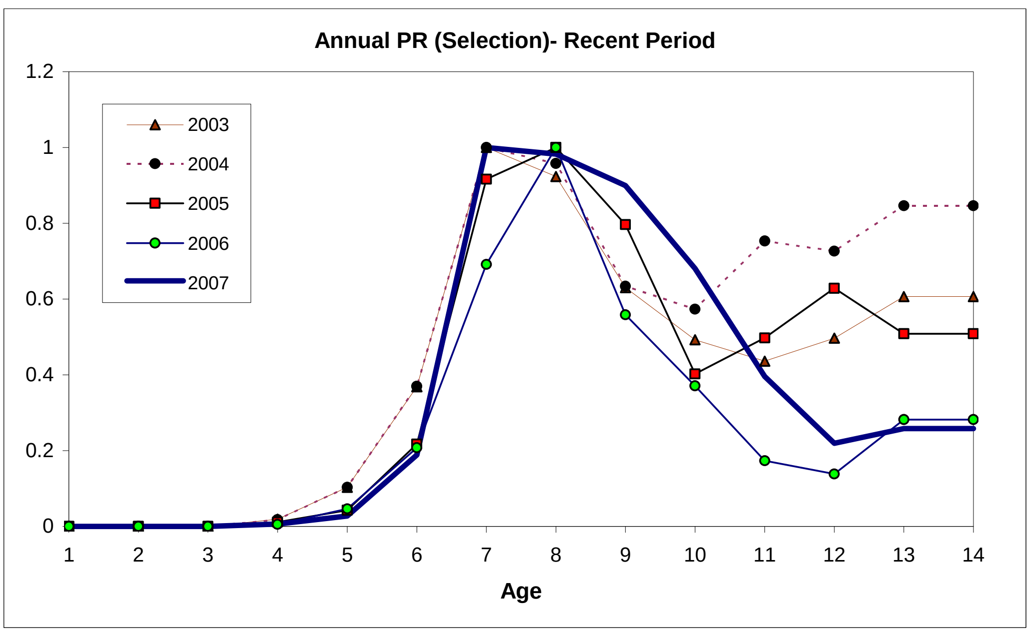

Figure 4b. Estimated selection over 2003-2007 from ADAPT analysis using the FRATIO plus-group method.

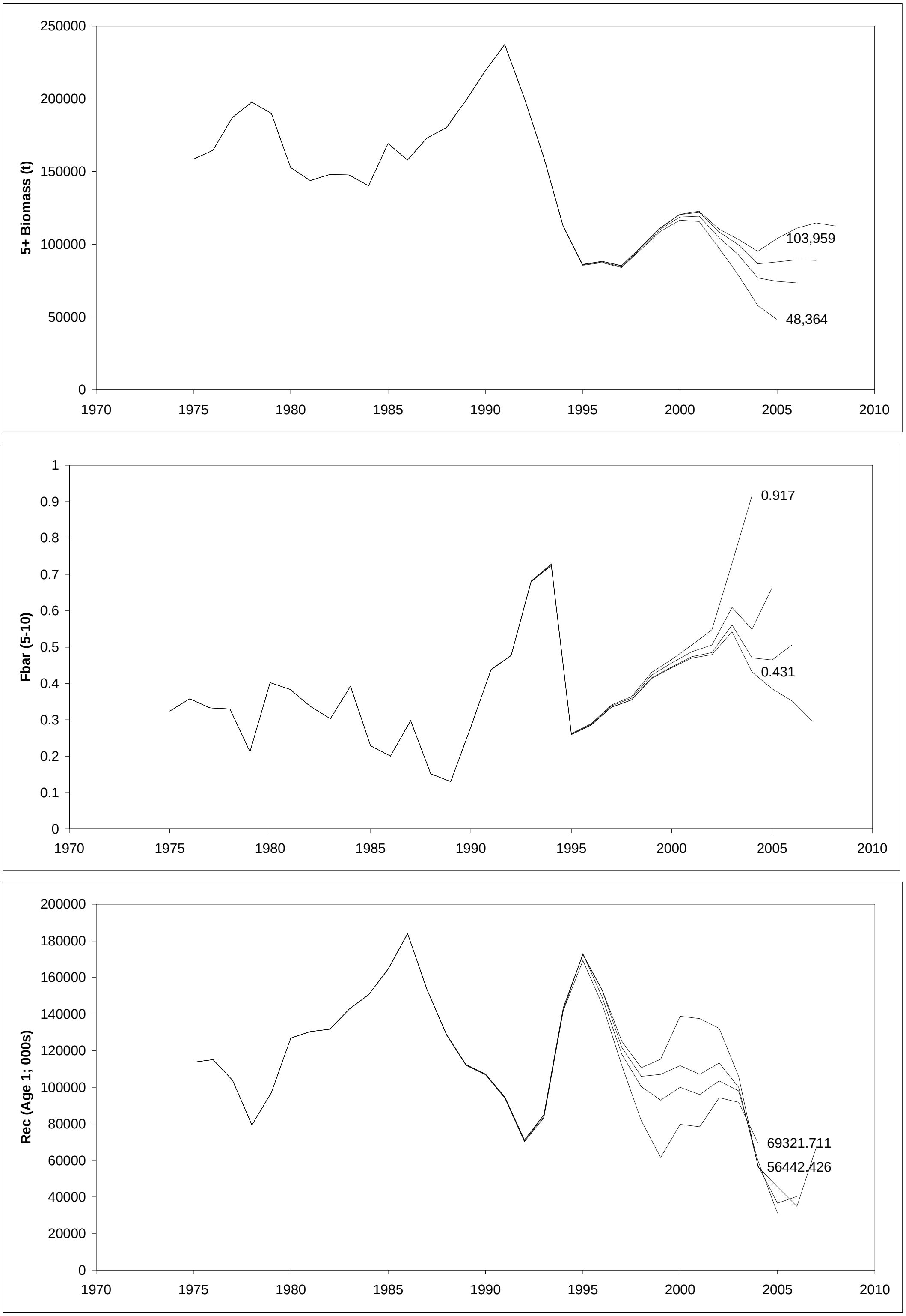

Figure 5. Three-year retrospective estimates of exploitable biomass, average fishing mortality and recruitment using the FIRST plus-group option. Text labels indicate the 2005 estimates of biomass and recruitment (2004 for average fishing mortality) from the "full assessment" and the earliest of the retrospective analyses.

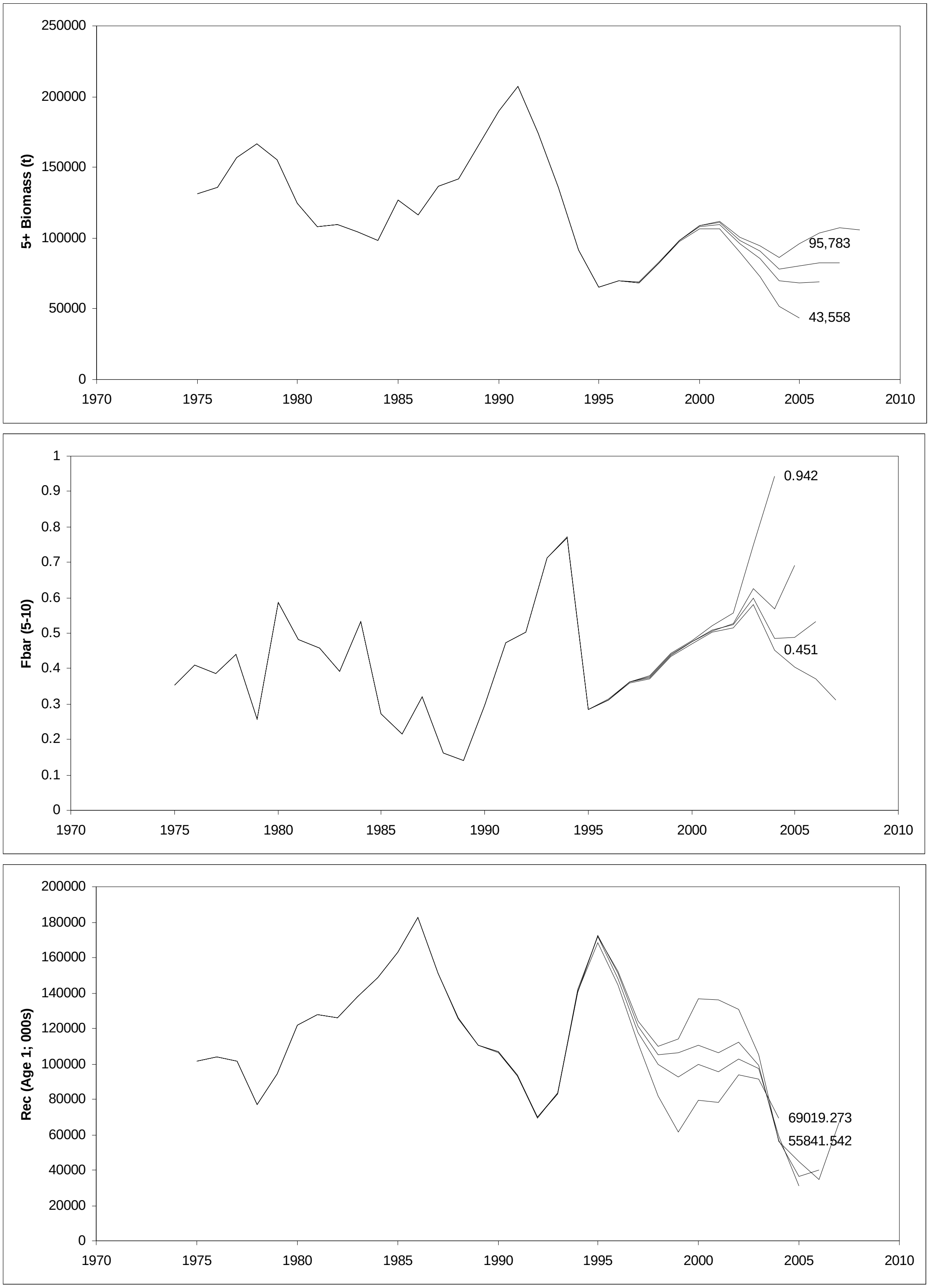

Figure 6. Three-year retrospective estimates of exploitable biomass, average fishing mortality and recruitment using the FRATIO plus-group option. Text labels indicate the 2005 estimates of biomass and recruitment (2004 for average fishing mortality) from the "full assessment" and the earliest of the retrospective analyses.

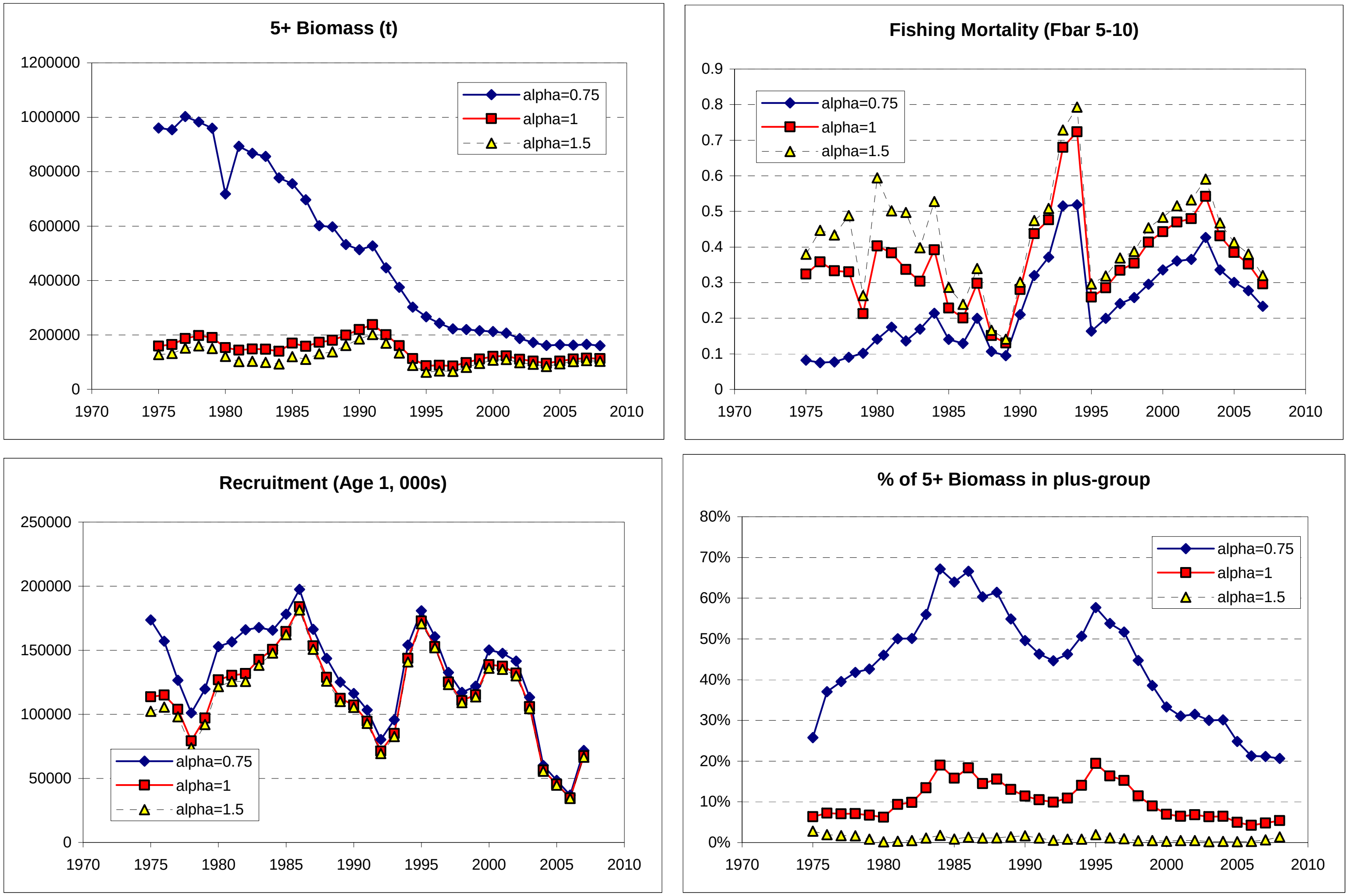

Figure 7. Comparison of ADAPT results for three values of the F-constraint multiplier assumed when using the FIRST plus-group option (refer to text for detail).

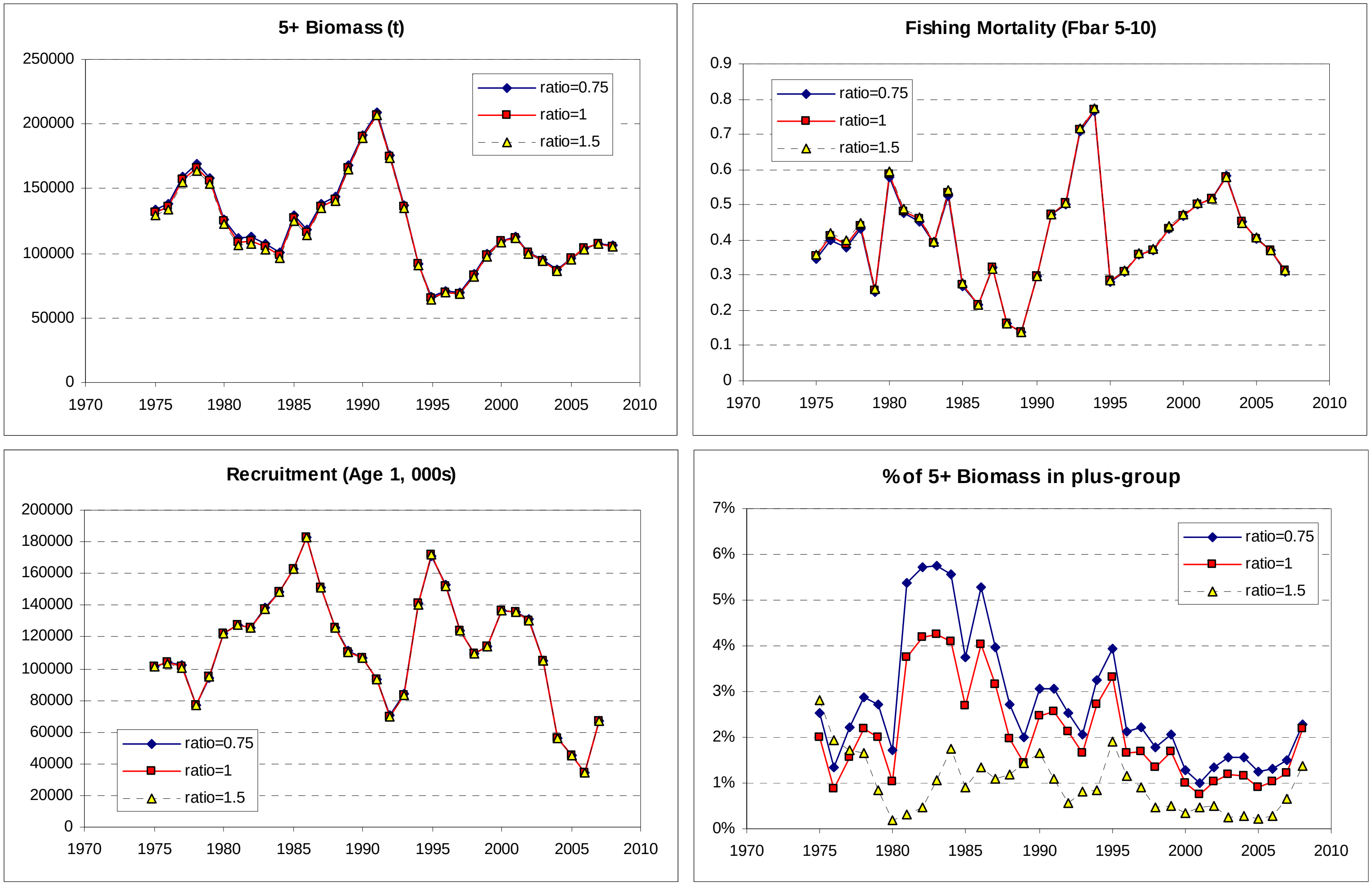

Figure 8. Comparison of ADAPT results for three values of the F-constraint multiplier assumed when using the FRATIO plus-group option (refer to text for detail).