Preliminary Statistical Catch-at-Age Assessments of Georges Bank/Gulf of Maine White Hake

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Summary

The Statistical Catch-at-Age assessments of the Georges Bank/Gulf of Maine white hake stock from GARM III are updated to include revised data, which also now extend for a further four years. With no change in methodology, an assessment based on these data results in lower spawning biomasses in absolute terms, likely in the main as a result of estimating a lesser doming effect in the commercial selectivity-at-age. As these data used are not yet fully finalised, only a preliminary investigation into refining the assessment methodology is carried out, where this involves development of a provisional new Reference case, computation of biological reference point values, and conducting a number of sensitivity tests. The aim is to advise and assist the final assessment process, and some further tests for running given finalised data are also suggested. The primary assessments run thus far suggest that the stock is currently not overfished and that overfishing is not occurring.

Introduction

This paper provides a preliminary update of the assessment of the Georges Bank/Gulf of Maine white hake stock – "preliminary" in the sense that the dataset used is not yet finalized, but is as was available about a week before the January 2013 NEFSC assessment meeting. This dataset is termed "new data" hereunder. The paper first builds a bridge from the GARM III assessment of Butterworth *et al*. (2008) to one based on these new data, which have been revised from those used previously and now extend to 2011 rather than to 2007. In this bridge-building exercise, the assessment methodology is unchanged from that used in GARM III.

The paper then proceeds to modify this "2011 – new data" assessment in a number of ways to provide a provisional new Reference Case assessment (RCp), and conducts a number of sensitivities to this assessment as well as computing various biological reference points. The results are not intended as final, but rather as one basis to guide specifications and selections of further runs to be conducted during the assessment meeting once the data have been finalized.

Data and Methodology

The algebraic details of the methods used for the SCAA assessments and BRP estimation are set out in Appendix A1. The data used for the assessments reported in this paper are as kindly provided by Katherine Sosebee (NEFSC) for the period 1963-2011 (except for catches commencing in 1950) and given in Appendix A2.

Appendix A3 provides a detailed description of and results for the bridge building exercise mentioned in the Introduction.

The following changes have been made from "2011 - new data" assessment with which the bridge-building exercise culminates to provide the provisional new (pending further data updates) Reference Case assessment “RCp”:

1. Baranov catch equation instead of Pope's approximation.
2. Survey season: spring and autumn instead of begin and mid-year (equation A1.9).
3. Survey variance: use input CV's and estimate additional variance (equation A1.16), instead of estimate year-independent variance.
4. ϕ estimated instead of fixed at 0.2.
5. μ_{spawn}=0.25 instead of 0.1667 (equation A1.6).
6. Use age-dependent σ_a for CAA (equations A1.18 and A1.21).
7. Flat commercial selectivity from age 6.
8. Commercial selectivity blocks (1963-1997, 1998-2011).

The first six of these changes are either necessitated by changes to or more accurate representation of input information, together with advances made since GARM III in the assessment methodology applied to other stocks in the region such as Gulf of Maine cod (see e.g. Butterworth and Rademeyer 2012). The necessity for change 6 in the case of white hake was confirmed through the use of AIC. Changes 7 and 8 eventuated from specific analyses for the preliminary white hake data. Regarding 7, freeing the parameter concerned resulted in only a very weak dome in the commercial selectivity vector, and little improvement of the likelihood or changes in key results compared to keeping selectivity flat at larger ages, so it was set to be flat for RCp. Inspection of proportions-at-age residuals suggested a systematic pattern change for the commercial catch proportions-at-age in the mid-1990s. Katherine Sosebee suggested two specific possibilities for the time of this change based on other information; a change from 1997 to 1998 was selected for distinguishing two commercial selectivity blocks based on a better AIC (where this criterion also clearly justified the split from the previous single block).

The list of sensitivities to RCp that are presented in this paper is given in Table 1.

Results

Table 2 lists estimates of primary parameters and management-related quantities for Georges' Bank/Gulf of Maine white hake for RCp and a series of sensitivities. Estimates of BRPs and current stock status estimates are summarized in Table 3.

Fig. 1 gives results for the RCp, while Fig. 2 plots its fit to survey and commercial data. Fig. 3 compares spawning biomass and recruitment trajectories for RCp and the different sensitivities. Fig. 4 compares the stock-recruitment curves for RCp (Ricker), sensitivity 2a (Beverton-Holt) and sensitivity 2b (modified Ricker, with γ estimated). The commercial and survey selectivities for RCp and the sensitivities related to selectivities (4a/b/c/d) are plotted in Fig. 5. Bubble plots of CAA residuals are compared for RCp, 4a (flat survey selectivity), 6a (sqrt(p)) and 6b (sqrt(p), flat survey selectivity). The fits to the survey and commercial CAA and CAL data for sensitivity 8c, for which CAA from pooled ALKs are excluded and replaced by CAL, are shown in Fig. 6. The fits to the survey biomass indices for sensitivity 9a, in which the *Albatross/Bigelow* calibration factor is estimated, are plotted in Fig. 7.

Discussion

The major feature of the bridge-building analyses of Appendix A3 is that the spawning biomasses estimated for the “2011 – new data” assessment are lower in absolute terms than their GARM III counterparts, with corresponding increases in estimates of fishing mortality and decreases in estimates of recruitment. This feature seems to arise primarily from the doming of the commercial selectivity now being estimated to be rather less than at the time of GARM III. The data changes having the most impact on the results are the modifications to the annual catches, followed by introducing catch-at-age information for further years through use of an arage ALK for years for which age data are not yet available.

As methodological updates applied to extend beyond the “2011 - new data” assessment of the bridge-building exercise reflect a preliminary exercise because of their use of unfinalised data, the associated discussion is limited to listing a few key observations from the results briefly.

1) The fits to the data do not suggest M values greater than 0.2. (Sensitivity 1)
2) The Ricker stock-recruitment form is favoured over Beverton-Holt, with the data suggesting a sharper peak than the standard Ricker form, though the evidence for preference in terms of improvements to the likelihood is not strong. (Sensitivity 2)
3) Fitting to aggregate abundance indices in terms of numbers, rather than biomass, results in higher current and pristine spawning biomass estimates, but current stock status relative to the MSY spawning biomass level is not greatly affected. If only the spring NEFSC survey data are used, this status is improved, with the reverse result if only the autumn survey data are used. (Sensitivity 3)
4) Investigation of alternative assumptions for selectivity functions show strong AIC support for a difference in the slopes of commercial and survey selectivities-at-age above age 6, with a preference for a near-flat commercial selectivity and strongly domed survey selectivities. The alternative sqrt(p) formulation for the distribution of the proportions-at-age residuals finds this same result, and suggests slightly improved current resource status relative to the MSY spawning biomass level than does the adjusted log-normal of RCp. Shifting the pre-1982 commercial selectivity towards a relatively larger catch of smaller hake has little impact on results. (Sensitivities 4 and 6)
5) When starting the assessment in 1963, the parameter which determines the initial age structure is poorly estimated, but this doesn’t impact seriously on the estimates of biological reference points in terms of precision, with starting in 1950 instead also making little difference (note results falling well within CIs for the 1963 start in early years in Fig. 3a). In contrast, for a start in 1982, although ϕ becomes estimable with reasonable precision, the stock-recruitment relationship cannot be reasonably estimated. (Sensitivity 5)
6) Removable of an internally estimated stock-recruitment relationship results, through differences in the related shrinkage of recent estimates of recruitment, in lower estimates of current abundance. (Sensitivity 7)
7) Without inclusion of catch proportions-at-age data for years without direct ageing through use of an average ALK, the precision of the estimates of many quantities deteriorates substantially. However fitting to catch-at-length data for those years provides near unchanged results in terms of both these values and their precision. (Sensitivity 8).
8) Refining the *Bigelow-Albatross* calibration factor within the assessment leads to a slightly improved estimate of current stock status. The estimate of this factor decreases from 2.235 to 2.096, with an improvement in the associated standard error from 0.173 to 0.155. (Sensitivity 9)
9) The RCp assessment and a number of key sensitivities all suggest that at present the stock is not overfished and that overfishing is not occurring. Estimates of current status and of catches under 0.75 F_{MSY} are rather more optimistic when based on fitted stock-recruitment curves than on F40% MSY proxies. For the latter, starting the assessment in 1963 yields slightly more positive results than starting it in 1982. (Table 3)

Further work

The assessment will be taken further given finalized data. In addition to the sensitivities examined above, other aspects that might then be examined include:

a) A retrospective analysis.
b) Forcing the survey bias factor (q) for the autumn survey (close to 2 for most of the results reported in this paper) to a value closer to 1.

c) When starting the assessment in 1982, estimating more elements of the starting numbers-at-age vector.
d) Considering inclusion of information from other surveys in the data fitted.
e) The sensitivity of results to the precision of estimates of annual catches has been examined, particularly through assigning fairly large CVs to catches from earlier years; this suggests that this uncertainty does not compromise the precision of estimates of BRPs from assessments over longer periods such as those that start in 1963. However, possible bias implications should also be tested by considering alternative assumptions for time trends in factors such as allowances for discards.
f) Extending the model age structure from 9+ to 10+ to be able to utilize weight-at-age information now available to age 10+ (though it would seem questionable whether the extra work required to effect this would be warranted given the likely small impact on results).

References

Butterworth DS, Rademeyer RA and Sosebee KA. 2008. Georges Bank/Gulf of Maine white hake. In Northeast Fisheries Science Center. 2008. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Department of Commerce, NOAA Fisheries, Northeast Fisheries Science Center Ref Doc. 08-15; 884 p + xvii: 590-642.

Butterworth DS and Rademeyer RA. 2012. Applications of Statistical Catch-at-Age Assessment Methodology to Gulf of Maine cod, October 2012.Document presented to SAW/SARC 55 Working Group on Gulf of Maine and Georges Bank cod Modeling Meeting, 15-19 October, 2012. 40pp.

Table 1: List of the sensitivities run. After each sub-heading, the RCp specifications are given in parenthesis.

1. Natural mortality (RCp: M=0.2)	
1a	M=0.4
1b	M incr: M increasing linearly from 0.2 at age 5 to 0.4 at age 9
2. Stock-recruitment curve (RCp: Ricker)	
2a	BH: Beverton-Holt stock-recruitment curve
2b	γ estimated: from the modified Ricker, eqn A1.4
3. Survey data (RCp: Fit to biomass, both surveys)	
3a	Fit to Numbers: for the survey indices
3b	Fit to Spring survey only: for both the index and CAA data
3c	Fit to Autumn survey only: for both the index and CAA data
4. Selectivities (RCp: flat comm from age 6, domed survey)	
4a	Flat survey selectivity: from age 6
4b	Pre-1982 comm sel shifted: shifted one year to the left
4c	Flat survey sel, domed comm sel: flat from age 6 for surveys, free for commercial
4d	Domed survey and comm sel
5. Start year (RCp: start in 1963)	
5a	Start in 1982
5b	Start in 1950
6. CAA error formulation (RCp: adjusted log-normal)	
6a	sqrt(p)
6b	sqrt(p), flat survey selectivity
7. No internal stock-recruitment (RCp: internal stock-recruit)	
7a	no SR
7b	no SR, start 1982
8. Excluding CAA from pooled ALK (RCp: include CAA from pooled ALK)	
8a	Surv CAL for yrs with pooled ALK
8b	Surv and comm CAL for yrs with pooled ALK
8c	Exclude CAA from pooled ALK: not fitting to any CAL
9. Calibration refinement (RCp: calibration refinement not included)	
9a	Bigelow calibration: $\Delta \ln q$ estimated (equation A1.33)

Table 2a: Results for RCp and some sensitivities. Mass units are '000 tons.

	RCp		1a		1b		2a		2b		3a		3b		3c	
			M =0.4		M incr		BH		γ estimated		Fit to Numbers		Fit to Spring survey only		Fit to Autumn survey only	
'-lnL:overall	-368.3		-365.3		-367.7		-367.1		-369.0		-362.0		-151.5		-280.9	
'-lnL:Survey	-34.3		-26.2		-28.5		-34.6		-34.2		-30.7		-6.9		-30.5	
'-lnL:CAAcom	-42.6		-46.4		-45.2		-42.6		-42.6		-43.4		-47.3		-48.5	
'-lnL:CAAsurv	-301.6		-301.6		-303.3		-301.3		-301.4		-300.4		-105.8		-214.1	
'-lnL:CALcom	-		-		-		-		-		-		-		-	
'-lnL:Catch	1.1		1.5		1.3		1.2		1.1		1.6		0.9		1.3	
'-lnL:CALsurv	-		-		-		-		-		-		-		-	
'-lnL:RecRes	9.0		7.4		7.9		10.2		8.1		10.9		7.7		10.8	
-lnL:calibration	-		-		-		-		-		-		-		-	
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
h	1.21	(0.14)	0.62	(0.15)	0.74	(0.15)	0.78	(0.09)	1.26	(0.13)	0.81	(0.14)	1.30	(0.15)	1.24	(0.15)
γ	1.00	-	1.00	-	1.00	-	1.00	-	2.11	(0.50)	1.00	-	1.00	-	1.00	-
θ	0.57	(0.29)	0.57	(0.21)	0.56	(0.19)	0.28	(0.34)	0.77	(0.17)	0.25	(0.29)	0.77	(0.19)	0.52	(0.28)
ϕ	0.01	(4.07)	0.00	(1000)	0.00	(1000)	0.02	(1.65)	0.00	(1000)	0.03	(4.07)	0.00	(1000)	0.02	(1.81)
K^{sp}	69.13	(0.14)	68.91	(0.19)	66.39	(0.17)	128.17	(0.20)	55.08	(0.17)	120.65	(0.14)	71.01	(0.14)	64.82	(0.15)
B^{sp}_{2011}	25.34	(0.17)	37.17	(0.18)	32.38	(0.18)	24.77	(0.17)	25.25	(0.18)	29.78	(0.17)	33.99	(0.23)	22.45	(0.19)
B^{sp}_{2011}/K^{sp}	0.37	(0.21)	0.54	(0.24)	0.49	(0.22)	0.19	(0.26)	0.46	(0.21)	0.25	(0.21)	0.48	(0.26)	0.35	(0.23)
B^{sp}_{MSY}	30.43	(0.10)	32.35	(0.13)	31.57	(0.12)	42.98	(0.16)	29.38	(0.13)	39.44	(0.10)	31.05	(0.11)	28.53	(0.10)
$MSYL^{sp}$	0.44	(0.11)	0.47	(0.16)	0.48	(0.13)	0.34	(0.07)	0.53	(0.24)	0.33	(0.11)	0.44	(0.12)	0.44	(0.11)
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	(0.18)	1.15	(0.18)	1.03	(0.18)	0.58	(0.23)	0.86	(0.20)	0.76	(0.18)	1.09	(0.22)	0.79	(0.19)
MSY	7.75	(0.10)	8.37	(0.13)	8.39	(0.12)	7.82	(0.15)	8.57	(0.13)	7.60	(0.10)	8.44	(0.10)	7.41	(0.10)
F_{MSY}	0.30	-	0.41	-	0.35	-	0.21	-	0.35	-	0.22	-	0.33	-	0.31	-
spring_q	1.16	(0.06)	0.54	(0.07)	0.86	(0.07)	1.16	(0.06)	1.16	(0.06)	1.06	(0.06)	1.10	(0.06)	-	
autumn_q	1.96	(0.05)	0.97	(0.07)	1.42	(0.07)	1.97	(0.05)	1.97	(0.05)	1.71	(0.05)	-		2.04	(0.05)
spring_σ_{Add}	0.16	(0.32)	0.17	(0.32)	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.13	(0.31)	0.20	(0.29)	-	
autumn_σ_{Add}	0.06	(0.48)	0.10	(0.40)	0.09	(0.41)	0.05	(0.49)	0.05	(0.49)	0.14	(0.30)	-		0.07	(0.33)

Table 2b: Results for RCp and some sensitivities. Mass units are '000 tons.

	RCp		4a		4b		4c		4d		5a		5b	
			Flat survey selectivity		Pre-1982 comm sel shifted		Flat survey sel, domed comm sel		Domed survey and comm sel		start in 1982		start in 1950	
'-lnL:overall	-368.3		-341.1		-366.6		-355.4		-369.6		-191.8		-369.6	
'-lnL:Survey	-34.3		-37.2		-33.9		-37.7		-29.8		-22.7		-33.9	
'-lnL:CAAcom	-42.6		-33.8		-42.7		-40.4		-47.2		-45.5		-42.2	
'-lnL:CAAsurv	-301.6		-287.3		-299.8		-295.7		-301.2		-131.0		-304.4	
'-lnL:CALcom	-		-		-		-		-		-		-	
'-lnL:Catch	1.1		5.9		1.0		6.2		1.4		1.3		1.1	
'-lnL:CALsurv	-		-		-		-		-		-		-	
'-lnL:RecRes	9.0		11.4		8.7		12.1		7.3		6.0		9.9	
-lnL:calibration	-		-		-		-		-		-		-	
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
h	1.21	(0.14)	1.47	(0.17)	1.19	(0.14)	1.44	(0.16)	0.98	(0.19)	0.86	(0.26)	1.25	(0.14)
γ	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
θ	0.57	(0.29)	0.19	(0.36)	0.57	(0.27)	0.22	(0.34)	0.61	(0.16)	0.04	(8.32)	0.45	(1.17)
ϕ	0.01	(4.07)	0.26	(0.19)	0.01	(2.94)	0.50	(0.32)	0.00	(1000)	0.25	(0.18)	0.53	(0.99)
K^{sp}	69.13	(0.14)	63.19	(0.31)	73.12	(0.14)	58.73	(0.28)	97.24	(0.24)	730.11	(8.27)	66.82	(0.12)
B^{sp}_{2011}	25.34	(0.17)	16.06	(0.18)	26.01	(0.17)	15.47	(0.17)	33.67	(0.23)	22.18	(0.20)	25.74	(0.17)
B^{sp}_{2011}/K^{sp}	0.37	(0.21)	0.25	(0.37)	0.36	(0.21)	0.26	(0.34)	0.35	(0.21)	0.03	(8.30)	0.39	(0.18)
B^{sp}_{MSY}	30.43	(0.10)	27.46	(0.23)	32.26	(0.10)	27.28	(0.25)	42.79	(0.18)	333.38	(8.07)	29.33	(0.10)
$MSYL^{sp}$	0.44	(0.11)	0.43	(0.11)	0.44	(0.10)	0.46	(0.17)	0.44	(0.15)	0.46	(0.22)	0.44	(0.11)
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	(0.18)	0.58	(0.29)	0.81	(0.17)	0.57	(0.32)	0.79	(0.19)	0.07	(8.10)	0.88	(0.17)
MSY	7.75	(0.10)	8.40	(0.23)	8.08	(0.10)	8.13	(0.21)	8.87	(0.13)	63.64	(8.07)	7.63	(0.09)
F_{MSY}	0.30	-	0.41	-	0.29	-	0.66	-	0.29	-	0.22	-	0.30	-
spring_q	1.16	(0.06)	1.24	(0.05)	1.15	(0.06)	1.30	(0.05)	0.98	(0.12)	1.14	(0.07)	1.16	(0.06)
autumn_q	1.96	(0.05)	2.17	(0.05)	1.96	(0.05)	2.28	(0.04)	1.65	(0.12)	2.09	(0.06)	1.97	(0.05)
spring_σ_{Add}	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.17	(0.32)	0.16	(0.32)	0.14	(0.39)	0.16	(0.32)
autumn_σ_{Add}	0.06	(0.48)	0.04	(0.54)	0.06	(0.47)	0.04	(0.55)	0.09	(0.46)	0.05	(0.82)	0.06	(0.48)

Table 2c: Results for RCp and some sensitivities. Note that for 7a, the BRP are estimated externally to the assessment (see Appendix A, section A1.5). For sensitivity 9a (Bigelow calibration), the first two survey *q*'s (and associated CVs) are for the *Albatross*, followed by those for the *Bigelow*. Mass units are '000 tons.

	RCp		6a		6b		7a		7b		8a		8b		8c		9a			
			sqrt(p)		sqrt(p), flat survey selectivity		no SR		no SR, start 1982		Surv CAL for yrs with pooled ALK		Surv and comm CAL for yrs with pooled ALK		Exclude CAA from pooled ALK		Bigelow calibration			
'-lnL:overall	-368.3		-1905		-1880		-376.3		-197.4		-79.6		-64.5		-158.9		-368.6			
'-lnL:Survey	-34.3		-33.1		-36.6		-36.5		-23.6		-35.0		-35.0		-38.3		-34.8			
'-lnL:CAAcom	-42.6		-327.9		-317.1		-44.1		-46.5		-24.2		-24.8		-22.7		-42.7			
'-lnL:CAAsurv	-301.6		-1556		-1545		-298.5		-129.5		-98.6		-96.5		-108.1		-301.7			
'-lnL:CALcom	-		-		-		-		-		-		13.7		-		-			
'-lnL:Catch	1.1		1.4		4.7		1.5		1.5		1.1		1.2		1.8		1.2			
'-lnL:CALsurv	-		-		-		-		-		66.9		66.6		-		-			
'-lnL:RecRes	9.0		11.0		13.6		1.3		0.7		10.2		10.2		8.4		9.0			
-lnL:calibration	-		-		-		-		-		-		-		-		0.3			
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000			
h	1.21	(0.14)	1.39	(0.13)	1.59	(0.16)	-		-		1.27	(0.16)	1.29	(0.15)	1.05	(0.21)	1.22	(0.14)		
γ	1.00	-	1.00	-	1.00	-	-		-		1.00	-	1.00	-	1.00	-	1.00	-		
θ	0.57	(0.29)	0.59	(0.30)	0.23	(0.28)	0.50	(0.13)	-		0.60	(0.20)	0.57	(0.58)	0.11	(0.80)	0.57	(0.29)		
ϕ	0.01	(4.07)	0.02	(2.48)	0.28	(0.22)	0.02	(1.71)	0.25	(0.10)	0.00	(1000)	0.01	(11.75)	0.38	(0.93)	0.01	(3.81)		
K^{sp}	69.13	(0.14)	63.76	(0.13)	53.93	(0.22)	68.32	(0.13)	-		65.64	(0.15)	64.19	(0.15)	95.32	(0.47)	68.82	(0.14)		
B^{sp}_{2011}	25.34	(0.17)	25.47	(0.18)	16.80	(0.18)	21.31	(0.17)	19.17	(0.09)	23.03	(0.19)	22.74	(0.19)	19.63	(0.19)	25.97	(0.17)		
B^{sp}_{2011}/K^{sp}	0.37	(0.21)	0.40	(0.19)	0.31	(0.29)	0.31	(0.13)	-		0.35	(0.21)	0.35	(0.23)	0.21	(0.54)	0.38	(0.21)		
B^{sp}_{MSY}	30.43	(0.10)	27.66	(0.10)	23.24	(0.16)	29.49	(0.09)	-		28.80	(0.11)	28.14	(0.11)	42.70	(0.35)	30.28	(0.10)		
$MSYL^{sp}$	0.44	(0.11)	0.43	(0.10)	0.43	(0.10)	0.43	(0.09)	-		0.44	(0.14)	0.44	(0.12)	0.45	(0.17)	0.44	(0.11)		
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	(0.18)	0.92	(0.17)	0.72	(0.23)	0.72	(0.09)	-		0.80	(0.20)	0.81	(0.20)	0.46	(0.44)	0.86	(0.18)		
MSY	7.75	(0.10)	8.01	(0.10)	7.66	(0.15)	7.50	(0.09)	-		7.46	(0.10)	7.53	(0.10)	9.45	(0.35)	7.76	(0.10)		
F_{MSY}	0.30	-	0.36	-	0.46	-	0.30		-		0.30	-	0.32	-	0.25	-	0.24	-		
spring_q	1.16	(0.06)	1.25	(0.06)	1.35	(0.05)	1.20	(0.06)	1.18	(0.07)	1.13	(0.07)	1.13	(0.07)	1.30	(0.08)	1.17	(0.06)	2.45	(0.10)
autumn_q	1.96	(0.05)	2.06	(0.06)	2.27	(0.05)	2.05	(0.05)	2.17	(0.06)	1.93	(0.07)	1.93	(0.07)	2.13	(0.07)	2.01	(0.05)	4.21	(0.09)
spring_σ_{Add}	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.14	(0.39)	0.18	(0.08)	0.16	(0.33)	0.18	(0.32)	0.16	(0.32)		
autumn_σ_{Add}	0.06	(0.48)	0.06	(0.47)	0.04	(0.52)	0.04	(0.53)	0.03	(0.95)	0.16	(0.33)	0.05	(0.52)	0.03	(0.70)	0.05	(0.50)		

Table 3: BRPs for RCp and some sensitivities. Mass units are tons.

		RCp	2a	7a	7b
			BH	no SR	no SR, start 1982
	Start year	1963	1963	1963	1982
	SR relationship	Ricker	Beverton-Holt	None (Ricker external)	
SR BRPs	$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	0.58	0.72	
	F_{2011}/F_{MSY}	0.45	0.67	0.54	
	MSY	7.75	7.82	7.50	
	$C_{2012}(0.75F_{MSY})$	6986	4883	5786	
	overfished	No	No	No	
	overfishing	No	No	No	
F40% BRPs	$B^{sp}_{2011}/B^{sp}_{MSY}$	0.71	0.69	0.61	0.57
	F_{2011}/F_{MSY}	0.75	0.77	0.90	1.01
	MSY	5.73	5.74	5.57	5.40
	$C_{2012}(0.75F_{MSY})$	4394	4299	3650	3274
	overfished	No	No	No	No
	overfishing	No	No	No	Yes

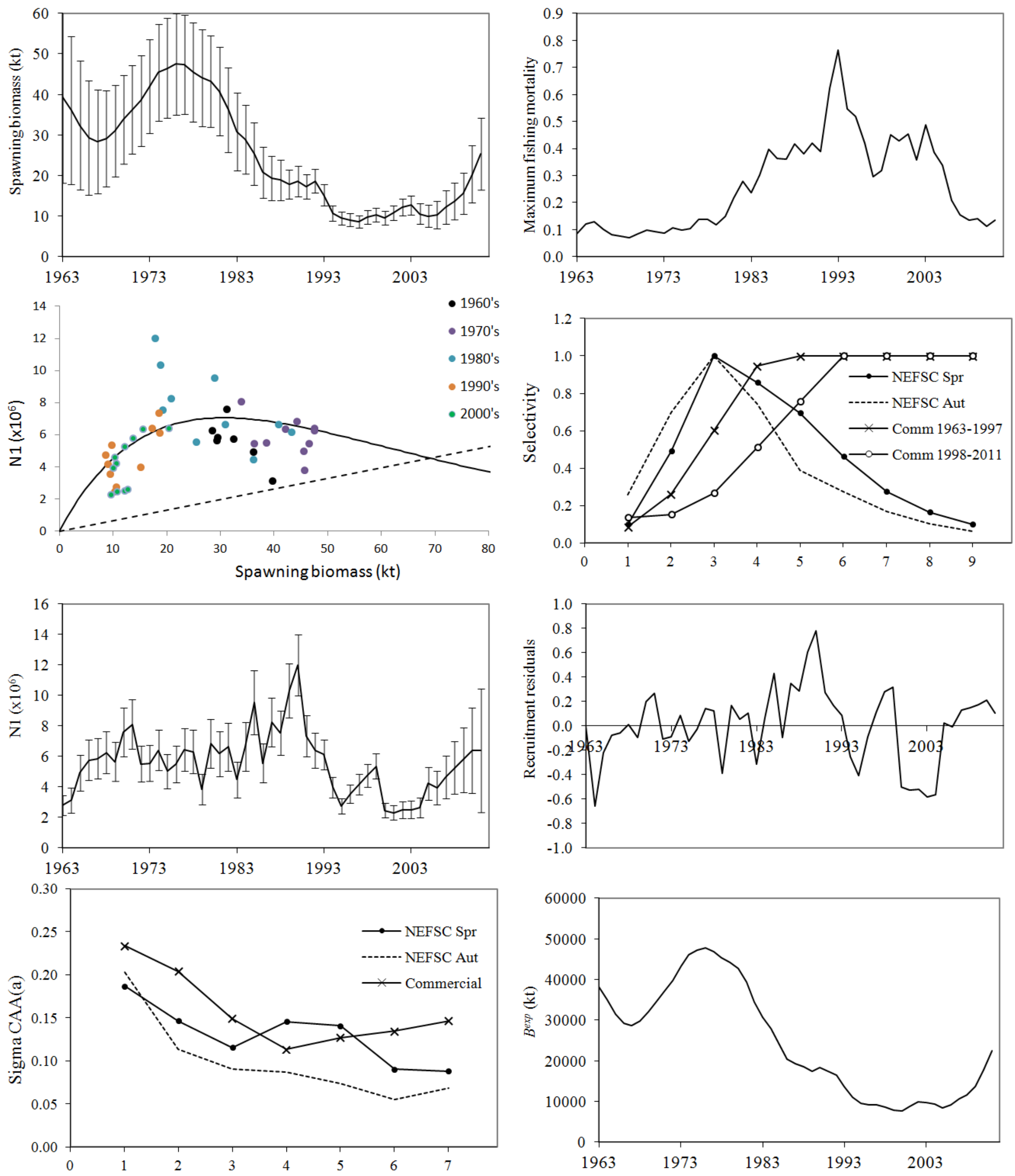

Fig. 1: Results for the RCp Georges Bank/Gulf of Maine white hake assessment.

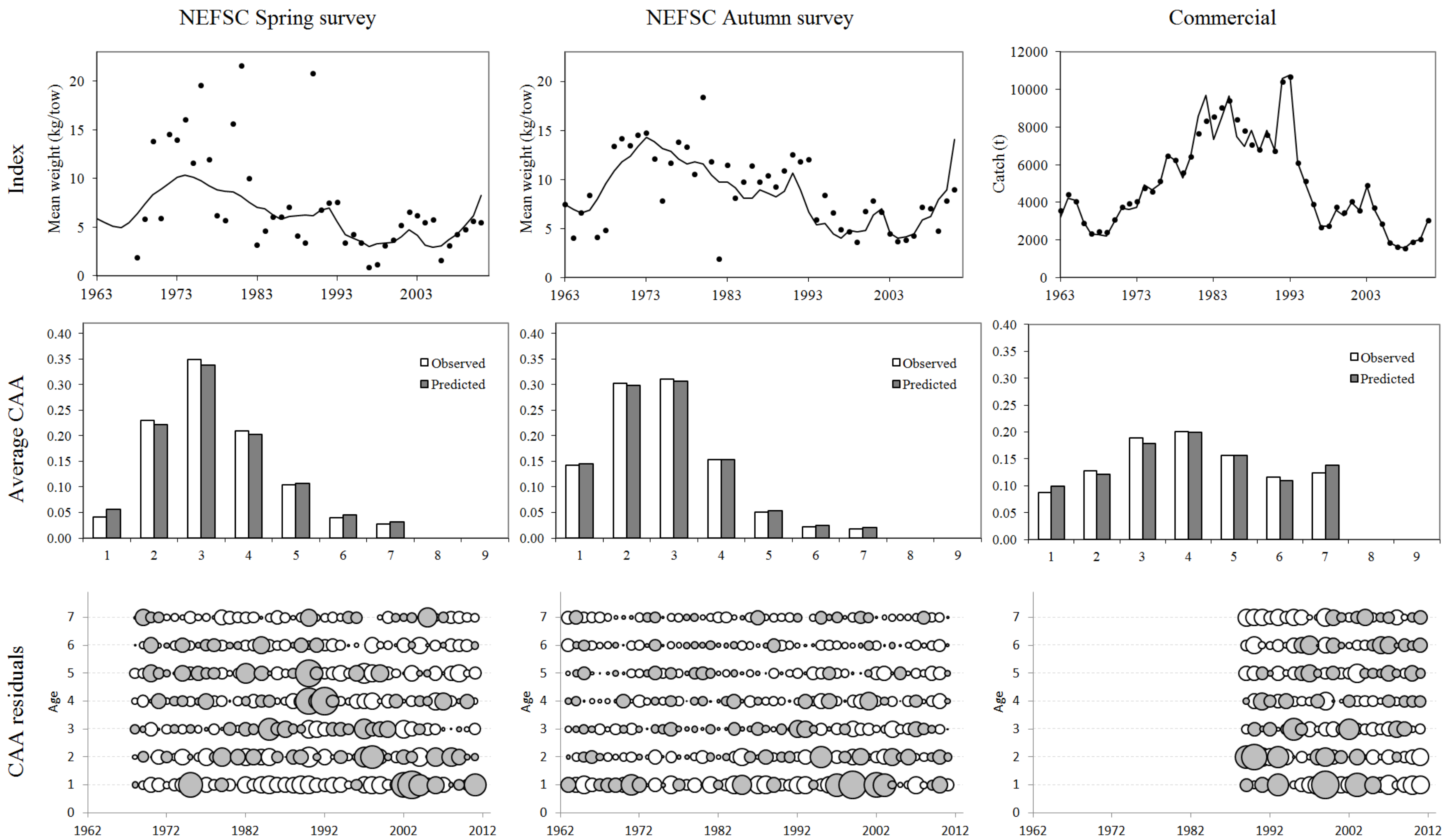

Fig. 2: Fit of RCp to the survey and commercial data

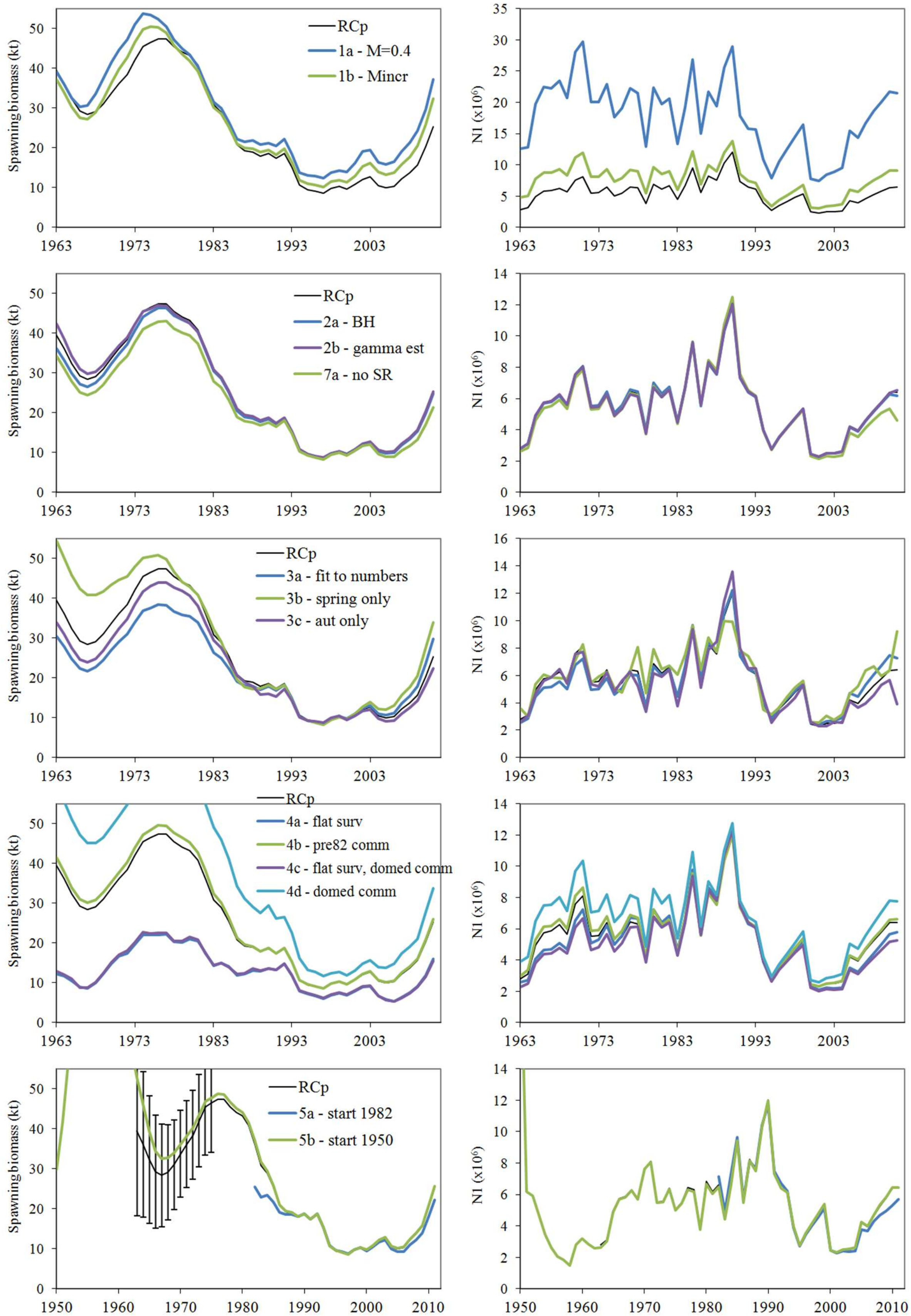

Fig. 3a: Spawning biomass and recruitment trajectories for RCp and some sensitivities. The 95% CIs shown in the bottom left plot are for RCp.

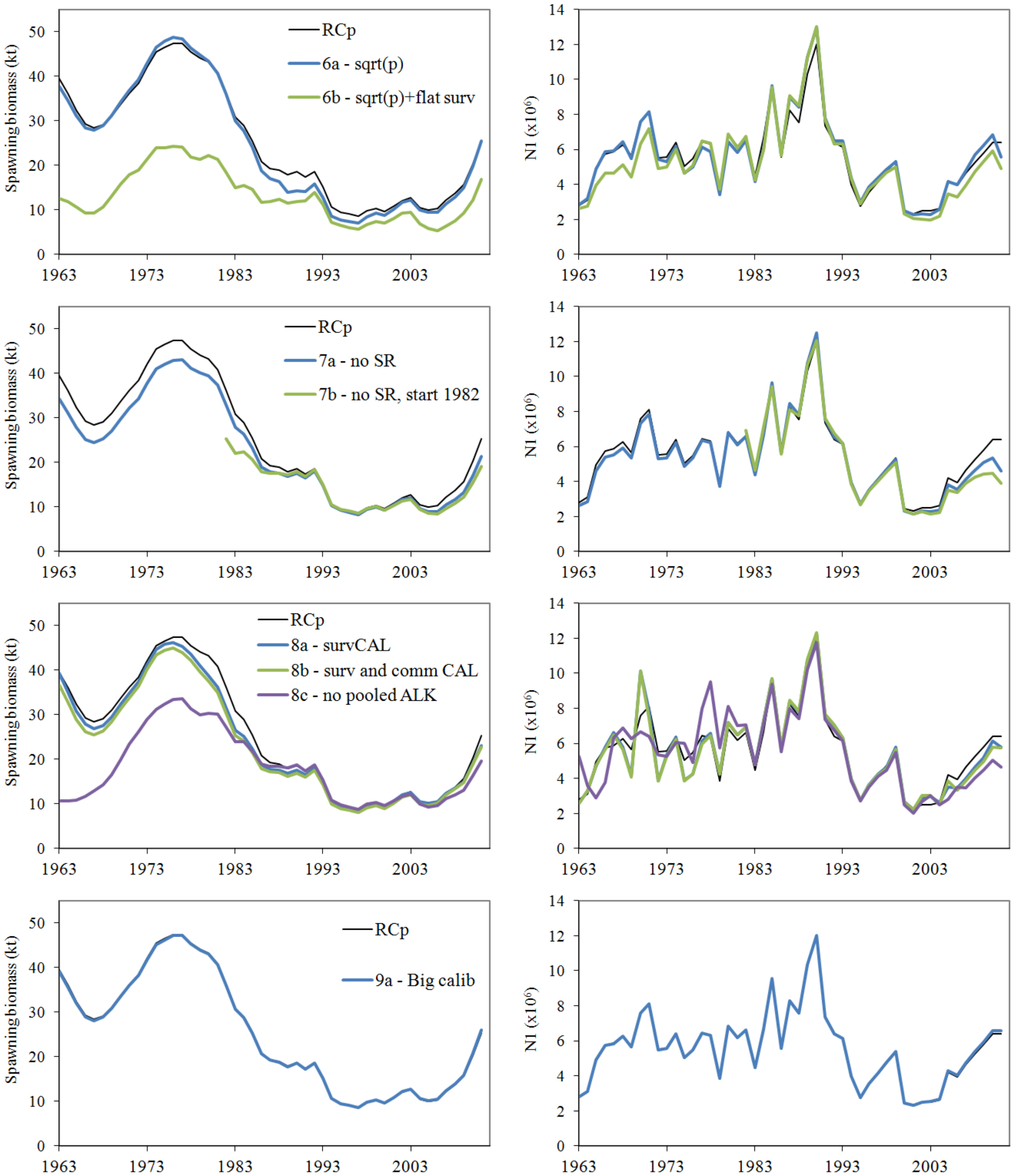

Fig. 3b: Spawning biomass and recruitment trajectories for RCp and some sensitivities.

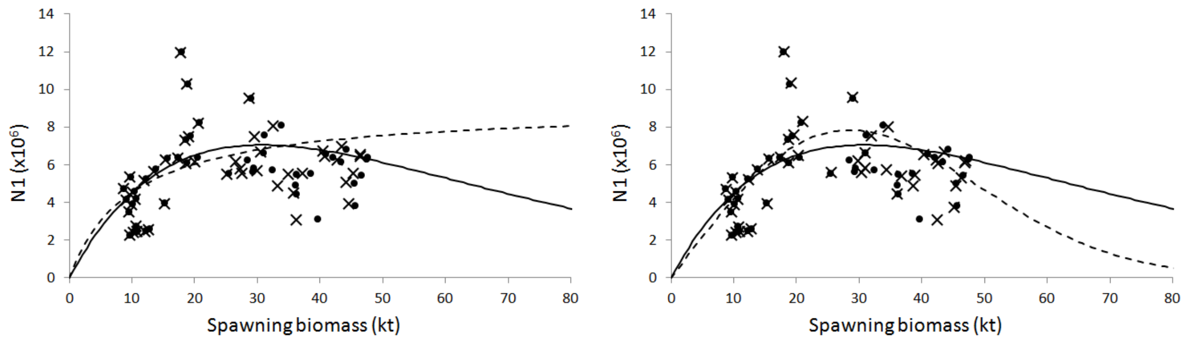

Fig. 4: Stock-recruitment curve and estimated recruitment for RCp (full line and solid dots) and 2a (Beverton-Holt) (dashed line and crosses) for the left-hand plot and 2b (γ estimated) (dashed line and crosses) for the right-hand plot. Note that that N1 values for year *y* are associated with spawning biomass values for the previous year.

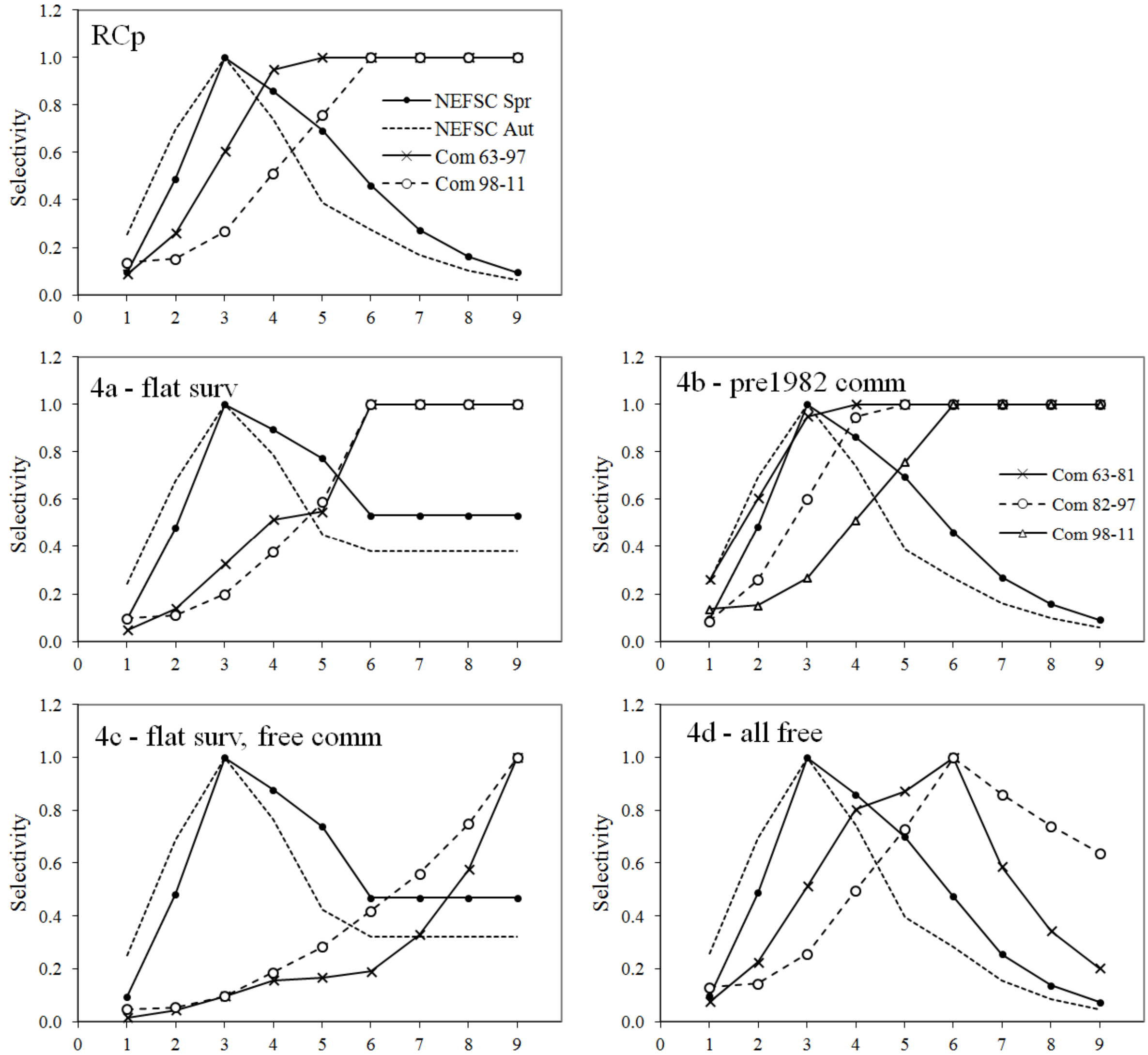

Fig. 5: Commercial and survey selectivities for RCp and some sensitivities.

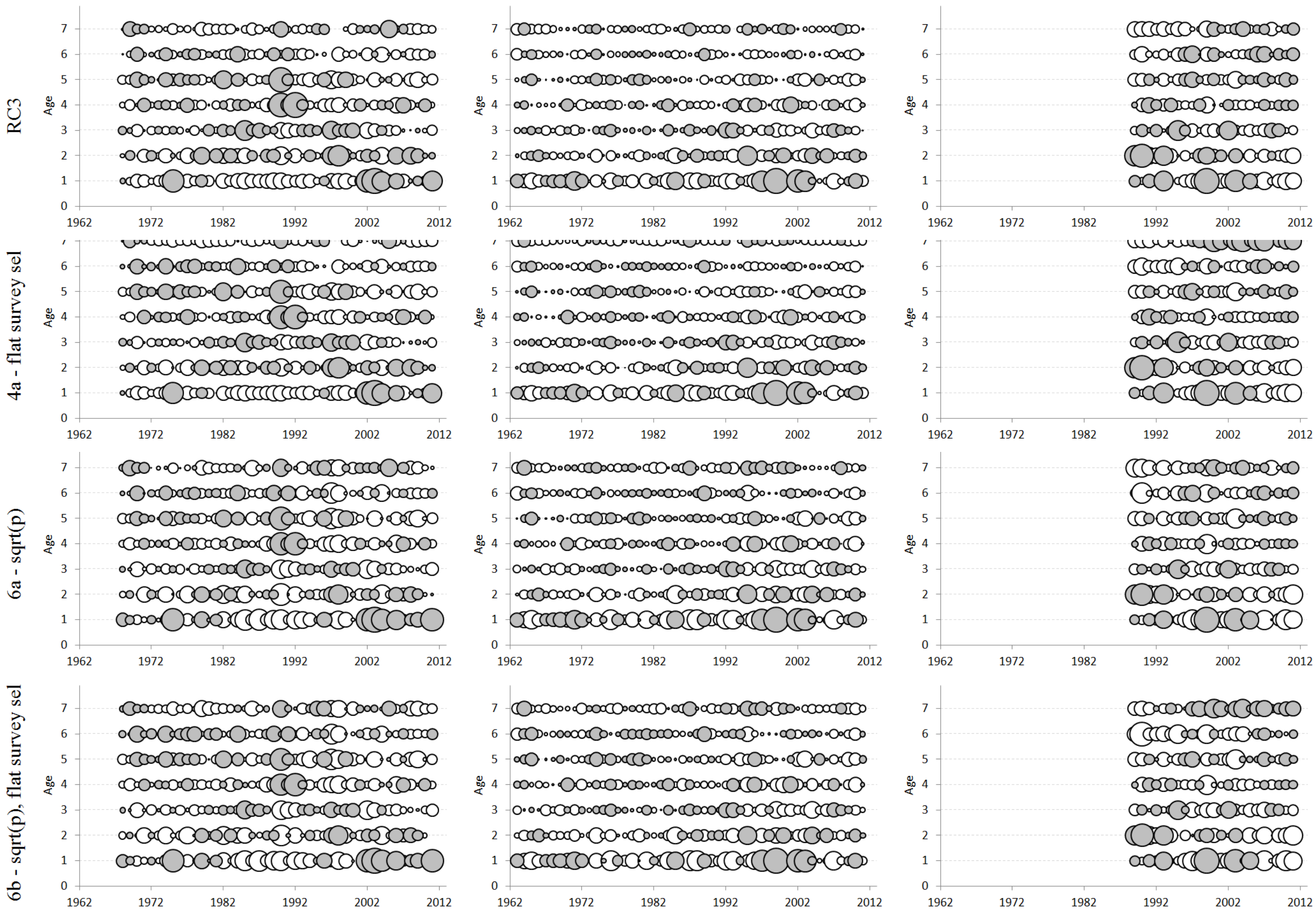

Fig. 6: CAA standardised residuals for RCp and some sensitivities.

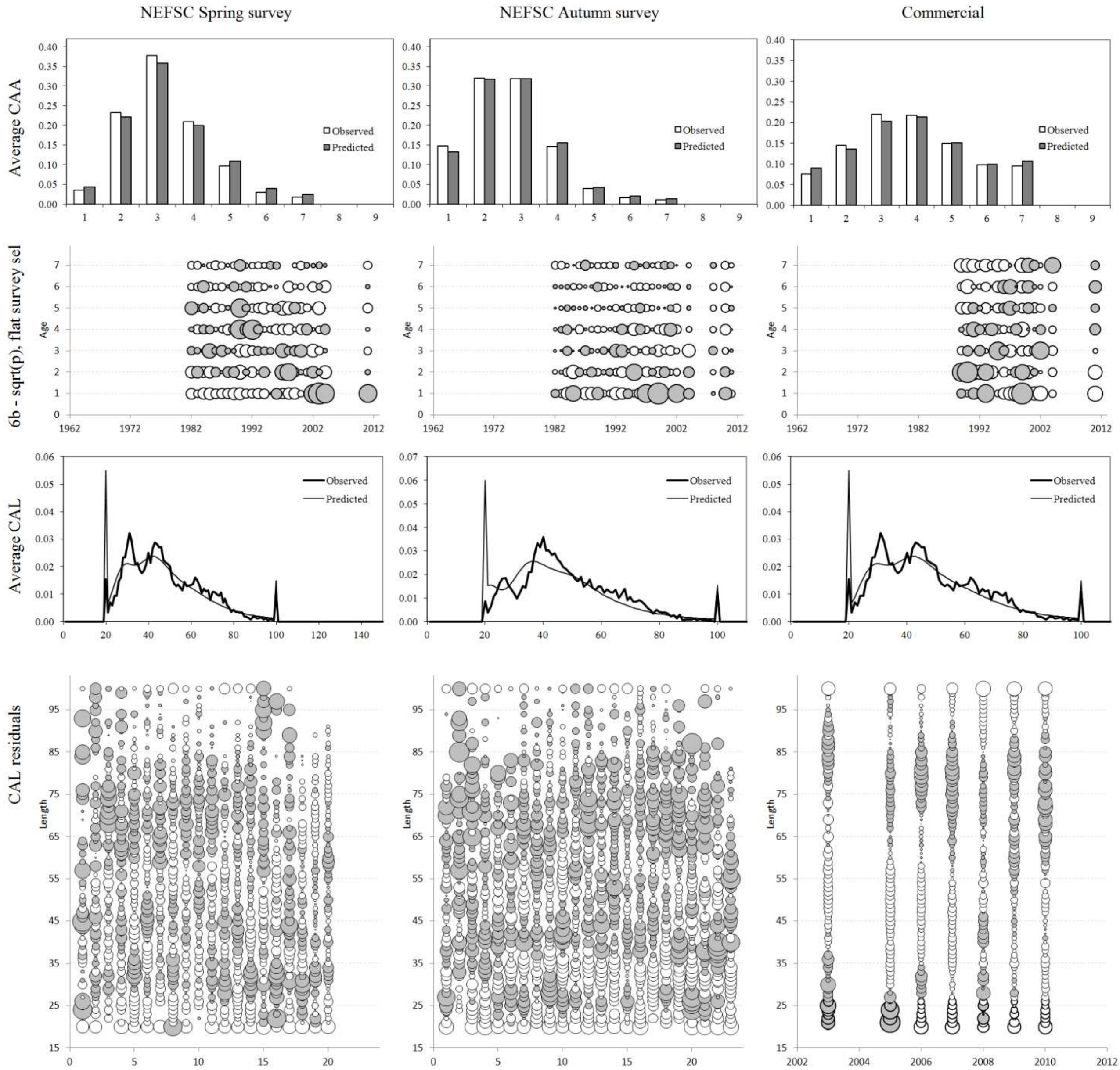

Fig. 7: Fit to CAA and CAL for sensitivity 8c.

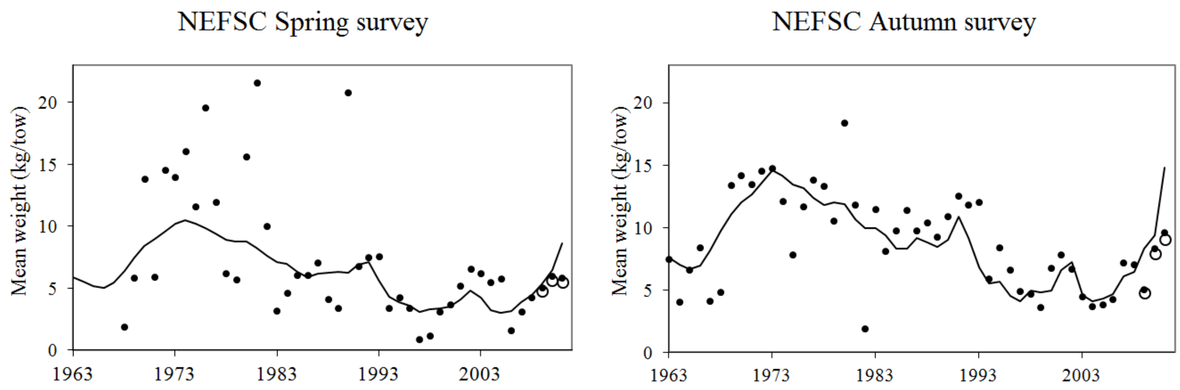

Fig. 8: Fit to NEFSC surveys adjusted for the calibration refinement. Open circles are the surveys with the existing calibration factor.

Appendix A1

Algebraic details of the Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the Statistical Catch-at-Age (SCAA) assessment model applied to white hake, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

Where options are provided under a particular section, the section concludes with a statement in **bold** as to which option was selected for the provisional Reference Case (RCp) run selected.

A1.1. Population dynamics

A1.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \qquad \text{(A1.1)}$$

$$N_{y+1,a+1} = N_{y,a}e^{-Z_{y,a}} \qquad \text{for } 1 \le a \le m-2 \qquad \text{(A1.2)}$$

$$N_{y+1,m} = N_{y,m-1}e^{-Z_{y,m-1}} + N_{y,m}e^{-Z_{y,m}} \qquad \text{(A1.3)}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y*,

R_y is the recruitment (number of 1-year-old fish) at the start of year *y*,

m is the maximum age considered (taken to be a plus-group).

$Z_{y,a} = F_y S_{y,a} + M_a$ is the total mortality in year *y* on fish of age *a*, where

M_a denotes the natural mortality rate for fish of age *a*,

F_y is the fishing mortality of a fully selected age class in year *y*, and

$S_{y,a}$ is the commercial selectivity at age *a* for year *y*.

A1.1.2. Recruitment

The number of recruits (i.e. new 1-year olds) at the start of year *y* is assumed to be related to the spawning stock size (i.e. the biomass of mature fish) by either a modified Ricker or a Beverton-Holt stock-recruitment relationship, allowing for annual fluctuation about the deterministic relationship.

For the modified Ricker:

$$R_y = \alpha B^{\rm sp}_{y-1} \exp\left[-\beta\left(B^{\rm sp}_{y-1}\right)^{\gamma}\right] e^{(\varsigma_y - (\sigma_{\rm R})^2/2)} \qquad \text{(A1.4)}$$

and for the (standard) Beverton-Holt:

$$R_y = \frac{\alpha B^{sp}_{y-1}}{\beta + B^{sp}_{y-1}} e^{(\varsigma_y - (\sigma_{\rm R})^2/2)} \qquad \text{(A1.5)}$$

where

α, β, and γ are spawning biomass-recruitment relationship parameters,

ς_y reflects fluctuation about the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation σ_R (which is input in the applications considered here); these residuals are treated as estimable parameters in the model fitting process.

B_y^{sp} is the spawning biomass at the start of year *y*, computed as:

$$B_y^{\text{sp}} = \sum_{a=1}^{m} f_a w_{y,a}^{\text{strt}} N_{y,a} e^{-Z_{y,a}\mu_{spawn}} \tag{A1.6}$$

because spawning for the cod stock under consideration is taken to occur three months (μ_{spawn} = 0.25) after the start of the year and some mortality has therefore occurred,
where

$w_{y,a}^{\text{strt}}$ is the mass of fish of age *a* during spawning, and

f_a is the proportion of fish of age *a* that are mature.

For RCp, the modified Ricker, with γ fixed to 1, has been used, i.e. the classical Ricker function.

A1.1.3. Total catch and catches-at-age

The total catch by mass in year *y* is given by:

$$C_y = \sum_{a=1}^{m} w_{y,a}^{\text{mid}} C_{y,a} = \sum_{a=1}^{m} w_{y,a}^{\text{mid}} N_{y,a} \; S_{y,a} F_y \left(1-e^{-Z_{y,a}}\right) / Z_{y,a} \tag{A1.7}$$

where

$w_{y,a}^{\text{mid}}$ denotes the mass of fish of age *a* landed in year *y*,

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age *a*, caught in year *y*.

The model estimate of survey index is computed as:

$$B_y^{\text{surv}} = \sum_{a=1}^{m} w_{y,a}^{\text{surv}} S_a^{\text{surv}} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \tag{A1.8}$$

for biomass indices and

$$N_y^{\text{surv}} = \sum_{a=1}^{m} S_a^{\text{surv}} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \tag{A1.9}$$

for numbers indices
where

S_a^{surv} is the survey selectivity for age *a*, which is taken to be year-independent.

T^{surv} is the season in which the survey is taking place (T^{surv}=3 for spring surveys and T^{surv}=9 for fall surveys), and

$w_{y,a}^{surv}$ denotes the mass of fish of age *a* from survey *surv* year, taken as $w_{y,a}^{strt}$ (Table A2.2) for the spring survey and $w_{y,a}^{mid}$ (Table A2.3) for the autumn survey.

RCp is fitted to biomass indices.

A1.1.4. Initial conditions

As the first year for which data (even annual catch data) are available for the white hake stock considered clearly does not correspond to the first year of (appreciable) exploitation, one cannot necessarily make the conventional assumption in the application of SCAA's that this initial year reflects a population (and its age-structure) at pre-exploitation equilibrium. For the first year (y_0) considered in the model therefore, the stock is assumed to be at a fraction (θ) of its pre-exploitation biomass, i.e.:

$$B_{y_0}^{\text{sp}} = \theta \cdot K^{\text{sp}} \tag{A1.10}$$

with the starting age structure:

$$N_{y_0,a} = R_{\text{start}} N_{\text{start},a} \qquad \text{for } 1 \le a \le m \qquad \text{(A1.11)}$$

where

$$N_{\text{start},1} = 1 \qquad \text{(A1.12)}$$

$$N_{\text{start},a} = N_{\text{start},a-1} e^{-M_{a-1}} (1 - \phi S_{a-1}) \qquad \text{for } 2 \le a \le m-1 \qquad \text{(A1.13)}$$

$$N_{\text{start},m} = N_{\text{start},m-1} e^{-M_{m-1}} (1 - \phi S_{m-1}) \Big/ (1 - e^{-M_m} (1 - \phi S_m)) \qquad \text{(A1.14)}$$

where ϕ characterises the average fishing proportion over the years immediately preceding y_0.

For RCp, θ and ϕ are estimated directly in the model fitting procedure.

A1.2. The (penalised) likelihood function

The model can be fit to (a subset of) survey abundance indices, and commercial and survey catch-at-age and catch-at-length data to estimate model parameters (which may include residuals about the stock-recruitment function, facilitated through the incorporation of a penalty function described below). Contributions by each of these to the negative of the (penalised) log-likelihood (- $\ell n L$) are as follows.

A1.2.1. Survey abundance data

The likelihood is calculated assuming that a survey biomass index is lognormally distributed about its expected value:

$$I_y^{surv} = \hat{I}_y^{surv} \exp\left(\varepsilon_y^{surv}\right) \quad \text{or} \quad \varepsilon_y^{surv} = \ell n\left(I_y^{surv}\right) - \ell n\left(\hat{I}_y^{surv}\right) \qquad \text{(A1.15)}$$

where

I_y^{surv} is the survey index for survey *surv* in year *y*,

$\hat{I}_y^{surv} = \hat{q}^{surv} \hat{B}_y^{surv}$ is the corresponding model estimate, where

$\hat{q}^{surv}$ is the constant of proportionality (catchability) for the survey biomass series *surv*, and

ε_y^{surv} from $N\left(0, \left(\sigma_y^{surv}\right)^2\right)$.

The contribution of the survey biomass data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell n L^{\text{survey}} = \sum_{surv} \sum_{y} \left\{ \ell n\left(\sqrt{\left(\sigma_y^{surv}\right)^2 + \left(\sigma_{Add}^{surv}\right)^2} \right) + \left(\varepsilon_y^{surv}\right)^2 / \left[2\left(\left(\sigma_y^{surv}\right)^2 + \left(\sigma_{Add}^{surv}\right)^2 \right) \right] \right\} \qquad \text{(A1.16)}$$

where

σ_y^{surv} is the standard deviation of the residuals for the logarithm of index *i* in year *y* (which are input), and

σ_{Add}^{surv} is the square root of the additional variance for survey biomass series *surv*, which is estimated in the model fitting procedure, with an upper bound of 0.5.

The catchability coefficient q^{surv} for survey biomass index *surv* is estimated by its maximum likelihood value:

$$\ell n\, \hat{q}^{surv} = 1 / n_{surv} \sum_{y} \left(\ln I_y^{surv} - \ln \hat{B}_y^{surv} \right) \qquad \text{(A1.17)}$$

A1.2.3. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of an “adjusted” lognormal error distribution is given by:

$$-\ell \mathrm{n}\, L^{\mathrm{CAA}} = \sum_y \sum_a \left[\ell n\left(\sigma_a^{com} / \sqrt{p_{y,a}}\right) + p_{y,a}\left(\ell n\, p_{y,a} - \ell n\, \hat{p}_{y,a}\right)^2 / 2\left(\sigma_a^{com}\right)^2 \right] \qquad \text{(A1.18)}$$

where

$p_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'}$ is the observed proportion of fish caught in year *y* that are of age *a*,

$\hat{p}_{y,a} = \hat{C}_{y,a} / \sum_{a'} \hat{C}_{y,a'}$ is the model-predicted proportion of fish caught in year *y* that are of age *a*,

where

$$\hat{C}_{y,a} = N_{y,a}\; S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right) \big/ Z_{y,a} \qquad \text{(A1.19)}$$

and

σ_a^{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y p_{y,a}\left(\ell n\, p_{y,a} - \ell n\, \hat{p}_{y,a}\right)^2 / \sum_y 1} \qquad \text{(A1.20)}$$

Commercial catches-at-age are incorporated in the likelihood function using equation (A1.18), for which the summation over age *a* is taken from age a_{minus} (considered as a minus group) to a_{plus} (a plus group).

In addition to this "adjusted" lognormal error distribution, some computations use an alternative "sqrt(p)" formulation, for which equation A1.18 is modified to:

$$-\ell \mathrm{n}\, L^{\mathrm{CAA}} = \sum_y \sum_a \left[\ell n\left(\sigma_a^{com}\right) + \left(\sqrt{p_{y,a}} - \sqrt{\hat{p}_{y,a}}\right)^2 / 2\left(\sigma_a^{\mathrm{com}}\right)^2 \right] \qquad \text{(A1.21)}$$

and equation A1.20 is adjusted similarly:

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y \left(\sqrt{p_{y,a}} - \sqrt{\hat{p}_{y,a}}\right)^2 / \sum_y 1} \qquad \text{(A1.22)}$$

This formulation mimics a multinomial form for the error distribution by forcing a near-equivalent variance-mean relationship for the error distributions.

A1.2.4. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, assuming an "adjusted" lognormal error distribution (equation (A1.18)) where:

$p_{y,a}^{surv} = C_{y,a}^{surv} / \sum_{a'} C_{y,a'}^{surv}$ is the observed proportion of fish of age *a* in year *y* for survey *surv*,

$\hat{p}_{y,a}^{surv}$ is the expected proportion of fish of age *a* in year *y* in the survey *surv*, given by:

$$\hat{p}_{y,a}^{surv} = S_a^{\mathrm{surv}} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \Big/ \sum_{a'=1}^{m} S_{a'}^{\mathrm{surv}} N_{y,a'}\, e^{-Z_{y,a'} T^{surv}/12} \quad . \qquad \text{(A1.23)}$$

RCp uses the "adjusted log-normal" formulation for the error distribution of the commercial catch proportions-at-age and survey catch proportions-at-age.

A1.2.5. Survey catches-at-length

In some runs, catches-at-length are also incorporated in the likelihood function. These data are incorporated in the similar manner as the catches-at-age. When the model is fit to catches-at-length, the predicted catches-at-age are converted to catches-at-length:

$$\hat{p}_{y,l}^{surv} = \sum_a \hat{p}_{y,a}^{surv} A_{a,l}^{strt} \qquad \text{(A1.24)}$$

for the spring survey, and

$$\hat{p}_{y,l}^{surv} = \sum_a \hat{p}_{y,a}^{surv} A_{a,l}^{mid} \qquad \text{(A1.25)}$$

for the fall survey,

where $A_{a,l}^{strt}$ and $A_{a,l}^{mid}$ are the proportions of fish of age a that fall in the length group l (i.e., $\sum_l A_{a,l}^{strt} = 1$ and $\sum_l A_{a,l}^{mid} = 1$ for all ages) at the beginning of the year and at the middle of the year respectively.

The matrices $A_{a,l}^{strt}$ and $A_{a,l}^{mid}$ are calculated under the assumption that length-at-age is normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$L_a^{strt} \sim N\left[L_\infty\left(1-e^{-\kappa(a-t_o)}\right);\left(\theta_a^{strt}\right)^2\right] \qquad \text{(A1.26)}$$

for the spring survey and

$$L_a^{mid} \sim N\left[L_\infty\left(1-e^{-\kappa(a+0.5-t_o)}\right);\left(\theta_a^{mid}\right)^2\right] \qquad \text{(A1.27)}$$

for the fall survey,

where

θ_a^{strt} and θ_a^{mid} are the standard deviation of begin and mid-year length-at-age a respectively, which are modelled to be proportional to the expected length-at-age a, i.e.:

$$\theta_a^{strt} = \beta\left[L_\infty\left(1-e^{-\kappa(a-t_o)}\right)\right] \qquad \text{(A1.28)}$$

and

$$\theta_a^{mid} = \beta\left[L_\infty\left(1-e^{-\kappa(a+0.5-t_o)}\right)\right] \qquad \text{(A1.29)}$$

with β an estimable parameter.

$L_\infty = 189\, cm$,

$\kappa = 0.0815\ yr^{-1}$,

$t_o = 0.0627\ yr$,

The following term is then added to the negative log-likelihood:

$$-\ell\text{n}\, L^{\text{CAL}} = w_{len} \sum_{surv}\sum_y\sum_l \left[\ell n\left(\sigma_{\text{len}}^{surv} / \sqrt{p_{y,l}^{surv}}\right) + p_{y,l}^{surv}\left(\ell n\, p_{y,l}^{surv} - \ell n\, \hat{p}_{y,l}^{surv}\right)^2 / 2\left(\sigma_{\text{len}}^{surv}\right)^2\right] \qquad \text{(A1.30)}$$

The w_{len} weighting factor may be set to a value less than 1 to downweight the contribution of the catch-at-length data (which tend to be positively correlated between adjacent length groups because the length distributions for adjacent ages overlap) to the overall negative log-likelihood compared to that of the CPUE data.

RCp does not incorporate any catch-at-length data.

A1.2.6. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be lognormally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-\ell n L^{\text{pen}} = \sum_{y=y_1+1}^{y_2}\left[\varepsilon_y^2 / 2\sigma_{\text{R}}^2\right] \qquad \text{(A1.31)}$$

where

ε_y from $N\left(0,(\sigma_R)^2\right)$,

σ_{R} is the standard deviation of the log-residuals, which is input.

Equation A1.31 is used when the stock-recruitment curve is estimated internally. In some analyses reported in this paper where BRP estimates are based on stock-recruitment curves estimated "externally" using the assessment outputs, this "stock-recruitment" term is included for the last two years only, simply to stabilise these estimates which are not well determined by the other data. In these cases, the ε_y are calculated as the deviations from the mean log recruitment for the ten preceding years, i.e. recruitment estimates for 2010 and 2011 are shrunk towards the geometric mean recruitment over the preceding decade.

A1.2.7. Catches

$$-\ell n L^{\text{Catch}} = \sum_y \left[\frac{\ell n C_y - \ell n \hat{C}_y}{2\sigma_{\text{C}}^2} \right] \qquad \text{(A1.32)}$$

where

C_y is the observed catch in year *y*,

$\hat{C}_y$ is the predicted catch in year *y* (equation A1.7), and

σ_{C} is the CV input: 0.5 for pre-1964 catches, 0.3 for catches between 1964 and 1981 and 0.1 for catches from 1982 onwards.

A1.2.8 Incorporation of Bigelow vs Albatross survey calibration

The survey data provided are adjusted for the years 2009 to 2011 which were obtained from *Bigelow* surveys; these have been adjusted to "*Albatross* equivalents" through use of calibration factors estimated independently from paired tow experiments (Miller *et al*., 2010). However the survey data before and after the switch of vessels also provide information on the calibration factors because they sample the same cohorts. Incorporation of this information in assessments in this paper has been effected by treating the estimate with its variance as a form of "prior" which is effectively updated in the penalised likelihood estimation when fitting the model. The following contribution is therefore added as a penalty (or a prior in a Bayesian contact) to the negative log-likelihood in the assessment:

$$-\ln L^{calib} = (\Delta \ln \hat{q} - \Delta \ln q)^2 \Big/ 2\sigma_{\Delta \ln q}^2 \qquad \text{(A1.33)}$$

where

$\Delta \ln q = \ln(2.235)$ is the logged ratio of the catchability of the *Bigelow* to the *Albatross*, with standard error $\sigma_{\Delta \ln q} = 0.173/2.235$,

$\Delta \ln \hat{q}$ is the logged ratio of the catchabilities, estimated directly in the fitting procedure, where $q_{Big}^{Spr/Aut} = e^{\Delta \ln \hat{q}} q_{Alb}^{Spr/Aut}$.

In RCp, the calibration parameters are fixed to those estimated by Miller *et al*. (2010).

A1.3. Estimation of precision

Where quoted, CV's or 95% probability interval estimates are based on the Hessian.

A1.4. Model parameters

A1.4.1. Fishing selectivity-at-age:

For the NEFSC offshore surveys, the fishing selectivities are estimated separately for ages 1 to age 7. The estimated proportional decrease from ages 6 to 7 is assumed to continue multiplicatively to age 9+; this decrease parameter is bounded by 0, i.e. no increase is permitted.

The commercial fishing selectivity, S_a, is estimated separately for ages a_{minus} (1) to 6, and is taken to be flat thereafter. It is taken to differ over two periods: a) pre-1997, and b) 1998-present. The selectivities are estimated directly for each period.

A1.4.2. Other parameters

Stock-recruit standard dev.		
σ_R	0.5	
Model plus group		
m	9	
Commercial CAA		
a_{minus}*	1	
a_{plus}	7	
Survey CAA	NEFSC spr	NEFSC fall
a_{minus}*	1	1
a_{plus}	7	7
Natural mortality:		
M	0.2 and age independent	
Proportion mature-at-age:		
f_a	input, see Table A2.7	
Weight-at-age:		
$w_{y,a}^{strt}$	input, see Table A2.2	
$w_{y,a}^{mid}$	input, see Table A2.3	
Initial conditions for a 1963 starting year:		
θ	estimated	
ϕ	estimated	

* Strictly not a minus group anymore since the catches at age zero are ignored.

A1.5.Biological Reference Points (BRPs)

It is possible to estimate BRPs internally within the assessment by fitting the stock-recruitment relationship directly within the assessment itself. The F_{MSY} estimate is obtained by using a bisection routine to find where the derivative of the equilibrium catch vs F relationship has a zero derivative. This has to be based on point estimates, so that the estimate of other BRPs are conditional on this point estimate of F_{MSY}, with no Hessian based CV available for this quantity.

For some results reported here, however, the stock-recruitment relationships are fitted to the estimates of recruitment and spawning biomass provided by the various assessments to provide a basis to estimate BRPs. The rationale for estimation external to the assessment itself is to avoid assumptions about the form of the relationship influencing the assessment results. These fits are achieved by minimising the following negative log-likelihood, where the $e^{-\frac{\sigma_R^2}{2}}$ term is added for consistency with equation A1.4, i.e. the stock-recruitment curves estimated are mean-unbiased rather than median unbiased:

$$-\ln L = \sum_{y=y1}^{2009} \left[\frac{\left(\ln(N_{y,1}) - \ln\left(\hat{N}_{y,1} e^{-\frac{\sigma_R^2}{2}} \right) \right)^2}{2\left((\sigma_R)^2 + (CV_y)^2 \right)} \right] \qquad \text{(A1.34)}$$

where

$N_{y,1}$ is the "observed" (assessment estimated) recruitment in year y,

$\hat{N}_{y,1}$ is the stock-recruitment model predicted recruitment in year *y*,

σ_R is the standard deviation of the log-residuals which is input (and set here to 0.5), and

CV_y is the Hessian-based CV for the "observed" recruitment in year *y*.

Note that the differential precision of the assessment estimates of recruitment is taken into account, and that the summation ends at 2009 because little by way of direct observation is as yet available to inform estimates of recruitment for 2010 and 2011.

References

Miller TJ, Das, C, Politis PJ, Miller AS, Lucey SM, Legault CM, Brown RW and Rago PJ. 2010. Estimation of *Albatross IV* to *Henry B. Bigelow* Calibration Factors. U.S. Depart. of Commerce, Northeast Fisheries Science Center Ref. Doc. 10-05; 233 pp.

Appendix A2

Data used in the Georges Bank/Gulf of Maine White hake SCAA assessment

Table A2.1: Total catch in tons of Georges Bank/Gulf of Maine white hake, 1950-2011.

Year	Total catch	Year	Total catch	Year	Total catch
1950	5492.3	1971	3756.6	1992	10414.4
1951	5551.6	1972	3911.3	1993	10666.4
1952	5428.7	1973	4025.5	1994	6091.5
1953	4665.3	1974	4748.0	1995	5121.6
1954	3841.5	1975	4575.2	1996	3885.0
1955	3528.6	1976	5130.4	1997	2665.7
1956	2933.0	1977	6455.2	1998	2747.0
1957	2605.9	1978	6232.0	1999	3741.3
1958	2026.2	1979	5550.7	2000	3438.3
1959	2372.3	1980	6406.2	2001	4039.5
1960	2624.1	1981	7665.3	2002	3548.8
1961	2365.1	1982	8322.9	2003	4887.7
1962	3262.1	1983	8539.2	2004	3721.2
1963	3561.0	1984	9011.4	2005	2848.9
1964	4424.5	1985	9403.8	2006	1854.2
1965	4050.2	1986	8406.2	2007	1621.9
1966	2892.6	1987	7786.5	2008	1551.0
1967	2324.3	1988	7041.6	2009	1874.0
1968	2445.9	1989	6786.0	2010	2014.4
1969	2397.6	1990	7586.5	2011	3039.0
1970	3077.3	1991	6718.7		

Table A2.2: Mean spawning weight-at-age (kg) for the Georges Bank/Gulf of Maine white hake stock. Pre-1989, the 1989-2011 average mean weight-at-age is assumed.

	1	2	3	4	5	6	7	8	9+
1989	0.1078	0.228	0.669	1.469	2.411	3.479	4.987	5.770	9.204
1990	0.1309	0.247	0.577	1.336	2.462	3.632	4.578	6.282	11.713
1991	0.1033	0.313	0.705	1.246	2.092	3.181	4.147	5.702	10.855
1992	0.0783	0.280	0.670	1.259	2.139	3.327	4.311	5.202	10.594
1993	0.0923	0.200	0.675	1.293	2.109	3.227	4.010	5.652	10.882
1994	0.0818	0.224	0.562	1.256	2.214	3.339	4.432	5.724	9.403
1995	0.1164	0.321	0.669	1.285	2.016	2.850	4.055	5.352	6.960
1996	0.1054	0.259	0.700	1.415	2.208	2.998	3.689	5.674	7.870
1997	0.1216	0.216	0.603	1.348	2.224	3.169	4.087	5.255	7.844
1998	0.1039	0.219	0.606	1.477	2.505	3.561	4.313	5.548	7.316
1999	0.0839	0.244	0.505	1.367	2.298	3.477	4.634	5.758	7.815
2000	0.093	0.174	0.499	1.268	2.222	3.017	4.352	5.764	7.239
2001	0.1604	0.185	0.665	1.224	2.246	3.310	4.411	5.601	7.528
2002	0.2744	0.518	0.786	1.787	2.436	3.363	4.215	5.260	6.847
2003	0.0815	0.327	0.839	1.788	2.734	3.761	4.673	5.402	7.054
2004	0.1387	0.254	0.573	1.509	2.727	3.827	5.284	6.153	8.078
2005	0.0603	0.284	0.724	1.486	2.597	3.709	4.756	6.358	8.804
2006	0.1167	0.194	0.661	1.579	2.757	3.704	4.601	5.868	10.071
2007	0.1098	0.248	0.658	1.507	2.675	3.764	4.669	5.613	10.680
2008	0.0763	0.218	0.566	1.477	2.592	3.675	4.568	5.527	9.580
2009	0.0814	0.235	0.630	1.376	2.508	3.736	4.589	5.402	7.239
2010	0.0872	0.229	0.625	1.500	2.506	3.578	4.635	5.582	10.914
2011	0.1355	0.303	0.934	1.749	2.739	3.614	4.610	5.955	8.887

Table A2.3: Mean weight-at-age (kg) of landings for the Georges Bank/Gulf of Maine white hake stock. Pre-1989, the 1989-2011 average mean weight-at-age is assumed.

	1	2	3	4	5	6	7	8	9+
1989	0.142	0.311	0.842	1.745	2.764	3.812	5.386	5.972	9.204
1990	0.175	0.325	0.786	1.682	2.925	4.164	5.017	6.785	11.713
1991	0.144	0.418	1.039	1.568	2.333	3.317	4.139	6.079	10.855
1992	0.107	0.390	0.849	1.385	2.499	3.973	4.914	5.831	10.594
1993	0.124	0.273	0.887	1.595	2.602	3.667	4.029	6.061	10.882
1994	0.129	0.301	0.807	1.494	2.608	3.782	4.873	6.822	9.402
1995	0.152	0.506	0.998	1.621	2.341	2.980	4.199	5.609	6.960
1996	0.134	0.338	0.823	1.685	2.576	3.393	4.105	6.595	7.870
1997	0.148	0.275	0.805	1.725	2.555	3.515	4.485	5.945	7.844
1998	0.138	0.267	0.900	2.000	3.019	4.204	4.777	6.170	7.316
1999	0.107	0.324	0.694	1.685	2.463	3.732	4.865	6.322	7.815
2000	0.117	0.222	0.619	1.713	2.551	3.339	4.700	6.274	7.239
2001	0.237	0.233	1.150	1.721	2.572	3.770	5.069	6.114	7.528
2002	0.291	0.765	1.444	2.228	2.898	3.845	4.456	5.358	6.847
2003	0.119	0.347	0.879	1.990	3.028	4.285	5.151	5.948	7.054
2004	0.176	0.371	0.737	1.977	3.193	4.303	5.868	6.724	8.078
2005	0.089	0.360	1.012	2.111	2.977	3.997	5.000	6.618	8.804
2006	0.150	0.286	0.895	1.973	3.150	4.131	4.936	6.357	10.071
2007	0.138	0.318	0.999	1.955	3.114	4.115	4.964	5.985	10.680
2008	0.111	0.274	0.754	1.795	2.985	3.993	4.813	5.832	9.579
2009	0.115	0.342	0.955	1.858	2.965	4.180	4.919	5.723	7.239
2010	0.132	0.324	0.844	1.879	2.910	3.930	4.881	5.946	10.914
2011	0.1719	0.4583	1.5847	2.5175	3.307	4.0266	4.9934	6.578	8.8866

Table A2.4: Commercial catches-at-age for the Georges Bank/Gulf of Maine white hake stock (numbers in thousands).

	1	2	3	4	5	6	7	8	9+
1989	704.657	1721.190	1318.864	1047.771	598.294	260.891	40.002	22.950	22.655
1990	708.689	3646.970	2516.495	1335.412	389.855	85.581	32.752	13.861	25.438
1991	417.288	410.848	1339.447	1337.178	760.057	176.123	40.613	14.854	35.112
1992	200.935	346.926	2800.851	2152.040	812.078	364.664	179.515	41.159	27.864
1993	1446.219	2533.121	2168.931	2340.345	883.467	305.951	101.477	12.655	21.151
1994	165.092	350.192	1075.562	1142.291	607.259	258.338	87.157	28.960	22.106
1995	105.715	470.224	1864.686	790.500	335.624	171.658	29.206	24.542	24.170
1996	44.522	138.835	566.763	529.220	425.035	260.671	68.822	14.591	14.715
1997	10.826	152.295	122.597	237.128	324.886	195.546	80.458	21.720	13.654
1998	60.787	213.954	142.486	200.748	192.924	167.853	97.697	38.063	22.157
1999	1524.689	830.616	362.074	279.935	289.884	172.422	98.442	73.698	35.659
2000	30.455	113.754	133.143	264.809	272.019	169.849	86.240	92.016	86.985
2001	27.763	162.883	388.145	378.075	249.338	218.729	117.685	69.861	54.252
2002	18.508	86.469	253.395	437.733	233.756	186.818	93.915	41.288	14.391
2003	414.710	241.762	114.536	183.000	242.814	281.445	189.034	130.440	83.663
2004	87.778	83.772	87.776	106.495	170.111	190.805	148.909	81.347	75.957
2005	255.187	46.473	66.361	121.002	162.549	139.496	74.835	65.436	71.931
2006	44.292	73.335	49.977	78.428	93.786	100.048	53.395	32.974	44.154
2007	16.412	26.768	47.718	87.961	96.224	90.845	47.084	25.293	31.136
2008	89.684	99.423	151.011	134.132	115.150	88.443	40.048	19.601	16.074
2009	49.598	54.844	136.986	148.408	117.907	108.041	65.096	35.578	16.164
2010	12.005	32.828	71.881	128.573	139.701	114.691	55.862	34.758	33.282
2011	12.877	20.112	75.819	161.054	148.220	148.544	85.615	55.143	70.114

Table A2.5: Mean numbers per tow at age (in bold for the years in which a pooled ALK was used), mean weight (kg) per tow and mean numbers per tow of white hake in NEFSC offshore spring research vessel bottom trawl survey.

	1	2	3	4	5	6	7	8	9+	Mean wt/tow (kg)	CV	numbers / tow	CV
1968	**0.1054**	**0.3564**	**0.6468**	**0.3118**	**0.0920**	**0.0548**	**0.0216**	**0.0182**	**0.0235**	1.937	(27.0)	1.631	(21.2)
1969	**0.1497**	**1.0233**	**1.4013**	**0.6956**	**0.3596**	**0.1174**	**0.0864**	**0.0516**	**0.1332**	5.848	(19.6)	4.018	(23.6)
1970	**0.1457**	**1.2249**	**1.7268**	**1.3533**	**1.2801**	**0.6096**	**0.1204**	**0.0704**	**0.1199**	13.813	(39.8)	6.651	(21.1)
1971	**0.1133**	**0.5923**	**1.0283**	**1.0065**	**0.5378**	**0.2012**	**0.0877**	**0.0686**	**0.0474**	5.930	(21.0)	3.683	(18.5)
1972	**0.3619**	**3.1629**	**3.6084**	**1.8274**	**1.4844**	**0.6803**	**0.1993**	**0.1177**	**0.1102**	14.583	(27.0)	11.553	(17.8)
1973	**0.2031**	**1.4711**	**4.2293**	**2.7303**	**1.0648**	**0.4546**	**0.1574**	**0.1056**	**0.1279**	14.016	(20.9)	10.544	(24.1)
1974	**0.1132**	**0.8389**	**2.0964**	**2.6523**	**1.9021**	**0.7792**	**0.1849**	**0.1164**	**0.1251**	16.068	(18.2)	8.809	(16.5)
1975	**1.1411**	**1.9486**	**2.8729**	**1.4396**	**1.0646**	**0.5664**	**0.1425**	**0.0749**	**0.0598**	11.591	(17.1)	9.313	(19.8)
1976	**0.2579**	**1.6218**	**3.5215**	**2.3277**	**1.8245**	**1.0120**	**0.2732**	**0.1561**	**0.2077**	19.616	(23.4)	11.202	(16.2)
1977	**0.0985**	**0.7411**	**1.9635**	**2.1551**	**1.0247**	**0.5553**	**0.1575**	**0.0746**	**0.1908**	12.008	(20.6)	6.961	(19.6)
1978	**0.1176**	**0.8397**	**0.8637**	**0.4970**	**0.5621**	**0.2865**	**0.0748**	**0.0396**	**0.0863**	6.254	(22.1)	3.367	(19.2)
1979	**0.3146**	**1.8406**	**2.0077**	**0.9113**	**0.4282**	**0.2457**	**0.0602**	**0.0199**	**0.0277**	5.693	(25.1)	5.856	(18.7)
1980	**0.4296**	**1.4291**	**4.9698**	**2.7324**	**1.2775**	**0.6862**	**0.1749**	**0.1078**	**0.0883**	15.607	(16.7)	11.896	(15.5)
1981	**0.9692**	**5.8239**	**3.6857**	**3.6138**	**2.0111**	**1.1795**	**0.3302**	**0.1188**	**0.1554**	21.612	(30.1)	17.888	(15.4)
1982	0.0488	0.8058	2.9733	0.9815	1.3927	0.2529	0.0614	0.0369	0.0814	10.031	(23.9)	6.635	(24.3)
1983	0.0592	1.0397	1.2285	0.5433	0.1752	0.0968	0.0453	0.0378	0.0000	3.232	(16.9)	3.226	(16.5)
1984	0.0225	0.2616	0.9816	0.6932	0.4667	0.1749	0.0723	0.0323	0.0091	4.605	(26.8)	2.714	(19.7)
1985	0.0234	0.7502	1.9720	1.2366	0.5065	0.1234	0.0364	0.0127	0.0460	6.056	(22.1)	4.707	(16.9)
1986	0.1082	3.3372	3.5906	1.0397	0.5213	0.2059	0.0000	0.0178	0.0000	6.083	(15.1)	8.821	(12.1)
1987	0.0106	1.4080	4.5032	1.2079	0.3526	0.1287	0.0120	0.0265	0.0449	7.079	(15.2)	7.695	(13.7)
1988	0.0917	1.6294	1.4568	0.8363	0.4970	0.1153	0.0410	0.0361	0.0071	4.103	(12.4)	4.711	(11.3)
1989	0.0282	1.1084	1.4652	0.3083	0.4127	0.1848	0.0247	0.0000	0.0000	3.440	(32.6)	3.532	(24.8)
1990	0.0698	1.8186	2.4924	4.9384	2.2076	0.3334	0.1450	0.1170	0.2013	20.805	(74.5)	12.323	(48.4)
1991	0.1428	2.9593	2.4882	2.0192	0.9302	0.3375	0.0395	0.0170	0.0405	6.813	(17.8)	9.015	(13.4)
1992	0.0056	0.9796	2.9314	3.4555	0.3591	0.0942	0.0376	0.0095	0.0000	7.485	(26.3)	7.872	(18.4)
1993	0.0402	1.6917	3.3089	2.5792	0.4750	0.0258	0.0023	0.0011	0.0000	7.584	(18.0)	8.124	(16.3)
1994	0.0388	1.4473	1.9586	0.7251	0.2224	0.0862	0.0093	0.0256	0.0000	3.415	(25.3)	4.513	(15.8)
1995	0.1125	0.7682	1.9574	0.7850	0.2755	0.1753	0.0386	0.0726	0.0000	4.283	(19.5)	4.185	(15.8)
1996	0.2299	0.4709	1.0625	0.5774	0.4682	0.0973	0.0248	0.0365	0.0409	3.426	(14.3)	3.009	(12.9)
1997	0.0429	0.7240	0.7884	0.2650	0.0545	0.0000	0.0000	0.0000	0.0000	0.893	(18.7)	1.875	(17.6)
1998	0.0144	1.0234	0.9315	0.1752	0.0717	0.0163	0.0000	0.0000	0.0000	1.168	(19.0)	2.233	(16.3)
1999	0.0449	0.6021	1.5300	0.5961	0.4177	0.0898	0.0538	0.0091	0.0000	3.095	(37.0)	3.344	(25.4)
2000	0.0885	1.5095	2.5822	0.8024	0.2790	0.0900	0.0141	0.0000	0.0000	3.692	(15.9)	5.366	(14.0)
2001	0.0582	0.4947	2.1425	1.4781	0.4575	0.1815	0.0182	0.0361	0.0447	5.210	(15.2)	4.912	(13.1)
2002	0.6856	1.0976	0.7497	1.7406	0.8154	0.1171	0.0684	0.0537	0.0141	6.605	(25.3)	5.342	(21.1)
2003	0.9350	1.2200	1.0798	0.7800	0.6762	0.4278	0.1588	0.0387	0.0205	6.203	(15.4)	5.337	(13.4)
2004	0.6236	0.5035	1.7796	1.0232	0.5166	0.1262	0.0926	0.0496	0.0323	5.477	(39.2)	4.747	(22.2)
2005	**0.2003**	**0.8331**	**1.0081**	**0.8291**	**0.3969**	**0.1433**	**0.1247**	**0.1520**	**0.0644**	5.763	(26.0)	3.752	(15.7)
2006	**0.3141**	**1.0863**	**0.6427**	**0.2305**	**0.1339**	**0.0524**	**0.0106**	**0.0286**	**0.0047**	1.586	(20.4)	2.504	(11.7)
2007	**0.0662**	**0.4980**	**1.0439**	**0.6306**	**0.2300**	**0.1056**	**0.0426**	**0.0169**	**0.0226**	3.099	(29.5)	2.656	(17.0)
2008	**0.4794**	**2.4547**	**2.2602**	**1.2944**	**0.2714**	**0.0924**	**0.0151**	**0.0059**	**0.0033**	4.246	(32.3)	6.877	(23.6)
2009	**0.5610**	**2.0851**	**2.3311**	**1.3242**	**0.3268**	**0.1034**	**0.0193**	**0.0059**	**0.0019**	4.767	(25.0)	6.759	(18.8)
2010	**0.2167**	**1.2915**	**1.7700**	**1.4127**	**0.4970**	**0.1531**	**0.0525**	**0.0141**	**0.0038**	5.652	(19.6)	5.411	(13.1)
2011	0.6882	1.2204	1.4323	0.9760	0.3904	0.2724	0.0761	0.0251	0.0084	5.521	(16.0)	5.095	(13.3)

Table A2.6: Mean numbers per tow at age (in bold for the years in which a pooled ALK was used), mean weight (kg) per tow and mean numbers per tow of white hake in NEFSC offshore autumn research vessel bottom trawl survey.

	1	2	3	4	5	6	7	8	9+	Mean wt/tow (kg)	CV	numbers / tow	CV
1963	**0.9163**	**1.3741**	**1.4625**	**0.9796**	**0.3664**	**0.0749**	**0.0051**	**0.0112**	**0.1299**	7.523	(19.0)	5.468	(13.0)
1964	**0.1195**	**0.4005**	**0.5308**	**0.3294**	**0.1365**	**0.0799**	**0.0314**	**0.0107**	**0.1107**	4.089	(22.1)	1.761	(18.5)
1965	**0.3594**	**1.2753**	**1.2198**	**0.5949**	**0.3685**	**0.1976**	**0.0356**	**0.0174**	**0.0525**	6.609	(16.7)	4.160	(19.8)
1966	**0.9573**	**3.1449**	**1.9368**	**0.8422**	**0.3313**	**0.1005**	**0.0604**	**0.0118**	**0.0648**	8.405	(13.6)	7.563	(13.7)
1967	**0.7867**	**1.4079**	**1.0458**	**0.4231**	**0.1518**	**0.0617**	**0.0057**	**0.0020**	**0.0389**	4.122	(18.8)	4.023	(15.9)
1968	**0.8621**	**1.1342**	**1.3397**	**0.6417**	**0.1696**	**0.0534**	**0.0168**	**0.0048**	**0.0429**	4.886	(25.1)	4.397	(22.3)
1969	**1.7227**	**2.8094**	**2.5698**	**1.7583**	**0.6351**	**0.2271**	**0.0838**	**0.0419**	**0.0549**	13.404	(15.2)	10.147	(12.5)
1970	**0.7893**	**1.9781**	**2.9890**	**2.0001**	**0.5626**	**0.2600**	**0.0576**	**0.0225**	**0.0986**	14.174	(16.0)	8.848	(12.5)
1971	**2.9745**	**2.8858**	**2.2704**	**1.7146**	**0.4887**	**0.2189**	**0.0726**	**0.0350**	**0.1518**	13.468	(11.6)	11.196	(21.7)
1972	**2.0370**	**4.5116**	**4.7995**	**1.2971**	**0.6470**	**0.2319**	**0.0580**	**0.0293**	**0.1218**	14.556	(18.4)	14.029	(28.4)
1973	**0.9754**	**2.1076**	**3.5616**	**1.7131**	**0.6334**	**0.3390**	**0.0666**	**0.0539**	**0.2551**	14.800	(17.2)	9.863	(15.9)
1974	**0.4037**	**0.8835**	**1.5748**	**1.3019**	**0.6457**	**0.2650**	**0.0718**	**0.0331**	**0.1574**	12.121	(14.8)	5.400	(13.1)
1975	**0.5518**	**1.4646**	**1.6073**	**0.6914**	**0.3484**	**0.2253**	**0.0806**	**0.0212**	**0.0681**	7.826	(13.5)	5.146	(13.1)
1976	**0.2125**	**1.2977**	**2.8008**	**1.3331**	**0.6003**	**0.2681**	**0.0610**	**0.0335**	**0.1052**	11.695	(15.9)	6.742	(17.2)
1977	**1.8781**	**2.7485**	**2.8406**	**1.5926**	**0.5216**	**0.2906**	**0.1053**	**0.0554**	**0.1565**	13.872	(11.2)	10.575	(11.0)
1978	**0.8696**	**2.5364**	**2.3629**	**1.1517**	**0.5905**	**0.3003**	**0.1228**	**0.0512**	**0.1673**	13.323	(12.3)	8.343	(11.2)
1979	**0.2136**	**1.5249**	**1.9599**	**0.9664**	**0.4154**	**0.2372**	**0.0783**	**0.0255**	**0.1272**	10.568	(16.1)	5.561	(12.0)
1980	**1.6777**	**1.4929**	**3.6967**	**2.3634**	**1.0263**	**0.3539**	**0.1359**	**0.0609**	**0.1446**	18.410	(25.3)	12.001	(17.1)
1981	**0.5467**	**3.1291**	**1.9866**	**1.4891**	**0.7266**	**0.3310**	**0.1083**	**0.0511**	**0.0184**	11.870	(11.7)	8.428	(12.3)
1982	0.3266	0.5433	0.6321	0.1867	0.1013	0.0589	0.0199	0.0000	0.0000	1.954	(21.8)	1.876	(17.8)
1983	0.5977	3.1534	2.8528	1.8063	0.2370	0.2625	0.0028	0.0000	0.0777	11.513	(12.9)	8.991	(13.3)
1984	0.3504	0.9706	2.1758	1.1276	0.3465	0.1040	0.0422	0.0116	0.0439	8.152	(10.8)	5.173	(10.1)
1985	3.2732	1.7677	2.0369	1.3962	0.4317	0.1232	0.0748	0.0082	0.0602	9.795	(19.3)	9.460	(15.7)
1986	1.2570	7.0940	4.3420	0.8370	0.4845	0.1536	0.0076	0.0024	0.0505	11.450	(9.9)	15.181	(12.0)
1987	0.5487	1.8369	3.7714	1.0967	0.2195	0.1118	0.0633	0.0743	0.0743	9.801	(16.2)	7.852	(10.1)
1988	0.5593	3.9489	2.1881	1.3588	0.3180	0.1032	0.0043	0.0003	0.0511	10.430	(16.7)	8.540	(11.7)
1989	3.3810	3.3155	3.7846	0.9140	0.3685	0.3513	0.0100	0.0084	0.0036	9.255	(11.4)	12.538	(17.7)
1990	1.9769	5.3091	3.8259	1.3655	0.3219	0.0382	0.0000	0.0013	0.0012	10.895	(19.6)	13.861	(13.8)
1991	1.1574	6.1843	4.3646	1.3777	0.3424	0.0479	0.0000	0.0075	0.0075	12.541	(18.8)	13.672	(14.6)
1992	0.4178	2.5760	5.8455	1.3604	0.1712	0.1117	0.0447	0.0365	0.0224	11.843	(10.5)	10.746	(8.5)
1993	0.6632	2.3969	4.3012	2.5471	0.4324	0.1128	0.0000	0.0000	0.0000	12.039	(12.9)	10.504	(12.0)
1994	1.0167	2.5558	2.4494	0.7570	0.1554	0.1116	0.0191	0.0000	0.0000	5.924	(10.4)	7.381	(10.6)
1995	0.5887	4.2878	2.8038	0.7044	0.1883	0.0035	0.1312	0.0024	0.0309	8.439	(11.9)	10.072	(9.9)
1996	0.3366	1.0406	1.5485	1.2708	0.3642	0.0314	0.0224	0.0283	0.0141	6.651	(13.8)	4.684	(10.0)
1997	1.7997	1.2606	0.9787	0.6282	0.2034	0.0606	0.0141	0.0224	0.0635	4.896	(14.8)	5.031	(12.7)
1998	0.4267	1.9725	1.6966	0.5376	0.1581	0.0839	0.0258	0.0181	0.0000	4.737	(11.8)	4.958	(9.6)
1999	2.4981	1.2990	1.1923	0.5449	0.1790	0.0686	0.0040	0.0000	0.0000	3.648	(14.8)	6.154	(20.0)
2000	0.5037	3.6025	2.0934	0.6905	0.3064	0.0994	0.0425	0.0418	0.0539	6.800	(11.8)	7.569	(11.2)
2001	0.2809	0.9877	2.0550	1.7167	0.3762	0.1513	0.0807	0.0000	0.0000	7.852	(10.5)	5.704	(11.3)
2002	1.1791	0.7503	1.0023	1.0124	0.1883	0.0744	0.0365	0.0000	0.0141	6.720	(16.3)	6.861	(25.3)
2003	**1.1062**	**0.7510**	**0.9807**	**0.6469**	**0.1889**	**0.1391**	**0.0468**	**0.0040**	**0.0008**	4.531	(17.1)	4.031	(14.7)
2004	0.5837	1.4422	0.6900	0.4022	0.1763	0.1647	0.0160	0.0076	0.0201	3.695	(15.4)	3.550	(13.1)
2005	**0.7024**	**1.0585**	**0.8488**	**0.4992**	**0.2320**	**0.0643**	**0.0218**	**0.0158**	**0.0134**	3.837	(15.8)	3.585	(13.3)
2006	**0.6905**	**2.2920**	**0.9503**	**0.4448**	**0.1860**	**0.0613**	**0.0199**	**0.0048**	**0.0194**	4.272	(11.1)	4.751	(9.9)
2007	**0.4585**	**1.8082**	**2.9736**	**1.0390**	**0.1509**	**0.0462**	**0.0030**	**0.0008**	**0.0382**	7.222	(15.0)	6.636	(12.5)
2008	0.8485	1.5986	2.0292	0.9903	0.1900	0.0872	0.0815	0.0455	0.0201	7.056	(16.6)	7.345	(13.5)
2009	**0.9492**	**1.7533**	**1.7027**	**0.5845**	**0.1229**	**0.0450**	**0.0162**	**0.0033**	**0.0020**	4.760	(15.2)	5.327	(12.3)
2010	1.6021	2.6998	1.9203	0.6548	0.1672	0.0581	0.0100	0.0139	0.0111	7.854	(17.0)	7.951	(13.5)
2011	0.6251	2.1497	2.0349	1.1169	0.4062	0.1619	0.0590	0.0341	0.0178	9.020	(16.8)	6.945	(13.6)

Table A2.7: Percentage of mature females for each age for the Georges Bank/Gulf of Maine white hake stock.

1	2	3	4	5	6	7	8	9+
0.058	0.268	0.683	0.927	0.987	0.998	1.000	1.000	1.000

Appendix A3

Bridge-building - the data effect

To understand how the data changes and additions impact the assessment, a bridge has been constructed to transition from the Georges Bank/Gulf of Maine white hake GARM III assessment to the corresponding assessment with updated data through 2011.

Spawning biomass, fishing proportion and recruitment trajectories are shown in Fig. A3.1 for the following runs:

a. "2007": GARM III SCAA assessment,

With updated commercial data through 2007:

b. "2007 - new catches": as above, with updated annual catches,

c. "2007 - new catches + comm CAA": as above, with updated commercial catches-at-age,

d. "2007 - new catches + comm CAA + comm WAA": as above, with updated catch mean weight-at-age,

With updated survey data through 2007:

e. "2007 - new indices": GARM III SCAA assessment with updated NEFSC survey indices,

f. "2007 - new indices + CAA (same yr)": as above with updated survey catch-at-age data for the same years as used for the GARM III SCAA assessment,

g. "2007 - new indices + CAA": as above, but also including further years of survey catch-at-age data.

With all updated data through 2007:

h. "2007 - new data": all updated commercial and survey data,

With all updated data through 2011:

i. "2011 - new data": including data through 2011.

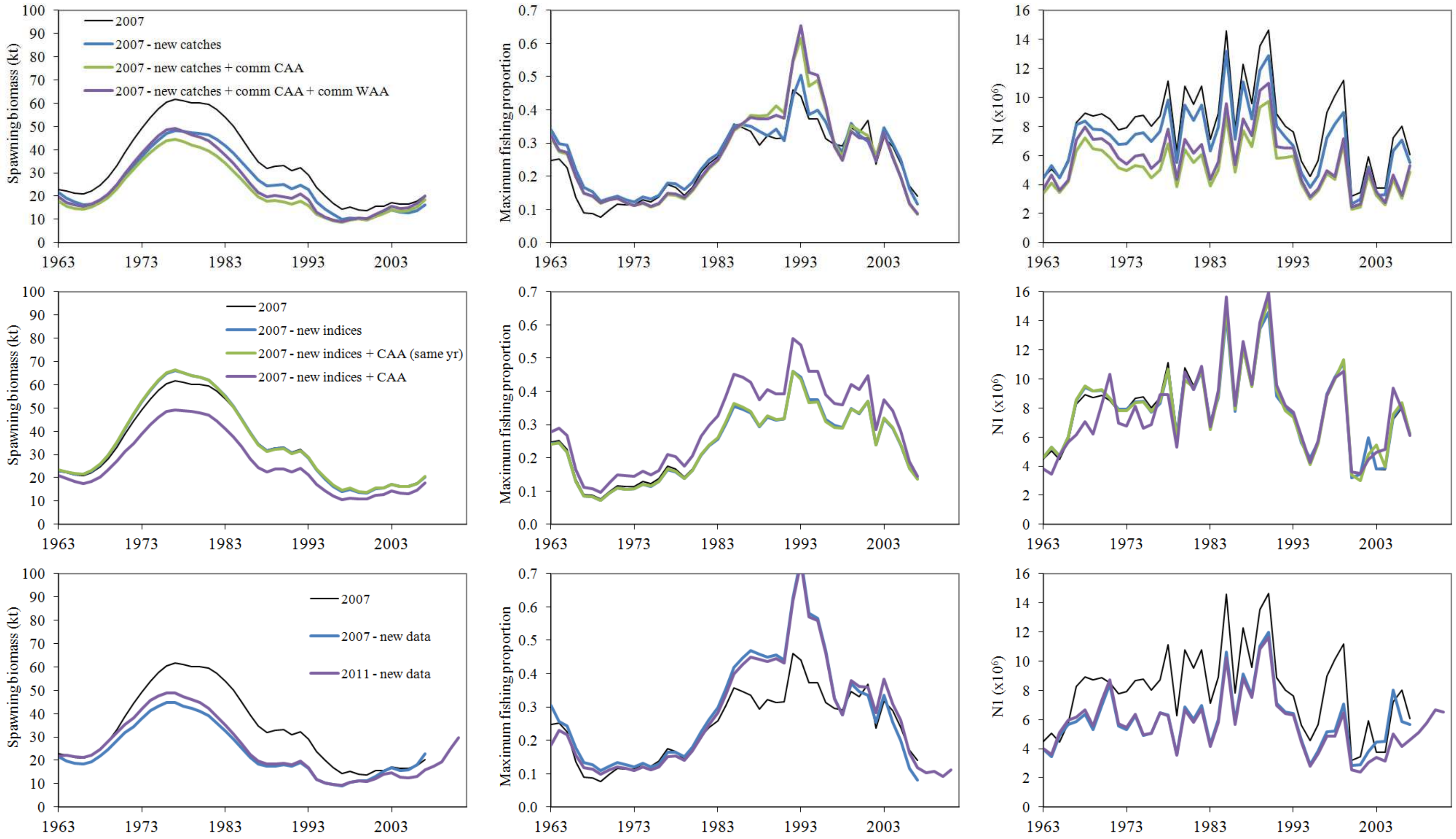

Fig. A3.1: Spawning biomass, maximum fishing proportion and recruitment (N1) trajectories.

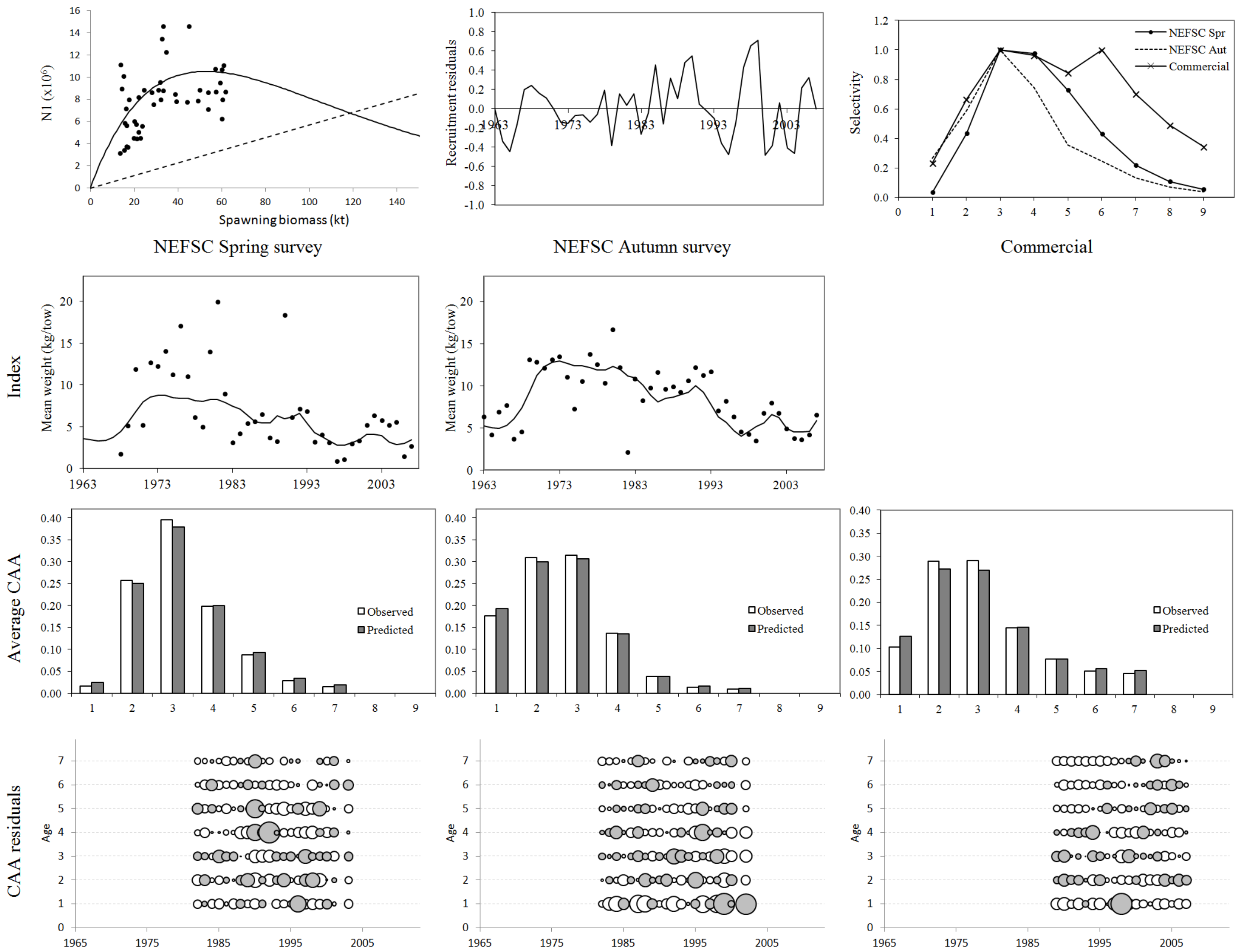

Fig. A3.2: Results for the "2007" white hake assessment.

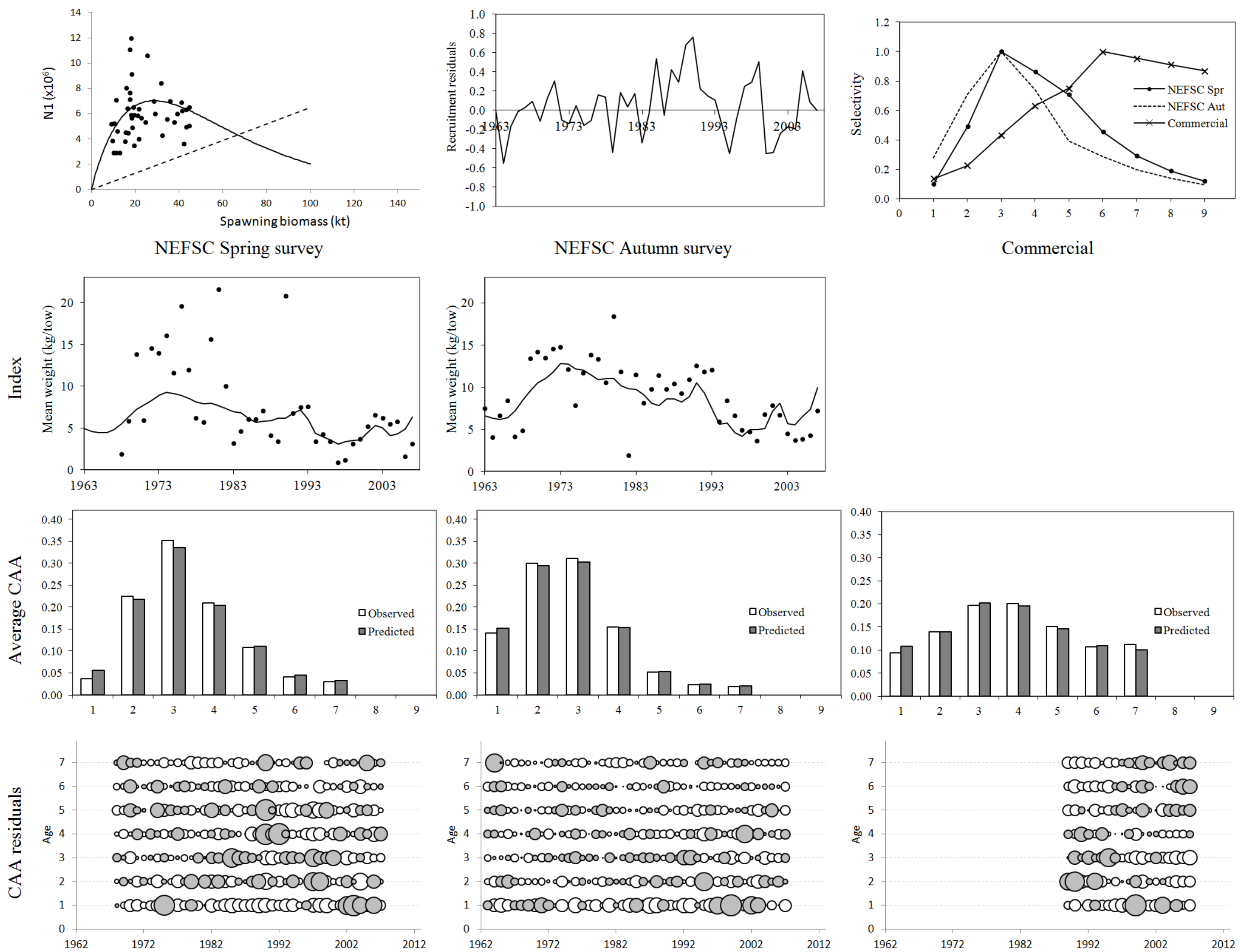

Fig. A3.3: Results for the "2007 - new data" white hake assessment.

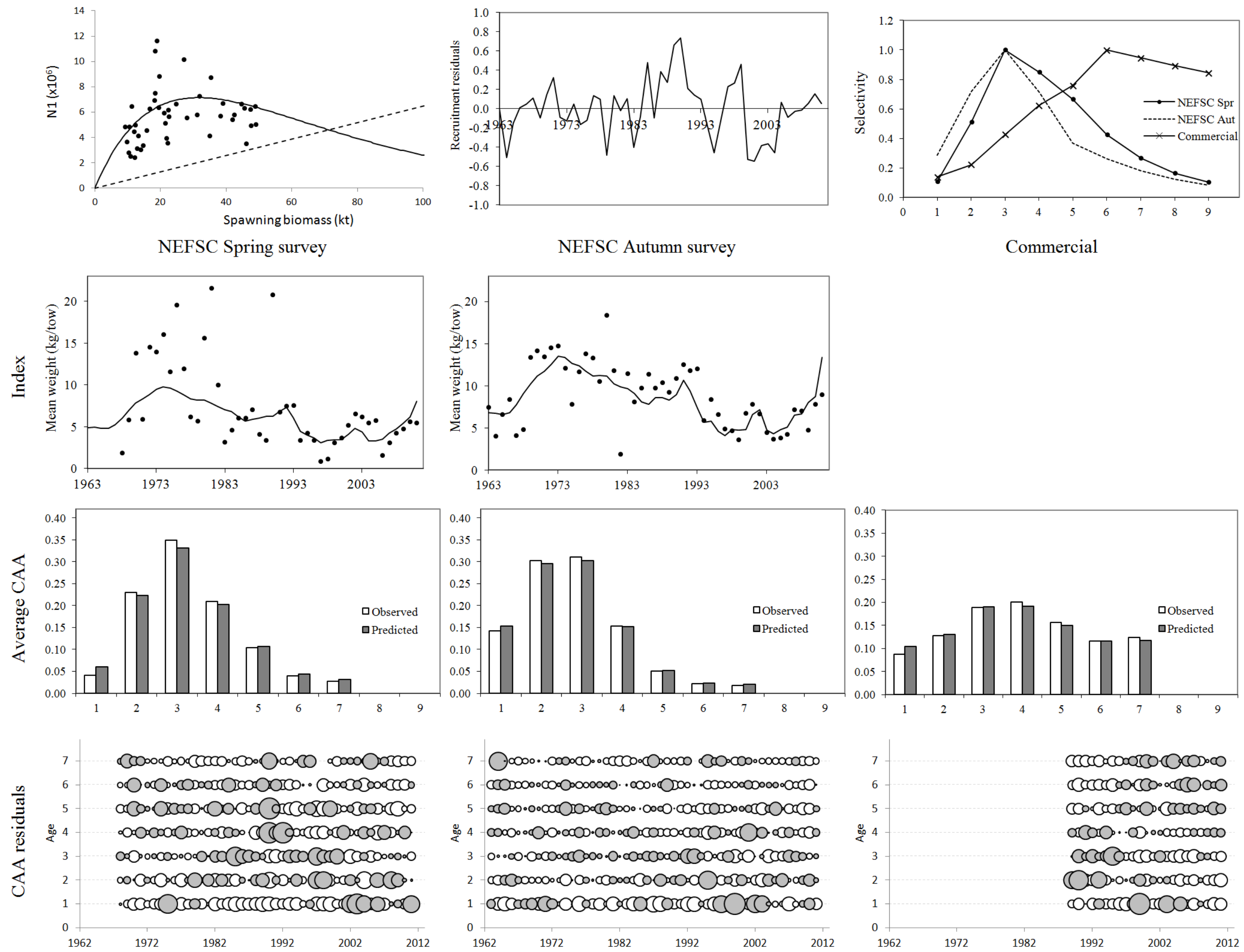

Fig. A3.4: Results for the "2011 - new data" white hake assessment.