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SCAA/ASPM Assessments of White Hake
Incorporating Data to 2007

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ABSTRACT

The preliminary SCAA/ASPM assessment of white hake presented to the previous GARM meeting is refined and updated, being advantaged by the greater availability of catch-at age information for the surveys and now also for commercial catches. Six assessment variants are presented, which reflect whether or not to take survey catch-at-length information into account in fitting the assessment models, whether to use a Ricker or a Beverton-Holt form for the stock-recruitment relationship, and whether or not to constrain the multiplicative bias factor for the autumn NEFSC survey swept-area estimates of biomass to preclude the possibility of herding. Imposing this last constraint leads to an appreciable deterioration in the overall likelihood of the model; the likelihood also indicates a slight preference for the Ricker over the Beverton-Holt form. Inclusion of the survey catch-at-length data in the likelihood leads to a considerable improvement in estimation precision, but also shows a marked overestimate by the model of the proportion of white hake of 20 cm and less in the autumn NEFSC surveys. Both variants are put forward as candidates to provide the basis for scientific management advice. The variant which includes the catch-at-length information reflects lesser abundance in absolute terms, a greater retrospective pattern, but also current abundance at a greater proportion of the MSY level, when compared to its counterpart. The estimation of current resource status in relation to the MSY level is critically dependent on the determination of the parameters which specify the starting (1963) numbers-at-age vector for the assessment.[1]

REFERENCE POINT SUMMARY

	Survey catch-at-length data		
	Included		Excluded
$B^{sp}{}_{2007}$	14	-	20
$B^{*sp}{}_{MSY}$	28	-	52
$B^{sp}{}_{2007}/ B^{*sp}{}_{MSY}$	0.50	-	0.38
F_{2007}	0.15	-	0.15
F_{MSY}	0.24	-	0.19

Note: Biomass units are '000 tons; F refers to age 6 where the commercial selectivity peaks; the * indicates that the deterministic estimate of $B^{sp}{}_{MSY}$ has been adjusted for the bias associated with the lognormal variability of recruitment about the Ricker stock-recruitment curve to which these results correspond.

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[1] F_{rebuild} -related statistics indicated in Table 3 have yet to be computed; this paper will be updated later to include these. The MSY and $B^{sp}{}_{MSY}$ proxy values related to $F_{40\%}$ also require recomputation to allow for indications of lower estimated recruitments at lower spawning biomasses for the assessments which exclude the catch-at-length data (see Fig. 3).

INTRODUCTION

This paper refines the initial SCAA/ASPM assessments of white hake reported to the previous GARM meeting (Butterworth and Rademeyer 2008a) by making use of updated data kindly provided by Katherine Sosebee (NEFSC). These data not only extend to a further year (2007), but also are a substantial advance on those previously available in that catch-at-age in addition to catch-at-length information is provided for the commercial catches and more of the surveys.

Because the assessments commence in 1963, specification/estimation is required of the parameters that specify the starting numbers-at-age, namely θ which is the ratio of the starting spawning biomass B^{sp} to that for the pristine resource K^{sp}, and ϕ which effectively specifies the extent to which the mean Z reflected by the starting age-structure of the population exceeds M (for full details, see Butterworth and Rademeyer (2008b), equations A.2.13 and 14) (see Table 1 for a full list of the symbols used in this paper, together with their definitions). Because information on catches prior to 1963 (Sosebee 2008) suggests relatively heavy exploitation of white hake in those earlier years, one cannot assume that the resource was at or very near to K^{sp} at that time, and as estimates of key management-related parameters prove to be quite sensitive to starting conditions, careful consideration is first given to this aspect of the assessment.

DATA AND METHODOLOGY

The data used for the assessments reported in this paper are as kindly provided by Katherine Sosebee (NEFSC) for the period 1963-2007. Catch-at-age information is provided for the commercial catches during the 1989 to 2007 period. For the surveys, catch-at-age information is available for the years 1982 to 2003/2002 (for the spring and autumn surveys respectively), with survey catch-at-length data being available for the remaining years. The plus-group for the age data fitted by the assessment model is 7+, though within the model itself, the age structure is taken to age 9+.

The SCAA/ASPM methodology applied is as specified in Appendix 2 of Butterworth and Rademeyer (2008b), augmented by the procedure to incorporate catch-at-length data in the likelihood that is detailed in Butterworth and Rademeyer (2008a). This procedure requires a value for the parameter β which relates to the width of the distribution of length at age about its expected value (see equation 3 of Butterworth and Rademeyer, 2008a). Since there appears to be insufficient information in the data to be able to satisfactorily treat this as an estimable parameter when fitting the assessment model, β was fixed to 0.15 for all computations. For obvious reasons, for years for which catch-at-age data are included in the likelihood, the corresponding catch-at-length data are omitted.

Table 2 shows results for what is subsequently adopted as a Reference Case assessment, and denoted by "A1", for three fixed values of each of θ and ϕ, as well at the best estimate of θ for each of these ϕ values. These results suggest that it is reasonable to estimate θ ; however ϕ is somewhat less well determined, though the highest value of 0.4 considered does show some deterioration in fits to the data. The decision was made to fix $\phi = 0.2$, noting that any bias introduced by this choice would tend to err on the conservative side in terms of the current status of the resource relative to its spawning biomass at MSY.

The results presented focus on three factors found to be particularly influential in relation to key results:

a) the shape of the stock-recruitment relationship (specifically here Ricker *vs* Beverton-Holt);
b) whether or not the survey catch-at-length data for years for which survey catch-at-age data are not available are included in the likelihood; and
c) whether free estimation of the multiplicative bias of the surveys (q) should be admitted, or rather a constraint applied that precludes the possibility of herding by the survey gear.

The possibility of forcing survey selectivity to be flat rather than domed was investigated, but goodness-of-fit deteriorated considerably. Allowing for the possibility of the assumed value of M of 0.2 yr^{-1} to increase at larger ages proved not to be justified in terms of AIC. Accordingly no further details of these sensitivity tests are reported below.

RESULTS

Table 3 lists the results obtained for the six assessments considered. Assessments A1 and A2 are for a Ricker stock-recruitment function and respectively include or exclude the catch-at-length data. Assessments B1 and B2 are corresponding cases with the Ricker replaced by the Beverton-Holt functional form. Calculations of BRP's (such as B^{*sp}_{MSY}) are based upon use of average values over 2003-2007 for weight-, fecundity- and selectivity-at-age.

For these assessments, parameters related to the multiplicative bias of the surveys (q) and the slopes of the selectivities-at-age for older ages were treated as freely estimable parameters (except that these slope parameters were constrained to preclude increases). However for the Autumn survey, q is always estimated to be well above 1 (and statistically significantly so in terms of the associated Hessian-based CV estimates in Table 3). This suggests considerable herding of hake by the gear for ages 3-5 by the survey gear, which is somewhat surprising given the sharp drop of estimated survey selectivity at higher and lower ages (see Fig. 2). For this reason, assessments C1 and C2 were also conducted; these have the same specifications as the A1 and A2 assessments, but add the constraint that q_autumn = 1.

For all six assessments B^{sp}_{2007} is estimated to be below B^{sp}_{MSY} . Their ratio increases as the Beverton-Holt form for the stock-recruitment function is changed to Ricker (B→A), then further as catch-at-length data are included in the likelihood (2→1), and further still if q_autumn is set to 1 (A→C).

Fig. 1 compares estimated spawning biomass trajectories for all six assessments, while Fig. 2 shows the selectivities-at-age and the fits to the abundance indices, and catch-at-age (and where relevant catch-at-length) proportions data for the surveys and the commercial fishery. In the interests of brevity, Fig. 2 is restricted to the A1 and A2 assessments, which for reasons given in the next section are selected as Reference cases. Fig. 3 shows fitted stock-recruitment curves for all four A and B assessments, while Fig. 4 gives results for retrospective analyses for the two Reference cases; there is a retrospective pattern (a tendency to over-estimate recent biomass), which is more marked for the A1 assessment which includes the catch-at-length data.

DISCUSSION

Comparison of the –lnL contributions for assessments A and C in Table 3 shows that the reasons that unconstrained fits to the data prefer a higher value for *q*_autumn are complex, with the fits to some components of the data improving and to others deteriorating (and differently so if the catch-at-length data are omitted when fitting the model) when this parameter is fixed at 1. Overall the log-likelihood deteriorates by some 14 units when *q*_autumn is fixed in this way.

There is very little to distinguish the Ricker and Beverton-Holt forms for the stock-recruitment function in terms of goodness of fit. The preference for Ricker on this basis is marginal, but it is also clear from Fig. 3 that the data provide little basis to constrain the asymptotic recruitment level for the Beverton-Holt form for assessment B2 which ignores the catch-at length data (hence the high K^{sp} estimate for this case). Further, if the shape parameter γ of the generalised Ricker form is estimated, the results (0.79 for A1 and 1.42 for A2) are close to the γ=1 of the standard Ricker form, and the Hessian-based CV's for $B^{sp}{}_{2007}/\ B^{*sp}{}_{MSY}$ do not increase greatly. For these reasons the Ricker form has been preferred for the Reference case.

Two features stand out when comparing the results for the two options for this Reference case (assessments A1 and A2). First it is evident from Table 3 that inclusion of the catch-at length data in the fit leads to an improvement in precision that is quite appreciable for some quantities (a doubling for K^{sp}, for example). On the other hand, Fig. 2a for the assessment which does include these data shows marked model mis-specification in one respect: the fit to the NEFSC Autumn survey catches-at-length is rather poor, with an average over 14% of the fish caught predicted to fall in the length group of 20 cm or below, but the corresponding observations averaging only 1%. Against this, inclusion of these data leads to a better fit to the commercial catch-at-age data, but also to a deterioration in the fit to the survey catch-at-age data. This indicates some conflict amongst the different sources of data and the model, which possibly could be resolved by adjustments to the manner in which the length distribution for hake of ages 1 and 2 caught (which may also be influenced by gear features or the behavioural patterns of small white hake) is modelled. A choice between these two assessment options depends on the relative importance attached to these various features. Hence we have left this aspect open by putting forward both as candidates for discussion as a basis for management recommendations.

Since survey indices show recent values similar to those in 1960s (see Fig. 2), it is not surprising that the assessment results for spawning biomass trajectories shown in Fig 1 indicate at the value of B^{sp} at present is similar to that in the 1960's. This in turn demonstrates that the determination of the values of the parameters, particularly θ, which specify the starting numbers-at-age vector for an assessment is critical to estimation of the current status of this resource relative to its MSY level.

ACKNOWLEDGMENTS

We thank Katherine Sosebee (NEFSC) for provision of the data upon which the analyses reported in this paper are based. Financial support by the Associated Fisheries of Maine is acknowledged.

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Table 1: Definitions of symbols used in presenting results (the order follows that used for Table 3). Unless otherwise indicated biomasses are "deterministic", i.e. as estimated in the model fit, prior to any bias adjustment for recruitment variability.

'-lnL:overall	Total negative log-likelihood
-lnL:Survey/CAAcom/CAAsurv /CALsurv/RecRes	Contributed to -lnL from survey indices/survey catch-at-age proportions/survey catch-at-length proportions/commercial catch-at-age proportions/ recruitment residuals
h	Stock recruitment curve steepness
γ	Parameter of generalised Ricker S/R function (γ=1 for Ricker)
θ	B^{sp}/K^{sp} for starting year
ϕ	$Z_a \approx M_a + \phi$ for starting year
K^{sp}	Pristine spawning biomass
$B^{sp}{}_{2007}$	Spawning biomass in 2007
MSYL^{sp}	$B^{sp}{}_{\text{MSY}}/K^{sp}$
$B^{sp}{}_{\text{MSY}}$	Spawning biomass at MSY
$B^{*sp}{}_{\text{MSY}}$	Spawning biomass at MSY adjusted for recruitment variability by multiplying by $\exp(-\sigma_R\text{out}^2/2)$
MSY	Maximum sustainable yield
MSY*	MSY adjusted for recruitment variability as above
F_{MSY}	Fishing mortality rate (F) at MSY (corresponds to F at the age at which commercial selectivity = 1)
$F_{rebuild}$	F to achieve 50% probability that B^{sp} recovers to $B^{*sp}{}_{\text{MSY}}$ by 2014
F_{2007}	F for year 2007
F_{2007} (av ages 4-5)	Average of F on ages 4 and 5 in 2007
$F_{40\%}$	F at which B^{sp}/R (R = recruitment) equals 40% of its value when F=0
$B^{*sp}{}_{\text{MSY}}$_40%	Spawning biomass corresponding to $F_{40\%}$; evaluated as $(B^{sp}/R$ for $F_{40\%})\overline{R}$ where $\overline{R}$ is average of recruitment estimates
MSY*_40%	MSY corresponding to $F_{40\%}$; evaluated as (Y/R for $F_{40\%})\overline{R}$; shown with * as based on average over fluctuations
C_{2008}	Catch in 2008, assumed equal to 2007 catch
C_{2009} (F_{MSY})	Projected 2009 catch under F_{MSY}
C_{2009} ($F_{\text{status quo}}$)	Projected 2009 catch under $F_{2009}=F_{2008}$
C_{2009} (F_{rebuild})	Projected 2009 catch under $F_{rebuild}$
q spring/autumn	Multiplicative bias for spring/autumn NEFSC survey swept-area-based biomass estimate relative to actual survey selectivity-at-age weighted biomass
Slope_com/surv 6/7	Selectivity slope given by $S_7 = e^{-Slope} S_6$
$\sigma_R$out	Standard deviation of distribution of logs of multiplicative recruitment residuals about estimated S/R relationship
$M1/M9+$	Natural mortality rate for age 1/9+

Table 2: Overall negative log-likelihood and current spawning biomass relative to B^{*sp}_{MSY} for a series of θ and ϕ values for assessment A1. For the final column, θ is estimated rather than fixed.

$\phi = 0.1$	θ	0.15	0.25	0.35	0.40
	'-lnL:overall	15.5	10.0	6.8	6.5
	$B^{sp}{}_{2007}/B^{sp}{}_{MSY}$	0.18	0.34	0.48	0.53
$\phi = 0.2$	θ	0.15	0.25	0.35	0.26
	'-lnL:overall	12.9	8.3	9.9	8.3
	$B^{sp}{}_{2007}/B^{sp}{}_{MSY}$	0.27	0.48	0.60	0.50
$\phi = 0.4$	θ	0.15	0.25	0.35	0.16
	'-lnL:overall	14.4	19.4	28.8	14.3
	$B^{sp}{}_{2007}/B^{sp}{}_{MSY}$	0.46	0.67	0.82	0.49

Table 3: Estimates of management quantities for the white hake. The symbols are defined in Table 1. Values in bold are inputs, and those in parentheses are Hessian based CV's. Mass units are '000 tons.

	Reference Case1		Reference Case2		Beverton-Holt		Beverton-Holt		q Aut=1		q Aut=1	
	Domed survey sel		Domed survey sel		Domed survey sel		Domed survey sel		Domed survey sel		Domed survey sel	
	with survey CAL		without survey CAL		with survey CAL		without survey CAL		with survey CAL		without survey CAL	
	A1		A2		B1		B2		C1		C2	
'-lnL:overall	8.3		-100.8		9.0		-100.6		23.2		-86.1	
'-lnL:Survey	-30.0		-32.2		-29.4		-32.1		-19.5		-29.5	
'-lnL:CAAcom	-13.4		-10.8		-13.4		-10.7		-10.8		-2.8	
'-lnL:CAAsurv	-52.0		-66.2		-51.9		-66.4		-41.2		-62.2	
'-lnL:CALsurv	89.5		-		88.9		-		86.1		-	
'-lnL:RecRes	14.2		8.4		14.8		8.5		8.6		8.5	
h	2.28	(0.17)	1.24	(0.27)	0.98*	-	0.76	(0.14)	1.38	(0.19)	0.60	(0.25)
γ	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**	-
θ	0.26	(0.16)	0.19	(0.23)	0.12	(0.20)	0.10	(0.33)	0.31	(0.18)	0.25	(0.29)
ϕ	**0.20**	-	**0.20**	-	**0.20**	-	**0.20**	-	**0.20**	-	**0.20**	-
K^{sp}	62.0	(0.16)	116.5	(0.32)	140.6	(0.09)	243.0	(0.35)	118.8	(0.16)	286.0	(0.32)
B^{sp}_{2007}	13.8	(0.26)	19.8	(0.31)	15.4	(0.24)	20.4	(0.30)	36.1	(0.19)	87.2	(0.18)
B^{sp}_{2007}/K^{sp}	0.22	(0.25)	0.17	(0.28)	0.11	(0.23)	0.08	(0.38)	0.30	(0.24)	0.30	(0.34)
$MSYL^{sp}$	0.41	(0.13)	0.42	(0.15)	0.27	(0.11)	0.31	(0.10)	0.41	(0.15)	0.45	(0.28)
B^{sp}_{MSY}	25.6	(0.18)	49.1	(0.23)	38.6	(0.17)	76.5	(0.30)	48.4	(0.12)	128.4	(0.15)
B^{*sp}_{MSY}	27.7	(0.18)	51.5	(0.23)	42.0	(0.17)	80.3	(0.30)	50.9	(0.12)	134.8	(0.15)
$B^{sp}_{2007}/B^{*sp}_{MSY}$	0.50	(0.25)	0.38	(0.24)	0.37	(0.23)	0.25	(0.32)	0.71	(0.21)	0.65	(0.22)
MSY	8.1	(0.07)	8.1	(0.12)	7.5	(0.09)	8.6	(0.22)	8.2	(0.09)	7.6	(0.14)
MSY^*	8.8	(0.07)	8.5	(0.12)	8.2	(0.09)	9.0	(0.22)	8.6	(0.09)	8.0	(0.14)
F_{MSY}	0.24	(0.00)	0.19	(0.00)	0.16	(0.00)	0.14	(0.00)	0.22	(0.00)	0.13	(0.00)
$F_{rebuild}$												
F_{2007}	0.15	(0.26)	0.15	(0.21)	0.14	(0.22)	0.15	(0.21)	0.10	(0.23)	0.08	(0.19)
F_{2007} (av ages 4-5)	0.13	(0.24)	0.14	(0.22)	0.12	(0.21)	0.14	(0.22)	0.09	(0.22)	0.06	(0.20)
$F_{40\%}$	0.10	(0.00)	0.13	(0.00)	0.11	(0.00)	0.13	(0.00)	0.14	(0.00)	0.16	(0.00)
$B^{*sp}_{MSY\_40\%}$	52.0	(0.13)	56.3	(0.15)	52.6	(0.12)	56.7	(0.14)	65.7	(0.08)	90.0	(0.08)
$MSY^*\_40\%$	6.9	(0.08)	5.8	(0.04)	6.8	(0.06)	5.8	(0.03)	6.1	(0.03)	6.8	(0.05)
C_{2008}	**2.2**	-	**2.2**	-	**2.2**	-	**2.2**	-	**2.2**	-	**2.2**	-
C_{2009} (F_{MSY})	6.7	(0.25)	4.9	(0.22)	4.9	(0.20)	3.7	(0.22)	8.6	(0.23)	5.8	(0.20)
C_{2009} ($F_{status\ quo}$)	2.8	(0.03)	2.7	(0.04)	2.8	(0.03)	2.7	(0.04)	2.7	(0.03)	2.6	(0.05)
C_{2009} ($F_{rebuild}$)												
q spring	1.04	(0.09)	1.09	(0.10)	1.02	(0.08)	1.08	(0.10)	0.78	(0.09)	0.64	(0.09)
q autumn	1.73	(0.08)	1.98	(0.10)	1.70	(0.08)	1.97	(0.10)	1.00	(0.01)	1.00	(0.01)
Slope_com 6/7	0.01	(0.15^+)	0.35	(0.50)	0.07	(0.13^+)	0.37	(0.45)	0.54	(0.20)	0.96	(0.10)
Slope_surv 6/7	0.42	(0.38)	0.69	(0.25)	0.43	(0.36)	0.69	(0.25)	0.68	(0.19)	0.89	(0.18)
$\sigma_R$out	0.40	(0.09)	0.31	(0.10)	0.41	(0.08)	0.31	(0.10)	0.31	(0.08)	0.31	(0.11)
M1	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M2	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M3	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M4	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M5	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M6	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M7	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M8	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	
M9+	**0.20**		**0.20**		**0.20**		**0.20**		**0.20**		**0.20**	

* Constraint boundary

$^+$ Hessian standard error instead of Hessian CV

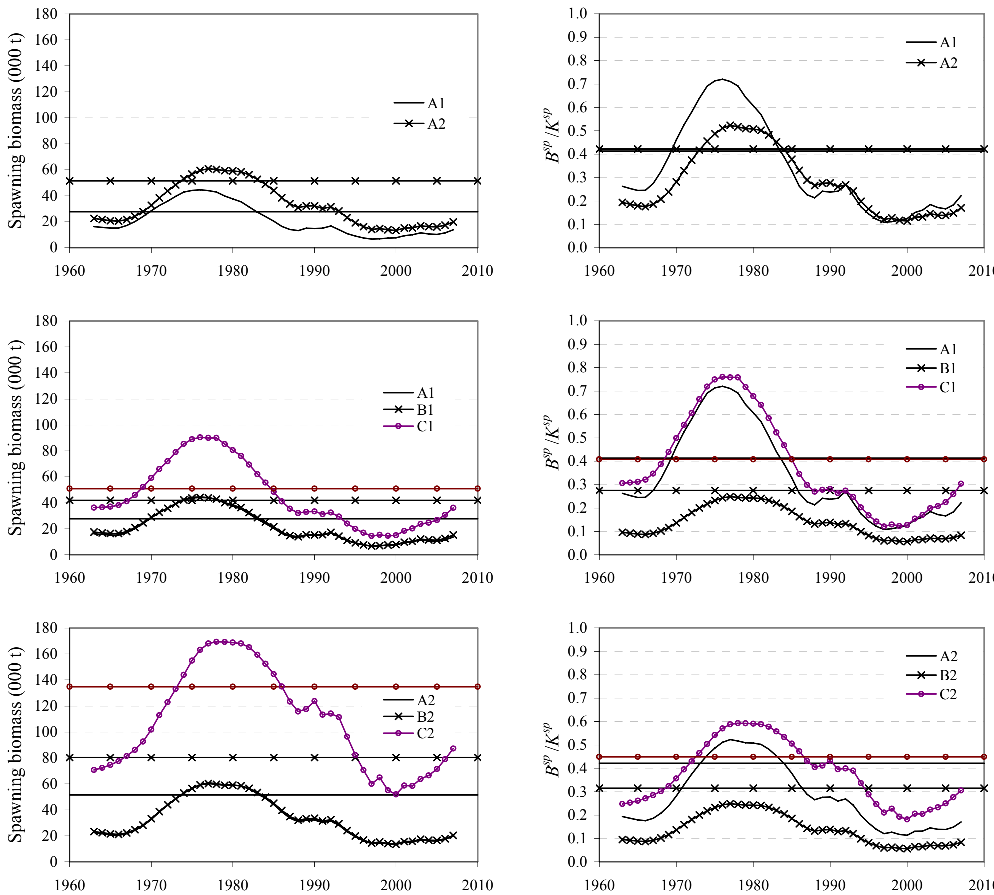

Fig. 1: Spawning biomass trajectories (in absolute terms and in terms of pre-exploitation level) for a series of assessments of white hake. The estimated B^{*sp}_{MSY} and MSYL are also shown.

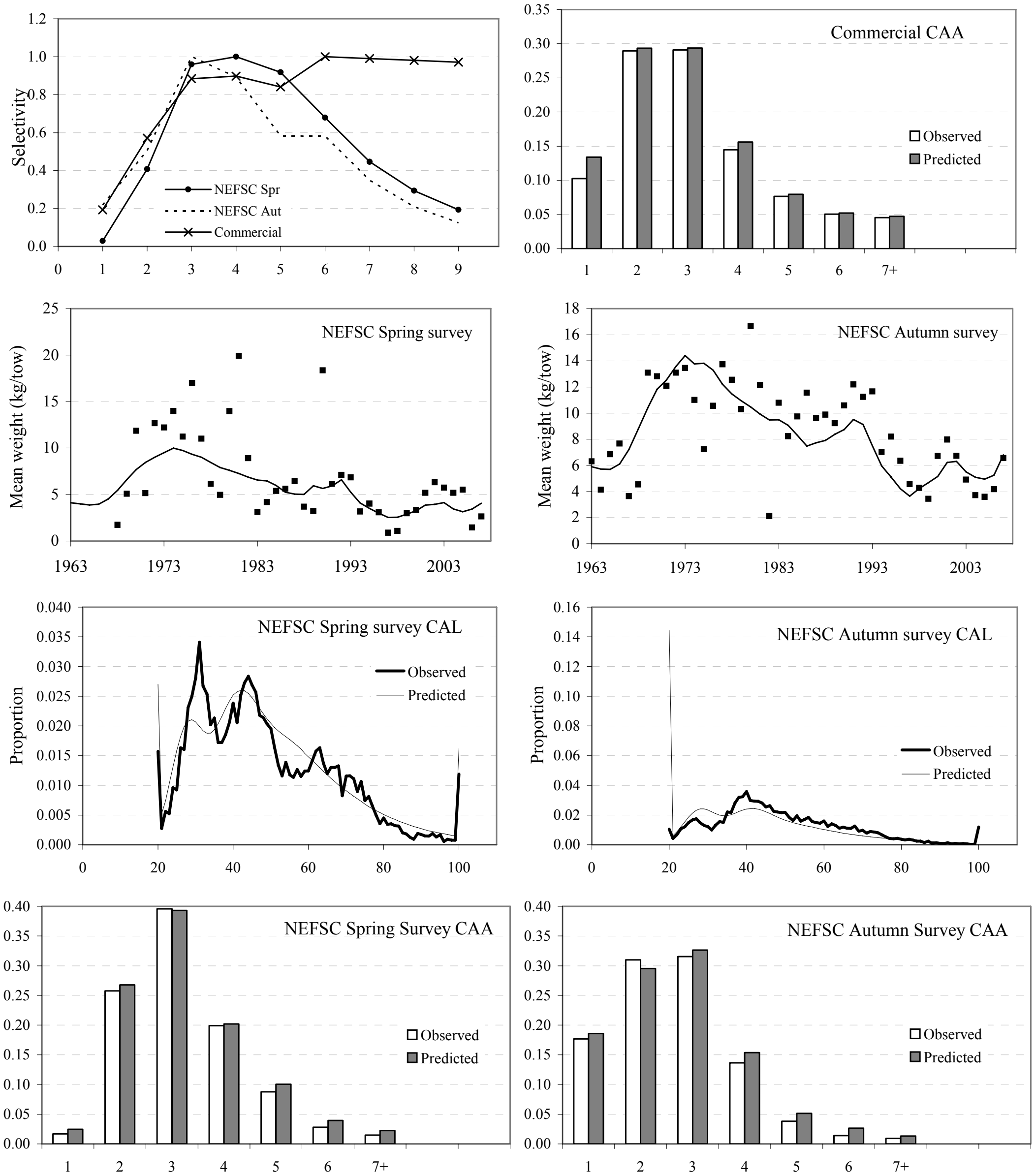

Fig. 2a: Estimates of selectivity-at-age and fits to the data for assessment A1.

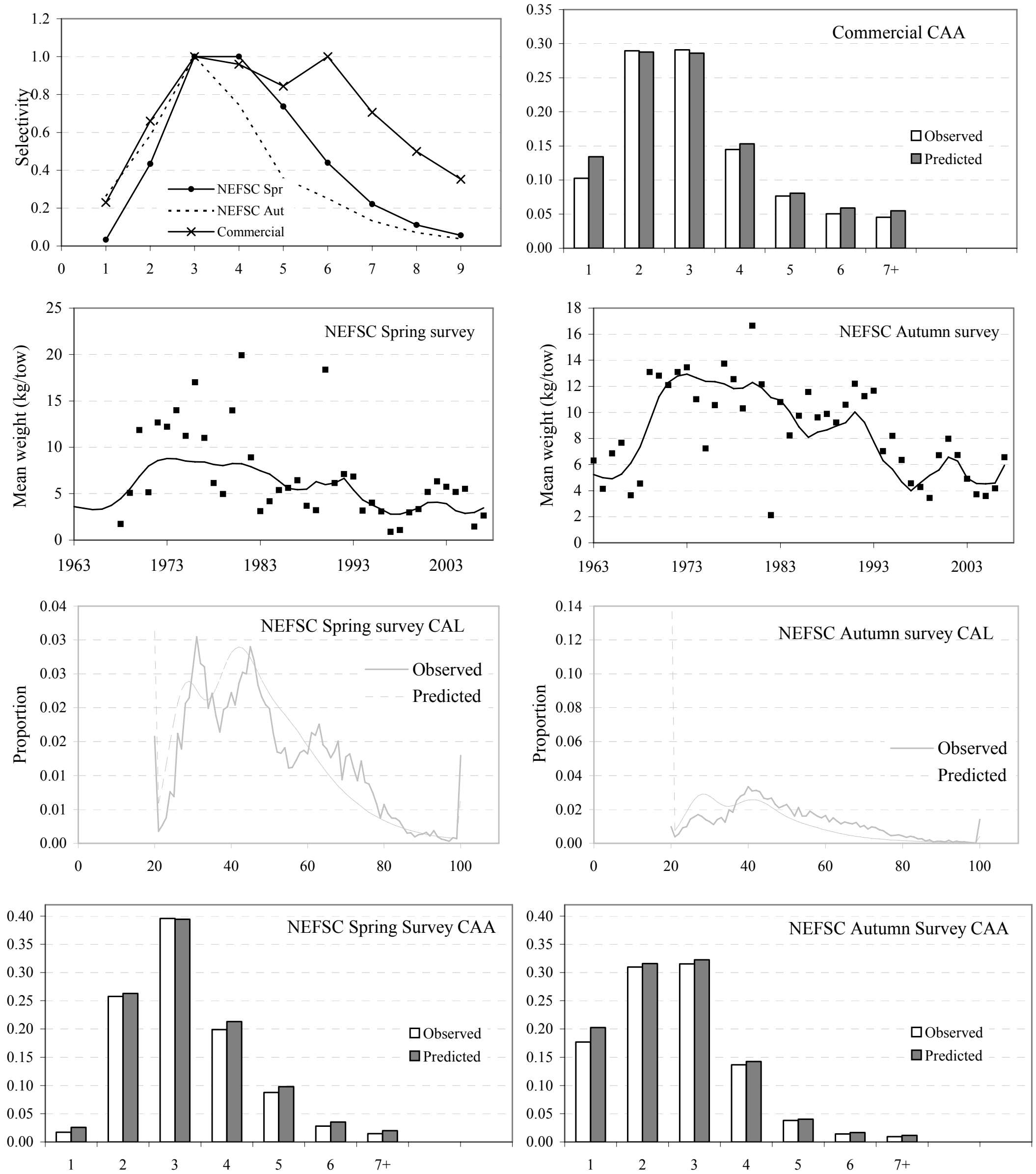

Fig. 2b: Estimates of selectivity-at-age and fits to the data for assessment A2 (this is not fitted to survey CAL, but the associated model predictions are nevertheless shown).

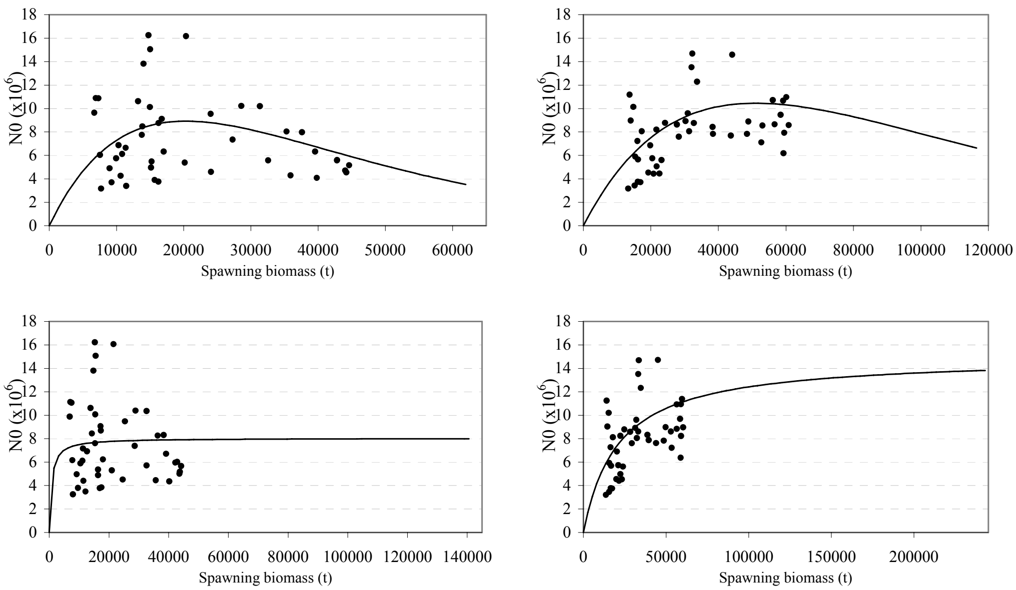

Fig 3: The estimated stock-recruitment curve and estimated recruitment and spawning biomass each year for assessments A1/A2 (Ricker – top left/right and B1/B2 (Beverton-Holt – bottom left/right). Note the different scales for the horizontal axes.

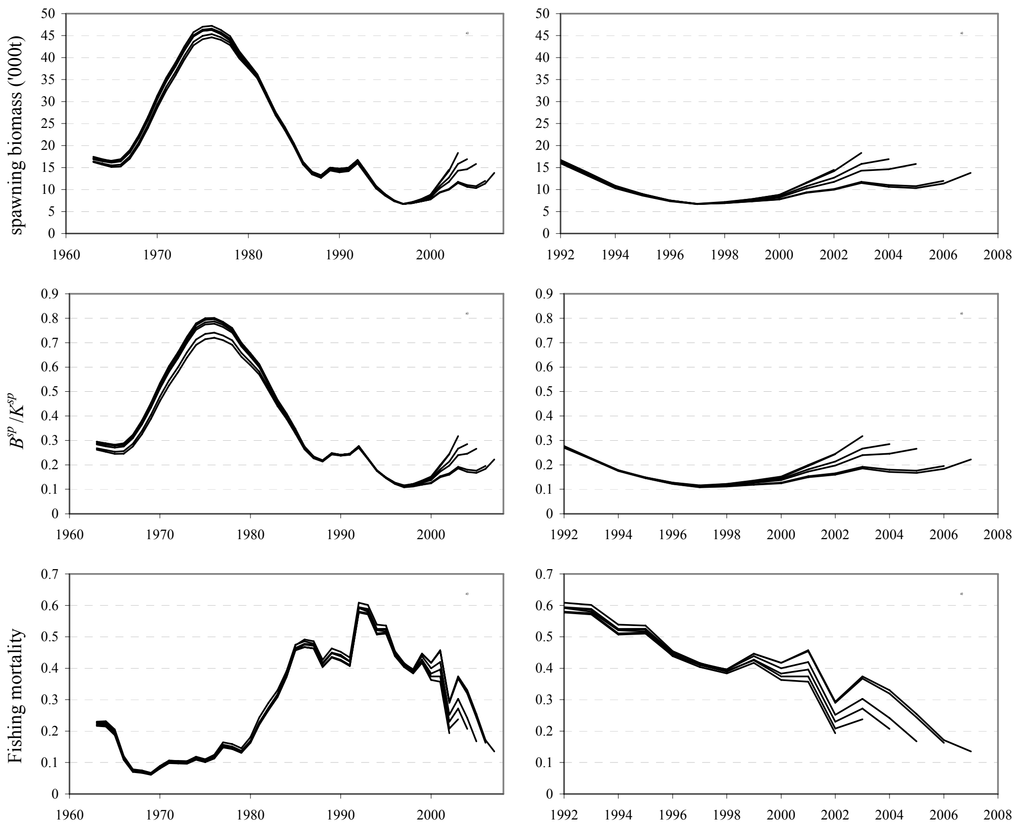

Fig. 4a: Retrospective analysis of white hake for assessment A1 for spawning biomass (in absolute terms, top panels, and relative to pre-exploitation levels, middle panels) and fully selected fishing mortality (lower panels).

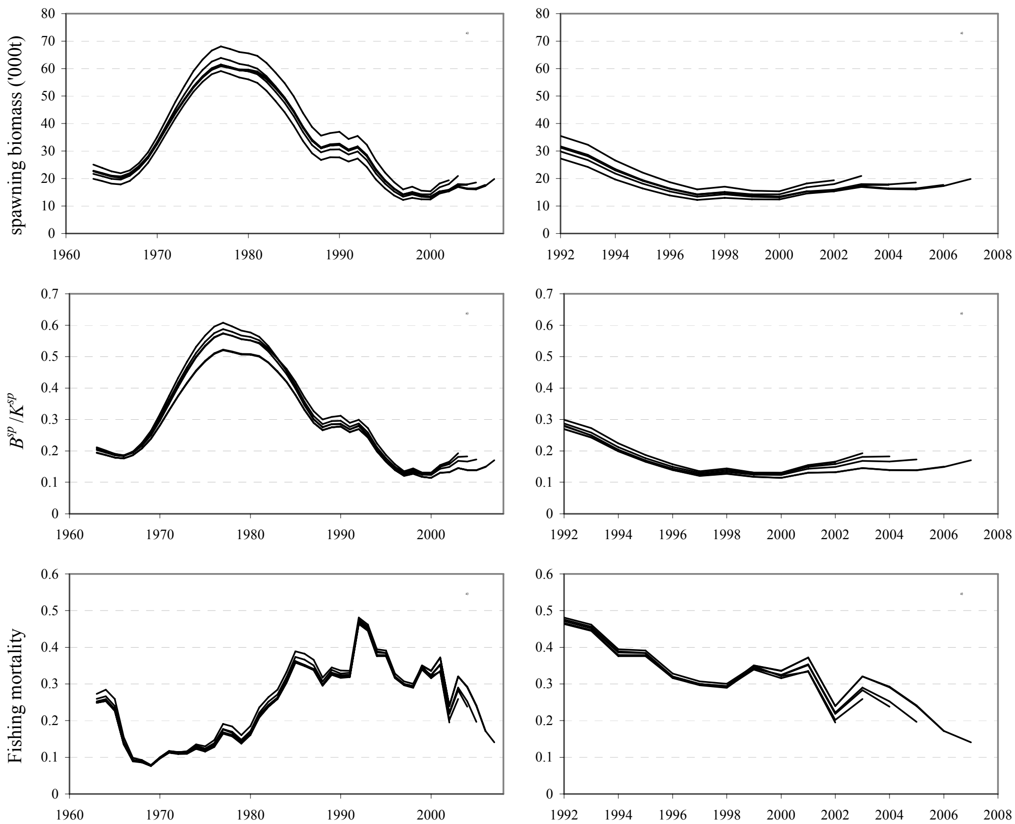

Fig. 4b: Retrospective analysis of white hake for assessment A2 for spawning biomass (in absolute terms, top panels, and relative to pre-exploitation levels, middle panels) and fully selected fishing mortality (lower panels).