New Zealand Fisheries
Assessment Report
2008/4
January 2008
ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2008/4
January 2008

Published by Ministry of Fisheries
Wellington
2008

ISSN 1175-1584

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Ministry of Fisheries
2008

Citation:
Francis, R.I.C.C. (2008).
Assessment of hoki (*Macruronus novaezelandiae*) in 2007.
New Zealand Fisheries Assessment Report 2008/4. 109 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Francis, R.I.C.C. (2008). Assessment of hoki (*Macruronus novaezelandiae*) in 2007. *New Zealand Fisheries Assessment Report 2008/4.* 109 p.

A new assessment is presented for hoki. This is similar to the 2006 assessment in using the same program (CASAL), stock structure (two stocks in four fishing grounds), and estimation procedure (Bayesian with lognormal errors, including a distinction between observation and process errors). Three data types were used: biomass indices (from trawl and acoustic surveys), proportions at age and sex (from trawl surveys and the four fisheries), and proportion spawning. Data new to this assessment were from a Cook Strait acoustic survey, two trawl surveys (Chatham Rise and sub-Antarctic), and proportions at age from the four fisheries.

A series of preliminary runs was carried out before the new year's data became available. From these it was concluded that (a) the recent decrease in the proportion of older male fish in catches in the west spawning fishery does not appear to have been caused primarily by changes in fishing behaviour; (b) ogive parameters do not seem to be the sole cause of poor performance in some Markov Chain Monte Carlo runs, but that it is difficult to measure this performance; (c) there is a non-urgent need to revise the catch-at-age data from the west spawning fishery; and (d) a revised form of a new prior distribution for natural mortality should be used in the current assessment.

Initial runs using the new year's data helped in deciding what assumptions should be made for the 2007 assessment. It was decided that additional weight should be given to all trawl-survey biomass estimates to ensure a good fit to the decline shown in the sub-Antarctic survey, and that the acoustic surveys should be given additional weight in one run.

The Hoki Working Group agreed on three final model runs which were similar to the runs used in 2006. These provided two alternative explanations for the relative lack of old fish in the data: age-dependent natural mortality, and domed selectivities for the spawning fisheries. They also included a run without the assumption of natal fidelity. Both hoki stocks are estimated to be at or near their lowest level since the fishery began, with the West stock being much more depleted (15–24 $\%B_0$) than the East stock (37–51 $\%B_0$). The West stock experienced an extended period of poor recruitment from 1995 to 2001, but there is evidence of better (though still below average) recruitment in subsequent years (2002–05). For both stocks, the projections suggest that neither stock is likely to increase in biomass unless either future recruitment is better than it has been in recent years or catches from the associated fisheries are reduced.

Analyses carried out after the assessment provided information likely to be useful in the 2008 assessment. A comparison of year-class strength estimates from the last six hoki assessments showed that, for some year classes, these estimates show a marked downward trend, particularly for weak year classes from the W stock. A detailed analysis showed that this trend was mostly caused by changes in model assumptions (mostly for the earlier assessments) and increasing information (mostly affecting recent year classes). Another analysis showed that poor diagnostics for one model run did not compromise the assessment. Finally, three phenomena which, for various reasons, were ignored in the assessment, were investigated: invisible juvenile mortality (caused, for example, by fatal damage to fish escaping from trawl nets), an increase in growth rates, and changes in fishery selectivities. No evidence was found that the assessment results would have been materially different had these phenomena been modelled.

1. INTRODUCTION

Hoki (*Macruronus novaezelandiae*) is the most abundant commercial fish species in New Zealand waters, and has been our largest fishery since the mid 1980s. It is widely distributed throughout New Zealand's Exclusive Economic Zone in depths of 50–800 m, but most commercial fishing is at depths of 200–800 m. There are four main fisheries: two on spawning grounds (west coast South Island and Cook Strait), and two on feeding grounds (Chatham Rise and Sub-Antarctic) (Figure 1). Since the introduction of the QMS, hoki has been managed as a single fishstock, HOK 1 (ignoring HOK 10, which is purely administrative). Until recently, the TACC has oscillated between 200 000 t and its initial (1986–87) level of 250 000 t. In response to a series of poor recruitments the TACC was dropped to 180 000 t for 2003–04, and again to 100 000 t for 2004–05 (Annala et al. 2004).

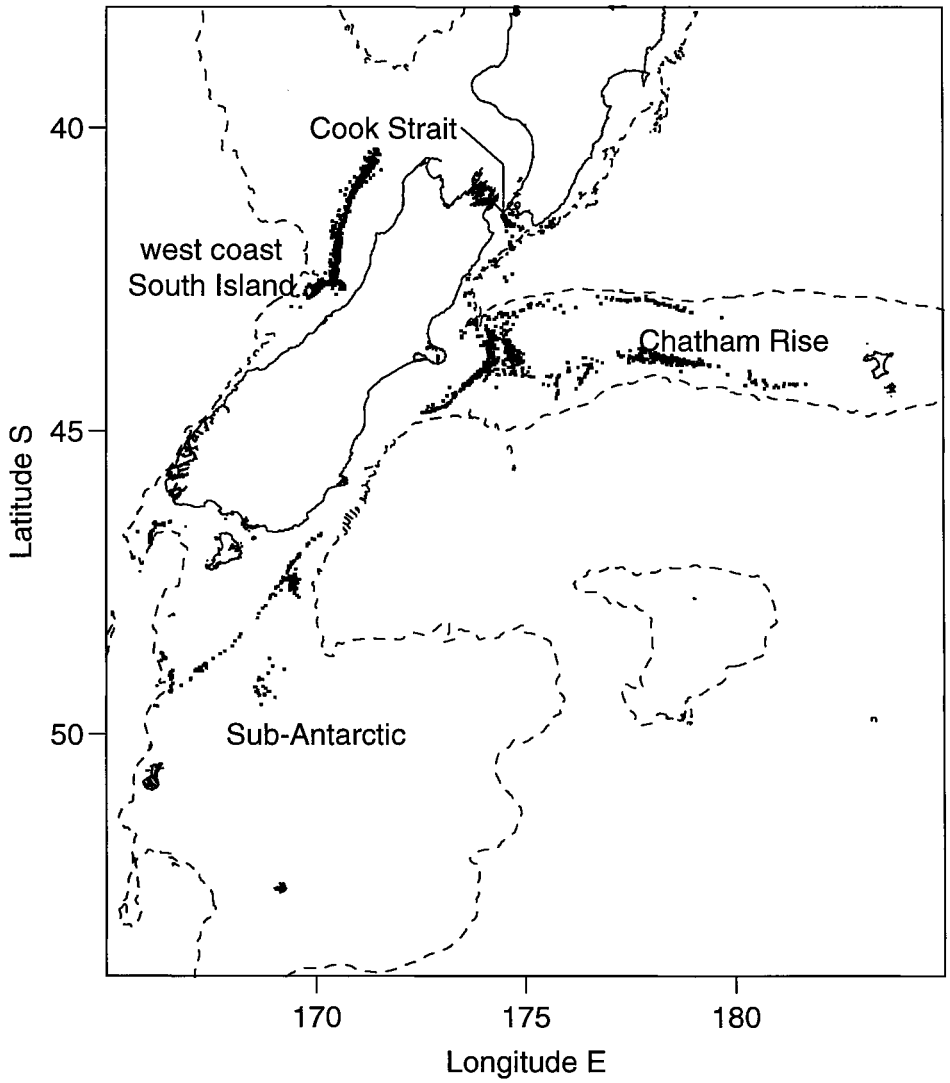

Figure 1: Southern New Zealand, showing the main hoki fishing grounds, the 1000 m contour (broken line), and the position of all 2005–06 tows from TCEPRs (Trawl Catch and Effort Processing Returns) in which at least 10 t of hoki was caught (dots).

Within HOK 1 two stocks are recognised — eastern and western — and these have been assessed separately since 1989. Originally, the two stocks were assessed in parallel models. More recently (since 1998 in NIWA assessments, and 2001 in industry-sponsored assessments) the stocks have been assessed simultaneously, using two-stock models. The complicated interactions inherent in a two-stock model, together with the large array of data sets that are available for HOK 1 — the 2004 NIWA assessment used more than 1800 individual observations spread over 15 data sets (Francis 2005) — make this one of the most complex of all New Zealand assessments. For most years in the 1990s there were two separate assessments — one funded by the Ministry of Fisheries (MFish) and one by industry — using different models and often reaching different conclusions.

This report documents the 2007 assessment of HOK 1, which is the sixth hoki assessment to use NIWA's general-purpose stock-assessment model CASAL (Bull et al. 2005). Since the last assessment (Francis 2007) there has been another acoustic survey in Cook Strait in July–August 2006 (O'Driscoll 2007) and two more trawl surveys – in the Sub-Antarctic in December 2006 (O'Driscoll & Bagley, unpublished results) and Chatham Rise in January 2007 (Stevens & O'Driscoll, unpublished results).

The work reported here addresses objective 1 of MFish project HOK2006/01: *To update the stock assessment of hoki in the year 2007, including estimates of biomass, risk and yields.*

2. PRELIMINARY ANALYSES

This section addresses several issues that arose during or after the 2006 hoki assessment (Francis 2007) and which it was not possible to deal with at the time. These were considered in the context of that assessment, with the intention that this work might provide information useful in designing the 2007 assessment. Most of the analyses use data only for the years that were available during the 2006 assessment. The starting point for many of these runs was one of the three final runs from 2006 (Table 1). Some abbreviations are useful to simplify references to various data sets and parts of the model (Table 2).

Table 1: Distinguishing characteristics for the three final model runs in the 2006 assessment.

Label	Response to old fish problem	Sex in model and selectivities length-based?	Natal fidelity assumed?
2.4	*M* dependent on age	Yes	Yes
2.5	Domed spawning selectivity	No	Yes
2.6	*M* dependent on age	Yes	No

2.1 Trends in sex ratios

In analyses carried out after the 2006 assessment (see section 7.2, Francis 2007) it was noted that certain trends in observed sex ratios were not replicated by the stock-assessment model, particularly for the Wspage data set (Figure 2).

In this Section I present some additional data and then investigate the possibility that the trend in Wspage was caused by changes in fishing behaviour.

Before doing so I will briefly explain a salient aspect of Figure 2 which attracted attention last year. It is hard to detect any trend in the proportions male for Espage, because the associated confidence intervals are much wider than those for Wspage. A closer look at the data revealed that the wider confidence intervals are simply caused by smaller sample sizes. Typically, 500 samples a year are collected for Wspage, but only 40 for Espage. The between-sample variability in proportion male is similar in the two data sets, despite that fact that most Wspage samples are individual tows, whereas all the Espage samples are landings deriving from multiple tows.

Table 2: Abbreviations used in describing the model and observations.

Quantity	Abbreviation	Description
Stock	E	eastern stock
	W	western stock
Area	CR	Chatham Rise
	CS	Cook Strait
	SA	sub-Antarctic
	WC	west coast South Island
Fishery	Esp	E spawning fishery
	Wsp	W spawning fishery
	Ensp1, Ensp2	first and second parts of E non-spawning fishery
	Wnsp1, Wnsp2	first and second parts of W non-spawning fishery
Observation	CSacous	CS acoustic biomass index
	WCacous	WC acoustic biomass index
	CRsumbio, CRsumage	biomass index & propns at age from CR summer trawl survey
	SAsumbio, SAsumage	biomass index & propns at age from SA summer trawl survey
	SAautbio, SAautage	biomass index & propns at age from SA autumn trawl survey
	pspawn	proportion spawning (estimated from SA autumn trawl survey)
	Espage, Wnspage, etc	proportions at age in catch from given fishery (from otoliths)
	EnspOLF, WnspOLF	proportions at age in catch from given fishery (from OLF[1])
Migrations	Ertn, Wrtn	return migrations of E and W fish from spawning
	Whome	migration of juvenile fish from CR to SA
	Espmg, Wspmg	spawning migrations of E and W fish
Selectivity	Espsl, Wspsl, Enspsl, Wnspsl	selectivity in commercial fisheries
	CRsl, SAsl	selectivity in trawl surveys

[1]OLF is a computer program that estimates proportions at age from length frequency data (Hicks et al. 2002).

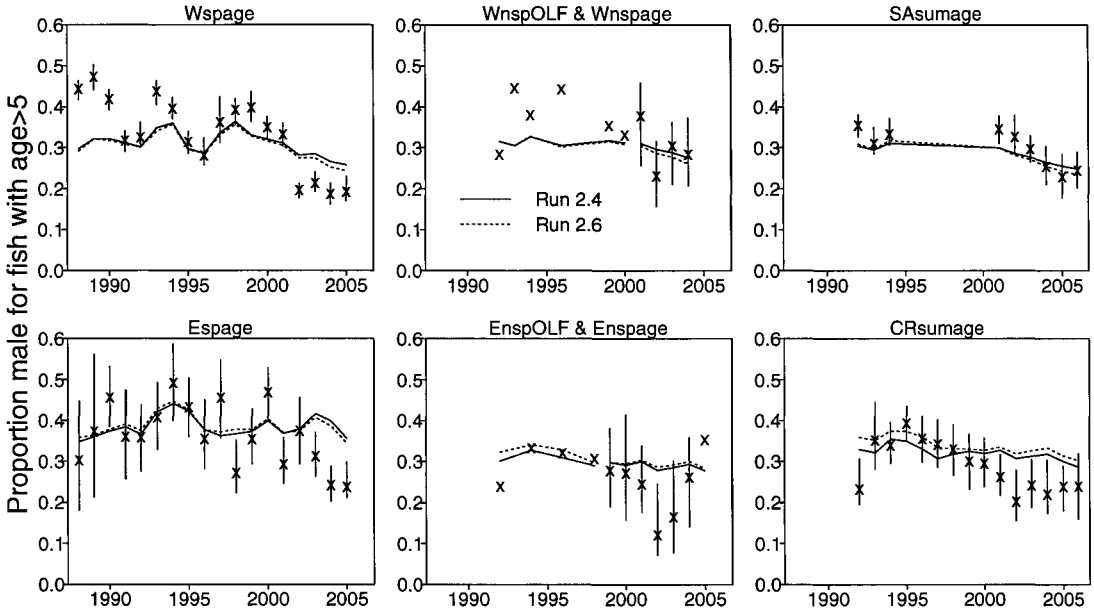

Figure 2: Observed ('x') and predicted (lines) proportions male, by year and at-age data set, for older fish (ages greater than 5 y). Predicted lines are from runs 2.4 and 2.6; vertical lines are 95% confidence intervals for the observed values (not available for the OLF observations).

2.1.1 Additional sex-ratio data from surveys in SA and CR

In areas SA and CR, the only survey data presented in last year's analyses of sex ratios were from the summer surveys. Sex ratios from these and some additional surveys are compared in Figure 3.

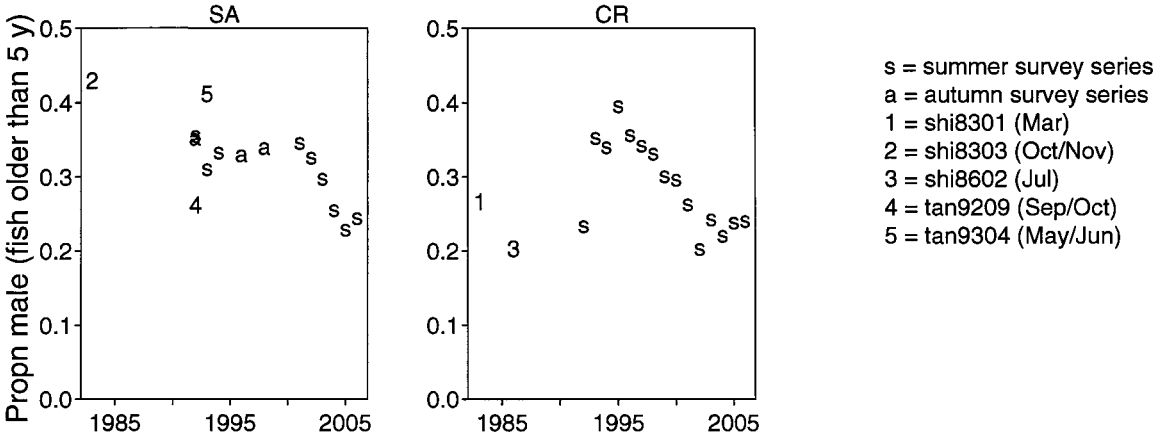

Figure 3: Proportion male for older fish (age > 5 y), by year, for survey data in areas SA and CR.

In general, the additional surveys, which fall into three groups, confirm patterns seen in the original data. Sex ratios from the first group – the autumn surveys in SA – are very consistent with those from the summer surveys in that area. The second group consists of three early surveys in SA (SHI8303, TAN9209 and TAN9304). Their sex ratios are quite variable, but consistent with the higher proportions male seen in the earliest summer surveys in this area. The third group, two early surveys in CR (SHI8301 and SHI8602), both show sex ratios similar to those for the first summer survey in this area. Taken together, all the CR surveys suggest that the proportion male (for older fish) in this area was low up to 1992, rose sharply in 1993, and then gradually fell thereafter. One thing that could conceivably cause this sharp rise in 1993 would be a very strong year class that was 6 years old in that survey. However, this explanation does not work because the year class concerned, which was born in 1986, is estimated to have been weak for both stocks. The cause of this sharp rise remains a mystery.

2.1.2 Was the Wspage trend caused by a change in fishing behaviour?

The clearest trend in the sex-ratio data shown in Figure 2 is in the Wspage data, which derives from the commercial fishery on the western spawning ground. One possible explanation for this trend is that the selectivity for this fishery has changed over time in such a way that females have become more selected over time, relative to males. Francis (2007) investigated this explanation but could find no evidence to support it. However, that analysis was indirect. It considered only the effects of changes in the assumptions of the stock-assessment model, and so could have been affected by interactions with other assumptions that appear unrelated. Here, I present a more direct approach to consider this explanation again. This involved analysing, outside the assessment model, detailed data from the commercial fishery.

For the new analyses I switched from an age-based to a length-based method of calculating proportion male. The two methods show similar trends (Figure 4) but the latter is more robust for present purposes because sample sizes are much larger for fish lengths than for otoliths.

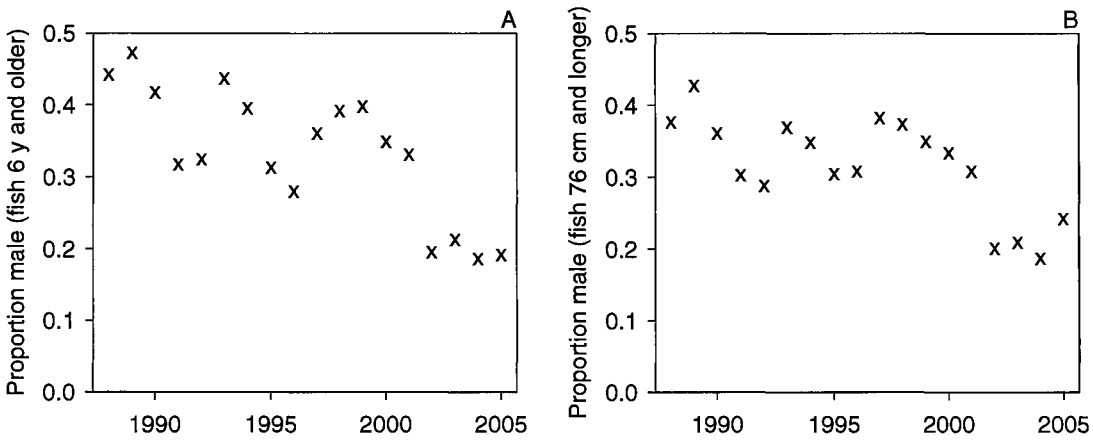

Figure 4: Comparison of A, age-based and B, length-based methods of presenting the sex-ratio trend in the Wspage data. The threshold length of 76 cm was chosen to mimic the trend shown with the age threshold of 6 y.

The fishing behaviour which determines the selectivity curve for a fishery depends partly on gear and vessel specifications (e.g., mesh size and horsepower) and partly on how the gear is used (e.g., timing and location of fishing). In the following analyses I was restricted to the indicators of fishing behaviour that are recorded in the observer database and vessel register. My aim in these analyses was to investigate the relationship between fishing behaviour and sex ratio (e.g., what sort of behaviour tends to produce a lower proportion of males) and thus see whether the trend in sex ratio in Wspage could have been caused by a change in fishing behaviour.

To investigate how fishing behaviour affects proportion male we need to disaggregate the data for each year. The length frequencies (LFs) used to calculate the proportions male were constructed from LFs for individual records (i.e., individual tows, for observer data, or individual landings, for market data) that were combined to produce LFs by stratum, and then an overall LF. Thus, we can disaggregate to the stratum level, or to the record level, with the latter showing considerably more variation than the former (Figure 5). Both levels of disaggregation were used.

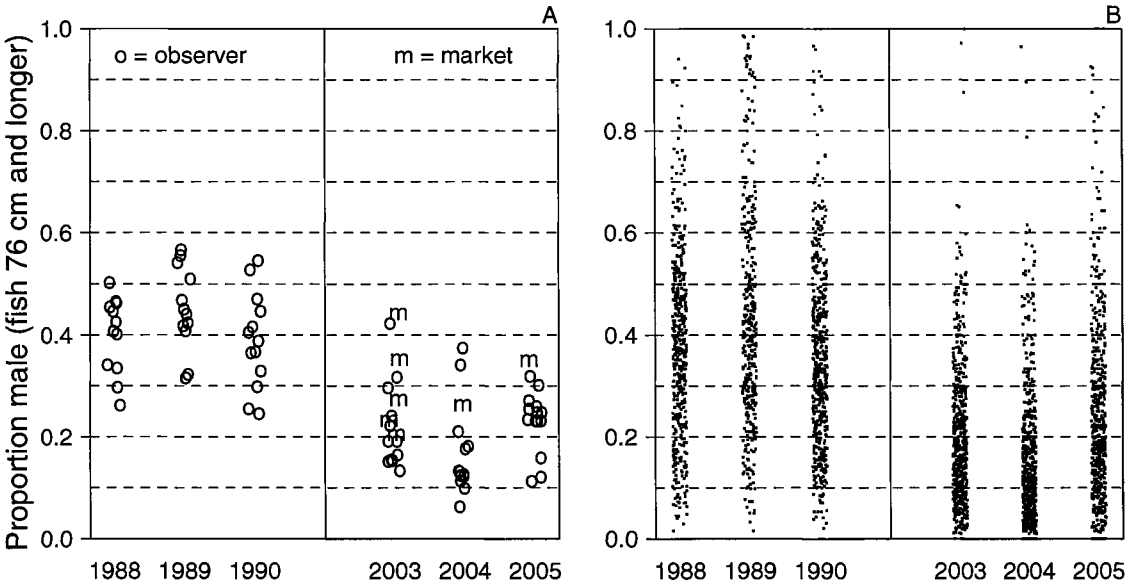

Figure 5: Proportion male for larger fish (those 76 cm or longer) in the western spawning fishery A, by stratum ('o' = observer stratum; 'm' = market stratum), and B, by record (a record corresponds to a tow, for observer data, or a landing, for market data) for the first three and last three years in the data series.

Some samples were not included in these analyses. Market samples were omitted because there is not much fishing-behaviour data available for them. Fortunately, most strata for Wspage used observer data (Table 3). A few strata that were well south of the main fishing ground (there was one in 1989, two in 1990, and none in the last three years) were ignored on the grounds that they were outliers, and thus likely to exert undue influence as regression predictors. The proportions male for these strata were neither very high or very low compared to other strata in the same year. More information about these southern strata is given below, in Section 2.3. Finally, data from 2002 were not included because they were temporarily unavailable at the time of the analysis.

Table 3: Number of strata used in calculating each year's LF for the western spawning fishery, and the number by data type (observer or market).

	Number of strata in each year								
Data type	1988	1989	1990	1991	1992	1993	1994	1995	1996
Observer	12	12	13	12	11	10	10	13	12
Market	0	0	0	0	0	0	0	0	0
All	12	12	13	12	11	10	10	13	12
	1997	1998	1999	2000	2001	2003	2004	2005	
Observer	10	9	9	12	12	13	14	15	
Market	0	0	0	0	0	5	1	1	
All	10	9	9	12	12	17	14	15	

Eight variables were used to characterise fishing behaviour. All were available for almost all observer records but only one (fday) was available for the market data (Table 4). For analyses at the stratum level, each variable was averaged over all tows in each stratum.

Table 4: Eight variables representing fishing behaviour.

Variable	Description	Percentage of observer records with data
fday	day of fishing year (for start of tow or landing)	100
lat, long	position of start of tow	100, 100
bdepth, ndepth	depth of bottom and net (at start of tow)	100, 99
hline	headline height of net	100
Vlen, Vtonne	length and tonnage of vessel	93, 93

Four generalised linear models (GLMs) were fitted, stepwise, to determine whether proportion male could be predicted (either at the stratum level, or for individual tows) from fishing behaviour (Table 5). By themselves, the behavioural variables were able to explain only a small percentage of the total deviance. When year was available as a predictor it was the first one selected, and the total deviance explained increased substantially.

2.1.3 Conclusions on sex-ratio trends

The additional survey data confirmed the trends seen in the original analysis. This makes the problem of these sex-ratio trends more complex, particularly in CR, where the gradual decrease in proportion male since the early 1990s seems to have been preceded by a sudden rise which was not seen in other areas.

No evidence was found to support the hypothesis that the changes in proportion male in the catch from the W spawning fishery were caused primarily by changes in fishing behaviour which altered the selectivity for this fishery.

Table 5: Details of four GLMs used to predict proportion male in Wspage. The upper two GLMs used stratum data and the lower two used tow data; in the left-hand GLMs only the behavioural variables (see Table 4) were used as potential predictors, whereas in the right-hand GLMs year was also offered as a predictor. Predictors explaining less than 1% additional deviance are not shown.

	Using only behavioural variables			Using behavioural variables and year		
Stratum data						
	Variable	Total % deviance explained	Additional % deviance explained	Variable	Total % deviance explained	Additional % deviance explained
	long	15.2	15.2	year	40.6	40.6
	Vlen	23.3	8.1	lat	51.3	10.7
	nheight	26.3	3.0	Vtonne	53.5	2.2
	Vtonne	27.9	1.6	bdepth	54.7	1.3
Tow data						
	Variable	Total % deviance explained	Additional % deviance explained	Variable	Total % deviance explained	Additional % deviance explained
	lat	2.9	2.9	year	13.3	13.3
	ndepth	4.7	1.8	lat	16.1	2.7
				ndepth	18.0	2.0

2.2 Investigating MCMC performance

The performance of MCMC runs for the hoki model was last investigated in depth after the 2004 assessment Francis (2005). It was shown that the worst MCMC traces were for ogive parameters that were estimated at a bound in the MPD phase and, because of this, had unrealistically low estimated variances (from the inverse Hessian at the MPD). It was recommended that such parameters be fixed in the MCMC phase, and this recommendation did seem to produce some improvement in overall MCMC performance (as judged by comparing cumulative distributions of MCMC samples for key model outputs) without any apparent decrease in the range of uncertainty covered by the posterior distribution. However, it was clear that MCMC performance was still far from ideal because some parameter traces were still poor.

The additional analyses described in this section were not successful in identifying a method for improving MCMC performance but they do help to increase our understand the problem of poor performance.

2.2.1 Are ogive parameters the problem?

One possible explanation for the poor MCMC performance is the large number of selectivity and migration ogive parameters that were estimated in each run (Table 6). In the earlier investigation (Francis 2005), poor traces were often associated with ogive parameters. Also, this type of parameter is inherently problematic because it can't be estimated directly; instead we must infer it very indirectly by comparing age distributions from different sources (different fisheries or surveys). Thus, our hypothesis is that ogive parameters will tend to show poor MCMC performance, and that the overall MCMC performance for a run will improve if some or all of these parameters are fixed.

To test this hypothesis, three MCMC chains were generated for a new run, labelled 2.5no.ogive, which was the same as run 2.5 except that all ogive parameters were fixed at their MPD estimated. This new run appeared to have better MCMC performance, at least according to the simple diagnostic that has been used in recent assessments (Figure 6; note how the three curves in each panel are almost coincident for 2.5no.ogive, but less so for 2.5). However, to continue this investigation we need a more quantitative and clear-cut measure of overall MCMC performance. If we can find such a

measure, and if this shows that 2.5no.ogive is clearly better than 2.5, then the next step would be to do a series of MCMC runs in which only some ogives were held fixed. By comparing the performance of these runs we may be able to identify which of the ogives are most responsible for poor performance.

Table 6: Number of parameters, by type, estimated in each of the three main runs from the 2006 assessment. Parameters fixed in MCMC runs were ignored; for run 2.6, the parameters determining annual variation in the number of juvenile fish migrating to SA from CR were classified as associated with year-class strength because they determine how each year-class is split between the E and W stocks.

Parameter type	Run		
	2.4	2.5	2.6
Biomass	2	2	1
Natural mortality	34	1	34
Year-class strength	60	60	61
Migration ogives	34	21	35
Selectivity ogives	10	13	12

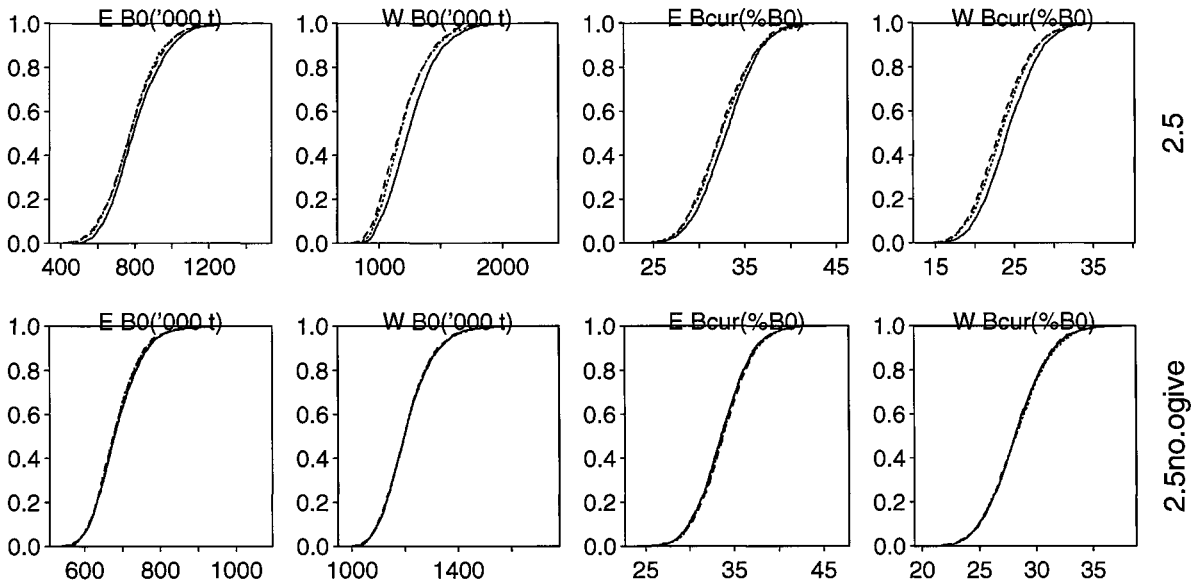

Figure 6: Diagnostics for MCMC chains for two model runs: 2.5 (top row) and 2.5no.ogive (bottom row). Each panel contains cumulative probability distributions, for B_0 or $B_{current}$, for three chains from the same model run.

What we need then, is a single score that measures overall MCMC performance for all parameters and all chains in a model run. Unfortunately it's not easy to find such a score. As a starting point I considered three statistical convergence tests provided by the Bayesian Output Analysis Program (http://www.public-health.uiowa.edu/BOA/): the Geweke test, the Heidelberger & Welch stationarity test, and the Gelman & Rubin test. The first two tests are applied separately to each parameter in each chain, whereas the third is applied jointly to all chains for each parameter. This means that for a run with n parameters and three chains we have a total of $7n$ statistical tests of convergence ($3n$ for the first test, $3n$ for the second, and n for the third).

The results from all these statistical tests do not give a clear answer to the question "which of runs 2.5 and 2.5no.ogive is better?". The Geweke test strongly prefers 2.5no.ogive, for which 71% of tests support convergence, over 2.5, for which the comparable figure is either 50% (for all parameters) or 48% (for the non-ogive parameters) (Table 7). However, the Heidelberger & Welch test slightly prefers 2.5, and the Gelman & Rubin test slightly prefers 2.5no.ogive.

Table 7: Percentage of parameters converging, in runs 2.5 and 2.5no.ogive, according to each of three statistical tests. Note that the Geweke and Heidelberger & Welch tests were applied separately to each MCMC chain, whereas the Gelman & Rubin test was applied to all chains jointly.

Statistical test	Chain	Run 2.5, all parameters	Run 2.5, non-ogive parameters	Run 2.5no.ogive all parameters
Geweke	1	54	59	86
	2	42	48	44
	3	54	38	84
	average	50	48	71
Heidelberger & Welch	1	72	67	100
	2	88	97	76
	3	97	98	75
	average	86	87	84
Gelman & Rubin	all	98	98	100

Another approach would be to restrict attention to the Gelman & Rubin test (on the grounds that it is the only one that considers all three chains at once) and use the value of the test statistic (which I shall call S_{GR}), rather than just whether the test is significant (not converged) or non-significant (converged). A parameter is deemed not to have converged if the associated $S_{GR} > 1.2$, so the smaller the value of S_{GR} the better. This statistic seems promising at first. When we applied the Gelman & Rubin test to run 2.5no.ogive we got 34 values of S_{GR} (one for each parameter), and the upper quartile of this set of 34 numbers was 1.029 (see the last number in the bottom row of Table 8). For run 2.5, if we restrict attention to the same 34 parameters the corresponding figure is 1.061 (the last number in the middle row of Table 8), which suggests that 2.5no.ogive is clearly better than 2.5. Further, if we compare the first two rows of Table 8 it seems clear that ogive parameters performed worse than non-ogive parameters in original run, 2.5 (at least according to S_{GR}). (In making these comparisons I have focussed on the upper quartile of S_{GR} because it varies more than the other quartiles.)

Table 8: Quartiles of the Gelman & Rubin test statistic, S_{GR}, for runs 2.5 and 2.5no.ogive.

Run	Parameters	Number of parameters	Quartiles of S_{GR} lower	middle	upper
2.5	all	97	1.012	1.032	1.082
	non-ogive	34	1.010	1.025	1.061
2.5no-ogive	all	34	1.010	1.021	1.029

So, now we have a single score – the upper quartile of S_{GR} – which may allow us to say whether, overall, one model run shows better MCMC convergence than another. This score may also be used to compare the convergence of groups of parameters within a single run. Unfortunately, when I compared ogive vs non-ogive parameters for all three main runs from 2006 I did not get consistent results: the non-ogive parameters appeared better for runs 2.5 and 2.6, but worse for run 2.4 (Table 9). Moreover, these results are sensitive to our choice of statistical test. When I applied the same procedure, but based it on a different test statistic, I got different results: with the Geweke test, the non-ogive parameters appeared better only for runs 2.4 and 2.5; with the Heidelberger & Welch test this was true only for run 2.5. All these results were based on comparing the upper quartiles of the test statistic. When, instead, the middle quartile was used, the results changed.

2.2.2 Conclusions about MCMC performance

The above results do not suggest that ogive parameters are the sole cause of poor MCMC performance. Perhaps more importantly, they also illustrate the difficulty of measuring the overall MCMC performance for a model run. Graphs like those in Figure 6 are useful as simple qualitative measures. However, they do not provide a definitive answer to the question 'Which run (or which set of parameters within a given run) has the better overall performance?'. It's not difficult to construct a single objective score (e.g., the upper quartile for S_{GR}) that will provide an answer to this question.

The problem is that there are many such scores, and they all provide different answers, none of which can be considered definitive.

I end this section by discussing a consequence of fixing model parameters. In general, we should expect this to result in an underestimation of uncertainty. That is, it is likely to reduce the range of 95% confidence limits inferred from the posterior distribution. This may not be serious if only a few problem parameters are fixed (see table 44 in Francis (2005)). However, when a large proportion of the parameters is fixed, as was done in run 2.5no.ogive, this can substantially reduce 95% confidence regions (Figure 7).

Table 9: Quartiles of the Gelman & Rubin test statistic, S_{GR}, for ogive and non-ogive parameters in runs 2.4, 2.5, and 2.6.

Run	Parameters	Number of parameters	Quartiles of S_{GR} lower	middle	upper
2.4	ogive	96	1.007	1.019	1.046
	non-ogive	44	1.023	1.061	1.129
2.5	ogive	63	1.028	1.072	1.104
	non-ogive	34	1.010	1.025	1.061
2.6	ogive	96	1.013	1.047	1.281
	non-ogive	47	1.013	1.053	1.214

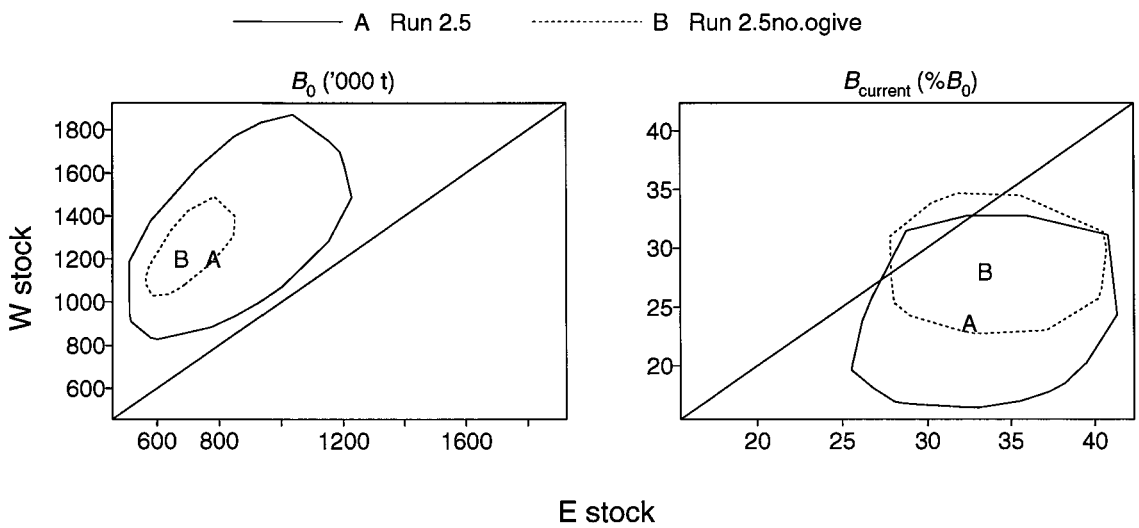

Figure 7: Estimates and approximate 95% confidence regions for virgin (B_0) and current ($B_{current}$ as %B_0) biomass by stock for runs 2.5 and 2.5no.ogive. In each panel the points 'A', 'B' indicate best estimates (median of the posterior distribution) and the polygons encloses approximate 95% confidence regions. Diagonal lines indicate equality ($y = x$).

2.3 Southern strata in the LFs for the west spawning fishery.

Here, I present more information about some of the data that were excluded from the analyses in Section 2.2. These were observer LFs in strata whose mean tow positions were south of 44° S, and thus much further south than the bulk of the fishery, which is near and north of the Hokitika Canyon (Figure 8).

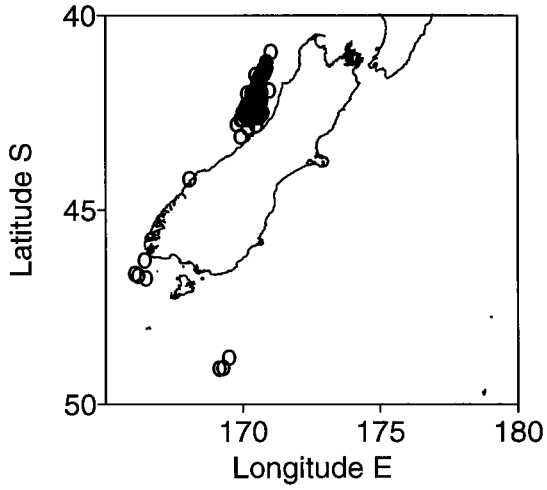

Figure 8: Mean tow positions of observer strata in Wspage for all years.

These southern strata fall into three general areas (Table 10). Those in the sub-Antarctic are clearly anomalous. The sub-Antarctic stratum in 1992 is particularly concerning because it has a high weight (it contributed 23% of the catch considered in constructing the Wspage proportions at age for that year). The reason for including the Puysegur strata need to be re-evaluated because current practice is to exclude tows from this area from Wspage. The one stratum from SW WCSI is of little concern because it has very low weight.

Fortunately, the inclusion of these southern strata will have had little effect on previous stock assessments because the age frequencies (AFs) for each year do not change much if they are omitted (Figure 9). In 1989, the first year these southern strata were used, the LF and AF from the southern stratum was quite different from those from all other strata, but this did not matter because this stratum contributed only 1.8% of the total catch for the year. In successive years, the contribution of the southern strata progressively increased, but the associated LFs and AFs became more and more like those from the other strata.

Because the effect of the southern strata was so minor, no attempt was made to modify the AFs for Wspage in the current assessment. It is expected that these data will be re-evaluated before the 2008 assessment as part of a general reconsideration of the stratification used for Wspage.

Table 10: Details of observer strata from Wspage for which the mean tow position was south of 44° S.

		Percentage of total	Mean tow position		
Year	Stratum	catch weight for year	Latitude S	Longitude E	General area
1989	12	1.8	-46.7	166.2	Puysegur
1990	12	4.4	-46.7	166.1	Puysegur
1990	13	5.4	-49.1	169.2	Sub-Antarctic
1991	11	2.3	-46.3	166.4	Puysegur
1991	12	10.1	-48.8	169.5	Sub-Antarctic
1992	10	3.6	-46.8	166.5	Puysegur
1992	11	23.0	-49.1	169.3	Sub-Antarctic
2001	2	0.0	-44.2	168.1	SW of WCSI

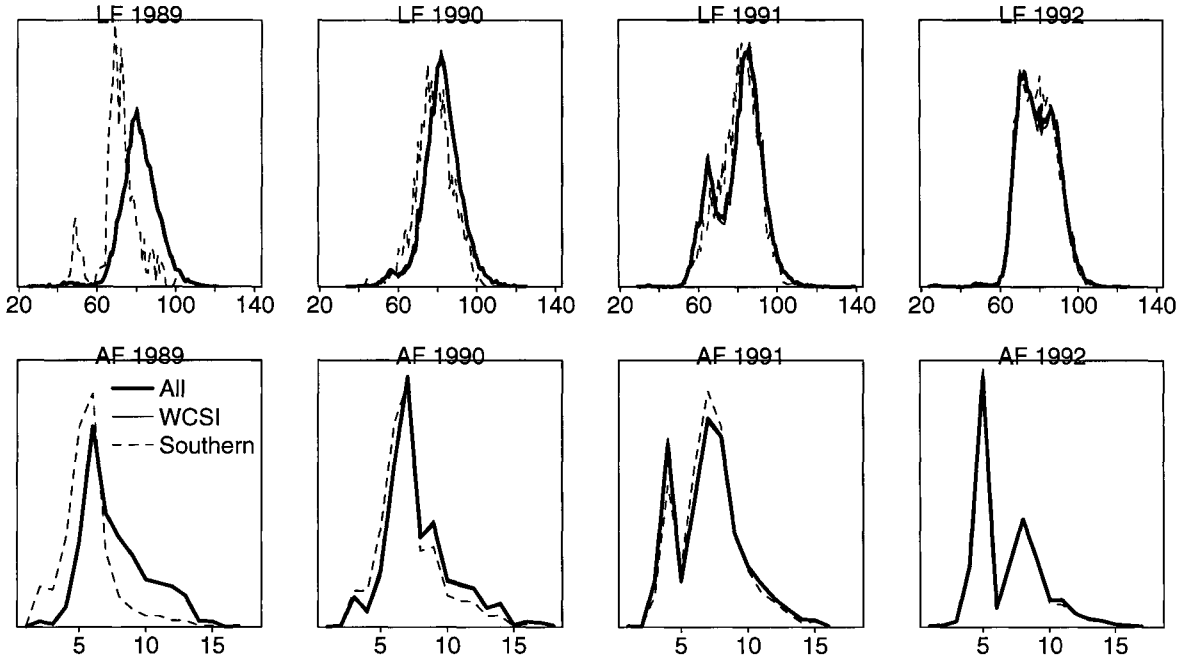

Figure 9: Comparison of three LFs (upper panels) and AFs (lower panels) from the W spawning fishery for those years in which a non-trivial proportion came from southern strata: from all strata (heavy lines); from WCSI strata (solid light line); and from southern strata (broken light line).

2.4 The effect of the new age-dependent prior for natural mortality

Two types of prior were used for natural mortality (*M*) in the 2006 assessment. For run 2.5, a lognormal prior with mean 0.298 and c.v. 0.153 was used, and this was applied to all fish (note that sex was ignored in this run). In the other two runs (2.4 and 2.6), two prior distributions were used: a lognormal, with mean 0.298 and c.v. 0.631, for the average of male and female *M*, and a normal, with mean 0.05 and s.d. 0.105, for the difference in *M* (male – female). A problem with these priors is that they do not vary with age. Although the estimated *M* is expected to be larger for young and old fish, and smaller for those of middle ages, this expectation is not reflected in the priors. To deal with this problem a new age-dependent prior was developed (Cordue 2006). This prior is markedly narrower at each age than the old priors were (Figure 10).

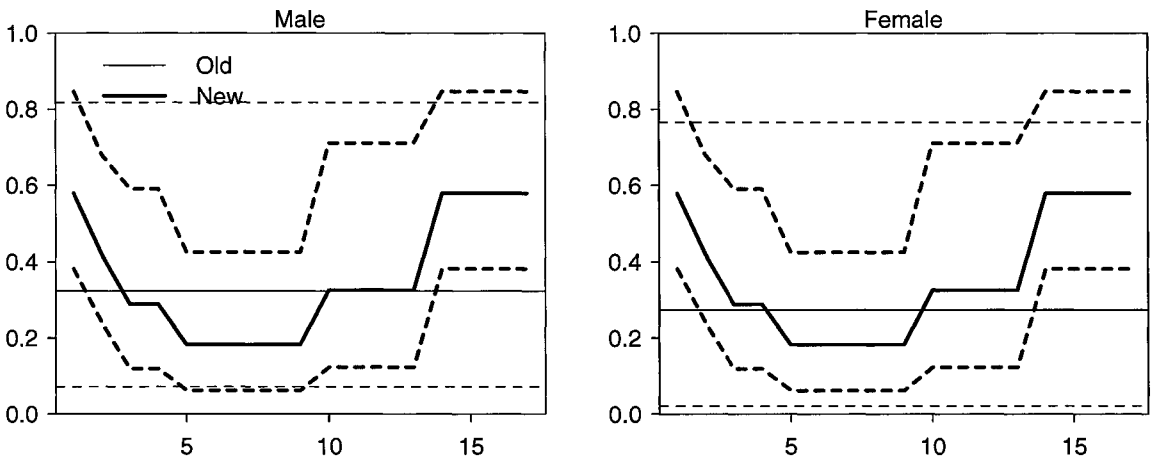

Figure 10: Comparison between old and new priors for *M*, for use in model runs in which the estimated *M* varies with age. The new priors are lognormal at each age; solid lines show the means of the priors, broken lines show 95% confidence intervals.

Two new runs, labelled 1.1 and 1.2, were done to investigate the effect of the new priors. Except for the use of the new priors these new runs were exactly the same as runs 3.7 and 3.8, respectively, of Francis (2007), which used the new double-exponential ogive for *M*. Note that runs 3.7 and 3.8 were the same as two of the main 2006 runs (2.4 and 2.6, respectively) except that they used the new double-exponential ogive for *M*. The new *M* prior substantially changed the estimated *M* ogives for the younger ages (Figure 11).

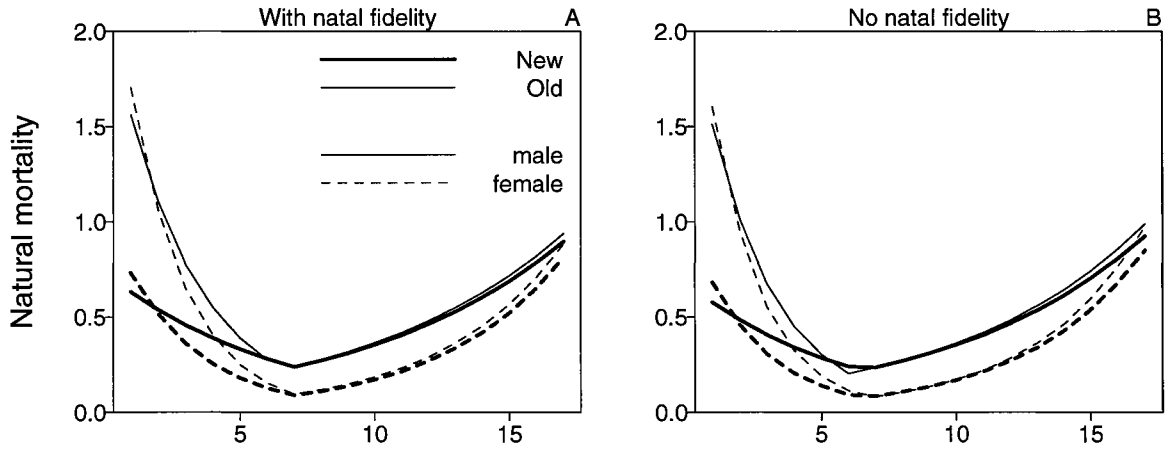

Figure 11: Comparison between natural mortality estimated using the new and old *M* priors for A, runs with natal fidelity (old run = 3.7, new run = 1.1) and with no natal fidelity (old run = 3.8, new run = 1.2).

On reflection, the Working Group decided that this new prior overstated the strength of our knowledge about natural mortality for hoki, which was mostly about the intermediate ages. Thus, it was decided to revise the prior so that only the part between ages 5 y and 9 y was used (i.e., no prior knowledge was assumed about the value of *M* for ages less than 5 y or greater than 9 y.

Runs 1.3 and 1.4 used this revised prior but were otherwise identical to the 2006 runs 3.7 and 3.8, respectively. The revised *M* prior increased the estimated *M* ogives for the younger ages, but had little effect on the older ages (Figure 12). Biomass trajectories were only slightly affected (Figure 13), as were estimated YCSs, selectivities, and migration ogives (not shown). The new *M* prior appears to be less restrictive than the old, because the overall goodness of fit to the data improved slightly (by 6 points with, and 15 points without, natal fidelity) (Table 11).

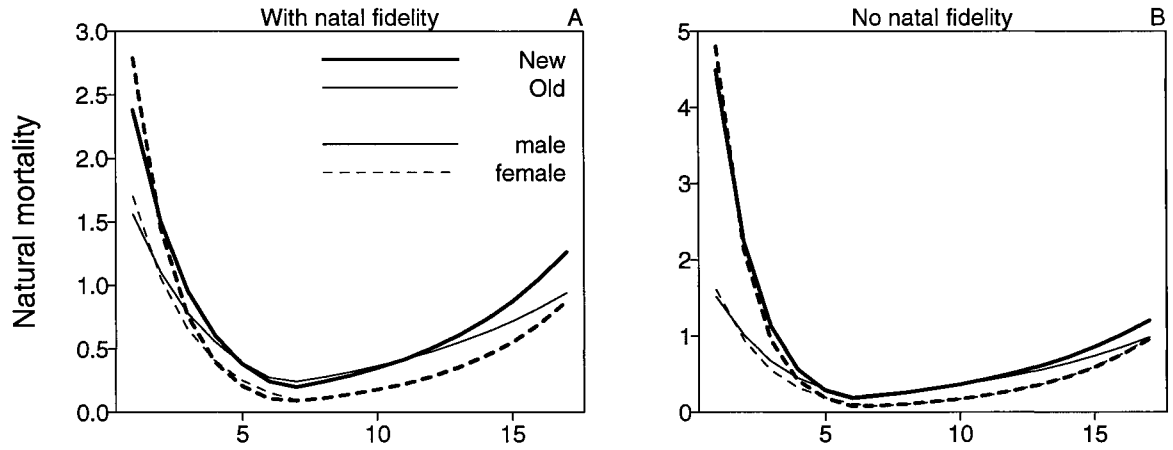

Figure 12: Comparison between age-dependent natural mortality estimated using the (revised) new and old *M* priors for A, runs with natal fidelity (old run = 3.7, new run = 1.3) and B, with no natal fidelity (old run = 3.8, new run = 1.4).

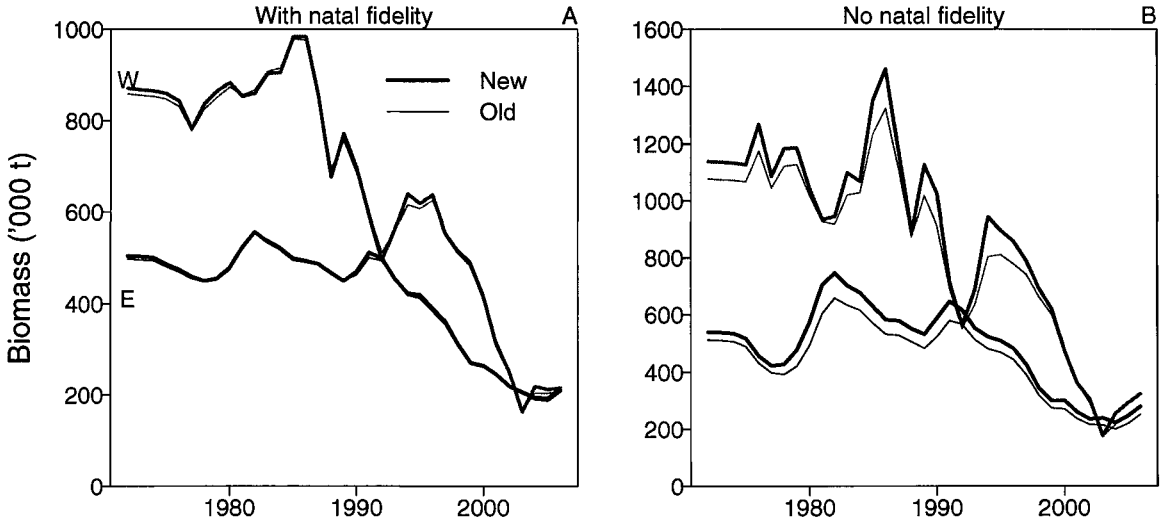

Figure 13: Comparison between SSBs estimated using the (revised) new and old *M* priors for A, runs with natal fidelity (old run = 3.7, new run = 1.3) and B, with no natal fidelity (old run = 3.8, new run = 1.4).

Table 11: Improvement in fit (as shown by the decrease in the objective function), by data set, associated with the (revised) new prior on *M*. Positive (or negative) numbers mean that the fit to the data improved (or degraded). The following data sets are excluded from the table because the change in goodness of fit was zero in both cases: CSacous, EnspOLF, Enspage.

	With natal fidelity (old run = 3.7, new run = 1.3)	No natal fidelity (old run = 3.8, new run = 1.4)
CRsumbio	-1	-3
SAautbio	0	1
SAsumbio	-1	0
WCacous	0	-1
CRsumage	3	1
SAautage	2	2
SAsumage	3	11
Espage	0	4
WnspOLF	1	0
Wnspage	1	1
Wspage	0	-1
pspawn	-1	0
All data	6	15

3. MODEL ASSUMPTIONS AND INPUTS FOR 2007

This section provides a fairly detailed summary of all model assumptions and inputs for the 2007 assessment. A complete description is contained, for the final runs only, in the files given in Appendix 1 (which should be read in conjunction with the CASAL manual, Bull et al. (2005)).

The model uses Bayesian estimation. In describing the model assumptions I will sometimes need to distinguish between different types of model runs: MPD versus MCMC, or initial versus final. MPD runs are so called because they estimate the Mode of the Posterior Distribution, which means they provide a point estimate, whereas MCMC (or full Bayesian) runs provide a sample from the posterior distribution using a Markov Chain Monte Carlo technique (this sample is sometimes referred to as a chain). MCMC runs are more informative, but much more time consuming to produce. For this reason only MPD runs were used for most of the initial exploratory analyses (Section 4). These runs

were used to define the assumptions for the final model runs (Section 5), which were full Bayesian, and whose results provide the formal stock assessment.

The model is based on the fishing year, which is labelled by its second part, so 1990 refers to the 1989–90 fishing year. This convention is applied throughout, so that, for instance, the most recent sub-Antarctic survey, carried out in November–December 2006, is referred to as the 2007 survey.

3.1 Model structure and catches

Two stocks are assessed. Fish from the eastern (E) stock spawn in Cook Strait (CS) and have their home grounds in Chatham Rise (CR); the western (W) stock spawn in west coast South Island (WC) and have their home grounds in sub-Antarctic (SA) (these areas are shown in Figure 1). Soon after being spawned, all juveniles move to CR. Two alternative assumptions concerning the juveniles are modelled. The original assumption is that the juveniles show natal fidelity – that is, they grow up to spawn on the ground where they were spawned. Under this assumption, the stock to which a fish belongs is determined at birth. At some time before age 8 all W juveniles migrate to their home ground, SA. The alternative assumption, used first in 2006, is that there is no natal fidelity. Each year, some juveniles choose to move from the nursery ground (CR) to SA, and thereby become W fish. Those fish remaining in CR by age 8 become E fish.

The model partition divides the population into two sexes, 17 age groups (1 to 17+), four areas corresponding to the four fisheries (CR, WC, SA, and CS), and two stocks (E and W). The annual cycle (Table 12) is the same as in 2006.

Table 12: Annual cycle of the assessment model, showing the processes taking place at each time step, their sequence within each time step, and the available observations (excluding catch at age). This is unchanged from that used in 2005. *M* fraction is the proportion of natural mortality which occurs within the time step. An age fraction of, say, 0.25 for a time step means that a 2+ fish is treated as being of age 2.25 in that time step. The last column ("propn. mort.") shows the proportion of that time step's mortality that is assumed to have taken place when each observation is made.

Step	Approx. months	Processes	*M* fraction	Age fraction	Observations label	Observations propn. mort.
1	Oct-Nov	migrations Wrtn: WC–>SA, Ertn: CS–>CR	0.17	0.25	–	
2	Dec-Mar	recruitment at age 1+ to CR (for both stocks)	0.33	0.60		
		part1, non-spawning fisheries (Ensp1, Wnsp1)			SAsum	0.5
					CRsum	0.6
3	Apr-Jun	migration Whome: CR–>SA	0.25	0.90		
		part2, non-spawning fisheries (Ensp2, Wnsp2)			SAaut	0.1
					pspawn	
4	End Jun	migrations Wspmg: SA–>WC, Espmg: CR–>CS	0.00	0.90	–	
5	Jul-Sep	increment ages	0.25	0.0	CSacous	0.5
		spawning fisheries (Esp, Wsp)			WCacous	0.5

As in 2006, the catches used in the model (Table 13) were calculated by apportioning the official total catch for each year amongst the six fisheries using the method described in Table 14, and the assumed catches for the current year are the same as those for the preceding year. The proportion of the catch taken from the western fisheries increased steadily between 1996 and 2002, but then dropped in 2003, and further in 2004, as fishers shifted effort from West Coast South Island (Wsp) to Cook Strait (Esp) in response to the assessments and poor catch rates in Wsp (Figure 14).

Table 13: Catches (t) by fishery and fishing year (1972 means fishing year 1971–72), as used in the assessment.

	Fishery					
Year	Ensp1	Ensp2	Wnsp1	Wnsp1	Esp	Wsp
1972	1500	2500	0	0	0	5000
1973	1500	2500	0	0	0	5000
1974	2200	3800	0	0	0	5000
1975	13100	22900	0	0	0	10000
1976	13500	23500	0	0	0	30000
1977	13900	24100	0	0	0	60000
1978	1100	1900	0	0	0	5000
1979	2200	3800	0	0	0	18000
1980	2900	5100	0	0	0	20000
1981	2900	5100	0	0	0	25000
1982	2600	4400	0	0	0	25000
1983	1500	8500	3200	3500	0	23300
1984	3200	6800	6700	5400	0	27900
1985	6200	3800	3000	6100	0	24900
1986	3700	13300	7200	3300	0	71500
1987	8800	8200	5900	5400	0	146700
1988	9000	6000	5400	7600	600	227000
1989	2300	2700	700	4900	7000	185900
1990	3300	9700	900	9100	14000	173000
1991	17400	14900	4400	12700	29700	135900
1992	33400	17500	14000	17400	25600	107200
1993	27400	19700	14700	10900	22200	100100
1994	16000	10600	5800	5500	35900	117200
1995	29600	16500	5900	7500	34400	80100
1996	37900	23900	5700	6800	59700	75900
1997	42400	28200	6900	15100	56500	96900
1998	55600	34200	10900	14600	46700	107100
1999	59200	23600	8800	14900	40500	97500
2000	43100	20500	14300	19500	39000	105600
2001	36300	20700	13200	16900	33700	109200
2002	24700	18800	16900	13400	24000	98300
2003	25100	18800	12800	8100	41400	78700
2004	17900	19100	6400	5300	40800	46300
2005	19600	14200	4500	2000	26700	39300
2006	22500	15100	2000	4800	20700	40700
2007	22500	15100	2000	4800	20700	40700

Table 14: Method of dividing annual catches into the six model fisheries (Esp, Wsp, Ensp1, Ensp2, Wnsp1, and Wnsp1). The small amount of catch reported in the areas west coast North Island and Challenger (typically 100 t per year) was ignored (which means that this catch is pro-rated across all fisheries).

Area	Oct–Mar	Apr–May	Jun–Sep
West coast South Island; Puysegur	Wsp	Wsp	Wsp
Sub-Antarctic	Wnsp1	Wnsp2	Wnsp2
Cook Strait; Pegasus	Ensp1	Ensp2	Esp
Chatham Rise; east coasts of South Island & North Island; null[1]	Ensp1	Ensp2	Ensp2

[1] no area stated

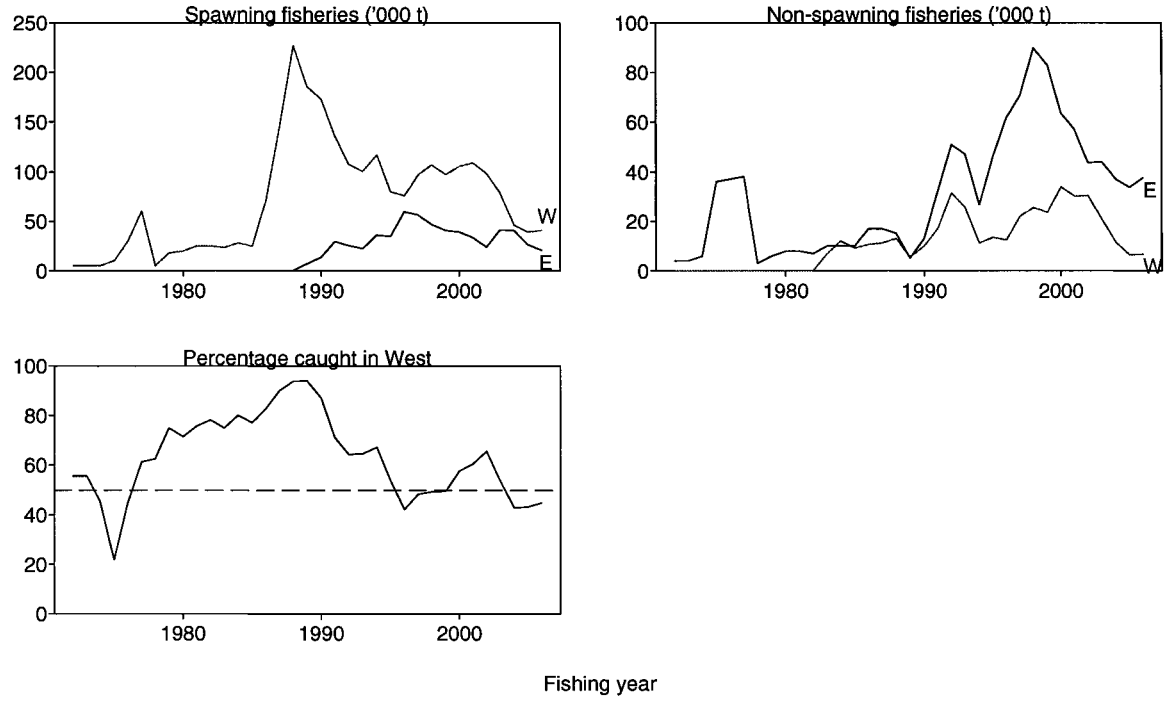

Figure 14: Annual catches by fishery for the spawning (top left panel) and non-spawning (top right panel) fisheries, and annual percentage of catch caught in western fisheries (Wsp, Wnsp1, Wnsp2) (bottom panel).

The fixed biological parameters in the model (Table 15) are unchanged from those used in 2006.

Table 15: Fixed biological parameters used by the model. Sources: a, Horn & Sullivan (1996) by sex, and Francis (2005) for both sexes combined; b, Francis (2003); c, assumed.

			W stock			E stock			Source
Type	Symbol	All fish	Male	Female	Both	Male	Female	Both	
Growth	L_∞		92.6	104.0	102.1	89.5	101.8	100.8	a
	k		0.261	0.213	0.206	0.232	0.161	0.164	
	t_0		-0.5	-0.6	-0.96	-1.23	-2.18	-2.16	
Length-weight	a	4.79×10^{-6}							b
[W(kg)=aL(cm)^b]	b	2.89							
Proportion by sex at birth		0.5							c

3.2 Ogives

The ogives used in the model are the same as in 2006: six selectivity ogives (one for each of the four fisheries — Espsl, Wspsl, Enspsl, Wnspsl — and one each for trawl surveys in areas CR and SA – CRsl, SAsl), and three migration ogives (for migrations Whome, Espmg, and Wspmg). As in previous years, two alternative sets of ogive assumptions were used for the final runs (Table 16).

The interpretation of the home migration ogive, Whome, differed according to whether or not natal fidelity was assumed. With natal fidelity (in runs 4.4 and 4.5) this ogive applied only to the W juveniles in CR and was the same in every year. At age 8, all W juveniles remaining in CR were forced to migrate to SA. Without natal fidelity (in run 4.7) this ogive applied to all juveniles in CR and was allowed to vary from year to year (it is this annual variation that determines what proportion of each year class grows up to be an E or W fish).

Table 16: Ogive assumptions for the three final runs. In the ogive constraints, $O_{7,F,E}$ refers to the ogive value at age 7 for female fish from the E stock, etc.

Runs	Ogive type	Description	Constraints
4.4, 4.7	Spawning selectivity	Length-based, logistic	same for M and F, same for E and W
	Non-spawning selectivity	Length-based, double-normal	same for M and F, must be domed[1]
	Survey selectivity	Length-based, double-normal	same for M and F, must be domed[1]
	Spawning migration	Free, ages 1–8	$O_{8,M,E} = O_{8,M,W}$, $O_{8,F,E} = O_{8,F,W} \geq 0.6$ $O_A = O_8$ for $A > 8$
4.4	Home migration	Free, ages 1–7	same for M and F, =1 for age > 7
4.7	Home migration	Free, ages 1–8	same for M and F, =0 for age > 8
4.5	Spawning selectivity	Age-based, double-normal	same for E and W
	Non-spawning selectivity	Age-based, double-normal	
	Survey selectivity	Age-based, double-normal	
	Home migration	Free, ages 1–7	=1 for age > 7
	Spawning migration	Free, ages 1–8	$O_A = O_8$ for $A > 8$

[1] see figure 11, and associated text, of Francis et al. (2003) for an explanation of what this means

As in previous years, the model attempted to estimate annual changes in Wspsl (the selectivity ogive for W spawning fishery). Following the recommendation of Francis (2006) these changes were restricted to years for which there were Wspage data (i.e., from 1988 onwards). The changes were driven by the median day of the fishery (Table 17). Annual changes in the selectivity for the other fisheries were not estimated because these were shown not to improve model fits in 2003 (Francis 2004).

Table 17: Median catch day by year for Wsp, as used in estimating annual changes in the selectivity Wspsl. The mean value was used for all years (including 2007) for which there was catch but no Wspage data.

1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
299	302	298	301	306	304	308	307	312	310	311	309

2000	2001	2002	2003	2004	2005	2006	Mean
309	309	308	309	307	309	310	305

3.3 Other structural assumptions

To describe the structural assumptions made in CASAL for the various model runs we need to distinguish between what we might call 'spawning' and 'biological' stocks. When the term 'stock' is used in the CASAL manual and input files it refers to biological stocks. All runs assumed two spawning stocks, but the number of biological stocks depended on whether natal fidelity was assumed. With natal fidelity, there were two biological stocks, and these corresponded exactly with the two spawning stocks. Without natal fidelity, the model assumed a single biological stock, but the adult population was divided into two spawning stocks, according to which spawning ground they migrated to each winter. It is important to understand that YCSs are estimated only for biological stocks. Thus, when natal fidelity was not assumed, CASAL produced just one vector of YCSs, which we interpret as referring to the combined effect of spawning in the two spawning grounds, as seen in the relative numbers of juveniles of each year class seen in CR.

For each biological stock, the population at the start of the fishery was assumed to have a stable age structure with biomass, B_0, and constant recruitment, R_0. The Francis parameterisation of recruitment was used. Thus, recruitment at age 1 in year y in each stock was given by $R_y = R_{mean}$ x YCS_{y-2} x $SR(SSB_{y-2})$, where YCS_y is the year-class strength for fish spawned in year y, SR is a Beverton-Holt stock-recruit relationship with assumed steepness 0.9 (following Cordue 2001), R_{mean} is the expected recruitment (ignoring the stock-recruit relationship), and SSB_y is the mid-season spawning stock

biomass in year y. R_0 is calculated as $R_{mean}Y_{mean}$, where Y_{mean} is the mean YCS over the years 1975 to 2002, inclusive (so R_0 is mean recruitment over those years, ignoring the effect of the stock-recruit relationship).

Thirty-one YCSs were estimated for each biological stock, for years 1975 to 2005, inclusive. YCSs for the initial years (1970 to 1974) were fixed at 1. For runs with two biological stocks (i.e., runs assuming natal fidelity) the E and W YCSs for 2005 were constrained (by a penalty function) to be equal for MPD runs, but this constraint was removed for the full Bayesian runs.

The maximum exploitation rates assumed were the same as in previous years: 0.3 in each part of the two non-spawning fisheries (which is approximately equivalent to 0.5 for the two parts combined), and 0.67 for both spawning fisheries. A penalty function was used to strongly discourage model estimates for which these maximum exploitation rates were exceeded.

As in previous years, the model's expected age distributions had ageing error applied to them before they were compared with the observed distributions (i.e., before they were used to calculate the objective function value).

3.4 Observations

Three types of observations were used in the model: biomass indices (Table 18), proportions at age (and sex) (Table 19, Figure 15), and proportion spawning (Table 20). Biomass indices new to this assessment came from an acoustic survey in Cook Strait in July/August 2006 (O'Driscoll 2007), and trawl surveys of the Sub-Antarctic in December 2006 (O'Driscoll & Bagley, unpublished results) and Chatham Rise in January 2007 (Stevens & O'Driscoll, unpublished results). The other CSacous indices in Table 18 differ from those used in previous assessments because they have been revised to use new target-strength estimates (WG-HOK-2007/7), but this revision is of little consequence to the assessment because the proportional changes in the indices were all very similar (an increase of about 9%).

The proportions-at-age data fall into three groups. The first group — trawl survey (CRsumage, SAsumage, SAautage) and spawning catch at age (Wspage, Espage) — is the most substantial and reliable. These data are otolith-based, and use an age-length key to transform proportions at length to proportions at age. The non-spawning otolith-based data (Enspage, Wnspage) are available only since sufficient otoliths have been collected from these fisheries. Because the fisheries are spread over many months, these proportions at age must be estimated directly (rather than via an age-length key). The third group of data (EnspOLF, WnspOLF), which is OLF-based (Hicks et al. 2002), is less reliable because of the difficulty of inferring age distributions from length data alone.

Although both trawl surveys provide information about year-class strengths (YCSs) the CR survey is more reliable for recent year classes. This is apparent in two ways. First, the between-survey consistency of estimated numbers at age for the youngest ages is much greater in CR than in SA (Figure 16). Second, the correlation between these estimates and model estimates of YCS is not strong until age 4 for the SA survey, but is quite strong at age 1 for the CR survey (Figure 17).

The proportions-spawning data (Table 20) are unchanged from last year because there has been no clear resolution concerning (a) differences between these and more recent data, and (b) some uncertainties about the original data (see sections 4.2-3 in Francis (2007)). The way the proportions-at-age data enters the model varies amongst data sets (Table 21). As in 2002 (and all subsequent years), all proportions less than 0.0001 were replaced by 0.0001 (for reasons, see Francis et al. (2003)). For the otolith-based data sets the maximum ages were set as high as was possible without allowing the percentage of data points requiring this adjustment to exceed 2%.

Table 18: Biomass indices ('000 t) used in the assessment, with observation and total c.v.s (respectively) in parentheses. Highlighted values are new to this assessment.

	CRsumbio	SAsumbio	SAautbio	CSacous	WCacous
1988	–	–	–	–	417 (0.22,0.60)
1989	–	–	–	–	249 (0.15,0.38)
1990	–	–	–	–	255 (0.06,0.40)
1991	–	–	–	180 (0.13,0.41)	340 (0.14,0.73)
1992	120 (0.08,0.21)	80 (0.07,0.21)	68 (0.08,0.22)	–	345 (0.14,0.49)
1993	186 (0.10,0.22)	87 (0.06,0.21)	–	583 (0.15,0.52)	550 (0.07,0.38)
1994	146 (0.10,0.22)	100 (0.09,0.22)	–	592 (0.06,0.91)	–
1995	120 (0.08,0.21)	–	–	427 (0.12,0.61)	–
1996	153 (0.10,0.22)	–	89 (0.09,0.22)	202 (0.09,0.57)	–
1997	158 (0.08,0.22)	–	–	295 (0.12,0.40)	654 (0.10,0.60)
1998	87 (0.11,0.23)	–	68 (0.11,0.23)	170 (0.10,0.44)	–
1999	109 (0.12,0.23)	–	–	243 (0.10,0.36)	–
2000	72 (0.12,0.23)	–	–	–	396 (0.14,0.60)
2001	60 (0.10,0.22)	56 (0.13,0.24)	–	220 (0.12,0.30)	–
2002	74 (0.11,0.23)	38 (0.16,0.26)	–	320 (0.13,0.35)	–
2003	53 (0.09,0.22)	40 (0.14,0.24)	–	225 (0.17,0.34)	–
2004	53 (0.13,0.24)	14 (0.13,0.24)	–	–	–
2005	85 (0.12,0.23)	18 (0.12,0.23)	–	132 (0.11,0.32)	–
2006	99 (0.11,0.23)	21 (0.13,0.24)	–	126 (0.17,0.34)	–
2007	70 (0.08,0.22)	14 (0.11,0.23)	–	–	–

Table 19: Description of the proportions-at-age observations used in the assessment. These data derive either from otoliths or from the length-frequency analysis program OLF (Hicks et al. 2002). Data from highlighted years are new to this assessment.

Area	Label	Data type	Years	Source of age data
WC	Wspage	Catch at age	1988–06	otoliths
SA	WnspOLF	Catch at age	1992–94, 96, 99–00	OLF
	Wnspage	Catch at age	2001–04, 06	otoliths
	SAsumage	Trawl survey	1992–94, 2001–07	otoliths
	SAautage	Trawl survey	1992, 96, 98	otoliths
CS	Espage	Catch at age	1988–06	otoliths
CR	EnspOLF	Catch at age	1992, 94, 96, 98	OLF
	Enspage	Catch at age	1999–06	otoliths
	CRsumage	Trawl survey	1992–07	otoliths

Table 20: Proportion spawning data, pspawn. These are estimates, from the 1992 and 1998 SAaut surveys, of the proportion, by age, of females that were expected to spawn in the following winter.

	Age						
Year	3	4	5	6	7	8	9+
1992	0.19	0.45	0.27	0.57	0.68	0.69	0.64
1998	0.28	0.60	0.40	0.40	0.40	0.40	0.52

Table 21: Age ranges used for at-age data sets. In all cases the last age was treated as a plus group.

	Age range	
Data set	Lower	Upper
Espage, Wspage, SAsumage, SAautage	2	15
Wnspage	2	13
CRsumage, Enspage	1	13
WnspOLF	2	6
EnspOLF	1	6
pspawn	3	9

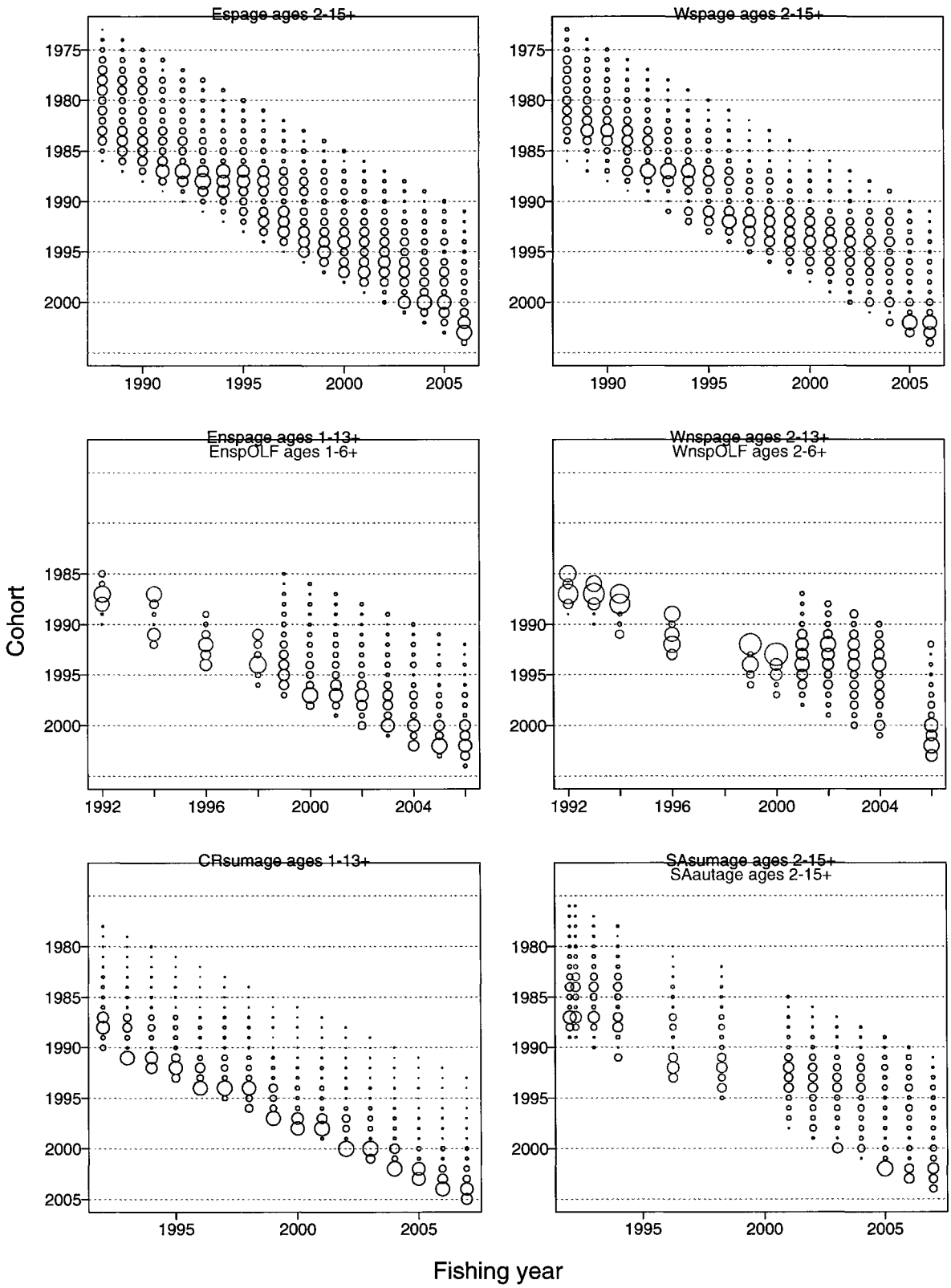

Figure 15: Proportions-at-age data, plotted by cohort and fishing year, with both sexes combined. The area of each circle is proportional to the associated proportion at age. Circle positions for the SAautage data have been offset horizontally to allow them to be plotted on the same panel as the SAsumage data. In all panels the right-most column of circles is new to this assessment.

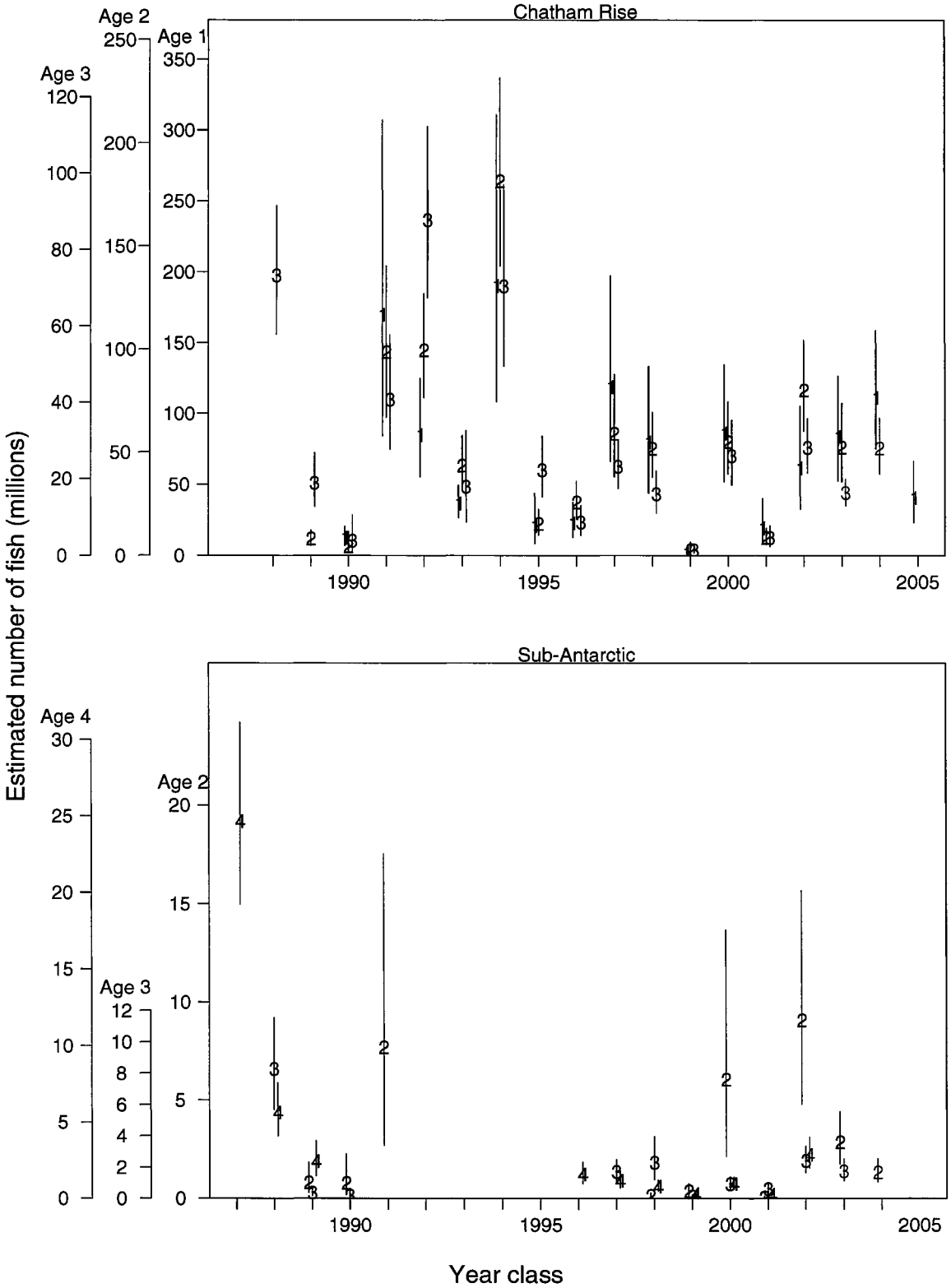

Figure 16: Estimated numbers at age for each of the three youngest ages in the two major trawl survey series. Vertical bars indicate 95% confidence intervals; data points new to this assessment are plotted in grey.

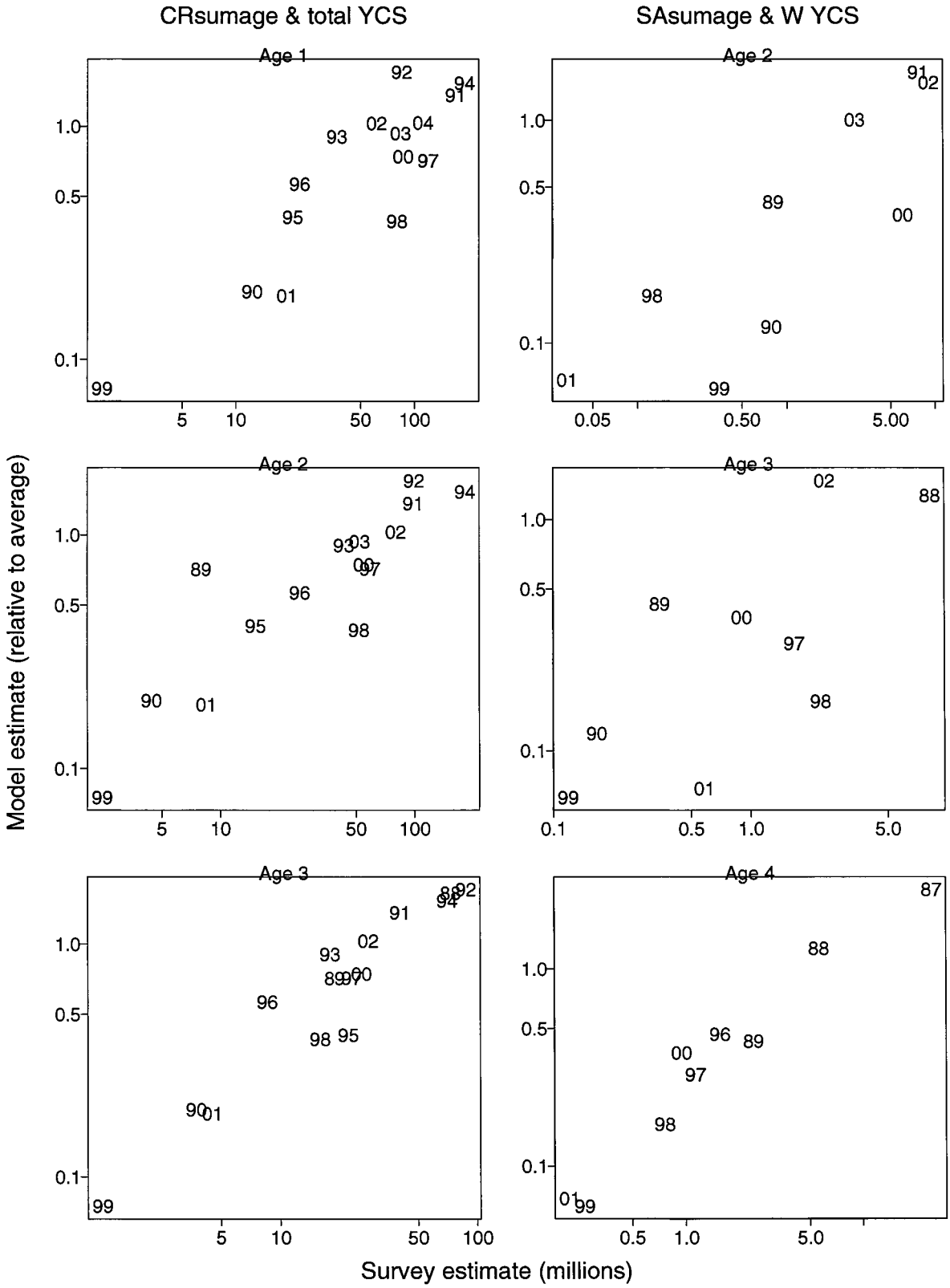

Figure 17: Comparison of survey and model estimates of YCSs (each point represents one year class and the plotting symbol identifies the year). Left panels compare CRsumage estimates at ages 1, 2, and 3 with model estimates of total (E + W) YCS; right panel compare SAsumage estimates at ages 2, 3, and 4 with model estimates of W YCS. The model estimates are from run 2.4 in the last assessment; only survey data available for that assessment are included in the plot.

For the 2006 Wspage data there was some uncertainty about tows from inside the 25 n. mile line, (which contributed 14% of the catch for that year). Two versions were considered, and these used exactly the same data for outside this line. To represent tows inside the line, the preferred version used observer data (in one stratum); the alternative version used market-sample data (in five fortnightly strata), but excluded landings from one large vessel on which the fish were, unbeknownst to the market samplers, sorted by length. Because the two versions differed only slightly in their estimates of the proportions at age for the entire 2006 catch from this fishery (Figure 18) only the preferred version was used in the assessment.

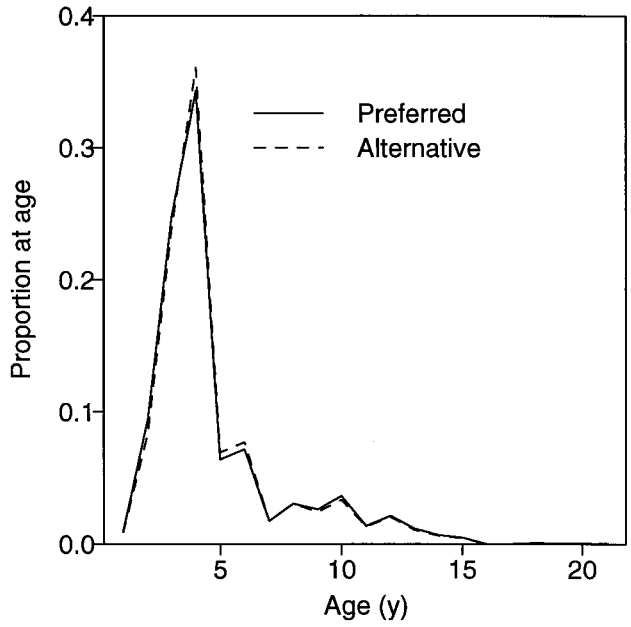

Figure 18: Two versions of the 2006 proportions-at-age data for the W spawning fishery: preferred (using observer data for tows inside the 25 n. mile line, solid line) and alternative (using market samples for tows inside the 25 n. mile line, broken line).

The proportion of young fish in the catch from the west spawning fishery is still much higher than it was in earlier years but is lower than it was in 2005 (Figure 19).

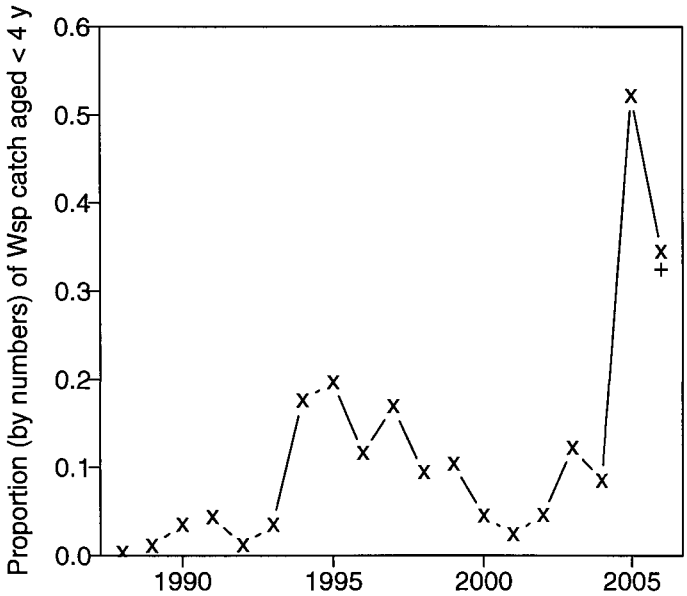

Figure 19: Annual proportion of young fish (aged less than 4 y) in the catch from the west spawning fishery. The proportion calculated from the alternative 2006 data set shown in Figure 9 is plotted as '+'. Note that all plotted proportions are based on numbers of fish; proportions based on weight would be much smaller.

There was some discussion in the WG as to whether the 2006 at-age data from the west non-spawning (sub-Antarctic) fishery should be used in the assessment because they suggest that the selectivity for this fishery has changed substantially to favour younger fish (see Figure 15). It was decided to include them on the grounds that the strongest information about YCSs in at-age data sets comes from the comparison of proportions at age for year classes that are close in age, and that such comparisons would be little affected by any change in selectivity.

3.5 Error assumptions

The error distributions assumed were robust lognormal (Bull et al. 2005) for the proportions-at-age data, and lognormal for all other data. This means that the weight assigned to each datum was controlled by an error c.v. In this section I describe how these c.v.s were assigned.

For the biomass indices, two alternative sets of c.v.s were available (see Table 18). The total c.v.s represent the best estimates of the uncertainty associated with these data, and were used in all initial model runs. For the acoustic indices, these were calculated using a simulation procedure intended to include all sources of uncertainty (O'Driscoll 2002), and the observation-error c.v.s were calculated in a similar way but including only the uncertainty associated with between-transect (and within-stratum) variation in total backscatter. For the trawl indices, the total c.v.s were calculated as the sum of an observation-error c.v. (using the standard formulae for stratified random surveys, e.g., Livingston & Stevens (2002)) and a process-error c.v., which was set at 0.2, (following Francis et al. 2001) (note that c.v.s add as squares: $c.v._{total}^2 = c.v._{process}^2 + c.v._{observation}^2$). In some model runs (see below) it was decided to upweight some biomass indices by using their observation, rather than total, c.v.s.

For almost all of the proportions-at-age observations, total c.v.s were treated as the sum of a process-error c.v. and an observation-error c.v. (the only exception was pspawn, for which an arbitrary c.v. of 0.25 was assumed, following Cordue (2001)). Observation-error c.v.s for the remaining otolith-based data were calculated by bootstrapping. For the OLF-based data the c.v.s used were the same as in 2004 (Francis 2005). As is typical with proportions, estimated c.v.s decreased as proportions increase (Figure 20).

Process-error c.v.s for the at-age data were estimated within the model (one c.v. for each data set) for all point estimates, as in previous years. For full Bayesian estimates, these c.v.s were fixed. Although there is some evidence that these process-error c.v.s should decrease with increasing age, there does not appear to be a strong need to implement such a relationship (Francis 2004).

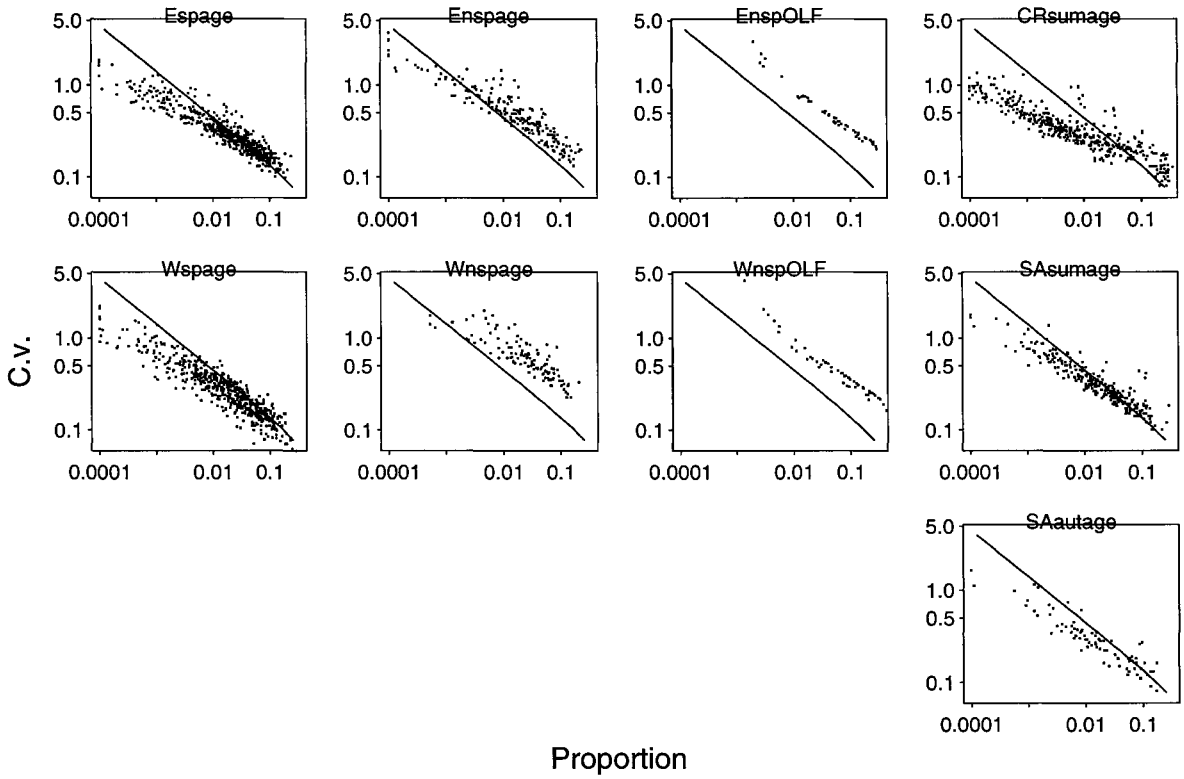

Figure 20: Observation-error c.v.s for the proportions-at-age data sets. Each point represents a proportion at a specific age and sex for a given year. The diagonal line, which is the same in each panel, is added to aid comparison between panels; it shows the relationship between proportion and c.v. that would hold with simple multinomial sampling with sample size 500.

3.6 Parameters, priors, and penalties

The number of parameters estimated in the final model runs was 139 (for runs 4.4 and 4.7) or 117 (for run 4.5) (Table 22). Most of the associated prior distributions were intended to be uninformative; the main exceptions were those for the catchabilities (O'Driscoll et al. 2002), pE, and natural mortality (Smith 2004). For selectivity[Wspsl].shift_a and migration[Whome].annual_variation_values, normal priors were used with standard deviations more or less arbitrarily chosen to discourage extreme values (see sections 7.1 and 7.3, respectively, of Francis (2006)).

As in previous assessments, the model estimated natural mortality separately by sex (when sex was included in the model) because of the trends with age in the sex ratio.

Table 22: Parameters estimated in the final model runs, and their associated prior distributions. Where the number of parameters varied between model runs the three values given are for runs 4.4, 4.5, and 4.7, respectively. Distribution parameters are: bounds for uniform and uniform-log; mean (in natural space) and c.v. for lognormal; and mean and s.d. for normal and beta.

Parameter(s)	Description	Distribution Type	Distribution Parameters		No. of parameters
log_Bmean_total	$\log(B_{mean,E} + B_{mean,W})$	uniform	12.6[a]	16.2	1,1,0
Bmean_prop_stock1 (=pE)[b]	$B_{mean,E}/(B_{mean,E} + B_{mean,W})$	beta[0.1,0.6][c]	0.344	0.072	1,1,0
Bmean	B_{mean} (for E + W)	uniform-log	10^5	10^7	0,0,1
recruitment.YCS	year-class strengths	lognormal	1	0.95	62,62,31
migration[Whome].annual_variation_values		normal	–[d]	1.0	0,0,32
q[CSacous].q	catchability, CSacous	lognormal	0.77	0.77	1
q[WCacous].q	catchability, WCacous	lognormal	0.57	0.68	1
q[CRsum].q	catchability, CRsumbio	lognormal	0.15	0.65	1
q[SAsum].q	catchability, SAsumbio	lognormal	0.17	0.61	1
q[SAaut].q	catchability, SAautbio	lognormal	0.17	0.61	1
natural_mortality	M_{male} & M_{female} ages 5–9	lognormal	0.182	0.509	8,0,8
natural_mortality.all	M	lognormal	0.298	0.153	0,1,0
process error c.v.s		uniform	0.1	1	7
selectivity[Wspsl].shift_a	Wspsl shift	normal	0	0.25	1
migrations	Whome, Wspmg, Espmg	uniform	various		40,24,40
comm. selectivities	Espsl,Wspsl,Enspsl,Wnspsl	uniform	various		8,9,8
surv. selectivities	CRsl, SAsl	uniform	various		6
					139,117,139

[a] A lower bound of 13 was used for run 4.5
[b] For run 4.7, this parameter was not estimated but a similar prior was assumed (see Appendix Section A1.3.2)
[c] This is a beta distribution scaled to have its range from 0 to 0.6, rather than the usual 0 to 1
[d] See Appendix Section A1.3.2

In addition to the priors, bounds were imposed for all parameters with non-uniform distributions. For the catchability parameters these were those calculated by O'Driscoll et al. (2002) (where they are called "overall bounds"); for other parameters they were usually set at the 0.001 and 0.999 quantiles of their distributions. Some bounds were adjusted in some runs to avoid poor model behaviour; these adjustments did not appear to have a significant effect on the model results.

Penalty functions were used for three purposes. First, any parameter combinations that caused any exploitation rate to exceed its assumed maximum (Section 3.3) were strongly penalised. Second, where there were two biological stocks, the most recent YCSs were forced to be the same for E and W (but this penalty was dropped in MCMC runs) (Section 3.3). The third use of penalty functions was to link the spawning migration ogives for the two stocks (as per the constraints in Table 16).

4. INITIAL ASSESSMENT RESULTS

The aim of the analyses presented in this section was to apply the ideas obtained from the preliminary analyses (Section 2), using the data new to this assessment, to investigate any problems that arose, and then to decide which runs would be used in the formal assessment (whose results are presented in Section 5).

4.1 Initial MPD runs

The aim for the initial MPDs was to explore runs that would be the same as the three final runs from 2006 (see Table 1) except that (a) they used an additional year's data, (b) they included two modifications arising from analyses since the 2006 assessment (the double-exponential ogive and new prior of age-dependent natural mortality), and (c) biomass indices would be upweighted (by switching from total c.v.s to observation c.v.s – see Table 18) only if necessary to obtain an acceptable fit (in 2006, trawl-survey biomass indices were upweighted in all final runs).

Runs 4.1–4.3 were the same as the three final runs from 2006 except for changes (a) and (b) above, and the use of 'natural' weighting (i.e., no upweighting) for all biomass indices. All three runs showed a poor fit to SAsumbio (Figure 21). When the trawl-survey biomass indices were upweighted, in runs 4.4–4.6, the fits to SAsumbio became acceptable (Table 23, Figure 22), but WCacous was not well fitted in run 4.6 (Table 23). Upweighting both trawl and acoustic indices, in run 4.7, improved the statistical measure of fit to WCacous (Table 23) though the visual fit was not greatly improved (Figure 23).

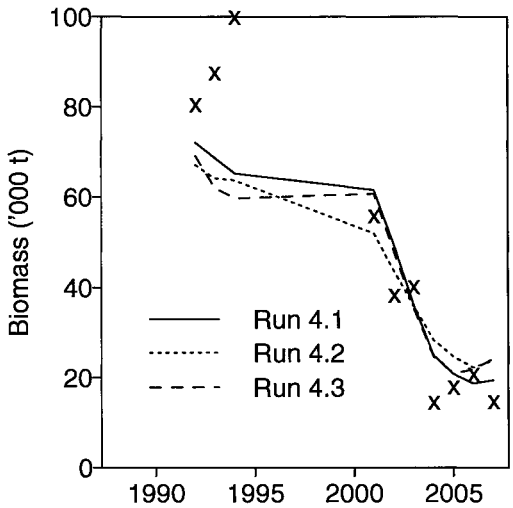

Figure 21: Fits to SAsumbio for runs 4.1 to 4.3, showing observed ('x') and expected values (lines).

Table 23: Goodness of fit of biomass indices, as measured by the SDNR (standard deviation of the normalised residuals), for some new model runs. For this table the normalised residuals were calculated using the original c.v.s (i.e., ignoring changes in c.v.s for upweighting trawl biomass data sets). The highlighted entries show poor fits that were improved in other runs by upweighting some or all biomass indices.

New run	Analogous 2006 run	Biomass indices upweighted in new run	CRsumbio	SAsumbio	SAautbio	CSacous	WCacous
4.1	2.4	None	0.84	1.27	0.83	1.05	1.13
4.2	2.5	None	0.82	1.59	0.85	1.07	0.98
4.3	2.6	None	0.90	1.52	0.85	1.12	1.28
4.4	2.4	Trawl	0.79	1.01	0.82	1.05	1.15
4.5	2.5	Trawl	0.77	1.00	0.93	1.07	1.05
4.6	2.6	Trawl	0.83	1.00	0.82	1.15	1.32
4.7	2.6	Trawl + acoustics	0.85	1.04	0.78	1.04	1.08

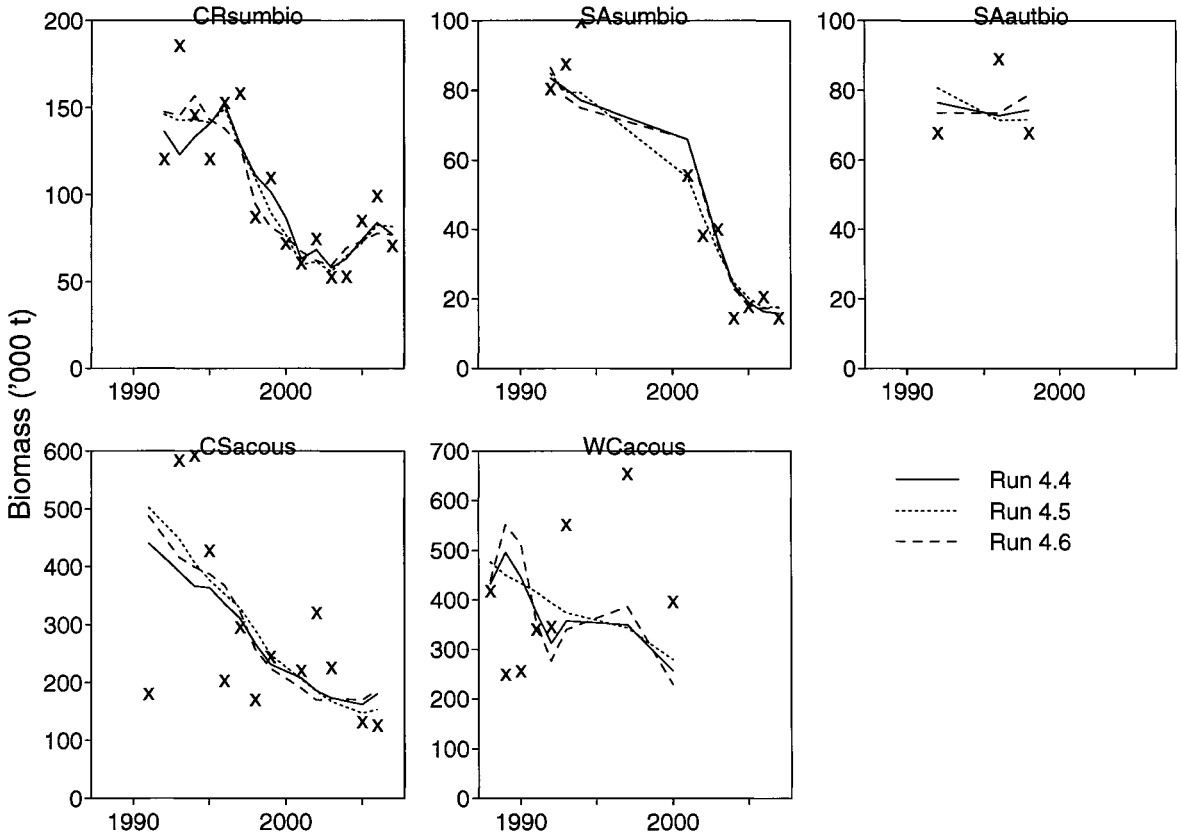

Figure 22: Fits to biomass indices for runs 4.4 to 4.6, showing observed ('x') and expected values (lines).

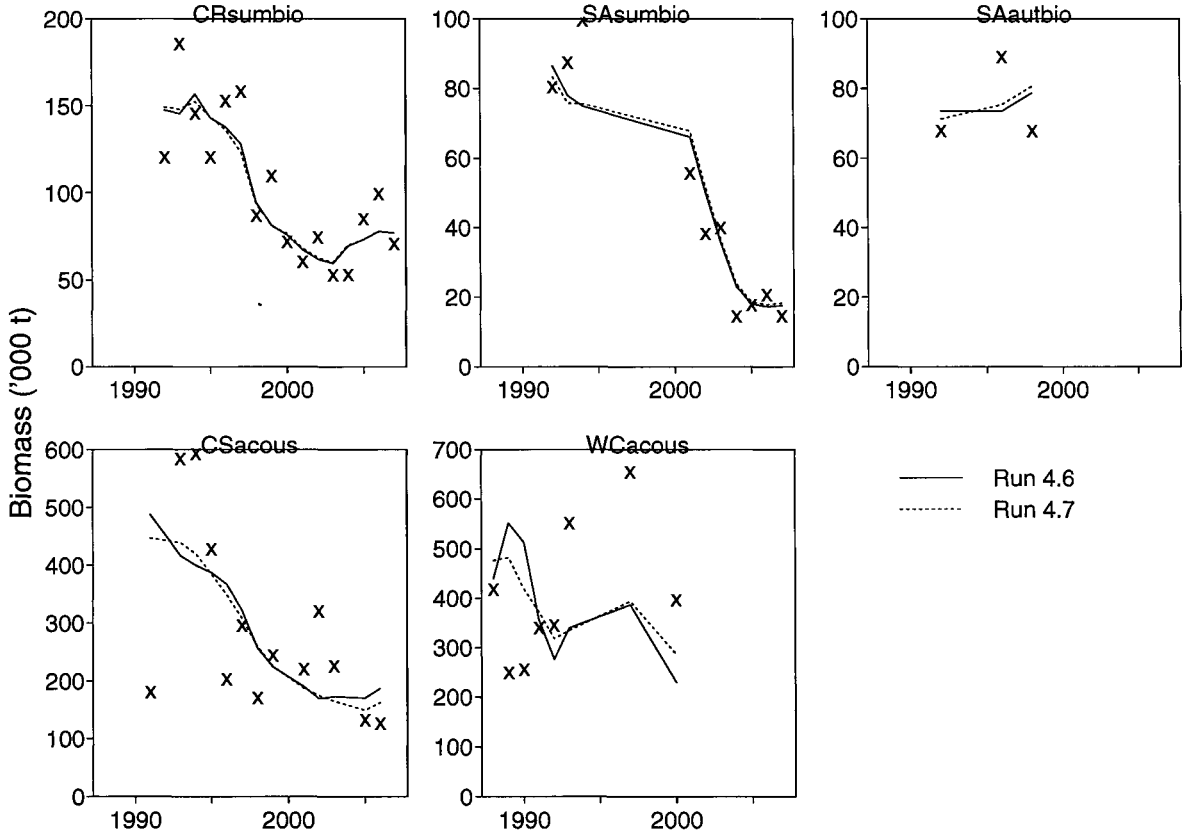

Figure 23: Fits to biomass indices for runs 4.6 and 4.7, showing observed ('x') and expected values (lines).

In comparison to the 2006 runs, all the new runs produce more pessimistic estimates of the status of the W stock in 2006, and estimates of unfished biomass (B_0) were almost always slightly lower (Table 24).

Table 24: Comparison of old and new biomass estimates for the individual stocks, E and W, and the combined E + W stock. In each group of runs, the first is from 2006 and the other(s) is (are) analogous run(s) for 2007.

	B_0 ('000 t)			$B_{2006}(\%B_0)$			$B_{2007}(\%B_0)$		
Run	E	W	E + W	E	W	E + W	E	W	E + W
2.4	509	866	1375	41	23	30	–	–	–
4.4	501	856	1357	41	17	26	45	16	27
2.5	642	1162	1804	33	28	30	–	–	–
4.5	636	1144	1779	32	24	27	34	23	27
2.6	557	1050	1607	45	23	31	–	–	–
4.6	543	1118	1661	45	20	29	46	19	28
4.7	457	888	1345	38	15	23	41	15	24

It was decided to adopt runs 4.4, 4.5, and 4.7 as final runs for 2007, and the plots in the remainder of this section compare these runs with the corresponding runs from 2006. Most of the differences between old and new runs are slight. Perhaps the most significant is the downward revision of W YCS estimates for the three years 2002–04 (Figure 24) (a similar pattern is seen in the estimated YCSs for E + W). The 2005 year classes, estimated for the first time this year, appear to be below average for both stocks, although these estimates must be quite uncertain. Changes in exploitation rates (Figure 25), biomass trajectories (Figure 26), selectivities (Figure 27), and migration ogives (Figure 28) are mostly minor. As expected from earlier work (see Section 2.4 above) estimates of age-dependent natural mortality are much higher than before for the youngest ages, but similar for other ages (Figure 29).

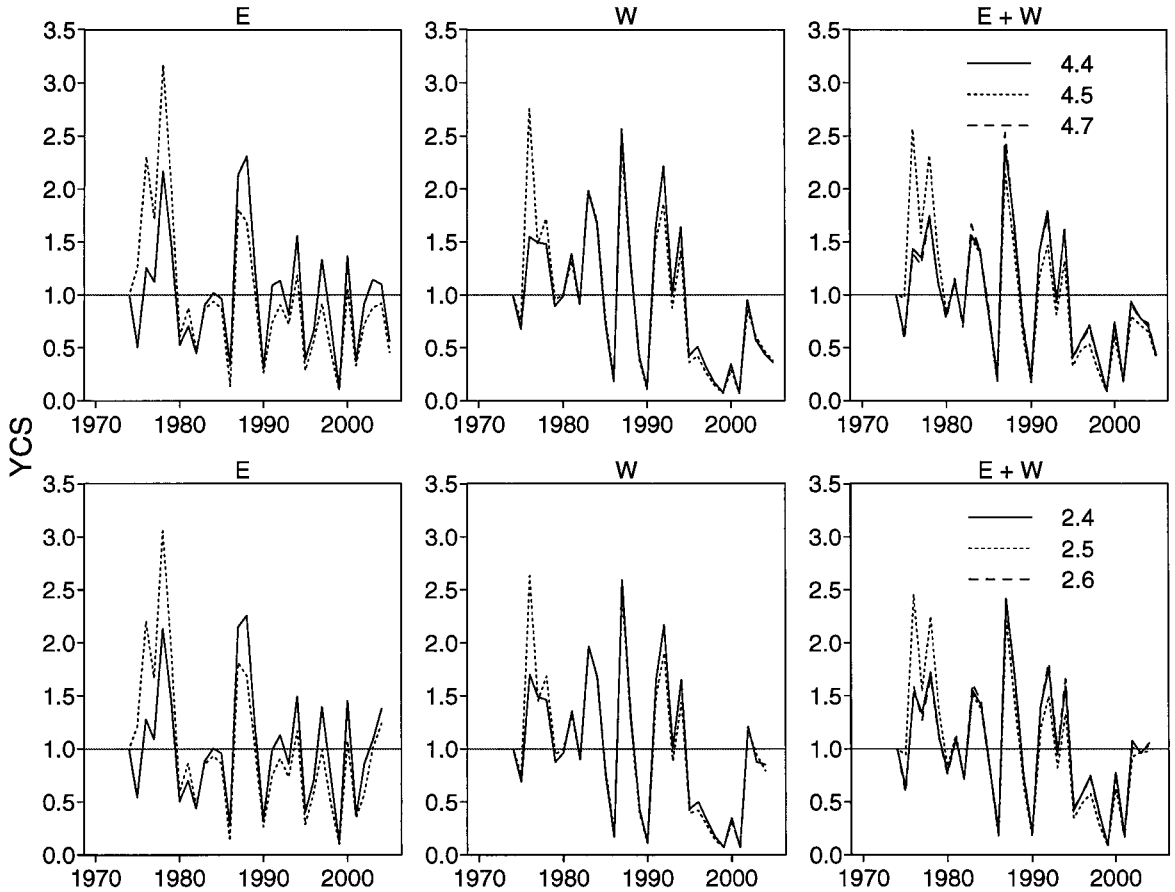

Figure 24: YCS estimates for new runs 4.4, 4.5, and 4.7 (upper panels) and the corresponding runs from last year's assessment (lower panels). Note that for runs 2.6 and 4.7, where there is no natal fidelity, YCSs are defined only for the E + W stocks combined.

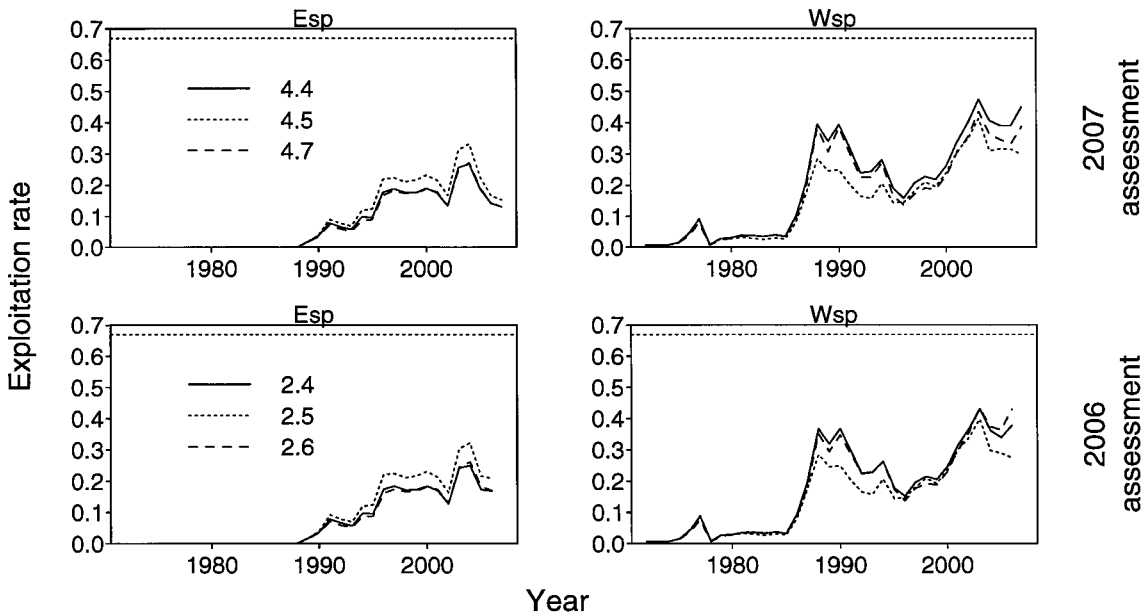

Figure 25: Estimated exploitation rates from runs 4.4, 4.5, and 4.7 (upper panels) and the corresponding runs from last year's assessment (lower panels).

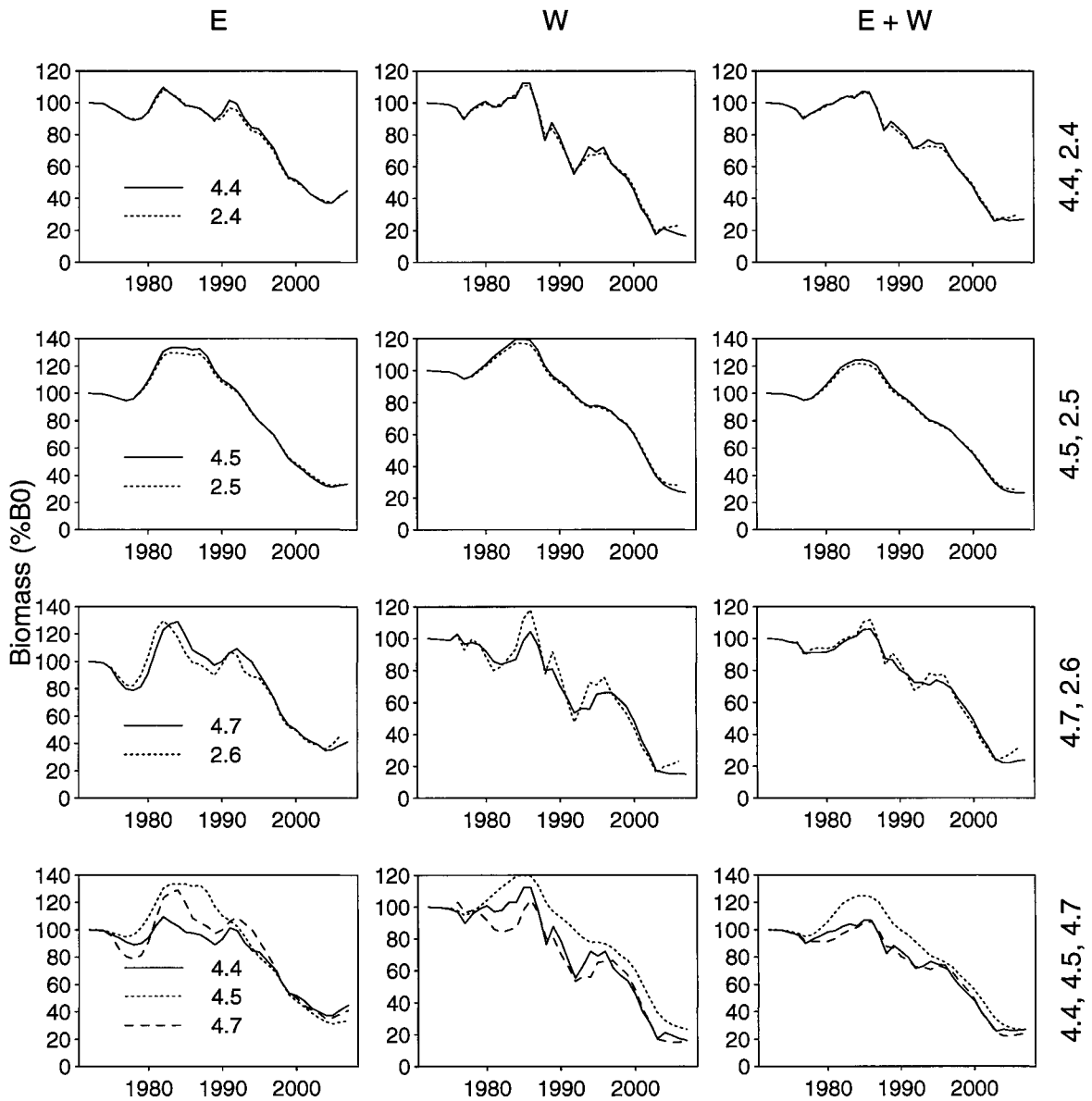

Figure 26: Comparison of biomass trajectories from different runs: E stock (left column), W stock (middle column), and E + W stocks combined (right column). The top three rows of panels compare each new run (solid lines) with the corresponding run from 2006 (broken lines); the bottom row compares the three new runs.

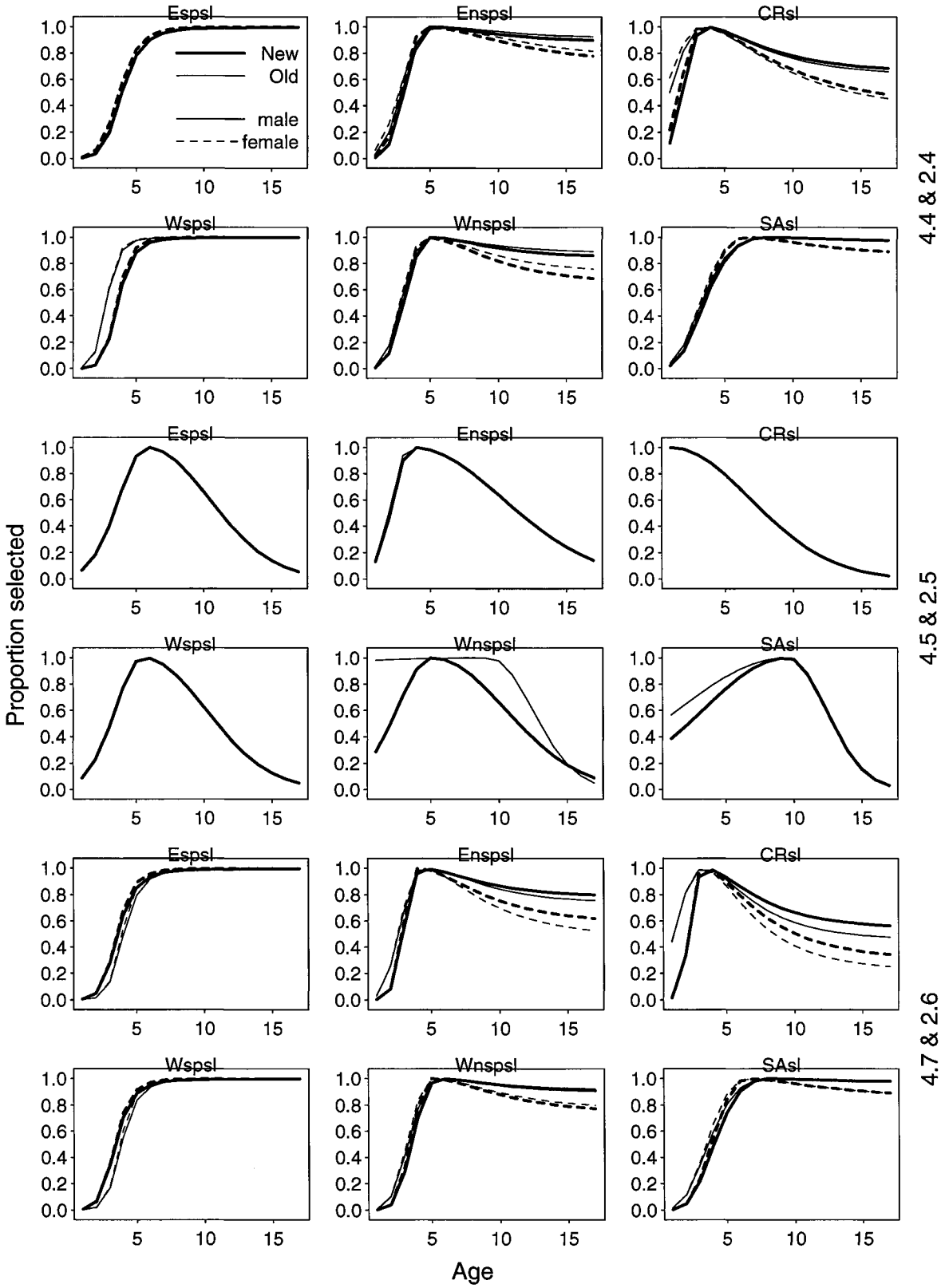

Figure 27: Estimated selectivity curves for new (heavy lines) and analogous 2006 runs (light lines).

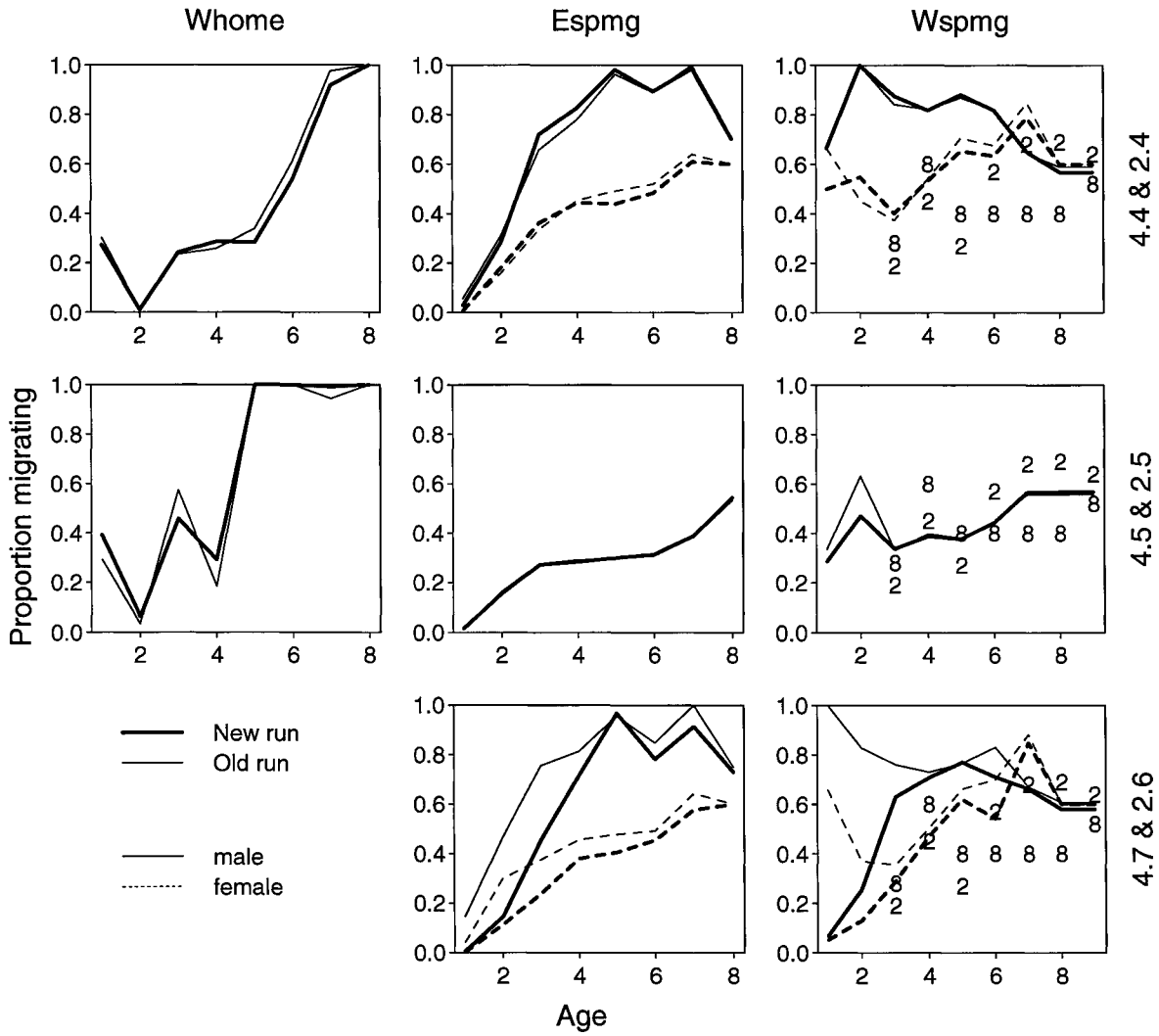

Figure 28: Estimated migration ogives for new and old runs. Each row of plots compares ogives from a new run (heavy lines) with those from the analogous 2006 runs (light lines). The Whome ogive for runs without natal fidelity are not plotted because they vary from year to year and have a different meaning from the ogive of the same name in the other runs. The observations pspawn are also plotted in the rightmost panels, with the plotting symbol identifying the year of sampling ('2' = 1992, '8' = 1998).

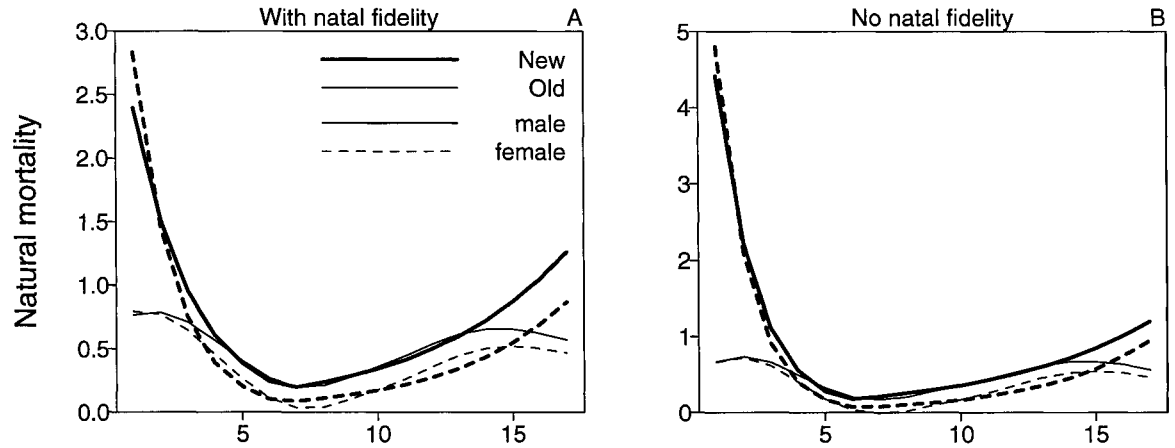

Figure 29: Comparison between age-dependent natural mortality estimated in the new runs (heavy lines) and the corresponding runs from 2006 (light lines): A, runs with natal fidelity (old run = 2.4, new run = 4.4) and B, with no natal fidelity (old run = 2.6, new run = 4.7).

4.2 Why have recent W YCSs decreased?

As noted above, the most significant change in the new assessment is that recent W YCSs have been revised downwards. To understand what caused this change, two new runs (labelled 4.8 and 4.9) were done that were the same as runs 4.4 and 4.5, respectively, except that the YCSs were constrained to be the same as those estimated in the analogous runs from 2006. We would expect this constraint to degrade the overall fit to the data. Also, the degradation in fit will be greatest for those data sets which were most responsible for the downward revision in the YCS estimates. By this measure, the responsibility for the revision is about evenly split between the biomass indices from the two summer trawl surveys (CRsumbio and SAsumbio) and all the at-age data (Table 25). This is remarkable when we consider that we have only two new observations of trawl-survey biomass, but we have many more new observations amongst the at-age data sets (160 for run 4.4, and 80 for run 4.5, in which sex is ignored). For those at-age data sets with new observations, we can separate the degradation in fit into two parts: that associated with the new observations and that with existing observations. This calculation shows that it is the new observations in these data sets that are mostly responsible for the revision in the YCS estimates, and that the responsibility is not confined to just one or two of these data sets (Figure 30).

Table 25: Degradation in fit, by data set, for runs 4.4 and 4.5, when the YCS estimates are constrained to be the same as in the analogous runs in 2006 (positive numbers indicate that this constraint made the data set fit worse). The following data sets are omitted from the table because the change in fit was zero (to the nearest integer): CSacous, WCacous, SAautbio, EnspOLF, WnspOLF.

	Run	
	4.4	4.5
CRsumbio	3	2
SAsumbio	3	5
CRsumage	3	-2
SAautage	2	1
SAsumage	4	1
Enspage	1	2
Espage	-3	1
Wnspage	3	1
Wspage	-3	0
pspawn	-1	0
All biomass data	6	7
All at-age data	7	5

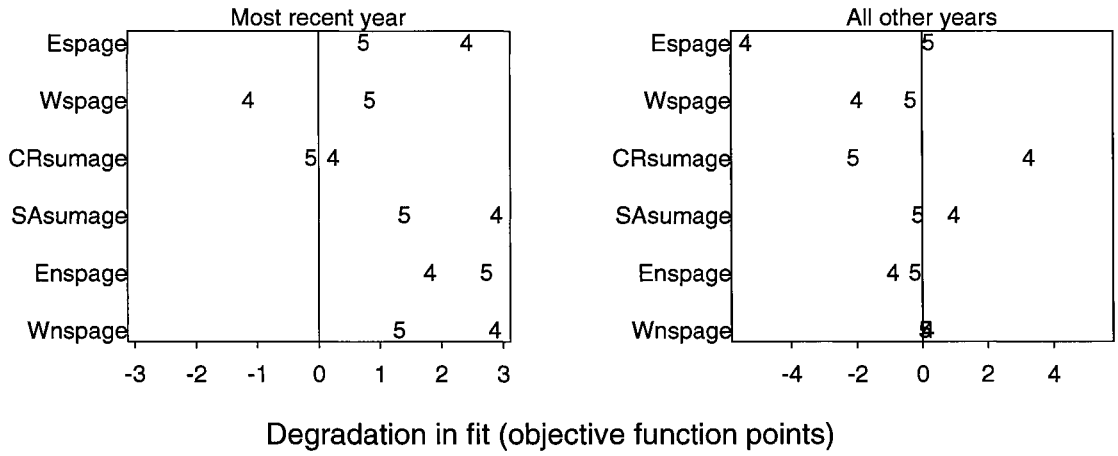

Figure 30: Degradation in fit of at-age data sets for runs 4.4 and 4.5 when the YCS estimates are forced to be the same as in the analogous runs in 2006: A, for the most recent year's data; B, for data from all other years. The plotting symbol identifies the run ('4' = run 4.4, '5' = run 4.5); positive numbers indicate that this constraint made the data set fit worse.

5. FINAL ASSESSMENT RESULTS

The three final runs adopted by the Working Group are distinguished by four characteristics (Table 26). The first is the mechanism used to deal with the problem of the lack of old fish in both fishery- and survey-based observations. Two mechanisms were considered: making *M* (natural mortality) dependent on age (runs 4.4 and 4.7) or allowing the spawning fishery selectivities (Espsl, Wspsl) to be domed (run 4.5). When the domed selectivities were used it was also necessary to combine sexes in the model and make the selectivities age-based (Francis 2005). The third distinguishing characteristic is the assumption concerning natal fidelity. Run 4.7 does not assume natal fidelity but is otherwise identical to run 4.4 (Table 26). As in previous years, biomass indices were upweighted when this was necessary to obtain good fits to these indices. This year, upweighting was done for the trawl indices in all runs, and the acoustic indices in run 4.7.

Table 26: Distinguishing characteristics for the three final model runs.

Label	Response to lack of old fish in the observations	Sex in model and selectivities length-based?	Natal fidelity assumed? *	Biomass indices upweighted
4.4	*M* dependent on age	Yes	Yes	Trawl
4.5	Domed spawning selectivity	No	Yes	Trawl
4.7	*M* dependent on age	Yes	No	Trawl & acoustics

* see Section 3.1 (above) for description of the natal fidelity assumption

Before MCMC chains were created for each run, adjustments were made for those ogive parameters that were estimated at a bound in the associated MPD run. Francis (2005) showed that the variances of such parameters are typically poorly estimated in the Hessian matrix, and this can degrade MCMC performance. Where these parameters were for migration or selectivity they were fixed (by setting both parameter bounds to the MPD estimate) (Table 27). Where natural mortality parameters were at bounds these bounds were shifted (see Appendix A1.2.4 for details).

Table 27: Migration and selectivity parameters held fixed in MCMC runs (with fixed values in parentheses).

Run	Parameters (fixed values)
4.4	Whome.2(0.01), WspmgM2(1), Enspsl.sR(44), CRsl.a1(64), SAsl.a1(84), SAsl.sR(44)
4.5	Whome.5(1), Whome.6(1), CRsl.a1(1), CRsl.sL(1)
4.7	Whome.3(0.01), Whome.6(0), Whome.8(0), CRsl.a1(64), SAsl.a1(84), SAsl.sR(44)

Three MCMC chains of length 2 million samples were created for each final run, each chain having a different starting point, which was generated by stepping randomly away from the MPD. Diagnostic plots comparing the three chains for each run suggest reasonably good convergence for 4.4 and 4.7, but not so good for 4.5 (Figure 31). For all the remaining results, the first quarter of each chain was discarded, the three chains for each run were concatenated, and the resulting chain was thinned to produce a posterior sample of length 1000.

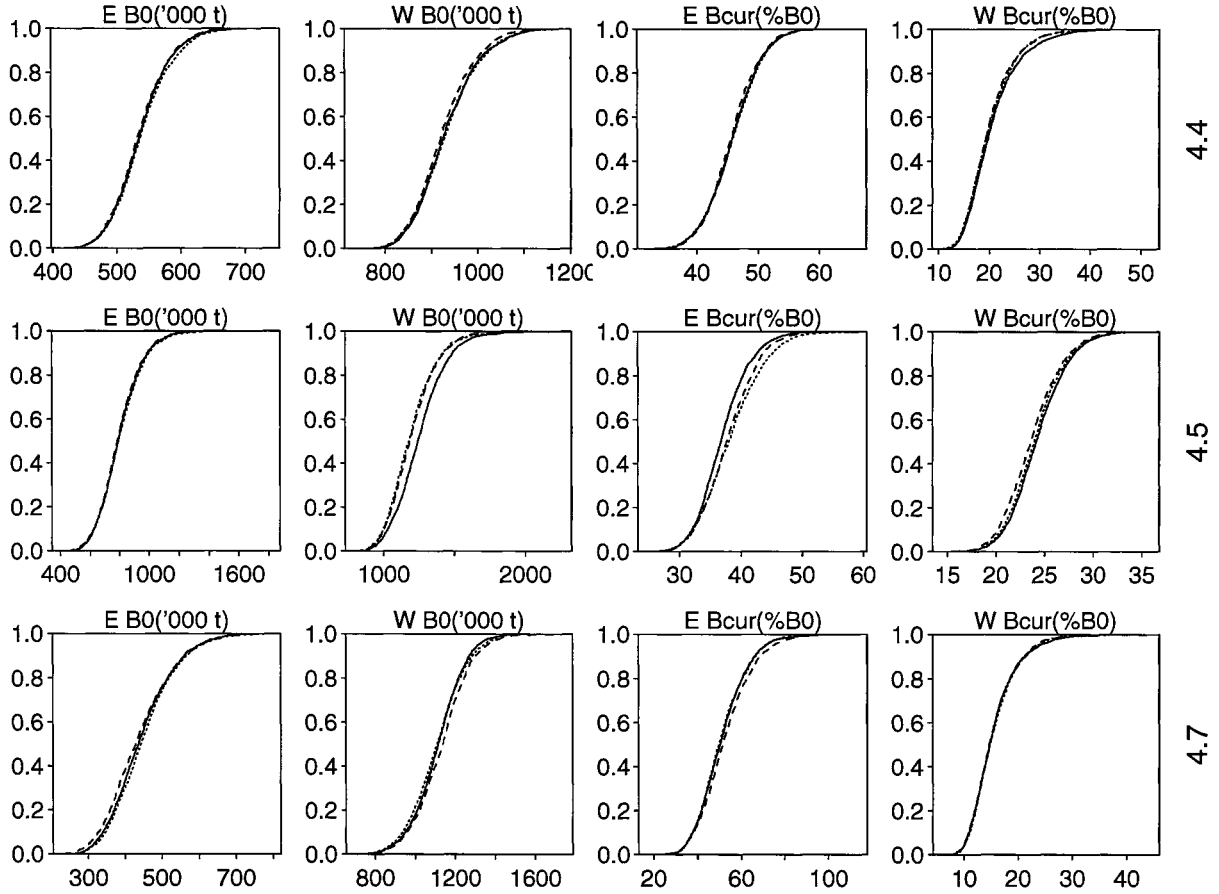

Figure 31: Diagnostics for MCMC chains for the three runs: 4.4 (top row), 4.5 (middle row), and 4.7 (bottom row). Each panel contains cumulative probability distributions, for B_0 or $B_{current}$, for three chains from the same model run.

The MCMC results show, as in 2006, that the W spawning stock was originally much larger than the E, but is currently about the same size or smaller (between 160 000 t and 290 000 t) and so is more depleted (Table 28, Figure 32). Also, the three runs, taken together, indicate a wider range of uncertainty than any one run (Figure 32). Compared to the 2006 assessment, the new results are similar for the E stock, but a bit more pessimistic for the W stock (Figure 33). In contrast to the 2006 assessment, there appears to have been little or no rebuilding of the W stock in recent years (Figures 34, 35). As suggested by the MPD runs, recent W YCSs are estimated to be below average (Figure 36). The selectivity and migration ogives for runs 4.4 and 4.7 are quite similar, but differ substantially from those for 4.5 (Figures 37, 38).

Table 28: Estimates of spawning biomass (medians of marginal posterior, with 95% confidence intervals in parentheses) for the three final runs. $B_{current}$ is the biomass in mid-season 2007.

	B_0 ('000 t)		$B_{current}$ ('000 t)		$B_{current}$ (%B_0)		
Run	E	W	E	W	E	W	E+W
4.4	535(466,639)	930(822,1083)	245(189,312)	182(118,321)	46(37,54)	20(13,32)	29(24,38)
4.5	792(545,1141)	1207(945,1614)	299(191,437)	288(185,465)	37(30,48)	24(19,31)	29(25,35)
4.7	432(297,651)	1115(847,1365)	221(158,288)	164(106,282)	51(32,77)	15(10,26)	25(21,30)

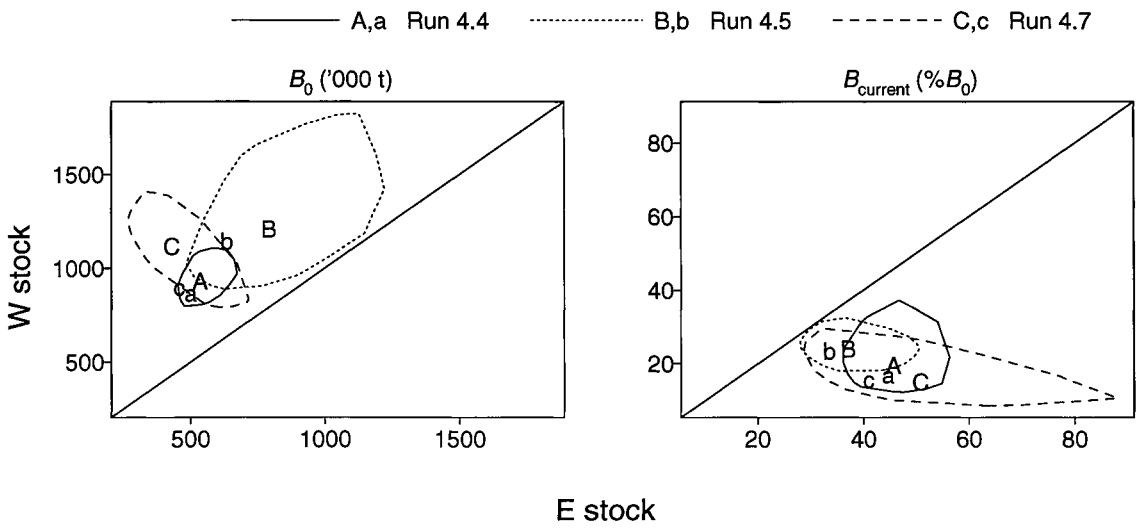

Figure 32: Estimates and approximate 95% confidence intervals for virgin (B_0) and current ($B_{current}$ as %B_0) biomass by stock. In each panel the points 'A', 'B', 'C' indicate best estimates (median of the posterior distribution), 'a','b', 'c' are the MPD estimates, and the polygons encloses approximate 95% confidence intervals. Diagonal lines indicate equality ($y = x$).

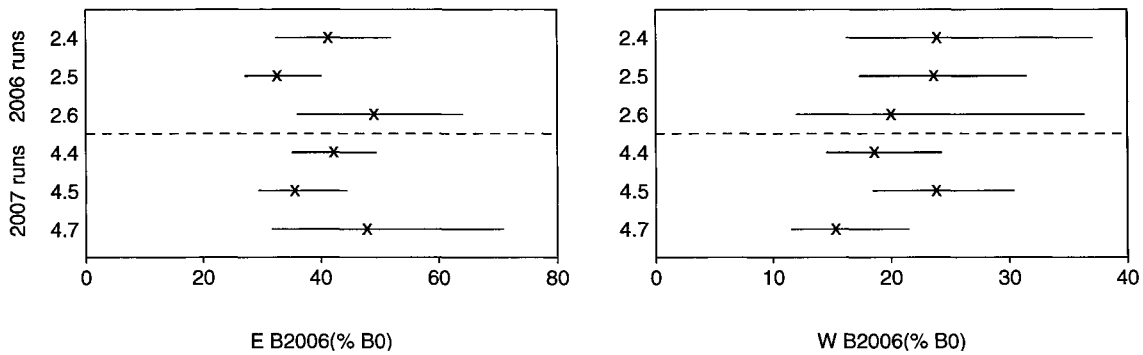

Figure 33: Comparison of 2007 runs (4.4, 4.5, 4.7) with those from 2006 (2.4, 2.5, 2.6): estimates of stock status in 2006 (B_{2006} as %B_0), with 95% confidence intervals shown as horizontal lines.

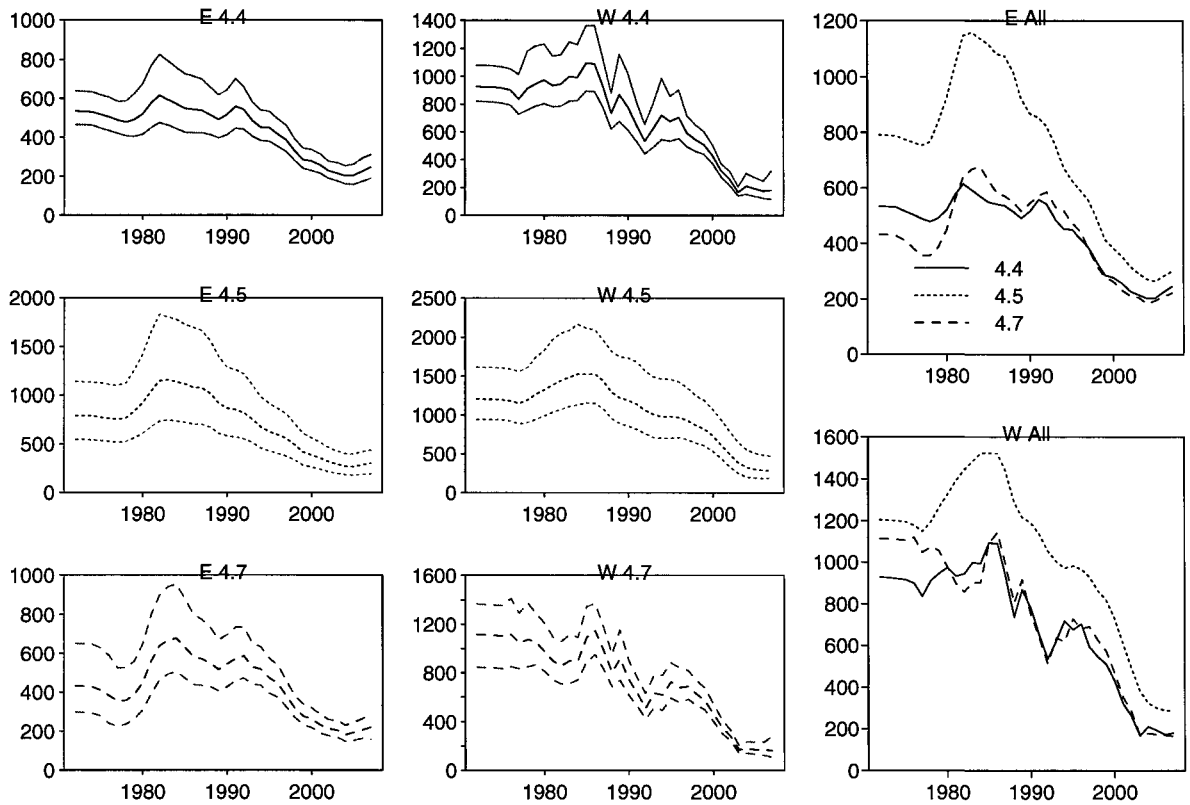

Figure 34: Estimated spawning-biomass trajectories from the three MCMC runs. The left and middle columns of panels show medians (black lines) and 95% confidence intervals (grey lines) by run for E (left panels) and W (middle panels). The two right panels show medians only for E (upper) and W (lower).

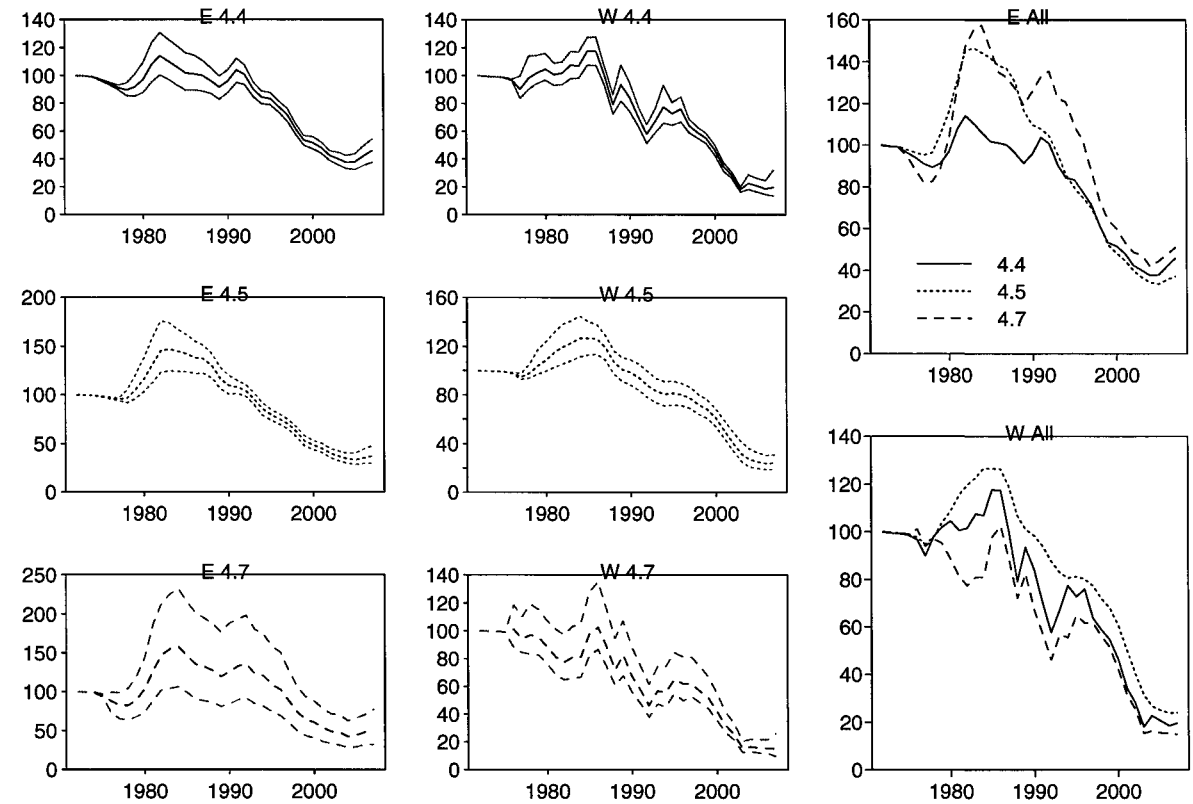

Figure 35: As for Figure 34, but plotted as %B_0.

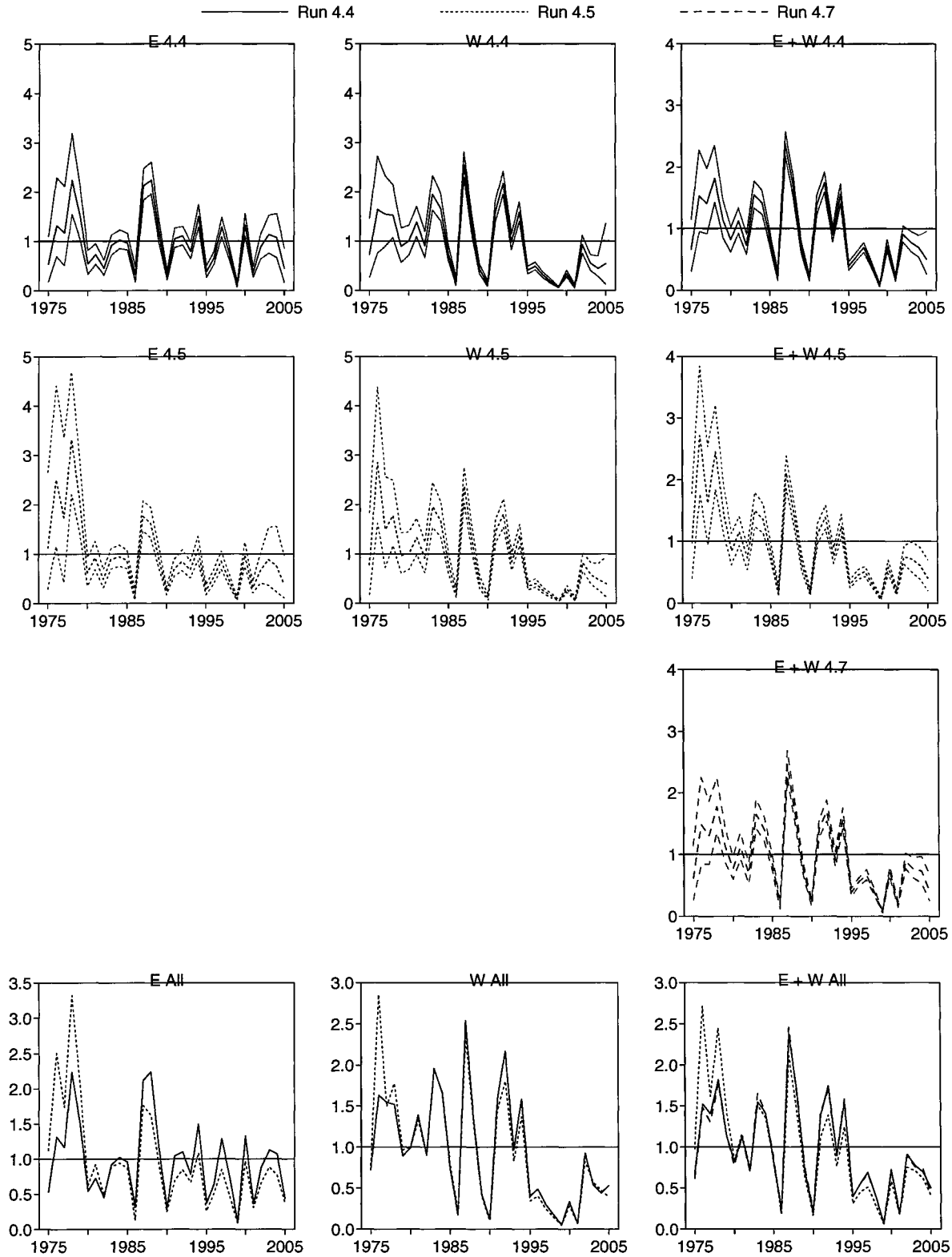

Figure 36: Estimated year-class strengths (YCSs) from the MCMC runs. The top three rows of panels show medians (black lines) and 95% confidence intervals (grey lines) by run for E (left panels), W (middle panels) and E + w (right panels). The bottom row of panels show medians only for all three runs. Note that, for run 4.7, YCSs are not defined for E and W stocks.

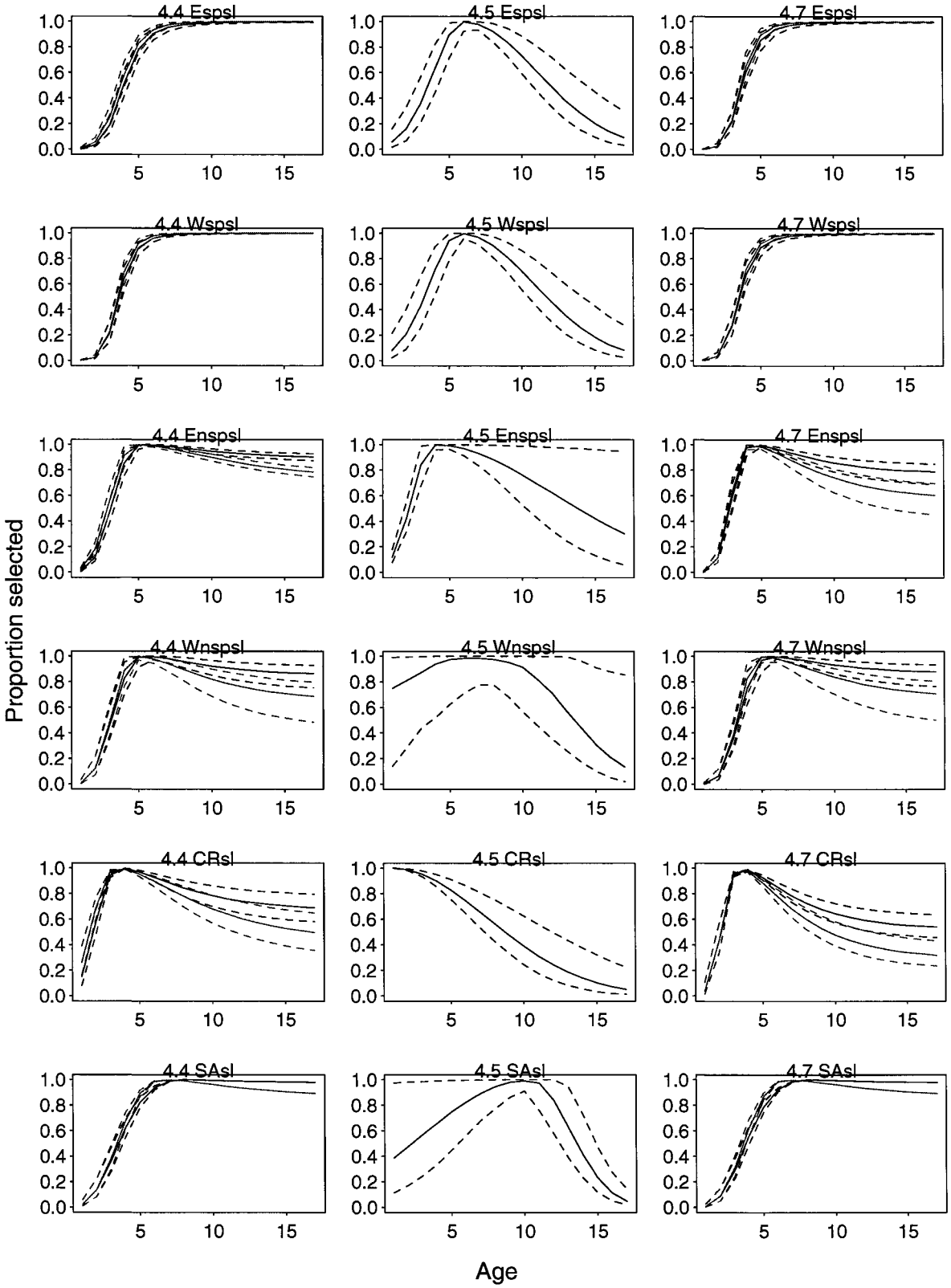

Figure 37: Posterior estimates of selectivity ogives for each of the three MCMC runs. Solid lines are medians, broken lines show 95% confidence intervals. Where ogives differ by sex they are plotted as black for males and grey for females. Where they differ by stock or time step the plotted curves are for one selected combination (E step 2 for Enspsl and CRsl, W step 2 for Wnspsl and SAsl).

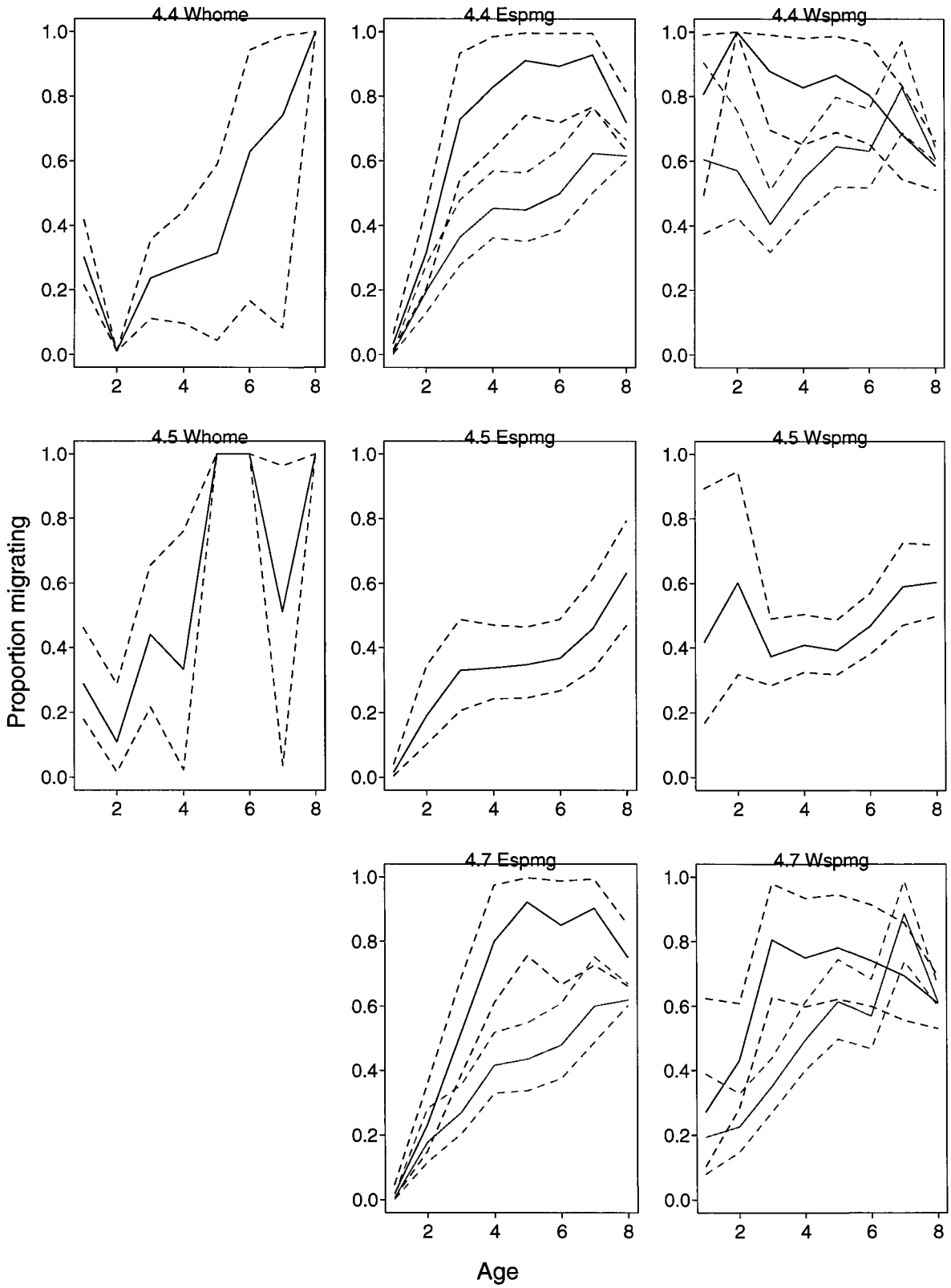

Figure 38: Migration ogives estimated in each of the three MCMC runs. Solid lines are medians, broken lines show 95% confidence intervals. Where ogives differ by sex they are plotted as black for males and grey for females. The Whome ogive is not plotted for the run without natal fidelity (4.7) because it varies from year to year and is not comparable with those for the other runs.

Estimates of natural mortality, for the two runs in which this is age-dependent, are quite similar for all but the youngest ages (Figure 39). A comparison of priors and posteriors for various parameters (Figure 40) revealed a surprisingly bimodal posterior for natural mortality in run 2.5. This was found to be an artefact of a very poor trace for the natural mortality parameter (Figure 41A). Why this trace was so poor, when the corresponding trace from 2006 was not (Figure 41B), and what can be done to improve this trace, are questions that were addressed after the assessment was finalised. Fortunately, the effect on the conclusions of the assessment were found to be minor (see Section 7.5).

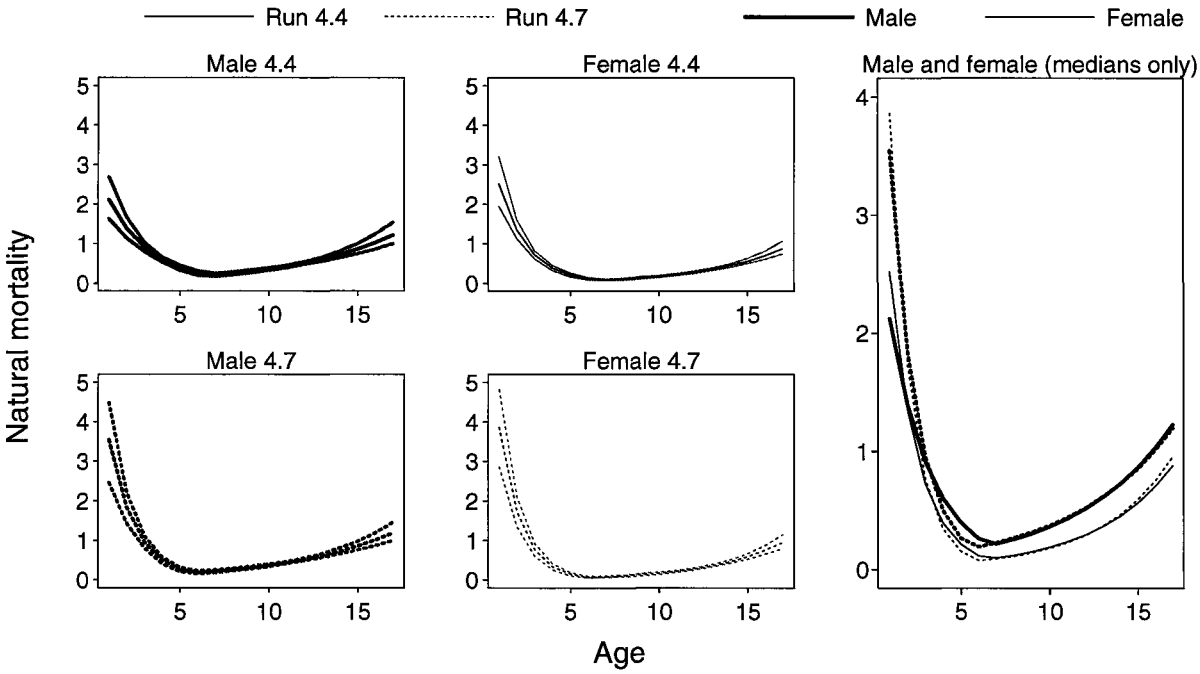

Figure 39: Estimates of age-dependent natural mortality ogives for runs 4.4 and 4.7. The left and middle columns of plots show median estimates (black lines) and 95% confidence intervals (grey lines) for each sex; the right panel shows just the medians by sex (heavy lines for males, light lines for females) for each run.

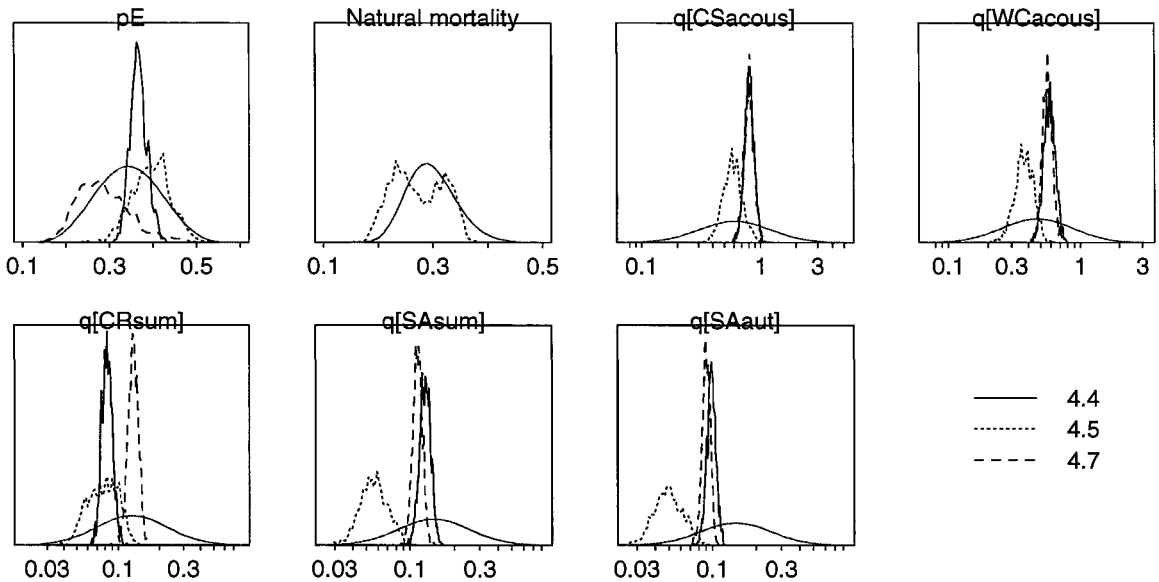

Figure 40: Prior (grey lines) and estimated posterior (black lines) distributions from the three MCMC runs for the following parameters: pE (proportion of B_0 in E stock), natural mortality (independent of age, run 4.5 only), and survey catchabilities (acoustic and trawl).

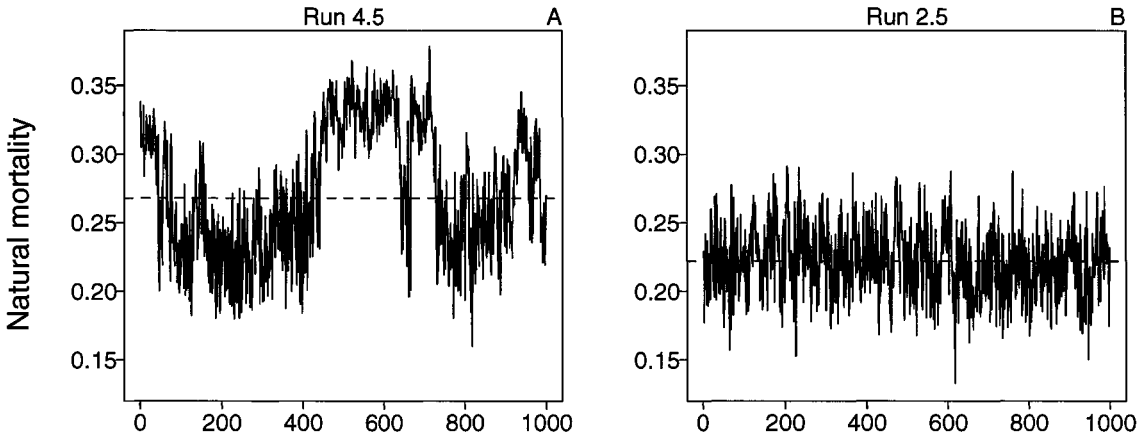

Figure 41: Traces for the natural mortality parameter for A, run 4.5, and B, the corresponding run from 2006 (2.6). The horizontal broken line in each panel shows the median value.

5.1 Projections

Five-year projections were carried out, for each of the three final runs (4.4, 4.5, and 4.7), under each of nine scenarios for future catch (Table 29). All but one of these scenarios were defined by specifying the total catch to be taken in each year (between 0 t and 106 000 t) and the percentage of that catch that would be taken from the E fisheries (between 50% and 75%) (the exception was scenario 80kt.cutCR, which is described below). The assumed catch levels for individual fisheries were proportional to those in 2006 (see Table 13), subject to these specifications.

Table 29: Nine scenarios for future catches in projections, and the recruitment assumptions considered for each scenario.

	Catches by fishery (t)				Area subtotals (t)		Total	Recruitment assumptions
Scenario	Ensp	Wnsp	Esp	Wsp	All E	All W	catch (t)	considered
100kt60%E	38 700	5 700	21 300	34 300	60 000	40 000	100 000	Long-term, recent
106kt55%E*	37 600	6 800	20 700	40 900	58 300	47 700	106 000	Recent
110kt60%E	42 600	6 300	23 400	37 700	66 000	44 000	110 000	Recent
100kt75%E	48 400	3 600	26 600	21 400	75 000	25 000	100 000	Recent
80kt50%E	25 800	5 700	14 200	34 300	40 000	40 000	80 000	Recent
80kt75%E	38 700	2 900	21 300	17 100	60 000	20 000	80 000	Recent
80kt60%E	30 900	4 600	17 100	27 400	48 000	32 000	80 000	Recent
80kt.cutCR	18 700	5 700	21 300	34 300	40 000	40 000	80 000	Recent
0kt	0	0	0	0	0	0	0	Recent

*status quo option

The first catch scenario (labelled 100kt60%E) assumes that the TAC will remain at 100 000 t and not be over-caught, and that the target 60:40 east-west split will be exactly achieved. This scenario was evaluated under two recruitment assumptions: 'long-term' (in which future recruitments were selected at random from those estimated for 1975–2003) and 'recent' (future recruitments selected from 1995–2003). For run 4.7, future multipliers for the Whome migration ogive were selected at random from those estimated for years 1977–2005, for the 'long-term' assumption, or for 1997–2005, for the 'recent' assumption. The recent recruitment option was considered because of the recent period of below-average recruitment for the western stock, which may persist in the short term. The eastern stock does not show such poor recruitment in recent years. With the first catch scenario, all three runs predicted that both stocks would increase under the long-term recruitment assumption, but show little change under the recent recruitment assumption (Figure 42).

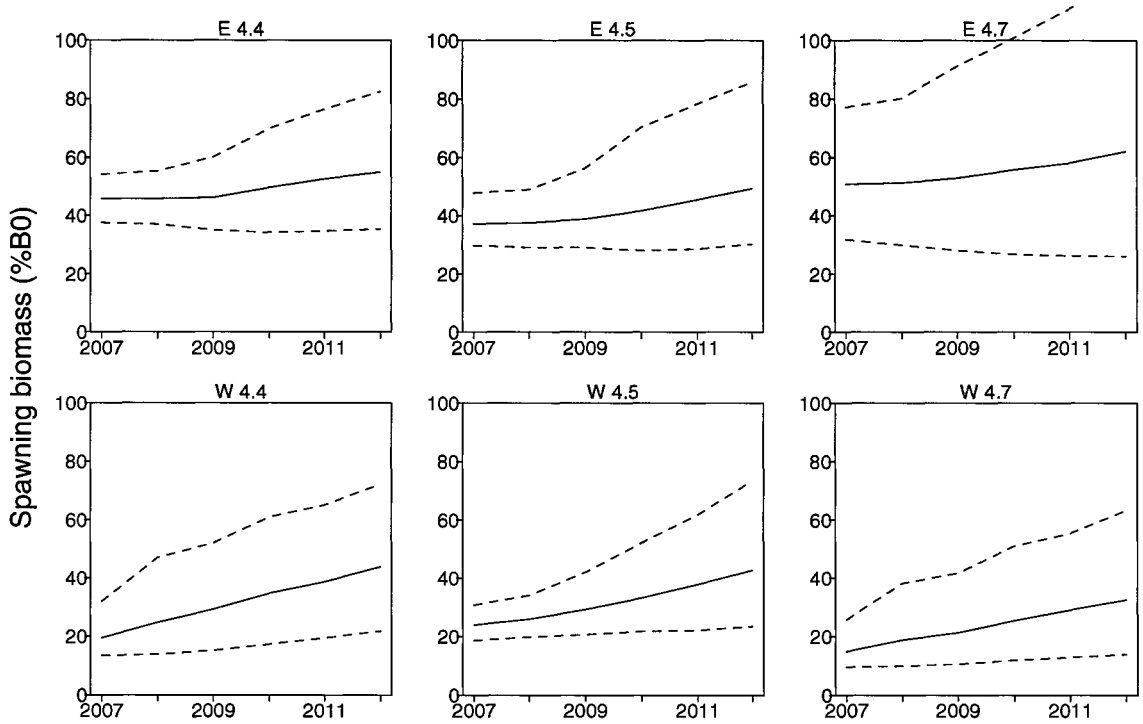

Figure 42A: Projected spawning biomass (as %B_0) for catch option 100kt60%E (see Table 29) assuming long-term recruitment: median (solid lines) and 95% confidence intervals (broken lines).

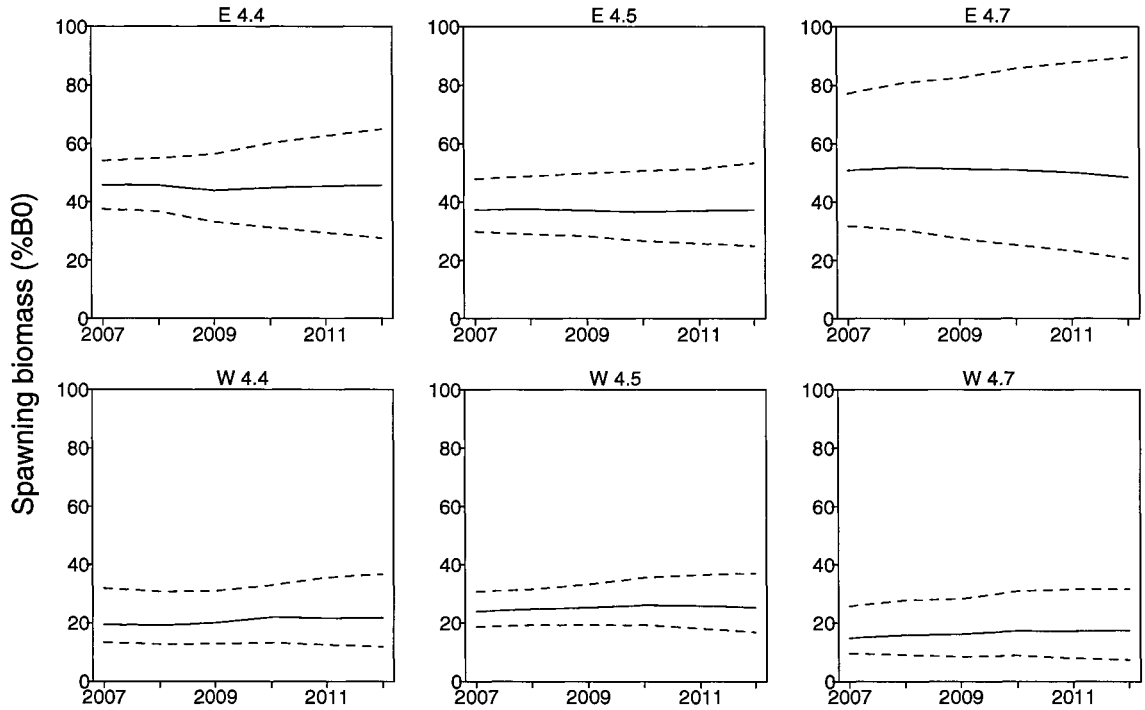

Figure 42B: As for Figure 42A but assuming recent recruitment.

The remaining eight scenarios were evaluated only with the recent recruitment assumption. The second scenario, 106kt55%E, may be thought to represent the status quo. It recognises the fact that the TAC has been over-caught in recent years and the target of a 60:40 east-west split has not been achieved. Four scenarios consider the effect of a catch reduction to 80 000 t, either with a specified east-west split (and assuming no overcatch), or, for scenario 80kt.cutCR, with the assumption that all the reduction in catch will come from the E non-spawning fishery (in area CR). The final scenario, with zero catch, is included to provide information about maximum rebuild rates under the recent recruitment assumption.

With the recent recruitment assumption, both stocks are expected to increase only if the annual catch from the associated fisheries is less than it was in 2006 (Table 30). For each stock, the expected amount of increase (or decrease) depends mainly on the annual catch from the associated fisheries (and, of course, the model run) (Figure 43). For the western stock, long term average recruitment has a greater influence on the speed and extent of stock rebuild than reducing catch.

Table 30: Estimated median spawning biomass in 2012 for the eastern stock (upper half of table) and western stock (lower half of table) for each of the seven future-catch scenarios of Table 29 and three final runs. Results are given for the early recruitment assumption for all catch options, and for both recruitment assumptions for catch scenario 100kt60%E. In each half of the table the catch options are sorted in increasing order of the combined annual catch from the associated fisheries (given in the second column). Also given, for comparison, is the estimated spawning biomass in 2007.

Eastern stock

		Spawning biomass in 2012 (%B_0)					
Catch	Annual catch from	Recent recruitment			Long-term recruitment		
scenario	all E fisheries (t)	Run 4.4	Run 4.5	Run 4.7	Run 4.4	Run 4.5	Run 4.7
0kt	0	69	50	82			
80kt50%E	40 000	53	41	60			
80kt.cutCR	40 000	52	41	59			
80kt60%E	48 000	50	40	55			
106kt55%E*	58 300	46	37	49			
80kt75%E	60 000	46	37	49			
100kt60%E	60 000	46	37	49	55	49	62
110kt60%E	66 000	44	36	45			
100kt75%E	75 000	40	34	40			
		Spawning biomass in 2007 (%B_0)					
		46	37	51			

Western stock

		Spawning biomass in 2012 (%B_0)					
Catch	Annual catch from	Recent recruitment			Long-term recruitment		
scenario	all W fisheries (t)	Run 4.4	Run 4.5	Run 4.7	Run 4.4	Run 4.5	Run 4.7
0kt	0	35	33	29			
80kt75%E	20 000	28	29	23			
100kt75%E	25 000	26	27	21			
80kt60%E	32 000	24	27	20			
80kt.cutCR	40 000	23	25	18			
80kt50%E	40 000	22	25	18			
100kt60%E	40 000	22	25	18	44	43	33
110kt60%E	44 000	20	24	16			
106kt55%E*	47 700	19	24	16			
		Spawning biomass in 2007 (%B0)					
		20	24	15			

* status quo option

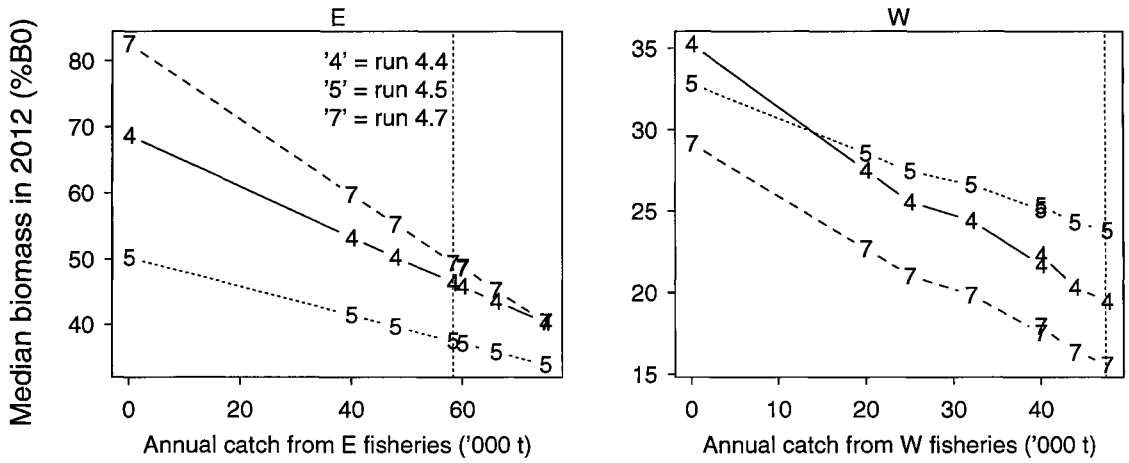

Figure 43: Results from all projections with recent recruitment: median biomass in 2012 for each stock plotted against the annual catch from fisheries on that stock. Each plotted point represents the results for one stock (E stock in left panel, W stock in right panel) with one of the catch scenarios of Table 29 and one model run (identified by the plotting symbol) and the vertical dotted lines show the 2006 catches. These results are also given in Table 30.

6. DISCUSSION

Both hoki stocks are estimated to be at or near their lowest level since the fishery began, with the W stock being much more depleted (15–24 %B_0) than the E stock (37–51 %B_0). This stock experienced an extended period of poor recruitment from 1995 to 2001, but there is evidence of better (though still below average) recruitment in subsequent years (2002–05). For both stocks, the projections suggest that neither stock is likely to increase in biomass unless either future recruitment is better than it has been in recent years or catches from the associated fisheries are reduced.

The uncertainty in this assessment is almost certainly greater than is implied by the confidence limits presented above. We may think of this uncertainty as having three types. The first of these – random error in the observations – is reasonably well dealt with in the assessment by the c.v.s that are assigned to individual observations. The second, which arises from annual variability in population processes (e.g., growth and migration – but not recruitment, which is modelled explicitly) and fleet behaviour (which affects selectivities), is more problematic. We deal with this, rather simplistically, by adding process error. This assumes that the structure of our model is correct "on average", but that the real world fluctuates about that average. The problem is that we cannot be at all sure about this assumption. This leads to the third type of uncertainty: we cannot be sure that our model assumptions are correct on average.

This is often called model uncertainty, and it is the type of uncertainty that is least well covered in this assessment. We have dealt with it by using three alternative model structures (expressed in our three final runs), each of which fits the data reasonably well. For some estimated quantities these produce markedly different results (e.g., for both stocks, the best estimate of current status – expressed as $B_{current}$ as %B_0 – in run 4.7 lies outside the 95% confidence interval of the estimate from run 4.5 – see Table 28). In this case, model uncertainty (the difference between best estimates) is comparable to the combined effects of observation and process uncertainty (which is shown in widths of the confidence intervals). However, none of our three models is totally satisfactory in terms of plausibility. For example, it is hard to understand what mechanisms could be responsible for either the sharp rise in natural mortality (for runs 4.4 and 4.7) or the steep fall in selectivity (for run 4.5) that are estimated after about age 8 (see Figures 37, 39). This is not a trivial matter as, typically, more than a third (by weight) of the catch from the spawning fisheries comes from fish of ages 8 and over.

Further, it is quite likely that these three models do not span the true range of model uncertainty. There may well be other model structures which are no less plausible but which produce significantly different estimates of stock status.

7. SOME POST-ASSESSMENT RESULTS

In this section I describe some additional analyses that were carried out after the assessment. These shed further light on the assessment, and will be of use in the 2008 assessment, but are presented separately because they were completed too late to affect the Working Group Report for 2007.

Five topics were investigated: trends in YCS estimates; the effect of invisible juvenile mortality; the increase in hoki growth rates; step changes in selectivities; and MCMC performance for run 4.5.

7.1. Trends in YCS estimates

A comparison of YCS estimates from the last six hoki assessments shows that, for some year classes, these estimates show a trend (Figure 44). The most dramatic of these trends have been for weak year classes from the W stock (e.g., 1997, 2000, and 2001), and the trend for these has always been downwards (i.e., estimates of a particular year class get smaller in assessments from successive years). However, there are instances of less dramatic upward trends (e.g., 1983, 1984, and 1987 for the W stock and 1985 for the E stock). In this section, I investigate some possible causes of these trends. Throughout, I ignore model runs that do not assume natal fidelity (e.g., run 4.7 in 2007), because they do not provide separate estimates of YCSs for the two stocks.

7.1.1 Changes in model assumptions or input data

One possible reason for these trends is that there have been many changes in model assumptions, and some changes in model inputs, over the last six assessments (Table 31). The standard way of investigating this possibility is called a retrospective analysis. This involves repeating the earlier assessments using exactly the same model assumptions that were used in the most recent assessment (i.e., that in 2007). Of course, the observations used in each of these retrospective assessments are restricted to what was available at the time, except that any subsequent revisions that have been made to these observations are included. Two sets of retrospective analyses were done, based on the 2007 runs 4.4 and 4.5, respectively (see Appendix 2 for procedural details) and the YCS estimates from these are plotted as dotted and broken lines, respectively, in Figure 44. Many of the large jumps seen in the YCS estimates from the original assessments appear to have been caused by changes in model assumptions or inputs, because they disappeared in the estimates from the retrospective assessments (e.g., see year classes 1997 and 1998 in Figure 44A and 1986 and 1990 in Figure 44B).

Which changes in assumptions (or inputs) caused those large jumps in YCS estimates that disappeared in the retrospective analyses? Note that the jumps that disappeared all occurred before 2004. A likely explanation is the changes made in the 2003 and 2004 assessments in reaction to the 'old fish problem' (the fact that expected numbers of old fish in the early assessments were typically much greater than indicated by the at-age observations from fisheries and surveys). The main changes were the removal of the plus group from at-age observations (in 2003), and the introduction (in 2004) of age-dependent natural mortality and domed spawning selectivity.

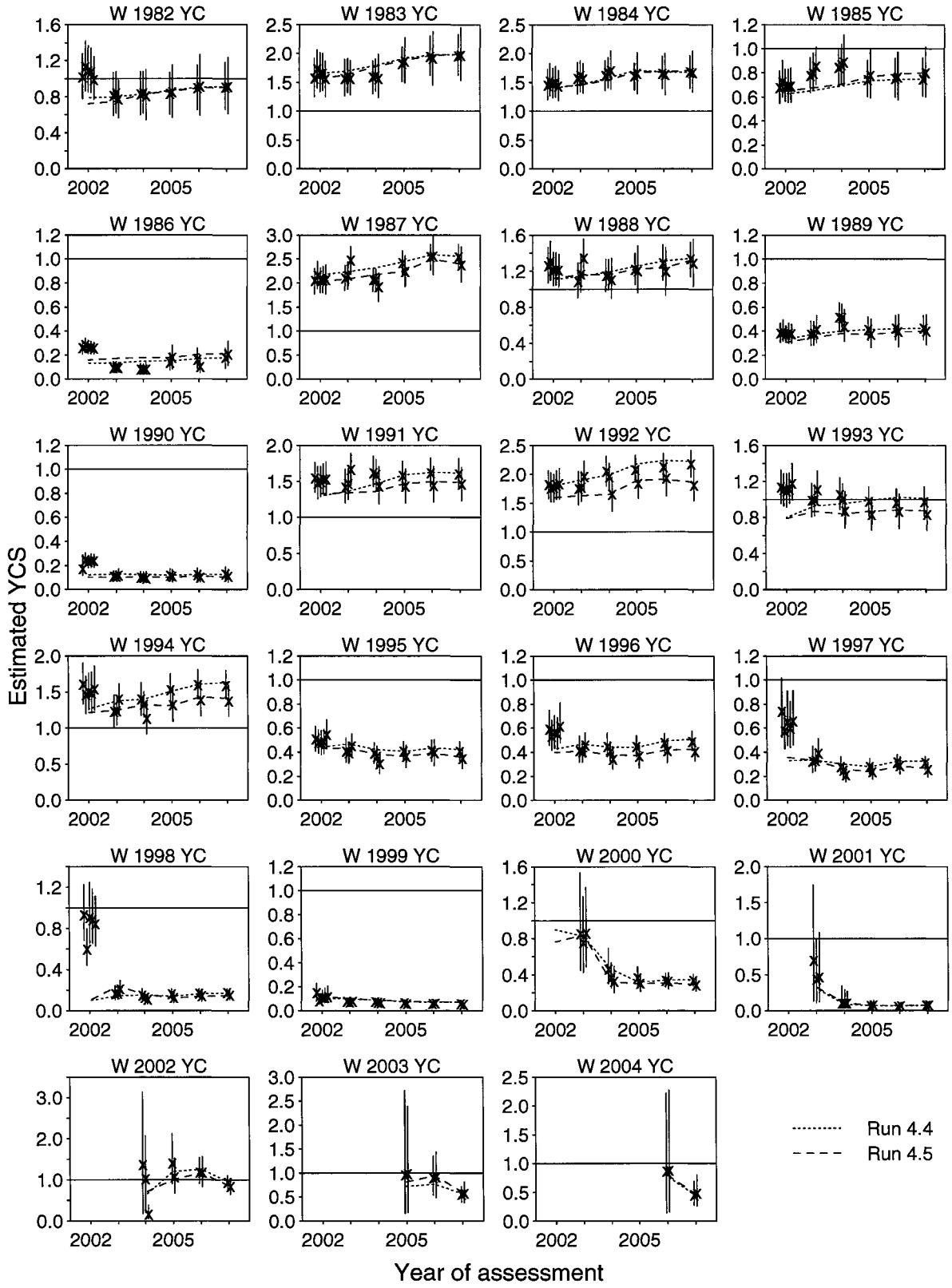

Figure 44A: Comparison of estimates of W YCSs (from 1982 to 2004) from successive assessments. Estimates (medians from MCMC runs) from the main runs in all assessments since 2002 are plotted as 'x', with vertical bars showing 95% confidence intervals; MPD estimates from two retrospective analyses are shown as dotted lines (for run 4.4) or broken lines (for run 4.5).

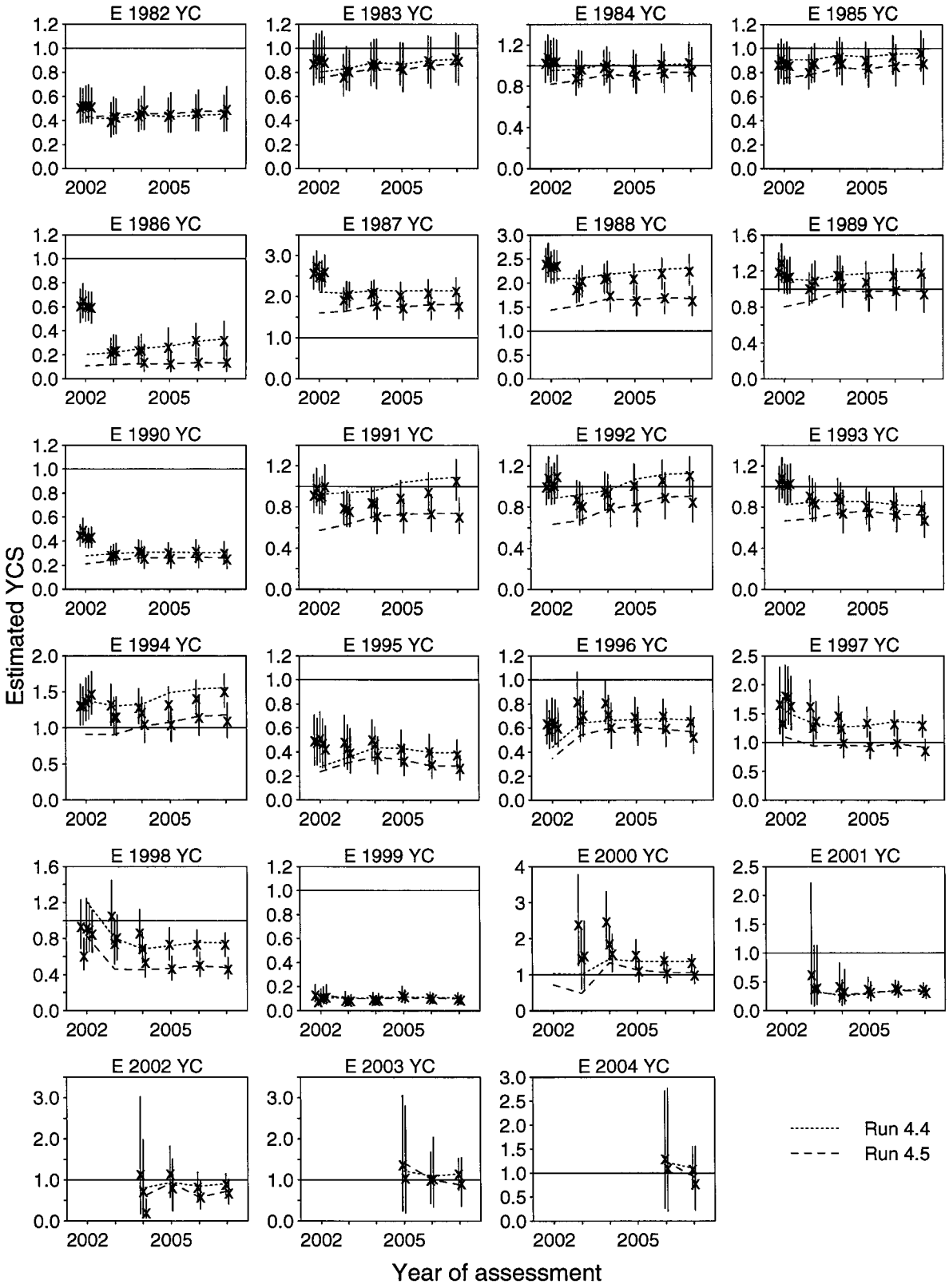

Figure 44B: As in Figure 44A, but for E YCSs.

Table 31: Changes in stock-assessment model assumptions and input data for each years since the first CASAL assessment of hoki in 2002.

Year	Changes
2003	Changed timing of spawning migrations from the middle to the end of the non-spawning fisheries (and after the autumn SA surveys)
	Earliest estimated YCS changed to 1977 from 1980
	Assumed Beverton-Holt stock-recruit relationship
	Disallowed annual variation in selectivities for Wnsp fishery
	Allowed for ageing error (expected to reduce bias in estimates of YCSs)
	Process errors for at-age data sets estimated within the model
	Non-uniform prior on pE
	Max. age of otolith-based at-age data increased from 10 (plus group) to 12 (no plus group)
	First use of otolith-based at-age data for non-spawning fisheries (Enspage & Wnspage)
	Forced equality of recent W and E YCSs extended from 2 y to 3 y
	Improvements in methods of converting ogives from size-based to age-based and implementing annual variation in selectivities
2004	First use of age-dependent natural mortality and domed spawning selectivities to cope with lack of old fish
	Maximum age in partition increased from 13 y to 17 y
	New parameterisation for YCSs
	Earliest estimated YCS changed to 1975 from 1977
	Change in priors for CSacous catchability and pE
	Max. age of otolith-based at-age data increased from 12 (no plus group) to 13/15 (plus group)
2005	For runs with domed spawning selectivities, spawning selectivities (rather than migrations) constrained to be equal
	Some at-age data revised
2006	Annual variation in Wsp selectivity restricted to years with significant data and constrained by non-uniform prior on controlling parameter
	Forced equality of recent W and E YCSs reduced from 3 y to 1 y
	Added smoothing penalty for age-dependent natural mortality
	First model run without the assumption of natal fidelity
2007	New parameterisation (double-exponential) and prior for age-dependent natural mortality

7.1.2 Changing definition of YCSs

A second possible reason for retrospective trends in YCSs is that the definition of YCSs varies slightly from assessment to assessment. One of the parameters estimated (for each stock) in each assessment is R_{mean} the mean recruitment (ignoring the stock-recruit relationship) over all years observed. A YCS of 1 for a particular year means that the recruitment for that year is estimated to be exactly equal to R_{mean}. But the meaning of R_{mean}, and thus of the YCSs, changes slightly with each new assessment, as we observe more and more year classes.

We can remove the effect of this changing definition by standardising all YCS estimates so that they average 1 for each stock over a specified range of years. When this standardisation was done (using the arbitrarily chosen year range 1975–1995) some trends were markedly reduced (Figure 45). The effect was greater for the W stock because most of the YCSs that have been estimated for the first time since the 2002 assessment have been below average. This standardisation was applied to all YCS estimates presented in the remainder of this section.

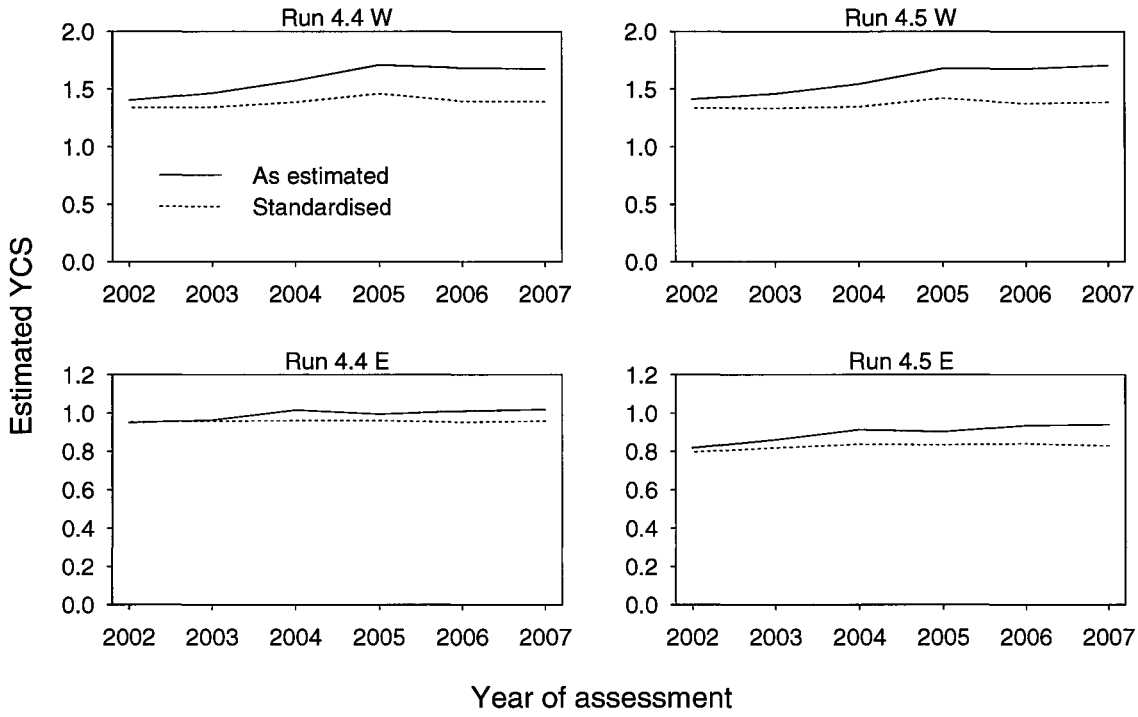

Figure 45: Illustration of the effect of standardising YCS estimates from different assessments. Each panel plots the retrospective estimates of the 1984 YCS from successive assessments: values as estimated (solid lines) and after standardisation (dotted lines).

7.1.3 Model error

YCS estimates may be affected by model error, i.e., model assumptions which are not true in the real world. An effect of model error is to produce conflicts between the model assumptions and inputs. Such a conflict would arise if, for example, the tonnage of fish killed by fishing differed from the catches input to the model. This could happen, for example, if young fish were dying because of loss of scales when they escaped through the codend meshes of trawl nets.

I used simulated observations to see whether model error was causing retrospective trends in estimated YCSs. Twenty sets of observations were simulated using CASAL (see section 6.9 of Bull et al. (2005)): 10 based on run 4.4, and 10 on run 4.5. The input files used in these simulations were the same as those used for these two runs except for two changes to the process-error c.v.s in the estimation files: those for the at-age data sets were set equal to their estimated values in each run, and those for the trawl-survey biomass indices were set to 0.2. The important point about the simulated observations is that they are, by definition, consistent with the model assumptions (including the catches). Thus there is no model error associated with estimates based on the simulated observations. A 5-year retrospective analysis was done for each set of simulated observations. The standardised YCS estimates for all retrospective analyses (with both real and simulated observations) are plotted in Figure 46.

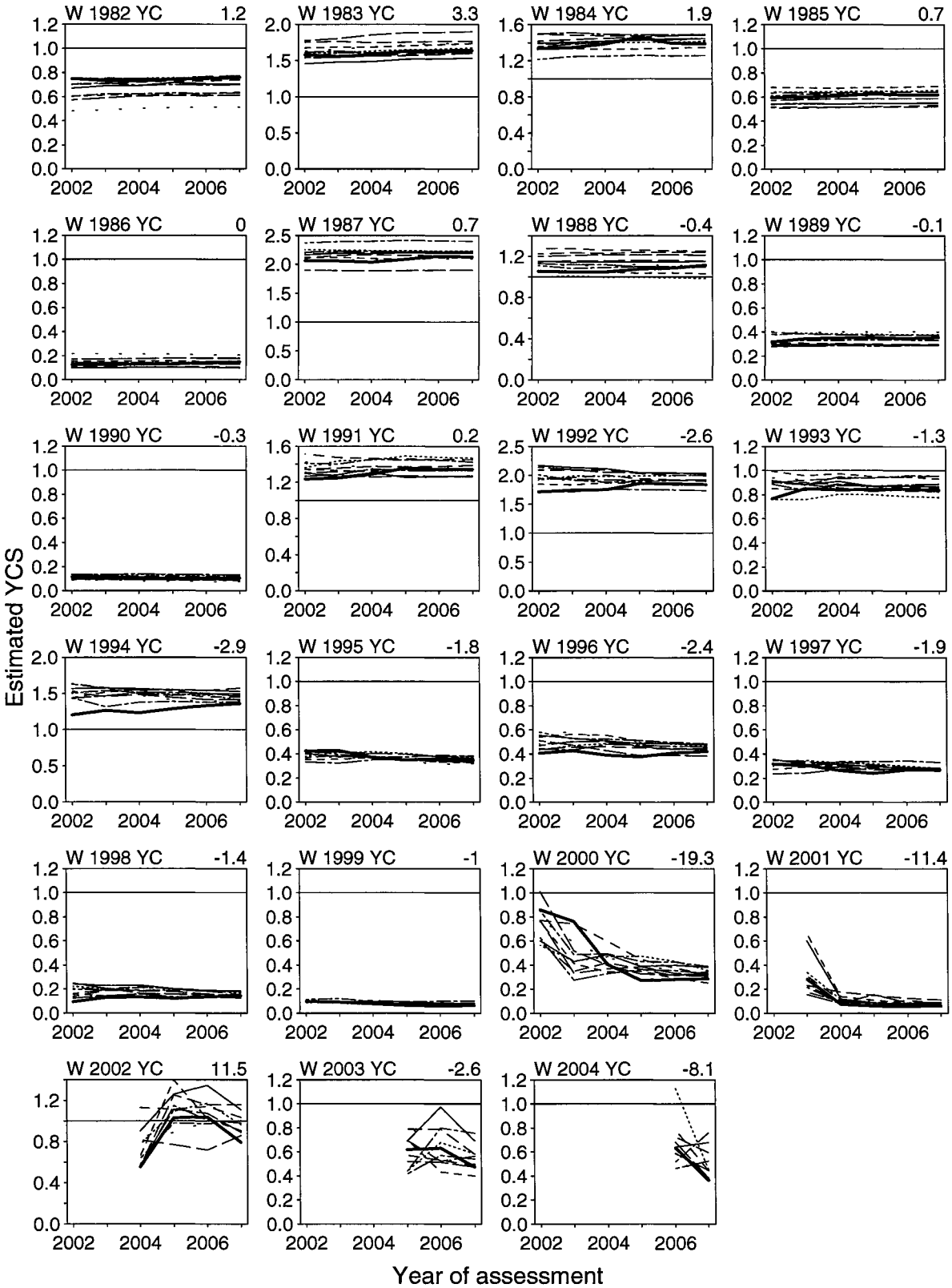

Figure 46A: Comparison of standardised estimates of W YCSs (from 1995 to 2004) from retrospective assessments associated with run 4.4. Heavy lines derive from the actual observations; the ten light lines derive from the ten sets of simulated observations. The percentage trend statistic, *T* (see text), is printed above the top-right corner of each panel. The horizontal solid line in each panel represents YCS = 1 as a point of reference.

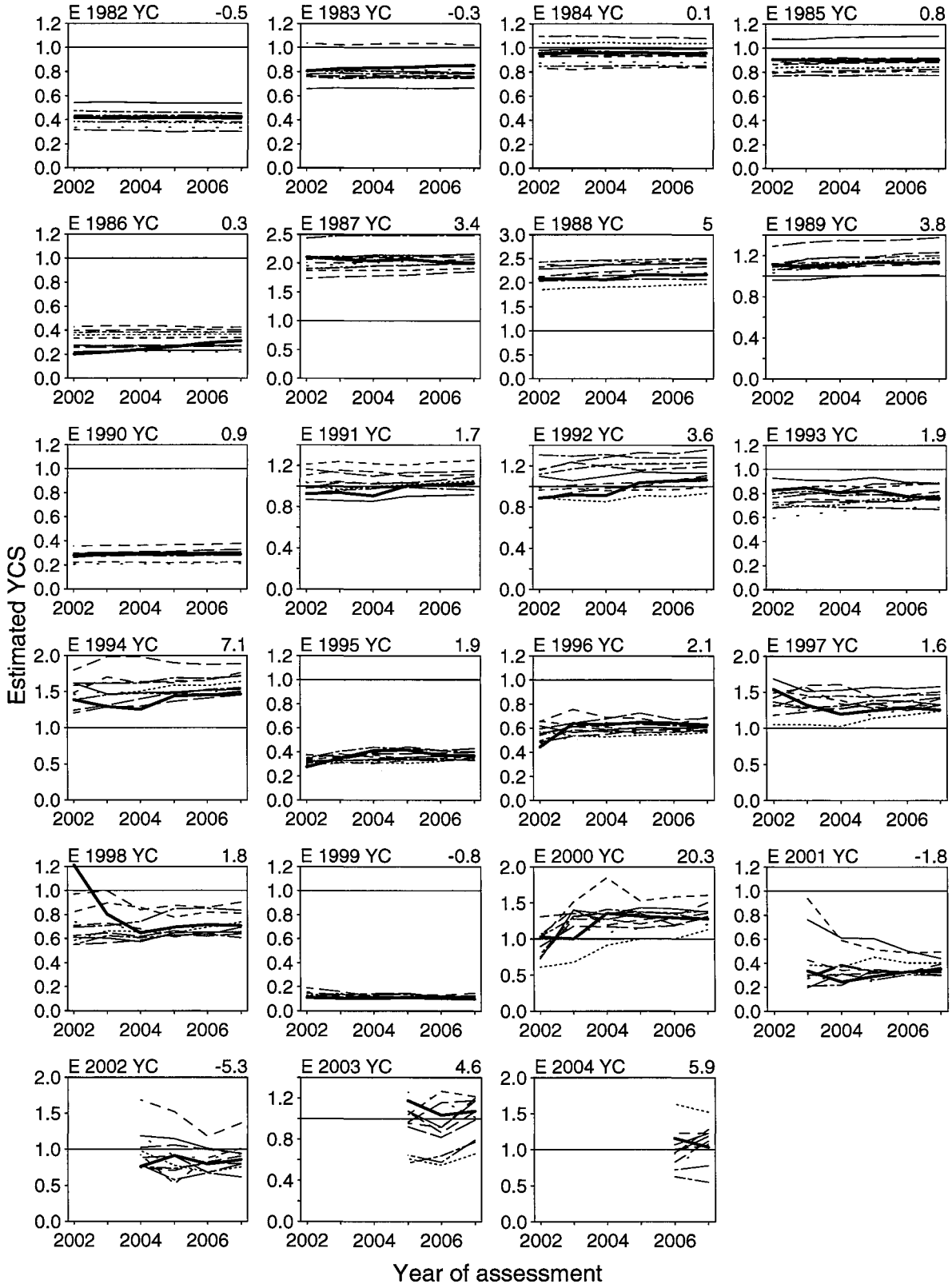

Figure 46B: As for Figure 46A, but for E YCS and run 4.4.

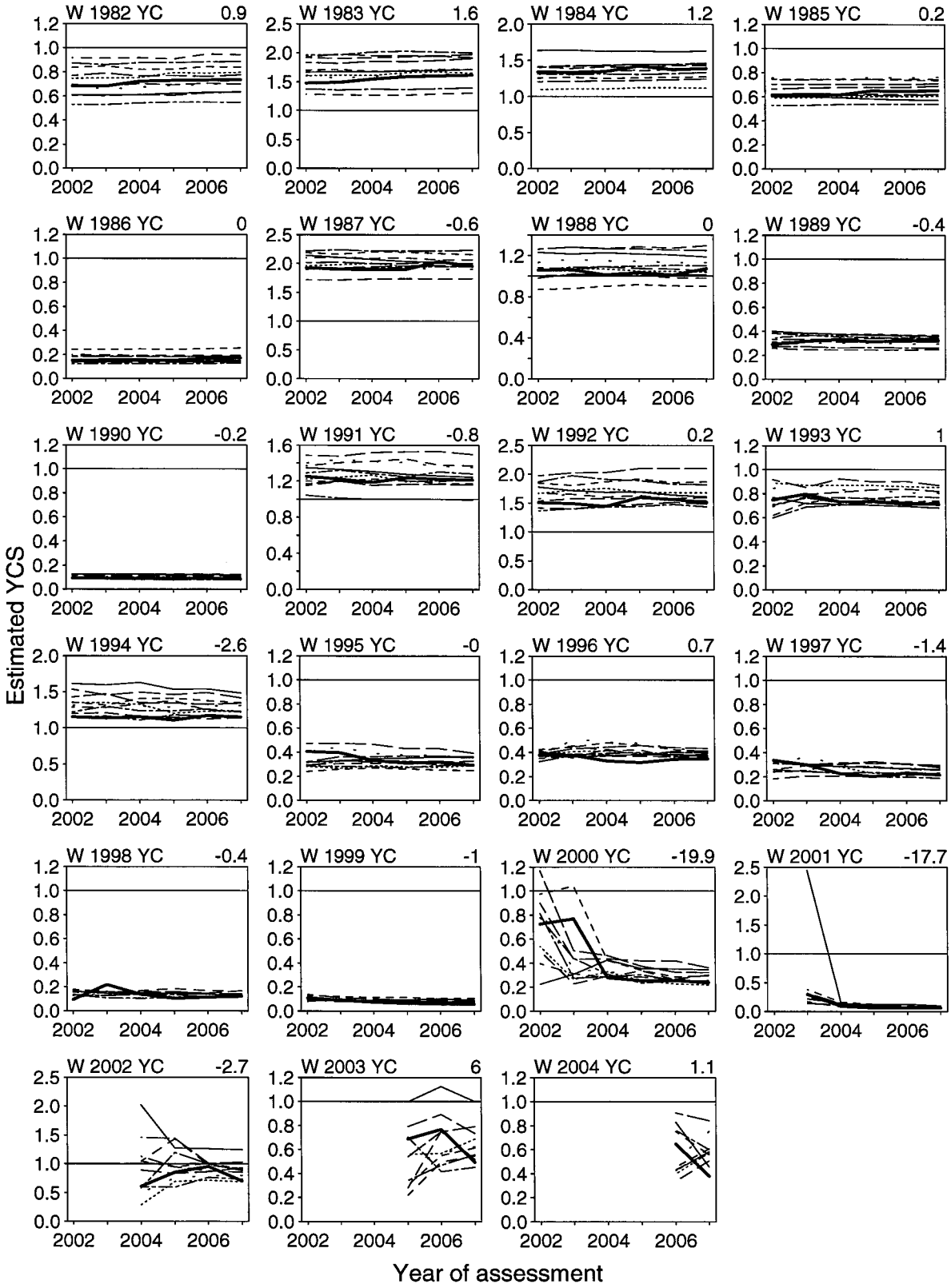

Figure 46C: As for Figure 46A, but for W YCS and run 4.5.

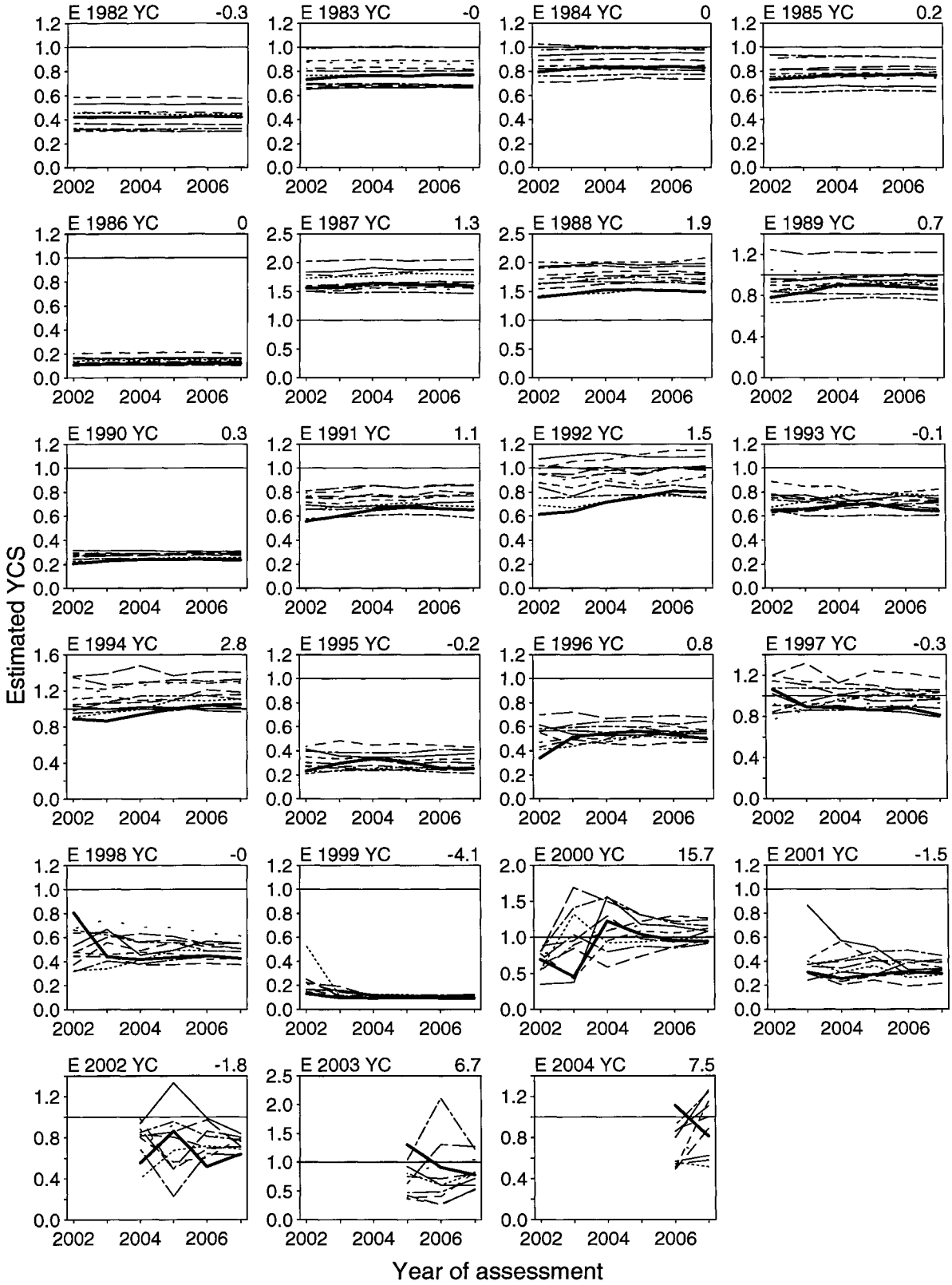

Figure 46D: As for Figure 46A, but for E YCS and run 4.5.

The first question to ask about Figure 46 is whether it provides any evidence that model error was responsible for retrospective trends. That is, do the trends in estimates from the actual observations (the heavy line in each panel) stand out as being inconsistent with those from simulated observations (light lines). It is hard to devise an objective way of answering this question, but my subjective judgment is that they don't. In most panels, one or more of the light lines shows a trend similar to that of the heavy line. Notice that the variation in trend amongst the light lines in a panel is sometimes quite substantial, especially for the most recent year classes. The most extreme example is perhaps for the W 2001 year class in Figure 46C, which was always estimated to be less than 0.5 except for one simulated data set for which the 2003 assessment resulted in an estimate of 2.5. [I checked, and found that this result was real – i.e., the assessment did converge – and derived from a simulated CRsumage age frequency for 2003 that was, by chance, very different from all the others].

The next question to ask about these results is how often the YCS estimates based on simulated observations show a trend that is of practical significance. It is important here to distinguish between practical and statistical significance. A simple test indicated a statistically significant trend in about one third of year classes (see Appendix 3 for details). However, for a trend to be of practical significance it has to be reasonably large compared to the typical range of YCSs. A reasonable indicator of practical significance is given by a percentage trend statistic, T, which is defined as the mean change in YCS (between the first and last assessment) as a percentage of the range of all YCSs in the actual 2007 assessment. Consider, for example, the W 1983 year class in Figure 46A. The mean estimated YCS increased from 1.61 (in 2002) to 1.68 (in 2007) and the range of W YCS estimates in run 4.4 was from 0.06 to 2.13. Therefore, $T = 100 \times (1.68–1.16)/(2.13–0.06) = 3.3\%$ for this year class. If we require $|T|$ to exceed 10% for practical significance then it is only in the most recent year classes that the retrospective trend YCSs is practically significant (for 2000, 2001, and 2002 in run 4.4 W; 2000 in run 4.4 E, 2000 and 2001 in run 4.5 W; and 2000 in run 4.5 E – see T statistics in Figure 46).

7.1.4 Trends associated with increasing information

Some retrospective trends in YCS estimates can be explained as the effect of the increase in information in successive assessments. The prior distribution for all YCSs is lognormal with mean 1 and c.v. 0.95 (see Table 22). When we first estimate a YCS, we have very little information about it, so we should expect our estimate to be near the mode of the prior distribution, which is 0.73. In subsequent assessments, as our information about this year class increases, the estimated YCS should become closer and closer to the true value. Thus, on average, we would expect a negative retrospective trend when the true YCS is less than 0.73, and a positive trend when it is greater than this value. In any retrospective analysis this trend would be most apparent for the year classes that were observed for the first time within the time frame of the analysis. The patterns shown by those trends identified in Section 7.1.3 as being of practical significance are consistent with their having been caused by increasing information.

Two other factors will affect these trends. The first is random observation errors which may, by chance, exaggerate or diminish these trends, depending on the direction of the errors. Second, the penalty function in the hoki assessment that forces the most recent YCSs for the E and W stocks to be equal (see Section 3.3) may modify these trends, although it is hard to predict exactly how.

7.1.5 Conclusions on trends in YCS estimates

We have identified two main causes for the retrospective trends shown in Figure 44: changes in model assumptions (mostly affecting the early assessments) and increasing information (mostly affecting recent year classes). Another, more minor, cause is the change in the definition of YCSs from assessment to assessment. Model error does not seem to have been a major cause of these trends.

7.2 Effects of invisible juvenile mortality on the assessment

In recent years there has been some concern about the possible effects of 'invisible' mortality of juvenile hoki. By 'invisible' I mean any fishery-induced mortality that is not apparent to the assessment model because there is no evidence of it in the data presented to the model. There are several mechanisms that could produce invisible mortality. For example, it could be that some juvenile fish encountered by a trawl net escape through the meshes, but then subsequently die from damage (e.g., extensive loss of scales) thereby incurred. Or, it could be that some proportion of the juvenile catch is dumped. In this section I investigate the effect of such invisible mortality on the stock assessment.

For this investigation I will make two assumptions. The first is that the pattern of invisible mortality is the same in all fisheries and has not varied with time. This pattern will be described by a retention curve, as illustrated in Figure 47. The plotted retention curve implies that for every 1-year old fish seen in the catch another four will be killed, and for every 2-year old seen, another one will be killed. The second assumption is that the fishery data used in the assessment (catches in tonnes and proportions at age) accurately represent the retained catch. CASAL has been modified to allow the user to specify such retention curves, and these may be functions of age or of length. For simplicity, all the retention curves used in this section will be age-based. Note that CASAL ignores fractional ages in age-based curves like this. Thus, for the curve in Figure 47A, the retention probability of 0.2 will apply to all 1+ fish, whether they are of 1.6 y (at step 2, in the first part of the non-spawning fisheries), or 1.9 y (at step 3, in the second part of the non-spawning fisheries) (see Table 12 for a reminder of the time steps within the model year). Note that 1-year old fish are not caught in the spawning fisheries because of the way the annual cycle is modelled in the hoki assessment: some 1+ fish migrate to spawn, but they become age 2 y before the fishery starts.

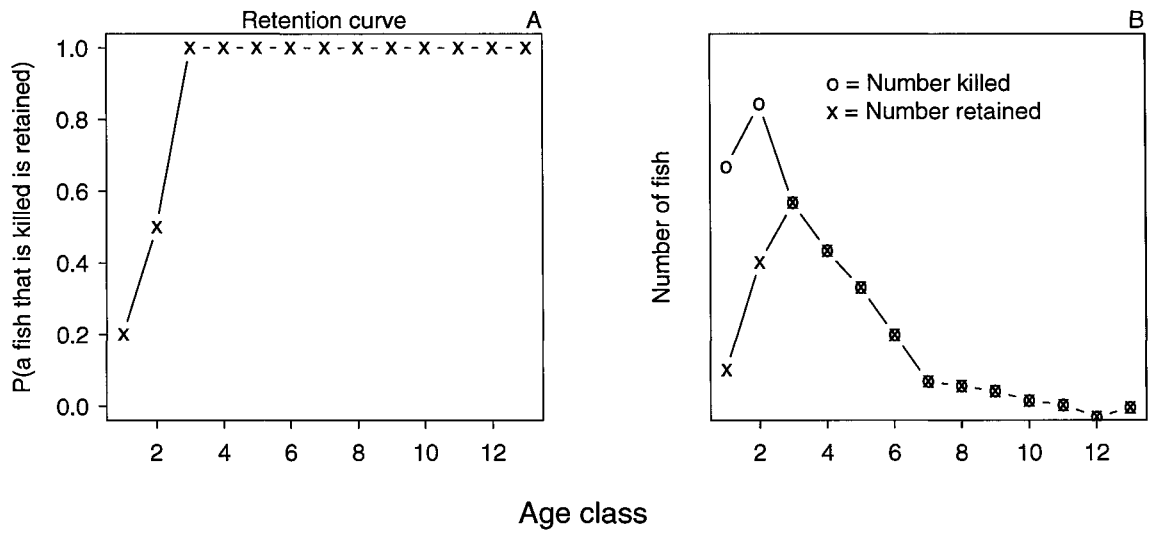

Figure 47: Illustration of the assumptions associated with modelling invisible mortality for juvenile fish: A, a retention curve, showing the proportion, by age, of killed fish that are retained in the reported catch; and B, the relationship between numbers at age for all fish killed by a fishery ('o') and the numbers retained in the catch ('x') assuming the retention curve in panel A.

Two new runs (4.16 and 4.17) were done to investigate the effect of invisible mortality, at the level described by the retention curve of Figure 47A, on the assessment. These runs used exactly the same assumptions and observations as runs 4.4 and 4.5, respectively, except for the addition of invisible mortality (for details of the associated CASAL input files see Appendix 4). The effect of this mortality on the assessment was generally small; it was only for the W stock in run 4.17 that the change in biomass was non-trivial (Figure 48). In this case, it decreased by 12% in tonnes, and from 23.4 $\%B_0$ to 20.9 $\%B_0$ (Table 32). The addition of invisible mortality very slightly improved the goodness of fit (the objective function value increased by 1 and 5, respectively).

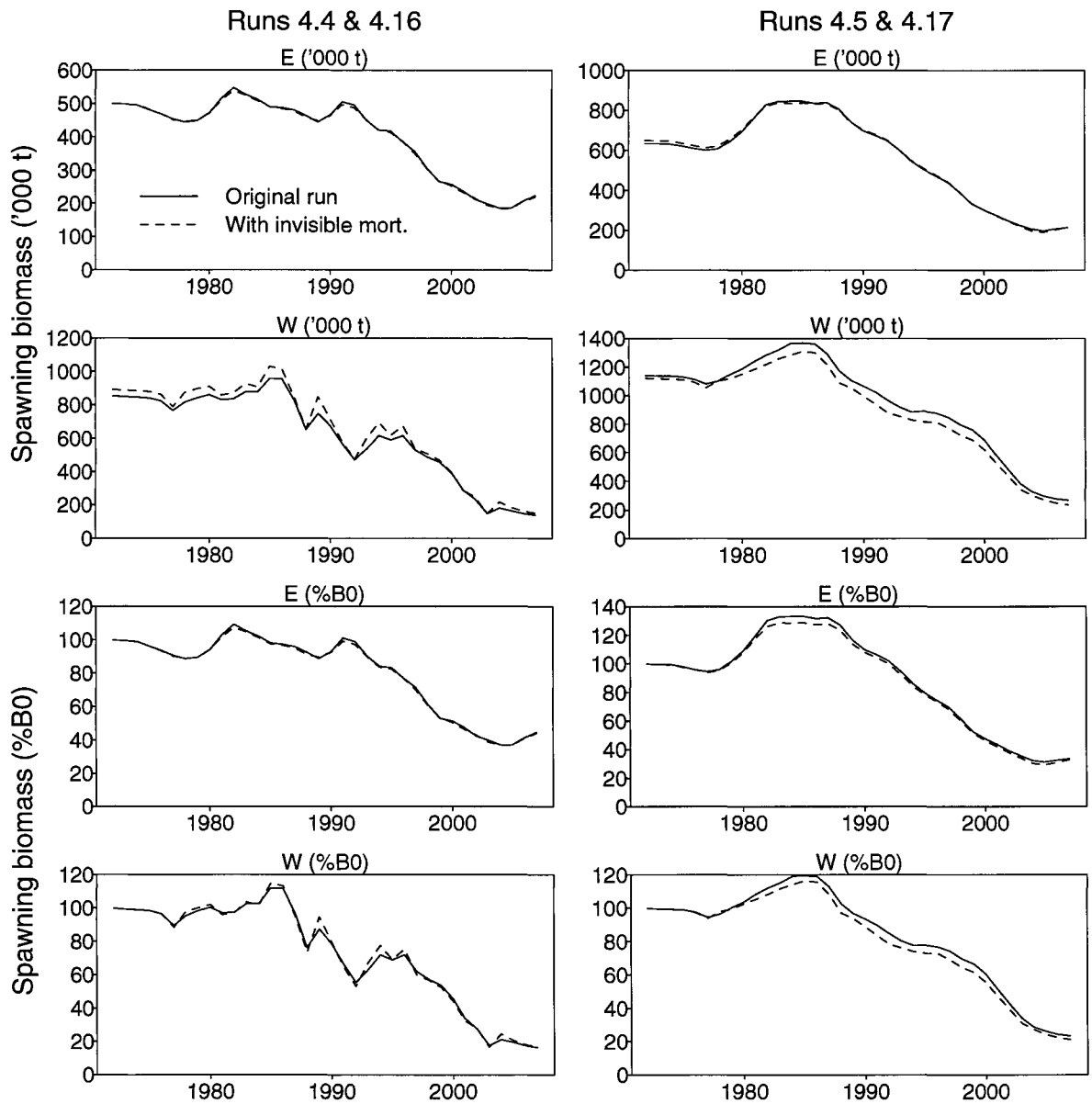

Figure 48: Biomass trajectories for two pairs of runs (4.4 and 4.16 in left panels, 4.5 and 4.17 in right panels). The two runs in each pair differed only in that the first assumed no invisible mortality and the second assumed invisible mortality as described by the retention curve of Figure 47A.

Table 32: Effect on estimated current biomass of E and W stocks of modifying the assessment by assuming invisible mortality as described by the retention curve of Figure 47A.

Original run	Modified run	% change in $B_{current}$ E	% change in $B_{current}$ W	E $B_{current}(\%B_0)$ Original	E $B_{current}(\%B_0)$ Modified	W $B_{current}(\%B_0)$ Original	W $B_{current}(\%B_0)$ Modified
4.4	4.16	-1.5	7.6	44.7	43.9	16.3	16.8
4.5	4.17	0.6	-12.0	33.6	33.0	23.4	20.9

The relatively small effect of invisible mortality in these assessments is explained, at least in part, by the fact that most deaths of 1+ and 2+ fish are caused by natural, rather than fishing mortality. Note that the proportion that die from fishing mortality in each year is the product of the selectivity curve (always low at ages 1 and 2 – see Figure 27) and the exploitation rate (always low for the non-spawning fisheries; highest for the W stock in recent years– see Figure 25). The proportion dying from natural mortality would be higher for run 4.5 (0.2), and much higher for run 4.4 (0.93 and 0.77 at ages 1 and 2, respectively) (these proportions were calculated as $1-e^{-M}$, averaging over males and females for run 4.4).

Two additional runs, 4.18 and 4.19, were done with higher rates of invisible mortality. For these, the retention curve was lower: 0.1 at age 1, 0.2 at age 2, and 1 for greater ages. For both runs, this slightly reduced current biomass for the E stock, but had no further effect on the W stock (Table 33). The goodness of fit decreased somewhat for these runs (the objective function value decreased by 24 and 7, respectively, relative to the original runs).

Table 33: Effect on estimated current biomass of E and W stocks of modifying the assessment by assuming invisible mortality described by a retention curve which was 0.1 at age 1, 0.2 at age 2, and 1 for greater ages.

Original run	Modified run	% change in $B_{current}$		E $B_{current}(\%B_0)$		W $B_{current}(\%B_0)$	
		E	W	Original	Modified	Original	Modified
4.4	4.18	-9.1	5.6	44.7	40.7	16.3	16.3
4.5	4.19	-5.4	-11.9	33.6	30.3	23.4	20.1

To evaluate the effect of invisible mortality on projected biomass, projections were done assuming status quo catches (i.e., scenario 106kt55%E in Table 29) and recent recruitment. To save time, these projections were based on MPD estimates only, whereas those presented above (in Section 5.1) used MCMC estimates. The difference is that the MPD-based projections consider only uncertainty associated with future recruitment, whereas those based on MCMC results also consider uncertainty in current status. (In the language of CASAL, these different types of projections are called point- and sample-based, respectively. The sample size for both types of projections was 1000.)

The levels of invisible mortality considered here had little effect on projected biomass (Figure 49). That is to say the lines associated with moderate (dotted lines) and greater invisible mortality (broken lines) are similar to those associated with no such mortality (light solid lines). The differences in trend between the MPD- and MCMC-based results in Figure 49 are generally slight.

7.2.1 Conclusions on invisible juvenile mortality

I conclude that the results from the 2007 assessment are unlikely to have been substantially biased because of invisible juvenile mortality unless this mortality has occurred at rates much greater than considered above.

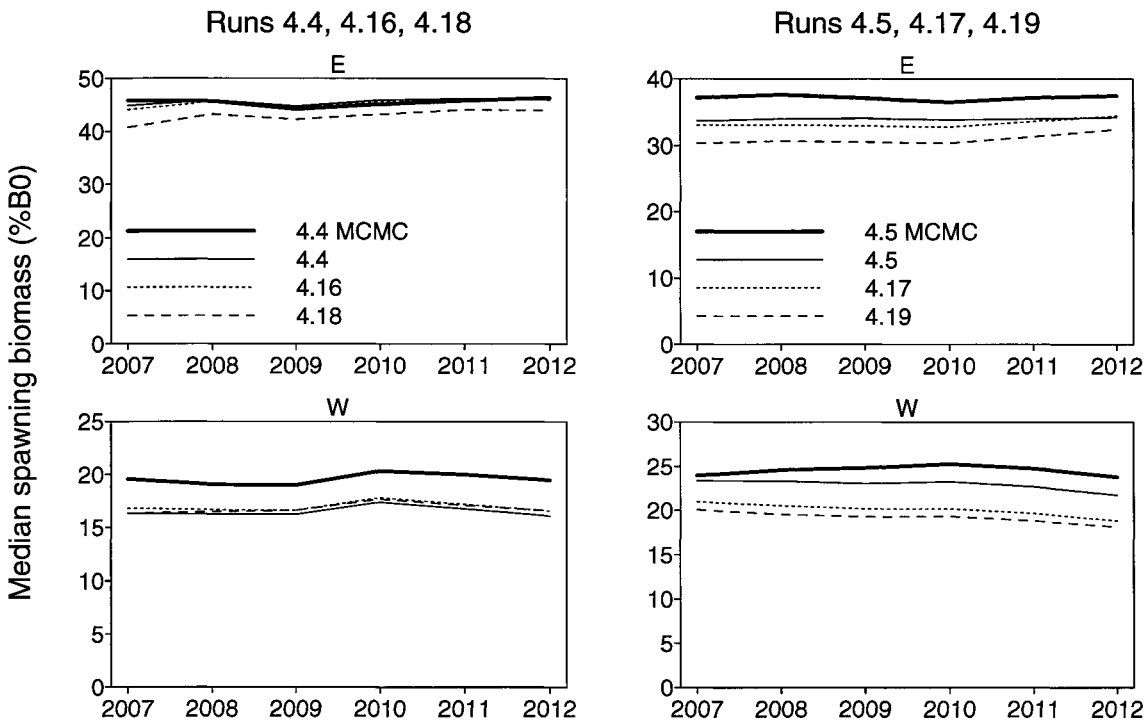

Figure 49: Effect of invisible mortality on projected spawning biomass assuming status quo catches (i.e., scenario 106kt55%E in Table 29) and recent recruitment. The three light lines in each panel compare MPD-based projection results with no invisible mortality (solid lines, runs 4.4 & 4.5), moderate invisible mortality (dotted lines, runs 4.16 & 4.17), and greater invisible mortality (broken lines, runs 4.18 & 4.19). The heavy line in each panel shows the corresponding MCMC-based projection results for the runs without invisible mortality.

7.3 Increase in hoki growth rates

Francis (2005) showed that, for both stocks, mean lengths at age had been gradually increasing since the mid to late 1980s. However, it was found that effects of including information about this increase in the stock assessment were (a) only a small change in the assessment results, and (b) substantially slower MCMC calculations. Because of this, all subsequent stock assessments have ignored this information (i.e., they have assumed no change in growth rates over time). In this section I re-examine the data on changes in growth rate and re-evaluate the decision to exclude information on these changes from the assessment assumptions.

An update of the analyses of Francis (2005), with four more years data, suggested that the increasing trend has continued (Figure 50). Between 1988 and 2006, mean lengths at age increased by about 7.5% (approximately 6 cm, on average) across all age classes, and the mean lengths at age assumed in the assessment model (based on the parameters in Table 15) lie between the observed (and smoothed) values for these two years (Figure 51).

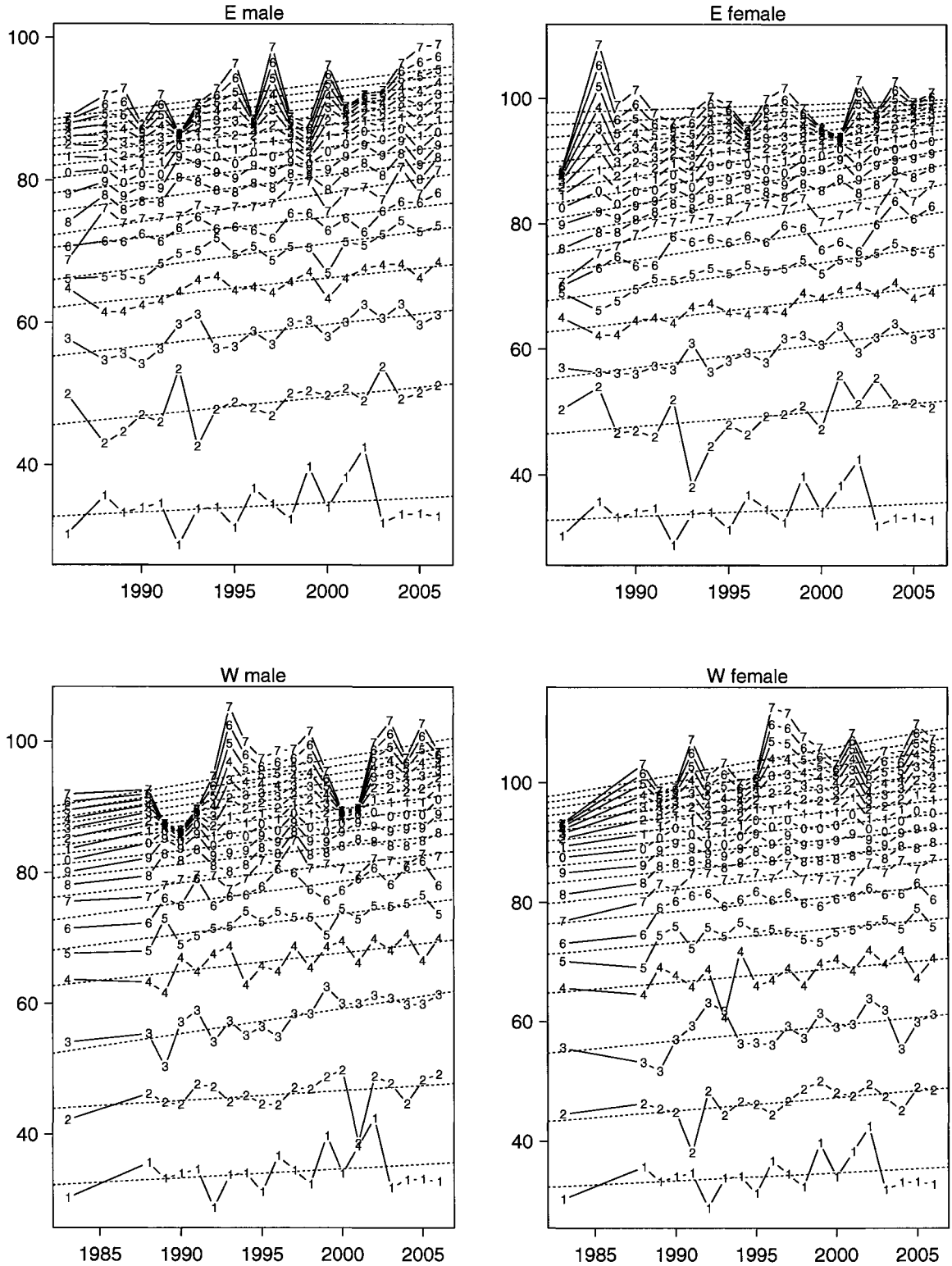

Figure 50: Mean lengths at age, by sex and stock, estimated from the observer data in the spawning fisheries (Espage and Wspage) and two *Shinkai Maru* surveys: SHI8602 for W, and SHI8303 for E. The plotting symbols indicate the last digit of the age represented. To clarify the trends, some mean lengths have been adjusted (see section 2.5.1 in Francis (2005)) and regression lines (dotted lines) have been added.

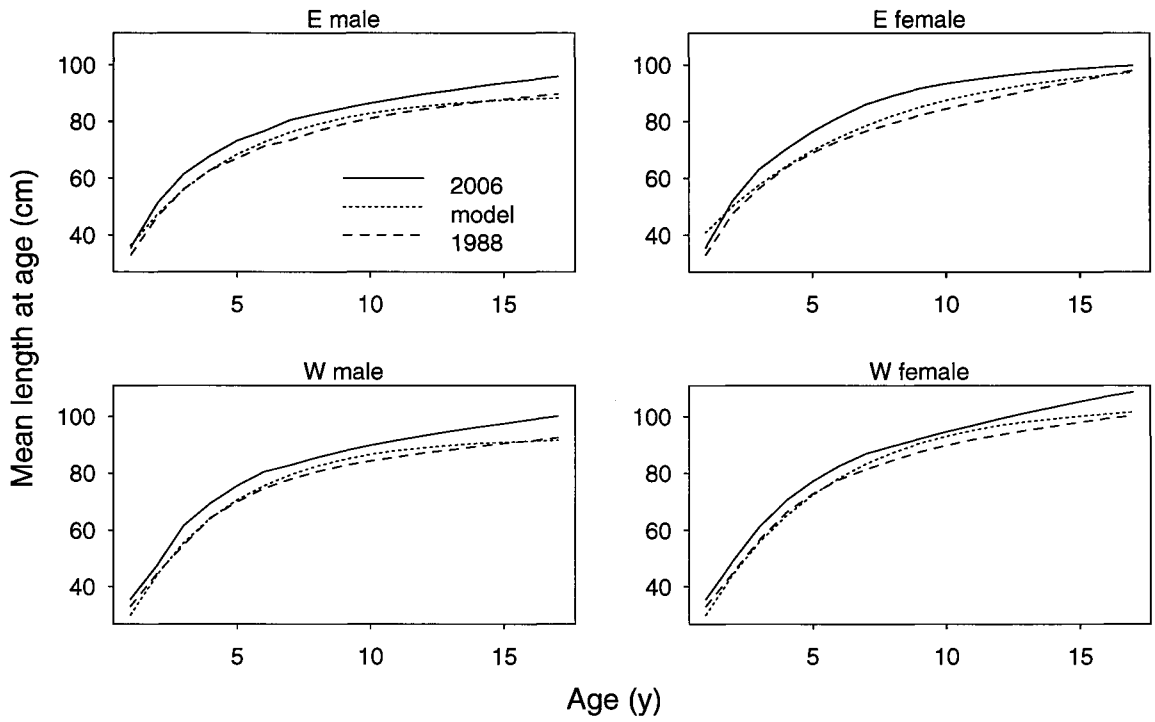

Figure 51: Comparison between smoothed mean lengths at age, by sex and stock, from observer data in 1988 (broken lines) and 2006 (solid lines) with those assumed in the assessment model (dotted lines). The lines for 1988 and 2006 were as estimated by the regression lines plotted in Figure 50.

7.3.1 Effect on the stock assessment

To evaluate the effect of using the change in growth rates in the stock assessment three new runs, 5.1–5.3, were done which were exactly the same as the final runs from the 2007 assessment (4.4, 4.5, and 4.7, respectively) except that mean lengths at age were taken from the values plotted in Figure 50 (see section 2.5.2 and appendix 3 of Francis (2005) for details of how this was done). In these runs, B_0 was calculated using mean lengths at age that were averaged over all years. Compared to those from the original runs, the biomass trajectories for the new runs were always lower in the earlier years, but similar in recent years, particularly when expressed as % B_0 (Figure 52). This pattern of a gradually decreasing gap between the old and new trajectories is to be expected, given the increasing trend in mean lengths at age. (Trajectories expressed as %B_0 are not presented for runs that don't assume natal fidelity – i.e., runs 4.7 and 5.3 – because B_0 is not well defined for the individual stocks in these runs.) In terms of goodness of fit to the data, the new runs differed little from the old runs (Table 34).

For all the runs plotted in Figure 52, within-cohort variation in length was ignored. That is, it was assumed that, at any given time, all fish of the same age, sex, and stock have the same length. Further runs, 5.4–5.6, were done that were the same as 5.1–5.3 except that within-cohort variation in length was allowed. This variation was assumed to be normally distributed with a c.v. that increased linearly with mean length at age. Biomass trajectories from these additional runs (not shown) were virtually identical with those from runs 5.1–5.3.

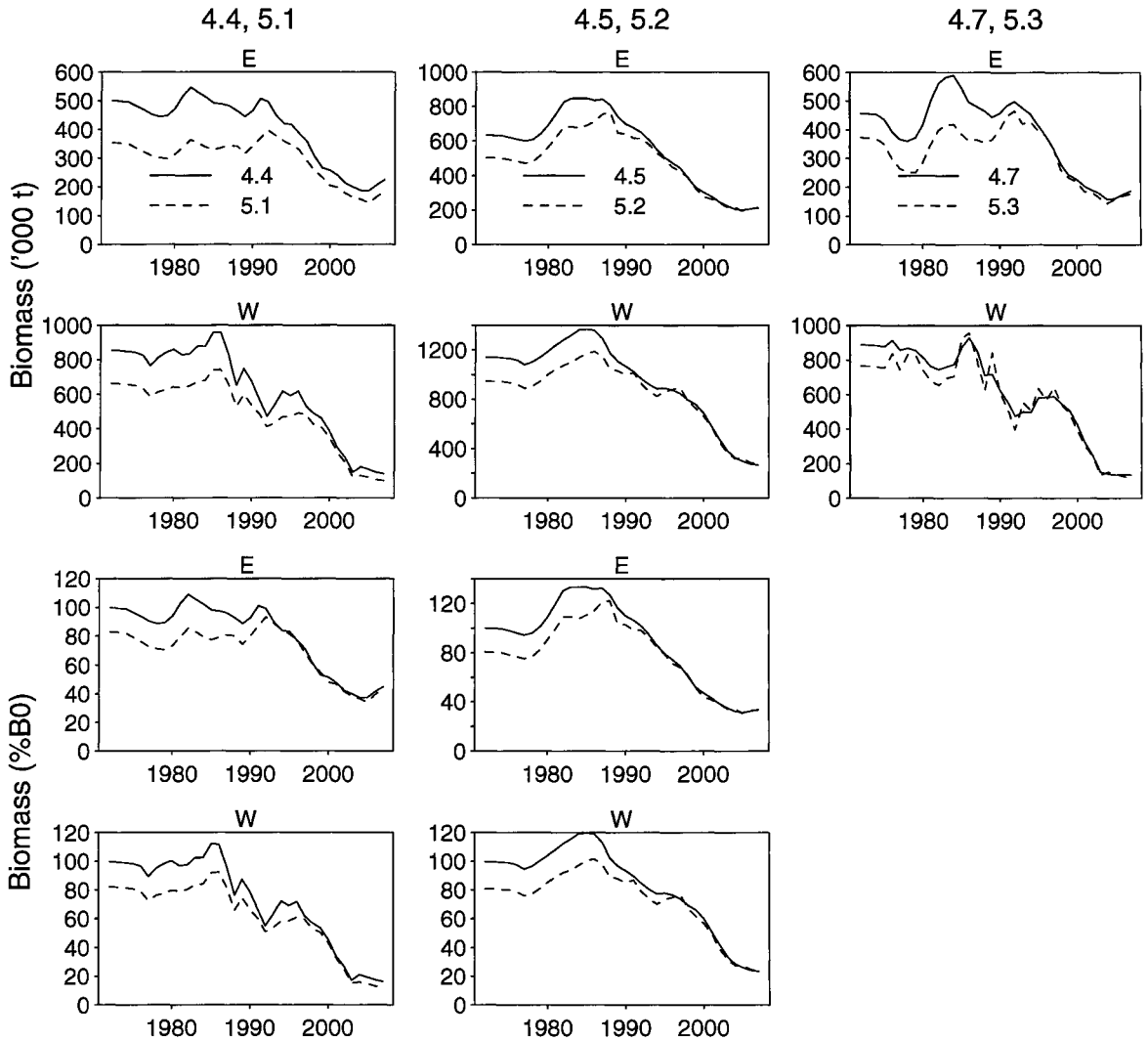

Figure 52: Effect of using mean length data on estimate biomass trajectories. Each panel compares biomass estimates from one of the main assessment runs (solid lines) with those from the analogous run using the mean length data (broken lines).

Table 34: Gain in goodness of fit when mean length data are used. The tabulated numbers are the change in the objective function component (rounded to the nearest integer) for individual data sets, with a positive number indicating an improvement in fit.

	From run 4.4 to run 5.1	From run 4.5 to run 5.2	From run 4.7 to run 5.3
CRsumbio	-4	-2	2
CSacous	1	0	-5
SAautbio	-1	0	-1
SAsumbio	-0	-0	-3
WCacous	1	0	8
CRsumage	-13	-2	6
SAautage	-3	-0	-4
SAsumage	-1	-0	-4
EnspOLF	-7	-0	-9
Enspage	-4	1	-14
Espage	34	-0	3
WnspOLF	-2	0	-1
Wnspage	-2	0	-0
Wspage	9	-1	21
pspawn	1	-0	-0
All data	8	-4	0

7.3.2 Are mean lengths at age still increasing?

It is of interest to know whether mean lengths at age are still increasing. That is, if we restrict attention to the last 5 or 10 years, say, do the data in Figure 50 still show an upward trend? The considerable year-to-year variation in these data make it hard to answer this question simply by visual inspection. A linear modelling approach was used to provide an answer. This analysis was restricted to most common age groups – ages 3 to 10 y – for which the estimated mean lengths at age would be most reliable. It was assumed that mean length changed proportionately at the same rate for all these age groups. This rate of change was estimated separately for each combination of sex and stock, and the analysis was repeated for three subsets of years: all years, last 10 years only, and last 5 years only.

Estimates from this model suggest that, at least for the last 10 years, mean lengths at age have continued to increase, although less so for the W than for the E stock (Table 35). The picture is less clear for the last 5 years: although all estimated rates of change have been positive, only three of the four estimates are significantly different from zero.

Table 35: Estimated annual rate of change in mean length at age by sex and stock, calculated using all years, just the last 10 y, and just the last 5 y. *, rate not significantly different from zero.

	Annual rate of change (%)		
Stock and sex	All years	Last 10 y	Last 5 y
E male	0.44	0.55	0.29*
E female	0.60	0.51	0.87
W male	0.42	0.26	0.12*
W female	0.34	0.28	0.06*

[For the reader interested in technical details, the model fitted used in this section was $\log(M_{ya}) = \alpha + \beta_a + \gamma y + \varepsilon_{ya}$, where M_{ya} is the observed mean length at age a in year y (as shown in Figure 50), ε_{ya} is an error term, and α, γ, and β_a (for a = 3,...,10) were estimated parameters. The percentage annual rate of change was calculated as $100(e^{\gamma} - 1)$.]

7.3.3 Conclusions about mean lengths at age

Mean lengths at age for both stocks have been increasing since at least 1988. However, it is still reasonable to ignore this increase in the stock assessment because this speeds up MCMC calculations and has little effect on the assessment results.

7.4 Step changes in selectivities

A strong assumption in all the final assessment runs was that the selectivity for each fishery, except Wsp, has not changed over time. For the Wsp fishery, annual changes in selectivity were allowed, but these were strictly tied to changes in the median day of the fishery (see Section 3.2). In this section I investigate the consequences of allowing some temporal changes in selectivity. Only changes that seemed sensible in the light of knowledge about changes in fishing practice, etc, were considered. Also, for technical reasons, only sudden, or step, changes were allowed. That is to say, instead of estimating a single selectivity for a fishery, we might estimate two or more selectivities, each of which was assumed to apply in an associated block of adjacent years.

A technical subcommittee discussed a range of factors that could have caused changes in selectivity and proposed six steps over the four fisheries (Appendix 5). Four of these (Table 36) were evaluated; the remaining two (at 1996 for Ensp and 2005 for Wnsp) were ignored because there were too few years data to estimate the selectivity before or after the step. It was also recommended by the

subcommittee that when a step in the Wsp selectivity is to be considered, the year-to-year variation that has been allowed in this selectivity (see Section 3.2) be restricted to the period before 1999.

Table 36: Step changes in selectivity that were investigated. Interpretation: the first line of the table describes a single step in 1999 for the Wsp fishery, which means that two selectivity curves would be estimated, WspslE (for which 11 y of data were available, 1988–1998) and WspslL (with 8 y of data, 1999–2006). In the new selectivity labels the last letter is 'E' for the early period, 'M' for the middle period (if any) and 'L' for the late period.

Fishery	Step year(s)	Selectivities estimated (no. of years)
Wsp	1999	WspslE (11 y), WspslL (8 y)
Esp	1996, 2001	EspslE (8 y), EspslM (5 y), EspslL (6 y)
Ensp	2001	EnspslE (6 y), EnspslL (6 y)

A series of model runs was done in which one or more of these steps was allowed. The first run, 5.7, was the same as the final run 4.4, except that year-to-year variation in the Wsp selectivity was disallowed from 1999 on, as recommended by the subcommittee. All other runs were modifications of 5.7. In those runs in which step changes were allowed in either or both of the spawning fisheries there was a need to modify the constraint Espsl = Wspsl that applies in run 4.4 (see Table 16). In these runs, it was decided to apply this constraint just to the earliest selectivity in each of these two fisheries.

Some results from this series of runs are presented in Table 37. Each of the first four runs after 5.7 allowed one step change only. Runs 5.8 and 5.9 showed much greater improvements in fit (45 and 34 points, respectively) than did the other two (14 and 10 points). Run 5.12 combined the step changes in 5.8 and 5.9, and was a clear improvement on both of these. However, neither of the last two runs, which extend run 5.12 by adding one more selectivity shift, result in substantial improvement of fit compared to 5.12. Thus, on the grounds of goodness of fit alone, it is worth considering run 5.12. The biomass trajectories from run 5.12 differ very little from those for run 4.4 (Figure 53). MPD-based projection results for run 5.12 were slightly more pessimistic for the W stock than those from run 4.4, but similar for the E stock (Figure 54). The effect of both of the selectivity shifts estimated in run 5.12 was that younger fish were more likely to be caught after the shift (Figure 55).

Table 37: Comparison of runs investigating step changes in selectivity

Run	Selectivity steps	Additional parameters (relative to run 5.7)	Improvement in fit (relative to run 5.7)	$B_{current}$ (%B_0) E	W
5.7	None	0	0	39	16
5.8	Wsp(1999)	2	45	50	15
5.9	Esp(1996)	2	34	36	18
5.10	Esp(2001)	2	14	38	16
5.11	Ensp(2001)	3	10	40	16
5.12	Wsp(1999) Esp(1996)	4	79	45	16
5.13	Wsp(1999) Esp(1996) Esp(2001)	6	82	45	16
5.14	Wsp(1999) Esp(1996) Ensp(2001)	7	87	46	16
4.4	None	0	32	45	16

7.4.1 Conclusions on step changes in selectivities

Although the data support allowing step changes in selectivities in both spawning fisheries, this has relatively little effect on the stock assessment. Thus it seems advisable to apply Occam's razor and not include these step changes in future assessments.

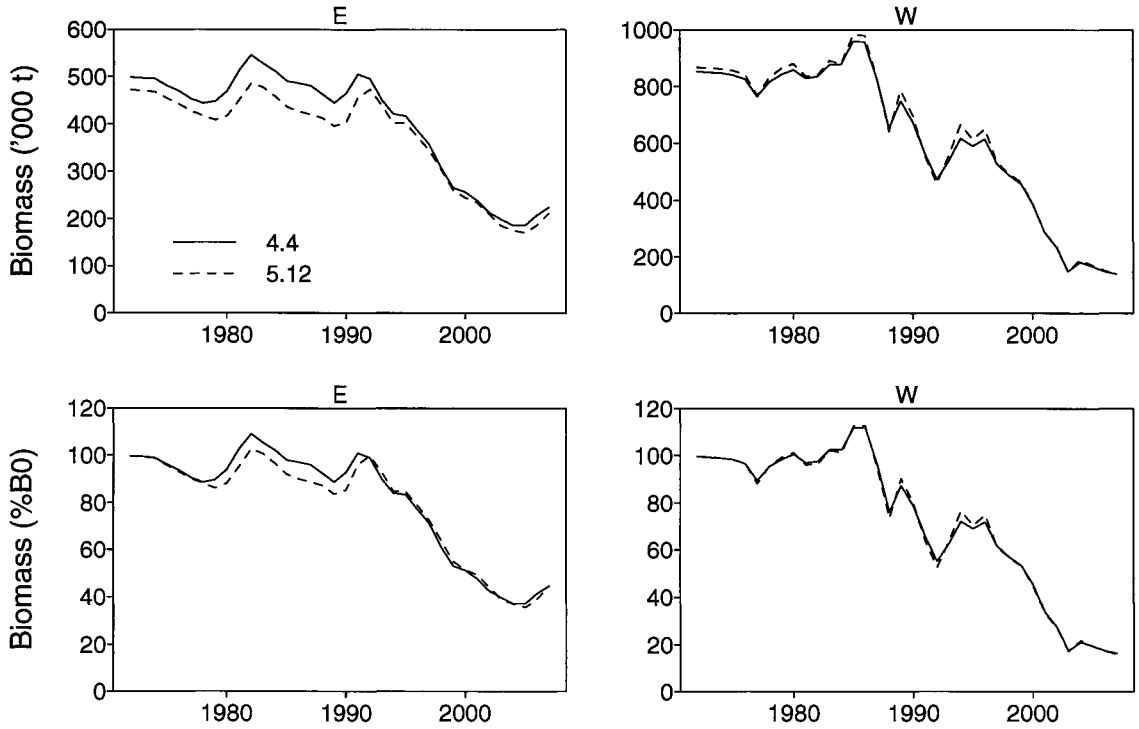

Figure 53: The effect of allowing step changes in selectivities on estimated biomass trajectories: comparison of trajectories from run 4.4 (with no steps, solid lines) and 5.12 (with a step at 1999 for Wsp and at 1996 for Esp, broken lines).

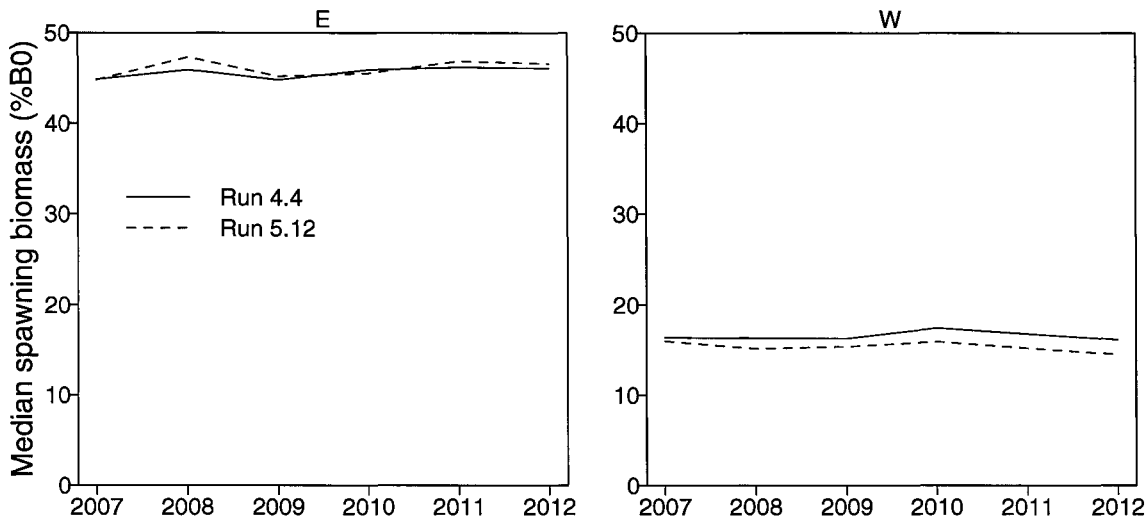

Figure 54: Effect of allowing step changes in selectivities on projected spawning biomass: MPD-based projection results for runs 4.4 and 5.12, assuming status quo catches (i.e., scenario 106kt55%E in Table 29) and recent recruitment.

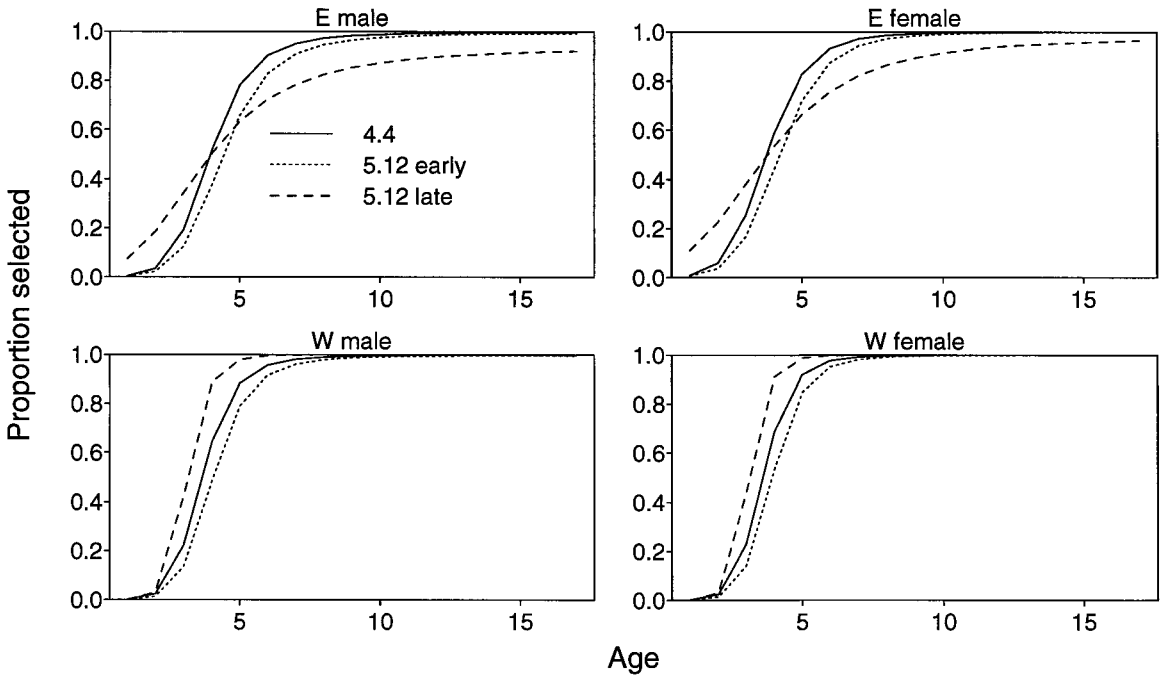

Figure 55: Comparison of the selectivities estimated in the two spawning fisheries in runs 4.4 and 5.12 (which was the same as 4.4 except that it allowed a selectivity step for both of these fisheries).

7.5 Improving the MCMC performance of run 4.5

Of the three final runs in the 2007 stock assessment, run 4.5 had the worst MCMC diagnostics (see Figure 31). At the time, it seemed that this poor performance could be related to the very poor trace for the natural mortality parameter, *M*, in this run (see Figure 41A), though it was not clear why this trace was so poor, when the trace from the corresponding model run in 2006 was not (see Figure 41B). In this section I show how the MCMC diagnostics for run 4.5, and the associated trace for *M*, can be substantially improved, and that, fortunately, this improvement has little effect on the conclusions of the assessment.

The poor trace for *M* in run 4.5 was eventually found to be connected to the relationship between *M* and four parameters – SAsl.sL, Wnspsl.sL, Wnspsl.sR, and Enspsl.sR – all associated with double-normal selectivity curves. In the names of these parameters, the endings 'sL' and 'sR' indicate that the parameter controls the steepness of the left- or right-hand limbs of the selectivity, respectively. Bivariate plots of these parameters with *M* for the run 4.5 MCMC sample (Figure 56) illustrate the problem. Note that when *M* is smaller than about 0.27,each of the two sL parameters can take a wide range of values. However, in the MCMC process, *M* can move away from such small values only if both the sL parameters are small. Thus, there is a tendency for *M* to get stuck at small values until such time as it happens, by chance, that the algorithm selects a trial parameter vector in which *M* is larger but both SAsl.sL and Wnspsl.sL are small. There is a similar tendency for *M* to get stuck at high values (above about 0.3). Consequently, there is a bottleneck of intermediate values (between about 0.27 and 0.3) that it is difficult for *M* to enter in the MCMC sample, and this is quite apparent if we look at values of *M* from the three MCMC chains that were done for run 4.5 (left panels, Figure 57). A consequence of this bottleneck is that the posteriors from the three chains were quite different, and two of them were bimodal (right panel, Figure 57).

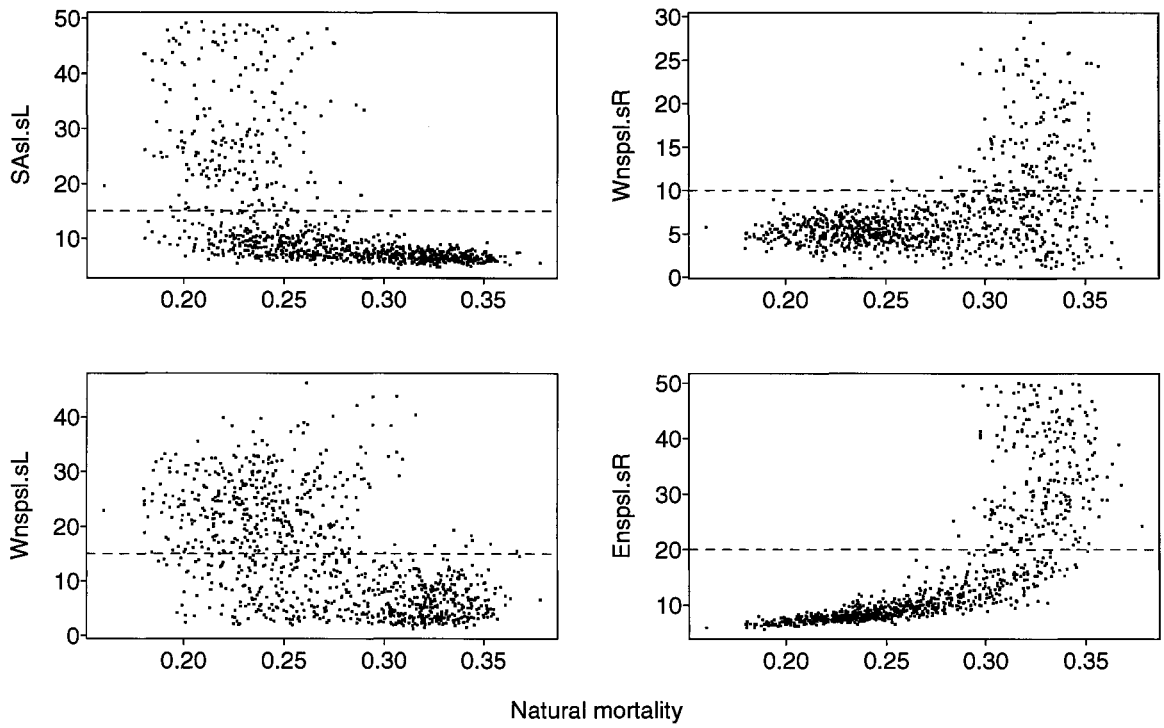

Figure 56: Bivariate plots of the MCMC sample from run 4.5, showing correlations between natural mortality, *M*, and four selectivity parameters. The dashed line in each panel shows the upper bound that was used for the associated selectivity parameter in run 4.5ubnd (see text for details).

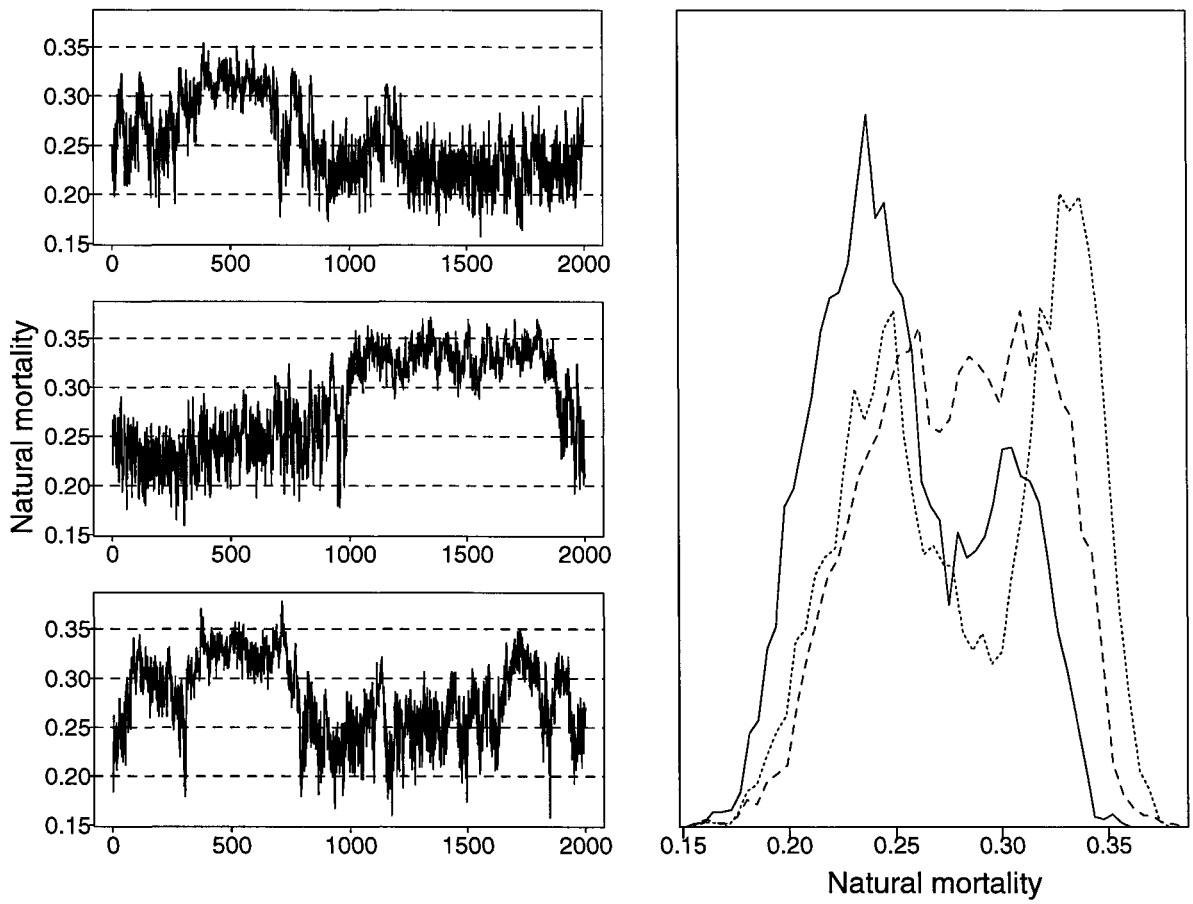

Figure 57: Traces for natural mortality from the three MCMC chains for run 4.5 (left panels), and the associated posterior distributions (right panel).

It was felt that this bottleneck might be avoided if the upper bounds on the selectivity parameters were reduced to the values shown by the dashed lines in Figure 56 (the upper bounds for all four parameters in run 4.5 were 50). A new run, labelled 4.5ubnd, was done using these bounds. Traces for *M* were much improved, with the three new chains producing very similar posteriors (Figure 58). The diagnostic plots for the new run were also improved (Figure 59). The changed bounds had relatively little effect on the median estimates of the associated selectivities, but the corresponding 95% confidence limits were clearly narrowed (Figure 60). However, when we look at the most important model outputs there was not much change in either point estimates or 95% confidence regions (Figure 61).

7.5.1 Conclusions for run 4.5

The main conclusion from these analyses is that the relatively poor diagnostics for run 4.5 did not compromise the assessment. The new run, 4.5ubnd, has much better diagnostics (both for biomass outputs and for *M*), but very similar estimates for the most important model outputs. This illustrates the difficulty of finding appropriate MCMC diagnostics.

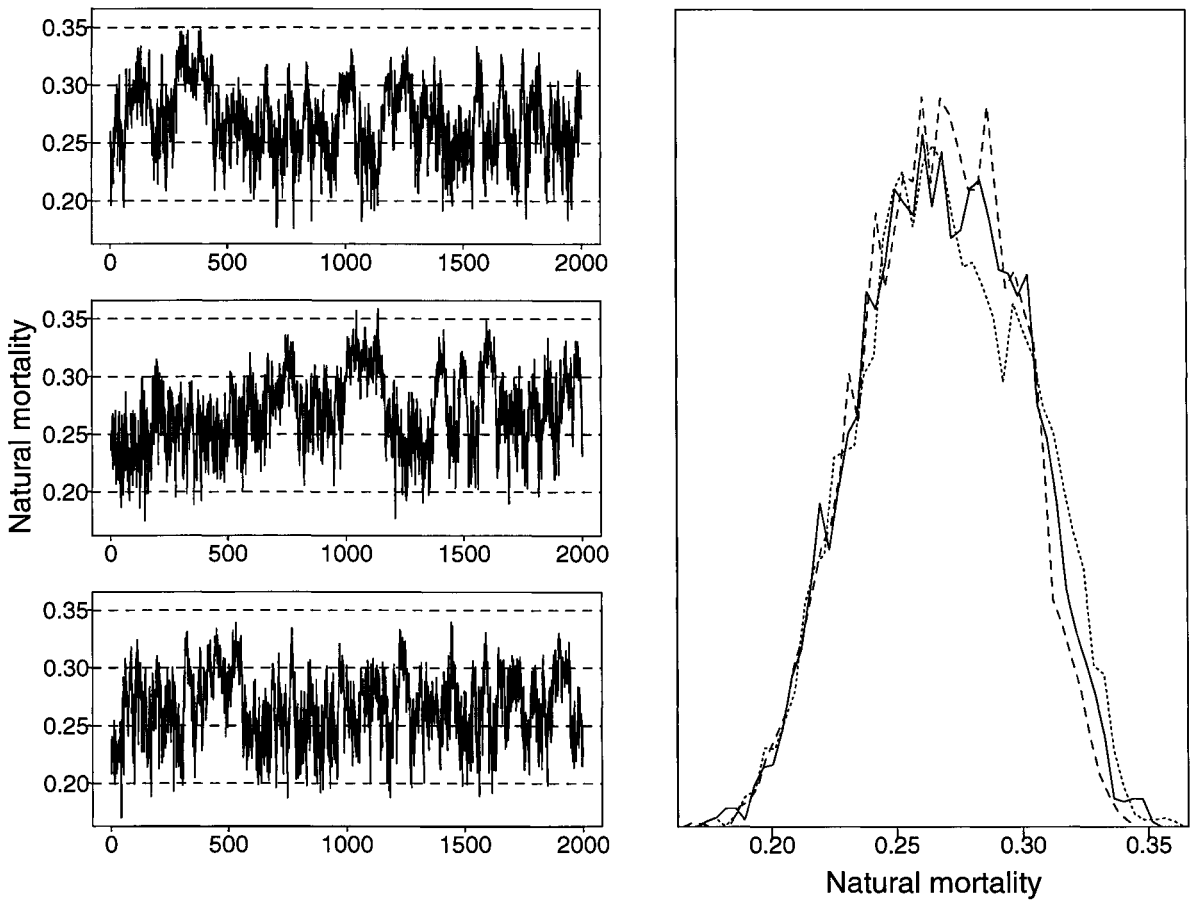

Figure 58: Traces for natural mortality from the three MCMC chains for run 4.5ubnd (left panels), and the associated posterior distributions (right panel).

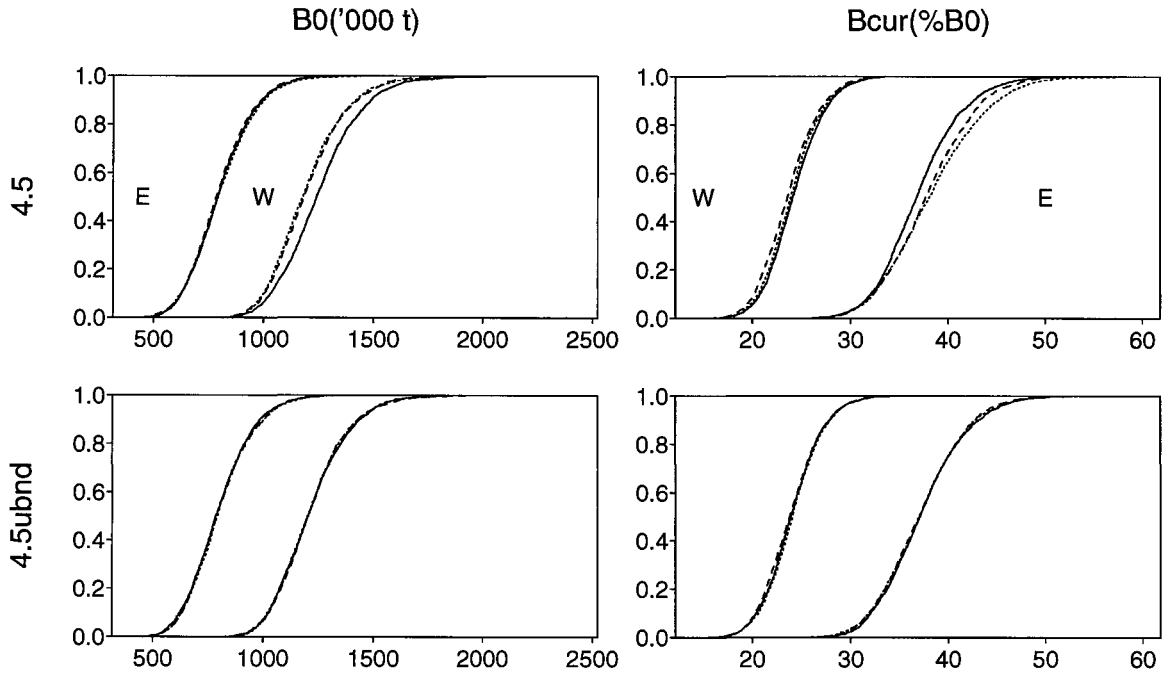

Figure 59: Diagnostics for MCMC chains for runs 4.5 (upper panels) and 4.5ubnd (lower panels). Each panel contains cumulative probability distributions, for B_0 or $B_{current}$, for three chains from the same model run.

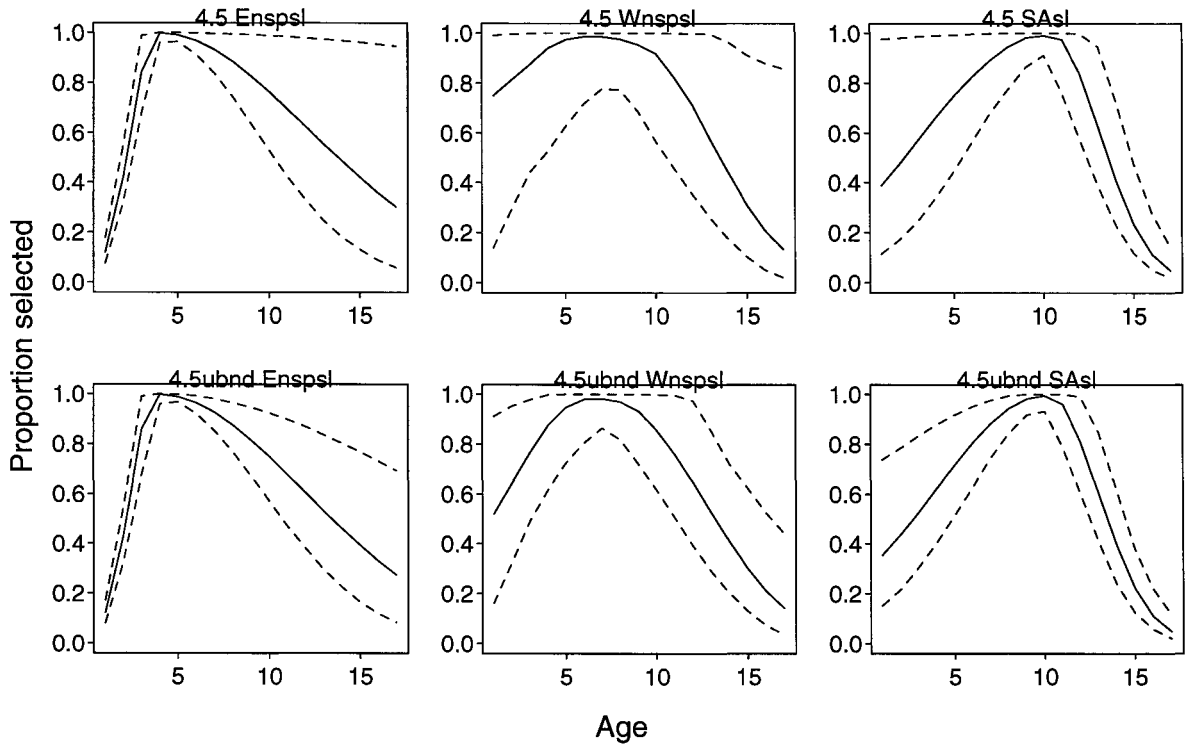

Figure 60: Effect of changed upper bounds for some selectivity parameters (SAsl.sL, Wnspsl.sL, Wnspsl.sR, and Enspsl.sR) on posterior estimates of the associated selectivity curves: the upper panel in each vertical pair shows the posterior estimates (solid lines are medians, broken lines are 95% confidence intervals) from run 4.5, and the lower panel shows the corresponding estimates from run 4.5ubnd.

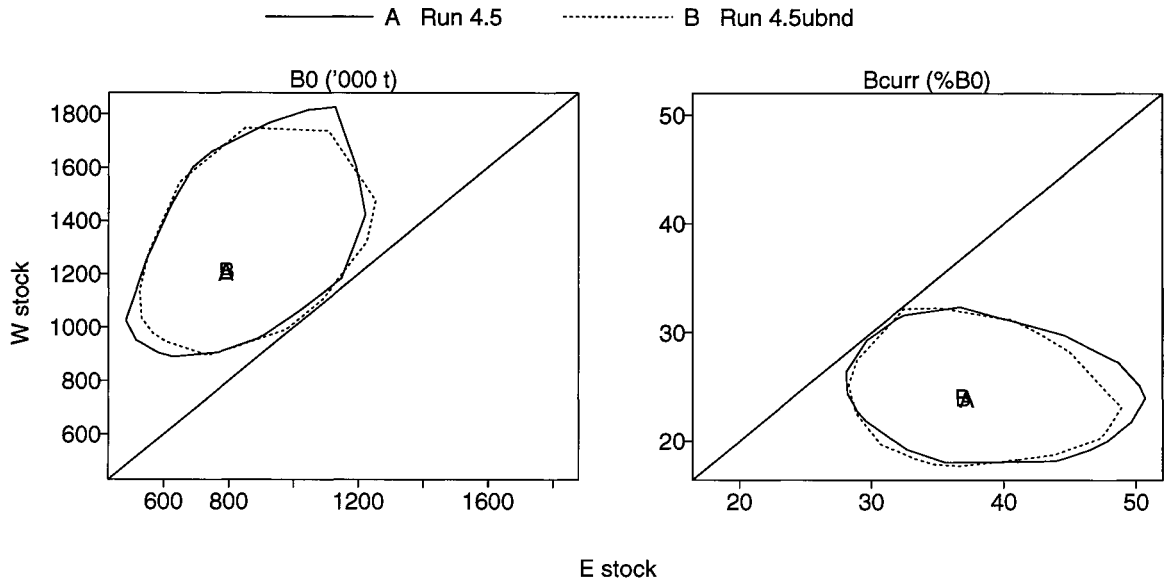

Figure 61: Estimates and approximate 95% confidence intervals for virgin (B_0) and current ($B_{current}$ as $\%B_0$) biomass by stock for runs 4.5 and 4.5ubnd. In each panel the points 'A', 'B', 'C' indicate best estimates (median of the posterior distribution) and the polygons enclose approximate 95% confidence intervals. Diagonal lines indicate equality ($y = x$).

8. ACKNOWLEDGMENTS

I am grateful to Sira Ballara, Richard O'Driscoll, and Darren Stevens for providing data; to members of the Hoki Working Group, in particular Rosie Hurst, for many suggestions during and after the assessment process; and to a technical subcommittee for Appendix 5. This work was funded under MFish project HOK2006/01.

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Appendix 1: Files defining the final runs

Each of the final model runs is completely defined, in the context provided by the CASAL manual (Bull et al. 2005), by two input files — population.csl and estimation.csl — and, for runs 4.4 and 4.7, a user.prior_penalty.cpp file. These files are presented in this appendix. In any line of the input files, text following the symbol # is treated as a comment, and the symbol @ marks the beginning of a command block.

A1.1 population.csl

The model structural assumptions for each run are completely defined by the file population.csl. I first present the file used for the MPD run 4.4, then list the differences between that and the corresponding files for the other main runs, and finally describe changes made to these files for MCMC and projection runs.

A1.1.1 population.csl for MPD run 4.4

```
# PARTITION
@size_based 0

@min_age 1
@max_age 17
@plus_group T

@sex_partition T
@n_areas 4
@area_names SA CR WC CS
@n_stocks 2
@stock_names E W
@mature_partition 0

@exclusions_char1 area  area  area
@exclusions_val1  SA    WC    CS
@exclusions_char2 stock stock stock
@exclusions_val2  E     E     W

# TIME SEQUENCE
@initial 1972
@current 2007
@final 2012

@annual_cycle
time_steps 5 # Oct-Nov, Dec-Mar, Apr-Jun, End Jun, Jul-Sep
recruitment_time 2
recruitment_areas CR CR
spawning_time 5
spawning_part_mort 0.5
spawning_areas CS WC
spawning_use_total_B T
spawning_p 1
aging_time 5
growth_props 0.25 0.60 0.90 0.90 0.0
M_props 0.17 0.33 0.25 0 0.25
baranov 0
fishery_names Ensp1 Wnsp1 Ensp2 Wnsp2 Esp Wsp
fishery_times 2     2     3     3     5   5
fishery_areas CR    SA    CR    SA    CS  WC
n_migrations 5
migration_names Ertn Wrtn Whome Espmg Wspmg
migration_times 1   1   3   4   4
migrate_from    CS  WC  CR  CR  SA
migrate_to      CR  SA  SA  CS  WC


# RECRUITMENT
@y_enter 2
@use_mean_YCS T
```

```
@recruitment E
first_free 1975
last_free 2002
YCS_years  1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
YCS          1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1
n_rinitial 5
SR BH
steepness 0.9
p_male 0.5
year_range 1975 2003 # to resample YCS from
@recruitment W
first_free 1975
last_free 2002
YCS_years  1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
YCS          1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1
n_rinitial 5
SR BH
steepness 0.9
p_male 0.5
year_range 1975 2003 # to resample YCS from

@randomisation_method empirical
@first_random_year 2006

# NATURAL MORTALITY
@natural_mortality
ogive_male double_exponential 1 17 7.1 0.2 1 0.8
ogive_female double_exponential 1 17 7.1 0.035 1 0.7

# FISHING
@fishery Ensp1
years  1972  1973  1974  1975  1976  1977  1978  1979  1980  1981  1982  1983  1984  1985
1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001
2002 2003 2004 2005 2006 2007
catches 1500 1500 2200 13100 13500 13900 1100 2200 2900 2900 2600 1500 3200 6200 3700 8800
9000 2300 3300 17400 33400 27400 16000 29600 37900 42400 55600 59200 43100 36300 24700 25100
17900 19600 22500 22500
U_max 0.3
selectivity Enspsl
future_years 2008 2009 2010 2011 2012
future_catches 22500 22500 22500 22500 22500

@fishery Ensp2
years  1972  1973  1974  1975  1976  1977  1978  1979  1980  1981  1982  1983  1984  1985
1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001
2002  2003 2004 2005 2006 2007
catches 2500 2500 3800 22900 23500 24100 1900 3800 5100 5100 4400 8500 6800 3800 13300 8200
6000 2700 9700 14900 17500 19700 10600 16500 23900 28200 34200 23600 20500 20700 18800 18800
19100 14200 15100 15100
U_max 0.3
selectivity Enspsl
future_years 2008 2009 2010 2011 2012
future_catches 15100 15100 15100 15100 15100

@fishery Wnsp1
years  1983  1984  1985  1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996
1997  1998  1999  2000  2001  2002 2003 2004 2005 2006 2007
catches 3200 6700 3000 7200 5900 5400 700 900 4400 14000 14700 5800 5900 5700 6900 10900 8800
14300 13200 16900 12800 6400  4500  2000  2000
U_max 0.3
selectivity Wnspsl
future_years 2008 2009 2010 2011 2012
future_catches 2000  2000 2000  2000 2000

@fishery Wnsp2
years  1983  1984  1985  1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996
1997  1998  1999  2000  2001  2002  2003 2004 2005 2006 2007
catches 3500 5400 6100 3300 5400 7600 4900 9100 12700 17400 10900 5500 7500 6800 15100 14600
14900 19500 16900 13400 8100 5300  2000  4800  4800
U_max 0.3
selectivity Wnspsl
future_years 2008 2009 2010 2011 2012
future_catches 4800  4800 4800  4800 4800
```

```
@fishery Wsp
years  1972  1973  1974  1975  1976  1977  1978  1979  1980  1981  1982  1983  1984  1985
1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001
2002  2003 2004 2005 2006 2007
catches 5000 5000 5000 10000 30000 60000 5000 18000 20000 25000 25000 23300 27900 24900 71500
146700 227000 185900 173000 135900 107200 100100 117200 80100 75900 96900 107100 97500 105600
109200 98300 78700 46300  39300  40700  40700
U_max 0.67
selectivity Wspsl
future_years 2008 2009 2010 2011 2012
future_catches 40700  40700 40700  40700 40700

@fishery Esp
years  1988  1989  1990  1991  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001
2002  2003 2004 2005 2006 2007
catches 600 7000 14000 29700 25600 22200 35900 34400 59700 56500 46700 40500 39000 33700 24000
41400 40800 26700 20700 20700
U_max 0.67
selectivity Espsl
future_years 2008 2009 2010 2011 2012
future_catches 20700 20700 20700 20700 20700

# COMMON SELECTIVITIES

@selectivity_names Enspsl Wnspsl Espsl Wspsl CRsl SAsl

@selectivity Enspsl
all size_based double_normal 72 28 28

@selectivity Wnspsl
all size_based double_normal 72 28 28

@selectivity Espsl
all size_based logistic 50 10

@selectivity Wspsl
all  size_based logistic 50 10
shift_E 305 305 305 305 305 305 305 305 305 305 305 305 305 305 305 305 299 302 298 301 306
304 308 307 312 310 311 309 309 309 308 309 307 309 310 305
shift_years 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
2007
shift_a 0

@selectivity CRsl
all size_based double_normal 72 28 28

@selectivity SAsl
all size_based double_normal 72 28 28

# MIGRATION

@migration Ertn
prop 1

@migration Wrtn
prop 1

@migration Whome
# W home: CR to SA
stock W
rates_male allvalues_bounded 1 8 0.1 0.1 0.43 0.56 0.88 0.9 0.95 1
rates_female allvalues_bounded 1 8 0.1 0.1 0.28 0.33 0.44 0.6 0.8 1

@migration Espmg
# E spawning: CR to CS
stock E
rates_male allvalues_bounded 1 8 0.1 0.2 0.3 0.4 0.5 0.6 0.6 0.6
rates_female allvalues_bounded 1 8 0.04 0.08 0.2 0.47 0.52 0.61 0.67 0.67

@migration Wspmg
# W spawning: SA to WC
stock W
rates_male allvalues_bounded 1 8 0.1 0.2 0.3 0.4 0.5 0.6 0.6 0.6
rates_female allvalues_bounded 1 8 0.04 0.08 0.2 0.47 0.52 0.61 0.67 0.67
```

```
# SIZE AT AGE
@size_at_age_type von_Bert

@size_at_age E
k_male 0.232
t0_male -1.23
Linf_male 89.5
k_female 0.161
t0_female -2.18
Linf_female 101.8

@size_at_age W
k_male 0.261
t0_male -0.50
Linf_male 92.6
k_female 0.213
t0_female -0.60
Linf_female 104.0

# SIZE-WEIGHT
@size_weight E
a 4.79e-09
b 2.89

@size_weight W
a 4.79e-09
b 2.89

# MATURITY
@maturity_props
all constant 1

# INITIALIZING THE PARTITION

@Rinitial_is_deviate 1

@initialization E
Rinitial 1

@initialization W
Rinitial 1

@log_Bmean_total 13.9
@Bmean_prop_stock1 0.25
```

A1.1.2 Differences in population.csl for run 4.5

The population.csl file for run 4.5 was as in Section A1.1.1 except for the following changes.

– `@sex_partition` was set to F,
– `p_male 0.5` was dropped from both `@recruitment` blocks,
– the natural mortality ogive was given as `all 0.275`, and `allow_negative_M` was dropped,
– selectivity specifications were changed as follows,

Enspsl: `all double_normal 3.82578 1.63038 17`
Wnspsl: `all double_normal 5.34802 2.12396 7.79647`
Espsl: `all double_normal 10.6006 7.58432 3.60395`
Wspsl: `all double_normal 10.3535 17 3.33346`
CRsl: `all double_normal 1.0008 1 8.71781`
SAsl: `all double_normal 10 5.5028 3.24635`

– the migration specifications were changed as follows,

Whome: `rates_all allvalues_bounded 1 8 0.1 0.1 0.43 0.56 0.88 0.9 0.95 1`
Espmg & Wspmg: `rates_all allvalues_bounded 1 8 0.1 0.2 0.3 0.4 0.5 0.6 0.6 0.6`

– sizes at age parameters were changed to

```
@size_at_age E
k 0.164
t0 -2.16
Linf 100.8
@size_at_age W
```

```
k 0.206
t0 -0.96
Linf 102.1
```

A1.1.3 Differences in population.csl for run 4.7

The population.csl file for run 4.7 was as in Section A1.1.1 except for the following changes.

– the following commands were removed: `@n_stocks`, `@stock_names`, `@log_Bmean_total`, `@Bmean_prop_stock1`, and all those starting `@exclusions`
– all instances of the subcommand `stock` were removed
– in command `@annual_cycle` the arguments to subcommands `recruitment_areas` and `spawning_areas` were changed to `CR` and `WC`, respectively
– for the following commands, the version labelled `E` was dropped, and the label `W` was dropped from the other version: `@recruitment`, `@size_at_age`, `@size_weight`
– the `@migration Whome` block was replaced by

```
@migration Whome
rates_all allvalues 0.183 0.01 0.109 0.137 0.124 0.23 0.088 0 0 0 0 0 0 0 0 0 0 0
annual_variation_years 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001
 2002 2003 2004 2005 2006 2007
annual_variation_values 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0
```

– the two `@initialization` blocks were replaced by the single block

```
@initialization
Rinitial 1
Bmean 1e6
```

A1.1.4 Differences in population.csl for MCMC and projection runs

Those selectivity and migration parameters to be held fixed in the MCMC runs were changed to the values given in Table 27. For projection runs `year_range` in the `@recruitment` blocks was changed to `1995 2003` where appropriate.

A1.2: estimation.csl files

The observations and estimation assumptions for each run are completely defined by the file estimation.csl. I first present the file used for the MPD run 4.4, then list the differences between that and the corresponding file for the other main runs, and finally describe changes made to these files for MCMC and projection runs.

A1.2.1 estimation.csl for run 4.4

The following is the file used for the MPD run.

```
# GENERAL

@estimator Bayes
@user_components prior_on_Mmale prior_on_Mfemale

# POINT ESTIMATION
@max_iters  2500
@max_evals  4000
@grad_tol 1e-6

# LIKELIHOOD OR POSTERIOR PROFILES

# MCMC
@MCMC
start 1
```

```
keep 1000
length 2000000
stepsize 0.02
adaptive_stepsize 1
adapt_at 20000 40000 60000 80000 100000
burn_in 1000
subsample_size 1000
systematic 1

# AGEING ERROR

@ageing_error
type misclassification_matrix
1 0.98 0.02 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2 0.03 0.94 0.03 0 0 0 0 0 0 0 0 0 0 0 0 0 0
3 0 0.05 0.9 0.05 0 0 0 0 0 0 0 0 0 0 0 0 0
4 0 0 0.06 0.88 0.06 0 0 0 0 0 0 0 0 0 0 0 0
5 0 0 0 0.07 0.86 0.07 0 0 0 0 0 0 0 0 0 0 0
6 0 0 0 0 0.08 0.84 0.08 0 0 0 0 0 0 0 0 0 0
7 0 0 0 0 0 0.09 0.82 0.09 0 0 0 0 0 0 0 0 0
8 0 0 0 0 0 0.01 0.11 0.76 0.11 0.01 0 0 0 0 0 0 0
9 0 0 0 0 0 0 0.01 0.11 0.76 0.11 0.01 0 0 0 0 0 0
10 0 0 0 0 0 0 0 0.01 0.12 0.74 0.12 0.01 0 0 0 0 0
11 0 0 0 0 0 0 0 0 0.01 0.13 0.72 0.13 0.01 0 0 0 0
12 0 0 0 0 0 0 0 0 0 0.01 0.14 0.7 0.14 0.01 0 0 0
13 0 0 0 0 0 0 0 0 0 0 0.01 0.15 0.68 0.15 0.01 0 0
14 0 0 0 0 0 0 0 0 0 0 0 0.02 0.15 0.66 0.15 0.02 0
15 0 0 0 0 0 0 0 0 0 0 0 0 0.02 0.16 0.64 0.16 0.02
16 0 0 0 0 0 0 0 0 0 0 0 0 0 0.02 0.16 0.63 0.19
17 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.02 0.17 0.81

# FREE PARAMETERS

@estimate
parameter q[CSacous].q
prior lognormal
mu 0.77
cv 0.77
lower_bound 0.022
upper_bound 3.8

@estimate
parameter q[WCacous].q
prior lognormal
mu 0.57
cv 0.68
lower_bound 0.032
upper_bound 3.1

@estimate
parameter q[CRsum].q
prior lognormal
mu 0.15
cv 0.65
lower_bound 0.016
upper_bound 0.51

@estimate
parameter q[SAsum].q
prior lognormal
mu 0.17
cv 0.61
lower_bound 0.020
upper_bound 0.51

@estimate
parameter q[SAaut].q
prior lognormal
mu 0.17
cv 0.61
lower_bound 0.020
upper_bound 0.51

@estimate
parameter catch_at[Espage].cv_process_error
prior uniform
lower_bound 0.1
```

```
upper_bound 1

@estimate
parameter catch_at[Wspage].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter catch_at[Enspage].cv_process_error
same catch_at[EnspOLF].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter catch_at[Wnspage].cv_process_error
same catch_at[WnspOLF].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter proportions_at[CRsumage].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter proportions_at[SAsumage].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter proportions_at[SAautage].cv_process_error
prior uniform
lower_bound 0.1
upper_bound 1

@estimate
parameter log_Bmean_total
phase 1
prior uniform
lower_bound 12.6
upper_bound 16.2

@estimate
parameter Bmean_prop_stock1
phase 1
prior beta
mu 0.344
stdev 0.072
A 0.1
B 0.6
lower_bound 0.11
upper_bound 0.59

@estimate
parameter recruitment[E].YCS
phase 1
prior lognormal
mu                  1       1       1       1       1       1       1       1       1       1
1       1       1       1       1       1       1       1       1       1       1       1
1       1       1       1       1       1       1       1       1
cv                0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
# bounds from round(qlnorm(c(0.001,0.999),-0.5*0.8^2,0.8),2)
lower_bound       0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
upper_bound       8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60
8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60
8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60

@estimate
```

```
parameter recruitment[W].YCS
phase 1
prior lognormal
mu                  1       1       1       1       1       1       1       1       1       1
1       1       1       1       1       1       1       1       1       1       1       1
1       1       1       1       1       1       1       1       1
cv                0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95    0.95
# bounds from round(qlnorm(c(0.001,0.999),-0.5*0.8^2,0.8),2)
lower_bound       0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
upper_bound       8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60
8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60
8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60    8.60

@estimate
parameter natural_mortality.ogive_male
prior uniform
lower_bound 5.1 0.1 0.5 0.5
upper_bound 9.1 0.3 5 2

@estimate
parameter natural_mortality.ogive_female
prior uniform
lower_bound 5.1 0.01 0.9 0.5
upper_bound 9.1 0.1 5 2

@estimate
parameter selectivity[Wspsl].shift_a
phase 1
prior normal-by-stdev
mu 0
stdev 0.25
lower_bound -10.24
upper_bound 2.24

@estimate
parameter migration[Whome].rates_male
same migration[Whome].rates_female
phase 1
prior uniform
lower_bound 0.01 0.01 0.01 0 0 0 0 1
upper_bound 1 1 1 1 1 1 1 1

@estimate
parameter migration[Espmg].rates_male
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0
upper_bound 1 1 1 1 1 1 1 1

@estimate
parameter migration[Wspmg].rates_male
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0
upper_bound 1 1 1 1 1 1 1 1

@estimate
parameter migration[Espmg].rates_female
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0.6
upper_bound 1 1 1 1 1 1 1 1

@estimate
parameter migration[Wspmg].rates_female
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0.6
upper_bound 1 1 1 1 1 1 1 1

@estimate
parameter selectivity[Enspsl].all
phase 1
```

```
prior uniform
lower_bound 64 4 4
upper_bound 84 44 44

@estimate
parameter selectivity[Wnspsl].all
phase 1
prior uniform
lower_bound 64 4 4
upper_bound 84 44 44

@estimate
parameter selectivity[Espsl].all
same selectivity[Wspsl].all
phase 1
prior uniform
lower_bound 6 4
upper_bound 80 60

@estimate
parameter selectivity[CRsl].all
#same selectivity[SAsl].all
phase 1
prior uniform
lower_bound 64 4 4
upper_bound 84 44 44

@estimate
parameter selectivity[SAsl].all
phase 1
prior uniform
lower_bound 64 4 4
upper_bound 84 44 44

# RELATIVITY CONSTANTS
@q_method nuisance

# OBSERVATIONS

@relative_abundance CSacous
step 5
proportion_mortality 0.5
area CS
biomass T
q CSacous
years 1991 1993 1994 1995 1996 1997 1998 1999 2001 2002 2003 2005 2006
1991 180000
1993 583000
1994 592000
1995 427000
1996 202000
1997 295000
1998 170000
1999 243000
2001 220000
2002 320000
2003 225000
2005 132000
2006 126000
dist lognormal
cv_1991 0.41
cv_1993 0.52
cv_1994 0.91
cv_1995 0.61
cv_1996 0.57
cv_1997 0.4
cv_1998 0.44
cv_1999 0.36
cv_2001 0.3
cv_2002 0.35
cv_2003 0.34
cv_2005 0.32
cv_2006 0.34

@relative_abundance WCacous
step 5
proportion_mortality 0.5
```

```
area WC
biomass T
q WCacous
years 1988 1989 1990 1991 1992 1993 1997 2000
# indices & cv from Table 26 of WG-HOK-2002/12
1988 417000
1989 249000
1990 255000
1991 340000
1992 345000
1993 550000
1997 654000
2000 396000
dist lognormal
cv_1988 0.60
cv_1989 0.38
cv_1990 0.40
cv_1991 0.73
cv_1992 0.49
cv_1993 0.38
cv_1997 0.60
cv_2000 0.60

@relative_abundance CRsumbio
step 2
proportion_mortality 0.6
area CR
biomass T
ogive CRsl
q CRsum
cv_process_error 0.0
years 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
dist lognormal
1992 120190
1993 185570
1994 145633
1995 120441
1996 152813
1997 157900
1998 86678
1999 109336
2000 71740
2001 60330
2002 74351
2003 52600
2004 52700
2005 84594
2006 99208
2007 70479
cv_1992 0.077
cv_1993 0.103
cv_1994 0.098
cv_1995 0.076
cv_1996 0.098
cv_1997 0.084
cv_1998 0.109
cv_1999 0.116
cv_2000 0.123
cv_2001 0.097
cv_2002 0.114
cv_2003 0.087
cv_2004 0.127
cv_2005 0.115
cv_2006 0.106
cv_2007 0.084

@relative_abundance SAsumbio
step 2
proportion_mortality 0.5
area SA
biomass T
ogive SAsl
q SAsum
cv_process_error 0.0
years 1992 1993 1994 2001 2002 2003 2004 2005 2006 2007
dist lognormal
1992 80285
```

```
1993 87359
1994 99695
2001 55662
2002 38145
2003 39890
2004 14318
2005 17665
2006 20517
2007 14488
cv_1992 0.068
cv_1993 0.061
cv_1994 0.092
cv_2001 0.126
cv_2002 0.160
cv_2003 0.140
cv_2004 0.129
cv_2005 0.120
cv_2006 0.130
cv_2007 0.106

@relative_abundance SAautbio
step 3
proportion_mortality 0.1
area SA
biomass T
ogive SAsl
q SAaut
cv_process_error 0.0
years 1992 1996 1998
dist lognormal
1992 67832
1996 89029
1998 67709
cv_1992 0.083
cv_1996 0.092
cv_1998 0.110

@catch_at Espage
years 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
2005 2006
fishery Esp
plus_group TRUE
sum_to_one TRUE
min_class 2 2
max_class 15 15
dist robustified-lognormal
r 0.01
cv_process_error 0.3
1988 0.00058 0.012458 0.049858 0.05121 0.028342 0.039184 0.028248 0.04186 0.037599 0.027803
0.016132 0.004854 0.004208 0.0001 0.001095 0.010803 0.054666 0.066632 0.03636 0.069579
0.050721 0.106285 0.106829 0.082452 0.042592 0.023255 0.005915 0.00038
1989 0.001804 0.050402 0.092955 0.074027 0.077042 0.030504 0.016056 0.017981 0.021964 0.033262
0.016183 0.017602 0.005045 0.0001 0.000819 0.021754 0.045046 0.080879 0.051946 0.02505
0.040653 0.039928 0.08806 0.081058 0.037839 0.018111 0.005276 0.008655
1990 0.001393 0.049083 0.096735 0.074735 0.085562 0.049249 0.021972 0.041834 0.01273 0.041236
0.038973 0.018174 0.001671 0.001289 0.0001 0.011923 0.033216 0.047972 0.054553 0.044659
0.026882 0.040717 0.028523 0.068665 0.054742 0.021188 0.018113 0.014112
1991 0.000113 0.050722 0.189332 0.107508 0.040049 0.043903 0.037377 0.014403 0.010514 0.008116
0.010468 0.013116 0.0001 0.004916 0.0001 0.031047 0.07945 0.034329 0.036029 0.053428 0.059389
0.023868 0.036542 0.016857 0.041138 0.037935 0.004151 0.015099
1992 0.00076 0.015987 0.094824 0.151854 0.023598 0.039854 0.048703 0.020388 0.012955 0.010803
0.004861 0.006724 0.002687 0.005152 0.000172 0.000806 0.072346 0.173124 0.02559 0.041234
0.066329 0.03881 0.032035 0.023755 0.02389 0.026538 0.026597 0.009624
1993 0.000528 0.023871 0.094584 0.206157 0.102843 0.014964 0.021136 0.026308 0.010101 0.005862
0.001284 0.002921 0.001699 0.0034 0.0001 0.005326 0.050088 0.152876 0.085654 0.014818 0.046598
0.037925 0.017316 0.012753 0.014133 0.012011 0.010422 0.024322
1994 0.000833 0.014024 0.037223 0.12786 0.130735 0.147158 0.011504 0.024432 0.009298 0.006726
0.00107 0.008652 0.0001 0.002109 0.000638 0.012168 0.022286 0.089368 0.101763 0.120992
0.015779 0.037325 0.026211 0.020506 0.010574 0.002056 0.004407 0.014204
1995 0.001183 0.026091 0.06063 0.046945 0.065035 0.136931 0.093043 0.009649 0.013003 0.010369
0.007801 0.001832 0.001427 0.001375 0.000722 0.012406 0.033685 0.029969 0.051139 0.097501
0.121582 0.022751 0.056298 0.030274 0.016762 0.019241 0.009892 0.022465
1996 0.004271 0.062924 0.107733 0.068569 0.01561 0.070531 0.081682 0.045823 0.003201 0.00605
0.001342 0.000359 0.001845 0.00042 0.001603 0.023591 0.051751 0.040331 0.01665 0.059343
0.111846 0.117577 0.014072 0.038051 0.021103 0.018255 0.00318 0.012288
```

1997 0.000375 0.047552 0.105519 0.111988 0.105 0.014367 0.04458 0.0481 0.028872 0.00437
0.005305 0.001727 0.00179 0.000318 0.00051 0.028959 0.086386 0.059054 0.065336 0.015436
0.044441 0.058238 0.060451 0.014529 0.020708 0.010465 0.008589 0.007035
1998 0.00234 0.125526 0.102843 0.101736 0.030964 0.026826 0.009024 0.028042 0.019162 0.012931
0.001423 0.003933 0.000697 0.000582 0.000417 0.040294 0.065874 0.069109 0.036989 0.051644
0.020546 0.07215 0.084022 0.043374 0.00976 0.025737 0.003776 0.01028
1999 0.008026 0.067967 0.163868 0.090711 0.065421 0.03257 0.019448 0.008052 0.012477 0.016274
0.006456 0.005037 0.001022 0.001114 0.002763 0.04002 0.07661 0.076158 0.053438 0.043021
0.034795 0.022098 0.040384 0.043204 0.038647 0.007107 0.004627 0.018687
2000 0.005601 0.100513 0.078224 0.048882 0.122492 0.069522 0.046208 0.016578 0.014292 0.011468
0.003884 0.002124 0.000441 0.00064 0.000909 0.073188 0.045646 0.033154 0.098225 0.056995
0.033147 0.026615 0.014939 0.041901 0.019855 0.018071 0.001572 0.014914
2001 0.000611 0.060511 0.123968 0.075423 0.041149 0.049995 0.036348 0.020751 0.007403 0.001369
0.003263 0.000882 0.0001 0.00052 0.001904 0.045205 0.084059 0.054629 0.05326 0.089781 0.089536
0.047469 0.032861 0.025071 0.025006 0.015095 0.008973 0.004857
2002 0.011744 0.013705 0.06026 0.089888 0.114274 0.046541 0.04752 0.02852 0.014238 0.010831
0.000445 0.001039 0.001866 0.00157 0.003627 0.004061 0.037127 0.066454 0.095704 0.09051
0.079004 0.057538 0.041704 0.024326 0.018768 0.01821 0.01333 0.007197
2003 0.007558 0.12682 0.019238 0.067798 0.062578 0.056047 0.0188 0.036885 0.010429 0.003556
0.001583 0.001195 0.000878 0.0001 0.00388 0.098047 0.018355 0.042309 0.106877 0.080179
0.060566 0.061741 0.044935 0.028866 0.010221 0.005412 0.01054 0.014608
2004 0.008891 0.05935 0.188539 0.036313 0.048938 0.031662 0.016493 0.006512 0.007459 0.003323
0.002776 0.001283 0.000352 0.000207 0.003254 0.021554 0.132225 0.056608 0.066768 0.059574
0.072914 0.033996 0.045311 0.026434 0.031711 0.018799 0.003035 0.015717
2005 0.007817 0.04325 0.100924 0.144372 0.015103 0.030183 0.033764 0.019777 0.005289 0.007214
0.002532 0.001455 0.0001 0.000374 0.002832 0.018424 0.053851 0.139639 0.024251 0.065604
0.098893 0.041527 0.010534 0.058868 0.015549 0.020747 0.020249 0.016876
2006 0.043106 0.23512 0.143325 0.052771 0.032816 0.010795 0.009719 0.011101 0.005948 0.001391
0.004183 0.000205 0.000937 0.0001 0.004641 0.105041 0.078236 0.039315 0.045757 0.025859
0.041906 0.030696 0.022015 0.014619 0.016946 0.0087 0.005649 0.009104
cvs_1988 1.07 0.35 0.23 0.25 0.3 0.31 0.34 0.3 0.32 0.31 0.46 0.63 0.91 1.63 1.27 0.5 0.23
0.24 0.25 0.19 0.2 0.16 0.16 0.17 0.23 0.29 0.48 0.9
cvs_1989 0.62 0.24 0.18 0.21 0.27 0.35 0.4 0.51 0.48 0.45 0.61 0.57 0.89 1.63 0.96 0.26 0.19
0.18 0.31 0.38 0.3 0.3 0.23 0.25 0.27 0.4 0.51 0.46
cvs_1990 0.84 0.29 0.21 0.2 0.18 0.22 0.31 0.29 0.39 0.3 0.3 0.41 0.83 1.07 1.63 0.4 0.25 0.2
0.19 0.23 0.25 0.26 0.26 0.22 0.24 0.34 0.39 0.38
cvs_1991 0.9 0.24 0.18 0.17 0.21 0.2 0.25 0.34 0.41 0.42 0.44 0.43 1.63 0.75 1.63 0.34 0.2
0.21 0.22 0.2 0.23 0.29 0.28 0.32 0.26 0.31 0.43 0.4
cvs_1992 0.87 0.25 0.13 0.12 0.2 0.21 0.2 0.27 0.35 0.42 0.53 0.56 0.75 0.49 1.65 0.56 0.17
0.11 0.23 0.19 0.16 0.2 0.27 0.27 0.29 0.29 0.29 0.36
cvs_1993 0.97 0.29 0.16 0.12 0.17 0.34 0.29 0.3 0.34 0.44 0.57 0.44 0.47 0.38 1.63 0.5 0.18
0.13 0.17 0.31 0.21 0.22 0.27 0.36 0.35 0.38 0.32 0.23
cvs_1994 0.84 0.27 0.26 0.18 0.16 0.14 0.31 0.35 0.43 0.46 0.87 0.77 1.63 0.75 1.15 0.46 0.28
0.17 0.16 0.16 0.28 0.22 0.22 0.29 0.37 0.55 0.44 0.27
cvs_1995 0.57 0.2 0.16 0.21 0.17 0.12 0.14 0.32 0.31 0.33 0.42 0.6 0.63 0.71 0.66 0.29 0.26
0.26 0.18 0.14 0.14 0.25 0.2 0.25 0.31 0.32 0.33 0.25
cvs_1996 0.51 0.21 0.18 0.21 0.29 0.18 0.17 0.21 0.38 0.49 0.68 1.09 0.88 1.01 0.54 0.24 0.17
0.19 0.31 0.2 0.16 0.18 0.3 0.28 0.3 0.36 0.55 0.37
cvs_1997 0.64 0.18 0.18 0.18 0.17 0.35 0.23 0.19 0.22 0.37 0.5 0.69 0.85 1.06 0.76 0.27 0.16
0.19 0.19 0.33 0.23 0.2 0.21 0.33 0.31 0.43 0.52 0.48
cvs_1998 0.67 0.18 0.17 0.15 0.24 0.29 0.33 0.24 0.28 0.32 0.56 0.57 0.8 0.7 0.64 0.17 0.13
0.16 0.25 0.2 0.28 0.21 0.2 0.24 0.42 0.51 0.82 0.43
cvs_1999 0.37 0.2 0.14 0.16 0.18 0.2 0.24 0.31 0.34 0.31 0.4 0.5 0.84 0.67 0.46 0.17 0.14 0.17
0.2 0.23 0.24 0.26 0.22 0.22 0.25 0.37 0.41 0.27
cvs_2000 0.39 0.13 0.17 0.21 0.15 0.18 0.21 0.28 0.31 0.32 0.39 0.51 0.85 0.77 0.53 0.12 0.17
0.22 0.16 0.19 0.22 0.22 0.28 0.21 0.22 0.27 0.48 0.28
cvs_2001 0.56 0.13 0.1 0.15 0.19 0.17 0.19 0.21 0.33 0.55 0.46 0.74 1.63 0.86 0.45 0.14 0.13
0.18 0.19 0.15 0.16 0.2 0.22 0.25 0.23 0.29 0.37 0.51
cvs_2002 0.23 0.28 0.17 0.14 0.14 0.21 0.21 0.25 0.34 0.4 0.67 0.76 0.82 0.74 0.45 0.54 0.22
0.17 0.15 0.15 0.16 0.18 0.21 0.24 0.29 0.28 0.33 0.33
cvs_2003 0.34 0.11 0.26 0.18 0.17 0.2 0.24 0.24 0.31 0.44 0.69 0.8 1.25 1.76 0.44 0.2 0.26
0.24 0.17 0.19 0.22 0.21 0.23 0.28 0.35 0.51 0.43 0.3
cvs_2004 0.27 0.16 0.1 0.19 0.16 0.18 0.22 0.29 0.33 0.44 0.42 0.64 0.94 0.79 0.55 0.24 0.12
0.18 0.16 0.16 0.15 0.2 0.21 0.24 0.24 0.28 0.45 0.28
cvs_2005 0.32 0.17 0.14 0.12 0.22 0.19 0.18 0.22 0.38 0.36 0.59 0.92 1.88 0.93 0.59 0.3 0.22
0.12 0.23 0.15 0.11 0.18 0.28 0.17 0.25 0.25 0.26 0.24
cvs_2006 0.29 0.17 0.16 0.2 0.24 0.3 0.32 0.31 0.39 0.55 0.54 1 0.92 1.25 0.58 0.19 0.2 0.22
0.22 0.25 0.23 0.27 0.26 0.32 0.3 0.35 0.48 0.35

@catch_at Wspage
years 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
2005 2006
fishery Wsp
plus_group TRUE
sum_to_one TRUE
min_class 2 2
max_class 15 15

```
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1988 0.001678 0.000486 0.041035 0.059667 0.083078 0.078727 0.050162 0.031998 0.033543 0.037817
0.043432 0.007387 0.004809 0.002862 0.000446 0.000479 0.018652 0.031969 0.052135 0.057365
0.065556 0.044748 0.070261 0.056272 0.060513 0.031297 0.014664 0.018963
1989 0.004261 0.002274 0.007714 0.075326 0.161215 0.068788 0.058877 0.038084 0.013478 0.023282
0.020031 0.014631 0.003039 0.001197 0.002903 0.001368 0.018341 0.035819 0.102087 0.079226
0.058867 0.056076 0.048334 0.034108 0.032555 0.026065 0.004867 0.007186
1990 0.000602 0.023864 0.010238 0.031759 0.080917 0.135357 0.045159 0.040147 0.01158 0.023903
0.02016 0.004754 0.007706 0.0001 0.001095 0.009517 0.007681 0.030569 0.102577 0.146884
0.055449 0.07595 0.039951 0.022809 0.022557 0.016283 0.018254 0.014176
1991 0.000133 0.023372 0.12695 0.02363 0.037645 0.06989 0.067336 0.027146 0.012433 0.00888
0.003143 0.004564 0.003694 0.0001 0.000303 0.019952 0.045085 0.019679 0.082125 0.125858
0.111615 0.062368 0.044856 0.031761 0.023657 0.012481 0.003778 0.007569
1992 0.001524 0.002761 0.05281 0.18574 0.01313 0.033746 0.056364 0.033559 0.011527 0.013975
0.002086 0.002359 0.000835 0.001368 0.000775 0.006303 0.038786 0.190126 0.014989 0.06149
0.105297 0.072371 0.028978 0.025787 0.018102 0.009802 0.008651 0.006758
1993 0.023612 0.001135 0.01495 0.129905 0.224032 0.027425 0.014456 0.018543 0.027046 0.006968
0.00553 0.000926 0.000418 0.0001 0.008299 0.002157 0.000568 0.074019 0.197067 0.041398
0.039808 0.046699 0.047742 0.018654 0.011041 0.005093 0.005015 0.007394
1994 0.047487 0.084928 0.004795 0.032728 0.079989 0.143038 0.02568 0.015205 0.010765 0.012977
0.002824 0.000655 0.000104 0.000889 0.017606 0.025997 0.005129 0.042483 0.114876 0.183583
0.030086 0.038825 0.029149 0.017658 0.011032 0.013116 0.001251 0.007145
1995 0.040673 0.108374 0.150441 0.016012 0.019287 0.062947 0.058005 0.008375 0.005693 0.011928
0.010456 0.000685 0.001002 0.000982 0.014378 0.033547 0.049374 0.014658 0.029807 0.127884
0.11859 0.032144 0.018611 0.029982 0.021572 0.00586 0.002608 0.006125
1996 0.020741 0.064102 0.245458 0.105144 0.015061 0.018398 0.023362 0.027987 0.009792 0.007347
0.002576 0.00389 0.000642 0.00172 0.005145 0.026146 0.077758 0.059333 0.022313 0.028567
0.101127 0.067027 0.02467 0.015091 0.007213 0.010894 0.002945 0.005551
1997 0.014527 0.097795 0.135609 0.156738 0.061953 0.013549 0.015037 0.016748 0.009364 0.002937
0.000827 0.000623 0.000482 0.0001 0.011827 0.044852 0.085548 0.115761 0.060172 0.017354
0.054597 0.035137 0.029385 0.004877 0.006148 0.005367 0.001708 0.000978
1998 0.007448 0.057872 0.126688 0.090672 0.110297 0.057899 0.007051 0.014169 0.019951 0.009207
0.00049 0.0001 0.001009 0.001562 0.009558 0.019655 0.049619 0.072671 0.094918 0.086242 0.02877
0.024833 0.061605 0.025281 0.006183 0.004691 0.004875 0.006686
1999 0.012212 0.061273 0.081571 0.109703 0.075858 0.085778 0.040474 0.00999 0.004724 0.002905
0.005267 0.001895 0.000251 0.002172 0.0061 0.024471 0.0385 0.089542 0.067279 0.10943 0.070417
0.033098 0.029925 0.0201 0.005606 0.00142 0.003798 0.006242
2000 0.000874 0.026126 0.069916 0.048788 0.094755 0.052042 0.063962 0.027456 0.004252 0.004915
0.002371 0.002236 0.0001 0.000199 0.001002 0.016738 0.057458 0.056473 0.141797 0.087227
0.116566 0.063631 0.01071 0.020446 0.015027 0.011169 0.000546 0.003219
2001 0.002152 0.011934 0.047705 0.0467 0.036348 0.094745 0.040829 0.041446 0.018258 0.001701
0.003077 0.004988 0.004192 0.0001 0.003034 0.006986 0.054705 0.085184 0.069238 0.182777
0.083151 0.101447 0.018922 0.006211 0.018586 0.005954 0.004561 0.005069
2002 0.016902 0.006352 0.053475 0.03681 0.044735 0.025393 0.03691 0.025071 0.014448 0.004159
0.002842 0.0001 0.000621 0.000324 0.014725 0.00756 0.030578 0.040844 0.105074 0.108396 0.17405
0.1122 0.07604 0.026183 0.014169 0.010209 0.003321 0.008511
2003 0.000944 0.068366 0.008453 0.030298 0.021597 0.043773 0.015985 0.045115 0.017376 0.012668
0.009498 0.0001 0.0001 0.001 0.001044 0.051627 0.011 0.040937 0.075015 0.107193 0.064905
0.1858 0.035424 0.090419 0.038305 0.00577 0.005525 0.011762
2004 0.050281 0.003213 0.078684 0.009742 0.018345 0.018237 0.020861 0.007698 0.034953 0.011583
0.014698 0.009154 0.000905 0.001984 0.029873 0.00194 0.067191 0.013711 0.035027 0.05291
0.107796 0.048398 0.135573 0.046129 0.094518 0.05724 0.001984 0.027373
2005 0.10882 0.290719 0.027119 0.057059 0.007948 0.01358 0.01165 0.010521 0.001556 0.011655
0.003408 0.005145 0.000223 0.000115 0.032036 0.090249 0.008246 0.042103 0.004783 0.026451
0.055818 0.048393 0.015704 0.056463 0.022053 0.030281 0.0137 0.004204
2006 0.06955 0.164527 0.228388 0.037254 0.036496 0.004595 0.008904 0.006075 0.003399 0.001592
0.003015 0.000961 0.001312 0.000207 0.02569 0.085095 0.118058 0.027064 0.035722 0.012962
0.021745 0.020295 0.033302 0.012132 0.018553 0.010825 0.005381 0.0069
cvs_1988 0.36 0.72 0.17 0.16 0.14 0.15 0.19 0.21 0.23 0.21 0.21 0.39 0.56 0.76 0.83 0.96 0.27
0.23 0.19 0.16 0.14 0.17 0.15 0.15 0.16 0.21 0.27 0.23
cvs_1989 0.28 0.52 0.35 0.16 0.11 0.16 0.19 0.23 0.34 0.31 0.33 0.41 0.63 0.89 0.34 0.84 0.33
0.24 0.13 0.17 0.2 0.21 0.21 0.24 0.27 0.29 0.51 0.43
cvs_1990 0.8 0.15 0.37 0.25 0.15 0.13 0.2 0.25 0.34 0.33 0.35 0.51 0.54 1.62 0.58 0.2 0.42
0.33 0.16 0.14 0.19 0.2 0.26 0.3 0.32 0.34 0.38 0.28
cvs_1991 0.88 0.19 0.08 0.2 0.17 0.12 0.11 0.22 0.3 0.37 0.47 0.5 0.56 1.62 1.23 0.22 0.17
0.27 0.13 0.1 0.11 0.15 0.19 0.22 0.26 0.32 0.48 0.44
cvs_1992 0.42 0.4 0.15 0.07 0.23 0.21 0.17 0.23 0.36 0.36 0.77 0.81 0.99 0.87 0.92 0.54 0.19
0.09 0.24 0.14 0.13 0.13 0.2 0.24 0.36 0.4 0.38 0.37
cvs_1993 0.27 0.68 0.27 0.1 0.08 0.24 0.33 0.33 0.28 0.5 0.57 1.02 1.53 2.21 0.3 0.52 0.49
0.12 0.07 0.14 0.17 0.15 0.14 0.21 0.29 0.37 0.49 0.36
cvs_1994 0.11 0.09 0.31 0.21 0.15 0.12 0.31 0.4 0.3 0.31 0.45 0.69 1.06 0.68 0.14 0.11 0.39
0.23 0.14 0.12 0.27 0.28 0.28 0.31 0.41 0.55 0.85 0.39
cvs_1995 0.16 0.08 0.07 0.24 0.24 0.13 0.13 0.29 0.4 0.3 0.35 0.74 1.05 0.88 0.18 0.12 0.12
0.28 0.18 0.09 0.11 0.18 0.22 0.19 0.22 0.34 0.55 0.4
```

```
cvs_1996 0.19 0.13 0.06 0.1 0.28 0.29 0.2 0.17 0.29 0.37 0.51 0.55 0.81 0.61 0.24 0.13 0.08
0.11 0.21 0.2 0.12 0.15 0.24 0.33 0.44 0.38 0.52 0.35
cvs_1997 0.26 0.11 0.14 0.14 0.19 0.32 0.31 0.33 0.4 0.55 1 1.11 1.48 2.11 0.28 0.18 0.15 0.12
0.18 0.29 0.18 0.22 0.27 0.43 0.47 0.45 0.56 0.6
cvs_1998 0.29 0.14 0.1 0.14 0.12 0.17 0.41 0.39 0.24 0.41 0.91 1.6 1.37 0.53 0.25 0.17 0.12
0.13 0.13 0.14 0.23 0.26 0.16 0.23 0.41 0.4 0.45 0.34
cvs_1999 0.22 0.13 0.14 0.12 0.15 0.13 0.17 0.28 0.38 0.49 0.39 0.81 1.23 0.37 0.21 0.15 0.19
0.13 0.17 0.14 0.19 0.23 0.25 0.29 0.39 0.52 0.51 0.33
cvs_2000 0.56 0.18 0.12 0.16 0.12 0.15 0.13 0.19 0.36 0.48 0.52 0.68 1.24 0.77 0.47 0.16 0.15
0.19 0.14 0.16 0.15 0.19 0.31 0.35 0.34 0.38 0.69 0.55
cvs_2001 0.28 0.18 0.12 0.14 0.18 0.11 0.17 0.17 0.25 0.46 0.57 0.55 0.65 1.62 0.28 0.27 0.14
0.16 0.17 0.12 0.17 0.15 0.27 0.36 0.3 0.38 0.4 0.41
cvs_2002 0.17 0.27 0.11 0.15 0.15 0.19 0.15 0.19 0.24 0.42 0.59 1.62 1.3 0.81 0.16 0.35 0.21
0.22 0.18 0.19 0.15 0.17 0.21 0.32 0.5 0.48 0.64 0.37
cvs_2003 0.37 0.09 0.26 0.17 0.2 0.16 0.24 0.19 0.23 0.3 0.34 0.91 1.69 0.8 0.35 0.07 0.24
0.23 0.19 0.19 0.23 0.15 0.25 0.24 0.3 0.62 0.57 0.47
cvs_2004 0.1 0.33 0.08 0.24 0.2 0.22 0.26 0.3 0.19 0.28 0.28 0.36 0.72 0.65 0.1 0.43 0.1 0.29
0.22 0.19 0.13 0.19 0.13 0.19 0.16 0.21 0.44 0.24
cvs_2005 0.11 0.06 0.22 0.12 0.28 0.28 0.27 0.32 0.47 0.28 0.41 0.45 1 1.22 0.15 0.08 0.33
0.15 0.34 0.21 0.15 0.16 0.22 0.15 0.21 0.19 0.27 0.36
cvs_2006 0.14 0.08 0.08 0.19 0.22 0.37 0.33 0.31 0.35 0.54 0.4 0.62 0.63 0.8 0.16 0.11 0.1
0.18 0.16 0.21 0.2 0.19 0.17 0.23 0.22 0.3 0.38 0.32

@catch_at EnspOLF
years 1992 1994 1996 1998
fishery Ensp1 Ensp2
plus_group TRUE
sum_to_one TRUE
min_class 1 1
max_class 6 6
dist robustified-lognormal
r 0.01
cv_process_error 0.40
1992 0.001971 0.002773 0.139603 0.239674 0.016513 0.018024 0.003236 0.00638 0.223724 0.253193
0.037324 0.057585
1994 0.051378 0.12707 0.003033 0.012884 0.062247 0.141961 0.054445 0.166833 0.002648 0.011949
0.080589 0.284963
1996 0.124375 0.083788 0.190084 0.05235 0.020482 0.020476 0.115241 0.089383 0.180607 0.064703
0.015231 0.04328
1998 0.014286 0.018717 0.250476 0.041871 0.035485 0.060743 0.018992 0.035358 0.283369 0.033255
0.069884 0.137565
cvs_1992 2.95 2.18 0.3 0.24 0.75 0.72 1.93 1.23 0.25 0.24 0.52 0.43
cvs_1994 0.4 0.27 1.59 0.72 0.37 0.26 0.39 0.25 1.75 0.75 0.33 0.2
cvs_1996 0.31 0.36 0.26 0.44 0.66 0.66 0.32 0.35 0.27 0.4 0.76 0.48
cvs_1998 0.75 0.66 0.23 0.47 0.5 0.4 0.66 0.5 0.22 0.51 0.38 0.29

@catch_at Enspage
years 1999 2000 2001 2002 2003 2004 2005 2006
fishery Ensp1 Ensp2
plus_group TRUE
sum_to_one TRUE
min_class 1 1
max_class 13 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1999 0.028365 0.078745 0.111057 0.07811 0.058704 0.034855 0.015107 0.006571 0.002184 0.003926
0.00573 0.0001 0.0001 0.024054 0.084892 0.113768 0.097387 0.078373 0.053568 0.025105 0.029118
0.028224 0.016211 0.010046 0.002977 0.012722
2000 0.055347 0.219434 0.035689 0.032361 0.040692 0.010608 0.009479 0.020441 0.00241 0.001722
0.004206 0.000345 0.001342 0.048251 0.21144 0.060892 0.051924 0.057119 0.032639 0.032483
0.013602 0.012591 0.007798 0.017282 0.005817 0.014085
2001 0.00984 0.042914 0.168107 0.071893 0.039999 0.023113 0.0223 0.010937 0.001473 0.001841
0.000851 0.00147 0.000693 0.006958 0.047996 0.16769 0.140612 0.047687 0.056469 0.027196
0.041985 0.02579 0.005787 0.011216 0.010845 0.014337
2002 0.044568 0.030164 0.091027 0.140929 0.05525 0.013754 0.004269 0.001317 0.004977 0.000498
0.0001 0.000138 0.000392 0.068154 0.018956 0.094279 0.168572 0.075114 0.043647 0.041987
0.028943 0.027315 0.010973 0.007755 0.008573 0.018349
2003 0.009433 0.126961 0.029471 0.0789 0.066811 0.019752 0.003583 0.006562 0.005246 0.002022
0.0001 0.000214 0.003439 0.003314 0.183549 0.060708 0.079213 0.112673 0.071891 0.017966
0.03829 0.022819 0.019064 0.014264 0.002541 0.021215
2004 0.078177 0.041228 0.120464 0.018888 0.020179 0.042937 0.003241 0.001022 0.016835 0.0001
0.009162 0.0001 0.006557 0.127927 0.039291 0.155874 0.041929 0.049683 0.077594 0.033923
0.005771 0.040183 0.019548 0.023333 0.010416 0.015639
2005 0.016011 0.204876 0.058728 0.087404 0.010839 0.027429 0.026166 0.006332 0.000787 0.003012
0.000687 0.000133 0.0001 0.018881 0.231997 0.059323 0.114371 0.014458 0.033462 0.026172
0.008461 0.002288 0.02159 0.002354 0.008953 0.015186
```

```
2006 0.013192 0.089271 0.145996 0.099149 0.103493 0.008871 0.012252 0.011726 0.00031 0.0001
0.001045 0.0001 0.0001 0.010719 0.058726 0.151038 0.074241 0.108083 0.015378 0.022301 0.031805
0.010957 0.00572 0.014539 0.002629 0.008259
cvs_1999 0.43 0.19 0.16 0.19 0.22 0.38 0.49 0.57 0.64 0.76 0.68 3.05 3.05 0.4 0.25 0.17 0.15
0.24 0.22 0.32 0.3 0.33 0.4 0.44 0.63 0.75
cvs_2000 0.48 0.2 0.37 0.55 0.38 0.52 0.49 0.55 1.48 1.22 0.87 1.53 1.13 0.44 0.19 0.21 0.49
0.37 0.53 0.32 0.45 0.74 0.59 0.44 0.61 0.66
cvs_2001 1.15 0.37 0.16 0.22 0.32 0.28 0.34 0.43 0.76 1.04 1.32 1 0.99 1.16 0.54 0.13 0.15
0.25 0.23 0.27 0.24 0.34 0.5 0.41 0.43 0.36
cvs_2002 0.36 0.55 0.24 0.17 0.23 0.42 0.55 0.76 0.65 1.41 2.14 1.41 1.47 0.31 0.72 0.23 0.13
0.19 0.39 0.29 0.38 0.38 0.55 0.55 0.68 0.38
cvs_2003 1.44 0.21 0.45 0.28 0.29 0.48 0.77 0.65 1.11 1.15 3.66 1.85 0.89 0.96 0.18 0.29 0.31
0.22 0.29 0.53 0.37 0.54 0.43 0.74 0.85 0.42
cvs_2004 0.34 0.34 0.18 0.51 0.41 0.4 0.93 1.15 0.48 2.04 1 2.04 0.91 0.27 0.39 0.19 0.31 0.32
0.27 0.38 0.63 0.35 0.52 0.42 0.66 0.54
cvs_2005 1.11 0.23 0.34 0.21 0.55 0.43 0.4 0.82 1.15 0.94 1.6 1.52 2.36 0.95 0.2 0.34 0.2 0.4
0.3 0.33 0.65 0.86 0.44 0.71 0.52 0.49
cvs_2006 0.7 0.29 0.22 0.18 0.18 0.71 0.62 0.5 1.64 3.1 1.21 3.1 3.1 0.65 0.24 0.15 0.27 0.19
0.41 0.39 0.38 0.48 0.71 0.48 0.72 0.53

@catch_at WnspOLF
years 1992 1993 1994 1996 1999 2000
fishery Wnsp1 Wnsp2
plus_group TRUE
sum_to_one TRUE
min_class 2 2
max_class 6 6
dist robustified-lognormal
r 0.01
cv_process_error 0.40
1992 0.000513 0.069983 0.247643 0.035601 0.090321 0.000358 0.039463 0.20539 0.081287 0.229441
1993 0.001374 0.003507 0.09544 0.207297 0.131884 0.002922 0.000571 0.076385 0.315805 0.164816
1994 0.034575 0.005491 0.004477 0.30187 0.157516 0.044797 0.015482 0.015432 0.161739 0.258621
1996 0.067057 0.219809 0.125497 0.032458 0.125447 0.058082 0.091381 0.111613 0.010617 0.15804
1999 0.01937 0.044974 0.184027 0.00541 0.195272 0.02537 0.02092 0.117066 0.029595 0.357995
2000 0.027396 0.010863 0.084783 0.073498 0.202657 0.016957 0.008963 0.071957 0.091712 0.411214
cvs_1992 27.77 0.41 0.25 0.54 0.37 80.16 0.52 0.27 0.38 0.25
cvs_1993 4.23 1.79 0.35 0.26 0.31 2.05 17.73 0.38 0.22 0.28
cvs_1994 0.53 1.34 1.52 0.22 0.29 0.48 0.77 0.77 0.28 0.24
cvs_1996 0.41 0.26 0.32 0.56 0.32 0.44 0.36 0.33 0.95 0.29
cvs_1999 0.62 0.43 0.24 1.16 0.24 0.55 0.6 0.29 0.51 0.19
cvs_2000 0.48 0.72 0.3 0.32 0.21 0.59 0.79 0.32 0.29 0.16

@catch_at Wnspage
years 2001 2002 2003 2004 2006
fishery Wnsp1 Wnsp2
plus_group TRUE
sum_to_one TRUE
min_class 2 2
max_class 13 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
2001 0.006428 0.02528 0.056092 0.074505 0.102406 0.059922 0.07132 0.039008 0.005955 0.000528
0.001302 0.000642 0.004654 0.007662 0.028573 0.05108 0.131218 0.093547 0.112788 0.065578
0.020695 0.011509 0.011379 0.017928
2002 0.00296 0.015645 0.024916 0.029136 0.008117 0.037101 0.044273 0.062022 0.033279 0.001253
0.002422 0.004872 0.017356 0.0076 0.00727 0.056957 0.056704 0.106738 0.131017 0.204772
0.052336 0.027643 0.031095 0.034516
2003 0.020962 0.016817 0.06103 0.031364 0.030368 0.016486 0.047394 0.052304 0.045731 0.023928
0.00313 0.018961 0.024124 0.012353 0.009576 0.039101 0.048484 0.049692 0.125586 0.068347
0.112789 0.060113 0.02546 0.055899
2004 0.01224 0.084823 0.005414 0.013767 0.03925 0.026775 0.025752 0.073498 0.020198 0.02267
0.008008 0.00223 0.02022 0.037841 0.013565 0.039215 0.062487 0.069377 0.033482 0.135771
0.091055 0.07543 0.052517 0.034416
2006 0.085558 0.147276 0.072572 0.118604 0.014767 0.019837 0.013842 0.003965 0.002755 0.005884
0.000521 0.013473 0.075273 0.129243 0.06616 0.099912 0.027541 0.030917 0.015672 0.0145
0.004682 0.008116 0.002242 0.026685
cvs_2001 1.75 0.85 0.52 0.42 0.3 0.41 0.35 0.47 0.68 1.4 1.47 1.28 1.96 1.38 0.6 0.5 0.31 0.34
0.27 0.35 0.69 0.6 0.88 0.6
cvs_2002 1.74 1.39 0.88 0.85 0.77 0.48 0.46 0.42 0.45 1.48 0.94 1.64 1.05 1.37 1.26 0.84 0.58
0.34 0.3 0.33 0.37 0.67 0.55 0.37
cvs_2003 0.73 0.91 0.35 0.53 0.5 0.67 0.4 0.44 0.48 0.54 0.88 0.81 0.66 0.78 0.7 0.46 0.34
0.41 0.22 0.3 0.31 0.37 0.6 0.43
cvs_2004 1.29 0.8 1.42 0.78 0.68 0.68 0.62 0.46 0.65 0.64 0.98 1.56 0.97 0.74 0.69 0.66 0.63
0.46 0.51 0.32 0.38 0.41 0.52 0.57
```

```
cvs_2006 0.45 0.22 0.36 0.26 0.54 0.52 0.61 0.96 1.07 1.13 1.74 0.61 0.46 0.24 0.31 0.3 0.42
0.54 0.53 0.55 0.89 0.6 0.98 0.49

@proportions_at CRsumage
step 2
proportion_mortality 0.6
area CR
ogive CRsl
years 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
plus_group TRUE
sum_to_one TRUE
min_class 1 1
max_class 13 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.034966 0.022567 0.229391 0.136503 0.021435 0.00477 0.007959 0.004573 0.001221 0.000592
0.000159 0.000139 0.000514 0.039462 0.025261 0.212063 0.180976 0.011572 0.013817 0.015815
0.014754 0.00499 0.002483 0.003488 0.002612 0.007919
1993 0.258028 0.004752 0.026873 0.108259 0.061772 0.005788 0.005947 0.00465 0.000962 0.0002
0.000189 0.00012 0.000481 0.2558 0.008564 0.030223 0.099329 0.094256 0.004242 0.007738
0.007634 0.00562 0.002698 0.000918 0.001374 0.003583
1994 0.16609 0.185217 0.00822 0.020932 0.055332 0.027211 0.004187 0.003168 0.002021 0.001868
0.0001 0.0001 0.001483 0.158118 0.191936 0.006061 0.027588 0.062214 0.043611 0.004871 0.010139
0.004905 0.004588 0.002853 0.001899 0.005286
1995 0.081642 0.226163 0.093485 0.010094 0.015778 0.021682 0.020554 0.001122 0.002025 0.001482
0.000668 0.0001 0.000152 0.086382 0.229582 0.093019 0.01909 0.023475 0.024679 0.03046 0.001958
0.005682 0.003716 0.003263 0.000818 0.002928
1996 0.255617 0.066984 0.110254 0.022686 0.003193 0.00747 0.008941 0.003005 0.0001 0.000196
0.000127 0.000192 0.000142 0.262028 0.050985 0.128507 0.039309 0.003729 0.007711 0.01335
0.009157 0.000588 0.002878 0.00144 0.000248 0.001163
1997 0.033731 0.301531 0.034759 0.041889 0.034494 0.004858 0.008394 0.008805 0.003283 0.000687
0.00062 0.000448 0.000166 0.034407 0.295244 0.024062 0.066975 0.053077 0.004204 0.009839
0.015778 0.013592 0.001715 0.002135 0.002477 0.00283
1998 0.077271 0.057856 0.241065 0.028864 0.02841 0.016923 0.001717 0.003966 0.005701 0.002717
0.000493 0.0001 0.000369 0.080374 0.047658 0.248586 0.049716 0.043448 0.026061 0.006841
0.007729 0.009494 0.006772 0.00239 0.002245 0.003234
1999 0.276664 0.063397 0.042024 0.076379 0.00617 0.011349 0.004341 0.001142 0.000362 0.000857
0.000812 0.000135 0.0001 0.251183 0.050515 0.056682 0.099591 0.01374 0.015046 0.013555
0.002778 0.000933 0.005644 0.003472 0.00083 0.002298
2000 0.247262 0.166926 0.024594 0.010304 0.015693 0.00487 0.005991 0.002518 0.000438 0.000196
0.000729 0.000123 0.0001 0.227645 0.185278 0.026469 0.012789 0.032312 0.012815 0.008818
0.003606 0.001802 0.001964 0.003781 0.00165 0.001327
2001 0.009017 0.295741 0.112052 0.011091 0.008715 0.012636 0.003598 0.00521 0.00184 0.000313
0.000907 0.000488 0.000589 0.010632 0.276945 0.143489 0.017751 0.016863 0.033556 0.004191
0.017235 0.005605 0.002303 0.002426 0.002294 0.004513
2002 0.275326 0.009755 0.055665 0.068647 0.013624 0.001204 0.004957 0.000821 0.000694 0.000223
0.000886 0.0001 0.000157 0.3564 0.008206 0.060794 0.087468 0.019315 0.00236 0.011422 0.004378
0.007064 0.003794 0.00066 0.002249 0.003831
2003 0.106175 0.297469 0.007753 0.026612 0.02111 0.007183 0.002912 0.003393 0.000116 0.000629
0.0001 0.0001 0.000414 0.106099 0.30695 0.005901 0.023442 0.036951 0.018852 0.002772 0.010582
0.002723 0.003574 0.003586 0.000774 0.003828
2004 0.284726 0.043582 0.1024 0.007579 0.01042 0.006078 0.002398 0.000376 0.000767 0.000139
0.00052 0.000392 0.000175 0.294586 0.036139 0.141954 0.014371 0.014881 0.017715 0.006618
0.002533 0.005017 0.001402 0.002375 0.001038 0.001818
2005 0.235285 0.217844 0.009298 0.019222 0.002043 0.003172 0.00152 0.000767 0.00024 0.001094
0.0003 0.000274 0.0001 0.220264 0.220372 0.015341 0.024997 0.003903 0.006727 0.007274 0.001706
0.000578 0.003972 0.000557 0.00109 0.002061
2006 0.267292 0.123986 0.074217 0.00574 0.01836 0.000435 0.001752 0.002883 0.00048 0.0001
0.000112 0.0001 0.0001 0.26317 0.125053 0.059577 0.008551 0.029135 0.001361 0.00474 0.005187
0.003193 0.000417 0.001308 0.000334 0.002416
2007 0.156794 0.215284 0.059879 0.032983 0.007968 0.008128 0.000471 0.001188 0.000836 0.000278
0.0001 0.0001 0.0001 0.1609 0.193265 0.068066 0.044255 0.015575 0.019403 0.002501 0.004075
0.002715 0.001898 0.000465 0.000933 0.001842
cvs_1992 0.28 0.36 0.09 0.11 0.22 0.32 0.25 0.27 0.49 0.74 0.97 1 0.59 0.25 0.22 0.08 0.1 0.29
0.24 0.2 0.19 0.31 0.44 0.42 0.39 0.23
cvs_1993 0.17 0.64 0.28 0.19 0.2 0.3 0.33 0.35 0.48 0.74 0.7 0.92 0.52 0.17 0.71 0.2 0.21 0.22
0.39 0.35 0.33 0.32 0.43 0.47 0.45 0.32
cvs_1994 0.13 0.13 0.94 0.2 0.15 0.17 0.31 0.34 0.49 0.66 0.94 0.94 0.59 0.13 0.12 0.95 0.22
0.16 0.17 0.25 0.24 0.32 0.32 0.37 0.45 0.27
cvs_1995 0.19 0.13 0.22 0.23 0.16 0.15 0.16 0.33 0.41 0.47 0.62 0.94 0.91 0.18 0.11 0.24 0.31
0.23 0.17 0.14 0.27 0.25 0.29 0.31 0.51 0.28
cvs_1996 0.12 0.2 0.17 0.25 0.34 0.25 0.24 0.29 0.7 0.64 0.84 0.79 0.64 0.16 0.22 0.17 0.21
0.34 0.28 0.22 0.23 0.39 0.36 0.4 0.67 0.4
cvs_1997 0.56 0.12 0.46 0.26 0.18 0.35 0.27 0.27 0.31 0.49 0.6 0.6 0.8 0.53 0.1 0.52 0.17 0.19
0.41 0.25 0.15 0.2 0.35 0.37 0.33 0.28
```

```
cvs_1998 0.27 0.21 0.11 0.29 0.2 0.23 0.47 0.36 0.3 0.42 0.81 0.94 0.51 0.26 0.21 0.1 0.22 0.2
0.19 0.28 0.27 0.24 0.3 0.38 0.5 0.35
cvs_1999 0.16 0.21 0.23 0.18 0.32 0.29 0.32 0.47 0.58 0.57 0.76 1.35 0.94 0.13 0.19 0.2 0.19
0.27 0.27 0.23 0.37 0.49 0.34 0.34 0.47 0.44
cvs_2000 0.18 0.18 0.24 0.29 0.24 0.29 0.28 0.32 0.48 0.74 0.66 0.96 0.94 0.17 0.18 0.29 0.27
0.22 0.27 0.28 0.34 0.42 0.39 0.35 0.41 0.37
cvs_2001 0.62 0.11 0.17 0.37 0.28 0.22 0.28 0.26 0.38 0.63 0.64 0.83 0.54 0.57 0.08 0.13 0.25
0.25 0.21 0.34 0.23 0.34 0.41 0.49 0.41 0.34
cvs_2002 0.11 0.77 0.2 0.19 0.27 0.43 0.29 0.48 0.54 1.21 1.29 1.19 0.86 0.13 0.97 0.24 0.21
0.24 0.37 0.29 0.33 0.32 0.39 0.6 0.55 0.33
cvs_2003 0.3 0.09 0.4 0.23 0.22 0.29 0.46 0.42 0.97 0.84 0.94 0.94 0.86 0.31 0.09 0.46 0.26
0.22 0.27 0.4 0.27 0.4 0.38 0.4 0.51 0.3
cvs_2004 0.18 0.29 0.23 0.39 0.33 0.34 0.43 0.7 0.7 1.04 0.71 1.24 0.72 0.13 0.35 0.21 0.33
0.28 0.28 0.3 0.36 0.35 0.42 0.39 0.49 0.36
cvs_2005 0.13 0.12 0.36 0.15 0.4 0.31 0.39 0.44 1 0.42 0.92 1 0.86 0.15 0.13 0.38 0.17 0.27
0.25 0.23 0.31 0.67 0.31 0.58 0.41 0.29
cvs_2006 0.11 0.16 0.16 0.4 0.22 0.64 0.35 0.36 0.64 0.95 0.76 0.95 0.95 0.09 0.15 0.16 0.32
0.18 0.52 0.37 0.29 0.33 0.87 0.47 0.8 0.29
cvs_2007 0.18 0.11 0.16 0.17 0.33 0.27 0.7 0.66 0.52 1.16 0.97 0.97 0.97 0.22 0.11 0.15 0.17
0.23 0.19 0.42 0.32 0.33 0.4 0.64 0.43 0.31

@proportions_at SAsumage
step 2
proportion_mortality 0.5
area SA
ogive SAsl
years 1992 1993 1994 2001 2002 2003 2004 2005 2006 2007
plus_group TRUE
sum_to_one TRUE
min_class 2 2
max_class 15 15
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.005611 0.076824 0.168323 0.015563 0.032337 0.058747 0.030781 0.011548 0.011844 0.004335
0.00292 0.001344 0.001927 0.000421 0.007024 0.052077 0.217685 0.015535 0.035258 0.106797
0.053503 0.028447 0.019531 0.010833 0.008604 0.00789 0.009064 0.005226
1993 0.005184 0.004251 0.081505 0.146575 0.006995 0.034509 0.07283 0.03627 0.009769 0.013108
0.001699 0.000989 0.001099 0.001581 0.008237 0.001646 0.014505 0.159784 0.030468 0.081031
0.128947 0.081721 0.027624 0.013829 0.0163 0.010338 0.006797 0.002407
1994 0.024259 0.002468 0.026795 0.138299 0.077096 0.011478 0.019907 0.050633 0.03558 0.00517
0.003417 0.003242 0.0001 0.000837 0.090204 0.0001 0.009164 0.083767 0.108029 0.010328 0.065047
0.108805 0.067622 0.022987 0.012897 0.010327 0.000619 0.010823
2001 0.002242 0.025913 0.015771 0.023411 0.078007 0.04676 0.094162 0.051018 0.008047 0.003959
0.002814 0.005617 0.0001 0.000114 0.001347 0.02148 0.028925 0.038588 0.119086 0.118786
0.158737 0.085691 0.016826 0.017733 0.008812 0.008369 0.004587 0.013097
2002 0.009117 0.062974 0.025614 0.031506 0.032522 0.061988 0.053661 0.061199 0.027584 0.003731
0.001847 0.003095 0.001359 0.000458 0.005711 0.03204 0.022206 0.049863 0.062005 0.132338
0.106399 0.093661 0.059711 0.022885 0.02359 0.005619 0.004768 0.002549
2003 0.116055 0.003449 0.013587 0.014568 0.018578 0.025746 0.059489 0.044377 0.037594 0.015808
0.002172 0.001805 0.0001 0.000888 0.114701 0.001054 0.015679 0.024124 0.05448 0.04029 0.121646
0.119379 0.079581 0.036155 0.012522 0.010346 0.012428 0.003399
2004 0.002384 0.054805 0.016858 0.022784 0.012631 0.029096 0.019183 0.034323 0.031565 0.031107
0.03051 0.0048 0.001467 0.002215 0.002372 0.072997 0.021085 0.031801 0.034644 0.066526 0.03033
0.146682 0.090662 0.116073 0.067298 0.00483 0.009985 0.010985
2005 0.270347 0.019515 0.028417 0.005973 0.011909 0.008577 0.006727 0.002997 0.012992 0.006641
0.015023 0.007843 0.001253 0.002734 0.289897 0.016223 0.030221 0.003033 0.013425 0.013344
0.0239 0.015671 0.046671 0.030508 0.058922 0.032063 0.008244 0.01693
2006 0.10442 0.100961 0.004058 0.022038 0.002066 0.010472 0.015977 0.023838 0.007687 0.031892
0.008957 0.015296 0.011502 0.0001 0.113628 0.080359 0.012724 0.037129 0.007696 0.032241
0.031528 0.074453 0.020544 0.082064 0.043108 0.045838 0.04487 0.014555
2007 0.069581 0.071038 0.136815 0.034364 0.029527 0.002745 0.004582 0.007455 0.005505 0.001183
0.00896 0.000786 0.001037 0.000286 0.059425 0.094727 0.138794 0.040292 0.05905 0.01797 0.03779
0.020112 0.041076 0.034068 0.041632 0.029276 0.00913 0.002793
cvs_1992 0.59 0.17 0.11 0.26 0.2 0.15 0.19 0.29 0.3 0.43 0.54 0.69 0.67 0.8 0.45 0.15 0.1 0.24
0.19 0.13 0.17 0.21 0.22 0.28 0.34 0.39 0.43 0.37
cvs_1993 0.67 0.36 0.14 0.1 0.34 0.22 0.14 0.18 0.27 0.31 0.53 0.75 0.76 0.62 0.7 0.61 0.26
0.1 0.23 0.18 0.14 0.17 0.25 0.35 0.3 0.48 0.49 0.54
cvs_1994 0.54 0.73 0.3 0.17 0.18 0.34 0.27 0.22 0.25 0.39 0.57 0.67 1.79 0.8 0.43 1.79 0.37
0.19 0.18 0.31 0.2 0.18 0.2 0.27 0.34 0.39 0.71 0.38
cvs_2001 0.59 0.25 0.33 0.29 0.17 0.19 0.14 0.17 0.37 0.56 0.63 0.6 1.79 1.34 0.71 0.23 0.24
0.2 0.12 0.12 0.1 0.14 0.25 0.3 0.34 0.38 0.54 0.35
cvs_2002 0.47 0.28 0.25 0.23 0.26 0.17 0.16 0.16 0.23 0.59 0.87 0.74 0.86 1.4 0.55 0.32 0.24
0.2 0.19 0.14 0.15 0.15 0.18 0.31 0.28 0.48 0.44 0.55
cvs_2003 0.41 0.47 0.28 0.31 0.32 0.28 0.19 0.2 0.22 0.32 0.63 0.87 1.79 1.09 0.36 0.5 0.25
0.27 0.22 0.25 0.18 0.17 0.18 0.24 0.36 0.29 0.4 0.41
```

```
cvs_2004 0.65 0.19 0.38 0.26 0.38 0.22 0.27 0.22 0.23 0.22 0.26 0.5 0.9 0.96 1.36 0.26 0.43
0.25 0.24 0.21 0.3 0.14 0.16 0.15 0.2 0.69 0.44 0.4
cvs_2005 0.12 0.33 0.23 0.42 0.32 0.34 0.37 0.61 0.3 0.37 0.3 0.36 0.72 0.58 0.18 0.35 0.24
0.47 0.32 0.34 0.28 0.34 0.26 0.29 0.24 0.27 0.44 0.34
cvs_2006 0.19 0.16 0.52 0.24 0.66 0.31 0.3 0.24 0.38 0.19 0.36 0.29 0.3 1.64 0.21 0.15 0.37
0.21 0.4 0.26 0.25 0.19 0.35 0.17 0.24 0.23 0.23 0.4
cvs_2007 0.21 0.17 0.13 0.2 0.23 0.67 0.5 0.51 0.51 0.88 0.46 0.89 1.24 1.61 0.25 0.16 0.12
0.21 0.19 0.38 0.26 0.32 0.22 0.23 0.23 0.26 0.54 0.75

@proportions_at SAautage
step 3
proportion_mortality 0.1
area SA
ogive SAsl
years 1992 1996 1998
plus_group T
sum_to_one TRUE
min_class 2 2
max_class 15 15
dist robustified-lognormal
r 0.01
cv_process_error 0.40
1992 0.013118 0.059901 0.13316 0.008441 0.028278 0.065237 0.064278 0.015269 0.008562 0.004832
0.001474 0.001256 0.001256 0.006192 0.0001 0.036813 0.17361 0.012739 0.052545 0.13831 0.079153
0.023387 0.021406 0.017684 0.009491 0.011604 0.008741 0.003163
1996 0.096951 0.174331 0.107319 0.003837 0.0079 0.032796 0.035954 0.00251 0.005663 0.008163
0.001266 0.00096 0.000569 0.00011 0.088084 0.15215 0.077643 0.007186 0.010082 0.05615 0.07618
0.006404 0.018146 0.017132 0.006386 0.002375 0.00231 0.001443
1998 0.014676 0.092163 0.057829 0.118981 0.071411 0.014817 0.01053 0.015554 0.015091 0.004496
0.005704 0.00091 0.002671 0.0001 0.020344 0.089263 0.054525 0.134439 0.091695 0.025744
0.020915 0.057038 0.038373 0.00852 0.010801 0.012873 0.003755 0.006783
cvs_1992 0.34 0.18 0.13 0.36 0.28 0.17 0.19 0.35 0.61 0.74 1.07 1.16 1.15 0.45 1.64 0.18 0.08
0.25 0.14 0.09 0.12 0.22 0.22 0.23 0.32 0.27 0.37 0.41
cvs_1996 0.27 0.16 0.16 0.43 0.3 0.2 0.18 0.34 0.35 0.35 0.59 0.77 0.98 1.12 0.26 0.13 0.16
0.37 0.29 0.18 0.18 0.3 0.28 0.29 0.38 0.55 0.7 0.53
cvs_1998 0.32 0.14 0.17 0.12 0.14 0.27 0.29 0.24 0.26 0.4 0.41 0.68 0.64 1.64 0.28 0.11 0.12
0.09 0.11 0.15 0.16 0.13 0.15 0.22 0.24 0.25 0.36 0.32

@proportions_migrating pspawn
years 1992 1998
sex 2
migration Wspmg
plus_group 1
min_class 3
max_class 9
dist lognormal
1992  0.19 0.45 0.27 0.57 0.68 0.69 0.64
1998  0.28 0.60 0.40 0.40 0.40 0.40 0.52
cv_1992 0.25
cv_1998 0.25

# PENALTIES

@YCS_difference_penalty
label YCS.eq.05
stock1 E
stock2 W
year 2005
multiplier 1000

@catch_limit_penalty
label Umax_Ensp1
fishery Ensp1
log_scale 1
multiplier 10000

@catch_limit_penalty
label Umax_Ensp2
fishery Ensp2
log_scale 1
multiplier 10000

@catch_limit_penalty
label Umax_Wnsp1
fishery Wnsp1
log_scale 1
multiplier 10000
```

```
@catch_limit_penalty
label Umax_Wnsp2
fishery Wnsp2
log_scale 1
multiplier 10000

@catch_limit_penalty
label Umax_Esp
fishery Esp
log_scale 1
multiplier 10000

@catch_limit_penalty
label Umax_Wsp
fishery Wsp
log_scale 1
multiplier 10000

@ogive_difference_penalty
label sp.migr.M
ogive1 migration[Espmg].rates_male
ogive2 migration[Wspmg].rates_male
class 8
multiplier 100

@ogive_difference_penalty
label sp.migr.F
ogive1 migration[Espmg].rates_female
ogive2 migration[Wspmg].rates_female
class 8
multiplier 100
```

A1.2.2 Differences in estimation.csl for MPD run 4.5

The estimation.csl file for run 4.5 was as in Section A1.2.1 except for the following changes.

– the command `@user_components` was dropped
– the lower bound of the prior for `log_Bmean_total` was increased to 13.0
– the two natural mortality `@estimate` blocks were replaced by

```
@estimate
parameter natural_mortality.all
phase 1
prior lognormal
mu 0.298
cv 0.153
lower_bound 0.22
upper_bound 0.40
```

– the `@estimate` blocks for the Whome migration were replaced by

```
@estimate
parameter migration[Whome].rates_all
phase 1
prior uniform
lower_bound 0.01 0.01 0.01 0 0 0 0 1
upper_bound 1 1 1 1 1 1 1 1
```

– the `@estimate` blocks for Espmg and Wspmg were replaced by

```
@estimate
parameter migration[Espmg].rates_all
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0
upper_bound 1 1 1 1 1 1 1 1
@estimate
parameter migration[Wspmg].rates_all
phase 1
prior uniform
lower_bound 0 0 0 0 0 0 0 0
upper_bound 1 1 1 1 1 1 1 1
```

– the `@estimate` blocks for selectivities were replaced by

```
@estimate
parameter selectivity[Enspsl].all
```

```
phase 1
prior uniform
lower_bound 1 1 1
upper_bound 17 50 50
@estimate
parameter selectivity[Wnspsl].all
phase 1
prior uniform
lower_bound 1 1 1
upper_bound 17 50 50
@estimate
parameter selectivity[Espsl].all
same selectivity[Wspsl].all
phase 1
prior uniform
lower_bound 1 1 1
upper_bound 17 50 50
@estimate
parameter selectivity[CRsl].all
phase 1
prior uniform
lower_bound 1 1 1
upper_bound 17 50 50
@estimate
parameter selectivity[SAsl].all
phase 1
prior uniform
lower_bound 1 1 1
upper_bound 17 50 50
```

– all at-age observation blocks were replaced by the following

```
@catch_at Espage
sexed F
years 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
2005 2006
fishery Esp
plus_group TRUE
sum_to_one TRUE
min_class 2
max_class 15
dist robustified-lognormal
r 0.01
cv_process_error 0.3
1988 0.001675 0.023261 0.104524 0.117842 0.064702 0.108763 0.078969 0.148145 0.144428 0.110255
0.058724 0.028109 0.010123 0.00048
1989 0.002623 0.072156 0.138001 0.154906 0.128988 0.055554 0.056709 0.057909 0.110024 0.11432
0.054022 0.035713 0.010321 0.008755
1990 0.001493 0.061006 0.129951 0.122707 0.140115 0.093908 0.048854 0.082551 0.041253 0.109901
0.093715 0.039362 0.019784 0.015401
1991 0.000213 0.081769 0.268782 0.141837 0.076078 0.097331 0.096766 0.038271 0.047056 0.024973
0.051606 0.051051 0.004251 0.020015
1992 0.000932 0.016793 0.16717 0.324978 0.049188 0.081088 0.115032 0.059198 0.04499 0.034558
0.028751 0.033262 0.029284 0.014776
1993 0.000628 0.029197 0.144672 0.359033 0.188497 0.029782 0.067734 0.064233 0.027417 0.018615
0.015417 0.014932 0.012121 0.027722
1994 0.001471 0.026192 0.059509 0.217228 0.232498 0.26815 0.027283 0.061757 0.035509 0.027232
0.011644 0.010708 0.004507 0.016313
1995 0.001905 0.038497 0.094315 0.076914 0.116174 0.234432 0.214625 0.0324 0.069301 0.040643
0.024563 0.021073 0.011319 0.02384
1996 0.005874 0.086515 0.159484 0.1089 0.03226 0.129874 0.193528 0.1634 0.017273 0.044101
0.022445 0.018614 0.005025 0.012708
1997 0.000885 0.076511 0.191905 0.171042 0.170336 0.029803 0.089021 0.106338 0.089323 0.018899
0.026013 0.012192 0.010379 0.007353
1998 0.002757 0.16582 0.168717 0.170845 0.067953 0.07847 0.02957 0.100192 0.103184 0.056305
0.011183 0.02967 0.004473 0.010862
1999 0.010789 0.107986 0.240478 0.166869 0.11886 0.075591 0.054243 0.030149 0.052861 0.059478
0.045103 0.012144 0.005648 0.019801
2000 0.006509 0.173701 0.123871 0.082036 0.220717 0.126517 0.079355 0.043194 0.029231 0.053369
0.023739 0.020196 0.002013 0.015554
2001 0.002515 0.105716 0.208027 0.130052 0.094409 0.139776 0.125884 0.06822 0.040264 0.02644
0.028269 0.015977 0.009073 0.005377
2002 0.015371 0.017766 0.097387 0.156342 0.209978 0.137051 0.126524 0.086058 0.055942 0.035157
0.019213 0.019249 0.015196 0.008767
2003 0.011438 0.224867 0.037593 0.110107 0.169455 0.136226 0.079366 0.098626 0.055364 0.032422
0.011804 0.006607 0.011418 0.014708
2004 0.012144 0.080904 0.320764 0.092921 0.115706 0.091236 0.089408 0.040508 0.05277 0.029757
0.034487 0.020082 0.003387 0.015924
2005 0.01065 0.061674 0.154776 0.284011 0.039354 0.095787 0.132656 0.061304 0.015823 0.066082
0.01808 0.022202 0.020349 0.017251
```

```
2006 0.047746 0.34016 0.221561 0.092086 0.078574 0.036654 0.051625 0.041798 0.027963 0.01601
0.021129 0.008905 0.006585 0.009204
cvs_1988 0.91 0.3 0.16 0.17 0.19 0.17 0.18 0.14 0.14 0.15 0.21 0.26 0.47 0.79
cvs_1989 0.52 0.19 0.14 0.14 0.2 0.26 0.24 0.26 0.21 0.22 0.26 0.35 0.51 0.46
cvs_1990 0.79 0.25 0.17 0.14 0.13 0.16 0.2 0.2 0.22 0.18 0.19 0.26 0.36 0.36
cvs_1991 0.9 0.2 0.14 0.14 0.15 0.14 0.17 0.22 0.24 0.26 0.23 0.26 0.42 0.35
cvs_1992 0.77 0.24 0.1 0.08 0.15 0.14 0.13 0.16 0.22 0.23 0.26 0.26 0.27 0.29
cvs_1993 0.86 0.25 0.12 0.09 0.12 0.23 0.17 0.18 0.21 0.28 0.32 0.32 0.28 0.21
cvs_1994 0.69 0.26 0.19 0.13 0.11 0.11 0.21 0.19 0.2 0.25 0.35 0.63 0.43 0.25
cvs_1995 0.43 0.16 0.14 0.16 0.12 0.09 0.1 0.2 0.17 0.2 0.25 0.3 0.3 0.24
cvs_1996 0.4 0.17 0.13 0.15 0.21 0.13 0.12 0.14 0.25 0.25 0.28 0.35 0.47 0.36
cvs_1997 0.52 0.15 0.12 0.13 0.13 0.24 0.16 0.14 0.16 0.27 0.27 0.38 0.45 0.46
cvs_1998 0.58 0.14 0.12 0.11 0.17 0.16 0.22 0.17 0.17 0.2 0.37 0.45 0.7 0.41
cvs_1999 0.3 0.14 0.1 0.12 0.14 0.16 0.18 0.21 0.19 0.18 0.22 0.3 0.37 0.26
cvs_2000 0.35 0.09 0.12 0.15 0.11 0.13 0.15 0.17 0.21 0.18 0.19 0.25 0.42 0.27
cvs_2001 0.37 0.1 0.08 0.12 0.14 0.11 0.13 0.15 0.19 0.24 0.21 0.28 0.37 0.47
cvs_2002 0.21 0.25 0.13 0.11 0.1 0.12 0.13 0.15 0.18 0.21 0.28 0.27 0.31 0.3
cvs_2003 0.27 0.11 0.18 0.14 0.12 0.14 0.18 0.16 0.2 0.25 0.32 0.44 0.41 0.3
cvs_2004 0.25 0.13 0.08 0.13 0.11 0.12 0.13 0.18 0.18 0.22 0.22 0.26 0.42 0.27
cvs_2005 0.28 0.15 0.12 0.08 0.16 0.12 0.1 0.14 0.23 0.15 0.23 0.24 0.25 0.24
cvs_2006 0.26 0.13 0.12 0.15 0.16 0.2 0.2 0.22 0.22 0.29 0.27 0.35 0.43 0.35

@catch_at Wspage
sexed F
years 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
2005 2006
fishery Wsp
plus_group TRUE
sum_to_one TRUE
min_class 2
max_class 15
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1988 0.002124 0.000965 0.059687 0.091636 0.135213 0.136092 0.115718 0.076746 0.103804 0.094089
0.103945 0.038684 0.019473 0.021825
1989 0.007164 0.003642 0.026055 0.111145 0.263302 0.148014 0.117744 0.09416 0.061812 0.05739
0.052586 0.040696 0.007906 0.008383
1990 0.001697 0.033381 0.017919 0.062328 0.183494 0.282242 0.100608 0.116097 0.051531 0.046712
0.042717 0.021037 0.02596 0.014276
1991 0.000436 0.043324 0.172034 0.043309 0.11977 0.195747 0.17895 0.089514 0.057289 0.040641
0.0268 0.017045 0.007472 0.007669
1992 0.002299 0.009064 0.091596 0.375865 0.028119 0.095236 0.161661 0.10593 0.040505 0.039762
0.020188 0.012161 0.009486 0.008126
1993 0.031912 0.003292 0.015517 0.203924 0.421099 0.068824 0.054264 0.065242 0.074788 0.025622
0.016571 0.006019 0.005432 0.007494
1994 0.065093 0.110925 0.009924 0.075212 0.194865 0.326621 0.055766 0.05403 0.039913 0.030635
0.013856 0.013772 0.001354 0.008034
1995 0.055052 0.141921 0.199815 0.03067 0.049094 0.19083 0.176595 0.040519 0.024303 0.04191
0.032029 0.006545 0.00361 0.007107
1996 0.025886 0.090248 0.323216 0.164476 0.037374 0.046965 0.124489 0.095015 0.034462 0.022437
0.009789 0.014784 0.003587 0.007271
1997 0.026354 0.142648 0.221157 0.272499 0.122125 0.030903 0.069634 0.051885 0.038749 0.007814
0.006975 0.00599 0.00219 0.001078
1998 0.017006 0.077527 0.176306 0.163343 0.205215 0.144141 0.035821 0.039003 0.081556 0.034487
0.006673 0.004791 0.005883 0.008248
1999 0.018312 0.085745 0.120071 0.199245 0.143137 0.195208 0.110891 0.043088 0.034648 0.023005
0.010872 0.003315 0.004049 0.008415
2000 0.001876 0.042864 0.127374 0.105261 0.236552 0.139269 0.180528 0.091086 0.014961 0.025361
0.017398 0.013406 0.000646 0.003418
2001 0.005186 0.01892 0.10241 0.131884 0.105586 0.277522 0.12398 0.142893 0.03718 0.007912
0.021663 0.010942 0.008753 0.005169
2002 0.031627 0.013912 0.084053 0.077654 0.149809 0.133789 0.21096 0.137271 0.090488 0.030342
0.017011 0.010309 0.003942 0.008835
2003 0.001988 0.119993 0.019453 0.071235 0.096612 0.150966 0.08089 0.230915 0.0528 0.103087
0.047803 0.00587 0.005625 0.012762
2004 0.080154 0.005152 0.145875 0.023452 0.053372 0.071147 0.128657 0.056096 0.170526 0.057712
0.109216 0.066394 0.002889 0.029357
2005 0.140856 0.380968 0.035365 0.099162 0.01273 0.040031 0.067468 0.058914 0.01726 0.068118
0.025461 0.035426 0.013923 0.004319
2006 0.09524 0.249622 0.346446 0.064317 0.072218 0.017557 0.030649 0.02637 0.036701 0.013725
0.021568 0.011787 0.006693 0.007107
cvs_1988 0.33 0.6 0.14 0.13 0.11 0.11 0.11 0.13 0.13 0.12 0.13 0.19 0.25 0.22
cvs_1989 0.22 0.45 0.25 0.13 0.08 0.12 0.14 0.16 0.18 0.19 0.21 0.24 0.4 0.39
cvs_1990 0.47 0.12 0.28 0.21 0.11 0.1 0.14 0.16 0.22 0.22 0.24 0.29 0.31 0.28
cvs_1991 0.9 0.14 0.07 0.16 0.1 0.08 0.08 0.12 0.16 0.19 0.24 0.27 0.37 0.43
cvs_1992 0.42 0.39 0.12 0.06 0.17 0.12 0.1 0.11 0.18 0.2 0.33 0.36 0.36 0.34
```

```
cvs_1993 0.22 0.42 0.26 0.08 0.05 0.13 0.15 0.15 0.14 0.2 0.27 0.35 0.47 0.36
cvs_1994 0.09 0.07 0.25 0.16 0.1 0.08 0.21 0.23 0.22 0.22 0.34 0.53 0.79 0.35
cvs_1995 0.13 0.07 0.06 0.18 0.14 0.07 0.09 0.15 0.2 0.16 0.18 0.31 0.49 0.37
cvs_1996 0.16 0.1 0.05 0.08 0.17 0.17 0.11 0.12 0.19 0.25 0.35 0.32 0.45 0.31
cvs_1997 0.19 0.09 0.1 0.09 0.13 0.22 0.16 0.18 0.23 0.34 0.43 0.42 0.55 0.58
cvs_1998 0.19 0.11 0.08 0.1 0.09 0.11 0.2 0.22 0.13 0.2 0.39 0.4 0.44 0.29
cvs_1999 0.16 0.11 0.11 0.09 0.11 0.1 0.13 0.19 0.23 0.26 0.28 0.51 0.48 0.26
cvs_2000 0.36 0.13 0.1 0.13 0.1 0.12 0.11 0.14 0.25 0.29 0.3 0.34 0.61 0.52
cvs_2001 0.2 0.15 0.09 0.11 0.13 0.09 0.13 0.12 0.18 0.3 0.27 0.32 0.37 0.4
cvs_2002 0.12 0.23 0.1 0.14 0.13 0.16 0.13 0.14 0.18 0.28 0.43 0.48 0.58 0.36
cvs_2003 0.25 0.06 0.18 0.15 0.15 0.14 0.19 0.13 0.18 0.21 0.25 0.61 0.56 0.44
cvs_2004 0.07 0.26 0.06 0.19 0.16 0.15 0.12 0.17 0.11 0.16 0.14 0.19 0.38 0.23
cvs_2005 0.09 0.05 0.19 0.09 0.22 0.17 0.13 0.14 0.2 0.13 0.19 0.17 0.26 0.35
cvs_2006 0.11 0.07 0.06 0.14 0.14 0.19 0.17 0.16 0.16 0.22 0.2 0.28 0.33 0.31

@catch_at EnspOLF
sexed F
years 1992 1994 1996 1998
fishery Ensp1 Ensp2
plus_group TRUE
sum_to_one TRUE
min_class 1
max_class 6
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.005207 0.009153 0.363327 0.492867 0.053837 0.07561
1994 0.105823 0.293903 0.005681 0.024833 0.142837 0.426923
1996 0.239616 0.173171 0.370691 0.117053 0.035713 0.063756
1998 0.033278 0.054074 0.533844 0.075126 0.105369 0.198308
cvs_1992 1.64 1.08 0.19 0.17 0.43 0.37
cvs_1994 0.28 0.18 1.18 0.52 0.24 0.16
cvs_1996 0.22 0.25 0.19 0.3 0.5 0.39
cvs_1998 0.49 0.4 0.16 0.35 0.3 0.23

@catch_at Enspage
sexed F
years 1999 2000 2001 2002 2003 2004 2005 2006
fishery Ensp1 Ensp2
plus_group TRUE
sum_to_one TRUE
min_class 1
max_class 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1999 0.052419 0.163637 0.224825 0.175497 0.137077 0.088423 0.040212 0.035689 0.030408 0.020137
0.015776 0.003077 0.012822
2000 0.103598 0.430875 0.096581 0.084285 0.097811 0.043247 0.041961 0.034043 0.015001 0.00952
0.021489 0.006162 0.015427
2001 0.016798 0.09091 0.335798 0.212505 0.087687 0.079581 0.049496 0.052922 0.027263 0.007629
0.012066 0.012316 0.01503
2002 0.112722 0.04912 0.185306 0.3095 0.130364 0.057401 0.046255 0.03026 0.032292 0.011472
0.007855 0.008711 0.018742
2003 0.012747 0.310511 0.090179 0.158113 0.179484 0.091643 0.021549 0.044851 0.028065 0.021085
0.014364 0.002755 0.024654
2004 0.206104 0.080519 0.276338 0.060817 0.069861 0.120532 0.037164 0.006793 0.057018 0.019648
0.032495 0.010516 0.022196
2005 0.034893 0.436873 0.118051 0.201775 0.025296 0.060892 0.052338 0.014793 0.003075 0.024603
0.003041 0.009086 0.015286
2006 0.023911 0.147997 0.297034 0.17339 0.211577 0.02425 0.034553 0.04353 0.011266 0.00582
0.015584 0.002728 0.008359
cvs_1999 0.29 0.16 0.12 0.12 0.17 0.2 0.27 0.27 0.31 0.35 0.37 0.62 0.74
cvs_2000 0.33 0.14 0.19 0.37 0.27 0.42 0.27 0.37 0.67 0.53 0.39 0.59 0.61
cvs_2001 0.83 0.34 0.1 0.13 0.2 0.18 0.21 0.21 0.32 0.45 0.4 0.39 0.35
cvs_2002 0.24 0.44 0.17 0.11 0.15 0.31 0.27 0.36 0.34 0.53 0.54 0.67 0.37
cvs_2003 1.09 0.14 0.24 0.21 0.18 0.25 0.46 0.33 0.48 0.4 0.73 0.79 0.39
cvs_2004 0.21 0.26 0.13 0.27 0.25 0.23 0.36 0.56 0.28 0.52 0.41 0.65 0.47
cvs_2005 0.72 0.15 0.24 0.15 0.33 0.25 0.26 0.51 0.7 0.4 0.66 0.51 0.49
cvs_2006 0.48 0.2 0.13 0.15 0.13 0.37 0.33 0.31 0.47 0.7 0.46 0.7 0.53

@catch_at WnspOLF
sexed F
years 1992 1993 1994 1996 1999 2000
fishery Wnsp1 Wnsp2
plus_group TRUE
sum_to_one TRUE
```

```
min_class 2
max_class 6
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.000871 0.109446 0.453033 0.116888 0.319762
1993 0.004296 0.004078 0.171825 0.523102 0.296699
1994 0.079372 0.020973 0.019909 0.463609 0.416136
1996 0.125139 0.311189 0.23711 0.043075 0.283486
1999 0.04474 0.065895 0.301093 0.035005 0.553267
2000 0.044353 0.019826 0.15674 0.16521 0.613871
cvs_1992 36.76 0.32 0.18 0.31 0.21
cvs_1993 1.94 2.92 0.26 0.17 0.21
cvs_1994 0.36 0.67 0.69 0.17 0.18
cvs_1996 0.3 0.21 0.23 0.48 0.22
cvs_1999 0.41 0.35 0.19 0.47 0.15
cvs_2000 0.37 0.53 0.22 0.22 0.13

@catch_at Wnspage
sexed F
years 2001 2002 2003 2004 2006
fishery Wnsp1 Wnsp2
plus_group TRUE
sum_to_one TRUE
min_class 2
max_class 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
2001 0.011082 0.032943 0.084665 0.125585 0.233624 0.15347 0.184107 0.104587 0.026649 0.012037
0.012682 0.018569
2002 0.020316 0.023245 0.032186 0.086094 0.064821 0.143838 0.17529 0.266794 0.085615 0.028895
0.033517 0.039388
2003 0.045086 0.029171 0.070606 0.070465 0.078852 0.066179 0.17298 0.120651 0.15852 0.084041
0.02859 0.07486
2004 0.03246 0.122664 0.018979 0.052982 0.101737 0.096152 0.059234 0.209268 0.111253 0.0981
0.060524 0.036646
2006 0.160831 0.276519 0.138732 0.218516 0.042308 0.050754 0.029515 0.018465 0.007437 0.014
0.002764 0.040158
cvs_2001 1.31 0.73 0.4 0.32 0.22 0.26 0.22 0.28 0.55 0.58 0.8 0.58
cvs_2002 0.93 1.04 0.74 0.63 0.51 0.28 0.25 0.27 0.29 0.64 0.52 0.38
cvs_2003 0.49 0.62 0.32 0.35 0.28 0.35 0.2 0.26 0.26 0.3 0.54 0.38
cvs_2004 0.78 0.6 0.64 0.53 0.47 0.39 0.39 0.26 0.34 0.35 0.47 0.54
cvs_2006 0.32 0.17 0.24 0.2 0.33 0.38 0.4 0.48 0.69 0.59 0.86 0.38

@proportions_at CRsumage
sexed F
step 2
proportion_mortality 0.6
area CR
ogive CRsl
years 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
plus_group TRUE
sum_to_one TRUE
min_class 1
max_class 13
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.074428 0.047828 0.441454 0.317479 0.033007 0.018587 0.023774 0.019327 0.006211 0.003075
0.003647 0.002751 0.008433
1993 0.513828 0.013316 0.057096 0.207588 0.156028 0.01003 0.013685 0.012284 0.006582 0.002898
0.001107 0.001494 0.004064
1994 0.324209 0.377154 0.014281 0.04852 0.117546 0.070822 0.009058 0.013307 0.006926 0.006456
0.002953 0.001999 0.006769
1995 0.168024 0.455745 0.186504 0.029184 0.039253 0.046361 0.051014 0.00308 0.007707 0.005198
0.003931 0.000918 0.00308
1996 0.517645 0.117969 0.238761 0.061995 0.006922 0.015181 0.022291 0.012162 0.000688 0.003074
0.001566 0.00044 0.001306
1997 0.068138 0.596775 0.058821 0.108864 0.087571 0.009062 0.018233 0.024583 0.016875 0.002402
0.002755 0.002925 0.002996
1998 0.157645 0.105514 0.489651 0.07858 0.071858 0.042984 0.008558 0.011695 0.015195 0.009489
0.002883 0.002345 0.003603
1999 0.527847 0.113911 0.098706 0.175969 0.01991 0.026396 0.017896 0.003921 0.001295 0.006501
0.004285 0.000965 0.002398
2000 0.474907 0.352204 0.051063 0.023093 0.048005 0.017685 0.014809 0.006124 0.00224 0.00216
0.00451 0.001773 0.001427
```

```
2001 0.019649 0.572686 0.255541 0.028842 0.025578 0.046192 0.007789 0.022445 0.007445 0.002616
0.003333 0.002782 0.005102
2002 0.631726 0.017961 0.116459 0.156115 0.032938 0.003563 0.016379 0.005199 0.007758 0.004018
0.001545 0.002349 0.003988
2003 0.212274 0.604419 0.013654 0.050054 0.058061 0.026035 0.005684 0.013975 0.002839 0.004203
0.003686 0.000874 0.004242
2004 0.579312 0.079721 0.244354 0.02195 0.025301 0.023793 0.009016 0.002909 0.005784 0.001541
0.002895 0.00143 0.001993
2005 0.455549 0.438216 0.024639 0.044219 0.005946 0.009899 0.008794 0.002473 0.000818 0.005066
0.000857 0.001363 0.002161
2006 0.530463 0.249038 0.133793 0.014291 0.047495 0.001797 0.006492 0.00807 0.003673 0.000517
0.00142 0.000434 0.002516
2007 0.317694 0.408549 0.127945 0.077238 0.023543 0.027531 0.002972 0.005263 0.00355 0.002175
0.000565 0.001033 0.001942
cvs_1992 0.19 0.21 0.06 0.07 0.18 0.2 0.16 0.16 0.27 0.38 0.4 0.37 0.22
cvs_1993 0.12 0.51 0.17 0.14 0.15 0.24 0.24 0.24 0.28 0.4 0.41 0.42 0.29
cvs_1994 0.09 0.09 0.67 0.15 0.11 0.12 0.2 0.2 0.27 0.3 0.36 0.43 0.25
cvs_1995 0.13 0.09 0.16 0.22 0.15 0.11 0.11 0.21 0.21 0.25 0.28 0.47 0.27
cvs_1996 0.1 0.15 0.12 0.16 0.24 0.19 0.16 0.19 0.35 0.34 0.38 0.51 0.36
cvs_1997 0.39 0.08 0.35 0.14 0.14 0.27 0.18 0.14 0.17 0.29 0.32 0.29 0.27
cvs_1998 0.19 0.15 0.07 0.18 0.14 0.15 0.24 0.22 0.19 0.25 0.34 0.48 0.32
cvs_1999 0.1 0.14 0.15 0.13 0.21 0.2 0.19 0.29 0.39 0.31 0.31 0.45 0.43
cvs_2000 0.12 0.13 0.19 0.2 0.17 0.21 0.2 0.24 0.35 0.36 0.31 0.39 0.35
cvs_2001 0.42 0.07 0.1 0.21 0.19 0.16 0.22 0.19 0.27 0.37 0.4 0.37 0.31
cvs_2002 0.09 0.61 0.16 0.15 0.18 0.29 0.22 0.29 0.29 0.37 0.78 0.53 0.32
cvs_2003 0.22 0.06 0.3 0.17 0.16 0.21 0.31 0.23 0.39 0.35 0.39 0.46 0.28
cvs_2004 0.11 0.22 0.16 0.25 0.22 0.22 0.25 0.33 0.32 0.39 0.35 0.49 0.34
cvs_2005 0.1 0.09 0.27 0.12 0.22 0.2 0.2 0.25 0.55 0.26 0.49 0.38 0.28
cvs_2006 0.07 0.11 0.11 0.25 0.14 0.43 0.28 0.23 0.3 0.72 0.43 0.65 0.28
cvs_2007 0.14 0.08 0.11 0.12 0.19 0.16 0.37 0.29 0.28 0.38 0.56 0.4 0.3

@proportions_at SAsumage
sexed F
step 2
proportion_mortality 0.5
area SA
ogive SAsl
years 1992 1993 1994 2001 2002 2003 2004 2005 2006 2007
plus_group TRUE
sum_to_one TRUE
min_class 2
max_class 15
dist robustified-lognormal
r 0.01
cv_process_error 0.4
1992 0.012635 0.128901 0.386008 0.031098 0.067595 0.165544 0.084284 0.039995 0.031375 0.015168
0.011524 0.009234 0.010991 0.005647
1993 0.013421 0.005897 0.09601 0.30636 0.037463 0.11554 0.201777 0.117991 0.037393 0.026937
0.017999 0.011327 0.007896 0.003988
1994 0.114463 0.002568 0.035959 0.222066 0.185125 0.021806 0.084954 0.159438 0.103202 0.028157
0.016314 0.013569 0.000719 0.01166
2001 0.003589 0.047393 0.044696 0.061999 0.197093 0.165546 0.252899 0.136709 0.024873 0.021692
0.011626 0.013986 0.004687 0.013211
2002 0.014828 0.095014 0.04782 0.081369 0.094527 0.194326 0.16006 0.15486 0.087295 0.026616
0.025437 0.008714 0.006127 0.003007
2003 0.230756 0.004503 0.029266 0.038692 0.073058 0.066036 0.181135 0.163756 0.117175 0.051963
0.014694 0.012151 0.012528 0.004287
2004 0.004756 0.127802 0.037943 0.054585 0.047275 0.095622 0.049513 0.181005 0.122227 0.14718
0.097808 0.00963 0.011452 0.0132
2005 0.560244 0.035738 0.058637 0.009006 0.025334 0.021922 0.030627 0.018667 0.059663 0.037149
0.073946 0.039906 0.009497 0.019664
2006 0.218048 0.18132 0.016782 0.059167 0.009762 0.042712 0.047505 0.098291 0.028231 0.113956
0.052065 0.061133 0.056372 0.014655
2007 0.129007 0.165764 0.275609 0.074656 0.088577 0.020715 0.042372 0.027566 0.04658 0.035251
0.050592 0.030062 0.010167 0.00308
cvs_1992 0.36 0.12 0.07 0.18 0.14 0.1 0.13 0.17 0.18 0.23 0.29 0.35 0.37 0.35
cvs_1993 0.5 0.31 0.13 0.07 0.2 0.14 0.1 0.13 0.2 0.23 0.28 0.44 0.43 0.41
cvs_1994 0.36 0.71 0.24 0.13 0.13 0.23 0.17 0.14 0.16 0.23 0.29 0.34 0.66 0.36
cvs_2001 0.45 0.17 0.19 0.17 0.1 0.1 0.08 0.11 0.21 0.27 0.3 0.33 0.53 0.35
cvs_2002 0.36 0.21 0.17 0.15 0.15 0.11 0.11 0.11 0.14 0.28 0.27 0.41 0.39 0.51
cvs_2003 0.27 0.38 0.19 0.2 0.18 0.19 0.14 0.14 0.14 0.19 0.32 0.28 0.4 0.4
cvs_2004 0.75 0.17 0.29 0.18 0.2 0.16 0.21 0.12 0.13 0.13 0.16 0.43 0.4 0.37
cvs_2005 0.11 0.24 0.17 0.32 0.22 0.24 0.23 0.3 0.21 0.24 0.2 0.23 0.4 0.31
cvs_2006 0.14 0.11 0.31 0.16 0.34 0.21 0.19 0.15 0.28 0.13 0.21 0.19 0.19 0.4
cvs_2007 0.16 0.11 0.09 0.14 0.15 0.34 0.24 0.27 0.21 0.23 0.21 0.26 0.5 0.7

@proportions_at SAautage
```

```
sexed F
step 3
proportion_mortality 0.1
area SA
ogive SAs1
years 1992 1996 1998
plus_group T
sum_to_one TRUE
min_class 2
max_class 15
dist robustified-lognormal
r 0.01
cv_process_error 0.34
1992 0.013218 0.096714 0.30677 0.02118 0.080823 0.203547 0.143431 0.038656 0.029968 0.022516
0.010965 0.01286 0.009997 0.009355
1996 0.185035 0.326481 0.184962 0.011023 0.017982 0.088946 0.112134 0.008914 0.023809 0.025295
0.007652 0.003335 0.002879 0.001553
1998 0.03502 0.181426 0.112354 0.25342 0.163106 0.040561 0.031445 0.072592 0.053464 0.013016
0.016505 0.013783 0.006426 0.006883
cvs_1992 0.34 0.13 0.07 0.21 0.13 0.08 0.11 0.19 0.23 0.24 0.31 0.27 0.35 0.33
cvs_1996 0.19 0.1 0.11 0.28 0.21 0.14 0.14 0.24 0.23 0.23 0.33 0.45 0.59 0.5
cvs_1998 0.21 0.09 0.11 0.07 0.09 0.14 0.14 0.11 0.13 0.2 0.21 0.24 0.34 0.32

@proportions_migrating pspawn
years 1992 1998
migration Wspmg
plus_group 1
min_class 3
max_class 9
dist lognormal
1992  0.19 0.45 0.27 0.57 0.68 0.69 0.64
1998  0.28 0.60 0.40 0.40 0.40 0.40 0.52
cv_1992 0.25
cv_1998 0.25
```

– the penalty `YCS.eq.04` was dropped
– the two ogive_difference_penalty blocks were replaced by

```
@ogive_difference_penalty
label sp.migr
ogive1 migration[Espmg].rates_all
ogive2 migration[Wspmg].rates_all
class 8
multiplier 100
```

A1.2.3 Differences in estimation.csl for MPD run 4.7

The estimation.csl file for run 4.7 was as in Section A1.2.1 except for the following changes.

– the `@user_components` command was change to

```
@user_components prior_on_pE penalty_on_annvar prior_on_Mmale prior_on_Mfemale
```

– the `@estimate` blocks for `log_Bmean_total` and `Bmean_prop_stock1` were replaced by

```
@estimate
parameter initialization.Bmean
phase 1
prior uniform-log
lower_bound 1e5
upper_bound 1e7
```

– the `@estimate` block for `recruitment[E].YCS` was dropped and, in that for `recruitment[W].YCS`, the parameter name was changed to `recruitment.YCS`
– for both `@estimate` blocks for natural mortality, the `upper_bound` subcommand was changed to

```
upper_bound 9.1 0.3 4.8 2
```

– the `@estimate` block for `migration[Whome].rates_male` was replaced by

```
@estimate
parameter migration[Whome].rates_all
phase 1
prior uniform
lower_bound 0.01 0.01 0.01 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
upper_bound 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0 0 0 0 0 0 0 0 0
@estimate
parameter migration[Whome].annual_variation_values
prior uniform
```

```
lower_bound -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5
-5 -5 -5 -5 -5 -5
upper_bound 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
```

– the c.v.s for the CSacous observations were changed to

```
cv_1991 0.13
cv_1993 0.15
cv_1994 0.06
cv_1995 0.12
cv_1996 0.09
cv_1997 0.12
cv_1998 0.10
cv_1999 0.10
cv_2001 0.12
cv_2002 0.13
cv_2003 0.17
cv_2005 0.11
cv_2006 0.17
```

– the c.v.s for the WCacous observations were changed to

```
cv_1988 0.22
cv_1989 0.15
cv_1990 0.06
cv_1991 0.14
cv_1992 0.14
cv_1993 0.07
cv_1997 0.10
cv_2000 0.14
```

– the `YCS.eq.05` penalty was dropped

A1.2.4 Differences in estimation.csl for MCMC and projection runs

For MCMC runs the following changes were made

– all `@estimate` blocks for process-error c.v.s were dropped,
– the `@YCS_difference_penalty` block in run 4.4 was dropped,
– ogive parameters were fixed at values specified in Table 25
– upper bound on prior for `natural_mortality.ogive_female[3]` was changed to 0.499 in run 4.7
– lower bound on prior for `natural_mortality.all` was changed to 0.12 for run 2.5
– all process-error c.v.s were replaced by their MPD estimates as follows

	4.4	4.5	4.7
Espage	0.31	0.23	0.31
Wspage	0.31	0.27	0.31
Enspage	0.31	0.31	0.33
Wnspage	0.22	0.28	0.19
CRsumage	0.36	0.48	0.39
SAsumage	0.41	0.43	0.44
SAautage	0.34	0.43	0.34

No further changes were made for projection runs.

A1.3: user.prior_penalty.cpp files

Both runs 4.4 and 4.7 used a CASAL extension (see chapter 12 of Bull et al. 2005) which involved compiling and linking the following versions of the C++ module user.prior_penalty.cpp with CASAL.

A1.3.1: user.prior_penalty.cpp file for run 4.4

```
#ifndef USER_PRIOR_PENALITY_CPP
#define USER_PRIOR_PENALITY_CPP

//############################## USER PRIOR PENALTY.cpp ##############################
#include "development.h"

////////////////////////////////////////////////////////////////////////////////////////
template<CDVM>
```

```
void user_prior_penalty(
std::vector<std::string>& free_scalar_names,
std::vector<DOUBLE>& free_scalar_vals,
std::vector<std::string>& free_vector_names,
std::vector<VECTOR>& free_vector_vals,
std::vector<std::string>& free_ogive_names,
std::vector<VECTOR>& free_ogive_arguments,
std::vector<std::string>& user_scalar_names,
std::vector<DOUBLE>& user_scalar_vals,
std::vector<std::string>& user_vector_names,
std::vector<VECTOR>& user_vector_vals,
std::vector<std::string>& objective_component_names,
std::vector<DOUBLE>& objective_component_vals){
/*
*** Chris Francis, 29/2/07 ***
Applies new age-based (but not sex-based) prior for age-dependent natural
mortality for use when a double_exponential ogive is used for M for each sex.
The priors are as defined in Patrick's report, WG-HOK-2007/11,
BUT APPLIED ONLY TO AGES 5-9:
Age       mu    sd
5-9   -1.817  0.48
Notes:
- it is assumed that the partition is from ages 1-17 and that the
        non-estimable parameters for both M ogives are x1=1 & x2=17
- Need to insert the following in estimation.csl:
   @user_components prior_on_Mmale prior_on_Mfemale
*/
DEBUG1("user_prior_penalty");
if (!in<std::string>(free_ogive_names,"natural_mortality.ogive_male")){
fatal("You need to estimate natural_mortality.ogive_male");}
if (!in<std::string>(free_ogive_names,"natural_mortality.ogive_female")){
fatal("You need to estimate natural_mortality.ogive_female");}
VECTOR mpars = free_ogive_arguments[pos<std::string>
(free_ogive_names,"natural_mortality.ogive_male")];
VECTOR fpars = free_ogive_arguments[pos<std::string>
(free_ogive_names,"natural_mortality.ogive_female")];
double mu = -1.817, sd = 0.48;
double mnM= exp(mu + 0.5 * pow(sd,2));
DOUBLE Mmale, Mfemale;
DOUBLE nlnprMmale =0., nlnprMfemale=0.;
for(int age = 5; age <= 9; age++){
  if(age <= mpars[1]){
    Mmale = mpars[2]*pow(mpars[3]/mpars[2],
                        ((age-mpars[1])/(1.-mpars[1])));
  } else {
    Mmale = mpars[2]*pow(mpars[4]/mpars[2],
                        ((age-mpars[1])/(17.-mpars[1])));
  }
  if(age <= fpars[1]){
    Mfemale = fpars[2]*pow(fpars[3]/fpars[2],
                          ((age-fpars[1])/(1.-fpars[1])));
  } else {
    Mfemale = fpars[2]*pow(fpars[4]/fpars[2],
                          ((age-fpars[1])/(17.-fpars[1])));
  }
  nlnprMmale += log(Mmale) + 0.5 * pow((log(Mmale/mnM)/sd)+
                                  0.5 * sd,2);
  nlnprMfemale += log(Mfemale) + 0.5 * pow((log(Mfemale/mnM)/sd)+
                                  0.5 * sd,2);
/*  cerr <<"Mmale "<<Mmale<<" Mfemale "<<Mfemale<<" nlnprMmale "<<nlnprMmale<<
    " nlnprMfemale "<<nlnprMfemale<<endl; */
}
objective_component_vals.push_back(nlnprMmale);
objective_component_names.push_back("prior_on_Mmale");
objective_component_vals.push_back(nlnprMfemale);
objective_component_names.push_back("prior_on_Mfemale");
}
#endif
```

A1.3.2: user.prior_penalty.cpp file for run 4.7

```
#ifndef USER_PRIOR_PENALITY_CPP
#define USER_PRIOR_PENALITY_CPP
```

```
//############################## USER PRIOR PENALTY.cpp ##############################
#include "development.h"

//////////////////////////////////////////////////////////////////////////////////////////
template<CDVM>
void user_prior_penalty(
std::vector<std::string>& free_scalar_names,
std::vector<DOUBLE>& free_scalar_vals,
std::vector<std::string>& free_vector_names,
std::vector<VECTOR>& free_vector_vals,
std::vector<std::string>& free_ogive_names,
std::vector<VECTOR>& free_ogive_arguments,
std::vector<std::string>& user_scalar_names,
std::vector<DOUBLE>& user_scalar_vals,
std::vector<std::string>& user_vector_names,
std::vector<VECTOR>& user_vector_vals,
std::vector<std::string>& objective_component_names,
std::vector<DOUBLE>& objective_component_vals){
/*
*** Chris Francis, 26/2/07 ***
Combines the functionality of user.prior-penalty_1stv2 and *_Mprior2.
(1) Applies a beta prior, with mu=0.344, sigma=0.072, A=0.1, B=0.6,
to pE, which is defined as the product, for i=1 to 8, of
(1-migration[Whome].rates_all[i])
(2) Calculates a normal prior with unspecified mean and variance = 1 for
migration[Whome].annual_variation_values
(3) Applies an age- (but not sex-based) priors for natural mortality
for use when a double_exponential ogive is used for M for each sex.
The priors are as defined in Patrick's report, WG-HOK-2007/11,
BUT APPLIED ONLY TO AGES 5-9:
Age       mu    sd
5-9   -1.817  0.48
Notes:
- from the beta parameters we calculate
        nu = (mu-A)/(B-A), tau = ((mu-A)*(B-mu)/simgma^2)-1,
        mm = (1-tau*nu), nn = (1-tau*(1-nu)),
        slope(x0) = (mm/(x0-A)) - (nn/(B-x0)),
        intcpt(x0) = mm*log(x0-A) + nn*log(B-x0) - x0*slope(x0)
        and slopei & intcpti are evaluated at x0 = A+0.01 (i=1) & B-0.01 (i=2)
- beta prior is normally not defined for pE < A or pE > B, but, for robustness,
        the definition is extended here using straight lines ar each end.
- it is assumed that the partition is from ages 1-17 and that the
        non-estimable parameters for both M ogives are x1=1 & x2=17
- Need to insert the following in estimation.csl:
   @user_components prior_on_pE penalty_on_annvar prior_on_Mmale prior_on_Mfemale
*/
DEBUG1("user_prior_penalty");
if (!in<std::string>(free_ogive_names,"migration[Whome].rates_all")){
fatal("You need to estimate migration[Whome].rates_all");}
VECTOR Whome = free_ogive_arguments[pos<std::string>
(free_ogive_names,"migration[Whome].rates_all")];
DOUBLE temp=1;
for(int i = 1; i <= 8; i++){
        temp=temp*(1-Whome[i]);
}
DOUBLE mm = -4.3921, nn = -4.6573, A = 0.1, B = 0.6;
DOUBLE slope1 = -429.71, intcpt1 = 70.816;
DOUBLE slope2 = 456.76, intcpt2 = -244.91;
DOUBLE nlnprior;
if (temp < 0.11){
        nlnprior = temp*slope1 + intcpt1;
        } else if (temp > 0.59){
        nlnprior = temp*slope2 + intcpt2;
        } else {
        nlnprior = mm*log(temp-A) + nn*log(B-temp);
}
objective_component_vals.push_back(nlnprior);
objective_component_names.push_back("prior_on_pE");
if (!in<std::string>(free_vector_names,"migration[Whome].annual_variation_values")){
fatal("You need to estimate migration[Whome].annual_variation_values");}
VECTOR annvar = free_vector_vals[pos<std::string>
(free_vector_names,"migration[Whome].annual_variation_values")];
temp=sum(annvar)/annvar.size();
objective_component_vals.push_back(0.5*sum(pow((annvar-temp),2)));
objective_component_names.push_back("penalty_on_annvar");
if (!in<std::string>(free_ogive_names,"natural_mortality.ogive_male")){
fatal("You need to estimate natural_mortality.ogive_male");}
```

```
if (!in<std::string>(free_ogive_names,"natural_mortality.ogive_female")){
fatal("You need to estimate natural_mortality.ogive_female");}
VECTOR mpars = free_ogive_arguments[pos<std::string>
(free_ogive_names,"natural_mortality.ogive_male")];
VECTOR fpars = free_ogive_arguments[pos<std::string>
(free_ogive_names,"natural_mortality.ogive_female")];
double mu = -1.817, sd = 0.48;
double mnM= exp(mu + 0.5 * pow(sd,2));
DOUBLE Mmale, Mfemale;
DOUBLE nlnprMmale =0., nlnprMfemale=0.;
for(int age = 5; age <= 9; age++){
  if(age <= mpars[1]){
    Mmale = mpars[2]*pow(mpars[3]/mpars[2],
                        ((age-mpars[1])/(1.-mpars[1])));
  } else {
    Mmale = mpars[2]*pow(mpars[4]/mpars[2],
                        ((age-mpars[1])/(17.-mpars[1])));
  }
  if(age <= fpars[1]){
    Mfemale = fpars[2]*pow(fpars[3]/fpars[2],
                          ((age-fpars[1])/(1.-fpars[1])));
  } else {
    Mfemale = fpars[2]*pow(fpars[4]/fpars[2],
                          ((age-fpars[1])/(17.-fpars[1])));
  }
  nlnprMmale += log(Mmale) + 0.5 * pow((log(Mmale/mnM)/sd)+
                                  0.5 * sd,2);
  nlnprMfemale += log(Mfemale) + 0.5 * pow((log(Mfemale/mnM)/sd)+
                                  0.5 * sd,2);
/*  cerr <<"Mmale "<<Mmale<<" Mfemale "<<Mfemale<<" nlnprMmale "<<nlnprMmale<<
    " nlnprMfemale "<<nlnprMfemale<<endl; */
}
objective_component_vals.push_back(nlnprMmale);
objective_component_names.push_back("prior_on_Mmale");
objective_component_vals.push_back(nlnprMfemale);
objective_component_names.push_back("prior_on_Mfemale");
}
#endif
```

Appendix 2: Details of retrospective analyses

In this appendix I document the implementation of the retrospective analyses of Section 7.1. Each of the retrospective analyses was based on a pair of CASAL input files (the population and estimation files) that contained the observations, either actual or simulated, and all parameters (including the actual catches) that were appropriate for an assessment in 2007. From this pair, five new pairs of files were created, by successively deleting one year's observations and making other associated changes, that were appropriate for assessments in 2006, 2005,..., and 2002. The following Splus function was used to do this.

```
"Make.retrospective.casal.files"<-
function(popname, estname, dir, nyr, cur.catch.assumed = T, cur.shift.E = 305,
       obscur = NULL, obscurm1 = NULL, dec.YCS.diff.penalty = T)
{
# Reads in existing CASAL input files (population and estimation)
# and writes input files for a retrospective analysis.  New files
# will have same names as existing files but with suffixes .1, .2, etc.
# For example, if @current is 2007 in <popfile> it will be
# 2006 in <popfile>.1, 2005 in <popfile>.2, etc.
#
# popname - name of existing population file
# estname - name of existing estimation file
# dir - directory in which popfile & estfile sit, and to which new input files
#       will be written
# nyr - number of retrospective years (e.g., nyr = 3 causes new input files
#       *.1, *.2, *.3 to be written)
# cur.catch.assumed - if T, then the catch (if any) in the current year
#       will always be an assumed value, set equal to the catch in the
#       preceding year
# cur.shift.E - if not null then the value of shift_E in the current year
#       for a slectivity that is shifted will always be an assumed value,
#       equal to cur.shift.E
```

```
# obscur, obscurm1 - names of observations in estfile that are expected to
#       have their latest values in the current year (for obscur) or
#       the current year - 1 (for obscurm1).  All observations not named
#       in either obscur or obscurm1 will remain unchanged in the
#       new input files
# dec.YCS.diff.penalty - if T, subcommand year of each YCS difference penalty
#       will be decremented for each successive retrospective year
#       (ignored if no such penalties)
#
# In addition to the changes (if any) specified by the arguments
# cur.catch.assumed and cur.shift.E, there are three types of changes to the
# original popfile, and the following objects, defined below, specify which
# commands/subcommands each type of change is applied to:
# - decrement: for each successive retrospective year subtract 1 from the
#         specified commands/subcommands
# - clip: for each successive retrospective year remove last element of
#         specified vectors
# - to.current: remove material after current year
# There is one type of change to the original estfile and the following
# object, defined in this function, specifies which commands/subcommands
# each type of change is applied to:
# - clipest: for each successive retrospective year remove last element of
#            the vectors specifying the bounds (and of any other vectors
#            of the same length) in the @estimate block of specified
#            parameter type
#
#
        unlapply <- function(lst, fun, ...)
        unlist(lapply(lst, fun, ...))
        len <- length
        is.in <- function(x, y)
        !is.na(match(x, y))
        decrement <- list(current = "value", final = "value",
                "first_random_year" = "value", fishery = "future_years",
                "disease_mortality" = "future_years", recruitment = "last_free",
                recruitment = list("year_range", 2), recruitment = list(
                "T_year_range", 2))
        clip <- list(recruitment = "YCS_years", recruitment = "YCS",
                recruitment = "Ts", recruitment = "Ts_years")
        to.current <- list(fishery = c("years", "catches"), fishery = c(
                "Fs_years", "Fs"), migration = c("annual_variation_years",
                "annual_variation_values"), "disease_mortality" = c("years",
                "index"), selectivity = c("shift_years", "shift_E"))
        clipest <- c("YCS", "annual_variation_values")
        fullpopname <- paste(dir, popname, sep = "/")
        popfile <- extract.csl.file(fullpopname)
        if(is.in("n_tags", names(popfile)))
                if(as.numeric(popfile$"n_tags"$value) > 0)
                        stop("Code not written for files with tagging partition"
                                )
        if(is.in("size_at-age_years", names(popfile)))
                stop("Code not written for files including @size_at-age_years")
        curyr <- as.numeric(popfile$current$value)
        if(cur.catch.assumed)
                fisheryindex <- (1:len(popfile))[unlapply(popfile, function(x)
                x$command == "fishery")]
        if(!is.null(cur.shift.E))
                shiftindx <- (1:len(popfile))[unlapply(popfile, function(x)
                is.in("shift_E", names(x)))]
        fullestname <- paste(dir, estname, sep = "/")
        estfile <- extract.csl.file(fullestname)
        obs <- c(obscur, obscurm1)
        obslastyr <- rep(c(curyr, curyr - 1), c(len(obscur), len(obscurm1)))
        obsindx <- match(obs, unlapply(estfile, function(x)
        if(len(x$value) > 0) x$value[1] else " "))
        if(any(is.na(obsindx))) {
                cat("Warning, following observations not found:", obs[is.na(
                        obsindx)], "\n")
                obs <- obs[!is.na(obsindx)]
                obslastyr <- obslastyr[!is.na(obsindx)]
                obsindx <- obsindx[!is.na(obsindx)]
        }
        obsempty <- rep(F, len(obsindx))
        for(iyr in 1:nyr) {
                curyr <- curyr - 1
                for(idec in 1:len(decrement)) {
# do popfile changes in decrement
```

```
                        if(is.list(decrement[[idec]])) {
                                subcmd <- decrement[[idec]][[1]]
                                vecindx <- decrement[[idec]][[2]]
                                decall <- F
                        }
                        else {
                                subcmd <- decrement[[idec]]
                                decall <- T
                        }
                        indx <- (1:len(popfile))[unlapply(popfile, function(x,
                                nm, sb)
                        x$command == nm & is.in(sb, names(x)), names(decrement)[
                                idec], subcmd)]
                        for(ii in indx) {
                                temp <- as.numeric(popfile[[ii]][[subcmd]])
                                if(decall)
                                  temp <- temp - 1
                                else temp[vecindx] <- temp[vecindx] - 1
                                popfile[[ii]][[subcmd]] <- paste(temp)
                        }
                }
                for(iclip in 1:len(clip)) {
# do popfile changes in clip
                        subcmd <- clip[[iclip]]
                        indx <- (1:len(popfile))[unlapply(popfile, function(x,
                                nm, sb)
                        x$command == nm & is.in(sb, names(x)), names(clip)[
                                iclip], subcmd)]
                        for(ii in indx) {
                                temp <- as.numeric(popfile[[ii]][[subcmd]])
                                popfile[[ii]][[subcmd]] <- paste(temp[ - len(
                                  temp)])
                        }
                }
                for(itoc in 1:len(to.current)) {
# do popfile changes in to.current
                        yrsubcmd <- to.current[[itoc]][1]
                        subcmd <- to.current[[itoc]][2]
                        indx <- (1:len(popfile))[unlapply(popfile, function(x,
                                nm, yr)
                        x$command == nm & is.in(yr, names(x)), names(to.current
                                )[itoc], yrsubcmd)]
                        for(ii in indx) {
                                years <- as.numeric(popfile[[ii]][[yrsubcmd]])
                                temp <- as.numeric(popfile[[ii]][[subcmd]])
                                sel <- years <= curyr
                                popfile[[ii]][[yrsubcmd]] <- paste(years[sel])
                                popfile[[ii]][[subcmd]] <- paste(temp[sel])
                        }
                }
                if(cur.catch.assumed) {
# do popfile changes for cur.catch.assumed
                        for(ii in fisheryindex) {
                                years <- as.numeric(popfile[[ii]]$year)
                                nyr <- len(years)
                                if(years[nyr] == curyr)
                                  popfile[[ii]]$catches[nyr] <- popfile[[ii]]$
                                    catches[nyr - 1]
                        }
                }
                if(!is.null(cur.shift.E)) {
# do popfile changes for cur.shift.E
                        for(ii in shiftindx) {
                                years <- as.numeric(popfile[[ii]]$"shift_years"
                                  )
                                sel <- years == curyr
                                if(any(sel))
                                  popfile[[ii]]$"shift_E"[sel] <- paste(
                                    cur.shift.E)
                        }
                }
                write.csl.file(popfile, paste(fullpopname, iyr, sep = "."))
                for(iclip in 1:len(clipest)) {
# do estfile changes in clipest
                        indx <- string.match(clipest[iclip], unlapply(estfile,
                                function(x)
                        if(is.in("parameter", names(x))) x$parameter else " "))
```

```
                        for(ii in indx) {
                                nn <- len(estfile[[ii]]$"lower_bound")
                                for(jj in 1:len(estfile[[ii]]))
                                  if(len(estfile[[ii]][[jj]]) == nn) estfile[[
                                      ii]][[jj]] <- estfile[[ii]][[jj]][ - nn]
                        }
                }
                obslastyr <- obslastyr - 1
                for(ii in obsindx) {
# remove obs from estfile where necessary
                        years <- as.numeric(estfile[[ii]]$years)
                        lastyr <- obslastyr[match(ii, obsindx)]
                        sel <- years <= lastyr
                        if(sum(sel) == 0)
                                obsempty[match(ii, obsindx)] <- T
                        else {
                                estfile[[ii]]$years <- paste(years[sel])
                                yrtodrop <- lastyr + 1
                                todrop <- string.match(yrtodrop, names(estfile[[
                                  ii]]))
                                if(len(todrop) > 0)
                                  estfile[[ii]] <- estfile[[ii]][ - todrop]
                        }
                }
                if(any(obsempty)) {
# drop empty observations
                        estfile <- estfile[ - obsindx[obsempty]]
                        obslastyr <- obslastyr[!obsempty]
                        obs <- obs[!obsempty]
                        obsindx <- match(obs, unlapply(estfile, function(x)
                        if(len(x$value) > 0) x$value[1] else " "))
                        obsempty <- obsempty[!obsempty]
                }
                if(dec.YCS.diff.penalty) {
# decrement year of YCS.diff.penalty
                        indx <- (1:len(estfile))[unlapply(estfile, function(x)
                        x$command == "YCS_difference_penalty")]
                        for(ii in indx)
                                estfile[[ii]]$year <- paste(as.numeric(estfile[[
                                  ii]]$year) - 1)
                }
                write.csl.file(estfile, paste(fullestname, iyr, sep = "."))
        }
        obsindx
}
```

Appendix 3: Testing for significant trends in Figure 46

In this Appendix I describe the statistical test for trend referred to in Section 7.1.3. This test was applied separately to each panel in Figure 46 and concerned just the YCS estimates based on simulated data (i.e., those plotted as light lines). The test statistic is the number, n, of simulated data sets for which the 2007 estimate of the YCS is greater than the first estimate in the retrospective analysis. Under the null hypothesis of no trend in the estimates we would expect n to be distributed according to a binomial distribution with parameters $N = 10$, $p = 0.5$. The trend was deemed statistically significant if $n > 8$ or $n < 2$ (which has probability 0.021 under the null hypothesis). This test detected a significant trend in 33 of the 92 panels of Figure 46 (Table A3.1).

Table A3.1: Values of n for each panel of Figure 46 (there is a statistically significant trend if $n > 8$ or $n < 2$).

Year class	Figure 46A (run 4.4, W stock)	Figure 46A (run 4.4, E stock)	Figure 46A (run 4.5, W stock)	Figure 46D (run 4.5, E stock)
1982	2	10	0	9
1983	0	7	1	6
1984	2	3	1	5
1985	0	0	3	2
1986	4	2	4	3
1987	2	0	6	2
1988	7	0	6	1
1989	6	0	6	4
1990	10	0	8	1
1991	5	2	7	1
1992	8	1	3	3
1993	6	3	4	6
1994	7	1	8	2
1995	9	1	2	6
1996	7	3	4	5
1997	8	4	8	5
1998	9	4	8	5
1999	10	7	10	10
2000	10	1	9	0
2001	10	3	10	5
2002	1	7	5	8
2003	6	1	2	1
2004	7	3	4	2

Appendix 4: CASAL input files to investigate invisible mortality

Section 7.2 describes runs 4.16 and 4.17, which were modifications of runs 4.4 and 4.5, respectively, to include invisible mortality. The population.csl files for the new runs were the same as those for the original runs except for the following changes.

– the following subcommand was added to all `@fishery` command blocks

```
retention_selectivity retsel
```

– the name retsel was added to `@selectivity_names`

– the following command block was added

```
@selectivity retsel
all allvalues_bounded 1 3 0.2 0.5 1
```

The estimation.csl files for the new runs were the same as those for the original runs.

Appendix 5: Proposed Selectivity Steps

What follows this paragraph is the report from a technical subcommittee charged with suggesting years at which there may have been a sudden change in the selectivity of one or more of the hoki fisheries. The report describes the years that were chosen, and the rationale for their choice. The subcommittee was convened by Rosie Hurst; other members were Vivian Haist, David Middleton, Richard O'Driscoll, and Richard Wells.

Factors considered, as best as we were able:

- Change in size/age structure of fished population
- Change in fleet structure (nationality, processing type)
- Change in gear type (twin trawls, BT v. MW trawl)
- Change in fleet operation (e.g., Code of Practice; operation inside restricted areas such as WCSI 25 mile area; issues with mopping up quota at the end of the fishing year)

All dates indicated for steps to be effective PRIOR to the start of the fishing season in that area

1. West coast South Island (Puysegur) spawning fishery

- 1999 : Rationale: Change in fish size through the season no longer apparent; more fishing by larger inshore vessels inside the line (targeting larger fish); surimi fleet much reduced in number and proportion of catch (size of fish was not an issue); about the time of the introduction of twin trawling on WCSI.

The existing procedure to use the date when 50% of the catch is taken is not required past 1998

2. Cook Strait

- 1996: Start of increased catch in northern area (from TCEPR) spawning fishery

- 2001: Start of Code of Practice requiring vessels to move on 0.5km north of the cable zone if catch of fish <60cm exceeds 10% of the total (COP v1)

3. Sub-Antarctic non-spawning fishery

- 2004/05: This is the first date where the proportion of the hoki catch not caught by the hoki target fishery declines significantly (from nearly 100% down to <80% by 2005/06). Size of hoki alters by target species (e.g., SQU, SWA catch smaller fish).

Not important to implement now as only 1 years observer data since the change?

4. Chatham Rise non-spawning fishery

- 1995/96: Evidence of increased targeting of small fish.

- 2000/01: Introduction of Code of Practice requiring vessels to move on 3km or change depth by 20m if catch of fish <60cm exceeds 10% of the total; minimum fishing depth 450m (COP v1, January 2001)