The 2015
stock assessment update
for
eastern and western
pink ling

ISL Client Report
for
AFMA

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Executive Summary

This document presents the final assessment results for ISL's assessment of pink ling in 2015. It was an update of the 2013 assessment in that essentially the same methods were applied and new data were added to existing time series. However, some new methods were needed to deal with the complications arising from trip limits applied to the eastern fisheries. In the eastern trawl CPUE analysis a "period effect" was estimated to adjust for the lower landings caused by the trip limits. Also, "landings multipliers" were estimated for the time periods when trip limits were in effect to adjust landings to total removals (i.e., to estimate fishery specific discards).

The period effects and landings multipliers were combined for two time periods when trip limits of 50 kg per day and 250 kg per day were in effect. It was shown that the trip limits were effective in reducing total removals but the 50 kg per day trip limit was barely any more effective than the 250 kg per day trip limit. Both limits affected the behavior of the fishers and reduced landings , but the lower trip limit had much greater discarding.

For the eastern stock, current stock status is estimated at 30% B_0 with a 95% CI of 21–45% B_0. The uncertainty in estimated stock status was amplified in the estimation of RBC which is estimated at 250 t with a 95% CI of 30–630 t. However, when a full Bayesian assessment is available to perform risk analysis, the use of a generic control rule is not needed to provide management advice on TACs.

Stochastic projections were performed for the eastern stock for a range of constant catch strategies from 300 t to 700 t per year. According to projections from the base model there is little risk to the stock over the next few years for total removals up to 550 t per year. For the "worst case" scenario (M = 0.23), total removals up to 500 t per year pose little risk. The base model projections suggest that the stock can be rebuilt to 48% B_0 within one mean generation time (8.8 years) when total removals are 300 t per year. If two mean generation times are allowed for the rebuild then total removals can be 400–500 t per year. Long-term yield is estimated at 540–640 t (95% CI).

For the western stock, current stock status is estimated at 73% B_0 with a 95% CI of 59–87% B_0. RBC is estimated at 990 t with a 95% CI of 640–1590 t. Long-term yield is estimated at 530–950 t (95% CI). Stochastic projections show little or no risk to the stock in the next few years for total removals up to 900 t per year.

Introduction

This document describes the stock assessment for the pink ling undertaken by ISL in 2015. It was an update of the 2013 assessment in that essentially the same methods were applied and new data were added to existing time series. However, some new methods were needed to deal with the complications arising from trip limits applied to the eastern fisheries. In the eastern trawl CPUE analysis a "period effect" was estimated to adjust for the lower landings caused by the trip limits. Also, "landings multipliers" were estimated for the time periods when trip limits were in effect to adjust landings to total removals (i.e., to estimate fishery specific discards).

Methods

Data preparation

The catch histories for each stock by method (trawl and non-trawl) were available from the previous assessment to the end of 2013. The catch histories were revised and extended to the end of 2015 as described in Appendix 1. The extension of the catch histories was complicated by the need to estimate discards in 2014 due to trip limits placed on the eastern trawl fishery. In the east, the trawl fishery catches dominate those from non-trawl methods (Figure 1). In the west, lower catches have been taken than in the east and the non-trawl methods are recently taking similar levels of catch to trawl (Figure 2).

For the eastern and western stocks, length frequency data by method (trawl, line), zone, sampling type (port, onboard), and depth stratum (0-300 m, 300-500 m, 500+ m)(samples scaled to individual catches) were supplied by CSIRO. Raw age-length data were also supplied (for which standard length measurements were converted to total length where appropriate).

The length frequency data were stratified and scaled following the 2013 assessment (Cordue, 2013). In the east, stratification was by depth and zone for the trawl data (which precluded the use of port samples) and by zone for line. For the west, there was no stratification (but the samples for some years were omitted where there were very few operations and/or fish).

The age-length data were also stratified and scaled for eastern trawl following Cordue (2013). Non-sexed age-length data (almost all from Zone 20) were used to construct age-length keys which were applied to the corresponding length frequencies to produce age frequencies for the eastern assessment.

The tables below give the years for which composition data were used in the base models (years with port-sampled length-data are in red). The absence of trawl composition data for the east in 2013 and 2014 is notable. There were some data but it did not meet the quality/quantity threshold adopted in the 2013 assessment for use in an assessment.

	Length frequencies		Conditional age-length		Age frequencies	
	Trawl	Line	Trawl	Line	Trawl	Line
East			1979			
			1994			
			1995			
			1996			
	1998		1998			
	1999		1999			
	2000					
	2001		2001			
	2002	2002, 2002				
	2003	2003		2003		
		2004, 2004		2004		
	2005	2005	2005			
	2006	2006, 2006				
		2007				
						2008
				2009		2009
			2010		2010	2010
			2011	2011	2011	2011
		2012		2012	2012	
		2013		2013		
		2014				

	Length frequencies		Conditional age-length	
	Trawl	Line	Trawl	Line
West			1987	
	1992			
	1993			
	1994			
	1995, 1995		1995	
	1996, 1996			
	1997, 1997		1997	
	1998, 1998		1998	
	1999, 1999		1999	
	2000, 2000			
	2001, 2001	2001		2001
	2002, 2002	2002	2002	
	2003, 2003	2003	2003	2003
	2004, 2004	2004	2004	2004
	2005, 2005	2005	2005	2005
	2006, 2006	2006	2006	2006
	2007	2007		2007

	2009			
	2010	2010	2010	2010
	2011		2011	
	2012	2012	2012	2012
	2013	2013	2013	2013
	2014	2014	2014	2014

CPUE indices

The trawl CPUE indices for east and west were updated using the methods of Cordue (2013) with the addition of an extra factor in the east to deal with the trip limits (Appendix 1). The imposition of trip limits reduced landings and this was corrected for in the analysis. So called "period effects" were estimated for three time periods: no trip limit; 50 kg per day; 250 kg per day.

Model structure

A single-area model with a single time-step was used for both stocks. Ages (1-30+), sex, and maturity were in the partition (although the latter is irrelevant as there were no fisheries that preferentially selected mature fish). The two fisheries (trawl and non-trawl) were assumed to be year-round and mortality was modelled using the Pope approximation to Baranov (CASAL's standard option). Further details of the models are:

Model years	1970-2015	Stock status assessed mid-year 2015
Biomass parameterisation	B_0	Estimated parameter. R_0 is derived.
Recruitment parameterisation	Haist, lognormal prior, sigmaR = 0.7	Also, a moderate penalty on year class strengths (YCS) averaging to 1.
YCS estimated (i.e., recruitment deviations)	East: 1969-1977, 1983-2010 West: 1975-2010	Cohorts 1978-1982 in the east were not well sampled and their YCS were assumed to equal 1.
Steepness	0.75	As used in 2012. A conservative value – it may be higher. Fixed.
Maturity	Logistic at age: a_{50} = 5 yr, ato95 = 2 yr	Approximates the length-based curve used in the 2012 assessment. Fixed.
Trawl selectivities	Three blocks in the east: 1970-99, 2000-2006, 2007-2015. Two in the west: 1970-	Estimated in the model. Timing of blocks indicated by events and confirmed by

	2006, 2007-2015. Double normal at age, same for males and females.	data analysis. Separate male and female selectivities in a sensitivity.
Non-trawl selectivities	Logistic at age, same for males and females.	Estimated in the model. Separate male and female selectivities in a sensitivity.
Growth	Separate male and female von Bertalanffy	Estimated in the model.
Length-weight relationship	a 2.93e-9 b 3.139	Fixed at 2012 assessment values. (cm to tonnes)

MPD methods

Model runs

The base models had the model structure described above and estimated *M*. For the western model the prior on *M* was broad: N(mean=0.2, CV=0.2). The MPD estimate of *M* for the east, when a broad prior was used, was at the upper bound (0.35). This was similar behaviour to what was seen in the 2013 assessment and as in that assessment the posterior for *M* from the western assessment was used as a prior for the eastern assessment: N(mean=0.23, CV=0.06)

For both assessments, MPD sensitivities were done at fixed *M* (low = 0.2, medium = 0.24, high = 0.28), low and high sigmaR (0.5, 0.8), alternative maturity ogives (shifted up or down one year), a tighter CV on the CPUE indices (10%), double the effective samples sizes on the age and length frequencies, sex-specific selectivities, and inclusion of the FIS indices. For the east, there were two additional sensitivities: including the 2014 trawl age frequency; and the exclusion of the period effects in the CPUE indices.

Data weighting

The data weights determined in the 2013 assessment were used. In theory they could be recalculated but they would change little from 2013 because there wasn't much more data.

The ranges for initial sample sizes and the final sample sizes are given below.

Data set	Initial range	Final range
East		
LF trawl	33-82	55-118
LF line	8-78	2-27
LF line (port)	2-10	7-33
AF trawl	45-53	5-6
AF line	33-59	3-7
Age-length trawl	72-707	16-170
Age-length line	57-309	13-76

West		
LF trawl	9-49	8-42
LF trawl (port)	4-29	4-28
LF line	5-40	4-33
Age-length trawl	92-528	23-132
Age-length line	40-370	9-92

MCMC methods

For the east, the base model was taken through to MCMC with three chains being run, each starting from a random jump away from the MPD estimate. The chains did not converge adequately with the first chain in particular being very different from the other two chains. An additional three chains were run and adequate convergence was achieved across the six chains (although the first chain was still different from the other five). However, the trawl selectivity for the period from 1986–1999 (trawl1) was estimated as being flat-topped whereas the trawl selectivities in the two later periods (trawl2, trawl3) were domed. A flat-topped trawl selectivity is contrary to the normal understanding of trawl selection in the east. In addition, the estimate of M at 0.26 with a 95%CI of 0.24-0.28 was considered a bit too high. For these two reasons the model was considered unacceptable.

A further eastern MCMC model was run where flat-topped trawl selectivities were excluded by using an informed prior on the right-hand variance parameter. It was thought that this approach would solve both problems as domed selectivities tend to reduce the need for a high natural mortality (as older fish are hidden rather than being killed).

For each of the three trawl selectivities the right-hand variance parameter was given a broad but informed prior:

Trawl1:	N(mean=15, CV=50%),	bounds: 1–40
Trawl2:	N(mean=10, CV=50%),	bounds: 1–40
Trawl3:	N(mean=10, CV=50%),	bounds: 1–40.

The higher mean for trawl1 was because of the much larger fleet present in that period and the availability of spawning fish (especially compared to the third period when the fleet was much smaller and spawning areas were mainly closed).

Three MCMC chains, starting from random jumps away from the MPD estimate, were run out to just over 3.4 million samples with one in each 1000 samples being retained. The first 400 stored samples were ignored in calculations (as a “burn in”). See Appendix 3 for chain diagnostics.

For the west, three MCMC chains of length over 6 million were run retaining every 1000th sample. The first 400 samples from each chain were discarded as a “burn-in”. The second chain behaved very differently from the other two chains after about 4000 samples had been stored. It went to a space of higher virgin biomass and higher natural mortality (see Appendix 3). The base model estimates were derived from the two consistent chains and the anomalous chain was ignored. This is a pragmatic response to the problem which is justified because the western stock has a very high estimated stock status. That is, refining the western estimates (by running extra/longer/modified chains) will make no difference to consequent management actions.

Estimation of RBC and long-term yield

The generic control rule was applied to each of the 3000 posterior samples assuming that the exploitation rates of the trawl to non-trawl fisheries were maintained in a ratio of 1.1 to 1 (from the MPD estimates in 2010–2013; ignoring the ratios in 2014 and 2015 which were very different given the eastern trip limits and the shift of effort from east to west).

F_{48} was determined by scaling exploitation rates (up or down) until the corresponding long-term equilibrium SSB, under deterministic recruitment, was equal to 48% B_0 (i.e., B_{48}). The estimate of RBC was taken to be the catch in 2016 associated with F_{target} where:

$$
\begin{aligned}
F_{target} &= F_{48} && \text{for } B_{current} \geq B_{35} \\
&= F_{48}\,(B_{current} - 0.2)/0.15 && \text{for } B_{20} < B_{current} < B_{35} \\
&= 0 && \text{for } B_{current} \leq B_{20}.
\end{aligned}
$$

The long-term yield was estimated as the catch associated with F_{48} when the stock reached deterministic equilibrium.

For each sample, deterministic projections were run at different levels of scaled exploitation rates to determine F_{48} and the associated catches, in 2016, and at equilibrium (by linear interpolation). The control rule was then applied to determine the RBC estimate for each member of the chain (and hence to an RBC posterior distribution).

Projections and risk assessment

For the western base model short-term projections (to 2022) were performed for constant catch strategies at 500 t to 900 t per year (assuming 60% of the catch was trawl as in recent years).

For the eastern base model, short-term (to 2022) and long-term projections (to 2050) were performed for constant catch strategies at zero catch and from 300 t to 700 t per year (assuming 68% of the catch is trawl which is the normal average just prior to the imposition of eastern trip limits).

For both stocks, full stochastic projections were used where year class strengths from 2011 onwards were randomly sampled from all estimated YCS. For the eastern stock, short-term projections were also done for a “poor recruitment” scenario where YCS were resampled from the 10 consecutive years with the lowest average recruitment (this happened for 1969–1978, where the average estimated YCS was 0.75).

Eight performance indicators were calculated for each constant catch strategy:

- $E(B_{2017}/B_0)$: mean stock status in 2017
- $E(B_{2022}/B_0)$: mean stock status in 2022
- $P(B_{2017} < 0.2)$: probability that SSB in 2017 is less than 20% B_0
- $P(B_{2022} < 0.2)$: probability that SSB in 2022 is less than 20% B_0
- $P(B_{2017} < 0.3)$: probability that SSB in 2017 is less than 30% B_0
- $P(B_{2022} < 0.3)$: probability that SSB in 2022 is less than 30% B_0
- $P(B_{2017} \geq 0.48)$: probability that SSB in 2017 is at least 48% B_0
- $P(B_{2022} \geq 0.48)$: probability that SSB in 2022 is at least 48% B_0

Also, for the eastern base model, the year in which there was at least a 50% probability of SSB exceeding 48% B_0 was determined for each constant catch strategy. To put the timeframe required to rebuild to the target in context, the mean generation time for ling was calculated: the average age of a mature fish in an unexploited population (assuming $M = 0.24$ and the base-model maturity assumption) – which was 8.8 years.

Results

Eastern stock

Effectiveness of trip limits
When standardizing the eastern trawl CPUE, "period effects" were estimated for time periods when different trip limits were in place (Appendix 1). Also, "landings multipliers" were estimated from the ISMP data for each of the same time periods. The period effects and landings multipliers can be combined to determine the effectiveness of the different trip limits on total removals for a standardized trip.

Suppose a "standard vessel" does a trip with n tows and denote the average landing per tow as L t.

In the absence of a trip limit, discards are minimal and total removals are: $C = nLm_1$ where $m_1 \approx 1.01$ (Appendix 1, Table A1.3).

Under a 50 kg per day trip limit:

total landings = nLp_{50} where $p_{50} \approx 1/1.72$ (1.72 the period effect, Appendix 1)
total removals = $nLp_{50}m_{50}$ where $m_{50} \approx 1.45$ (the landings multiplier, Appendix 1).

Under a 250 kg per day trip limit:

total landings = nLp_{250} where $p_{250} \approx 1/1.25$ (1.25 the period effect, Appendix 1)
total removals = $nLp_{250}m_{250}$ where $m_{50} \approx 1.11$ (the landings multiplier, Appendix 1).

The ratios of the total removals, under each trip limit level, to the total removals under no trip limit are:

50 kg: $p_{50}m_{50} / m_1 \approx 0.83$
250 kg: $p_{250}m_{250} / m_1 \approx 0.88$.

That is, the trip limits are effective in reducing total removals but the 50 kg per day trip limit is barely any more effective than the 250 kg per day trip limit. Both limits affect the behavior of the vessels and reduce landings (the period effects), but the lower trip limit has much greater discarding (the landings multipliers).

MPD results

The trawl CPUE is fitted very well by the model including the recent upward trend (Figure 3). Fits to length and age frequencies are generally good (see Appendix 2). As expected females are estimated to be larger at age than males (Figure 4). The trawl selectivities for each of the three time periods are all estimated to be domed while the non-trawl selectivities are forced to be flat-topped (Figure 5). Year class strength (YCS) estimates are between 0.5 and 2 except in 1977 (weak) and 1992, 1996 (strong)(Figure 6). The estimated stock status trajectory steadily trends downward to reach 20% B_0 in 2010 before increasing to almost 30% B_0 (Figure 7).

The MPD estimates are most sensitive to the treatment of natural mortality (M) (Table 1, Figure 8). As M increases the estimates of virgin SSB (B_0) decrease, while current SSB (B_{2015}), and current stock status (B_{2015}/B_0) increase. The MPD estimates of current stock status from all the runs (except EstM1 where M hit the upper bound) are bounded by the Low M and High M runs (Table 1, Figure 8).

Table 1: Eastern base and sensitivities, MPD: estimates of natural mortality (*M*), virgin SSB (B_0), current SSB (B_{2015}), and current stock status ($ss_{2015} = B_{2015}/B_0$). Natural mortality was estimated in every run except for: Fixed M, Low M, and High M. The prior was taken from the western posterior for *M* except for the run EstM1 (where a much broader prior was used and the estimate hit the upper bound*). The high and low values in each column are highlighted (ignoring run EstM1).

	M	B_0 (t)	B_{2015} (t)	ss_{2015} (% B_0)	Prior on *M*
Base	0.24	5420	1540	29	N(0.23,CV=0.06)
Fixed M	0.24	5500	1530	28	None
Low M	0.20	6920	1350	20	None
High M	0.28	4700	1720	37	None
Low sigmaR (0.5)	0.25	5450	1580	29	N(0.23,CV=0.06)
High sigmaR (0.8)	0.24	5390	1530	28	N(0.23,CV=0.06)
Maturity – 1 year	0.24	5860	1890	32	N(0.23,CV=0.06)
Maturity + 1 year	0.24	4920	1240	25	N(0.23,CV=0.06)
CPUE CV=0.1	0.24	5380	1550	29	N(0.23,CV=0.06)
Effective N × 2	0.24	5540	1480	27	N(0.23,CV=0.06)
Sex-specific sels.	0.24	5480	1560	28	N(0.23,CV=0.06)
FIS indices	0.24	5400	1570	29	N(0.23,CV=0.06)
No period effs.	0.24	5310	1370	26	N(0.23,CV=0.06)
Plus 2014 comp.	0.24	5400	1530	28	N(0.23,CV=0.06)
EstM1	0.35*	4210	2240	53	N(0.20,CV=0.20)

The MPD estimates of *M* are a little higher than for the western stock which had MPD estimates of 0.22 for the base and 0.23 for some sensitivities (see Table ?). However, the estimates were constrained by a relatively tight prior N(0.23, CV=0.06) which was taken from the western posterior. The tight prior was used because without such help the estimate of *M* went off to the upper bound of 0.35 (Table 1). That run had not found the minimum because with a uniform prior it appears that the MPD estimate of *M* is at about 0.31 although the profile is very flat (Figure 9). The driver of high *M*s is the trawl age-length data (Figure 9). This is not an ideal source of information for *M* because of the domed selectivity (although under the assumptions of the model the selectivity and *M* are not actually confounded).

MCMC results

The original base model had a flat-topped selectivity for the trawl fishery up to 1999 and then switched to domed selection. This was in contrast to the MPD results (all domed selection) and as a consequence the MCMC model showed much higher current stock status than estimated in the MPD. In the final base model, the mean and shape of the priors on the selectivity right-hand variance parameters, combined with the upper bounds, ensured that the posterior could not include any flat-topped selectivities (Figure 10).

The MCMC estimate of *M* is 0.245 with a fairly tight 95% CI (Table 1). Virgin SSB is estimated of the order of 5400 t and current SSB at about 1600 t with stock status from about 20–45% B_0 (Table 2). When *M* is fixed at 0.23 (the median estimate in the west) a higher virgin biomass is estimated with a lower current stock status (Table 2)

Table 2: Eastern base, MCMC: estimates of *M*, virgin SSB, current SSB, and current stock status. The median and 95% CI are given. Also shown are the probabilities of current stock status being below 20% B_0, 30% B_0, or being at or above the target of 48% B_0.

	M	B_0 (t)	B_{2015} (t)	$ss_{2015}(\%B_0)$	P(ss_{2015} < 0.2)	P(ss_{2015} < 0.3)	P(ss_{2015} ≥ 0.48)
Base	0.245	5400	1590	30			
	0.22–0.26	4860–6330	1130–2600	21–45	0.01	0.46	0.01
M=0.23	0.23	5860	1540	26			
	0.23–0.23	5500–6300	1130–2140	20–35	0.03	0.82	0.00

Two selectivities were estimated for the non-trawl fishery for port and at-sea sampling but they were quite similar (Figure 11). The three trawl selectivities were estimated to be domed as expected (Figure 12). The priors encouraged the selectivity in the first period to be less domed than those in the other two periods but this has not been translated into the posteriors (Figure 12).

The estimated year class strengths (YCSs) do not show any extreme values except for a weak cohort in 1977 (Figure 13). There were two strong cohorts in 1992 and 1996 (Figure 13).

Application of the generic harvest control rule to the MCMC samples allowed the Bayesian estimation of the associated RBC and long-term yield. The RBC in 2016 is extremely uncertain because estimated stock status almost spans the range from 20% B_0 (F = 0) to above 35% B_0 ($F = F_{48}$) (Table 3). Long-term yield appears to well estimated at a bit below 600 t (Table 3).

Table 3: Eastern base, MCMC: estimates of RBC and deterministic long-term yield for the generic harvest control rule.

	RBC (t)	Long-term yield (t)
Median	250	580
95% CI	30–630	540–640

The estimated RBC is just 250 t, but it is only of academic interest as the RBC is so poorly estimated. In any case, it is inappropriate to base management advice on the output from a generic control rule when a full Bayesian assessment is available to perform a risk analysis.

MCMC constant catch projections

For the base model, the projections suggest that catches up to 550 t pose little risk of the SSB going below 20% B_0 in the next few years (Table 3). However, for constant catches of about 550 t per year or higher, the rebuild year (the year in which there is at least a 50% probability of being above 48% B_0) goes out beyond 2050 (Table 4).

Under the poor recruitment scenario (cohorts from 2011 onwards being resampling from the 1969 to 1978 YCS which had an average YCS of 0.75), there is more than a 10% risk of the stock going below 20% B_0 as early as 2017 for catches above 450 t (Table 5). However, there is no reason to believe that average YCS would be as low as that estimated from 1969 to 1978 because *recent* average YCS has been at about 0.95 (Figure 14).

Table 3: MCMC projection results for the new base model showing the expected SSB in 2017 and 2022 under different constant catch scenarios with the associated probabilities of being below 20% or 30% B_0 and at or above the target of 48% B_0.

Catch (t)	E(B_{17}/B_0)	E(B_{22}/B_0)	P(ss_{17} < 0.2)	P(ss_{22} < 0.2)	P(ss_{17} < 0.3)	P(ss_{22} < 0.3)	P(ss_{17} ≥ 0.48)	P(ss_{22} ≥ 0.48)
0	38	63	0.00	0.00	0.13	0.00	0.10	0.92
300	35	48	0.01	0.00	0.26	0.03	0.06	0.48
400	33	43	0.02	0.01	0.38	0.12	0.05	0.31
500	31	38	0.04	0.04	0.48	0.25	0.03	0.18
550	30	35	0.07	0.08	0.54	0.35	0.02	0.13
600	29	32	0.09	0.13	0.56	0.44	0.02	0.09
700	27	27	0.15	0.28	0.68	0.64	0.01	0.04

Table 4: Rebuild years for the new base model under different constant catch scenarios.

Catch (t)	Rebuild year
0	2020
300	2023
400	2026
500	2036
550	>2050
600	>2050
700	>2050

Table 5: MCMC projection results for the new base model with "poor recruitment" showing the expected SSB in 2017 and 2022 under different constant catch scenarios with the associated probabilities of being below 20% or 30% B_0 and at or above the target of 48% B_0.

Catch (t)	E(B_{17}/B_0)	E(B_{22}/B_0)	P(ss_{17} < 0.2)	P(ss_{22} < 0.2)	P(ss_{17} < 0.3)	P(ss_{22} < 0.3)	P(ss_{17} ≥ 0.48)	P(ss_{22} ≥ 0.48)
0	35	50	0.00	0.00	0.27	0.01	0.05	0.55
300	32	36	0.03	0.05	0.45	0.29	0.03	0.11
400	30	31	0.07	0.14	0.57	0.51	0.02	0.05
450	29	28	0.09	0.21	0.62	0.61	0.01	0.03
500	28	25	0.14	0.32	0.67	0.71	0.01	0.02
550	27	23	0.17	0.40	0.71	0.78	0.00	0.01

For the "worst case" scenario of $M = 0.23$, the projections suggest that catches up to 500 t pose little risk of the SSB going below 20% B_0 in the next few years and SSB is likely to increase over the period (Table 4).

Table 4: MCMC projection results for M = 0.23 showing the expected SSB in 2017 and 2022 under different constant catch scenarios with the associated probabilities of SSB increasing or being below 20%.

Catch (t)	E(B_{17}/B_0)	E(B_{22}/B_0)	P(ss_{17} > ss_{15})	P(ss_{22} > ss_{15})	P(ss_{17} < 0.2)	P(ss_{22} < 0.2)
0	35	59	1.00	1.00	0.00	0.00
300	32	45	0.96	0.99	0.01	0.00
400	30	40	0.87	0.96	0.03	0.01
500	28	34	0.71	0.84	0.06	0.06
550	27	32	0.63	0.75	0.09	0.10

Western stock

MPD results

The trawl CPUE is not fitted well by the model as the fit does not extend to the main peak or the main trough, although it does fit the recent upward trend (Figure 16). Fits to length and age frequencies are generally good (see Appendix 2). As expected females are estimated to be larger at age than males (Figure 17). The trawl selectivities for the two time periods are estimated to be only slightly domed and the port-sampled trawl selectivity is very domed; while the non-trawl selectivity was forced to be flat-topped (Figure 18). Year class strength (YCS) estimates are between 0.5 and 2 except in 1999 (weak) and 1991 (strong)(Figure 19). Good recruitment is estimated to be feeding into the fisheries and SSB from the 2008 and 2009 YCS (Figure 19). The stock status trajectory is estimated to have always been above the target of 48% B_0 (Figure 20).

The MPD estimates are most sensitive to the treatment of M (Table 5, Figure 21). As M increases so do the estimates of virgin SSB (B_0), current SSB (B_{2015}), and current stock status (B_{2015}/B_0). The MPD estimates of current stock status from all the runs are bounded by the Low M and High M runs (Table 5, Figure 21).

Table 5: Western base and sensitivities, MPD: estimates of natural mortality (M), virgin SSB (B_0), current SSB (B_{2015}), and current stock status ($ss_{2015} = B_{2015}/B_0$). Natural mortality is estimated in every run except for: Fixed M, Low M, and High M. An informed but broad prior was used for M: N(mean=0.2, CV=0.2). The high and low values in each column are highlighted.

	M	B_0 (t)	B_{2015} (t)	ss_{2015} (% B_0)
Base	0.22	5110	3630	71
Fixed M	0.24	5380	4090	76
Low M	0.20	4970	3130	63
High M	0.28	7100	6390	90
Low sigmaR (0.5)	0.23	5410	3960	73
High sigmaR (0.8)	0.22	5010	3510	70
Maturity – 1 year	0.22	5660	4180	74
Maturity + 1 year	0.23	4530	2970	66
CPUE CV=0.1	0.23	4990	3620	72
Effective N × 2	0.22	5060	3410	67
Sex-specific sels.	0.23	5140	3730	72
FIS indices	0.23	5340	4150	78

MCMC estimates

The MCMC results were derived from chains 1 and 3 combined with chain 2 being ignored. This means that the higher virgin biomass-natural mortality space found by chain 2 was ignored. It would be possible, with enough resources, to eventually achieve convergence over the full space but when stock status is estimated at around 70% B_0 it hardly matters that this is perhaps somewhat of an underestimate.

The MCMC estimate of M is 0.23 but there is quite a broad 95% CI (Table 6). Virgin SSB is estimated of the order of 5500 t and current SSB at about 4000 t with stock status from about 60–90% B_0 (Table 6). As an alternative to using just chains 1 and 3, if all three chains are used, up until the point that chain 2 went off to the alternative space, then the MCMC estimates are almost identical to the base (Table 6).

Table 6: MCMC estimates of *M*, virgin SSB, current SSB, and current stock status. The median and 95% CI are given. Also shown are the probabilities of current stock status being below 20% B_0, 30% B_0, or being at or above the target of 48% B_0.

	M	B_0 (t)	B_{2015} (t)	$ss_{2015}(\%B_0)$	P(ss_{2015} < 0.2)	P(ss_{2015} < 0.3)	P(ss_{2015} ≥ 0.48)
Base	0.23	5510	4050	73			
	0.20–0.26	4460–6780	2720–5760	59–87	0.00	0.00	1.00
3 chains (all stopped	0.23	5520	4000	72			
at sample 4400)	0.20–0.26	4470–6780	2550–5750	56–87	0.00	0.00	1.00
Chain 2 (samples	0.26	7770	6690	86			
4401–6346)	0.24–0.28	6170–8540	4900–7860	78–96	0.00	0.00	1.00

Three selectivities were estimated for the trawl fishery and one for the non-trawl fishery (Figure 22). The two at-sea selectivities (one for an early period, one for a later period) are very similar and fairly flat topped (Figure 22). The port-sampling trawl selectivity has similar initial selection but takes fewer older fish (perhaps being related to the type of vessels that are sampled at port rather than at sea in the west). The non-trawl selectivity was forced to be flat topped and, as expected, shows fish being first selected at an older age than for the trawl fishery (Figure 22).

The estimated year class strengths (YCSs) do not show any extreme values with lows no worse than about 0.4 and highs no greater than about 2 (Figure 23). There was a period of good recruitment in the early 1990s and two of the most recent estimated YCSs are above average (2008 and 2009, Figure 23). The 2008 and 2009 cohorts are almost fully recruited into the fisheries and into the SSB and contribute to the recent acceleration of an upward trend (Figure 24).

Application of the generic harvest control rule to the MCMC samples allowed the Bayesian estimation of the associated RBC and long-term yield. The RBC in 2016 is higher than the long term yield because of the high current stock status and good recent recruitment (Table 7).

Table 7: MCMC estimates of RBC and deterministic long-term yield for the generic harvest control rule.

	RBC (t)	**Long-term yield (t)**
Median	990	680
95% CI	640–1590	530–950

MCMC constant catch projections

Constant catch projections, with recruitment resampled from all estimated YCS, were performed for the base MCMC model (Table 8). Total catches were assumed to be 60% trawl and 40% non-trawl (in 2013 and 2014 respectively it was 66% and 55%). For annual catches up to 900 t, SSB is expected to be above the target and there is little or no risk of projected SSB being below 30% B_0 up to and including the year 2022 (Table 8).

Table 8: MCMC projection results showing the expected SSB in 2017 and 2022 under different constant catch scenarios with the associated probabilities of being below 20% or 30% B_0 and at or above the target of 48% B_0.

Catch (t)	**E(B_{17}/B_0)**	**E(B_{22}/B_0)**	**P(ss_{17} < 0.2)**	**P(ss_{22} < 0.2)**	**P(ss_{17} < 0.3)**	**P(ss_{22} < 0.3)**	**P(ss_{17} ≥ 0.48)**	**P(ss_{22} ≥ 0.48)**
500	72	68	0.00	0.00	0.00	0.00	1.00	0.95
600	70	64	0.00	0.00	0.00	0.00	0.99	0.90
700	69	59	0.00	0.00	0.00	0.01	0.99	0.80
800	68	56	0.00	0.00	0.00	0.03	0.99	0.71
900	67	52	0.00	0.01	0.00	0.06	0.98	0.59

Conclusions

For the eastern stock, current stock status is estimated at 30% B_0 with a 95% CI of 21–45% B_0. The uncertainty in estimated stock status was amplified in the estimation of RBC which is estimated at 250 t with a 95% CI of 30–630 t. Long-term yield is estimated at 540–640 t (95% CI).

According to projections from the base model there is little risk to the stock over the next few years for total removals up to 550 t per year. For the "worst case" scenario (M = 0.23), total removals up to 500 t per year pose little risk. Higher risks are estimated if stochastic recruitment is drawn from the lowest 10 consecutive YCSs. I would give little or no weight to that run as recent YCS are about average and there is no reason to believe that we will move into a temporary regime shift where average recruitment is 75% of what we can normally expect. The risks seen in the base model are primarily generated by sequences of poor YCS – those results answer the question "what happens if we get poor recruitment?" and also provide an estimate of the probability of such a thing happening.

The base model projections suggest that the stock can be rebuilt to 48% B_0 within one mean generation time (8.8 years) when total removals are 300 t per year. If two mean generation times are allowed for the rebuild then total removals can be 400–500 t per year.

For the western stock, current stock status is estimated at 73% B_0 with a 95% CI of 59–87% B_0. RBC is estimated at 990 t with a 95% CI of 640–1590 t. Long-term yield is estimated at 530–950 t (95% CI). Stochastic projections show little or no risk to the stock in the next few years for total removals up to 900 t per year.

Acknowledgements

This work was funded by AFMA. Thanks to CSIRO for providing raw and processed catch, effort, discard, and composition data. Also, the stock assessment package CASAL was developed by NIWA who hold copyright to the product but make it freely available for use by others (Bull et al. 2012).

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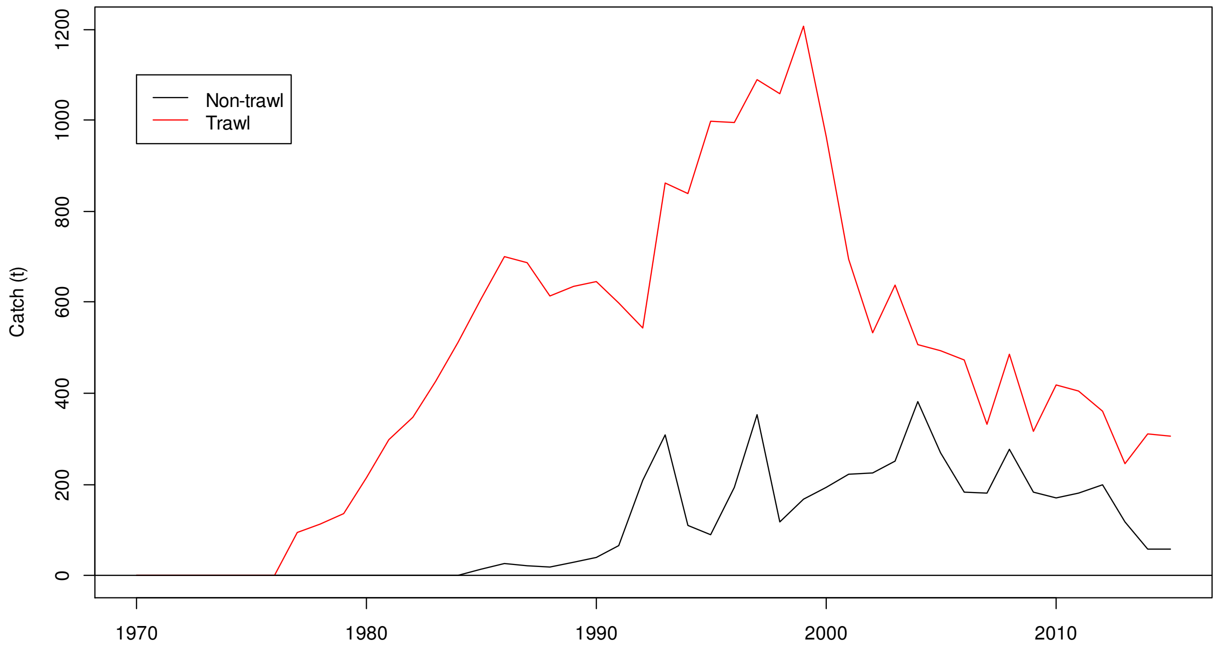

Figure 1: Eastern base model: catch history for the trawl and non-trawl fisheries by calendar year.

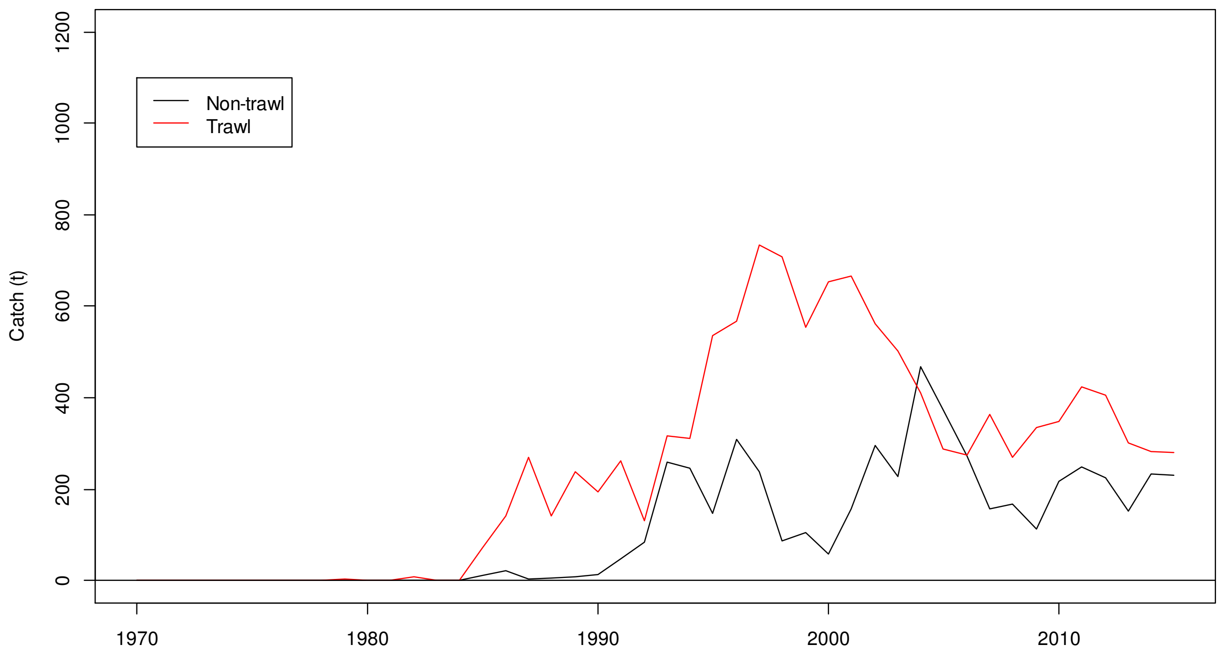

Figure 2: Western base model: catch history for the trawl and non-trawl fisheries by calendar year.

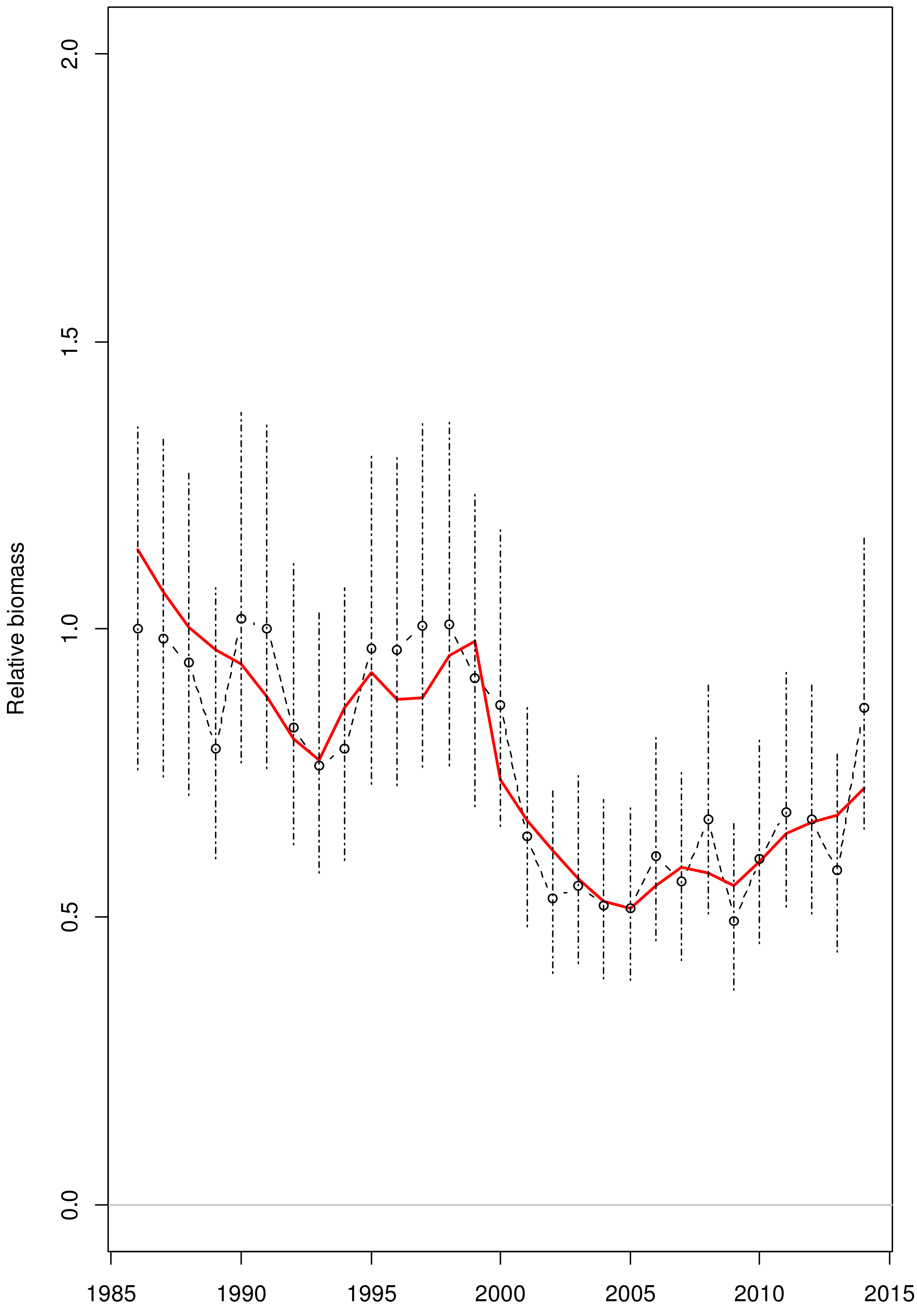

Figure 3: Eastern base model: MPD fit to the trawl CPUE indices. The open circles are the indices and the dashed vertical lines are 95% confidence intervals (assuming a lognormal distribution and a CV of 15% for each index).

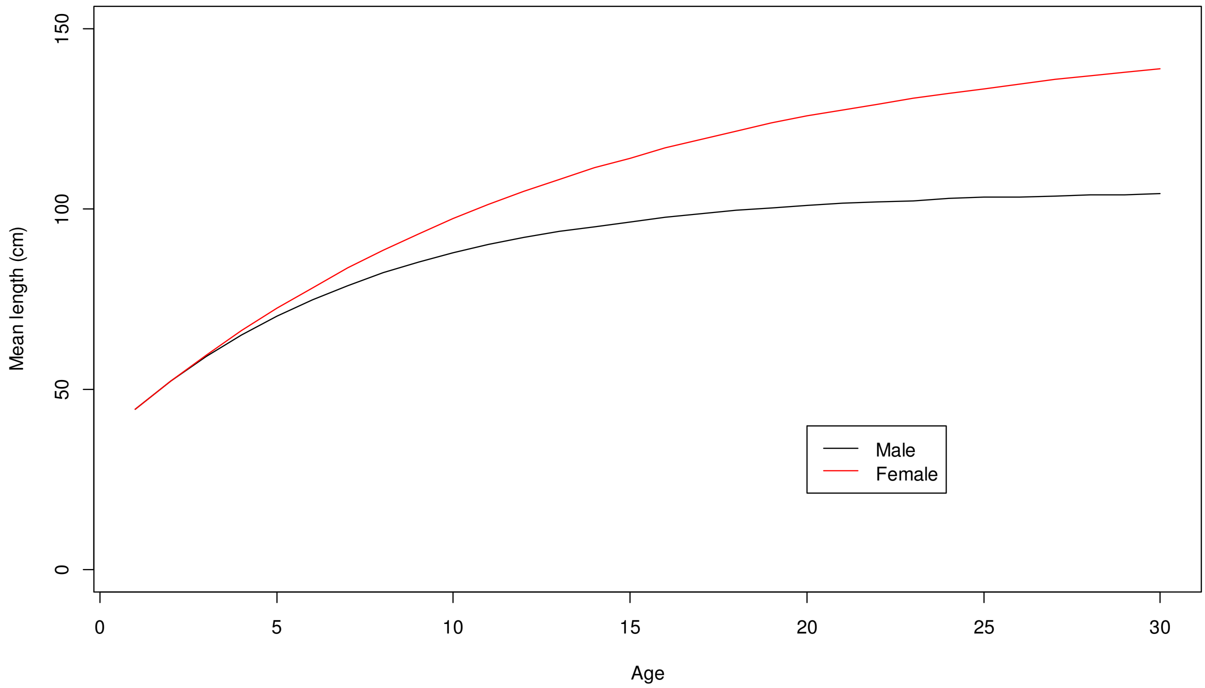

Figure 4: Eastern base model: MPD estimates of male and female growth curves.

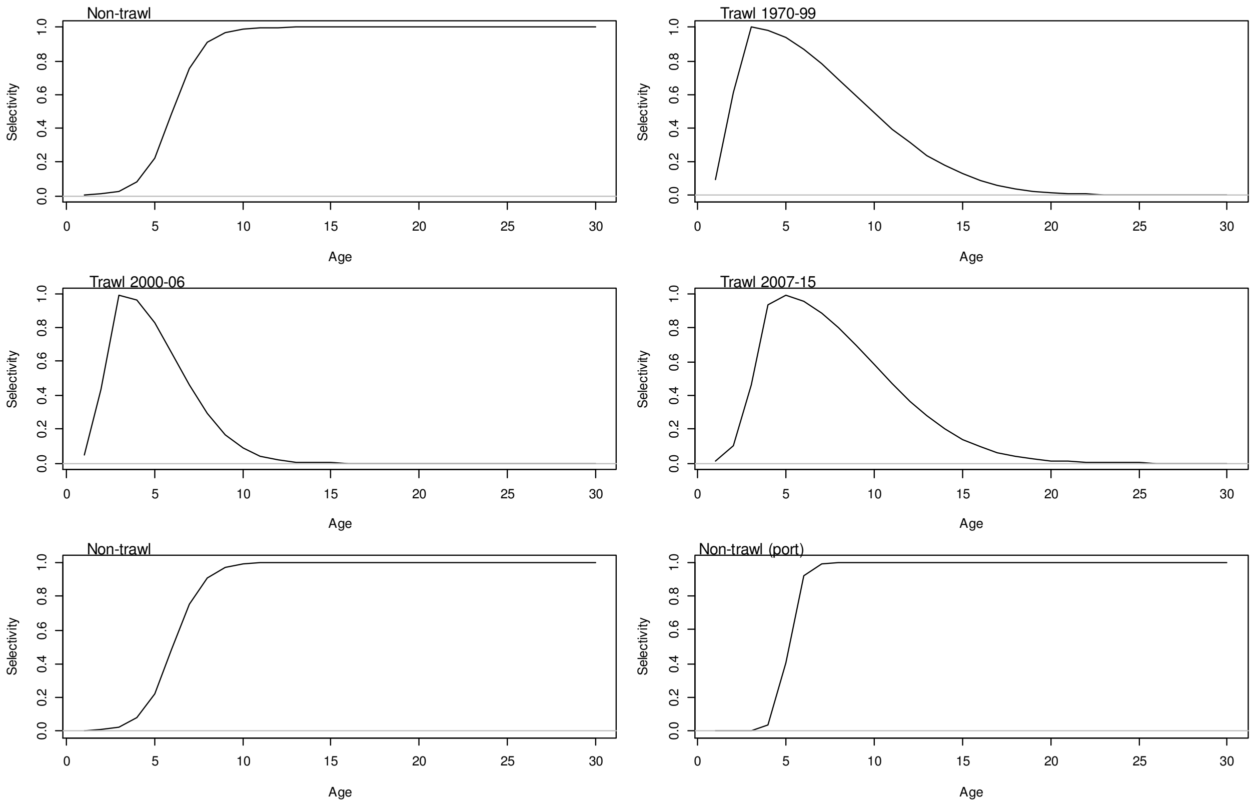

Figure 5: Eastern base model: MPD estimates of fishery selectivities. Non-trawl shown twice to allow easier comparison with non-trawl port.

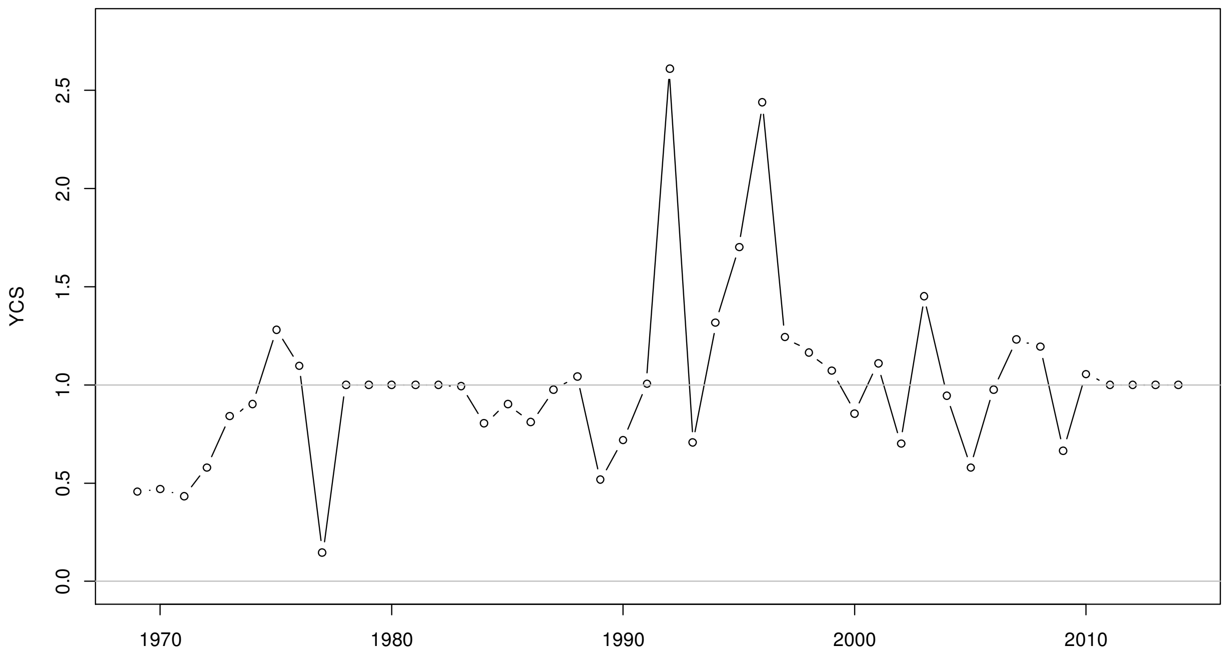

Figure 6: Eastern base model: MPD estimates of year class strength (YCS).

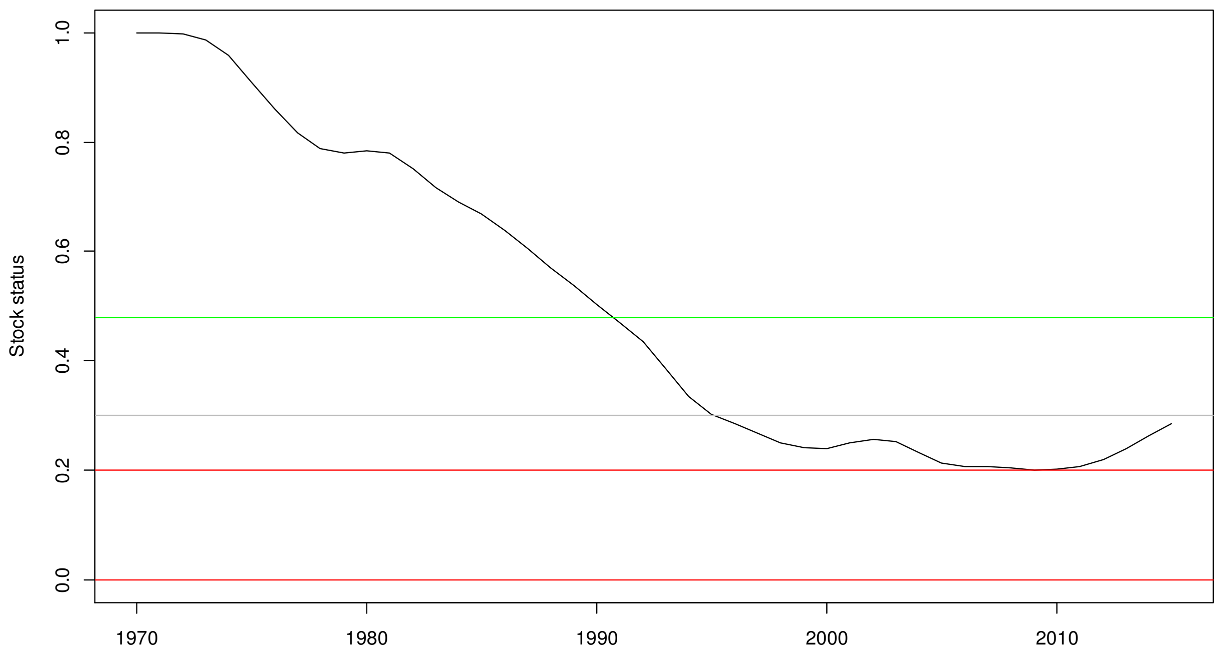

Figure 7: Eastern base model: MPD stock status trajectory. Horizontal lines are plotted at the limit reference point (0.2, red), the target (0.48, green), and at 0.3 (grey).

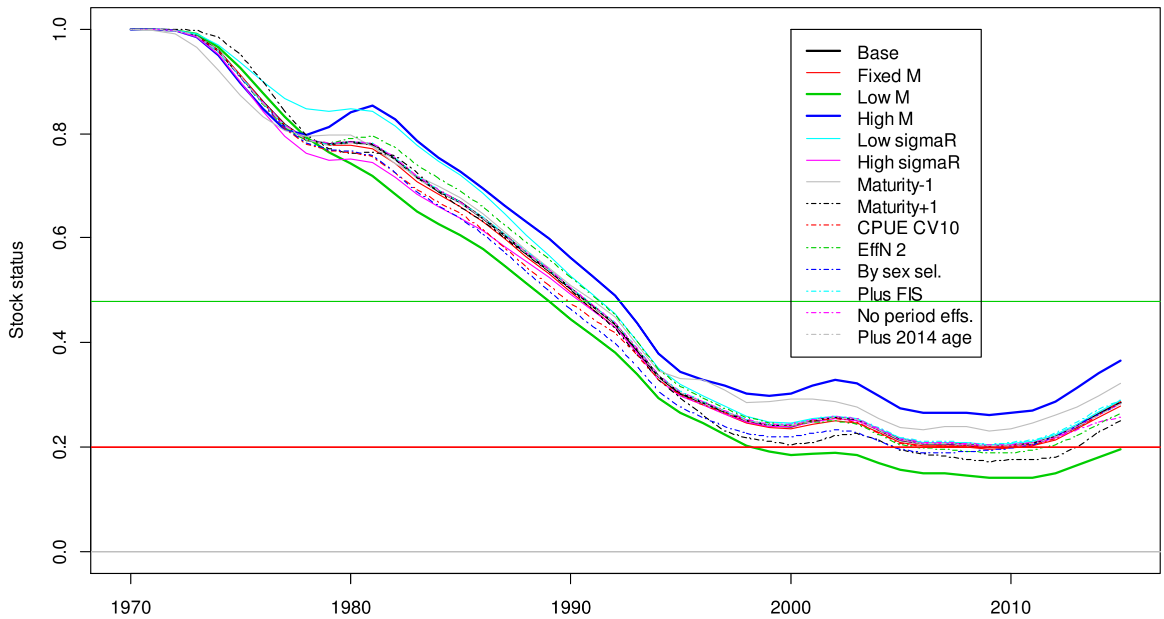

Figure 8: Eastern base model and sensitivities: MPD stock status trajectories. Horizontal lines are plotted at the limit reference point (0.2, red) and the target (0.48,green).

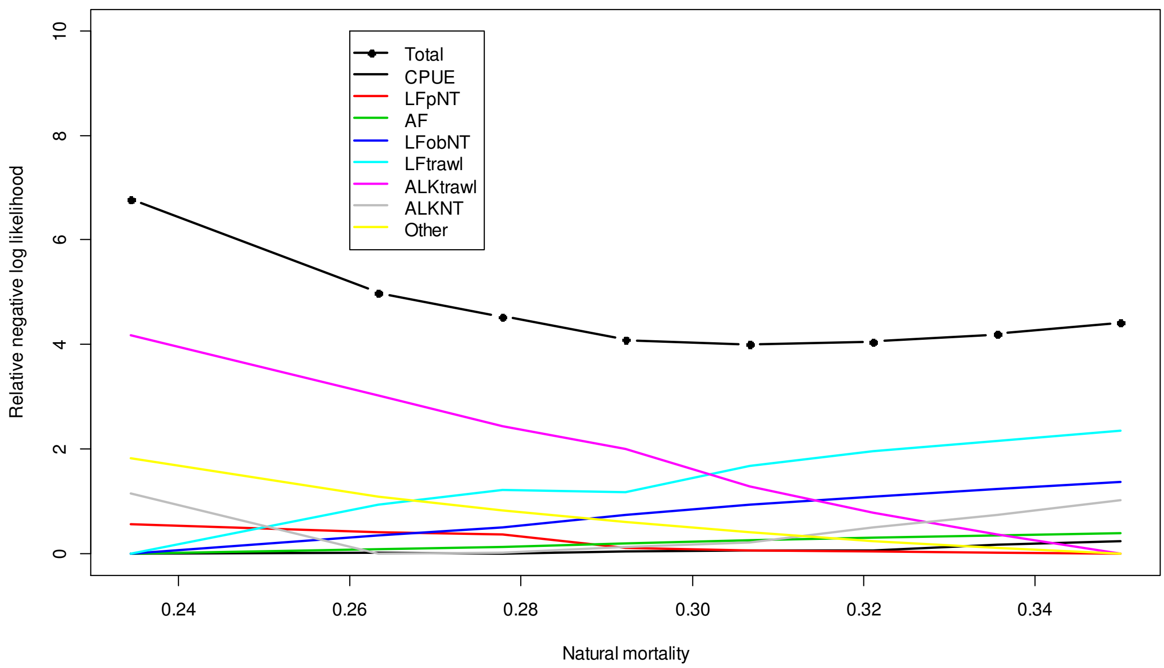

Figure 9: Eastern model: likelihood profile for M when estimated with a uniform prior. The total objective function is very flat for $M > 0.29$.

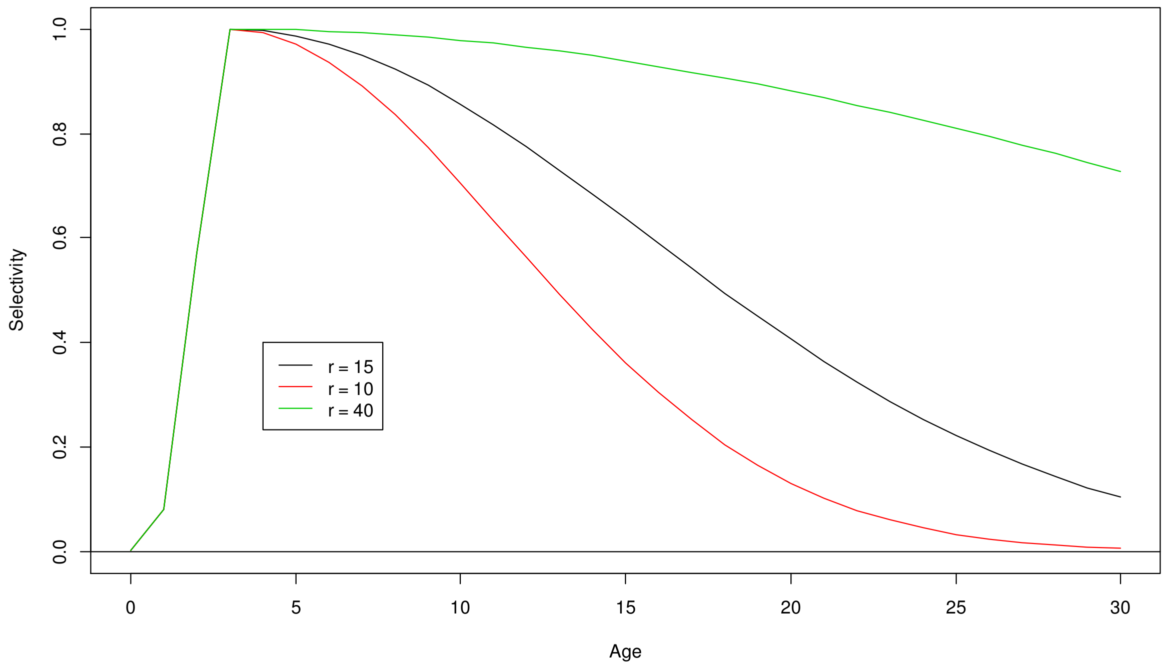

Figure 10: Eastern base model, MCMC: double normal selectivities illustrating the effect of the right-hand variance parameter *r* = 10, 15, 40. Values of *r* = 10, 15 were used as the mean of the normal prior for the trawl selectivities and the priors had upper bounds of 40.

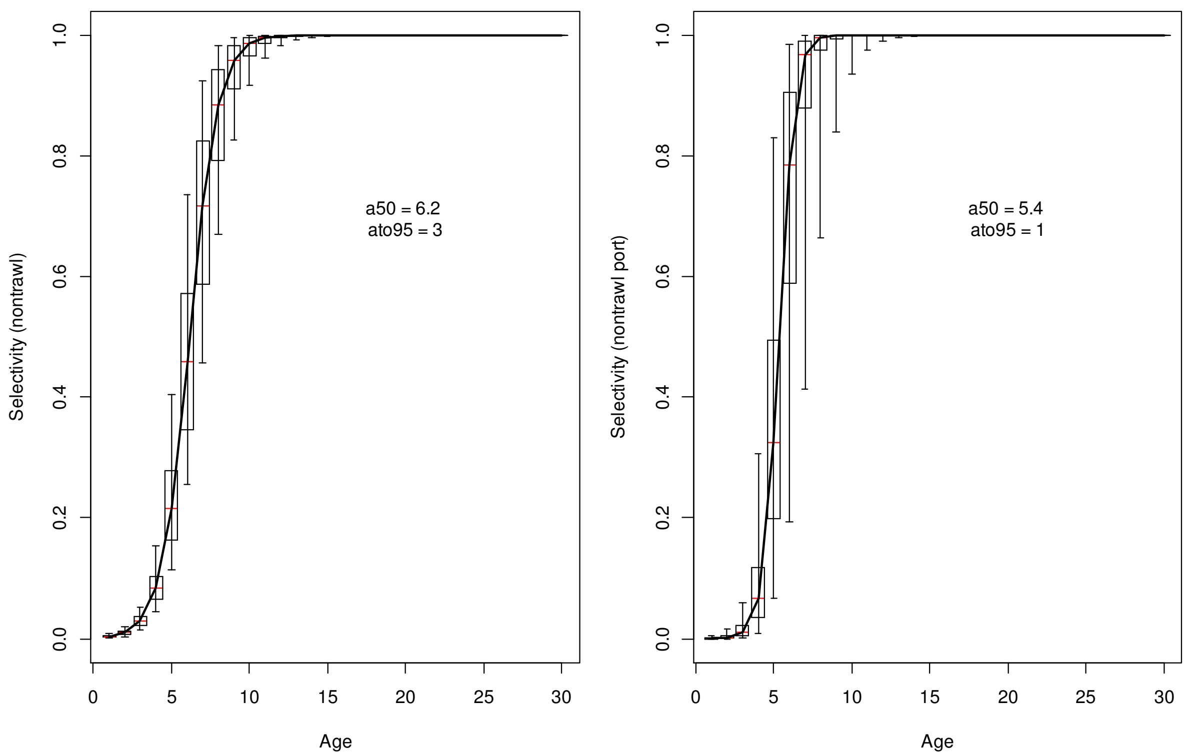

Figure 11: Eastern base model, MCMC: estimated non-trawl fishery selectivities. The box covers the middle 50% of the samples and the whiskers extend to 95% CIs.

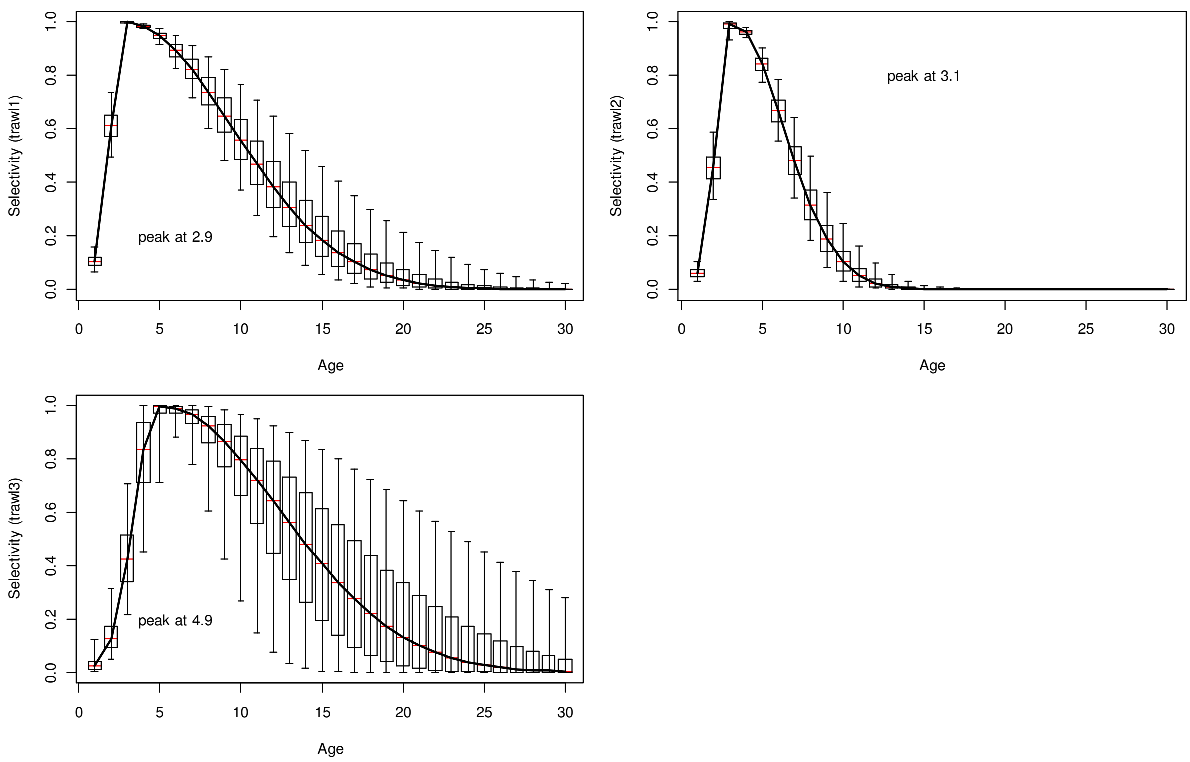

Figure 12: Eastern base model, MCMC: estimated trawl fishery selectivities. The box covers the middle 50% of the samples and the whiskers extend to 95% CIs.

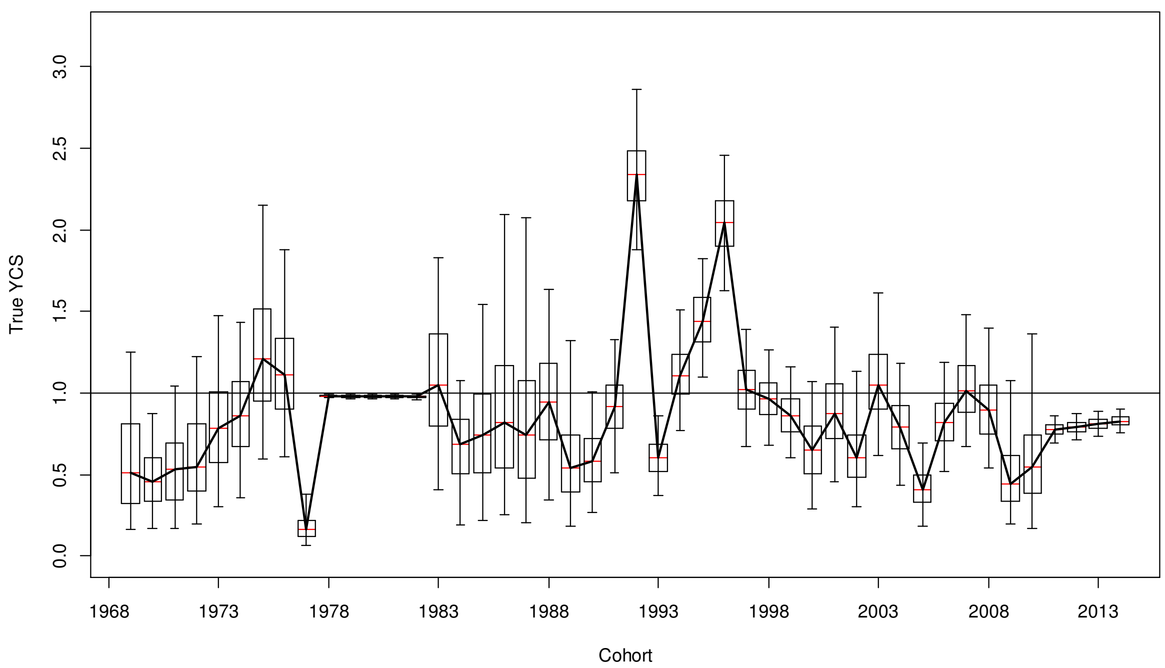

Figure 13: Eastern base model, MCMC: estimated "true" year class strengths (YCS). "True" YCS are recruitment numbers divided by virgin recruitment (i.e., includes the effect of the stock recruitment relationship). The box covers the middle 50% of the samples and the whiskers extend to 95% CIs.

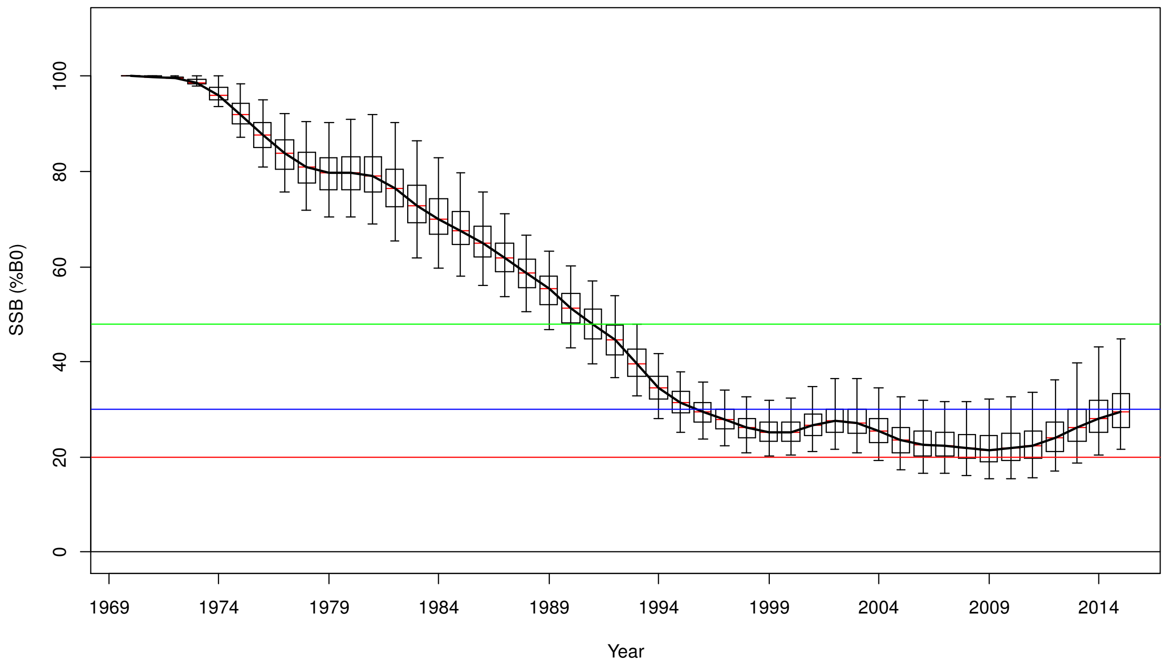

Figure 14: Eastern base model, MCMC: stock status trajectory. The box covers the middle 50% of the samples and the whiskers extend to 95% CIs. Horizontal lines are plotted at 20%, 30%, and 48% B_0.

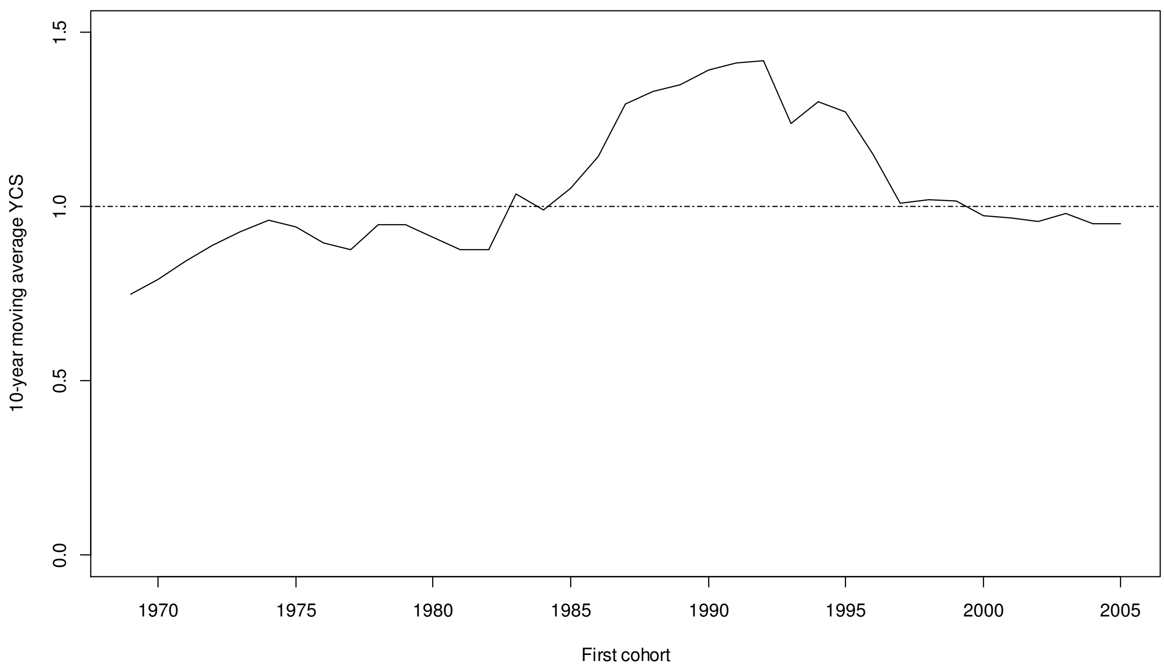

Figure 15: Eastern base model, MCMC: a 10-year moving average for the estimated YCS. The 10-year average YCS is plotted against the first cohort used in the average.

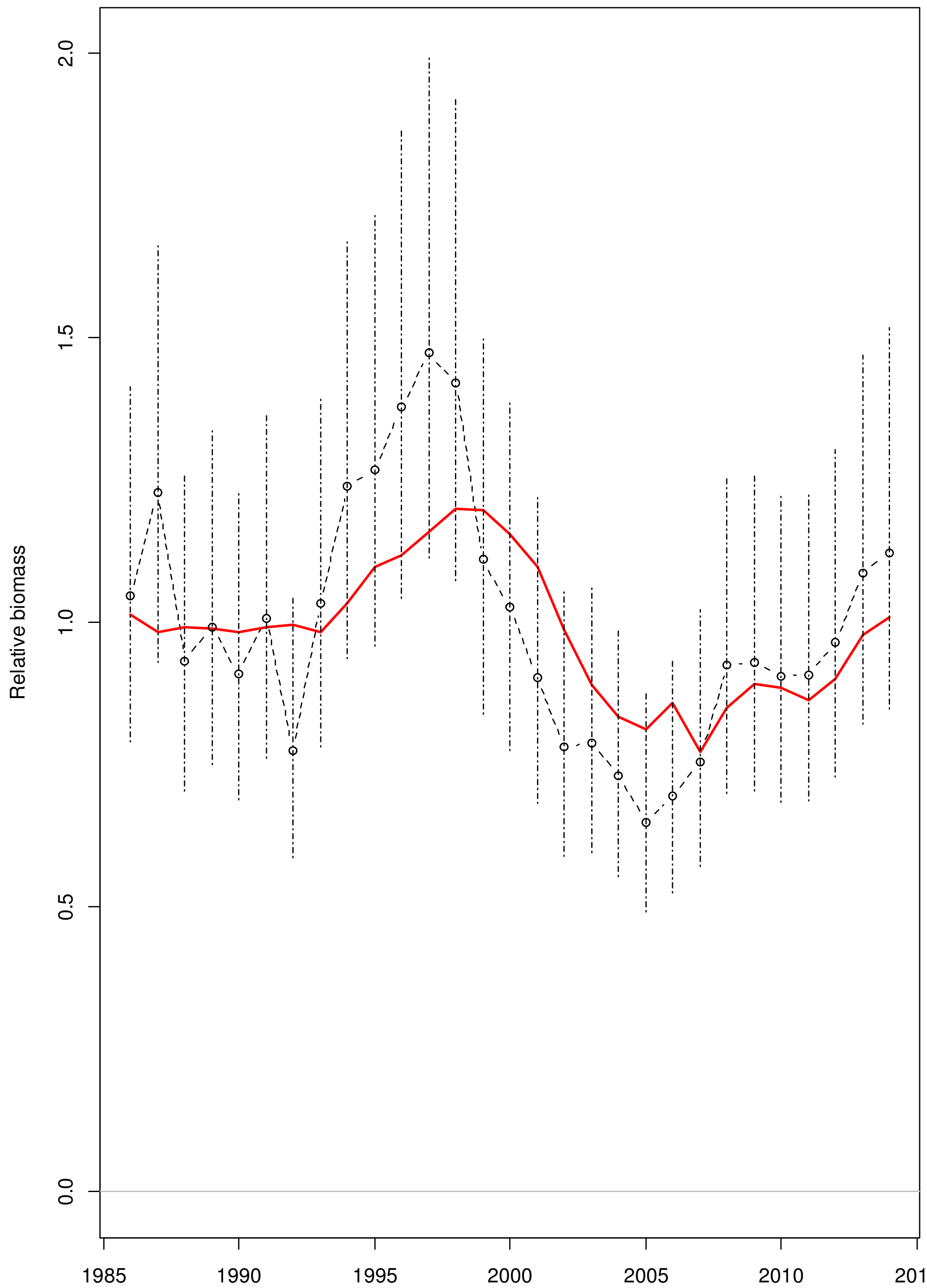

Figure 16: Western base model: MPD fit to the trawl CPUE indices. The open circles are the indices and the dashed vertical lines are 95% confidence intervals (assuming a lognormal distribution and a CV of 15% for each index).

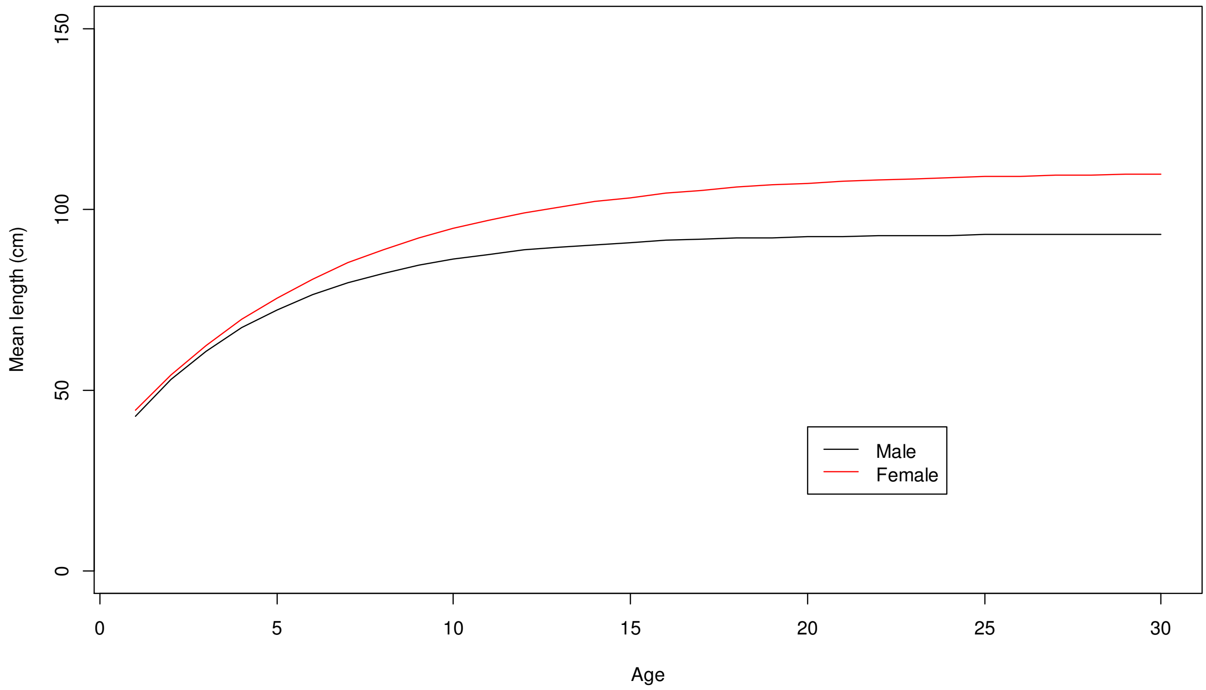

Figure 17: Western base model: MPD estimates of male and female growth curves.

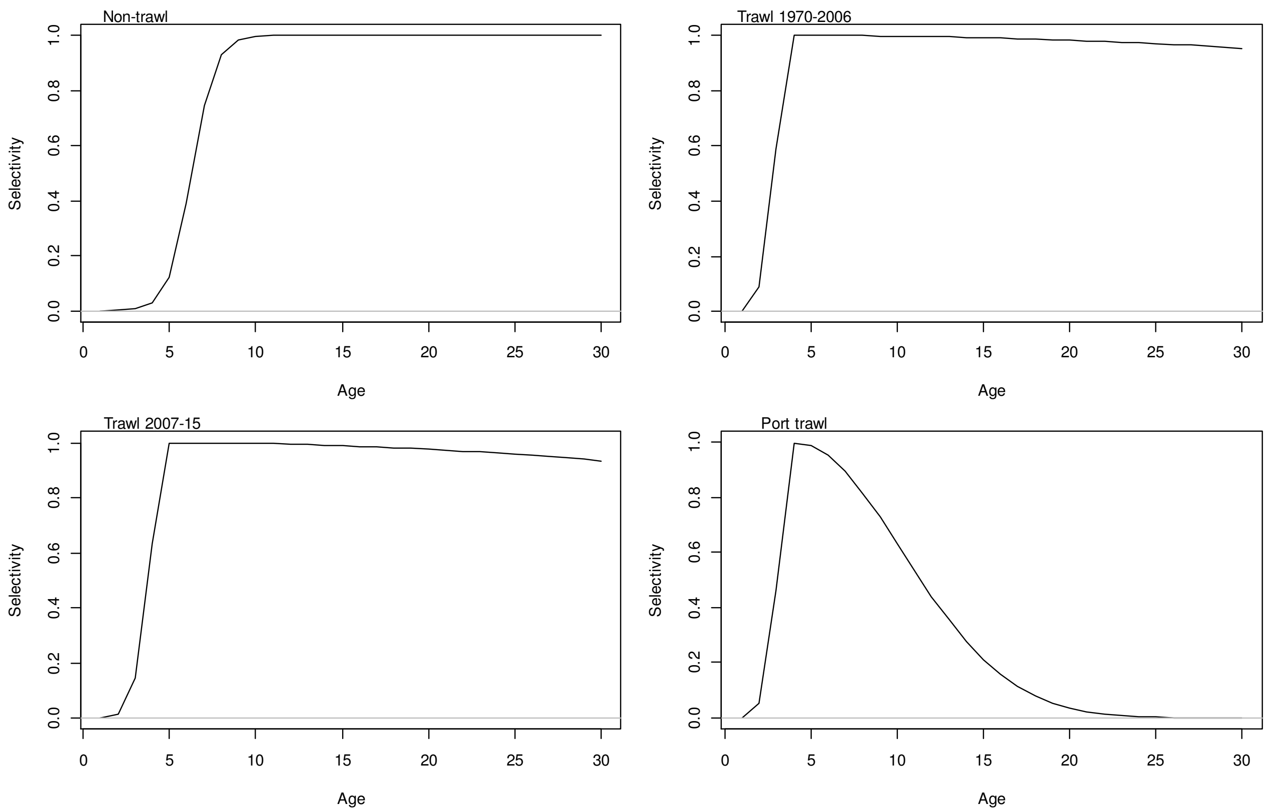

Figure 18: Western base model: MPD estimates of fishery selectivities.

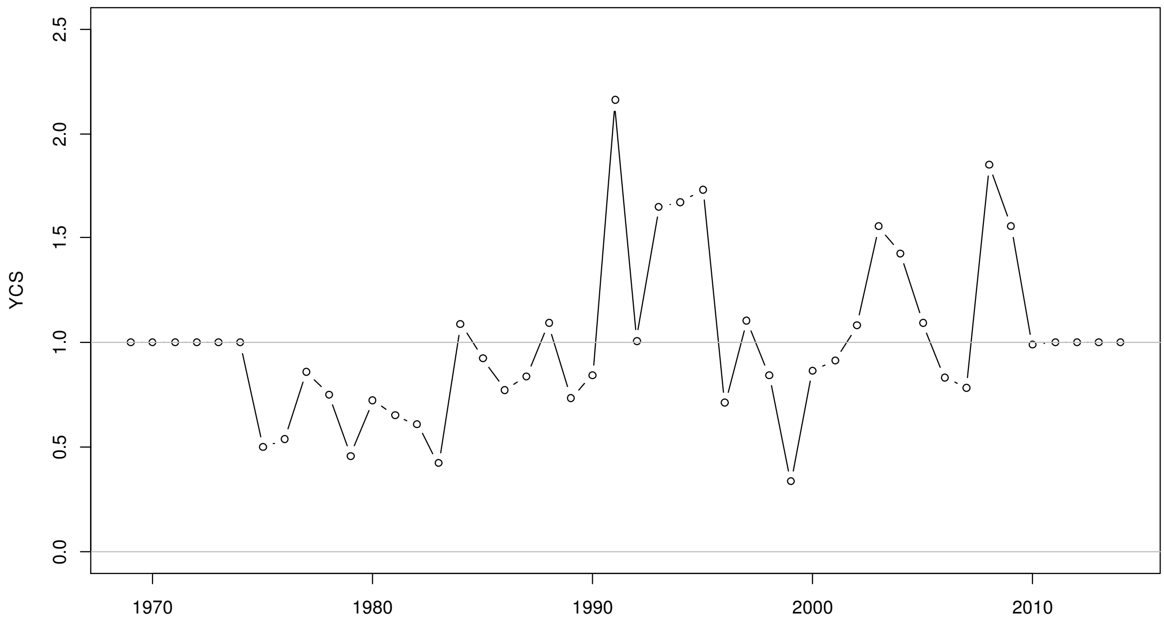

Figure 19: Western base model: MPD estimates of year class strength (YCS).

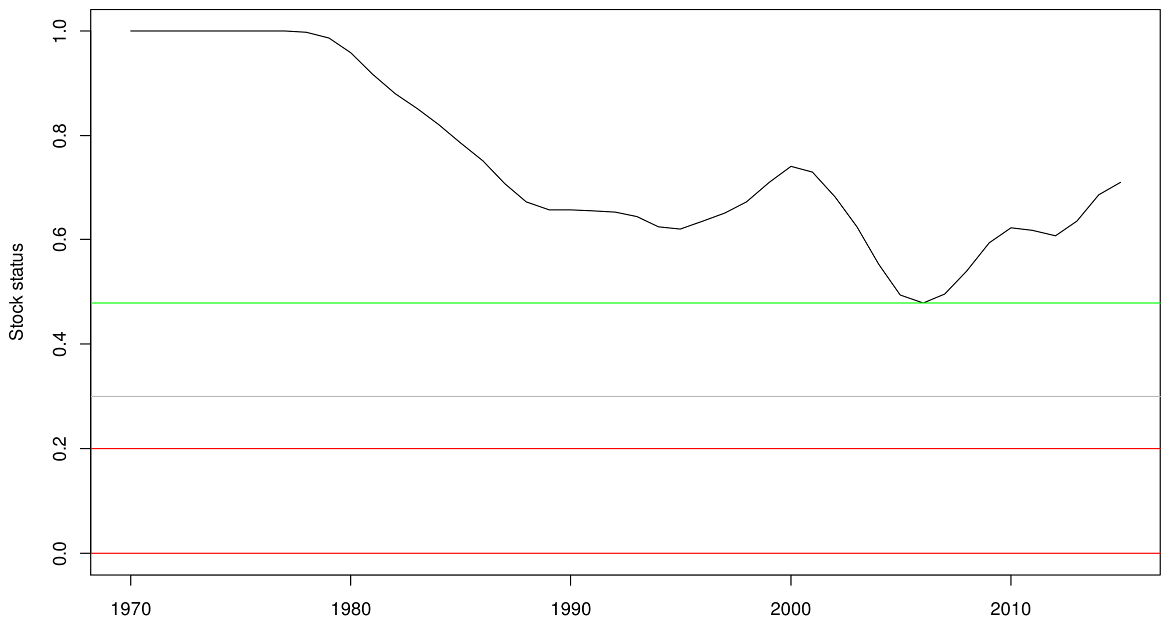

Figure 20: Western base model: MPD stock status trajectory. Horizontal lines are plotted at the limit reference point (0.2, red), the target (0.48, green), and at 0.3 (grey).

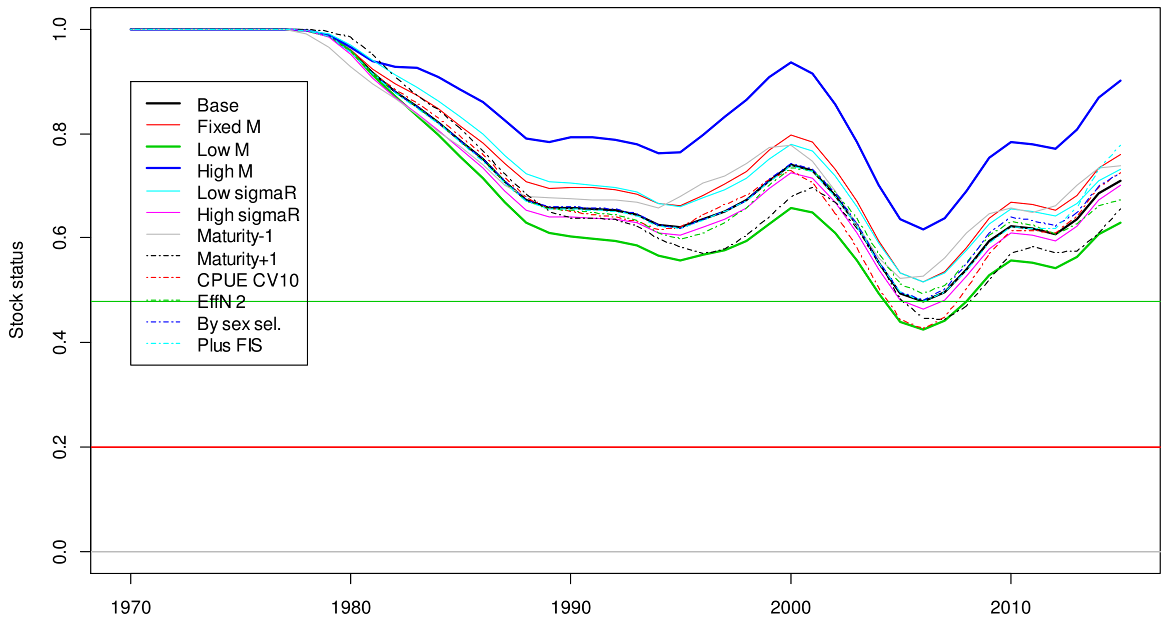

Figure 21: Western base model and sensitivities: MPD stock status trajectories. Horizontal lines are plotted at the limit reference point (0.2, red) and the target (0.48,green).

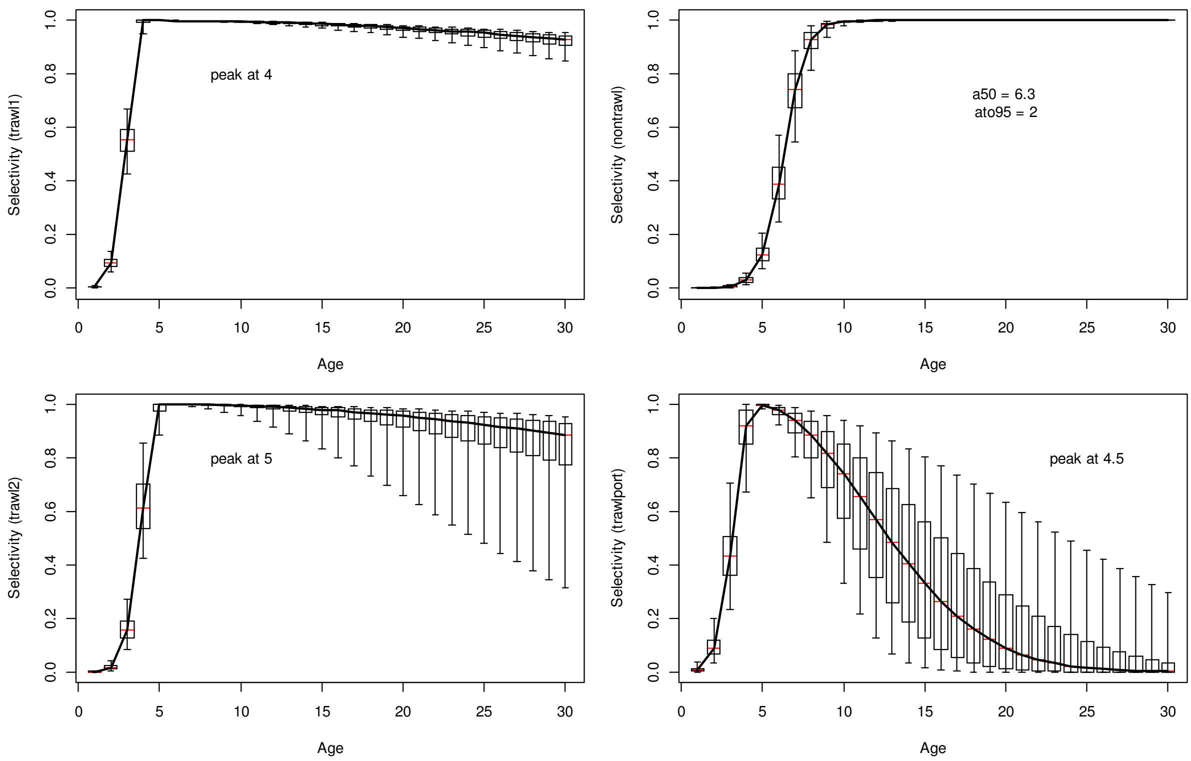

Figure 22: Western base model, MCMC: estimated fishery selectivities. The box covers the middle 50% of the samples and the whiskers extend to 95% CIs.

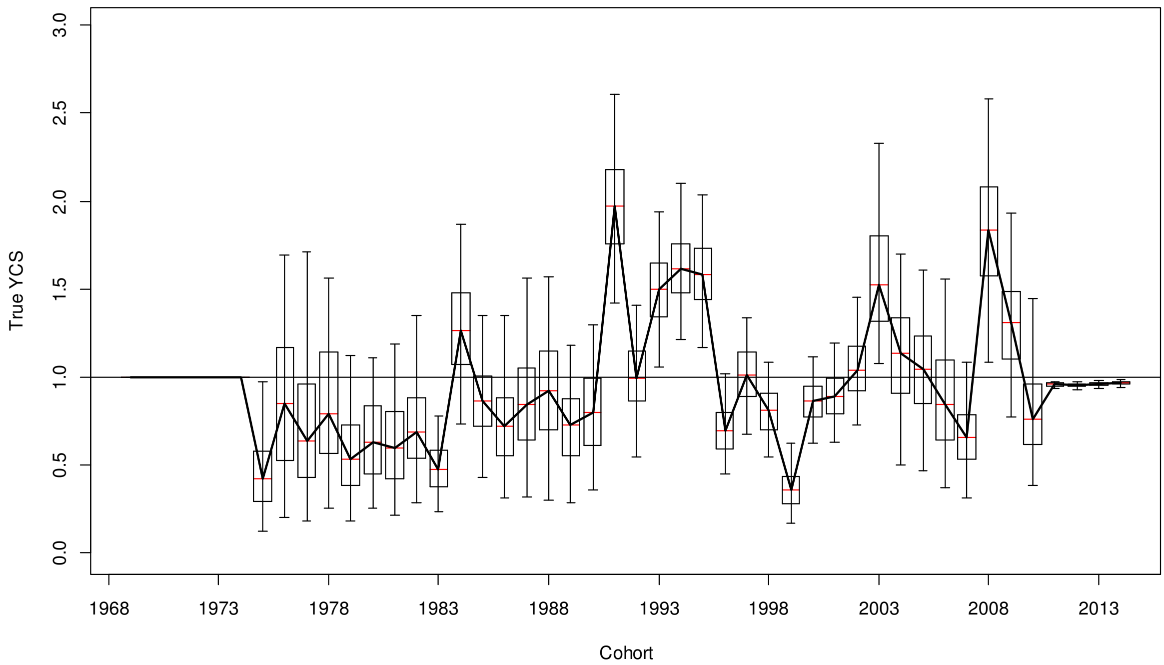

Figure 23: Western base model, MCMC: estimated "true" year class strengths (YCS). "True" YCS are recruitment numbers divided by virgin recruitment (i.e., includes the effect of the stock recruitment relationship). The box covers the middle 50% of the samples and the whiskers extend to 95% CIs.

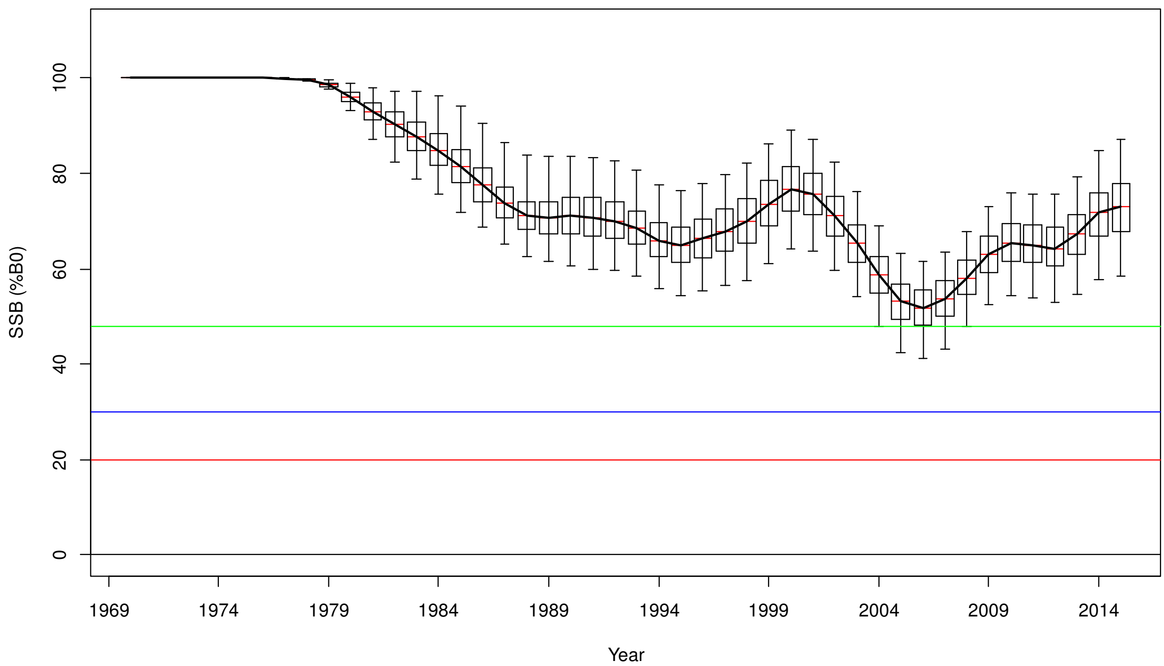

Figure 24: Western base model, MCMC: stock status trajectory. The box covers the middle 50% of the samples and the whiskers extend to 95% CIs. Horizontal lines are plotted at 20%, 30%, and 48% B_0.

Appendix 1: discards, catch history, and trawl CPUE

This document describes the updating of the catch histories including discards during the recent period of trip limits on the eastern fisheries. The updating of the trawl CPUE is also described.

Methods

The updating of catch histories and CPUE indices is normally straightforward. However, given the recent and changeable trip limits on the eastern ling fishery this update is relatively complicated. The stock assessment models require data on catch (landings plus discards) rather than just landings. The recent trip limits could have been expected to cause some level of additional discarding in the eastern fisheries. The scale of the discards has to be quantified and used to prepare the eastern catch history and to give context to the eastern CPUE indices.

AFMA supplied a list of the different eastern trip limits:

26 September 2013 to 30 April 2014:	50 kg per day
1 May 2014 to 11 February 2015:	250 kg per day
12 February 2015 to 19 May 2015:	50 kg per day
From 20 May 2015:	175 kg per day.

CSIRO supplied ISL with the raw discard data from the ISMP that are used to calculate annual fishery wide discard rates (e.g., Upston and Klaer 2013). These data were used to estimate discards by calendar year and for the above time periods (to the end of 2014) for the eastern and western trawl and non-trawl fisheries. The stock and fishery specific discards were used to move from estimated landings to catch estimates for 2013 and 2014.

Stock and method definition

The eastern stock is associated with zones 10, 20, and 30 (with catches and data from zone 60 assigned to zone 20). The western stock is associated with zones 40, 50, and 80 (although zone 80 is only included in terms of landings).

For each stock, the model has a trawl fishery and a non-trawl fishery. The trawl fishery is demersal trawl, while non-trawl is every other method (mainly longline).

Discard estimates

Two different approaches were used to estimate the scale of discards by calendar year and in the periods affected by the trip limits (restricted to the end of 2014):

1 January 2013 to 25 September 2013	no limit
26 September 2013 to 30 April 2014:	50 kg per day
1 May 2014 to 31 December 2014:	250 kg per day

The ISMP data consist of station records with the associated weight of retained and discarded ling. The data are collected by observers who are on a vessel for a whole trip. The observers sample most shots while they are onboard.

For the *i*th *trip* let:

d_i = total observed discarded weight of ling
l_i = total observed landed whole weight of ling.

In terms of modifying landings, we wish to estimate the multiplier that should be applied to the landings to give the catch. That is, we want to estimate m: $C = m\,L$ where L is a given landing and C is the associated catch.

For each fishing method and each year or period under consideration two estimates were made of m:

$$\widehat{m} = \frac{\sum_i l_i + d_i}{\sum_i l_i}$$

and

$$\widetilde{m} = \frac{1}{n}\sum_i \frac{l_i + d_i}{l_i}$$

where summation is over the trips within the period given the fishing method. For both estimation methods, trips which landed less than 50 kg of ling were excluded. This avoids potentially very large estimates of m from trips which may have landed almost no ling and discarded twice as much. The first method is robust to those sorts of trips (unless they were the only type of trips sampled during a particular year) and is "self-weighting" in terms of ling landings (with trips that landed lots of ling getting more weight). However, I prefer the second method because intuitively it is a more direct simple-random-sampling estimate of m (i.e., assuming the allocation of observers to trips is random). For the second method, 95% confidence intervals were calculated for the three periods using simple bootstrapping (sampling from the individual trip estimates of m with replacement).

In addition to the landings multiplier m, estimates of the discard ratio, p, were also made by the two methods ($p = D/C$ where D is a total discard and C the associated total catch).

Catch estimates

CSIRO supplied a spreadsheet of landing and discard estimates for pink ling from 1994 to 2014. The table included Commonwealth landing and discard estimates and State catches.

These were totals combined across stocks and methods. CSIRO also supplied GenLog data for ling consisting of station records and estimated whole weight of landed ling. The catch histories used in the 2013 assessment were constructed by Andre Punt using similar data where the total catches were split between stocks and fishing methods using the proportions from the GenLog data.

The total catches from the CSIRO table were compared with the total catches from the 2013 assessment over the period 1994-2013 and found be almost identical up to 2011. Therefore, the model catch histories were updated only for 2012, 2013, and 2014.

For 2012, the Commonwealth total catch (landings + discards) was split into east and west by fishing method using the proportions from GenLog. Then the NSW catch was added to the eastern catch split by method in proportion to the Commonwealth catches. The other state catches were within rounding error and ignored.

For 2013 and 2014 the three periods of trip limits in the east had to be accounted for using period, stock, and fishing-method specific discard estimates. The Commonwealth landings for each calendar year were split by stock and fishing method using the GenLog proportions. For the west, year and fishing-method specific discards were then added to give the final catches. In the east, the Commonwealth catches were split by month within method to allow the different discard multipliers to be applied (one for each period). The Commonwealth catches by calendar year were then totaled and the NSW catches added to the east in proportion to the Commonwealth catches. The other state catches were within rounding error and ignored.

The assumed catches for 2015 were calculated by scaling down the 2015 TAC by the ratio of the 2014 total catch to the 2014 TAC and then using the 2014 proportions across stock and method to split the total catch.

CPUE trawl analysis

The methods used by ISL in the 2013 assessment were applied (Cordue 2013). However, in some eastern runs, “period effects” were estimated to account for the discard and avoidance behaviour in 2013 and 2014.

The eastern and western trawl fisheries were modelled separately. When the eastern “period effects” were not estimated, the form of the models was the same for both east and west:

$$\log(\text{retained whole ling}) \sim \text{year} + \text{month} + \text{DorN} + \text{hours} + \text{depth} + \text{latitude} + \text{vessel}$$

All explanatory variables were categorical:

year:	1986-2014
month:	1-12
DorN:	four codes: day (D), night (N), mixed (M), and unknown (U)
hours:	cut into a factor with 12 levels from 0.5-10 hrs (west) and 10 levels from 0.5-8 hrs (east)
depth:	cut into a factor with 11 levels from 200-750 m (50 m bins)
latitude:	cut into a factor with 9 levels (east) and 8 levels (west)
vessel:	individual effects for any vessel present in at least three years within a "block"

For the east, the potential changes in vessel effects were modelled by allowing most vessels to change their vessel effect between blocks of time:

east: 1986-1999, 2000-2006, 2007-2012.

The split from 2006-2007 is indicated by the timing of the structural adjustment and also by the logbook data where the number of vessels approximately halves from 2006 to 2007. The eastern split from 1999-2000 is indicated by advice from the industry that ling quota associated with eastern trawl vessels was sold to support the developing line fishery (and also supported by logbook data – see Cordue 2013). In the 2013 assessment time-blocking of vessel effects made no difference to the western indices and so it was not done for this assessment.

The link between blocks was maintained by requiring that some vessels retained a constant vessel effect over the break points. This is needed to ensure that vessel and year effects are not confounded within a block. The same linking vessels from the 2013 assessment were used in this analysis. For each pair of blocks, candidate linking vessels had been determined and ordered from "best" to "worst" in terms of consistency of fishing behaviour (Cordue 2013). As in 2013, the base CPUE model uses the top three linking vessels for each pair of blocks.

In the eastern model, to account for the additional discards in 2013 and 2014 and avoidance behaviour (which is not compensated for by other effects) a "period effect" was estimated. This was a categorical variable with three levels:

Period 1:	1 January 1986 to 25 September 2013	no limit
Period 2:	26 September 2013 to 30 April 2014	50 kg per day
Period 3:	1 May 2014 to 31 December 2014	250 kg per day

Because Period 2 is partly in 2013 and partly in 2014 the period effects are not confounded with the year effects.

Results

Discard estimates

In the east, there were 26 trawl trips with observed discards in 2013 and 2014 (with at least 50 kg of ling retained) and there were 9 such non-trawl trips (Table A1.1). In Period 2 there were no non-trawl trips but there were few landings so the lack of a data-based discard estimate is not a concern.

Table A1.1: The number of ISMP "trips" (defined as a gap of at least 3 days between observed operations) in the east during the three different periods of trip limits in 2013 and 2014.

	Trawl	Non-trawl
1 Jan. 2013 to 25 Sep. 2013	8	6
26 Sep. 2013 to 30 Apr. 2014	8	0
1 May 2014 to 31 Dec. 2014	10	3

The eastern estimates of *m* were very similar for the two methods (Table A1.2). Therefore, it does not matter which method is used to adjust the landings to catches. For eastern trawl there is a substantial adjustment (~ 1.5) required during the period that had a 50 kg per day trip limit; a moderate adjustment (~ 1.1) is required for trawl when the 250 kg per day trip limit was in place; and the estimated adjustments for non-trawl are minor (Table A1.2). For the second period, where there are no data to estimate *m* for non-trawl, it was taken to equal 1.1 on the basis that it should be higher than the estimate for the third period because there was a more restrictive trip limit.

Table A1.2: Estimates of the landings multiplier (*m*) and the discard ratio (*p*) in the east during the three different periods of trip limits in 2013 and 2014. Two different estimation methods were used (method 1 = ratio of sums; method 2 = mean of ratios). * For the non-trawl, in the second period, an educated guess was made for *m* as there were no data.

	Trawl				**Non-trawl**			
	Method 1		**Method 2**		**Method 1**		**Method 2**	
	p	*m*	*p*	*m*	*p*	*m*	*p*	*m*
1 Jan. 2013 to 25 Sep. 2013	0.00	1.00	0.01	1.01	0.00	1.00	0.00	1.00
26 Sep. 2013 to 30 Apr. 2014	0.30	1.43	0.23	1.45	No data	No data	No data	1.1*
1 May 2014 to 31 Dec. 2014	0.13	1.14	0.05	1.11	0.02	1.02	0.04	1.04

The 95% confidence intervals for the estimates of *m* (by method 2) are broad for the second and third periods when trip limits were in place (Table A1.3).

Table A1.3: Point and interval estimates of the landings multipliers (*m*) in the east during the three different periods of trip limits in 2013 and 2014.

	Estimated landings multiplier (*m*)	Bootstrap 95% CI
1 Jan. 2013 to 25 Sep. 2013	1.01	1.00–1.02
26 Sep. 2013 to 30 Apr. 2014	1.45	1.10–1.87
1 May 2014 to 31 Dec. 2014	1.11	1.00–1.42

In the west only minor discarding appeared to occur in 2013 and 2014 (Table A1.4).

Table A1.4: Point estimates of the landings multiplier (*m*) for trawl and non-trawl in the west during 2013 and 2014 (using method 2).

	Trawl	Non-trawl
2013	1.02	1.02
2014	1.00	1.02

The overall discard ratio for 2013 supplied by CSIRO was 0.03 which gives a landings multiplier of 1.03. These were only slightly up on the discard ratio and landings multiplier in 2012 of 0.02 and 1.02.

Catch estimates

The eastern and western stock assessment models each have a trawl and a non-trawl fishery. The model catch histories used in the 2013 assessment were updated with revisions to 2012 and 2013 and the addition of catches in 2014 and 2015 (assumed).

The new estimates in 2012 and 2013 are just a bit higher overall than the values used in the 2013 assessment (Table A1.5). There is a notable shift of non-trawl catch in the east to non-trawl catch in the west from 2013 to 2014 (Table A1.5).

Table A1.5: Model catch histories by stock and fishing method for 2012 to 2015. The catches (t) are landings plus estimated discards. For 2012 and 2013 the values used in the 2013 assessment are given in parentheses.

	East		West		Total
	Trawl	Non-trawl	Trawl	Non-trawl	East+West
2012	(360) 362	(152) 199	(374) 404	(188) 226	(1074) 1191
2013	(279) 247	(119) 117	(290) 300	(146) 153	(834) 886
2014	317	59	283	234	886
2015	306	57	279	230	872

CPUE analysis

Eastern trawl

The unstandardised trawl CPUE is flat from 1986 to the late 1990s before it declines steeply to a trough in the early 2000s and then rises (noisily) through to 2014 (see “year only” in Figure 1). Standardising for day-or-night, depth, and month effects has little impact on the unstandardised trend (Figure A1.1). However, when the vessel effects (without time blocking) are estimated the upward trend from the trough through to 2014 is replaced with a flat trend (Figure A1.1). The additional estimation of latitude and tow-duration effects then has little impact on the indices.

The inclusion of time-blocking (linked with the “top” three vessels) has a minor impact on the indices, raising them a little after about 2000 (Figure A1.2). The estimation of period effects increases the 2013 index slightly and substantially raises the 2014 index (Figure A1.2). The indices from the full 2015 model are very similar to those used in 2013 except for the addition of another two years (Figure A1.3).

The impact of the period effects is consistent with the landings multipliers that were estimated using the ISMP data for the second and third periods. Indeed, the period effects are stronger than the associated landings multipliers (Table A1.6) which is consistent with an additional avoidance component associated with the trip limits (i.e., vessels may avoid catching ling without substantially altering the depth or latitude that they are fishing at).

Table A1.6: Point and interval estimates for landings multipliers from the ISMP data and implied landings multipliers from the estimated period effects (being the reciprocal of the period effect).

	Estimated landings multiplier		95% confidence intervals	
	ISMP	CPUE	ISMP	CPUE
26 Sep. 2013 to 30 Apr. 2014	1.45	1.72	1.10–1.87	1.47–2.02
1 May 2014 to 31 Dec. 2014	1.11	1.25	1.00–1.42	1.02–1.55

The estimation of the period effects appears essential given the estimated landings multipliers from the ISMP data. It is also justified on AIC grounds with a 60 point reduction in AIC with the addition of only 2 parameters. The examination of box plots of the standardized residuals before and after the estimation of period effects shows a clear pattern consistent with a genuine effect and an improved AIC (Figures A1.4 and A1.5).

The residuals for the model look fine with the median close to zero over most of the range of fitted values (Figure A1.6) and not too far off being normal (Figure A1.7).

The depth effects are strong with a peak at 500–600 m (Figure A1.8). The day-or-night effects are very minimal (Figure A1.9). As expected, the tow duration is a strong effect with catch increasing with increasing time (Figure A1.10). Latitude is also a strong effect (Figure A1.11). The month effect peaks in June (Figure A1.12). The trip-limit period effects are quite strong and sensible with lower expected catches when the 50 kg per day limit was in place compared to when the 250 kg per day limit was in place (Figure A1.13). Most vessel effects are between 0.3 and 1.5 with only one vessel higher at about 2.5 (Figure A1.14).

Western trawl

In the 2013 assessment the western trawl CPUE indices calculated by CSIRO were used in ISL's assessment. The indices calculated by ISL were very similar even though two time blocks had been used. In this assessment no time blocking has been used for the western trawl CPUE and the indices are very similar to those used in 2013 except for the additional two years (Figure A1.15). The indices have a peak in 1997 followed by a strong decline through to 2005 and then an upward trend through to 2014 (Figure A1.15).

The unstandardized indices have a similar shape to the standardised indices except that they show a less steep decline from 1997 and a stronger upward trend from 2005 to 2014 (Figure A1.16). The difference in the indices occurs when the duration effect is estimated (Figure A1.16). The duration effect has a strong impact because of a shift towards longer tow duration since about 2000 (Figure A1.17).

The residuals for the model look fine with the median close to zero over most of the range of fitted values (Figure A1.18) and not too far off being normal (Figure A1.19).

The depth effect peaks at 500–550 m (Figure A1.20) but it is not nearly as strong as the depth effect in the east (see Figure A1.8). As for the east the day-or-night effects are minimal (Figure A1.21). As expected, the tow duration is a strong effect with catch increasing with increasing time (Figure A1.22). Latitude is important (Figure A1.23) but not nearly as much as in the east (see Figure A1.11). The month effects are not very strong and peak in September and October (Figure A1.24) compared to June in the east (see Figure A1.12). Most vessel effects are between 0.5 and 2 with only one vessel higher at about 2.5 (Figure A1.25).

Acknowledgements

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References

Cordue, P.L. 2013. Compilation of 2013 pink ling Slope RAG documents from ISL. Draft document. *For* SETFIA and Australian Longline PTY Ltd. 284 p.

Upston, J. and Klaer, N. 2013. Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – Discard estimation 2012. CSIRO report to the Australian Fisheries Management Authority.

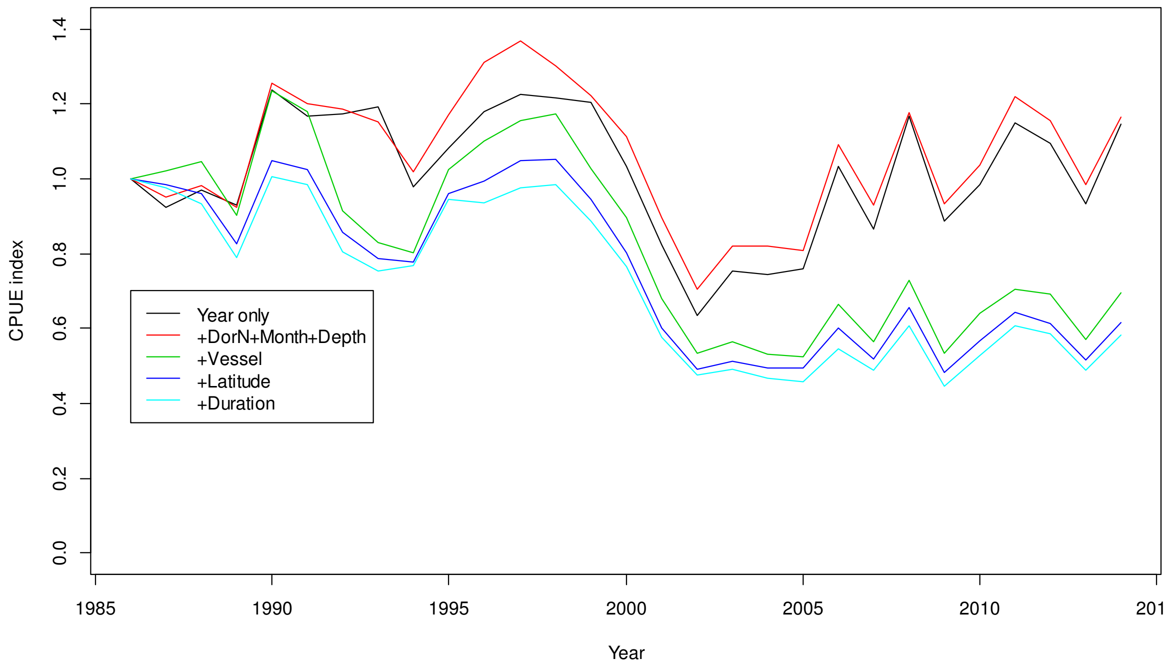

Figure A1.1: Eastern trawl CPUE indices moving progressively from only fitting year effects through to the full model except for time blocking and period effects.

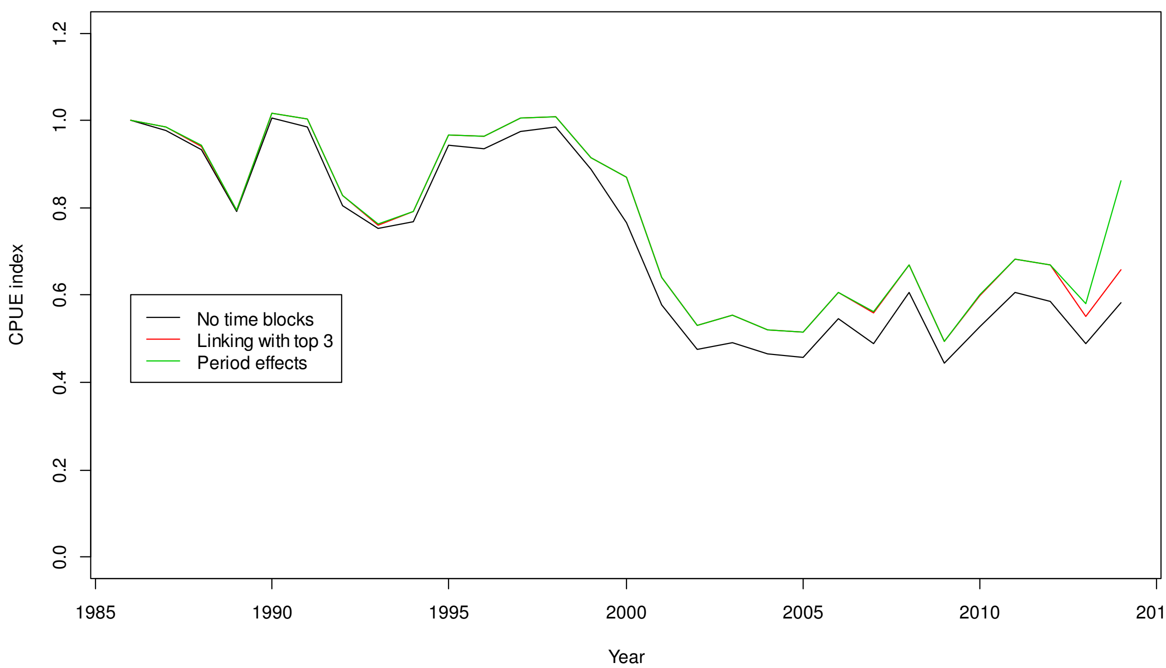

Figure A1.2: Eastern trawl CPUE indices for the full model without time blocking or period effects ("No time blocks"), the full model excluding period effects ("Linking with top 3"), and the full model ("Period effects").

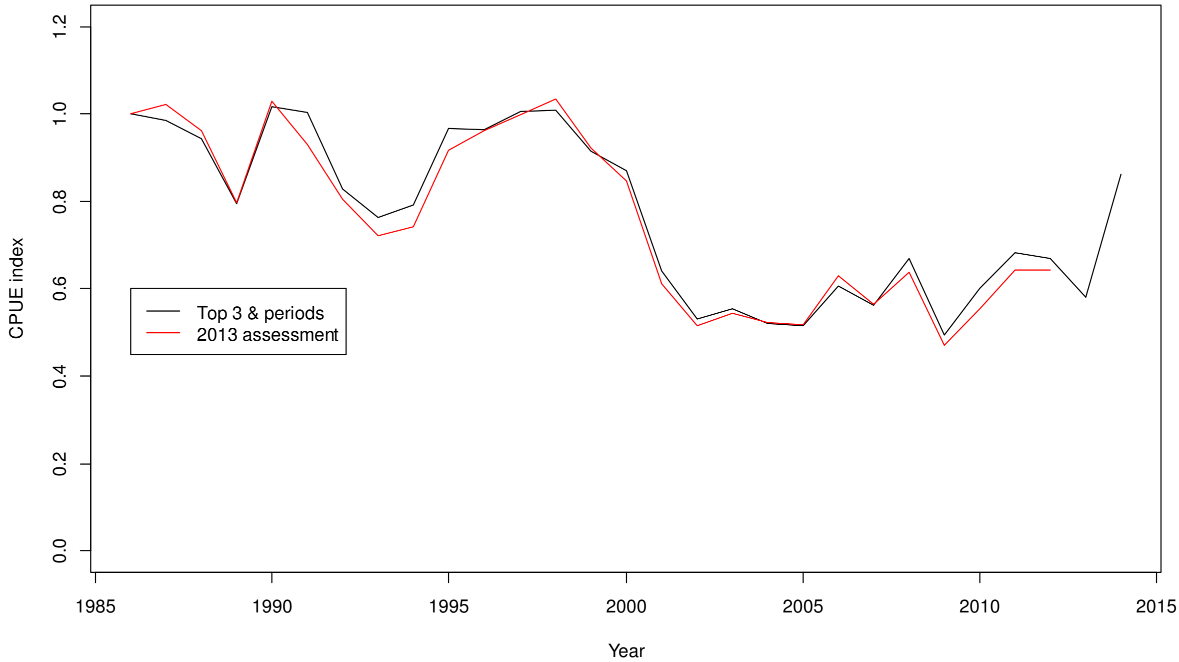

Figure A1.3: Eastern trawl CPUE comparing the base model in 2013 with the full model in 2015 ("Top 3 and periods").

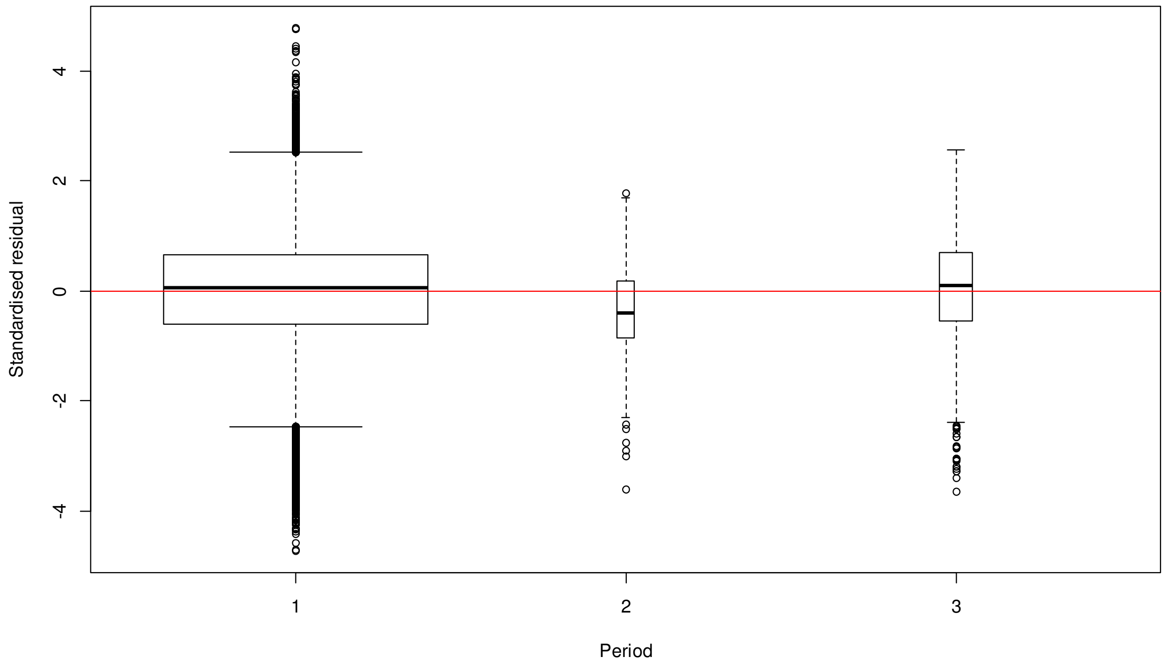

Figure A1.4: Eastern trawl CPUE standardised residuals by trip-limit period when period effects are not estimated.

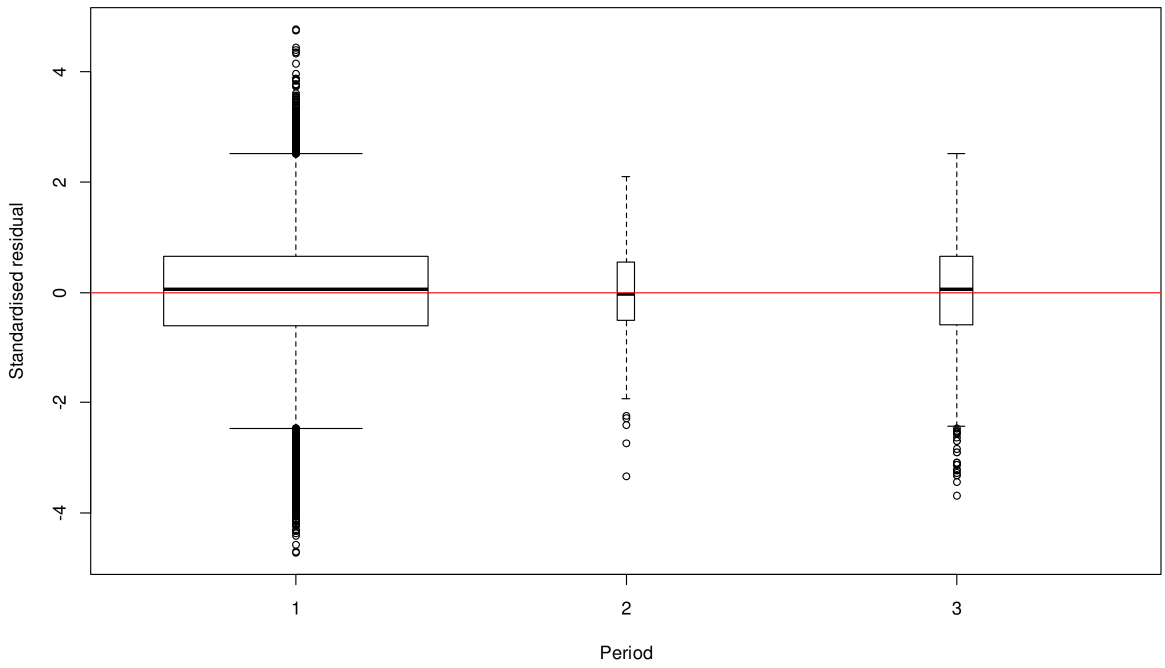

Figure A1.5: Eastern trawl CPUE standardised residuals by trip-limit period for the full model (i.e., period effects are estimated).

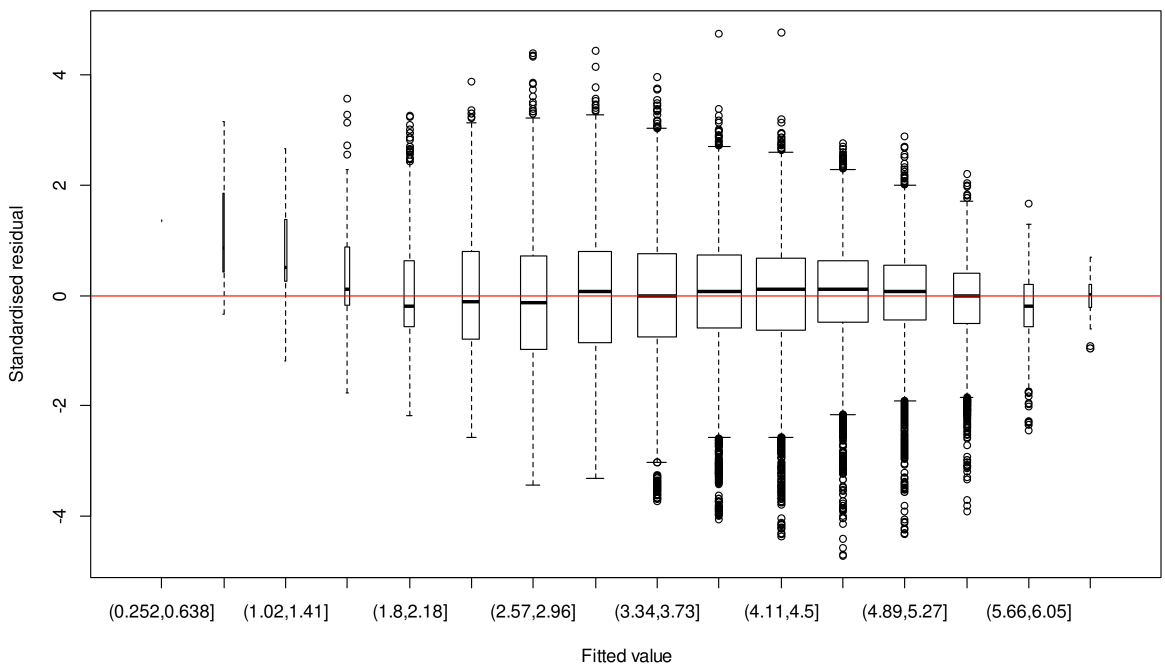

Figure A1.6: Eastern trawl CPUE boxplot of standardised residuals versus fitted values. Each box covers the middle 50% of the distribution and the horizontal line marks the median. The width of each box is proportion to the number of observations in the fitted value range.

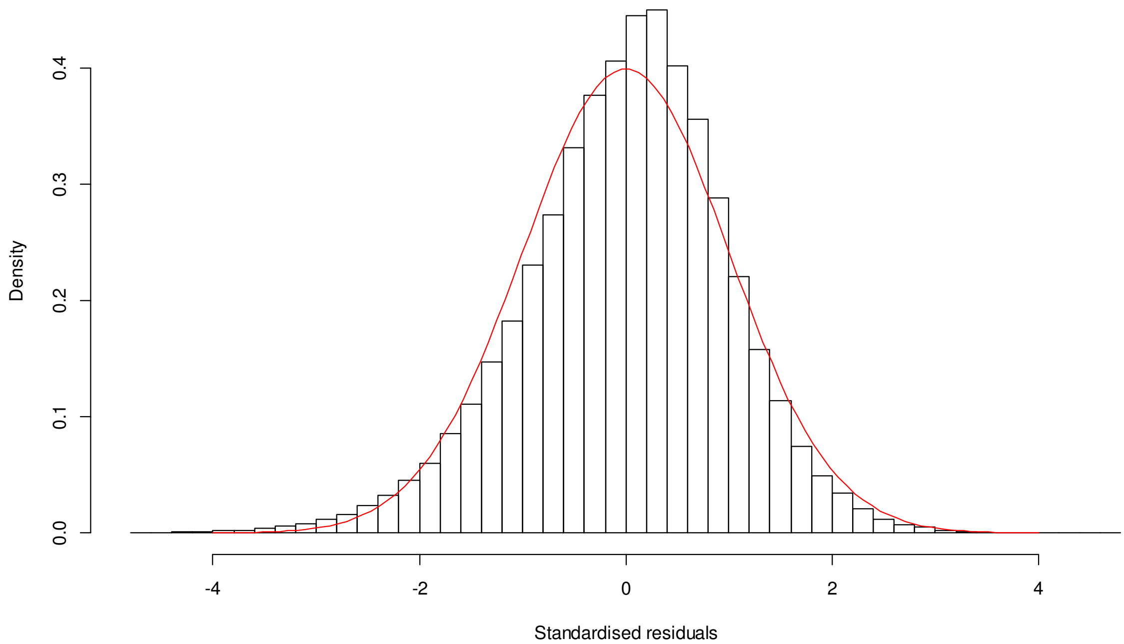

Figure A1.7: Eastern trawl CPUE: histogram of standardised residuals compared to a N(0,1) density.

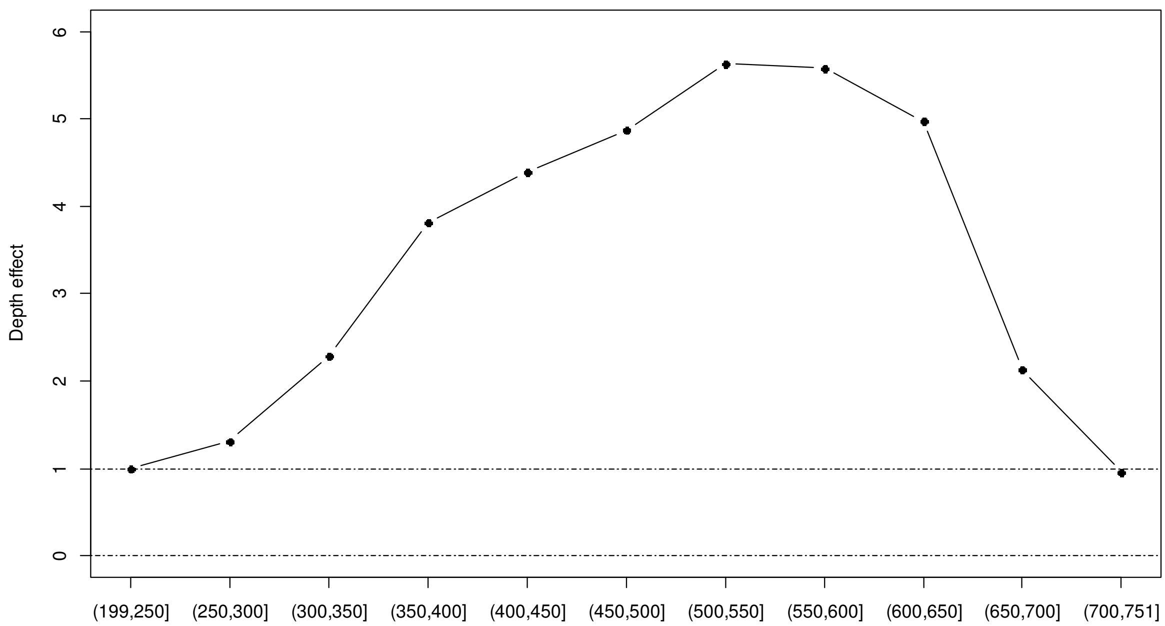

Figure A1.8: Eastern trawl CPUE full model: depth effects from 200 to 750 m.

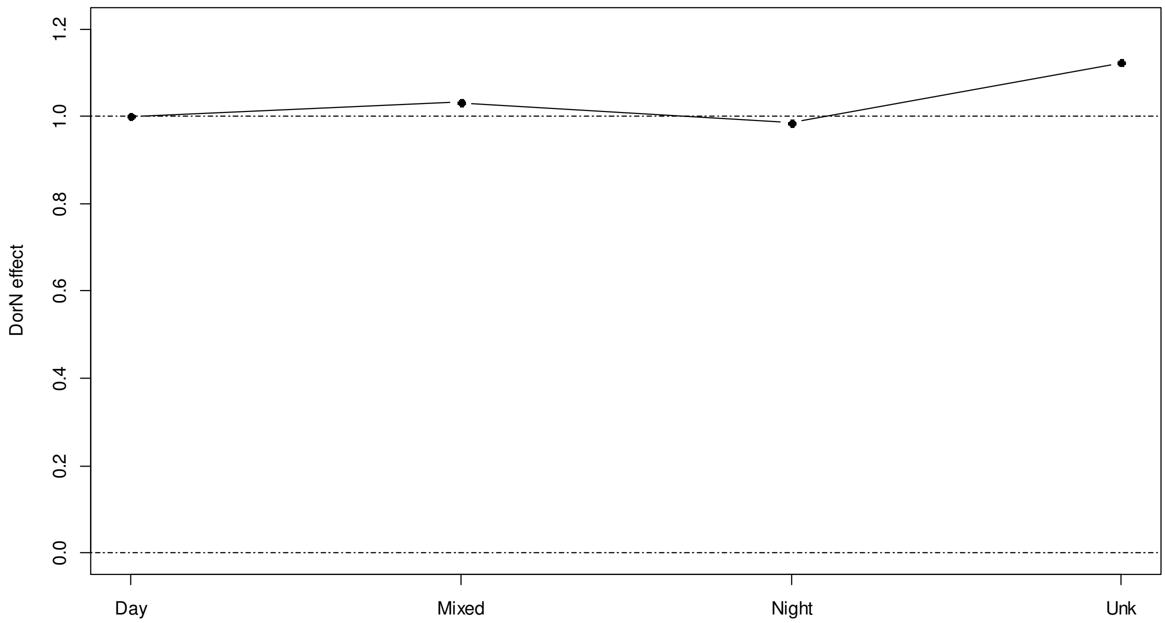

Figure A1.9: Eastern trawl CPUE full model: day-or-night effects for the start of the trawl shot (“Unk” is unknown which represents a very small number of records).

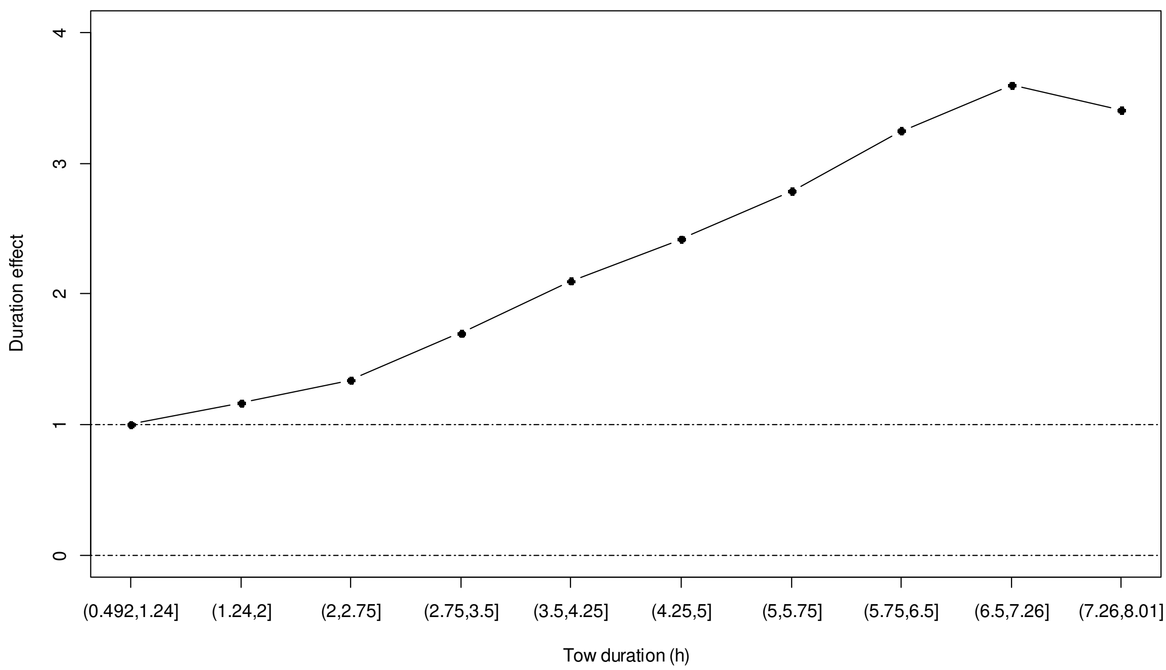

Figure A1.10: Eastern trawl CPUE full model: tow duration effects.

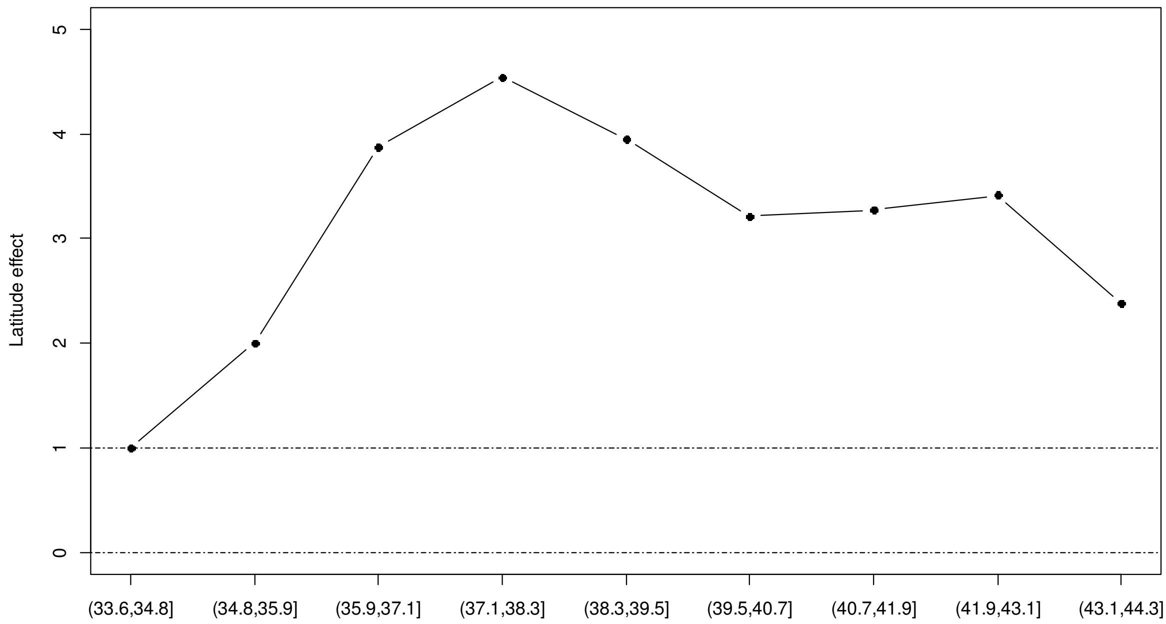

Figure A1.11: Eastern trawl CPUE full model: latitude effects (degrees south).

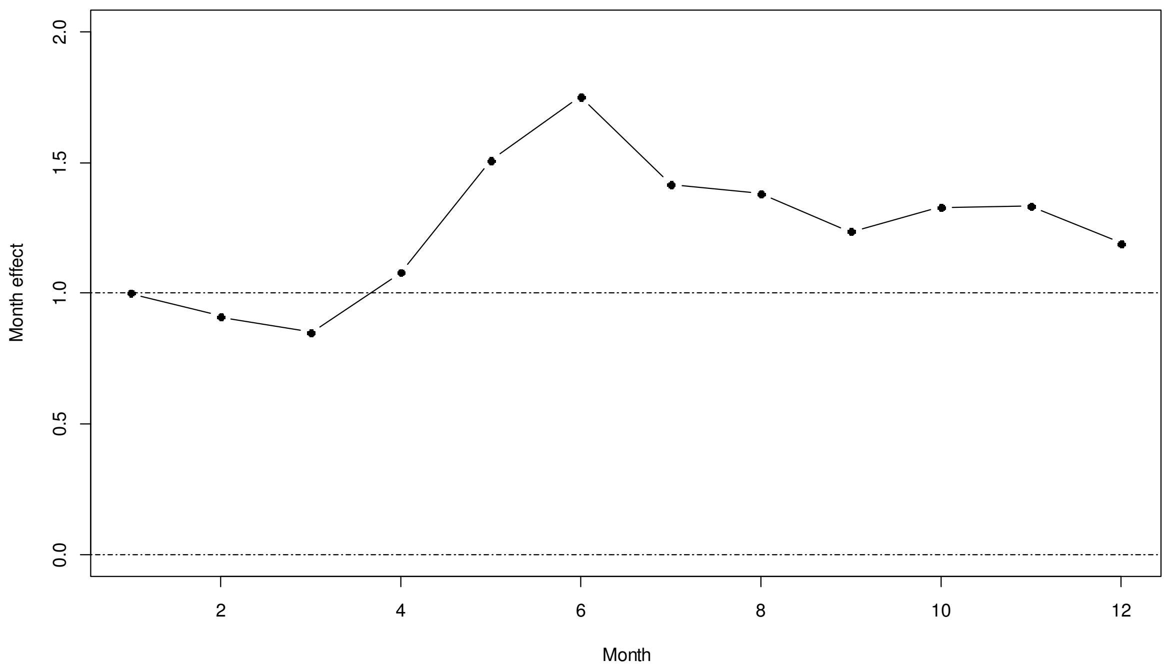

Figure A1.12: Eastern trawl CPUE full model: month effects.

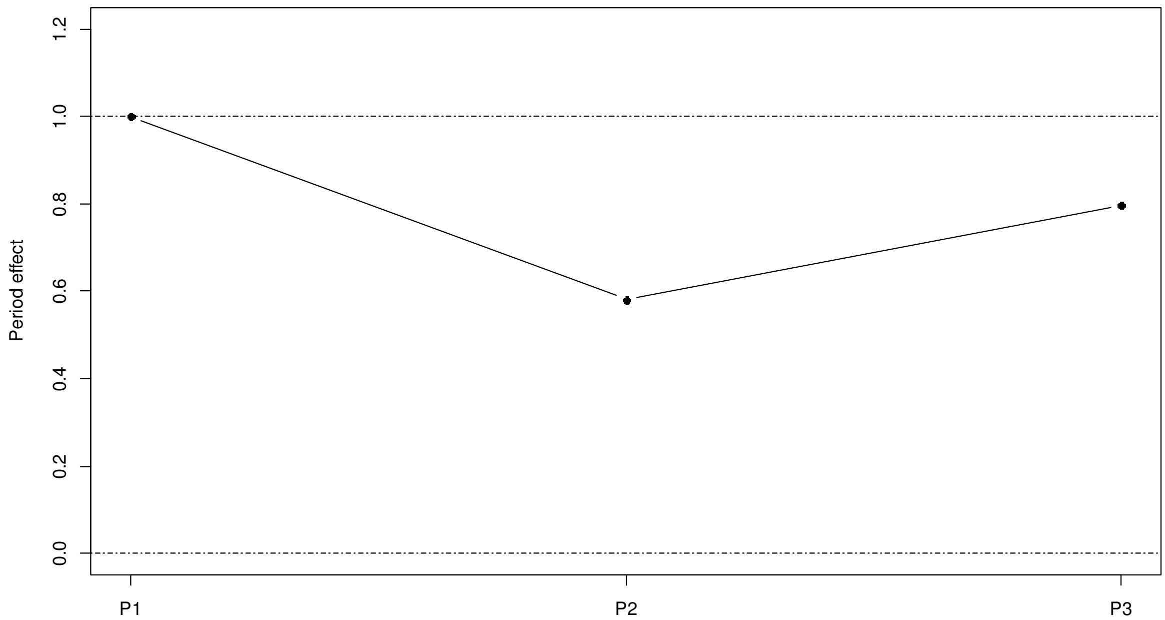

Figure A1.13: Eastern trawl CPUE full model: trip-limit period effects (no trip limits for P1; 50 kg per day for P2; 250 kg per day for P3).

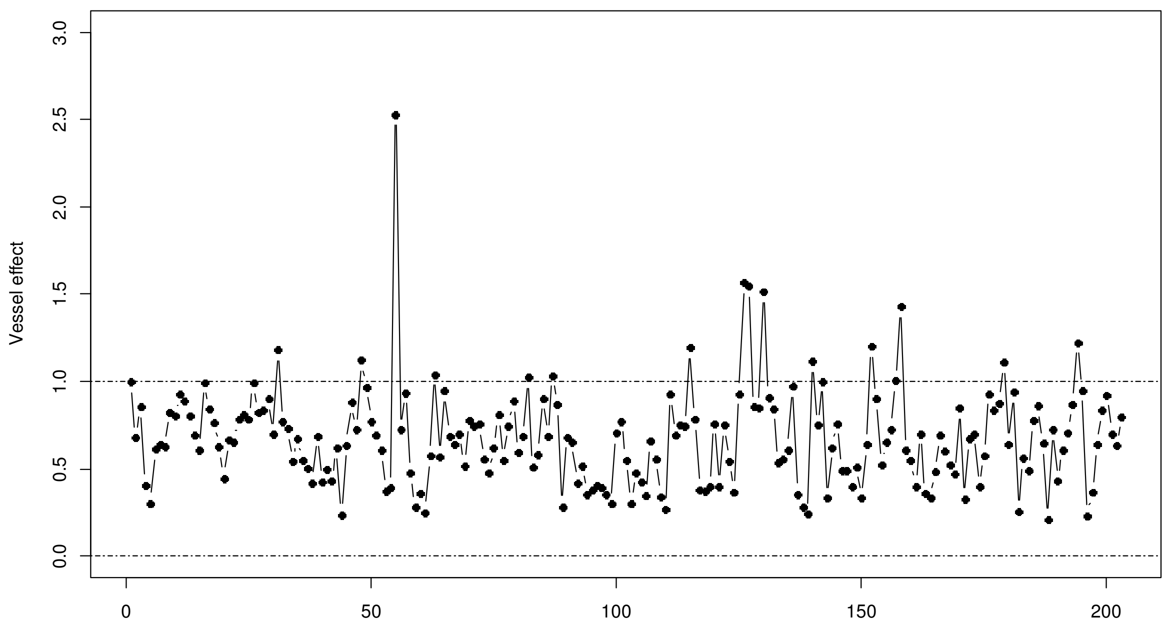

Figure A1.14: Eastern trawl CPUE full model: vessel effects. Other than the three vessels linking each time block, vessels are given a new code within each of the three time blocks (see text). (So some vessels have as many as three vessel effects estimated.)

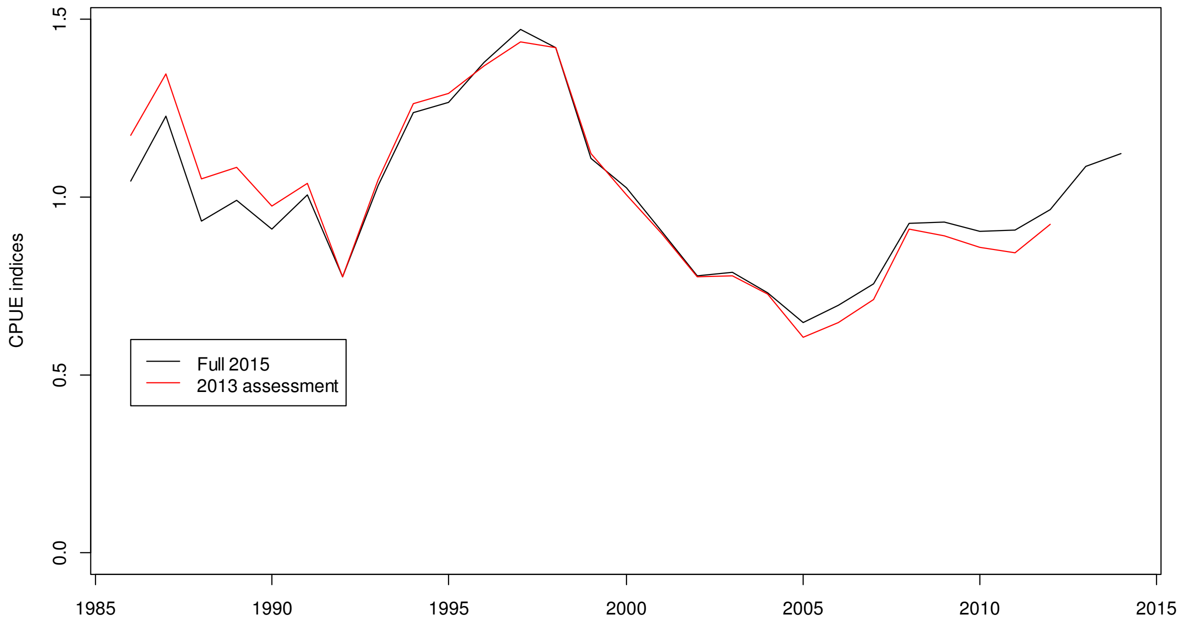

Figure A1.15: Western trawl CPUE: comparison of the full model in 2015 with the indices used in the 2013 assessment (from CSIRO).

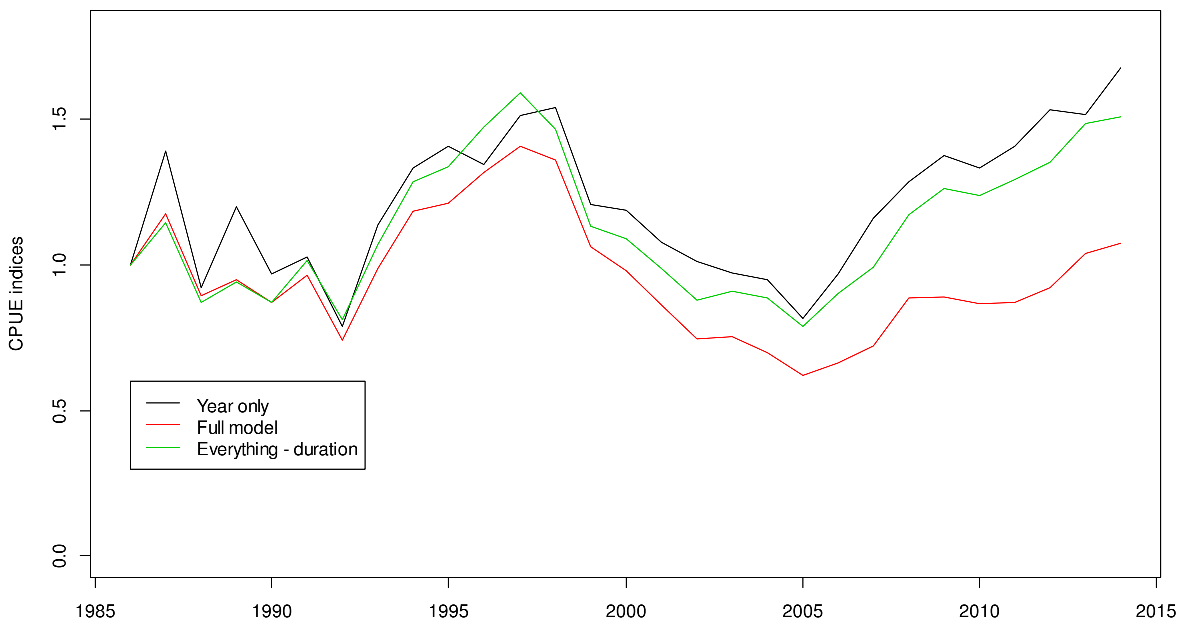

Figure A1.16: Western trawl CPUE indices for only year effects, the full model, and the full model except for the tow duration effect. It shows that the tow duration effect is what matters.

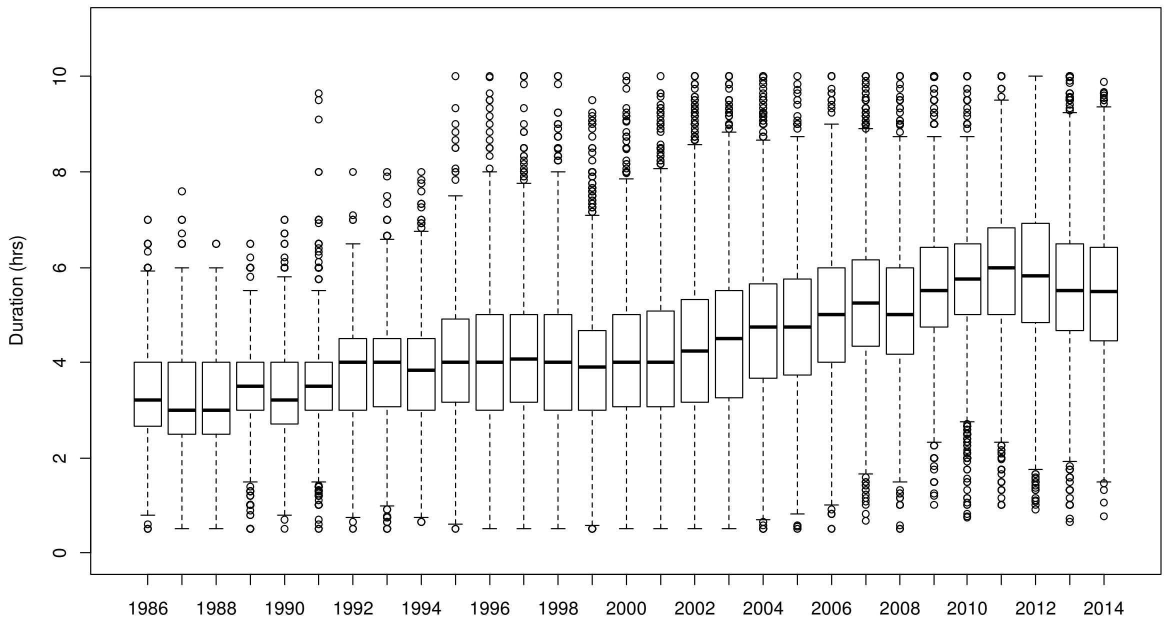

Figure A1.17: Western trawl CPUE: the distribution of tow duration by year. Each box covers the middle 50% of the distribution and the horizontal line marks the median.

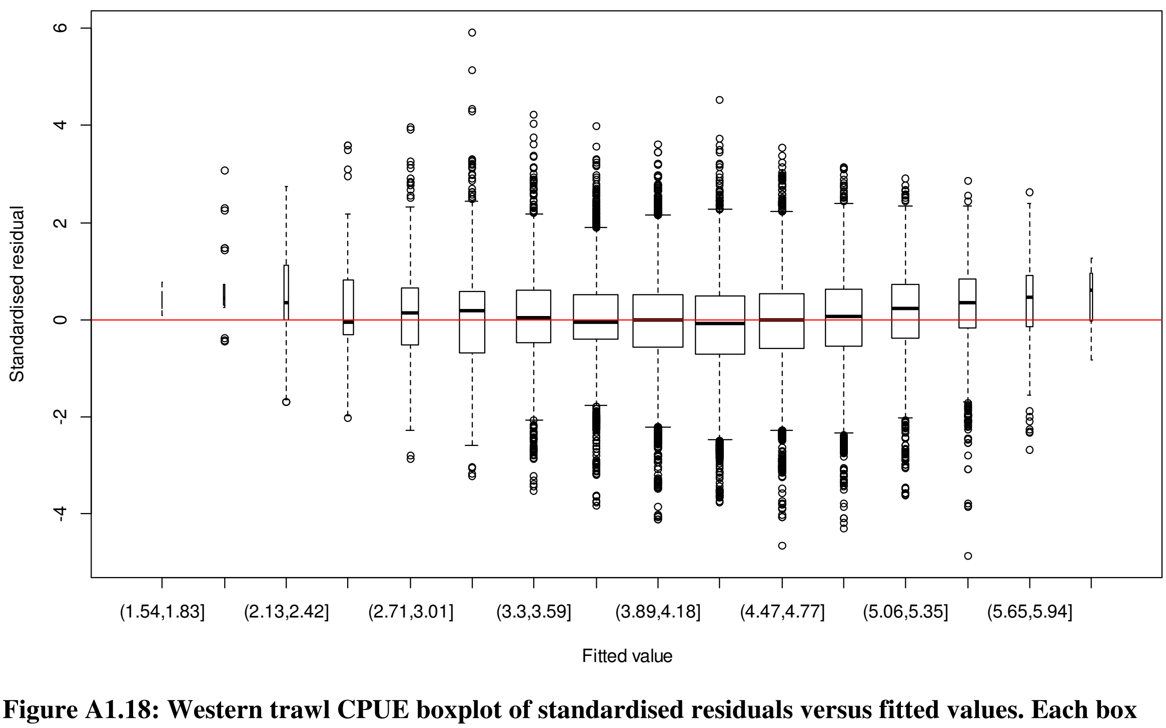

Figure A1.18: Western trawl CPUE boxplot of standardised residuals versus fitted values. Each box covers the middle 50% of the distribution and the horizontal line marks the median. The width of each box is proportion to the number of observations in the fitted value range.

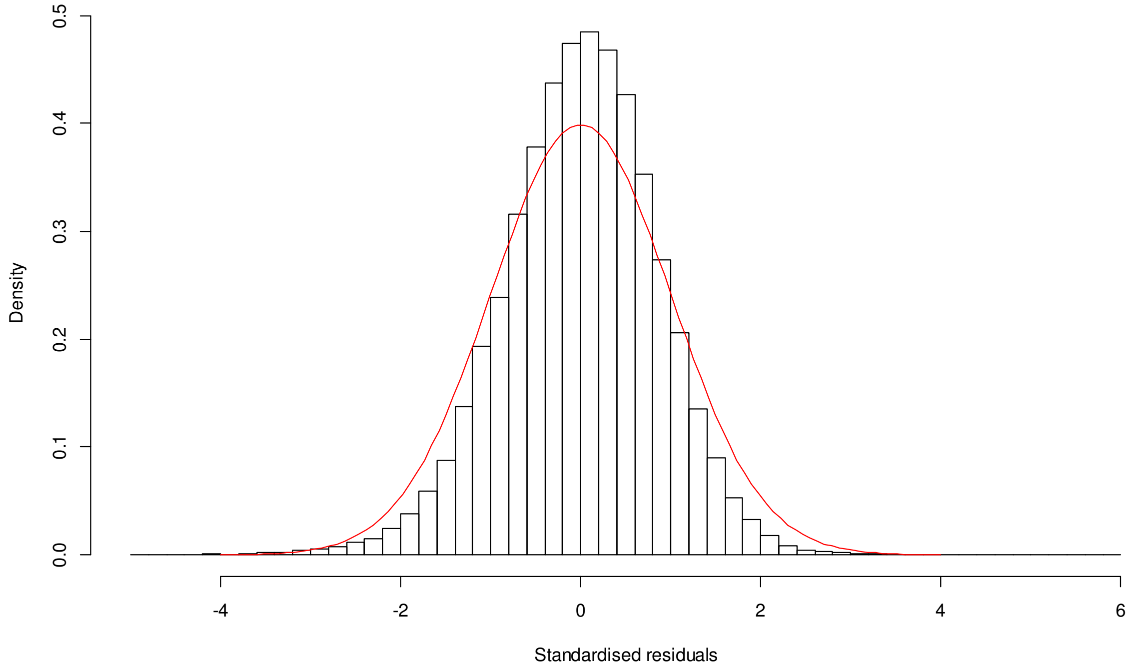

Figure A1.19: Western trawl CPUE: histogram of standardised residuals compared to a N(0,1) density.

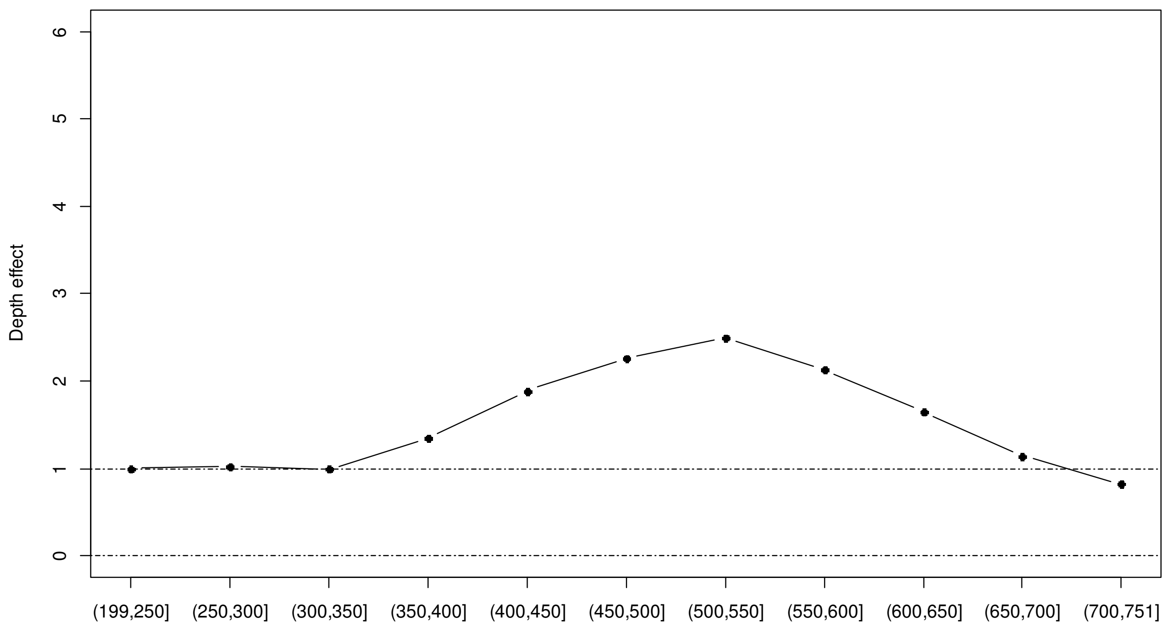

Figure A1.20: Western trawl CPUE full model: depth effects from 200 to 750 m.

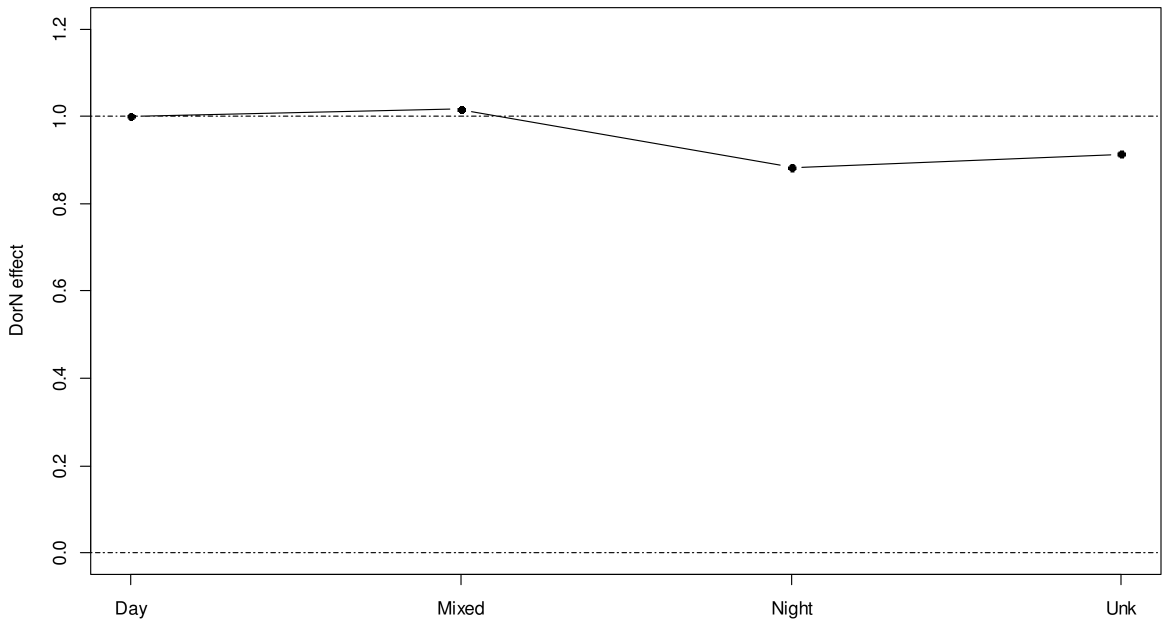

Figure A1.21: Western trawl CPUE full model: day-or-night effects for the start of the trawl shot ("Unk" is unknown which represents a very small number of records).

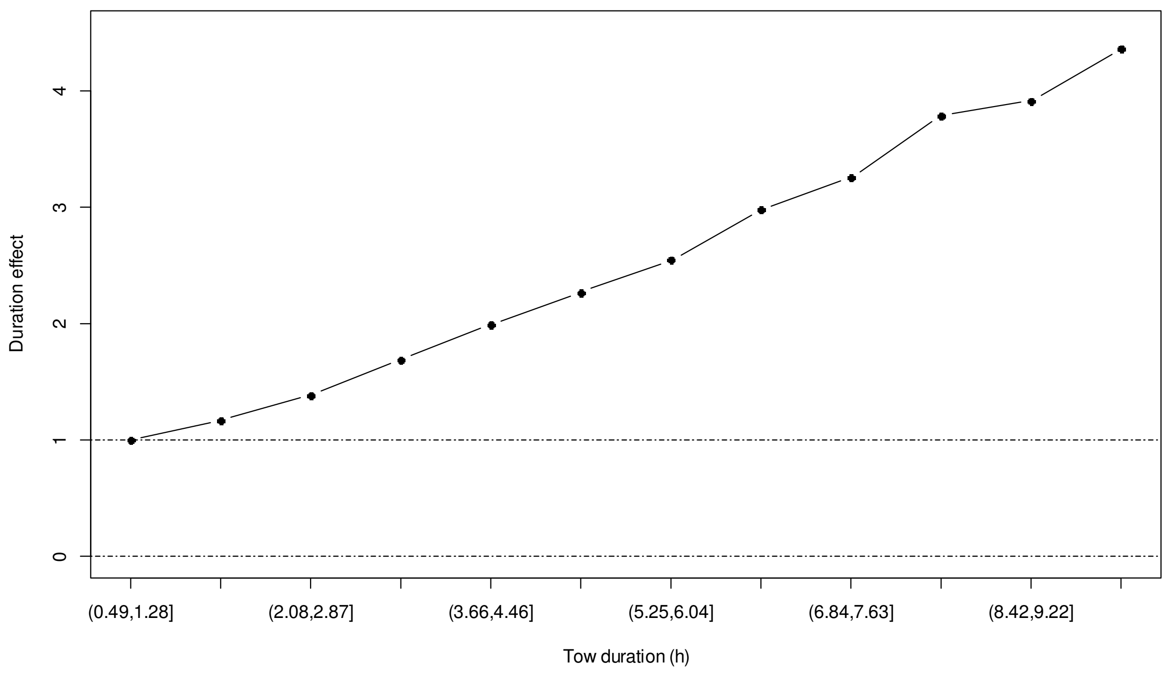

Figure A1.22: Western trawl CPUE full model: tow duration effects.

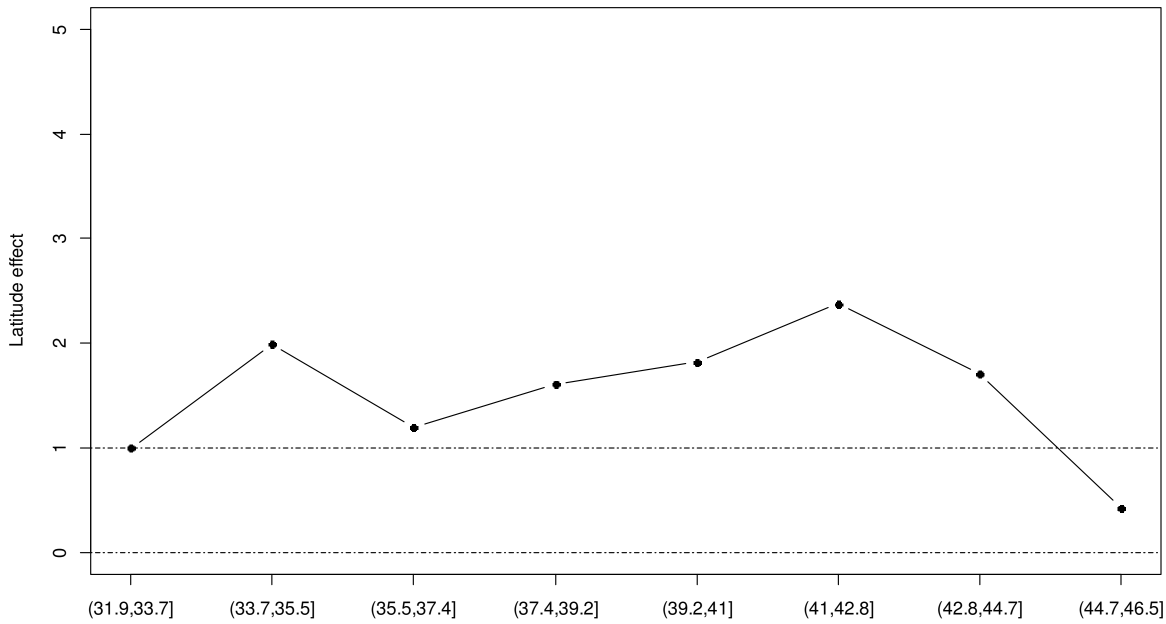

Figure A1.23: Western trawl CPUE full model: latitude effects (degrees south).

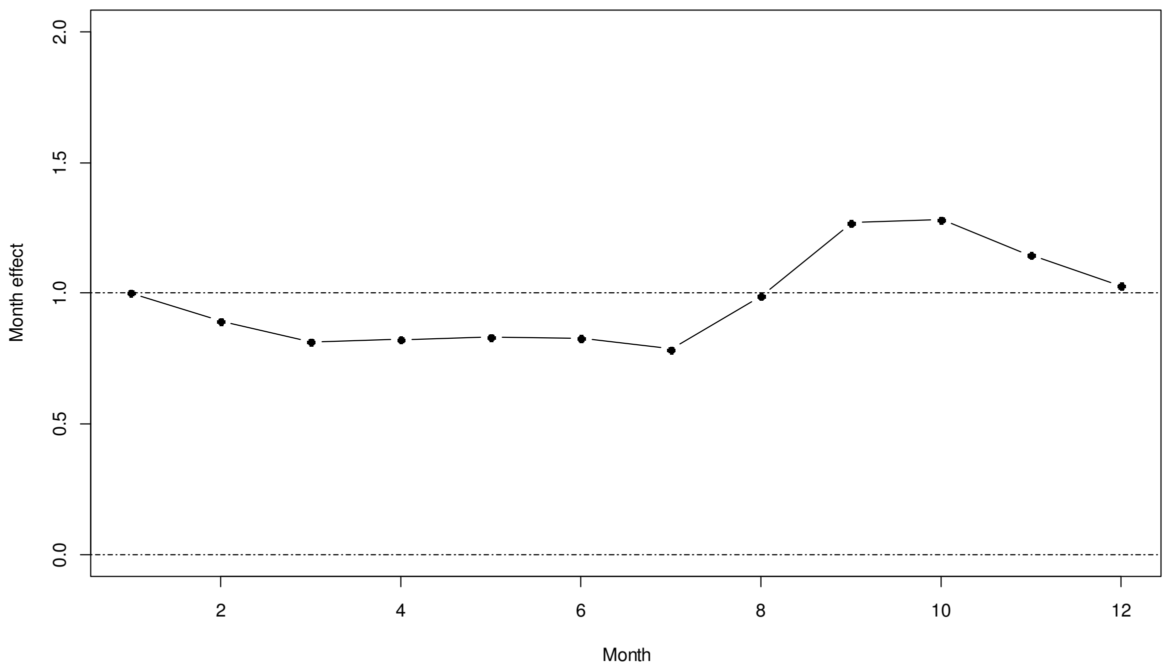

Figure A1.24: Western trawl CPUE full model: month effects.

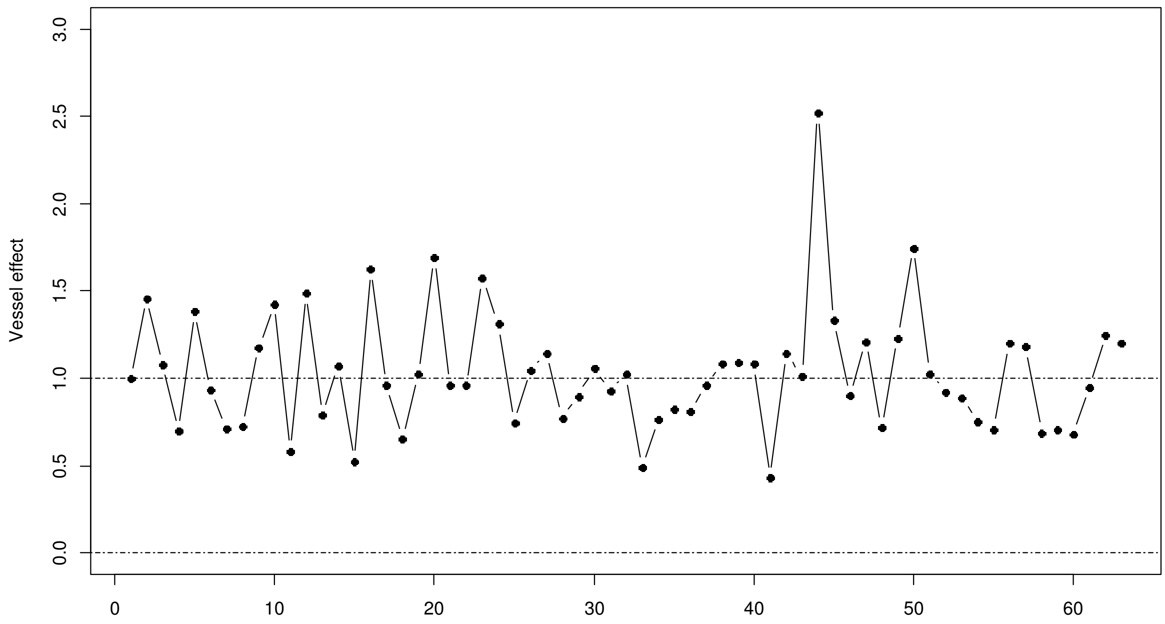

Figure A1.25: Western trawl CPUE full model: vessel effects. Time blocking was not used so each vessel had a single effect estimated.

Appendix 2: MPD fits to length and age frequencies

The MPD fits to the eastern age and length frequencies are given below for completeness. The fits are good especially given the low effective sample sizes that result from applying the Francis weighting.

The MPD fits to the western length frequencies are also given. As for the east, the fits are good given the low effective sample sizes.

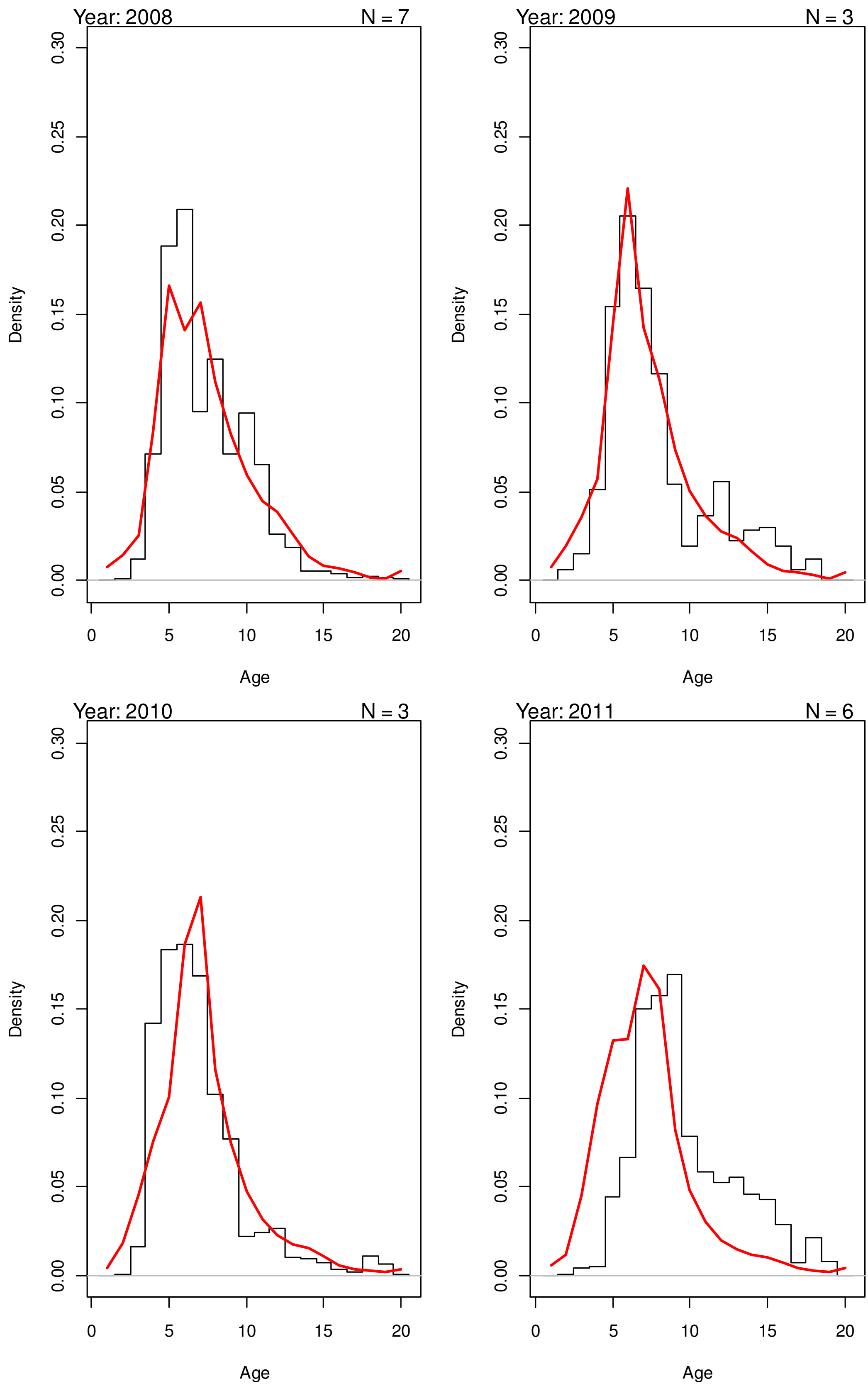

Figure A2.1: Eastern base model MPD fits to non-trawl age frequencies (year and tuned effective sample size given).

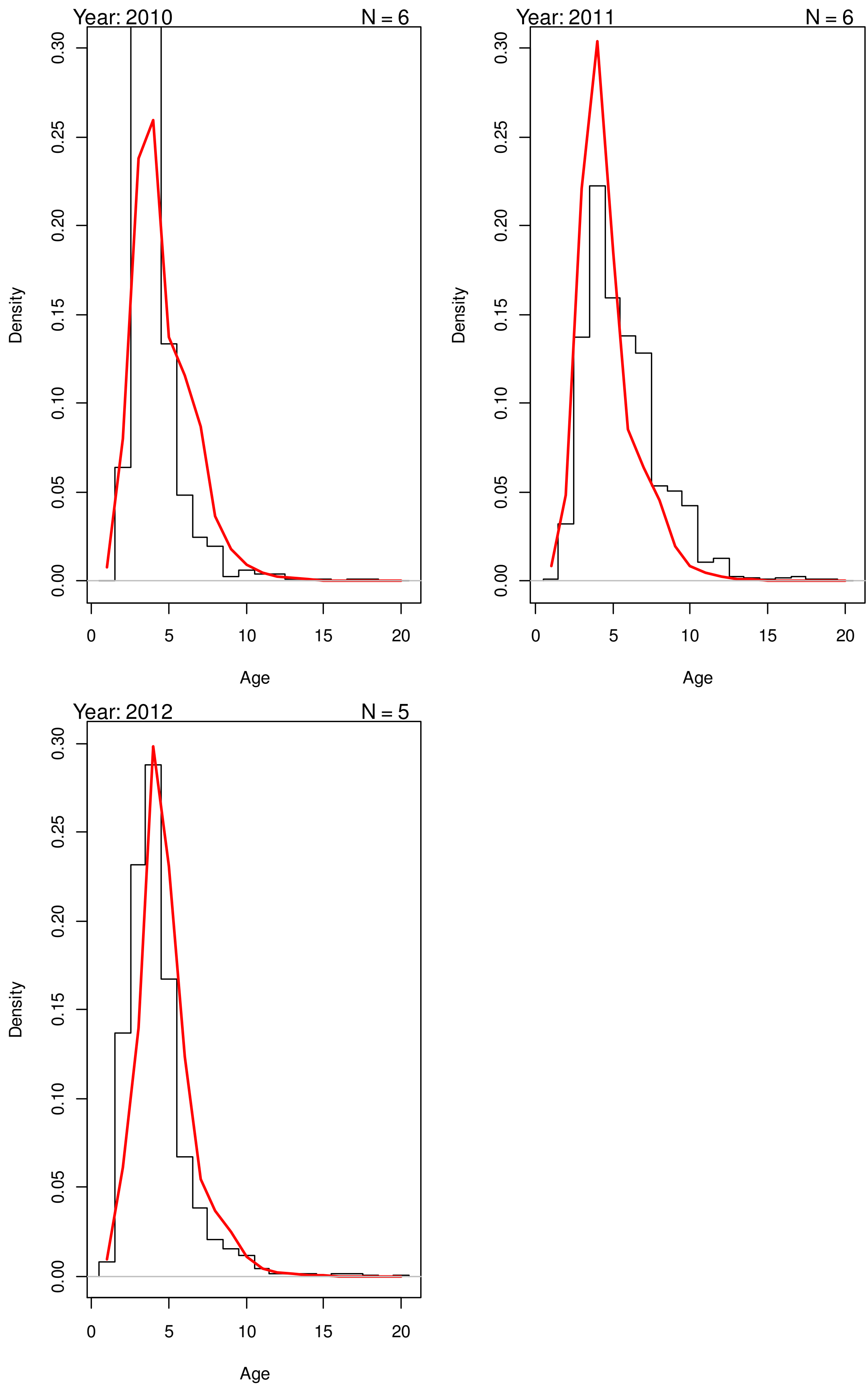

Figure A2.2: Eastern base model MPD fits to trawl age frequencies (year and tuned effective sample size given).

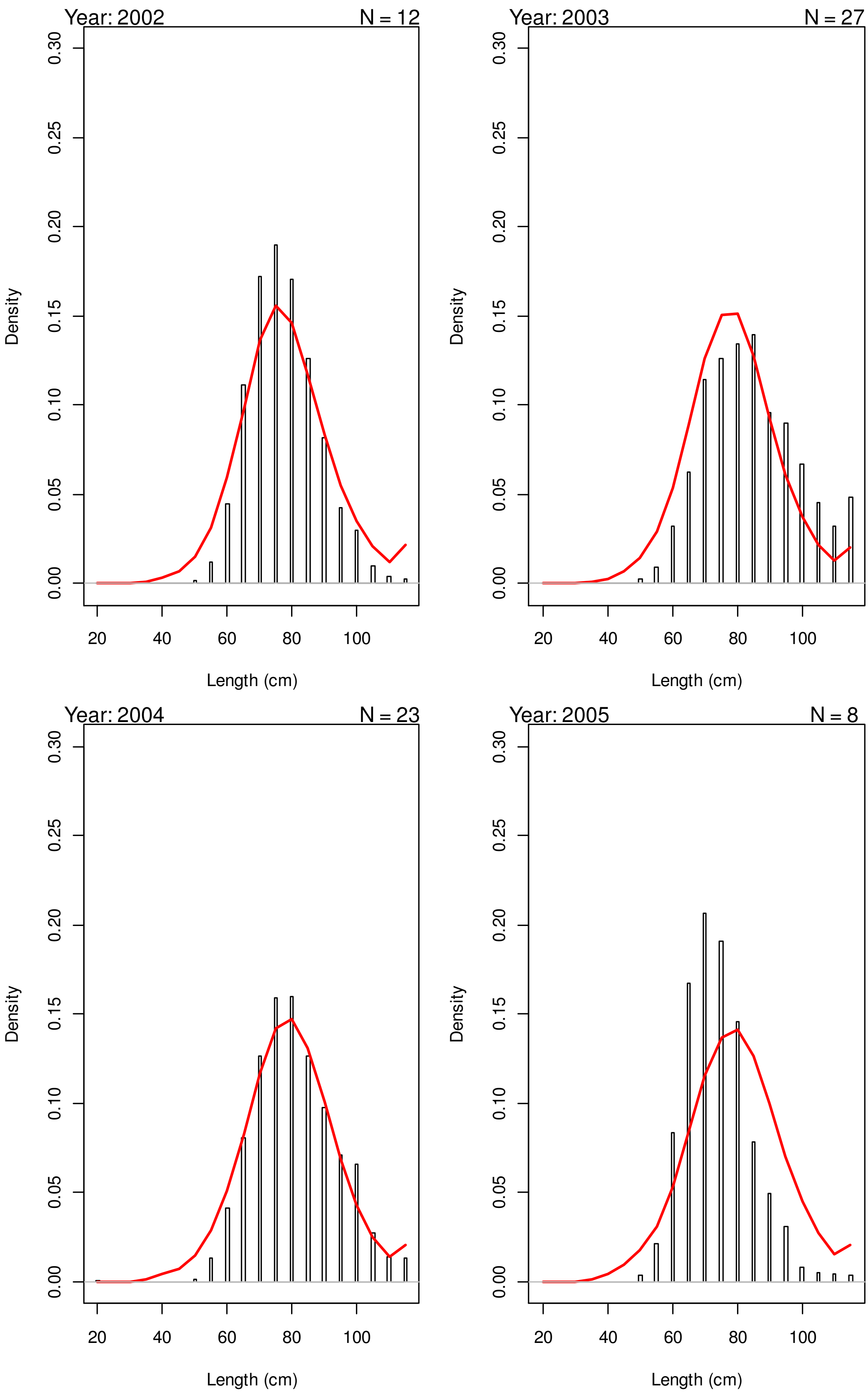

Figure A2.3: Eastern base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

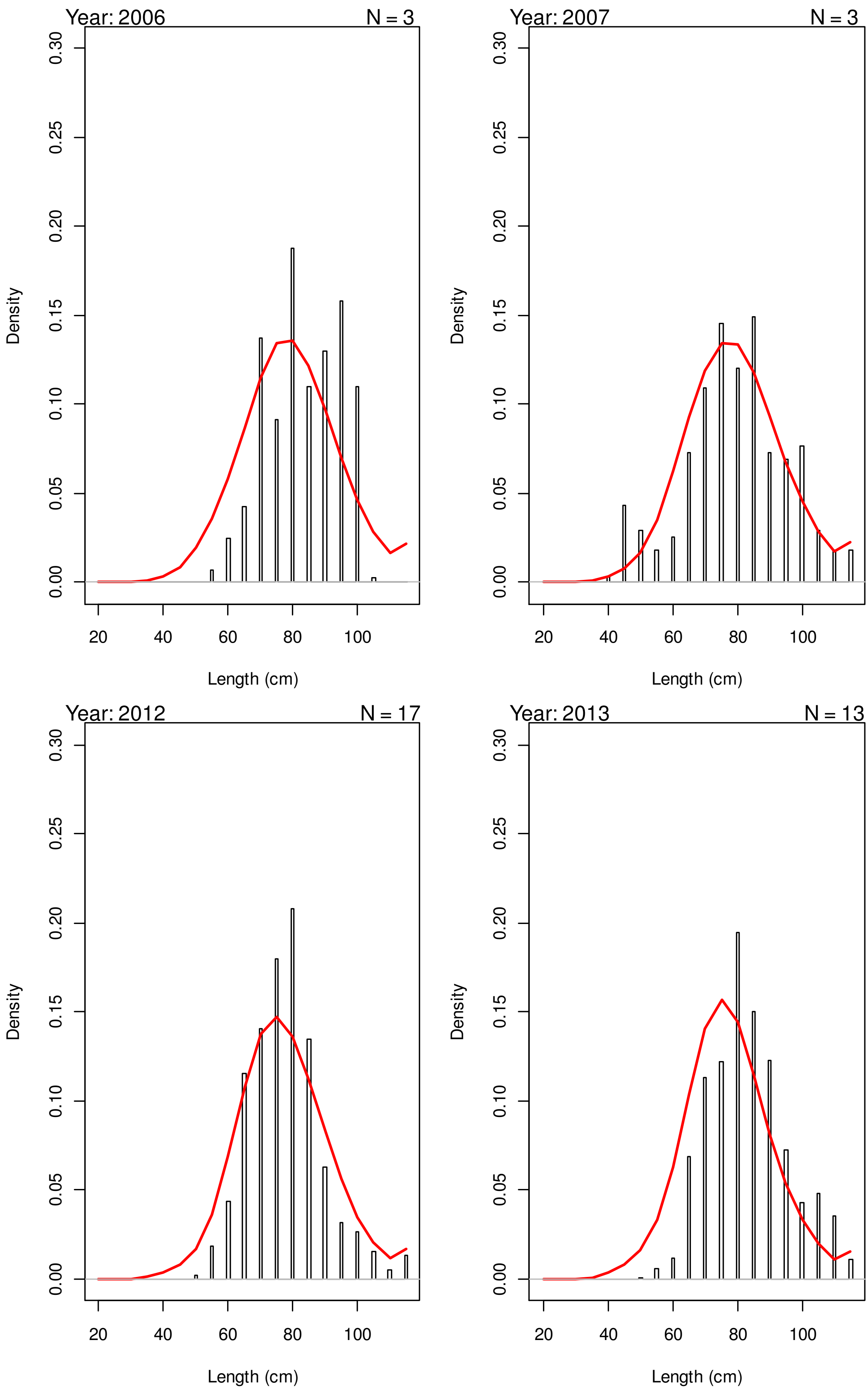

Figure A2.3: Eastern base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

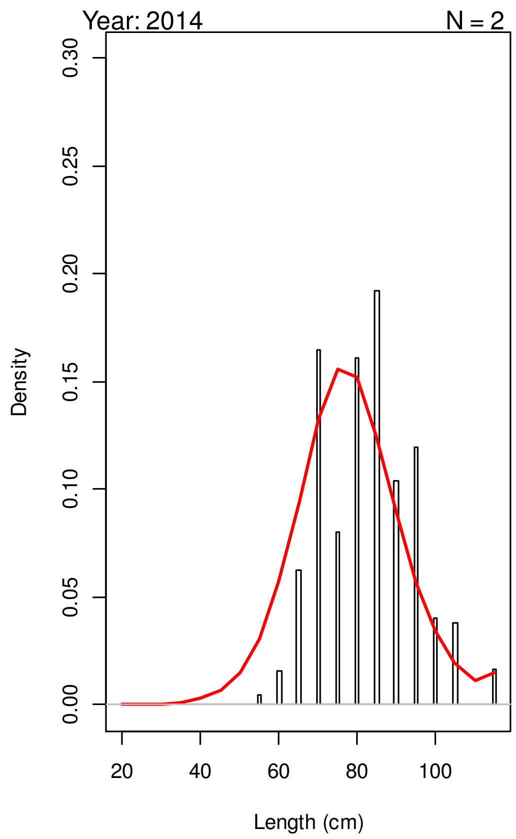

Figure A2.3: Eastern base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

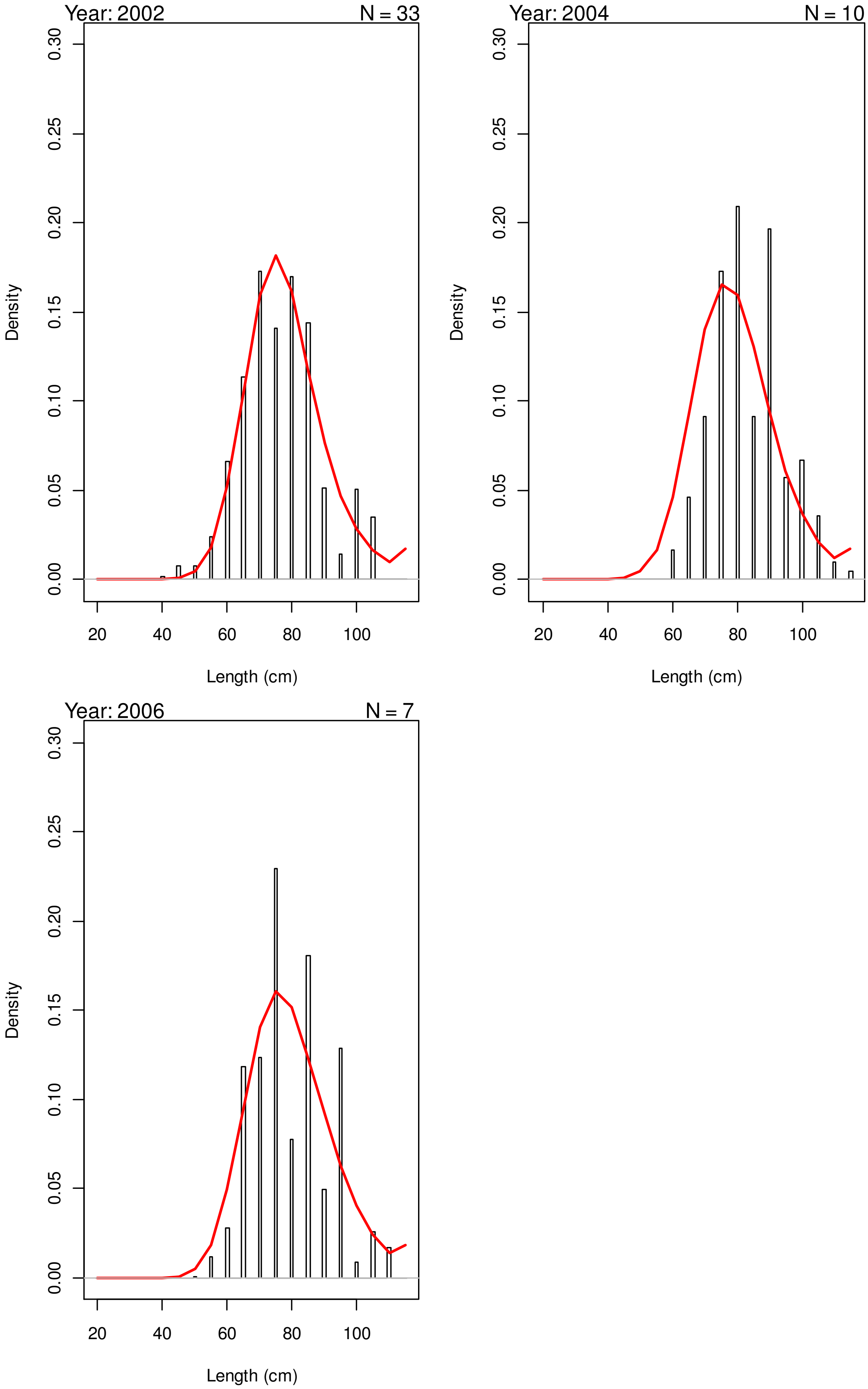

Figure A2.4: Eastern base model MPD fits to port non-trawl length frequencies (year and tuned effective sample size given).

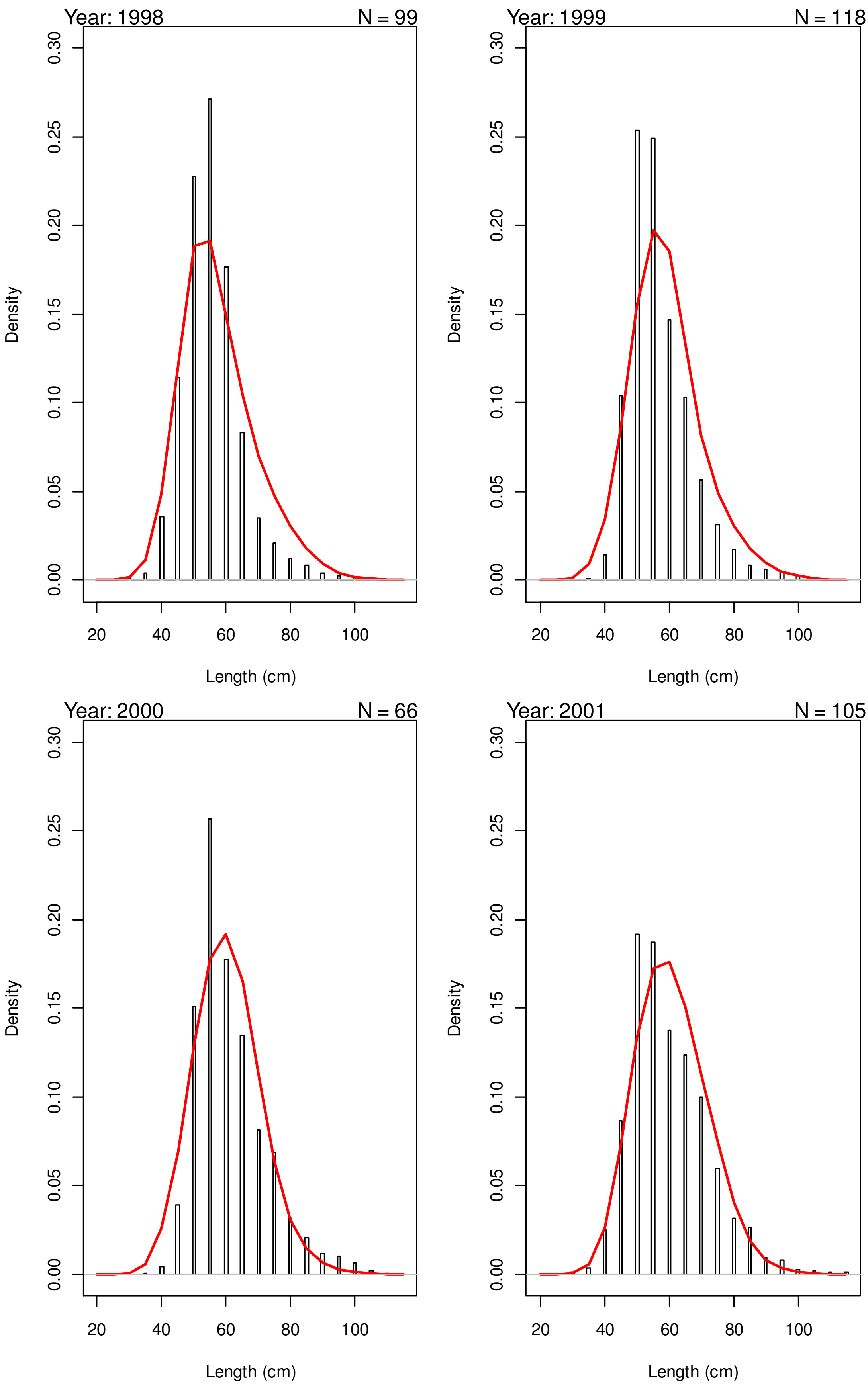

Figure A2.5: Eastern base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

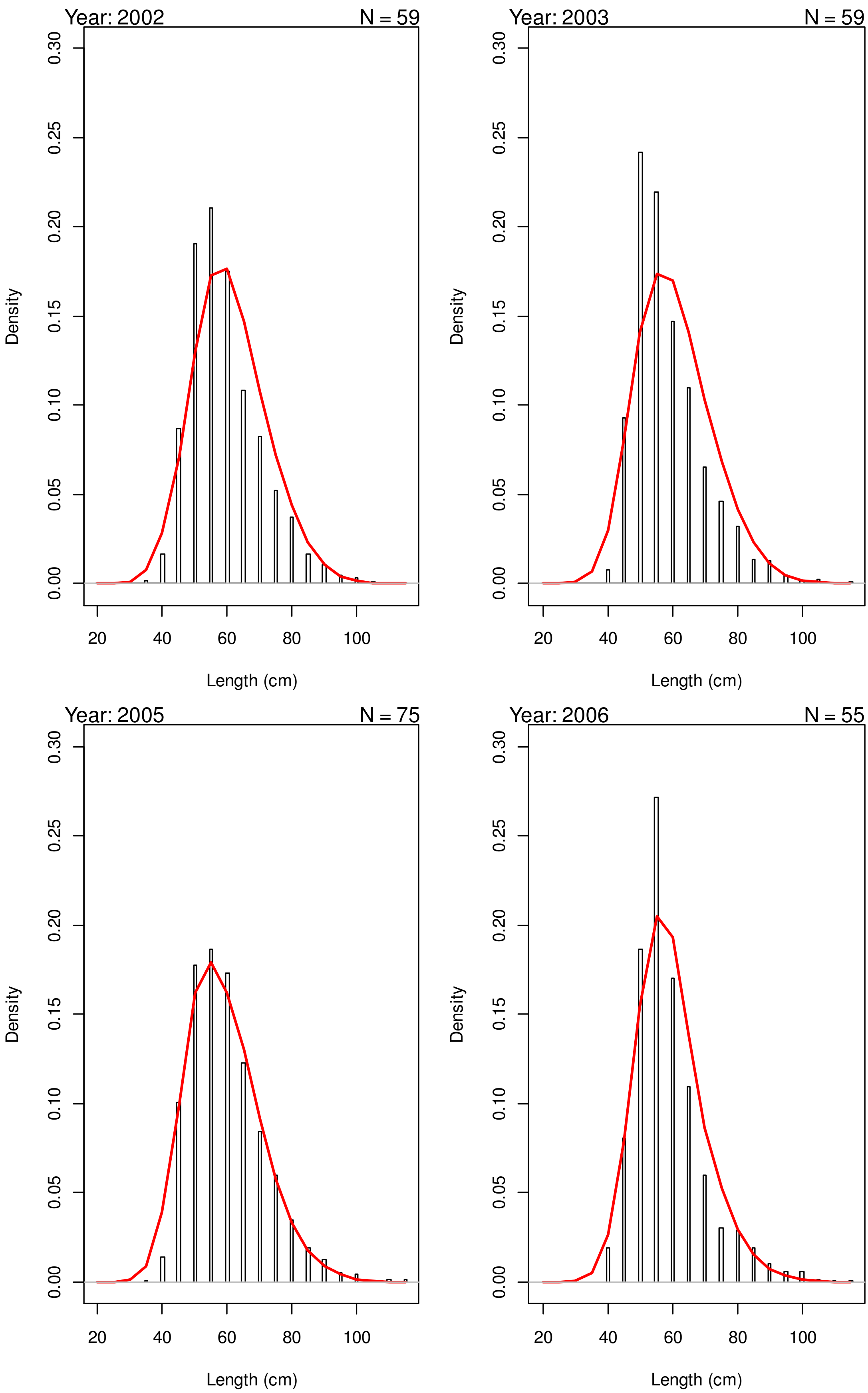

Figure A2.5: Eastern base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

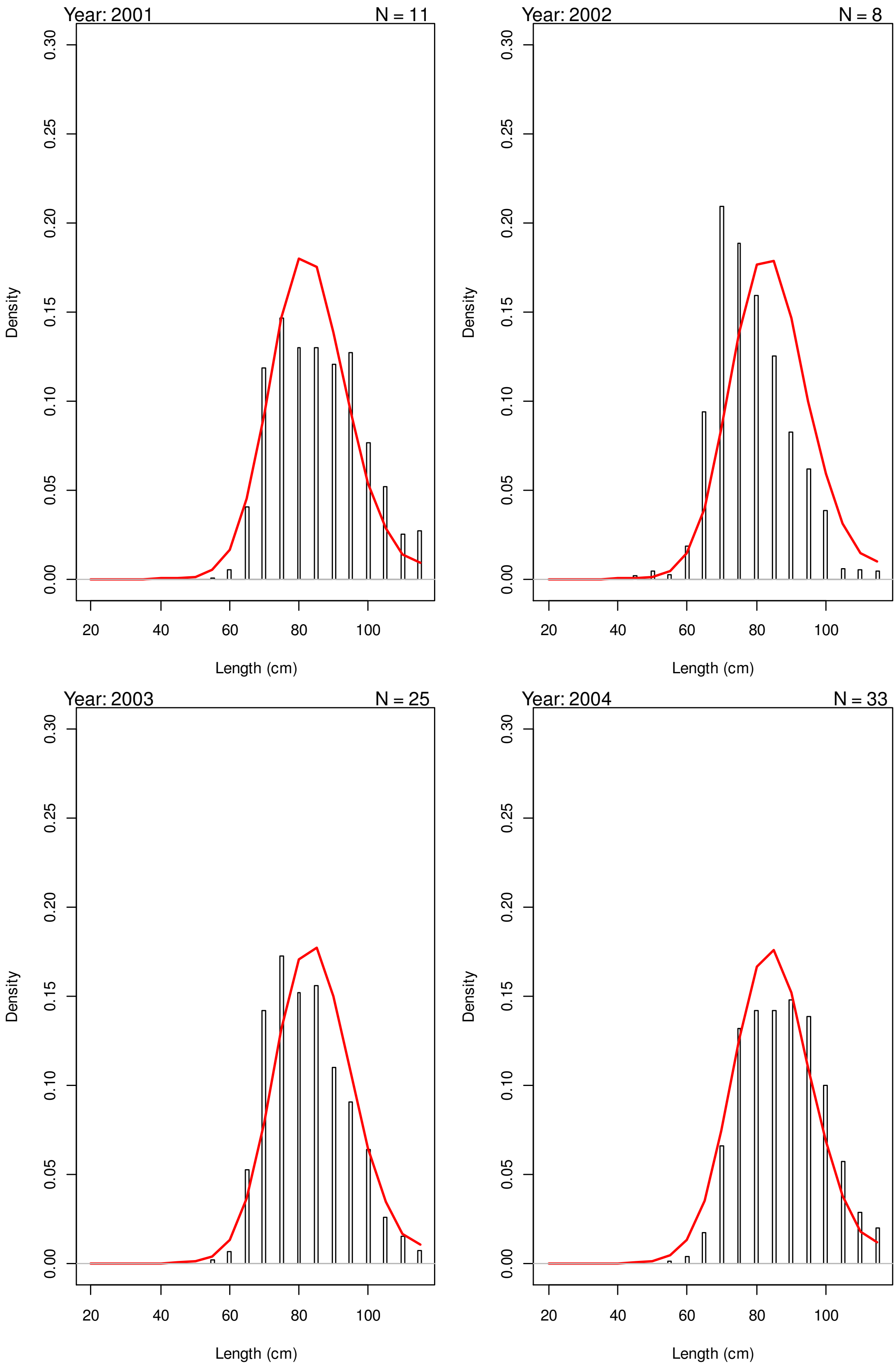

Figure A2.6: Western base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

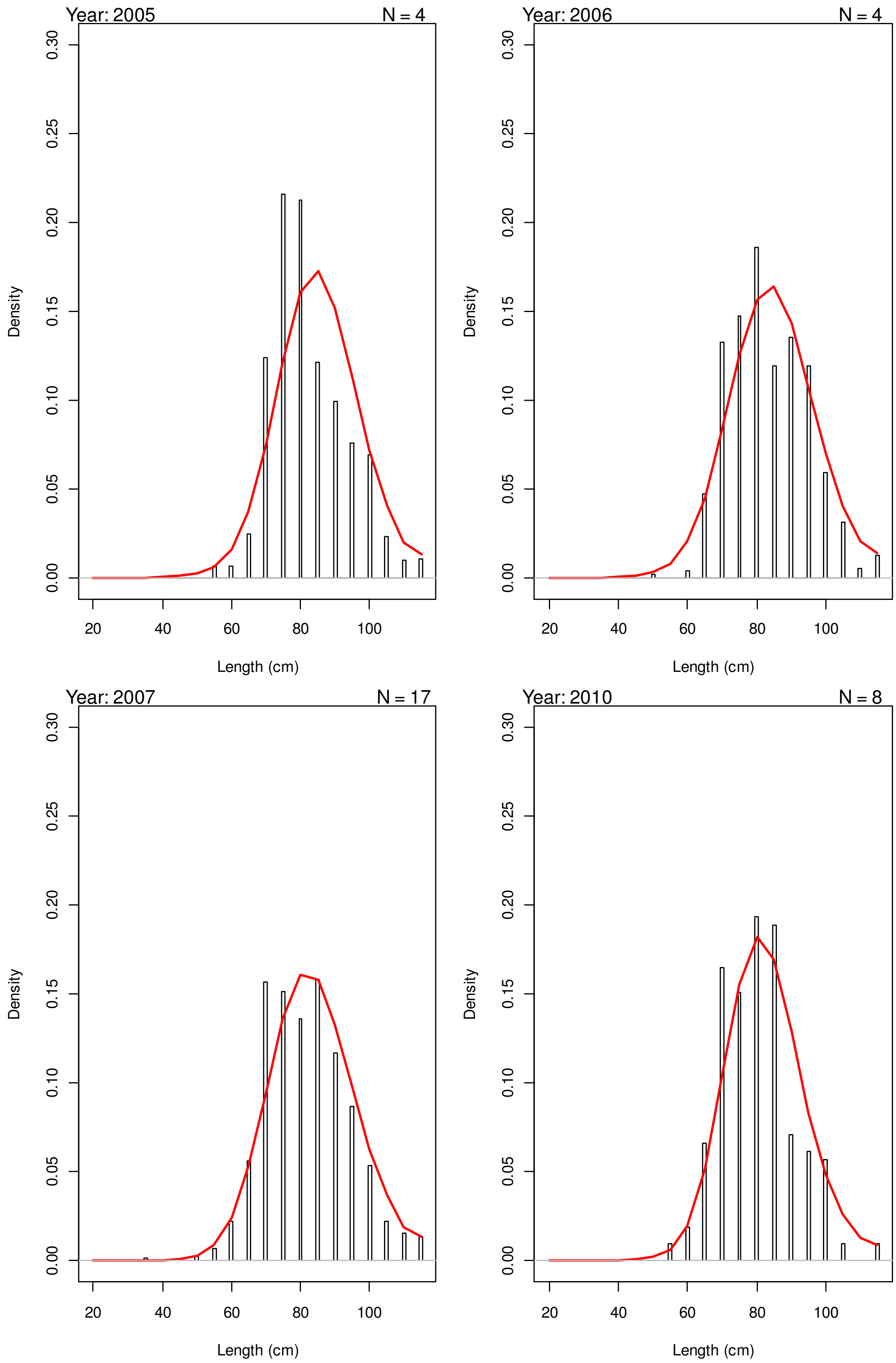

Figure A2.6: Western base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

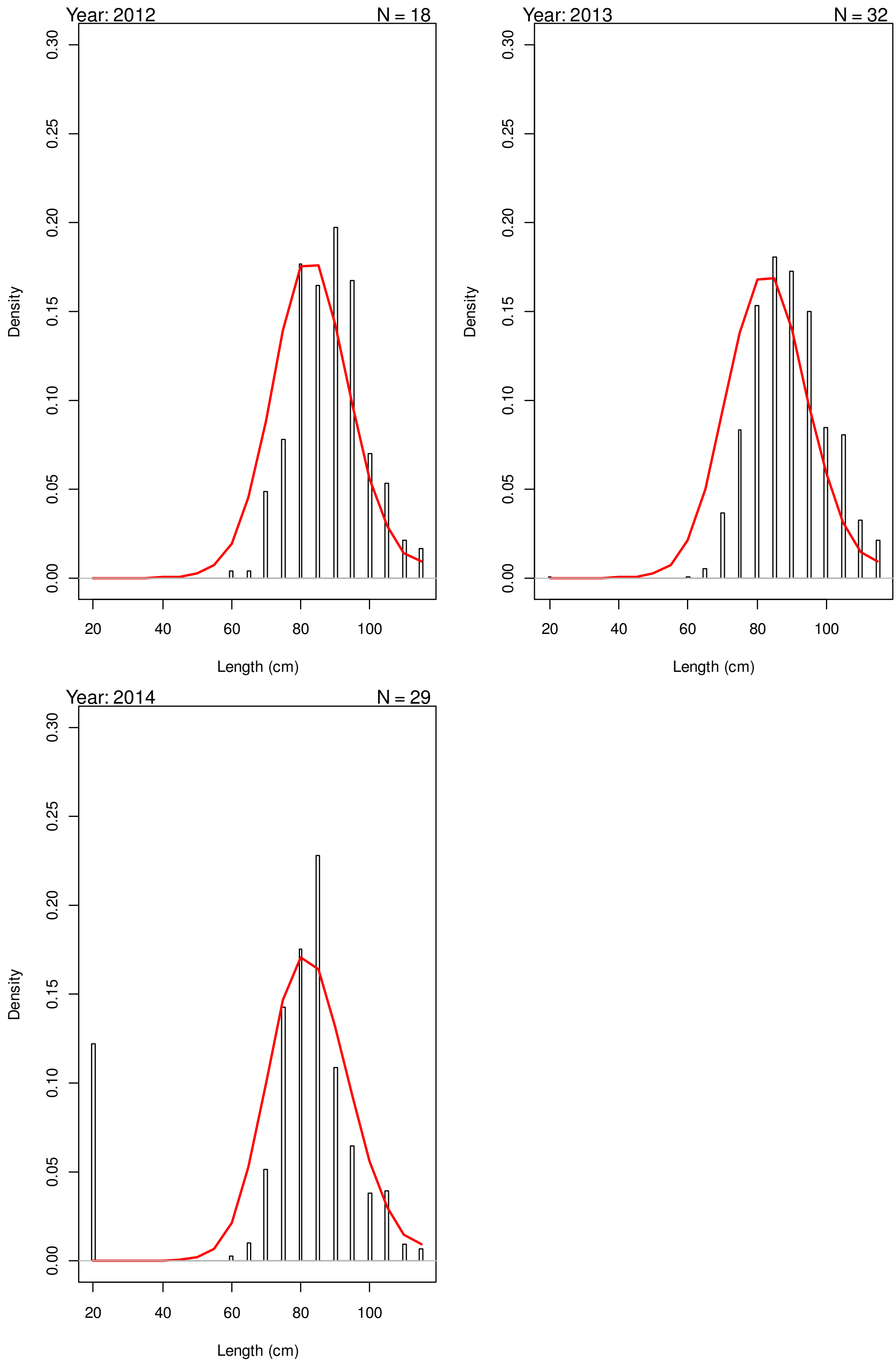

Figure A2.6: Western base model MPD fits to non-trawl length frequencies (year and tuned effective sample size given).

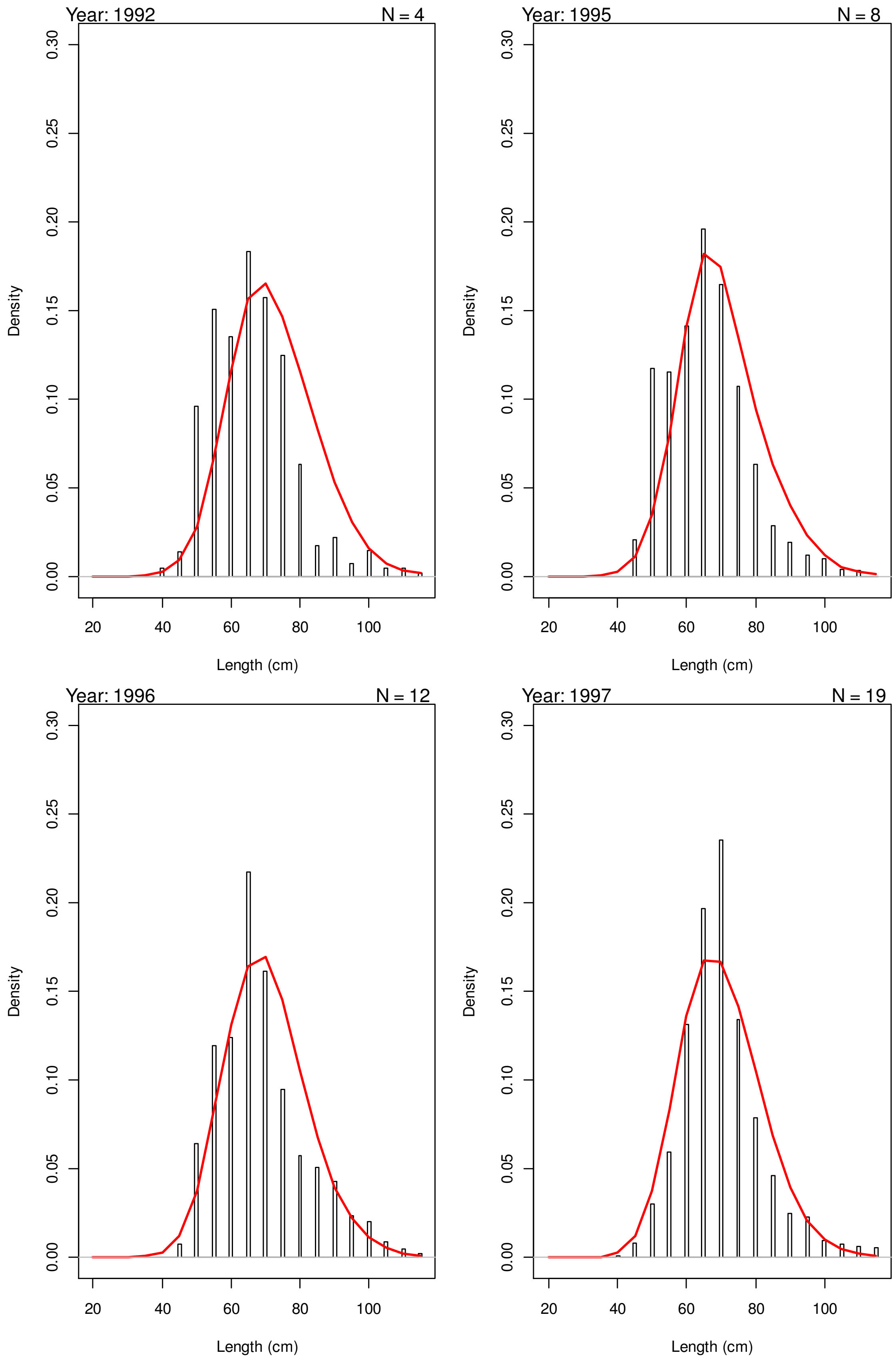

Figure A2.7: Western base model MPD fits to port trawl length frequencies (year and tuned effective sample size given).

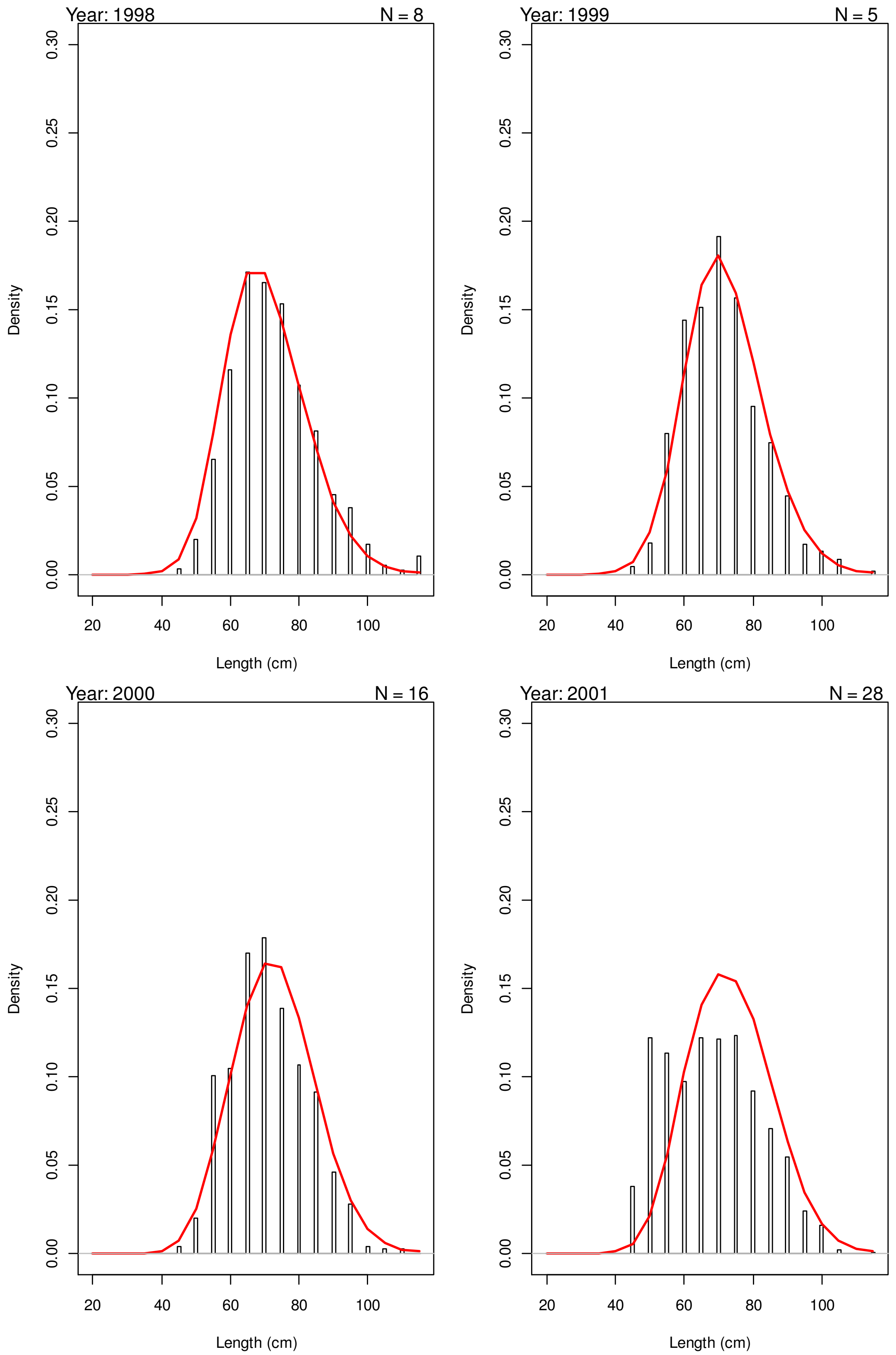

Figure A2.7: Western base model MPD fits to port trawl length frequencies (year and tuned effective sample size given).

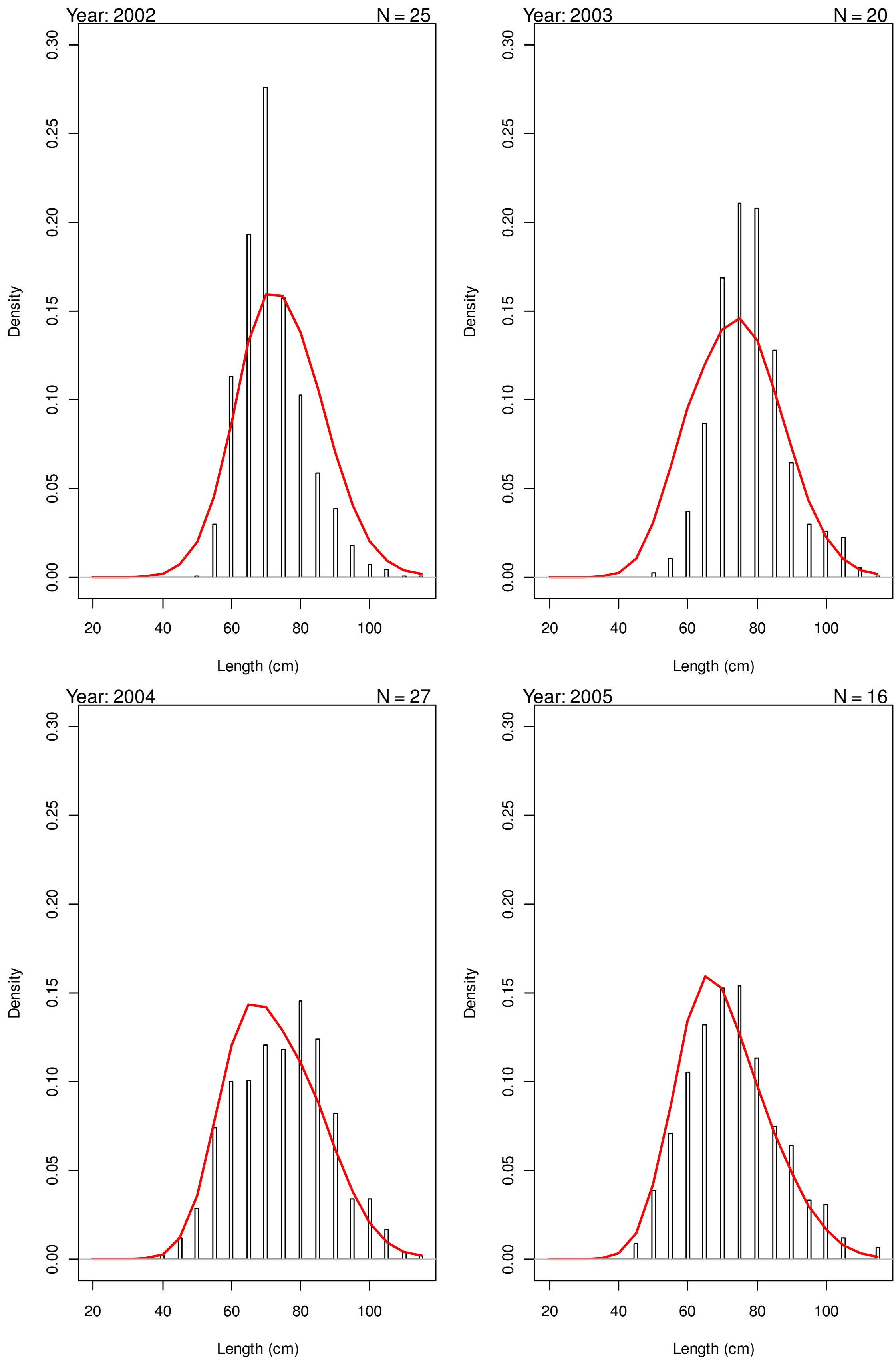

Figure A2.7: Western base model MPD fits to port trawl length frequencies (year and tuned effective sample size given).

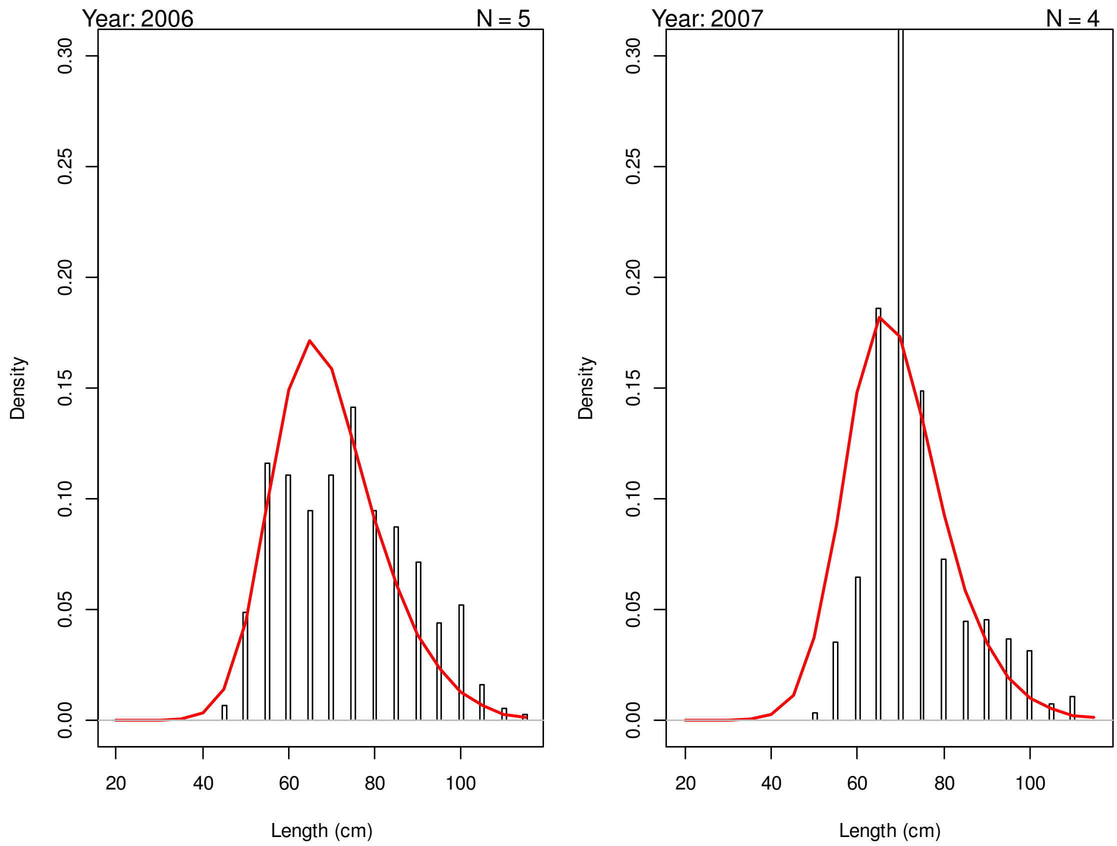

Figure A2.7: Western base model MPD fits to port trawl length frequencies (year and tuned effective sample size given).

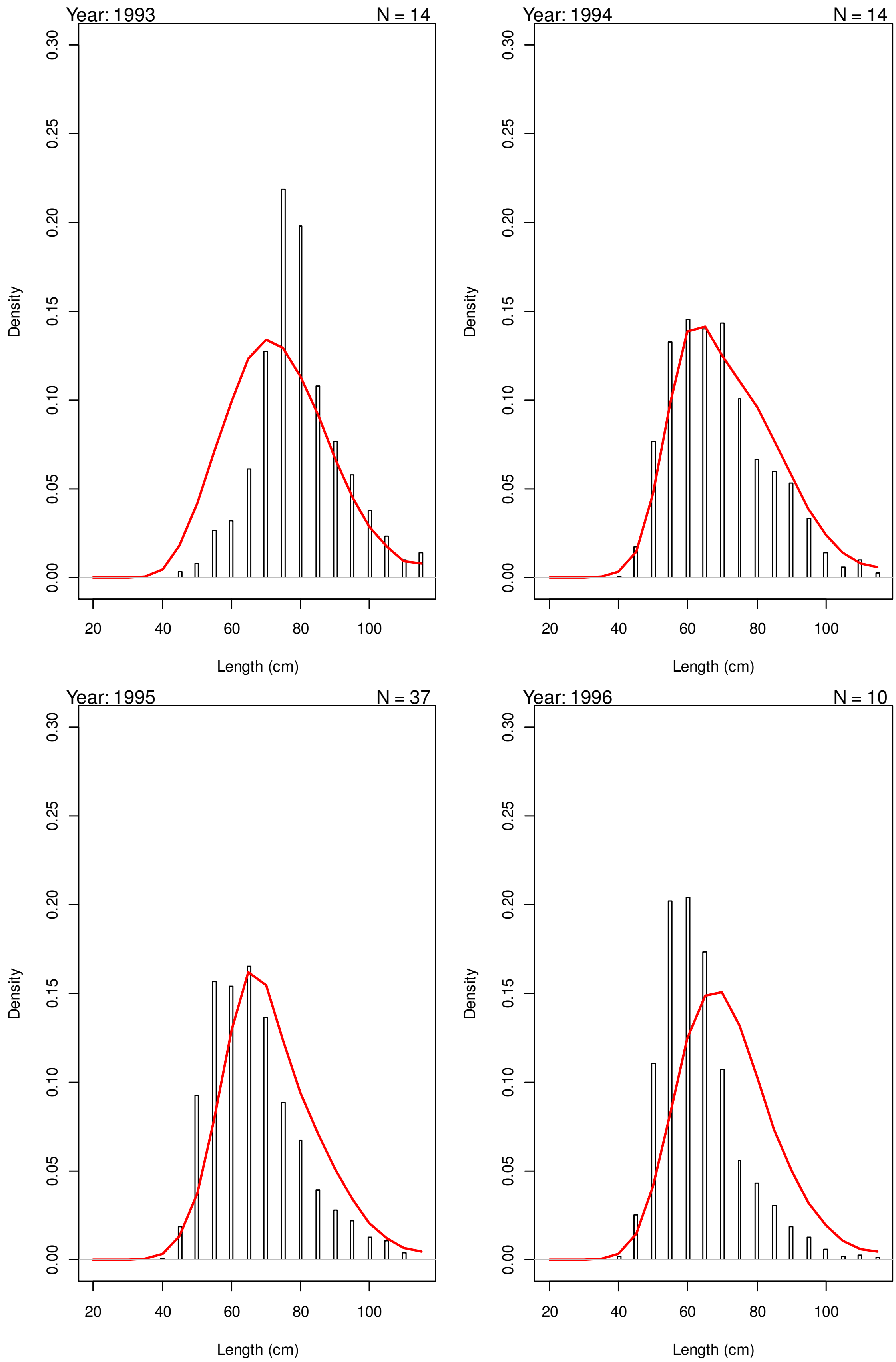

Figure A2.8: Western base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

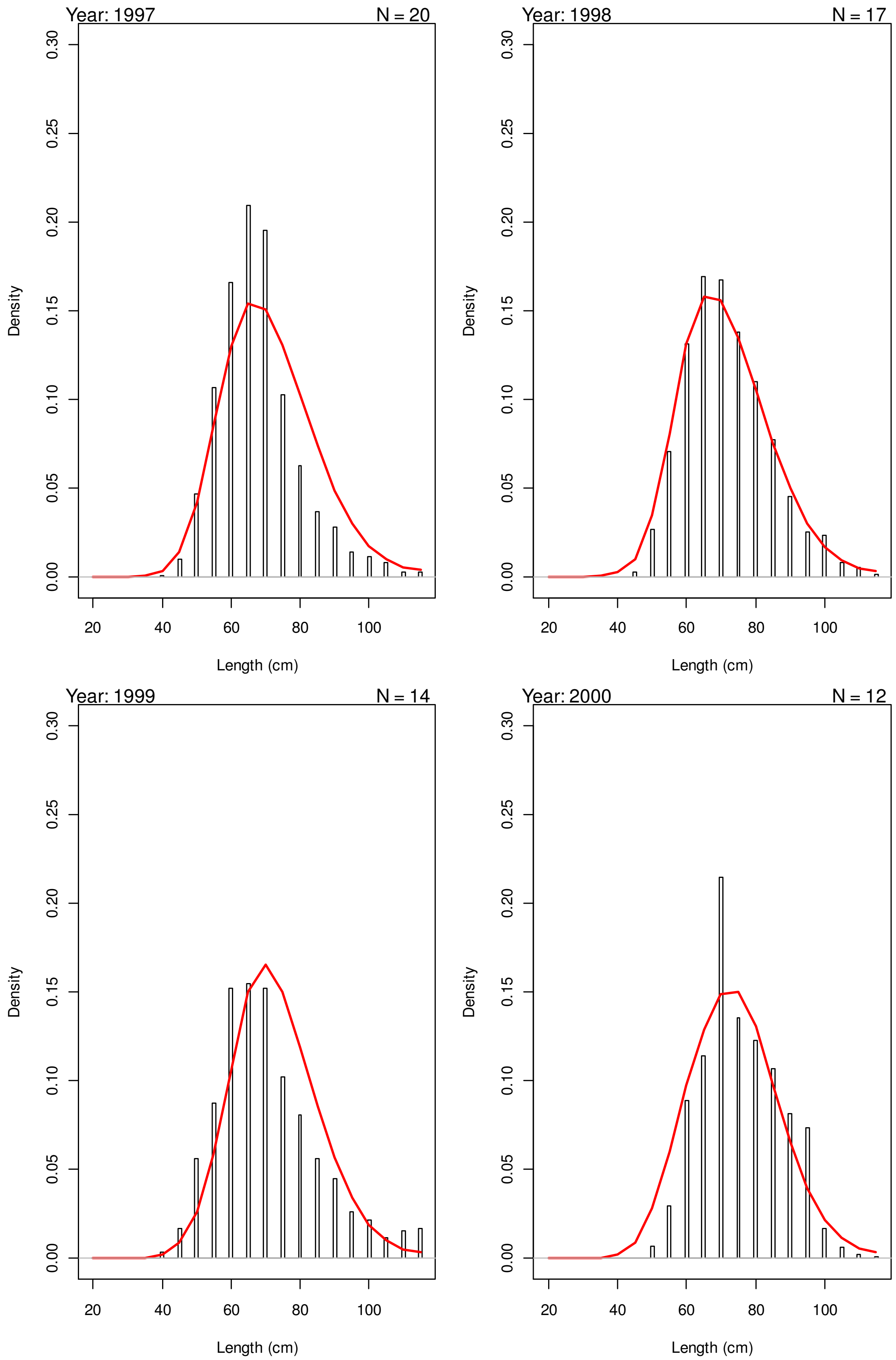

Figure A2.8: Western base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

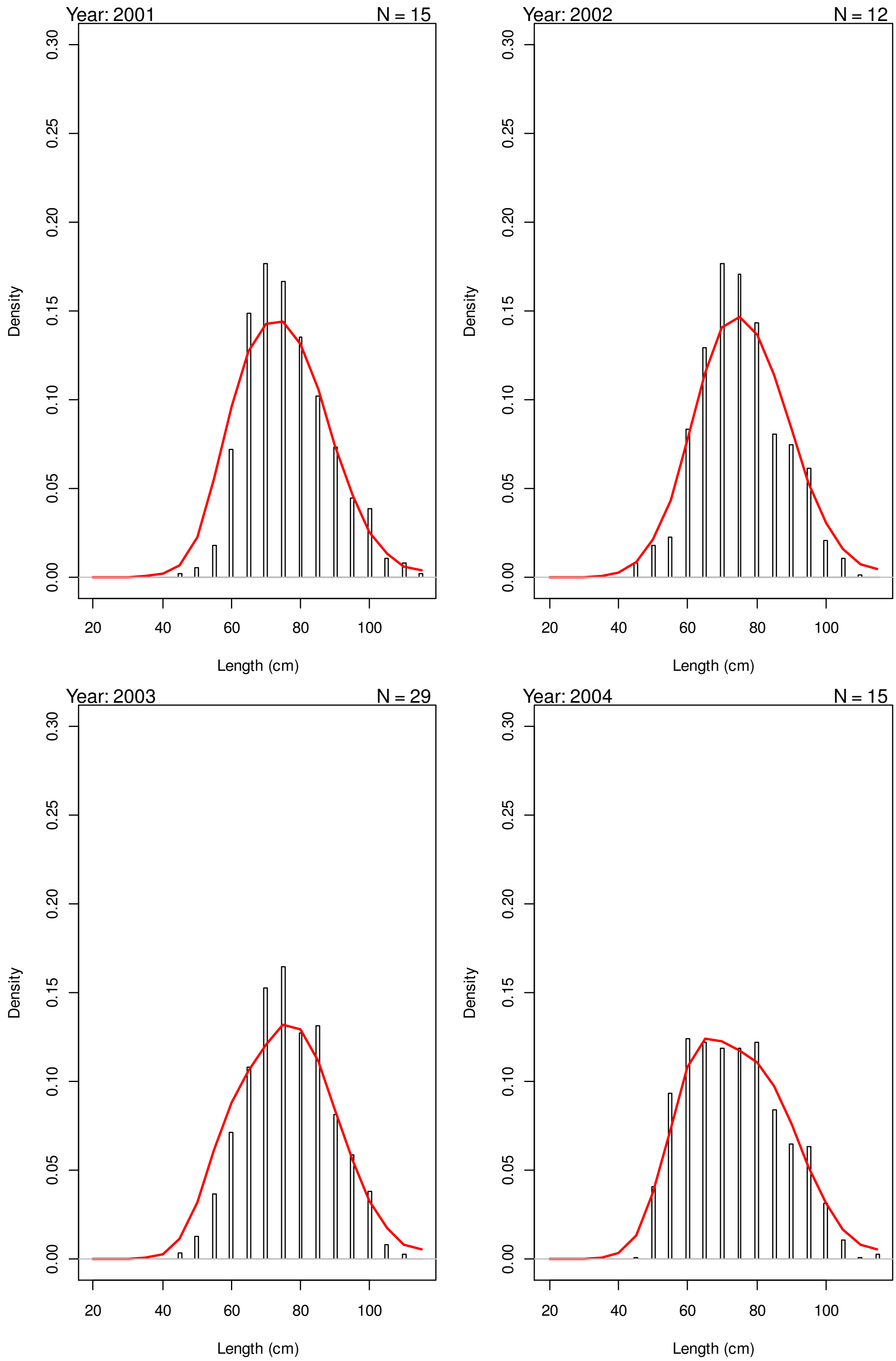

Figure A2.8: Western base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

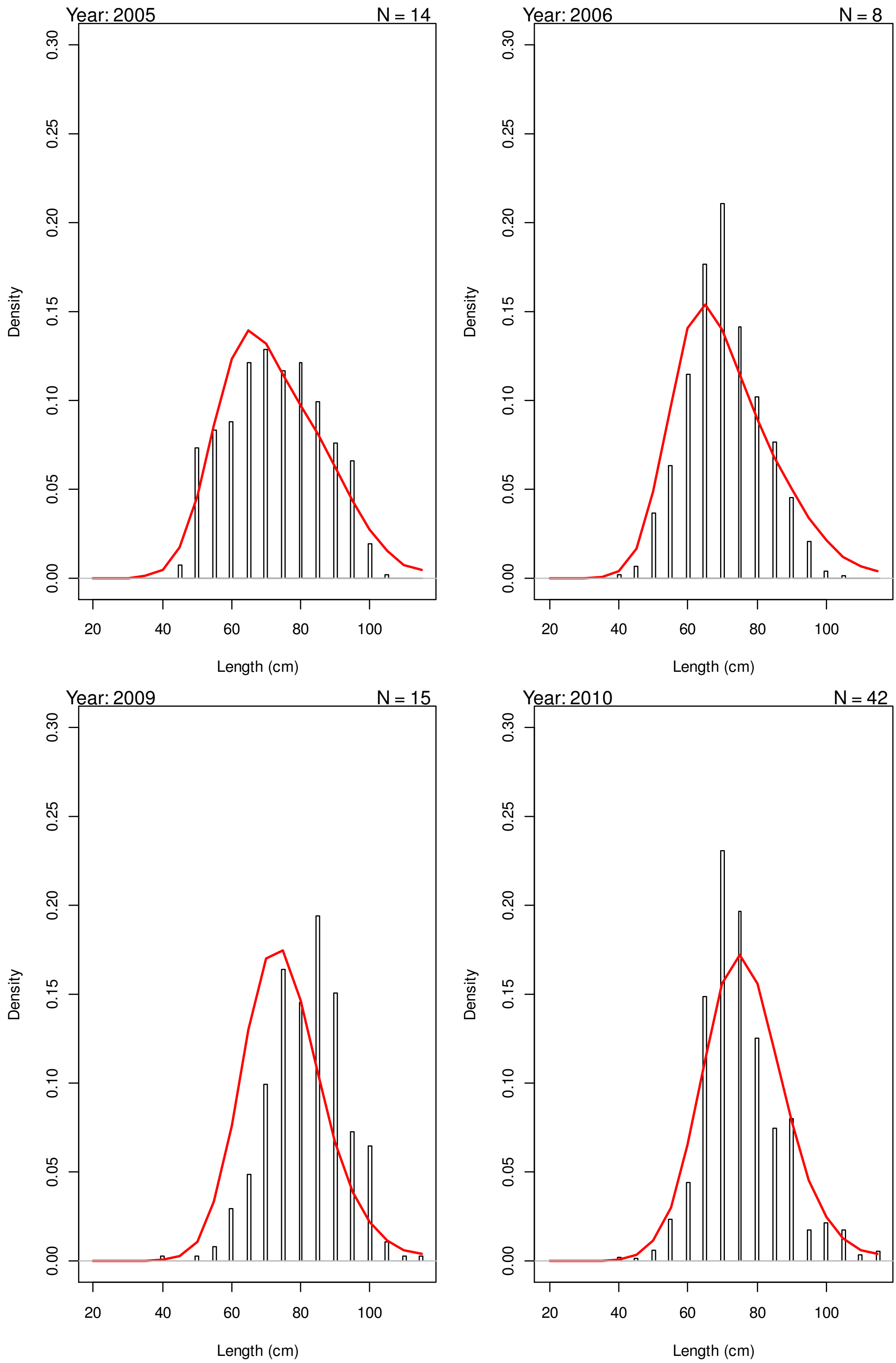

Figure A2.8: Western base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

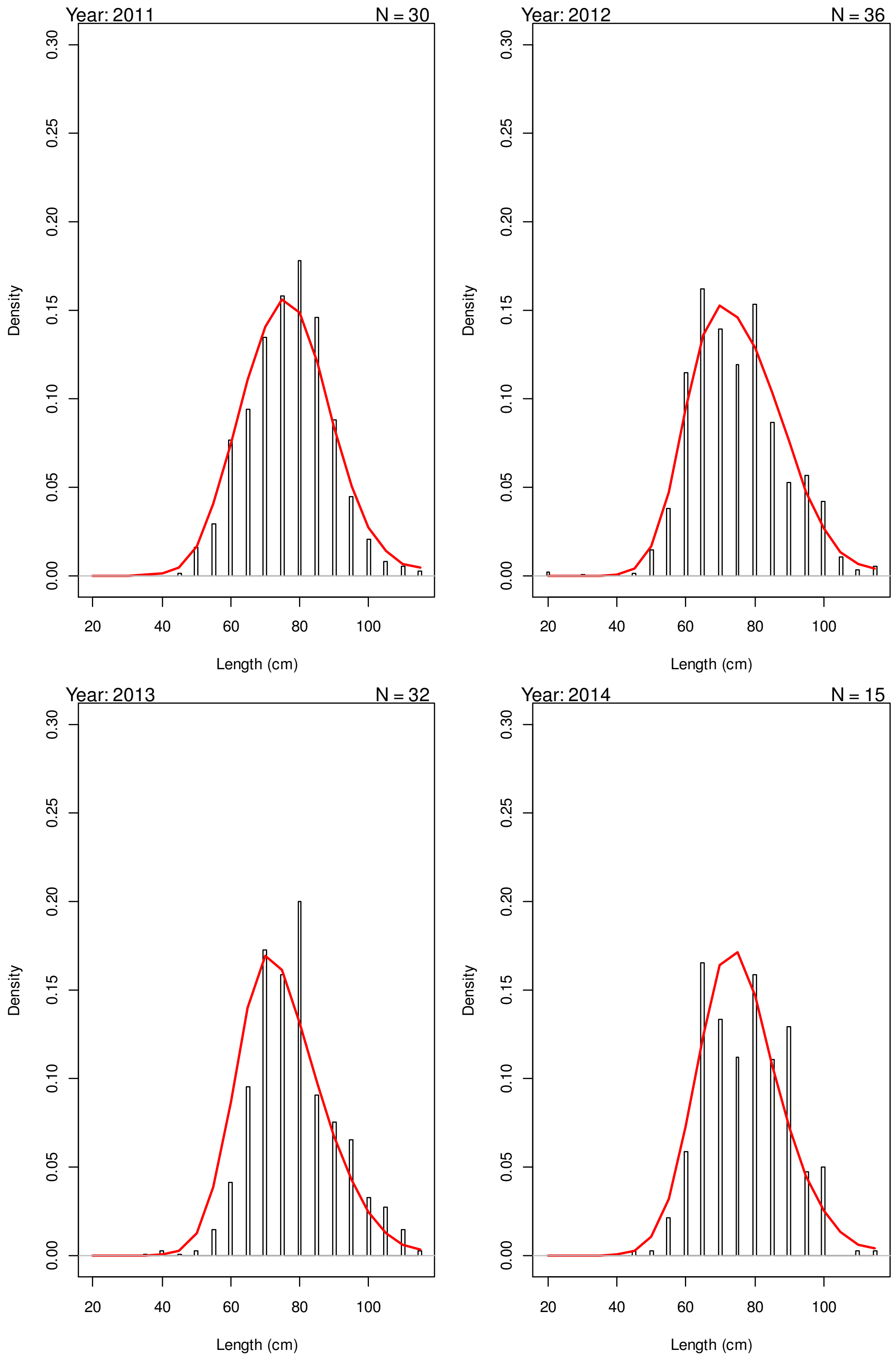

Figure A2.8: Western base model MPD fits to trawl length frequencies (year and tuned effective sample size given).

Appendix 3: MCMC convergence diagnostics

For the east, the three final base model chains were adequately converged for virgin SSB, current SSB, current stock status, and the convergence was excellent for M (Figures A3.1-5). The chains were allowed to run for an extra two days after these results were generated. The estimates from the longer chains were almost identical to the earlier results.

For the west, there were major convergence issues, but they were overcome by ignoring the anomalous second chain. Given the very high stock status in the west there was little point in refining the estimates through improved chain convergence.

Three MCMC chains of length over 6 million were run retaining every 1000th sample. The first 400 samples from each chain were discarded as a "burn-in". The second chain behaved differently from the other two chains after about 4000 samples had been retained (e.g., see Figure A3.6). It starting sampling in a space with higher virgin SSB and higher natural mortality (see Figures A3.7, A3.9, and A3.12). The remaining two chains sampled very similar space (see Figures A3.6-10 for virgin SSB; Figures A3.9-11 for natural mortality). The anomalous behaviour of chain 2 for virgin SSB and natural mortality flowed through into the samples for current SSB and current stock status (Figures A3.13-15 for current SSB; Figures A3.16-18 for current stock status). For current stock status it makes little difference whether all chains are used or just the two consistent chains (Figure A3.17).

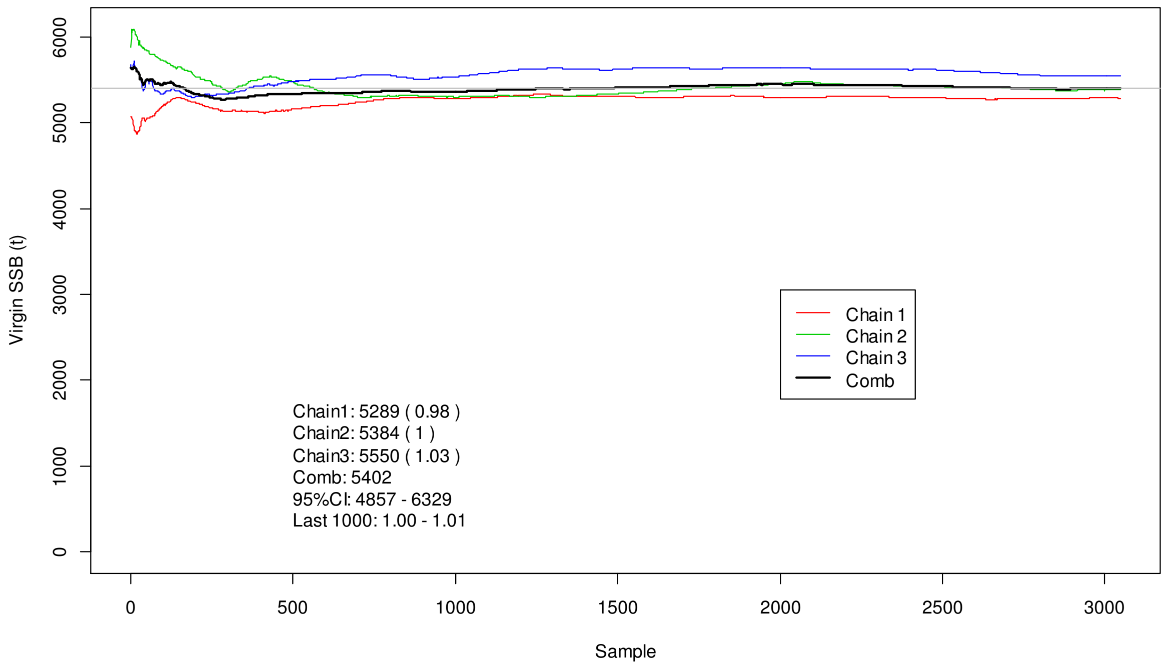

Figure A3.1: Eastern base model: cumulative medians for virgin SSB from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples. Within the parentheses are the ratio of the final individual medians to the final combined median.

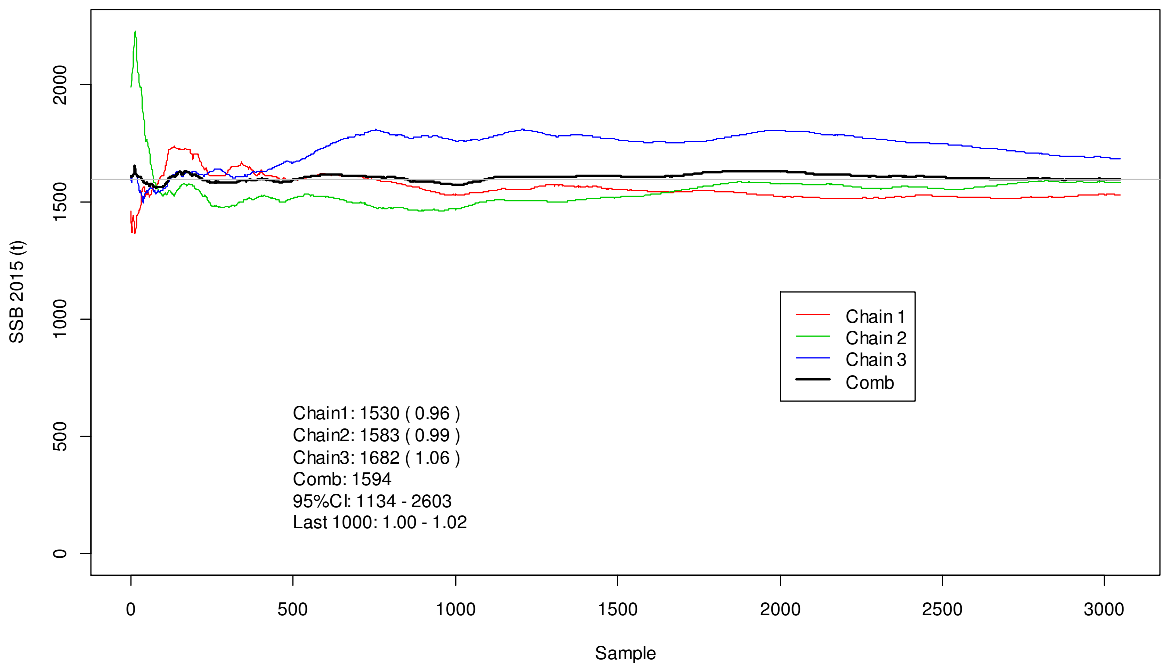

Figure A3.2: Eastern base model: cumulative medians for current SSB from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples. Within the parentheses are the ratio of the final individual medians to the final combined median.

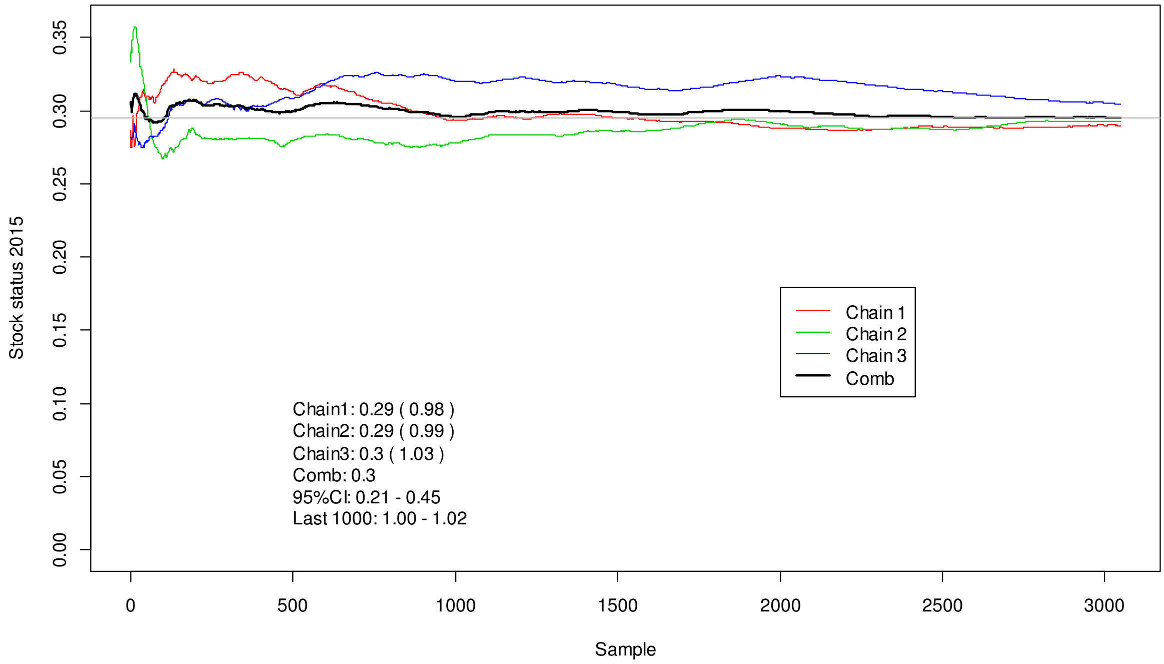

Figure A3.3: Eastern base model: cumulative medians for current stock status from the three chains for the new base eastern model and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples. Within the parentheses are the ratio of the final individual medians to the final combined median.

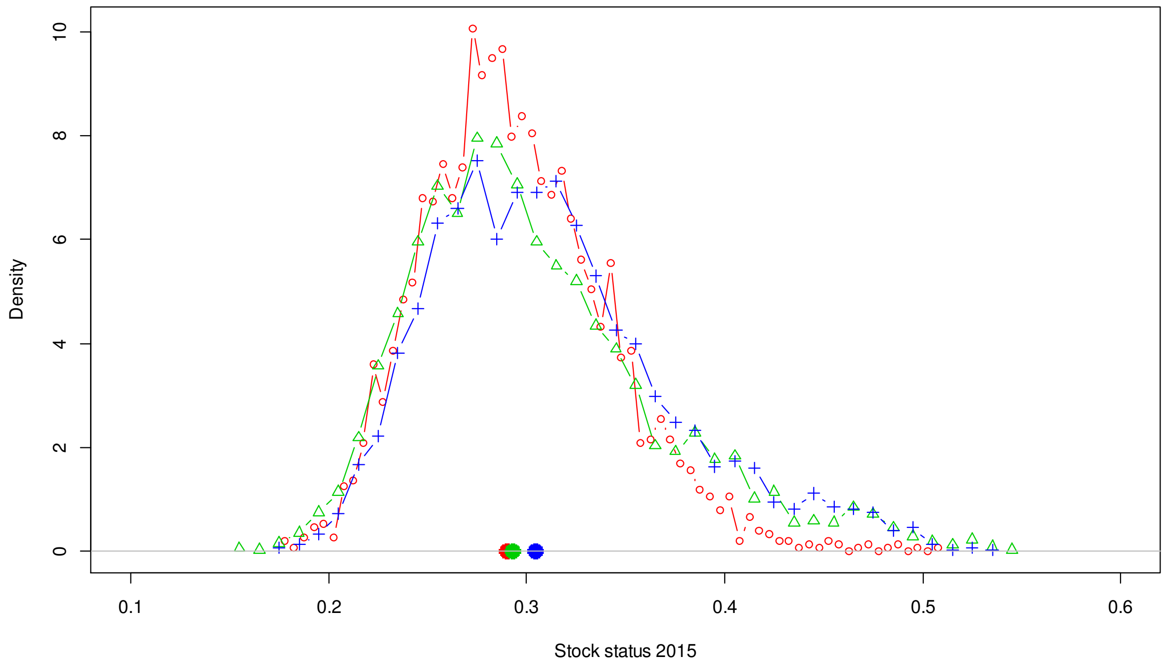

Figure A3.4: Eastern base model: a comparison of the marginal posterior distributions for current stock status for the three chains.

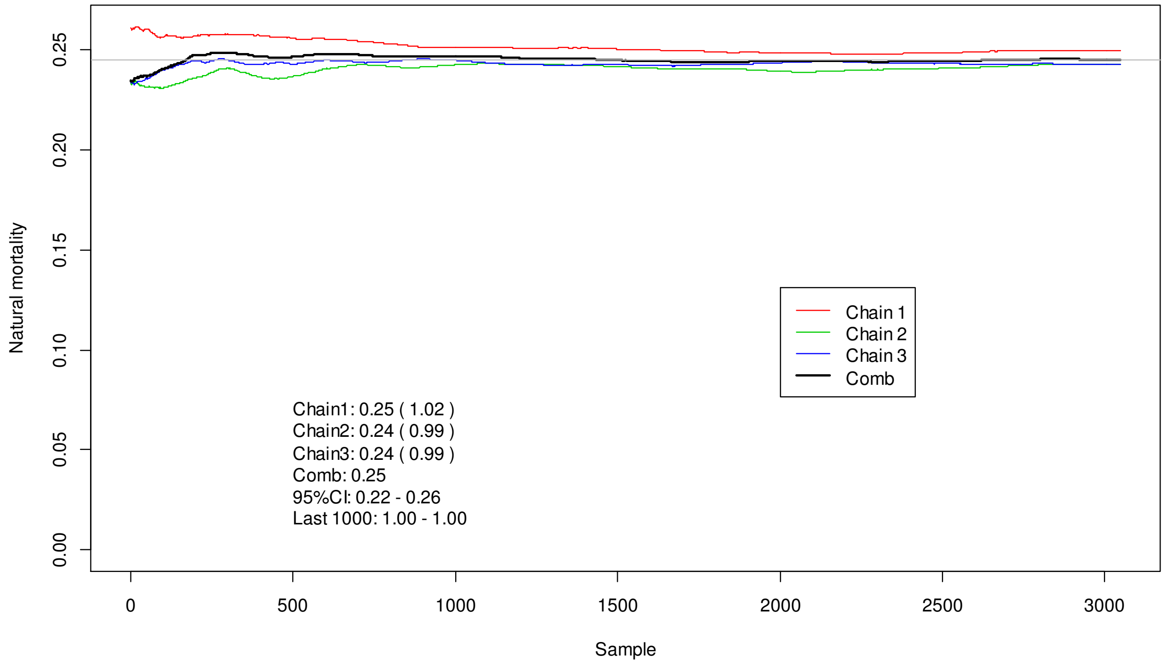

Figure A3.5: Eastern base model: cumulative medians for natural mortality from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has hardly changed over the last 1000 stored samples. Within the parentheses are the ratio of the final individual medians to the final combined median.

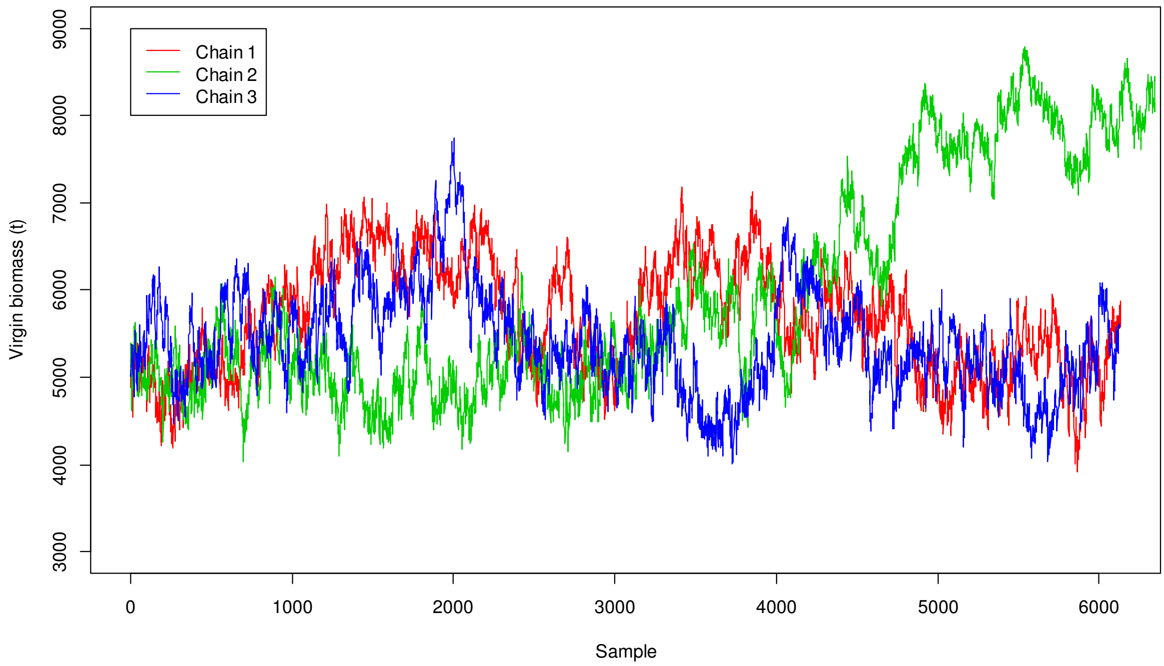

Figure A3.6: Western base model: the three MCMC chains showing the anomalous performance of the second chain for virgin biomass (from about sample 4400).

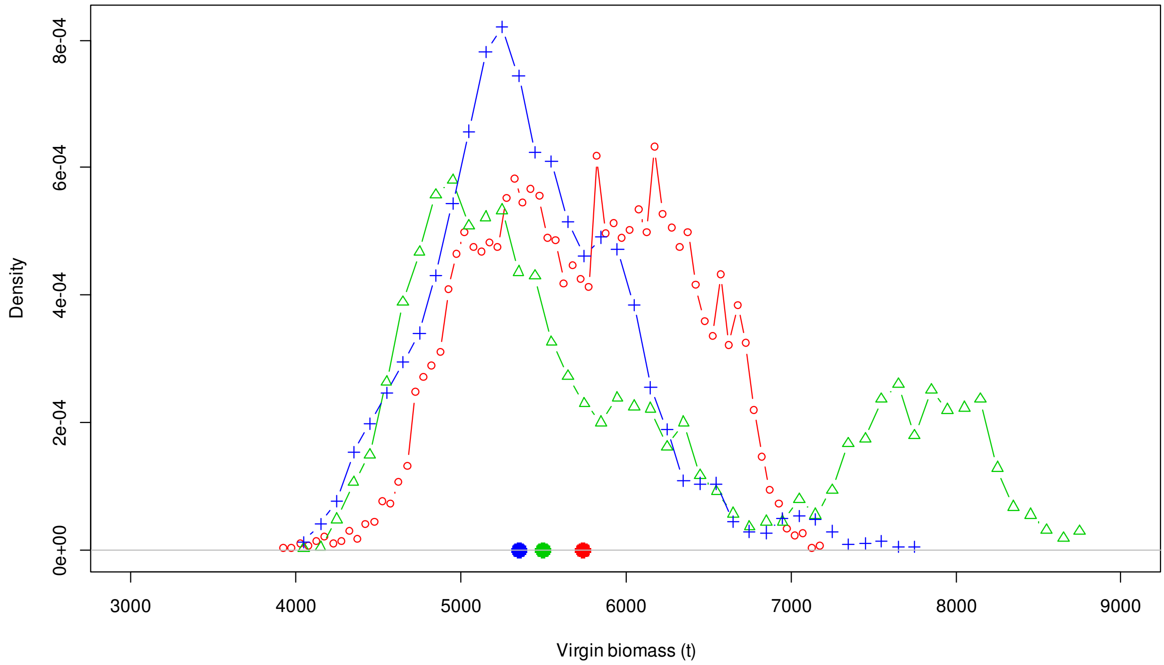

Figure A3.7: Western base model: a comparison of the marginal posterior distributions for virgin biomass from the three chains. Chain 2 has found a secondary space with higher virgin biomass.

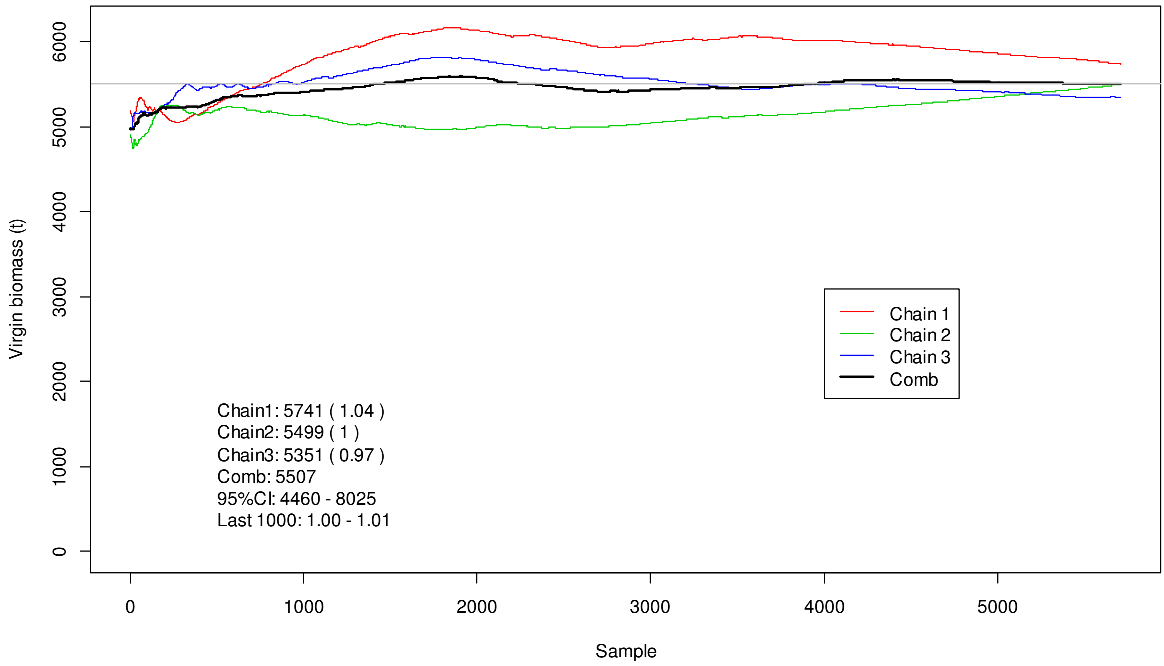

Figure A3.8: Western base model: cumulative medians for virgin biomass from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples (but chain 2 is continuing an upward trend). Within the parentheses are the ratio of the final individual medians to the final combined median.

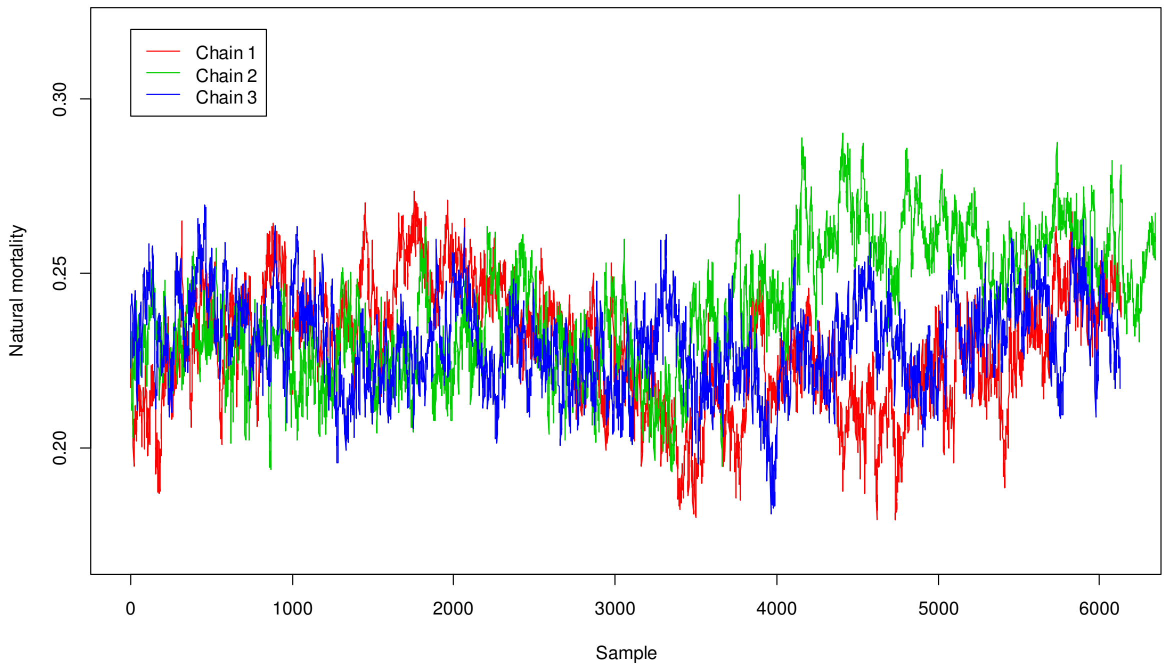

Figure A3.9: Western base model: the three MCMC chains showing the anomalous performance of the second chain for natural mortality (from about sample 4100).

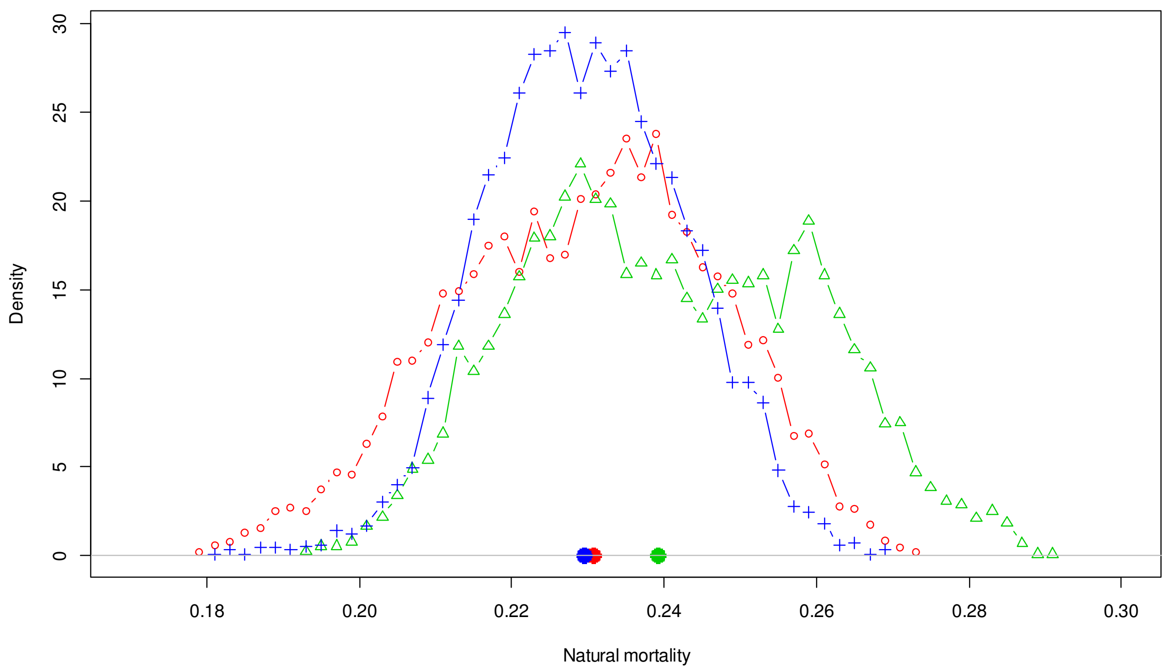

Figure A3.10: Western base model: a comparison of the marginal posterior distributions for natural mortality from the three chains. Chain 2 has found a secondary space with higher natural mortality (with a mode at 0.26).

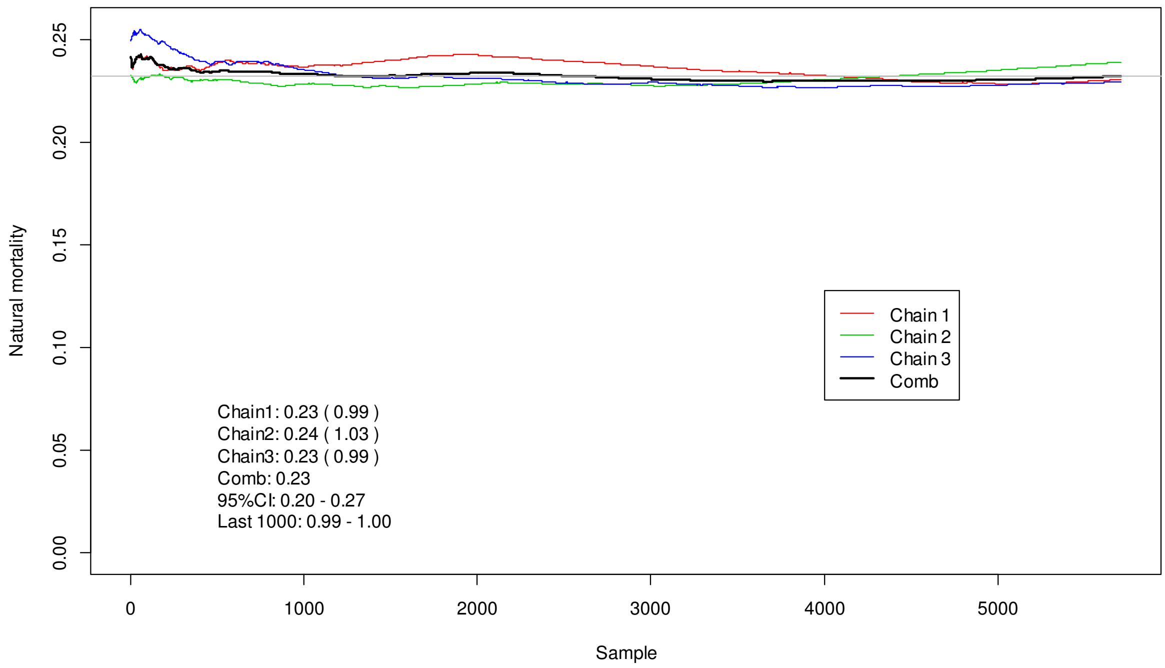

Figure A3.11: Western base model: cumulative medians for natural mortality from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples (but chain 2 has begun an upward trend). Within the parentheses are the ratio of the final individual medians to the final combined median.

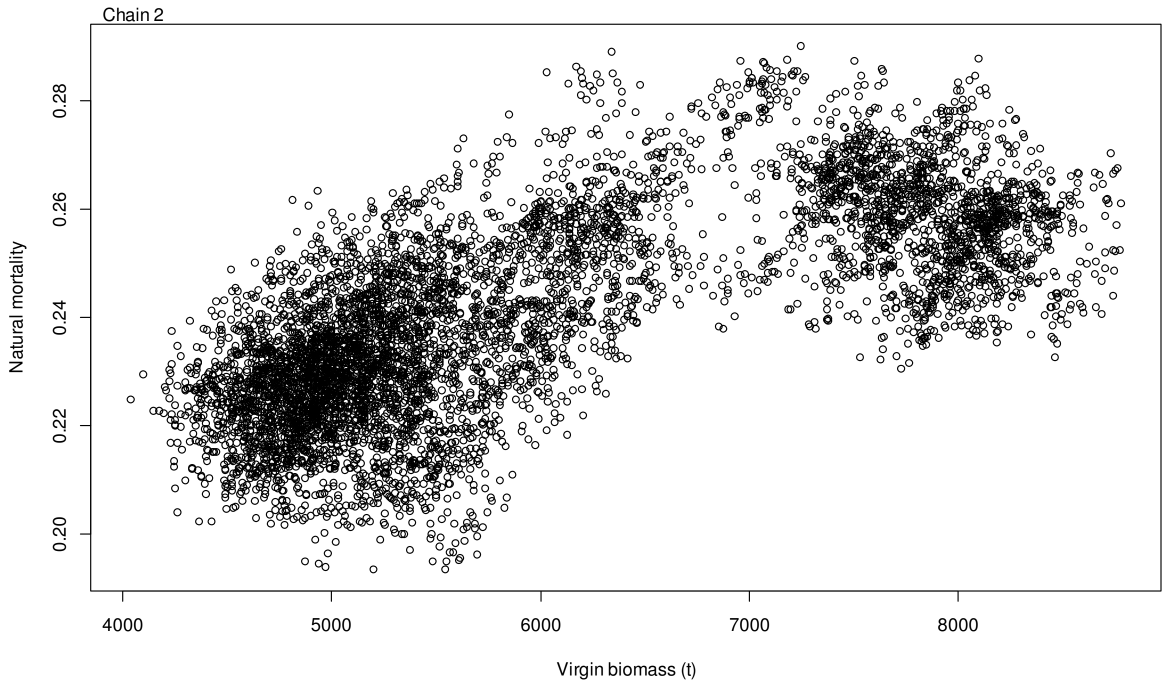

Figure A3.12: Western base model: scatter plot of virgin biomass and natural mortality from chain 2. The secondary space found by chain 2 has higher virgin biomass and (generally) higher natural mortality than the primary space.

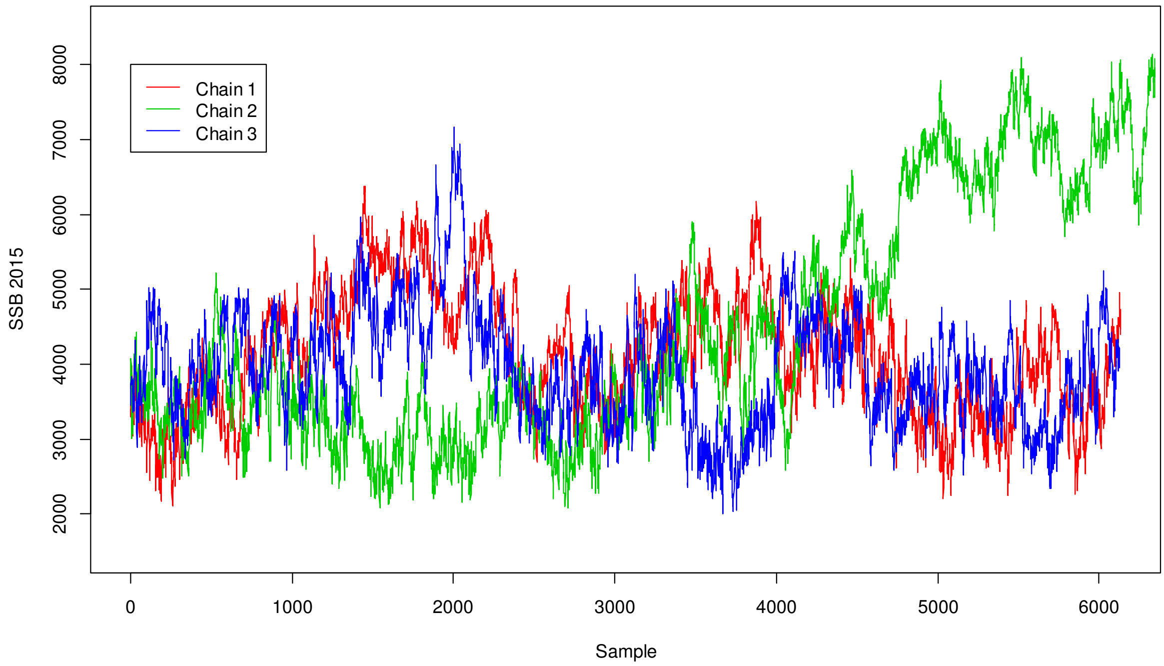

Figure A3.13: Western base model: the three MCMC chains showing the anomalous performance of the second chain for current SSB (from about sample 4400).

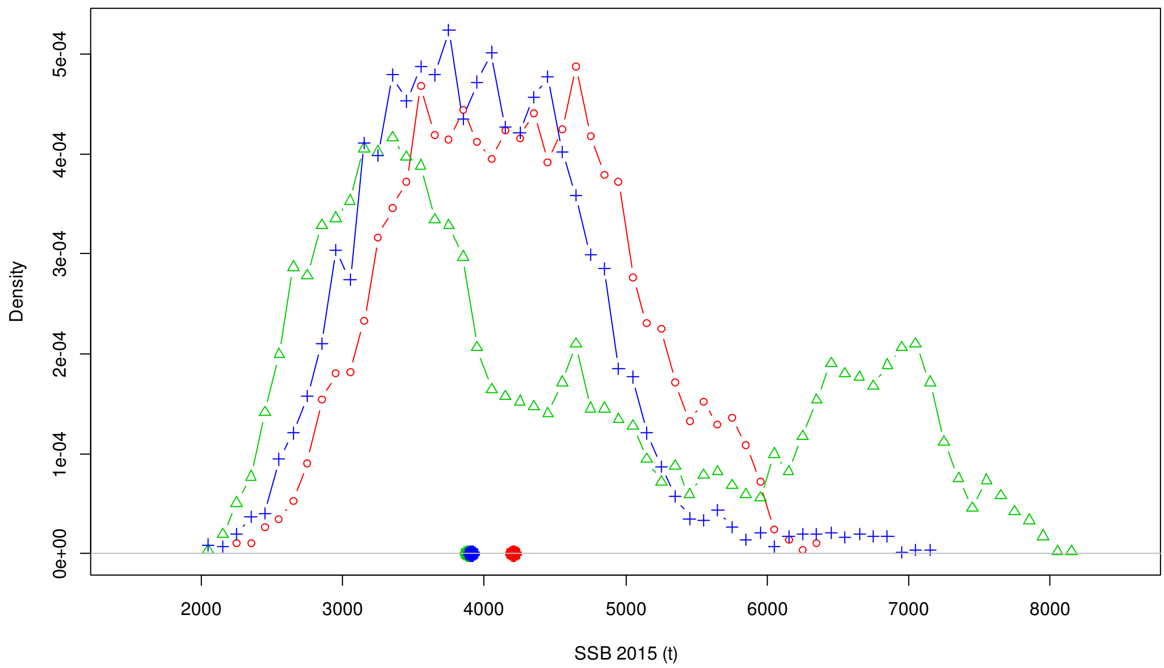

Figure A3.14: Western base model: a comparison of the marginal posterior distributions for current SSB from the three chains. Chain 2 has found a secondary space with higher current SSB.

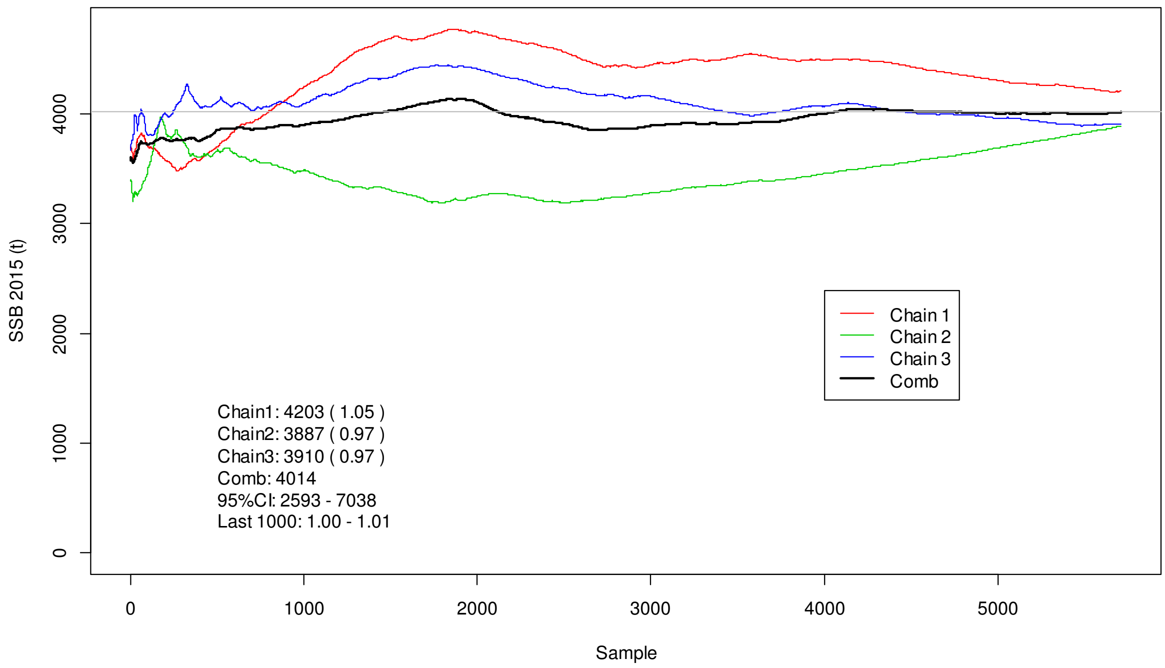

Figure A3.15: Western base model: cumulative medians for current SSB from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples (but chain 2 is continuing an upward trend). Within the parentheses are the ratio of the final individual medians to the final combined median.

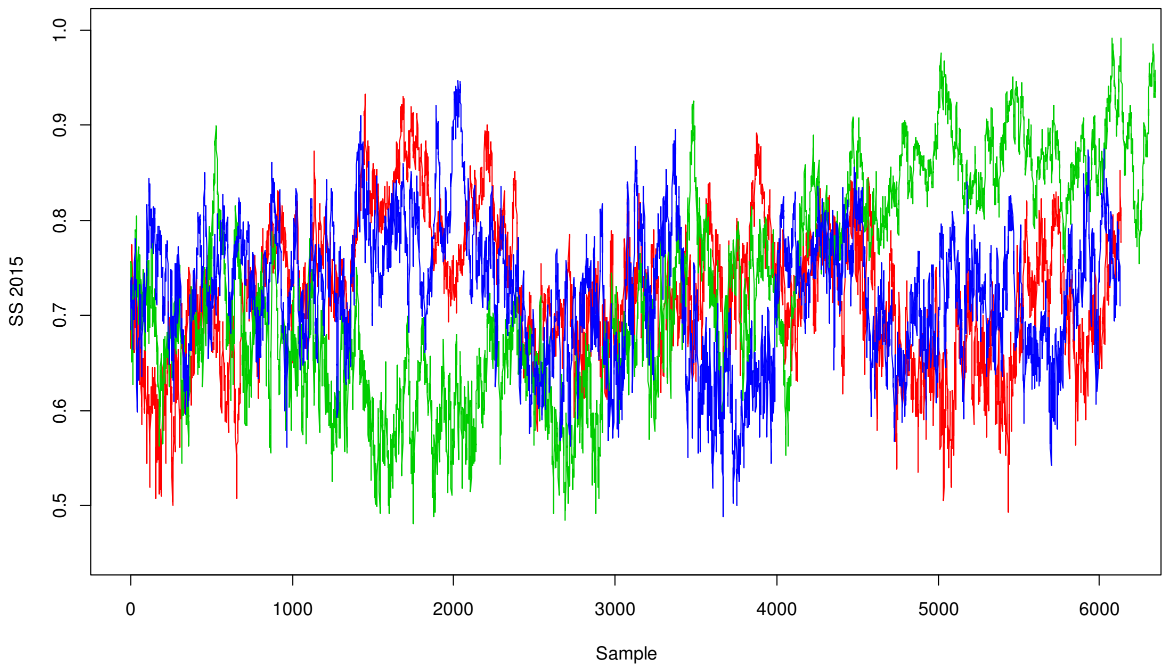

Figure A3.16: Western base model: the three MCMC chains showing the anomalous performance of the second chain for current stock status (from about sample 4400).

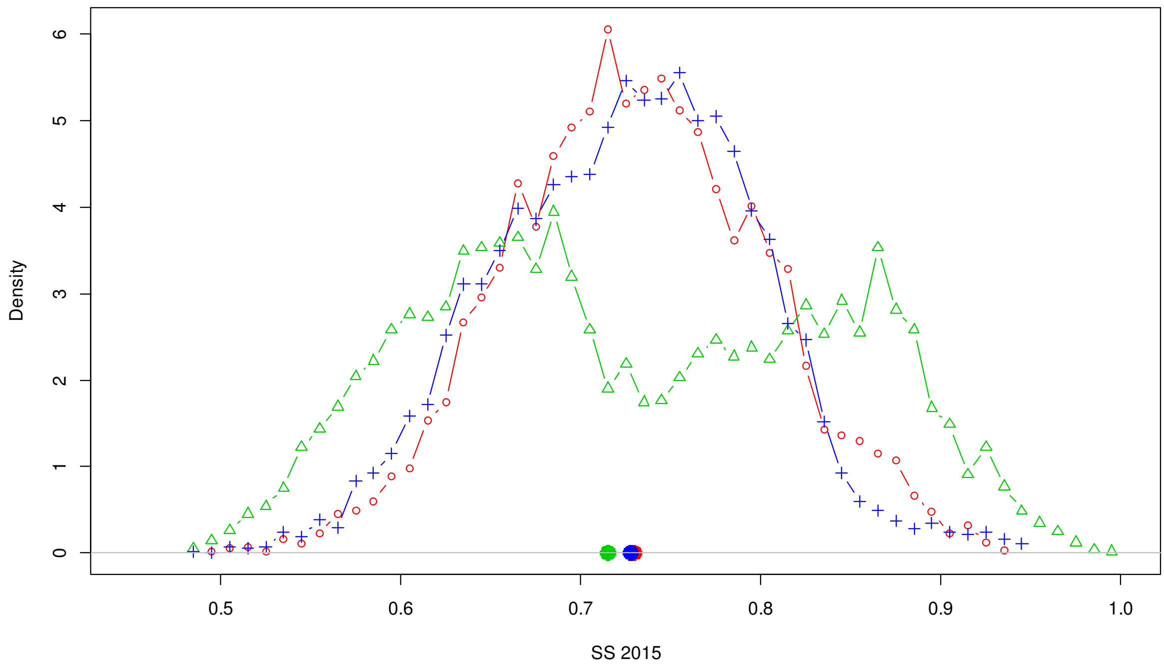

Figure A3.17: Western base model: a comparison of the marginal posterior distributions for current stock status from the three chains. Chain 2 has found a secondary space with higher current stock status.

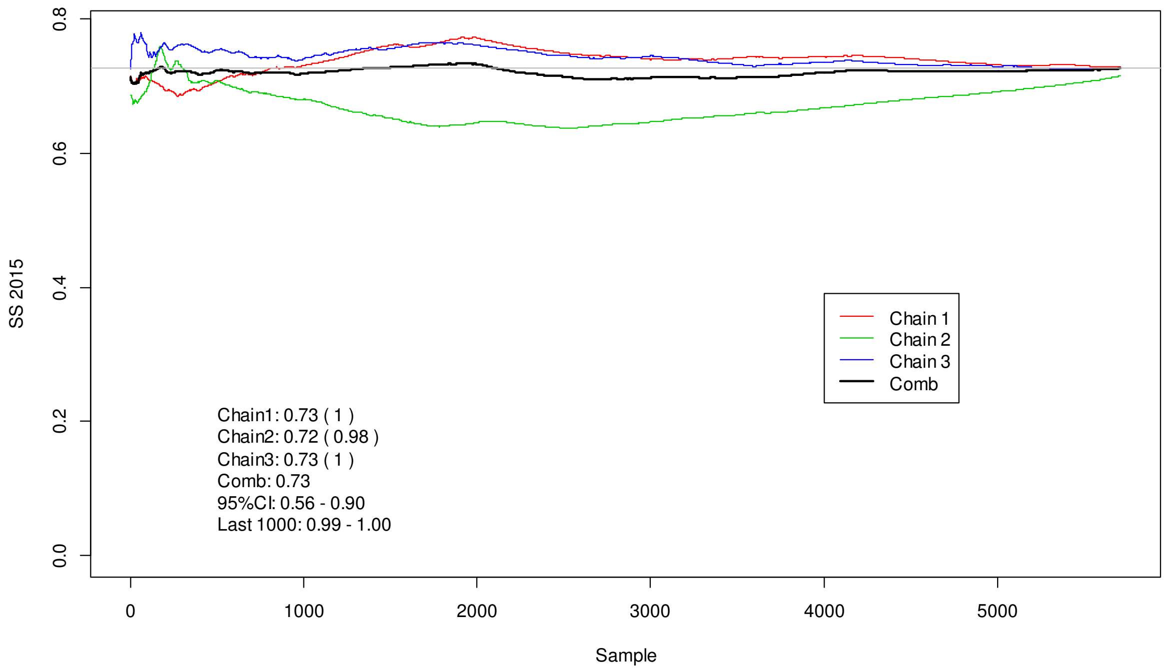

Figure A3.18: Western base model: cumulative medians for current stock status from the three chains and the cumulative median for the three chains combined ("Comb"). The combined median has barely changed over the last 1000 stored samples (but chain 2 is continuing an upward trend). Within the parentheses are the ratio of the final individual medians to the final combined median.