Compilation of 2013 pink ling Slope RAG documents from ISL

P.L. Cordue, ISL
11 November 2013

This document is a compilation of all the documents supplied by ISL to the Slope RAG during 2013 for the pink ling assessment.

Documents are generally in reverse date order (most recent documents first), except the three CPUE documents are grouped together.

The first document contains a summary of the stock assessment results from the models which the RAG agreed to use as the base models for providing management advice.

Pink Ling assessment results

P.L. Cordue, ISL
11 November 2013

Summary

This report summarises the results of ISL's pink ling assessment that was presented to the Slope RAG in November 2013. It contains the final assessment results from the models which were accepted by the RAG as the base models for the eastern and western stocks. These results differ slightly from those presented to the meeting due to some corrections and additions.

For both stocks, the base models (and some sensitivities) were taken through to MCMC to provide posterior distributions for virgin biomass, current stock status (depletion), and RBC (as estimated from the ling control rule). Also, for the eastern stock, a brief risk analysis was performed.

For the eastern stock, current stock status was estimated at 25% B_0 with a 95% CI of 17–38% B_0. The imprecision in estimated stock status was amplified in the estimation of RBC which had a 95% CI of 0–550 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. The 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 250 t per year. If two mean generation times are allowed for the rebuild then total removals can be up to 400 t per year. Long-term yield is estimated at 540–640 t (95% CI). That is not to say that constant catches should be taken for more than a period of 2-3 years. The results merely indicate that it is safe to take constant catches in the range of 250-400 t per year until a new assessment becomes available.

For the western stock there is considerable uncertainty with regard to the strength of recent recruitment. This uncertainty flows through into the estimates of stock status and RBC (with the upper limits of the 95% CIs corresponding to very strong recent recruitment). Current stock status is estimated at 58% B_0 with a 95% CI of 41–86% B_0. RBC is estimated at 807 t with a 95% CI of 430–1710 t. Long-term yield is estimated at 470–960 t (95% CI).

Detailed results

The following tables provide further results, some of which may wish to be presented in the AFMA documentation of the 2013 assessment. Details of the methods and run specifications can be found below (in "2013 Pink ling stock assessment: final ISL model results").

Table 1: MPD estimates: virgin biomass (B_0), stock status ($B_{current}/B_0$), natural mortality (M), and RBC estimates for the base models.

Stock	B_0 (t)	Stock status (% B_0)	M (yr^{-1})	RBC (t)
East	5550	23	0.24	75
West	4590	52	0.23	619

Table 2: Eastern model, MCMC: median and 95% credibility intervals for natural mortality, virgin biomass, and current stock status for the base model and two sensitivities.

Model	M (yr^{-1})		B_0 (t)		Stock status (% B_0)	
	Median	95% CI	Median	95% CI	Median	95% CI
Base	0.24	0.22–0.26	5620	4990–6460	25	17–38
Fixed *M*	0.24		5510	5090–6060	25	18–33
Split CPUE	0.24	0.22–0.26	5720	5030–6610	25	16–40

Table 3: Eastern model, MCMC: estimated probabilities of current SSB exceeding reference points for the base model and two sensitivities.

Model	P($B_{2013} \geq 20\%\ B_0$)	P($B_{2013} \geq 35\%\ B_0$)	P($B_{2013} \geq 48\%\ B_0$)
Base	0.85	0.07	0.00
Fixed *M*	0.91	0.01	0.00
Split CPUE	0.83	0.08	0.00

Table 4: Eastern model, MCMC: median and 95% credibility intervals for the RBC calculated from the ling control rule and the yield when the biomass is in deterministic equilibrium at 48% B_0.

	Median (t)	95% CI (t)
RBC	122	0–550
Long-term yield	582	540–640

Table 5: Eastern model, MCMC, stochastic projections: performance indicators for constant catch strategies ranging from zero catch up to 500 t annual catch. "E" denotes expected value (average). "P" denotes probability. B_i is the mid-year female spawning biomass in year *i*. The rebuild year is the first year in which at least 50% of the projections are at or above 48% B_0.

Annual catch (t)	$E(B_{2015}/B_0)$	$E(B_{2020}/B_0)$	$P(B_{2015} > B_{2013})$	$P(B_{2020} > B_{2013})$	$P(B_{2015} < 0.2)$	$P(B_{2020} < 0.2)$	Rebuild year
0	0.33	0.56	1.00	1.00	0.01	0.00	2019
250	0.30	0.44	0.98	0.99	0.04	0.00	2022
300	0.30	0.42	0.96	0.99	0.05	0.01	2024
350	0.29	0.39	0.93	0.97	0.07	0.02	2026
400	0.28	0.37	0.88	0.93	0.09	0.04	2029
450	0.28	0.35	0.82	0.90	0.11	0.07	2034
500	0.27	0.32	0.75	0.82	0.14	0.11	2047

Table 6: Western model, MCMC: median and 95% credibility intervals for natural mortality, virgin biomass, and current stock status for the base model and one sensitivity.

Model		M (yr^{-1})		B_0 (t)		Stock status (% B_0)
	Median	**95% CI**	**Median**	**95% CI**	**Median**	**95% CI**
Base	0.23	0.20–0.27	5130	4030–6730	58	41–86
Fixed *M*	0.24		4830	4150–5940	56	46–67

Table 7: Western model, MCMC: estimated probabilities of current SSB exceeding reference points for the base model and two sensitivities.

Model	P($B_{2013} \geq 20\%\ B_0$)	P($B_{2013} \geq 35\%\ B_0$)	P($B_{2013} \geq 48\%\ B_0$)
Base	1.00	1.00	0.86
Fixed *M*	1.00	1.00	0.95

Table 8: Western model, MCMC: median and 95% credibility intervals for the RBC calculated from the ling control rule and the yield when the biomass is in deterministic equilibrium at 48% B_0.

	Median (t)	95% CI (t)
RBC	807	430–1710
Long-term yield	661	470–960

2013 Pink ling stock assessment: final ISL model results

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Executive Summary

This document presents the final assessment results for ISL's assessment of pink ling in 2013. Methods and previous work on data preparation, including CPUE analysis for the trawl fishery, are summarised.

The base models presented conform with the base-model specifications agreed at the September RAG meeting. Final details of the base model specifications were agreed by email and include the use of time-blocking for the eastern trawl CPUE series (with the top three linking vessels used) and the exclusion of the non-trawl CPUE indices (for both stocks).

For both stocks, the base models (and some sensitivities) were taken through to MCMC to provide posterior distributions for virgin biomass, current stock status (depletion), and RBC (as estimated from the ling control rule). Also, for the eastern stock, a brief risk analysis was performed.

For the eastern stock, current stock status was estimated at 25% B_0 with a 95% CI of 17–38% B_0. The imprecision in estimated stock status was amplified in the estimation of RBC which had a 95% CI of 0–550 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 250 t to 500 t per year. The 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 250 t per year. If two mean generation times are allowed for the rebuild then total removals can be up to 400 t per year. Long-term yield is estimated at 540–640 t (95% CI).

For the western stock there is considerable uncertainty with regard to the strength of recent recruitment. This uncertainty flows through into the estimates of stock status and RBC (with the upper limits of the 95% CIs corresponding to very strong recent recruitment). Current stock status is estimated at 58% B_0 with a 95% CI of 41–86% B_0. RBC is estimated at 807 t with a 95% CI of 430–1710 t. Long-term yield is estimated at 470–960 t (95% CI).

Introduction

This document describes the model results for the pink ling assessment undertaken by ISL in 2013. The stock assessment methods, including data preparation and the derivation of CPUE indices, are summarised (details are given in earlier Slope RAG documents: Cordue, drafts 1-6, Cordue & Punt, draft). The ISL base models for the eastern and western stocks conform with the base-model specifications agreed at the September Slope RAG meeting. The base models and some sensitivities are taken through to MCMC.

Some additional work done during the November RAG meeting is given in Appendix 5.

Methods

Data preparation

For the eastern and western stocks, catch histories (trawl, non-trawl) and 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 earlier recommendations (Cordue, draft 1). In the east, stratification was by depth and zone for the trawl data (which precluded the use of port samples). For the west, and for line in the east, 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 as recommended earlier (Cordue, drafts 2, 4). 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).

	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	

	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

CPUE indices

The results of ISL's CPUE analysis of trawl data were presented at the September RAG meeting (Cordue, draft 3). The analysis filtered catch records based on depth and catches of species (other than ling) in an attempt to define a consistent "fishery" in which ling was a bycatch species (although ling targeting was not explicitly excluded). Also, the issue of potential changes in ling catchability from 1999 to 2000 (in the east, due to the sale of ling quota from trawl operators to line operators) and from 2006 to 2007 (structural adjustment) was addressed by time-blocking of vessel effects. The indices produced by ISL were almost identical to those produced by CSIRO for the western fishery, but they were quite different in the east.

After the September RAG meeting, further analysis was done for the eastern fishery (Cordue, draft 5). It was shown that the results were sensitive to the filters that were used and to the choice of 'linking vessels" (vessels assumed to have constant vessel effects across two consecutive time blocks). Nevertheless, it was agreed (by email) to use an eastern CPUE time series, with time-blocking and linking vessels, in the base stock assessment model. The chosen indices had minimal filtering and used three linking vessels chosen objectively (Cordue, draft 6). The base indices are intermediate between indices produced by using two or four objectively chosen linking vessels. Also, the base indices are not very different from the indices produced by CSIRO (see Cordue, draft 6).

In the western assessment, the CSIRO indices were used in ISL's base model.

It was agreed, by email, that the CPUE indices for the line fisheries, produced by CSIRO, would not be used in the base models because they had limited spatial coverage (when minimal requirements were placed on an acceptable number of records in each block, e.g., see Table 5 in Whitten et al. draft).

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	1970-2013	Stock status assessed mid-year 2013
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, 1983-2009 West: 1975-2009 initially, but 2009 dropped as its very high estimate was based on little data.	Required to have at least 8 observations in the sexed age-length data used

Steepness	0.75	As used in 2012. A conservative value – it could 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, 2007-2013. Two in the west: 1970-2006, 2007-2013. Double normal at age, same for males and females.	Estimated in the model. Timing of blocks indicated by events and confirmed by 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 N(mean=0.2, CV=0.2). For the east, the prior on *M* was taken from an early portion of the western MCMC chains and was N(mean=0.22, CV=0.06). See "Estimation of natural mortality" below.

For both assessments, MPD sensitivities were done at fixed *M* (low = 0.2, medium = 0.24, high = 0.28), alternative maturity ogives (shifted up or down one year), and SSB defined as beginning of year biomass (rather than mid-year). Retrospective models for the 2012 assessment were also done for both stocks as were models which included the non-trawl CPUE indices (CV = 0.2). For the east there were additional sensitivities: include Kapala biomass indices and length frequencies; use CSIRO trawl CPUE indices; use two-linking-vessel trawl CPUE; and split the fully-linked (no time blocks) trawl CPUE into two series 1986-1999, 2000-2012 with a prior on the q-ratio, LN(mean=1,CV=0.2).

Data weighting

The CVs for the trawl CPUE indices were determined following the recommendation of Francis (2011) to fit a smoother outside the model and estimate the CV from the residuals (see Appendix 1).

Length data were modelled with multinomial distributions with effective sample sizes initially assumed to be equal to the number of operations (onboard sampling) or landings (port sampling). Age frequencies had a starting sample size equal to the number of otoliths divided by 10. The age-length data had initial sample sizes equal to the number of otoliths. The effective sample sizes were tuned following the iterative reweighting approach of Francis (2011) and as extended to conditional age data in Appendix 1. However, the age-length data were not fully tuned as this would have created problems estimating growth within the model (i.e., effective sample sizes would have been so low that growth would have been mis-specified). The age-length data were only thinned by a factor of 4 and, for the line data, the top15% of fish, by length, were retained (to help with growth estimation).

The ranges for initial sample sizes and the final sample sizes (after tuning) are given below.

Data set	**Initial range**	**Final range**
East		
LF trawl	33-82	55-118
LF line	8-78	3-27
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

The biggest change from initial effective sample sizes was for the age frequencies which, in terms of mean age, were not fitted well by the model. The Francis method essentially determines effective sample sizes on the basis of the fit to annual mean lengths or ages (the fits for each data set are given in Appendix 2).

Estimation of natural mortality (*M*)

The initial MPD estimate of *M* for the east was rather high (0.27) and the likelihood profile suggested it was sensitive to the weights used for the age-length data and the trawl length frequencies (Appendix 3). It was concluded that *M* would not be well estimated in the eastern model. However, for the western model the MPD estimate of *M* seemed sensible for ling (0.23) and from the likelihood profile it looked like it was relatively insensitive to the data weights (Appendix 3). Therefore, it was decided to first estimate *M* in the western assessment and then use the western posterior distribution as a prior for *M* in the eastern assessment. As it happened, there was insufficient time to wait for the western MCMC to finish and the prior for *M* was chosen from the early part of the chains (after a burn-in period). The prior used for the eastern base model was *M* ~ N(mean=0.22, CV=0.06).

Estimation of sex-specific selectivities
Initial eastern models used sex-specific fishing selectivities. However, the eastern trawl selectivities varied greatly across time blocks (Appendix 3). Runs were done using sex-independent selectivities (i.e., the same selectivities for males and females) and the likelihoods and age-length residuals were examined. There was no apparent residual pattern by sex in the age-length data and the improvement in likelihood when using sex-specific selectivities did not justify the use of the extra parameters (Appendix 3). Therefore, sex-independent selectivities were used for the eastern and western base models.

Estimation of RBC and long-term yield
The pink ling control rule was applied using the MPD estimate of parameters and assuming that the exploitation rates of the trawl and non-trawl fisheries were maintained in the same proportion as was estimated for 2013. F_{48} was determined by scaling the current 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 2014 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.

MCMC methods

For the east, three models were taken through to MCMC: base, fixed $M = 0.24$, and split trawl-CPUE. For the west, there were two MCMC models: base, fixed $M = 0.24$.

Three independent chains of at least 1 million were run for each model (much longer chains were needed for the western base (3 million) and split trawl-CPUE (5 million)). One in every one thousand samples were retained. A burn-in length was determined for each model using plots of the objective function for the three chains, looking for when the chains fluctuated over a consistent range. For each model, histograms of the three chains (with the burn-in removed) showed good agreement between the main variables of interest (virgin biomass, stock status and natural mortality) except for the western base and the split-trawl CPUE (these were not well converged for current stock status – but they were “adequately” converged in that much longer chains would be unlikely to change the median estimated stock status). A single chain for each model was formed by combining the three chains with the burn-in removed. The chains for the western base model and the split trawl-CPUE were thinned to retain 3000 samples.

Estimation of RBC and long-term yield

The methods applied to the MPD estimates were applied to each sample from the final chain. This was done by running deterministic projections at different levels of scaled exploitation rates (assuming the trawl and non-trawl proportions at the MPD) and determining F_{48} and the associated catches, in 2014, 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 eastern base model, short and long-term projections (to 2050) were performed for constant catch strategies at zero catch and from 250 t to 500 t (split between trawl and non-trawl in proportion to the MPD exploitation rates in 2013). These were full stochastic projections where year class strengths from 2010 onwards were randomly sampled from the last 10 years that were estimated (2000-2009) – to reflect recent recruitment, which may be a little less than long-term average recruitment.

Six performance indicators were calculated for each constant catch strategy:

- $E(B_{2015}/B_0)$: mean stock status in 2015
- $E(B_{2020}/B_0)$: mean stock status in 2020
- $P(B_{2015} > B_{2013})$: probability that SSB in 2015 is greater than that in 2013
- $P(B_{2020} > B_{2013})$: probability that SSB in 2020 is greater than that in 2013
- $P(B_{2015} > 0.2)$: probability that SSB in 2015 is greater than 20% B_0
- $P(B_{2020} > 0.2)$: probability that SSB in 2020 is greater than 20% B_0

Also, 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

MPD results

The model provided an excellent fit to the trawl CPUE time series (Figure 1). The estimated growth curves were consistent with the sexed age-length data from the line fishery (Figure 2). The trawl selectivities were estimated to be highly domed with the mode shifting higher over each time period (2.8 years, 3.1 years, 4.5 years)(Figure 3). The trawl-selectivity modes are at younger ages than the assumed 50% maturity at 5 years and the estimated 50% selection for the non-trawl fishery of 5.9 years. The selection for non-trawl port-sampled fish showed somewhat younger fish were sampled at port compared to those sampled at sea (Figure 4).

The estimated year class strengths (YCS) showed moderate variability (standard deviation of log YCS = 0.54) with weak recent YCS in 2005 and 2009 (Figure 5).

Estimated stock status (depletion) for the MPD base model is just above 20% B_0 in 2013 (Table 1, Figure 6). The MPD estimates of virgin biomass and stock status are sensitive to *M* (as expected) and also to the use of sex-independent selectivities as opposed to sex-specific selectivities. The latter result is because of the paucity of data with which to estimate sex-specific selectivities for the trawl fishery in three different time blocks. The high estimated stock status for the sex-specific selectivities model is because a very domed trawl selectivity for females is estimated for 2007-2013 (see Appendix 3). This means that females are relatively invulnerable to trawl fishing during this period and therefore SSB (which is female only) increases quickly (Figure 6).

The estimate of *M* is very stable (Table 1) due to the very strong prior placed on it. It cannot be considered a reliable estimate of *M* because the strong prior was constructed from the early chains in the western base model before they had converged (although they were consistent at the time). The base model is almost a fixed-*M* model, but for the MCMC estimation it is preferable to use it instead of a fixed-*M* model as it allows *M* to move (at least a little bit).

Table 1: Eastern stock, MPD estimates: virgin biomass (B_0), stock status ($B_{current}/B_0$), and natural mortality (*M*) estimates for the base model and sensitivity runs. * This differs from the result in Whitten et al. draft (which was in error).

Model run	B_0 (t)	Stock status (% B_0)	M (yr^{-1})
Base	5550	23	0.24
Sex-specific selectivities	5820	31	0.23
Fixed and lower *M*	6830	17	0.20
Fixed and higher *M*	4670	33	0.28
Maturity 1 year younger	6010	27	0.23
Maturity 1 year older	5090	20	0.24
Including line CPUE	5490	18	0.24
Including Kapala data	5510	23	0.23
CSIRO trawl CPUE	5420	22	0.24
Two-linking-vessel CPUE	5660	27	0.24
Split fully-linked CPUE	5550	23	0.24
Split fully-linked CPUE (no prior)	5570	24	0.24
Beginning-of-year SSB	6140	26	0.24
Retrospective 2012	5570	23	0.24
SS3 2012 assessment*	6930	19	0.24

The MPD estimate of RBC for the eastern base model is just 75 t. This is despite the current exploitation rates corresponding to F_{40} and the catch at F_{48} being 337 t. The penalty in the control rule is very severe because the MPD estimate of stock status is close to 20% B_0.

MCMC results

For the base model, the non-trawl fishing selectivity and the corresponding port-sampling selection pattern are reasonably tightly estimated (Figure 8). The same is true for the trawl-fishing selectivity pattern in the second time block, but the selectivities in the other time blocks are less well estimated (Figure 8). In particular the selectivity pattern in the most recent time block is very imprecise. The pattern of MCMC estimated year class strengths is similar to that in the MPDs (Figure 9).

In the base model, virgin biomass (mid-year, female only) is estimated to be about 5500 t (Table 2, Figure 10). Current stock status (depletion) is estimated at 25% B_0 with a fairly broad credibility interval (Table 2, Figure 11).

Table 2: Eastern model, MCMC: median and 95% credibility intervals for natural mortality, virgin biomass, and current stock status for the base model and two sensitivities.

Model		***M*** **(yr^{-1})**		**B_0 (t)**		**Stock status (%B_0)**
	Median	**95% CI**	**Median**	**95% CI**	**Median**	**95% CI**
Base	0.24	0.22–0.26	5620	4990–6460	25	17–38
Fixed *M*	0.24		5510	5090–6060	25	18–33
Split CPUE	0.24	0.22–0.26	5720	5030–6610	25	16–40

The base-model SSB trajectory shows median estimated SSB at a bit above 20% B_0 since the mid 2000s with an increase in the last two years (Figure 12). The distribution of SSB (as a percentage of B_0) in each year of the trajectory is quite broad. According to the base model and sensitivities, current biomass is very likely to be above the limit reference point of 20% B_0 and very unlikely to be above the target of 48% B_0 (Table 3). There is more than a 2.5% chance of the current biomass being below 20% B_0 and of being above 35% B_0 – which is of relevance to the imprecision to be expected in the estimation of RBC.

Table 3: Eastern model, MCMC: estimated probabilities of current SSB exceeding reference points for the base model and two sensitivities.

Model	P($B_{2013} \geq$ 20% B_0)	P($B_{2013} \geq$ 35% B_0)	P($B_{2013} \geq$ 48% B_0)
Base	0.85	0.07	0.00
Fixed *M*	0.91	0.01	0.00
Split CPUE	0.83	0.08	0.00

The RBC calculated from the ling control rule is very poorly estimated with the 95% CI extending from 0 t to over 500 t (Table 4, Figure 13). This is primarily because of the uncertainty in current stock status which has a 95% CI extending from below 20% B_0 to over 35% B_0 (which are defining limits in the control rule).

Long-term yield appears well-estimated and is in the region of about 600 t (Table 4).

Table 4: Eastern base model, MCMC: median and 95% credibility intervals for the RBC calculated from the ling control rule and the yield when the biomass is in deterministic equilibrium at 48% B_0.

	Median (t)	95% CI (t)
RBC	122	0–550
Long-term yield	582	540–640

The median RBC is just 122 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 assessment.

It is very likely that the eastern stock is below the management target of 48% B_0 and hence future total removals need to be below the long-term yield to allow SSB to rebuild towards the target. According to the base model, this can be done in a suitable timeframe (e.g., no more than 2 times the mean generation time of 8.8 years) with a constant annual catch of up to 400 t (Table 5). If total removals are 250 t per year then the rebuild would be expected in about one mean generation time (Table 5).

Table 5: Eastern base model, MCMC: performance indicators for stochastic projections using constant-catch rebuilding strategies (the "rebuild year" corresponds to a 50% probability of being at or above 48% B_0).

Annual catch (t)	$E(B_{2015}/B_0)$	$E(B_{2020}/B_0)$	$P(B_{2015} > B_{2013})$	$P(B_{2020} > B_{2013})$	$P(B_{2015} < 0.2)$	$P(B_{2020} < 0.2)$	Rebuild year
0	0.33	0.56	1.00	1.00	0.01	0.00	2019
250	0.30	0.44	0.98	0.99	0.04	0.00	2022
300	0.30	0.42	0.96	0.99	0.05	0.01	2024
350	0.29	0.39	0.93	0.97	0.07	0.02	2026
400	0.28	0.37	0.88	0.93	0.09	0.04	2029
450	0.28	0.35	0.82	0.90	0.11	0.07	2034
500	0.27	0.32	0.75	0.82	0.14	0.11	2047

Western stock

MPD results

The model provided a poor fit to the trawl CPUE time series. The predictions follow the same trend but fail to reach the height of the peaks or the depths of the troughs (Figure 15). The estimated growth curves are consistent with the sexed age-length data from the line fishery (Figure 16). The trawl selectivities are estimated to be slightly domed with the mode shifting higher between the two time periods (3.9 years, 4.9 years)(Figure 17). The trawl-selectivity modes are at younger ages than the assumed 50% maturity at 5 years and the estimated 50% selection for the non-trawl fishery of 6.0 years. The selection for trawl-caught port-sampled fish is highly domed in comparison to the at-sea sampling (Figure 17).

The estimated year class strengths (YCS) showed low to moderate variability (standard deviation of log YCS = 0.41) with some relatively recent good recruitment from the 2003 and 2004 cohorts (Figure 18).

Estimated stock status (depletion) for the MPD base model is just above 50% B_0 in 2013 (Table 6, Figure 19). The MPD estimates of virgin biomass and stock status show some sensitivity to M (as expected) but are fairly robust to the other scenarios (Table 6, Figure 20). The estimate of M is very robust to the scenarios investigated (Table 6).

Table 6: Western stock, MPD estimates: virgin biomass (B_0), stock status ($B_{current}/B_0$), and natural mortality (M) estimates for the base model and sensitivity runs.

Model run	B_0 (t)	Stock status (% B_0)	M (yr^{-1})
Base	4590	52	0.23
Sex-specific selectivities	4600	53	0.23
Fixed and lower *M*	4450	45	0.20
Fixed and higher *M*	6070	65	0.28
Maturity 1 year younger	5130	56	0.23
Maturity 1 year older	4040	49	0.23
Including line CPUE	4550	51	0.23
Beginning-of-year SSB	5080	55	0.23
Trawl CPUE CV 10%	4550	55	0.23
Retrospective 2012	4320	49	0.23
SS3 2012 assessment	4710	43	0.21

The poor fit the trawl CPUE indices was investigated to see if it could be improved by specifying a constant CV of 10% in a sensitivity run (in the base model the CV is 15%). This improved the fit to the CPUE indices somewhat but not dramatically (Figure 21). It had little effect on the estimates of virgin biomass and stock status (Table 6).

The MPD estimate of current exploitation rates corresponds to F_{58} and the estimate of RBC is 619 t (being the 2014 catch at 1.4 times the current exploitation rates). The MPD estimate of long-term yield is 578 t.

MCMC results

For the base model, the non-trawl fishing selectivity is reasonably tightly estimated (Figure 22). The same is not true for the trawl-fishing selectivity patterns or the port sampling of trawl-caught fish (Figure 22). The trawl selectivities may or may not be domed, although it seems likely that the port-sampling selectivity is more domed than the at-sea fishing selection pattern.

The pattern of MCMC estimated year class strengths is similar to that in the MPDs except that the 2008 YCS is very imprecise – it could be very strong or well below average (Figure 23). The uncertainty in the 2008 YCS is the major cause of uncertainty with regard to current stock status and RBC.

Natural mortality appears to be well estimated, with the median at 0.23 and a fairly tight credibility interval (Table 7, Figure 24). The prior used for *M* in the eastern base model was N(mean=0.22, CV=0.06); had there been time to wait for the western model to finish, the prior would have been N(mean=0.23, CV=0.07), which would have given slightly more optimistic results for the eastern stock.

In the base model, virgin biomass (mid-year, female only) is estimated to be about 5000 t (Table 7, Figure 25). Current stock status (depletion) is estimated at 58% B_0 with a very broad credibility interval (Table 7, Figure 26).

Table 7: Western model, MCMC: median and 95% credibility intervals for natural mortality, virgin biomass, and current stock status for the base model and one sensitivity.

Model		***M*** **(yr^{-1})**		***B$_0$*** **(t)**		**Stock status (%*B$_0$*)**
	Median	**95% CI**	**Median**	**95% CI**	**Median**	**95% CI**
Base	0.23	0.20–0.27	5130	4030–6730	58	41–86
Fixed *M*	0.24		4830	4150–5940	56	46–67

The base-model SSB trajectory shows median estimated SSB at about 60% B_0 for the last five years (Figure 27). According to the base model and the sensitivity, current biomass is very likely to be above the target reference point of 48% B_0 (Table 8). There is a zero probability estimated for the biomass to be below 35% B_0.

Table 8: Western model, MCMC: estimated probabilities of current SSB exceeding reference points for the base model and two sensitivities.

Model	**P($B_{2013} \geq$ 20% B_0)**	**P($B_{2013} \geq$ 35% B_0)**	**P($B_{2013} \geq$ 48% B_0)**
Base	1.00	1.00	0.86
Fixed *M*	1.00	1.00	0.95

The RBC calculated from the ling control rule is imprecisely estimated with the 95% CI extending from 430 t to over 1700 t (Table 9, Figure 28). This is mainly due to the large uncertainty in current stock status (because of uncertainty in recent recruitment). Long-term yield is also fairly imprecise with the 95% CI from about 500–1000 t (Table 9, Figure 29).

Table 9: Western base model, MCMC: median and 95% credibility intervals for the RBC calculated from the ling control rule and the yield when the biomass is in deterministic equilibrium at 48% B_0.

	Median (t)	95% CI (t)
RBC	807	430–1710
Long-term yield	661	470–960

Acknowledgements

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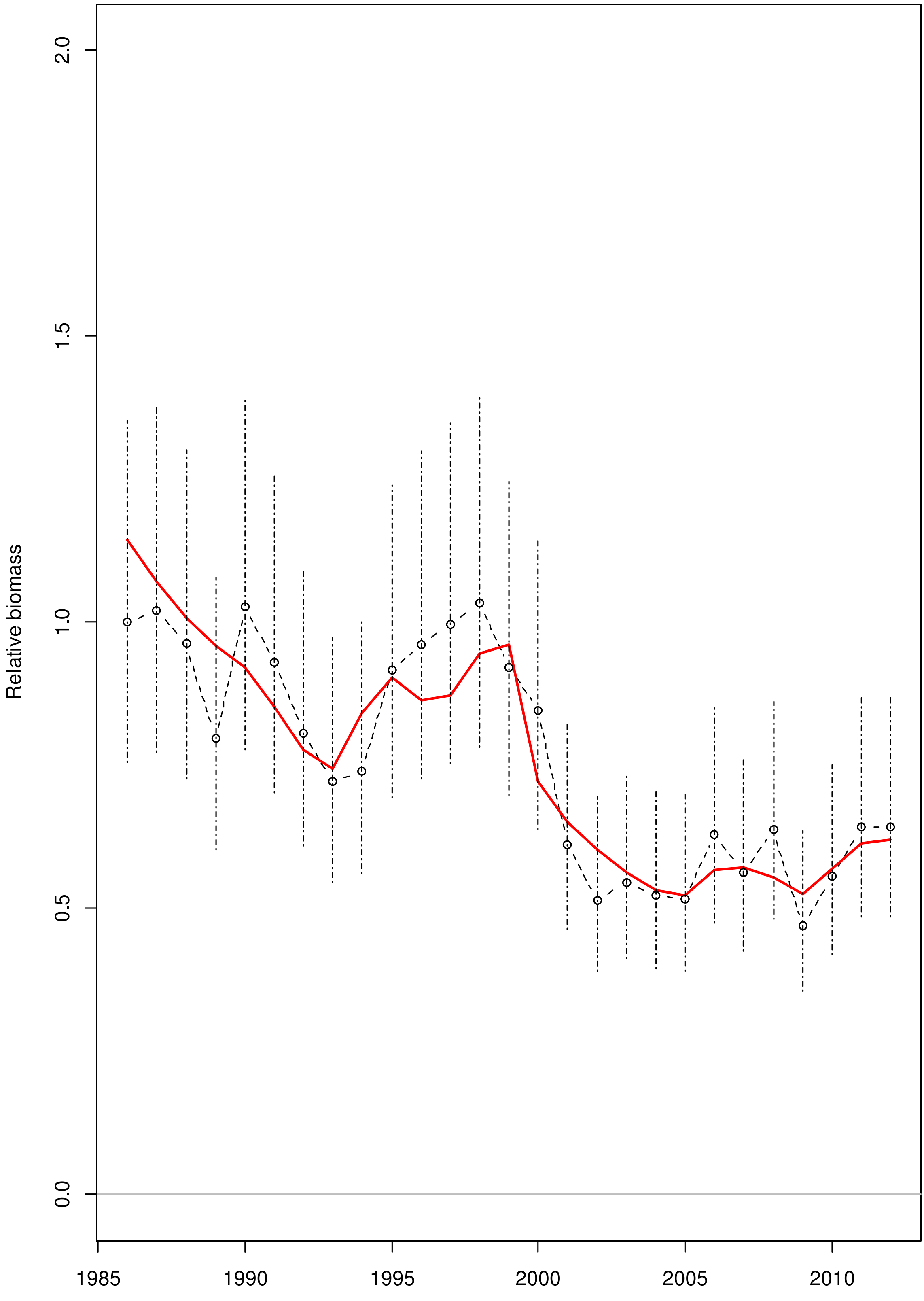


Figure 1: Eastern base model MPD-fit to trawl CPUE indices. Dashed lines are 95% CIs.

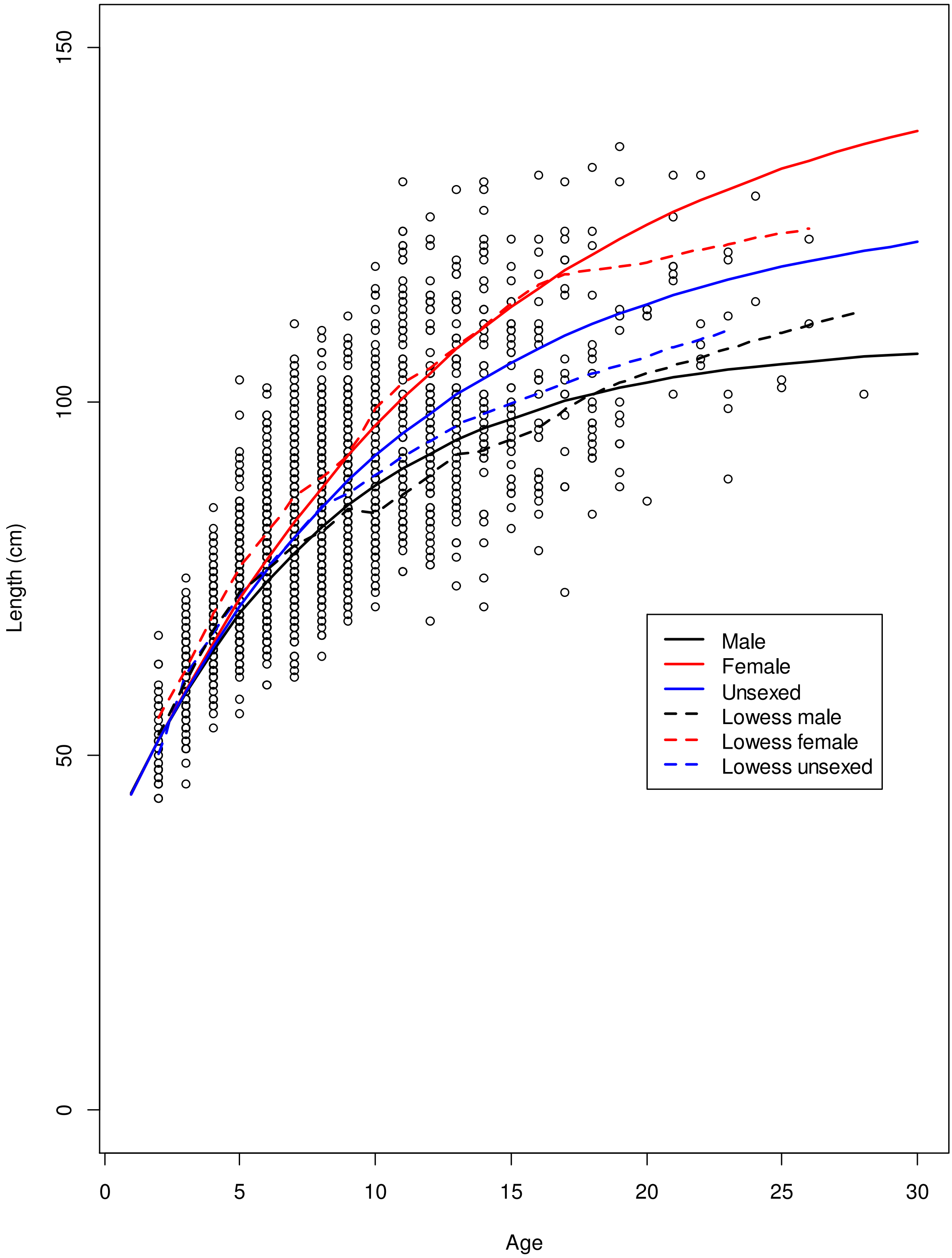


Figure 2: Eastern base model MPD: "fit" to age-length data from the line fishery. Model growth curves shown as solid lines. Lowess fits to data shown as dashed lines.

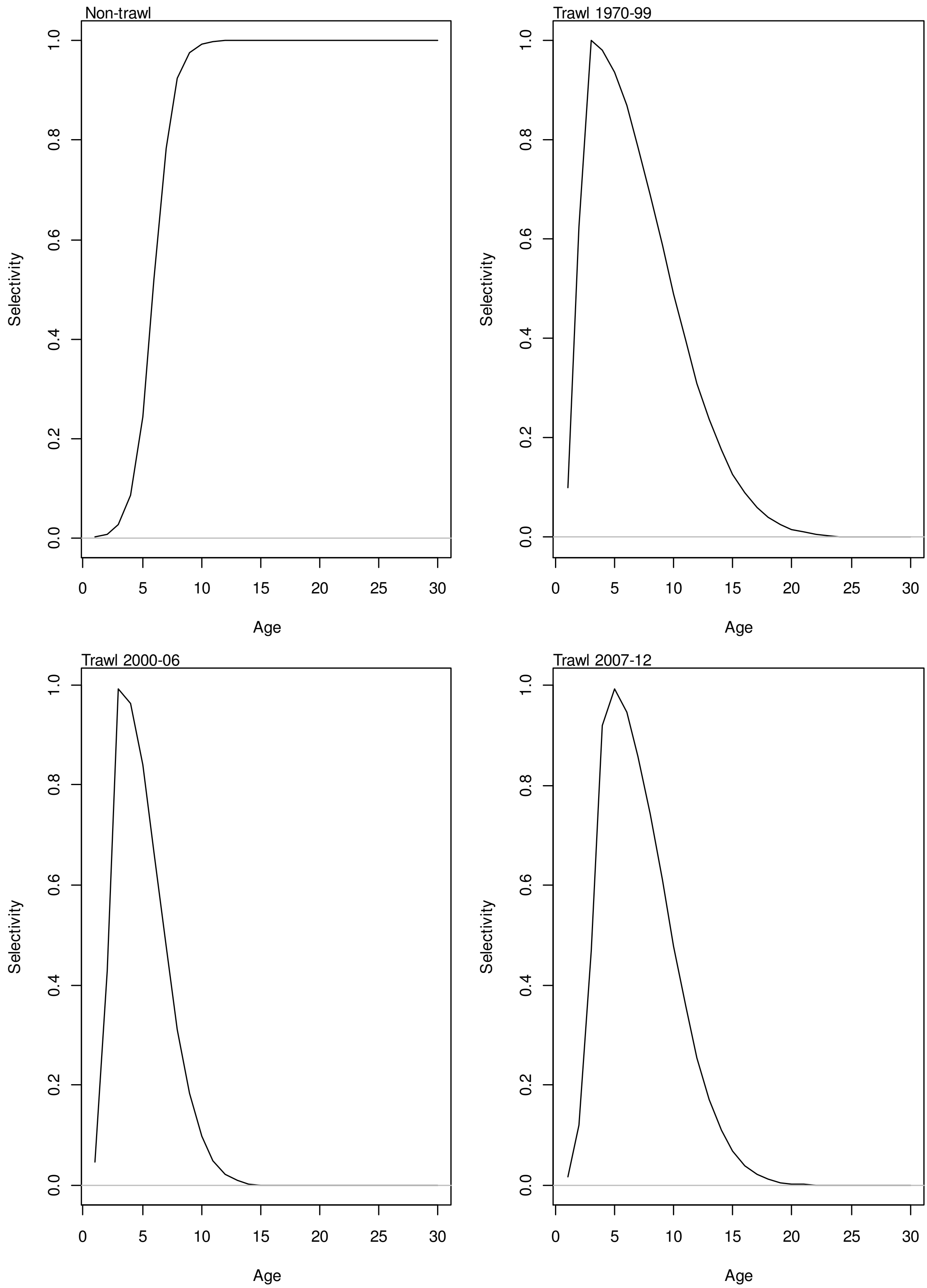


Figure 3: Eastern base model MPD: estimated fishery selectivities (age-based, sex independent, three time blocks for trawl).

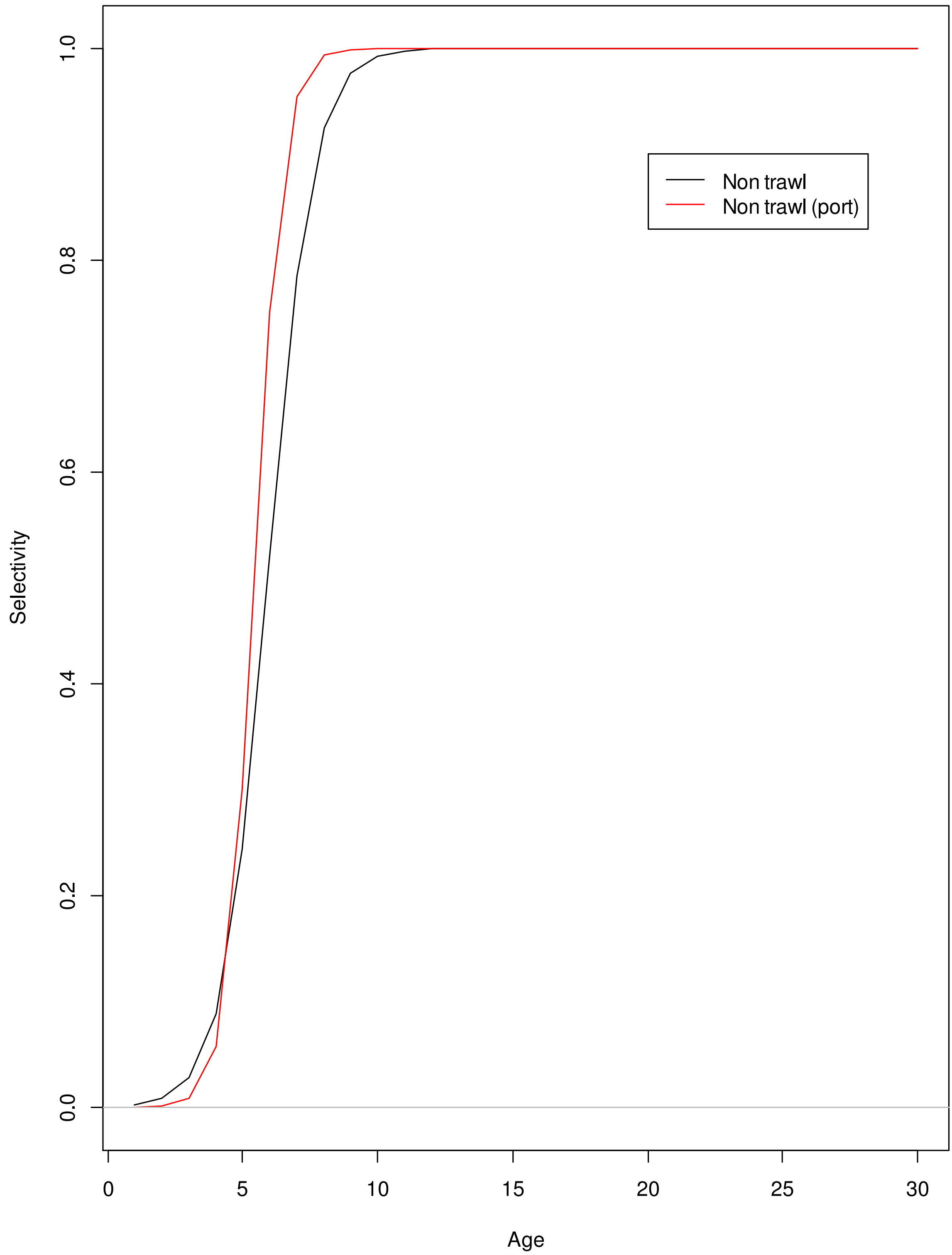


Figure 4: Eastern base model MPD: estimated fishery selectivity for the non-trawl fishery and the corresponding ogive for the port sampled non-trawl fish.

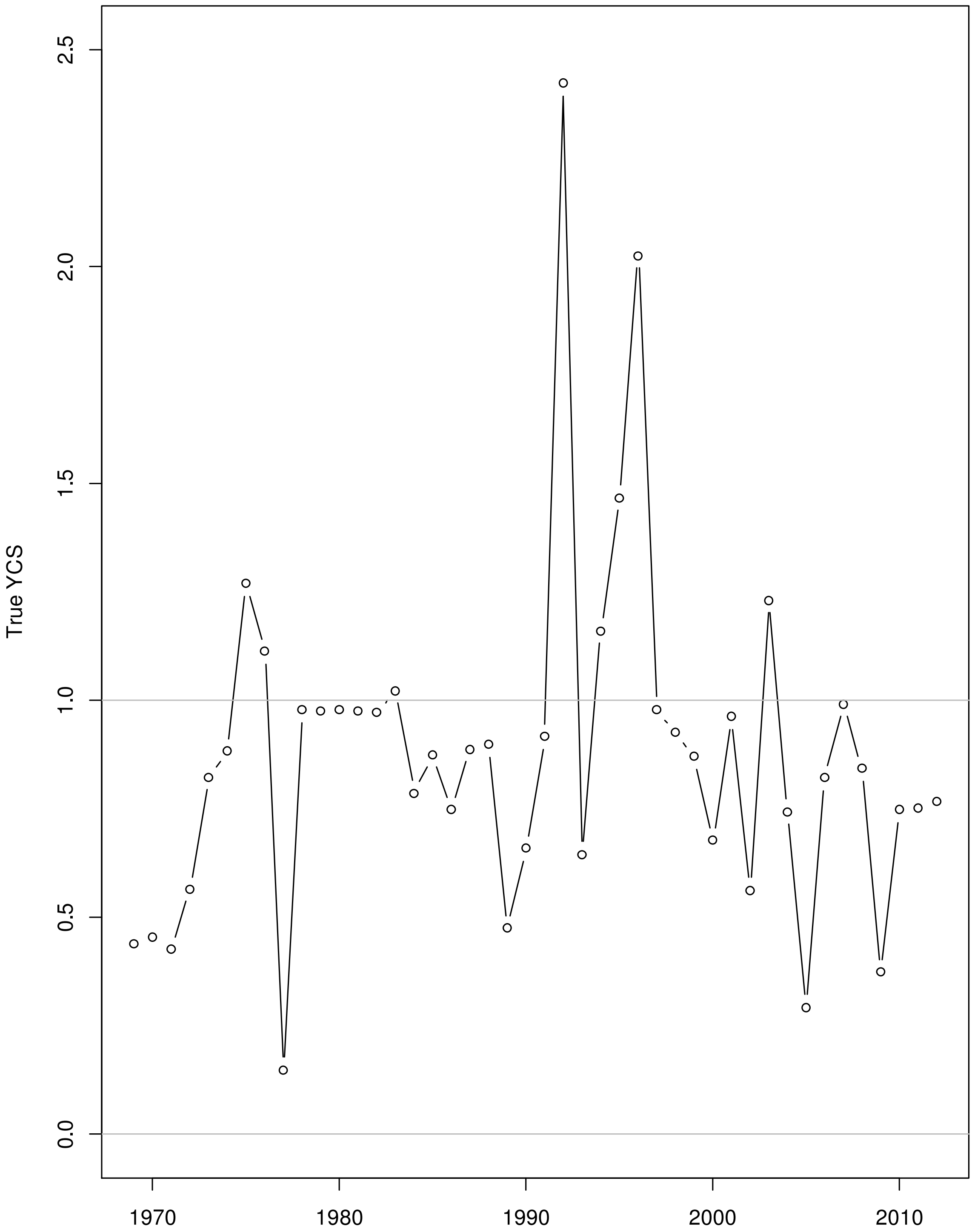


Figure 5: Eastern base model MPD: estimated "true year class strengths" (annual recruitment divided by virgin recruitment).

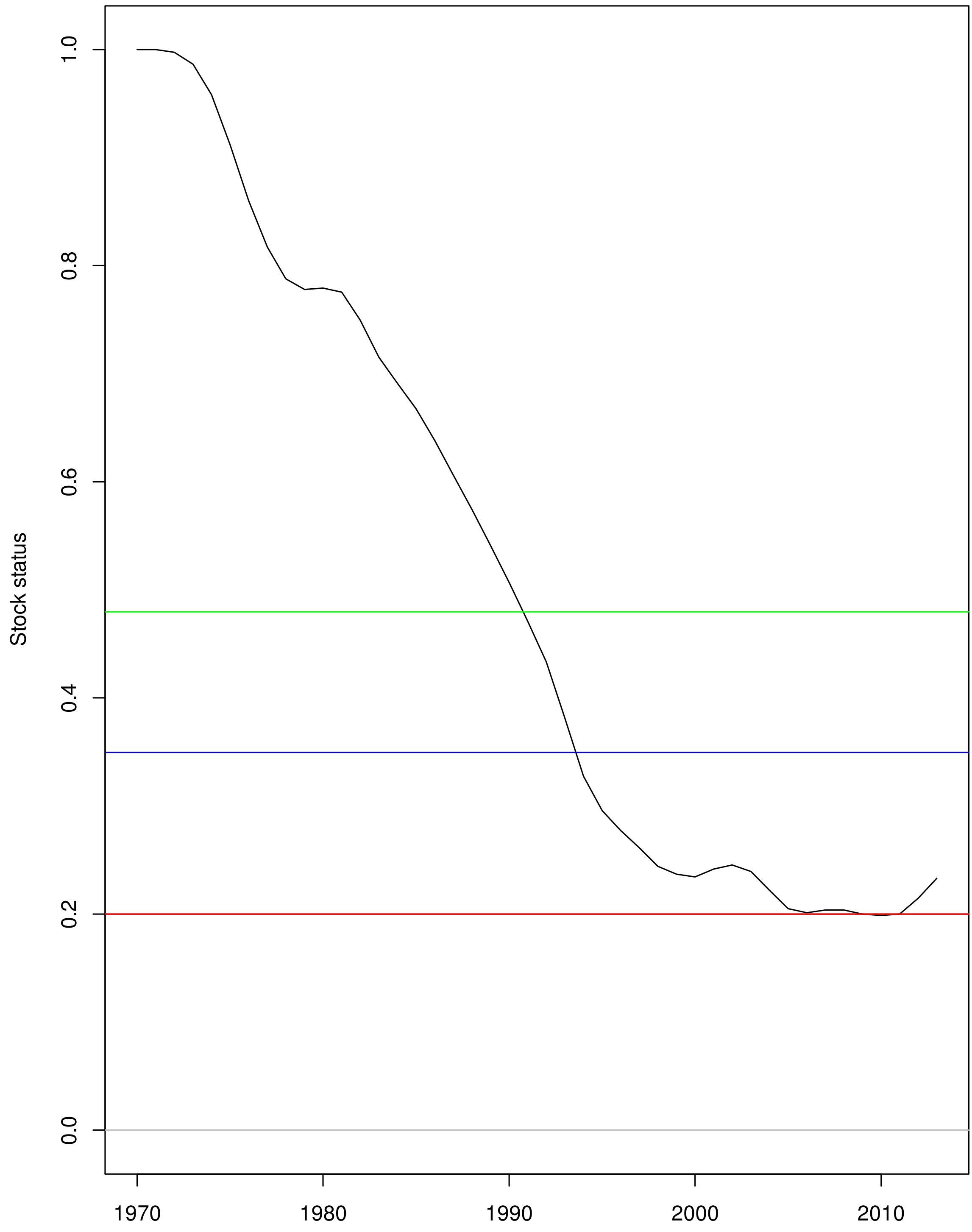


Figure 6: Eastern base model MPD: estimated stock status (annual SSB divided by virgin SSB; female biomass only; mid-year). Lines at 0.2, 0.35, and 0.48.

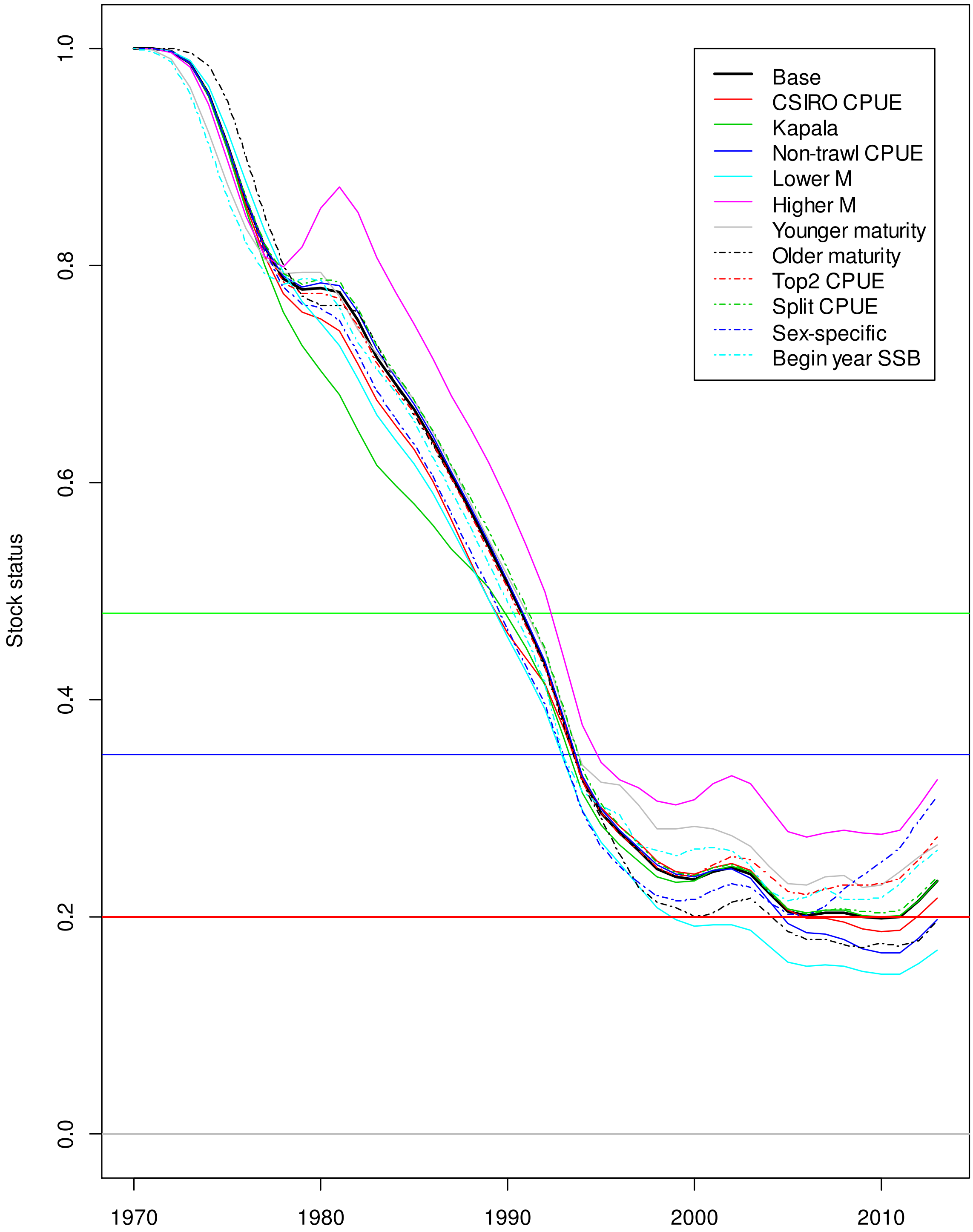


Figure 7: Eastern base model MPD: estimated stock status for the base model and sensitivity runs. Lines at 0.2, 0.35, and 0.48.

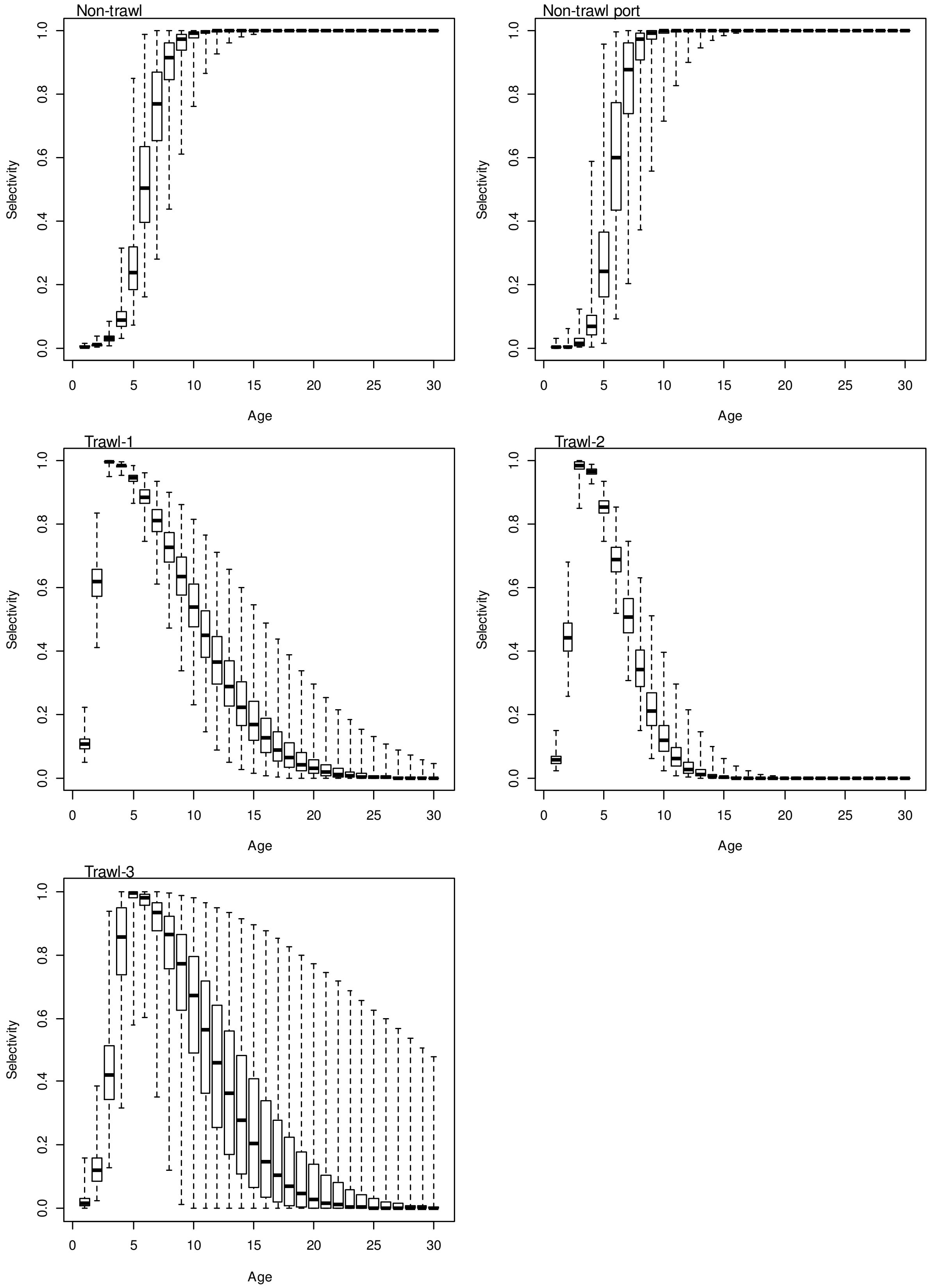


Figure 8: Eastern base model, MCMC: estimated fishing selectivities. Each box contains the middle 50% of the distribution. Whiskers extend over the full range.

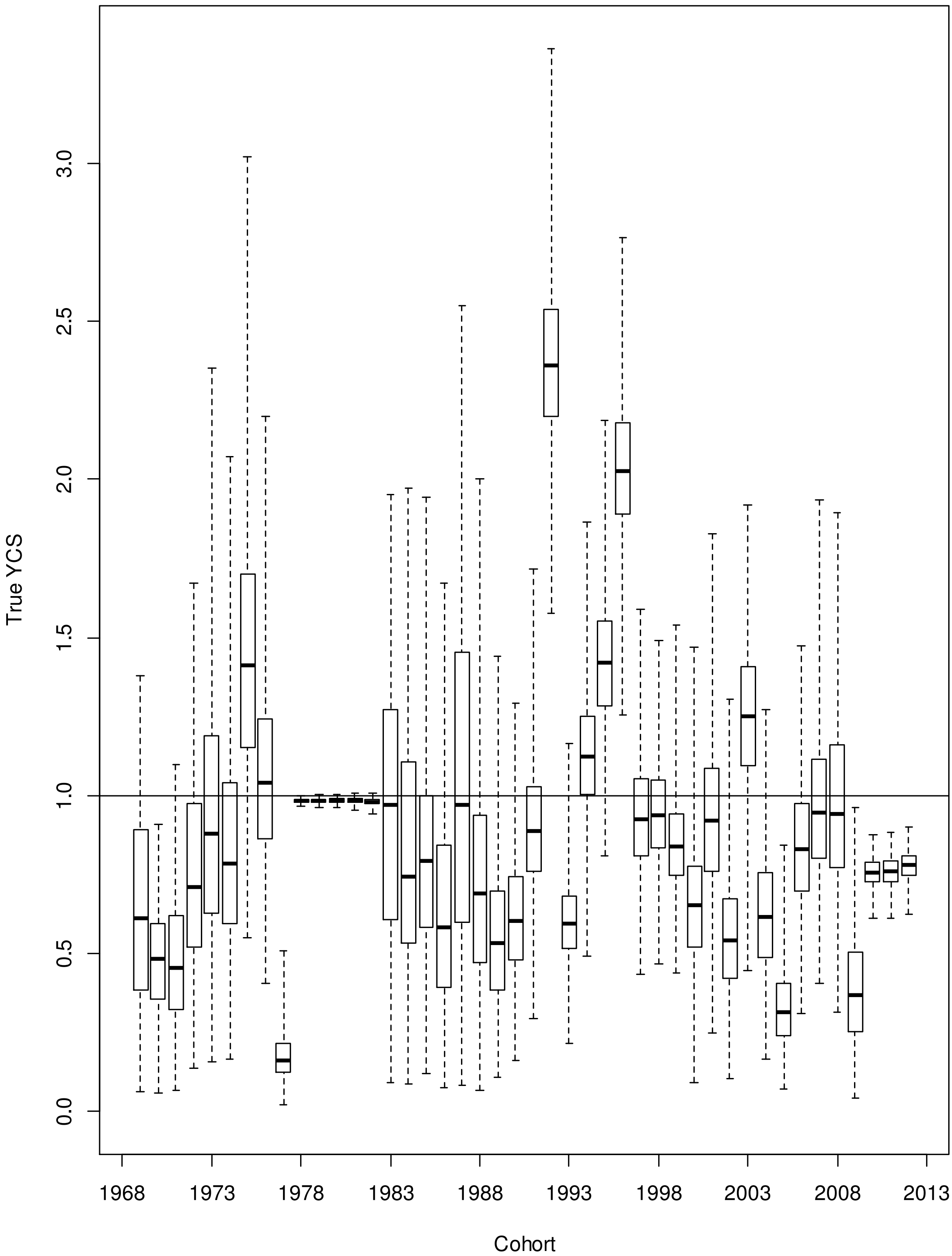


Figure 9: Eastern base model, MCMC: estimated true year class strengths (*R_y/R_0*). Each box contains the middle 50% of the distribution. Whiskers extend over the full range.

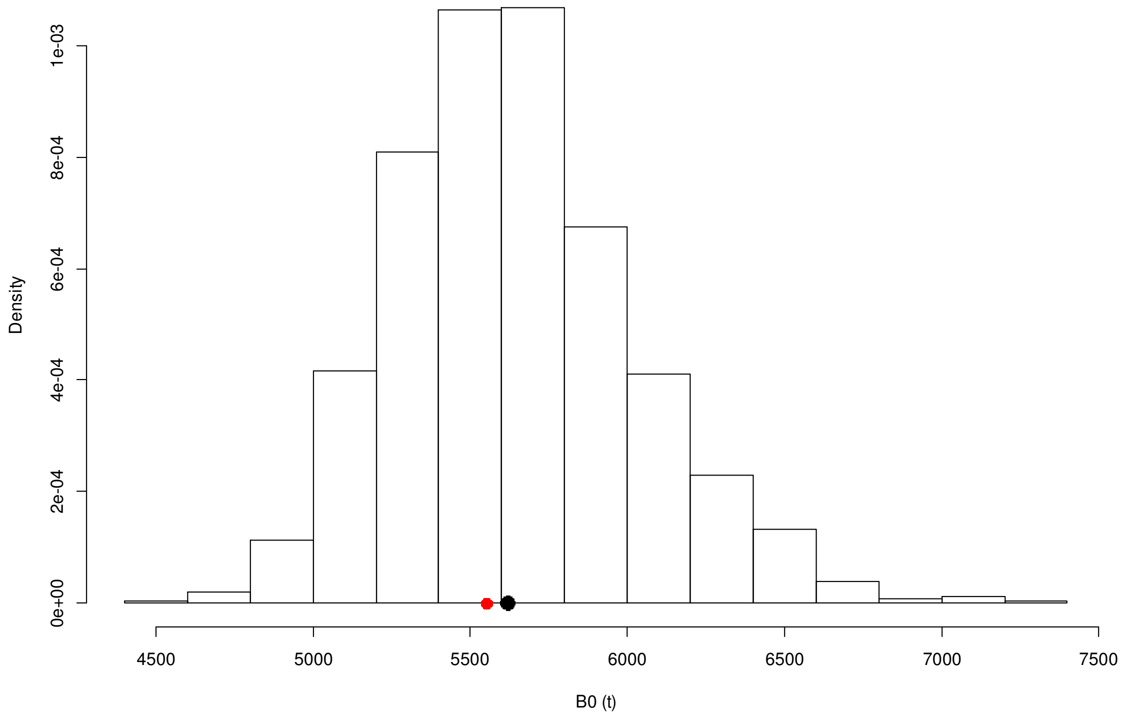


Figure 10: Eastern base model, MCMC: marginal posterior distribution for B_0. The black dot marks the median of the posterior and the red dot the MPD estimate.

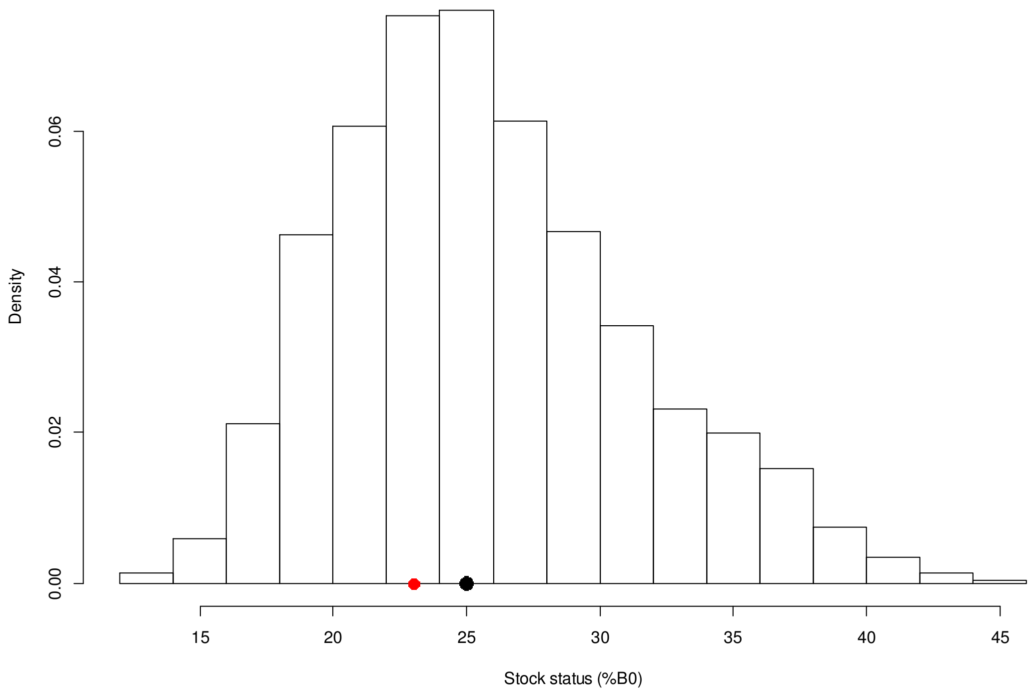


Figure 11: Eastern base model, MCMC: marginal posterior distribution for stock status (B_{2013}/B_0). The black dot marks the median of the posterior and the red dot the MPD estimate.

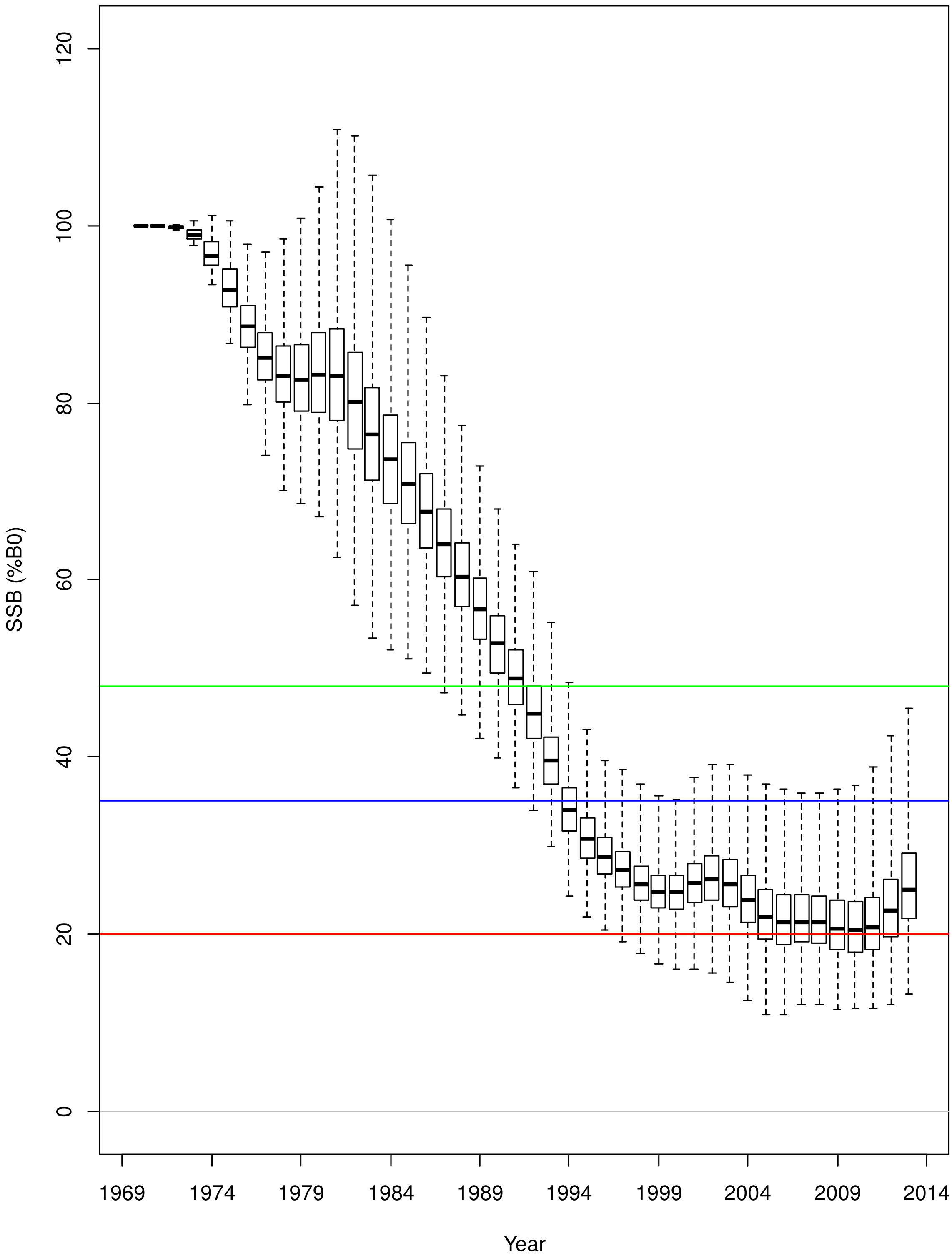


Figure 12: Eastern base model, MCMC: SSB trajectory. Each box contains the middle 50% of the distribution. Whiskers extend over the full range. Lines at 20%, 35%, and 48%.

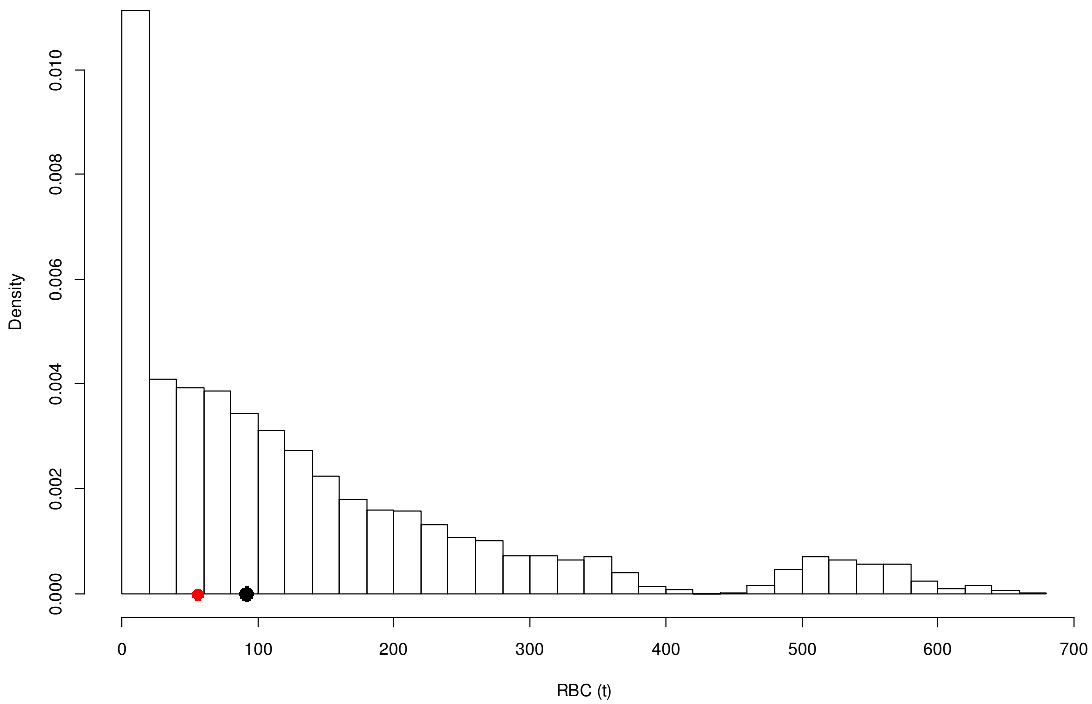


Figure 13: Eastern base model, MCMC: marginal posterior distribution for RBC. The black dot marks the median of the posterior and the red dot the MPD estimate.

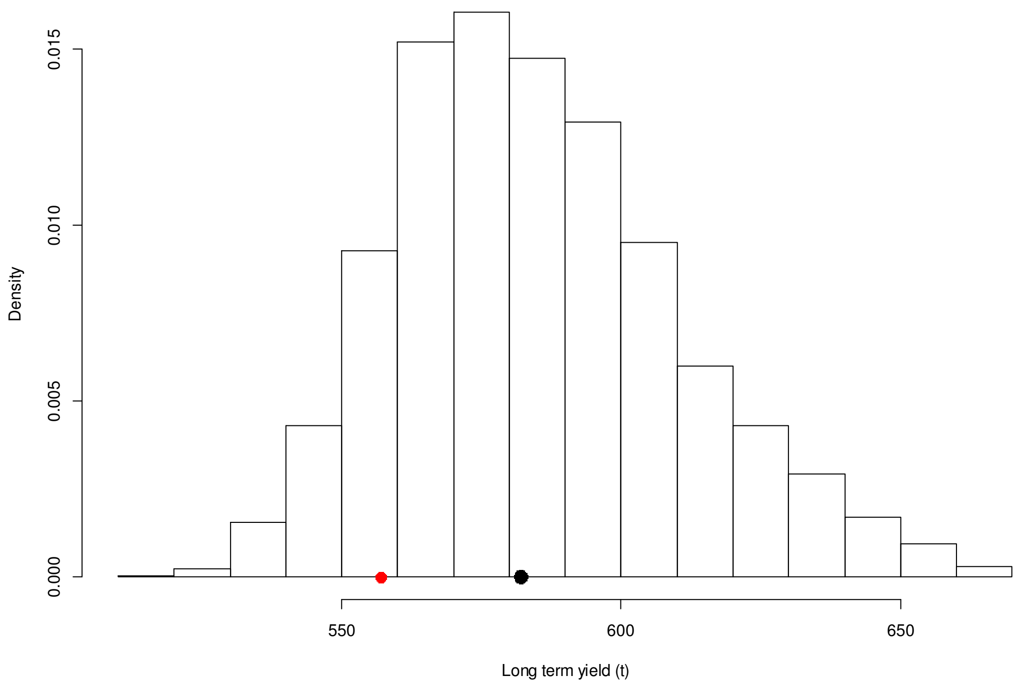


Figure 14: Eastern base model, MCMC: marginal posterior distribution for long-term yield. The black dot marks the median of the posterior and the red dot the MPD estimate.

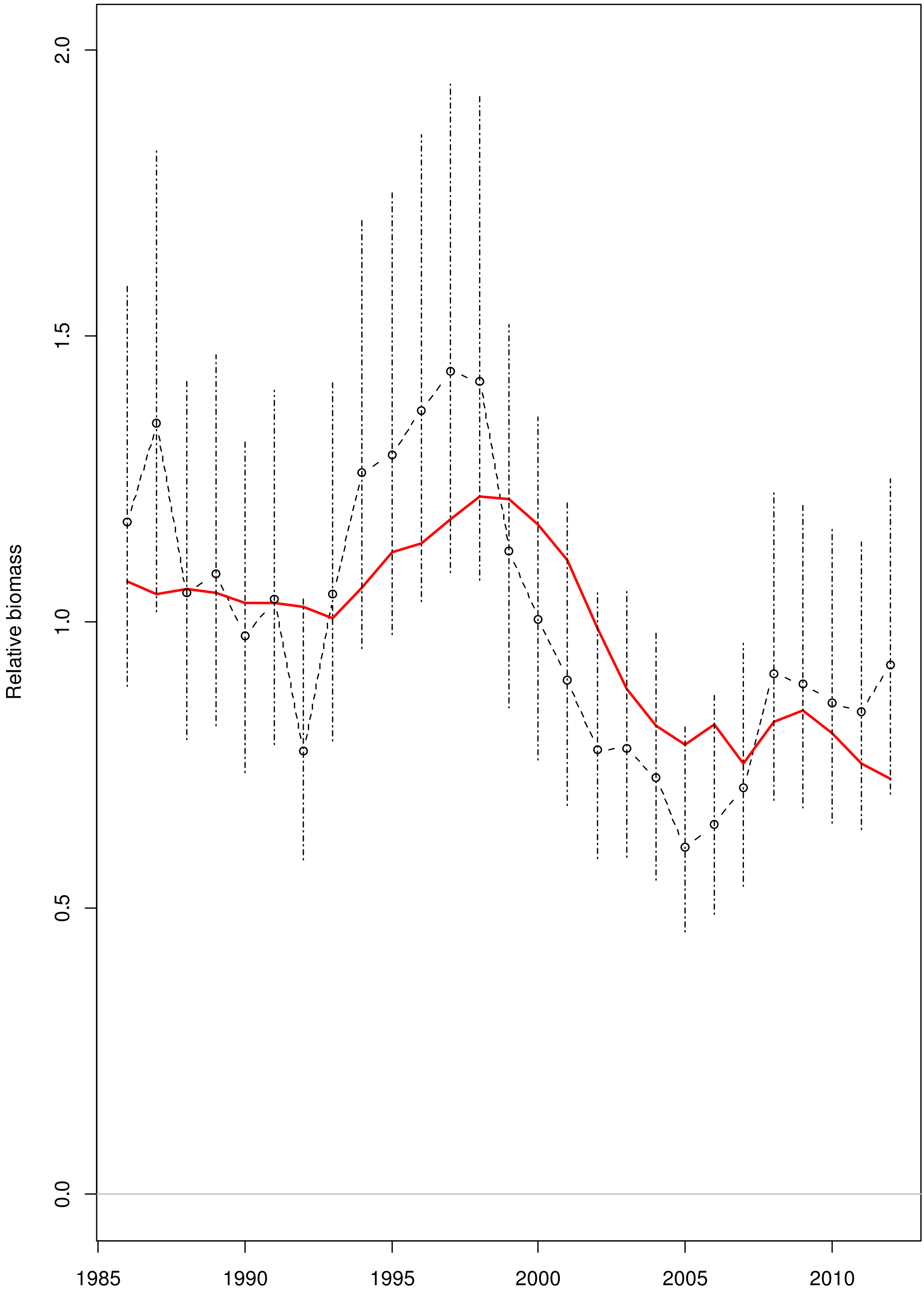


Figure 15: Western base model MPD-fit to trawl CPUE indices. Dashed lines are 95% CIs.

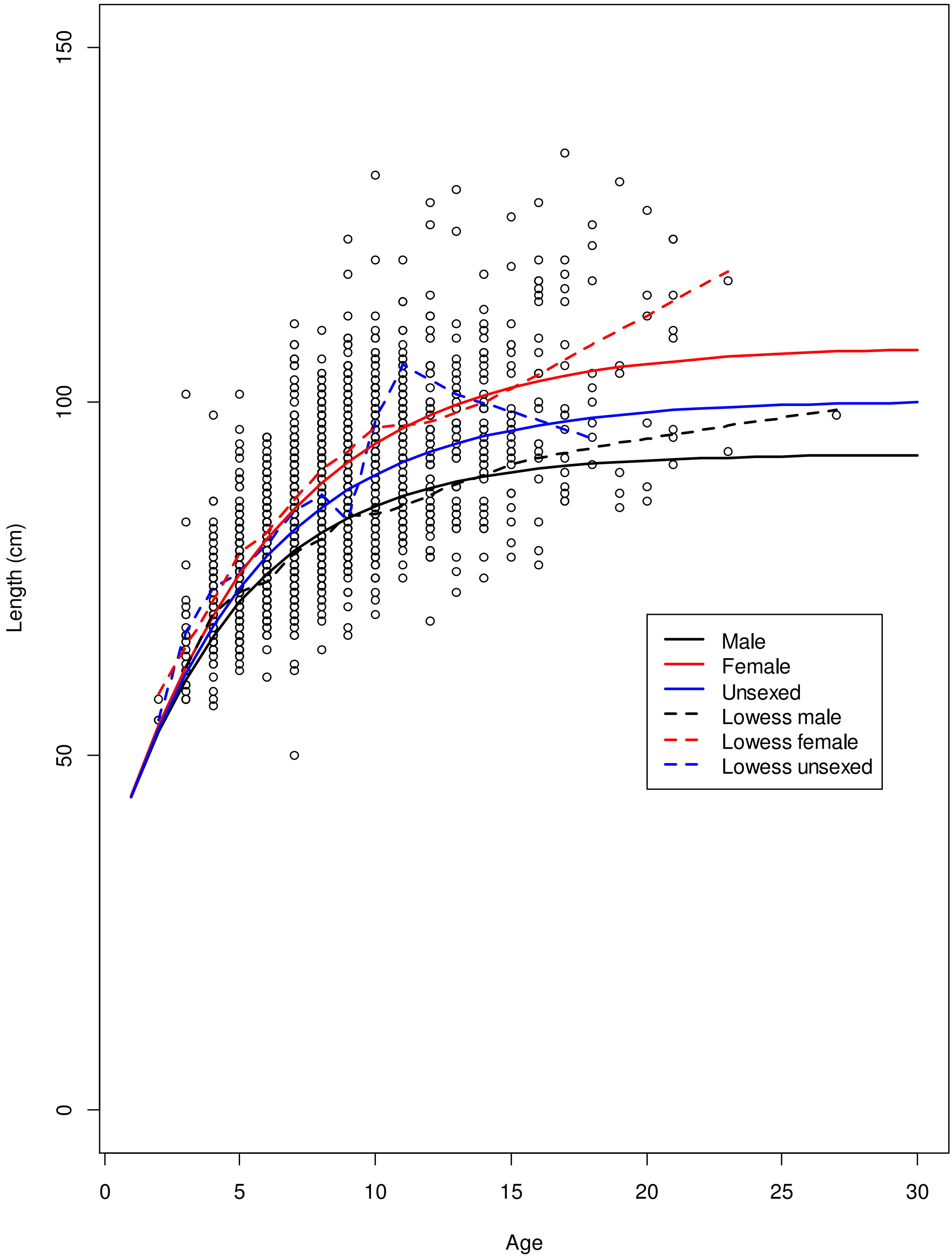


Figure 16: Western base model MPD: "fit" to age-length data from the line fishery. Model growth curves shown as solid lines. Lowess fits to data shown as dashed lines.

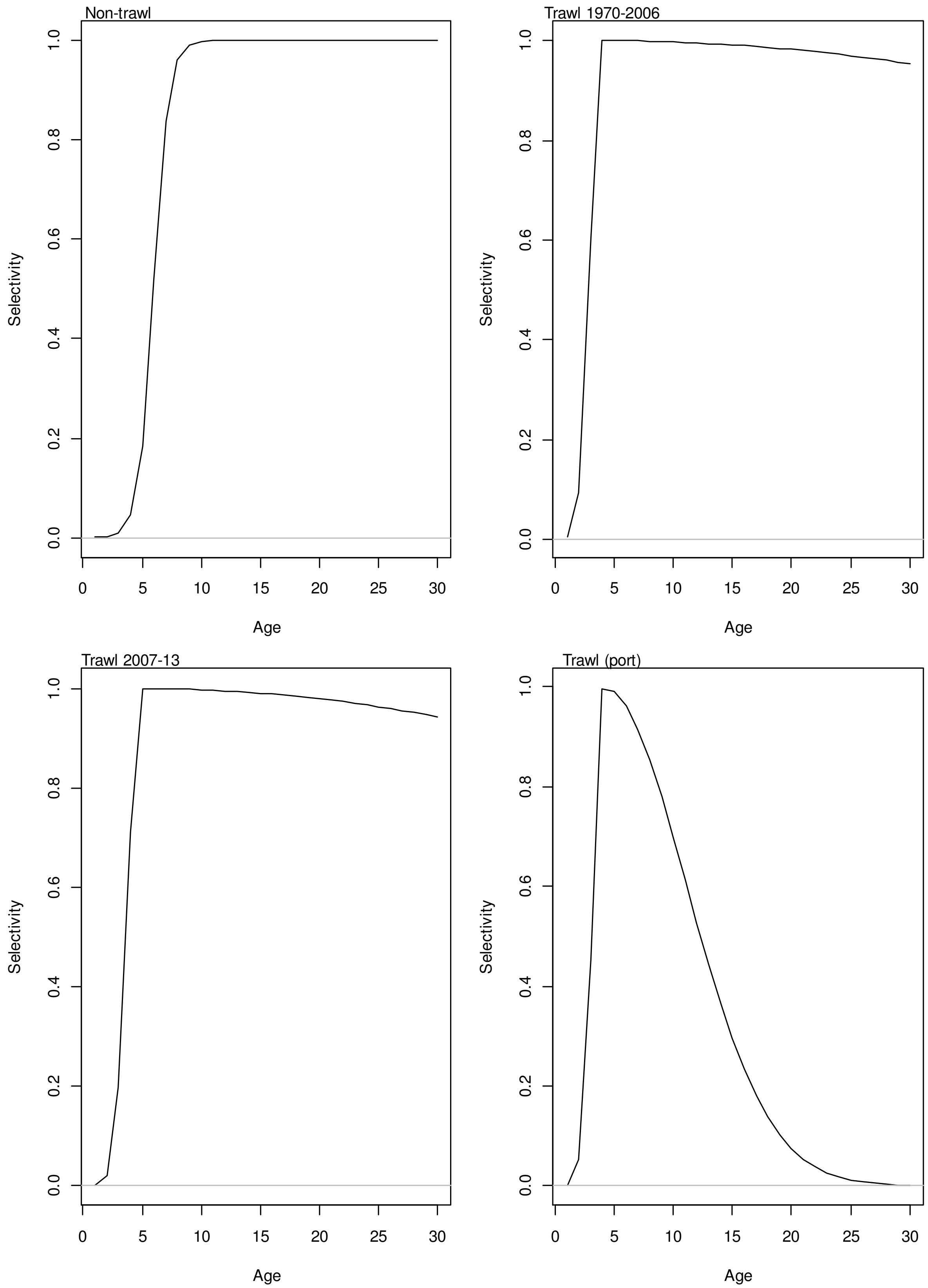


Figure 17: Western base model MPD: estimated fishery selectivities and the ogive for port sampling of trawl-caught fish (age-based, sex independent, two time blocks for trawl).

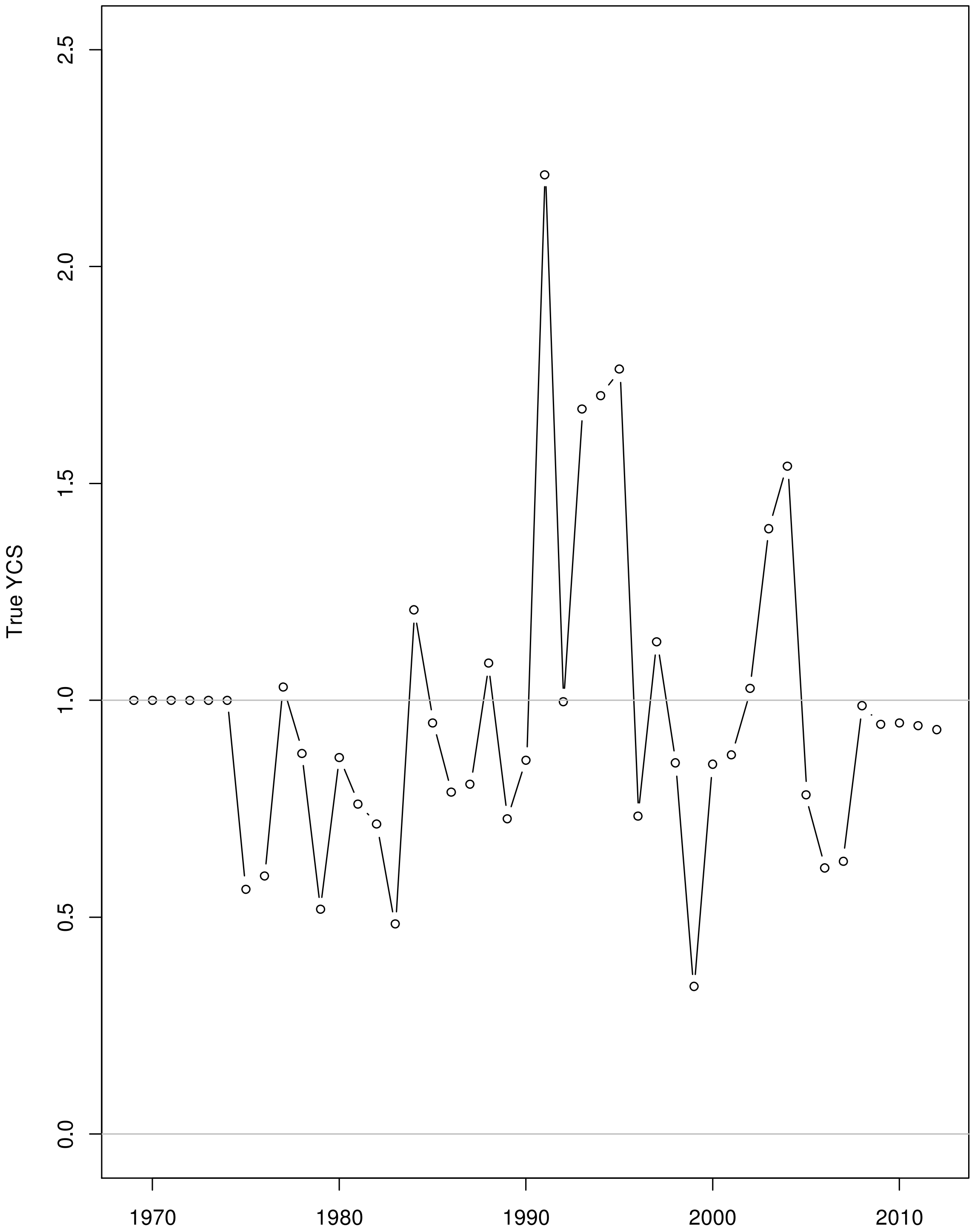


Figure 18: Western base model MPD: estimated "true year class strengths" (annual recruitment divided by virgin recruitment).

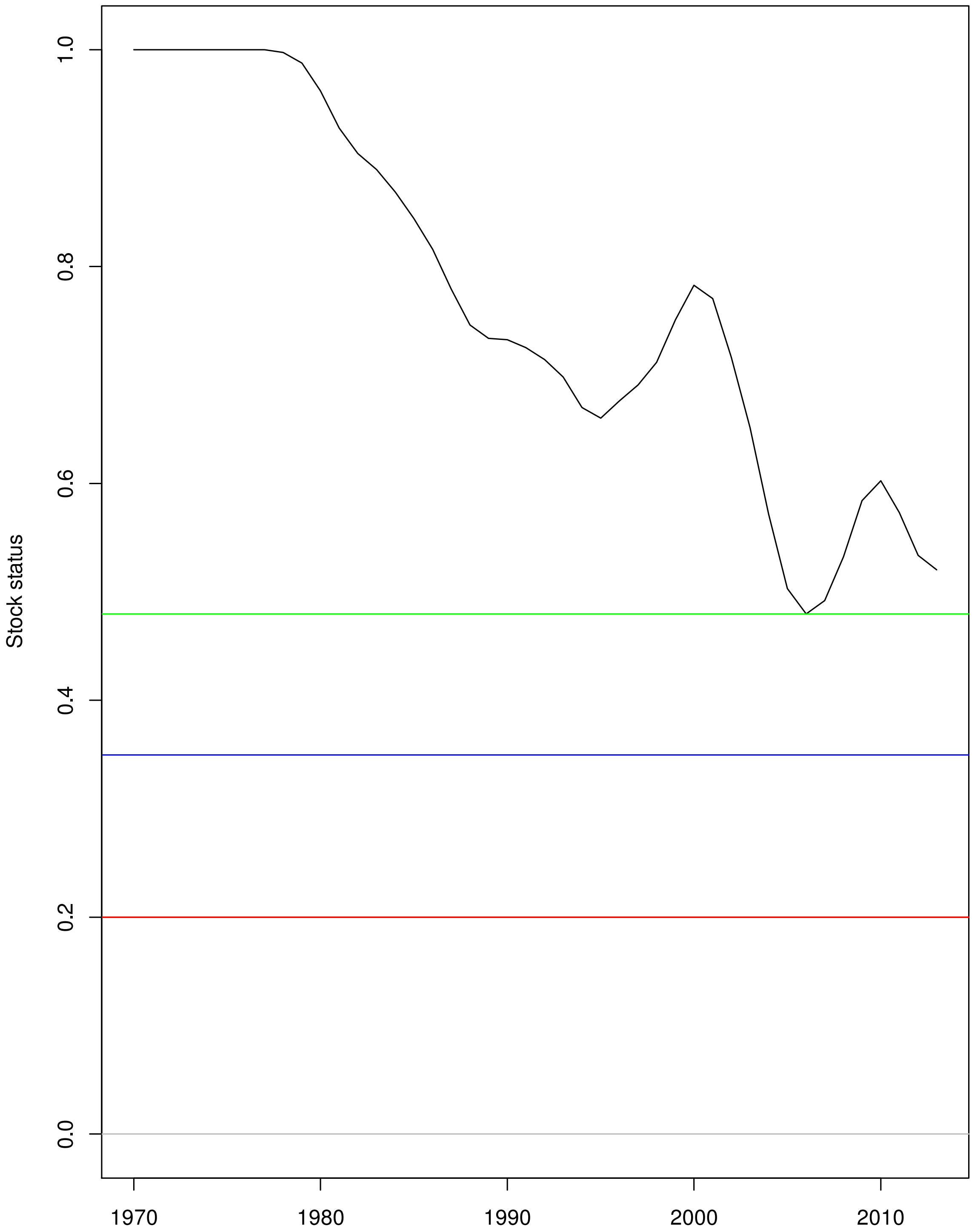


Figure 19: Western base model MPD: estimated stock status (annual SSB divided by virgin SSB; female biomass only; mid-year). Lines at 0.2, 0.35, and 0.48.

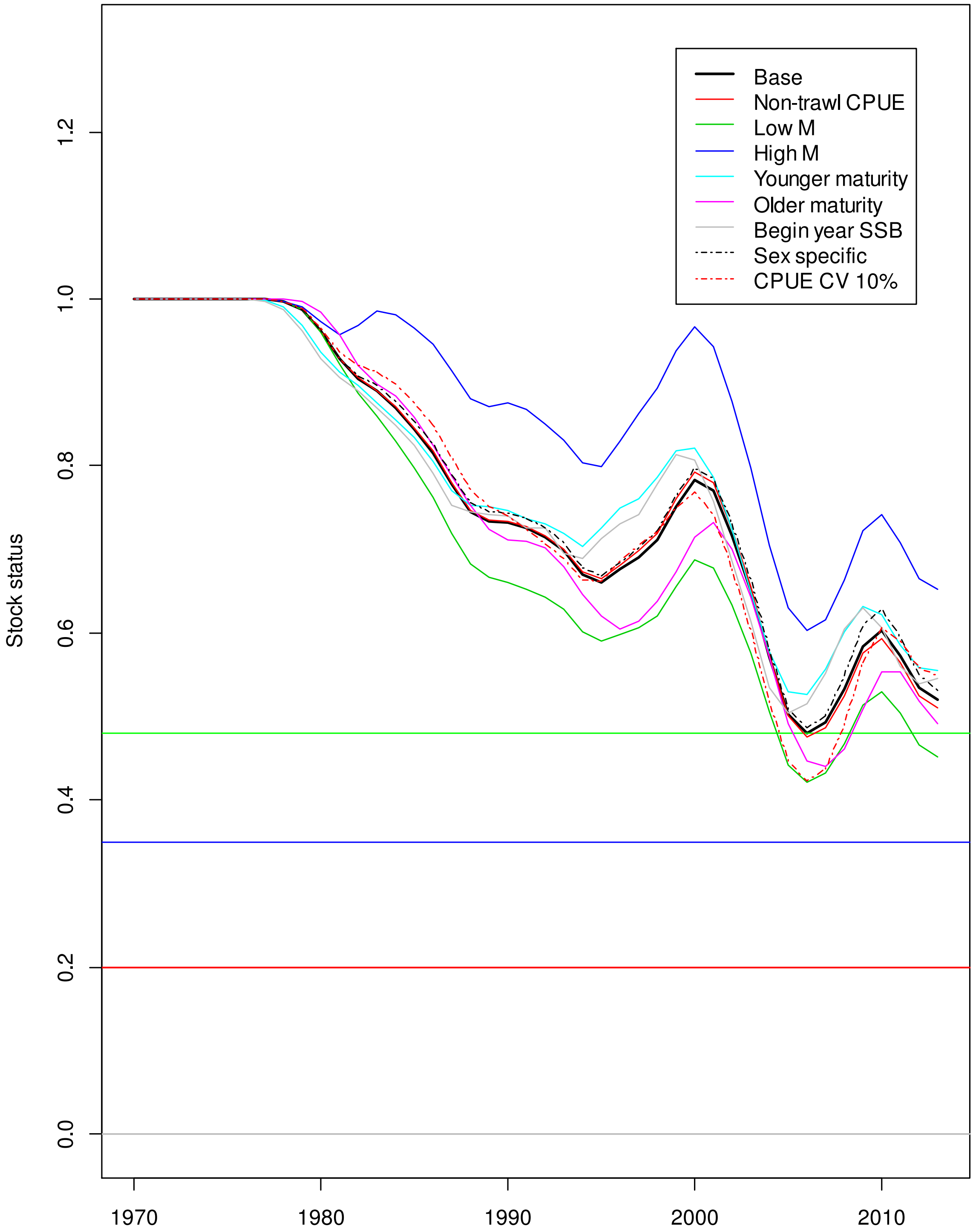


Figure 20: Western base model MPD: estimated stock status for the base model and sensitivity runs. Lines at 0.2, 0.35, and 0.48.

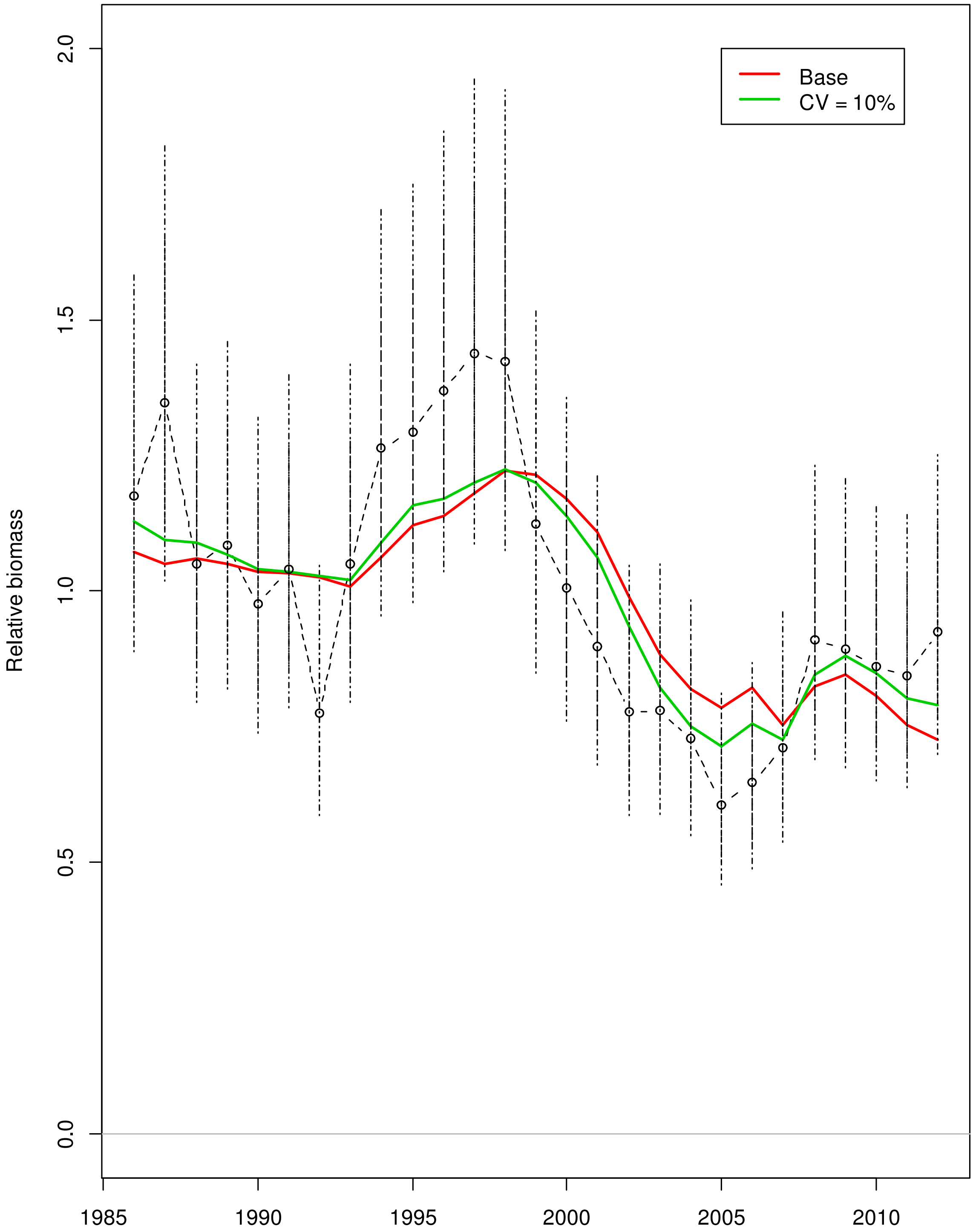


Figure 21: Western base model MPD-fit to trawl CPUE indices (CV = 15%) compared to the fit when the CPUE CV = 10%. Dashed lines are 95% CIs (for the CV = 15%).

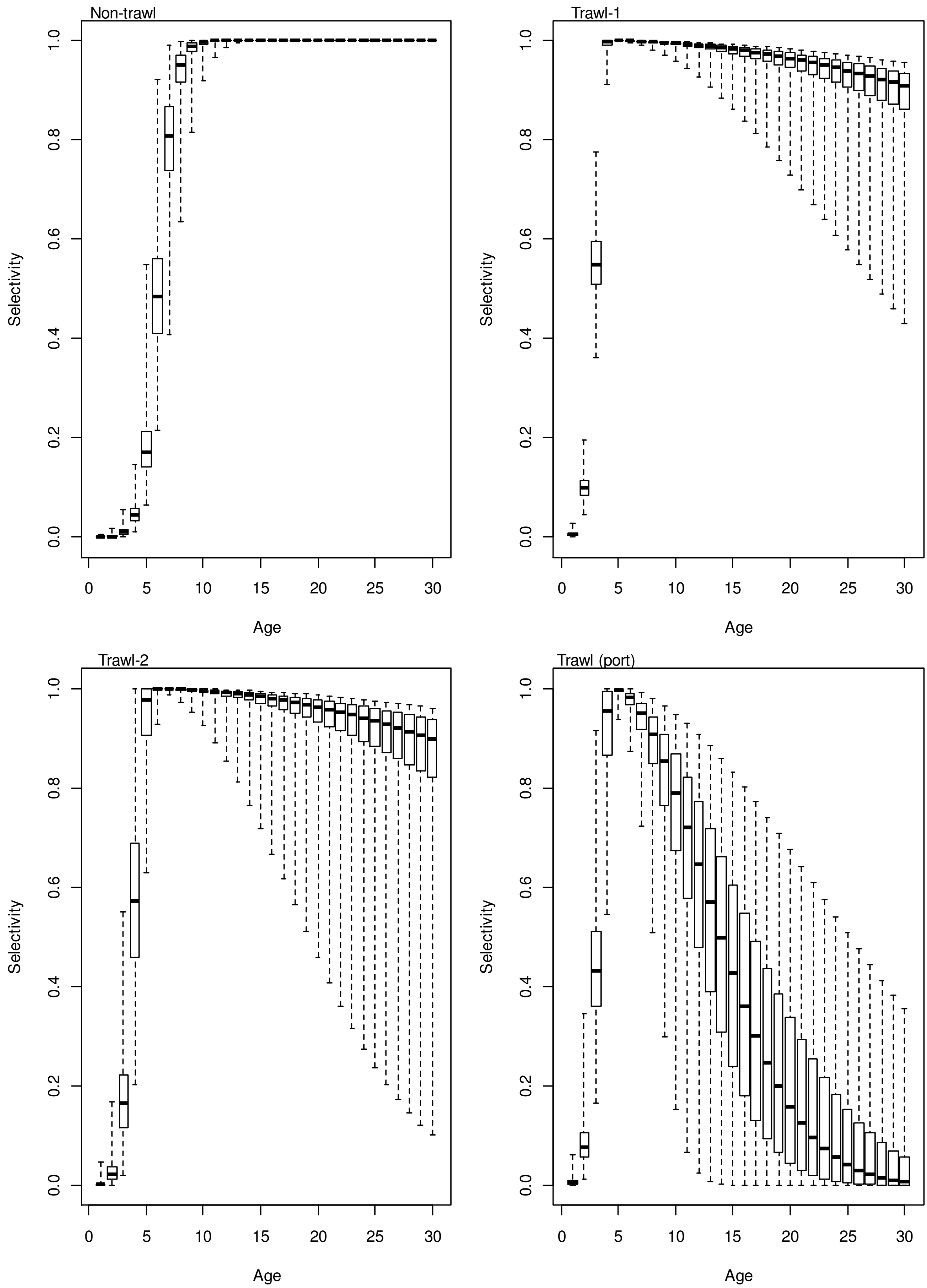


Figure 22: Western base model, MCMC: estimated fishing selectivities. Each box contains the middle 50% of the distribution. Whiskers extend over the full range.

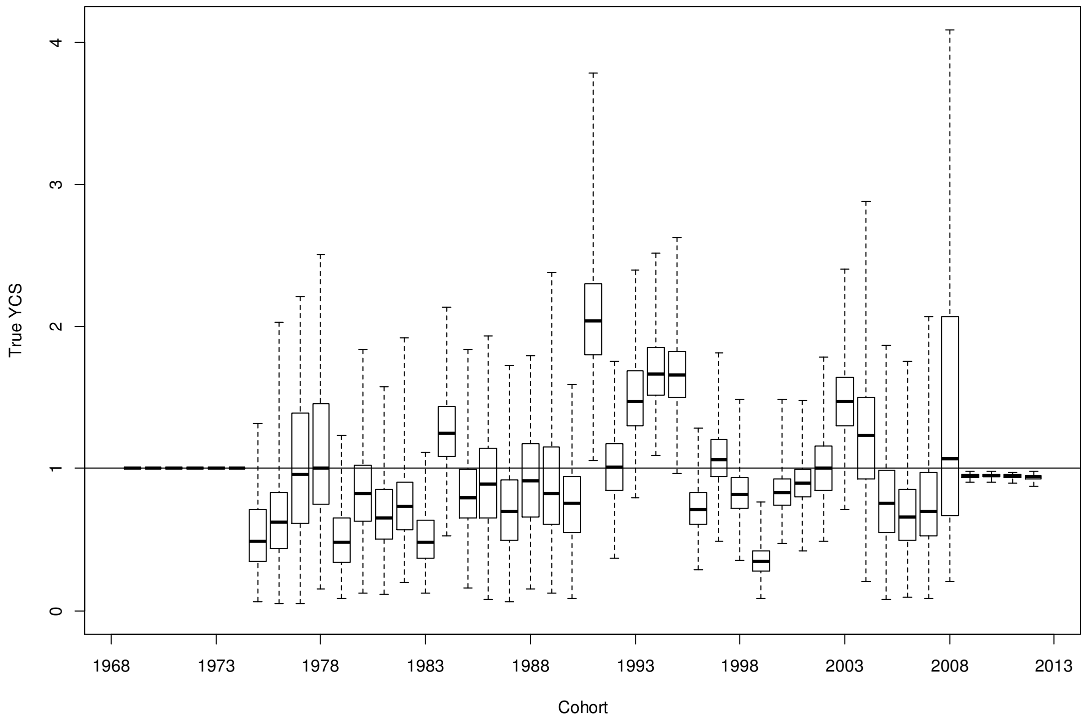


Figure 23: Western base model, MCMC: estimated true year class strengths (R_y/R_0). Each box contains the middle 50% of the distribution. Whiskers extend over full range.

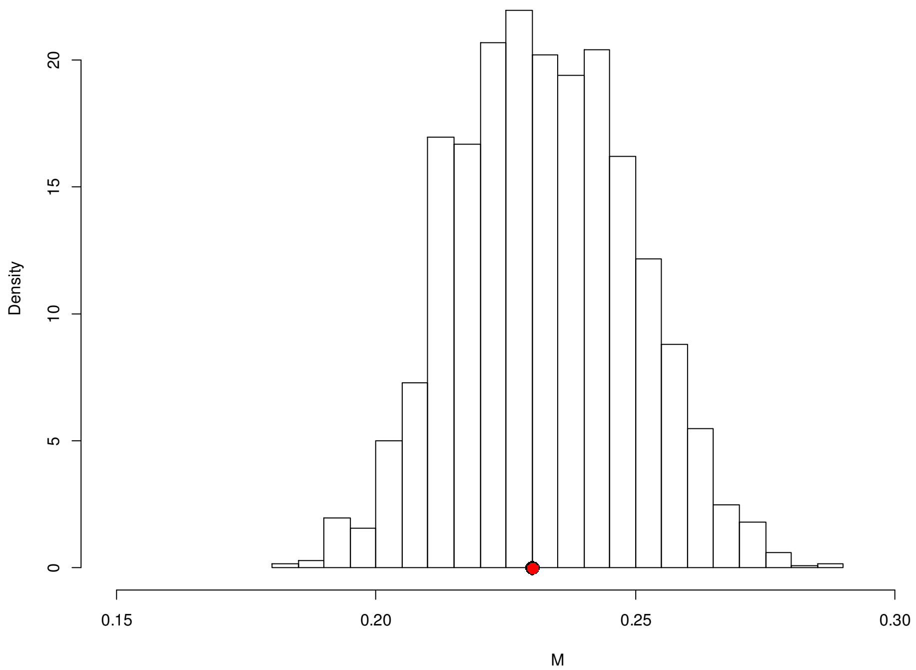


Figure 24: Western base model, MCMC: marginal posterior distribution for natural mortality status (*M*). The black dot marks the median of the posterior and the red dot the MPD estimate.

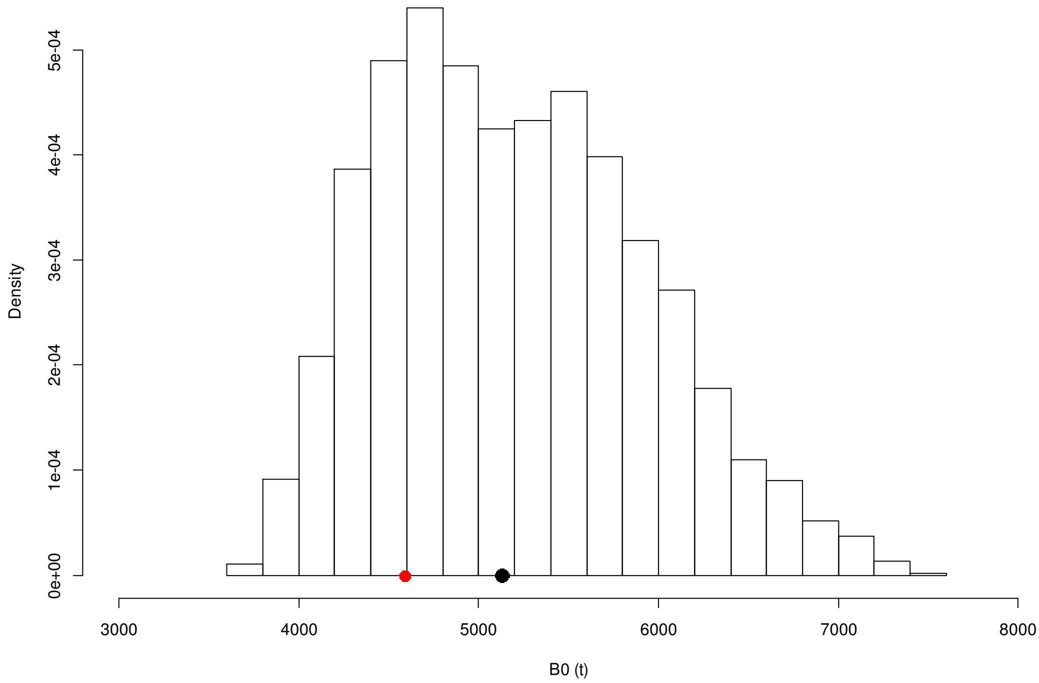


Figure 25: Western base model, MCMC: marginal posterior distribution for B_0. The black dot marks the median of the posterior and the red dot the MPD estimate.

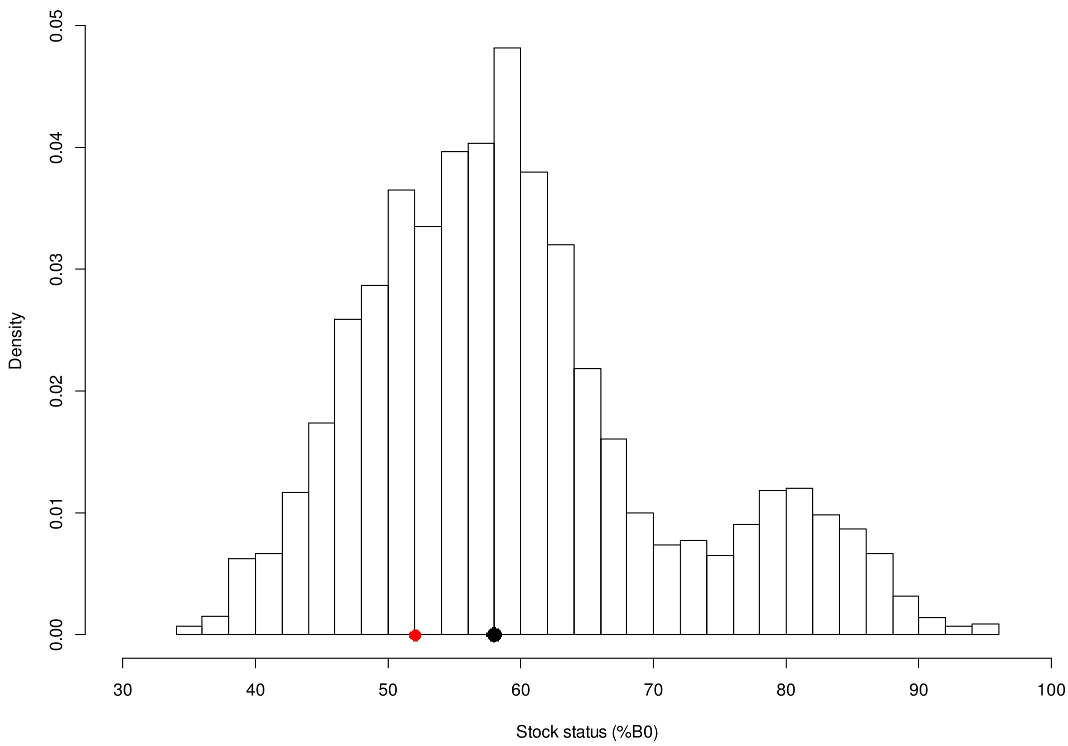


Figure 26: Western base model, MCMC: marginal posterior distribution for stock status (B_{2013}/B_0). The black dot marks the median of the posterior and the red dot the MPD estimate.

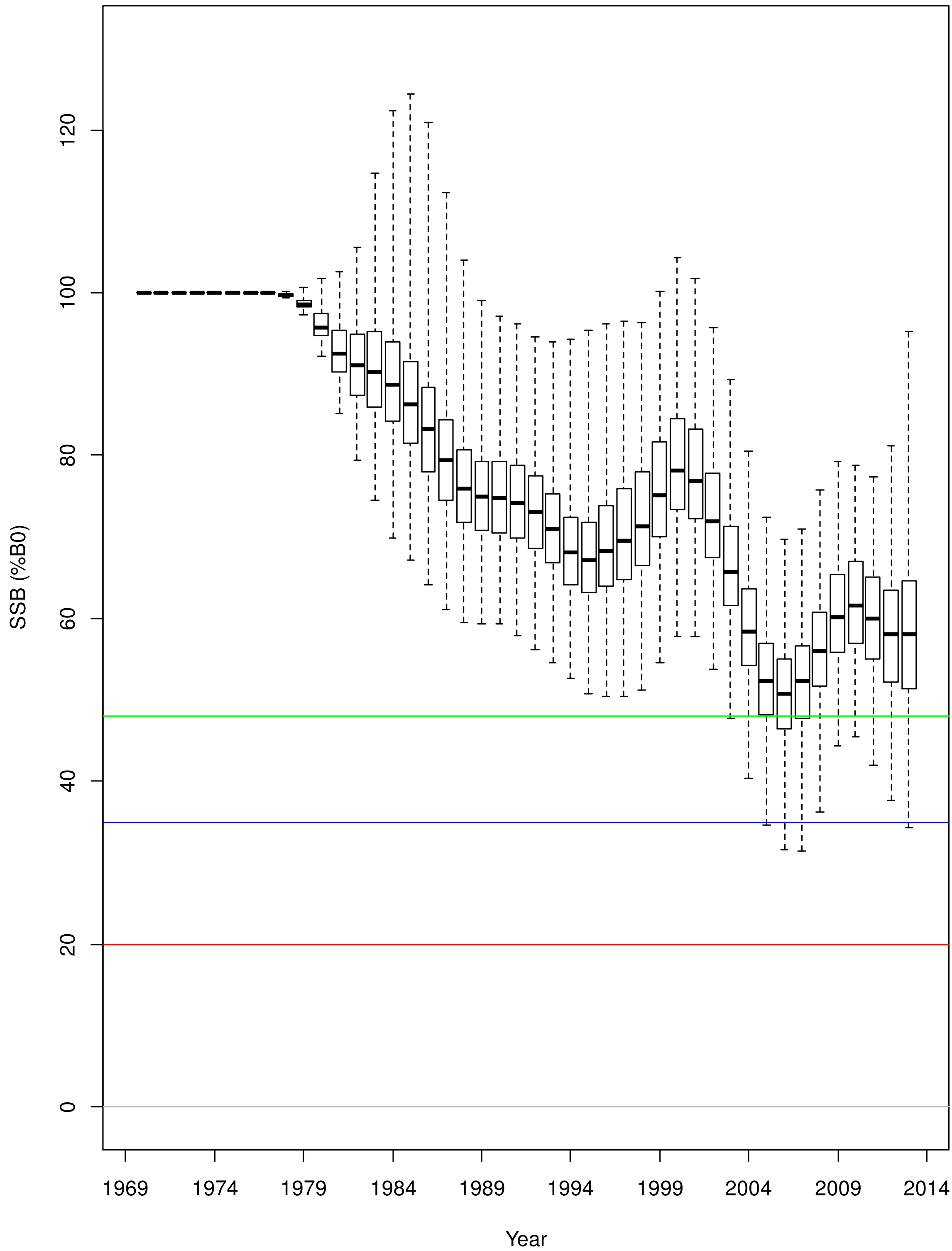


Figure 27: Western base model, MCMC: SSB trajectory. Each box contains the middle 50% of the distribution. Whiskers extend over the full range. Lines at 20%, 35%, and 48%.

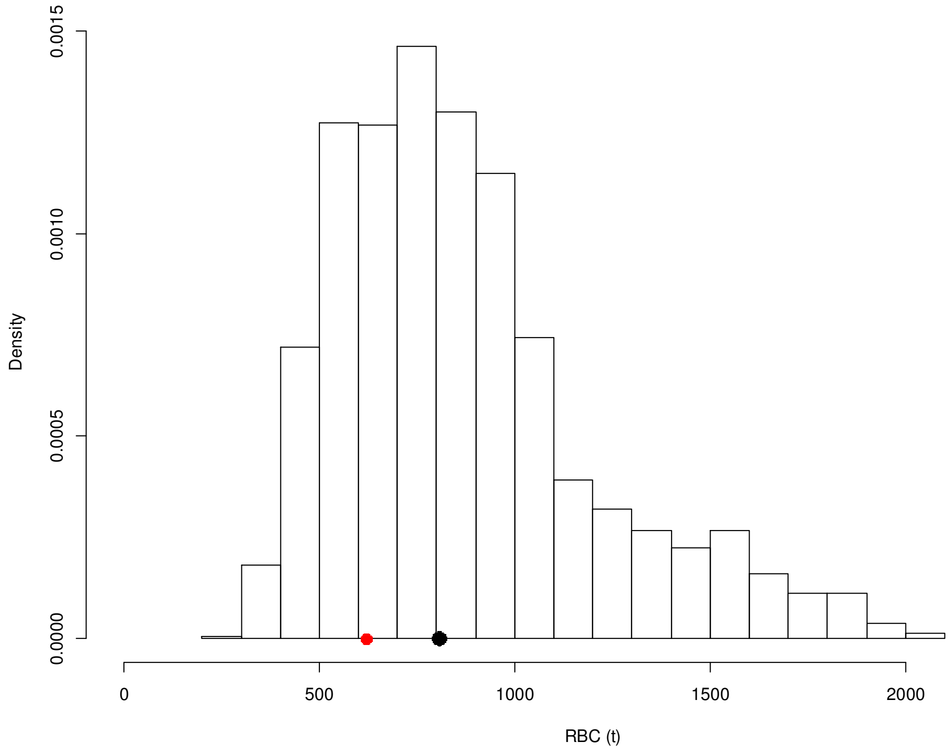


Figure 28: Western base model, MCMC: marginal posterior distribution for RBC. The black dot marks the median of the posterior and the red dot the MPD estimate.

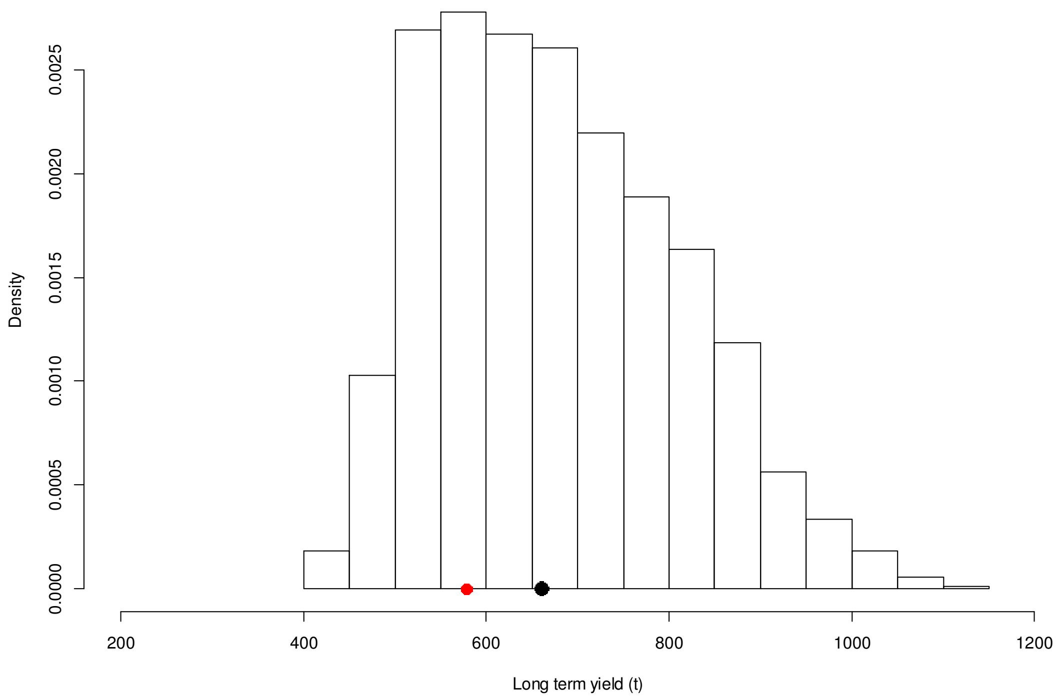


Figure 29: Western base model, MCMC: marginal posterior distribution for long term yield. The black dot marks the median of the posterior and the red dot the MPD estimate.

Appendix 1: Data weighting following Francis

Francis (2011) proposed methods to determine a constant CV for a biomass time series and to calculate the effective sample sizes for age and length frequencies assumed to have multinomial distributions. This appendix provides explicit equations for the calculation of a CV for a CPUE time series and also extends the method Francis applied to age and length frequencies to conditional age-at-length data.

CPUE indices

Francis (2011) proposed that a biomass time series should be fitted by a smoother outside of the model and that a constant CV be estimated for the time series. The idea is to choose a level of smoothness which corresponds to what would be considered a good fit within the stock assessment model (thus allowing for assumptions with regard to natural mortality and how variable a biomass trajectory should be).

For each pink ling stock, the trawl CPUE indices (X_i) were assumed to be median-unbiased relative biomass indices with a constant CV:

$$\ln\left(X_i\right) = \ln\left(qB_i\right) + \ln\left(\varepsilon_i\right)$$

where q is the proportionality constant, B_i is the selected biomass in year i, and $\ln\left(\varepsilon_i\right) \sim \mathrm{N}\left(0, \sigma^2\right)$. The maximum likelihood estimator of the CV was used for given qB_i (which are obtained from the fit given by the smoother):

$$\widehat{\sigma^2} = \frac{1}{n}\sum_i \left[\ln\left(\frac{x_i}{qB_i}\right)\right]^2$$

and

$$\widehat{CV} = \sqrt{e^{\widehat{\sigma^2}} - 1}$$

For pink ling: The lowess smoother in R was used and a CV of 15% was chosen by eye for both the eastern and western trawl CPUE indices (Figures A1.1 and A1.2). A CV of 10% could be justified on the basis of the fits that have been seen in preliminary stock assessment models. A CV of 20% is too high.

Conditional age-length data

Francis (2011) developed equations for his method TA1.8 for age and length frequencies which were assumed to have multinomial distributions. The method can be extended to conditional age-at-length data in several ways. However, following the principle of having only a single standardised residual each year (i.e., mean age in our case) a natural approach for conditional age-at-length data is to standardize "observed mean age – expected mean age (given the lengths and sexes of the aged fish)".

We develop the equations assuming we have independent samples within each length class and across length classes. In reality this is far from the truth, but we hope that once we have an appropriate vector of effective sample sizes that the derived distribution is approximately "correct".

For a given year, assume that there are n_j independent samples of age for the jth length class and let A_{ji} be the ith sample. Suppose there are m length classes (note, the classes can be defined by sex *and* length) and N is the total number of age samples. Then the observed mean age is,

$$\overline{A} = \frac{1}{N}\sum_{j=1}^{m}\sum_{i=1}^{n_j} A_{ji} = \frac{1}{N}\sum_{j=1}^{m} n_j \overline{A}_j$$

We need an equation for the variance of $\overline{A}$ so that we can work out how to standardise the variance of the annual residual, $\overline{A}-\overline{S}$, where $\overline{S}$ = E($\overline{A}$) is the mean age (given the lengths and sexes of the aged fish) for the catch from the specified fishery (i.e., calculated from the age-length structure of the catch).

Within a given length class the age samples are independent and identically distributed, so it is easy to calculate $\overline{S}$ and work out the variance of each $\overline{A}_j$ (and hence to the variance of $\overline{A}-\overline{S}$).

Let,

$$\mu_j = \mathrm{E}\left(A_{ji}\right) = \sum_{a=\min(age)}^{a=\max(age)} p_{ja} a$$

where p_{ja} is the proportion of fish at age a in the jth length class for the catch after perturbation by ageing error (if any). Then we have:

$$\mathrm{E}\left(\overline{A}\right) = \frac{1}{N}\sum_{j=1}^{m} n_j \mathrm{E}\left(\overline{A}_j\right) = \frac{1}{N}\sum_{j=1}^{m} n_j \mu_j$$

Also, let

$$\mu_{j2} = \mathrm{E}\left(A_{ji}^2\right) = \sum_{a=\min(age)}^{a=\max(age)} p_{ja} a^2$$

Then,

$$\mathrm{Var}\left(A_{ji}\right) = \mathrm{E}\left(A_{ji}^2\right) - \left(\mathrm{E}\left[A_{ji}\right]\right)^2 = \mu_{j2} - \mu_j^2$$

and

$$Var\left(\overline{A}_j\right) = \frac{1}{n_j}\left(\mu_{j2} - \mu_j^2\right)$$

Again, from independence assumptions (in this theoretical setting where we have independent samples and a "correct" effective sample size),

$$\mathrm{Var}\left(\overline{A}\right) = \frac{1}{N^2}\sum_{j=1}^{m} n_j\left(\mu_{j2} - \mu_j^2\right)$$

We can rejig this equation to get to a form that Francis used for TA1.8:

We have,

$$N = \sum_{j=1}^{m} n_j \text{ and let } r_j = \frac{n_j}{N}$$

then,

$$\mathrm{Var}\left(\overline{A}\right) = \frac{1}{N}\sum_{j=1}^{m} r_j\left(\mu_{j2} - \mu_j^2\right) = \frac{v}{N}$$

We can now generalise to the residual in any year *y*:

$$\mathrm{Var}\left(\overline{A}_y - \overline{S}_y\right) = \mathrm{Var}(\overline{A}_y) = \frac{v_y}{N_y}$$

and adopt the notation and iterative reweighting scheme of Francis (2011) whereby we want to find *w* to scale our original vector of sample sizes $\tilde{N}_y$: $N_y = w\tilde{N}_y$

We note that,

$$\mathrm{Var}\left(\overline{A}_y - \overline{S}_y\right) = \frac{v_y}{N_y} = \frac{v_y}{w\tilde{N}_y}$$

and therefore,

$$\mathrm{Var}\left(\frac{\bar{A}_y - \bar{S}_y}{\left(v_y / \tilde{N}_y\right)^{0.5}}\right) = \frac{v_y}{w\tilde{N}_y}\frac{\tilde{N}_y}{v_y} = \frac{1}{w}$$

It follows that if we can iteratively reweight until we get $w = 1$ then all of our standardised residuals will have a variance of 1 (which is what is expected of standardised residuals). The scalar at each iteration can be chosen by guesswork, aiming to get the "standard deviation of the standardised residuals equal to 1". Alternatively, we can use the formula that Francis (2011) obtained by equating the variance of the "vector of annual standardised residuals" (a vector of numerical values available at each iteration) to the formula for the variance of each standardised residual (note the subscript y on the right-hand "Var" operator):

$$\frac{1}{w} = \mathrm{Var}\left(\frac{\bar{A}_y - \bar{S}_y}{\left(v_y / \tilde{N}_y\right)^{0.5}}\right) = \mathrm{Var}_y\left(\frac{\bar{A}_y - \bar{S}_y}{\left(v_y / \tilde{N}_y\right)^{0.5}}\right)$$

$$\rightarrow w = 1 / \mathrm{Var}_y\left(\frac{\bar{A}_y - \bar{S}_y}{\left(v_y / \tilde{N}_y\right)^{0.5}}\right)$$

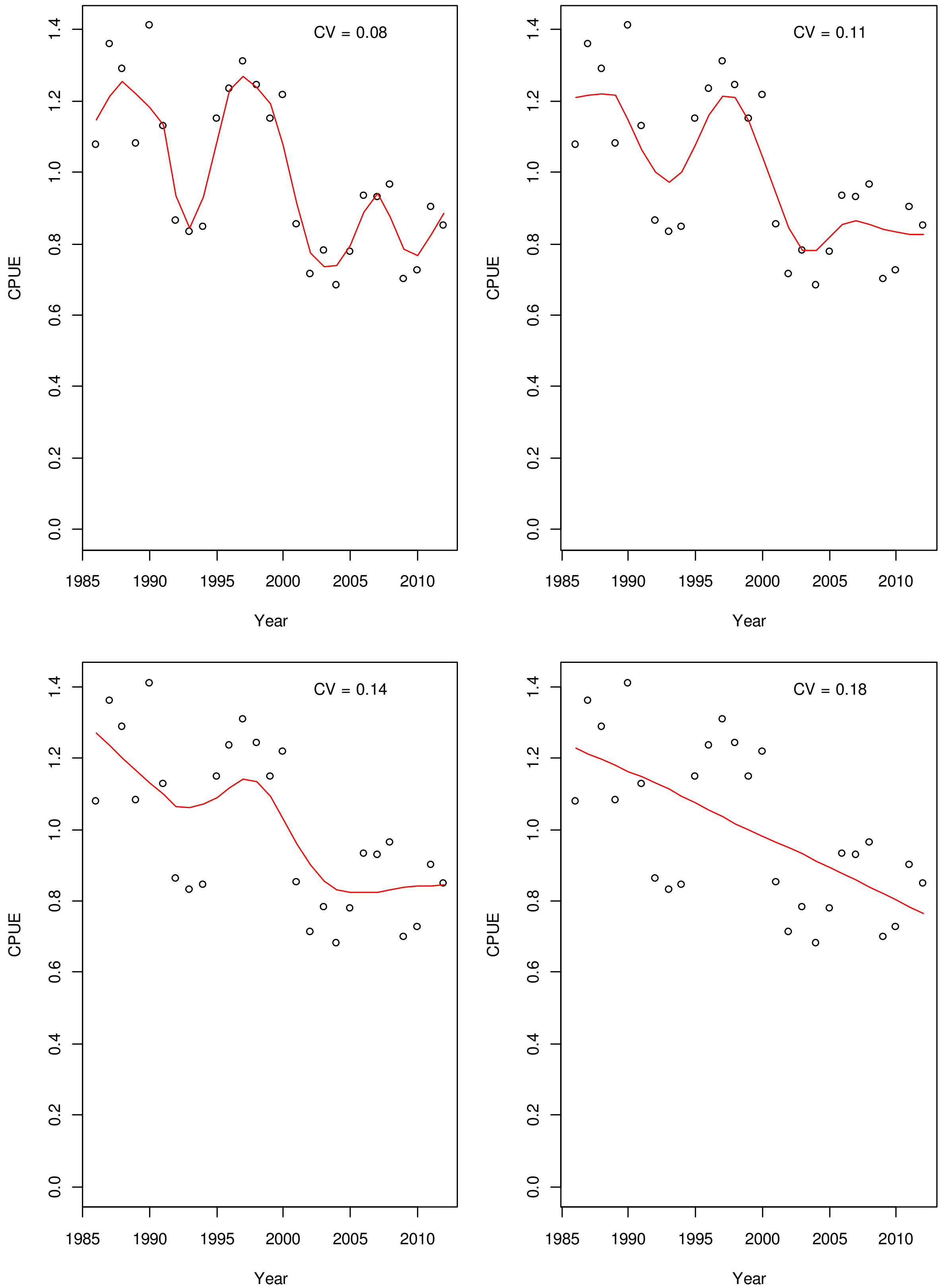


Figure A1.1: Lowess fits to the original ISL-base eastern-trawl CPUE indices at different levels of smoothness with the corresponding estimated CV.

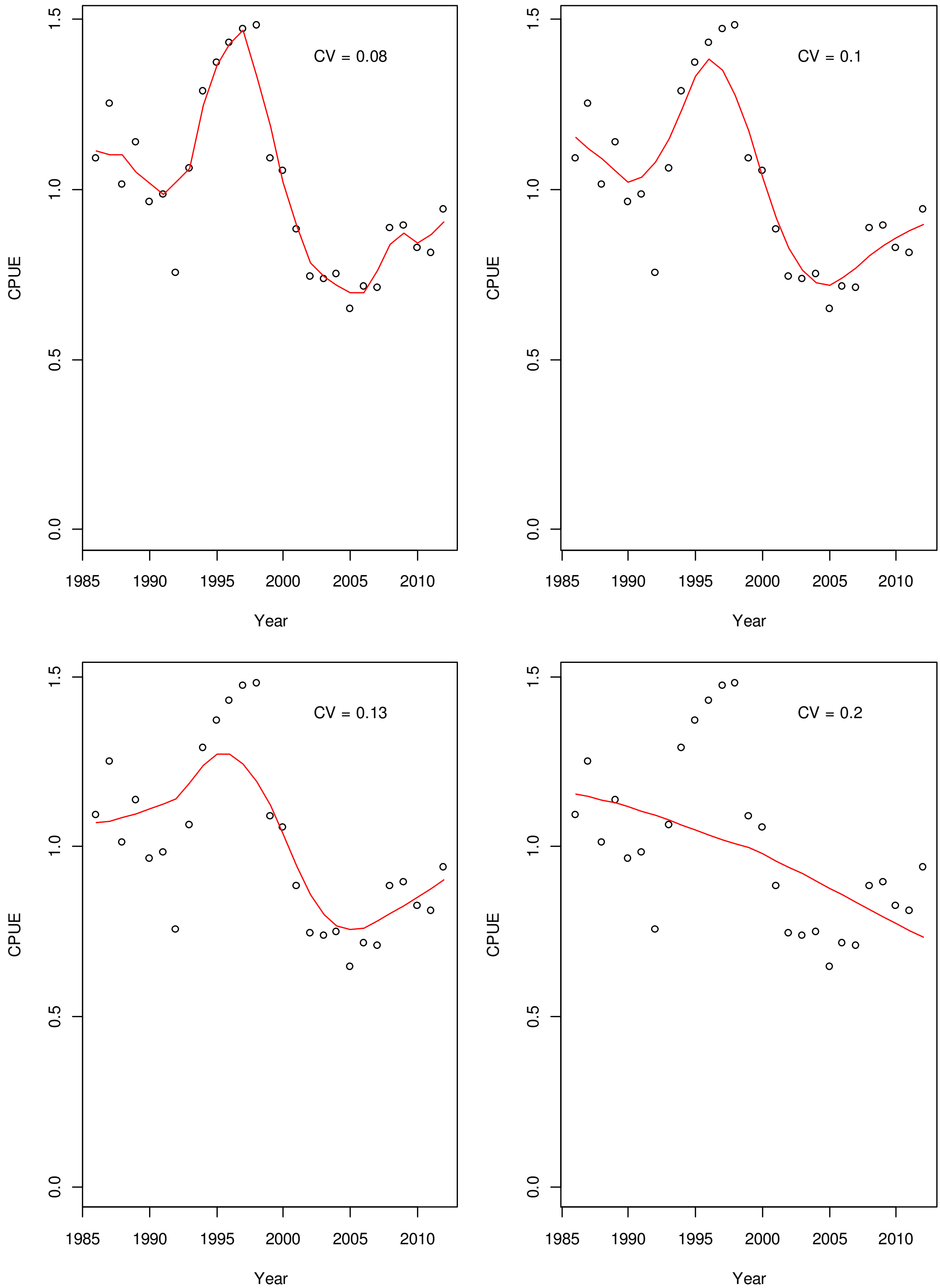
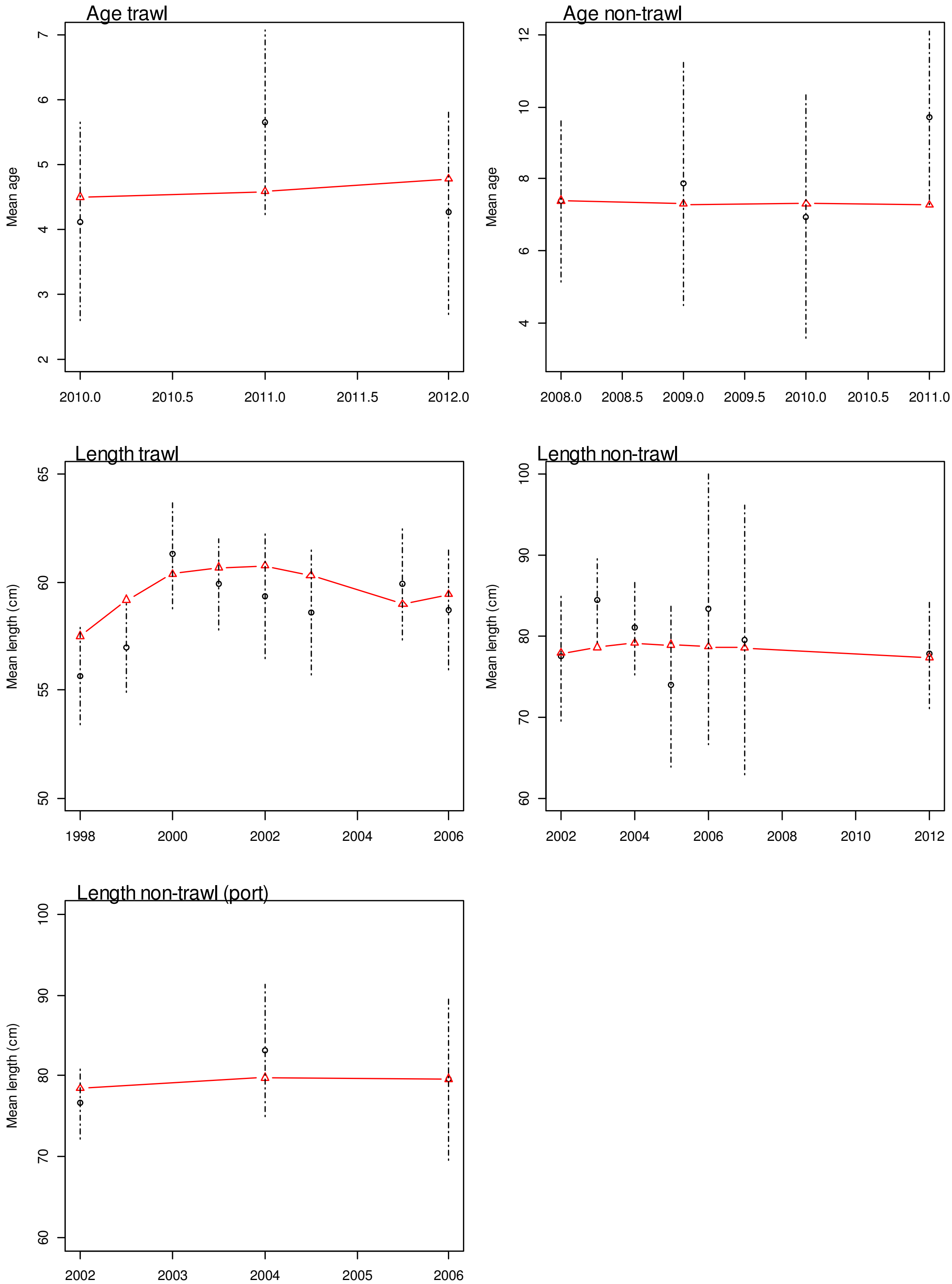
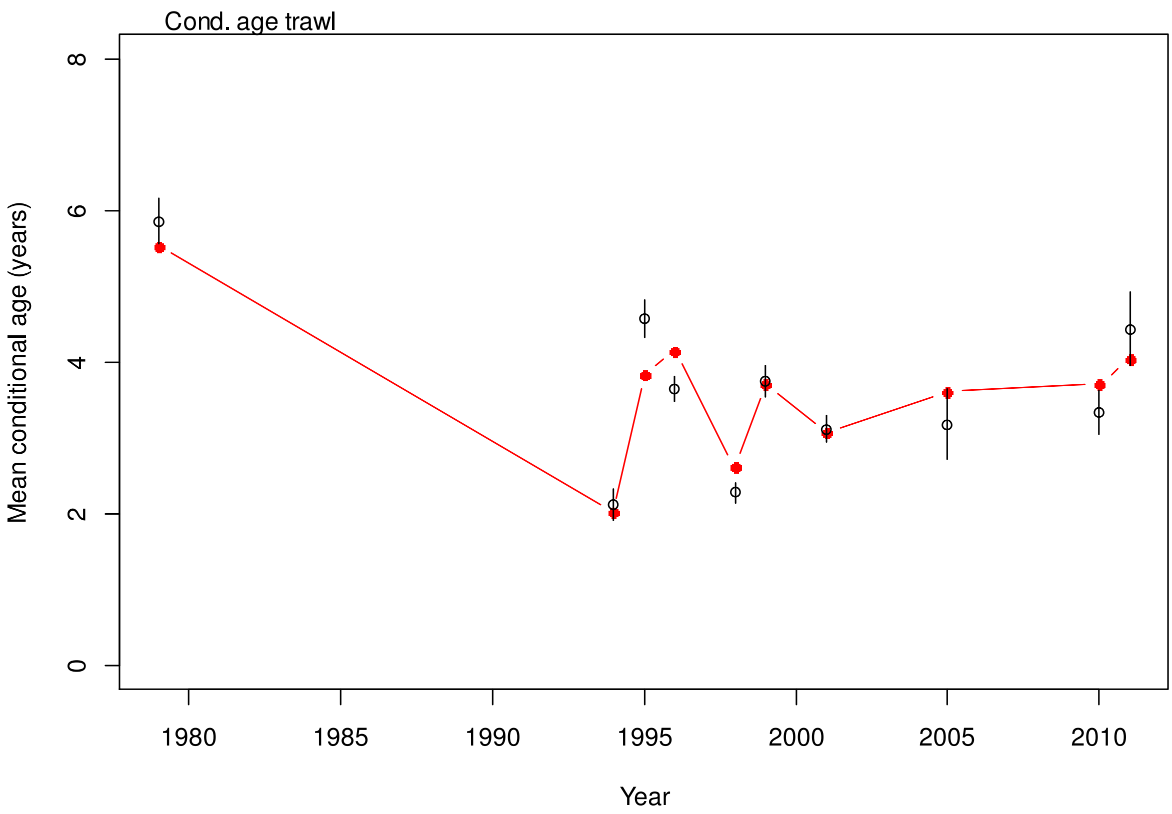


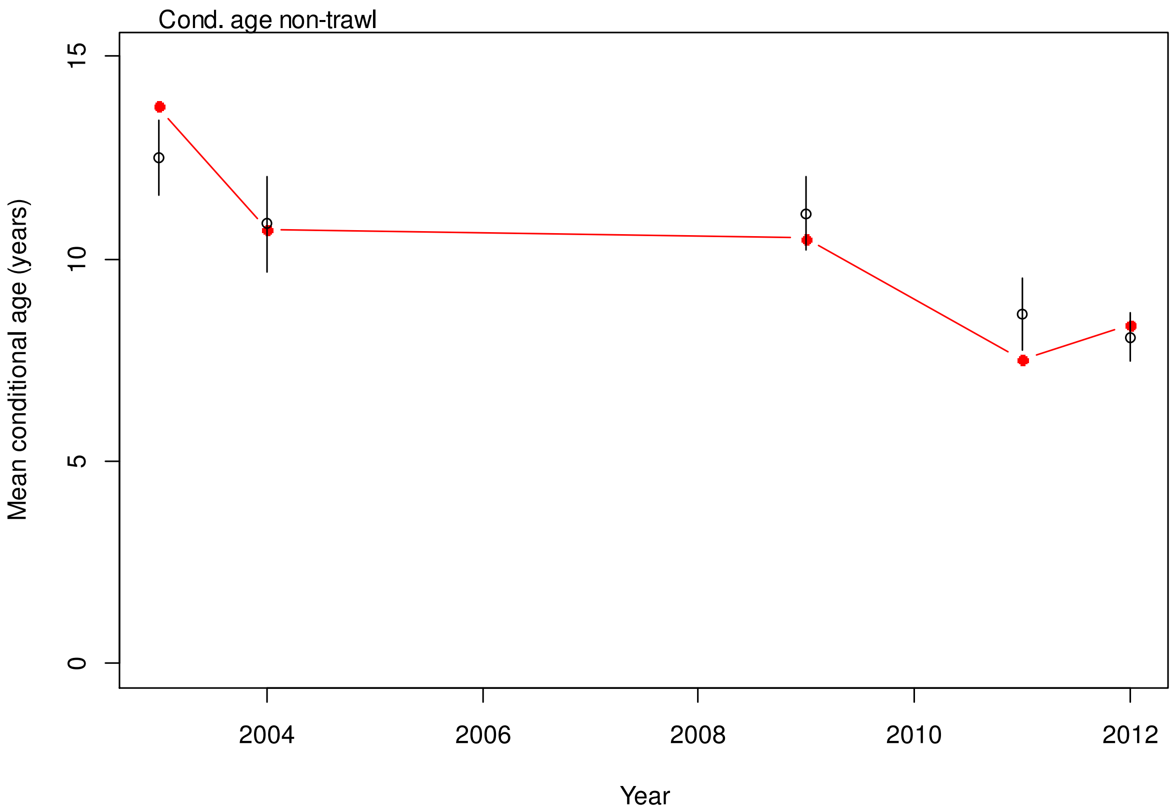
Figure A1.2: Lowess fits to the original ISL-base western-trawl CPUE indices at different levels of smoothness with the corresponding estimated CV.

Appendix 2: MPD fits to annual mean age, mean length, and mean conditional age (for Francis weighting)

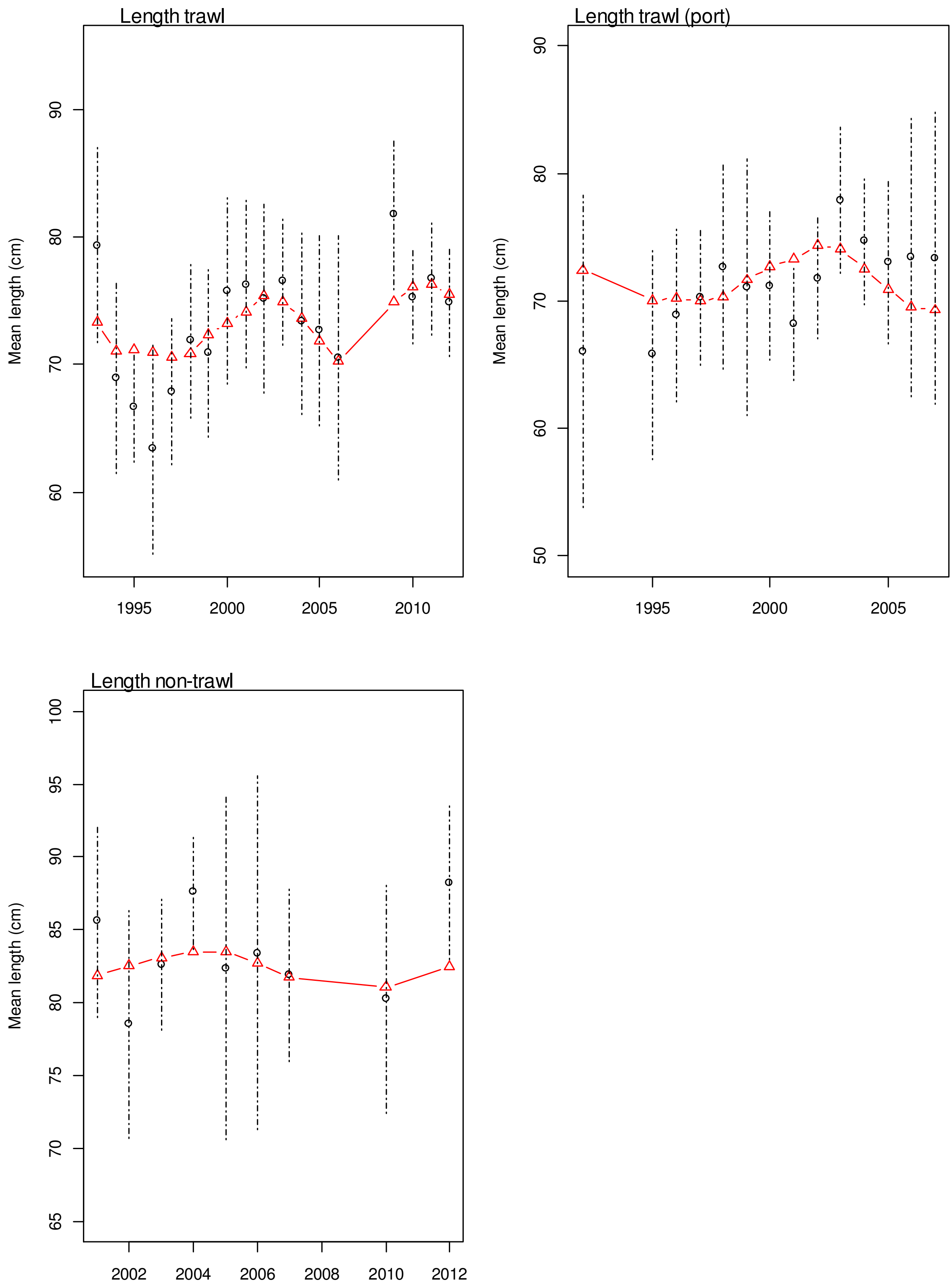


Eastern base model: fits to annual mean age and length. Dashed lines are 95% confidence intervals for the final effective sample sizes.

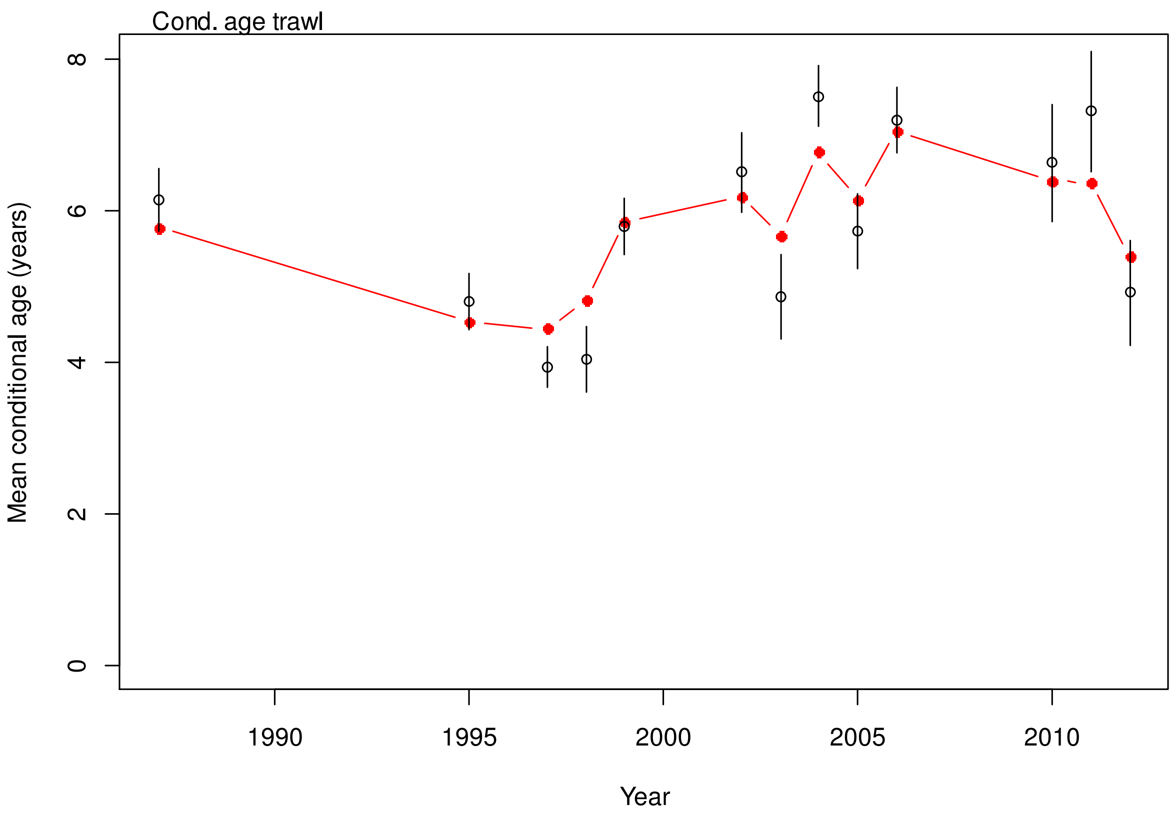


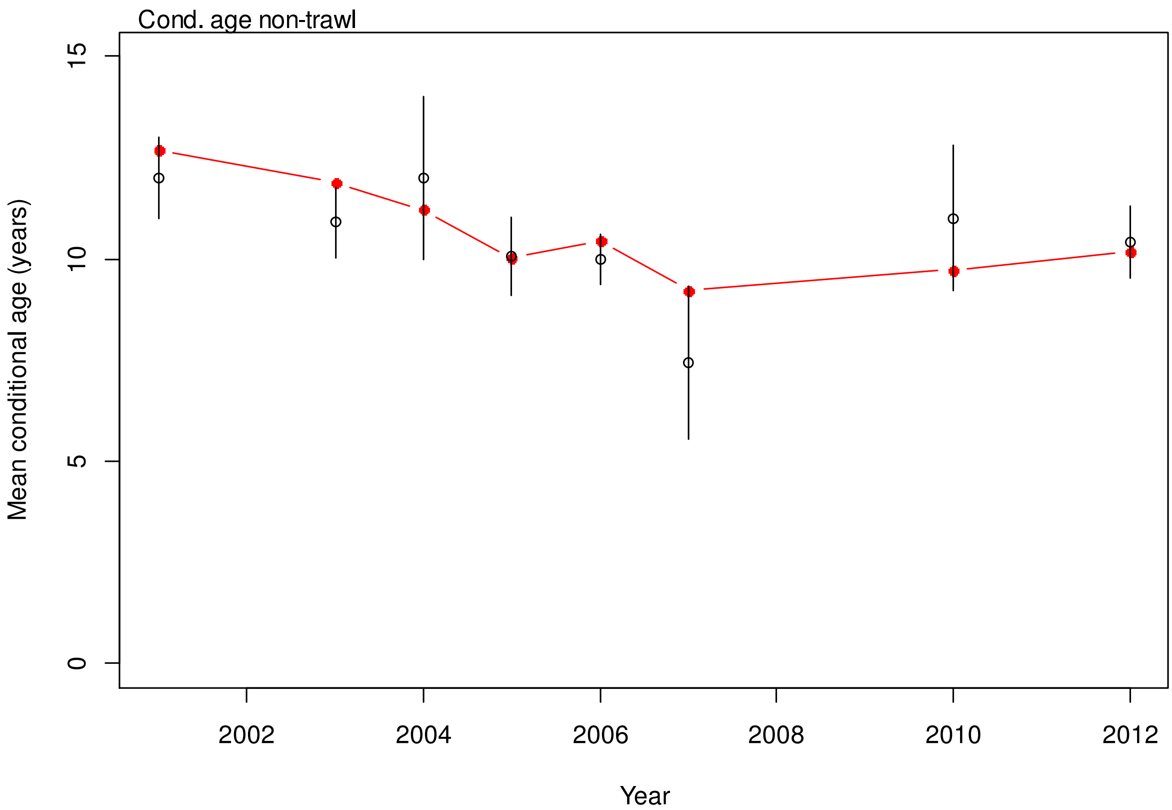


Eastern base model: fits to mean conditional age. Vertical lines are 95% confidence intervals for the final effective sample sizes.



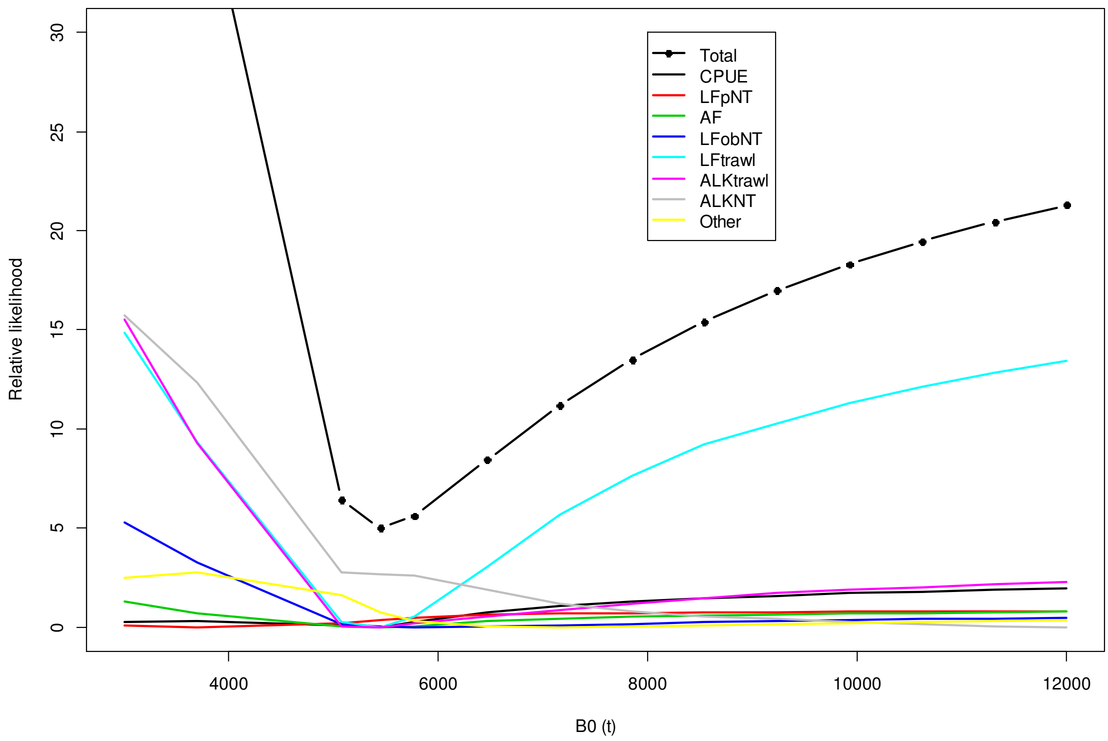
Western base model: fits to annual mean length. Dashed lines are 95% confidence intervals for the final effective sample sizes.



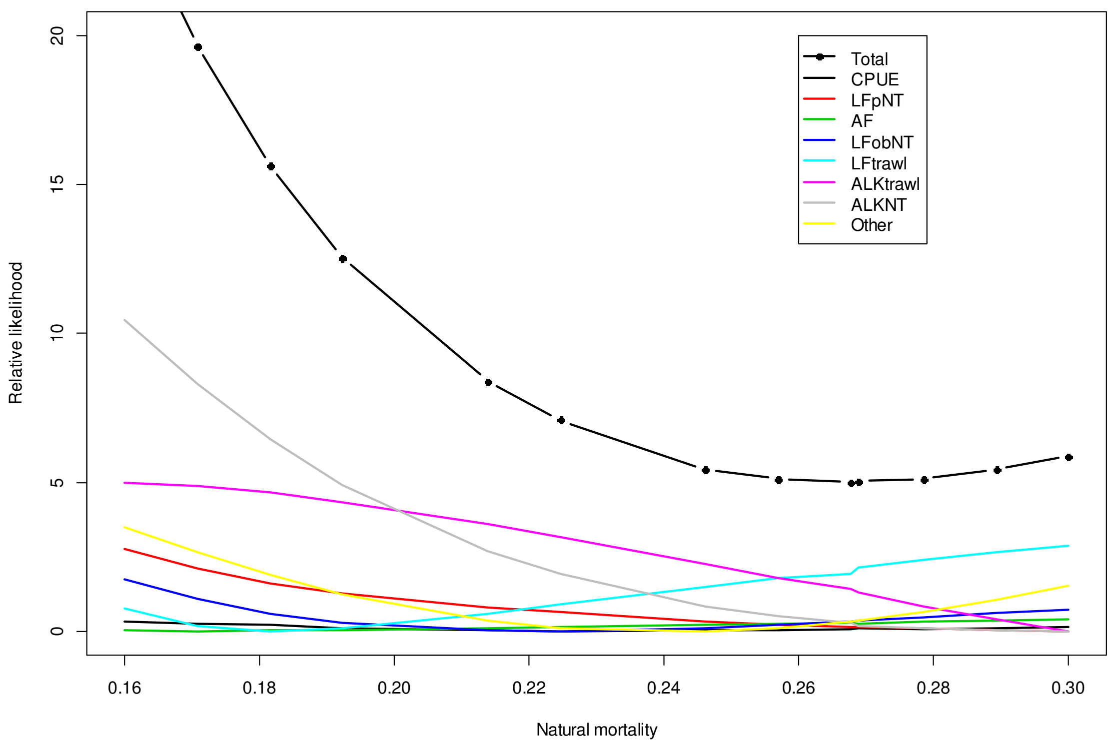


Western base model: fits to mean conditional age. Vertical lines are 95% confidence intervals for the final effective sample sizes.

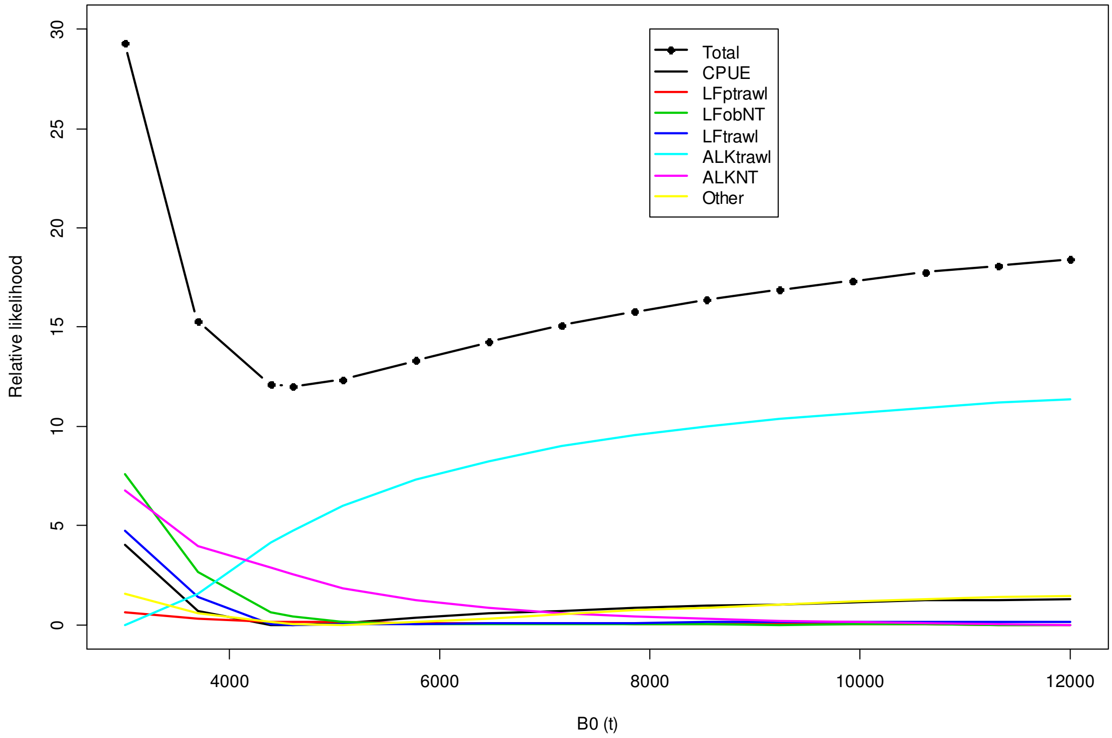
Appendix 3: Likelihood profiles and some miscellaneous MPD diagnostics



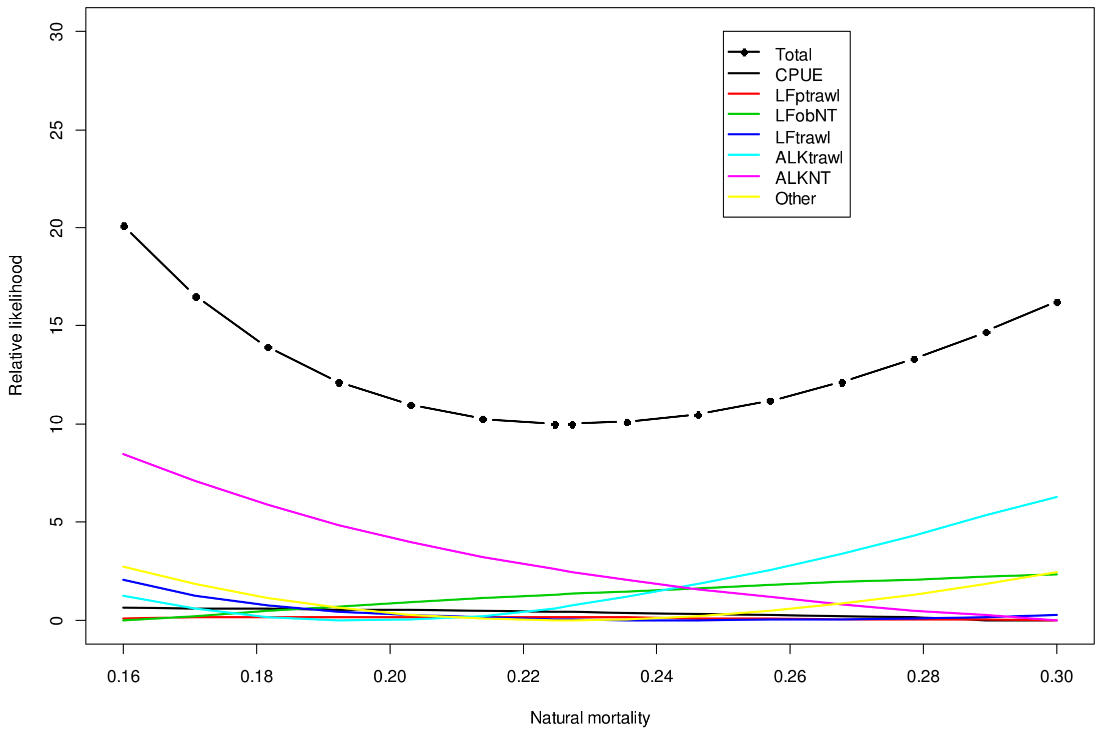
Eastern base model: likelihood profile for B_0.



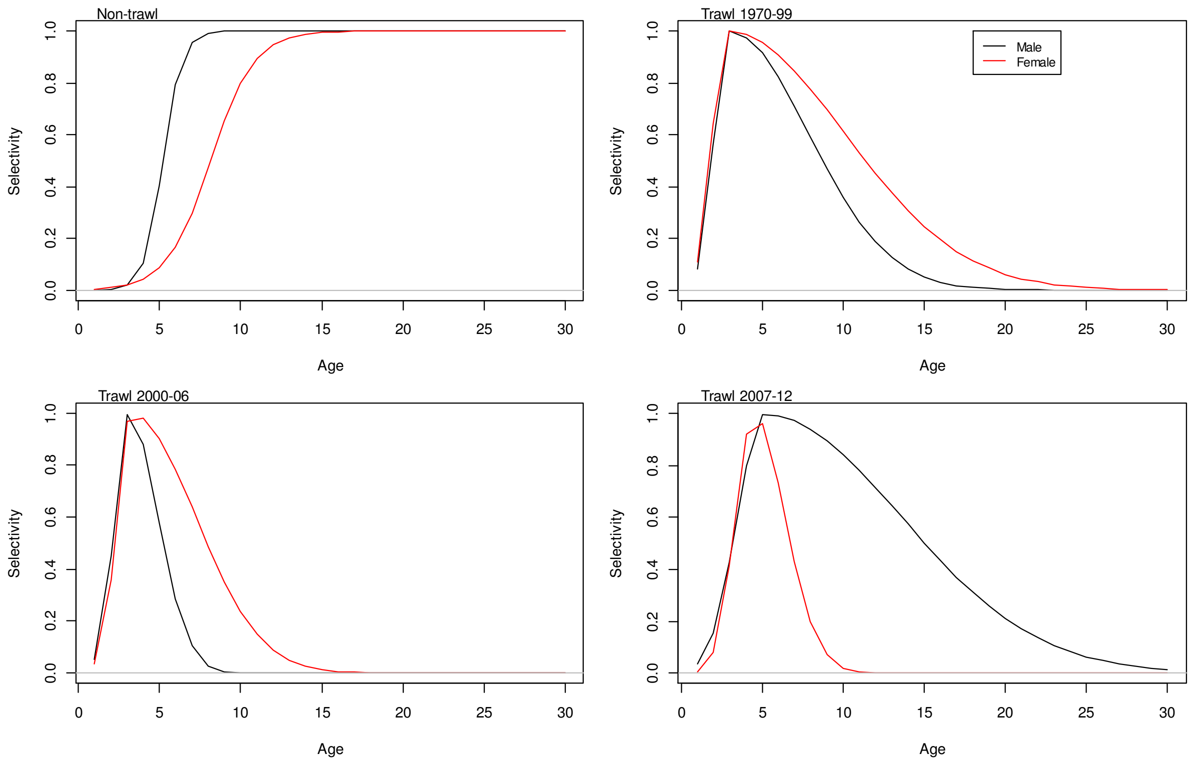
Eastern base model: likelihood profile for M.



Western base model: likelihood profile for B_0.



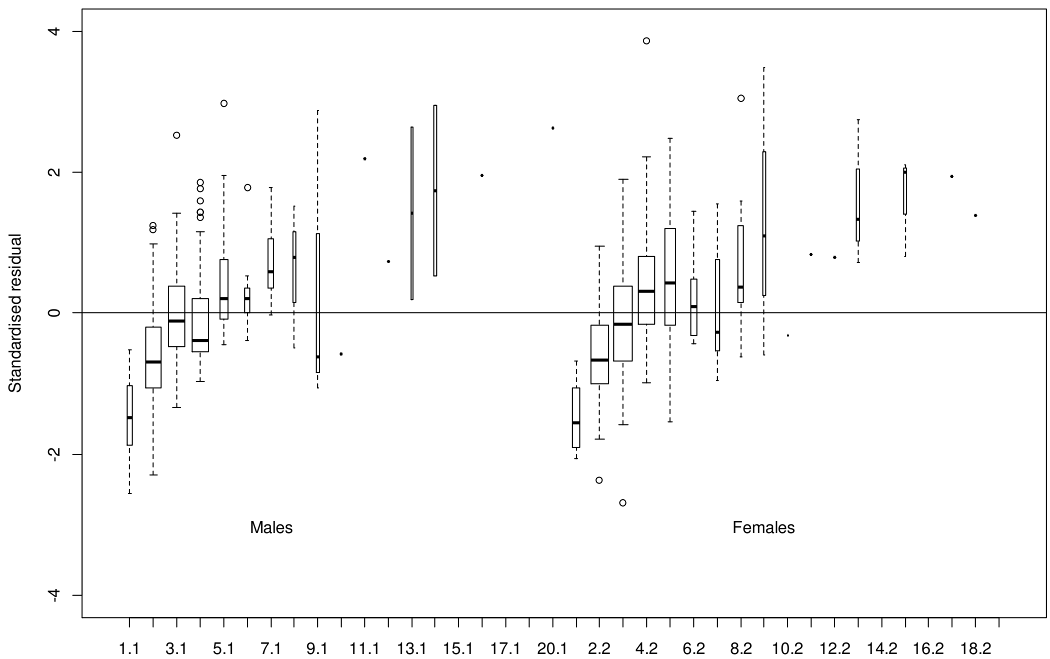
Western base model: likelihood profile for M.



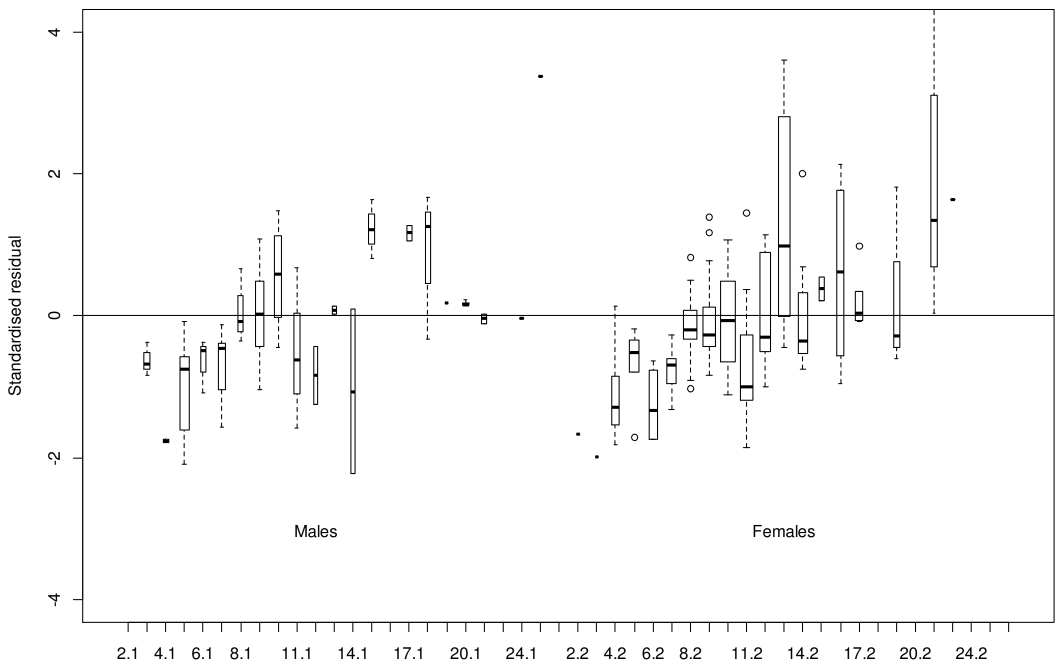
Eastern model: sensitivity with sex-specific fishing selectivities (which vary enormously across the three time blocks).

Table: Total objective function value for the models with sex-independent and sex-specific fishing selectivities. AIC (for example) requires at least 2 log-likelihood units for each extra parameter to justify the use of the extra parameters.

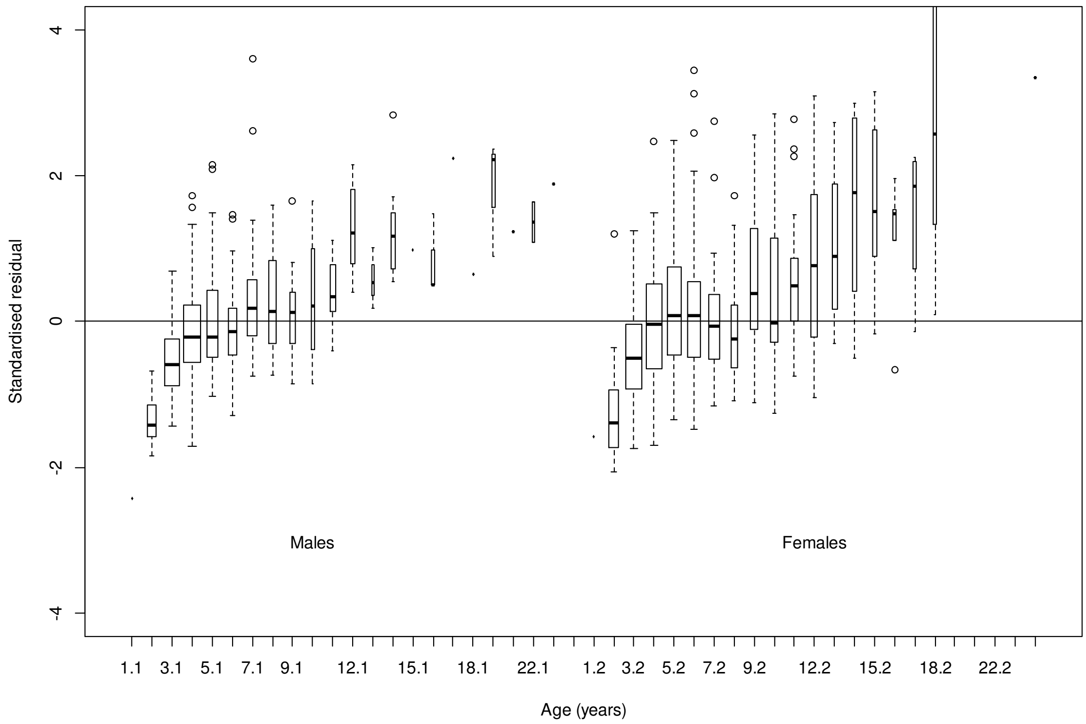
Stock	**No sex**	**Sex-specific**	**Difference**	**Extra parameters**
East	1670	1662	8	13
West	2941	2937	4	11



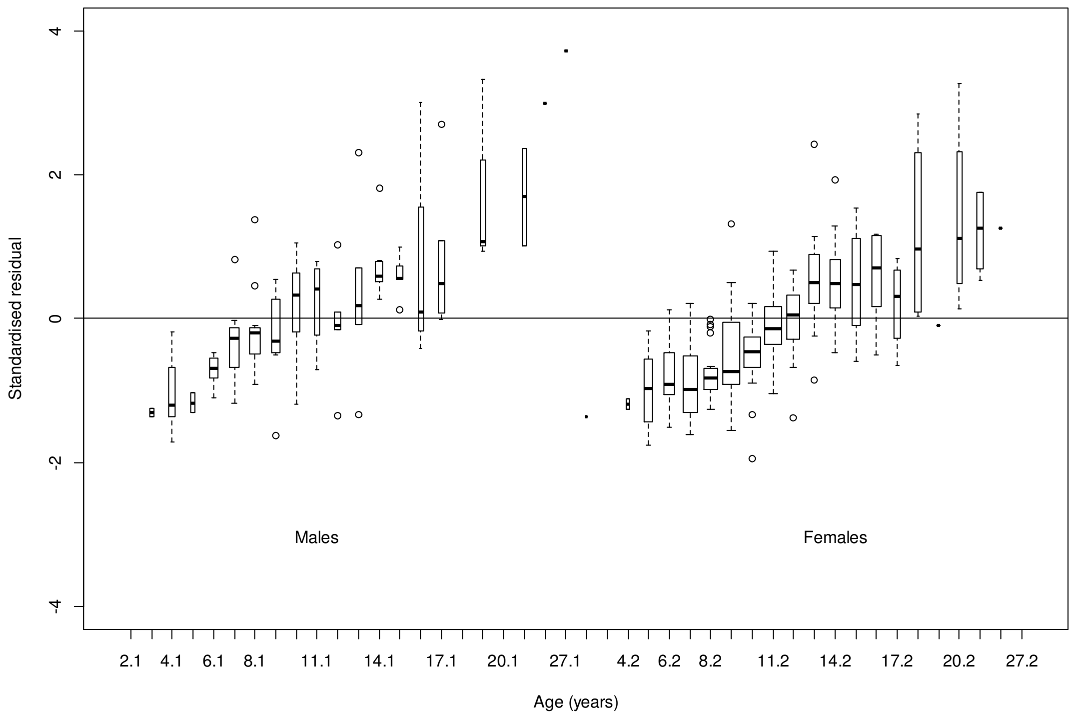
Eastern base model: boxplot of standardised residuals for conditional age data, by sex and age, for trawl-caught fish, (dominant pattern is by age – related to growth and selectivity; similar pattern for both sexes).



Eastern base model: boxplot of standardised residuals for conditional age data, by sex and age, for line-caught fish, (slightly different pattern for males and females).

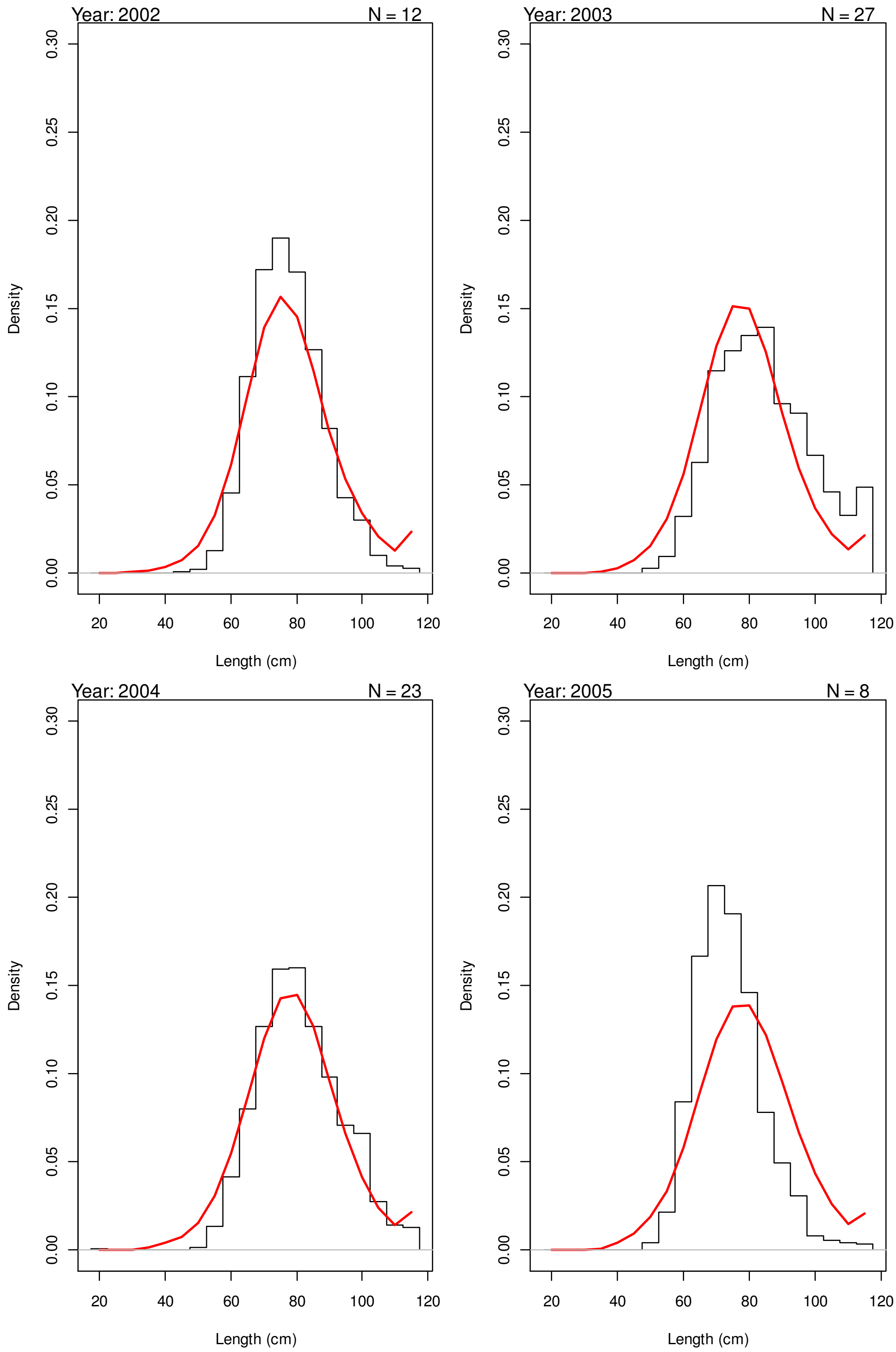


Western base model: boxplot of standardised residuals for conditional age data, by sex and age, for trawl-caught fish, (dominant pattern is by age – related to growth and selectivity; similar pattern for both sexes).

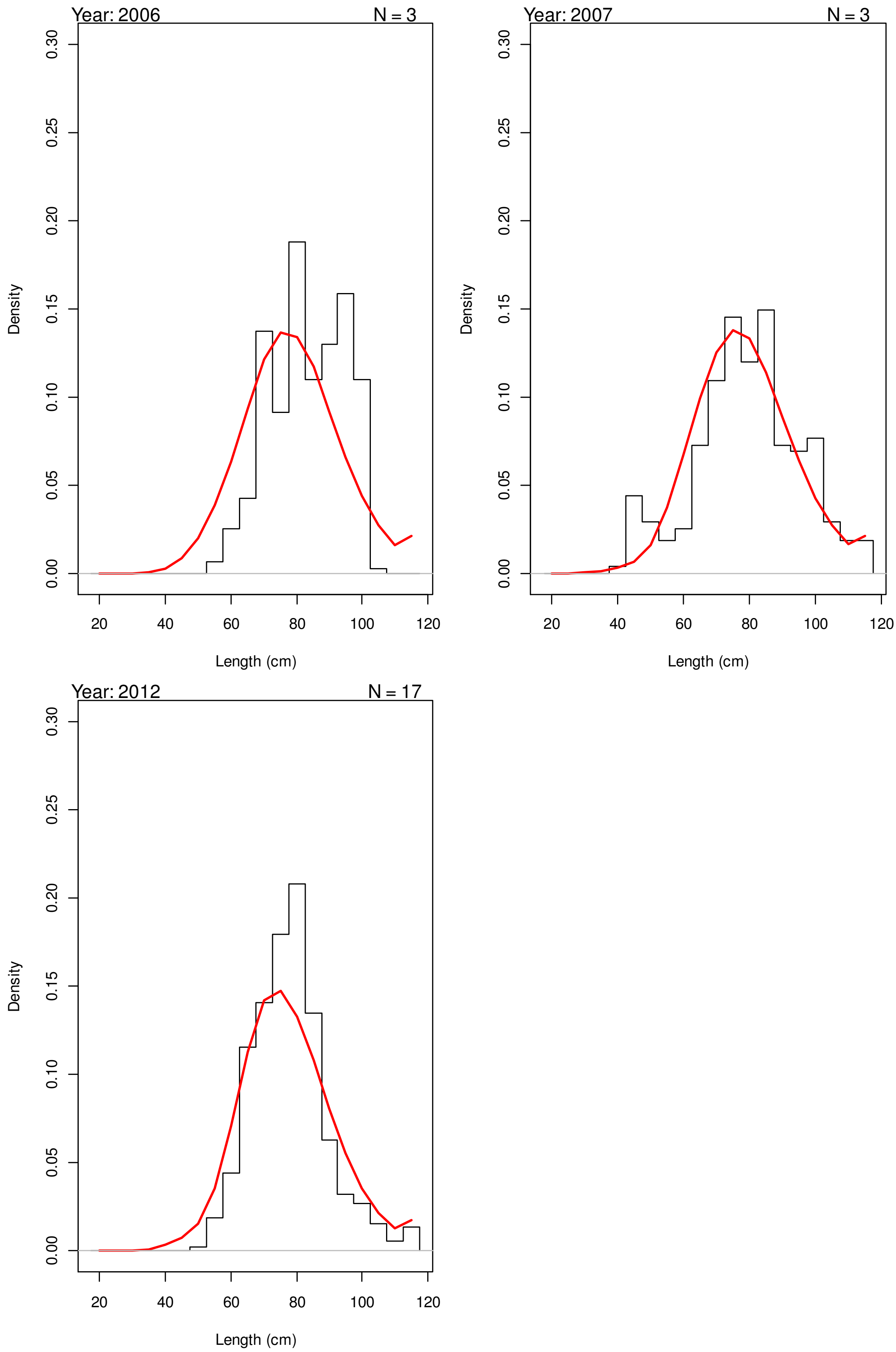


Eastern base model: boxplot of standardised residuals for conditional age data, by sex and age, for line-caught fish, (similar pattern for both sexes).

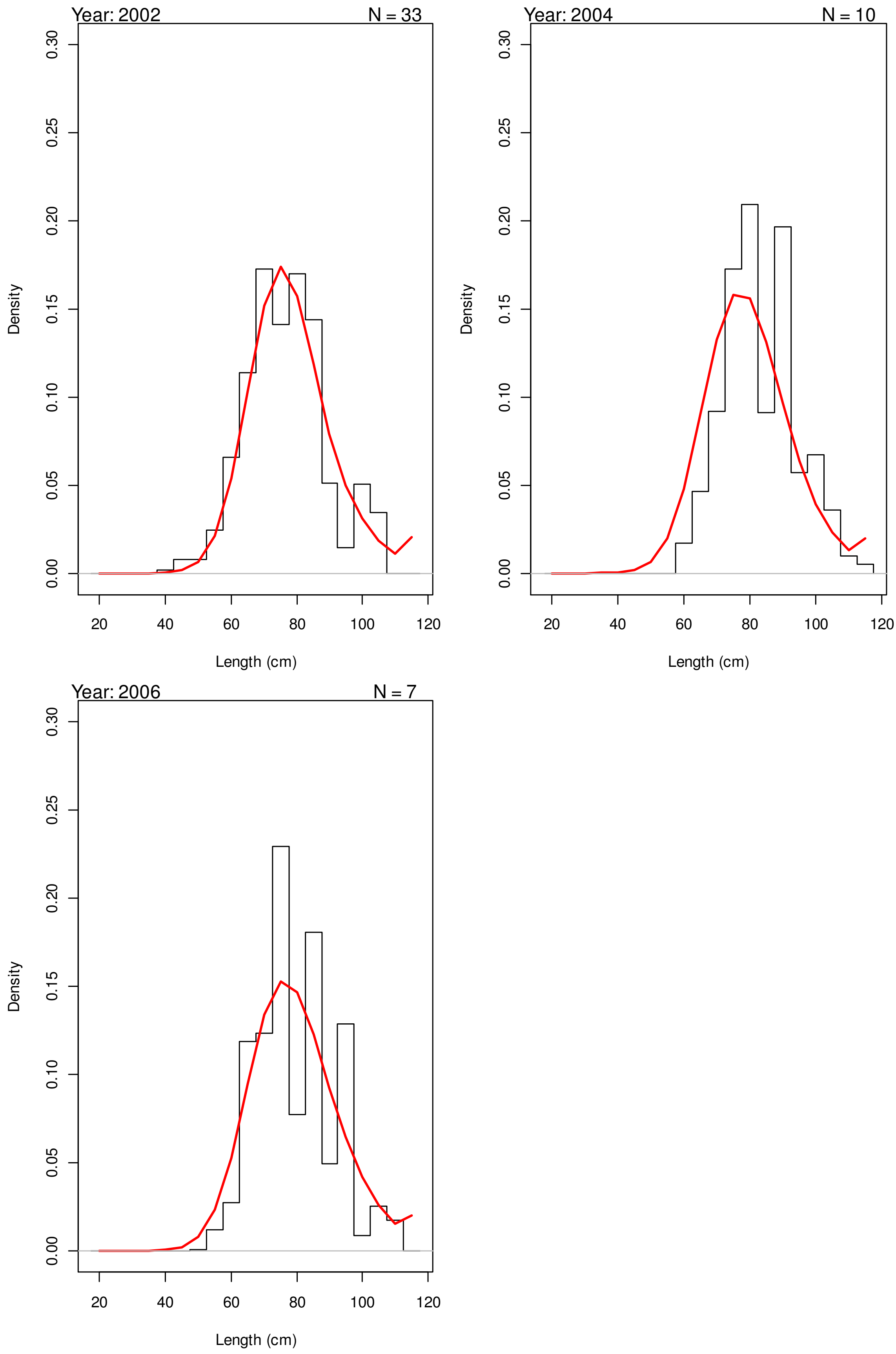
Appendix 4: MPD fits to age and length frequencies



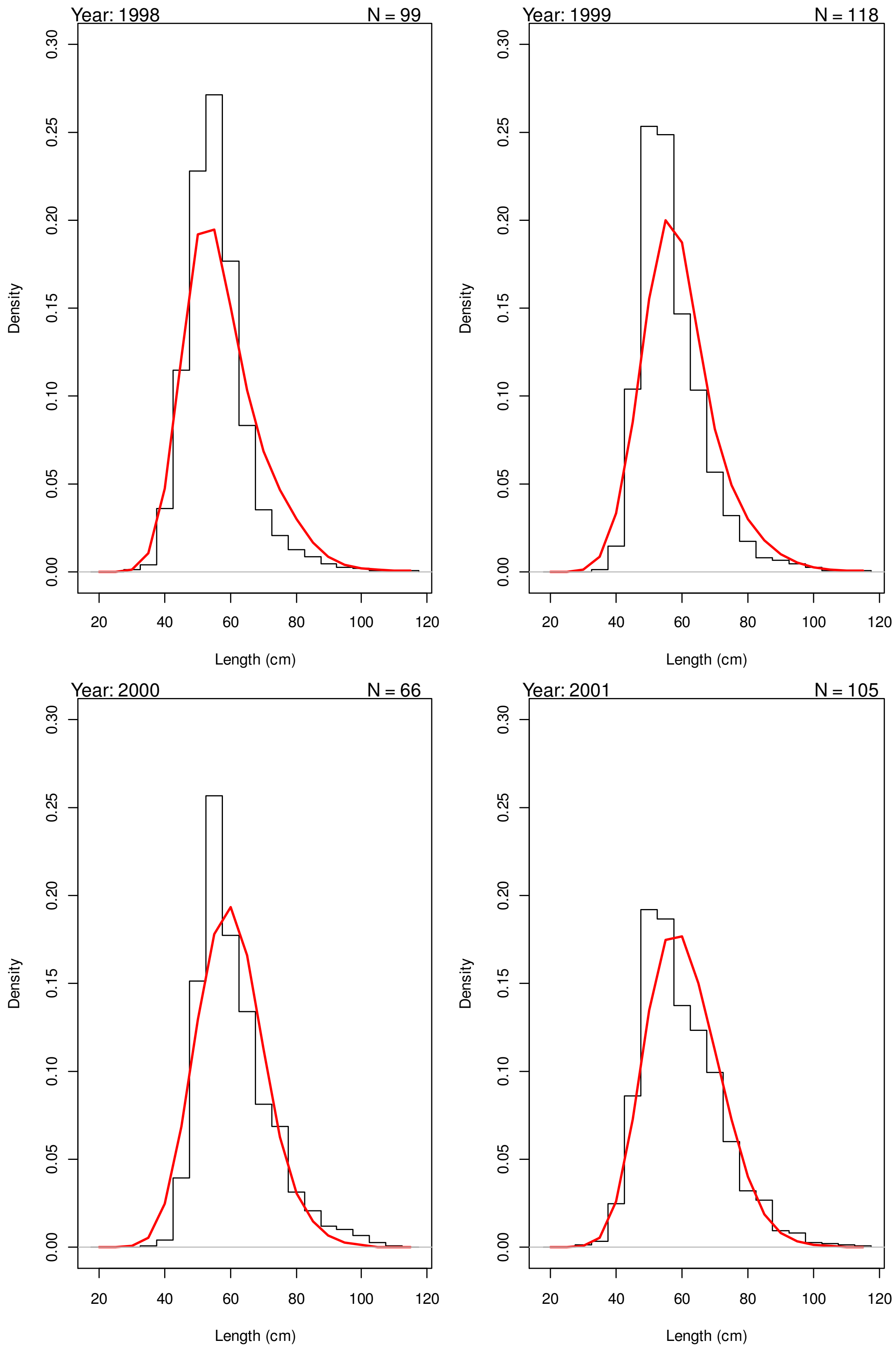
Eastern base model: non trawl length frequencies (1 of 2)



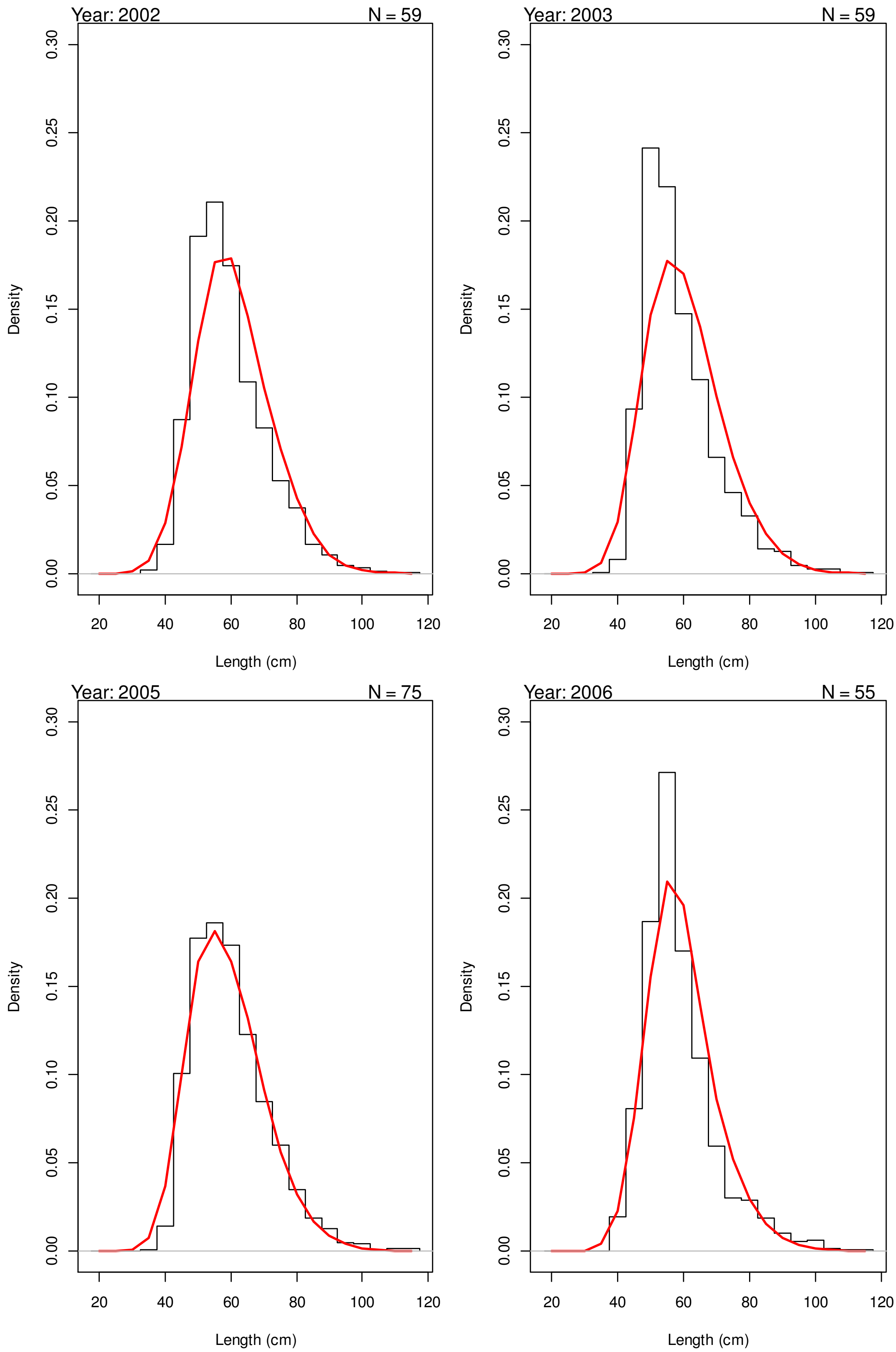
Eastern base model: non trawl length frequencies (2 of 2)



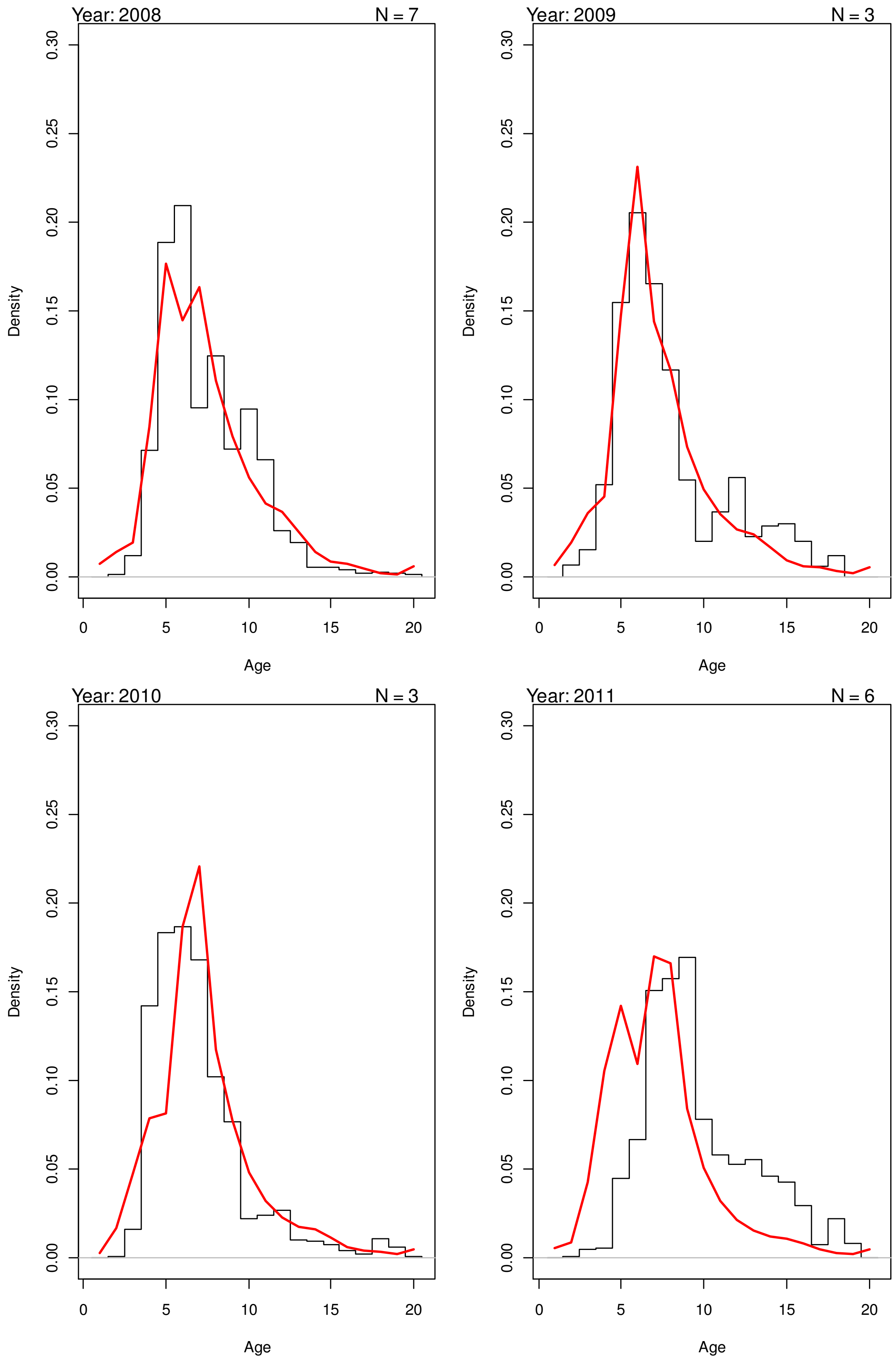
Eastern base model: port sampled non-trawl length frequencies



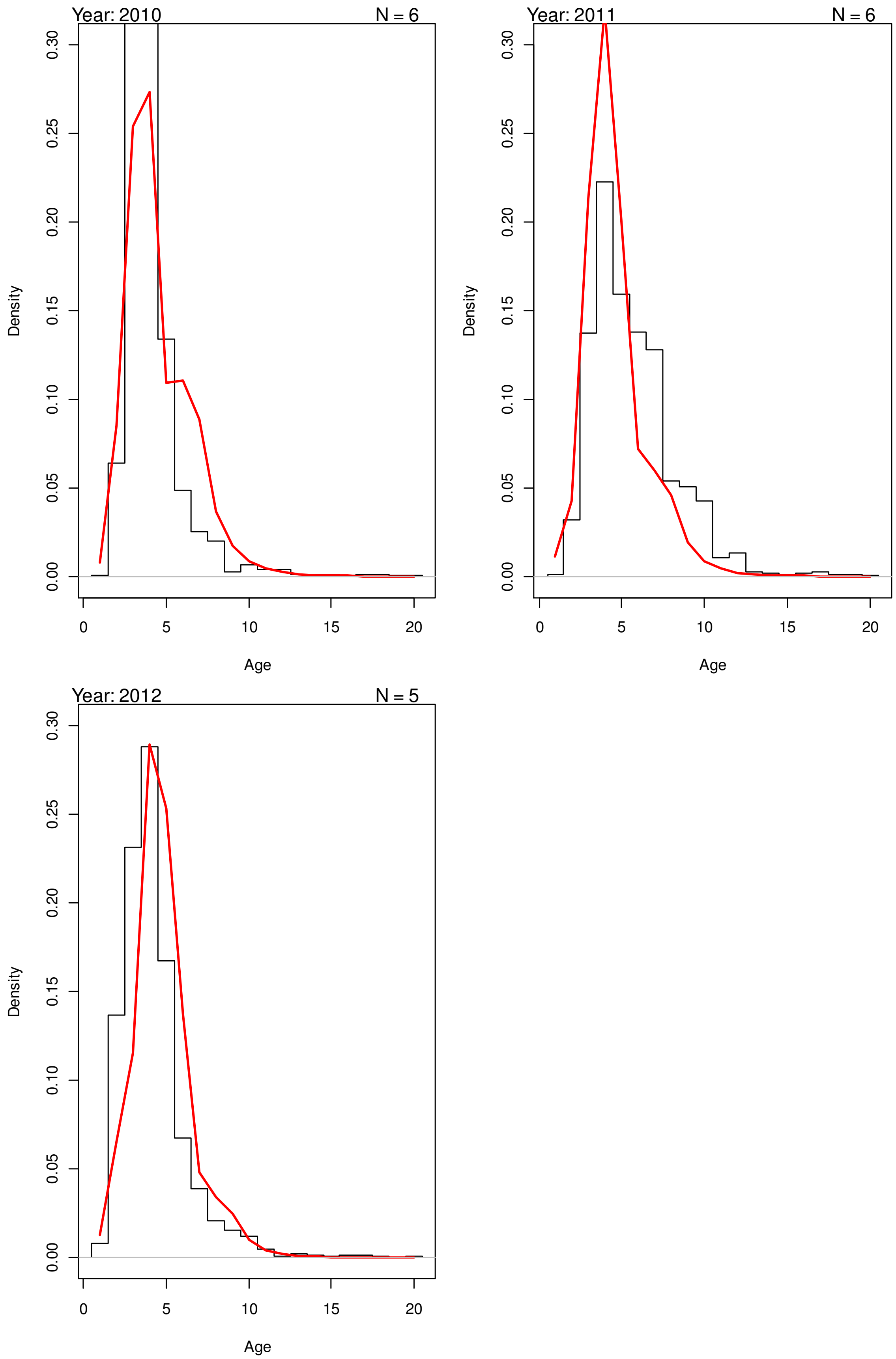
Eastern base model: trawl length frequencies (1 of 2)



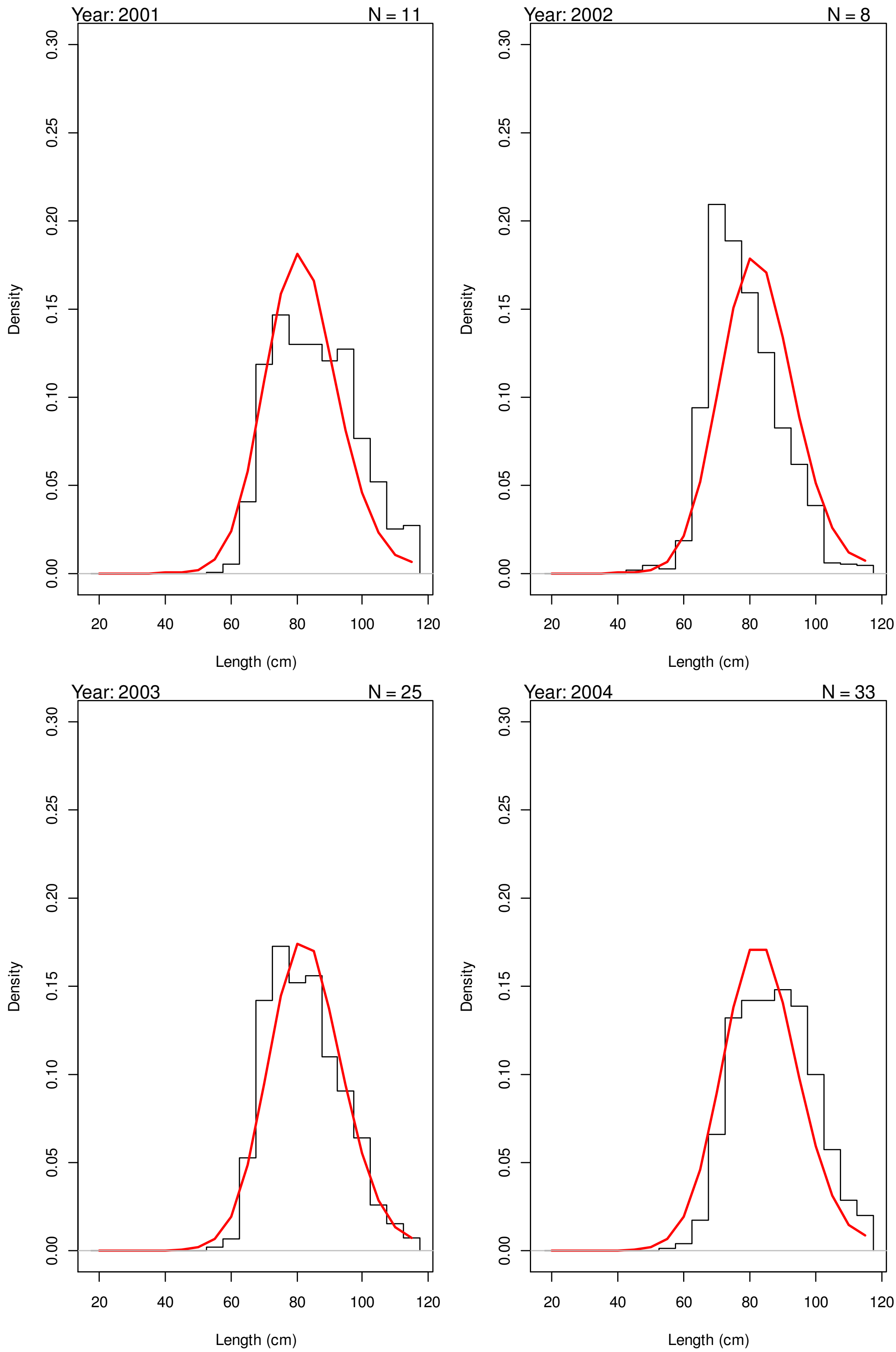
Eastern base model: trawl length frequencies (2 of 2)



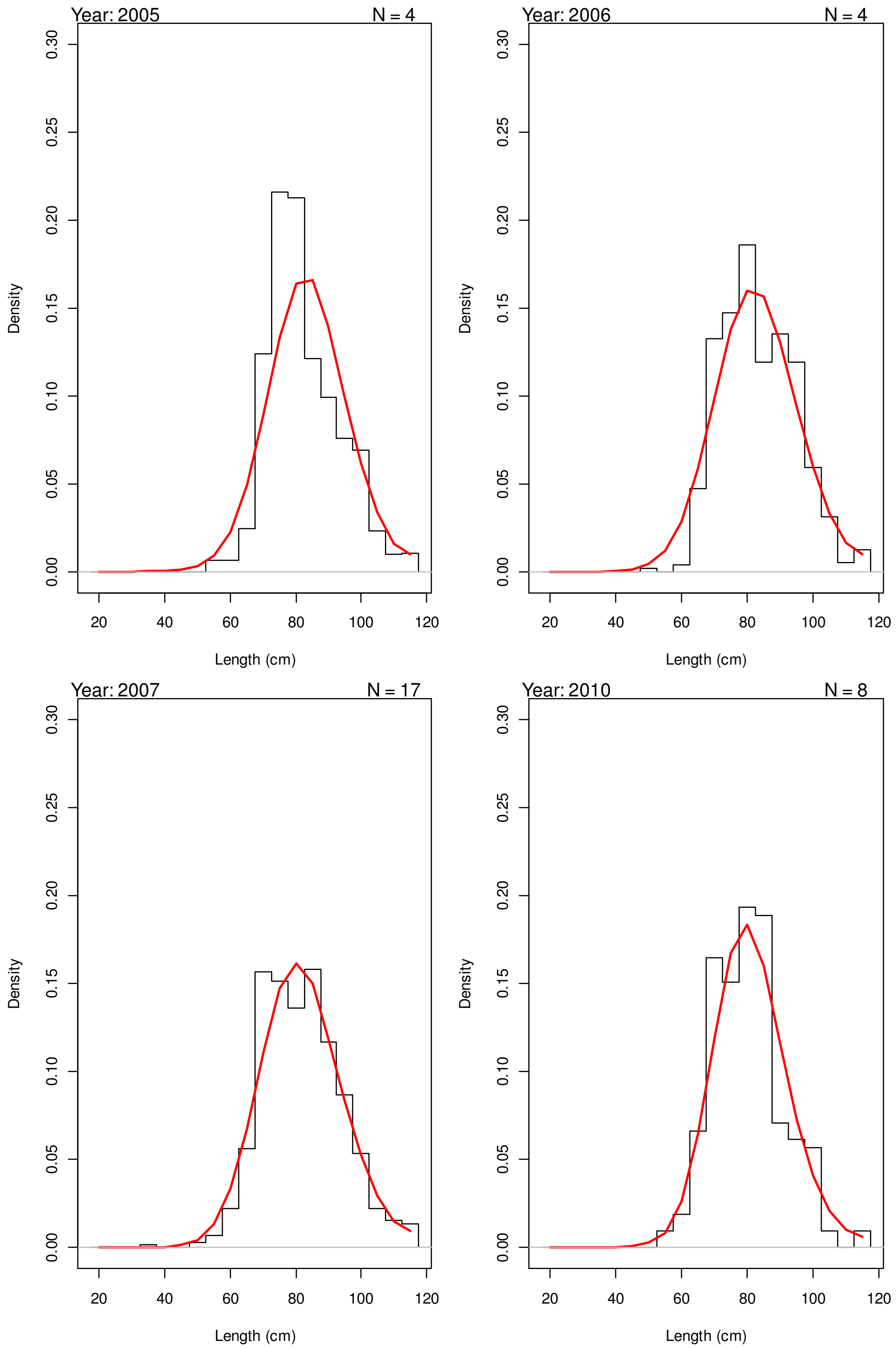
Eastern base model: non trawl age frequencies



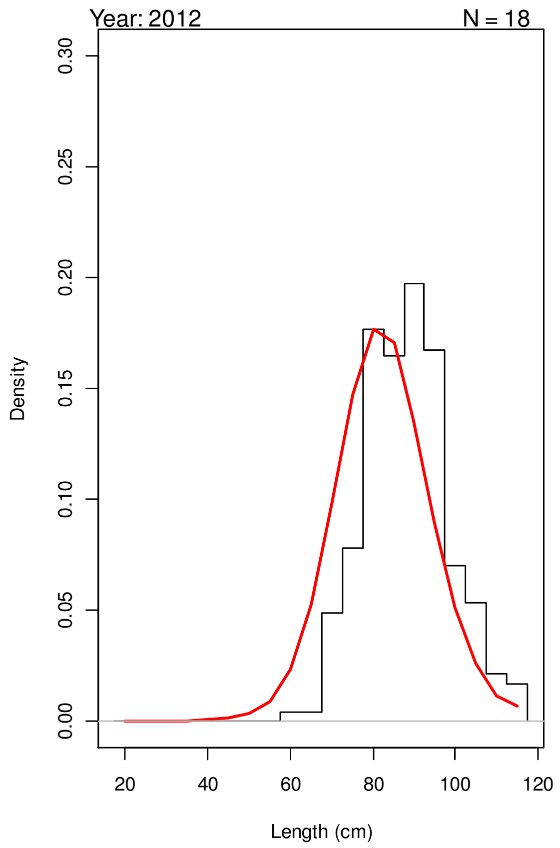
Eastern base model: trawl age frequencies



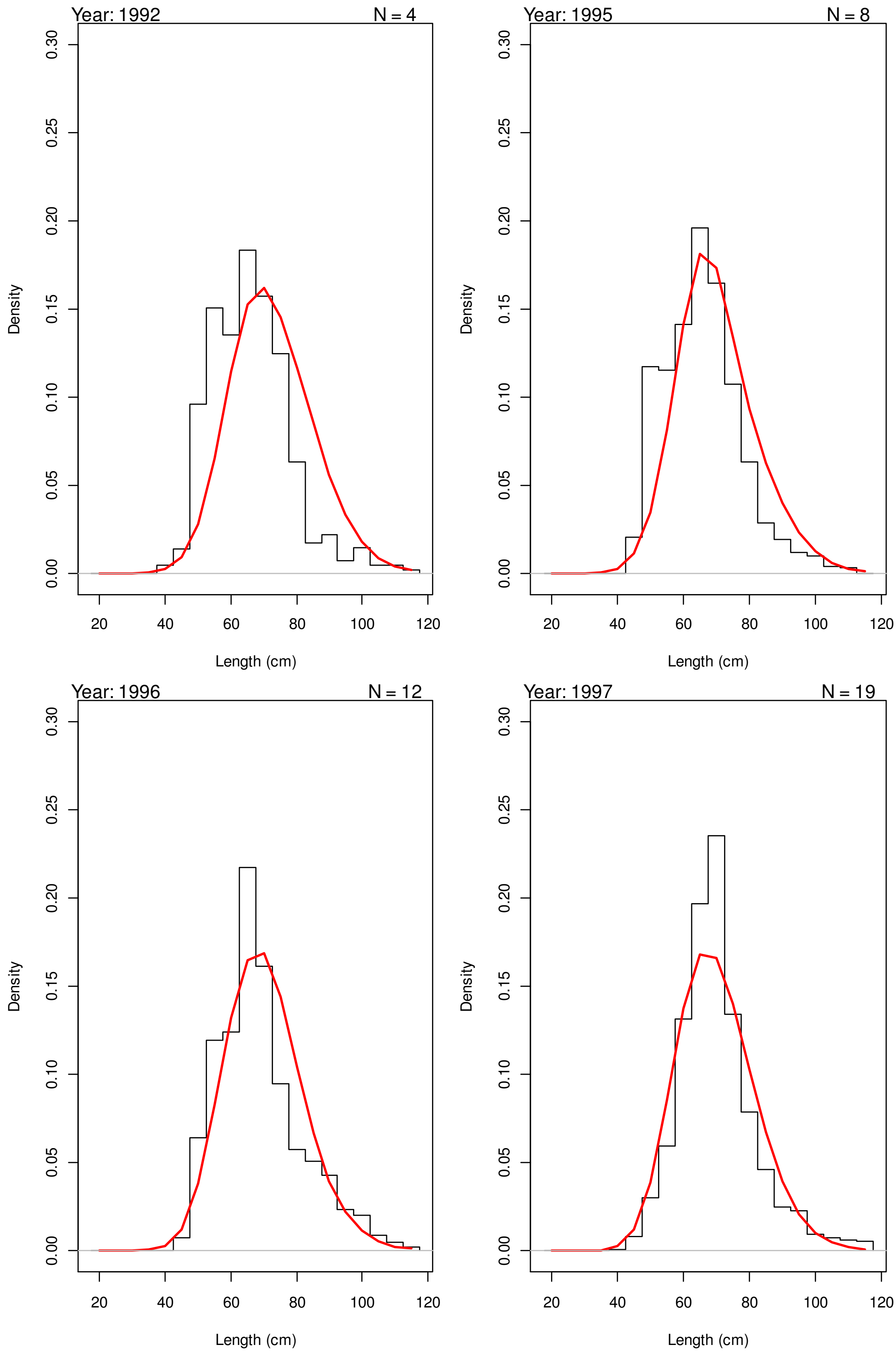
Western base model: non-trawl length frequencies (1 of 3)



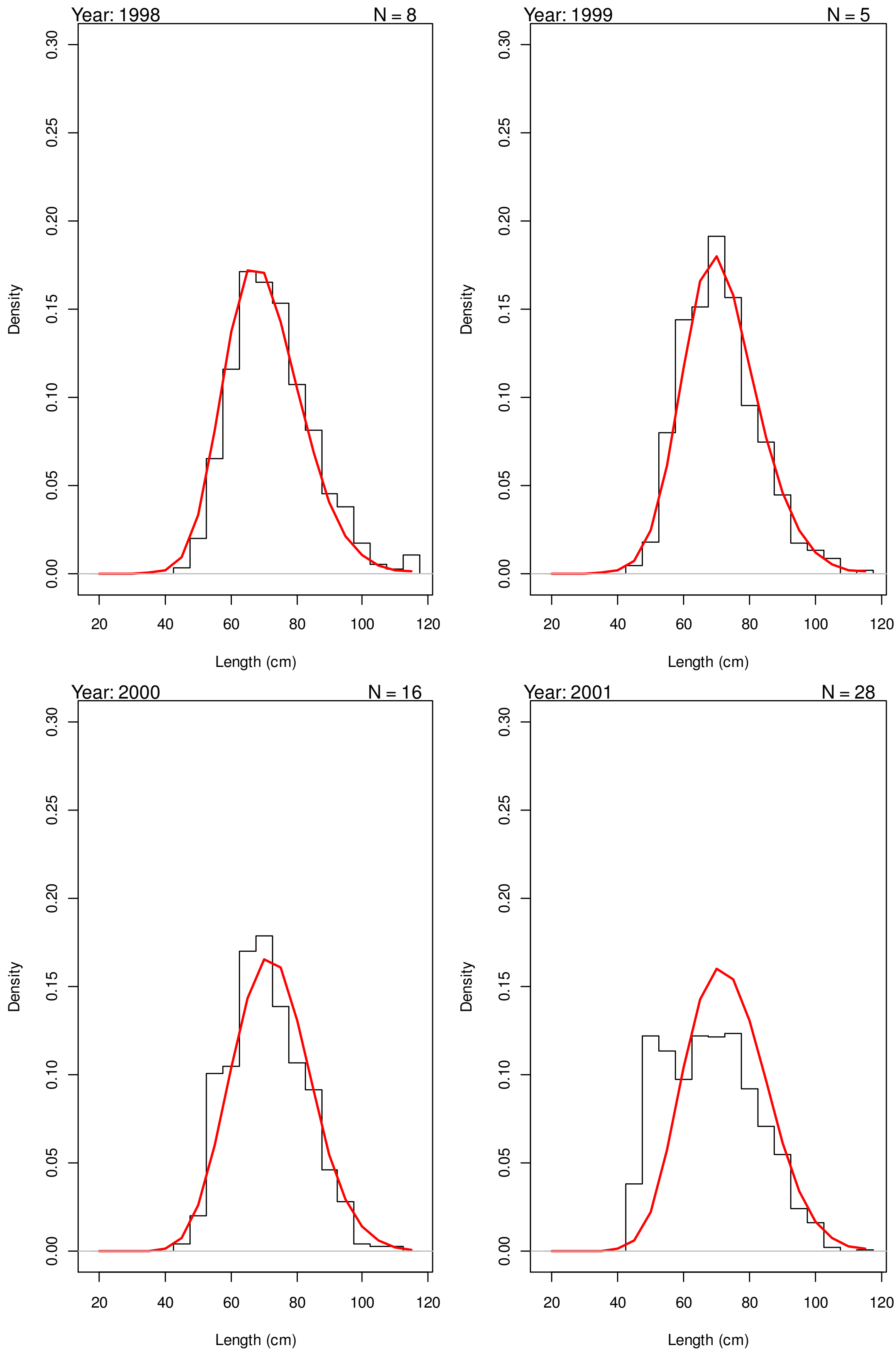
Western base model: non-trawl length frequencies (2 of 3)



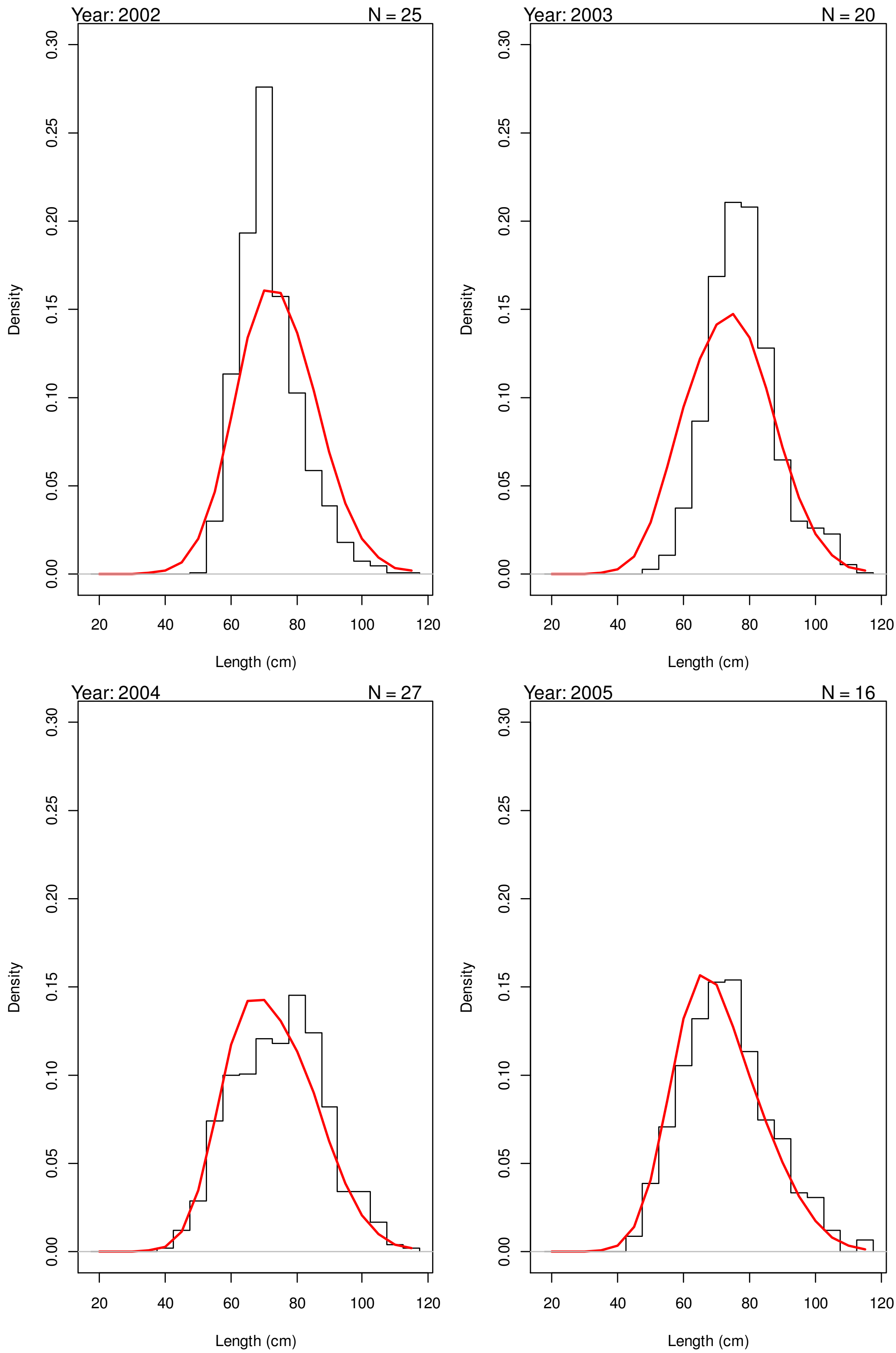
Western base model: non-trawl length frequencies (3 of 3)



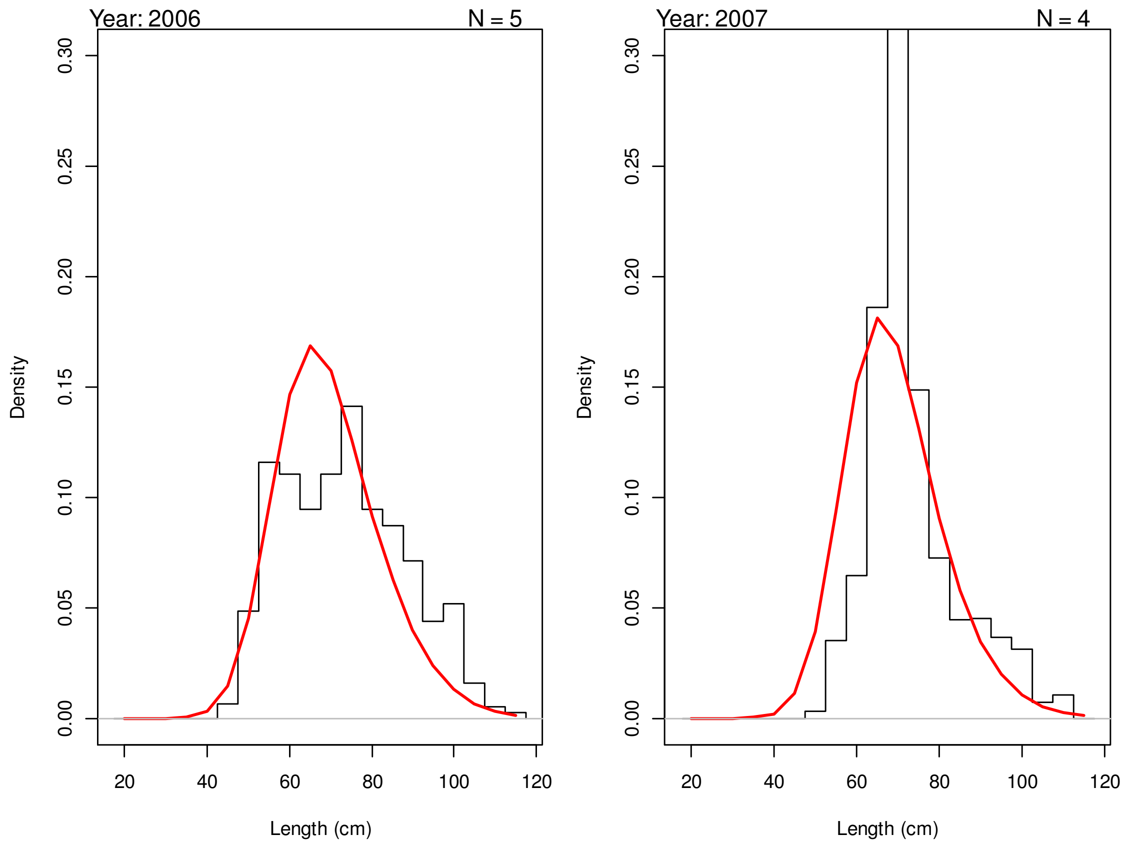
Western base model: port-sampled trawl length frequencies (1 of 4)



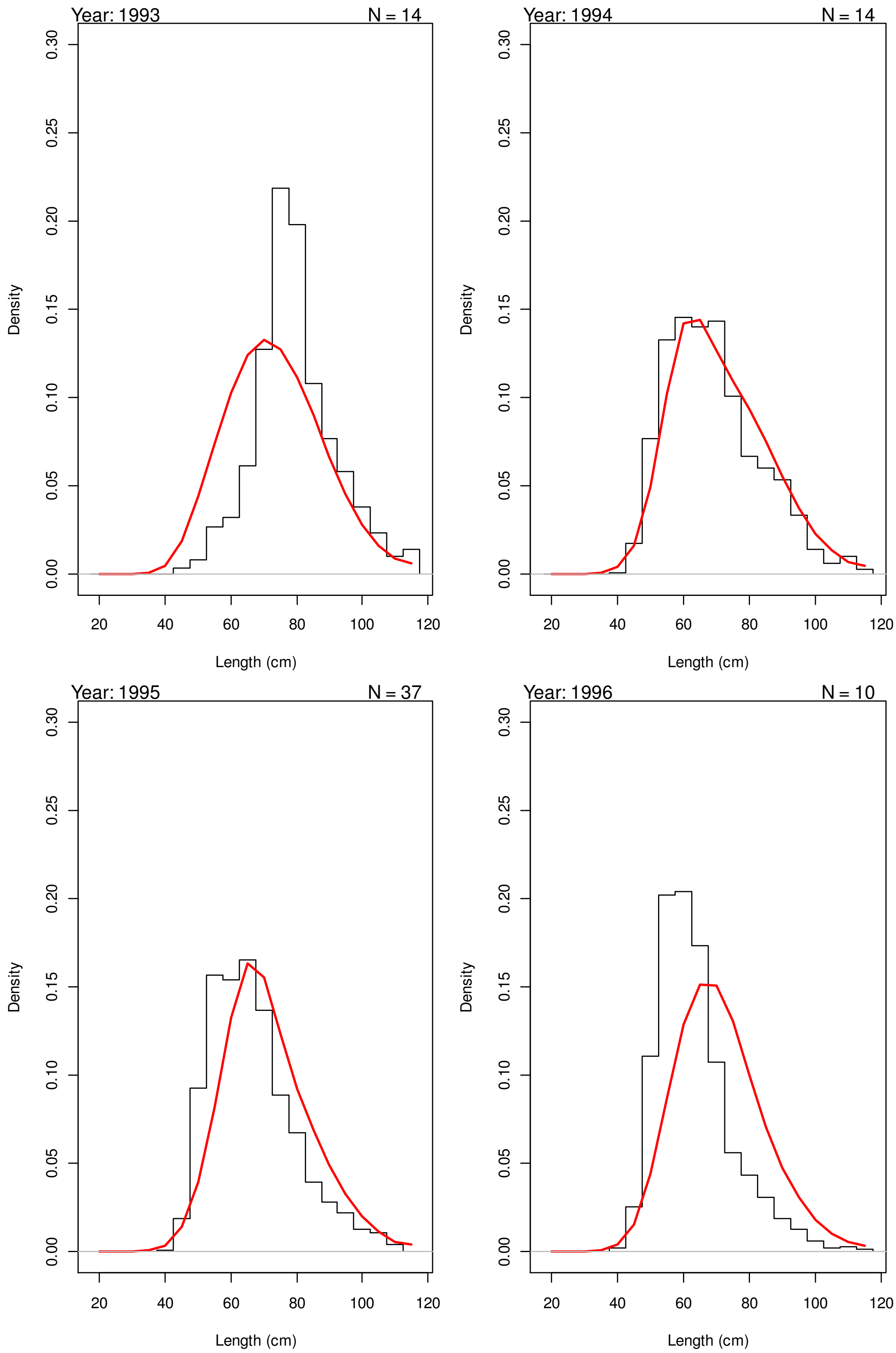
Western base model: port-sampled trawl length frequencies (2 of 4)



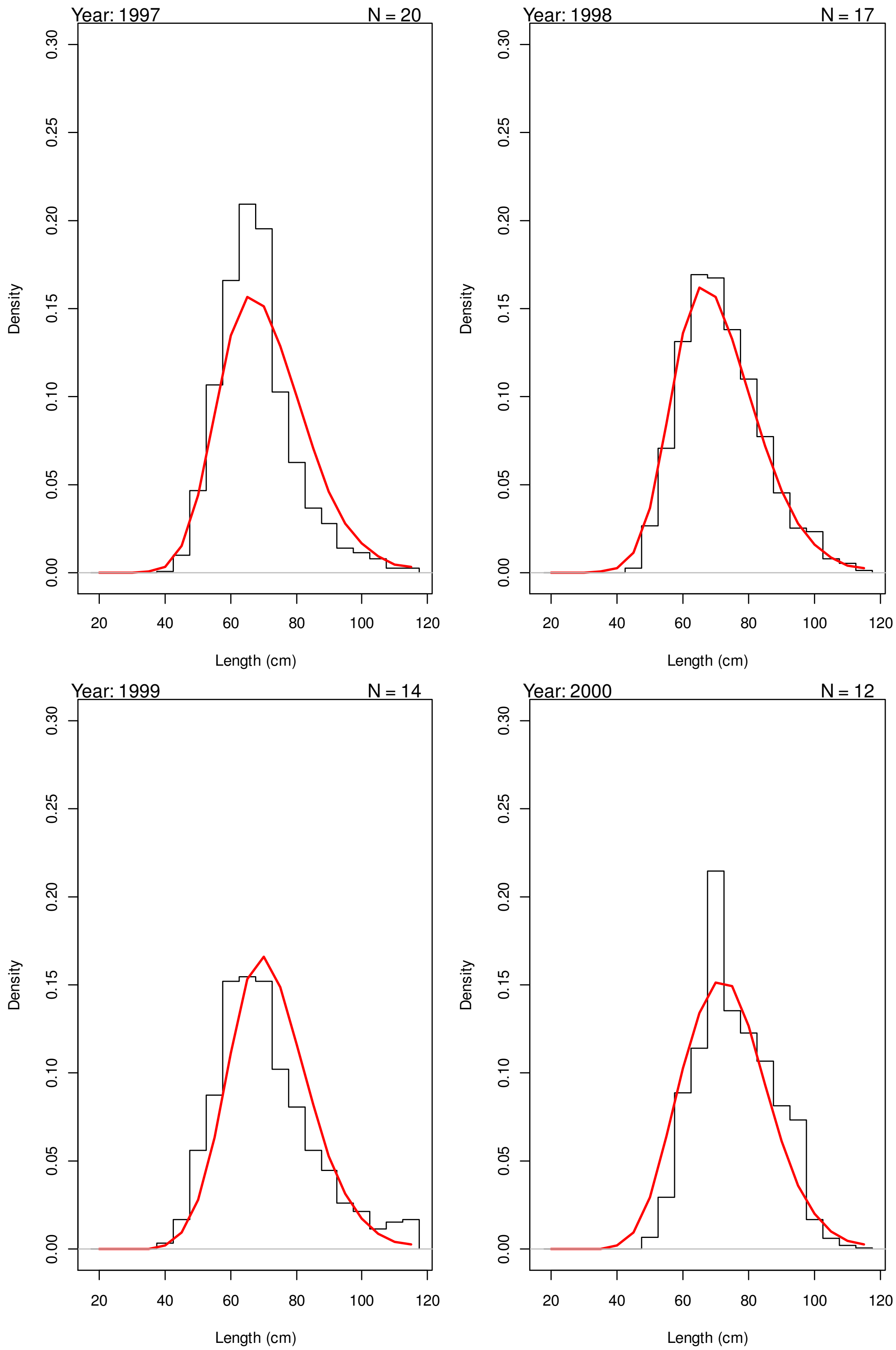
Western base model: port-sampled trawl length frequencies (3 of 4)



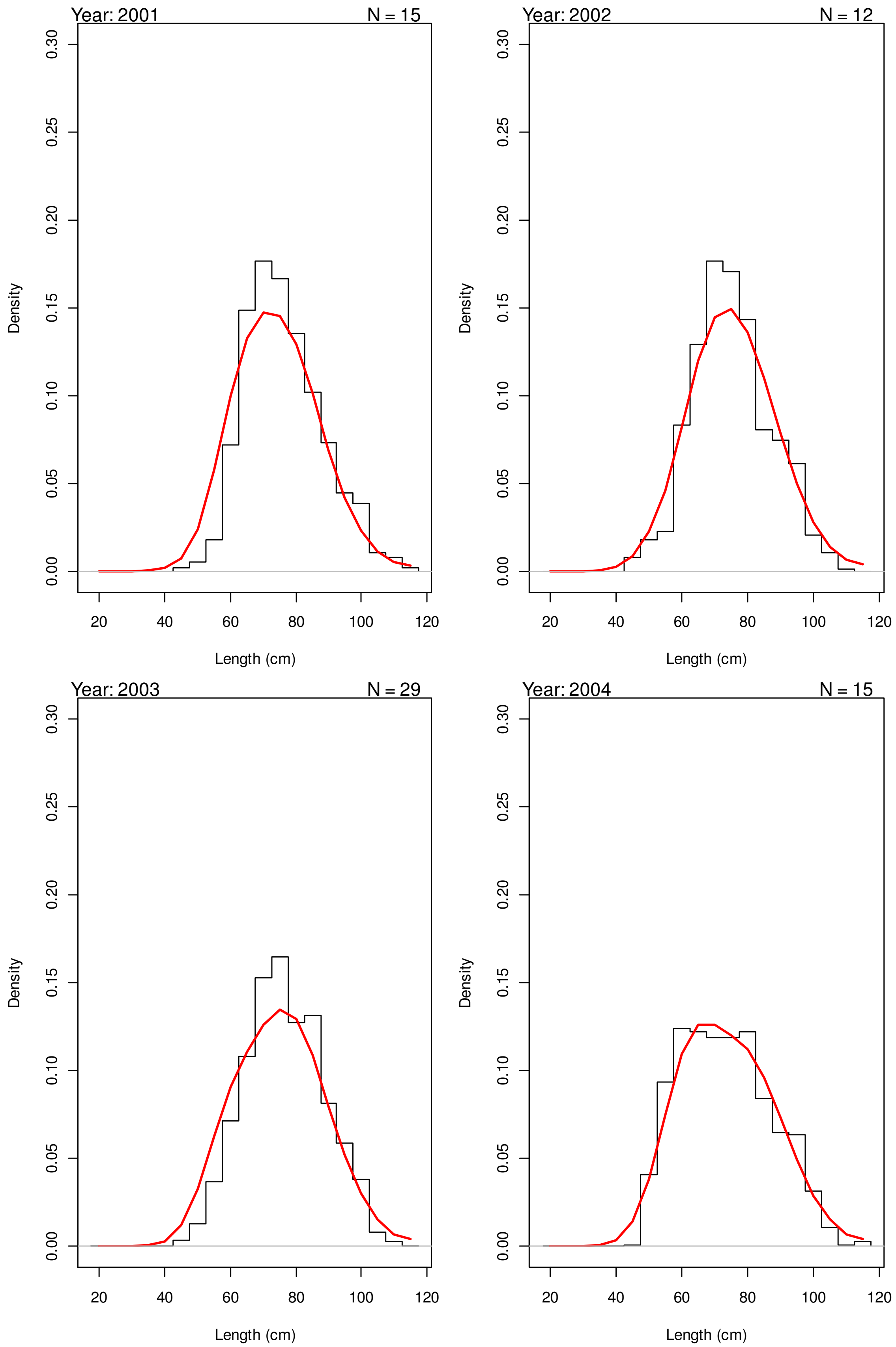
Western base model: port-sampled trawl length frequencies (4 of 4)



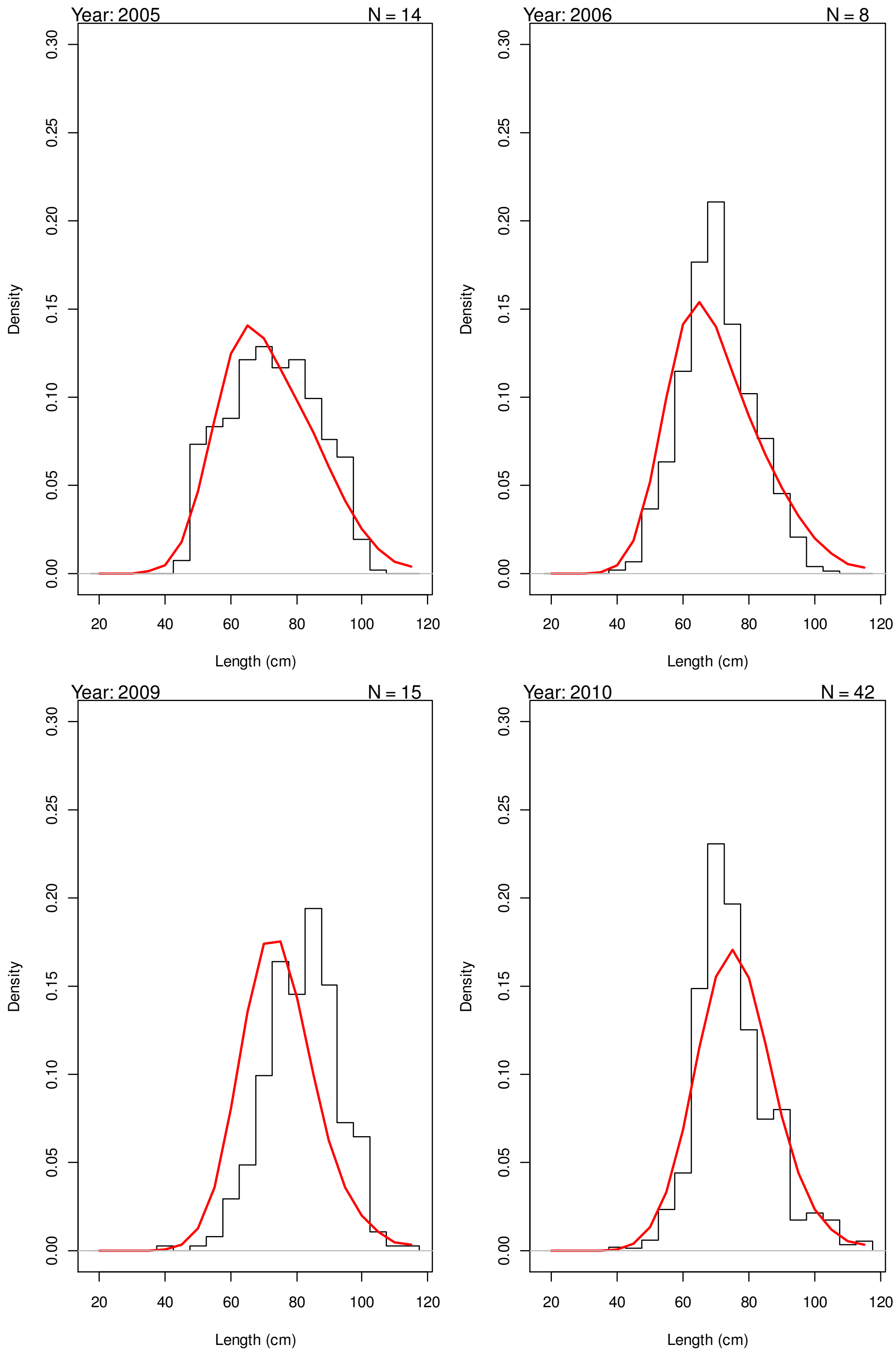
Western base model: trawl length frequencies (1 of 5)



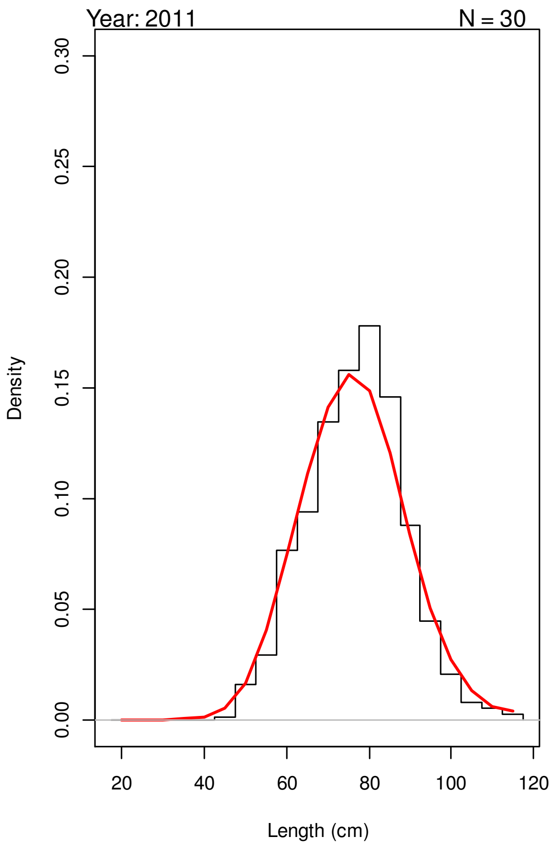
Western base model: trawl length frequencies (2 of 5)

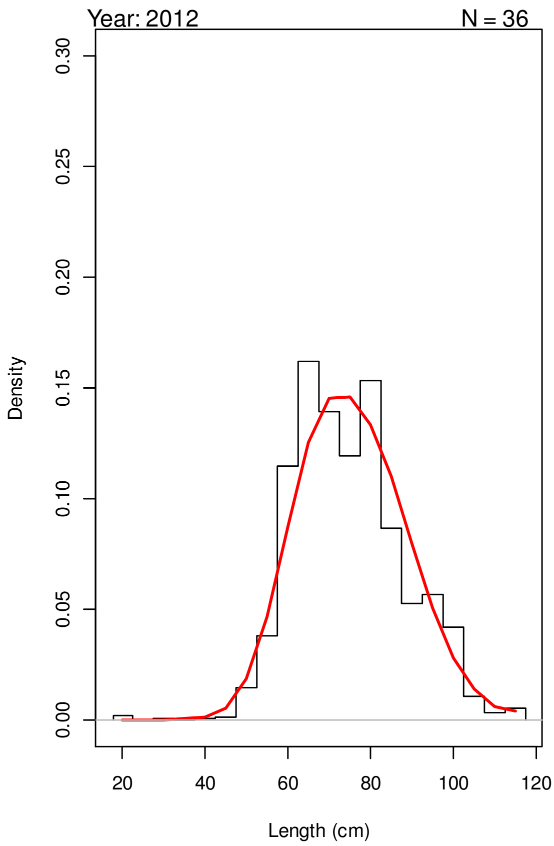


Western base model: trawl length frequencies (3 of 5)



Western base model: trawl length frequencies (4 of 5)





Western base model: trawl length frequencies (5 of 5)

Appendix 5: Comparison of eastern base model with "SS3-type" runs

During the November RAG meeting two additional MPD sensitivity runs were done for the eastern base model to see if the difference between the ISL model and CSIRO's model using length-based selection (which was contrary to the base model specification) was due to the length-based selection. According to the results below (Table A5.1, Figure A5.1), it appears that much of the difference was due to the difference in fishing selectivities and the use of beginning-of-year SSB (the CSIRO model estimated stock status at 19% B_0).

Table A5.1: Eastern base model compared with "SS3-type" alternative models: using length-based selection for the fishing selectivities; additionally using beginning-of-year SSB.

Model	B_0	Stock status (depletion)	M	Total objective	Neg. Log. Like. Trawl CPUE
Base	5549	0.23	0.24	1670.45	-46.1
Length selectivities	6326	0.17	0.23	1684.42	-46.4
+ Beginning of year	7059	0.19	0.24	1688.00	-44.3

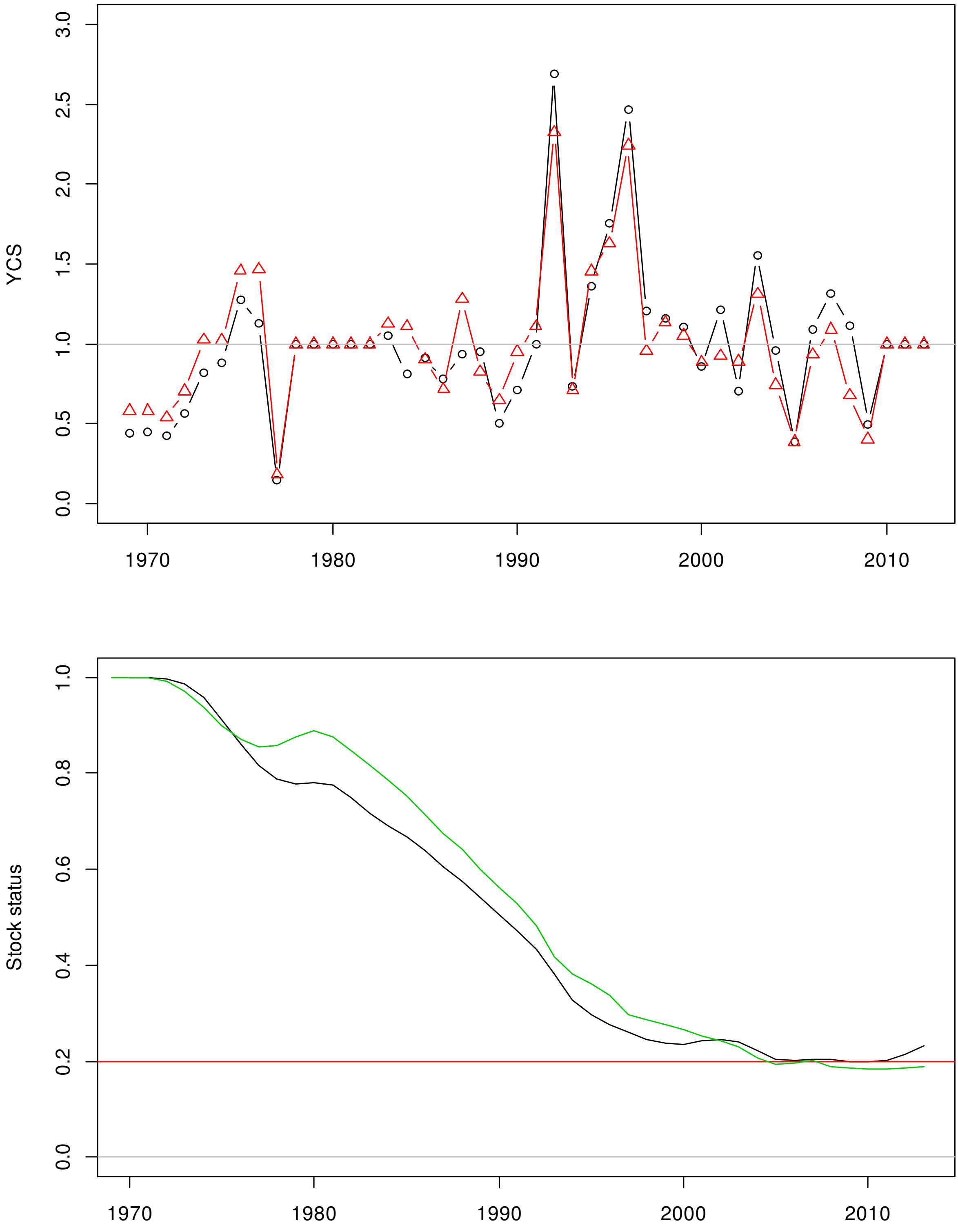


Figure A5.1: Eastern ISL-base model compared with an "SS3-type" model: length-based selectivities and beginning-of-year SSB (ISL-base model in black).

Final eastern CPUE analysis from ISL in 2013

P.L. Cordue, ISL
16 October 2013

Introduction

This is a short document, the final in the series, on CPUE analysis from ISL in 2013 with regard to pink ling. The previous document, dated 30 September 2013, and entitled, "*A further look at filtering and vessel-linking for pink ling CPUE*" contains details of the potential linking vessels to use in the eastern trawl CPUE analysis.

Methods

Filtering

The species-based filtering for the analyses in this document was very minimal:

lig > 0 & gem < 250.

This filter just deals with the gemfish targeting problem in 1986-1989. Further work is needed on filtering for the eastern trawl analysis but there is no more time available in 2013. The other filters used in the previous analyses (associated with depth, tow duration, latitude, longitude, and missing values) were still used; as were the same explanatory variables.

Vessel linking

The top four candidate linking vessels for each of the two time-block pairs were progressively added as linking vessels to the CPUE standardisation:

- top 2 vessels for each pair of time blocks
- top 3 vessels for each pair of time blocks
- top 4 vessels for each pair of time blocks.

The CPUE indices in each case were calculated, compared with each other, and with CSIRO's eastern trawl indices.

Results and Conclusions

The use of just the two top linking vessels for each pair of time blocks leaves a little kink in the CPUE indices from 1999 to 2000, with the indices from 2000 onwards all raised relative to the indices when there are no time blocks (Figure 1). Adding the third linking vessel to each time block moves the indices, from 2000 onwards, down a bit (Figure 1). When the fourth vessel is added there are only subtle difference between the resulting indices and the no-time-block indices (Figure 1).

In comparison to the CSIRO indices the biggest difference is from 1986 to 1989 because of the gemfish filtering (Figure 2). As expected, the time-blocked indices (for the two or three top linking vessels) from 2000 onwards are above the CSIRO indices because of the time blocking (Figure 2).

The CPUE indices with the top three linking vessels is a natural choice for the eastern base stock-assessment model as it is intermediate for the two time-blocked series using two or four linking vessels (Figure 1). It is also intermediate between the CSIRO indices and the time-blocked indices using two linking vessels (Figure 2). The natural sensitivities to run in the stock assessment are the CSIRO indices and the time-blocked indices using two linking vessels.

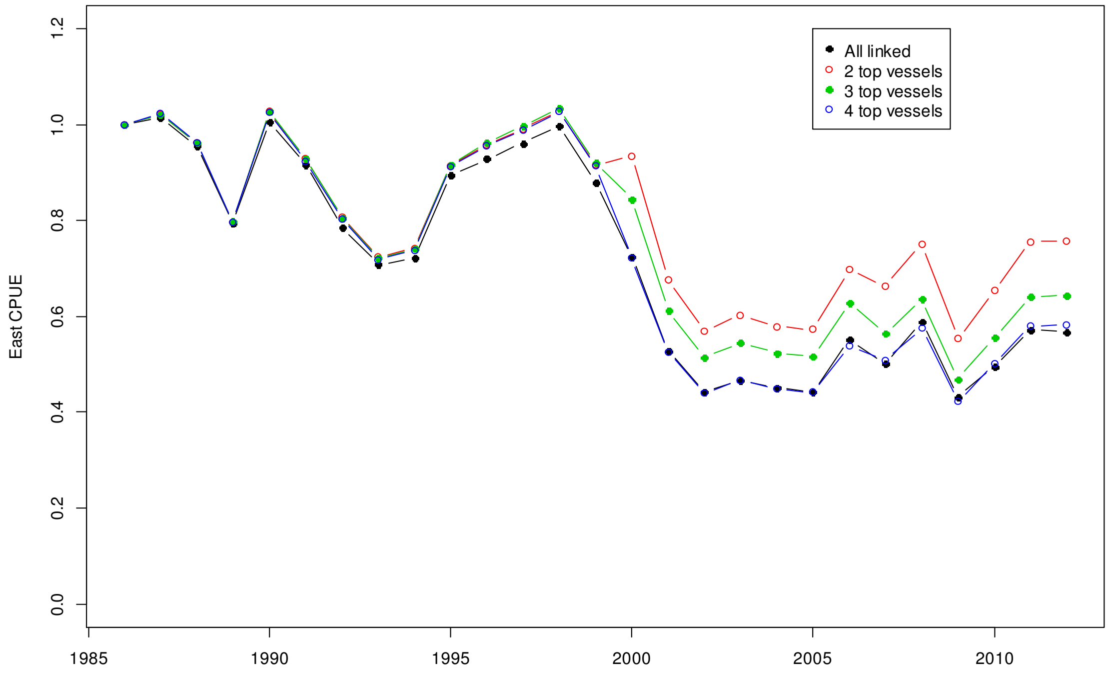


Figure 1: Standardised CPUE for eastern trawl when all vessels are linked (no time blocks), or the top 2, 3, or 4 candidate vessels are linked across their respective time blocks.

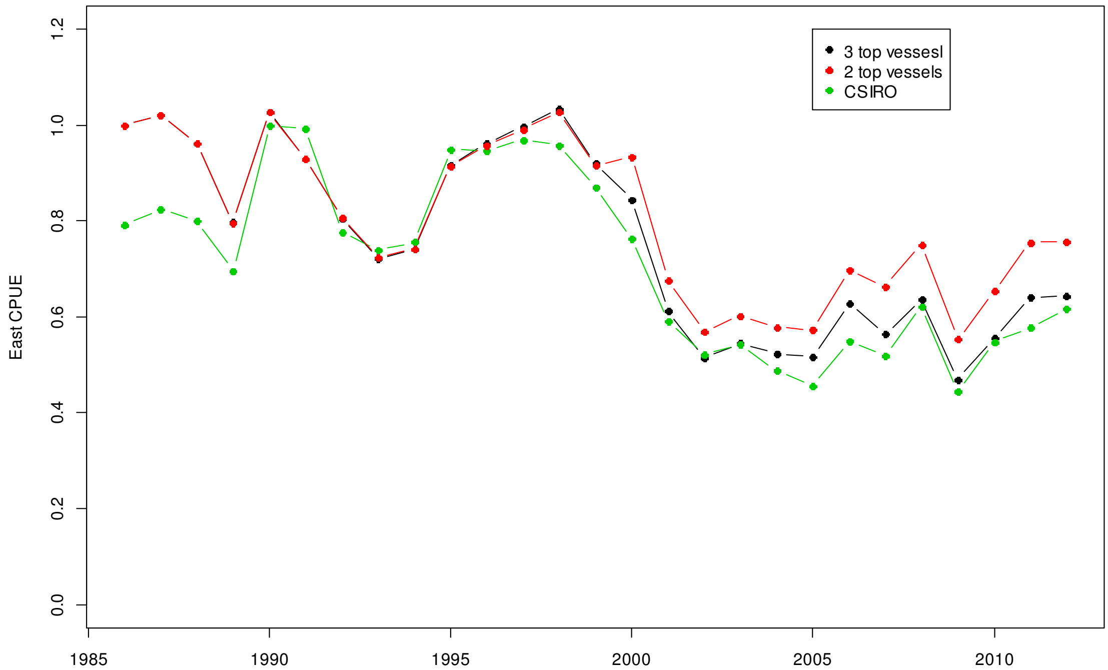


Figure 2: Standardised CPUE for eastern trawl when the top 3 or 4 candidate vessels are linked across their respective time blocks; compared to the CSIRO indices (no time blocks and no gemfish filter).

A further look at filtering and vessel-linking for pink ling CPUE

P.L. Cordue
30 September 2013

Introduction

At the September Slope RAG meeting it was suggested that ISL conduct further CPUE analysis to look at how robust the indices were to the choice of vessels used in the linking of time blocks and also how filtering was affecting the indices. The main concern was for the eastern stock and therefore the additional analysis only deals with that stock.

A recommendation is made on the methods to use to construct the CPUE indices for use in the base eastern stock assessment model.

Methods

Filtering
Logbook catch records for the eastern zones (10, 20, 30, 60) were filtered according to various criteria and standardised CPUE indices were calculated without time-blocking of vessel effects. Many filters were tried, but results are presented in this document for the following filters:

1: lig > 0 and (gre > 0 or trs > 0 or oth > 0 or red > 0)
2: lig > 0 and gem < 250 and (gre > 0 or trs > 0 or oth > 0 or red > 0)
3: lig > 0 and (gre > 0 or trs > 0)

For filter 2, various models with second order interactions were run: depth*latitude, depth*month, month*latitude, and all three together.

Time-blocking of vessel effects
Formal statistics were calculated for each vessel which potentially could be used as a linking-vessel between time blocks for the eastern-stock CPUE standardisation. This allows fully objective methods to be developed for the choice of linking vessels. Standardised CPUE indices were calculated for one such method to compare with the existing indices proposed as ISL's base eastern model. The indices were also compared with those from no time blocking (i.e., all vessels linking across all time blocks) and those from no vessel linkage at all (simply for comparative purposes – not a viable option because of the confounding between year and vessel effects).
The filter used in these models was the one originally proposed by ISL:

4: lig > 0 and (gre > 100 or trs > 100 or oth > 100 or red > 100)

The acceptance rule for a vessel to be a candidate as a linking vessel between two time blocks was determined before filtering: at least 30 records in at least 4 years in each block; and a CV of less than 50% for the annual proportions of positive ling tows in each time block. The time blocks were [1986-1999], [2000-2006], and [2007-2012].

The statistics calculated for each candidate vessel for each linkage were:

- mean of the annual proportions of positive ling trawls within each block
- ratio of the (above) block means
- absolute value of the log of the ratio
- the difference between the proportion of positive ling tows in each block
- 95% CI for the above difference

Note the distinction between the mean of the annual proportions within a block (which is where the proportion of positive ling tows is calculated for each year and then the mean of the proportions is calculated) and the proportion of positive ling tows within a block (which is where the number of positive tows in the whole time block is divided by the number of tows in the time block).

Results

Filtering
With regard to filtering of catch records for the eastern stock, it was noted at the meeting that the differences in the first time block (1986-1999) between the ISL and CSIRO CPUE indices were due to the use of different records – i.e., the filtering procedure used. Two of the early points in the ISL series are higher than the CSIRO points, and the points from 1991-1999 are lower (Figure 1). This indicates that the choice of filter can be important. That is, it matters whether one uses all positive ling records in the main depth range or whether one excludes some records in an attempt to obtain data from a "consistent fishery".

The reason why it is desirable to define a fishery to some extent (through filtering) is to avoid strong targeting behaviour (on any species) confounding year effects. The problem is that in some years there may be a lot of targeting on some particular species or group of species. The model may not be able to account for the change in targeting with the variables available to it (e.g., depth, month, latitude).

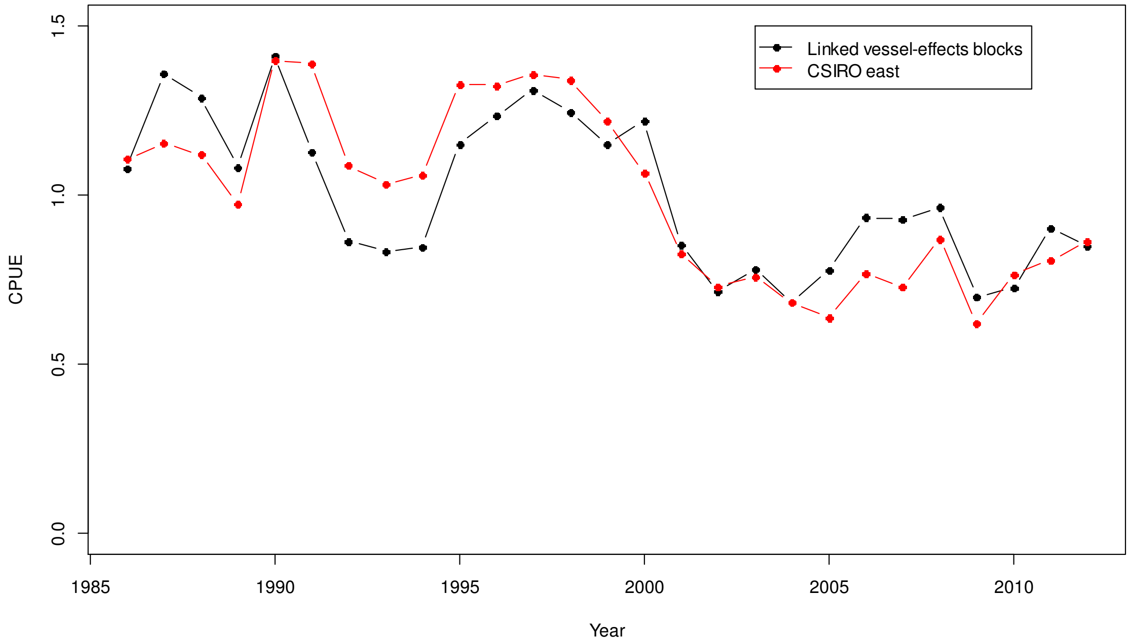


Figure 1: A comparison of the base ISL eastern trawl CPUE indices and the CSIRO indices.

In the eastern data, a classic example of this problem is the targeting of gemfish in 1986-1988 when the catches were huge compared to later years. All other things being equal (e.g., depth, month, latitude), when vessels were targeting gemfish, it seems likely that the average ling catch was different from when they were not targeting gemfish. Similarly, when vessels were "targeting" ling (to the extent that they could), then average ling catches were higher than when vessels were not "targeting" ling. It is easy to deal with the problem of gemfish targeting because records with "large" gemfish catches can simply be removed. It is much more difficult to deal with ling "targeting" because we must not use a filter that depends on the amount of ling that was caught in each trawl.

The exclusion of "large" gemfish catches (by using filter 2) causes the 1986-1988 CPUE indices to increase relative to those produced by the filter which includes them (filter 1). The change in the indices only occurs in the years (1986-1988) which had the very high levels of gemfish catch/targeting (Figure 2).

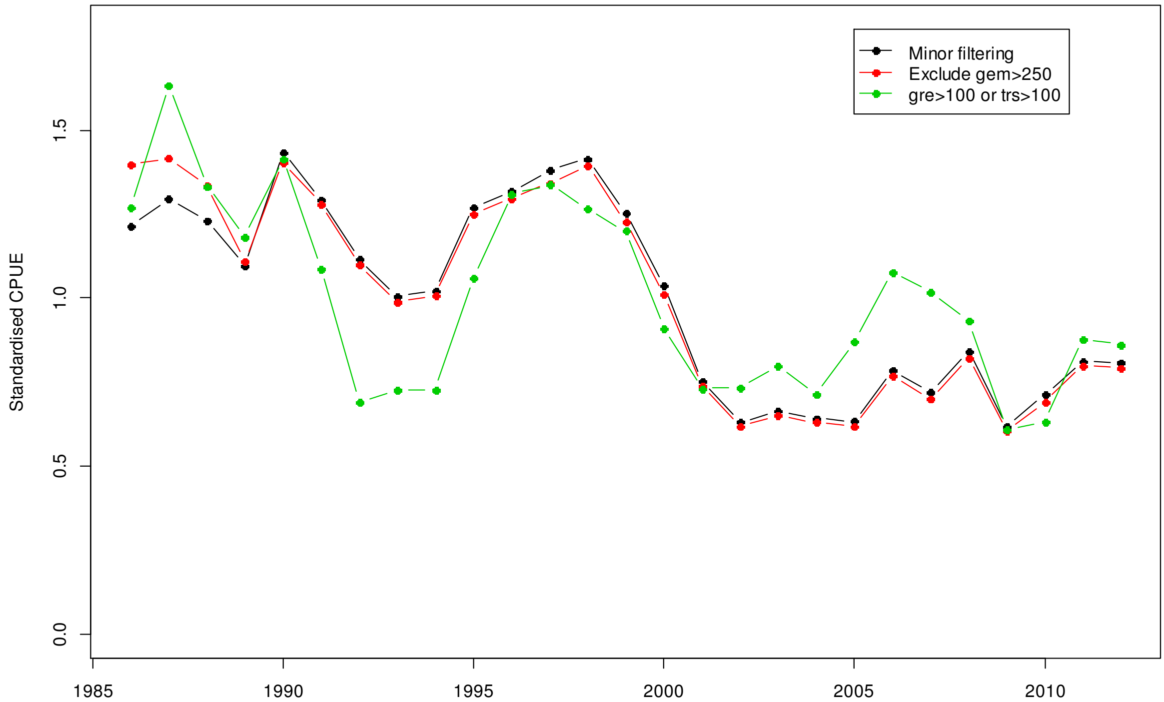


Figure 2: Eastern-stock pink ling CPUE indices calculated using the three filters defined in the text: "Minor filtering" (filter 1), "Exclude gem>250" (filter 2), "gre>100 or trs>100" (filter 3).

When the grenadier and silver-warehou filter is used (filter 3) there is a bigger dip in the indices from 1991-1995 compared to the indices produced by the other two filters (Figure 2). This indicates that the signal from the "gre-trs fishery", for ling abundance, is different from the signal from a more loosely defined fishery. It doesn't mean, necessarily, that it is the "wrong" signal.

The choice of filter to use in the east is somewhat problematic because there is a lot of ling caught in trawls which retain the "oth" (other) species category. It is clear that some filtering should be done (i.e., records with "large" gemfish catches should be excluded).

My recommendation for the eastern base model is to use the following filter:

lig > 0 and gem < 250 and (gre > 0 or trs > 0 or oth > 0).

This is minor filtering in terms of the ling catch retained (92% before excluding gem, and 89% after excluding gem; including red only increases catches slightly so it has been dropped from the filter).

The results for the interaction models are not given because the inclusion of interactions barely altered the standardised indices.

Time-blocking of vessel effects

The original method of determining vessels to use in the linking of time blocks was mainly based on each vessel's proportion of positive ling tows between the two blocks under consideration. Plots of the proportion of positive tows by year and boxplots of depth and duration were examined by eye to find vessels which appeared to have fairly constant behaviour across the two time blocks. This was a subjective method that could be hard for someone else to duplicate.

To test the sensitivity of CPUE indices to the choice of linking vessels, an alternative set of vessels was chosen using an objective rule based only on the proportion of positive ling tows (Tables 1 and 2). The rule was simply to take the three vessels which had the ratio of the mean annual proportion of positive ling tows closest to zero (which suggests that their ling targeting behaviour is little changed between the two blocks). An alternative statistic based on the difference in the (single) proportion of positive ling tows in each block was also calculated with a 95% CI (Tables 1 and 2). This provides an alternative statistic to use in selecting the vessels with little change in their targeting (i.e., we are looking for vessels for which the confidence interval spans zero, going from a negative to a positive value).

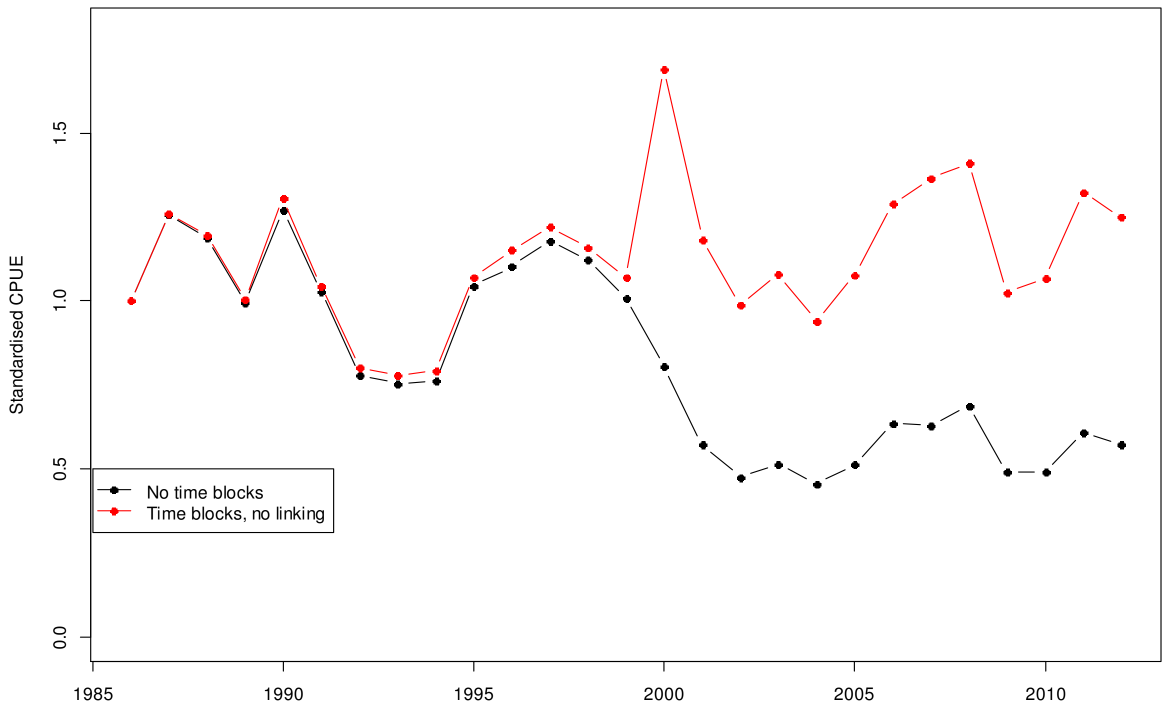


Figure 3: Eastern-stock pink ling standardised CPUE indices when no time blocking is used and when three time blocks are used *without* any linking vessels (not recommended).

It is clear from Tables 1 and 2 that there are very few candidate vessels that appear to have consistent ling targeting across the time blocks. We already know that some vessel linking needs to be done across time blocks or the year and vessel effects are completely confounded.

There is a continuum between no time blocking, which corresponds to all vessels being used to link all time blocks, and the use of time blocks with no linking vessels. As expected, the use of no linking vessels allows the year effects (standardised CPUE indices) to go “wild” (Figure 3). The difference between the two lines in Figure 3 represents the full range of the continuum that CPUE indices can span given the choice of which vessels to link with and the number of linking vessels. Any linkage at all will quickly bring the indices down from the “wild” ones but how close they end up to the no-time-block indices depends on which vessels are used.

Figure 4: Eastern-stock pink ling standardised CPUE indices when no time blocking is used and when three time blocks are used with linking vessels chosen subjectively (original choice) or objectively by one particular method (see text).

There is a difference in the standardised CPUE indices depending on the method used to choose the linking vessels (Figure 4). The difference is all in the linkage choice for the middle time block, with the CPUE indices, for the objective method, being partway between the no-time-block indices and the indices from the subjective method (Figure 4). The change in linking vessels for the second time block appears not to matter much (as the same trend is apparent).

The need for time-blocking seems clear (as there were known events occurring which could/did alter ling targeting behaviour). However, the CPUE indices are sensitive to the choice of linking vessels for the first two time blocks. That makes it important to use an objective method to choose these vessels. The sensitivity is in the level of increase in the indices from 2000-2012, but there is no sensitivity to the direction in which the indices move.

My recommendation for the method to select linking vessels is to require that two criteria be meet:

- **0.9 ≤ block ratio ≤ 1.1**
- **block difference 95% CI: lower limit < 0 and upper limit > 0**

This method selects vessels 1, 2, and 4 (from Table 1) to link time blocks [1986-1999] and [2000-2006]. And, it selects vessels 1 and 2 (from Table 2) to link time blocks [2000-2006] and [2007-2012].

Conclusion and recommendation

The choice of filter is important for the eastern stock CPUE standardisation. It is clear that some filtering (in addition to depth) is needed (e.g., to remove the confounding in 1986-1988 between the gemfish-targeting effect and the year effects). However, it is not yet clear exactly which filter should be used to provide the best chance of obtaining a legitimate biomass signal. To have no filtering is not a good option as it is at the extreme of a continuum. Therefore, I suggest for the base model that a small move is made in the right direction with a filter to remove the gemfish targeting but to include most of the ling catch in the eastern zones:

- **lig > 0 and gem < 250 and (gre > 0 or trs > 0 or oth > 0).**

On the question of time blocking, there is a clear need to do it to address the issues of the sale of ling quota from trawl fishers to line fishers that started in 1999-2000 and the structural adjustment from 2006-2007. Again, to have no time blocking is to be at one extreme of a continuum. Therefore, a move in the right direction is suggested. An objective method of choosing the linking vessels is needed and I recommend two criteria be used together:

- **0.9 ≤ block ratio ≤ 1.1**
- **block difference 95% CI: lower limit < 0 and upper limit > 0**

Table 1: Statistics for candidate vessels for linking blocks [1986-1999] and [2000-2006]. The means are for the proportion of positive ling tows in each block (Mean1, Mean 2); the ratio is Mean2/Mean1; Abslog is a measure of how close the ratio is to zero and the table is sorted on this value; the block difference and the associated 95% confidence interval is for the proportion of positive ling tows in the first block minus the proportion in the second block. Arbitrary vessel numbering for privacy. * vessel used in subjective linking. # vessel used in objective linking.

Vessel	Mean1	Mean2	Ratio	AbsLog	Block difference	Lower 95% CI	Upper 95% CI
#1	0.31	0.31	0.97	0.03	0.01	-0.03	0.04
#*2	0.45	0.48	1.06	0.06	-0.02	-0.05	0.01
#3	0.67	0.63	0.94	0.06	0.07	0.03	0.11
4	0.40	0.36	0.90	0.10	0.02	-0.01	0.05
*5	0.29	0.26	0.90	0.10	0.04	0.00	0.07
6	0.54	0.64	1.19	0.17	-0.08	-0.10	-0.06
7	0.52	0.64	1.22	0.20	-0.12	-0.15	-0.08
8	0.29	0.35	1.23	0.21	-0.05	-0.08	-0.02
9	0.36	0.53	1.47	0.38	-0.19	-0.23	-0.15
*10	0.09	0.06	0.67	0.40	0.02	0.01	0.04
11	0.22	0.34	1.58	0.46	-0.12	-0.17	-0.08
12	0.23	0.13	0.57	0.57	0.10	0.07	0.12
13	0.40	0.77	1.93	0.66	-0.35	-0.38	-0.32
14	0.51	0.22	0.44	0.83	0.26	0.20	0.32

Table 1a: Additional statistics for Vessels 1-5: number of years in each time block, number of records in each time block, proportion of ling catch in each time block, and the proportion of ling records in zone 20 (including zone 60).

Vessel	Number of years		Number of records		Proportion of catch		Proportion of records in zone 20	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
1	14	7	426	201	0.78	0.22	0.84	0.97
2	8	7	713	788	0.47	0.53	0.70	0.95
3	6	7	334	479	0.62	0.38	0.98	0.97
4	13	7	536	364	0.74	0.26	0.01	0.00
5	12	7	234	102	0.83	0.17	0.36	0.01

Table 2: Statistics for candidate vessels for linking blocks [2000-2006] and [2007-2012]. The means are for the proportion of positive ling tows in each block (Mean1, Mean 2); the ratio is Mean2/Mean1; Abslog is a measure of how close the ratio is to zero and the table is sorted on this value; the block difference and the associated 95% confidence interval is for the proportion of positive ling tows in the first block minus the proportion in the second block. Arbitrary vessel numbering for privacy. * vessel used in subjective linking. # vessel used in objective linking.

Vessel	Mean1	Mean2	Ratio	AbsLog	Block difference	Lower 95% CI	Upper 95% CI
#1	0.34	0.36	1.04	0.04	0.00	-0.05	0.06
#*2	0.63	0.6	0.95	0.05	0.02	-0.02	0.06
#3	0.48	0.45	0.93	0.07	0.05	0.00	0.09
4	0.48	0.52	1.09	0.09	-0.03	-0.06	0.00
*5	0.06	0.07	1.17	0.16	-0.01	-0.03	0.01
6	0.42	0.34	0.81	0.21	0.08	0.05	0.11
7	0.57	0.46	0.81	0.21	0.14	0.12	0.16
8	0.64	0.50	0.79	0.24	0.15	0.12	0.17
9	0.13	0.10	0.73	0.32	0.03	0.01	0.06
10	0.77	0.51	0.65	0.43	0.21	0.17	0.25
11	0.64	0.35	0.54	0.61	0.29	0.26	0.32
12	0.55	0.26	0.47	0.75	0.28	0.24	0.33

Table 2a: Additional statistics for Vessels 1-5: number of years in each time block, number of records in each time block, proportion of ling catch in each time block, and the proportion of ling records in zone 20 (including zone 60).

Vessel	Number of years		Number of records		Proportion of catch		Proportion of records in zone 20	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
1	7	6	124	87	0.71	0.29	1.00	1.00
2	7	6	479	431	0.43	0.57	0.97	1.00
3	5	6	249	392	0.39	0.61	0.69	0.81
4	7	6	788	841	0.49	0.51	0.95	0.83
5	7	6	63	51	0.65	0.35	0.00	0.02

Analysis of trawl catch and effort data to produce standardised CPUE indices for pink ling

P.L. Cordue
7 September 2013

Introduction

Detailed trawl logbook data were analysed to determine suitable subsets of data to use in producing standardised ling CPUE indices for the eastern and western stocks. The complication of possible “regime shifts” in ling targeting caused by the movement of quota in 1999-2000 from trawl fishers to line fishers, and the structural adjustment in 2006, were addressed in the CPUE standardisation.

Methods

Detailed logbook data were supplied by CSIRO for a list of 157 vessels that took about 99% of the ling catch over the period 1985-2013. All records were supplied for each vessel irrespective of whether they reported retained ling or not on a particular station. Each record contained estimated green-weight for about 30 species including an “OTH” category which contained all of the *other* species (see Klaer and Smith 2012 for details of the species and other fields).

The detailed data were imported into R and restricted to trawl stations only (some vessels had in some years used gear other than OT). For the descriptive analysis as many records as possible were used. For the production of CPUE indices, records were restricted to the years 1986-2012 and records with missing values in explanatory variables were excluded.

The east and west CPUE standardisations were done separately. However, in most of the descriptive analysis all zones were dealt with together. Summary plots were produced by zone to determine, for the “ling vessels”, the main species caught in the zones and the seasonality of the catches (Appendix 1). Summary plots were also produced by species to look at trends and characteristics by depth, month, year, zone, and their association with ling (Appendix 2). Summary plots were also produced for individual vessels to examine whether their ling targeting behaviour may have changed over time.

The objective of the descriptive analysis was to determine suitable subsets of data to use in the CPUE standardisations. The form of the models were the same for both east and west:

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

All explanatory variables were categorical:

year:	1986-2012
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 two years within a "block"

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
west: 1986-2006, 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 the split is also supported by the logbook data (see Results below).

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.

Results

Filters

The species summaries and zone summaries were used to define filtering criteria for the ling CPUE analysis. The objective was to define a consistent "fishery" in which ling was a "major" bycatch. The point being to try to get a consistent subset of data across years; although the depth filtering of 200-750 m has already done some of the job. Depths beyond 750 m were excluded because the catches are very intermittent across years (and are therefore unlikely to provide useful information on abundance). Short tows were also excluded as they are likely to be highly targeted.

In the west (Zones 40, 50) there were obvious seasonal fisheries for GRE and TRS and during the ling spawning season (September-November) a reasonable proportion of ling (LIG) was also caught in Zone 40 (See Appendices). The filter used for the base model in the western ling CPUE analysis was:

West: LIG > 0 & (GRE > 100 | TRS > 100)

where each species code denotes the species catch (kg). This filter retained 62% of the logbook ling catch and 66,000 records. Very similar results were obtained from a threshold of 0 (92% of the catch) and 200 (48% of the catch). The key point is that GRE and TRS are associated with ling in the west.

In the east (Zones 10, 20, 30 with Zone 60 included in Zone 20) the situation is more complex with a mixture of species, in particular the “mixed bag” OTH, making up the bulk of the catches in ling depths (see Appendices). There used to be an ORO fishery in Zone 30 and a GEM fishery in Zone 10. Also, there is an inshore FLT fishery in all of the eastern zones. A mix of species, associated with ling and its depth range, were used in the filter:

East: LIG > 0 & (RED > 100 | OTH > 100 | TRS > 100 | GRE > 100)

Various other filters were tried (e.g., higher and lower values than the threshold of 100; excluding moderate-large GEM catches) but they made little difference to the results. The original filter was at a threshold of 0 which accounted for 93% of the ling logbook catch in the eastern zones (406,000 records). At a threshold of 100 only 40% of the catch was accounted for but it was still 171,000 records – more than enough. At a threshold of 200 which was just 23% of the catch the analysis still gave very similar results.

Eastern split 1999-2000

There has been much debate about a potential change in ling catchability in the eastern stock after the 1999 sell-off of ling quota from the trawl fleet. The 2010 assessment split the trawl CPUE time series into two segments with the break at 1999. However, the split was removed in 2011 because of an apparent lack of evidence for a real change.

The detailed logbook data does point to a change in ling targeting in the eastern zones, especially in Zones 10 and 20. The first indication is from catch per tow (including zeroes) for all of the trawl logbook records (Figure TB1). Ling catch per tow was trending slightly upwards in Zones 20 and 30 until 1999 when it started heading down. This is unlikely to be a biomass signal – it relates more to ling targeting and/or reporting of small ling catches. In the eastern and western zones, the proportion of tows that reported no retained ling were all trending down until 1999 (Figure TB2). In Zones 30, 40, and 50, the trends (of varying levels of steepness) continued beyond 1999. However, in Zone 10 there was a steep increase from 1999 to 2000; and in Zone 20, the proportion of zeroes stopped going down and moved up slightly.

For many species there seemed to be a general trending down in the proportion of zero tows over time (see Appendices) which suggests that there was better reporting of small catches. However, ling is not alone in reversing that trend in Zone 10 in 1999. The same reversal is seen to some degree for DOM, GRE, and REG.

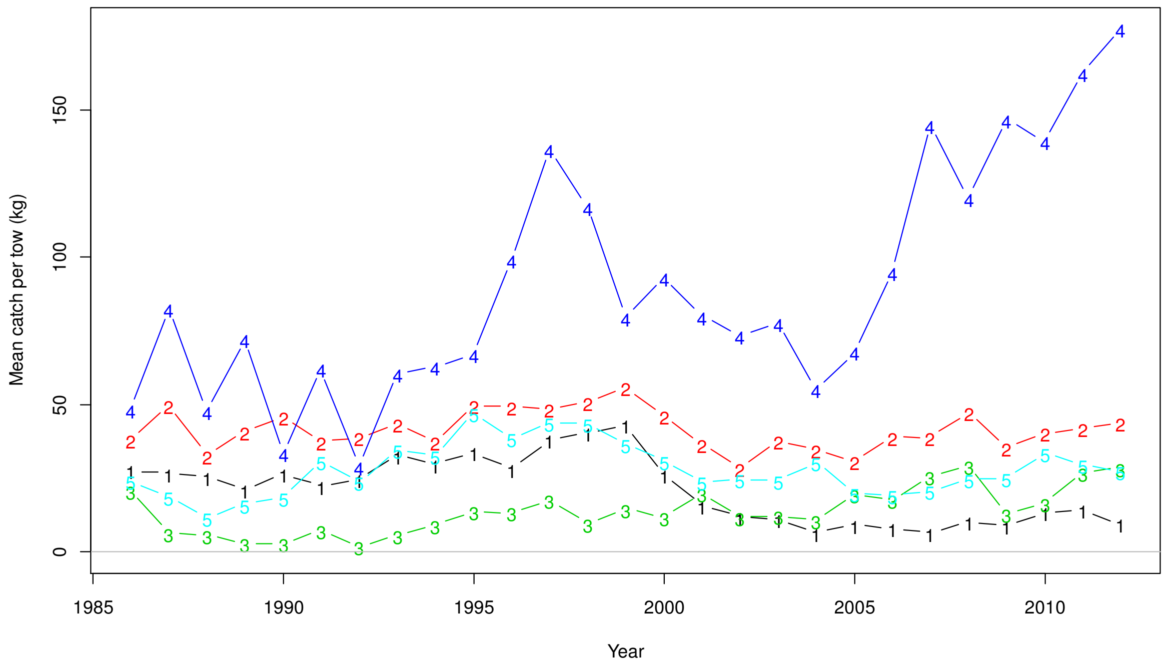


Figure TB1: Arithmetic ling catch per tow by zone and year ("1" = Zone 10, etc).

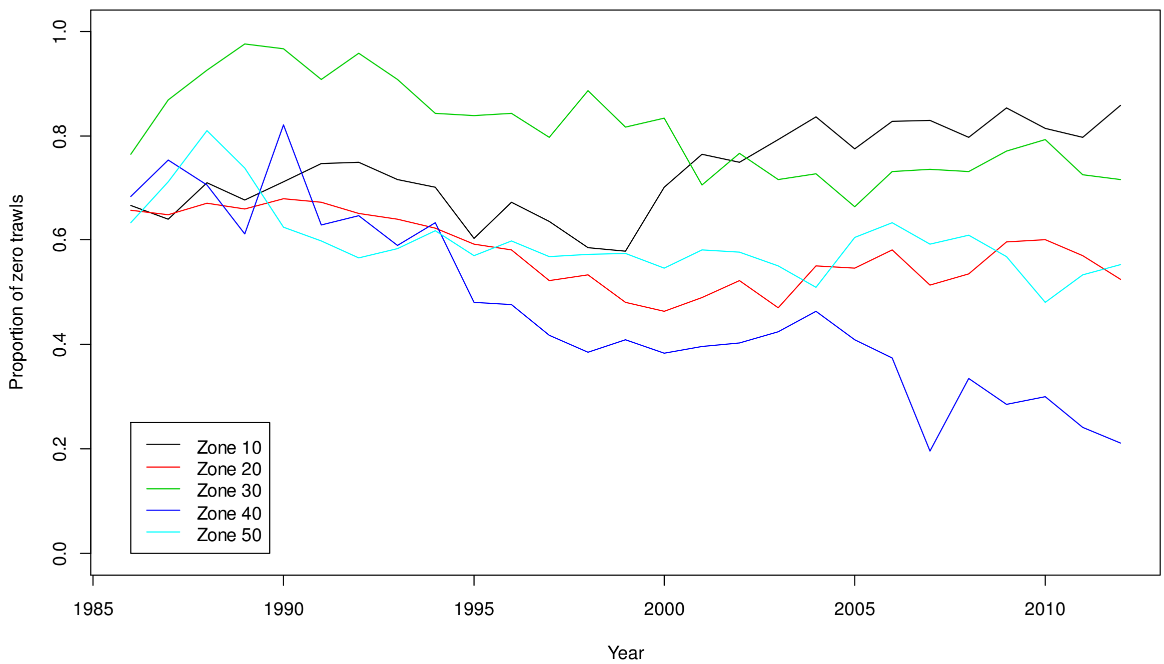


Figure TB2: The proportion of trawls for which zero retained ling was reported, by zone and year.

An analysis of individual vessels by year also indicated that 1999 to 2000 was a time of change in Zone 10, with the vast majority of vessels who fished regularly in Zone 10 showing an increase in the proportion of zero ling tows from 1999 to 2000.

There is little doubt that there was a move away from ling targeting in some of the eastern trawl fishery from 1999 to 2000. However, that does not necessarily mean that a standardisation cannot deal with the change. If the movement away from targeting ling just involved a change in depth or zone then that could be accounted for. What cannot be accounted for are more subtle changes such as moving away from an area where too much ling is being caught while staying in the same zone and depth.

Vessels that did not appear to change ling-targeting behaviour across time blocks

In the east and the west I searched for vessels which maintained a fairly constant depth range, tow duration, and proportion of zero ling tows across the time blocks. For the west, three vessels were found that spanned the 2006-2007 breakpoint. In the east, there were far more vessels available but it was difficult to find vessels that hadn't changed their behaviour. However, there was one vessel that spanned all three time blocks and two more which spanned the 1999-2000 breakpoint and an additional one which spanned 2006-2007. See Appendix 3 for the plots on which my assessment was made. The callsigns of the vessels are available but are not given here.

CPUE standardisation results

In the east, the use of time blocks has a substantial effect on the CPUE indices (Figure 1). Essentially there is shift upwards of all of the points from 2000 onwards, with little change in the trend from 2000 to 2012. This suggests that there was a shift in ling targeting after 1999 and that it cannot be accounted for just by depth and area. There was little change in the trend after 2006 so it appears that the vessels remaining after the structural adjustment have not had a major change in their ling-targeting behaviour (or at least their reported retained ling catches).

The ISL and CSIRO indices have similar trends but they differ particularly in recent years with the ISL indices being higher from 2005-2008 (Figure 2). How much difference the use of one or the other will make in the stock assessment is hard to judge, but I suspect that the ISL indices will lead to higher estimated stock status. The CSIRO indices were calculated without time blocking which would seem to be an essential element to include.

For the east, the other effects show some interesting patterns. There is a very strong depth effect with the peak catch rates at about 500 m (Figure 3). The day-or-night effects are minor (Figure 4). The tow duration is important with catches increasing with longer duration although not in a linear fashion (as is assumed in the CSIRO model)(Figure 5). There is a very strong latitude effect with catches peaking in Zone 20 (Figure 6). There are moderate month effects with highest catches in June (Figure 7). The peak season could vary by zone/latitude but a latitude-season interaction did not change the year effects in an earlier model.

The vessel effects show only moderate variation and therefore changes in a single vessel's effect across time blocks are not unreasonable (Figure 8).

In the west, the use of the two time blocks had little effect on the CPUE indices (Figure 9). Also, the ISL indices are very similar to those produced by CSIRO (Figure 10). As in the east, there is a depth effect (but it is only moderate here)(Figure 11) and there is very little day-night effect (Figure 12). The tow duration effect is linear as assumed by CSIRO (Figure 13). The latitude effect is not strong but catches do peak in Zone 40 (Figure 14). The seasonal effect is moderate with catches peaking in September/October during the spawning season (Figure 15). Vessel effects show moderate variation with little change within vessels across time blocks (Figure 16).

Eastern stock diagnostics

The use of the time blocks allows the model extra freedom to deal with the residual patterns, across time, within individual vessels. Because there was a preponderance of apparent decrease in vessel effectiveness after 1999, the year effects and vessel effects have shifted accordingly. The use of the time blocks shifted the 2000-2012 year effects up by 30-40% compared to the effects without time blocks (Figure 17). The median vessel effects were reduced not nearly so much, shifting down by just 13% (Figure 18). Other changes in effects were examined and they were minor.

There were no obvious problems with the residuals in the CPUE model (Figures 19 and 20).

Zone-based CPUE indices

At CSIRO's request the latitude factor was replaced with a zone factor in the ISL models and a combined-zone model was produced for each stock together with individual trends by zone (i.e., putting in a zone-year interaction). For both east and west the use of the latitude factor or the zone factor made almost no difference to the estimated year effects (Figures 21 and 22).

The individual-zone trends appear similar in the east although the indices for Zone 30 are very noisy (Figure 21). In the west the trends in Zones 40 and 50 obviously differ in recent years with Zone 40 trending upwards and Zone 50 being flat (Figure 22). In both the east and the west, the individual trends, when averaged in any sensible way will produce something very similar to the combined-zone models (so the different individual-zone trends is not a problem for a spatially-aggregated stock assessment model).

Conclusion

The automated, generic, CSIRO approach is adequate for the western CPUE standardisation. However, in the east a more detailed analysis is needed, including filtering of records and, most importantly, an allowance for possible changes in vessel effects across the 1999-2000 boundary. The structural adjustment and the reduction in ling quotas is also a cause for concern in terms of the ability of CPUE to track abundance. However, it appears that there is nothing in the data that confirms this is a problem – though it still remains an issue.

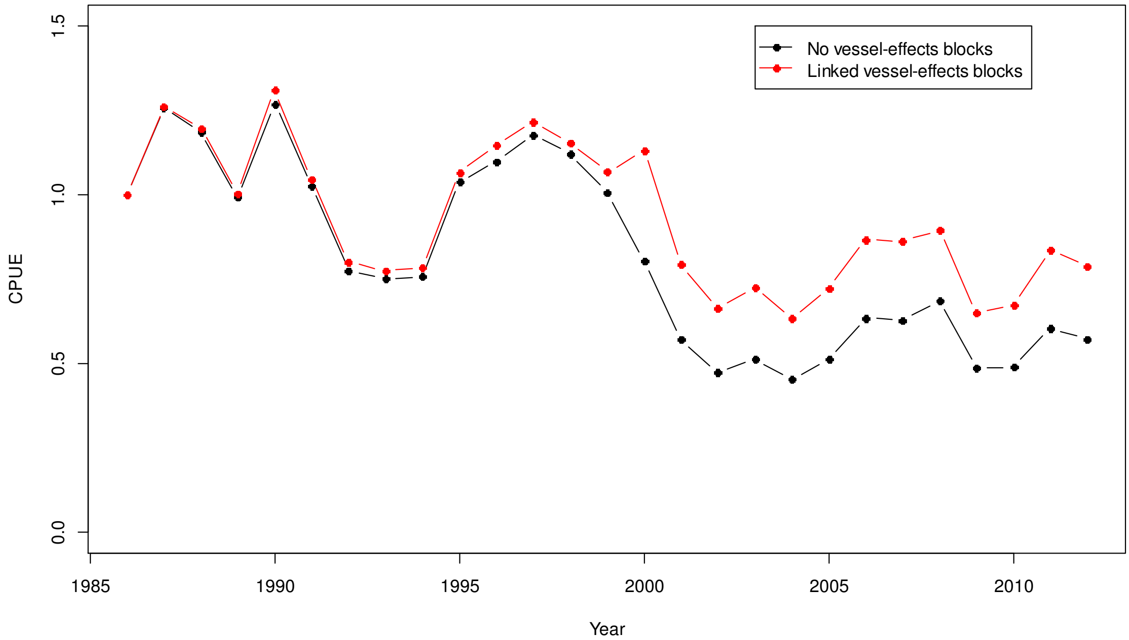


Figure 1: Standardised eastern trawl CPUE when vessel effects are blocked and when they are not.

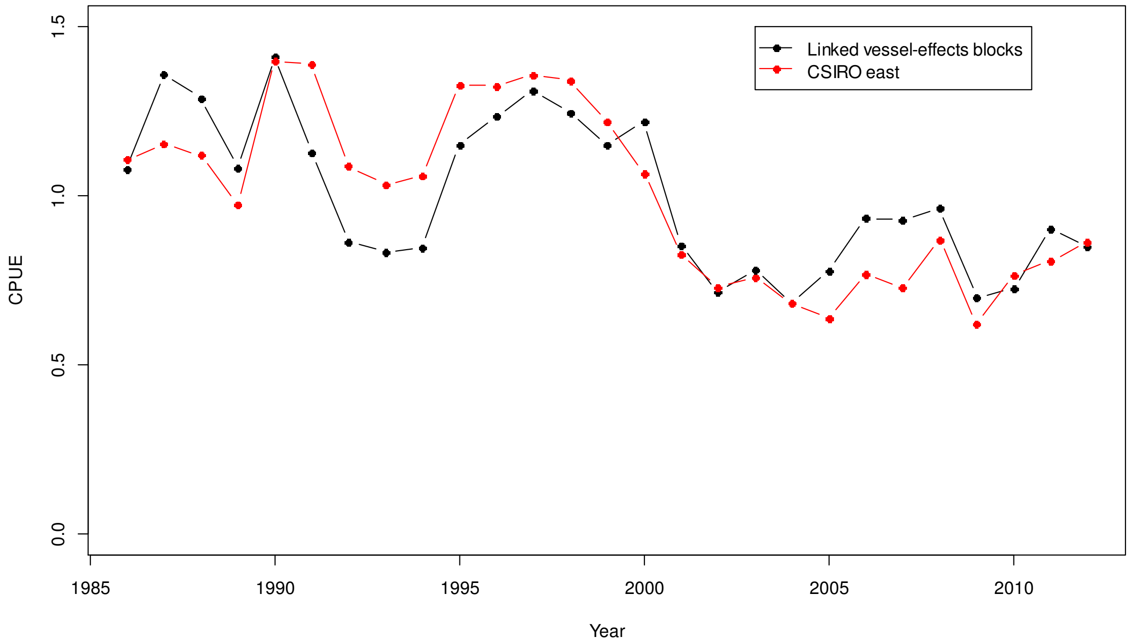


Figure 2: A comparison of the base ISL eastern trawl CPUE indices and the CSIRO indices.

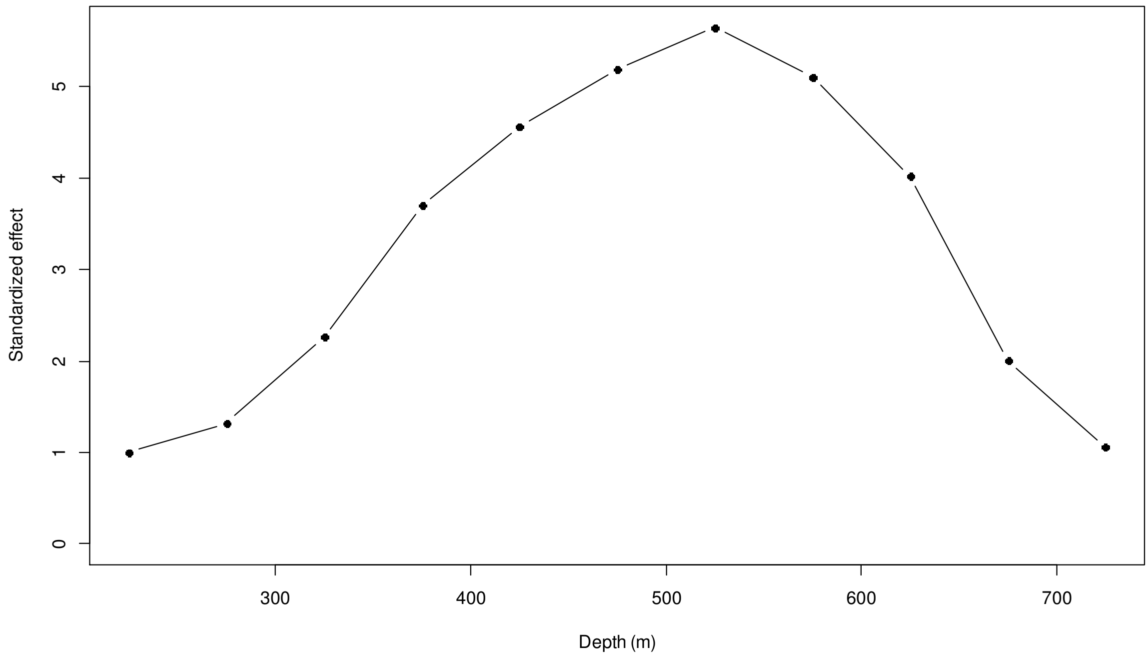


Figure 3: Depth effects for the ISL base eastern tawl CPUE model .

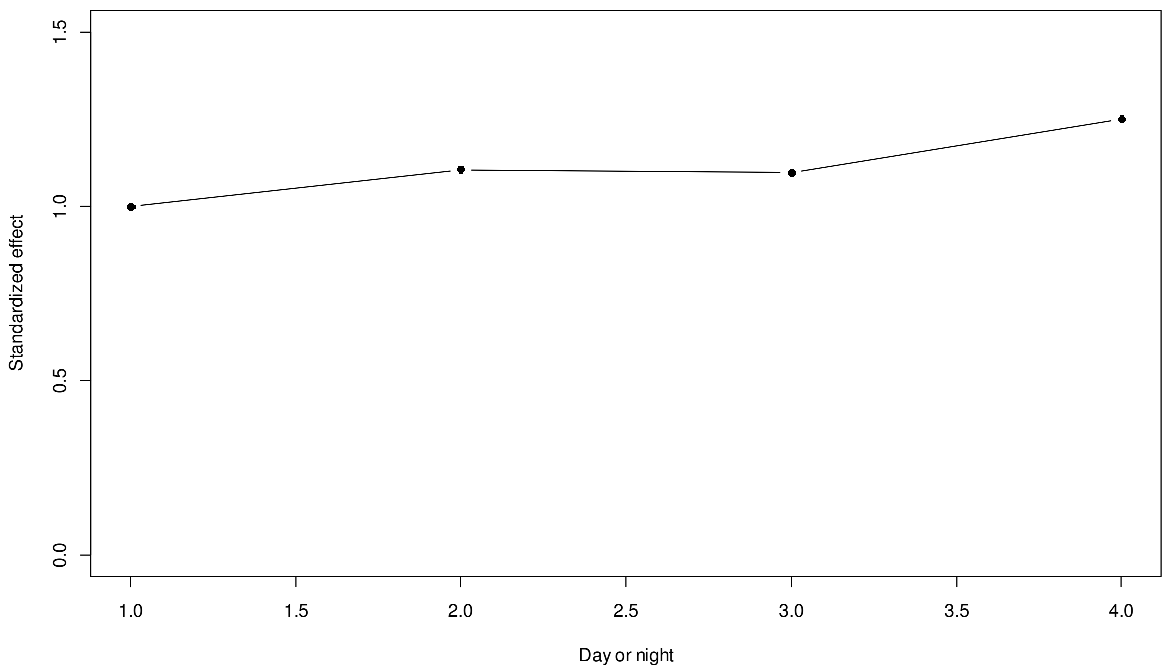


Figure 4: Day or night effect for the ISL base eastern trawl CPUE model.

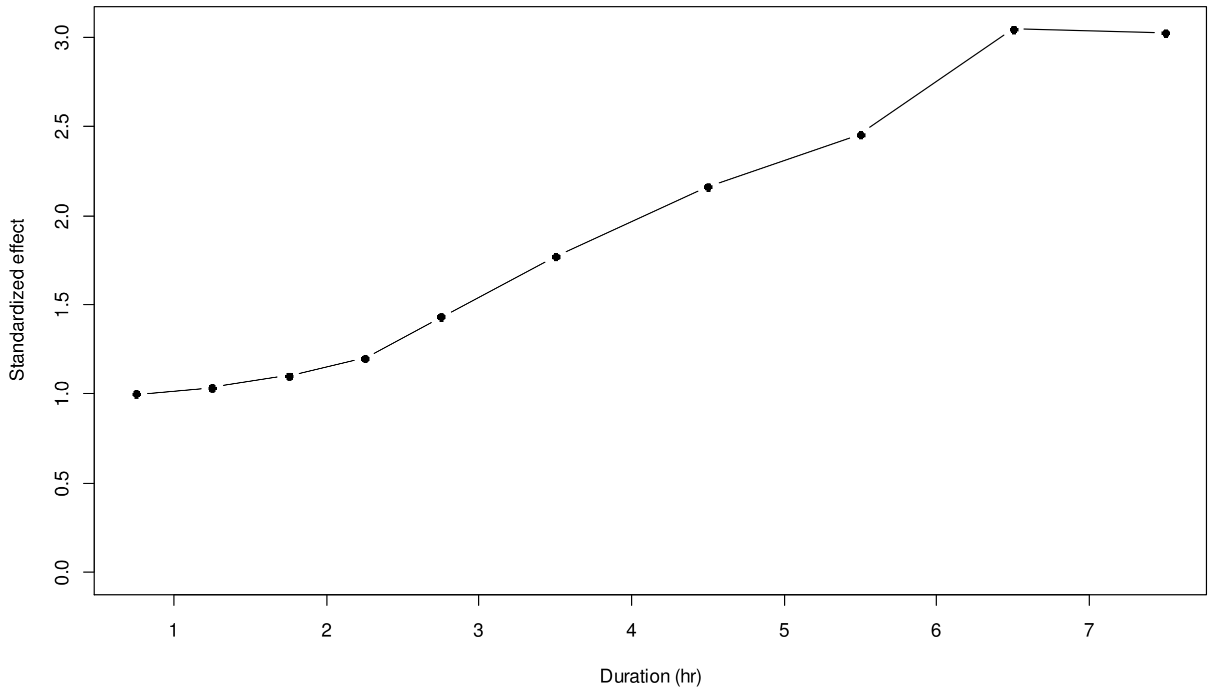


Figure 5: Trawl duration effect for the ISL base eastern trawl CPUE model.

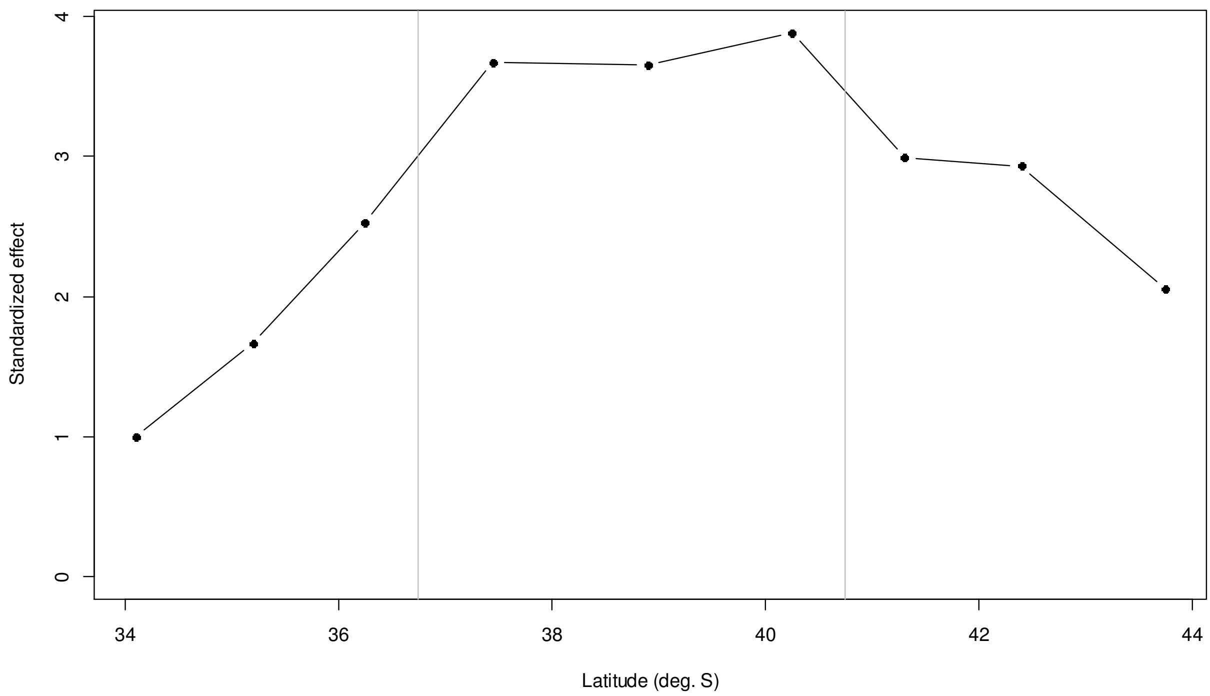


Figure 6: Latitude effect for the ISL base eastern trawl CPUE model. The grey lines mark the boundaries of Zone 20.

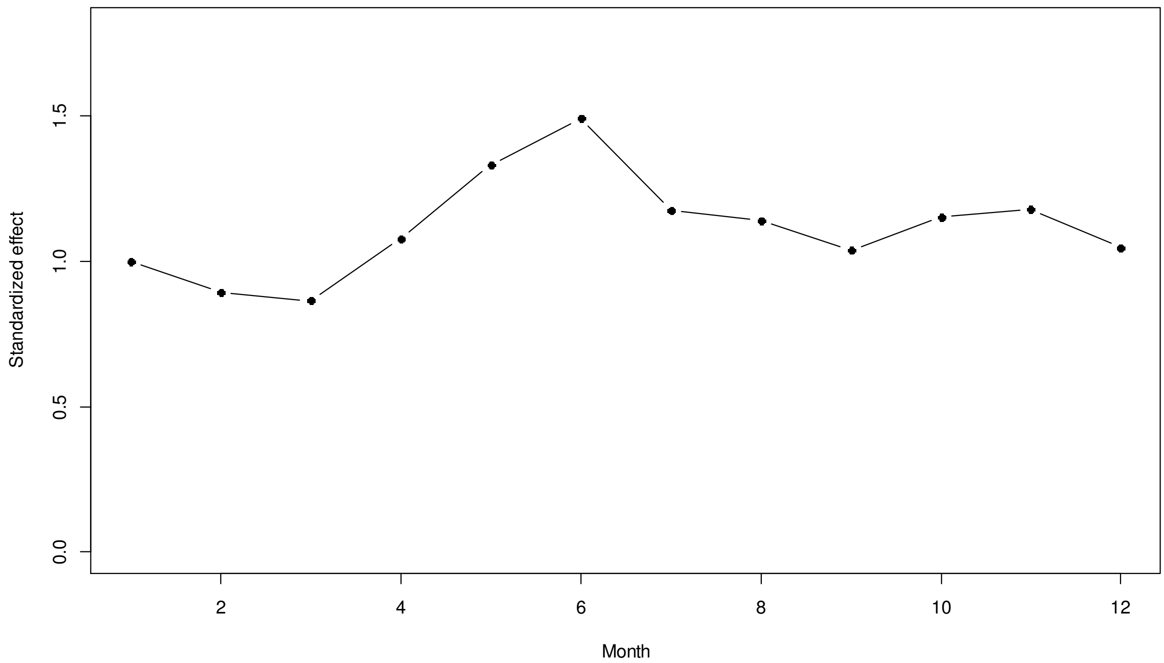


Figure 7: Month effect for the ISL base eastern trawl CPUE model.

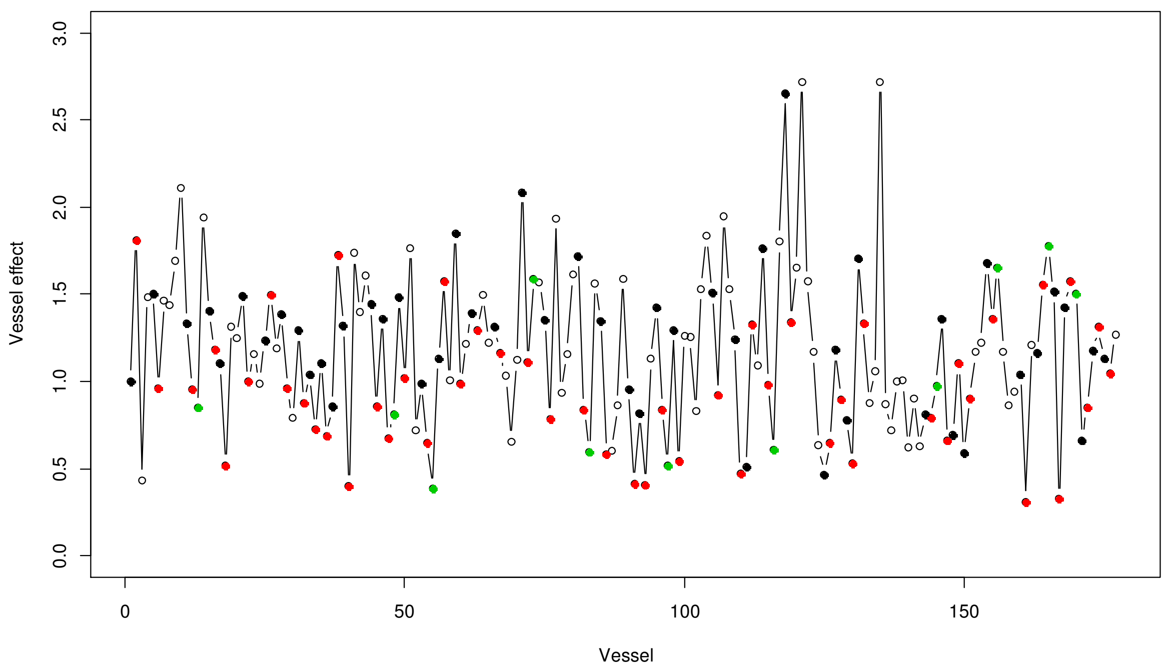


Figure 8: Vessel effects for the ISL base eastern trawl CPUE model. Consecutive black, red, and green dots are for the same vessel in three different time blocks. Consecutive black and red dots are for the same vessel in two time blocks. Open circles are for vessels with a single effect across blocks or occuring only in a single block.

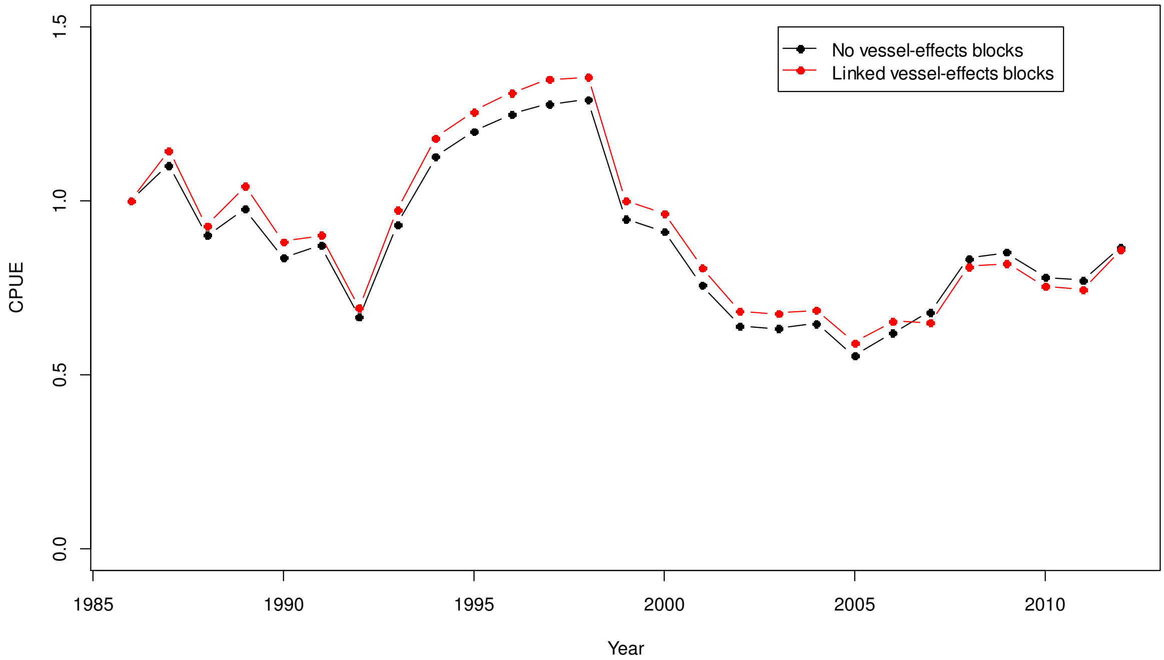


Figure 9: Standardised western trawl CPUE when vessel effects are blocked and when they are not.

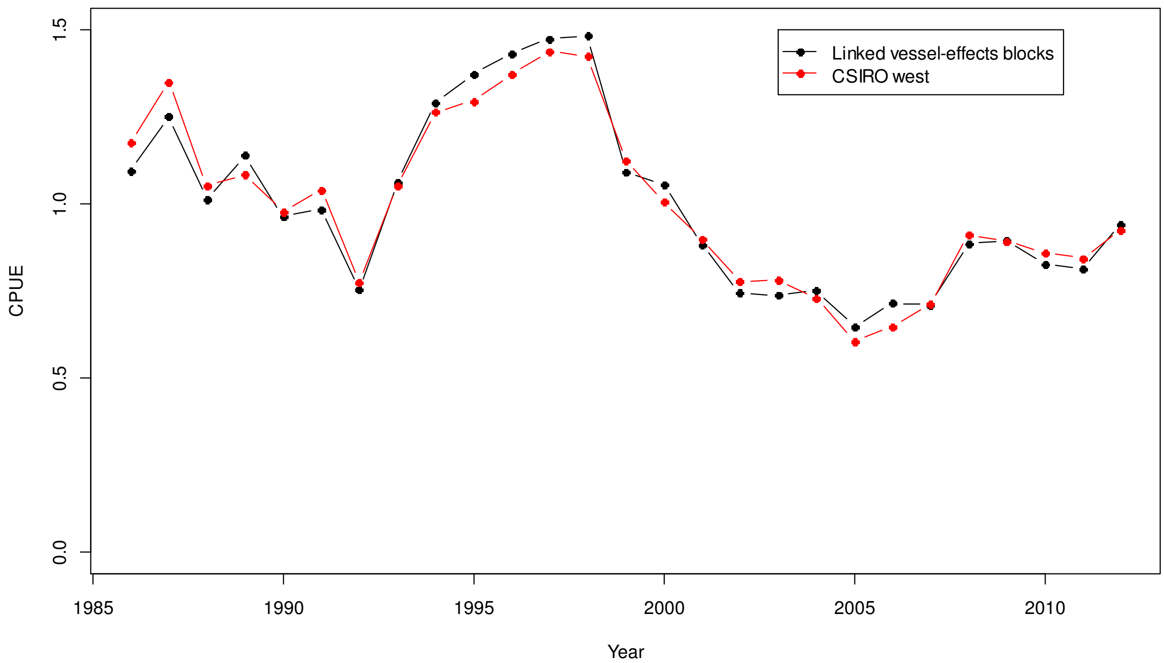


Figure 10: A comparison of the base ISL western trawl CPUE indices and the CSIRO indices.

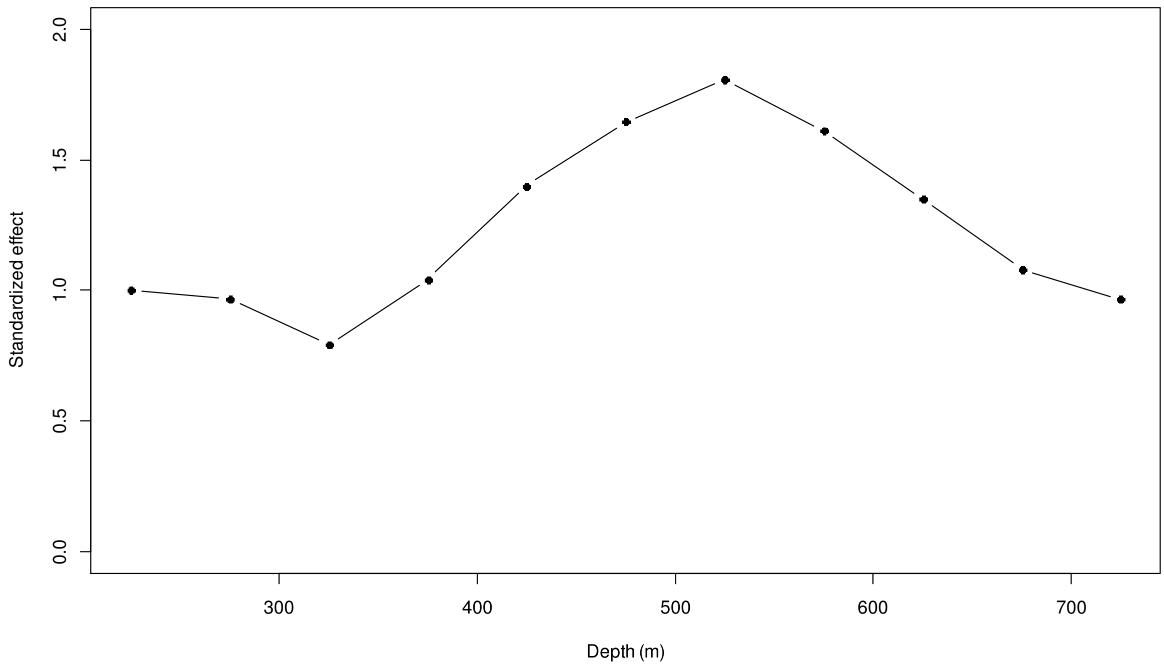


Figure 11: Depth effects for the ISL base western tawl CPUE model .

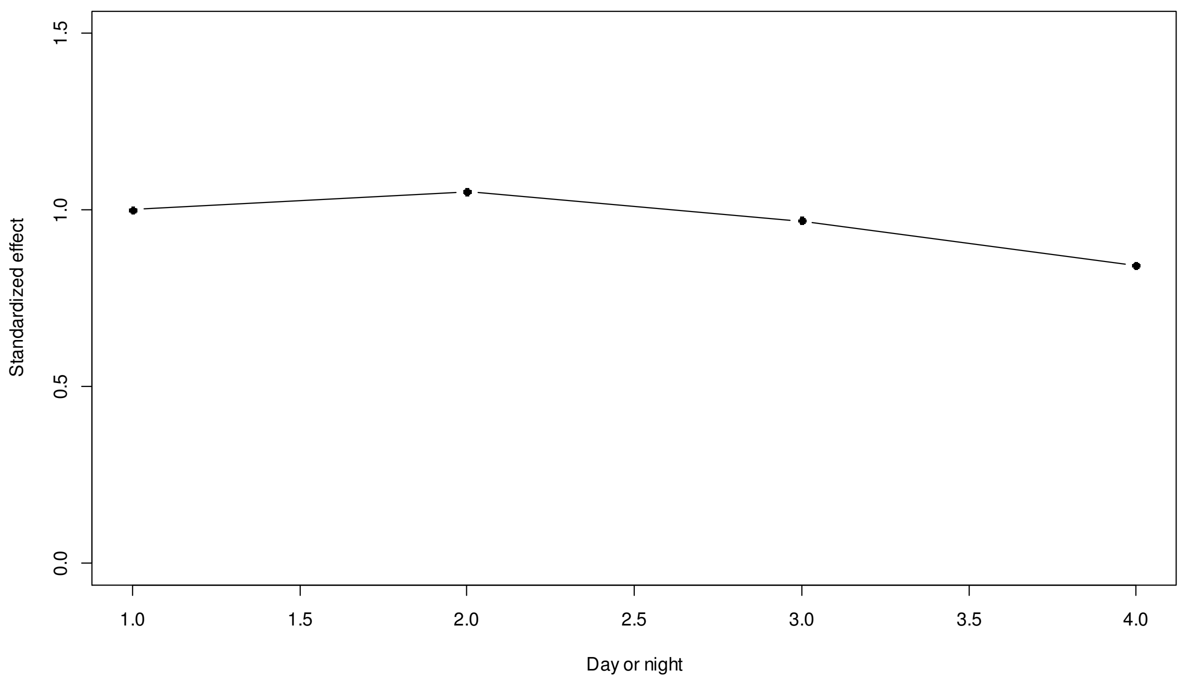


Figure 12: Day or night effects for the ISL base western tawl CPUE model .

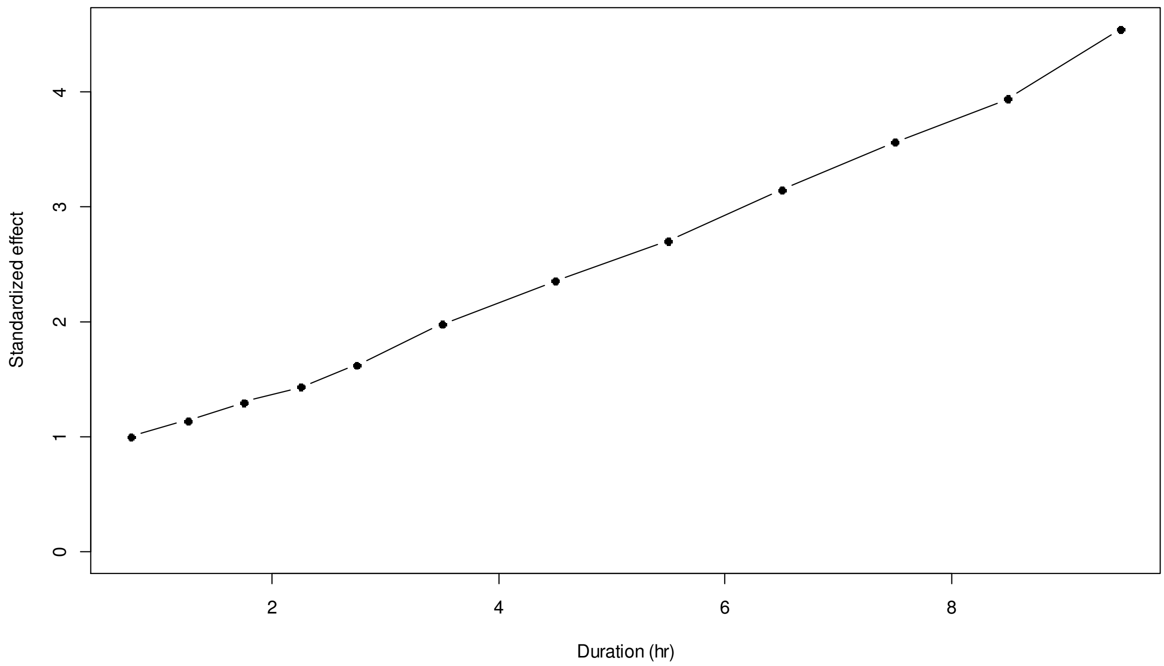


Figure 13: Tow duration effects for the ISL base western tawl CPUE model .

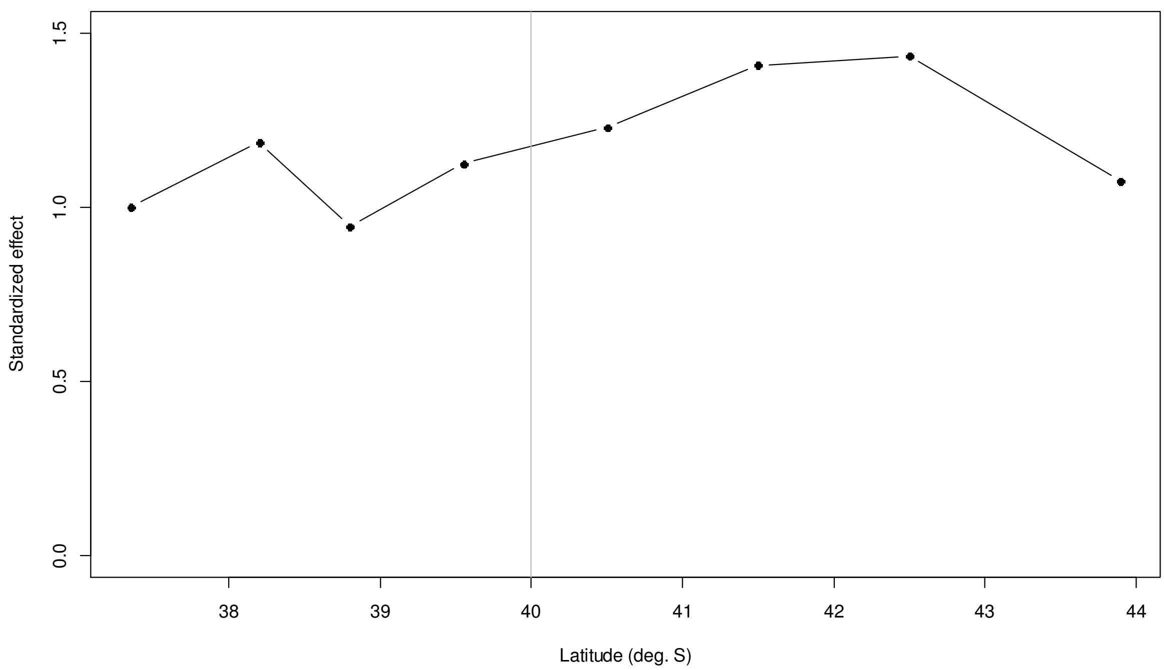


Figure 14: Latitude effects for the ISL base western tawl CPUE model . The grey line marks the boundary between Zones 40 and 50.

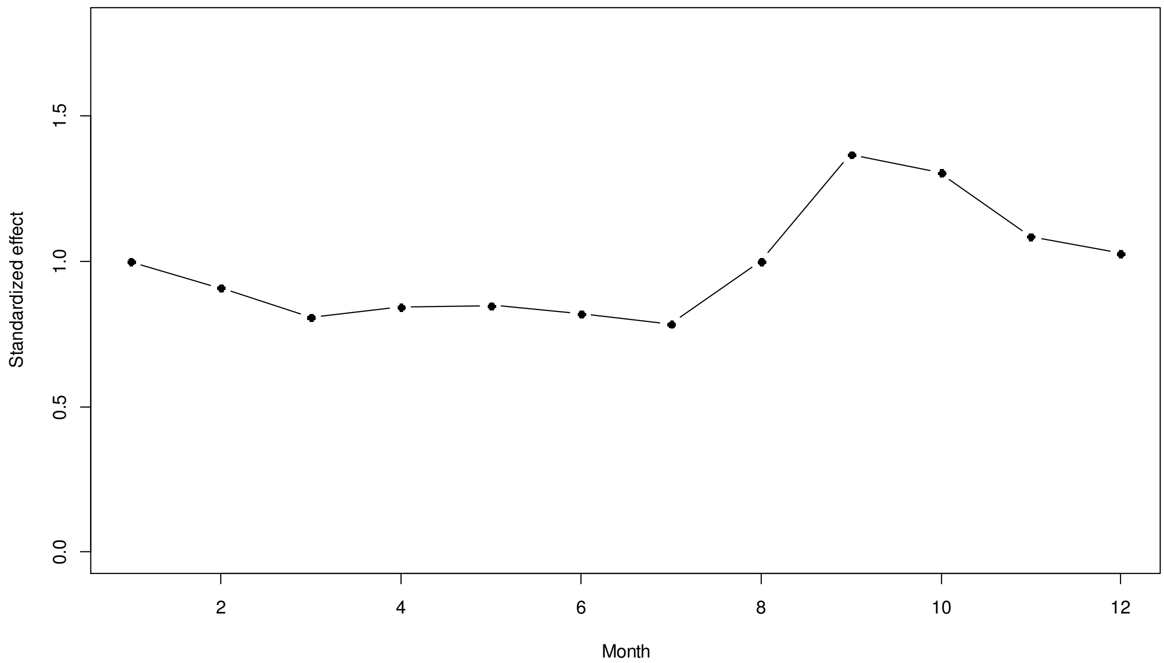


Figure 15: Month effects for the ISL base western tawl CPUE model .

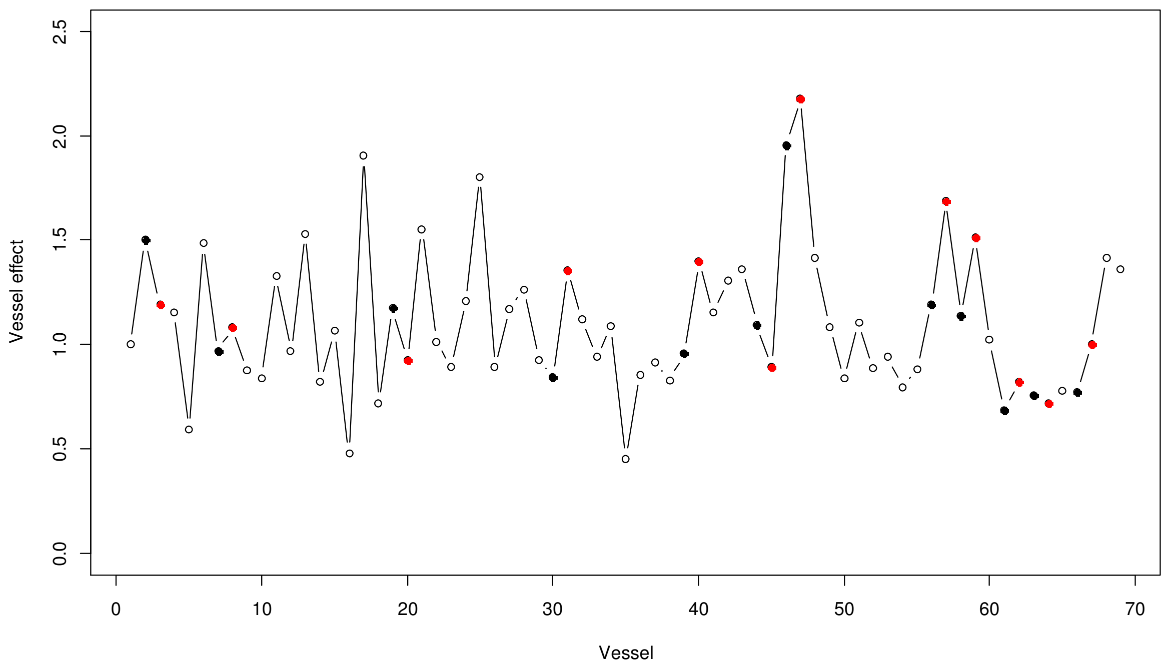


Figure 16: Vessel effects for the ISL base western trawl CPUE model. Consecutive black and red dots are for the same vessel in the two different time blocks. Open circles are for vessels with a single effect across blocks or occuring only in a single block.

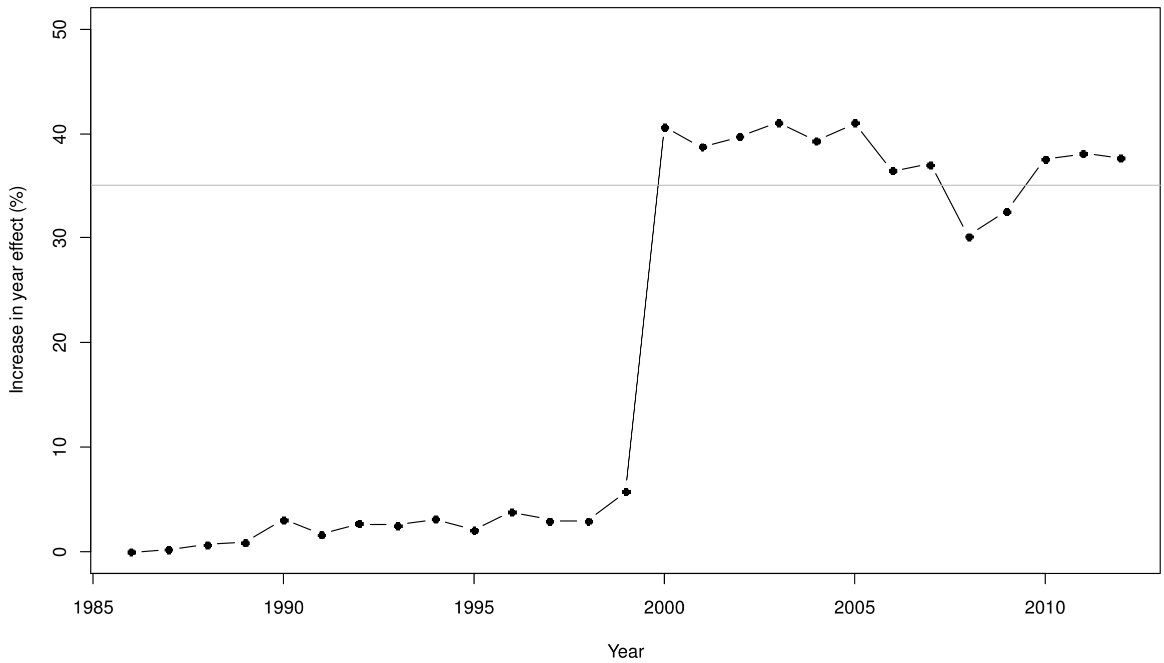


Figure 17: The percentage increase in each year effect when vessel-effect blocking was introduced for the eastern trawl CPUE standardiasion. The grey line is at 35%.

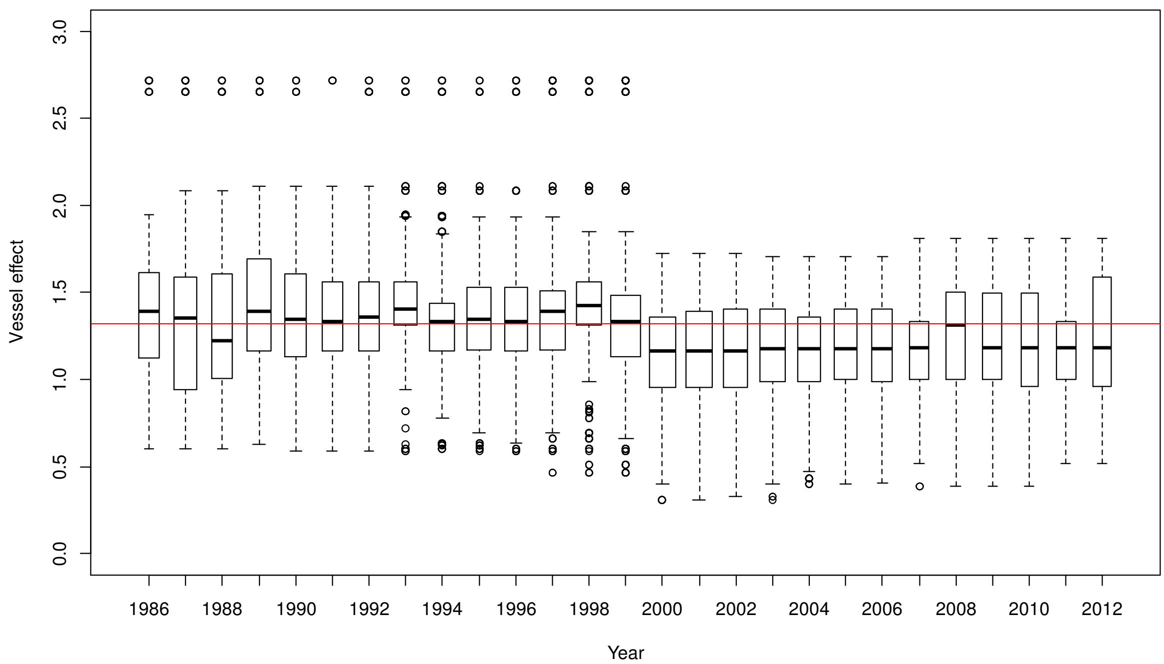


Figure 18: Boxplot of the annual vessel effects for the ISL base eastern trawl CPUE model. The red line is at the median across all records (1.32). The median vessel effects for each block are: 1.35 [1986-1999], 1.18 [2000-2006], 1.18 [2007-2012].

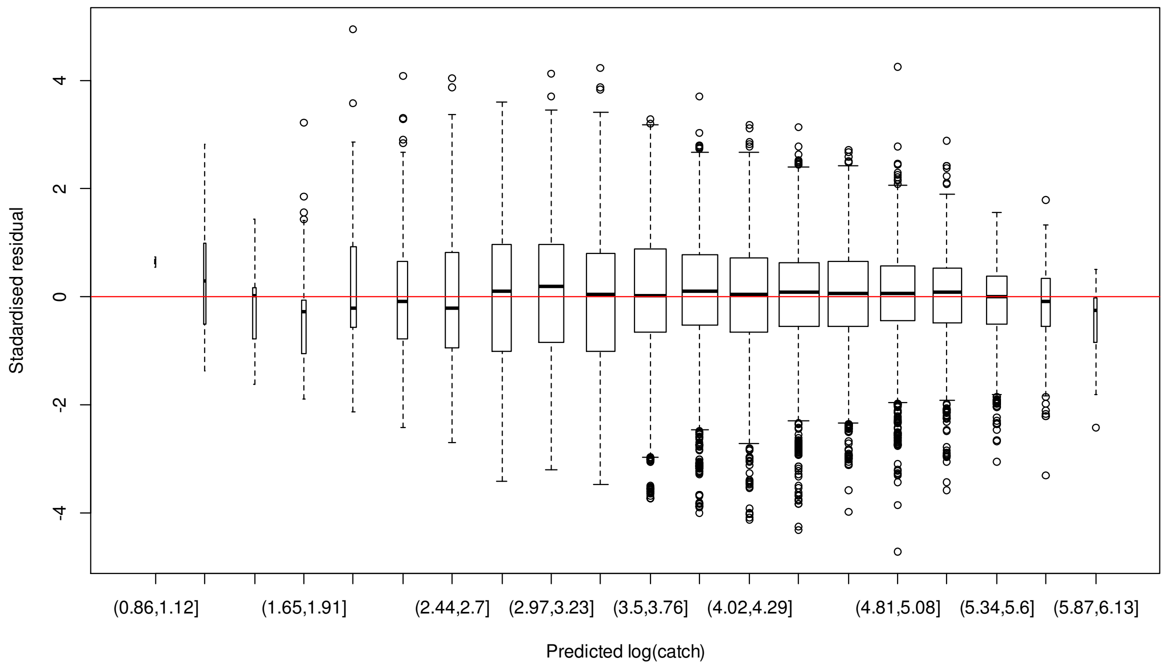


Figure 19: Standardised residuals vs predicted values for the ISL base eastern trawl CPUE model.

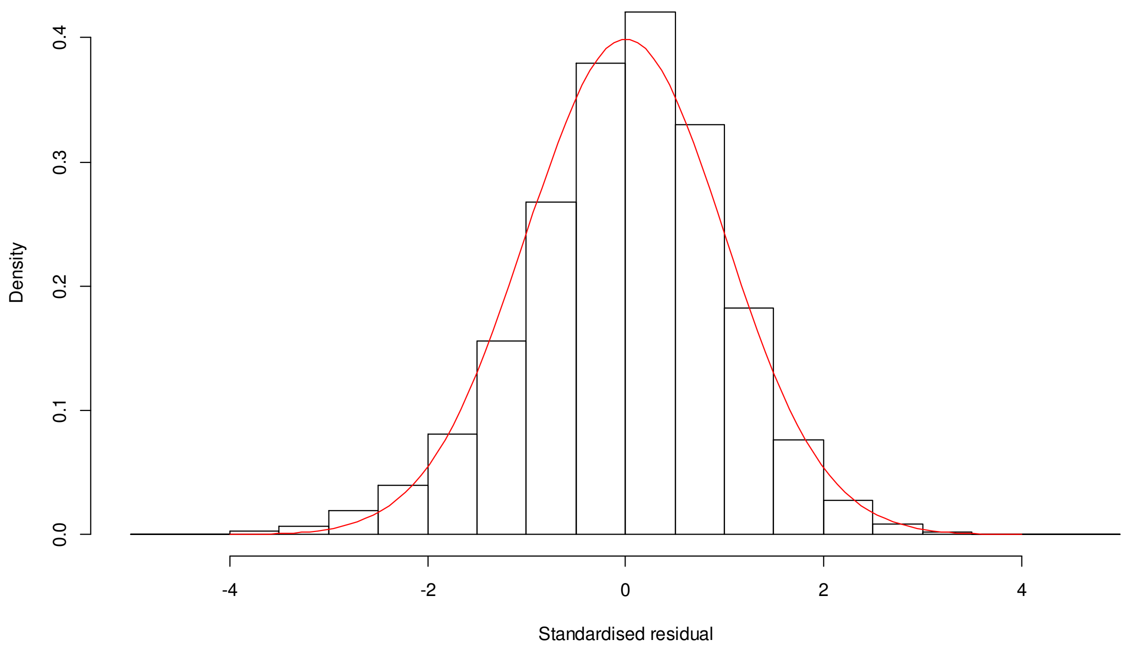


Figure 20: Standardised residuals compared to a N(0,1) density for the ISL base eastern trawl CPUE model.

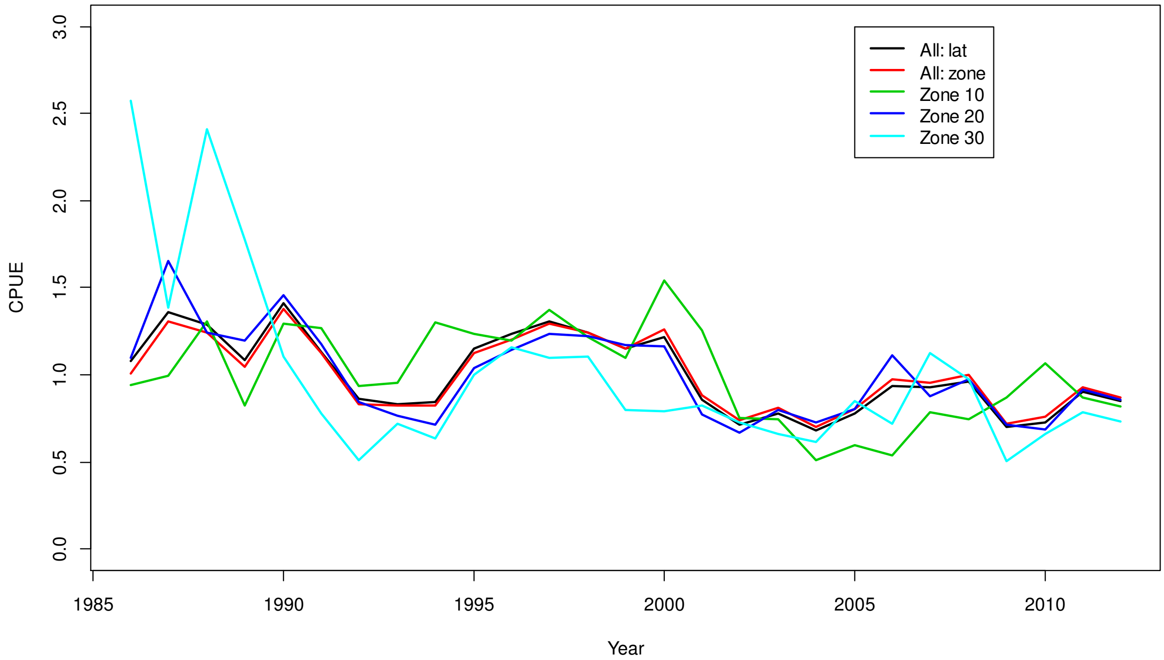


Figure 21: A comparison of the base ISL eastern trawl CPUE indices and ISL zone-based indices for all zones and for individual zones.

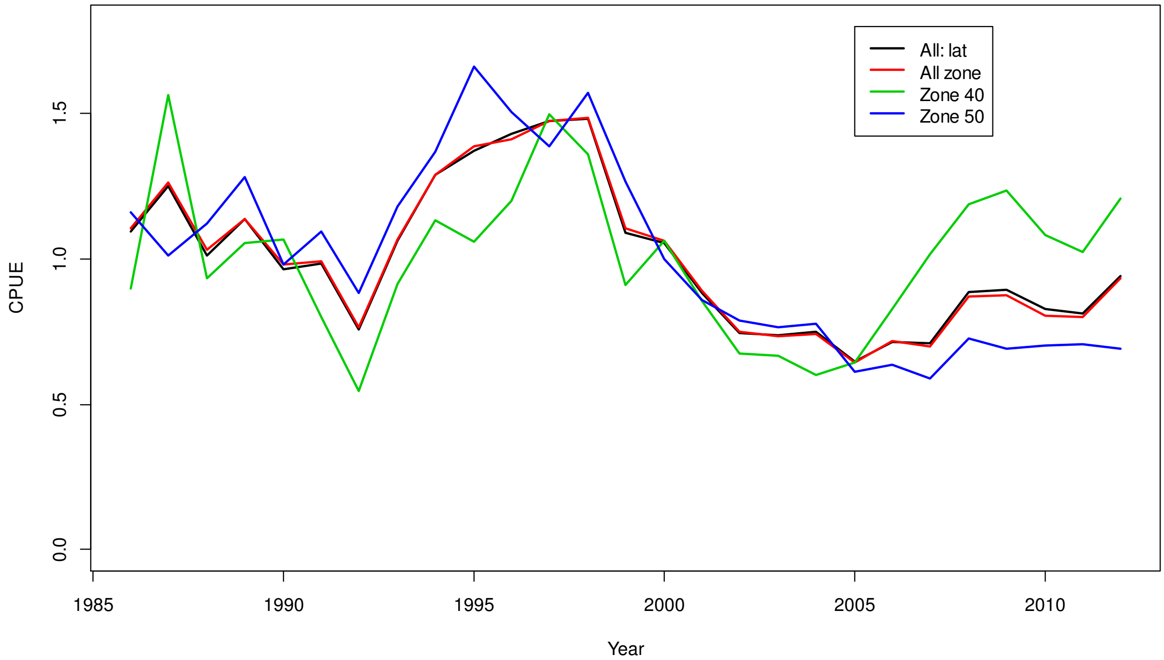
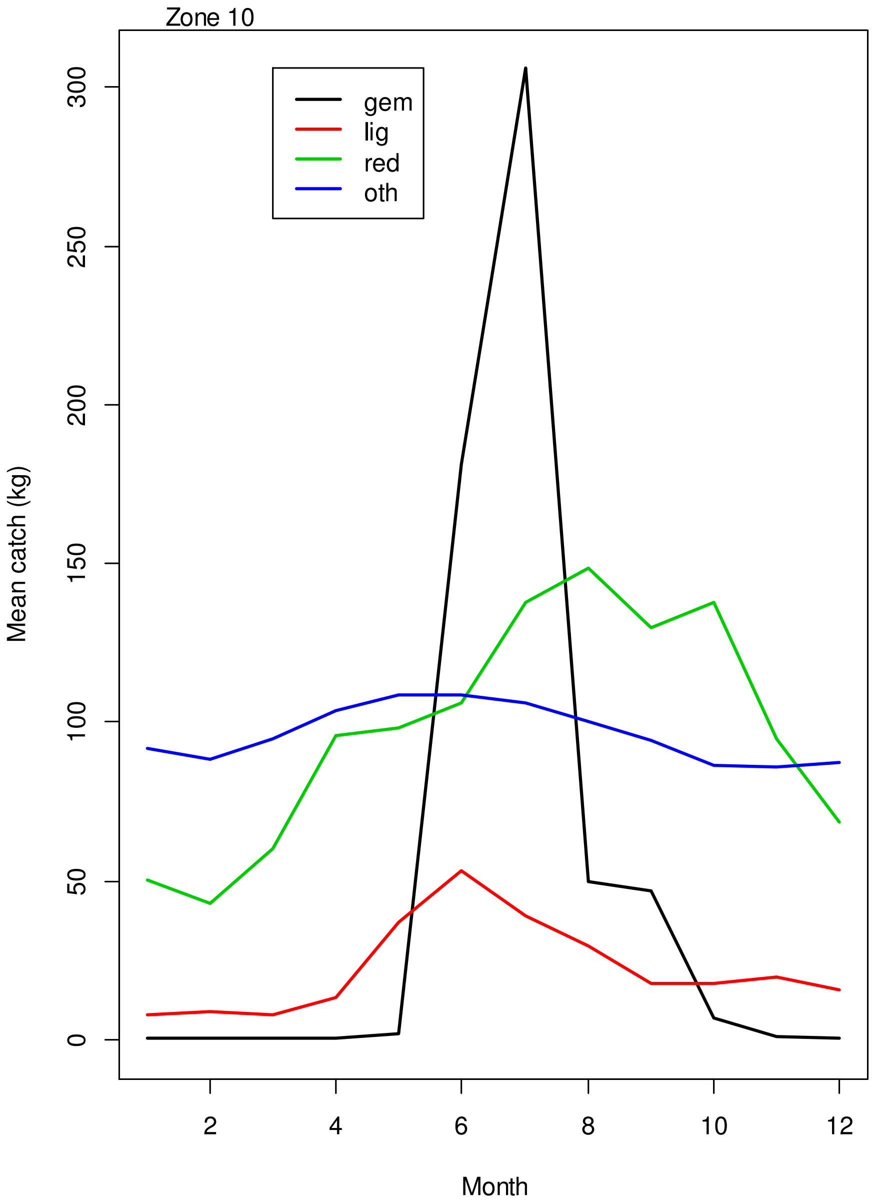
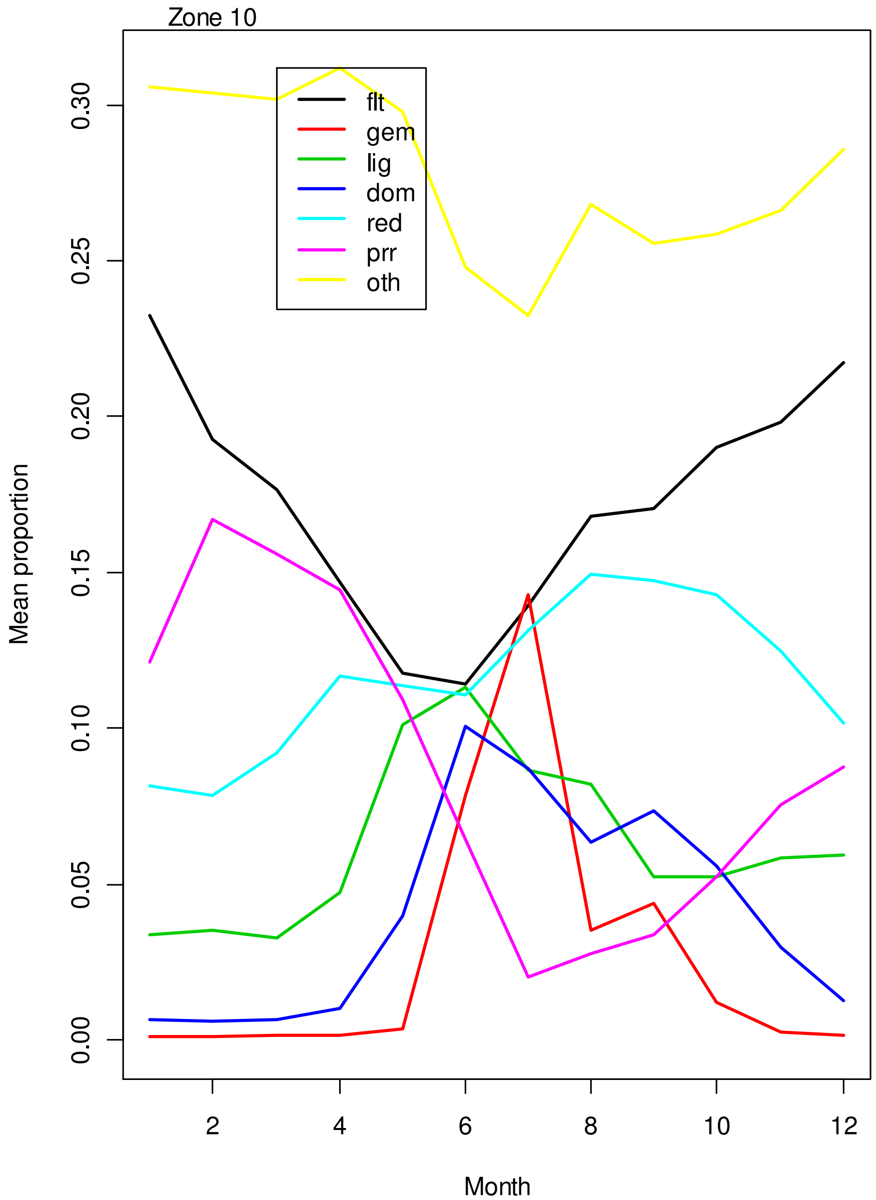


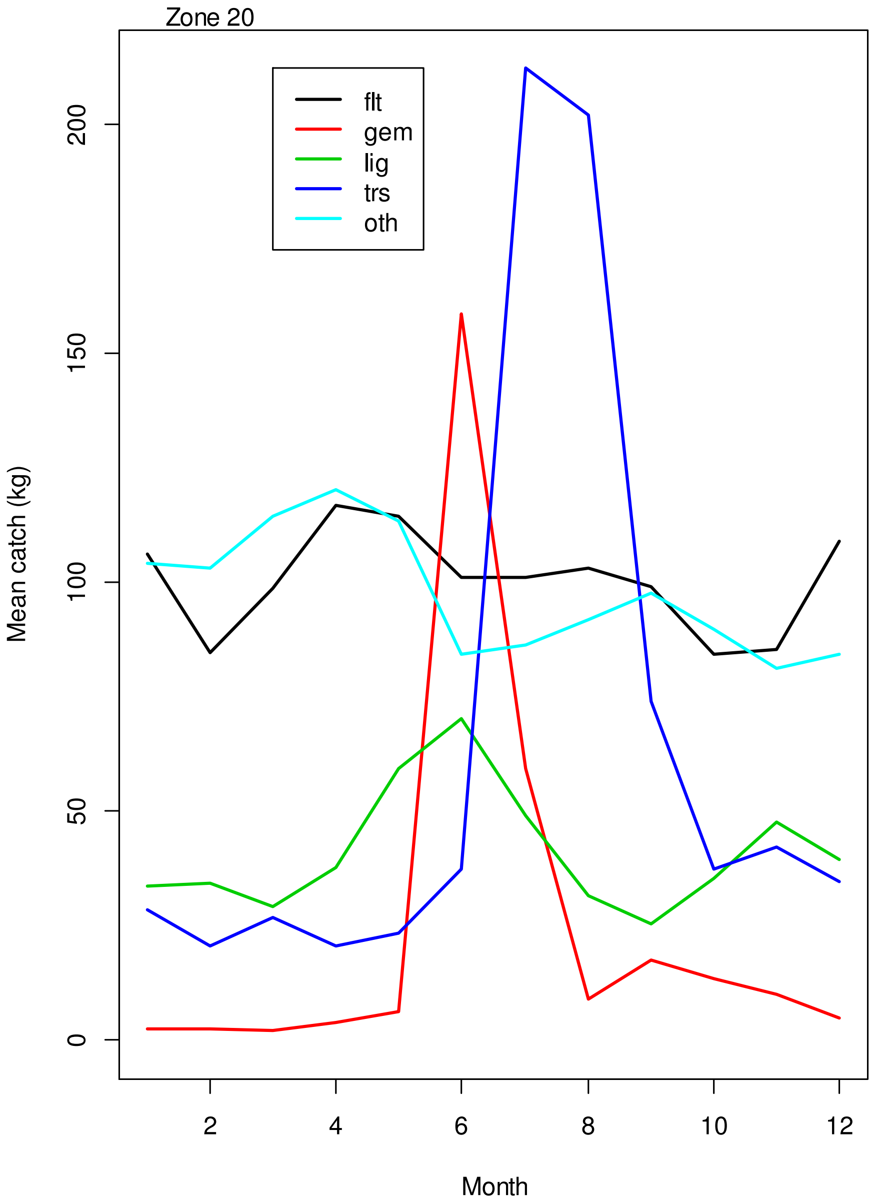
Figure 22: A comparison of the base ISL western trawl CPUE indices and ISL zone-based indices for all zones and for individual zones.

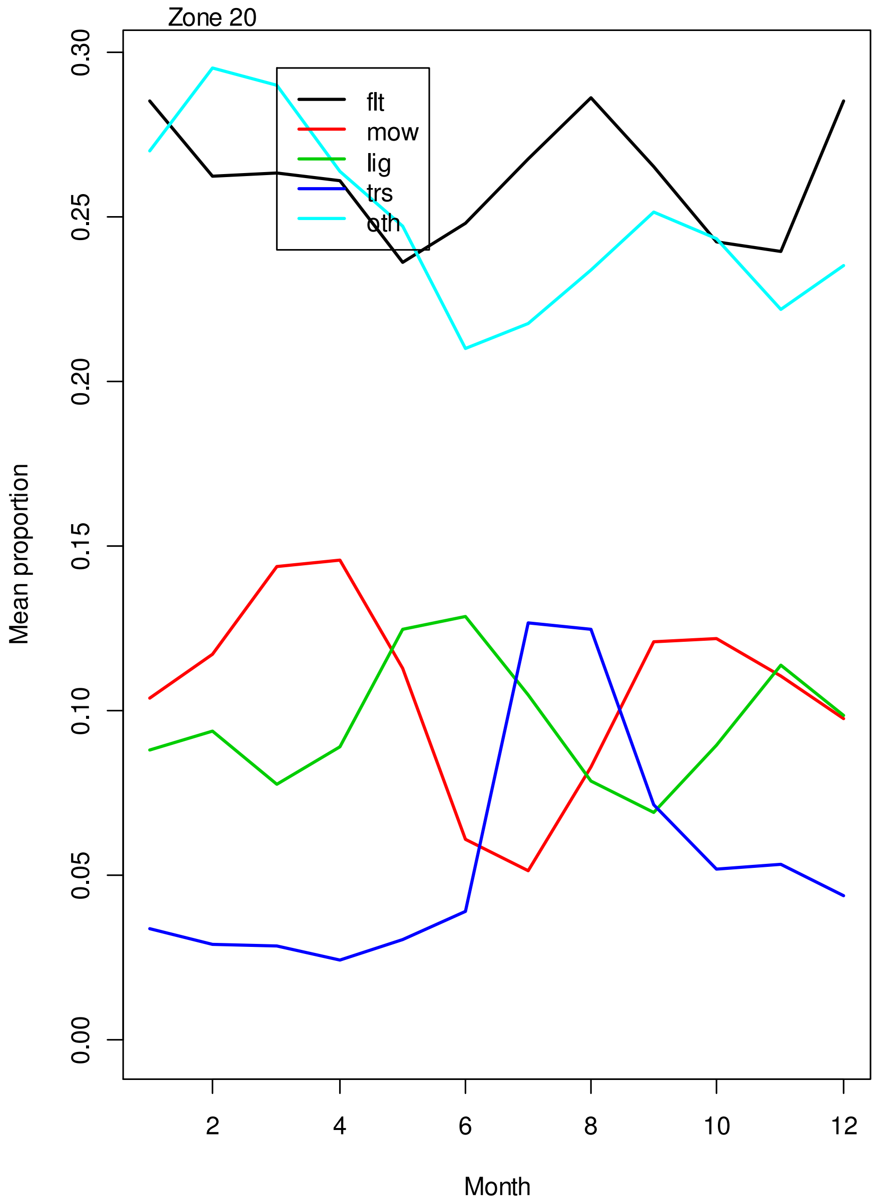
Appendix 1: Summary plots by zone

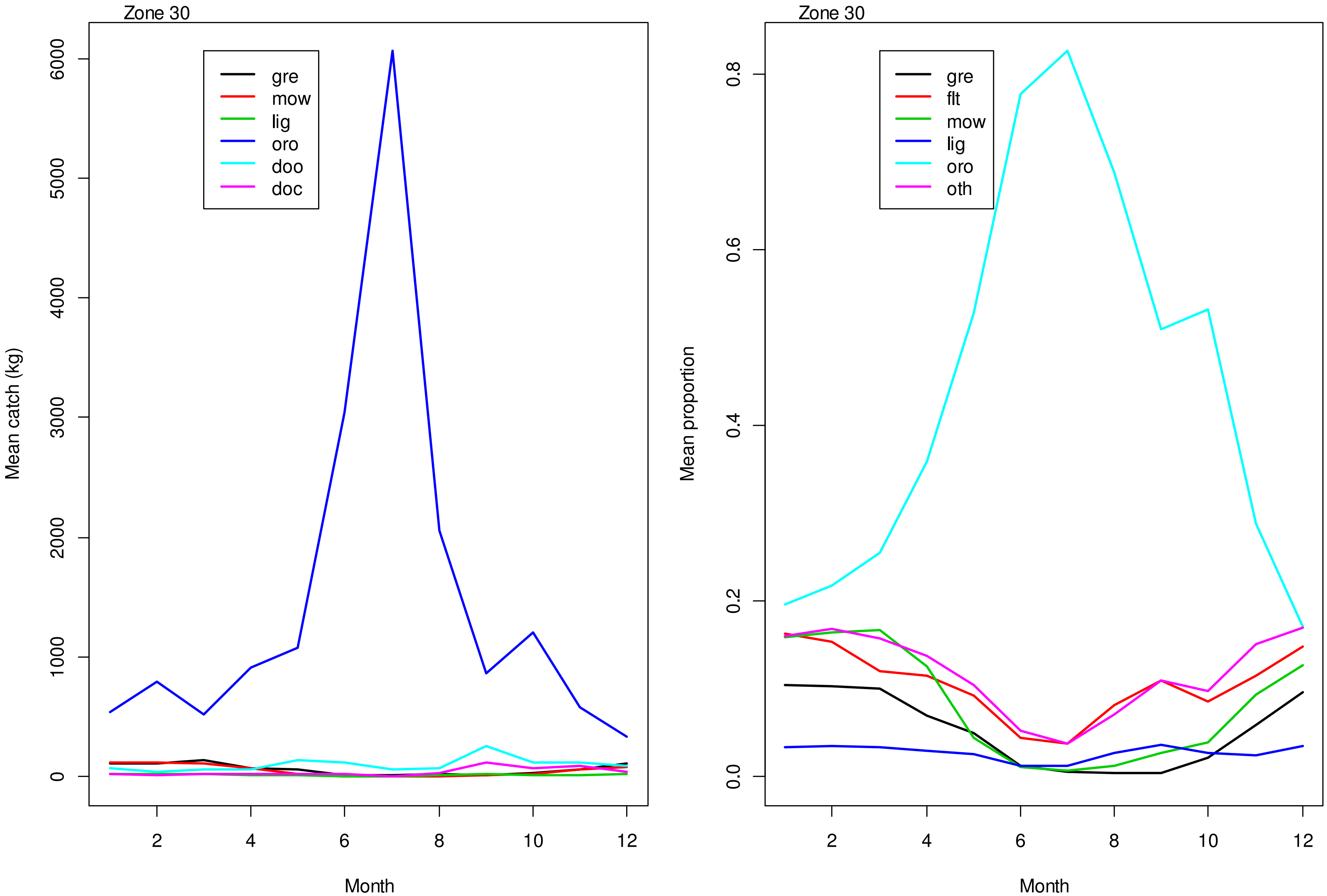
For each of Zones 10-80 two summary plots for catch by species, aggregated over all years, are given. The plots are for the 157 vessels which accounted for about 99% of the ling catch. The plots, from left to right, are mean catch by month and mean proportion-of-total-catch by month (given for the species which were above some cutoff on the maximum monthly value).

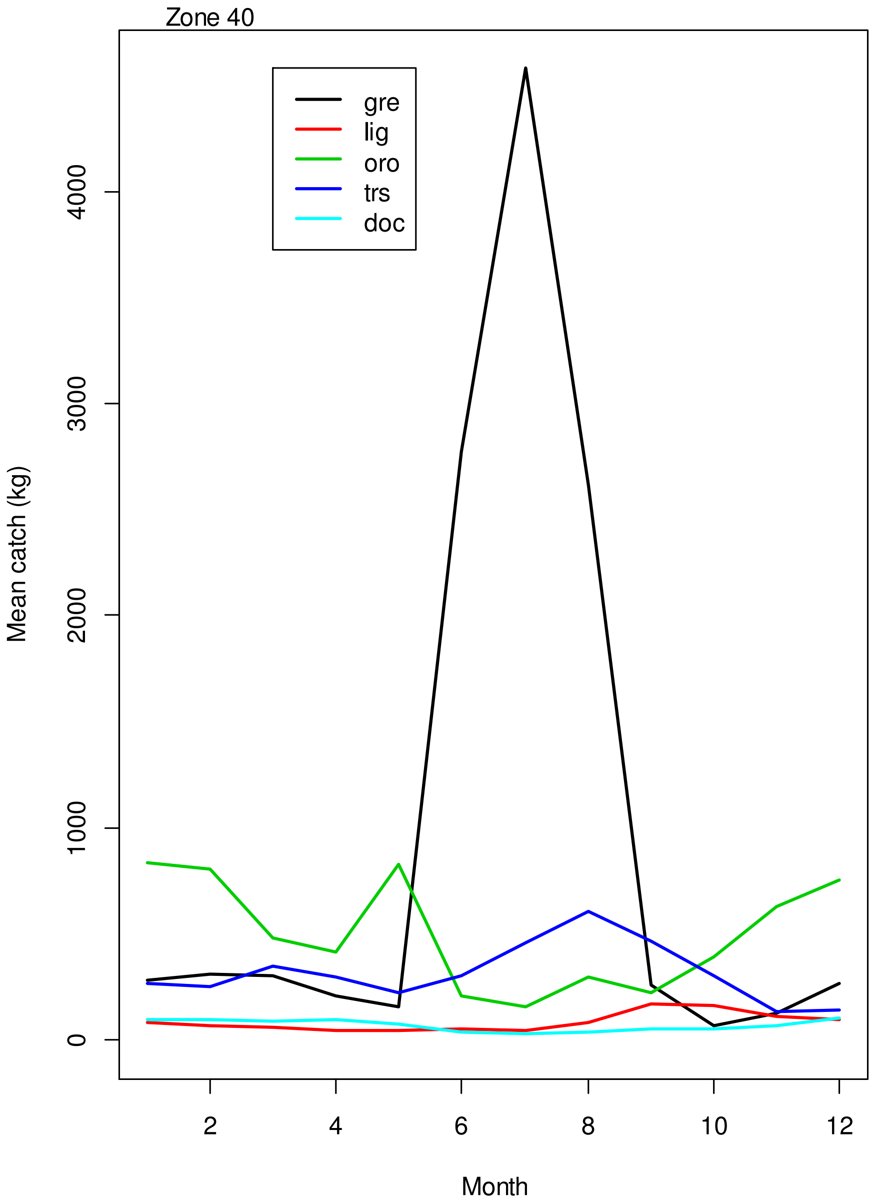

Zone 10
gem
lig
red
oth
Mean catch (kg)
0
50
100
150
200
250
300
2
4
6
8
10
12
Month

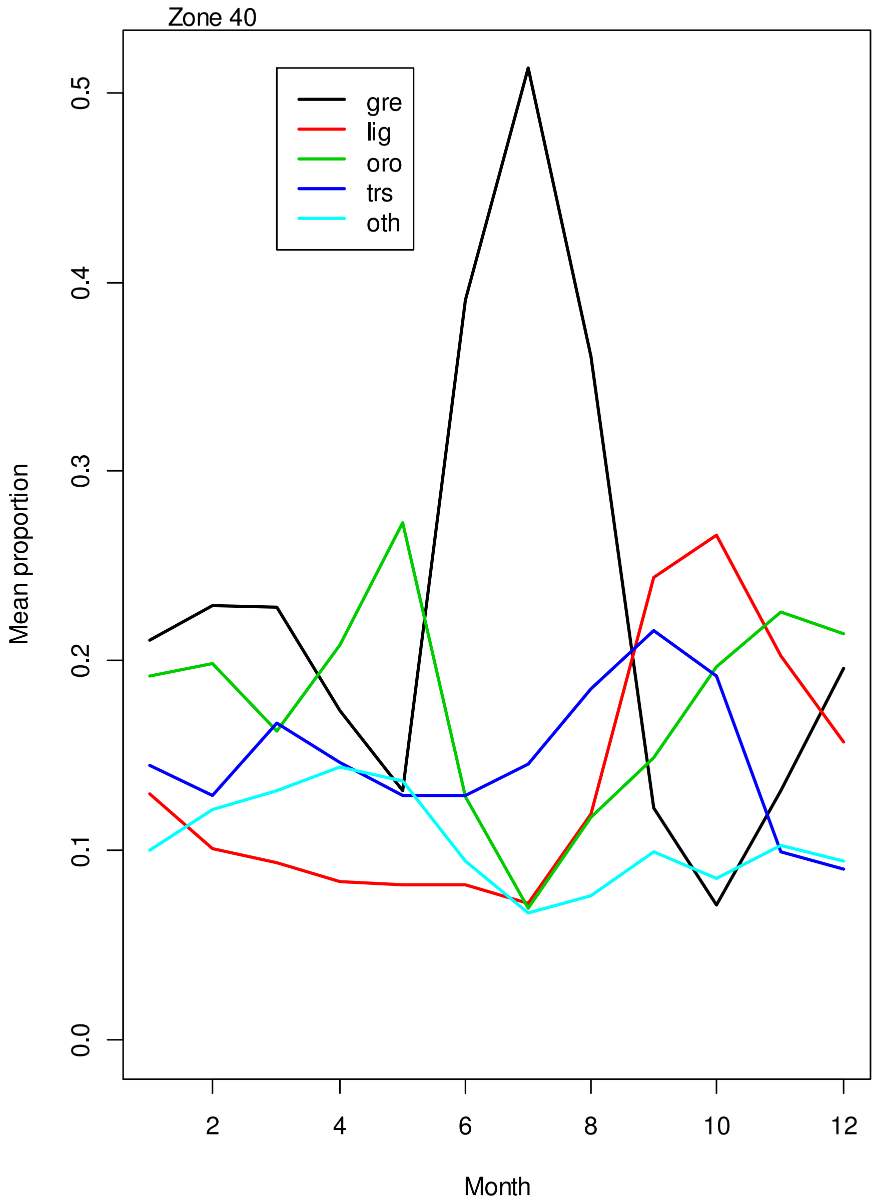

Zone 10
flt
gem
lig
dom
red
prr
oth
Mean proportion
0.00
0.05
0.10
0.15
0.20
0.25
0.30
2
4
6
8
10
12
Month

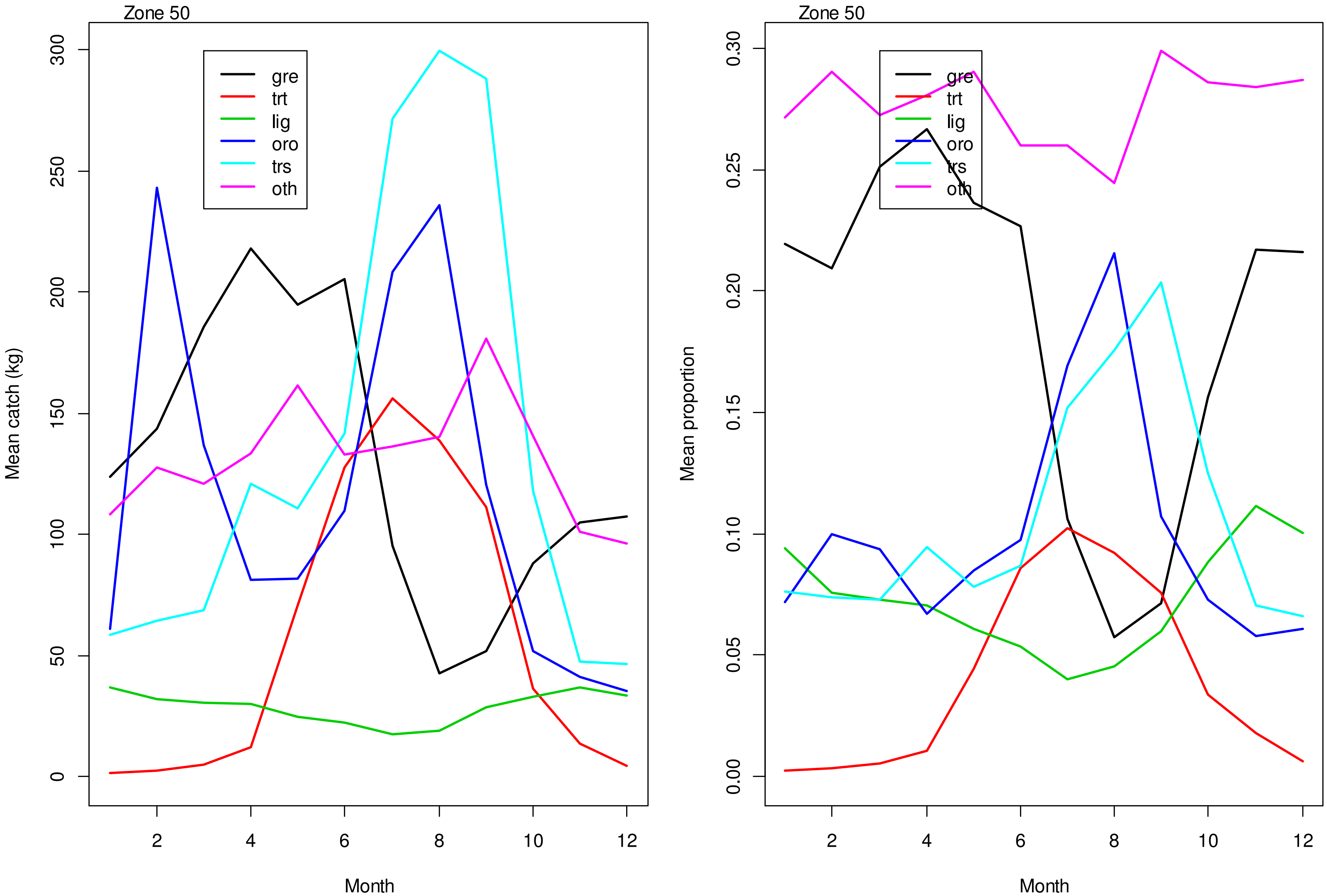

Zone 20
flt
gem
lig
trs
oth
Mean catch (kg)
0
50
100
150
200
2
4
6
8
10
12
Month

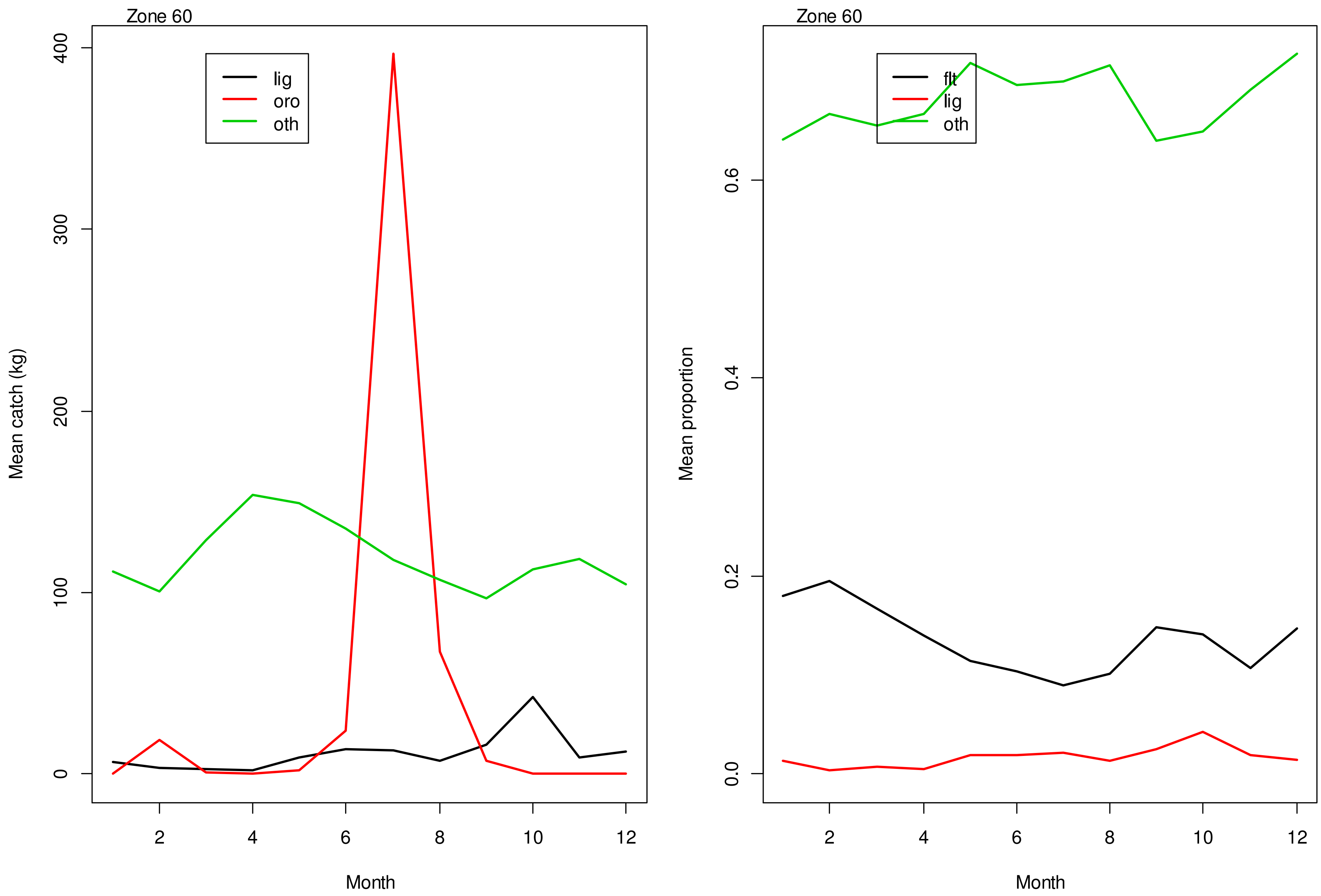

Zone 20
flt
mow
lig
trs
oth
Mean proportion
0.00
0.05
0.10
0.15
0.20
0.25
0.30
2
4
6
8
10
12
Month

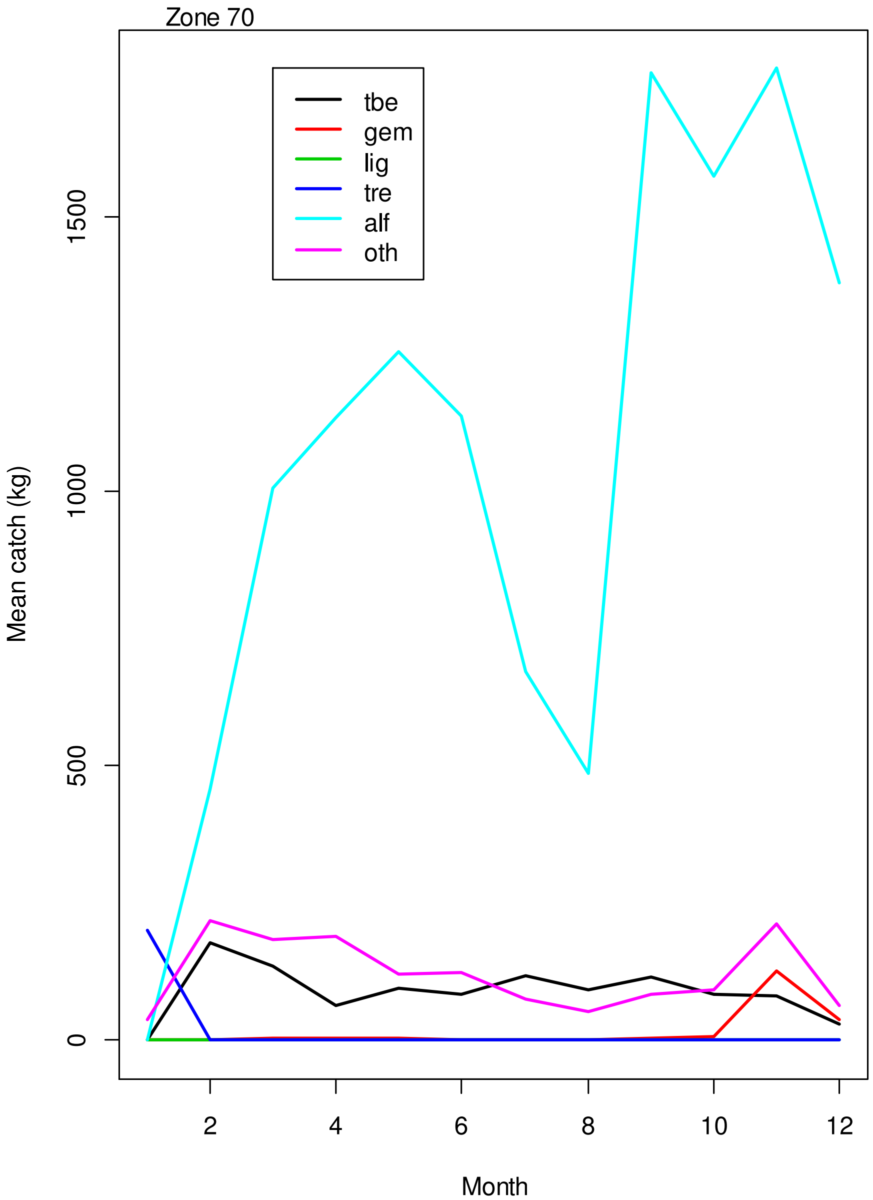

Zone 30
gre
mow
lig
oro
doo
doc
Mean catch (kg)
0
1000
2000
3000
4000
5000
6000
2
4
6
8
10
12
Month
Zone 30
gre
flt
mow
lig
oro
oth
Mean proportion
0.0
0.2
0.4
0.6
0.8
2
4
6
8
10
12
Month

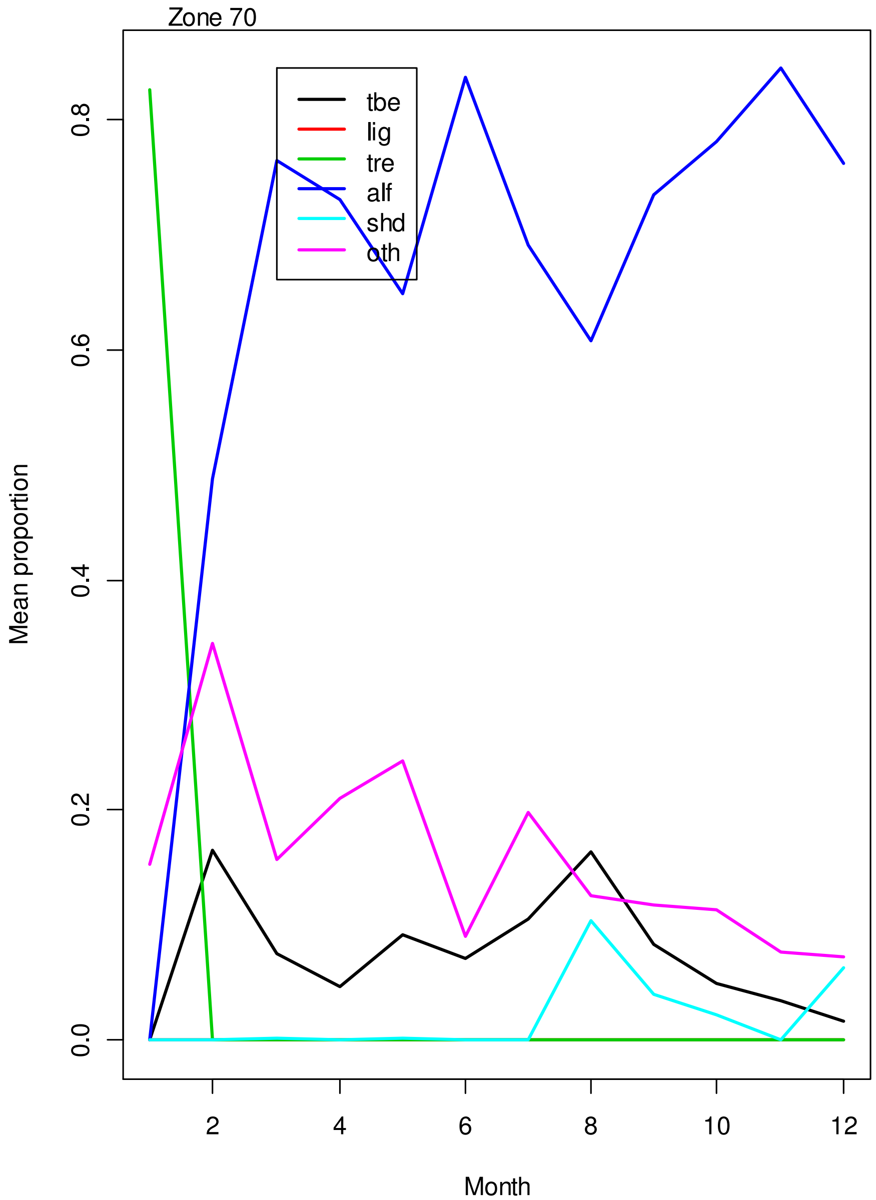

Zone 40
gre
lig
oro
trs
doc
Mean catch (kg)
0
1000
2000
3000
4000
2
4
6
8
10
12
Month

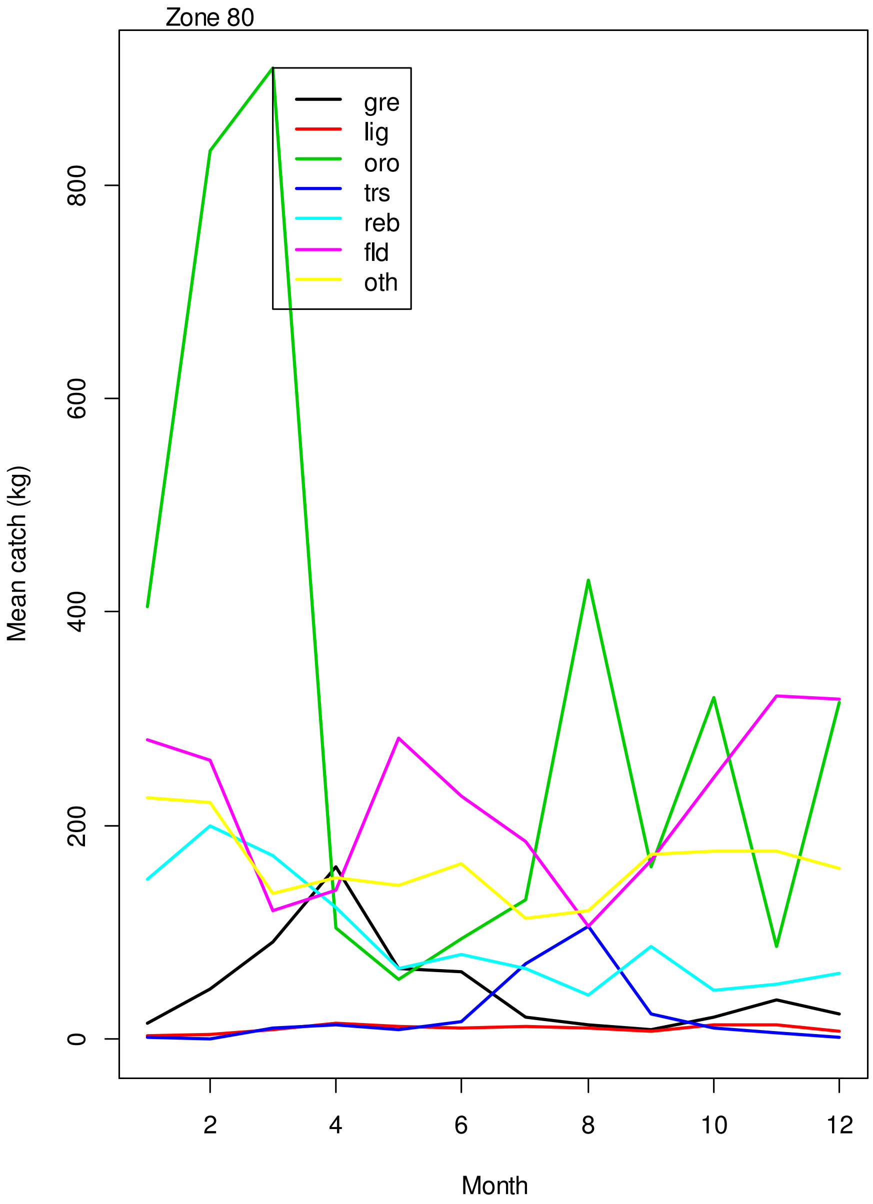

Zone 40
gre
lig
oro
trs
oth
Mean proportion
0.0
0.1
0.2
0.3
0.4
0.5
2
4
6
8
10
12
Month

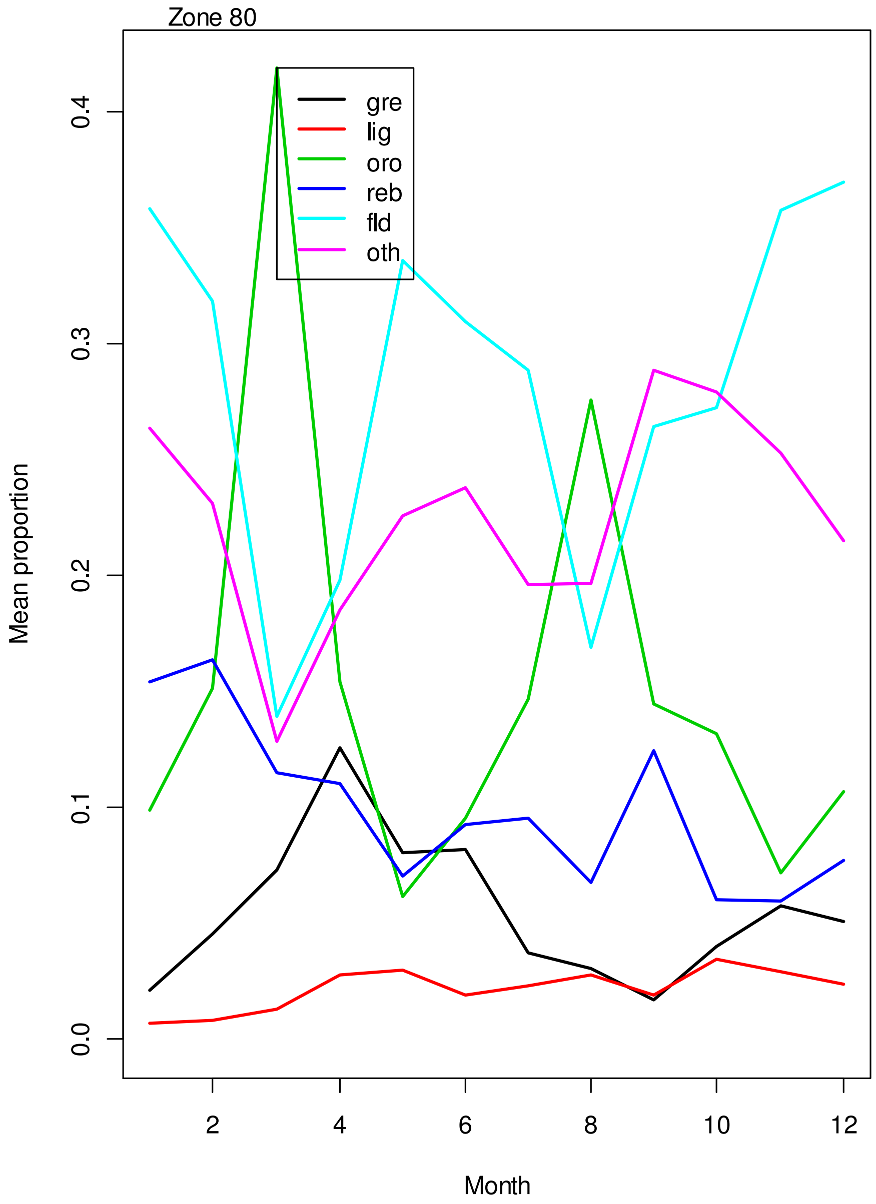

Zone 50
Mean catch (kg)
Month
gre
trt
lig
oro
trs
oth
Zone 50
Mean proportion
Month
gre
trt
lig
oro
trs
oth


Zone 60
lig
oro
oth
Mean catch (kg)
0
100
200
300
400
2
4
6
8
10
12
Month
Zone 60
flt
lig
oth
Mean proportion
0.0
0.2
0.4
0.6
2
4
6
8
10
12
Month


Zone 70
tbe
gem
lig
tre
alf
oth
Mean catch (kg)
0
500
1000
1500
2
4
6
8
10
12
Month


Zone 70
tbe
lig
tre
alf
shd
oth
Mean proportion
0.0
0.2
0.4
0.6
0.8
2
4
6
8
10
12
Month


Zone 80
gre
lig
oro
trs
reb
fld
oth
Mean catch (kg)
0
200
400
600
800
2
4
6
8
10
12
Month

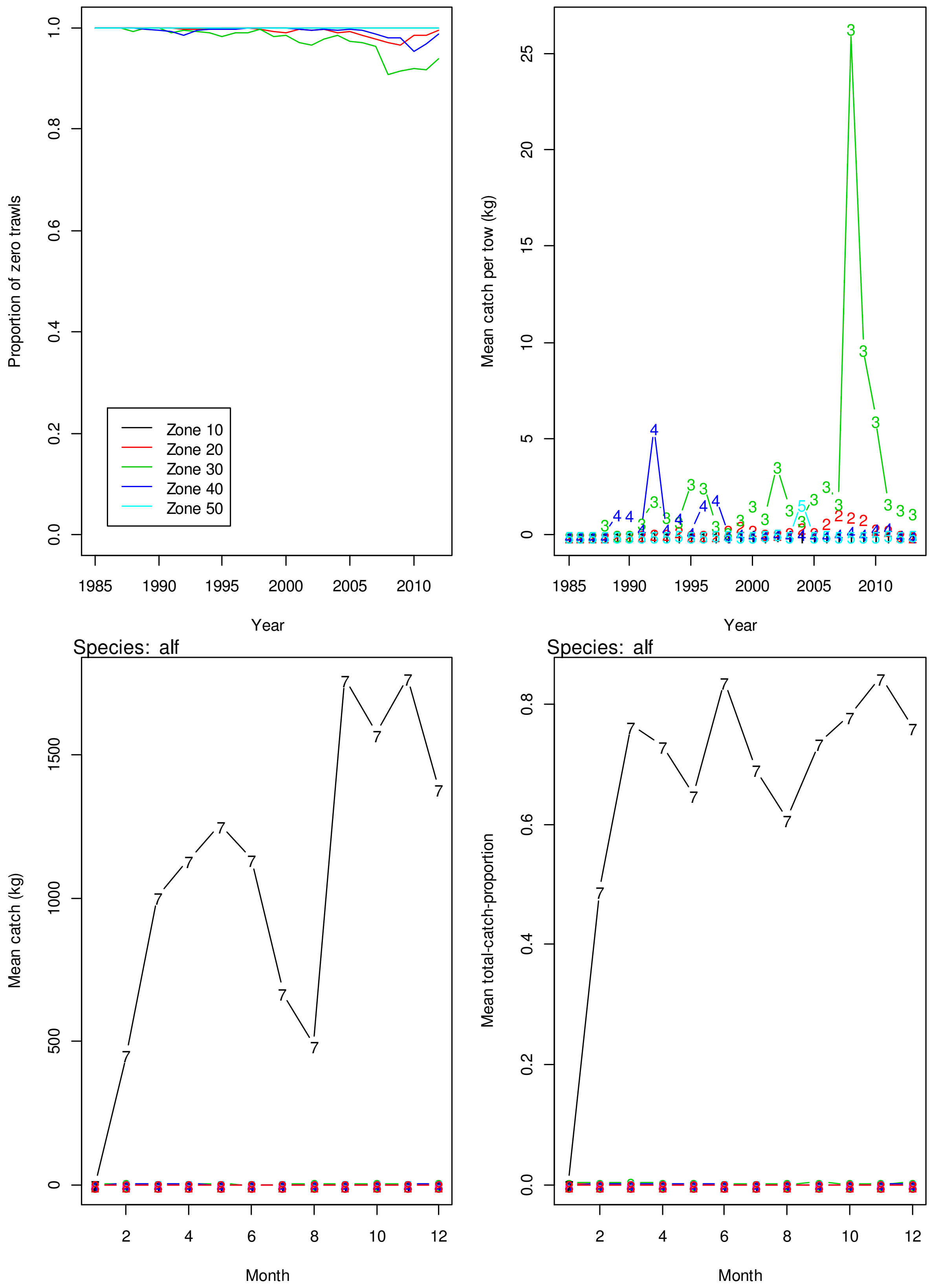

Zone 80
gre
lig
oro
reb
fld
oth
Mean proportion
0.0
0.1
0.2
0.3
0.4
2
4
6
8
10
12
Month

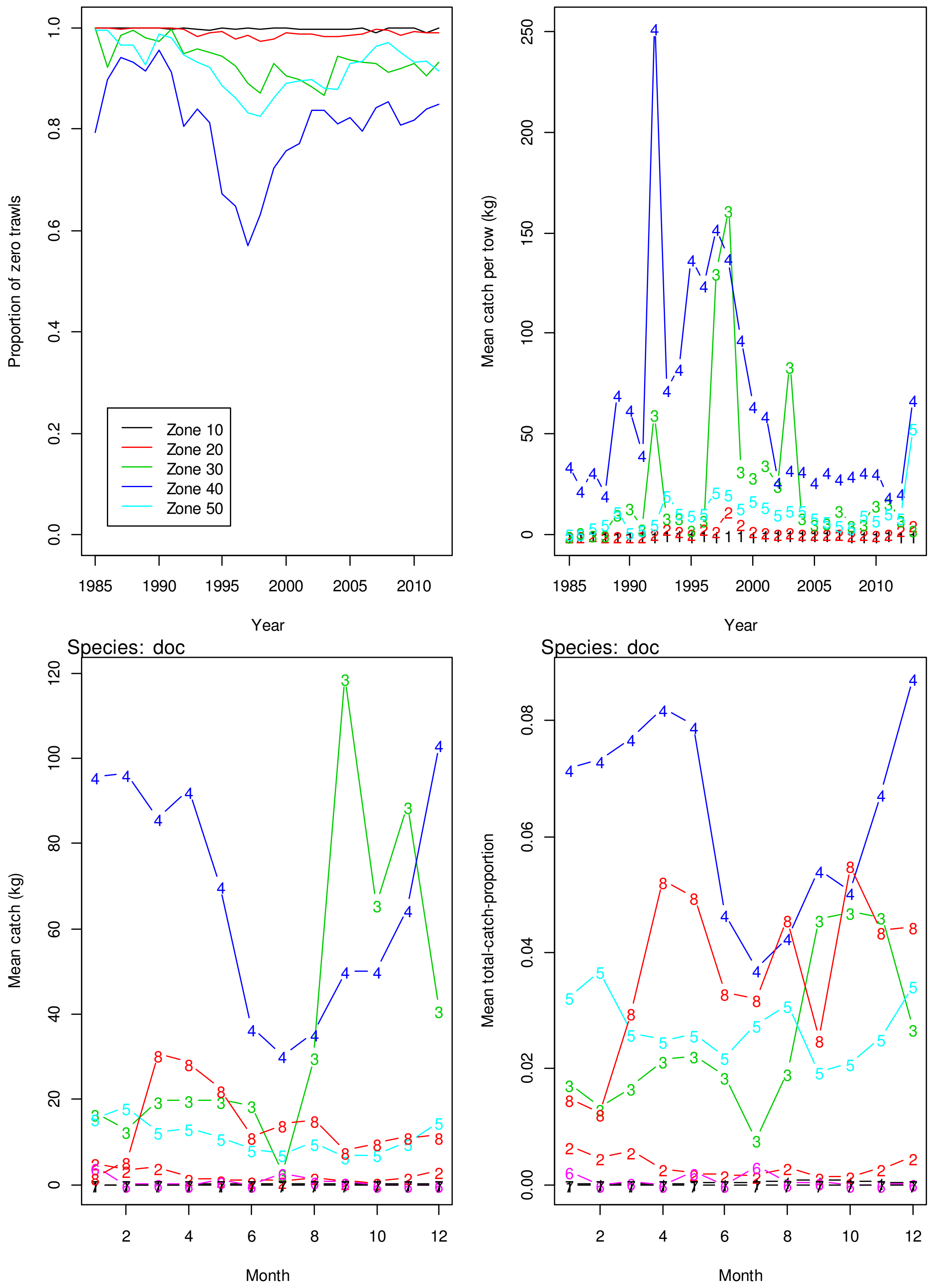
Appendix 2: Species summary plots

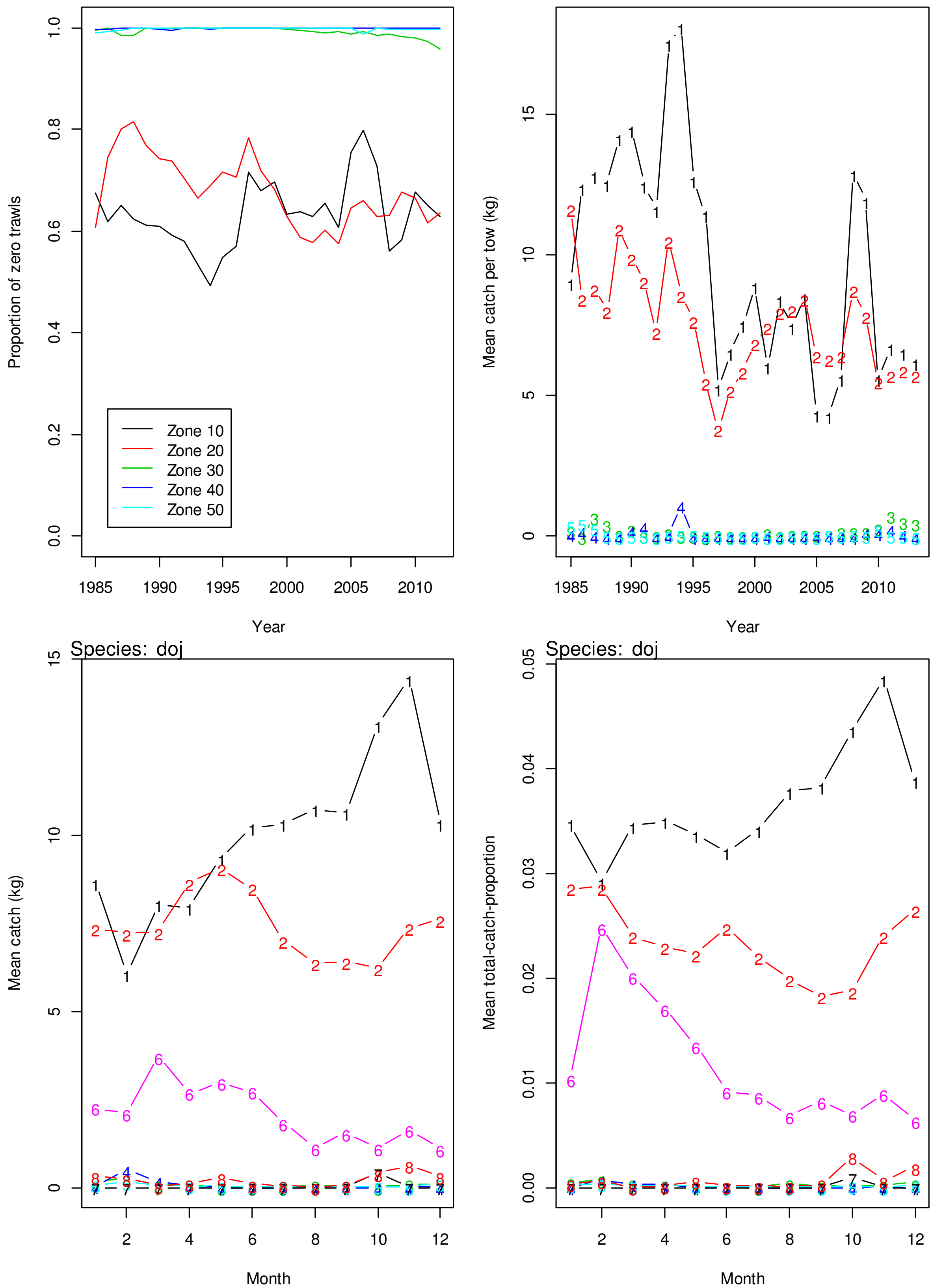
These plots are in two sections. They are for catches associated with the 157 vessels which caught about 99% of the ling trawl catch. They do not cover catches from all trawl vessels – just those associated with ling in this study.

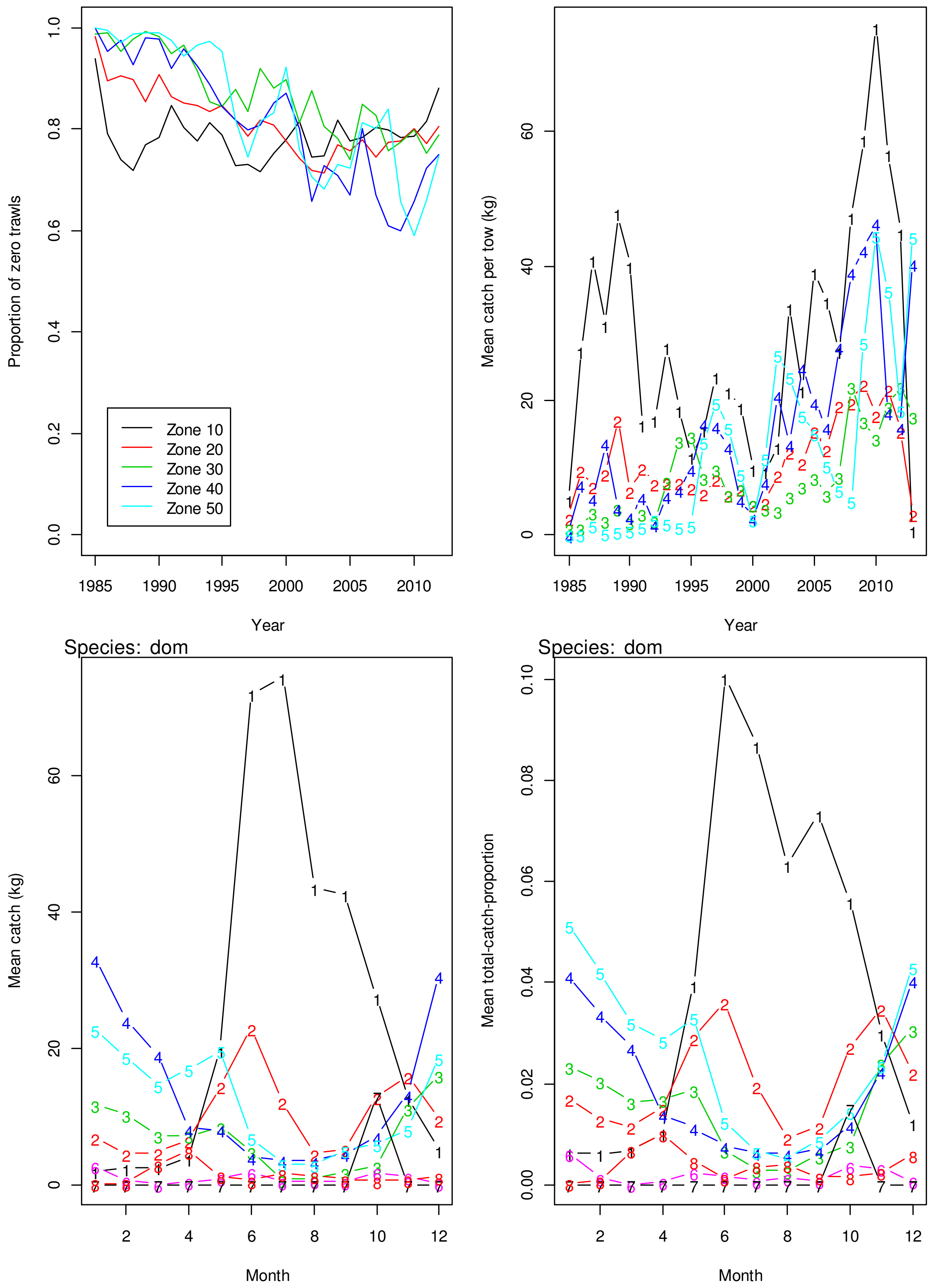
The first section has four plots for each species: proportion of tows on which a zero catch was recorded for the species, by zone (10-50) and year; mean catch per tow by zone(10-50) and year; mean catch per tow by month, aggregated over years, for zones 10-80; mean proportion-of-total-catch by month, aggregated over years, for zones 10-80.

The second section also has four plots for each species: mean catch per tow by depth class and zone (10-80) aggregated over years; mean catch per tow by depth class and month, aggregated over years; mean catch per tow by depth class and year; annual correlation coefficient for the species catch and ling catch by zone (10-50).

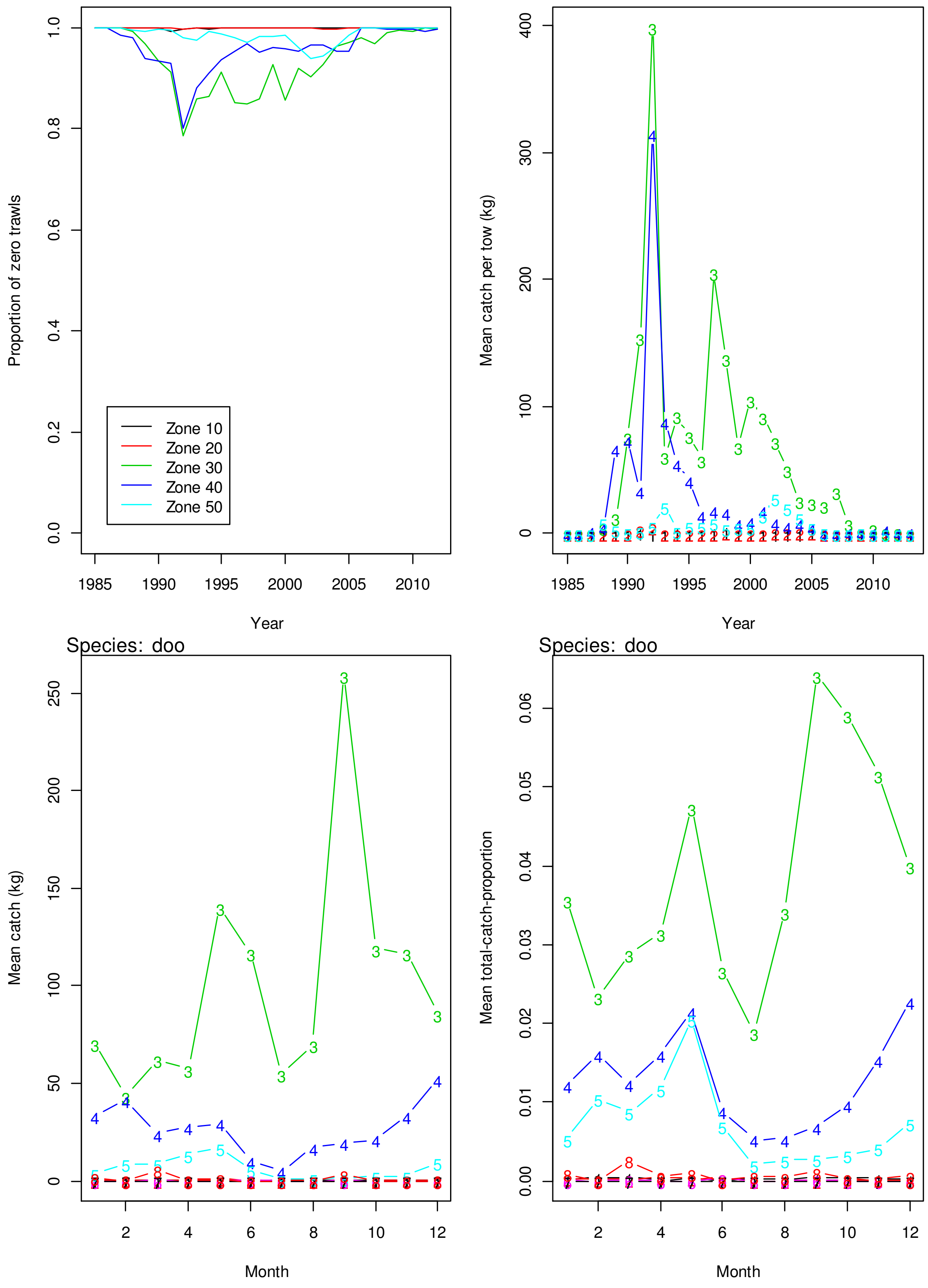

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: alf
Mean catch (kg)
Month
Species: alf
Mean total-catch-proportion
Month


Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: doc
Mean catch (kg)
Month
Species: doc
Mean total-catch-proportion
Month

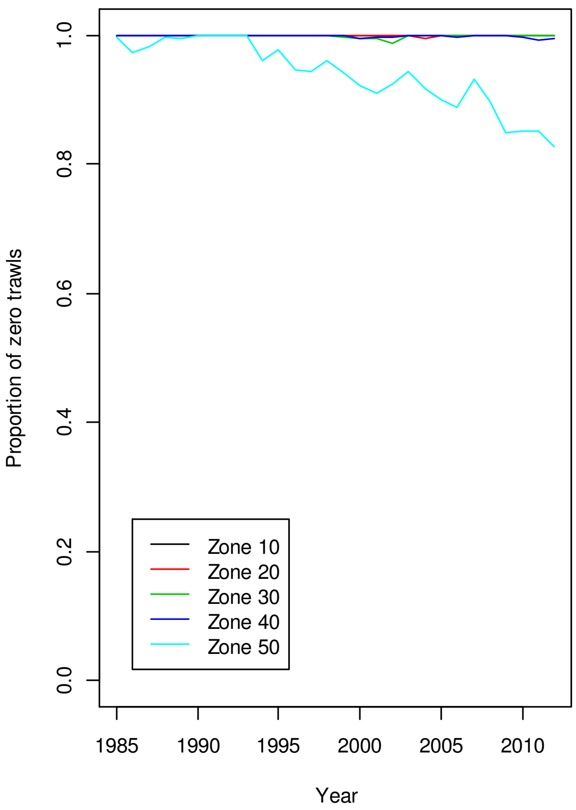

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: doj
Mean catch (kg)
Month
Species: doj
Mean total-catch-proportion
Month

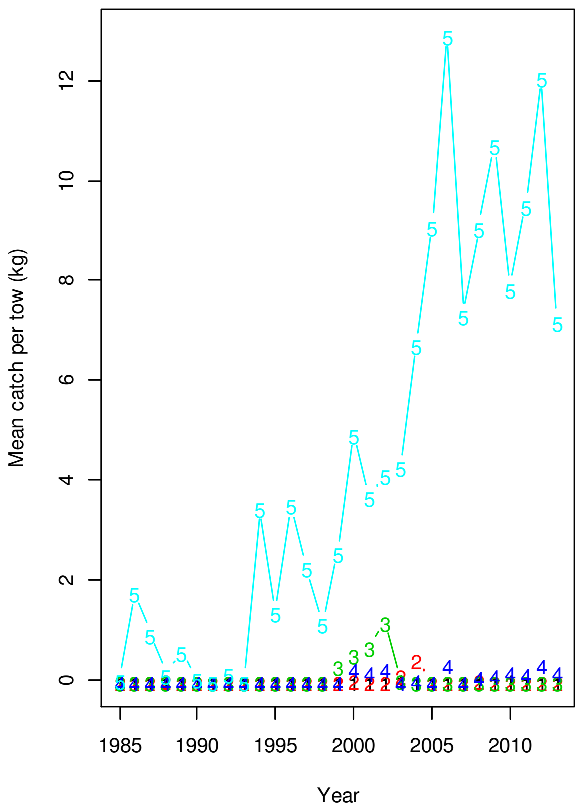


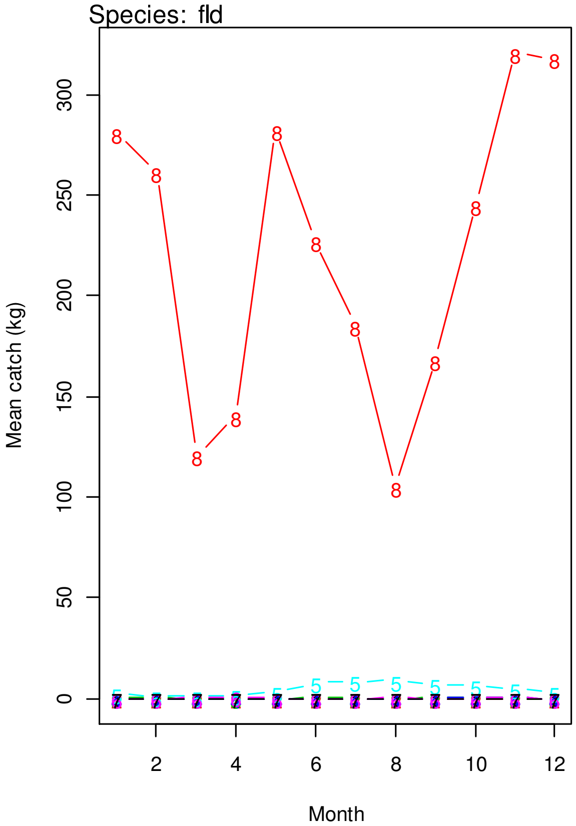
Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: dom
Mean catch (kg)
Month
Species: dom
Mean total-catch-proportion
Month

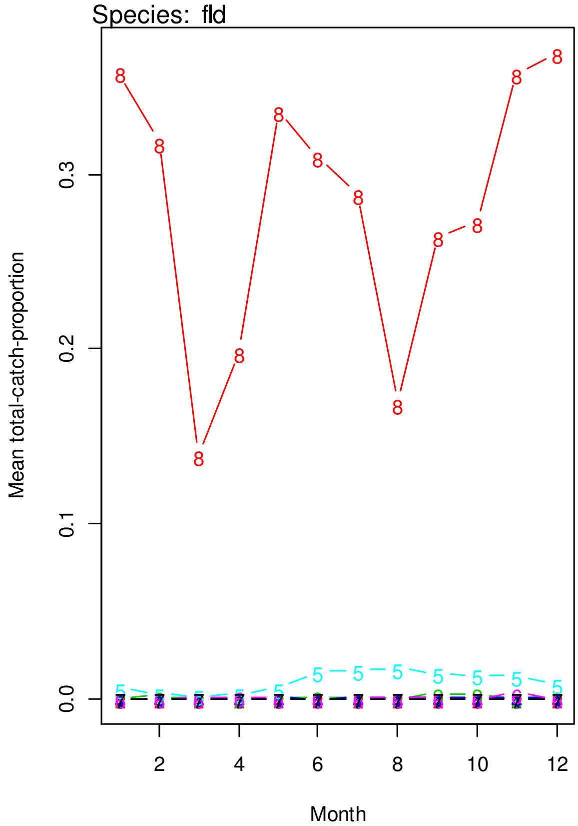


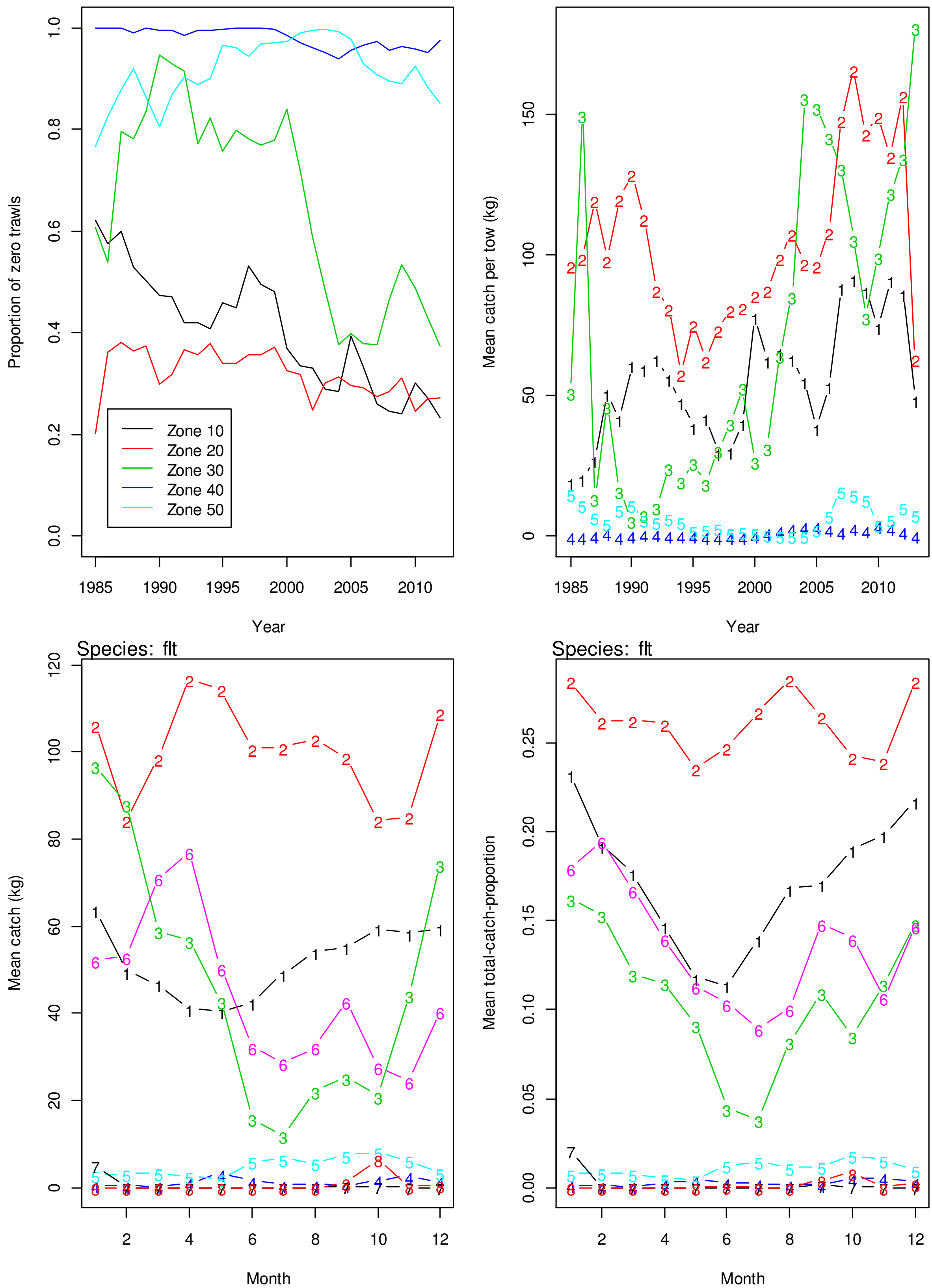
Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: doo
Mean catch (kg)
Month
Species: doo
Mean total-catch-proportion
Month


Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
0.0
0.2
0.4
0.6
0.8
1.0
1985
1990
1995
2000
2005
2010

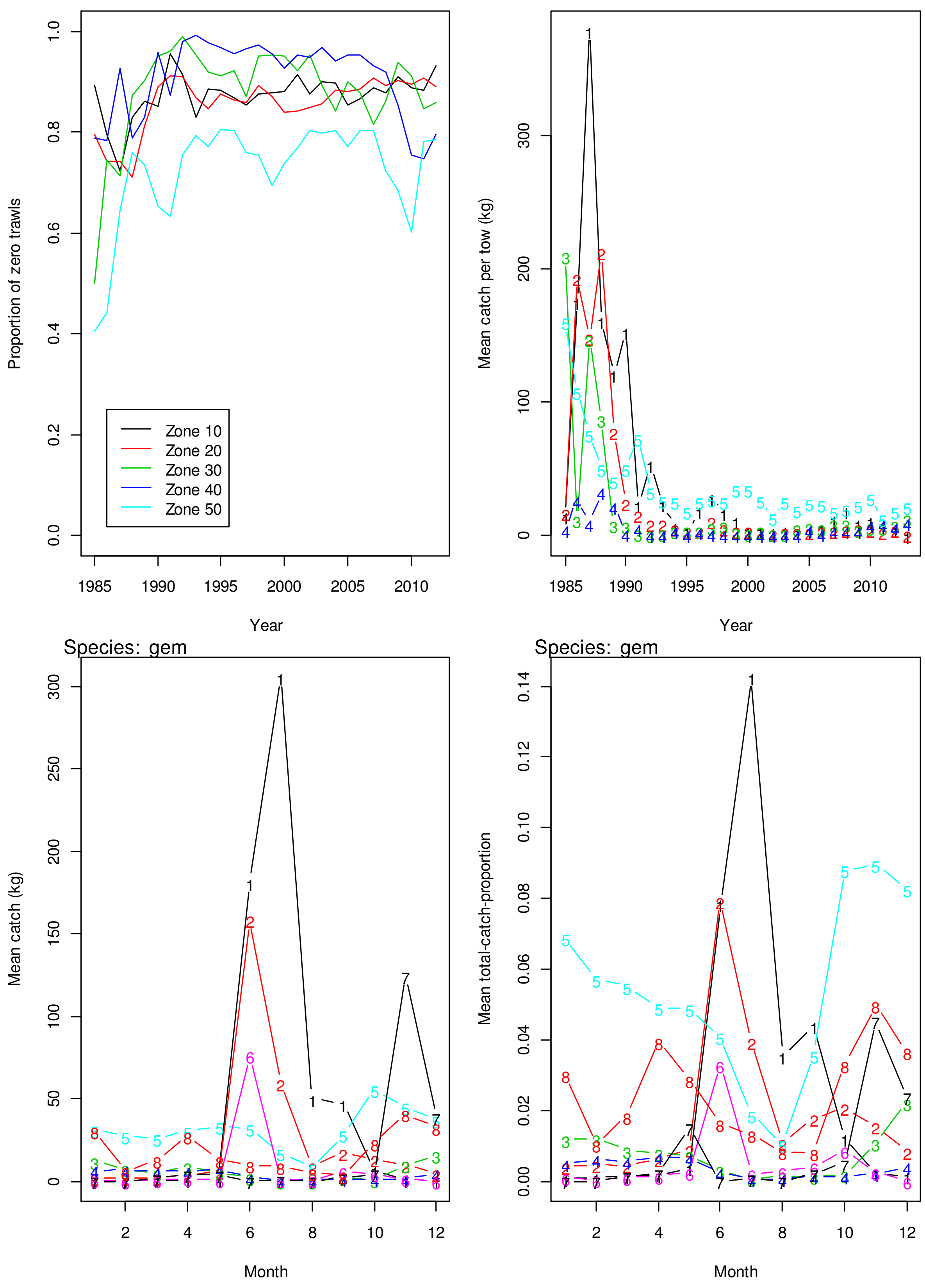

Mean catch per tow (kg)
Year
0
2
4
6
8
10
12
1985
1990
1995
2000
2005
2010


Species: fld
Mean catch (kg)
Month
0
50
100
150
200
250
300
2
4
6
8
10
12

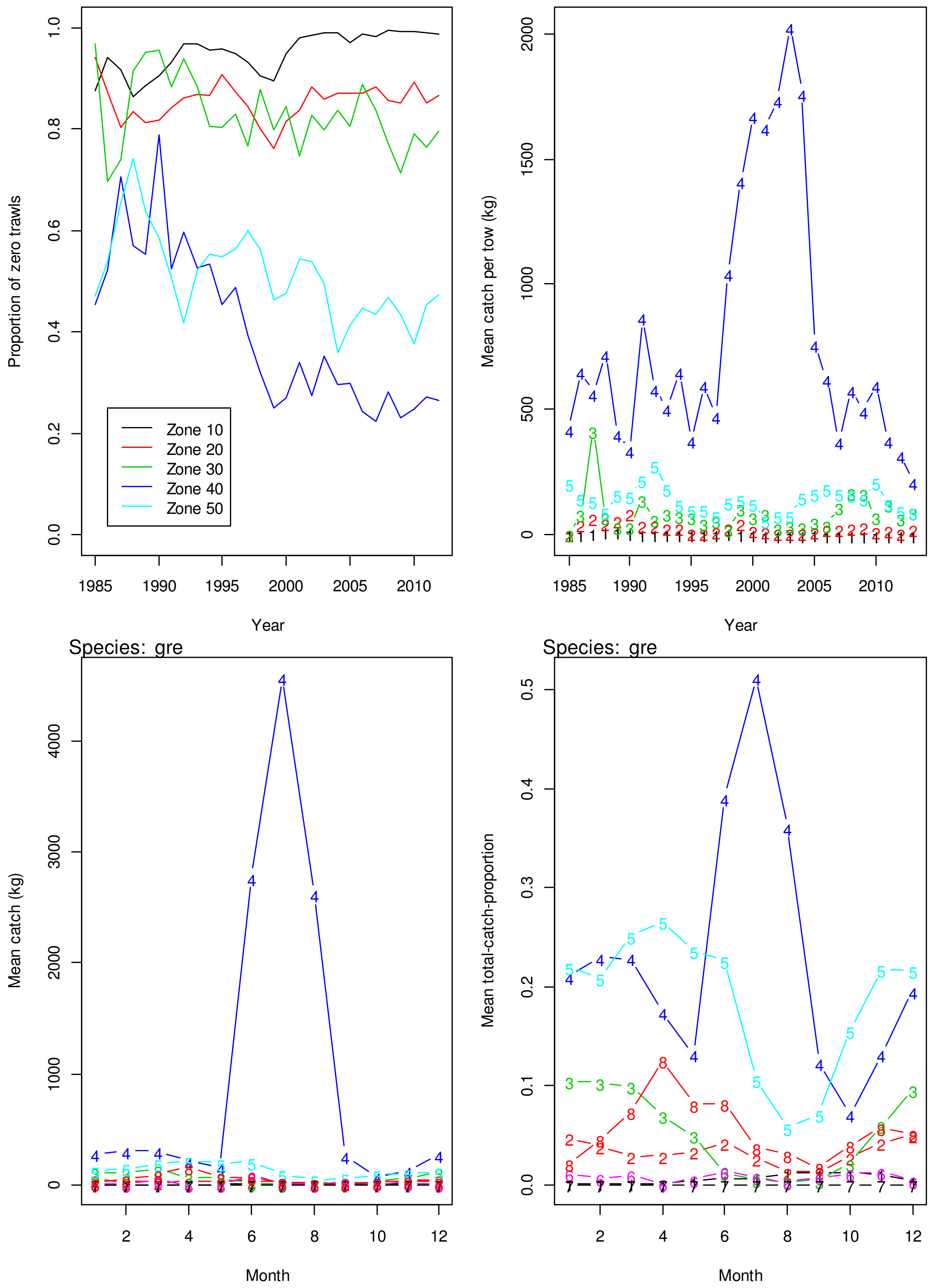

Species: fld
Mean total-catch-proportion
Month
0.0
0.1
0.2
0.3
2
4
6
8
10
12

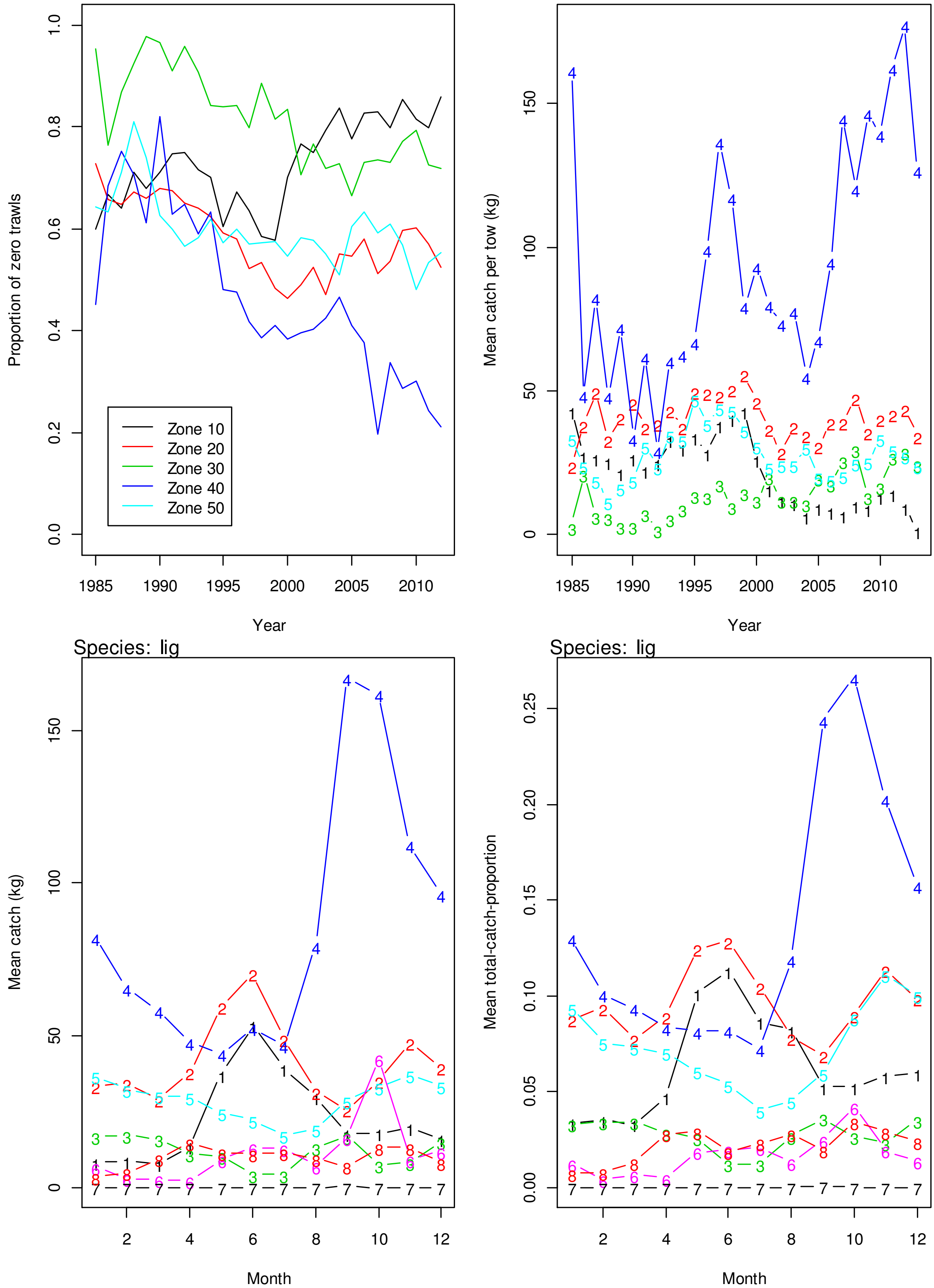


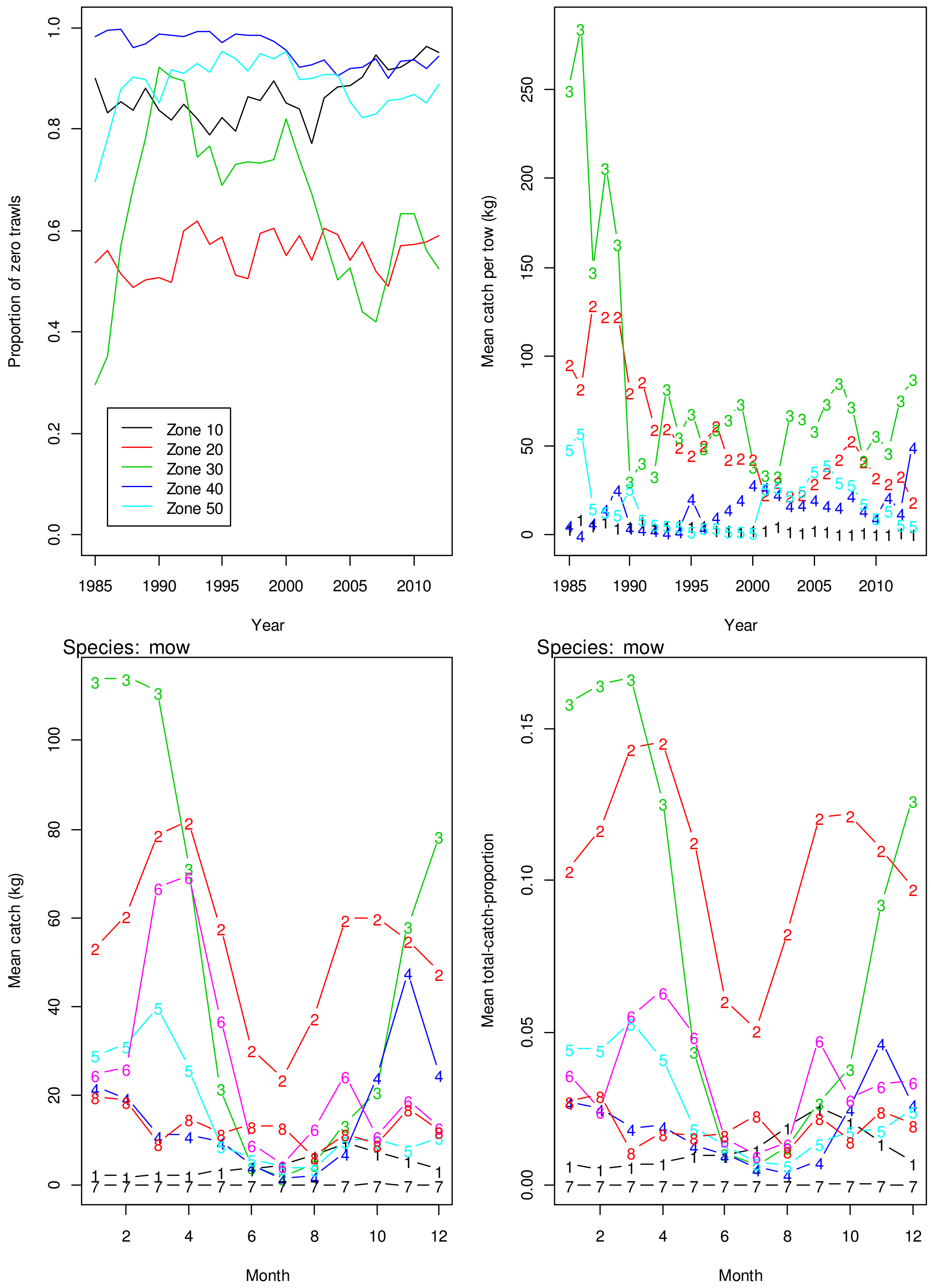
Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: flt
Mean catch (kg)
Month
Species: flt
Mean total-catch-proportion
Month

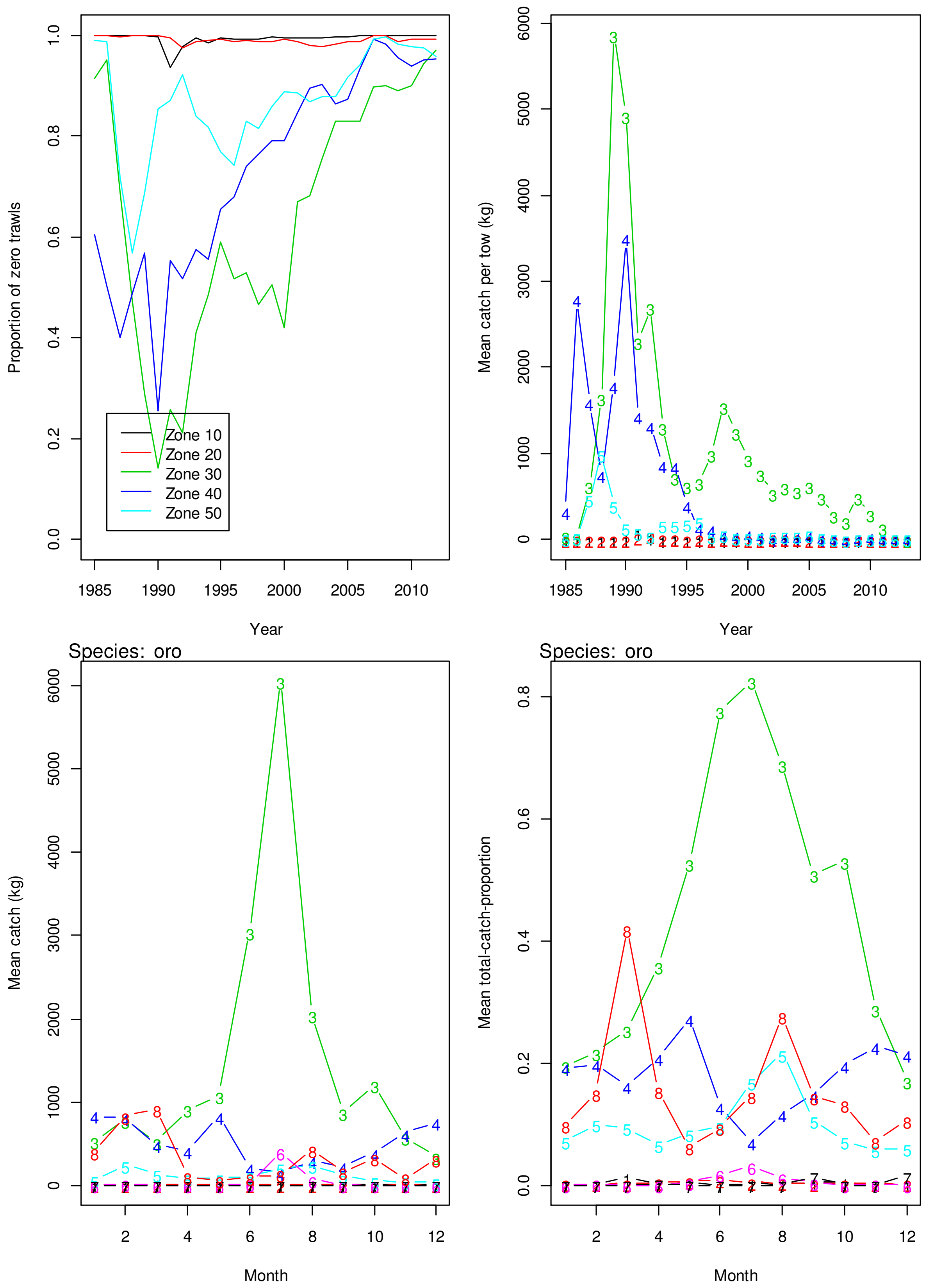


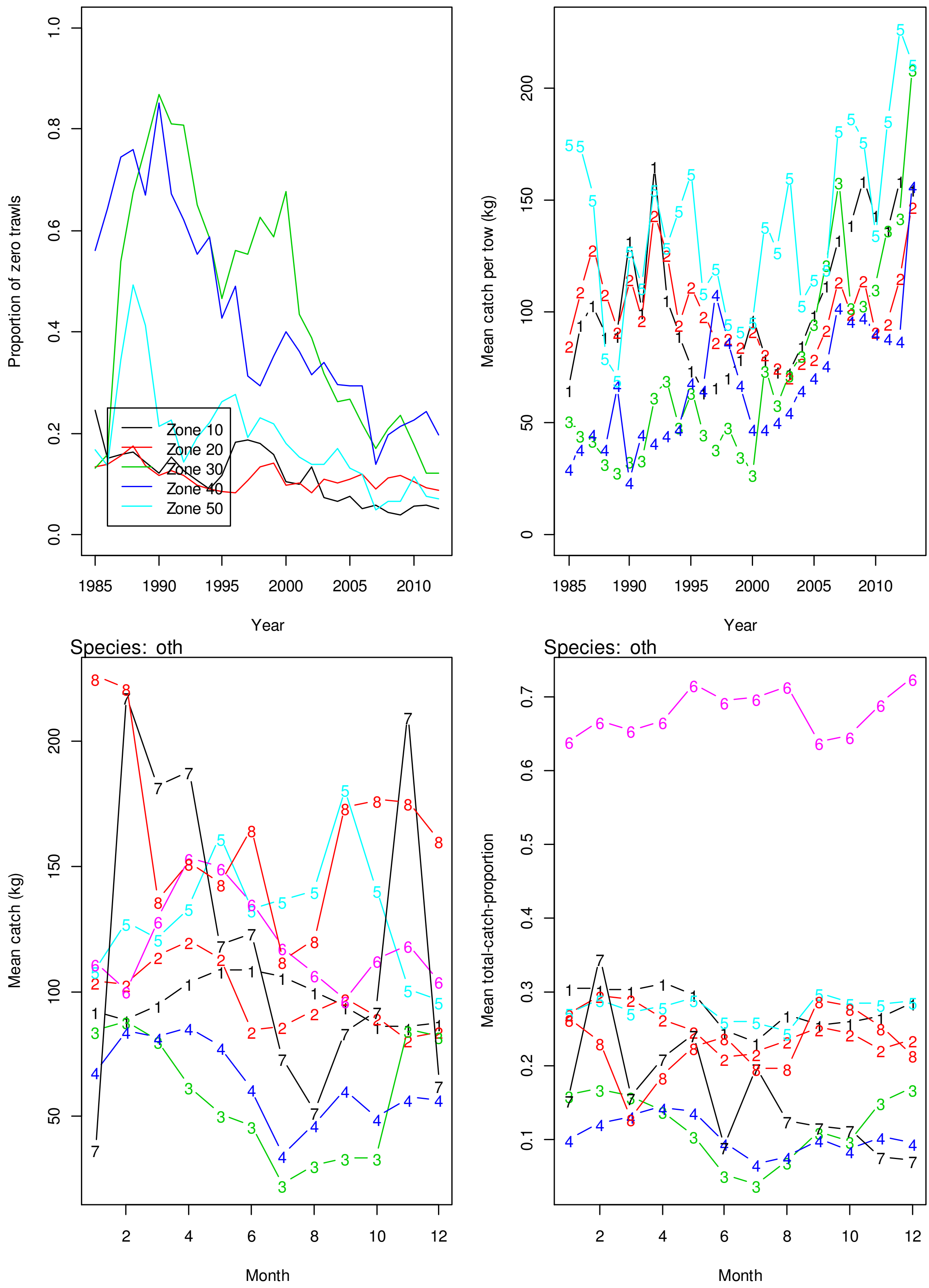
Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: gem
Mean catch (kg)
Month
Species: gem
Mean total-catch-proportion
Month

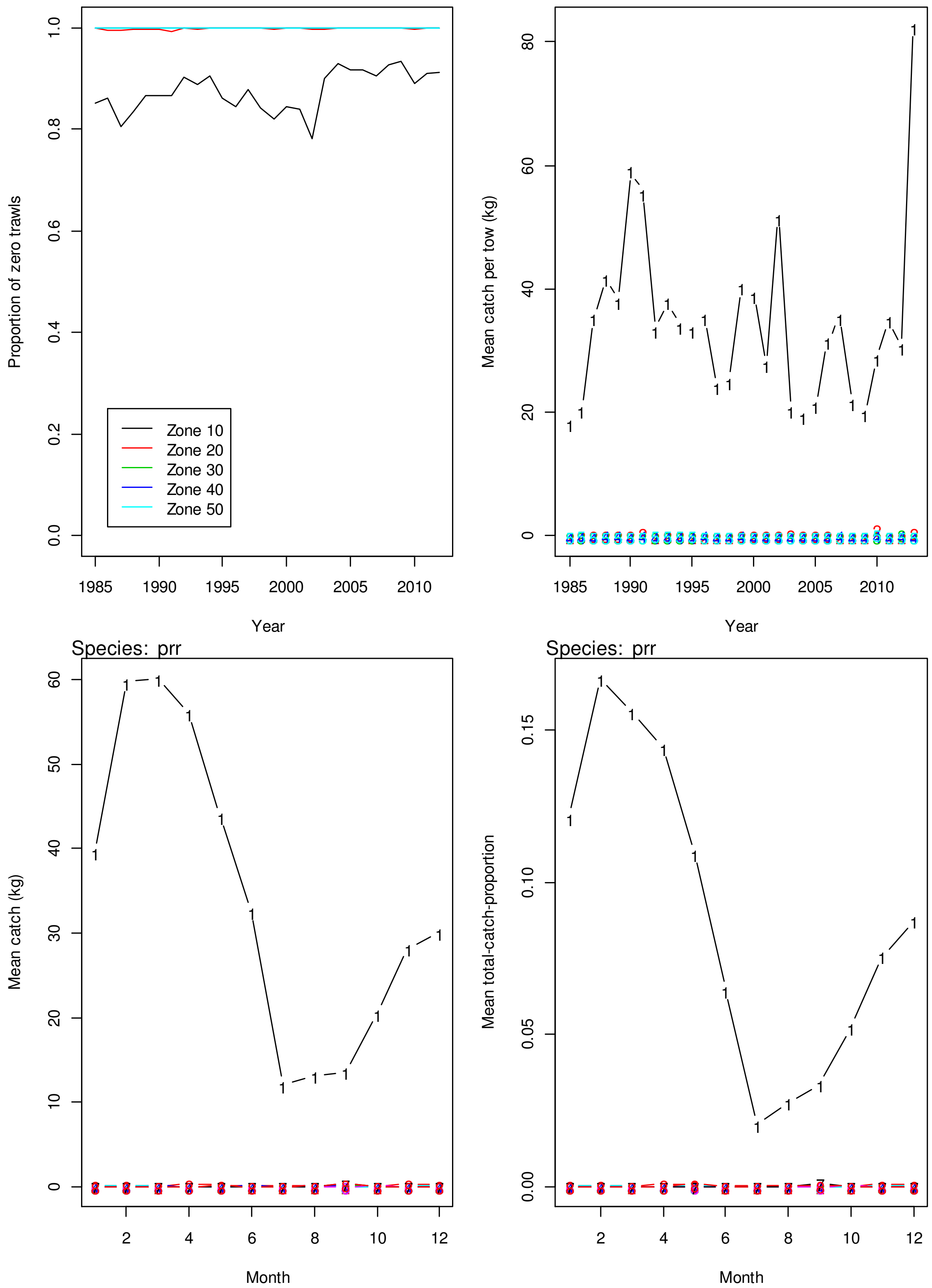

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: gre
Mean catch (kg)
Month
Species: gre
Mean total-catch-proportion
Month

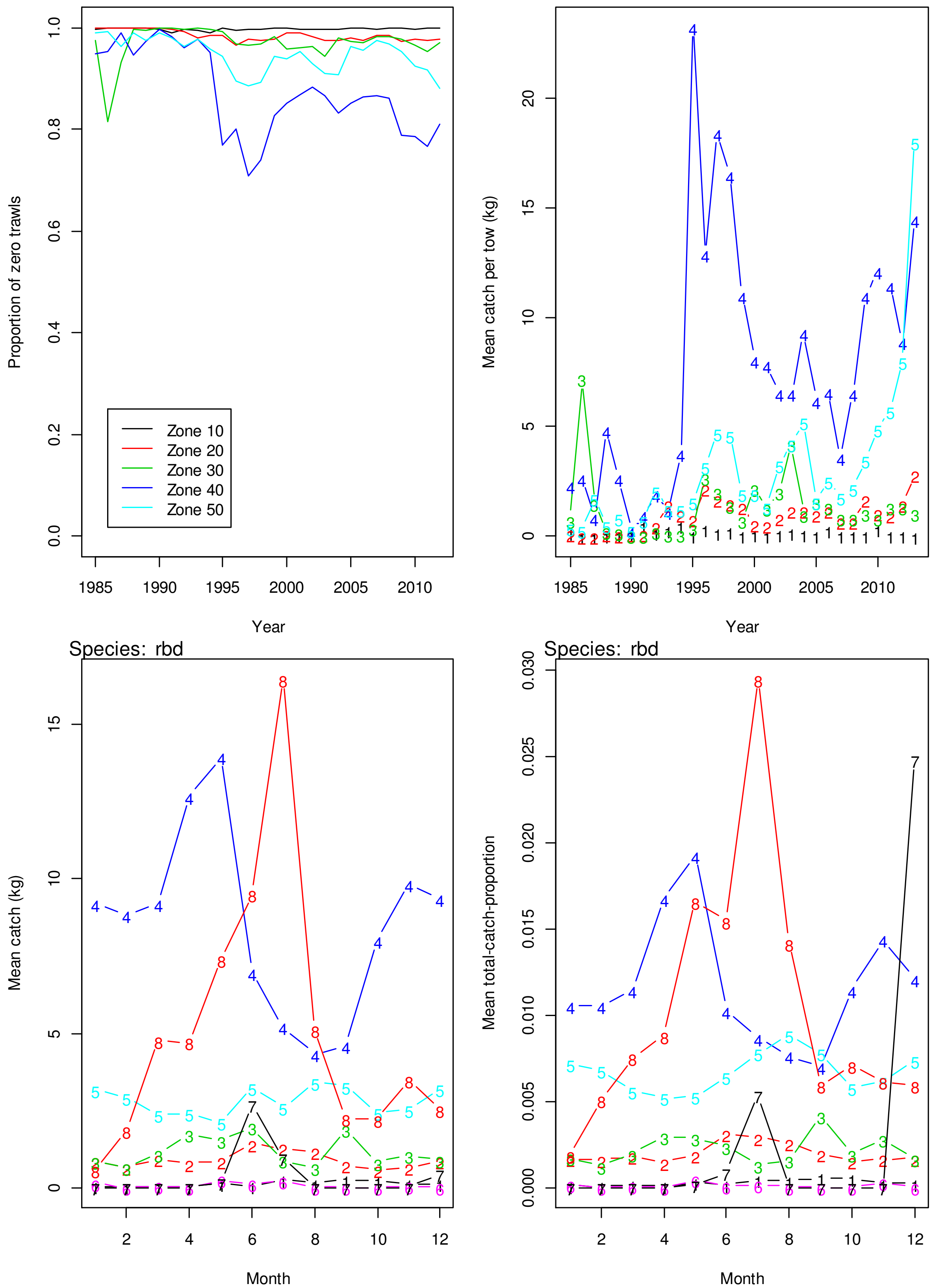

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: lig
Mean catch (kg)
Month
Species: lig
Mean total-catch-proportion
Month

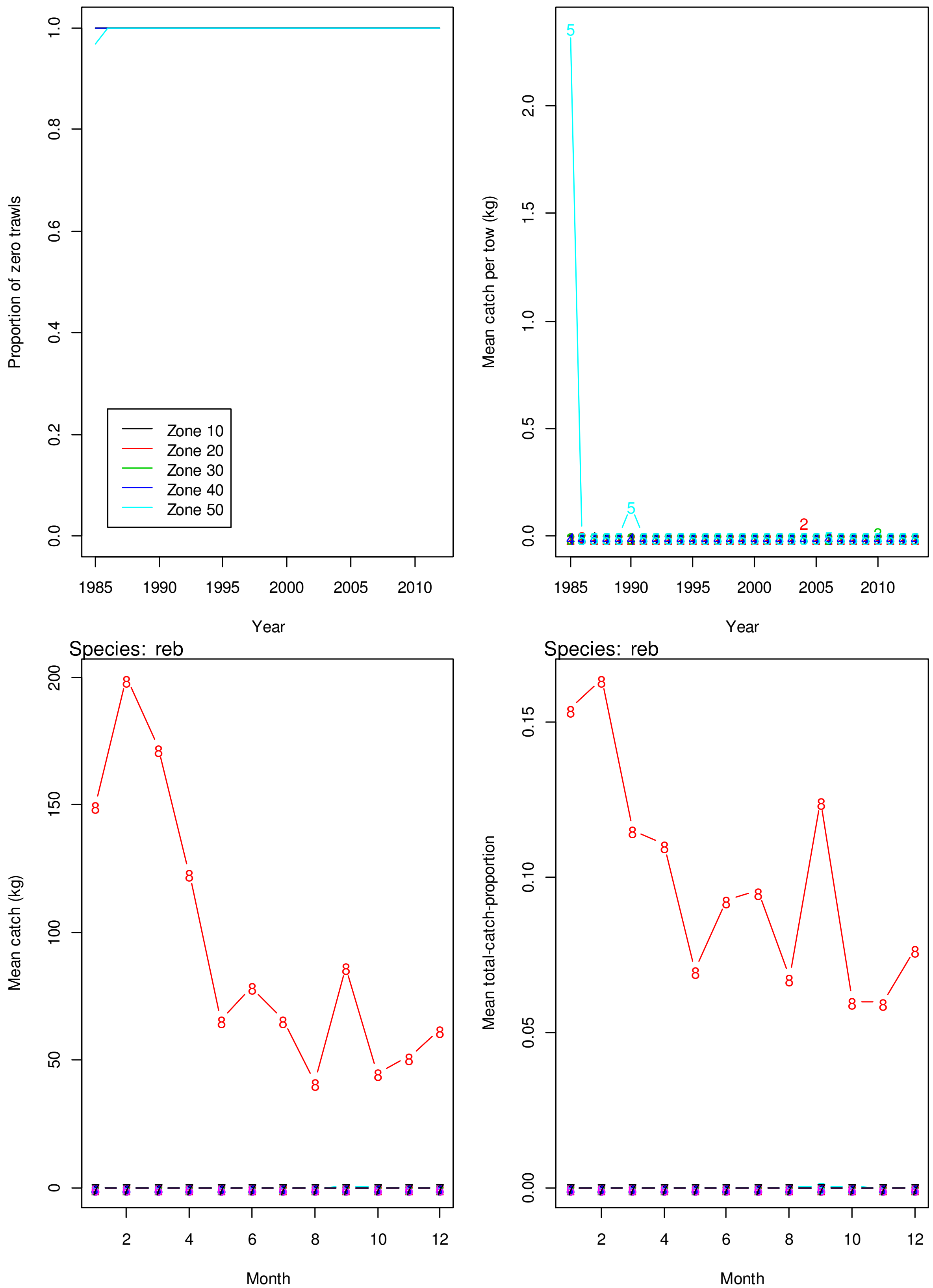

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: mow
Mean catch (kg)
Month
Species: mow
Mean total-catch-proportion
Month

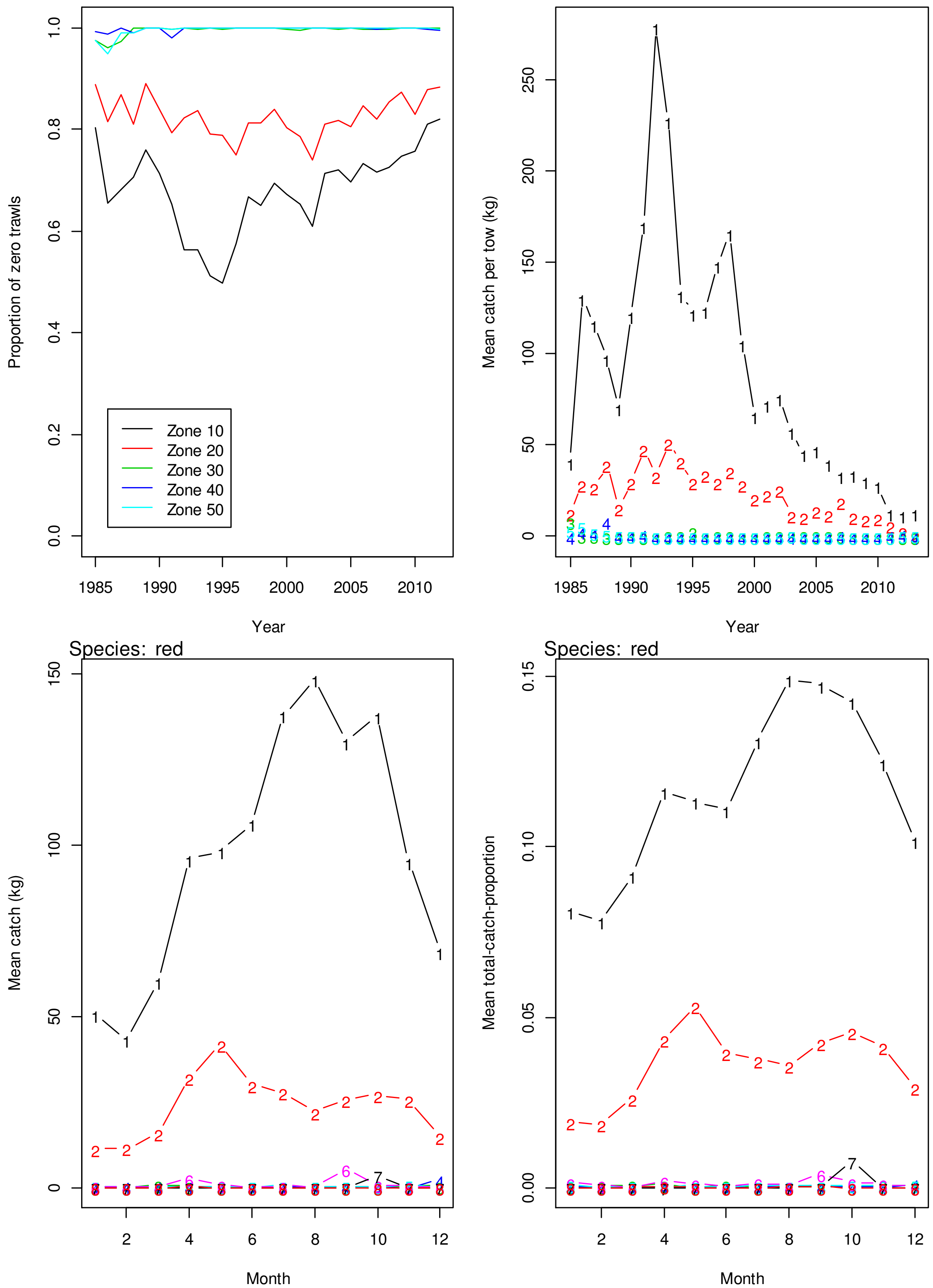

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: oro
Mean catch (kg)
Month
Species: oro
Mean total-catch-proportion
Month

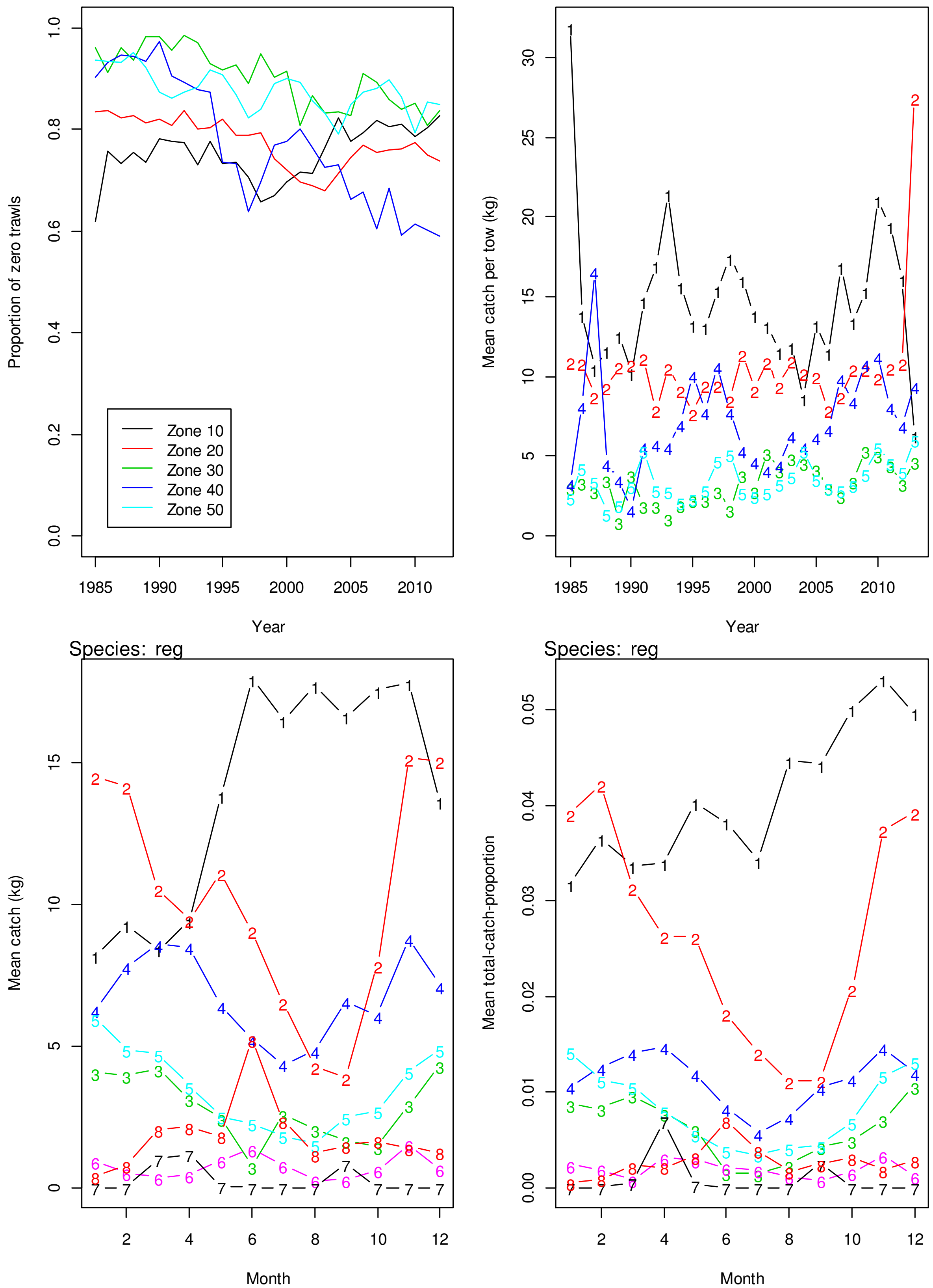

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: oth
Mean catch (kg)
Month
Species: oth
Mean total-catch-proportion
Month

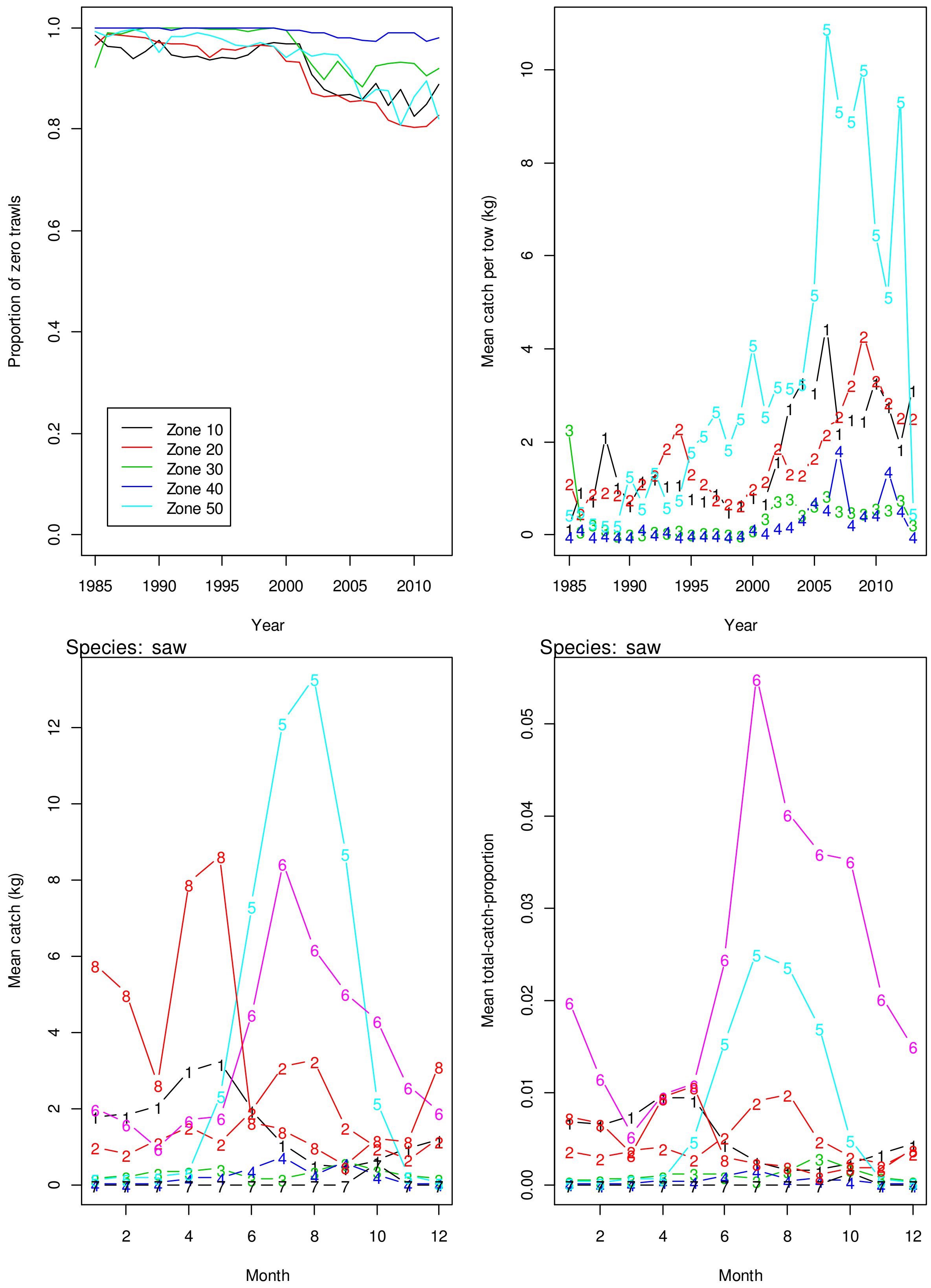

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: prr
Mean catch (kg)
Month
Species: prr
Mean total-catch-proportion
Month


Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: rbd
Mean catch (kg)
Month
Species: rbd
Mean total-catch-proportion
Month

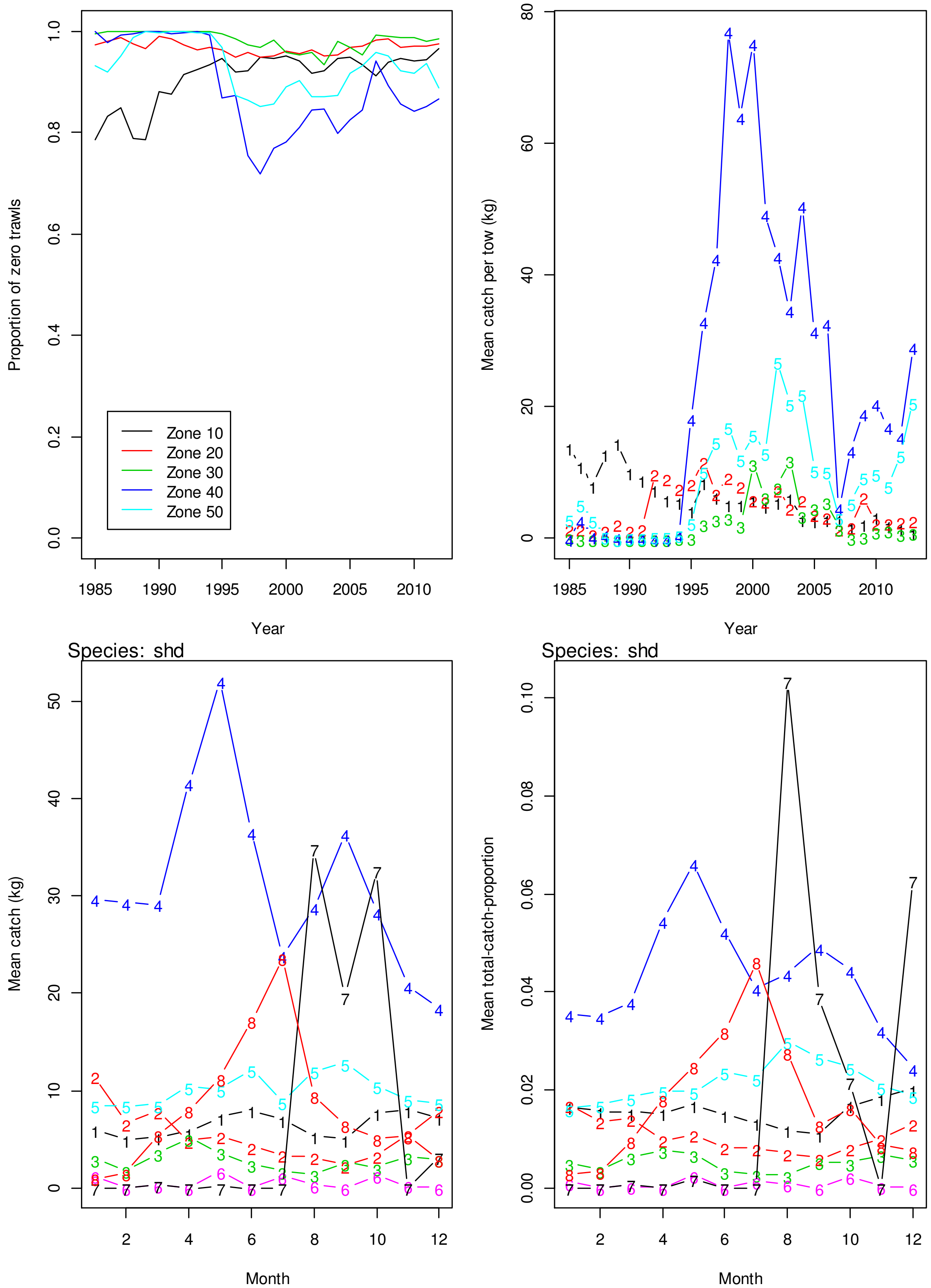

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: reb
Mean catch (kg)
Month
Species: reb
Mean total-catch-proportion
Month

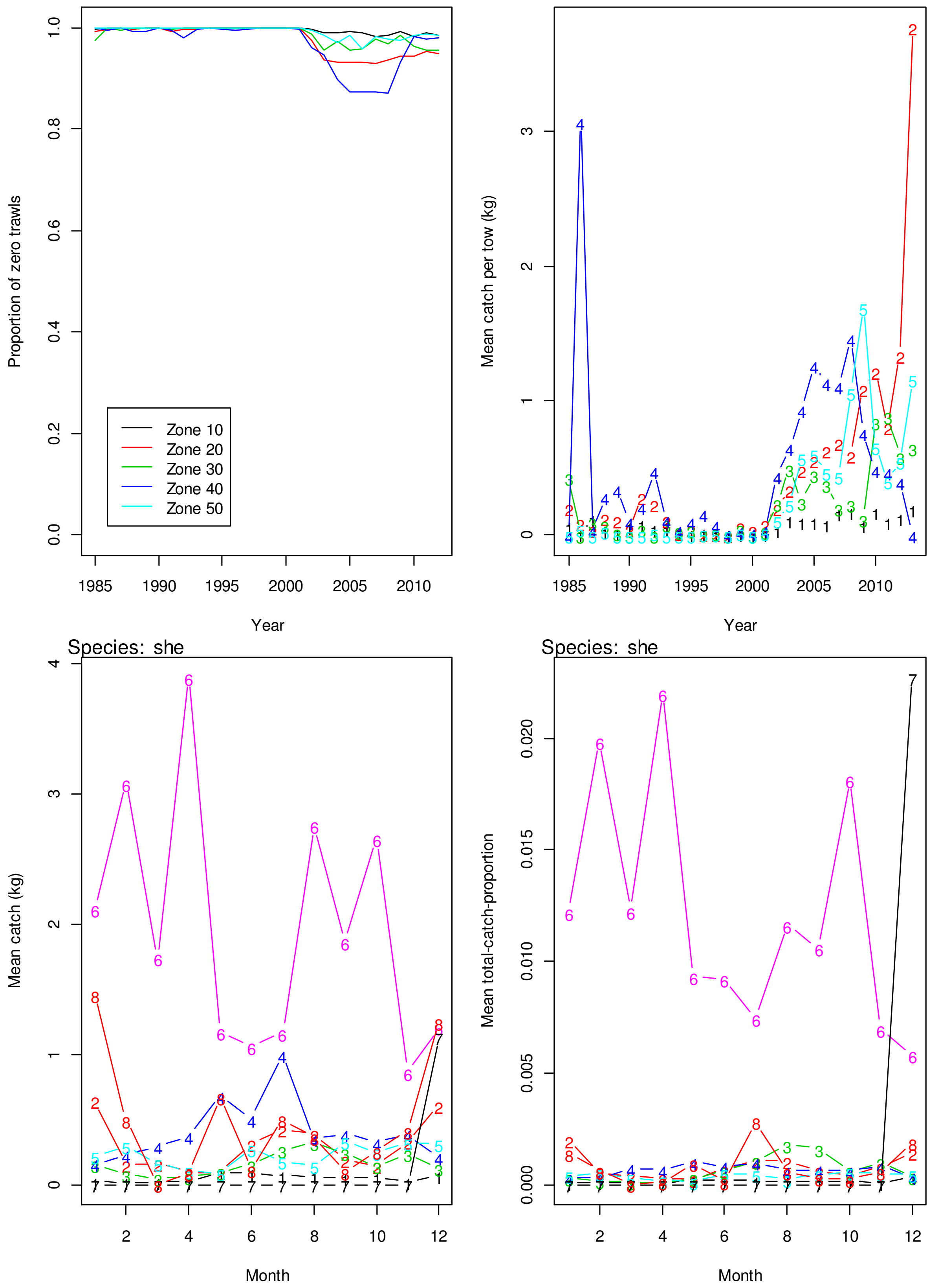

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: red
Mean catch (kg)
Month
Species: red
Mean total-catch-proportion
Month

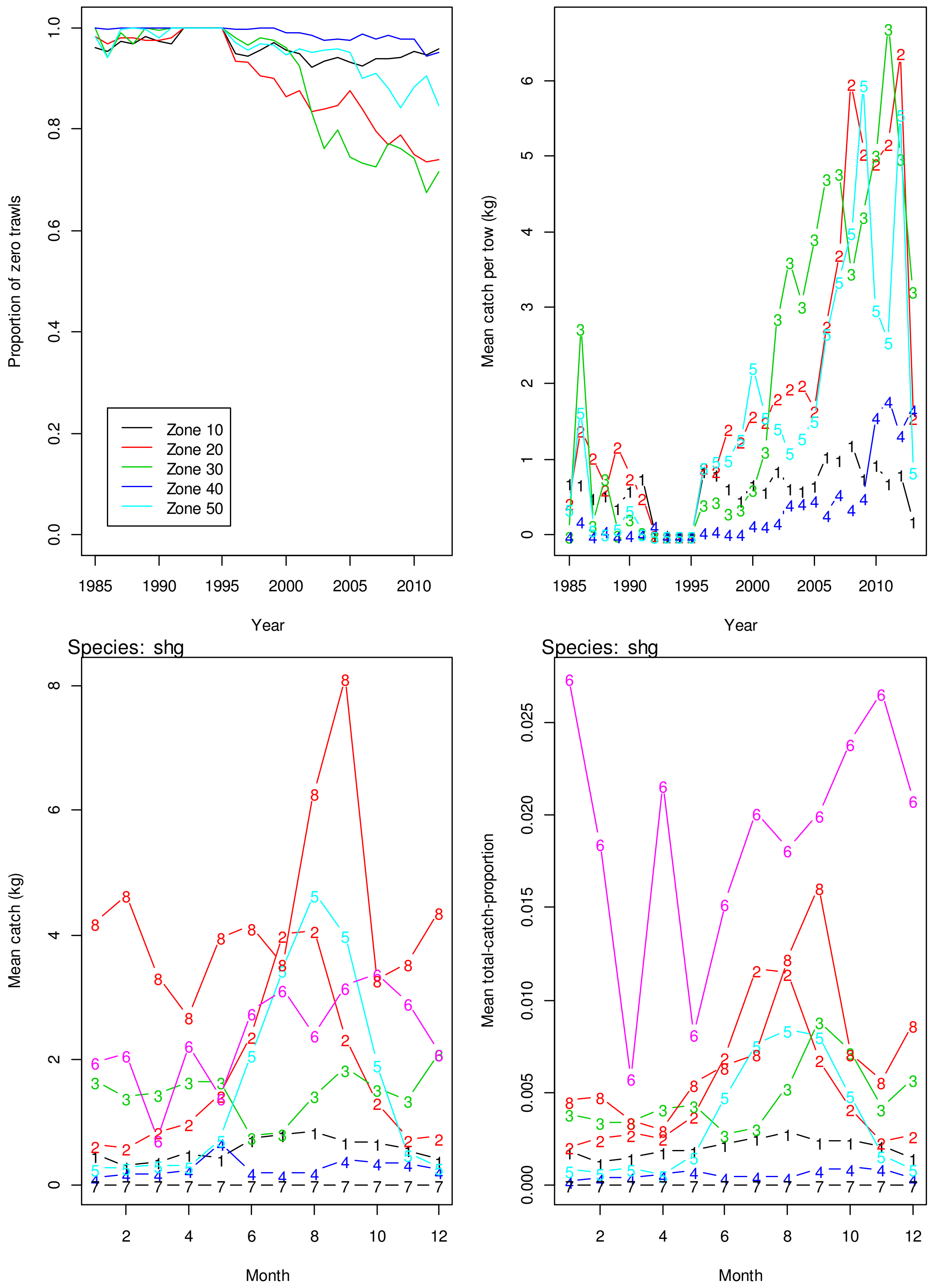

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: reg
Mean catch (kg)
Month
Species: reg
Mean total-catch-proportion
Month



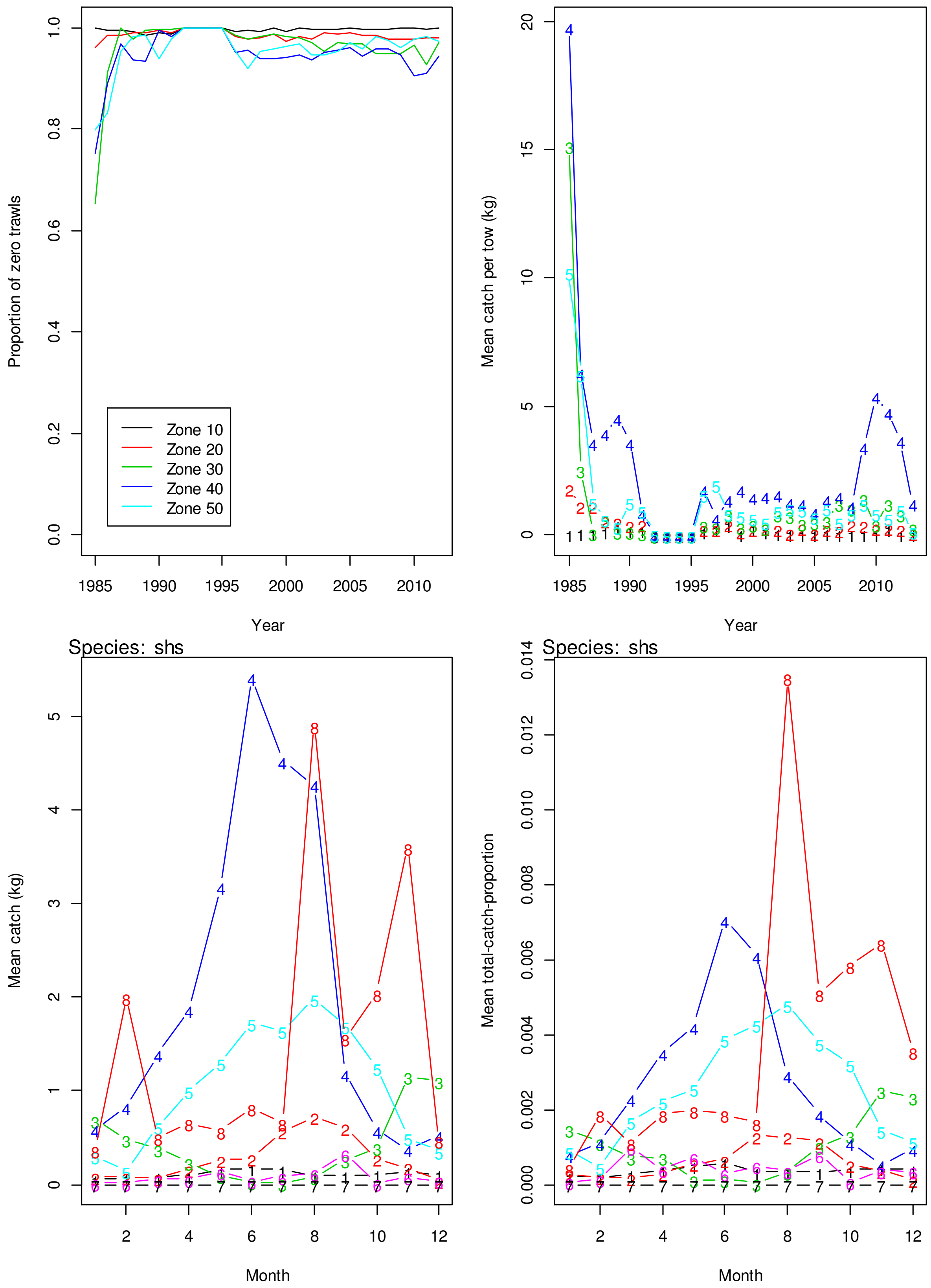
Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: saw
Mean catch (kg)
Month
Species: saw
Mean total-catch-proportion
Month


Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: shd
Mean catch (kg)
Month
Species: shd
Mean total-catch-proportion
Month

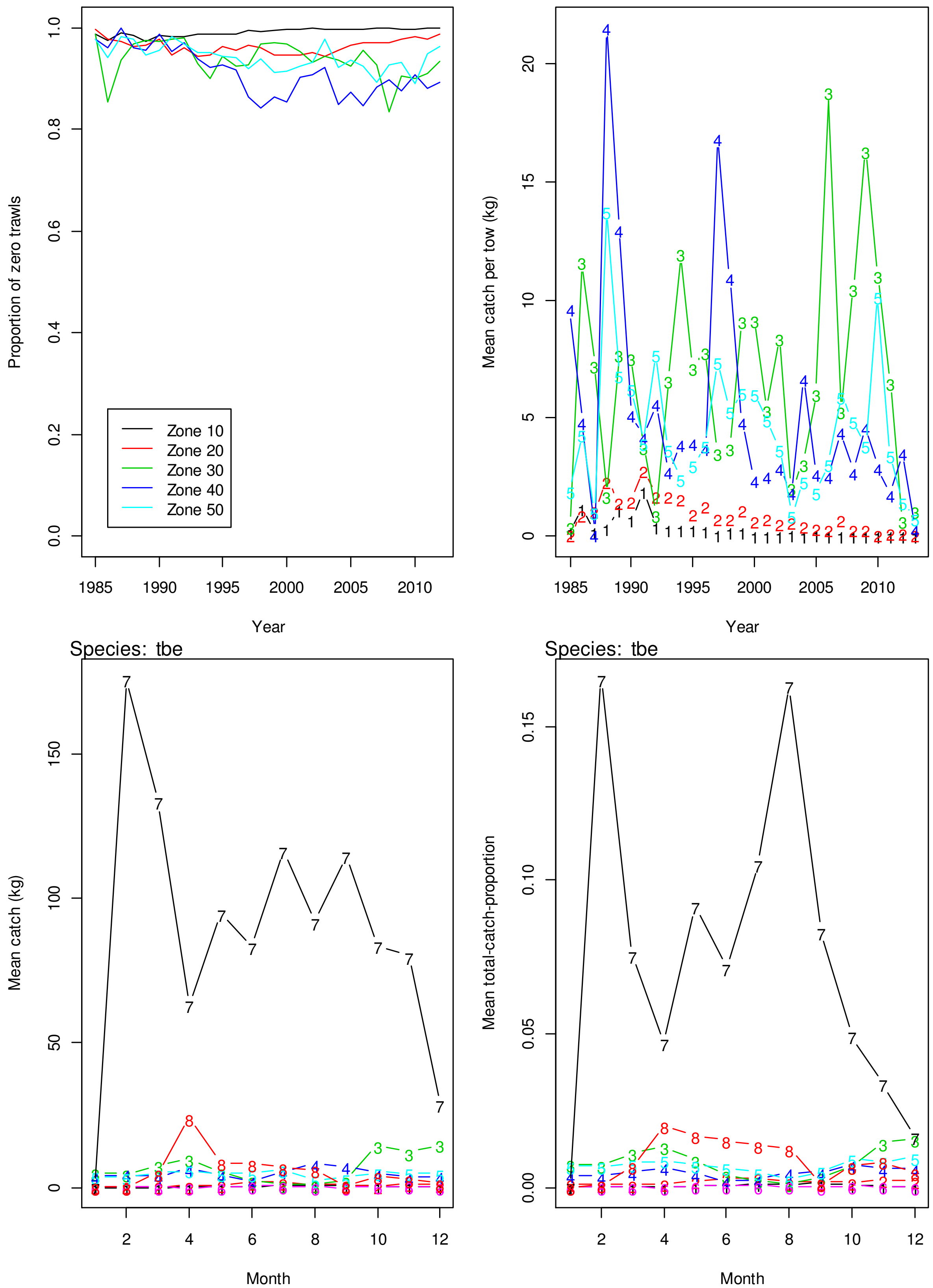

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: she
Mean catch (kg)
Month
Species: she
Mean total-catch-proportion
Month

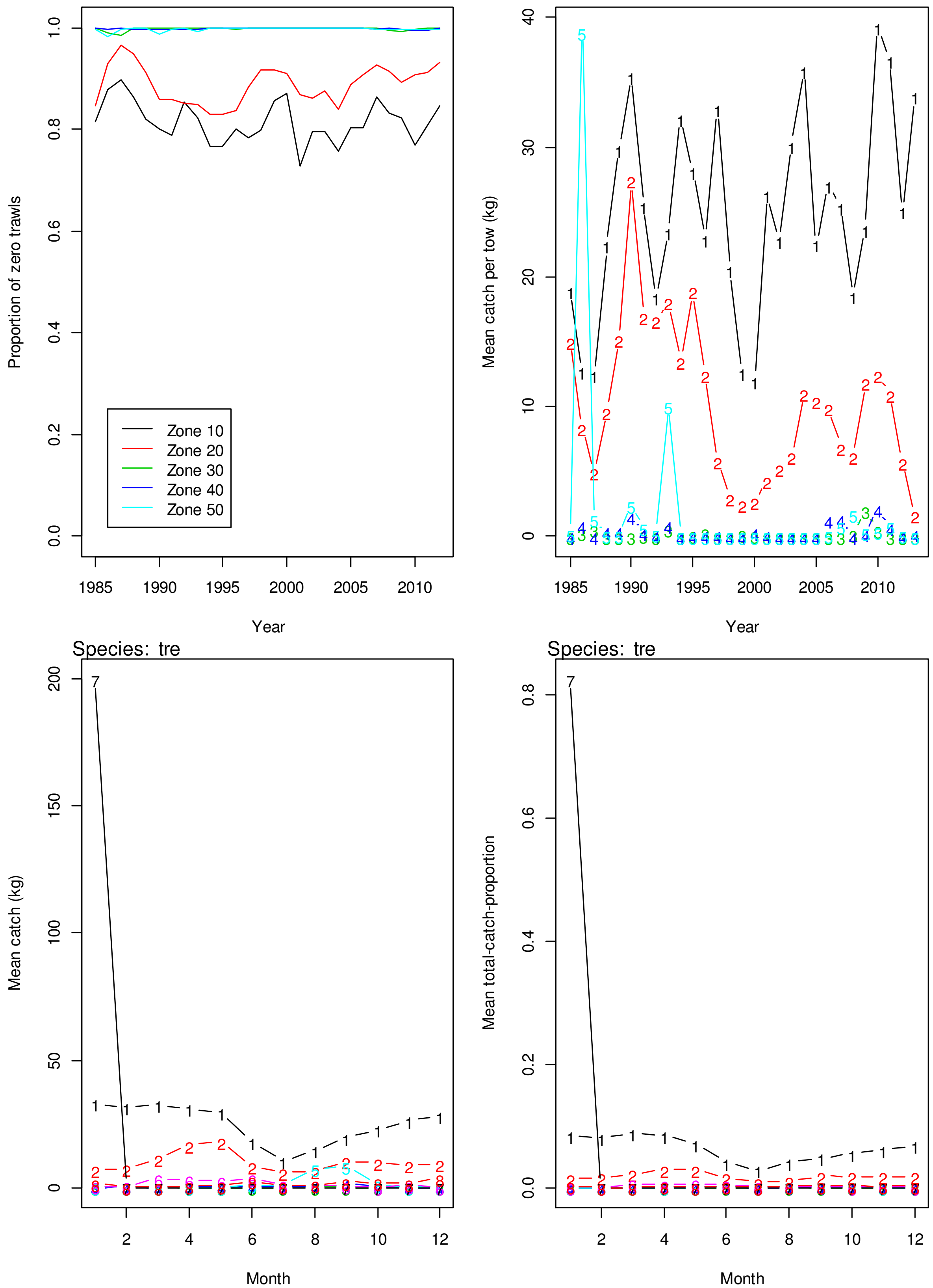


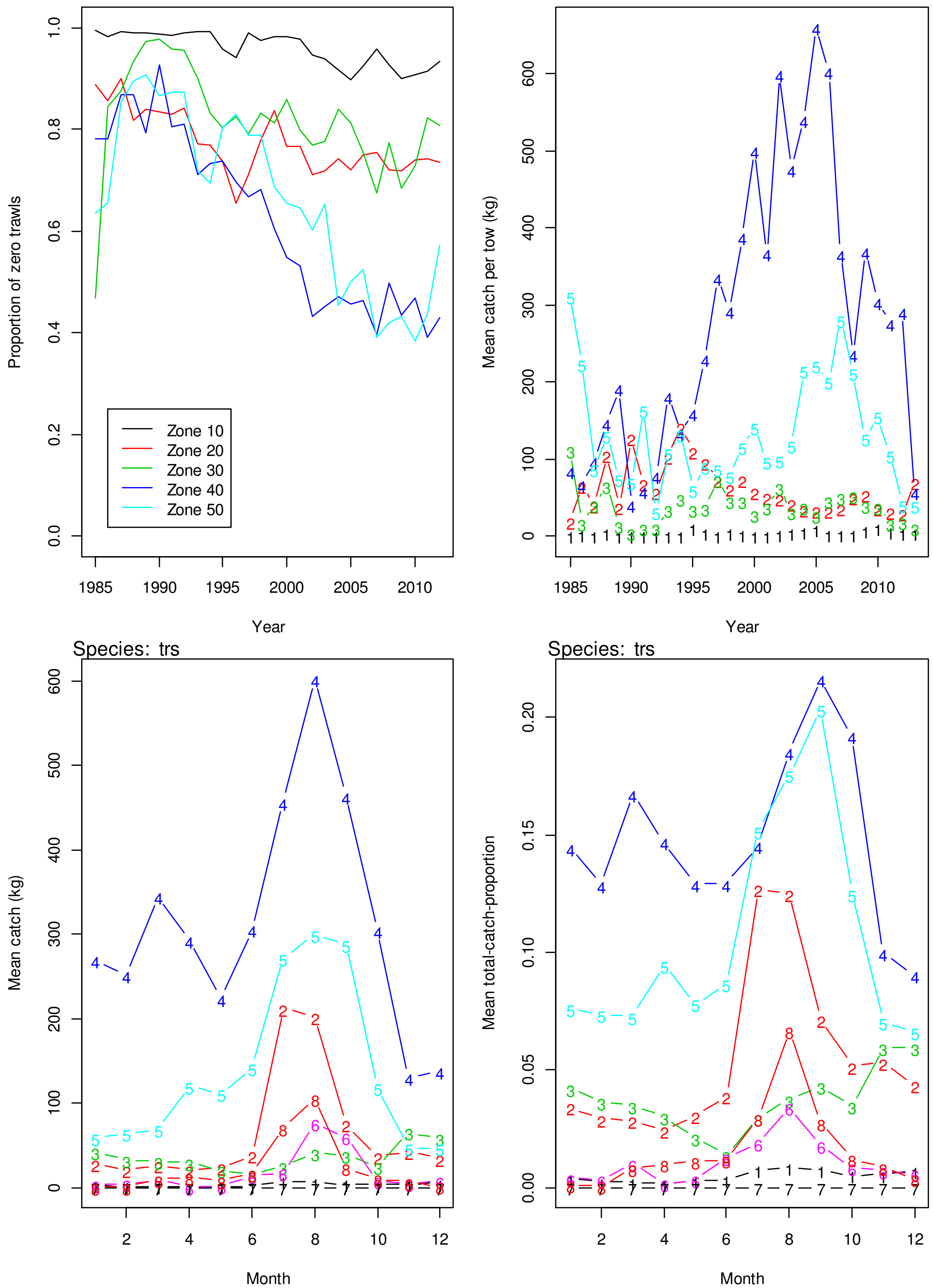
Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: shg
Mean catch (kg)
Month
Species: shg
Mean total-catch-proportion
Month

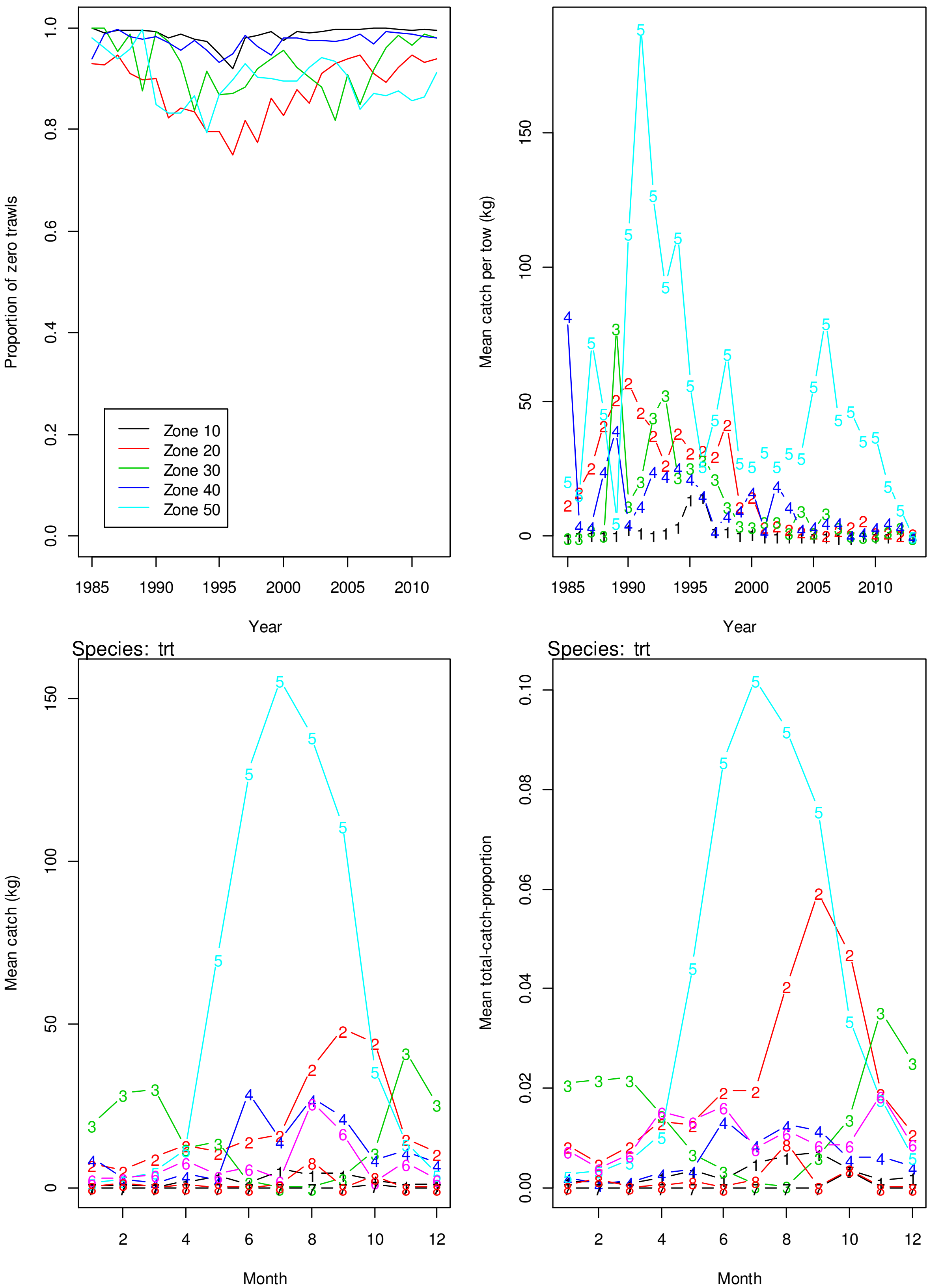


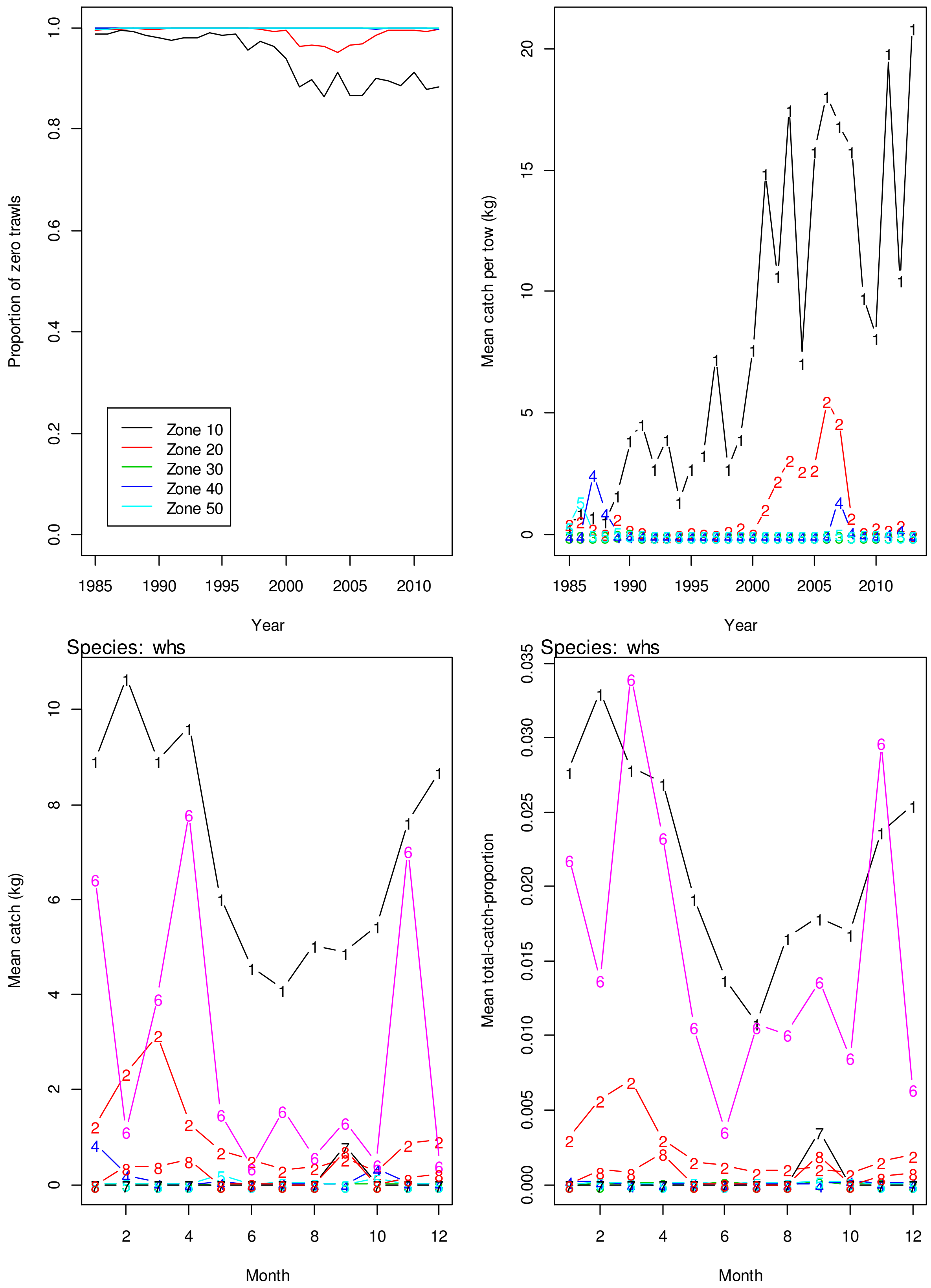
Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: shs
Mean catch (kg)
Month
Species: shs
Mean total-catch-proportion
Month


Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: tbe
Mean catch (kg)
Month
Species: tbe
Mean total-catch-proportion
Month

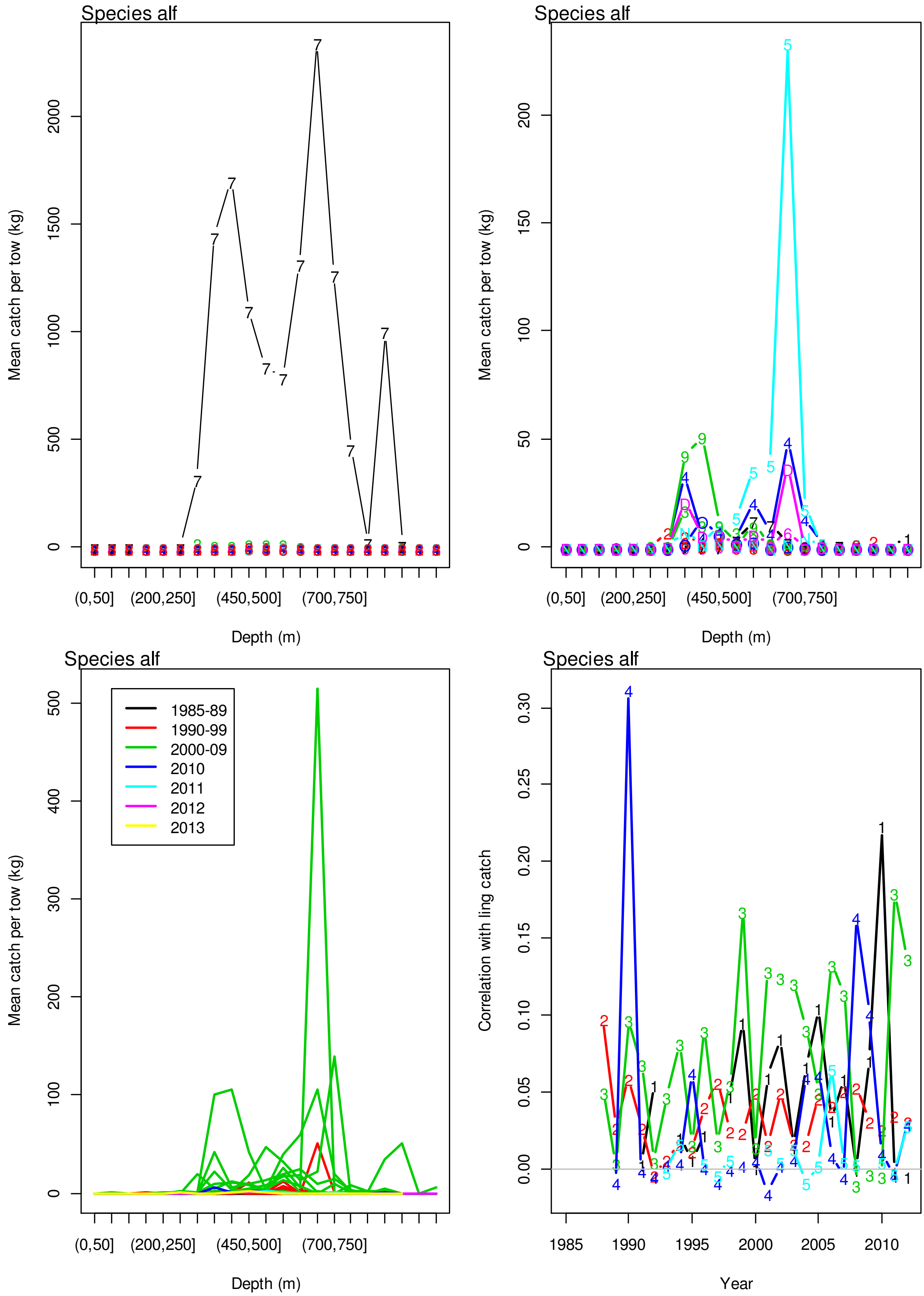

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: tre
Mean catch (kg)
Month
Species: tre
Mean total-catch-proportion
Month

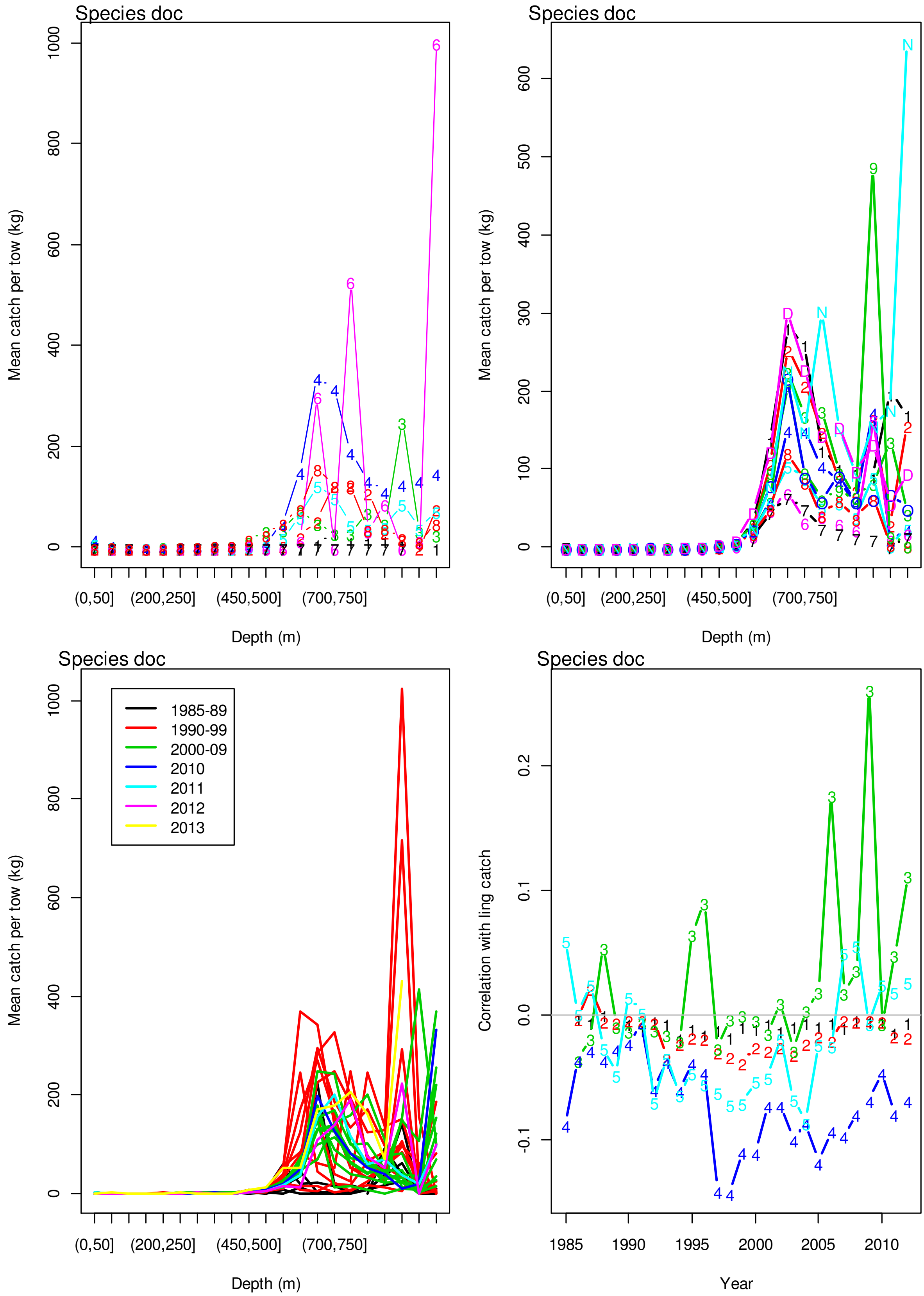

Proportion of zero trawls
Year
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Mean catch per tow (kg)
Year
Species: trs
Mean catch (kg)
Month
Species: trs
Mean total-catch-proportion
Month


Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: trt
Mean catch (kg)
Month
Species: trt
Mean total-catch-proportion
Month

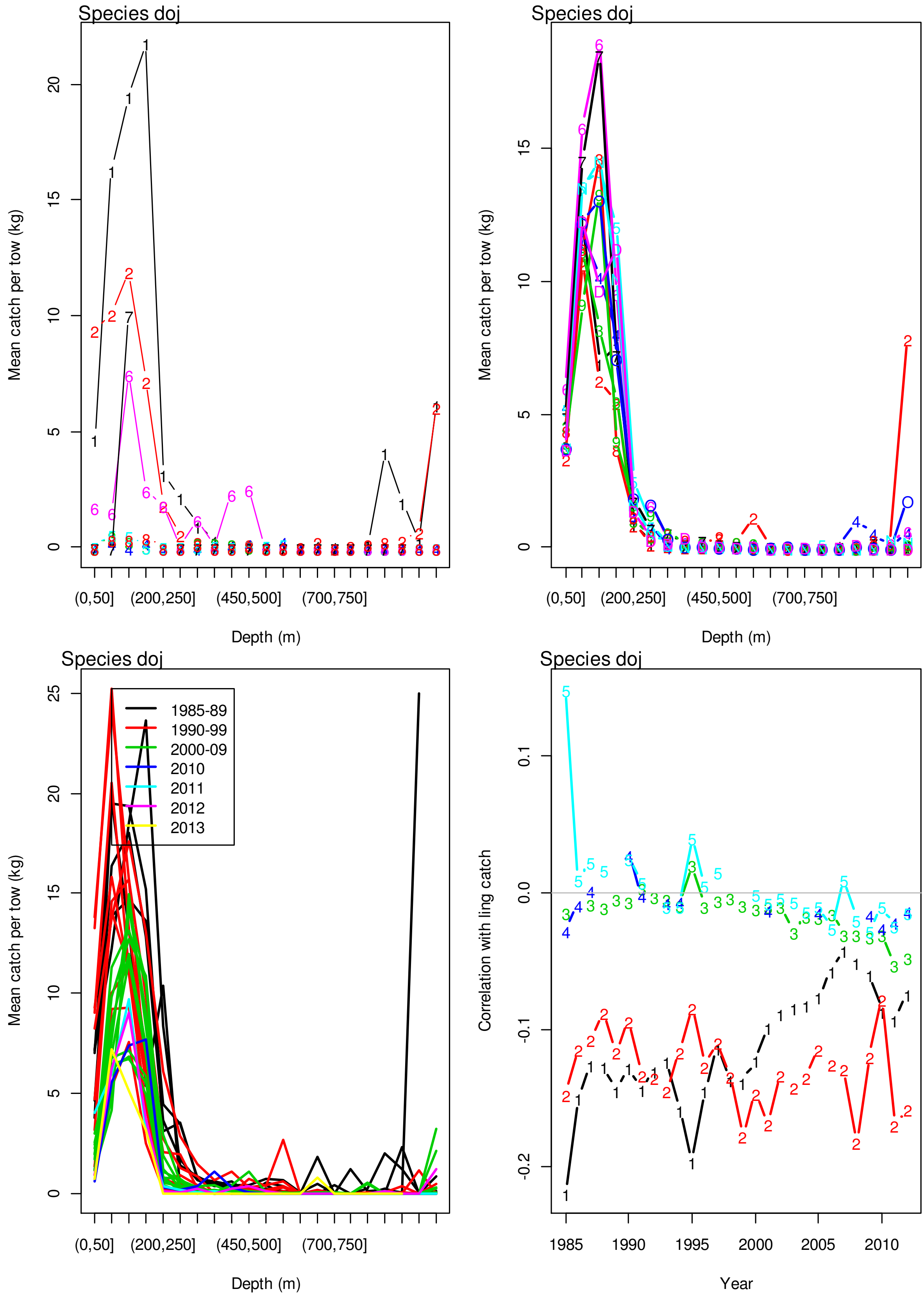

Proportion of zero trawls
Zone 10
Zone 20
Zone 30
Zone 40
Zone 50
Year
Mean catch per tow (kg)
Year
Species: whs
Mean catch (kg)
Month
Species: whs
Mean total-catch-proportion
Month

Appendix 2 (continued): four more plots for each species

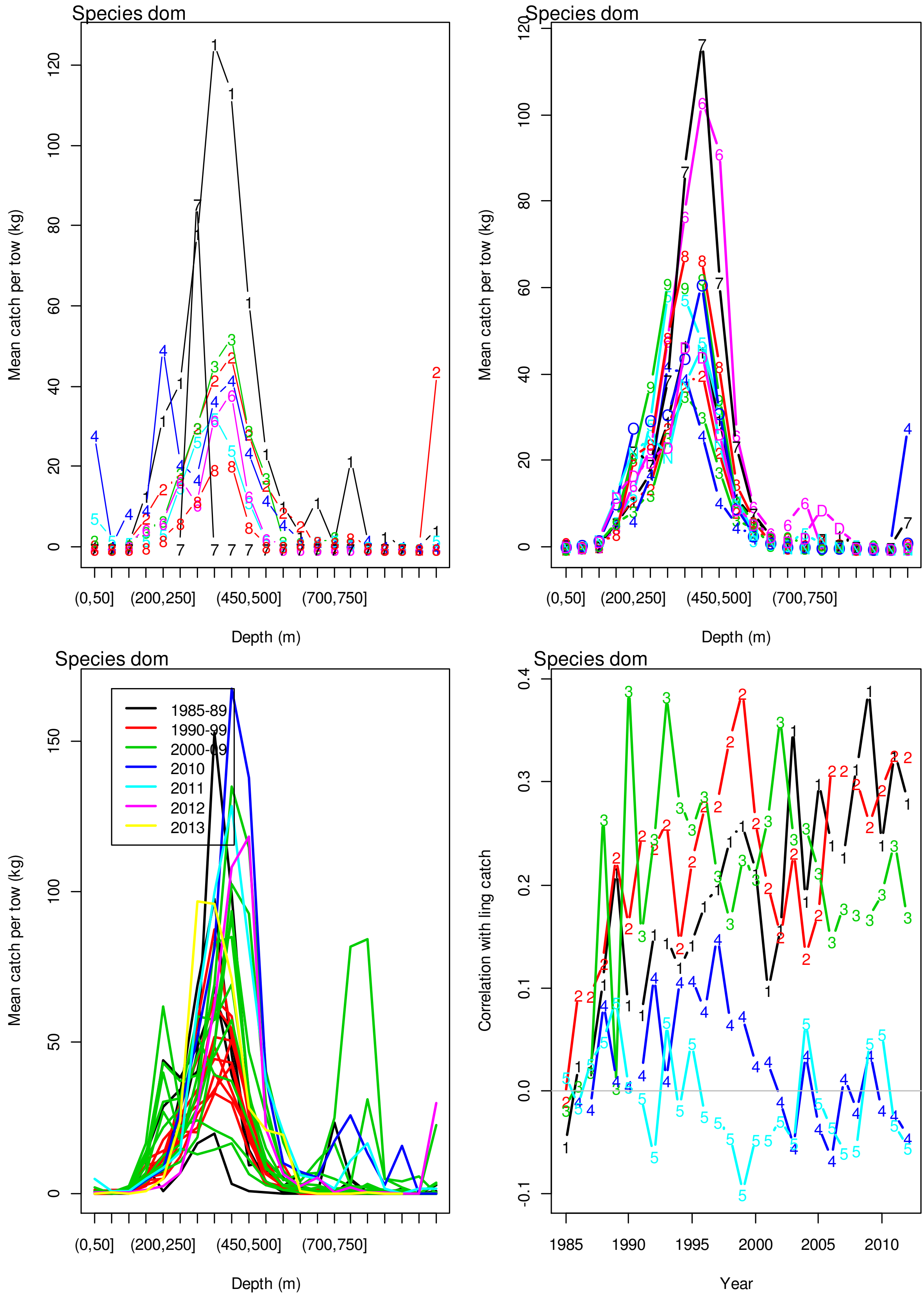

Species alf
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species alf
Mean catch per tow (kg)
Depth (m)
Species alf
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species alf
Correlation with ling catch
Year

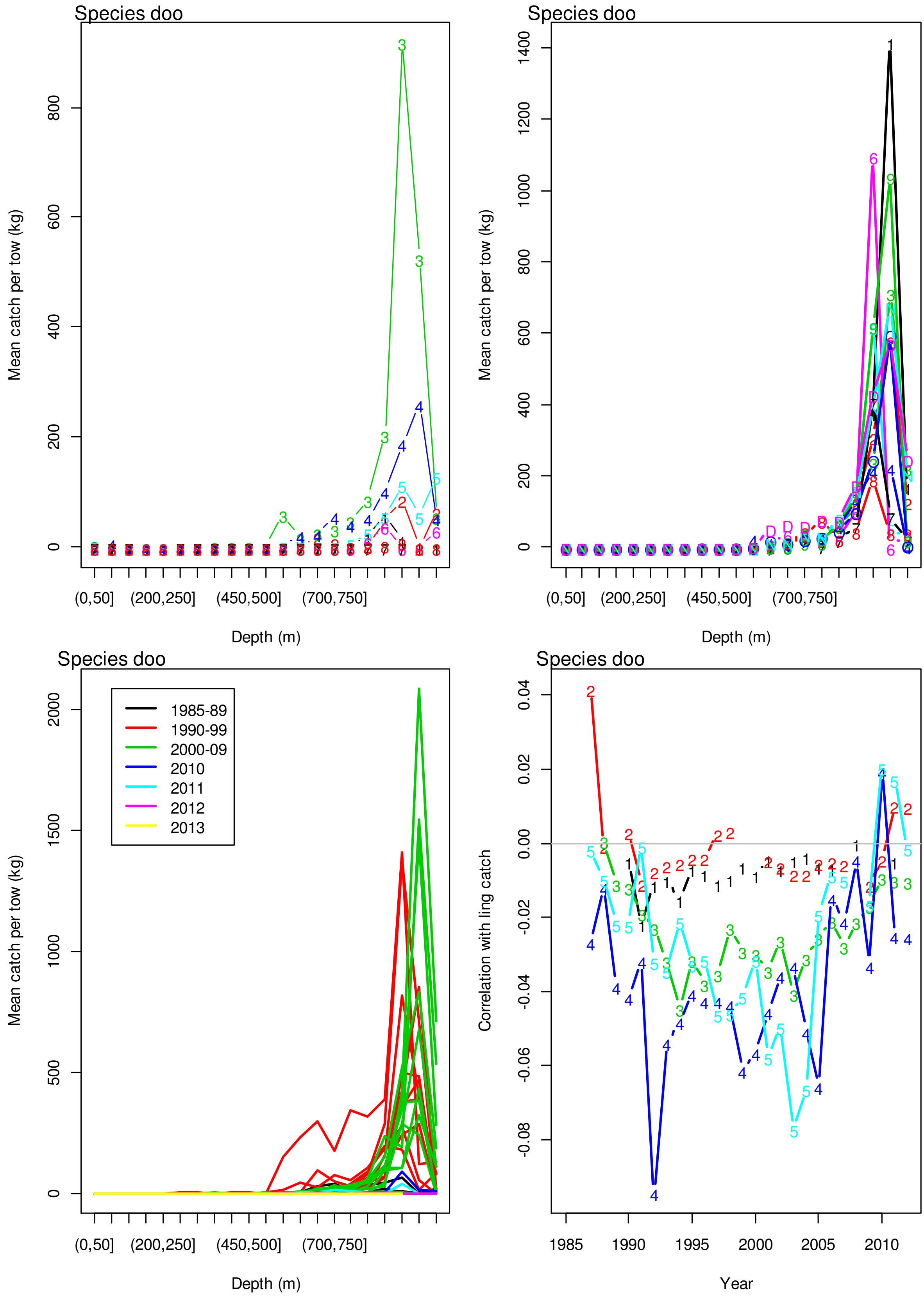


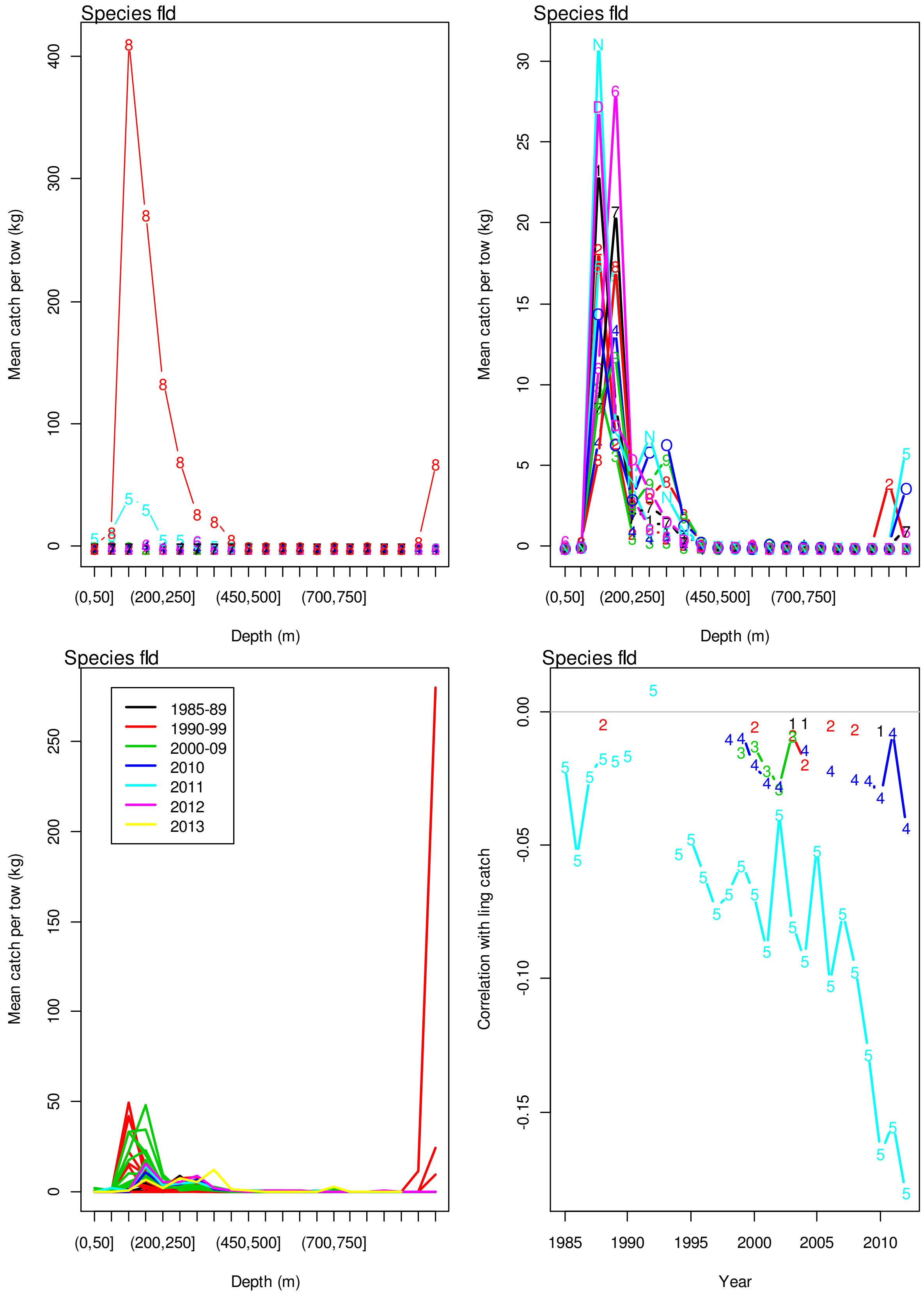
Species doc
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species doc
Mean catch per tow (kg)
Depth (m)
Species doc
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species doc
Correlation with ling catch
Year

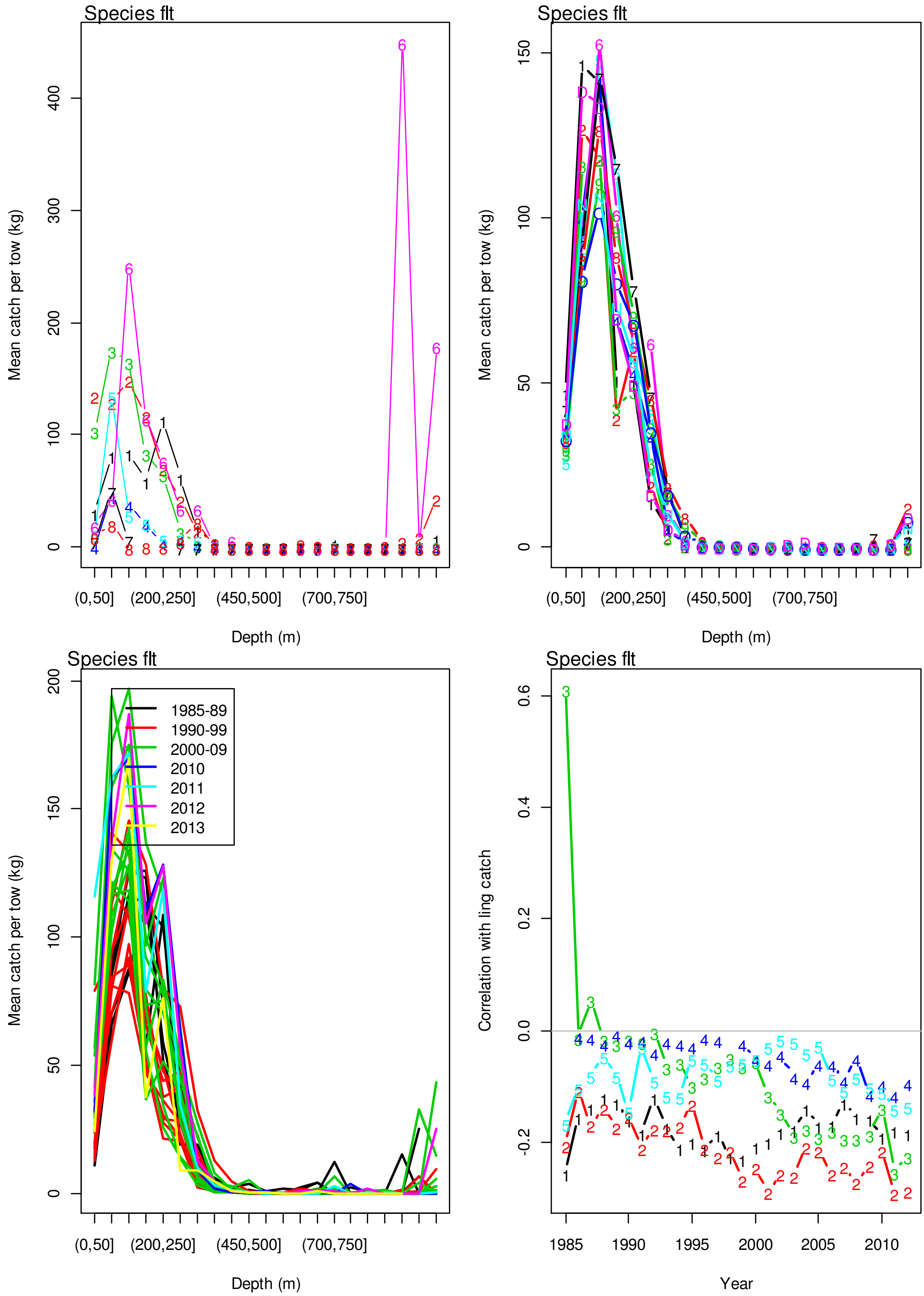


Species doj
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Correlation with ling catch
Year
1985-89
1990-99
2000-09
2010
2011
2012
2013

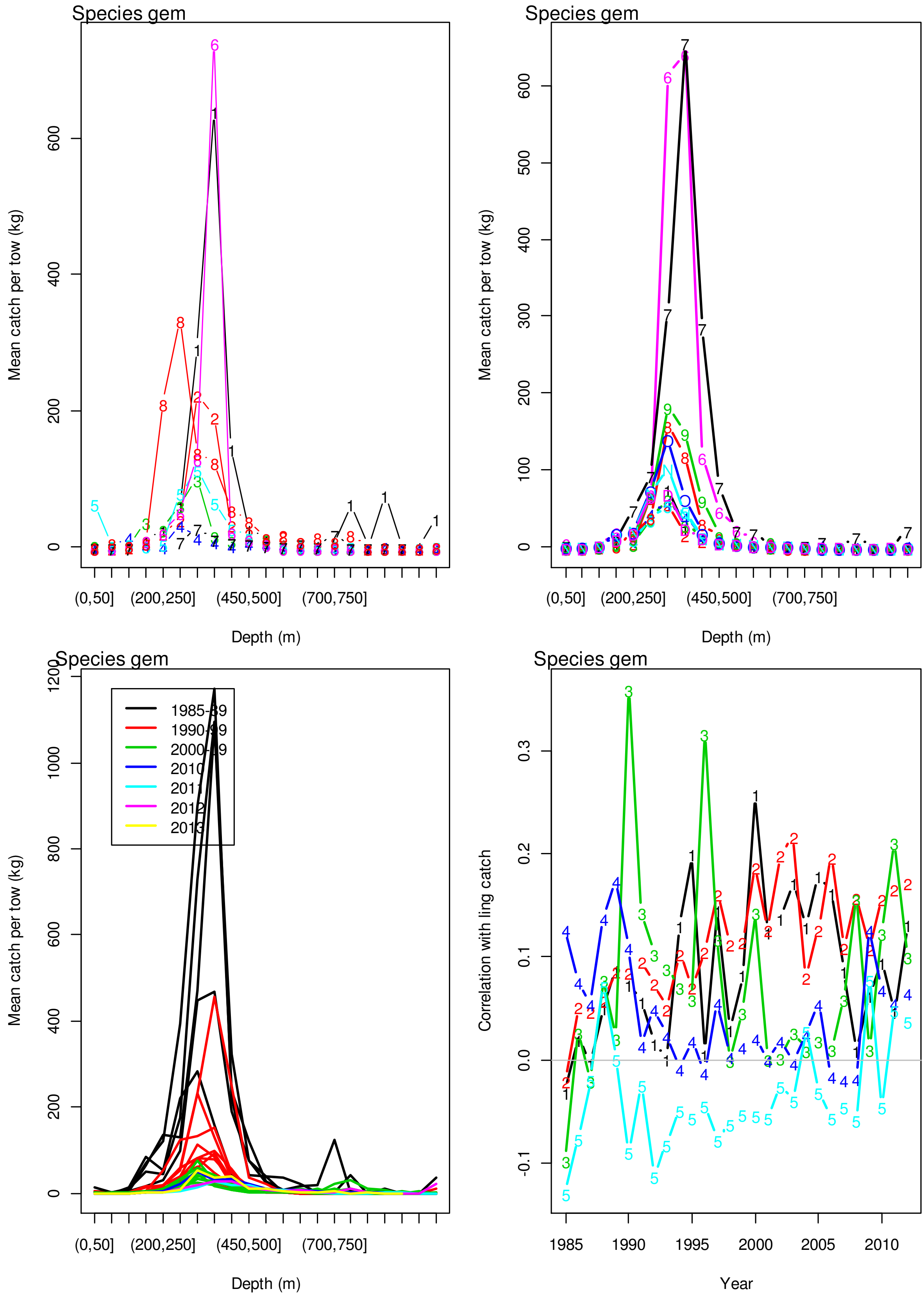

Species dom
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Correlation with ling catch
Year
1985-89
1990-99
2000-09
2010
2011
2012
2013

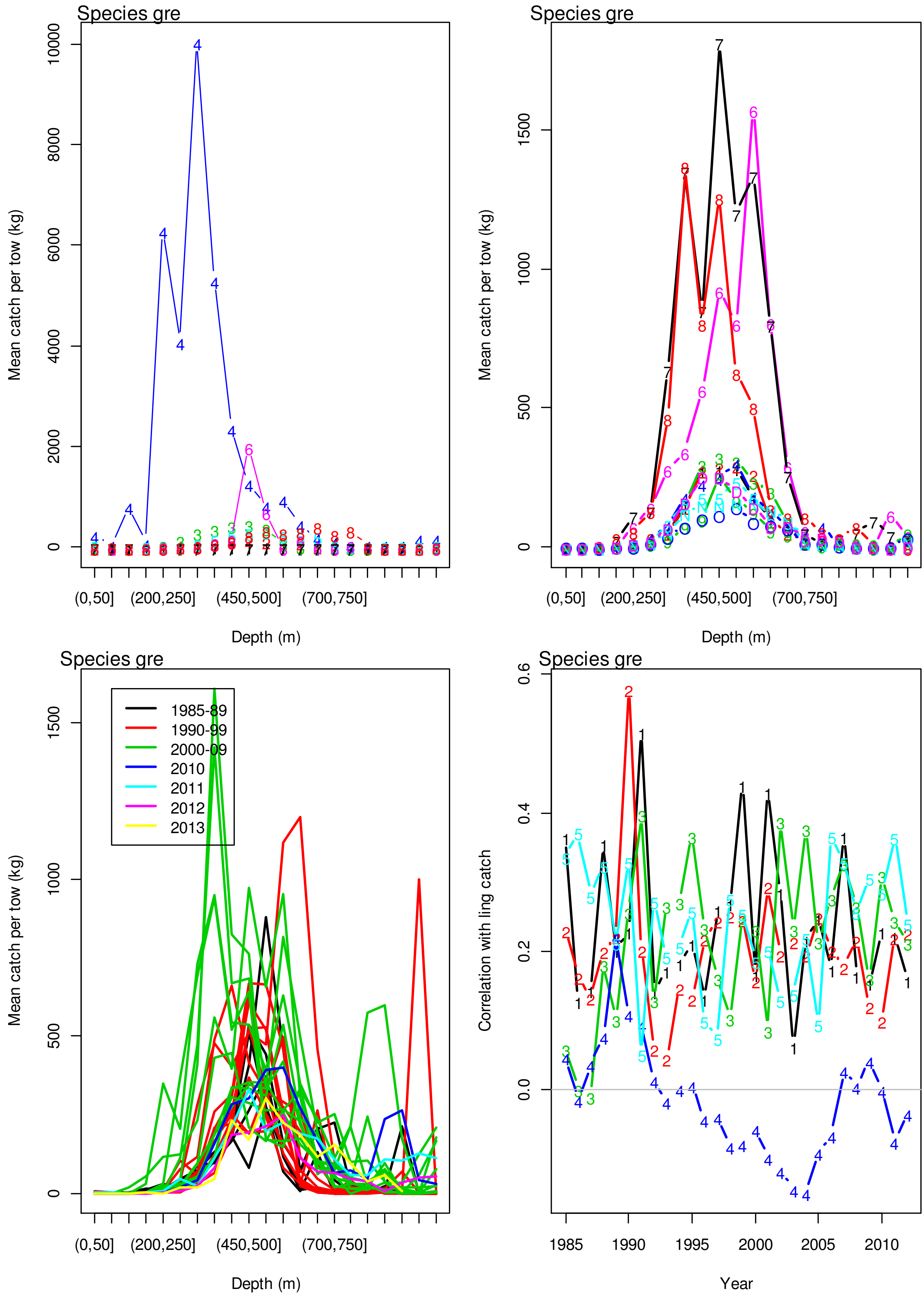

Species doo
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species doo
Mean catch per tow (kg)
Depth (m)
Species doo
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species doo
Correlation with ling catch
Year
1985
1990
1995
2000
2005
2010

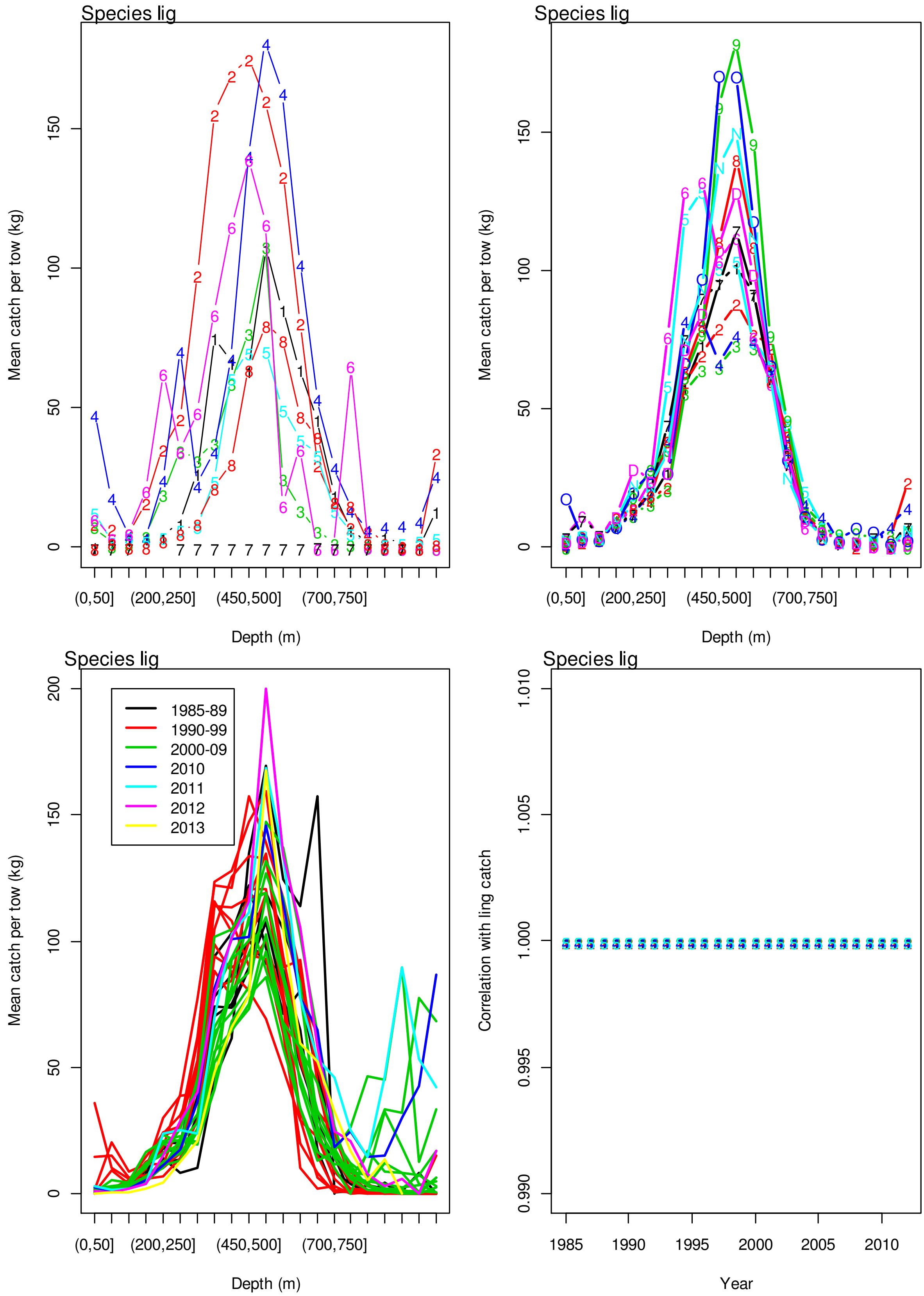

Species fld
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
1985-89
1990-99
2000-09
2010
2011
2012
2013
Correlation with ling catch
Year

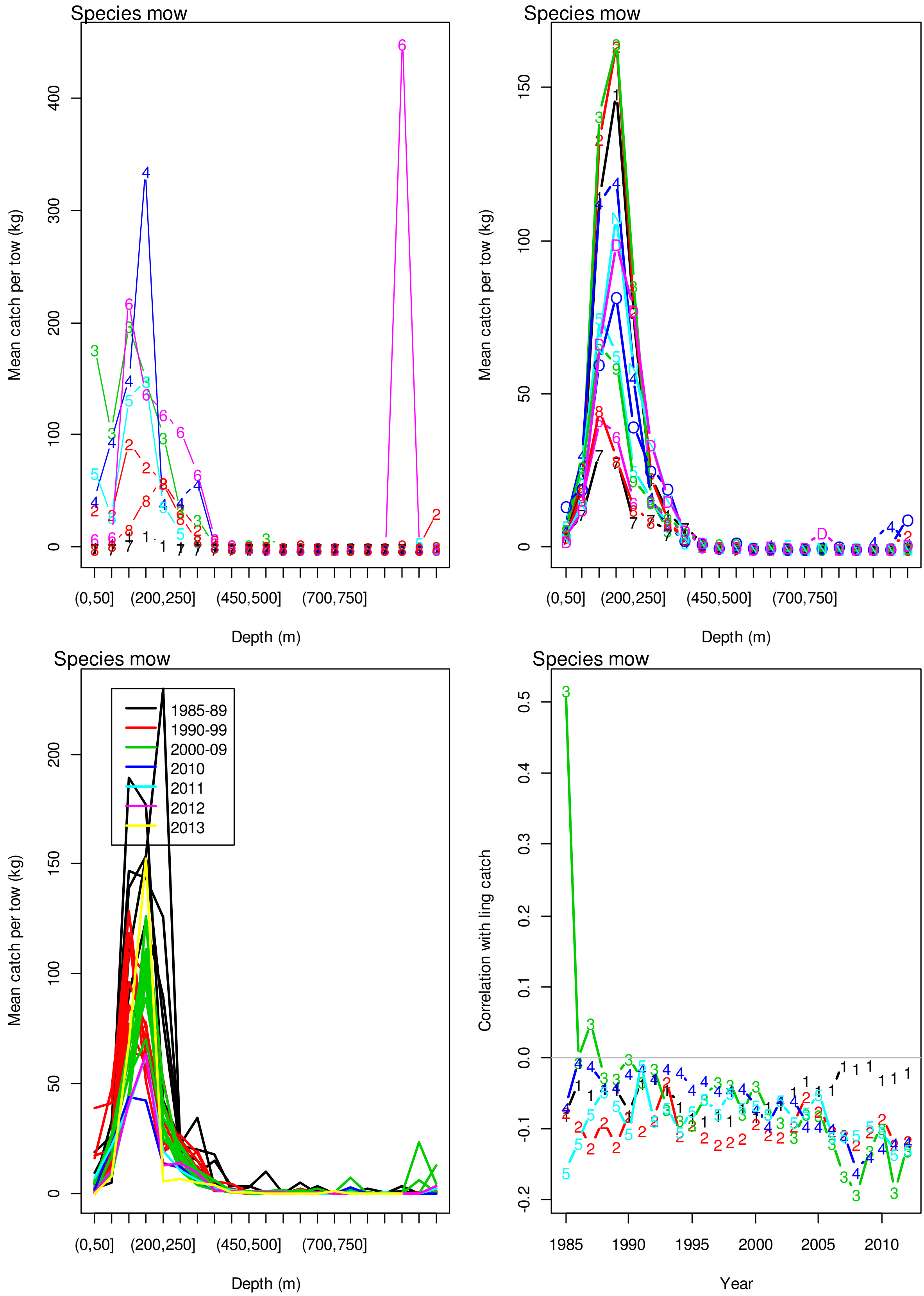


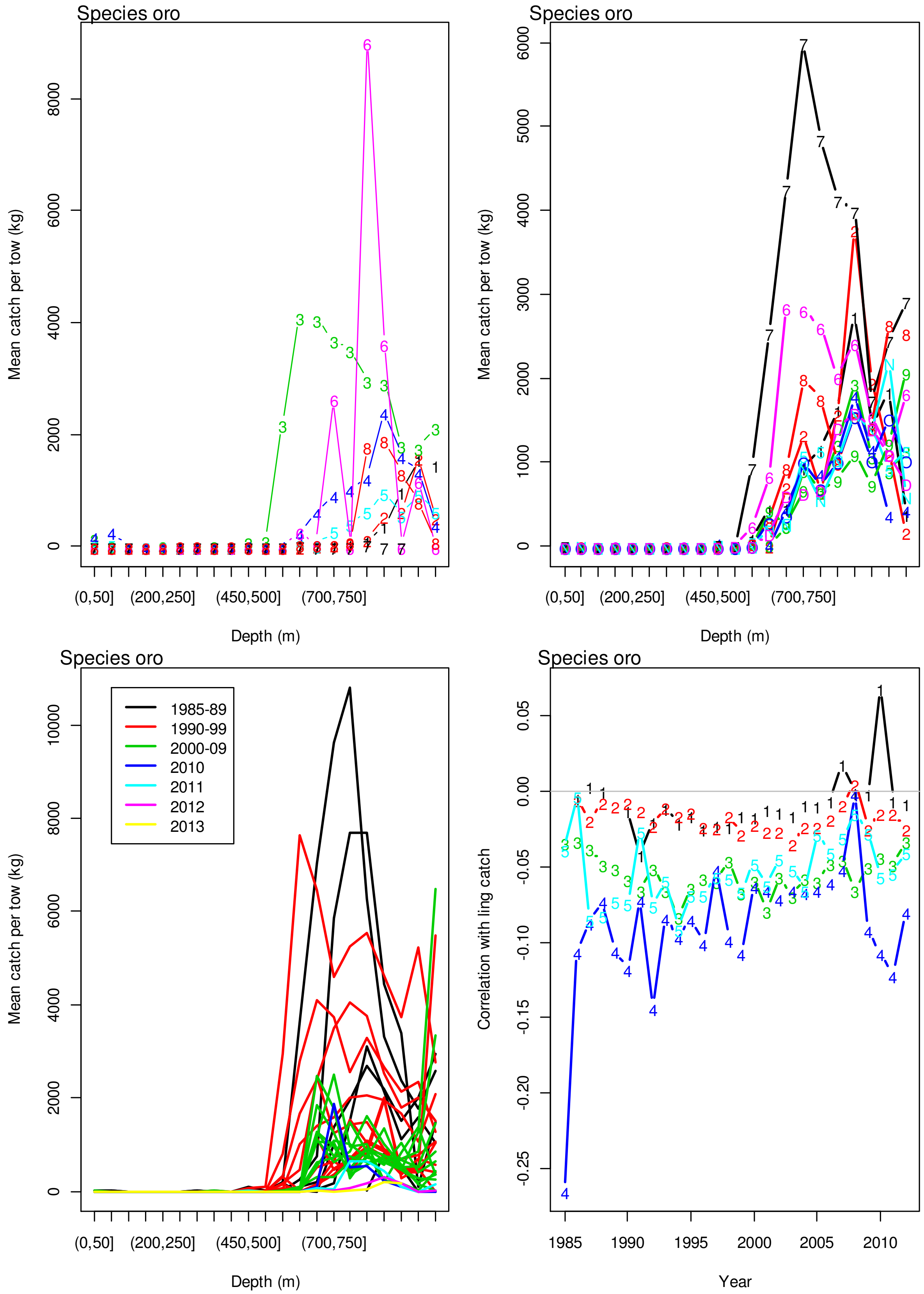
Species flt
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species flt
Mean catch per tow (kg)
Depth (m)
Species flt
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species flt
Correlation with ling catch
Year

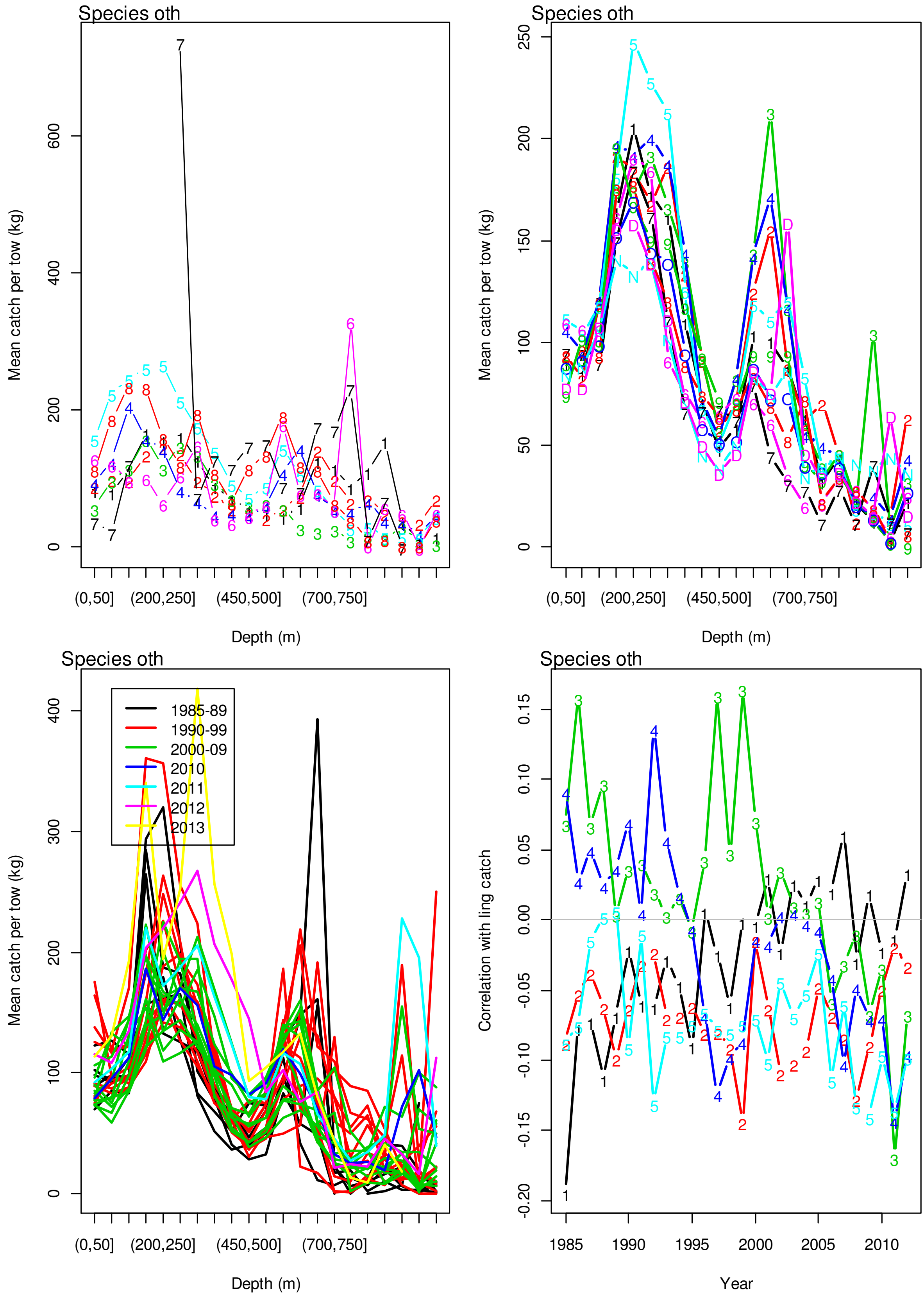

Species gem
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species gem
Mean catch per tow (kg)
Depth (m)
Species gem
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species gem
Correlation with ling catch
Year


Species gre
Mean catch per tow (kg)
0
2000
4000
6000
8000
10000
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)
Species gre
Mean catch per tow (kg)
0
500
1000
1500
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)
Species gre
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
0
500
1000
1500
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)
Species gre
Correlation with ling catch
0.0
0.2
0.4
0.6
1985
1990
1995
2000
2005
2010
Year

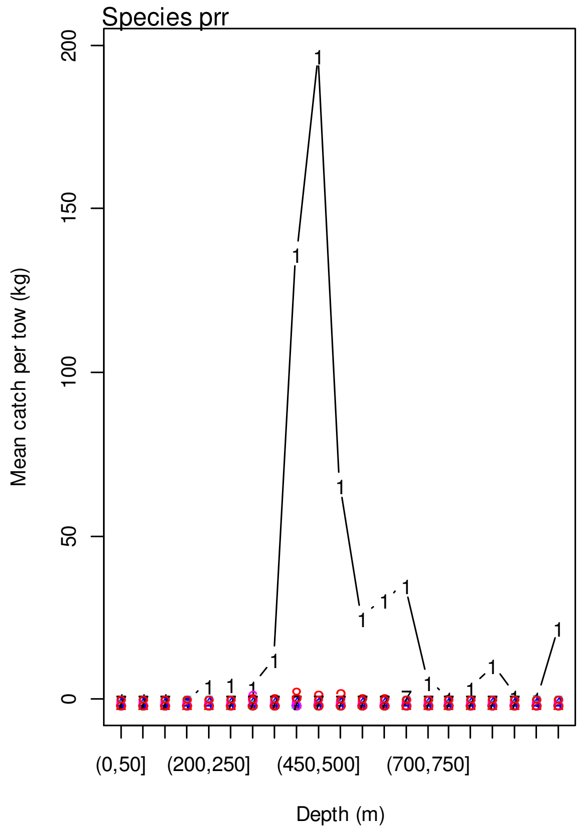

Species lig
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species lig
Mean catch per tow (kg)
Depth (m)
Species lig
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species lig
Correlation with ling catch
Year

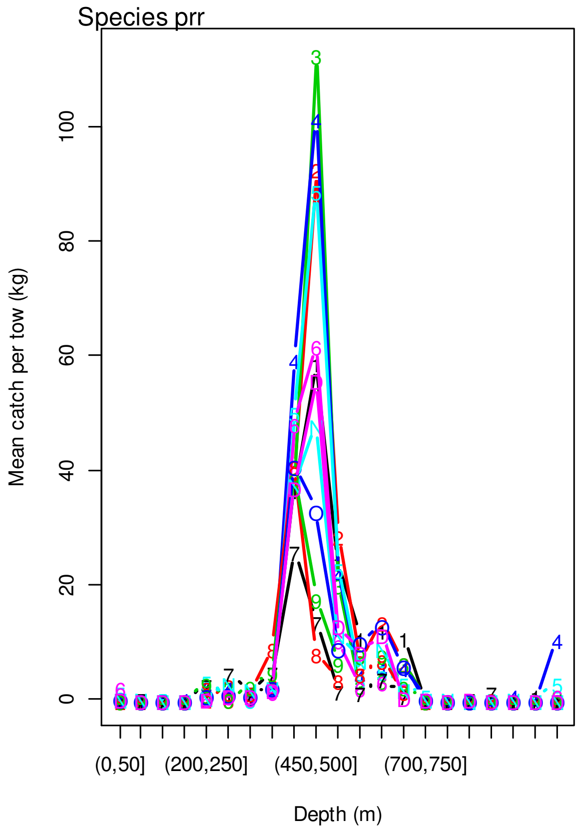

Species mow
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species mow
Mean catch per tow (kg)
Depth (m)
Species mow
Mean catch per tow (kg)
1985-89
1990-99
2000-09
2010
2011
2012
2013
Depth (m)
Species mow
Correlation with ling catch
Year
1985
1990
1995
2000
2005
2010

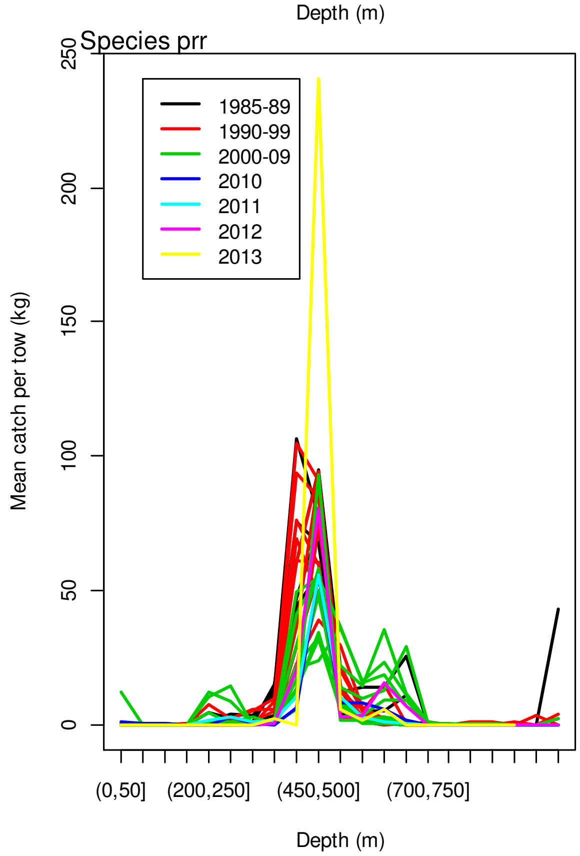

Species oro
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species oro
Mean catch per tow (kg)
Depth (m)
Species oro
Mean catch per tow (kg)
1985-89
1990-99
2000-09
2010
2011
2012
2013
Depth (m)
Species oro
Correlation with ling catch
Year
1985
1990
1995
2000
2005
2010

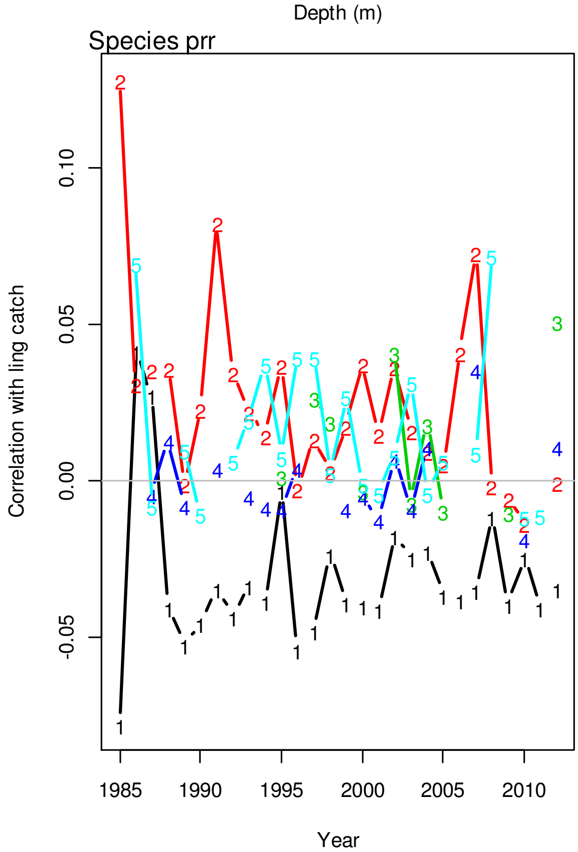


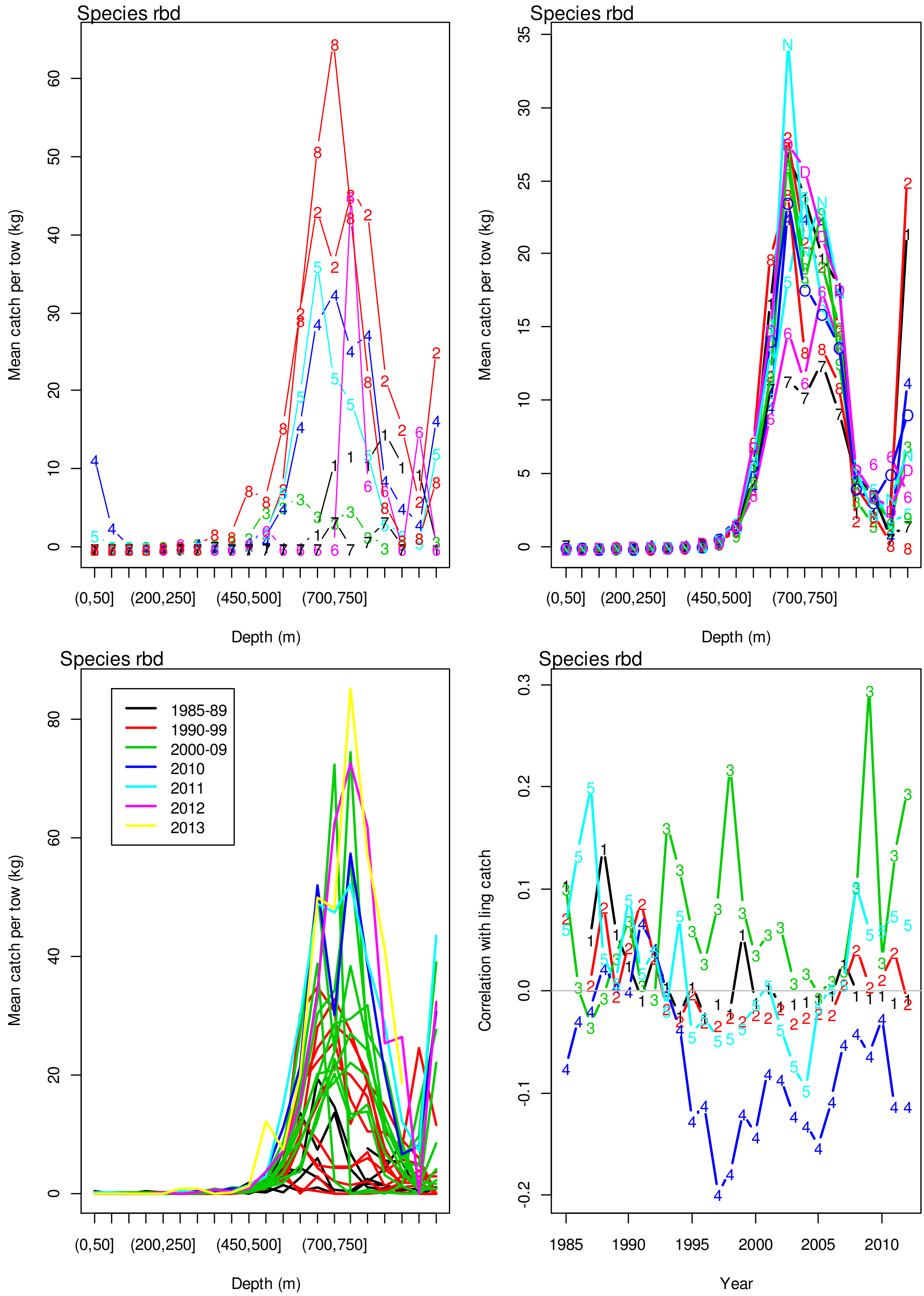
Species oth
Mean catch per tow (kg)
Depth (m)
Species oth
Mean catch per tow (kg)
Depth (m)
Species oth
Mean catch per tow (kg)
1985-89
1990-99
2000-09
2010
2011
2012
2013
Depth (m)
Species oth
Correlation with ling catch
Year


Species prr
Mean catch per tow (kg)
0
50
100
150
200
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

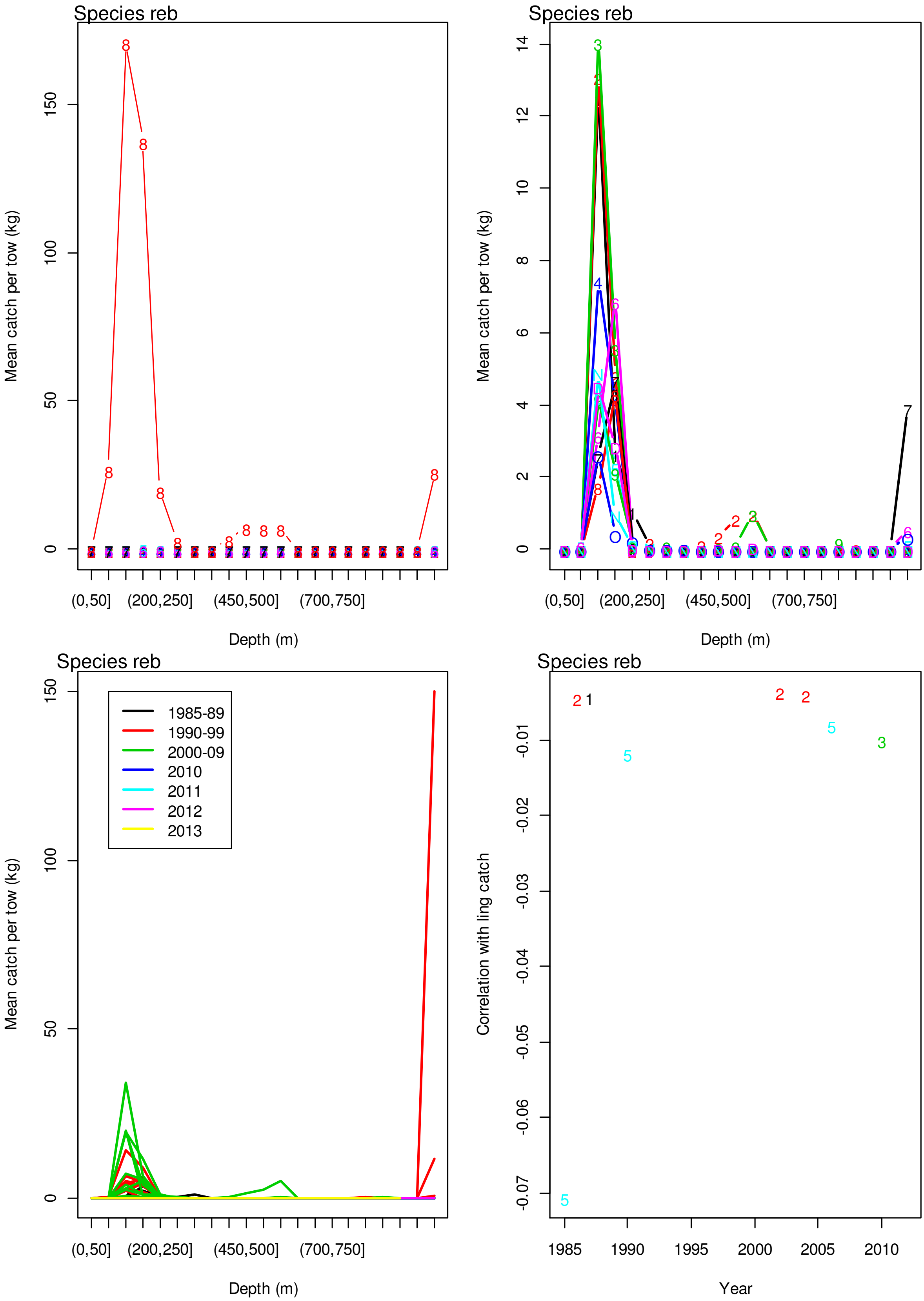

Species prr
Mean catch per tow (kg)
0
20
40
60
80
100
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

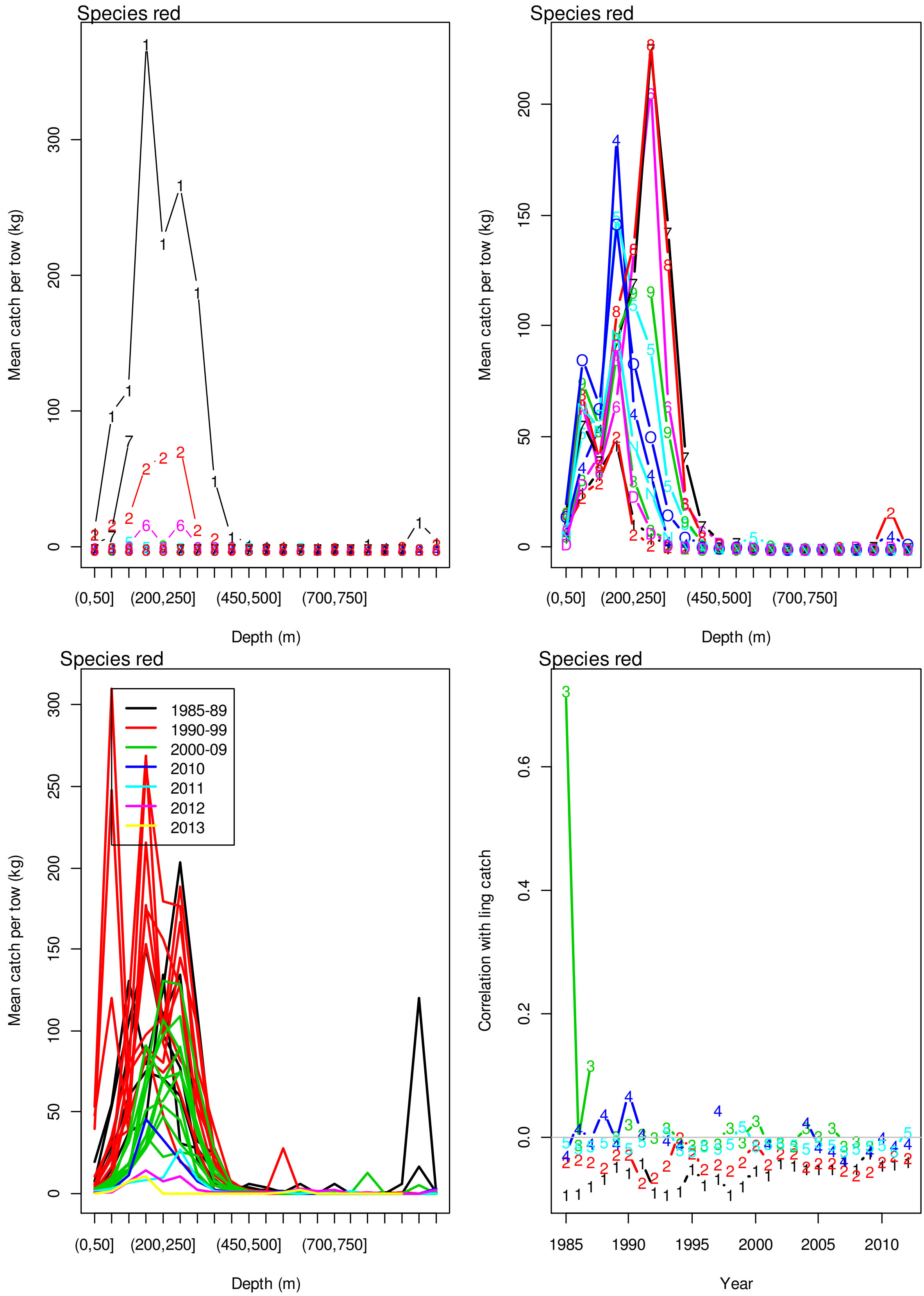

Species prr
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
0
50
100
150
200
250
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

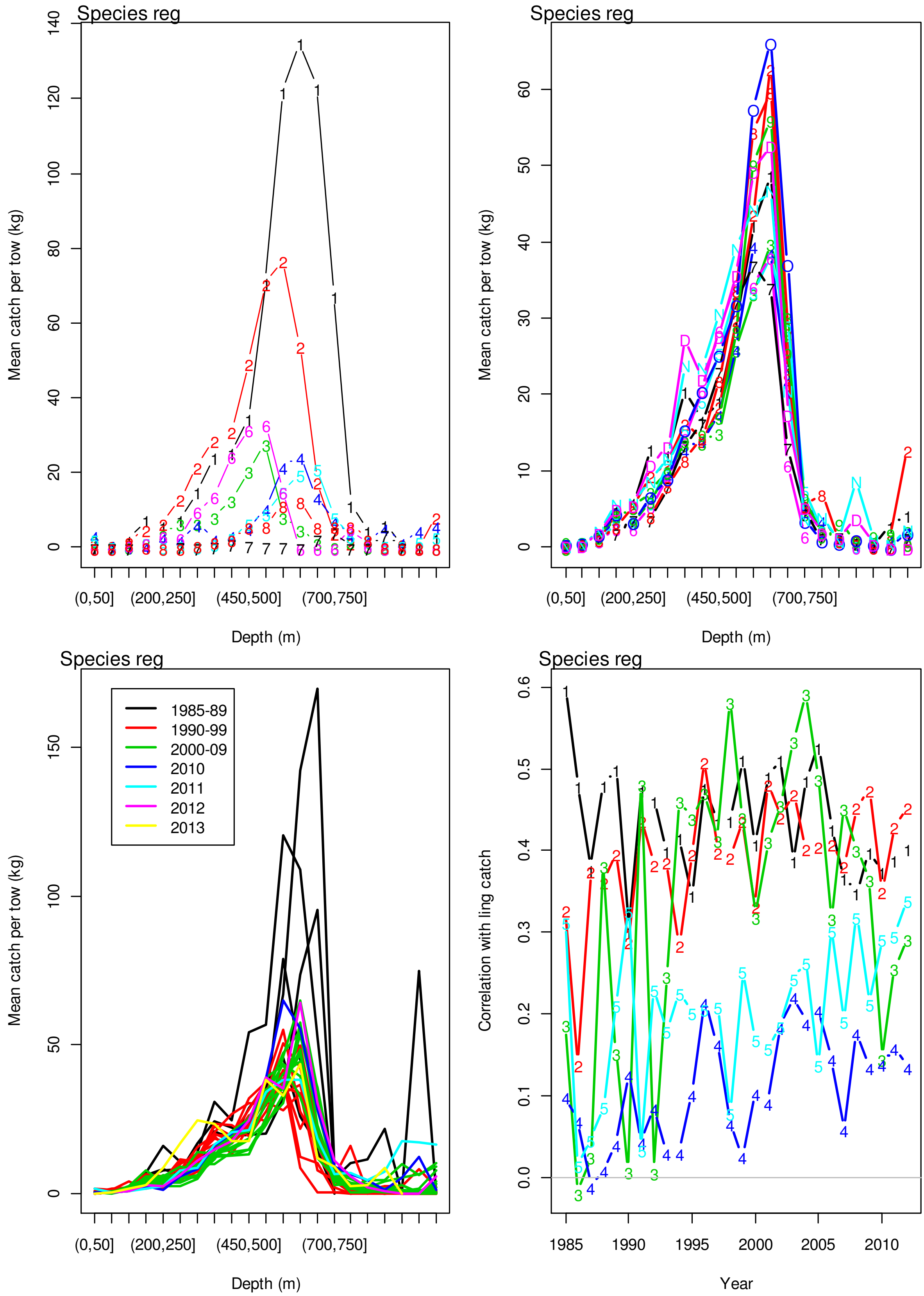

Species prr
Correlation with ling catch
-0.05
0.00
0.05
0.10
1985
1990
1995
2000
2005
2010
Year



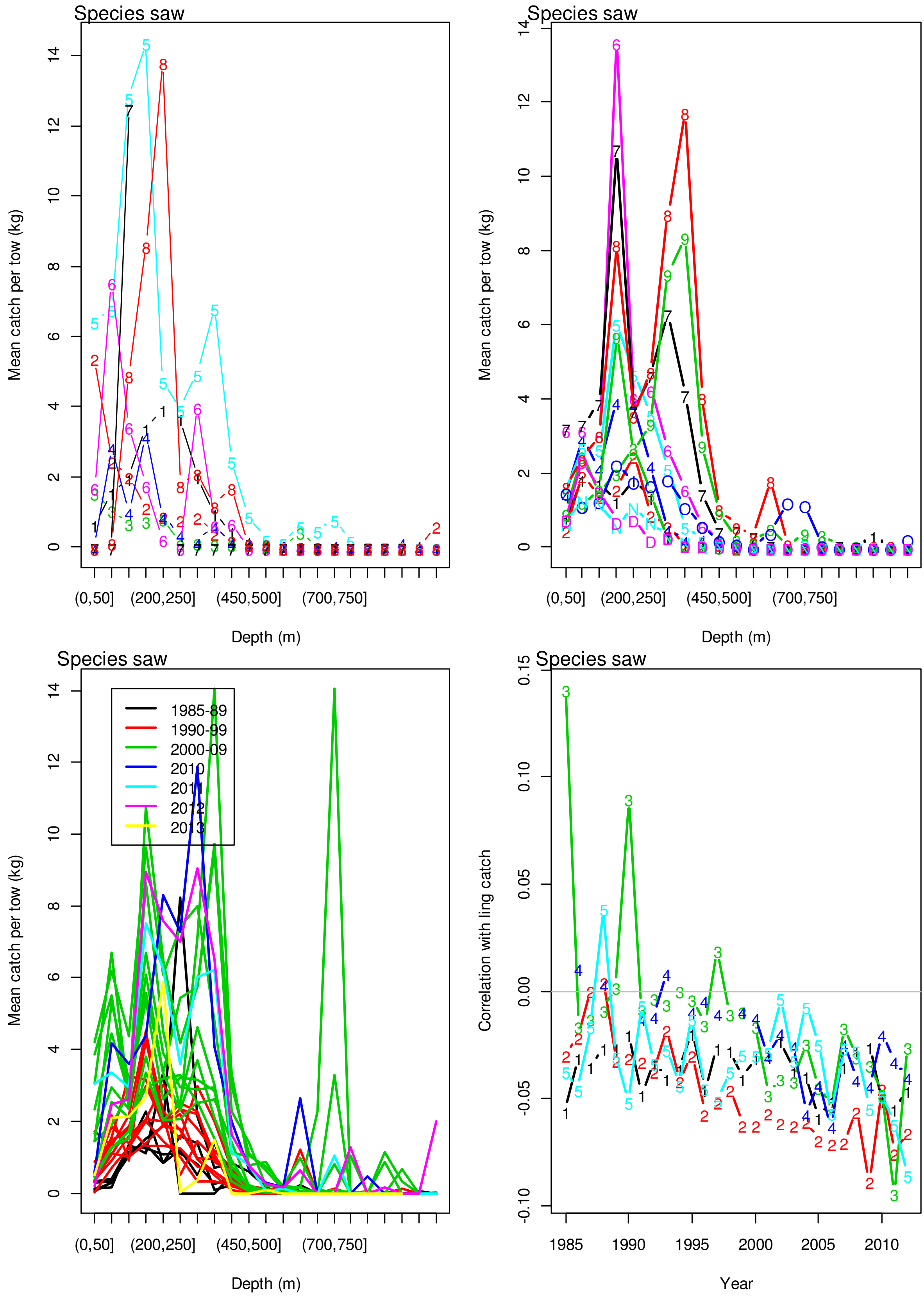
Species rbd
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species rbd
Mean catch per tow (kg)
Depth (m)
Species rbd
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species rbd
Correlation with ling catch
Year


Species reb
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species reb
Mean catch per tow (kg)
Depth (m)
Species reb
Mean catch per tow (kg)
Depth (m)
1985-89
1990-99
2000-09
2010
2011
2012
2013
Species reb
Correlation with ling catch
Year
1985
1990
1995
2000
2005
2010

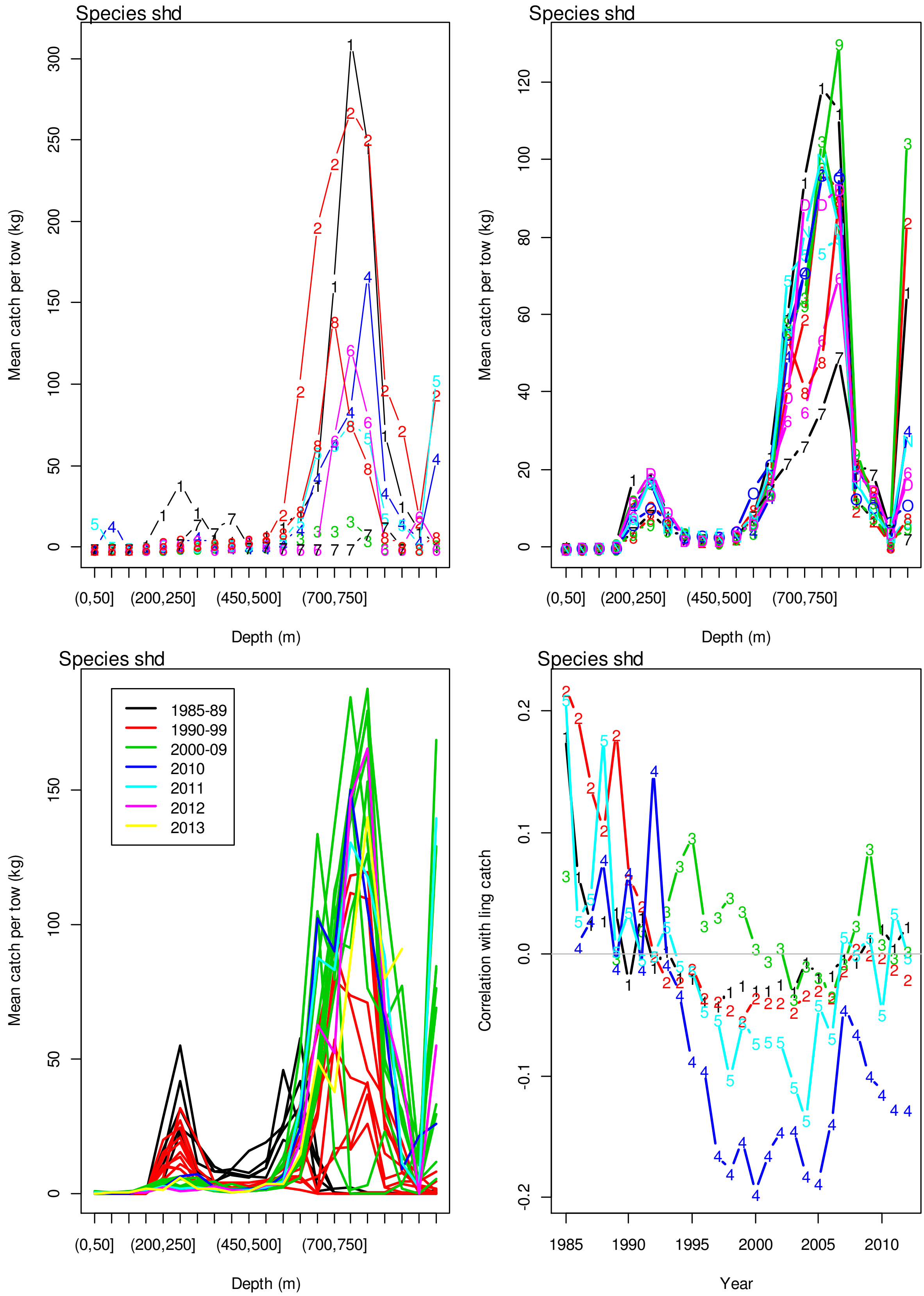

Species red
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Correlation with ling catch
Year
1985-89
1990-99
2000-09
2010
2011
2012
2013

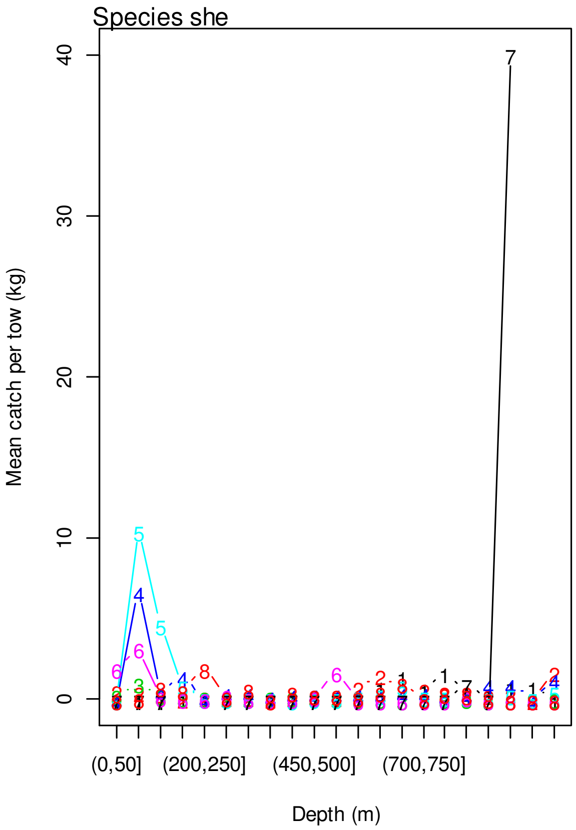


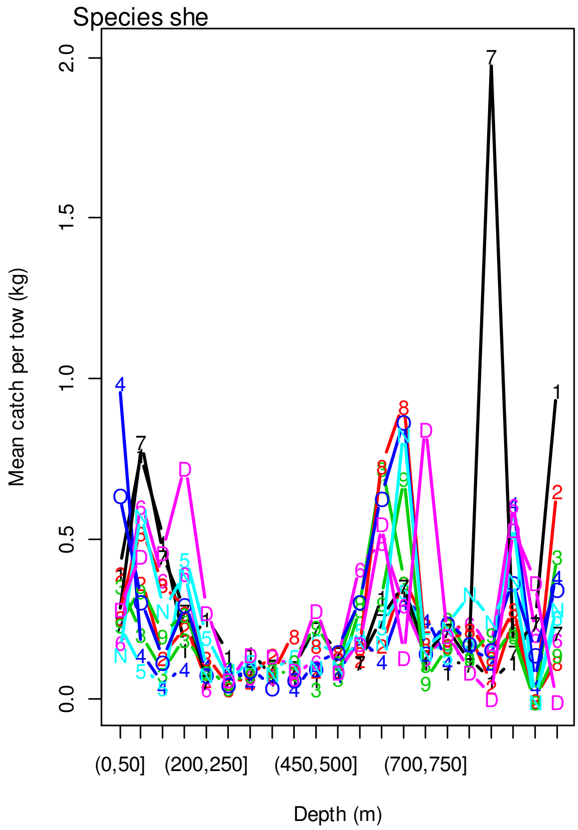
Species reg
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species reg
Mean catch per tow (kg)
Depth (m)
Species reg
Mean catch per tow (kg)
Depth (m)
1985-89
1990-99
2000-09
2010
2011
2012
2013
Species reg
Correlation with ling catch
Year
1985
1990
1995
2000
2005
2010

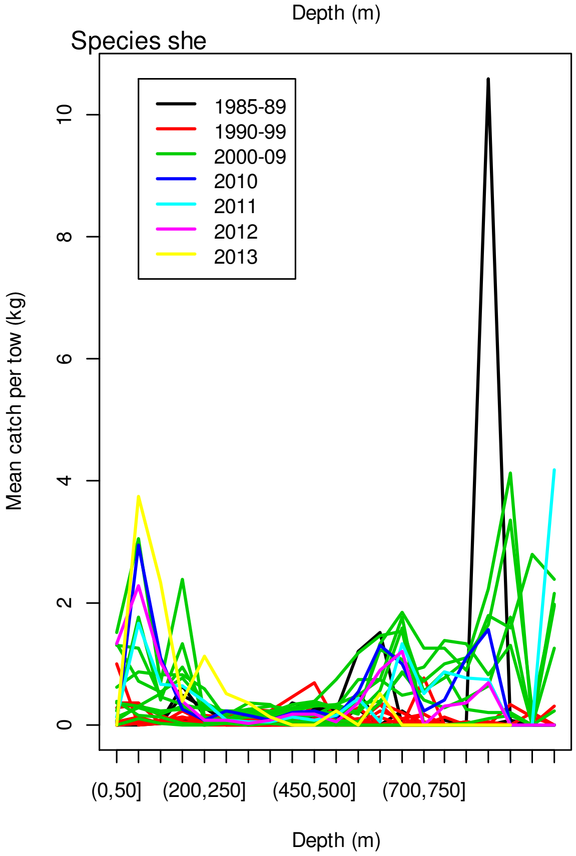


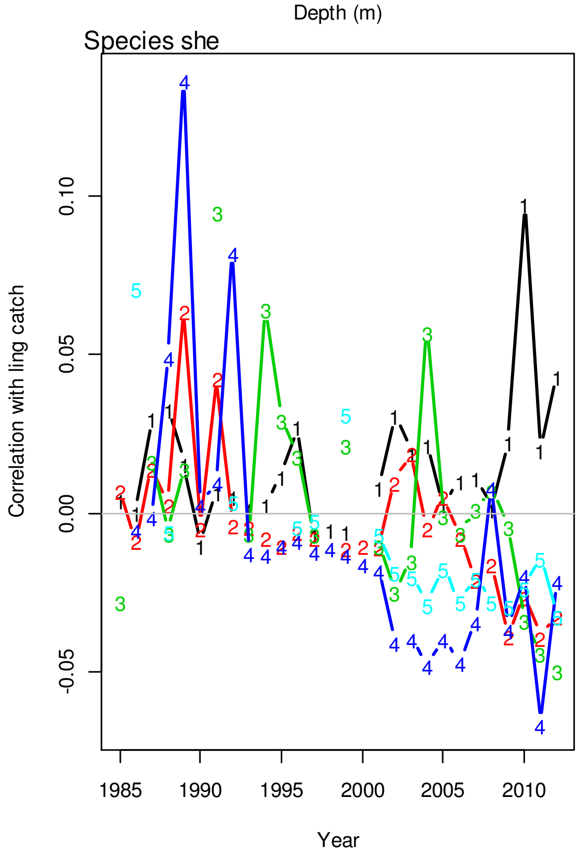
Species saw
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species saw
Mean catch per tow (kg)
Depth (m)
Species saw
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
Depth (m)
Species saw
Correlation with ling catch
Year

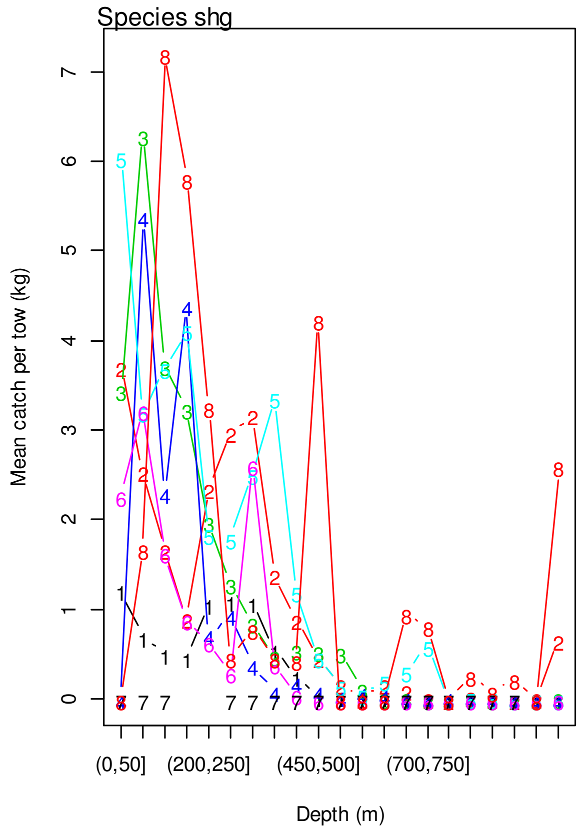

Species shd
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
1985-89
1990-99
2000-09
2010
2011
2012
2013
Correlation with ling catch
Year

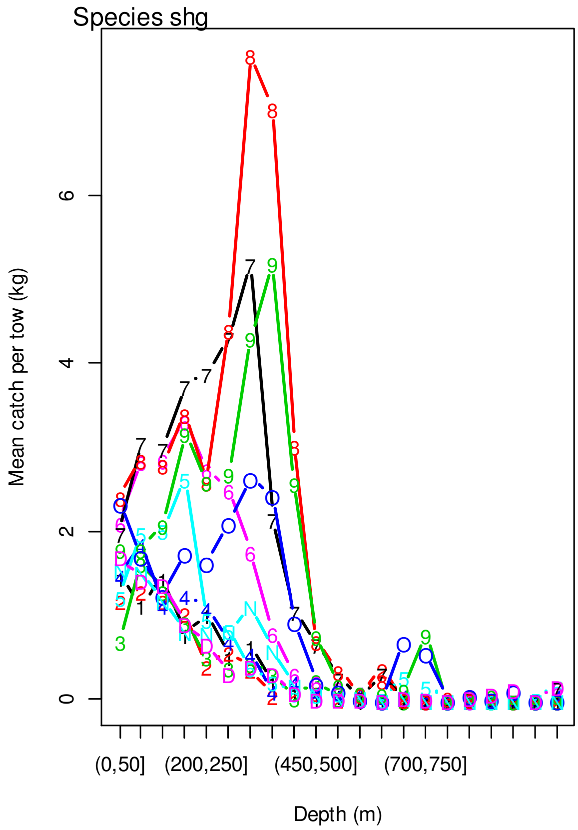

Species she
Mean catch per tow (kg)
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

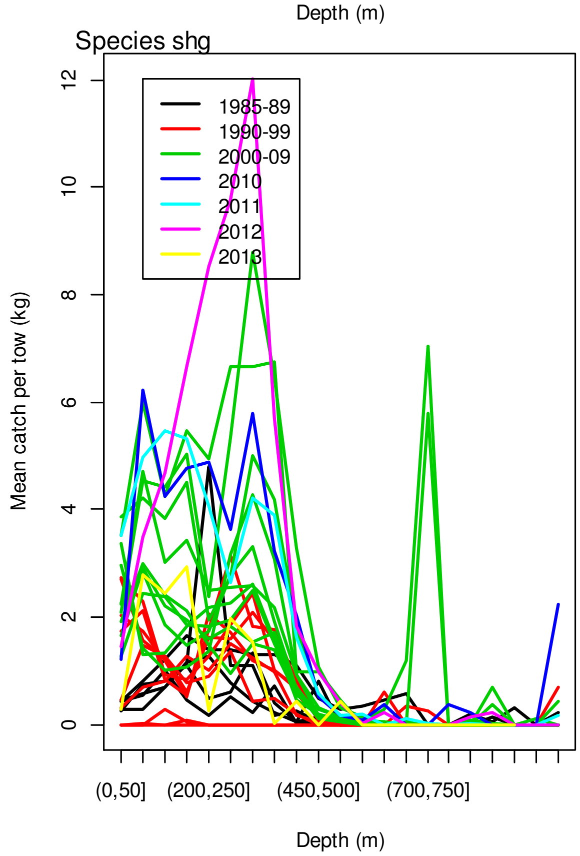

Species she
Mean catch per tow (kg)
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

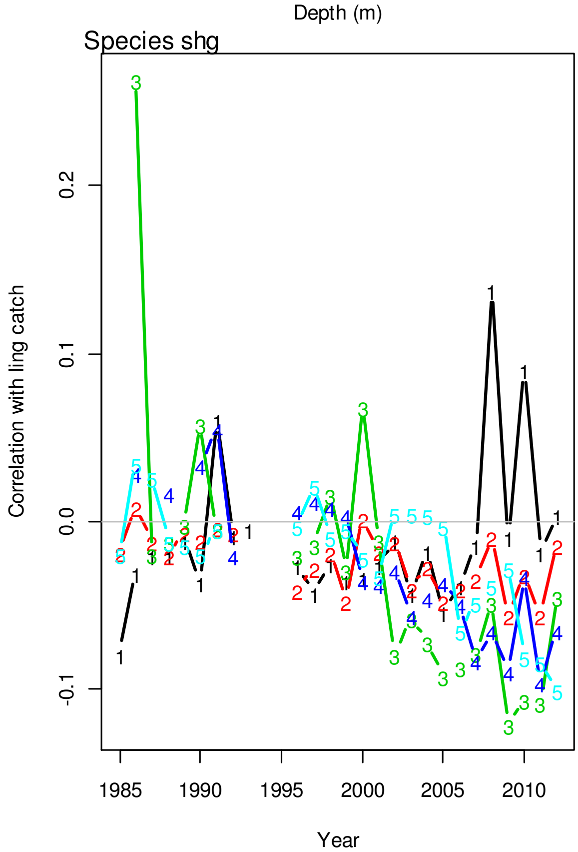

Species she
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
(0,50]
(200,250]
(450,500]
(700,750]
Depth (m)

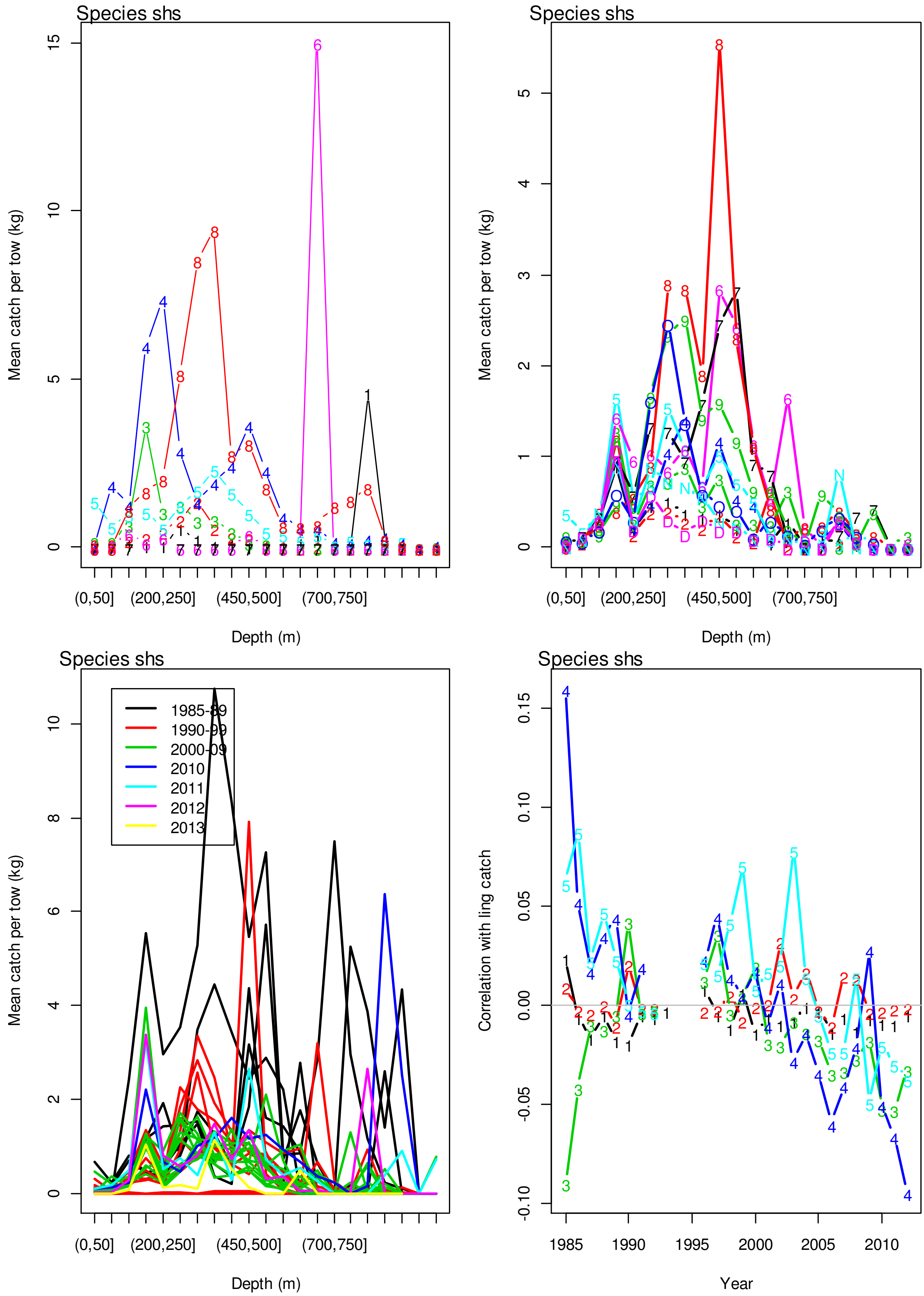

Species she
Correlation with ling catch
1985
1990
1995
2000
2005
2010
Year


Species shg
Mean catch per tow (kg)
0 1 2 3 4 5 6 7
(0,50] (200,250] (450,500] (700,750]
Depth (m)


Species shg
Mean catch per tow (kg)
0 2 4 6
(0,50] (200,250] (450,500] (700,750]
Depth (m)


Species shg
1985-89
1990-99
2000-09
2010
2011
2012
2013
Mean catch per tow (kg)
0 2 4 6 8 10 12
(0,50] (200,250] (450,500] (700,750]
Depth (m)


Species shg
Correlation with ling catch
-0.1 0.0 0.1 0.2
1985 1990 1995 2000 2005 2010
Year


Species shs
Mean catch per tow (kg)
Depth (m)
(0,50]
(200,250]
(450,500]
(700,750]
Species shs
Mean catch per tow (kg)
Depth (m)
Species shs
1985-89
1990-99
2000-09
2010
2011
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2013
Mean catch per tow (kg)
Depth (m)
Species shs
Correlation with ling catch
Year
1985
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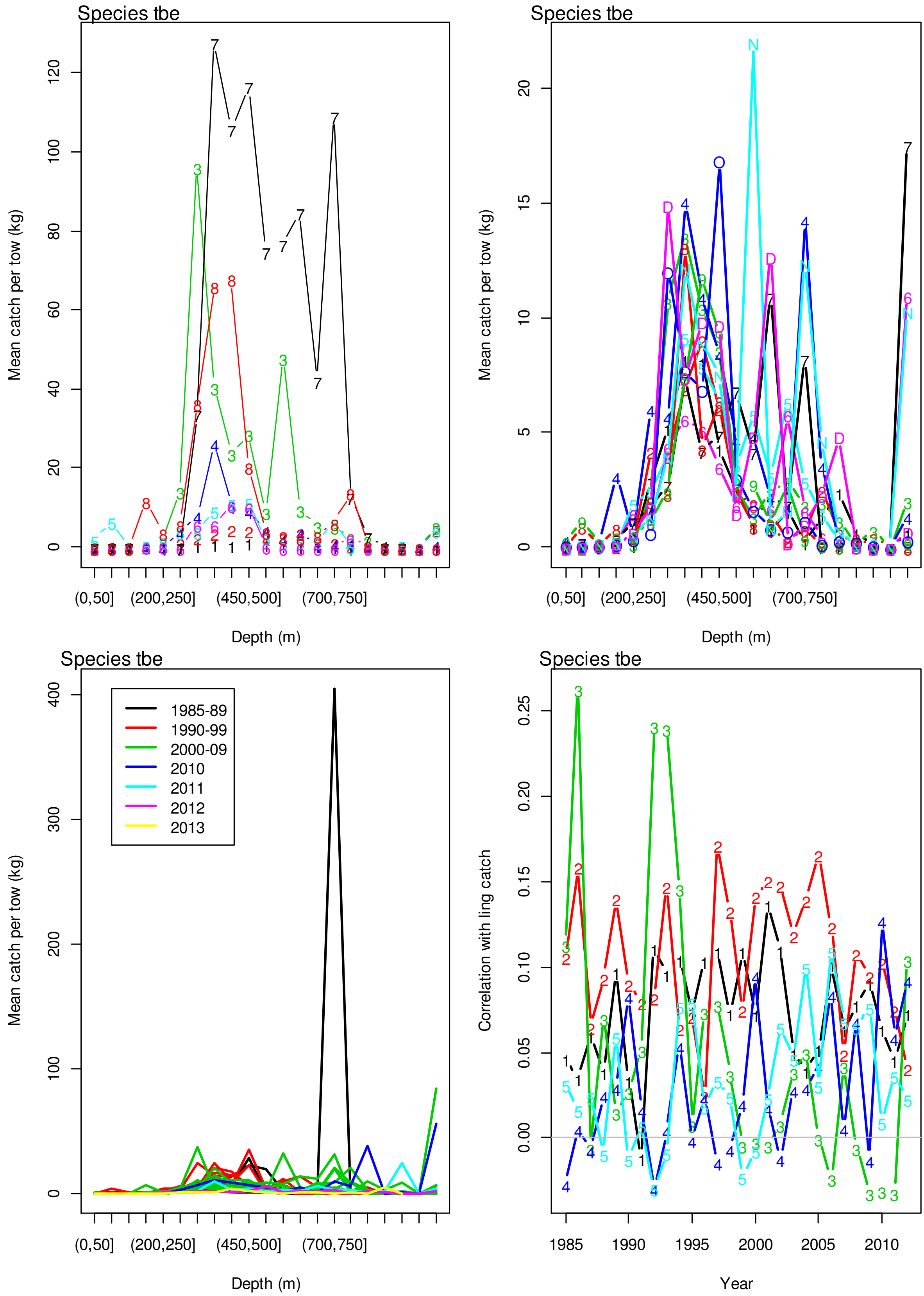
1995
2000
2005
2010



Species tbe
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Species tbe
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1985-89
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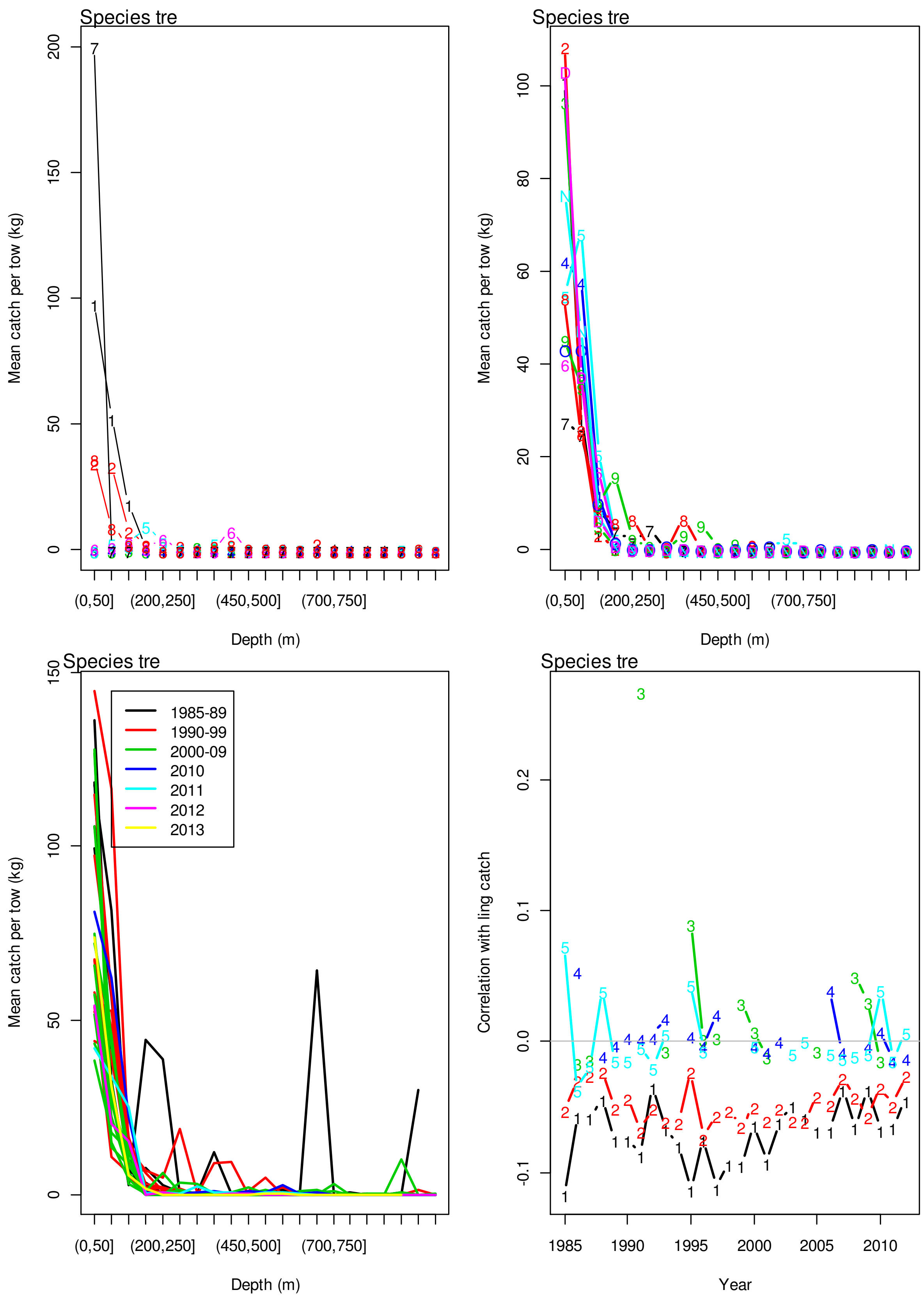
Depth (m)
Species tbe
Correlation with ling catch
Year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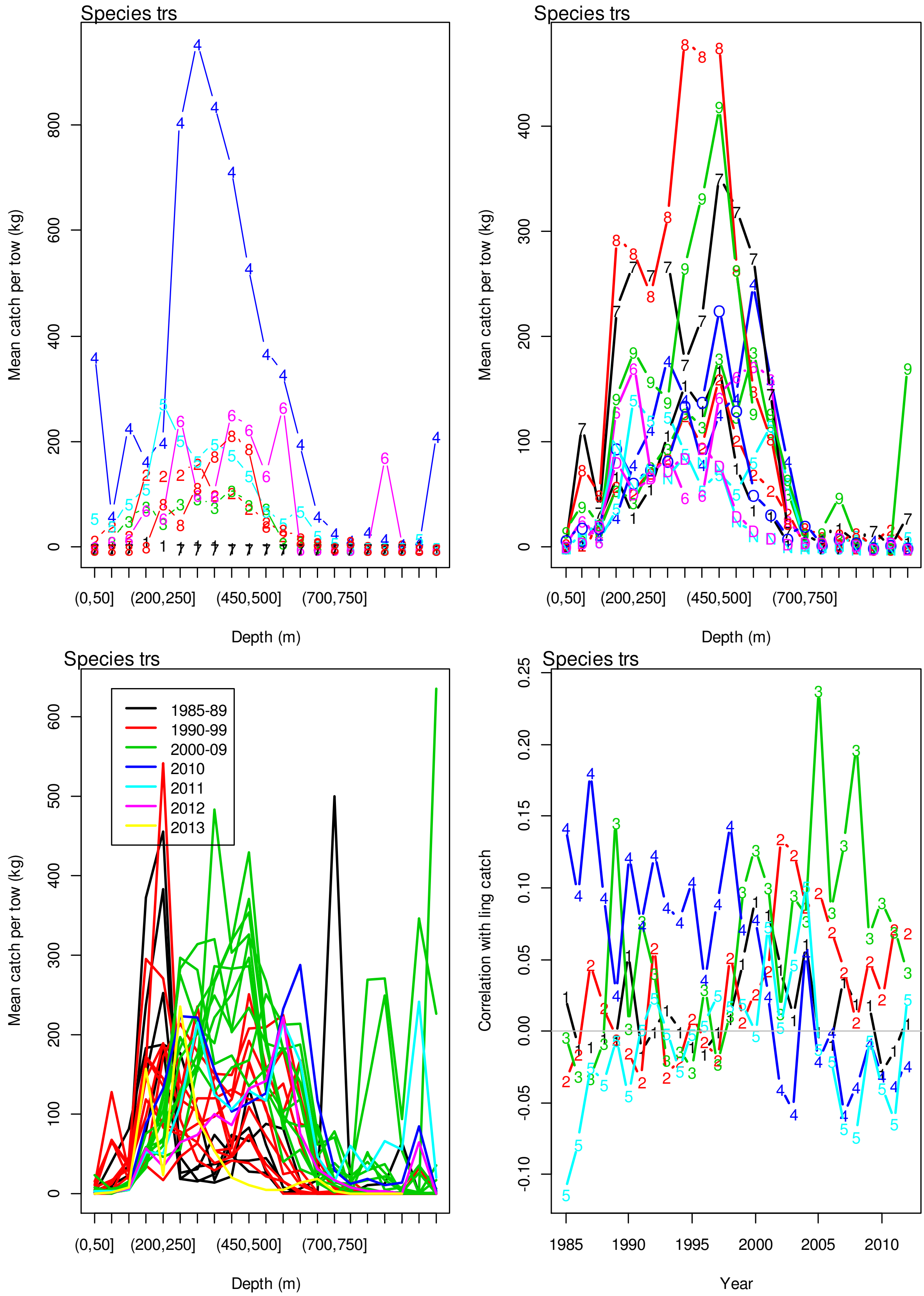
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Species trs
Mean catch per tow (kg)
Depth (m)
Species trs
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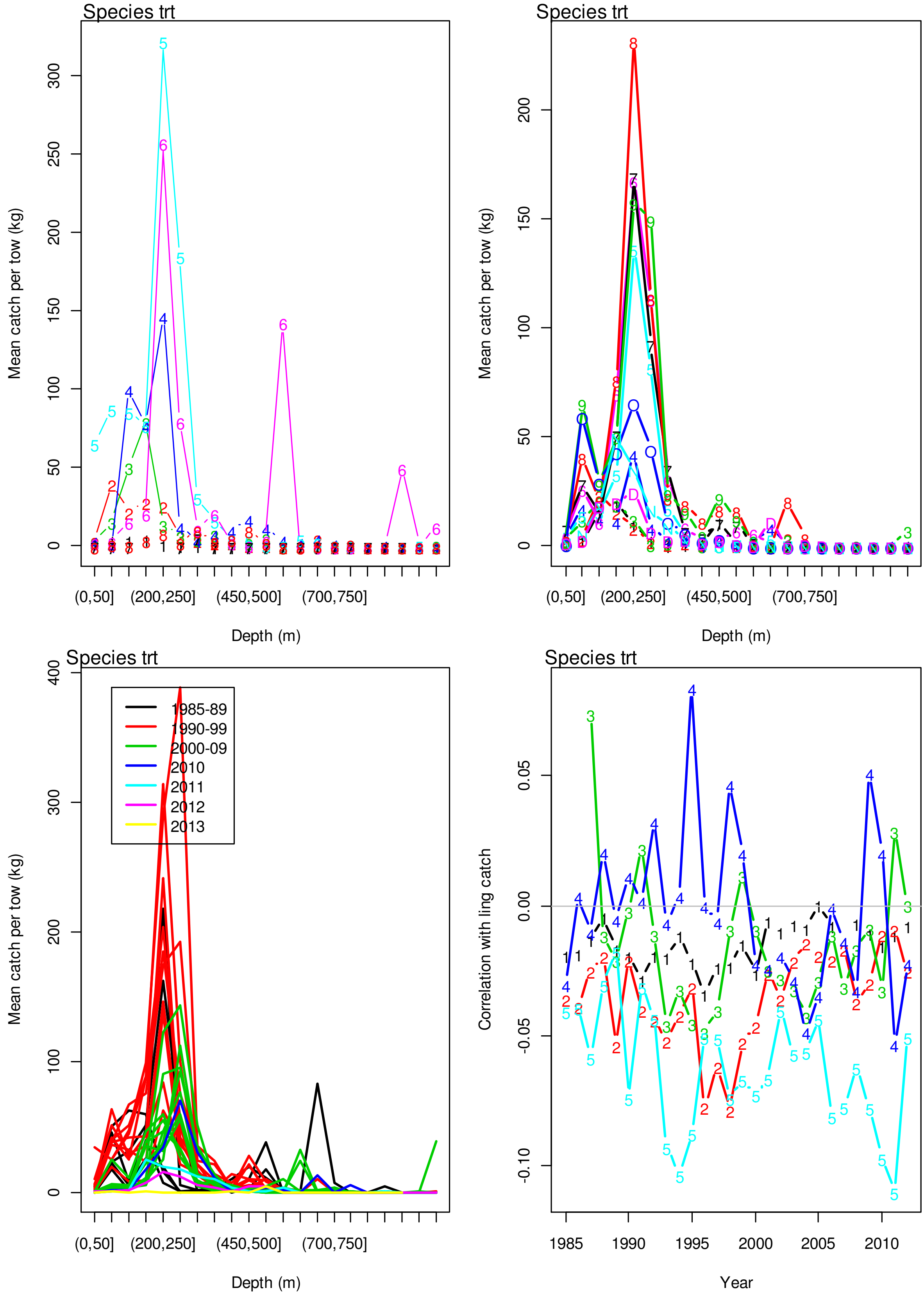
Mean catch per tow (kg)
Depth (m)
Species trs
Correlation with ling catch
Year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Species trt
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1990-99
2000-09
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Mean catch per tow (kg)
Depth (m)
Species trt
Correlation with ling catch
Year
1985
1990
1995
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2005
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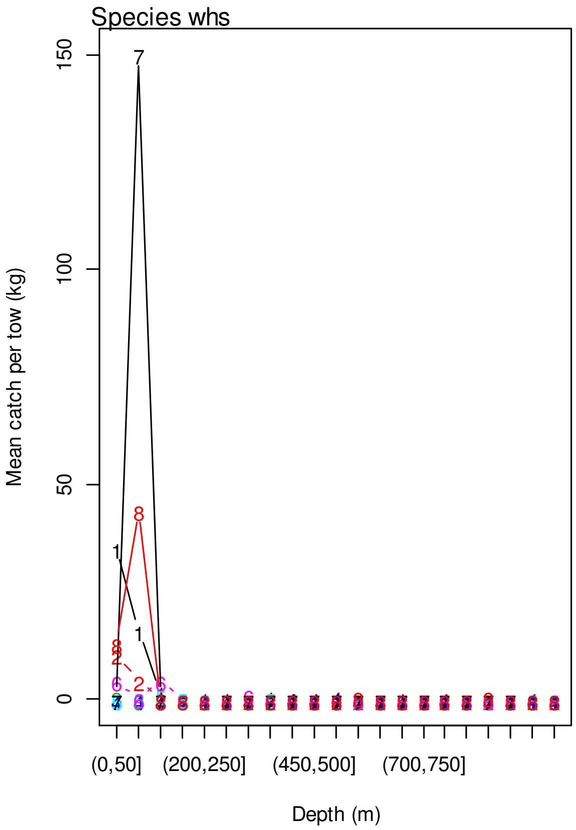
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Mean catch per tow (kg)
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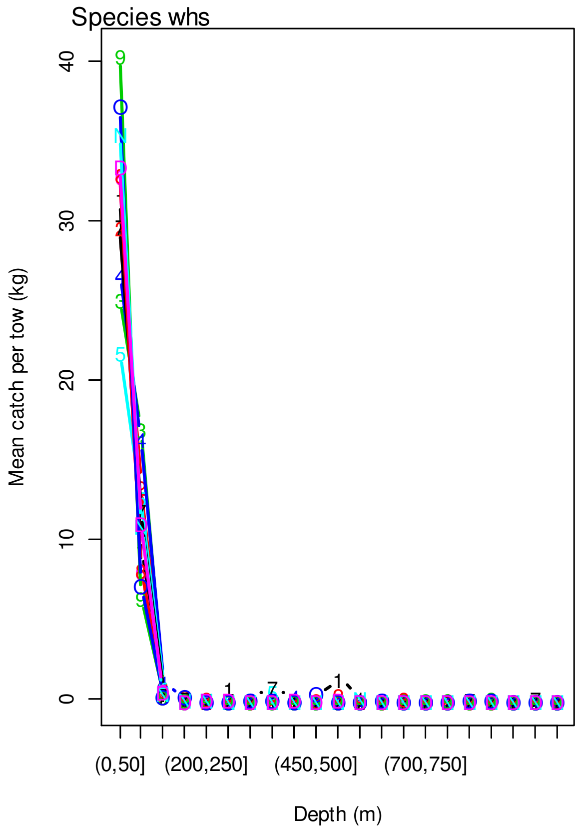
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Mean catch per tow (kg)
Depth (m)
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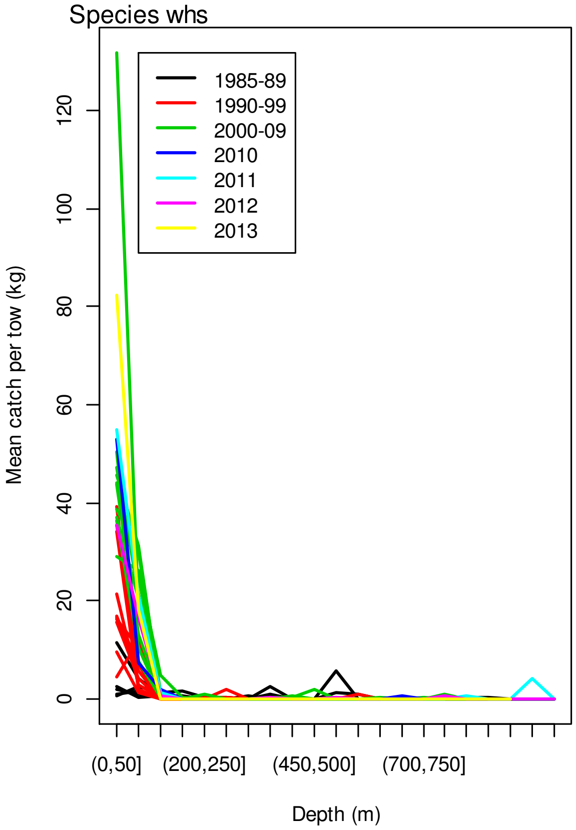
Species whs
1985-89
1990-99
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Mean catch per tow (kg)
Depth (m)
(0,50]
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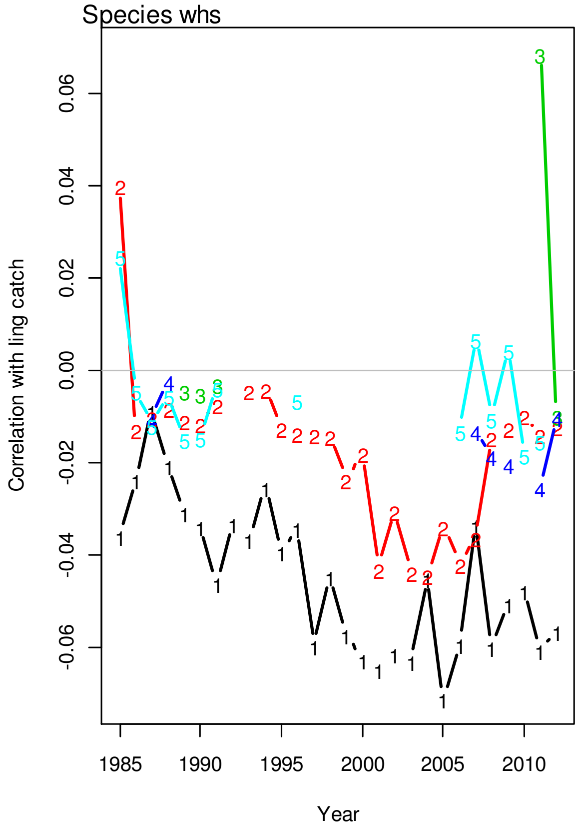
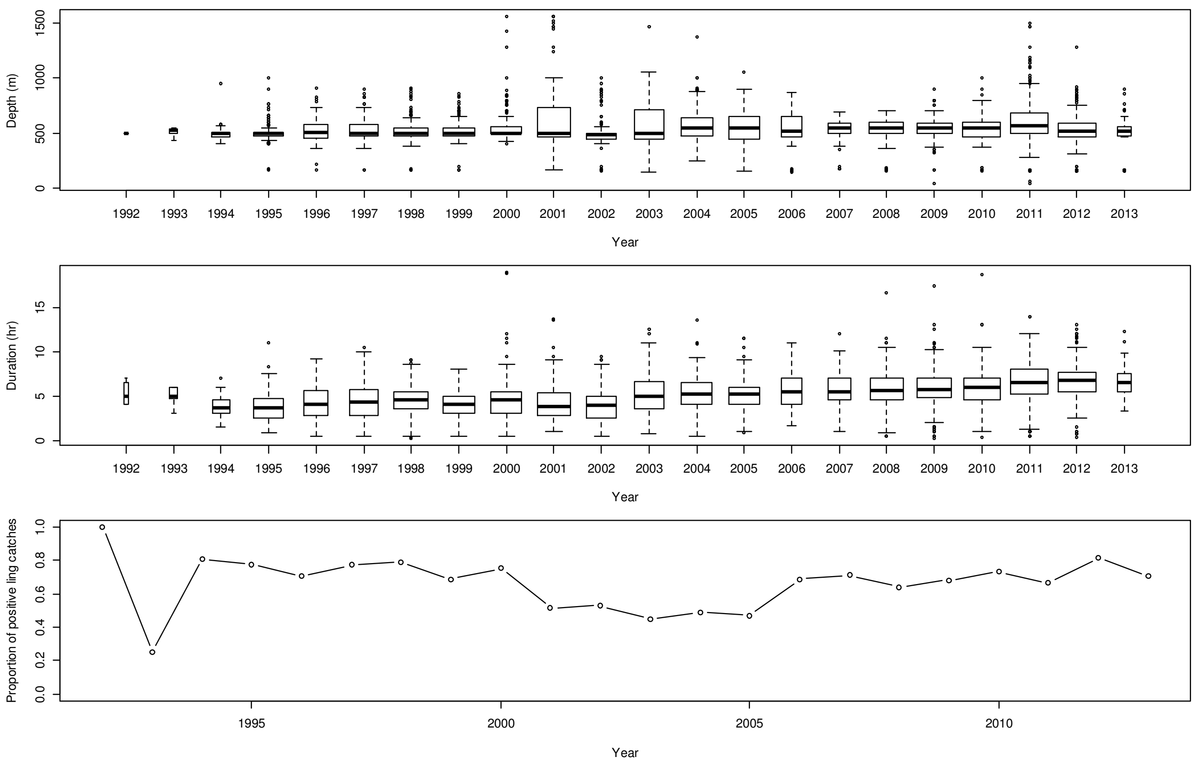
(450,500]
(700,750]


Species whs
Correlation with ling catch
Year

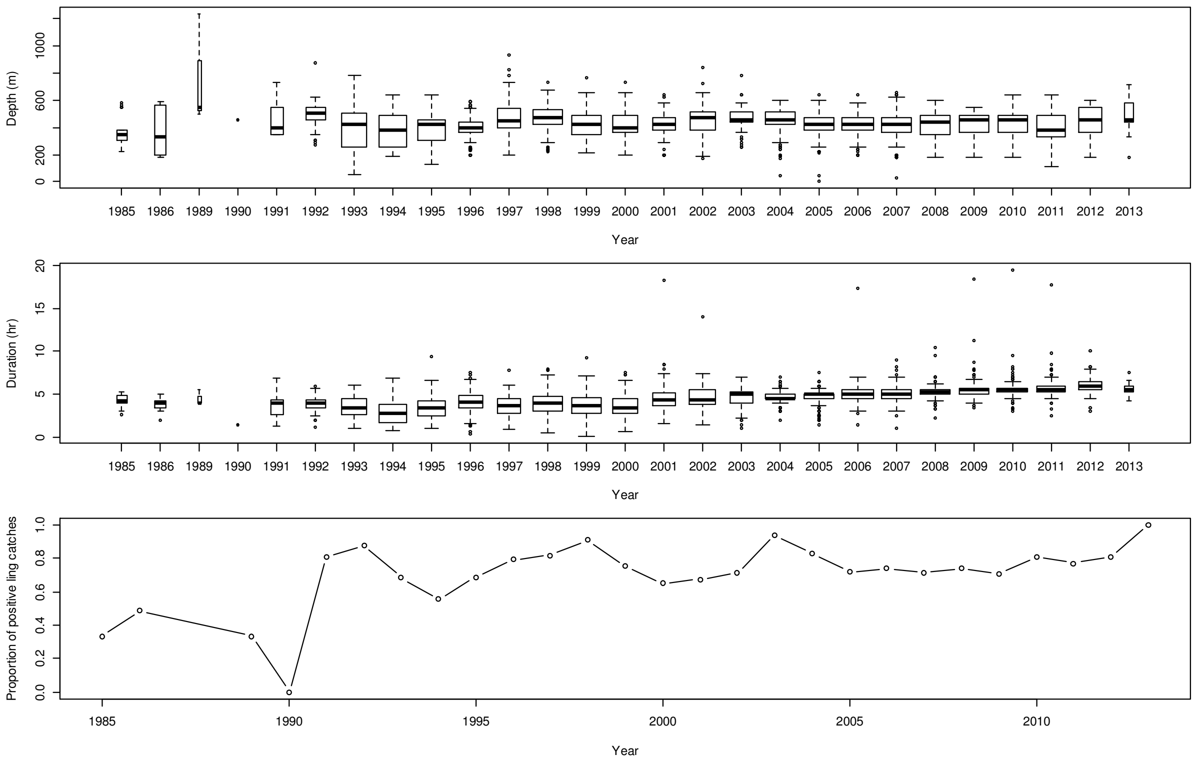
Appendix 3: Plots for vessels selected to have constant vessel effects

For the west, three vessels were selected to have constant vessel effects over the whole time period – see the first three plots below.

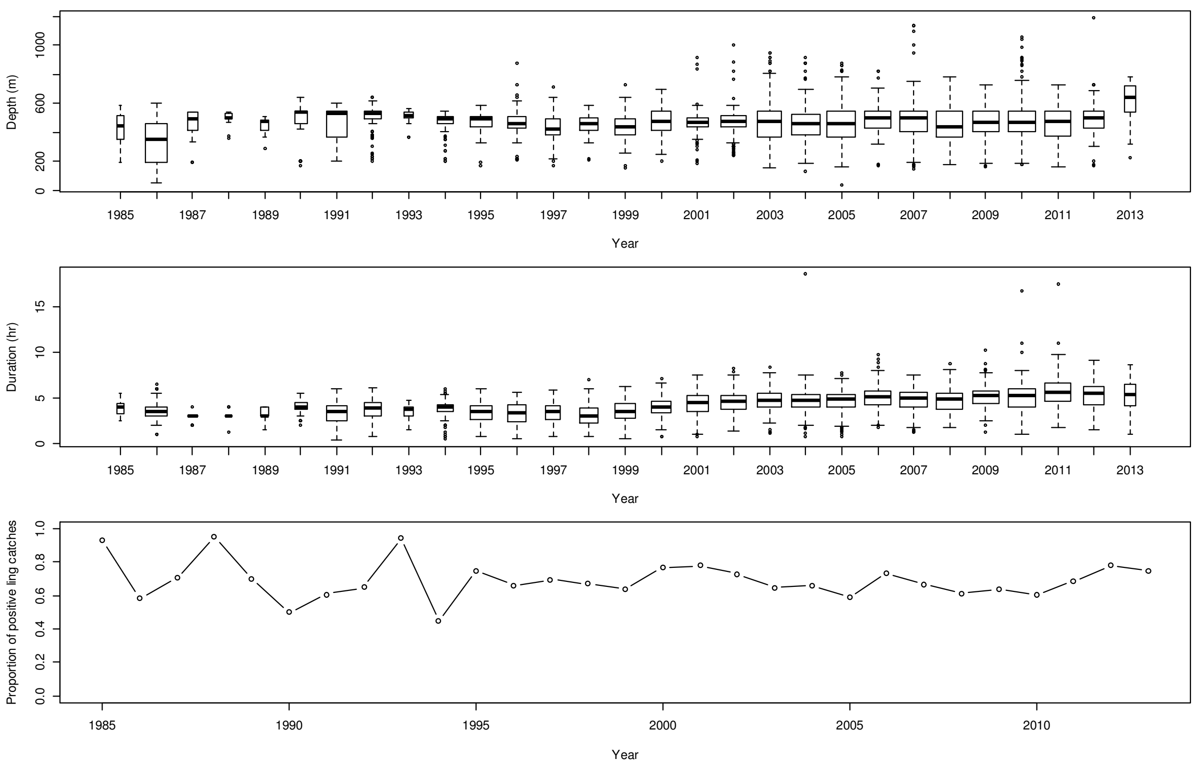
For the east, there was one vessel that gave a weak link over the whole time period – it didn't catch much ling but at least it seemed fairly consistent. There were two additional vessels spanning the break at 1999-2000 and a single additional vessel covering 2006-2007.



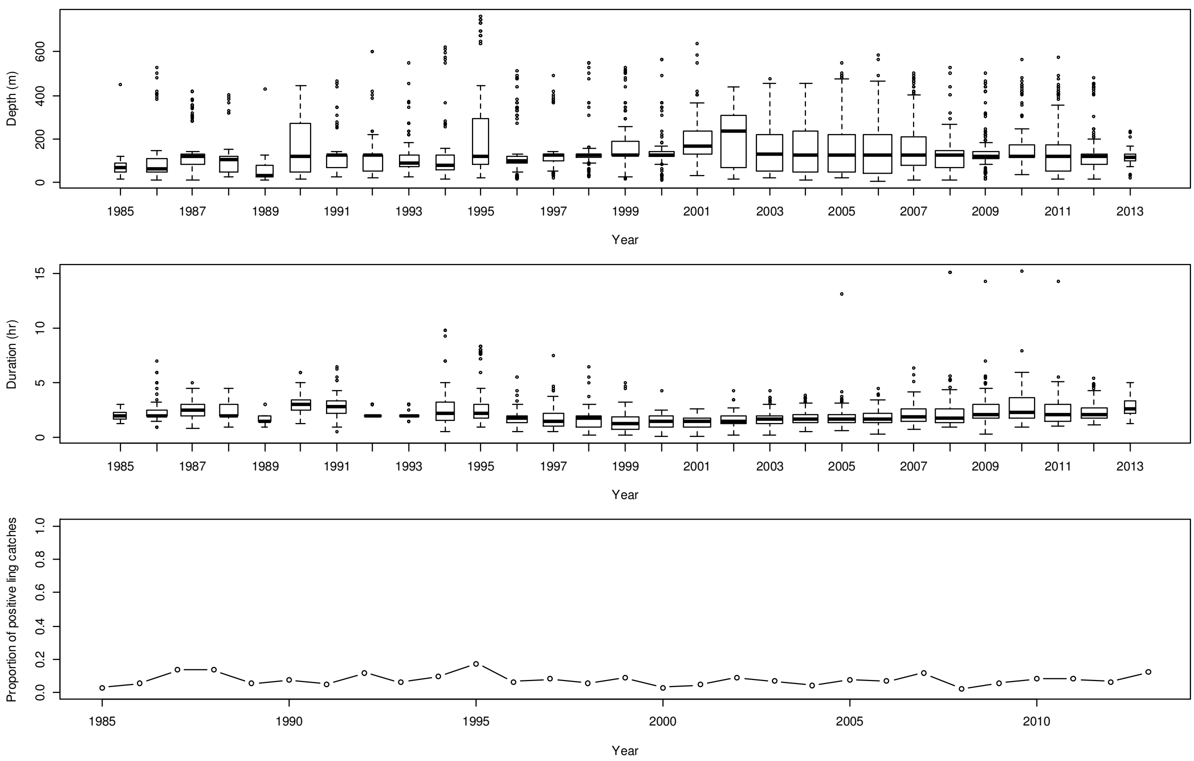
West vessel 1.



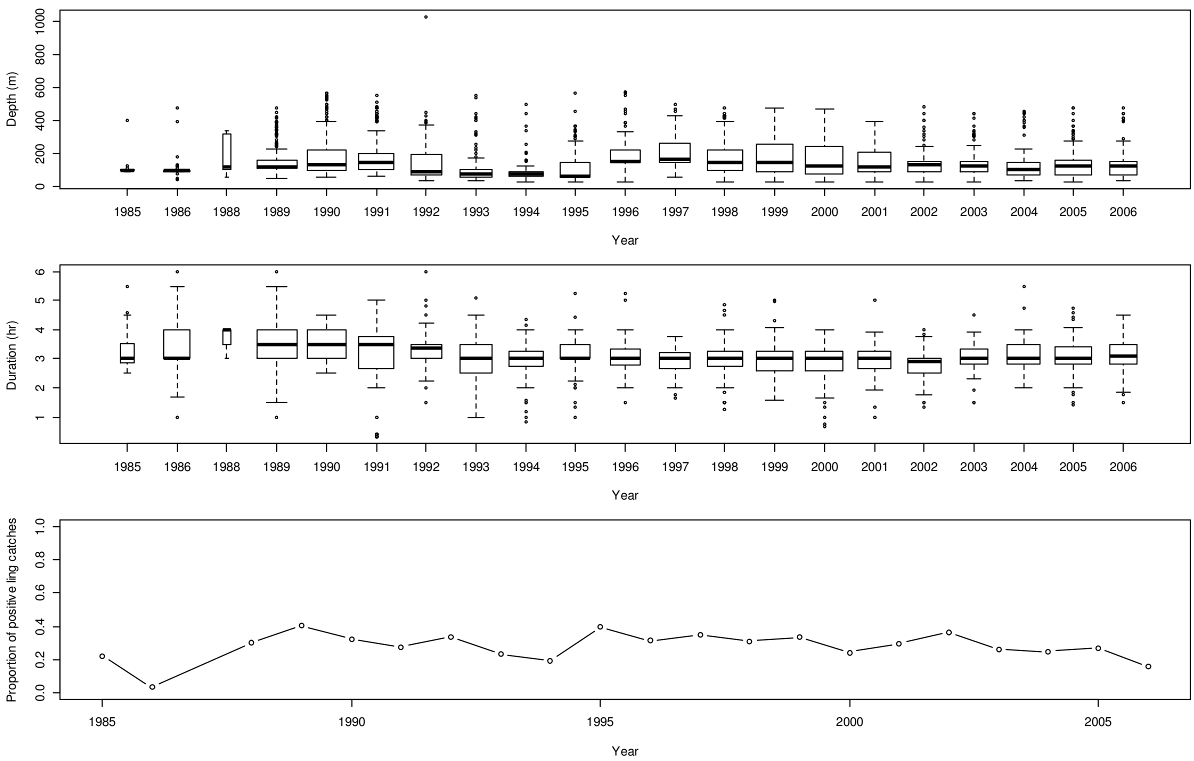
West vessel 2.



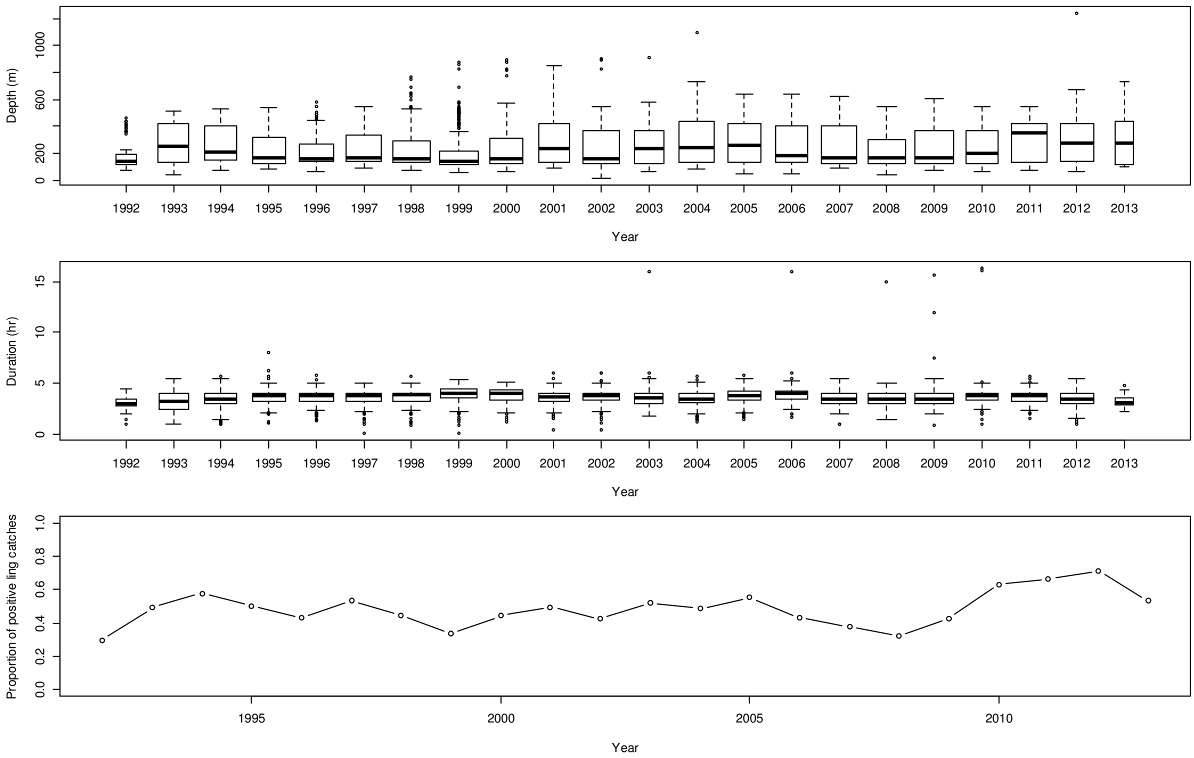
West vessel 3.



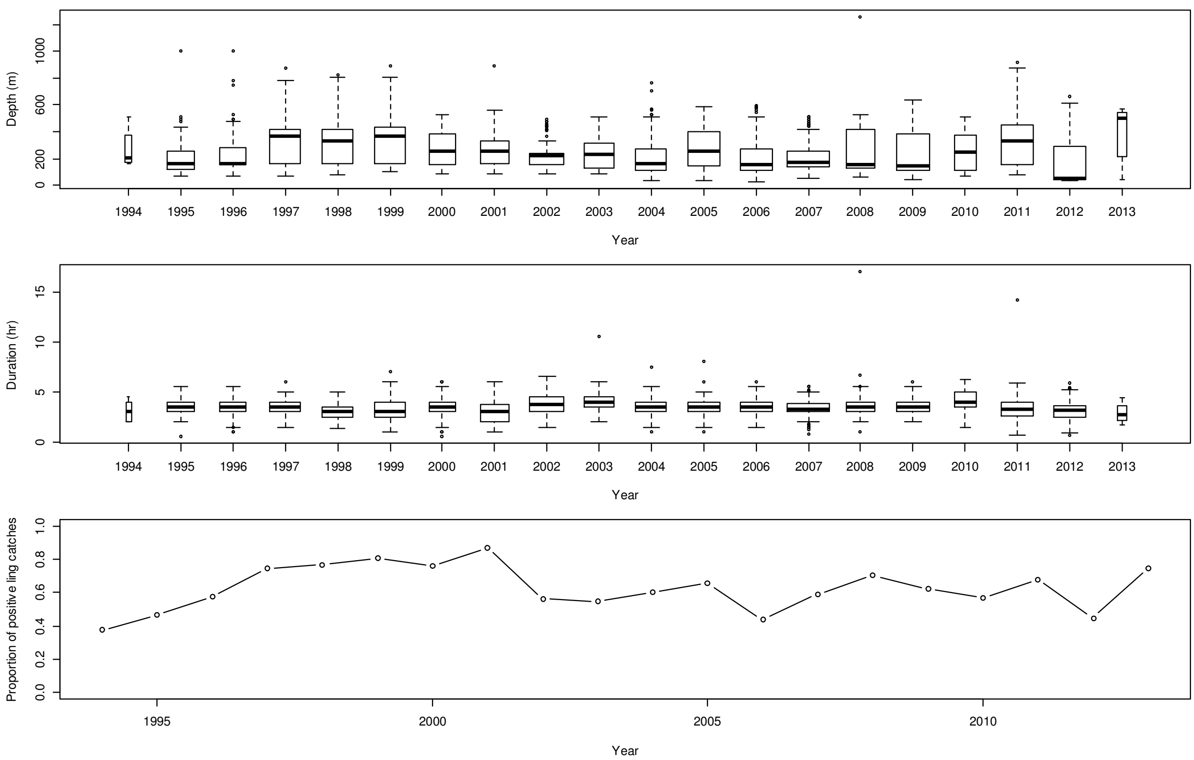
East vessel 1 (link across all three blocks).



East vessel 2 (1986-1999, 2000-2006 link).



East vessel 3 (1986-1999, 2000-2006 link).



East vessel 4 (2000-2006, 2007-2012 link)

Preliminary stock assessment for pink ling: ISL models

P.L. Cordue
15 September 2013

Executive Summary

This document provides a summary and many details with regard to preliminary stock assessments of Australian pink ling (eastern and western stocks) performed by ISL for consideration at the September 2013 Slope RAG meeting. The document describes the development of an ISL "base" eastern model and a western "reference" model. These are for illustrative purposes as the RAG will make the choices as to which data and model structures are used in the 2013 base models used to provide management advice.

The eastern and western assessments have very different challenges to deal with in terms of providing a reliable stock assessment. For the east, the issues are mainly to do with data preparation, while in the west, the issues primarily involve model and data weighting decisions.

The analysis of length and age-at-length data (performed by ISL and described in other draft RAG documents) showed that the eastern data had to be stratified and scaled to some extent otherwise the model would be given misleading signals. There is a trade-off between how much stratification and scaling is done and how much data can be used in the model. The acceptance rules used in the ISL-base model appear to provide a good balance between the quality and quantity of data used. The analysis also showed that the assumption of length-based selection in the fisheries was not fully supported; and there was little support for the use of cohort-specific growth.

ISL's CPUE analysis, to some extent, was able to deal with the issues of the sale of trawl quota in the east in 1999 and the structural adjustment in 2006. The approach used to allow a change in vessel behaviour to alter the trawl CPUE indices had a strong effect on the eastern indices over the 1999-2000 breakpoint but little effect over the 2006-2007 breakpoint (in the east and the west). Consequently the choice of the ISL or CSIRO CPUE indices in the east has an impact on the assessment results, but it is not important in the west.

In the western assessment, there is a strong conflict between the trawl age-length data and the trawl CPUE indices. This indicates that a down-weighting of the trawl age-length data is required. However, when this is done the estimate of *M* appears to be a bit too high. As there are little data in the western assessment to provide information on *M*, it is best to either fix *M* at a "sensible" value, or to use a strongly informed prior. In both cases, it appears that the eastern assessment can provide the needed information on *M*.

Introduction

This document provides a summary and many details with regard to preliminary stock assessments of Australian pink ling (eastern and western stocks) performed by ISL for consideration at the September 2013 Slope RAG meeting. The document describes the development of an ISL "base" eastern model and a western "reference" model. These are for illustrative purposes as the RAG will make the choices as to which data and model structures are used in the 2013 base models. The work could not have been done without the help and cooperation of CSIRO scientists. CSIRO supplied ISL with raw and processed data and there were numerous email discussions on modelling and data issues. My particular thanks to Andre Punt and Neil Klaer.

Methods

Numerous issues were considered during the preparation of this stock assessment (Cordue & Punt draft). Issues not brought into question and which followed the approach used by CSIRO in 2012 were:

- Assumption of two stocks, east (Zones 10, 20, 30) and west (Zones 40, 50) (except Zone 60 is now included in Zone 20)
- Construction of catch history (except Zone 60 is now included in Zone 20)
- Two fisheries: trawl and non-trawl
- Discards not modelled
- Use of a two-sex population model
- Plus-group at age 30 in the population
- Construction and use of the ageing error matrix

In terms of other issues considered in Cordue & Punt (draft) the following options were chosen in ISL's preferred models:

Issue	Option chosen for base models
Construction of length frequencies for spatially-aggregated models	Length frequency data were analysed and it was concluded that stratification by depth and/or zone was appropriate (see details of exactly how LFs were prepared in the base models below). (See Cordue, draft-1.)
Construction of CPUE indices from trawl catch and effort data	The standard NZ approach of a detailed data analysis followed by an appropriate standardisation was followed. The ISL and CSIRO indices are very similar in the west and quite different in the east. (See Cordue, draft-3.)
Preparation of age data sets	Age-length data were analysed and it was concluded that some stratification and scaling was required in the east (Cordue, draft-2). The use of age-length keys was also deemed appropriate for the unsexed age-length data.
Use of Kapala data	Excluded as it is very unlikely to be representative of the eastern **stock**.
Use of non-trawl CPUE indices	Excluded as it is very unlikely to be tracking biomass at the **stock** level.
Definition of Spawning Stock Biomass (1)	Female only
Definition of Spawning Stock Biomass (2)	Mid-year (i.e., after half of the mortality)
Estimation of growth (1)	Estimated inside the model
Estimation of growth (2)	No cohort specific growth as an analysis of the age-length data showed that there were few if any important cohort effects (Cordue, draft-2).
Estimation of natural mortality	Estimated inside the model as a single constant with a moderately informed prior
Weighting of trawl CPUE indices between years	Constant CV of 15% derived following Francis (2011)
Weighting of data sets	Standard NZ approach following the spirit of Francis (2011)
Potential changes in ling catchability (trawl fishery sale of quota; structural adjustment)	Dealt with in the CPUE analysis (see Cordue, draft-3)
Spatial modelling	No spatial modelling was done as the single-area models look appropriate.

New issues

Two additional issues arose since the distribution of Cordue and Punt (draft).

The first relates to the use of length-based selectivities for the trawl and non-trawl fisheries (as was done in the 2012 assessment). Specifying length-based selectivities for the trawl and non-trawl fisheries is counter-indicated by the data which show that the two fisheries have very different age structure at given length (Cordue, draft-2). The trawl fishery catches younger fish at given length than the non-trawl fishery. If length-based selectivities are used then the age-length data are essentially assumed to be population age structure at length for both fisheries. For the ISL models, it was decided to use explicitly age-based selectivities for both fisheries. (Note, "length based" selectivities in age-structured models – which do not use "growth morphs" – are actually age-based selectivities as only numbers at age are maintained in the model over time and length is just produced as needed. In a sexed-model, using length selection is a way of saving parameters as the male-female differences in the corresponding age-selectivities come off the growth curves – i.e., length selection is a **restricted** subset of age selection.)

Also, an issue with regard to growth estimation was noticed after looking at CSIRO's 2013 model results. The CSIRO estimated growth curves, for the spatially-aggregated eastern model, were very different from the ISL estimates. I eventually deduced that the CSIRO model estimates were being driven by unsexed age-length data which had been fitted in their models. Only the sexed age-length data were used as individual observations of fish at age and length in the ISL models. As a good fit to the sexed age-length data is essential to get good growth estimates ,the approach used by CSIRO needs to modified to some extent. I suggested a down-weighting of the non-sexed age length data as a possibility.

Stratification and scaling of LFs

Length frequency data, scaled from the sample numbers to the numbers in the sampled trawl/set/landing were supplied by CSIRO for each combination of east/west, trawl/non-trawl, zone, and depth stratum (for onboard samples).

Cordue (draft-1) showed that stratification and scaling of length data was needed for the eastern zones because of variation in length across zones and by depth within zone. The onboard length data for the eastern-trawl were stratified by depth (0-300m, 300-500m, 500m+) and zone (SF10, SF20, SF30). For each year and zone, a depth stratum was required to have at least 2 operations and 30 fish to be used for scaling. Further, for each year at least 80% of the catch had to represented by scaled LFs otherwise that year was dropped. Scaling was by numbers of fish in the catch as estimated using the length-weight relationship and the LF in each depth stratum within each zone. There was adequate sampling for appropriate stratification for two years in the first time block (1998-99), six years in the middle time block, and three years in the last time block (Table 1) – which looks like an adequate number of LFs to estimate trawl-fishery selectivities (with the help of age-length data which play a role because of the age-based selectivities). The port samples for the eastern-trawl were not used as they could not be assigned to depth. This should not matter as there are plenty of measured fish included in the model – and we don't want length frequencies to do much more than inform on selectivities and, perhaps, year class strengths (YCS).

Table 1: Number of trawls sampled (onboard) and number of fish measured for eastern trawl length data. Highlighted fields indicate data that were used. See text for acceptance rules.

	Number of trawls sampled			Number of fish measured		
	SF10	SF20	SF30	SF10	SF20	SF30
1993	0	11	0	0	370	0
1994	0	16	0	0	1026	0
1995	0	6	0	0	704	0
1996	0	28	0	0	2110	0
1997	0	20	1	0	1100	114
1998	36	26	7	3541	2649	728
1999	63	15	4	4814	2260	488
2000	34	6	6	2104	548	516
2001	46	22	5	2723	2276	514
2002	20	17	4	1126	1402	454
2003	19	20	2	1119	1528	237
2004	21	1	0	749	63	0
2005	26	23	3	1039	1509	217
2006	15	22	1	716	2408	9
2007	6	7	0	110	66	0
2008	5	7	1	200	161	5
2009	4	10	0	98	371	0
2010	9	15	1	254	385	7
2011	9	28	2	153	642	32
2012	9	11	8	220	212	200

The eastern-non-trawl LFs were stratified by zone only as the catch is just in Zones 20 and 30 which do not have the very strong depth effect seen in Zone 10. Port and onboard samples were combined as it is assumed that they have the same selectivity pattern (following the 2012 stock assessment). The number of operations was calculated as onboard operations + 3 times the port operations. Although the factor of 3 is fairly arbitrary it recognizes that port samples are of landings which contain a multiple number of shots. Years were accepted if they had at least 5 operations and 100 fish (Table 2).

Table 2: Number of calculated operations (see text) and number of fish measured for eastern non-trawl length data (port and onboard combined, Zones 20 and 30 combined). Highlighted fields indicate data that were used. See text for acceptance rules.

	Total number of operations	Total number of fish
2000	3	10
2001	0	0
2002	64	4586
2003	81	4362
2004	78	5831
2005	27	1367
2006	14	788
2007	8	275
2008	9	256
2009	23	892
2010	36	1235
2011	31	1049
2012	48	1114

For the west, no stratification appeared to be needed and port and onboard samples were combined within gear-type (using operations = onboard + 3 times port). Almost all data were used with the acceptance rule of at least 5 operations and 100 fish (Table 3).

Table 3: Number of calculated operations (see text) and number of fish measured for western length data (port and onboard combined, Zones 40 and 50 combined). Highlighted fields indicate data that were used. See text for acceptance rules.

	Total number of operations		Total number of fish measured	
	Trawl	Non-trawl	Trawl	Non-trawl
1992	15	0	539	0
1993	16	0	904	0
1994	17	0	1236	0
1995	68	0	4810	0
1996	51	3	2538	234
1997	81	0	4920	0
1998	44	0	3042	0
1999	31	1	1979	351
2000	62	9	2188	58
2001	105	13	3576	1566

2002	92	10	2507	2459
2003	97	31	3423	2382
2004	99	40	2769	4696
2005	68	8	1933	684
2006	27	5	937	397
2007	12	21	828	727
2008	5	0	133	0
2009	24	0	258	0
2010	49	10	494	212
2011	35	0	685	0
2012	43	22	827	805

Stratification and scaling of age-length data

Cordue (draft-2) showed that stratification and scaling of age-length data was needed for the eastern zones because of variation in age at length across the zones. It was recommended that only Zones 10 and 20 be used for trawl (as Zone 30 has little trawl catch) and Zones 20 and 30 be used for non-trawl (as Zone 10 has almost no non-trawl catch). To increase the amount of data (and number of years) that were used, fairly lenient criteria were adopted. For eastern-trawl the rule was at least 2 operations and 29 fish in each stratum. For western-trawl (which was not stratified) the rule was at least 4 operations and 90 fish in Zones 40 and 50 combined. This resulted in little loss of data with a good number of years represented and plenty of individual sexed age-length data for the model (to inform with regard to growth and YCS)(Table 4).

Table 4: Number of apparent sampling operations and number of sexed fish for trawl age-length data. Highlighted fields indicate data that were used (yellow = east, green = west). See text for acceptance rules.

	Number of operations					Number of fish (aged, sexed, measured)				
	SF10	SF20	SF30	SF40	SF50	SF10	SF20	SF30	SF40	SF50
1979	4	2	0	0	0	139	241	0	0	0
1982	0	0	1	0	0	0	0	23	0	0
1983	0	0	5	0	0	0	0	146	0	0
1984	0	0	2	0	0	0	0	4	0	0
1985	0	0	5	0	0	0	0	141	0	0
1986	0	0	1	0	0	0	0	31	0	0
1987	0	0	0	0	5	0	0	0	0	487
1988	0	0	0	0	3	0	0	0	0	309
1989	0	0	0	0	2	0	0	0	0	185
1993	0	0	0	5	0	0	0	0	46	0
1994	2	2	0	2	1	93	47	0	14	247
1995	3	2	0	1	3	92	195	0	1	314

1996	28	2	1	2	2	673	34	21	11	66
1997	19	0	0	0	6	570	0	0	0	528
1998	16	3	0	5	4	418	125	0	109	95
1999	13	4	0	15	4	324	134	0	330	154
2000	4	1	0	3	1	109	21	0	44	27
2001	7	2	1	1	0	290	103	48	93	0
2002	6	0	2	2	2	220	0	100	99	99
2003	2	0	0	3	2	78	0	0	95	81
2004	3	0	1	3	13	61	0	6	144	332
2005	3	4	1	1	6	43	29	57	78	202
2006	0	0	3	1	12	0	0	27	50	424
2007	0	12	1	2	0	0	0	198	0	0
2008	0	6	0	2	0	0	0	0	45	0
2009	0	30	1	3	1	0	0	0	16	23
2010	11	36	0	6	2	89	113	0	95	0
2011	4	31	4	3	3	31	49	38	45	47
2012	2	18	2	2	4	21	125	42	24	72

The eastern-trawl age-length data were scaled by the relative average proportions of catch in Zones 10 and 20 in each of the time blocks used in the eastern trawl fishery. That is, a constant scalar was used within each time block rather than scaling to the annual catch proportions. The idea is to present a consistent set of data to the model within each time-block (within which is assumed a constant selectivity). The catch proportions for each time block were:

	1986-1999	2000-2006	2007-2012
SF10	0.35	0.21	0.19
SF20	0.65	0.79	0.81

For the first time block the average was calculated from 1986 to 1999 to avoid the early period of relatively low catches that were dominated by Zone 10 (again, an attempt to present a consistent signal to the model).

For the non-trawl sexed age-length data no stratification was attempted as there were almost no years with adequate samples in both potential strata (east: Zones 20 and 30; west: zones 40 and 50). In both the east and west, 2 operations and 40 fish were required. This meant that most of the individual age-length measurements were used (Table 5).

Table 5: Number of apparent sampling operations and number of sexed fish for non-trawl age-length data. Highlighted fields indicate data that were used (yellow = east, green = west). See text for acceptance rules.

	SF10	SF20	SF30	SF40	SF50	SF10	SF20	SF30	SF40	SF50
1995	1	1	0	0	0	12	2	0	0	0
1999	0	0	0	0	1	0	0	0	0	154
2000	1	0	1	1	0	94	0	248	3	0
2001	0	0	0	3	0	0	0	0	275	0
2002	0	0	0	1	0	0	0	0	50	0
2003	0	8	3	12	0	0	279	30	305	0
2004	0	4	0	2	0	0	93	0	48	0
2005	0	1	0	0	3	0	48	0	0	137
2006	0	0	0	1	2	0	0	0	124	246
2007	0	3	0	3	0	0	14	0	40	0
2008	0	13	0	0	0	0	0	0	0	0
2009	0	20	4	1	1	0	147	0	8	0
2010	0	24	0	4	0	0	0	0	48	0
2011	0	24	9	0	0	0	23	34	0	0
2012	0	11	0	2	1	0	181	0	181	7

The **number of operations** were used as starting values for the effective sample sizes of the LFs. For the age-length data, the observations go in as individual fish, so that fish numbers determine the effective sample size. However, the data can still be down-weighted by maintaining the same proportions of age-at-length (and sex) but putting in fewer individual fish.

For the eastern assessment, only the middle-time-block LFs were tuned, but sample sizes in the other blocks were scaled by the same factor (it is desirable to have at least 5 years in a block for tuning). The non-trawl LFs were not tuned as they would have had so little weight on them that the predicted mean lengths would have been badly biased low (there is a conflict with some of the age-length data through the age-based selectivities). For them the effective sample sizes were fixed at two times the number of operations.

For the western assessment, both time blocks were tuned for the trawl data. As for the east, the non-trawl data required two times the number of operations to keep the estimated mean length at selection fairly unbiased. Also, a serious conflict was seen between the trawl age-length data and the trawl CPUE indices which required the weight on the trawl age-length data to be reduced (fish numbers were halved).

Construction of age frequencies

In the eastern assessment, some of the stratified length frequencies in recent years were converted to age frequencies using the unsexed age-length data from Zone 20 (and, for 2012, some unused sexed age-length data). This was considered reasonable despite the variation of age at length between the eastern zones because Zone 20 has older fish at length than Zone 10 and younger fish at length than Zone 30 (Cordue, draft-2) and also it has most of the catch in recent times. At least 200 fish were required in each year. Length bins of 5 cm were used and proportions-at-age across all years and eastern zones (within gear type) were assumed for bins which had no year-specific data. Good numbers of fish were available for 2010-2012 for trawl and for 2008-2011 for non-trawl and a high proportion of each length frequency was covered with year-specific data:

Eastern fishery	**Year**	**Proportion of LF covered (%)**	**Number of fish**
Trawl	2010	97	501
	2011	95	532
	2012	95	447
Non-trawl	2008	95	585
	2009	100	353
	2010	94	333
	2011	100	511

The effective sample sizes in the model were fixed at a tenth of the number of fish (not really enough years in each time series to apply the methods of Francis, 2011).

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	1970-2013	Stock status assessed mid-year 2013
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, 1983-2009 West: 1975-2009 initially, but 2009 dropped as its very high estimate was based on little data.	Required to have at least 8 observations in the sexed age-length data used
Steepness	0.75	As used in 2012. A conservative value – it could

		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, 2007-2013. Two in the west: 1970-2006, 2007-2013. Separate male and female selectivities, double normal at age.	Estimated in the model. Timing of blocks indicated by events and confirmed by data analysis. Different from the block timing used by CSIRO.
Non-trawl selectivities	Logistic at age, separate for males and females.	Estimated in the model
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)

Results

Eastern stock

Data preparation

It is hard to know how much difference good data preparation will make to stock assessment results. However, the only way to find out is to do it. A number of small changes, each favouring good practice, can have a strong cumulative effect.

The stratification of the eastern-trawl LFs may perhaps not make much difference (as a single component of change) but it does present a more consistent signal to the model than it would have got otherwise (Figure TB1). The timing of a 1999 to 2000 change in selectivity is confirmed as is a shift to higher mean lengths in recent years (a probable shift in selectivity as a consequence of the structural adjustment). In comparison, the unstratified LFs present a noisy picture although the first two points would perhaps be omitted as they have very low sample sizes.

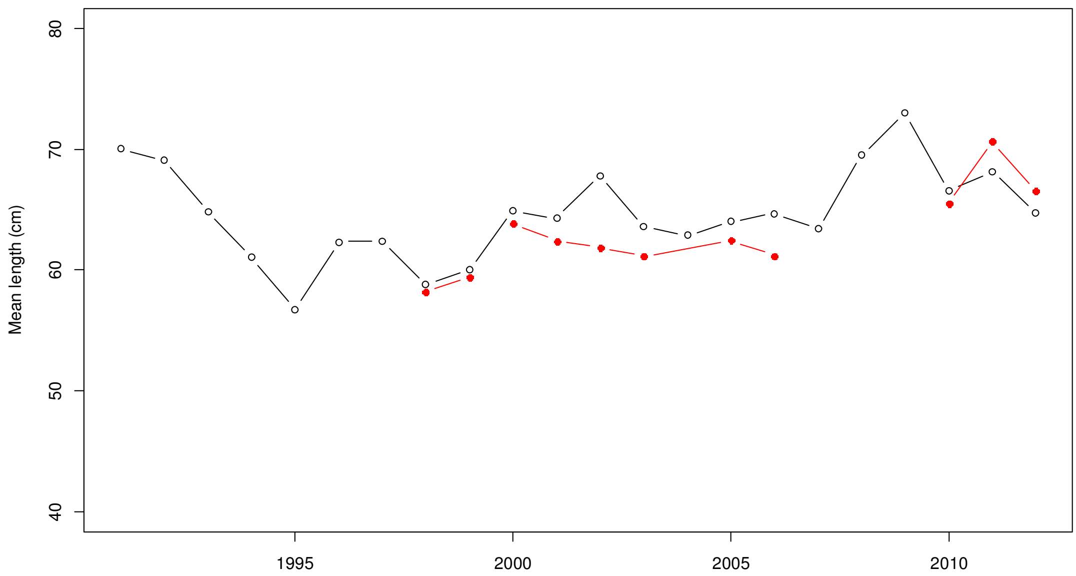


Figure TB1: Mean length for unstratified east-trawl LFs (open symbols) and depth and zone stratified LFs (solid symbols).

MPD fits

The fit to the ISL trawl CPUE series is good (Figure 1). The 1986 point is missed, but after that the fit is very good. The fit to the non-trawl age frequencies is also good given that they jump around and the effective sample sizes are less than 60 (Figure 2). The same comments apply to the trawl age frequencies (Figure 3). For the length frequencies the effective sample sizes are larger. The fits are reasonable except that the predictions fail to get as "peaky" as the observations and there is a tendency for the predicted means (and modes) to be a bit higher than the observations (Figures 4 and 5).

For the age-length data, that are input as individual measurements, it is difficult to produce plots that show how well the data are fitted. Numerous conditional age-at-length plots can be produced but the sheer quantity of them reduces their usefulness. However, at a minimum the age-length data should be seen to be consistent with the estimated growth curves. This is the case for the ISL models where only sexed age-length data were used as individual measurements. The fit to the male age-length data looks excellent (Figure 6) as does the fit to the female age-length data although the L_{inf} looks like it is getting a bit high (Figure 7). This has no consequence as there is little biomass beyond about age 20 even in the virgin population.

Likelihood profiles

It is sometimes useful to check likelihood profiles as models are developed to make sure that composition data are not driving the biomass signals entirely and also to see if there appears to be a sound basis for estimating parameters such as natural mortality (*M*).

The likelihood profile for B_0 shows a well-defined minimum at about 6000 t (Figure 8). In terms of individual components most of them find a minimum in the 6000-8000 t range; the exceptions are the age-length data from trawl and the trawl CPUE (Figure 8). The trawl CPUE has its minimum negative-log-likelihood at a low level probably because it is quite up-and-down which means it is easier to fit when there is low biomass (as that can be pushed around more easily by variation in recruitment). Just about everything is saying "don't go too low", and the three components that say "don't go too high" include the CPUE (Figure 8). Overall, the balance doesn't look too bad.

For *M* there is a serious conflict between the trawl age-length data and the trawl length frequencies (Figure 9). The trawl length frequencies oppose all other data sets as it favours a value of *M* at about 0.15 (Figure 9). Most other components favour a value in the 0.24-0.30 range. An informed prior was put on *M* to discourage values above 0.3 (the prior is moderately informed being normal with mean=0.2 and cv=0.2 (it is based on NZ ling and the standard default for *M* of 0.2).

MPD estimates

The estimated fishing selectivities show marked differences between gears and sexes and, for trawl, between time blocks (Figure 10). The non-trawl was forced to be asymptotic and the trawl selectivities were allowed to be domed – and the estimates are very domed (Figure 10). Males are selected preferentially compared to females for the non-trawl fishery and the trawl fishery in the last time block, which is inconsistent with length-based selection (as females grow faster – Figure 11). The shift in the mode of the trawl selectivities over time shows a move to progressively larger fish (Figure 10).

The pattern of recruitment estimated suggests moderate recruitment variability with no very large YCS and only one very weak YCS in 1977 (Figure 12). There are no extended periods of low or strong recruitment estimated (Figure 12).

The estimated female spawning biomass trajectory shows a steady decline from a local peak in 1980 to a level of about 25-30% B_0 since the mid 1990s (Figure 13).

Audit trail from the 2012 base model

In the 2012 eastern base model the catch histories for trawl and non-trawl were accidently swapped (I noticed this when looking at the SS3 data and control files which were supplied by CSIRO). The base model had an estimate for 2013 beginning-of-year stock depletion of 26% B_0. When the catches are correctly entered the estimate is 19% B_0 (I fixed the catches and reran the SS3 model).

It is important to understand what changes in data and/or model structure can move us from the 19% B_0 estimate up to the 30% B_0 estimate in the ISL base model. Therefore, a series of runs were done with intermediate steps between the 2012 SS3/CSIRO model (with correct catches) and the 2013 CASAL/ISL base model (Table 6) The results are revealing (Table 6, Figure 14).

The first step was a switch from SS3 to a CASAL run with the ISL base-model structure, the most recent catch history estimates, no trawl-caught port length samples, and a constant CV of 15% on the trawl CPUE. The comparison is 19% (SS3) to 12% (CASAL: step 1). The difference is not large and is due mainly, I think, to minor differences between SS3 and CASAL, the differences in the selectivity parameterisations, and the use of mid-year stock depletion instead of beginning-of-year (SS3). Dropping the port data had little effect as I have done other runs including the port data and got similar results.

The second step was to drop the Kapala data and switch to the properly stratified composition data. This made a big difference with a jump from 12% to 20%. Sensitivity tests suggest that the exclusion of the Kapala data has little impact and hence this change was due to the different composition data and the change in relative weightings associated with it. I believe that the change in composition data was the most important component because the two runs have very similar estimates of biomass and natural mortality (Table 6). When comparing the estimates from the two runs I found that the big changes were for selectivity and YCS.

Dropping the non-trawl CPUE boosted the estimate a little bit from 20% to 23%. The biggest change was when the ISL trawl CPUE series was introduced and this increased the 2012 stock-status estimate from 23% to 32% (Table 6). The inclusion of the newly available data in 2013 reduced the estimate of 2012 stock status from 32% to 31%.

Table 6: Eastern stock: audit trail from SS3 2012 base model to 2013 ISL base model. Estimated female virgin biomass (B_0), stock status in the 2012 assessment year, and natural mortality are given for a series of runs linking the two models. * SS3 virgin biomass estimates are not comparable with CASAL virgin biomass estimates because of a different maturity definition.

Model run	B_0 (t)	Stock status ($\%B_0$)	M (yr^{-1})
SS3 2012 base with data to the end of 2011	7296*	26	0.24
SS3: trawl and non-trawl catches the right way round	6926*	19	0.24
As above, CASAL with ISL base-model structure	5734	12	0.26
As above, drop Kapala data and use ISL age & length	5675	20	0.24
As above, drop non-trawl CPUE	5752	23	0.24
As above, switch to ISL trawl CPUE	6039	32	0.25
As above, add in new data = ISL base model	5932	31	0.25

MPD sensitivities

Various sensitivities to the base model were run (Table 7, Figure 15). The sensitivity of stock status to the trawl CPUE time series was confirmed with the lowest estimate of stock status, among all the runs tried, occurring when the CSIRO CPUE series was used (Table 7, Figure 15). Alternative maturity schedules had almost no effect on current stock status, but did change the trajectory in earlier years (Figure 15). The inclusion of the Kapala data had little effect, but including the non-trawl CPUE reduced stock status from 30% to 26%. Lower and higher values of *M* (which cannot be ruled out) produced lower and higher values of stock status (24% and 38% B_0).

Table 7: Eastern stock: ISL-base-model sensitivities. Estimated female virgin biomass (B_0), stock status in the 2013 assessment year (mid-year B_{13}/B_0), and natural mortality are given for a series of runs which differ from the base model in only one respect.

Model run	B_0 (t)	Stock status ($\%B_0$)	M (yr^{-1})
ISL base model	5932	30	0.25
Using CSIRO trawl CPUE	5644	22	0.25
Including Kapala data	5710	32	0.25
Including non-trawl CPUE	5517	26	0.26
With fixed and lower *M*	6604	24	0.22
With fixed and higher *M*	5602	38	0.28
With maturity ogive shifted 1 year younger	6429	30	0.25
With maturity ogive shifted 1 year older	5271	31	0.26

Preliminary MCMC results

For the eastern assessment there was time to run a preliminary MCMC to obtain estimates of the posterior distribution. The median of the marginal posterior distribution, for each parameter/derived-parameter of interest, is usually used as the point estimate for that parameter. It has superior statistical properties as an estimator compared to the MPD. This is intuitively reasonable, as it provides an estimate of centrality for the whole distribution rather than just the location of the peak (i.e., the median is in the middle of the most likely place to find the true value).

Three independent chains of 1.7 million were each run. One in every one thousand samples were retained. Plots of the three chains showed good agreement between the main variables of interest (virgin and current biomass, stock status and natural mortality). A burn-in of 400,000 was indicated by plots of the objective function and this was used. The remaining parts of each of the three chains were combined.

The YCS are fairly well determined and recent recruitment is a bit below average, with poor recruitment estimated for 2009 (Figure 27). Fishing selectivities are fairly well determined with definite doming for the trawl fishery and an increase in the age of full selection over the time blocks (Figure 28).

Virgin biomass was estimated in the 5000-6500 t range (Table 8, Figure 29) with current female mid-year spawning biomass from 1400-2800 t (Table 8). The current stock status/depletion has a median of 35% B_0 with a 95% CI of 25-46% B_0. The MCMC median is a bit higher than the MPD estimate (Figure 30). Natural mortality is fairly tightly estimated with a median at 0.27 (Table 8).

The spawning-stock biomass trajectory shows a peak above virgin levels in the 1980s followed by a steady decline to about 30% B_0 in the late 1990s and a slow increase from then to about 35% B_0 (Figure 31).

Table 8: MCMC estimates for the ISL eastern base model. The point estimate (median of marginal posterior distribution) and the 95% credibility interval are given for virgin biomass, current biomass stock status, and natural mortality.

	B_0 (t)	B_{2013} (t)	Stock status (% B_0)	M (y^{-1})
Median	5738	1990	35	0.27
95% CI	5140-6422	1366-2825	25-46	0.24-0.30

Western stock

Data preparation

For the western stock, data preparation was not an issue as there seemed to be little variation in mean length or age-at-length by zone or depth. Also, the detailed CPUE analysis yielded almost identical indices to those produced by CSIRO's generic approach.

MPD fits

The fit to the trawl CPUE indices in the reference model is very good except for a strong residual pattern associated with the steep rise and decline of the indices during the 1990s and early 2000s (Figure 16). The predicted biomass does not rise or decline as steeply as the indices but it does peak in the same year (1998).

The fits to the length frequencies are very good, especially for trawl, given the low effective sample sizes used (Figures 17 and 18). The fits to the sexed age-length data look good except that the male growth curve has slightly more curvature through the middle than the data show – perhaps a slight failing caused by requiring the von Bertalanffy parameterisation (Figures 19 and 20).

MPD estimates

The estimated fishing selectivities, as for the eastern stock, show a departure from just length based selection, with males preferentially selected at young ages in the non-trawl fishery (Figure 21). There is also a significant shift in estimated selection in the two trawl time blocks (Figure 21). As in the east, and as expected, females grow to a larger size than males (Figure 22) although the estimated mean-lengths at infinity are smaller than in the east (see Figure 11). The estimated YCS, as for the east, showed only moderate variability, with just a couple of YCS being above 2 and no very low ones (Figure 23).

The estimated female spawning-biomass trajectory shows two periods of increase and decline, and the biomass stays between 80-120% of its virgin levels up until the mid 2000s and is still estimated at 70% B_0 in 2013 (Figure 24). The high estimates of stock status are driven by natural mortality which was estimated at 0.3 (Table 9).

MPD sensitivities

A serious of sensitivity runs for the western reference model were revealing. The results are not sensitive to the use of the CSIRO or ISL trawl CPUE indices or the use or not of the non-trawl CPUE indices (Table 9, Figure 25). They are also insensitive to the use of younger or older maturity.

There is a dramatic sensitivity to the weight placed on the trawl age-length data, with greater weight decreasing estimated stock status (Table 9, Figure 25). In the reference model effective numbers for the trawl age-length data were halved, and in the sensitivity run the full numbers were used. In the sensitivity run, not only is there a huge decrease in estimated stock status (71% B_0 down to 47% B_0) but there is an associated large decrease in the estimate of M

(0.3 down to 0.22). It is clear that the weight on the trawl age-length data had to be reduced as it was preventing a good fit the trawl CPUE indices (Table 9, Figure 26). However, the reduction in weight on the age-length data allowed the estimate of *M* to "blow out" a bit and led to the somewhat implausible estimate of stock status.

Fixing, rather than estimating *M*, shows that the model can still fit the trawl CPUE indices well at lower values of *M* - although the fit is not quite as good (Table 9). Essentially the model is trying to fit the steep decline from 1998. If there is high weight on the trawl age-length data then it cannot fit the CPUE decline until a year after 1998 (Figure 26). However, when the weight is taken off that data, it can fit the decline a year earlier and it can estimate a higher value of *M* (which also helps fit the decline because it can then kill fish more quickly). The solution to this problem is to either fix *M* (at a "sensible" value) or estimate it with a strongly informed prior. Since the eastern assessment appears to provide a good estimate of *M*, the posterior from the eastern assessment is the obvious prior to use for the western assessment (this is currently ISL's preferred option for a western base model – but discussions at the RAG meeting may change this view).

Table 9: Western stock: ISL-reference-model sensitivities. Estimated female virgin biomass (B_0), stock status in the 2013 assessment year (mid-year B_{13}/B_0), and natural mortality are given for a series of runs which differ from the base model in only one respect.

Model run	B_0 (t)	Stock status (% B_0)	M (yr^{-1})	Trawl CPUE neg-log-like.
ISL reference model	12222	71	0.30	-40.6
Using CSIRO trawl CPUE	12148	71	0.30	-40.7
Including non-trawl CPUE	12186	70	0.30	-40.8
With fixed and lower *M*	5965	58	0.26	-39.7
With fixed and even lower *M*	4890	48	0.22	-38.3
With maturity ogive shifted 1 year younger	13277	74	0.30	-40.7
With maturity ogive shifted 1 year older	10121	68	0.30	-40.5
Twice the effective sample size on trawl age-length	3872	47	0.21	-28.1

Conclusions

The eastern and western assessments have very different challenges to deal with in terms of providing a reliable stock assessment. For the east, the issues are mainly to do with data preparation, while in the west, the issues primarily involve model and data weighting decisions.

The analysis of length and age-at-length data showed that the eastern data had to be stratified and scaled to some extent otherwise the model would be given misleading signals. There is a trade-off between how much stratification and scaling is done and how much data can be used in the model. The acceptance rules used in the ISL-base model appear to provide a good balance between the quality and quantity of data used. The analysis also showed that the assumption of length-based selection in the fisheries was not supported; nor was the use of cohort-specific growth.

The CPUE analysis, to some extent, was able to deal with the issue of the sale of trawl quota in the east in 1999 and the structural adjustment in 2006. The approach used to allow a change in vessel behaviour to alter the trawl CPUE indices had a strong effect on the eastern indices over the 1999-2000 breakpoint but little effect over the 2006-2007 breakpoint. Consequently the choice of the ISL or CSIRO CPUE indices in the east has an impact on the assessment results, but it is not important in the west.

In the western assessment, there is a strong conflict between the trawl age-length data and the trawl CPUE indices. This indicates that a down-weighting of the trawl age-length data is required. However, when this is done the estimate of M appears to be a bit too high. As there are little data in the western assessment to provide information on M, it is best to either fix M at a "sensible" value, or to use a strongly informed prior. In both cases, it appears that the eastern assessment can provide the needed information on M.

Acknowledgements

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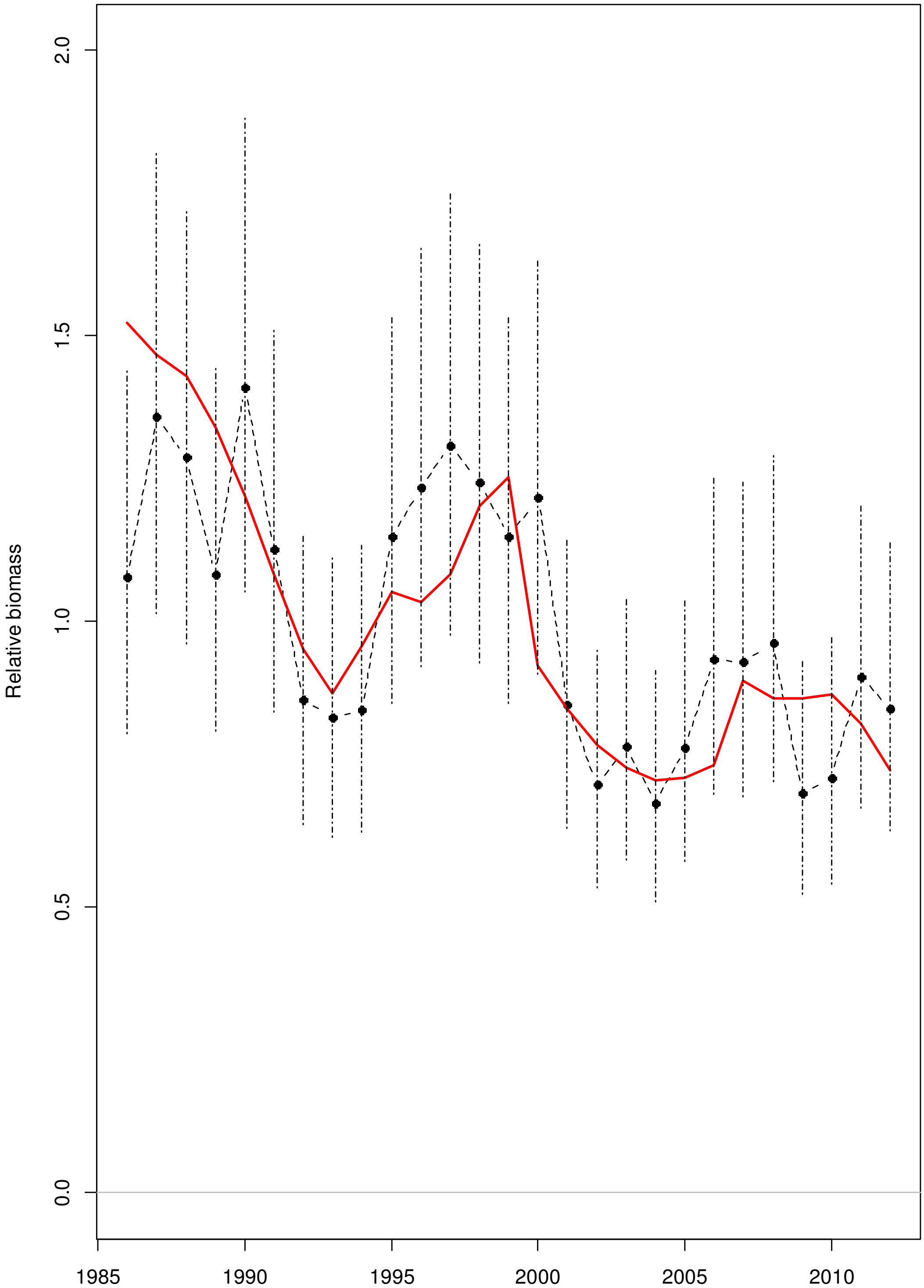

Figure 1: Eastern base model fit to trawl CPUE indices. Dashed lines are 95% CIs.

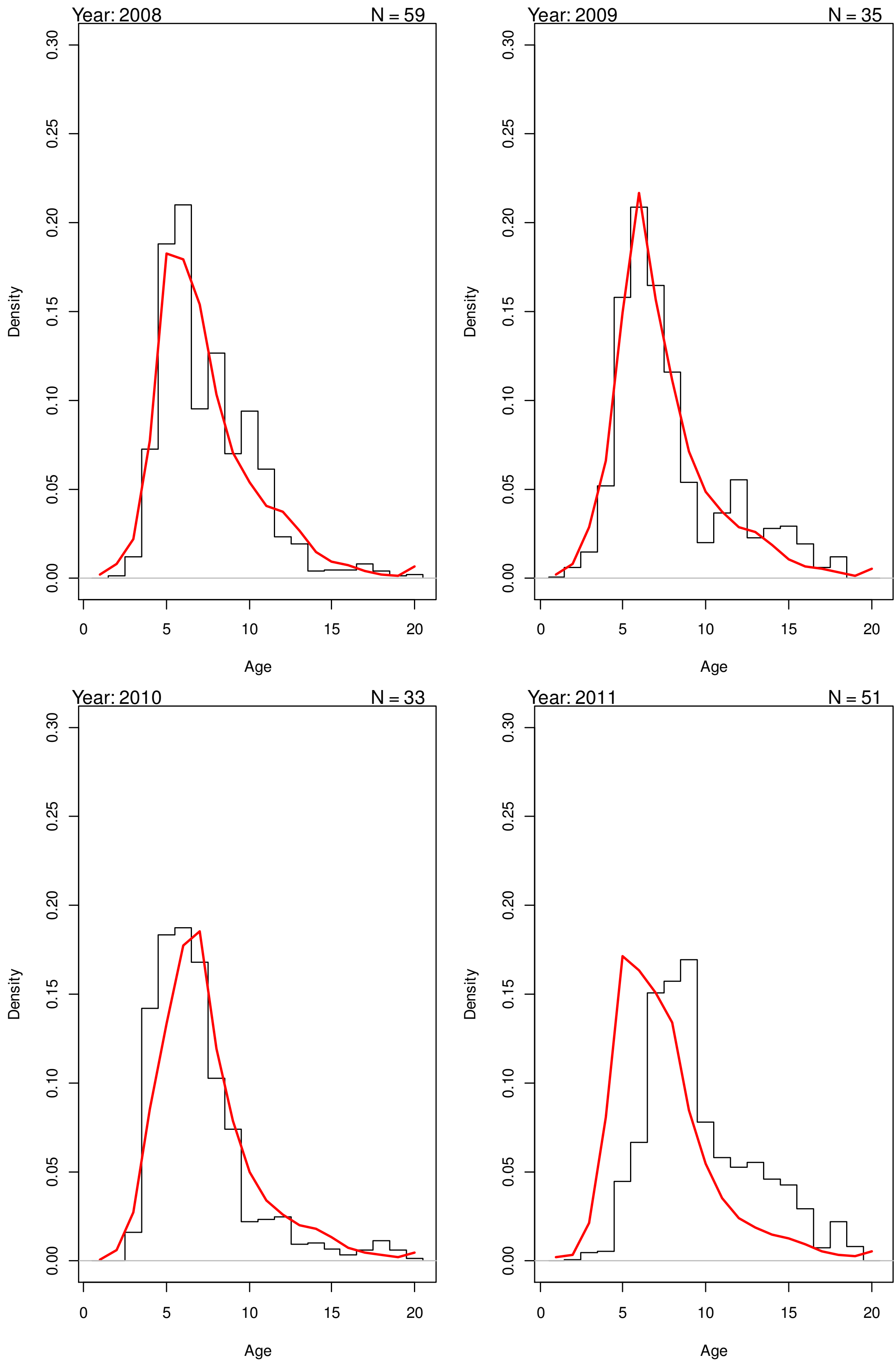

Figure 2: Eastern base model fit to non-trawl age frequencies.

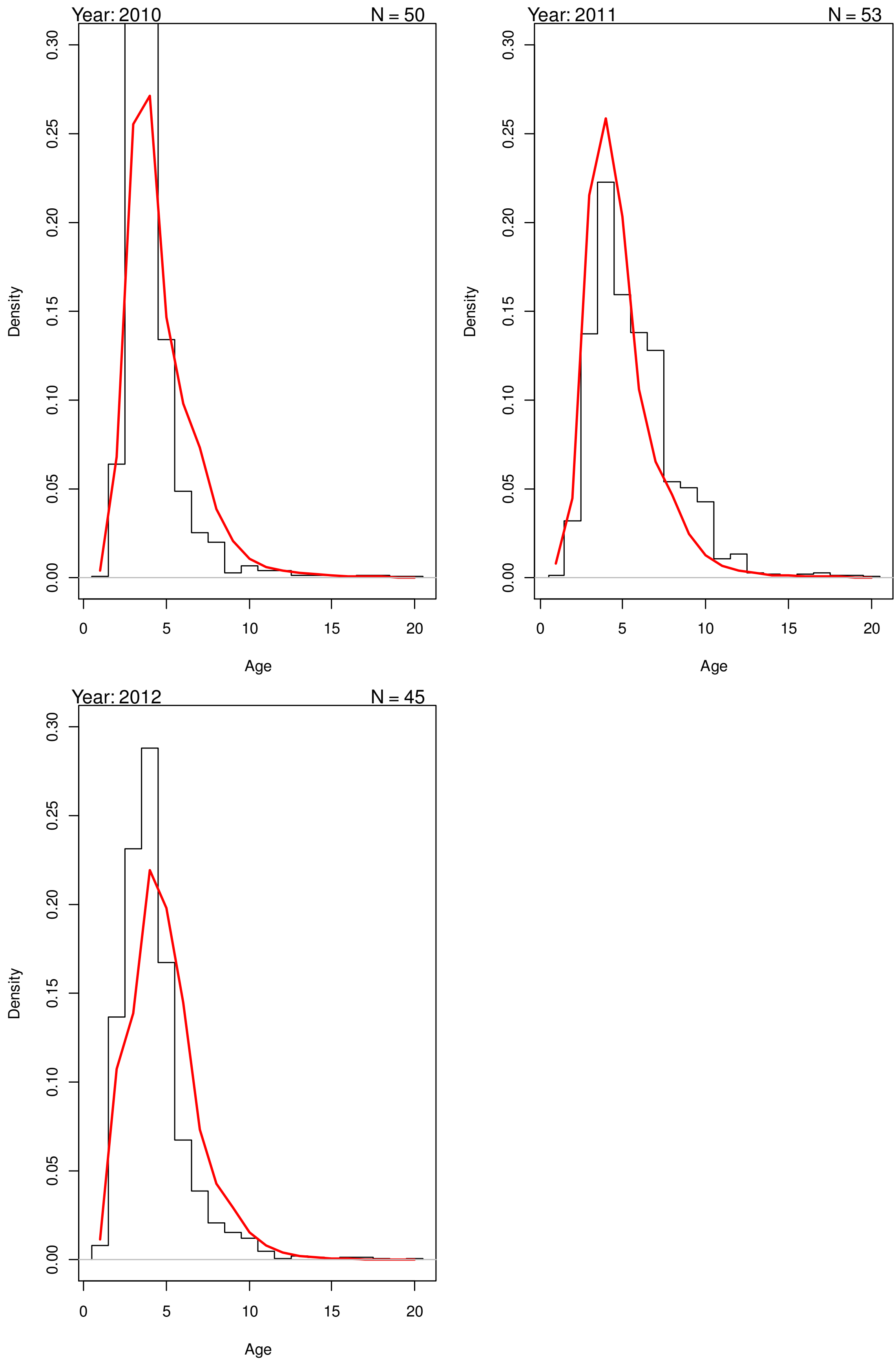

Figure 3: Eastern base model fit to trawl age frequencies.

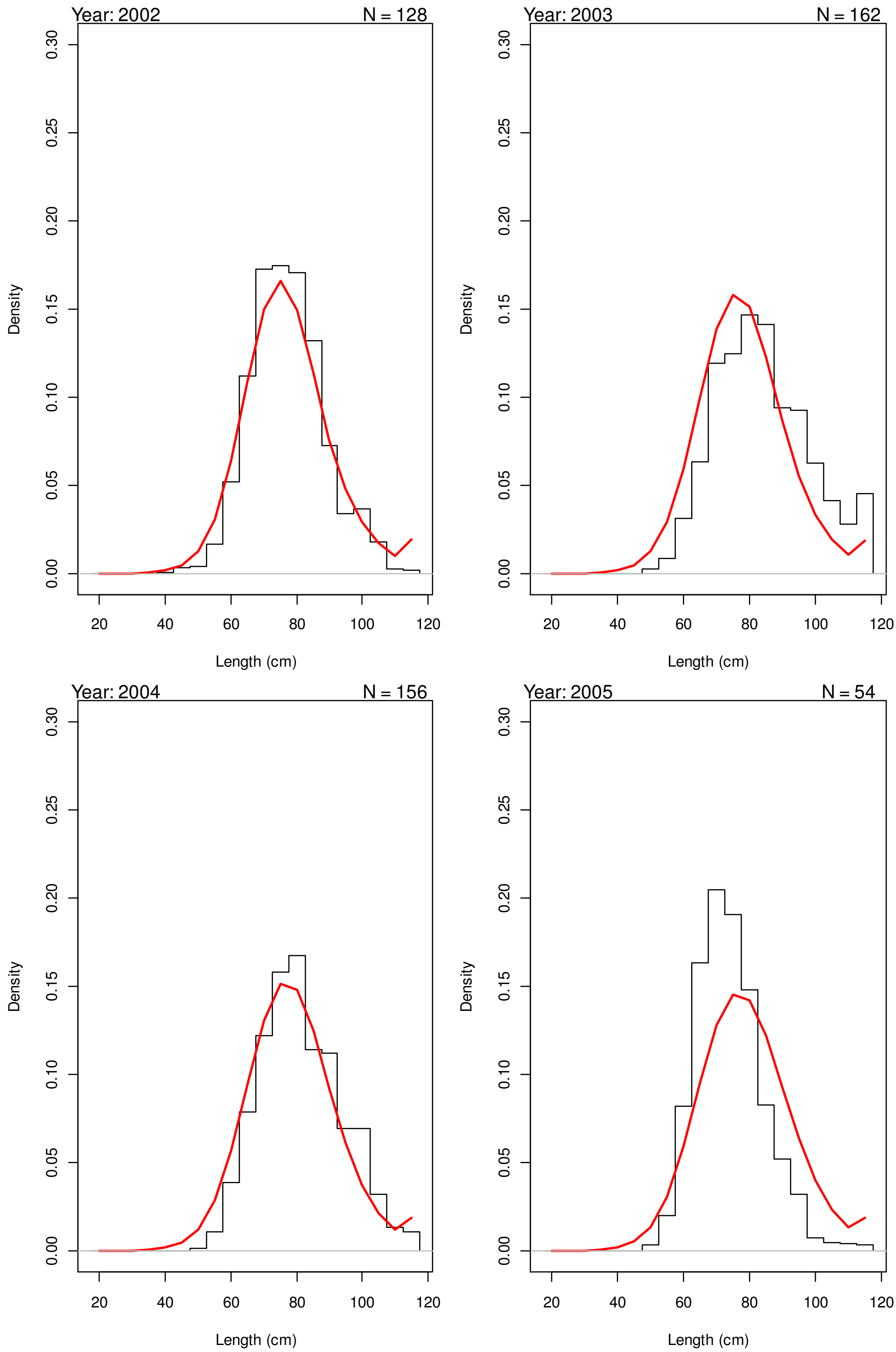

Figure 4: Eastern base model fit to non-trawl length frequencies (2002-2005).

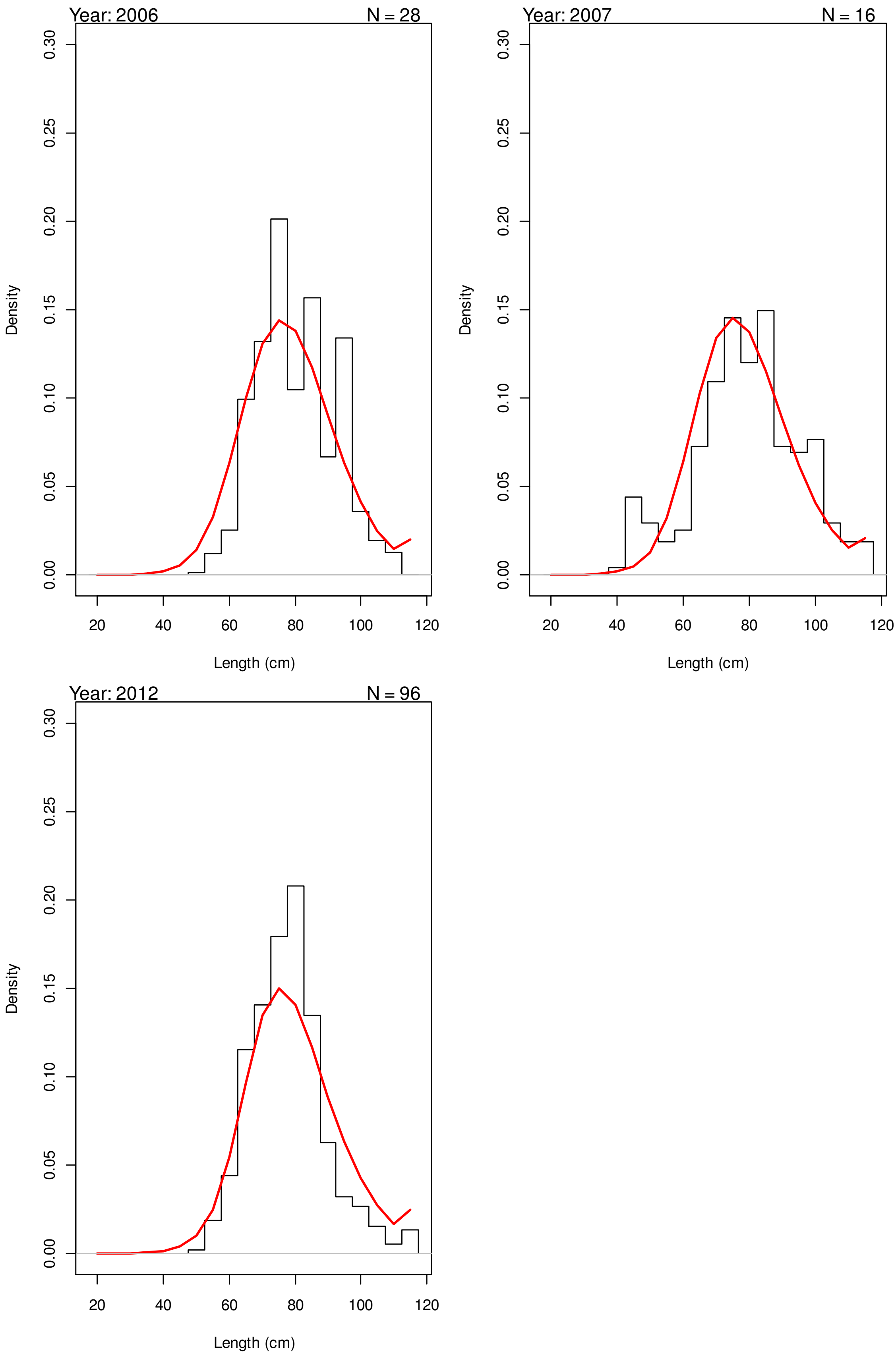

Figure 4 (cont): Eastern base model fit to non-trawl length frequencies (2006, 2007, 2012).

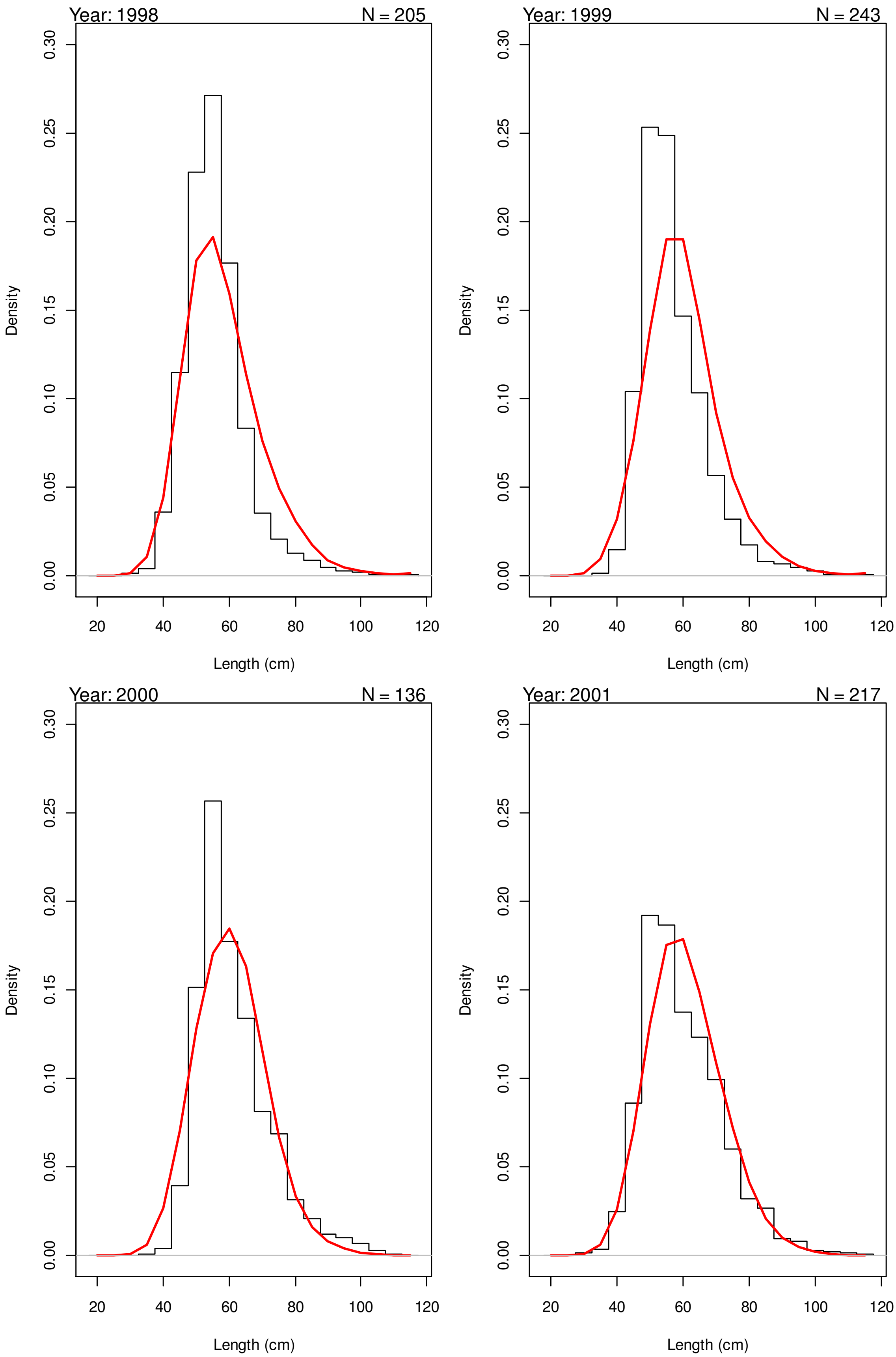

Figure 5: Eastern base model fit to trawl length frequencies (1998-2001).

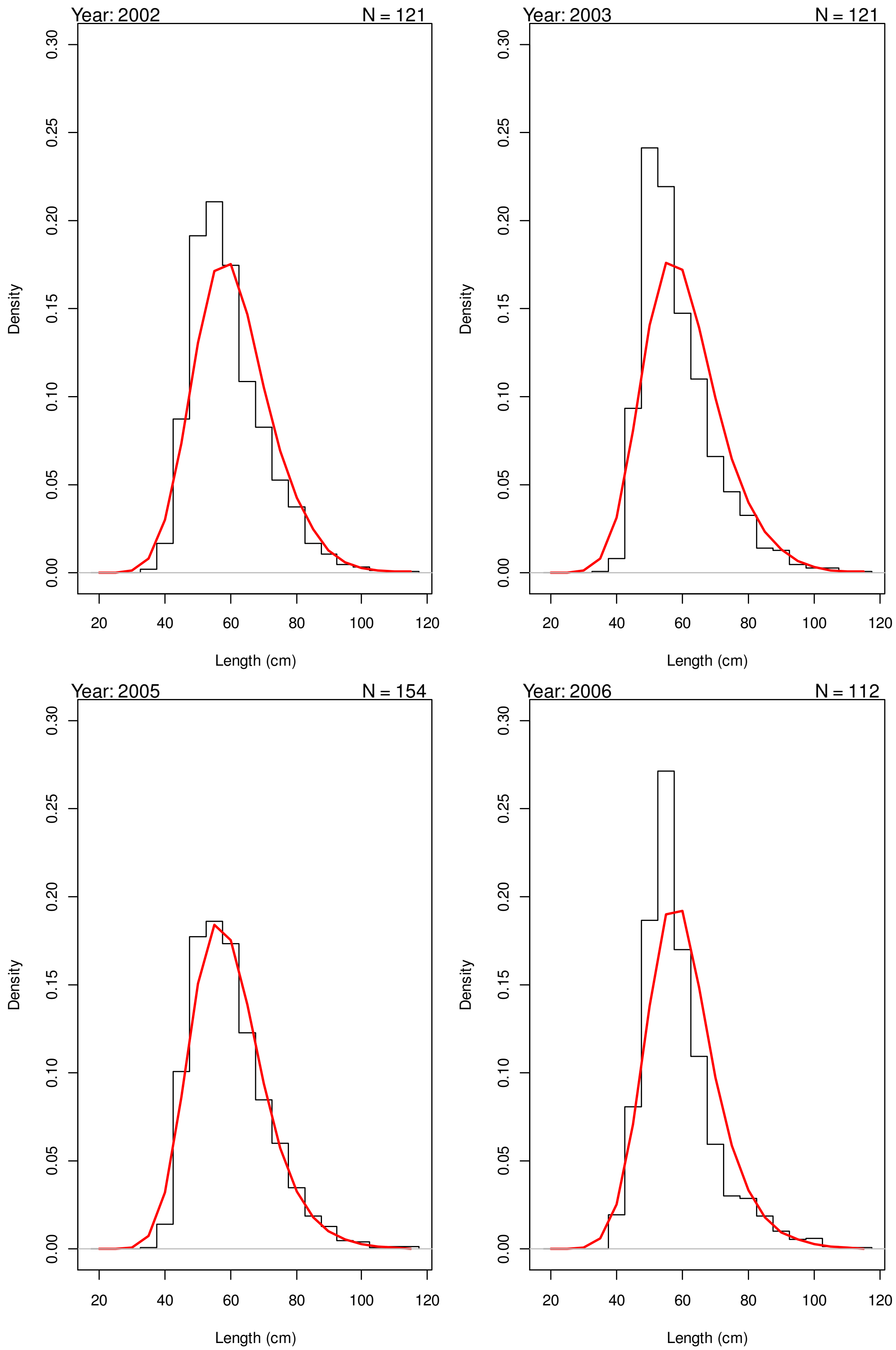

Figure 5 (cont): Eastern base model fit to trawl length frequencies (2002-2006).

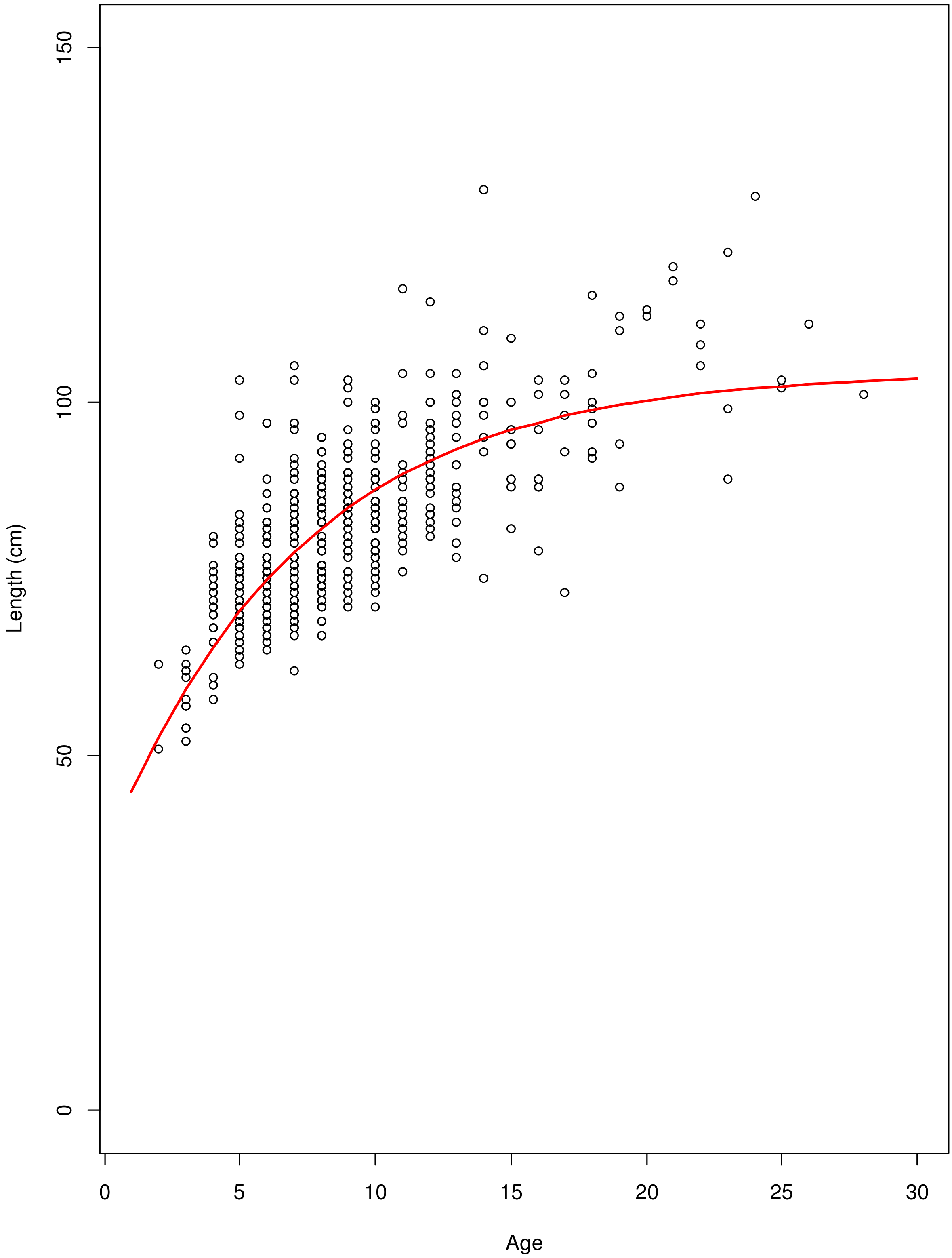

Figure 6: Eastern base model: comparison of estimated male growth curve to all male age-length data, caught by line, in the eastern zones.

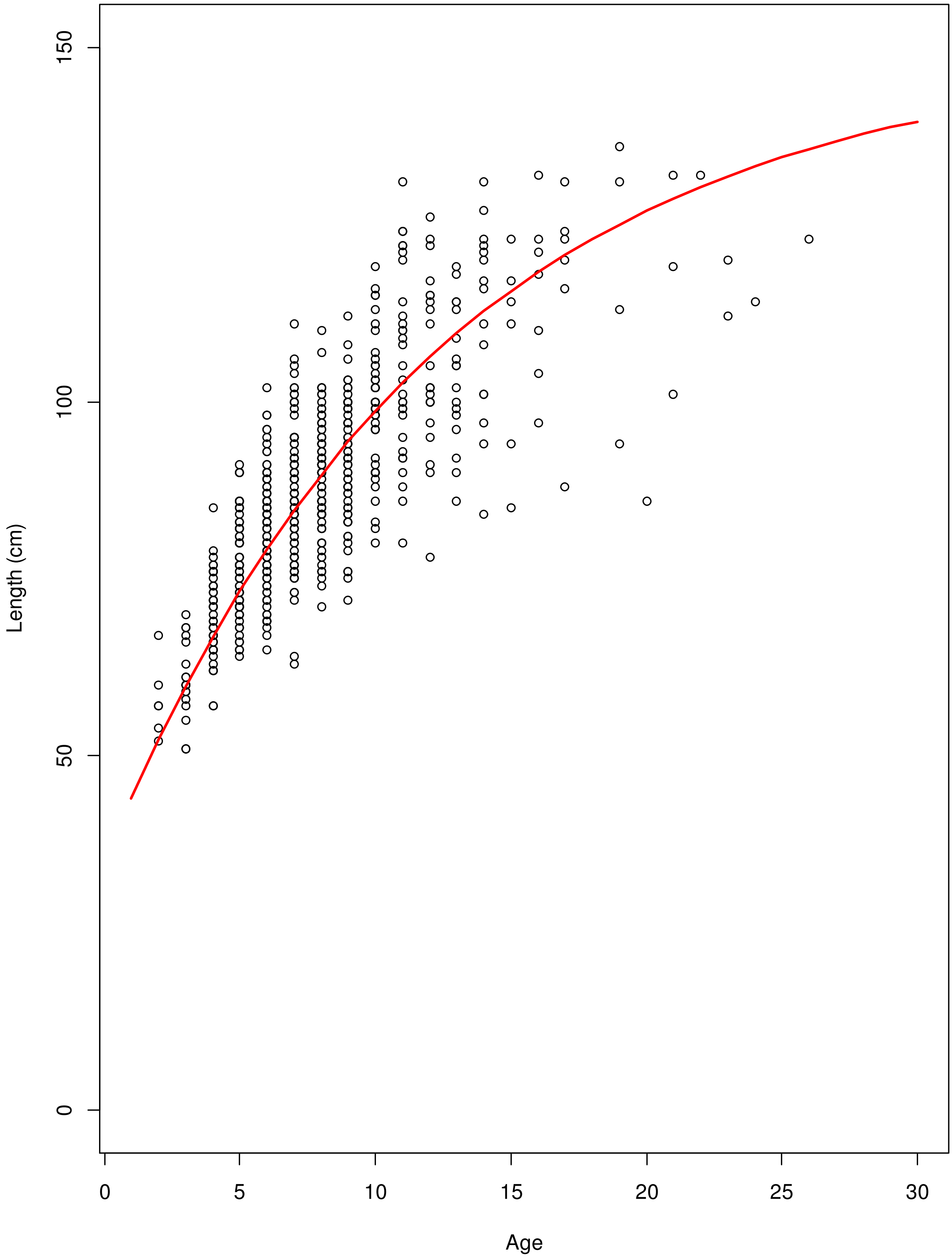

Figure 7: Eastern base model: comparison of estimated female growth curve to all female age-length data, caught by line, in the eastern zones.

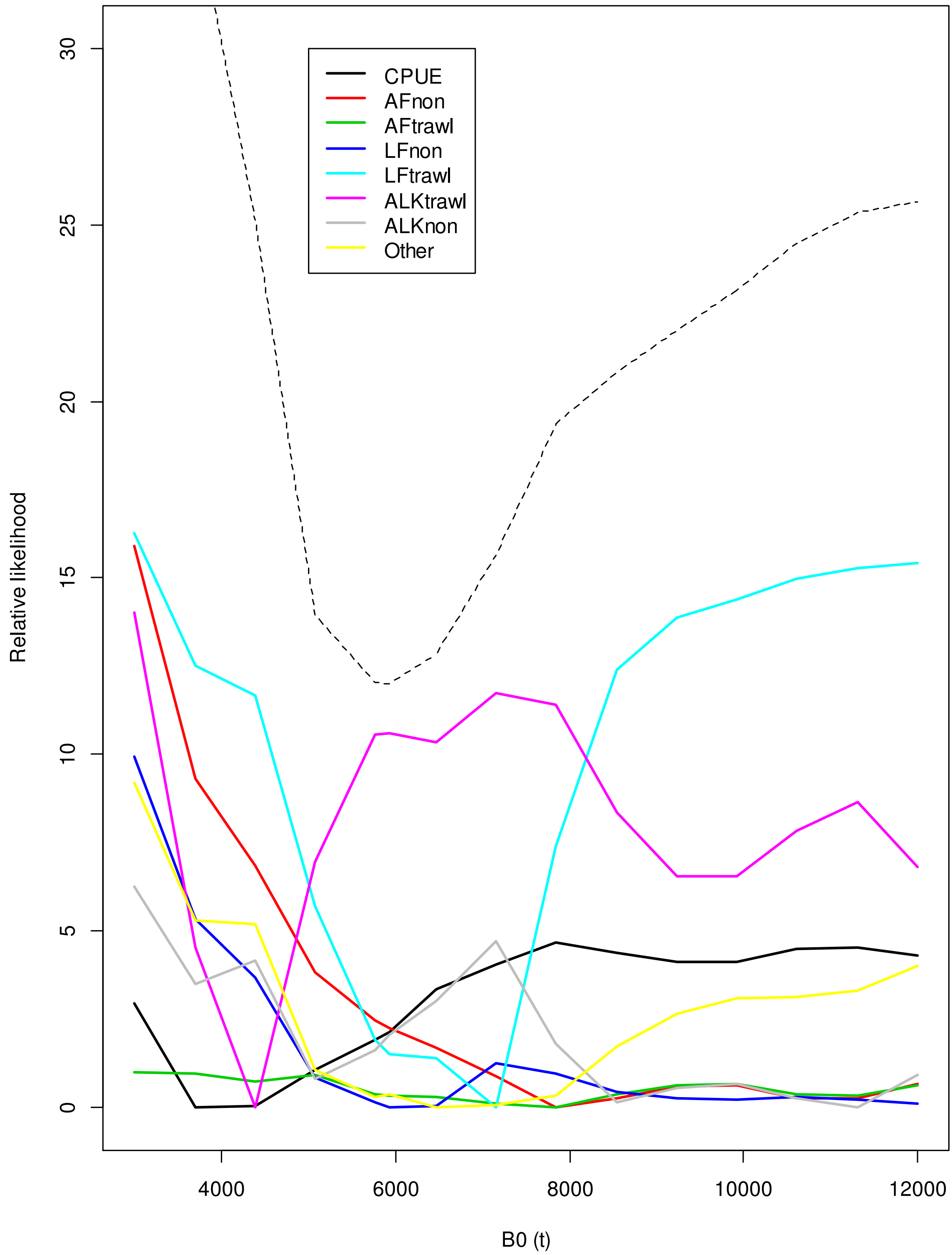

Figure 8: Eastern base model: likelihood profile for B_0 showing each of the grouped components (ALK = age-length data). The dashed line shows the shape of the total negative log likelihood.

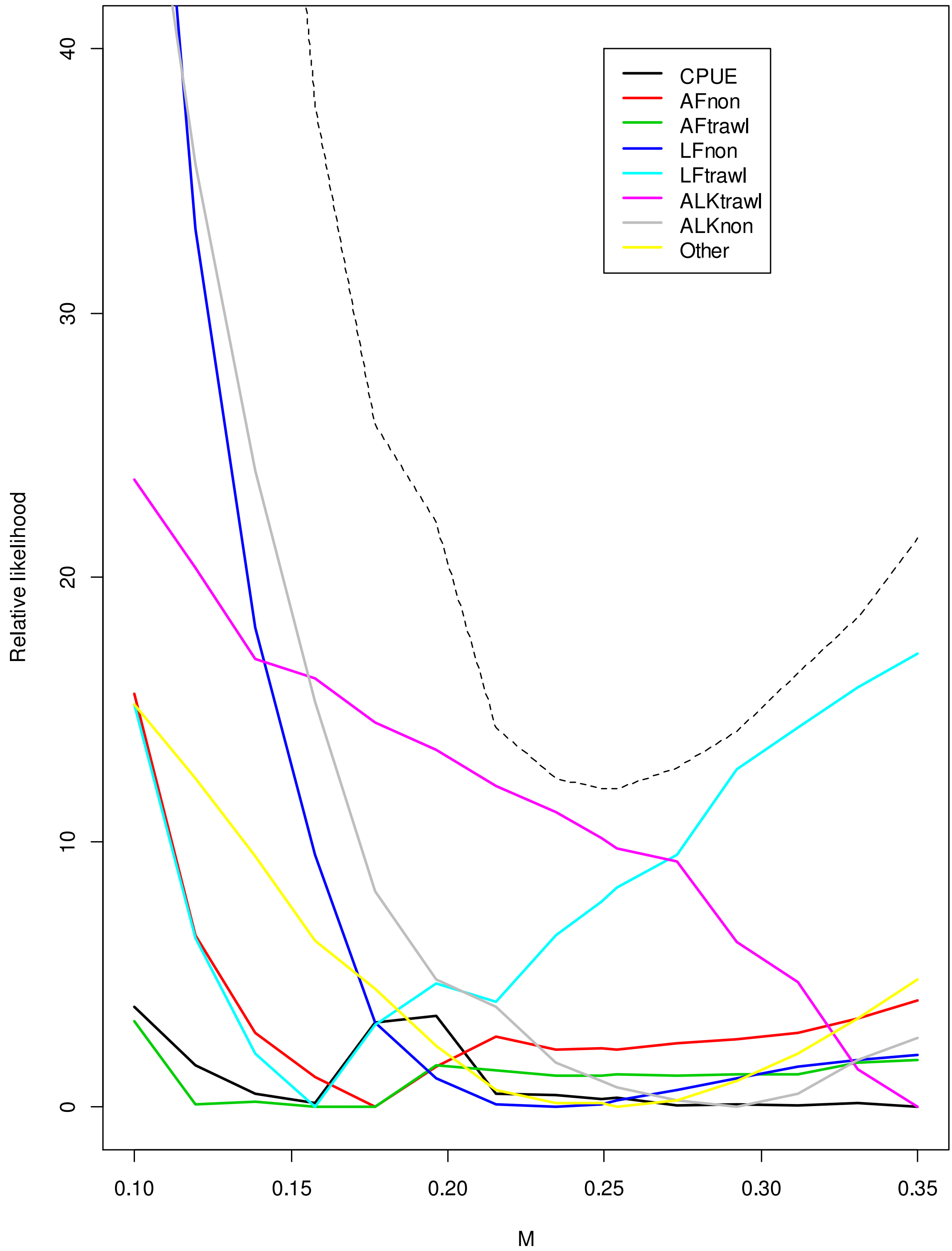

Figure 9: Eastern base model: likelihood profile for *M* showing each of the grouped components (ALK = age-length data). The dashed line shows the shape of the total negative log likelihood.

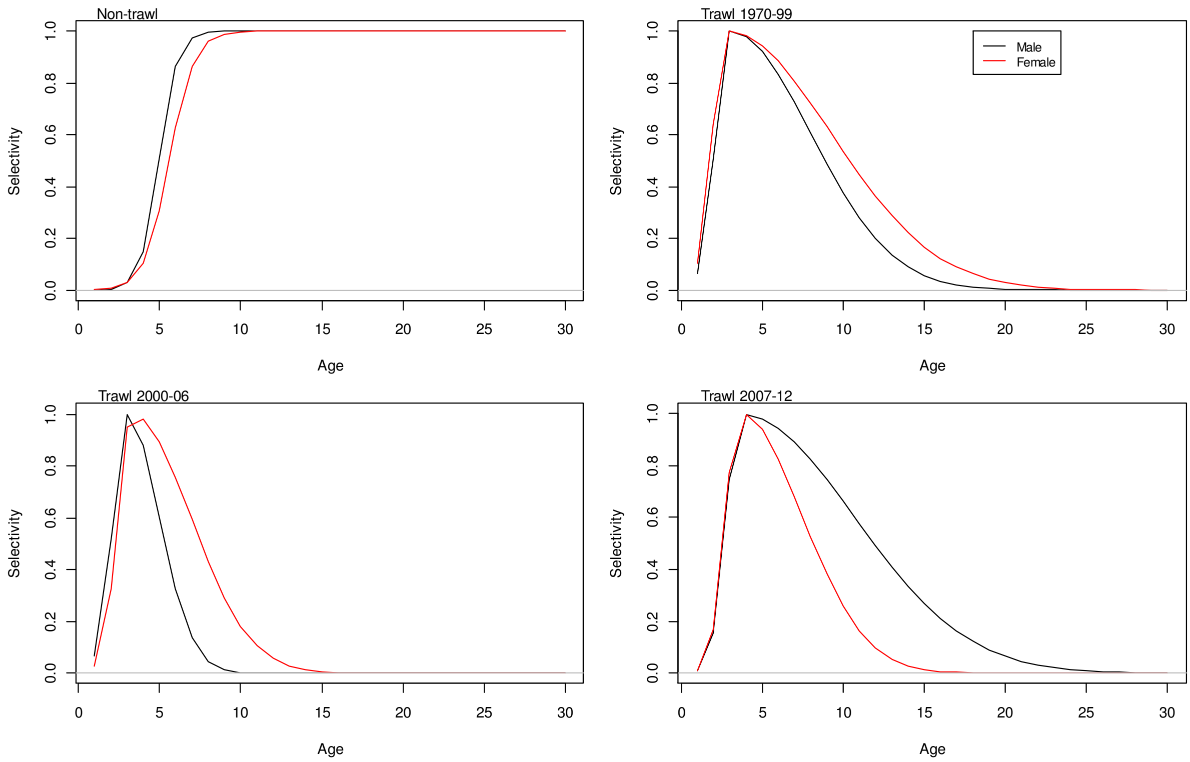

Figure 10: Eastern base model: estimated fishery selectivities (age-based, sex specific, three time blocks for trawl).

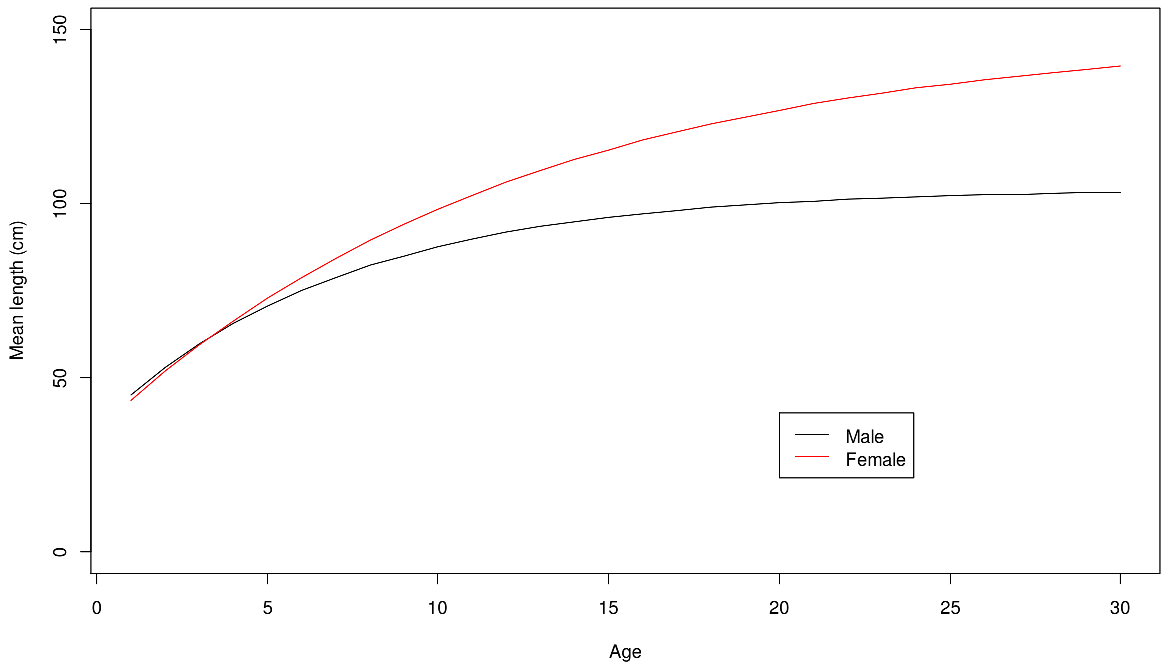

Figure 11: Eastern base model: estimated growth curves (sex specific).

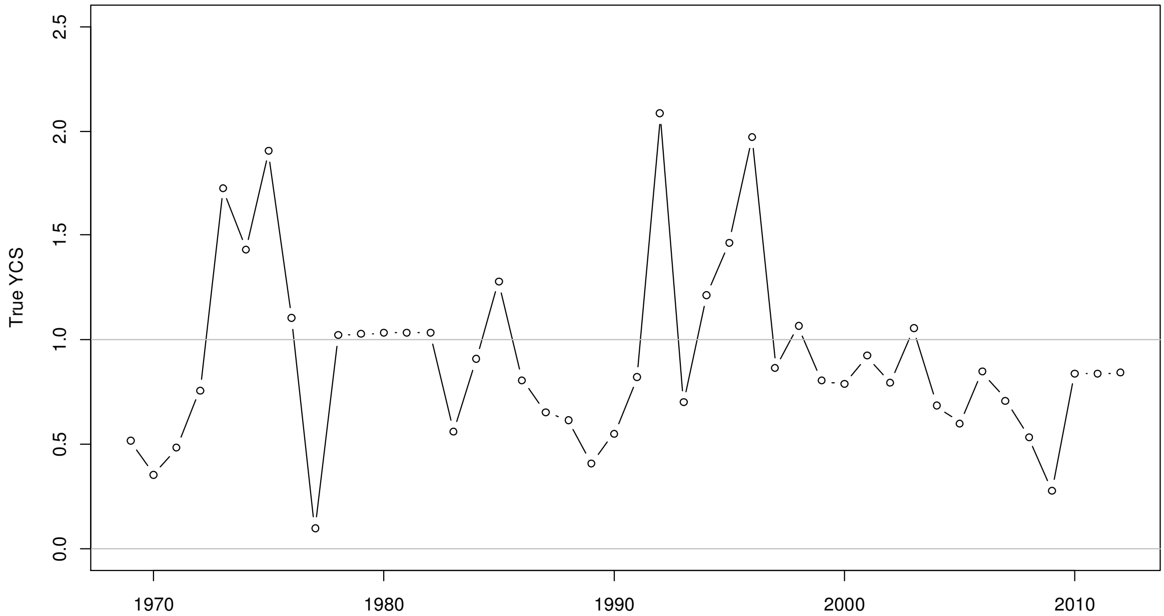

Figure 12: Eastern base model: estimated "true year class strengths" (annual recruitment divided by virgin recruitment).

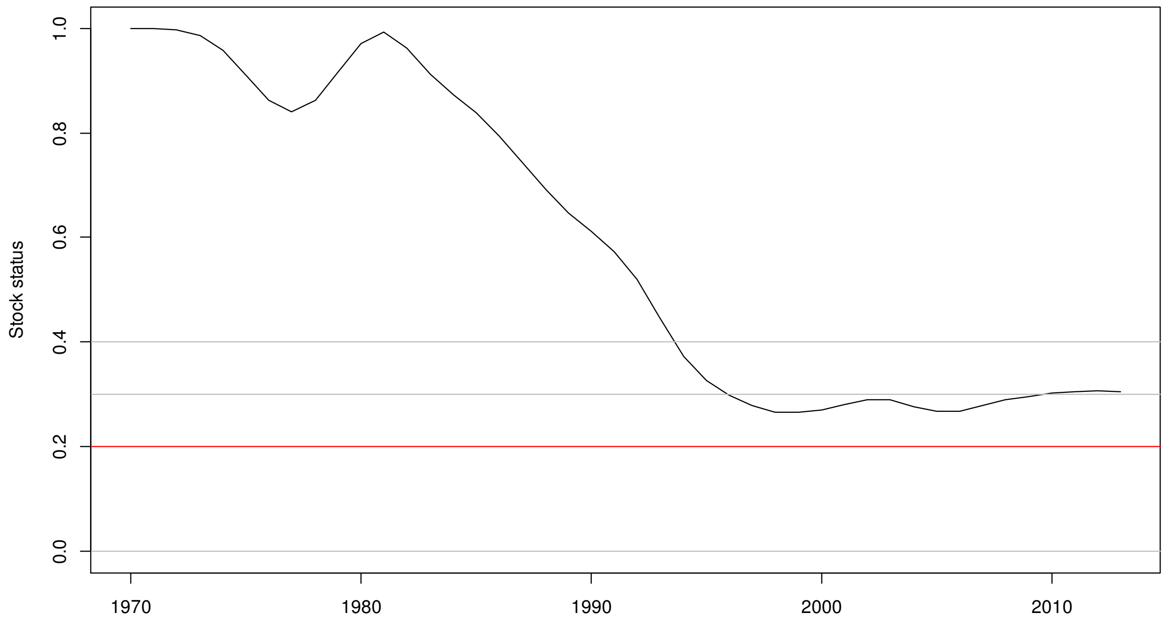

Figure 13: Eastern base model: estimated stock status (annual SSB divided by virgin SSB; female biomass only; mid-year). Grey lines at 0.3 and 0.4, red line at 0.2.

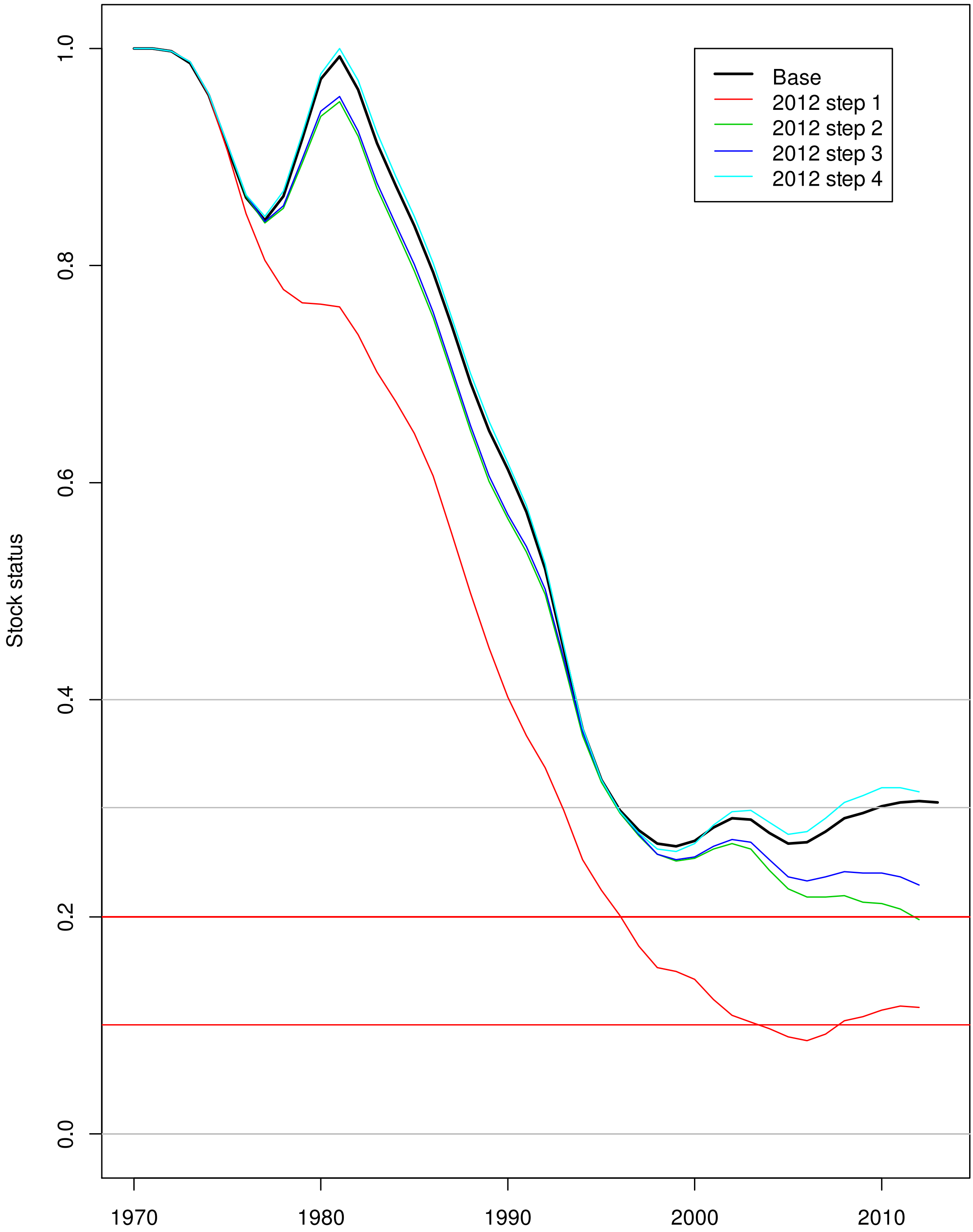

Figure 14: Eastern base model: stock status audit trail for CASAL models, starting with compatible data used in the 2012 assessment and the ISL base model structure (see text for details of steps 1-4). Grey lines at 0.3 and 0.4, red lines at 0.1 and 0.2.

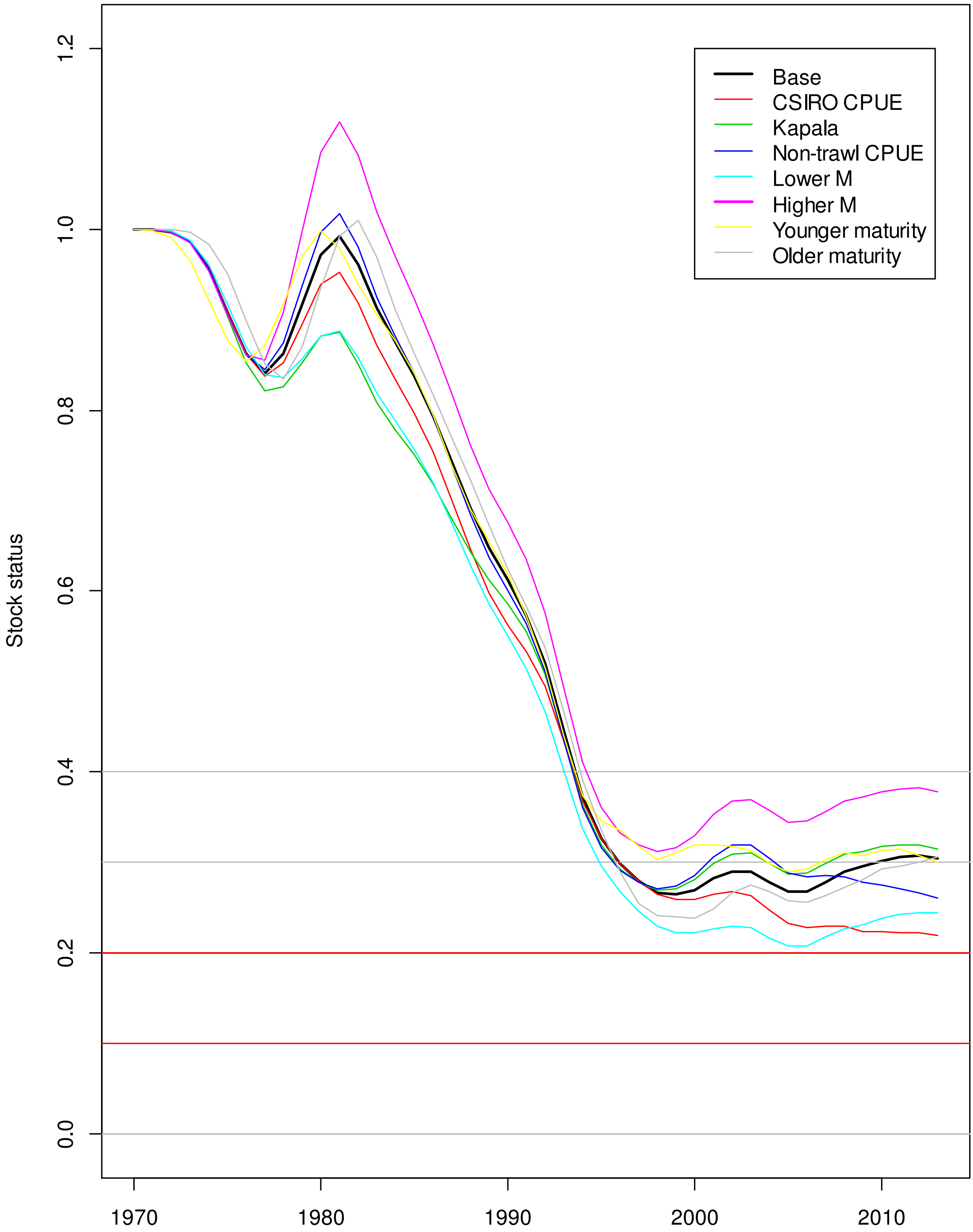

Figure 15: Eastern base model: estimated stock status for the base model and sensitivity runs. Grey lines at 0.3 and 0.4, red lines at 0.1 and 0.2.

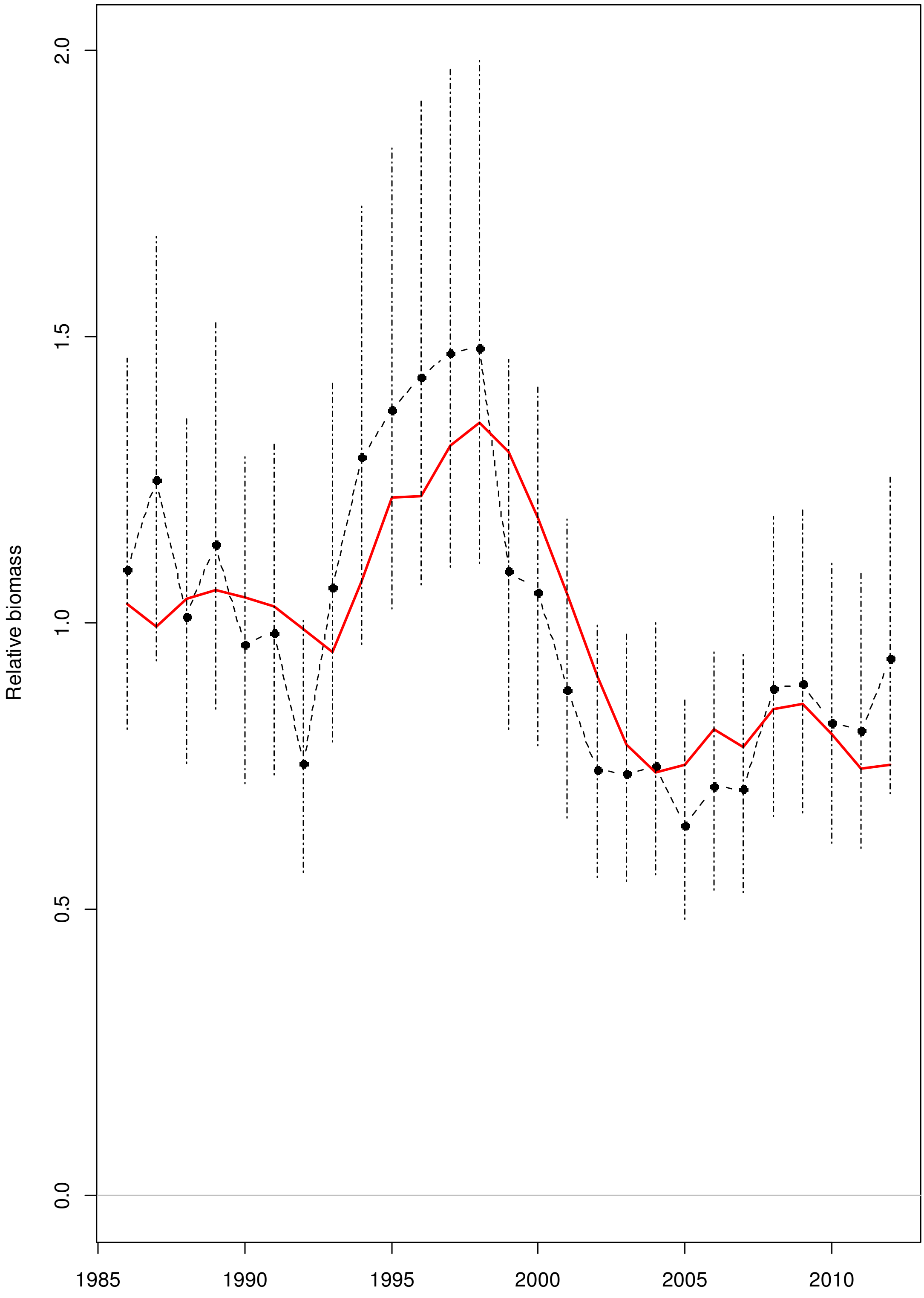

Figure 16: Western reference model: fit to ISL trawl CPUE indices. The dashed lines show 95% CIs.

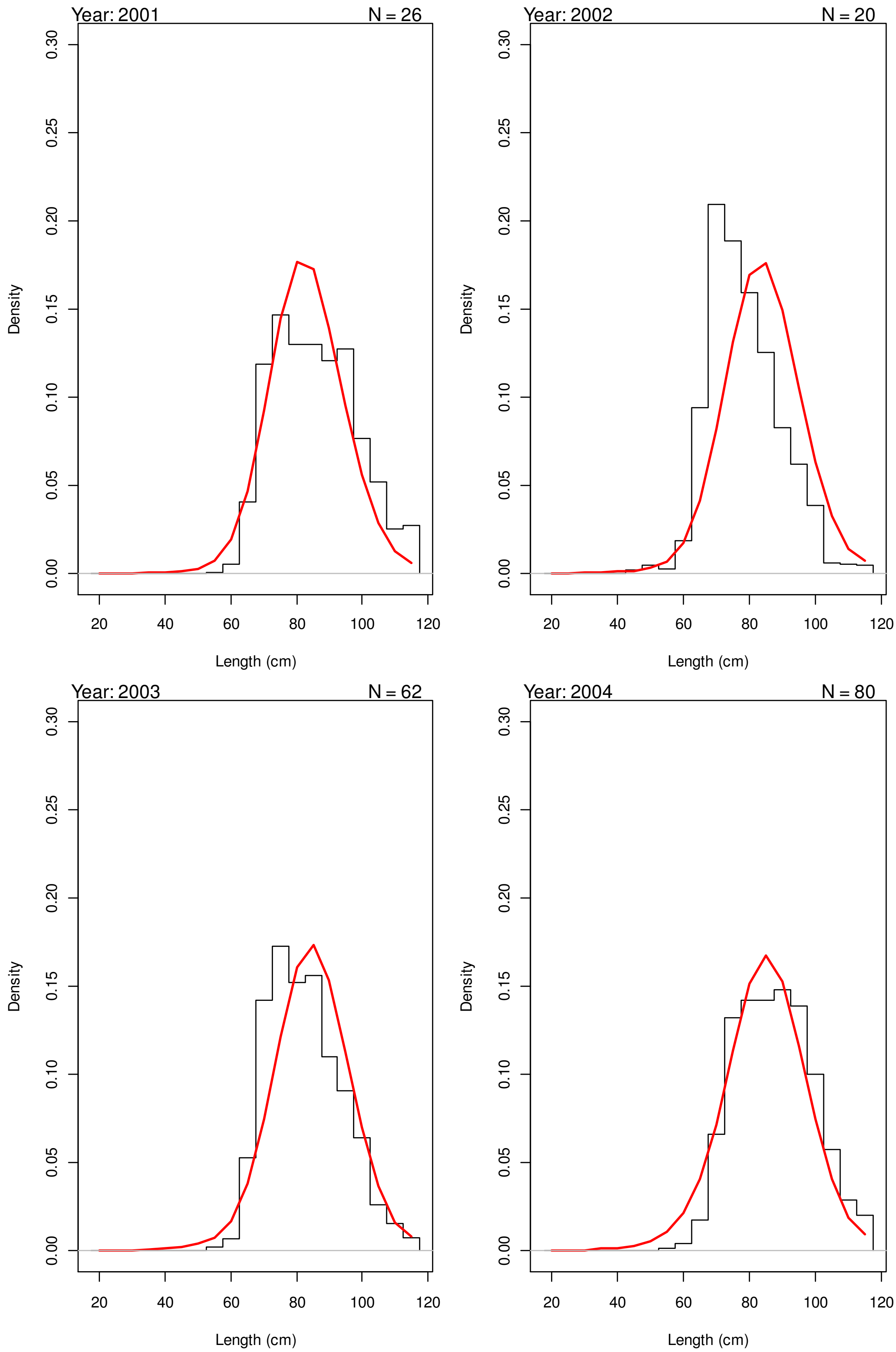

Figure 17: Western reference model fit to non-trawl length frequencies (2001-2004).

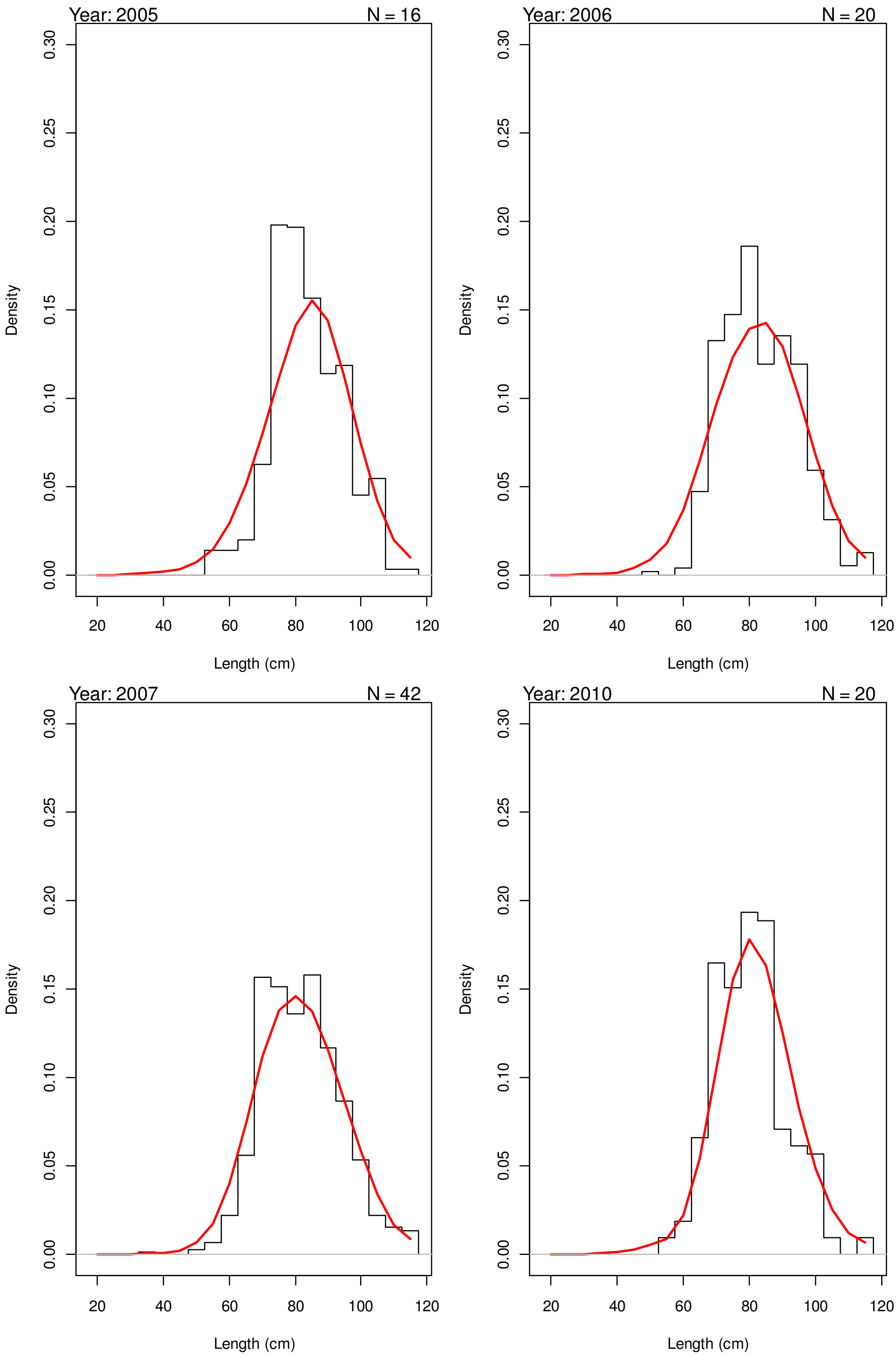

Figure 17 (cont): Western reference model fit to non-trawl length frequencies (2005-2007, 2010).

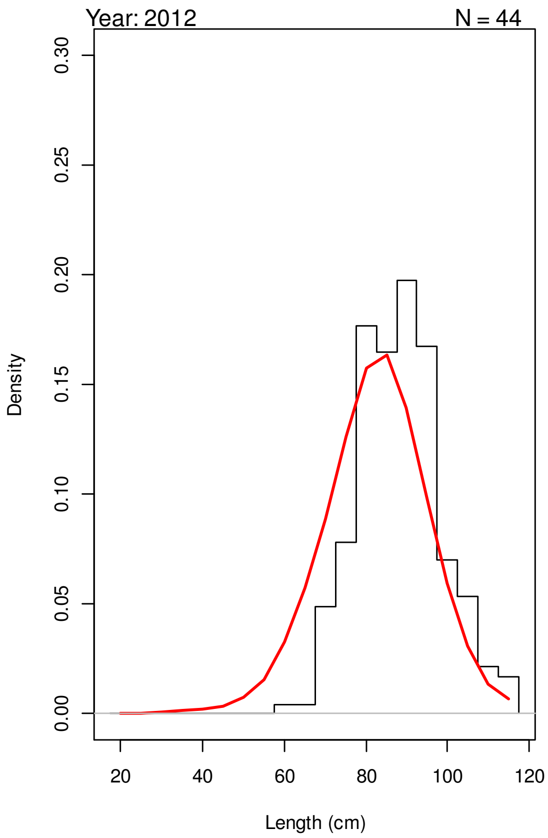

Figure 17 (cont): Western reference model fit to non-trawl length frequencies (2012).

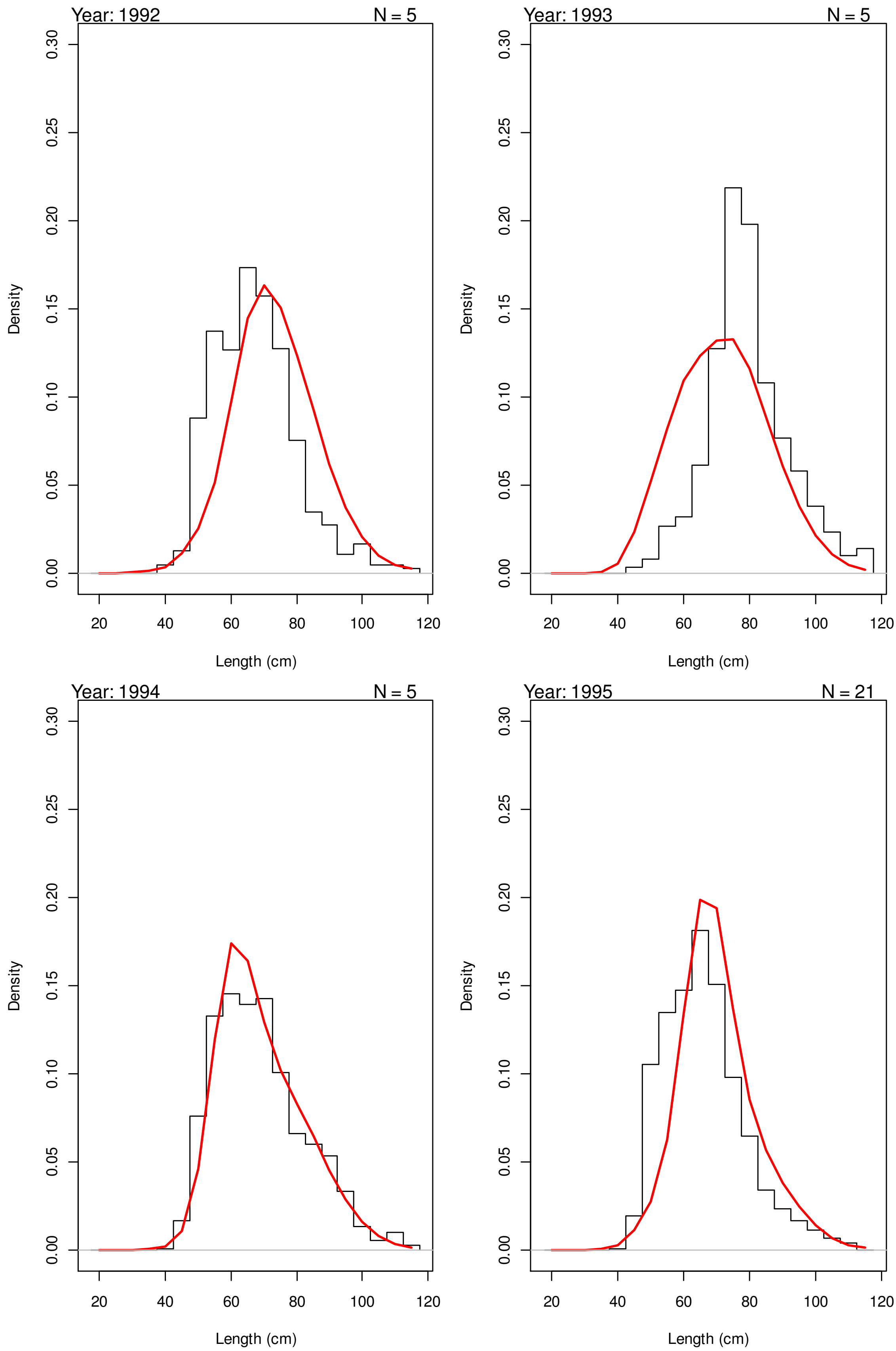

Figure 18: Western reference model fit to trawl length frequencies (1992-1995).

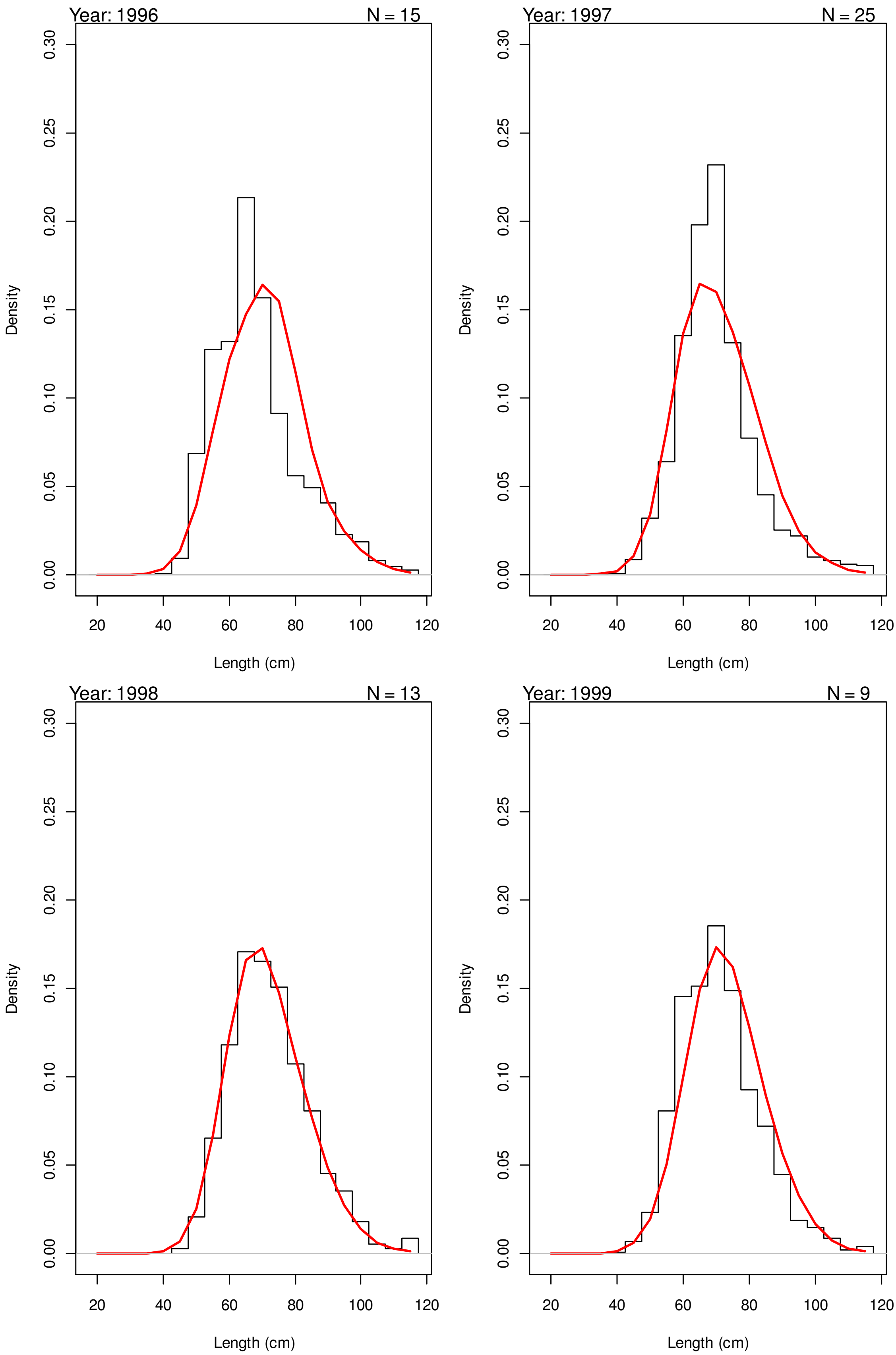

Figure 18 (cont): Western reference model fit to trawl length frequencies (1996-1999).

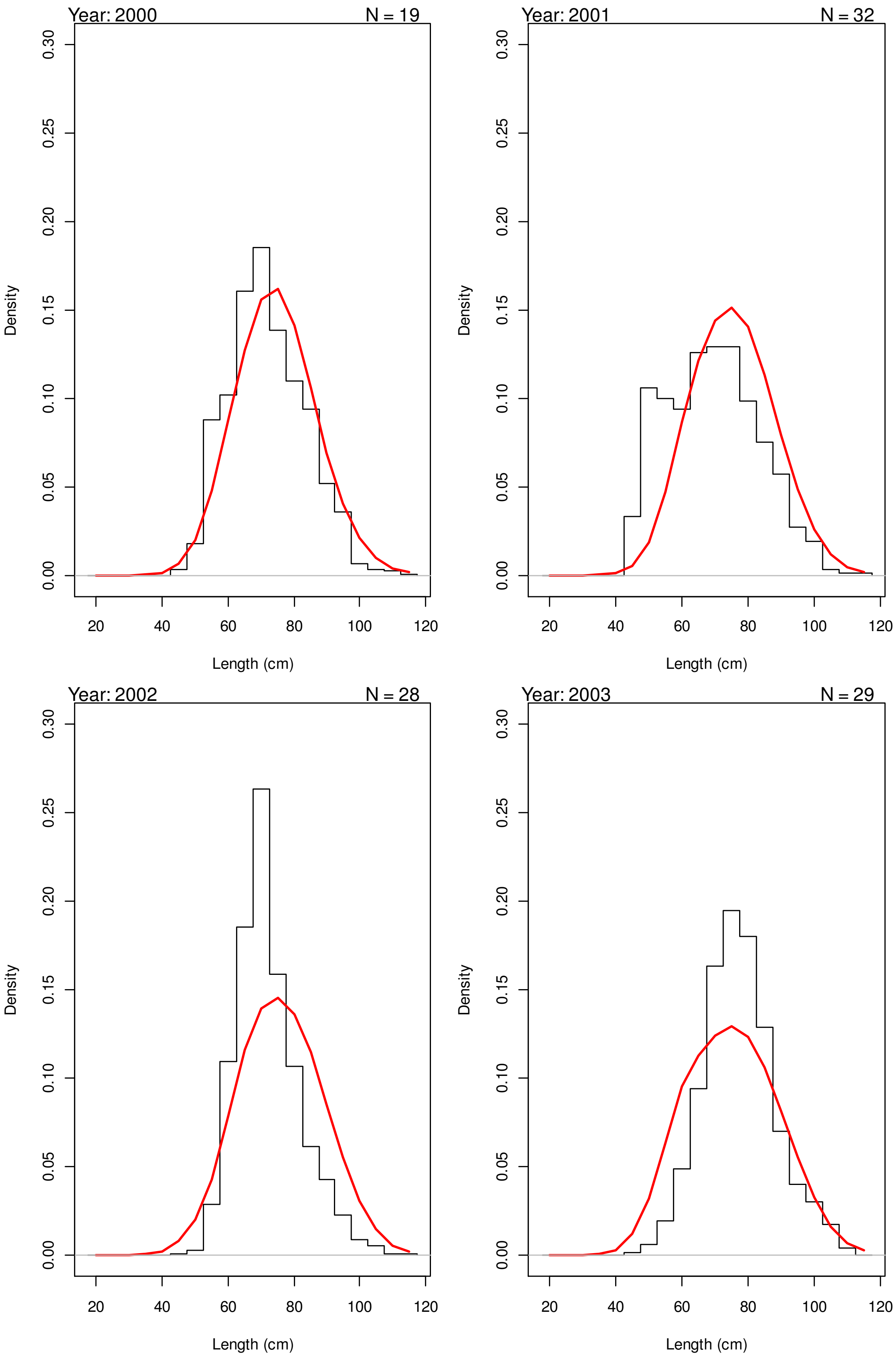

Figure 18 (cont): Western reference model fit to trawl length frequencies (2000-2003).

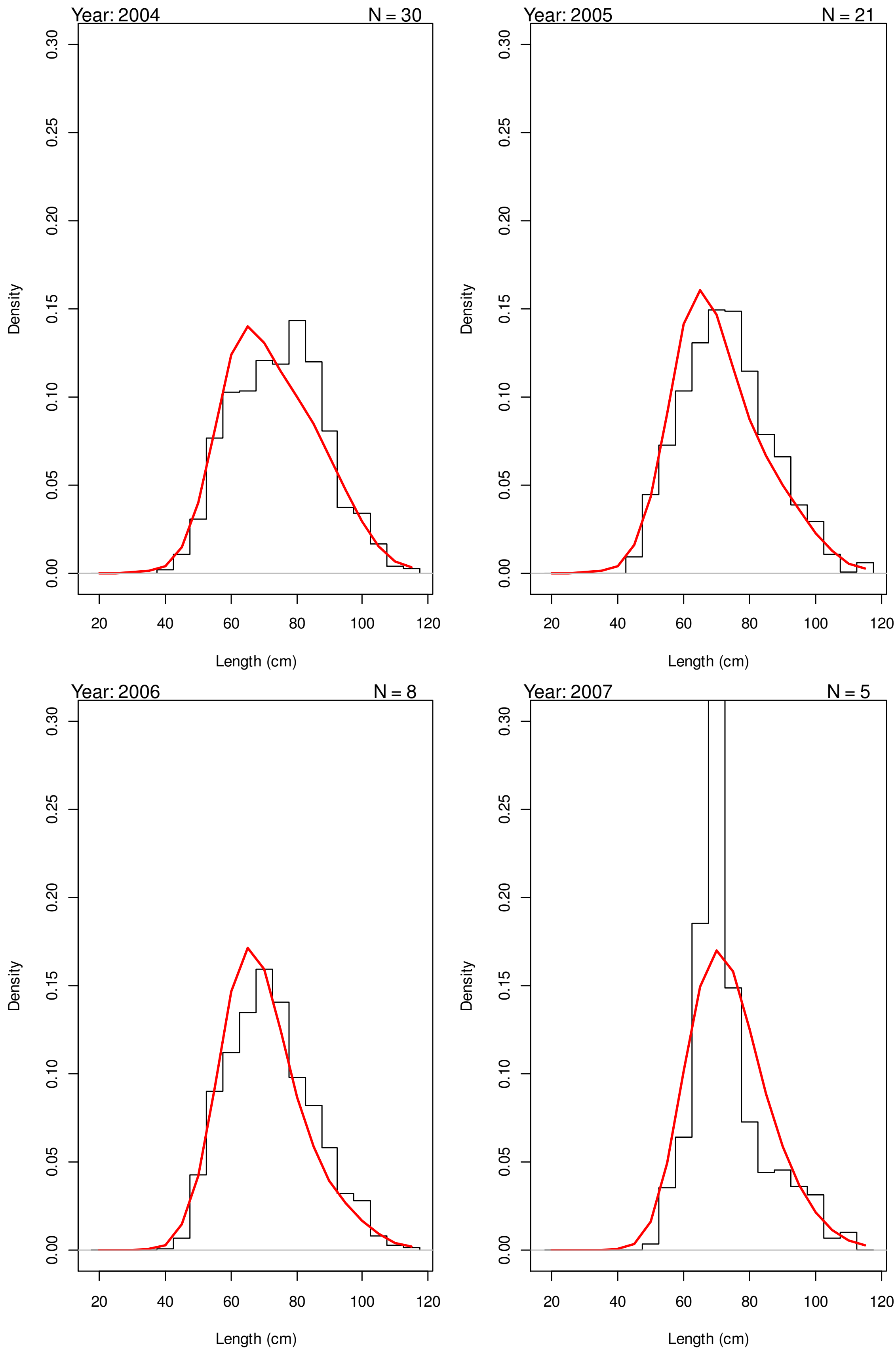

Figure 18 (cont): Western reference model fit to trawl length frequencies (2004-2007).

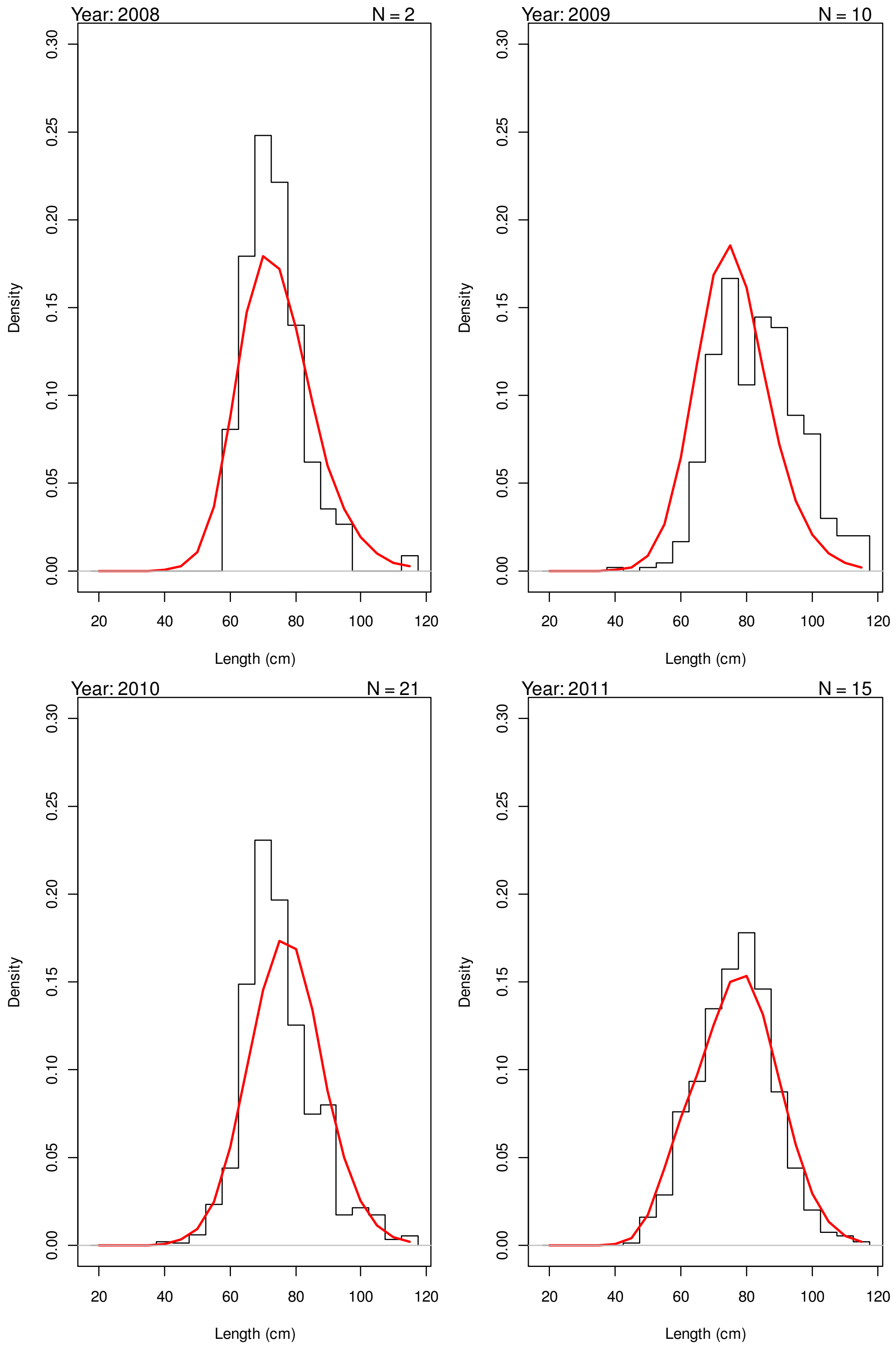

Figure 18 (cont): Western reference model fit to trawl length frequencies (2008-2011).

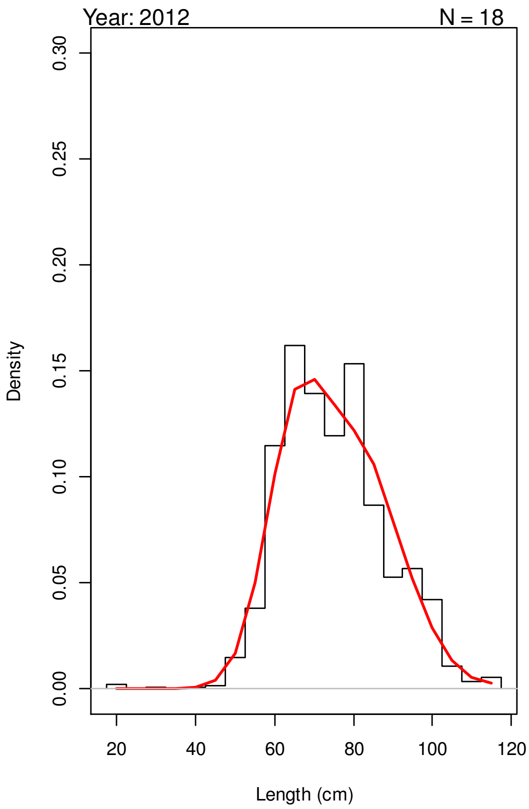

Figure 18 (cont): Western reference model fit to trawl length frequencies (2012).

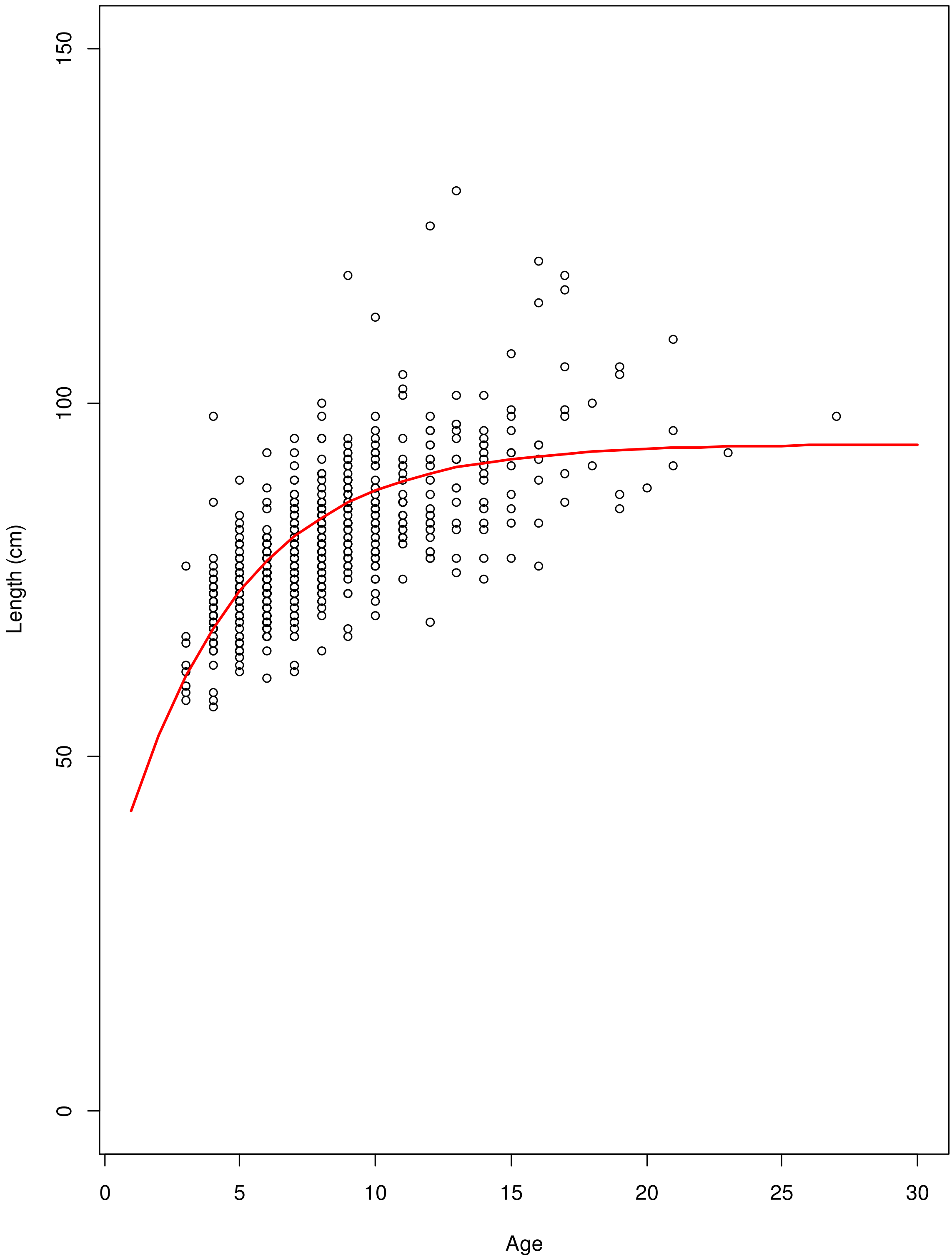

Figure 19: Western reference model: comparison of estimated male growth curve to all male age-length data, caught by line, in the western zones.

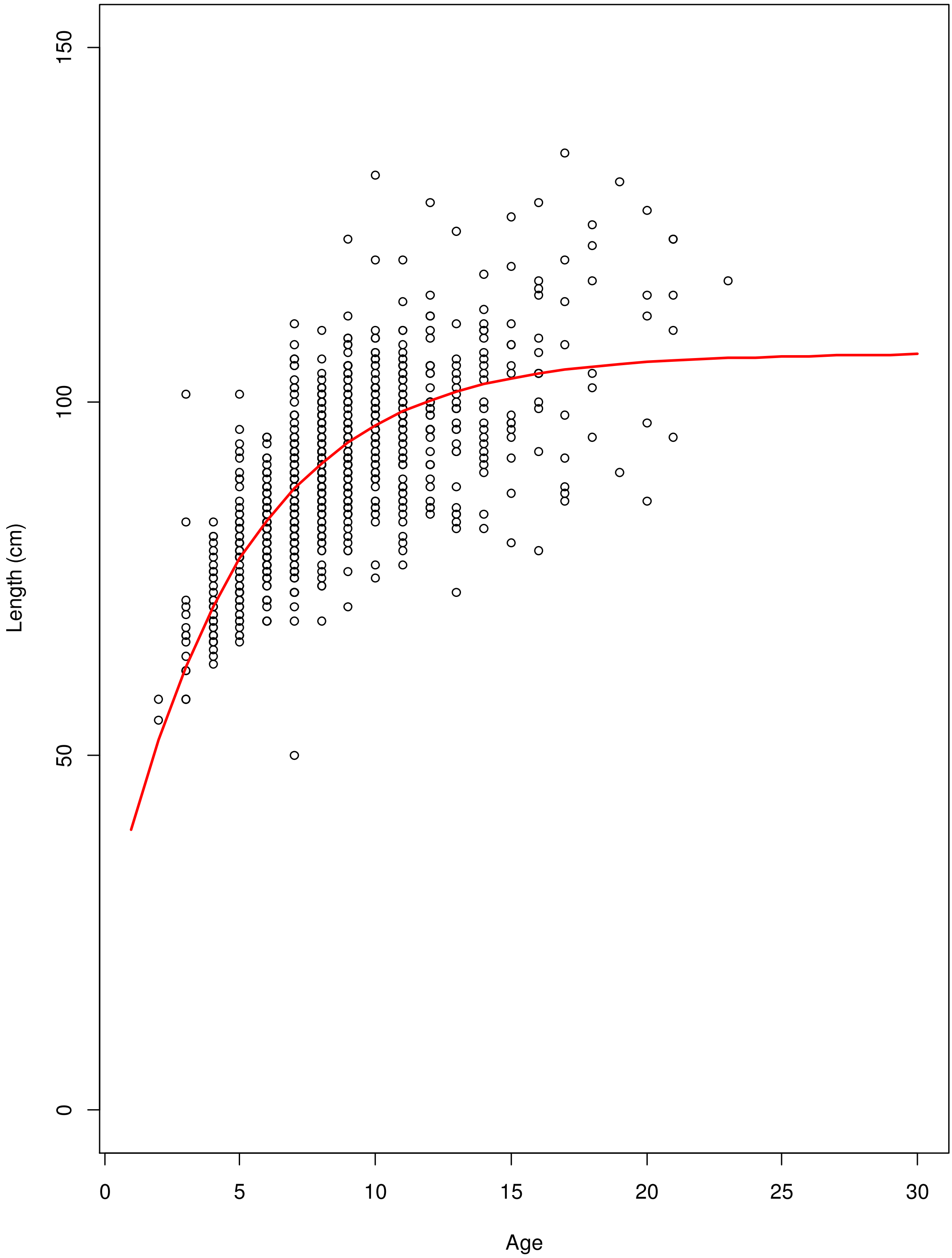

Figure 20: Western reference model: comparison of estimated female growth curve to all female age-length data, caught by line, in the western zones.

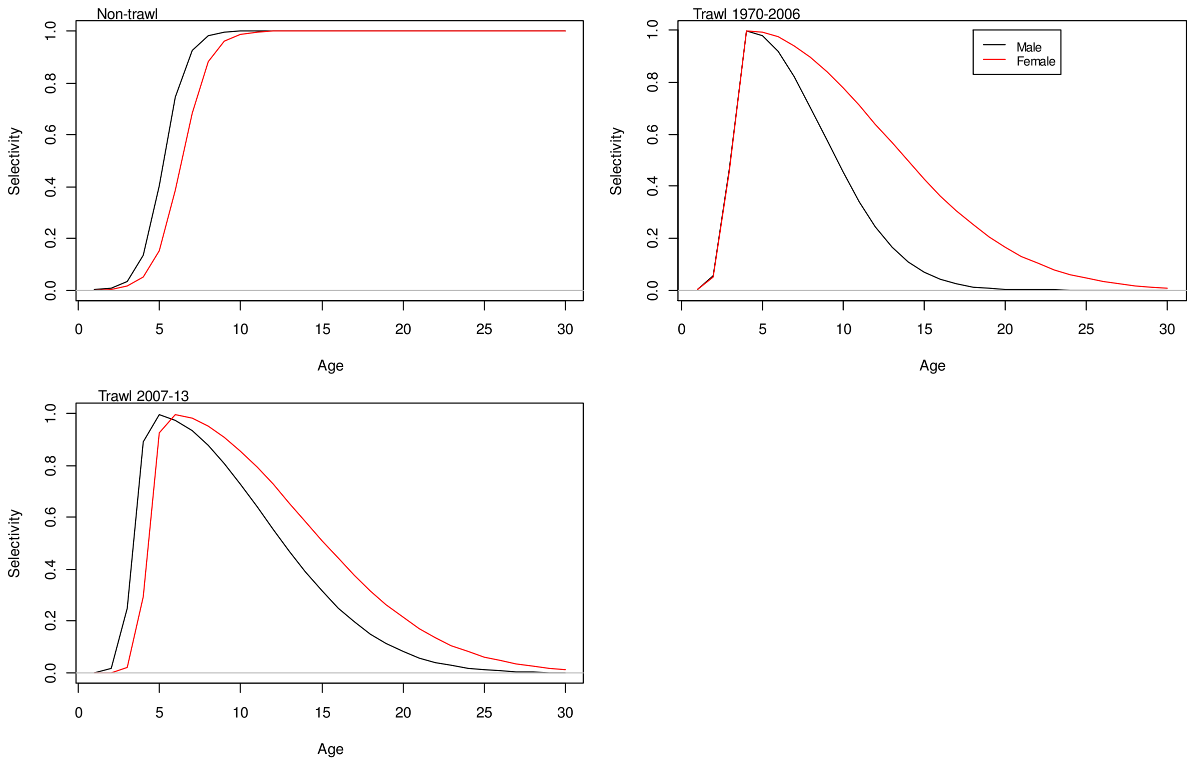

Figure 21: Western reference model: estimated fishery selectivities (age-based, sex specific, two time blocks for trawl).

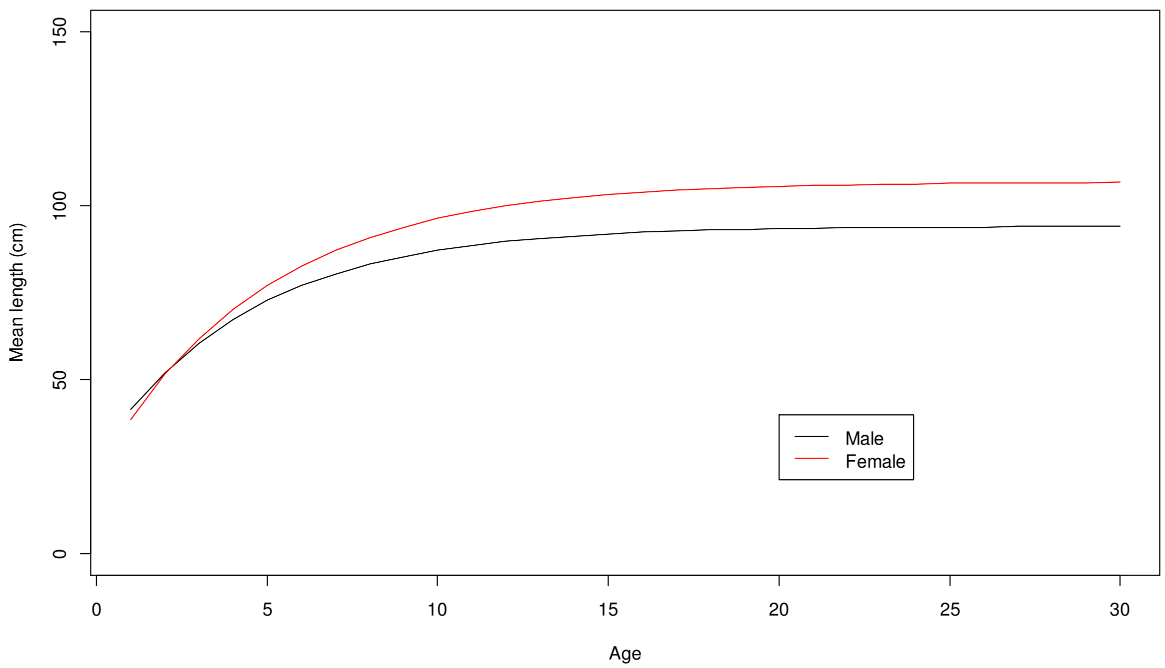

Figure 22: Western reference model: estimated growth curves (sex specific).

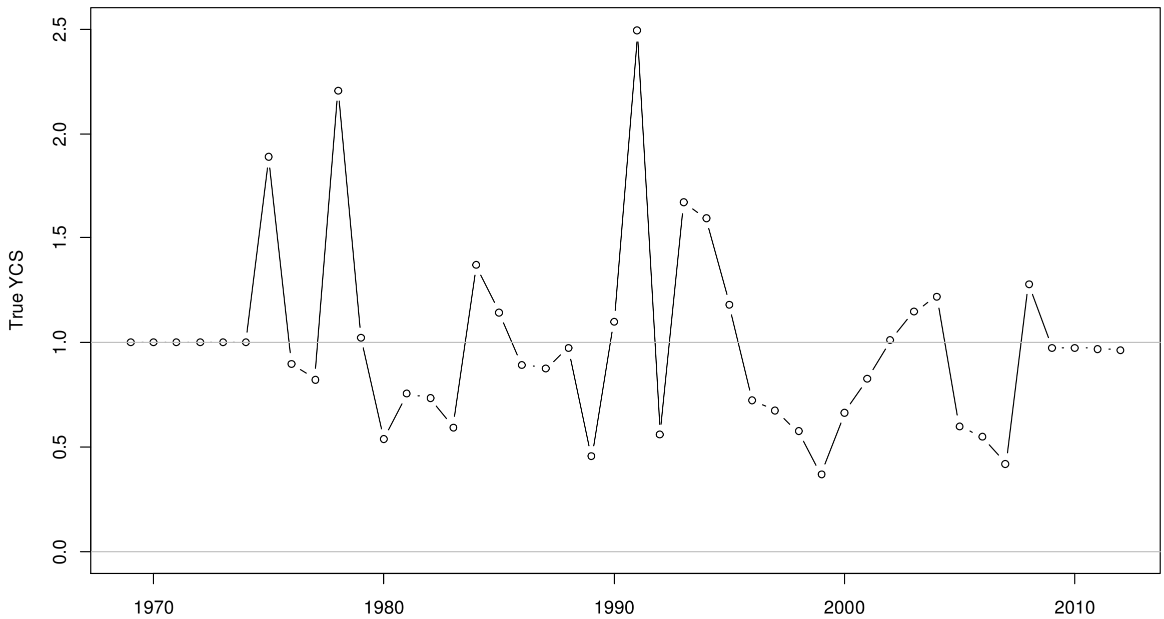

Figure 23: Western reference model: estimated "true year class strengths" (annual recruitment divided by virgin recruitment).

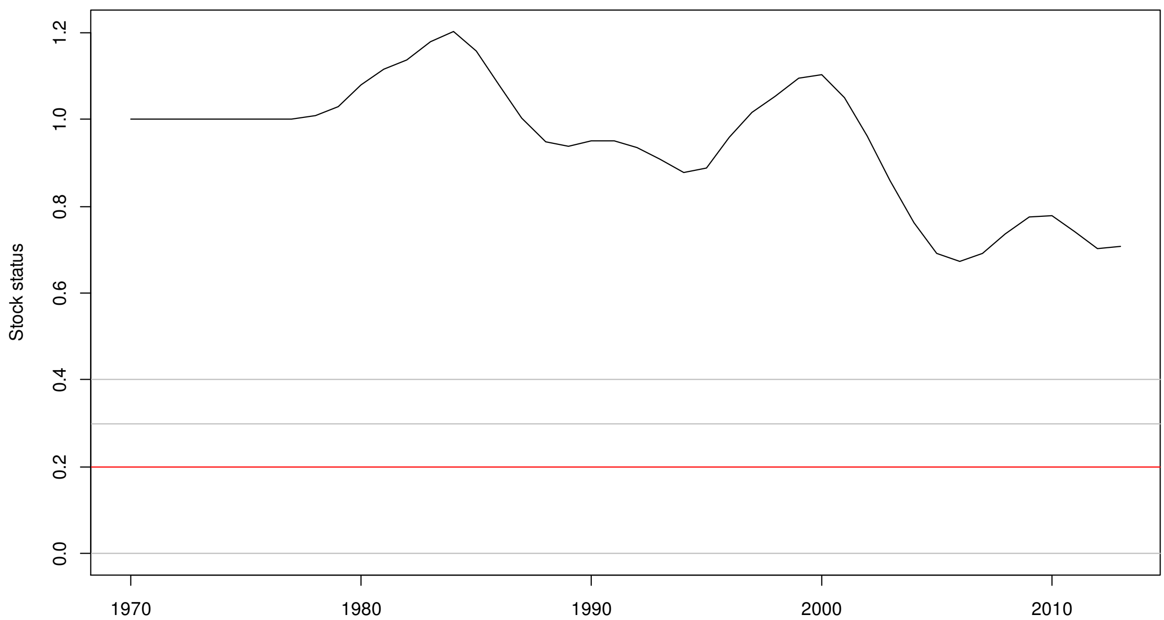

Figure 24: Western reference model: estimated stock status (annual SSB divided by virgin SSB; female biomass only; mid-year). Grey lines at 0.3 and 0.4, red line at 0.2.

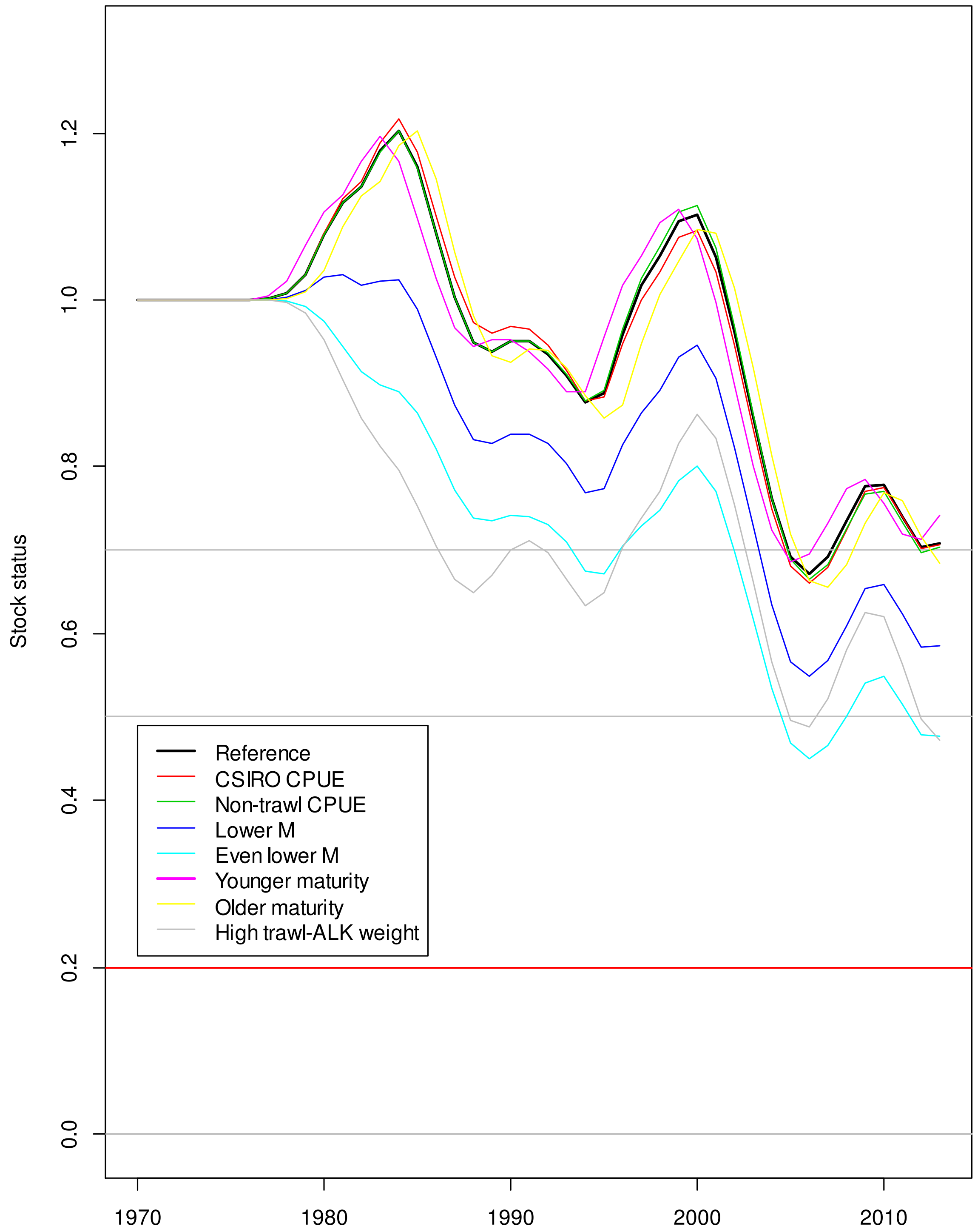

Figure 25: Western reference model: estimated stock status for the reference model and sensitivity runs. Grey lines at 0.5 and 0.7, red line at 0.2.

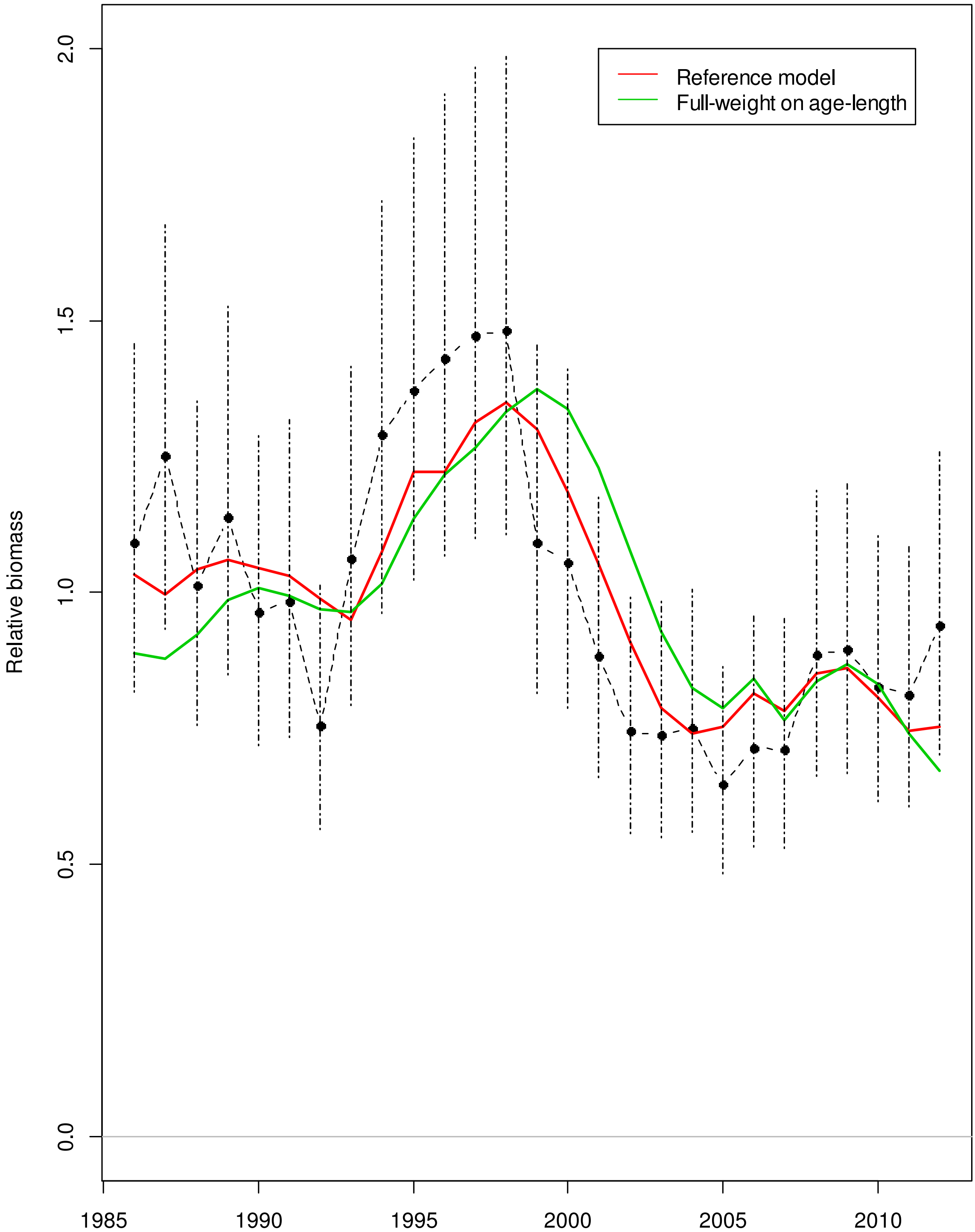

Figure 26: Western reference model: fit to ISL trawl CPUE indices for the reference model (half weight on trawl age-length data) and the run with full weight on the trawl age-length data . The dashed lines show 95% CIs.

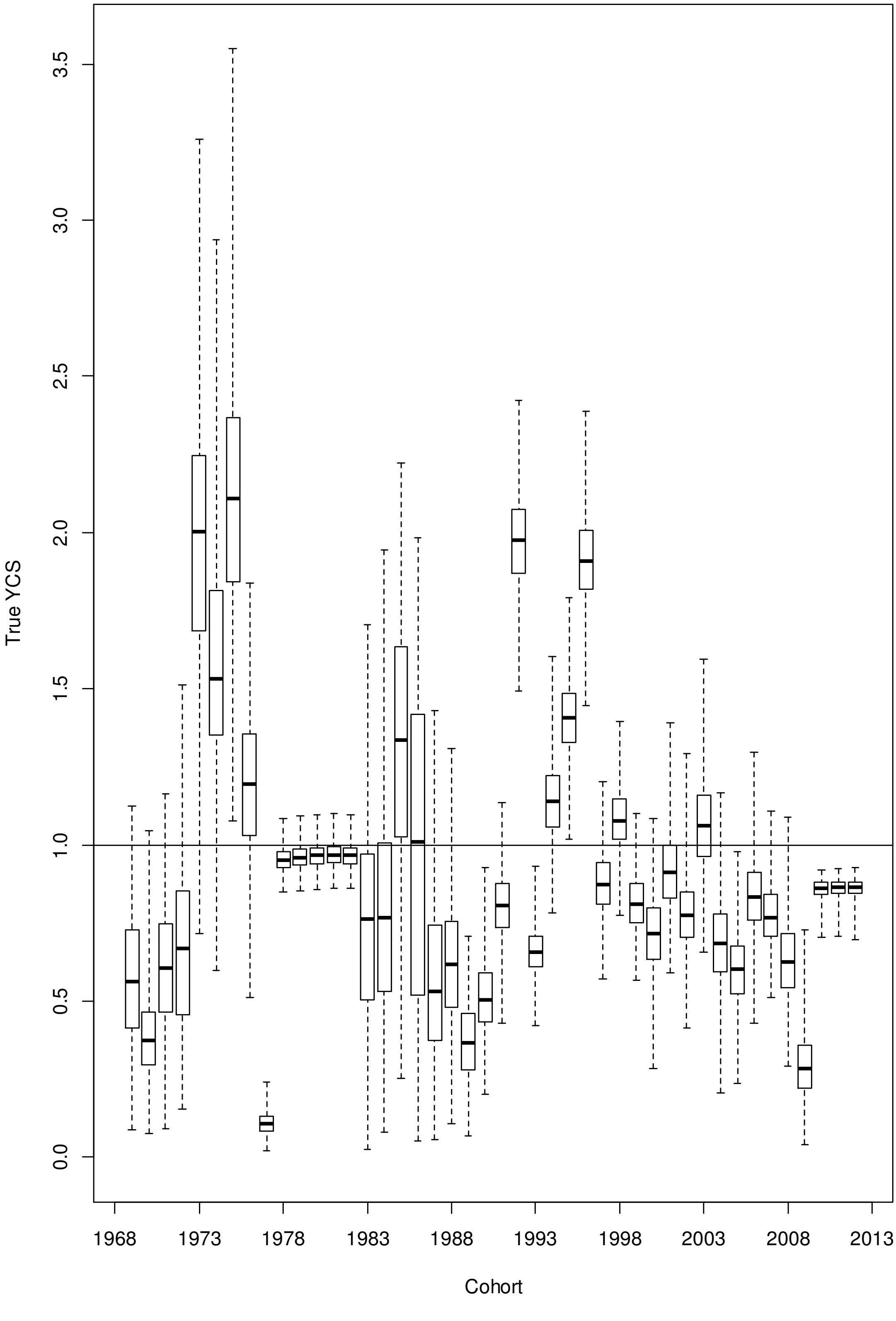

Figure 27: Eastern ISL base model: posterior distribution of "true" YCS (*R_y/R_0*; over the full range of MCMC samples). Each box contains 50% of the samples, the line within each box marks the median.

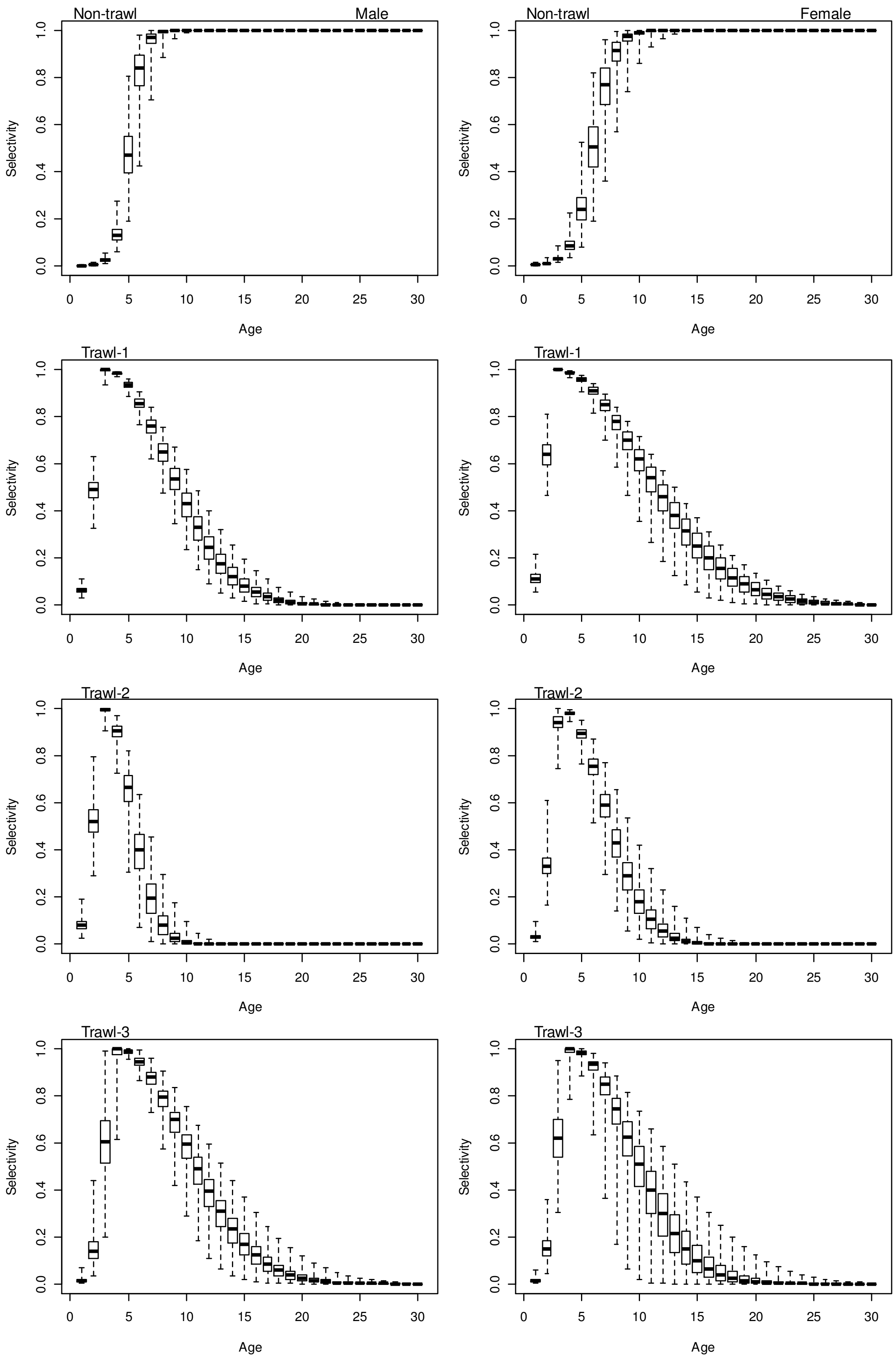

Figure 28: Eastern ISL base model: posterior distributions for fishing selectivities (over the full range of MCMC samples). Each box contains 50% of the samples, the line within each box marks the median.

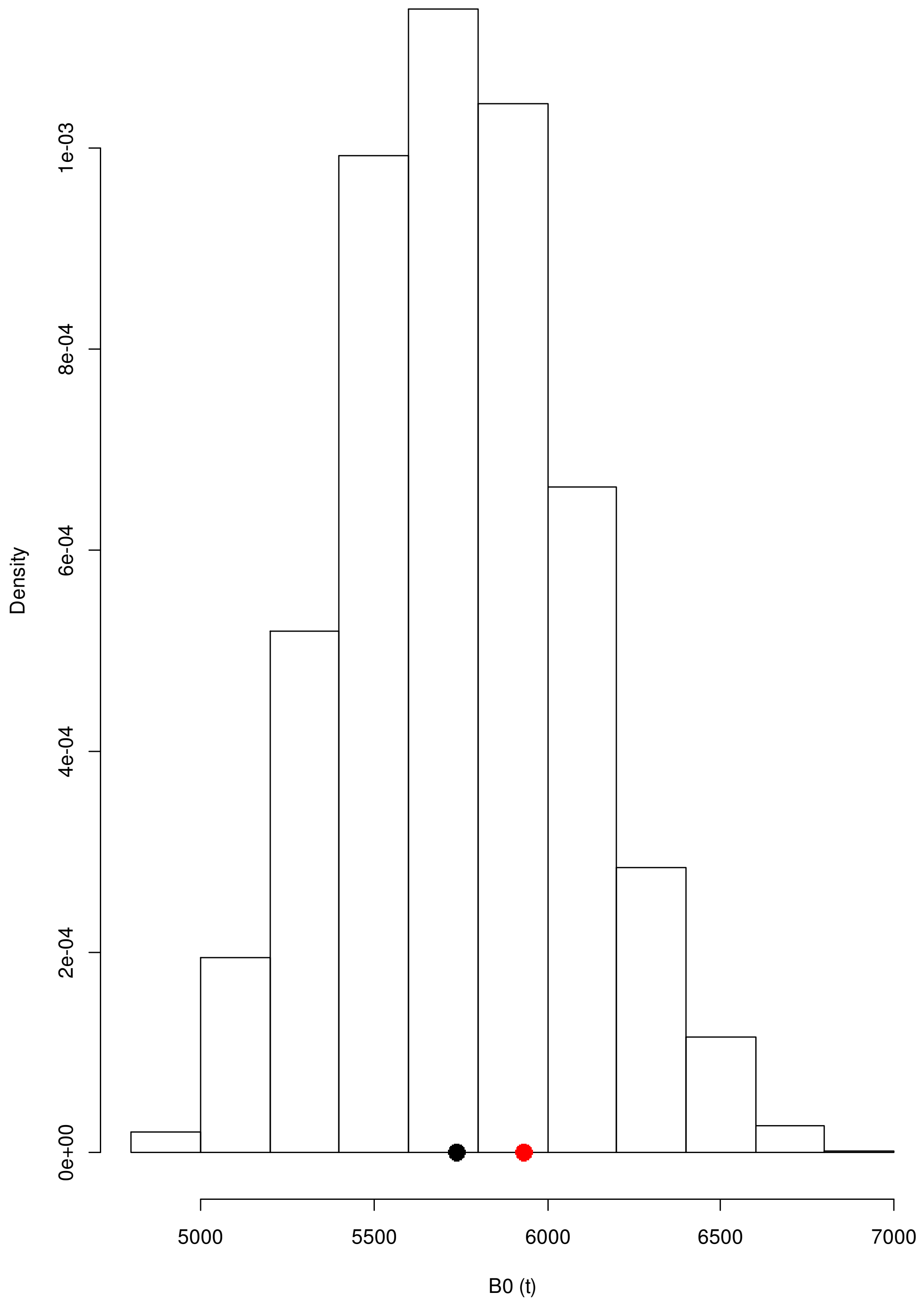

Figure 29: Eastern ISL base model: posterior distribution of B_0 with the median marked in black and the MPD estimate in red.

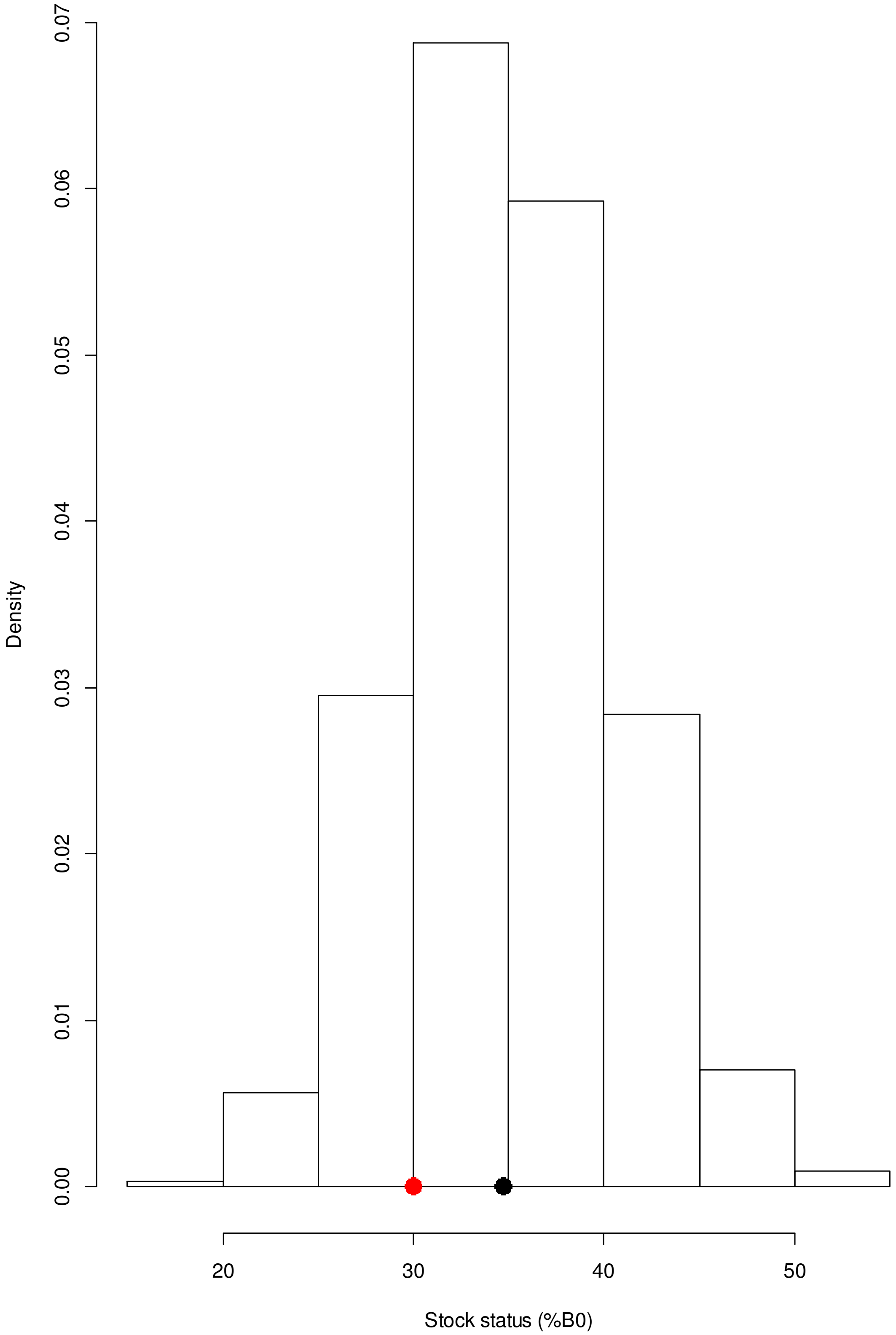

Figure 30: Eastern ISL base model: posterior distribution of stock status (B_{13}/B_0) with the median marked in black and the MPD estimate in red.

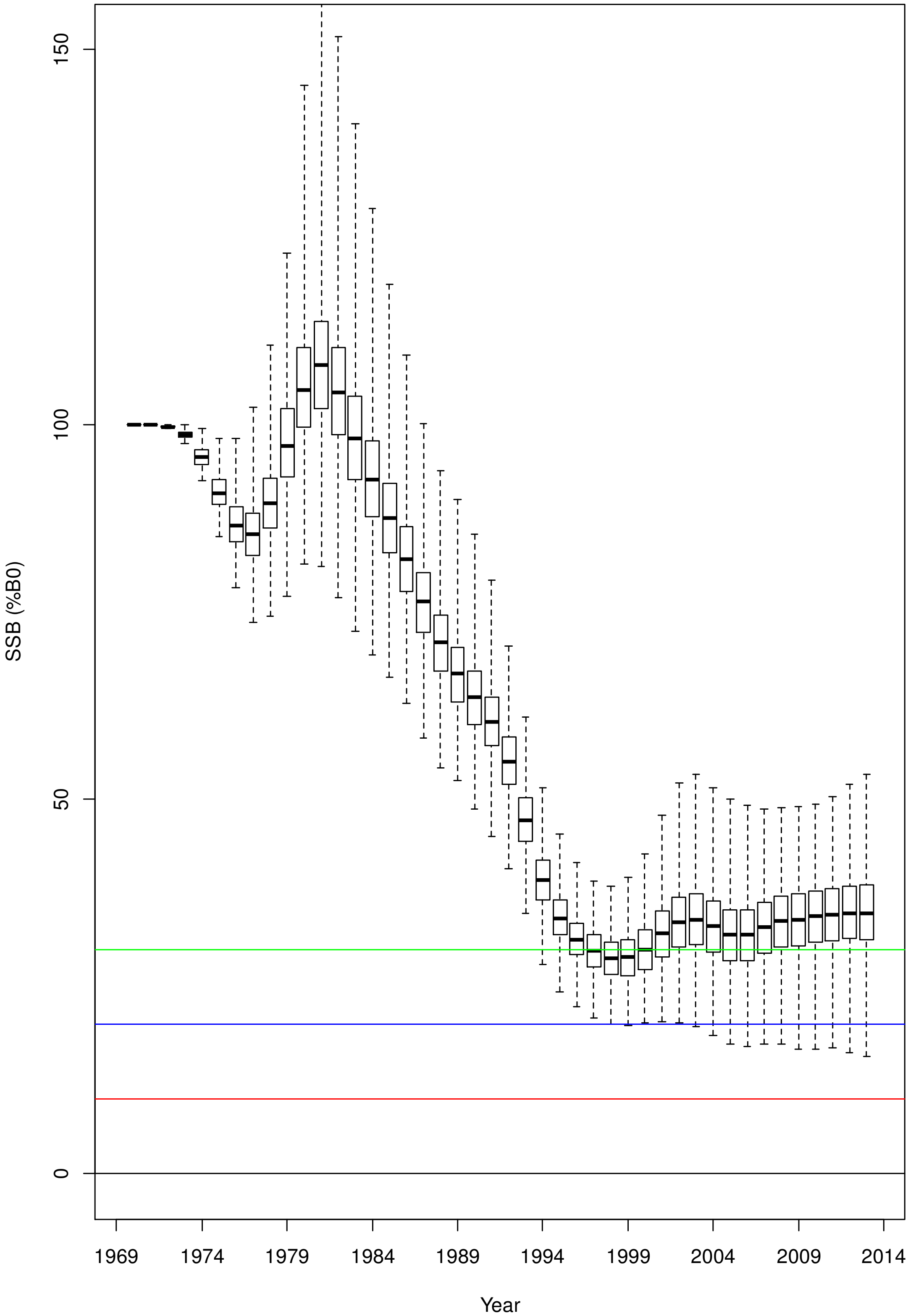

Figure 31: Eastern ISL base model: spawning-stock biomass trajectory. Each box contains 50% of the samples (in that year), the line within each box marks the median, and the dashed lines extend over the full range of MCMC samples. Green line at 30%.

Tabulated issues for stock assessment of pink ling 2013

Patrick L. Cordue and André E. Punt
7 September 2013

Introduction

This report documents the main issues discussed by André and Patrick during the 2013 pink ling assessment with regard to the spatially-aggregated models. The report is not comprehensive in that some (hopefully) minor issues are not documented and not all aspects of the assessment are covered.

There is also a section on spatial modeling which André put together but the issues there have not been discussed.

In particular, the following components of the assessment were **not** brought into issue and the approach taken by CSIRO in 2012 was continued:

- Assumption of two stocks, east (Zones 10, 20, 30) and west (Zones 40, 50) (except Zone 60 is now included in Zone 20)
- Construction of catch history (except Zone 60 is now included in Zone 20)
- Two fisheries: trawl and non-trawl
- Discards not modelled
- Construction of non-trawl CPUE indices
- Use of a two-sex population model
- Plus-group at age 30 in the population
- Construction and use of the ageing error matrix

The major issues which arose during the assessment were: (TO BE FILLED IN FURTHER WHEN WE KNOW FOR SURE)

- The preparation and use of composition data (pages 3,4,6)
- The derivation of standardised trawl CPUE for the eastern stock (page 5)
- The use of the trawl CPUE indices – whether to split series and/or ignore some points (page 16)
- Relative and absolute weighting of different data sets in the stock assessment models (page 15)

The bulk of this report consists of a series of tabulated issues. For each issue the nature of the issue is stated and several options are given, each with its advantages (pros) and disadvantages (cons). A statement is made on the **importance** of the issue and this is judged in terms of how much difference the **choice of option** could make to the results. Andre and Patrick individually graded each of the options and chose a single option as their individual preferred choice. Generally, two gradings were made by each person, an initial grading which was chosen before reviewing diagnostics and a final grading chosen after diagnostics were prepared and examined. Important diagnostics are referenced in the tables and the reader is directed to the appendices or another draft document. Do not pay too much attention to the number of records listed in tables in the appendices. These may differ from the actual number of records used in later analysis as different filtering criteria were used. **Where final grades are not filled in, it means that the person has not yet reviewed/seen the diagnostics.**

A grade of "Not a good option" is used sparingly in the initial grading because it means that the person believes there are **serious** technical issues with the option (there are minor technical issues with almost every option). However, in the final grading, after diagnostics have been examined, "Not a good option" also includes cases where the diagnostics suggest that the option should not be used in this assessment. The assignment of a grade is independent of whether the choice of option is considered important or not.

Key to tables

Names: An = André Punt, P = Patrick Cordue
Fill colour: **Black** = **Preferred option**, Green = Acceptable option, Red = Not a good option.
In the 2012 column, **black** indicates the assumption used in the 2012 east and west base models.

Data Issues

Issue	Options	Pros	Cons
Construction of length frequencies for spatially-aggregated models: possible scaling and stratification by zone, sampling method (port – including Sydney Market, onboard), fishing method (trawl, non-trawl), and depth. **Importance** depends on average magnitude of effective sample sizes (N). Can impact on point estimates and reference points through changes in estimated selectivity. **Moderate-Major** (high weight); Minor-**Moderate** (low weight). Low weight: N ~ 10 High weight: N ~ 100	Scale sample to catch/landing and combine across zones. Separate LFs by sampling-method and fishing method. (**Simple**)	Simple approach which uses all of the data.	Unlikely to be representative of the catch because of unbalanced sampling across zones.
	As above but stratify by zone. (**Simple zone stratification**)	Still relatively simple and uses all of the data.	Still doesn't deal with unbalanced sampling due to zero samples in some zones in some years.
	Conduct a quick analysis to determine if there are substantial size differences between zones within fishing method. Stratify accordingly. Exclude years when inadequate sampling across strata. Separate LFs by sampling and fishing methods. (**Analyze and stratify**)	Standard approach which deals with unbalanced sampling across zones.	Extra analysis time needed. Produces four LF time series whereas perhaps only two are needed. Some data may be excluded.
	As above but check to see if separation of sampling methods is justified. If not, then separate LFs for fishing method only. Also check on need for stratification by depth. (**Perhaps combine port and onboard; check depth**)	The most comprehensive approach which deals with the unbalanced sampling and may produce just two LF time series.	Extra analysis time needed. Potential difficulty in finding a suitable starting vector of sample sizes if onboard and port combined. Some data may be excluded.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Construction of length frequencies for spatially-aggregated models			An	At	M	N	P		An	At	M	N	P
	Simple							Descriptive analysis and linear modelling of length (see **Appendix 1** and **Appendix 2**)					
	Simple zone stratification												
	Analyze and stratify												
	Perhaps combine port and onboard; check depth												

Issue	Options	Pros	Cons
Construction of CPUE indices from trawl catch and effort data for use as biomass indices.	**Standard CSIRO** approach using zone and month level positive-catch data with depth filtering	A quick approach which may be adequate and can be applied generically to most SESSF stocks.	It doesn't provide much understanding of the "fisheries" and may not deliver the best biomass indices.
Importance depends on how different the CPUE indices are from the two approaches.	**Standard NZ approach**: a detailed descriptive analysis, selective filtering, and use of fine-scale data in the standardization.	Potentially provides some understanding of what "fisheries" are operating and hence gives a good chance of filtering the data appropriately.	Requires much more analysis time and may not provide biomass indices that are any different from the quicker CSIRO approach.
Potentially: Minor, **Moderate**, or **Major**			

Issue	Options (short description)	**2012**	**Initial preferences**					Diagnostics checked	**Final preferences**				
Construction of CPUE indices from trawl catch and effort data			An	At	M	N	P		An	At	M	N	P
	Standard CSIRO							Analysis of catch and effort data (see **cpue.docx**) – the CSIRO approach is fine for the west, but perhaps not for the east.					
	Standard NZ approach												

Issue	Options	Pros	Cons
Preparation of age data sets.	**Use all age data as age-at-length** without any stratification or scaling	A common SS3 approach.	No stratification or scaling, so unbalanced sampling may mean that data are unrepresentative.
Importance is hard to judge before results are seen and it will depend on data weightings.	Use all age data as age-at-length but attempt **some stratification and scaling**	Data may be more representative than if no stratification and scaling.	Requires extra work and given the small sample sizes and unbalanced nature of the data may be fruitless.
Potentially: Minor, **Moderate**, or **Major**	**Use age data as age-length keys** which are applied to LFs to produce catch-at-age, by method, in years when sampling is adequate. Possibly age-length keys by zone.	A standard approach which allows data to be stratified and scaled. Not all age data will be used but remainder could be fitted as age-at-length.	None associated with construction. Complicates modelling a bit as double use of LF data must be avoided. There are years with age but no length data and length-classes with no age data.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Preparation of age data sets			An	At	M	N	P		An	At	M	N	P
	Use all age data as age-at-length							Analysis of age-length data (see **Appendix 3**)					
	Some stratification and scaling												
	Use age data as age-length keys												

Issue	Options	Pros	Cons
Use of Kapala data **Importance:** Minor-**Moderate** (because there are little data and large CVs are likely to be applied to the biomass indices)	Use biomass times series and LFs	Fishery independent data covering a broad range of years.	Data collected from only a small part of Zone 10 and so very unlikely to be representative of the eastern stock. Length data are only available for two years.
	Exclude the data	Follows the philosophy of quality over quantity.	Excludes the only fishery independent data

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Use of Kapala data			An	At	M	N	P		An	At	M	N	P
	Use biomass times series and LFs												
	Exclude the data												

Issue	Options	Pros	Cons
Use of non-trawl CPUE indices as biomass indices	**Calculate and use as in the past** as biomass indices	Provides another potential biomass signal. The non-trawl fishery is a major component of the fishery as ling is a key target species.	It may not be a genuine biomass index as it is derived from a small number of vessels and sets targeting a relatively small area
Importance: Minor-**Moderate** (depending on how much weight goes on the indices)	Exclude the data	Follows the philosophy of quality over quantity if the data are considered of poor quality.	May exclude a valid signal.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Use of non-trawl CPUE indices			An	At	M	N	P		An	At	M	N	P
	Calculate and use as in the past												
	Exclude the data												

Modelling issues

Issue	Options	Pros	Cons
Definition of Spawning Stock Biomass (1): sexes	**Male + female** spawning biomass	Standard NZ approach.	An unlikely proxy for expected fertilized egg production. Females are larger than males and if gear is length-selective females could suffer higher exploitation.
Importance: Minor-**Moderate**	**Female** spawning biomass	Simple and a reasonable proxy for expected fertilized egg production.	Assumes egg production is proportional to biomass and ignores effect of males.
	Expected **egg production**	The best option if good fecundity data are available.	Ignores effect of males. Little or no data available to define egg production.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Definition of Spawning Stock Biomass (1)			An	At	M	N	P		An	At	M	N	P
	Male + female												
	Female												
	Egg production												

Issue	Options	Pros	Cons
Definition of Spawning Stock Biomass (2): timing.	**Beginning of year**	SS3 default for a single-season model	Assumes that fishing mortality during the year has no effect on the spawning potential of the stock. Gives stocks some extra resilience to high *F*.
Importance depends on level of *F* for stock depletion estimates and on various factors with regard to reference points.	**Middle of spawning season** (after half the mortality; mid-year if no explicit spawning season).	A logical assumption given that spawning potential in each year is likely to be related to the “average” spawning biomass engaged in spawning.	May lead to age-0 being 6 months long in SS3 models?
Minor for stock depletion estimates. Minor-**Moderate** for reference points.			

Issue	Options (short description)	**2012**	Initial preferences					Diagnostics checked	Final preferences				
Definition of Spawning Stock Biomass (2)			An	At	M	N	P		An	At	M	N	P
	Beginning of year												
	Middle of spawning season												

Issue	Options	Pros	Cons
Estimation of growth (1) **Importance**: Minor-**Moderate**	Estimate growth **inside** the base model	A natural approach which is likely to give the best estimate of growth as the model can account for selectivities and recruitment variability.	It can mean that data used in the model to allow good estimation of growth can dominate biomass indices (i.e., in the objective function).
	Estimate growth **outside** the model	A simple approach which avoids faulty biomass signals from “growth data” distorting model results.	Leads to poor growth estimates if selectivity means that a Lee effect is present, which when fixed in the model may distort model results.
	Estimate growth in a special model run and fix growth in the base model. (**Two runs**)	Could be the best of both worlds as the special run can put extra weight on the “growth data” to provide the best growth estimate.	Requires two runs and does not allow growth uncertainty to be included in overall uncertainty.

Issue	**Options (short description)**	**2012**	**Initial preferences**					**Diagnostics checked**	**Final preferences**				
Estimation of growth (1)			An	At	M	N	P		An	At	M	N	P
	Inside							SS3 model fits					
	Outside												
	Two runs												

Issue	Options	Pros	Cons
Estimation of growth (2): cohort specific *k* **Importance**: Minor-**Moderate**	Estimate **cohort specific *k*** for some cohorts.	Attempts to account for variation and trends in growth trajectories across cohorts.	Requires well-balanced and properly scaled age-length data to have any chance of capturing real trends.
	Estimate a **single *k*** across all cohorts	Normally adequate.	Not adequate if there are major trends in growth.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Estimation of growth (2)			An	At	M	N	P		An	At	M	N	P
	Cohort specific *k*							Analysis of age-length data (see **Appendix 3**). SS3 model fits.					
	Single *k*												

Issue	Options	Pros	Cons
Estimation of natural mortality	**Estimate outside the model** as a single constant and fix; do sensitivities to low and high values	Simple and transparent.	Might do better inside the model. Depending on data availability the estimate from outside the model might just be an educated guess.
Importance: Minor-**Moderate**	Estimate inside the model as a **single constant**	Allows all of the data to contribute to the estimation. Allowance for selectivities and YCS are made.	The data may not have much information on M – but the model will give an estimate anyway.
	Estimate inside the model as **sex specific**	As for a single constant. No reason not to if a sexed model	As for a single constant but could lead to unrealistic or imprecise estimates.
	Estimate inside the model as **age and sex specific** (e.g., double exponential by age)	Realistic scenario	Needs excellent age data otherwise too complicated.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Estimation of natural mortality			An	At	M	N	P		An	At	M	N	P
	Estimate outside the model												
	Single constant												
	Sex specific												
	Age and sex specific												

Issue	Options	Pros	Cons
Weighting of trawl CPUE indices between years	Compare CPUE trends between zones and assign CVs to individual points on the basis of similarities. (**CSIRO 2012**)	Was done this way in 2012. Attempts to accounts to some extent for between-zone variation in trends in CPUE	Hard to understand why this approach would provide sensible results. The CVs assigned to some years for the east CPUE indices were very low (2-4%).
Importance: Minor	Assign CPUE indices the **same CV across years**.	A simple approach justified on the basis that most of the CV should be coming from process error (and not observation error).	Some points in the time series are more or less reliable than others.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Weighting of trawl CPUE indices between years			An	At	M	N	P		An	At	M	N	P
	CSIRO 2012												
	Same CV across years												

Issue	Options	Pros	Cons
Weighting of data sets **Importance** depends on how much the biomass signals from different data sets agree or disagree and the emphasis the different methods put on the data sets. Both methods emphasize the fit to the biomass indices so importance should be Minor-**Moderate**	**Standard CSIRO** approach: emphasis on biomass indices and iterative reweighting of effective sample sizes and CVs	Accepted approach in Australia. Aimed at fitting biomass indices well.	Does not account for correlations in composition data.
	Standard NZ approach: emphasis on biomass indices and iterative reweighting of effective samples sizes following Francis method (gives low weights to LFs and AFs).	Accepted approach in NZ. Aimed at fitting biomass indices well. Accounts for correlations in composition data.	It is just one approach – there is no perfect solution. As with other iterative procedures, results depend on how many parameters are estimated and model structure.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Weighting of data sets			An	At	M	N	P		An	At	M	N	P
	Standard CSIRO							SS3 model fits to CPUE indices					
	Standard NZ												

Issue	Options	Pros	Cons
The potential changes in ling catchability caused by the loss of quota in 1999-2000 in the eastern trawl fishery and the structural adjustment in 2006-2007 for both east and west. **Importance** is hard to judge before results are seen and it will depend on data weightings. Potentially: Minor, **Moderate**, or **Major**	**Assume no change** but allow time-block fishery selectivities	Simple. Allows full time series of indices to be used.	There may have been changes in catchability.
	Deal with the issue in the **CPUE analysis**	Allows the CPUE data to decide the issue. Allows full time series of indices to be used.	There is some potential for the analysis to get it wrong.
	Split the eastern trawl CPUE series (different qs 1986-1999, 2000-2012)	Simple and addresses the issue which industry has repeatedly raised.	Reduces the power of the time series and the model may estimate an unrealistic change in q.
	Ignore CPUE indices from 2007 onwards (**Ignore from 2007**)	Simple and follows the "quality data only" philosophy.	No biomass indices in recent years. Could be an over-reaction to problems with CPUE.
	Ignore CPUE indices from 2000 onwards (east) and 2007 onwards (west) (**Ignore many points**)	Simple and follows the "quality data only" philosophy.	Could be a **big** over-reaction to problems with CPUE.

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
			An	At	M	N	P		An	At	M	N	P
Potential changes in ling catchability													
	Assume no change							Detailed CPUE analysis (see **cpue.docx**)					
	CPUE analysis												
	Split the eastern trawl CPUE												
	Ignore from 2007												
	Ignore many points												

Spatial modelling

Issue	Options	Pros	Cons
Number of zones **Importance: Major**	**Standard**: Zones 10, 20, 30 (East) Zones 40, 50 (west)	This is the way the data are assembled and have been analyzed in the past	There are no a priori reasons why these spatial strata are appropriate
	Alternative: Something else	One would need to reanalyze the data spatially and find spatial strata which appear more homogenous	Insufficient time to do a spatial analysis of catch, effort, length-frequency, and age data and re-assemble all the data inputs

Issue	**Options (short description)**	**2012**	**Initial preferences**					**Diagnostics checked**	**Final preferences**				
Number of zones			An	At	M	N	P		An	At	M	N	P
	Standard												
	Alternative												

Issue	Options	Pros	Cons
Movement assumptions **Importance: Major**	Larvae only	This is consistent with what is understood about ling biology; fewer parameters	Some adult movement may occur
	Adults and larvae	Some adult movement may occur	More complicated model; not consistent with general understanding of ling biology; more parameters
	Full mixing	No additional parameters to model movement (can split fleets across areas using different selectivities). Can be seen as pragmatic solution given noisy data.	The assumption of full mixing among areas is unlikely for ling.

Issue	**Options (short description)**	**2012**	**Initial preferences**					**Diagnostics checked**	**Final preferences**				
Movement assumptions			An	At	M	N	P		An	At	M	N	P
	Larvae only												
	Adults and larvae												
	Full mixing												

Issue	Options	Pros	Cons
Area-dependent growth Importance: **Moderate-Major**	Not area-dependent	Simple, fewer parameters	Growth may differ spatially
	Growth parameters area-specific	More realistic	Additional parameters; may be fitting to noise

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Area-dependent growth			An	At	M	N	P		An	At	M	N	P
	Not area-dependent							SS3 estimates which varied a lot between areas					
	Growth parameters area-specific												

Issue	Options	Pros	Cons
Time-dependence in larval distribution **Importance: Major**	Time independent	Simple, few parameters	Ignoring time-dependence in larval distribution could lead to poor fits and implicitly that local spawning is not very important
	Time dependence, no priors	More realistic	More parameters, may be unstable if there is insufficient data in some spatial area
	Time dependence, with priors	More realistic, less likely to be unstable	More parameters, there may be problems developing priors

Issue	Options (short description)	2012	Initial preferences					Diagnostics checked	Final preferences				
Time-dependence in larval distribution			An	At	M	N	P		An	At	M	N	P
	Time independent							Time-independent leads to poorer fits than perfect mixing.					
	Time dependence, no priors												
	Time dependence, with priors												

Appendix 1: Analysis of pink ling length data by depth and zone

P.L. Cordue
20 August 2013

Introduction

The raw length data from port and onboard sampling were analyzed with regard to various factors including depth (onboard data) and zone (onboard and port data). The primary questions being addressed were whether the length structure of ling could be expected to vary across zones (within stock) and/or with depth. This question is relevant to which length data should be used in the stock assessment and how it should be scaled and stratified.

Methods

Data from the almost flat files “LIGonboardlf.txt” and “LIGportlf.txt” were loaded into R for analysis as dataframes. Each row corresponded to fish of a certain length sampled from a particular tow/set/landing. The dataframes were expanded into fully-flat files by duplicating each record according to the total number of fish measured at the given length. Maximum depths recorded as zero were converted to missing values. The zone was calculated for each recorded position in the onboard sampling data (using CSIRO’s standard SEF zone definition and algorithm).

Various histograms and boxplots were produced to examine the data, mainly just for the trawl catches. For the onboard data two linear models were used to explore which factors were the main determinants of length.

The first model had no interactions:

length ~ year + month + zone + maxdepth + length-code + gear

where maxdepth was fitted as a cubic and other variables were categorical.

The second model was as above except that zone-maxdepth interactions were fitted. The “length-code” indicates what type of length measurement was taken (e.g., total, standard).

For the port data a single model was used:

length ~ year + month + zone + grade + length-code + gear

and all variables were categorical.

Results

In the eastern zones, the port-sampling data showed a clear difference in the raw lengths across zones for the **trawl** fleet (gear code = “OT”) with smaller lengths in Zone 10 catches, and similar larger lengths in Zones 20 and 30 (Figure 1). However, in the onboard-sampling data it was Zones 10 and 20 that had similar sized smaller fish with Zone 30 having larger fish (Figure 2).

For the **trawl** catch in the western zones, there was quite a lot of variability across years within zone and there were no clear differences between Zones 40 and 50 or between port and onboard sampling (Figures 3 and 4).

The depth distribution of the **trawl** sampling varied considerably across years for the eastern zones (Figure 5) but was much less variable for the western zones (Figure 6). This indicates that it could be very misleading, for the eastern stock, to simply examine raw trawl length data by zone as any apparent differences could actually be driven by changes in depth distribution (assuming there is a depth effect).

The only way to get at the likely effects is through some type of model standardization – such as linear modelling.

The models had adjusted R^2 of 46% (onboard non-interaction), 47% (onboard interaction), and 37% (port). Almost everything was highly significant because of the large number of records and the (false) assumption of independent errors. However, the models are just used to check for “important” factors with regard to length structure in the catch and significance levels are not relevant. Confidence intervals were calculated but they were all very tight and are not presented because they over-estimate the level of precision.

The results are focused on the onboard models as they can account for depth effects whereas the port model cannot.

A major effect that needed to be accounted for was gear and both onboard models estimated similar effects (Figure 7). Year effects were fitted to allow for recruitment variability. Both onboard models estimated very similar year effects (Figures 8).

The non-interaction model estimated a strong depth effect with a steady increase in the expected length of ling from 50-1000 m (Figure 9). The interaction model strongly suggested that there were important depth effects within zone with a major effect in Zone 10 (Figure 10). The relative zone effects differ by depth in the interaction model but a comparison of the zone effects between the two models at a maximum depth of 400 m shows similar effects (Figure 11). The port model estimated a similar pattern of zone effects as well (Figure 12).

Conclusions

There are important zone effects and important depth effects within some of the zones.

Zone 10 shows a strong effect, typically having smaller ling than zones 20 and 30. There is a very strong depth effect in Zone 10 and a strong depth effect in Zone 20. For the eastern stock assessment, **trawl** length data should be stratified by depth within zone. Because of the strong depth effects in zones 10 and 20, port data should not be used unless it can be assigned to a depth range. For non-trawl data there is less need for stratification as there is no catch in Zone 10.

In the western zones, the depth effects are not very strong and the zones have similar sized ling. For the stock assessment it is probably unnecessary to stratify by zone or depth and the port data can probably be combined with the onboard data.

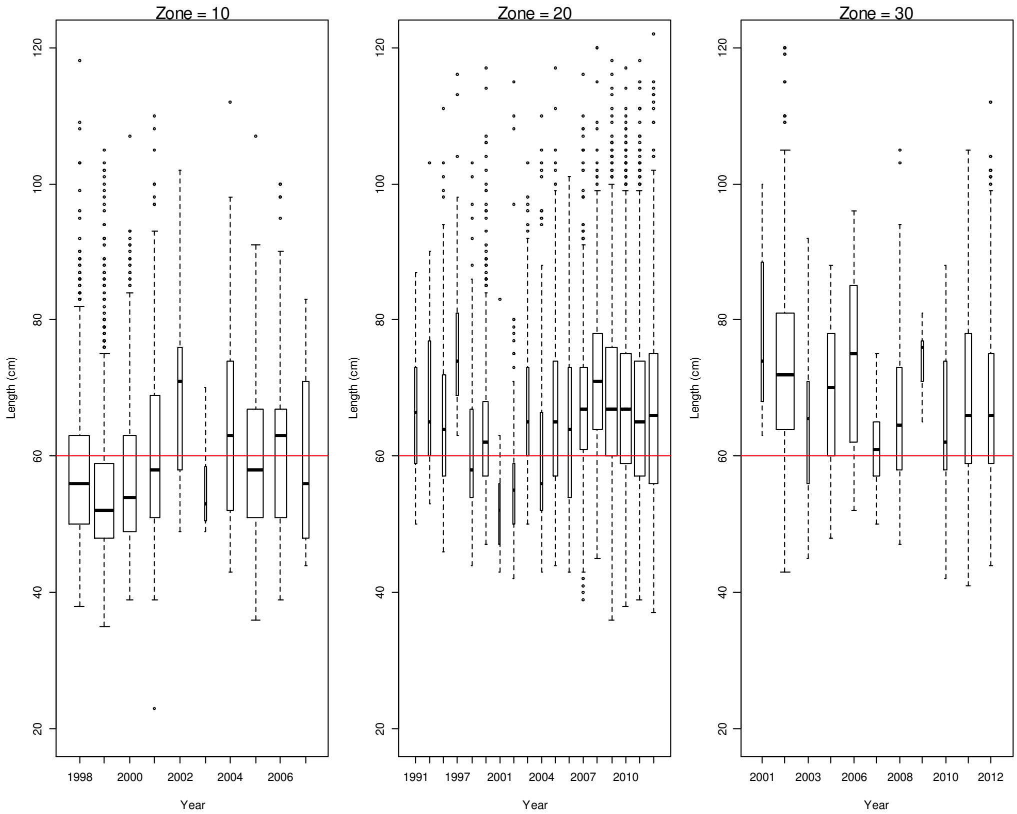

Figure 1: Boxplots of raw lengths by eastern zone and year for the port sampling of ling (OT only).

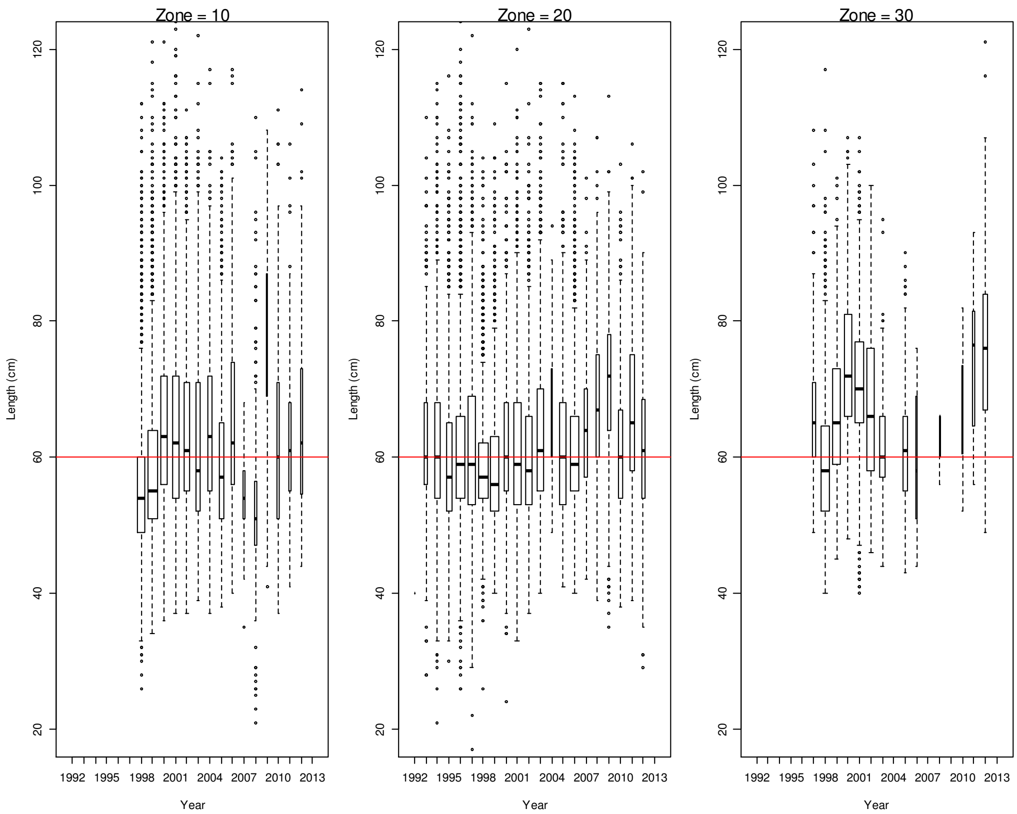

Figure 2: Boxplots of raw lengths by eastern zone and year for the onboard sampling of ling (OT only).

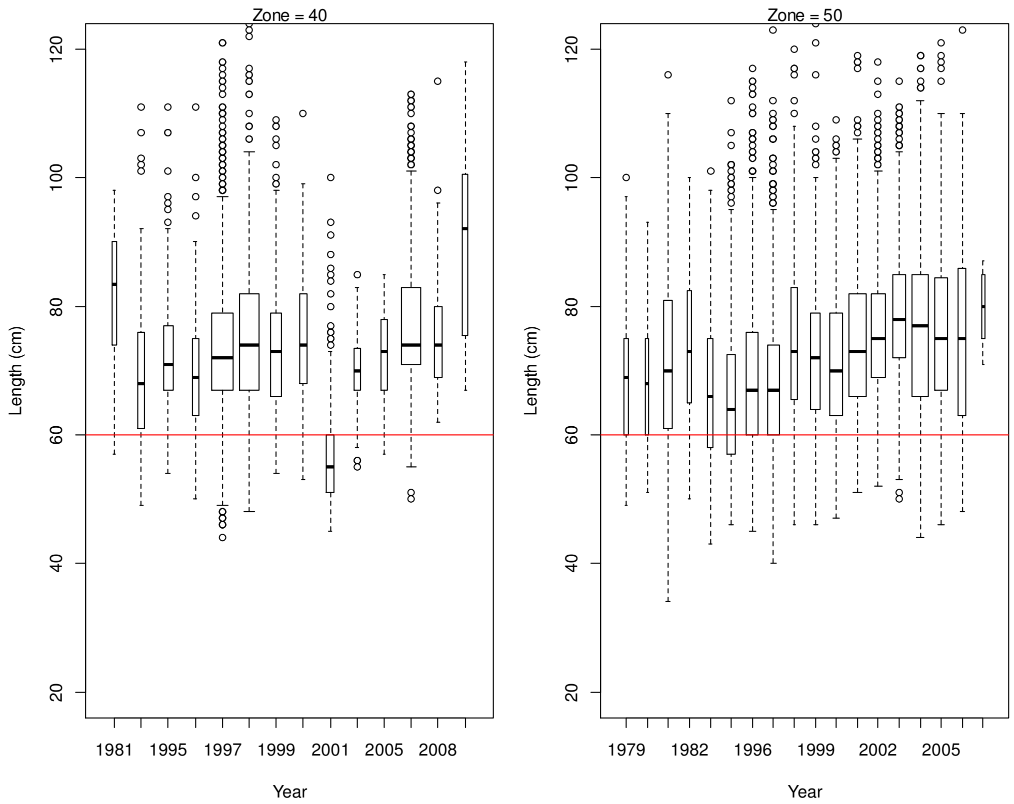

Figure 3: Boxplots of raw lengths by western zone and year for the port sampling of ling (OT only).

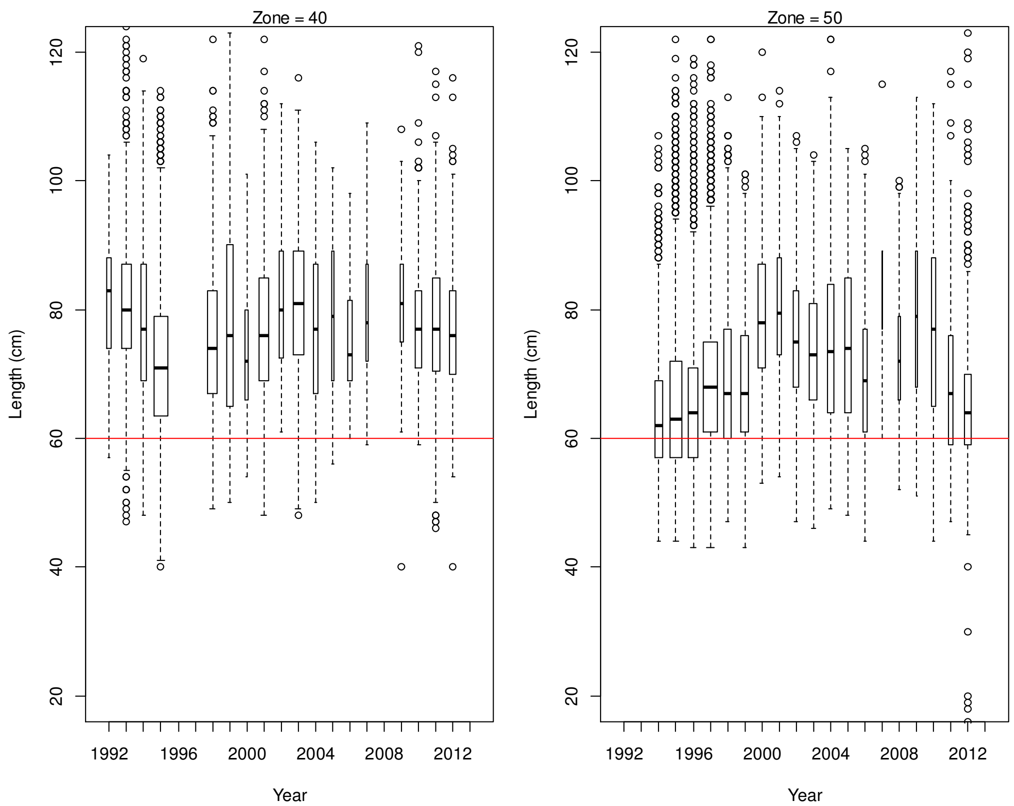

Figure 4: Boxplots of raw lengths by western zone and year for the onboard sampling of ling (OT only).

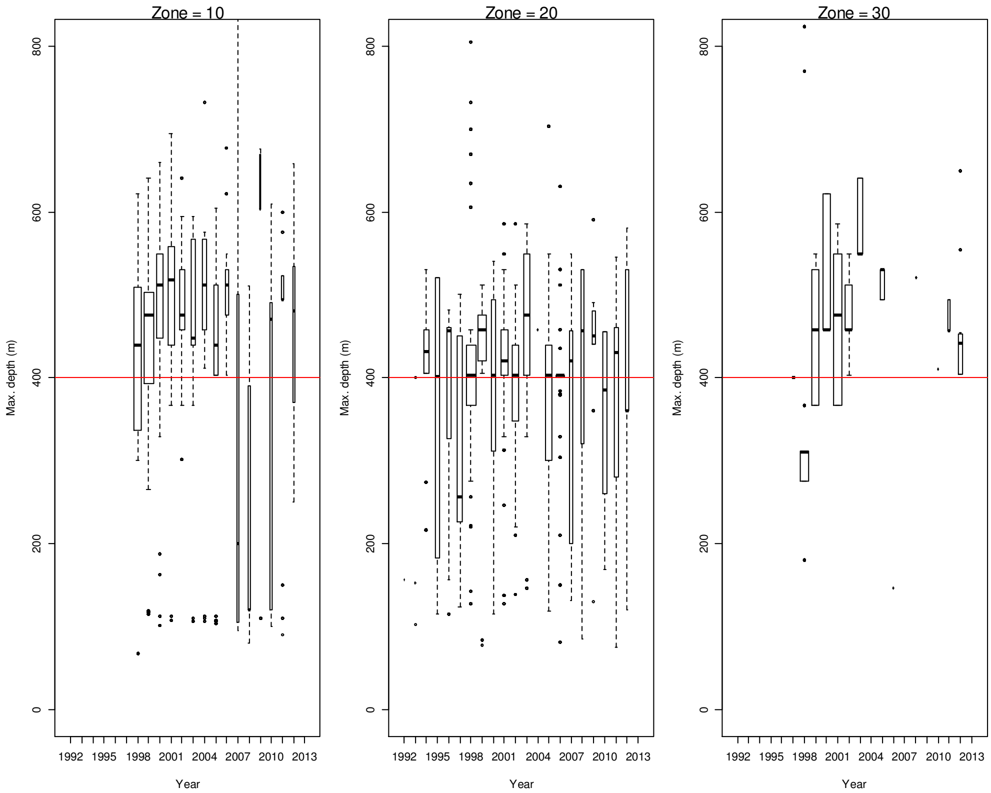

Figure 5: Boxplots of max. depth by eastern zone and year for the onboard sampling of ling (OT only).

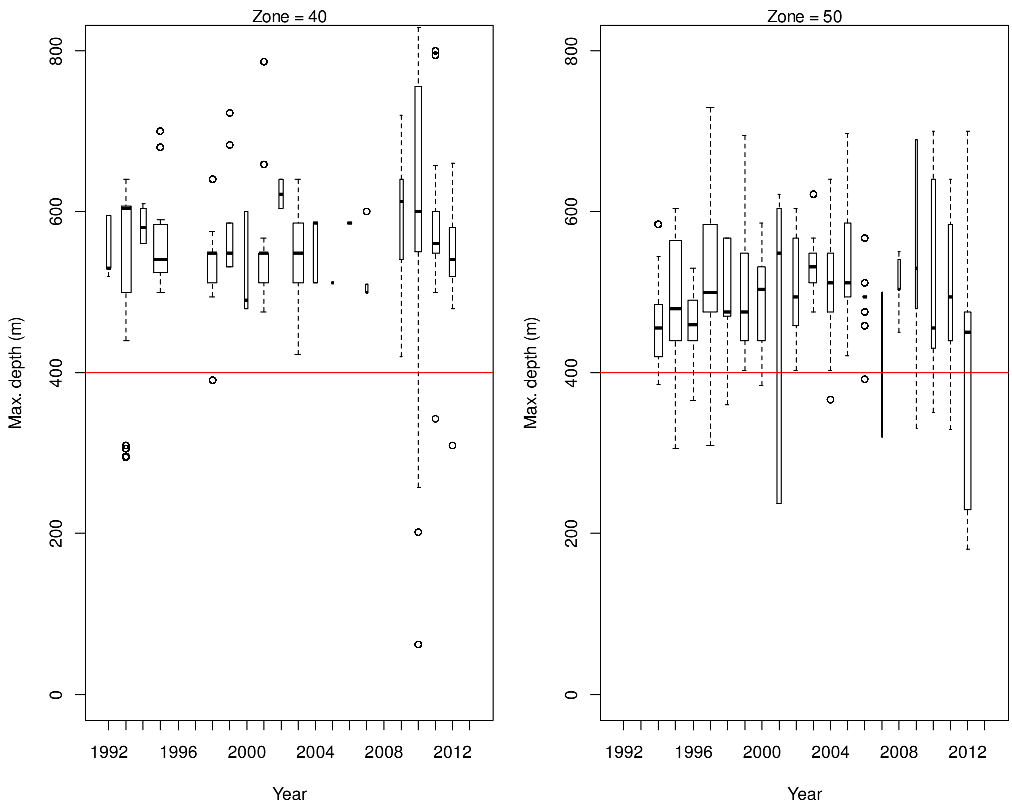

Figure 6: Boxplots of max. depth by western zone and year for the onboard sampling of ling (OT only).

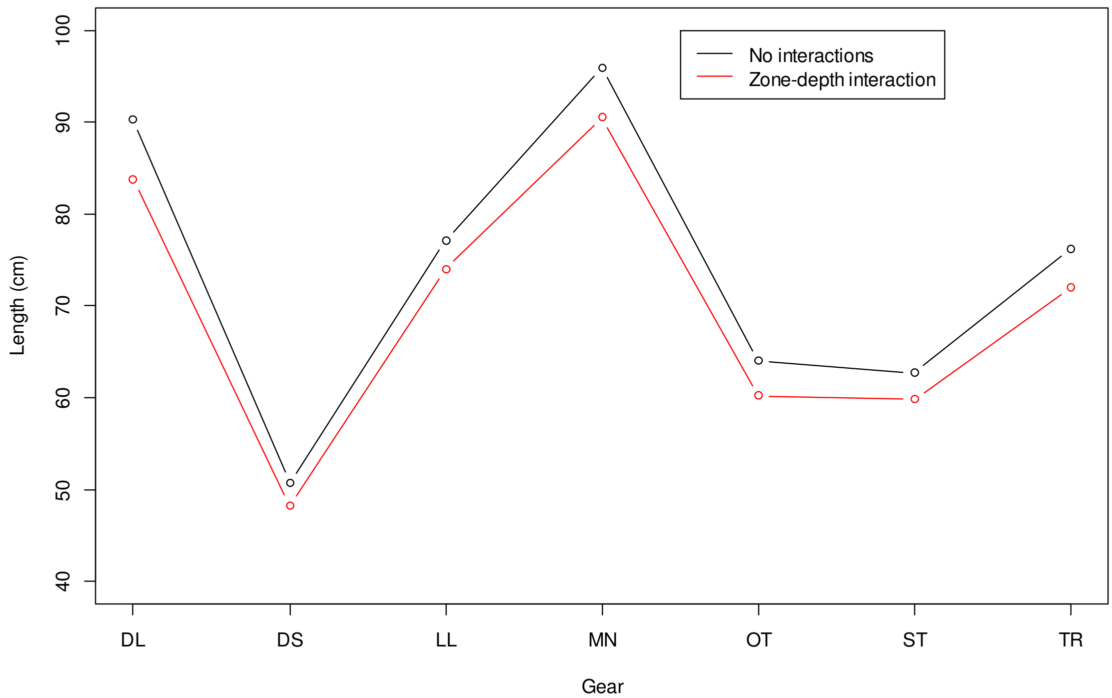

Figure 7: Expected length of ling by gear according to the onboard linear models (standardized to June 2000, zone 10, max. depth 400 m, total length).

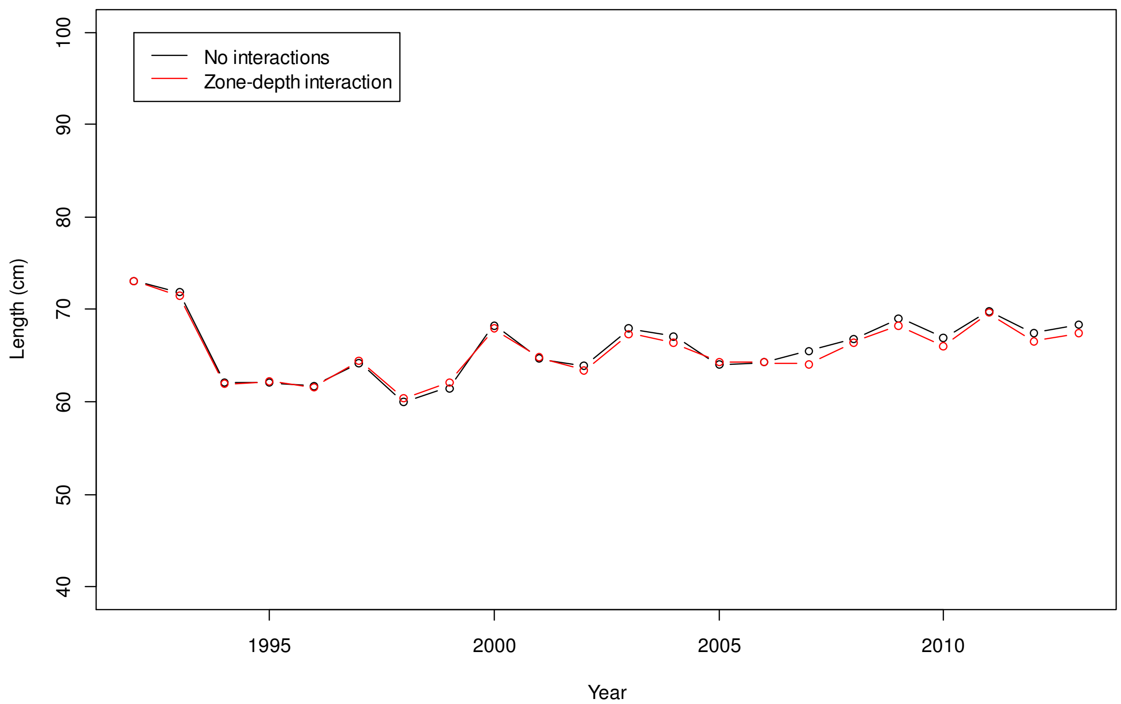

Figure 8: Expected length of ling by year according to the onboard linear models (standardized to June, zone 20, max. depth 400 m, gear OT, total length).

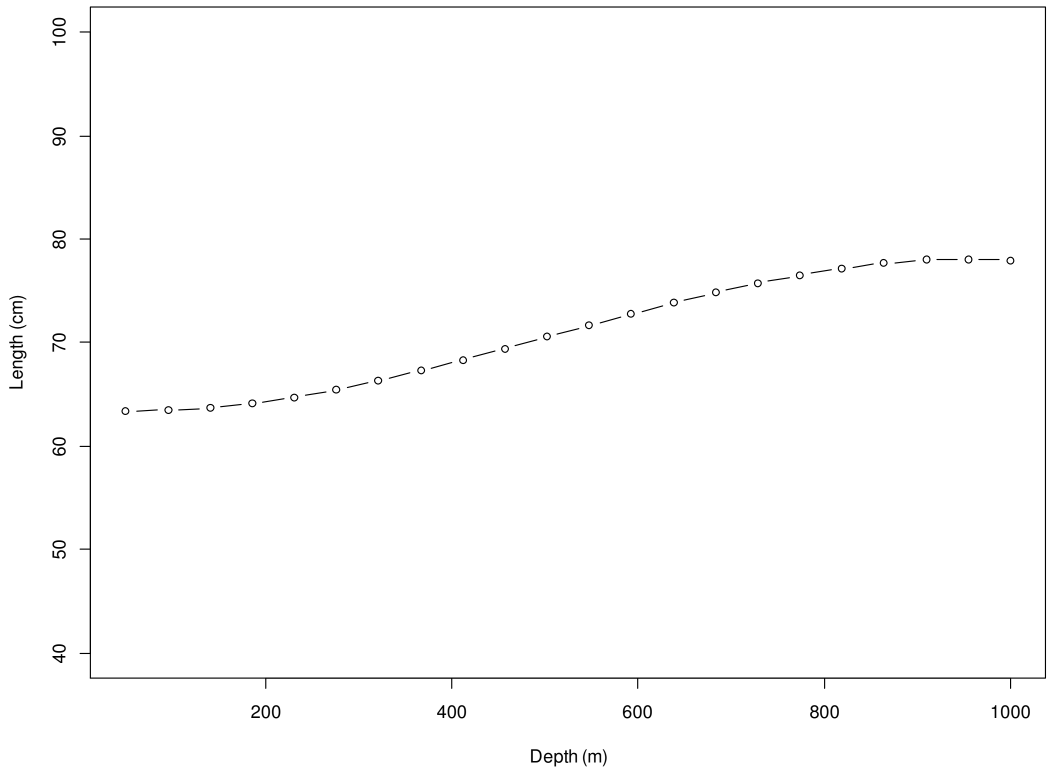

Figure 9: Expected length of ling by maximum depth according to the onboard non-interaction model (standardized to June 2000, zone 20, gear OT, total length).

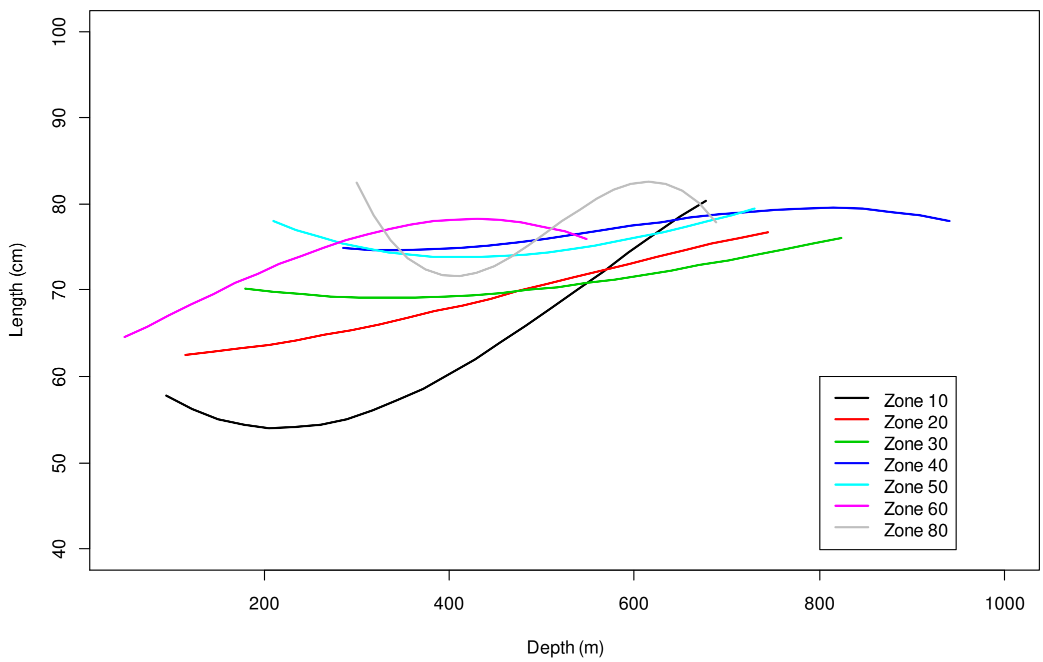

Figure 10: Expected length of ling by maximum depth within zone according to the onboard interaction model (standardized to June 2000, gear OT, total length). Effects plotted over 99% of the depth range.

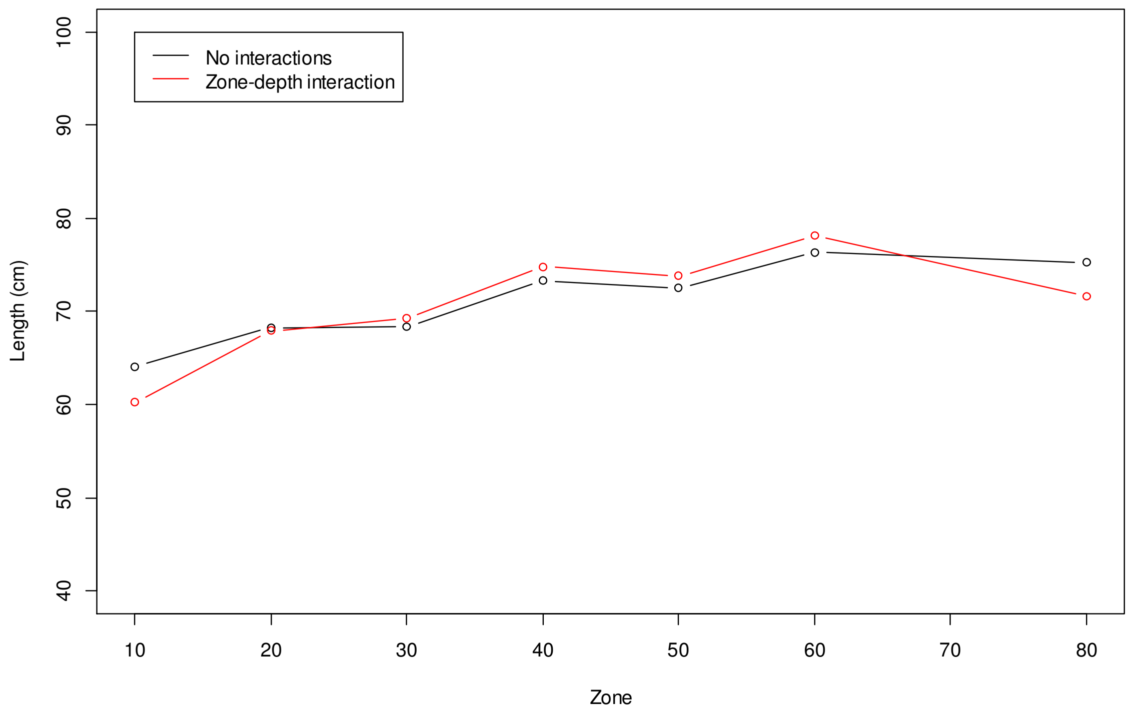

Figure 11: Expected length of ling by zone according to the onboard linear models (standardized to June 2000, max. depth 400 m, gear OT, total length).

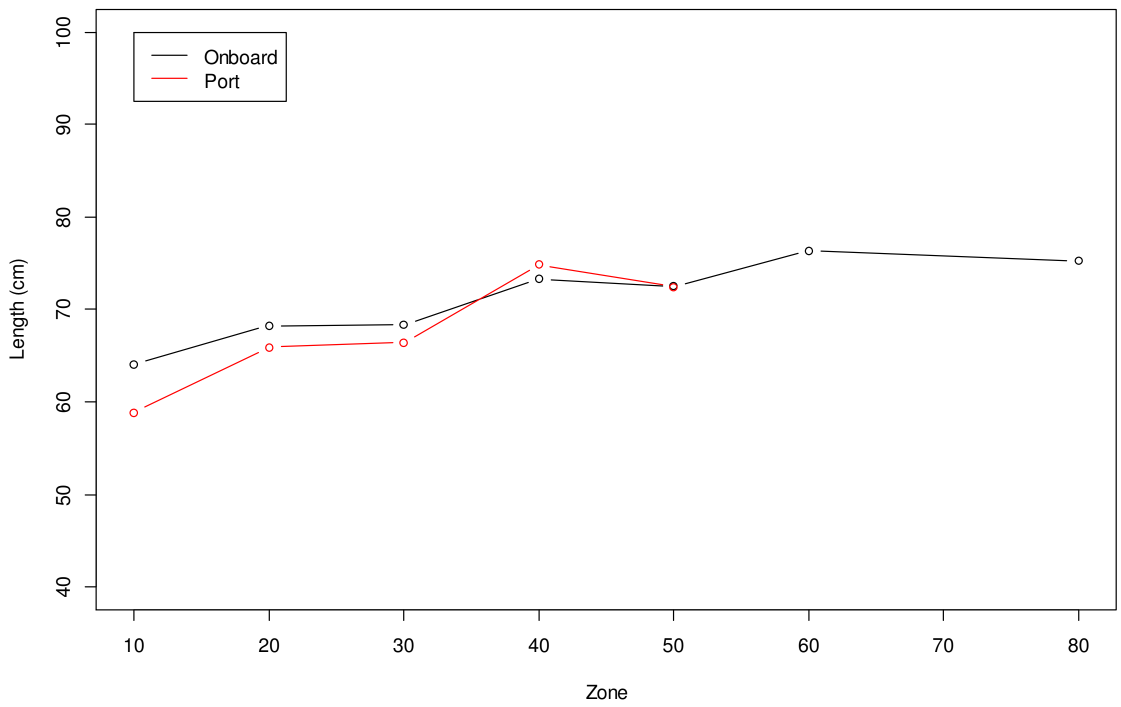

Figure 12: Expected length of ling by zone according to the onboard non-interaction model and the port model (standardized to June 2000, max. depth 400 m, gear OT, grade ALL, total length).

Appendix 2: Stratification of trawl length data in the eastern zones

P.L. Cordue
20 August 2013

Methods

For the eastern zones I looked at how much trawl length data would be available each year under three different stratifications: none, zone only, and depth and zone (by depth within Zones 10 and 20, no depth strata in Zone 30). The depth strata were 0-300 m, 300-500 m, and 500^+ m.

It was required that at least 30 fish were within each cell for scaling purposes and that a year would be excluded from the stock assessment if more than 10% of the annual catch could not be adequately scaled (i.e., if cells with less than 30 fish corresponded to more than 10% of the catch).

Results

No stratification allows all of the data to be used from on-board and port sampling, but it is not a viable stock assessment option as there are zone and depth effects and the sampling is very unbalanced. However, it serves as a baseline from which to measure how many years of data are excluded if some form of stratification is used. With no-stratification, the years 1993-2012 are covered by on-board sampling (Table 1) and the years 1998-2012 are covered by port sampling (assuming that at least 4 sampled landings are required in each year)(Table 2). That is, on-board 20 years, port 15 years.

For the on-board sampling, stratification by zone covers 13 out of the 20 possible years (Table 1). Adding in the depth stratification within Zones 10 and 20 eliminates another 5 years leaving 8 of the years from 1998 to 2012 covered (Table 1).

The port sampling did not adequately cover Zone 10 in recent years and stratification by zone reduces the number of years covered from 15 down to 8 (spanning 1998 to 2008)(Table 2). As no depth information is (directly) recorded for the port sampling it would not be easy to stratify by depth and zone and it is assumed that no years could be used in the assessment under that stratification.

Table 1: Total number of fish measurements available each year from on-board sampling of trawl to use in the eastern stock assessment under different levels of stratification. In the depth and zone stratification Zone 30 is not stratified by depth. In the stratifications a year is excluded from use if more than 10% of the annual catch cannot be scaled with at least 30 fish in each cell.

Year	Number of tows sampled	No stratification	Stratification by zone	Stratification by depth and zone
1992	1	1	–	–
1993	20	497	–	–
1994	30	1103	–	–
1995	18	1013	–	–
1996	68	2438	–	–
1997	70	2180	–	–
1998	79	7097	7097	7097
1999	82	7562	7562	–
2000	48	3179	3179	3179
2001	76	5546	5546	5546
2002	41	2982	2982	2982
2003	41	2884	2884	2884
2004	22	812	812	–
2005	53	2765	2765	2765
2006	38	3133	3133	3133
2007	35	531	–	–
2008	23	829	–	–
2009	16	507	507	–
2010	38	750	750	–
2011	46	846	846	–
2012	34	660	660	660

Table 2: Total number of fish measurements available each year from port sampling of trawl to use in the eastern stock assessment under different levels of stratification. In the depth and zone stratification Zone 30 is not stratified by depth. In the stratifications a year is excluded from use if more than 10% of the annual catch cannot be scaled with at least 30 fish in each cell.

Year	Number of landings sampled	No stratification	Stratification by zone	Stratification by depth and zone
1991	2	100	–	–
1992	1	54	–	–
1993	–	–	–	–
1994	–	–	–	–
1995	3	248	–	–
1996	–	–	–	–
1997	1	102	–	–
1998	17	1417	1417	–
1999	25	1482	1482	–
2000	9	489	–	–
2001	14	345	–	–
2002	30	2813	2813	–
2003	6	214	–	–
2004	7	201	201	–
2005	26	1447	1447	–
2006	20	1123	1123	–
2007	12	1364	1364	–
2008	8	1771	1771	–
2009	48	2507	–	–
2010	62	2510	–	–
2011	59	2448	–	–
2012	41	1915	–	–

Appendix 3: A look at the pink ling age-length data

P.L. Cordue
26 August 2013

Introduction

The age-length data were explored with regard to sample sizes and differences in proportion-at-age for given length across zones and gear type. Descriptive plots and categorical linear models were used. Also, the question of whether there are important cohort effects with regard to growth was explored with categorical linear models.

Methods

Data with missing lengths or ages were excluded from the analysis. The number of tows/sets/landings that were sampled for age-length data was determined by distinguishing the records according to: year, month, batch, zone, gear, area, and vessel. Cohort was defined as year – age.

Six broad length classes were defined with breaks at: 0, 50, 70, 80, 90, 100, 150 cm. The proportion-at-age was calculated for each zone (10-50) within each length class, for the trawl and non-trawl data separately. Lowess lines were fitted to the length-at-age data within zone for the trawl and non-trawl data separately.

A linear model to explain age was fitted to check if the zone effects were significant:

age ~ year + month + zone + gear + sex + length-class

where all explanatory variables were categorical.

Various linear models to explain length were fitted to check for the importance of year and cohort effects with regard to growth:

length ~ month + zone + gear + sex + age
length ~ month + zone + gear + sex + age + year
length ~ month + zone + gear + sex + age + cohort
length ~ month + zone + gear + sex + age + year + cohort

where all explanatory variables were categorical.

Results

Sample sizes
The sampling effort across zones is very patchy for trawl (Table 1) and non-trawl (Table 2). Within the non-trawl data, the sampling is also very patchy across the different gear types (Table 3). The sampling is so sparse, in terms of trawls/landings sampled, that there are no years for the east or west when at least 5 age-length trawl samples were obtained from every zone (Table 1). The same statement is almost true for the non-trawl sampling, except that in 2011 there were at least 5 samples in every eastern zone (ignoring Zone 10 where there is almost no non-trawl catch)(Table 2). The only reasonable level of sampling occurs for trawl: zone 10 (1996-1999), zone 20 (2007-2012), zone 50 (2004-2006); and non-trawl: zone 20 (2008-2012). Of course, the lack of over-lapping years means that the sampling is very unbalanced by zone.

In terms of the number of fish aged, the unbalanced nature of the sampling is the same but there are reasonable numbers of fish in a number of zones in a number of years (Tables 4 and 5). In the eastern trawl data, the number of fish ages is very unbalanced by zone with an early emphasis on Zone 30 (1983-1985), a shift to Zone 10 (1996-2002), and a final shift to Zone 20 in the later years (2007-2011). Relatively speaking the western trawl data is quite balanced (Table 4).

The non-trawl data in the east is almost all from Zone 20, except in 2000 when there are good numbers of fish from Zones 10 and 30 as well (Table 5) – a very unusual year as there is almost no non-trawl catch from Zone 10. For the non-trawl in the west, there is only one year (2006) with reasonable numbers of fish from both zones (Table 5).

Length-at-age
The lowess fits to the trawl data by zone show similar fits for zones 30, 40, and 50, with quite different fits in Zones 10 and 20 (Figure 1). The fits are a product of the trawl selectivities in each zone, the type of sampling done in each zone, and possibly even relative exploitation rates (if selectivities are by length). While suggestive of growth patterns, there are possible confounding effects. The non-trawl data had much more variable fits but were again suggestive of some possible differences across zones (Figure 2).

Conditional proportion-at-age
When the data were split into the broad length classes for analysis pooled over years and sex, there were adequate numbers of aged fish in each length class and zone for the trawl data (Table 6). However, for the non-trawl there were only adequate numbers for the middle four length classes and zones 20-50 (Table 7).

The proportions-at-age within length class for the trawl data show marked differences between zones (Figure 3). Zones 10 and 20 stand out as having younger fish than the other zones (for the four middle length classes), with Zone 10 in particular having the youngest fish. For the non-trawl data Zones 20 and 30 show marked differences from each other while Zones 40 and 50 appear fairly similar to each other (Figure 4).

As a check to see if the zone differences, in the pooled analysis, were not just driven by year and sex differences, a linear model was used to explain age in terms of the full set of explanatory variables. Everything was highly significant, as expected, including the zone effects (and gear effects). As with the descriptive plots, Zone 10 had the youngest mean-age at length, Zone 20 the next youngest, and then Zones 30-50 had almost identical mean-age at length (Figure 5). The difference in mean age between Zone 10 and Zone 30 was 0.75 years.

Looking for important cohort effects

Stepwise forward linear regression was used to see if there were any important cohort effects for length-at-age. The model results showed that year effects were more important than cohort effects (Tables 8 and 9). This was true for models fitted to all zones and when separate models were fitted to only the eastern or the western zones. In all but one of the models, all of the individual cohort effects failed to achieve a high level of significance, whereas year effects often did (Table 9).

Conclusions and recommendations

The analysis is strongly suggestive of important differences between zones and between fishing methods in proportion-at-age for given length in the catch. The western zones (40 and 50) appear to have very similar mean-age at length, but the eastern zones show increasing mean-age at length for Zones 10, 20, and 30.

The sampling is very unbalanced especially for the eastern trawl data. Therefore, it is probably important for stock assessment to stratify the age-length data to some extent.

I suggest the following approach:

- eastern stock:
    - trawl: stratify and scale by zone but ignore Zone 30 (little catch)
    - non-trawl: stratify and scale by zone but ignore Zone 10 (almost no catch)
- western stock:
    - trawl: no stratification
    - non-trawl: no stratification

In terms of estimating growth, the data are too unbalanced to estimate cohort effects as these are confounded with other effects that are difficult to eliminate (e.g., month, non-trawl gear types, depth, and year).

Table 1: Number of tows/landings sampled for age-length data in the trawl fishery by zone and year.

	SF10	SF20	SF30	SF40	SF50
1979	4	2	0	0	0
1982	0	0	1	0	0
1983	0	0	5	0	0
1984	0	0	2	0	0
1985	0	0	5	0	0
1986	0	0	1	0	0
1987	0	0	0	0	5
1988	0	0	0	0	3
1989	0	0	0	0	2
1993	0	0	0	5	0
1994	2	2	0	2	1
1995	3	2	0	1	3
1996	29	2	1	2	2
1997	19	0	0	0	6
1998	16	3	0	5	4
1999	14	4	0	15	4
2000	4	1	0	3	1
2001	7	2	1	1	0
2002	6	0	2	2	2
2003	2	0	0	3	2
2004	3	0	1	3	13
2005	3	3	1	1	6
2006	0	0	3	1	12
2007	0	14	1	2	0
2008	0	6	0	2	0
2009	0	30	1	3	1
2010	11	36	0	6	2
2011	4	31	4	3	3
2012	2	18	2	2	4

Table 2: Number of sets/landings sampled for age-length data in the non-trawl fishery by zone and year.

	SF10	SF20	SF30	SF40	SF50
1994	0	1	0	0	0
1995	1	3	0	0	1
1996	0	0	0	0	1
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	3	0	1	1
2000	1	2	1	1	0
2001	0	1	0	4	0
2002	0	4	0	2	0
2003	0	8	4	12	0
2004	0	6	1	2	0
2005	0	1	0	0	3
2006	0	0	0	1	3
2007	1	5	0	4	0
2008	0	13	0	0	0
2009	0	24	4	1	1
2010	0	24	0	5	0
2011	0	29	9	0	0
2012	0	13	0	2	1

Table 3: Number of sets/landings sampled for age-length data in the non-trawl fishery by gear and year (for all zones including GAB).

	ALL	DL	DS	Hook	MN	MWT	Tr	UNKNO
1994	0	0	0	0	0	0	0	1
1995	0	0	2	2	0	0	0	1
1996	0	0	0	0	0	0	0	1
1999	0	0	0	2	0	0	3	0
2000	0	0	1	3	1	0	0	0
2001	0	0	0	3	1	0	1	0
2002	0	0	4	1	0	0	1	0
2003	0	0	0	24	0	0	0	0
2004	0	0	1	8	0	0	0	0
2005	0	0	0	5	0	0	0	0
2006	0	0	0	3	0	1	0	0
2007	0	0	2	8	0	0	0	0
2008	0	0	0	15	0	0	0	0
2009	27	3	4	4	0	0	0	0

2010	0	0	0	36	0	0	0	0
2011	0	0	5	46	0	0	0	0
2012	17	0	1	0	0	0	0	0

Table 4: Number of fish ages by zone and year for the trawl data

	SF10	SF20	SF30	SF40	SF50
1979	153	247	0	0	0
1982	0	0	23	0	0
1983	0	0	148	0	0
1984	0	0	143	0	0
1985	0	0	143	0	0
1986	0	0	34	0	0
1987	0	0	0	0	564
1988	0	0	0	0	326
1989	0	0	0	0	190
1993	0	0	0	50	0
1994	129	89	0	14	247
1995	138	203	0	1	322
1996	792	34	31	11	68
1997	589	0	0	0	553
1998	542	127	0	109	100
1999	406	134	0	331	165
2000	110	21	0	44	27
2001	295	112	48	93	0
2002	244	0	100	99	99
2003	78	0	0	95	81
2004	61	0	6	144	334
2005	102	65	59	78	202
2006	0	0	27	50	424
2007	0	262	198	130	0
2008	0	325	0	45	0
2009	0	599	17	40	25
2010	158	545	0	95	34
2011	47	532	71	48	47
2012	21	25	62	0	0

Table 5: Number of fish ages by zone and year for the non-trawl data.

	SF10	SF20	SF30	SF40	SF50
1994	0	17	0	0	0
1995	12	31	0	0	155
1996	0	0	0	0	70
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	134	0	0	155
2000	94	124	248	3	0
2001	0	2	0	323	0
2002	0	90	0	99	0
2003	0	279	31	322	0
2004	0	95	0	48	0
2005	0	51	0	0	137
2006	0	0	0	125	276
2007	0	98	0	95	0
2008	0	585	0	0	0
2009	0	486	20	8	15
2010	0	333	0	48	0
2011	0	537	109	0	0
2012	0	0	0	0	0

Table 6: Number of fish ages per length class and zone for trawl gear (OT).

	(0,50]	(50,70]	(70,80]	(80,90]	(90,100]	(100,150]
SF10	1003	2322	312	129	59	40
SF20	225	2179	690	160	44	22
SF30	27	349	316	271	108	39
SF40	43	440	493	312	142	47
SF50	161	1992	743	528	264	120

Table 7: Number of fish ages per length class and zone for non-trawl gear.

	(0,50]	(50,70]	(70,80]	(80,90]	(90,100]	(100,150]
SF10	0	3	19	58	25	1
SF20	63	967	772	515	307	238
SF30	1	57	151	116	49	34
SF40	0	86	316	292	218	159
SF50	114	199	182	195	100	18

Table 8: Adjusted R^2 for linear models explaining length in terms of month, zone, gear, sex, and age (Reference model) with the addition of year or cohort or both. Results are shown for all zones and just eastern zones or just western zones.

Model	**All zones**	**East only**	**West only**
Reference	0.781	0.778	0.771
+ year	0.803	0.813	0.783
+cohort	0.785	0.788	0.776
+ year + cohort	0.807	0.819	0.787

Table 9: Number of individual year or cohort effects significant at the 0.001 level for linear models explaining length in terms of month, zone, gear, sex, and age (Reference model) with the addition of year or cohort or both. Results are shown for all zones and just eastern zones or just western zones.

(Model) effect	**All zones**	**East only**	**West only**
(Reference)	–	–	–
(+ year) year	19	14	11
(+cohort) cohort	0	0	0
(+ year + cohort) year	14	10	3
(+ year + cohort) cohort	2	0	0

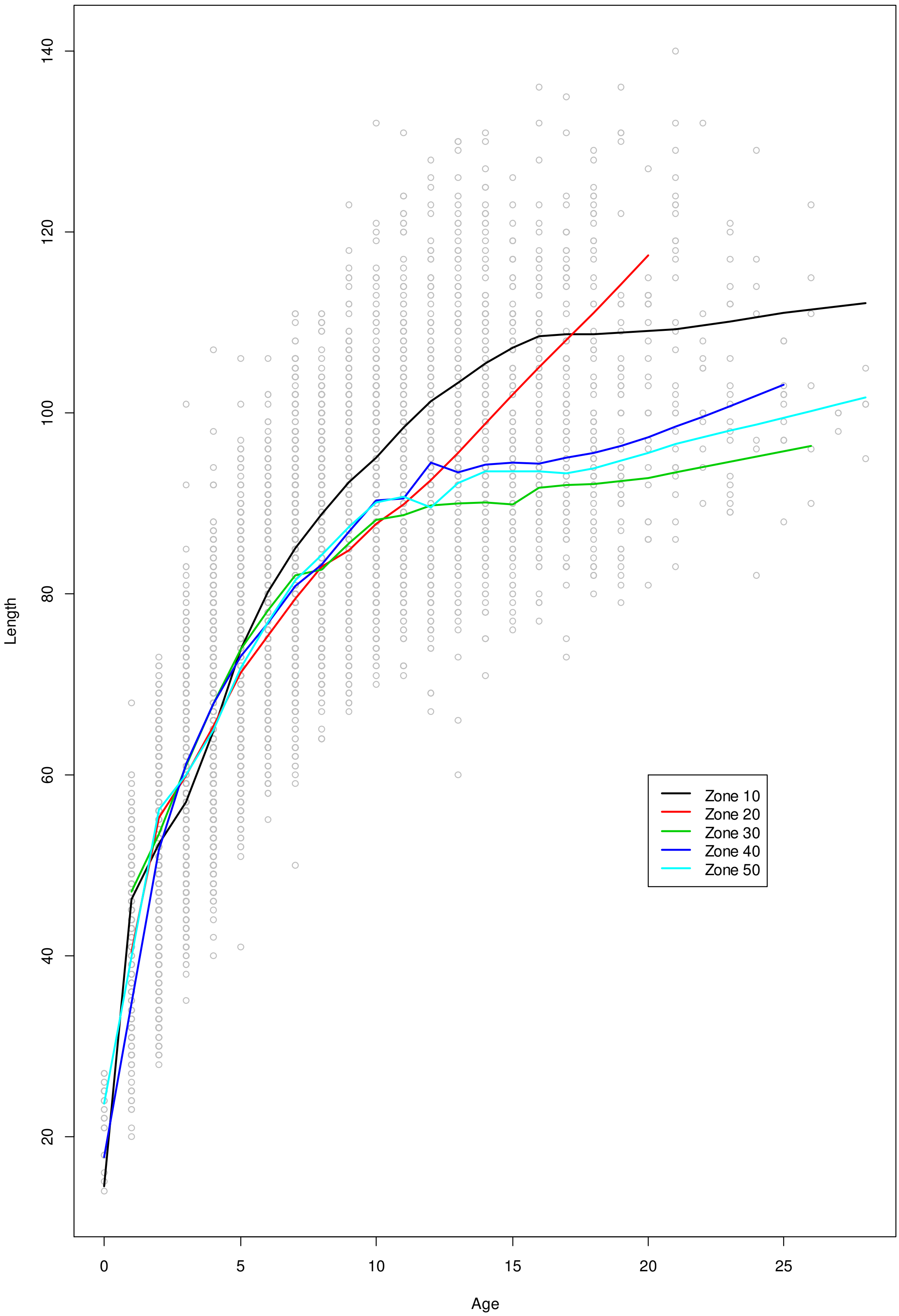

Figure 1: Lowess fits to length at age by zone for trawl data pooled across sex and year.

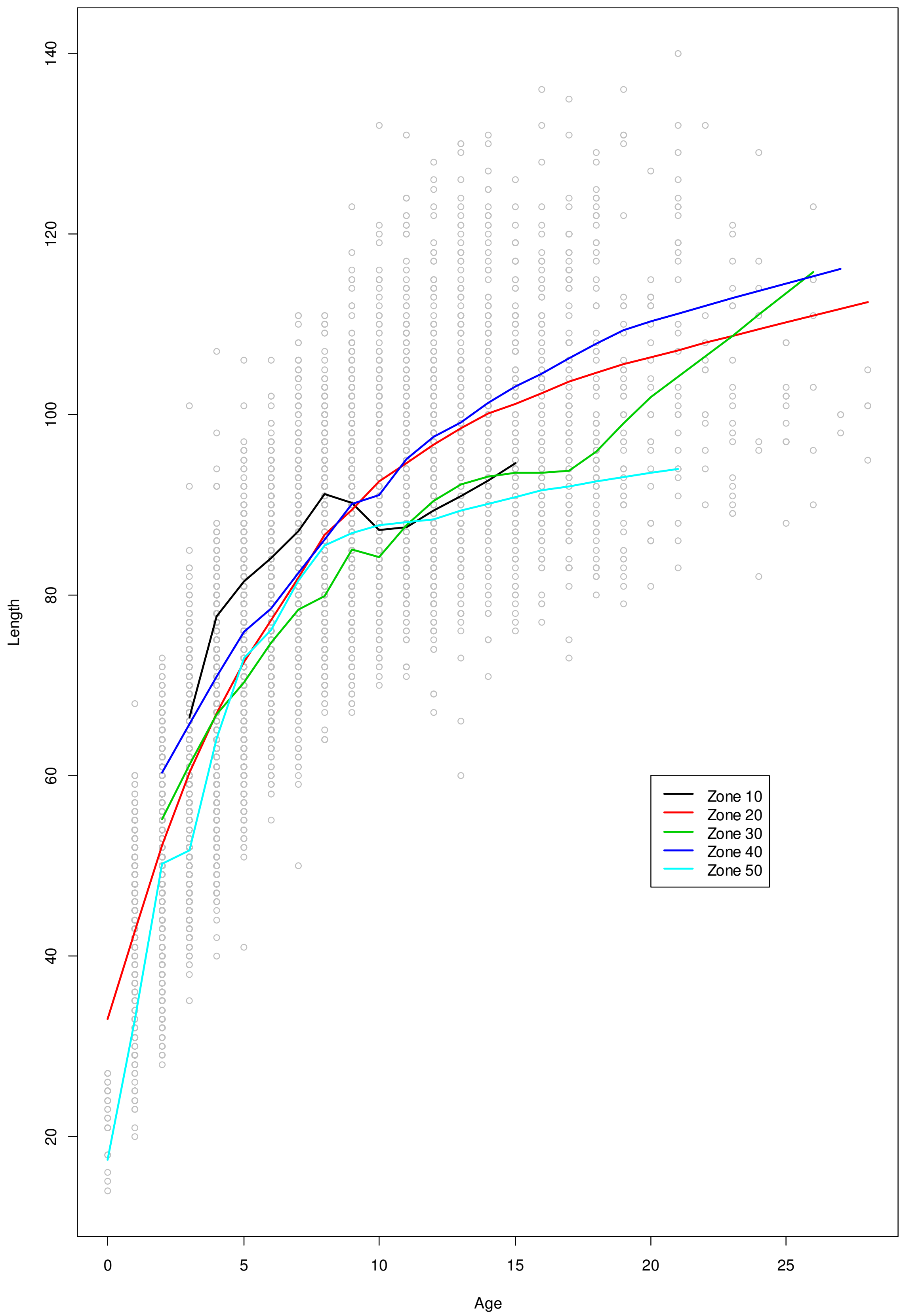

Figure 2: Lowess fits to length at age by zone for non-trawl data pooled across sex and year.

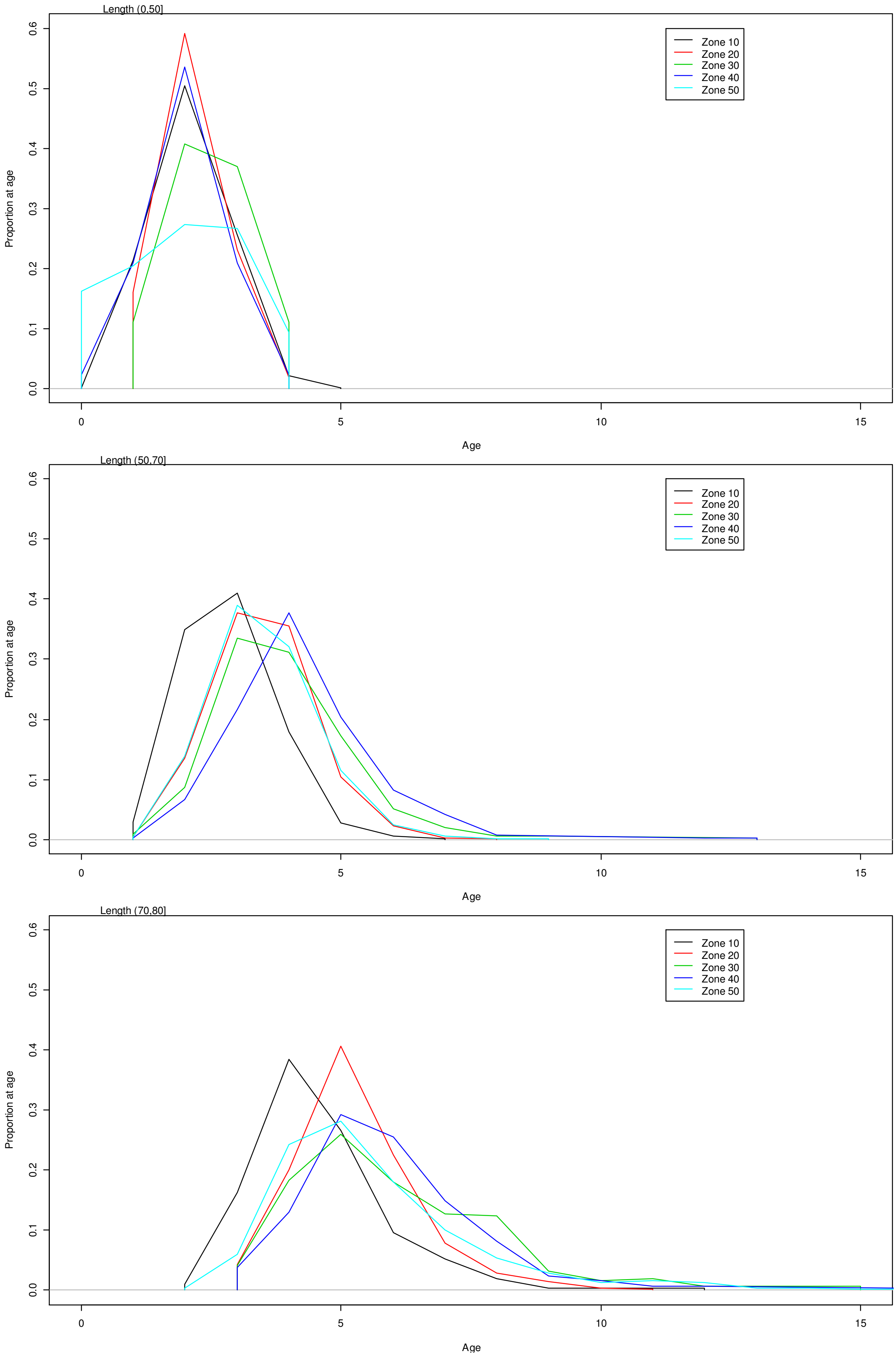

Figure 3: Proportion-at-age by zone and length class (first 3 classes) for the trawl data.

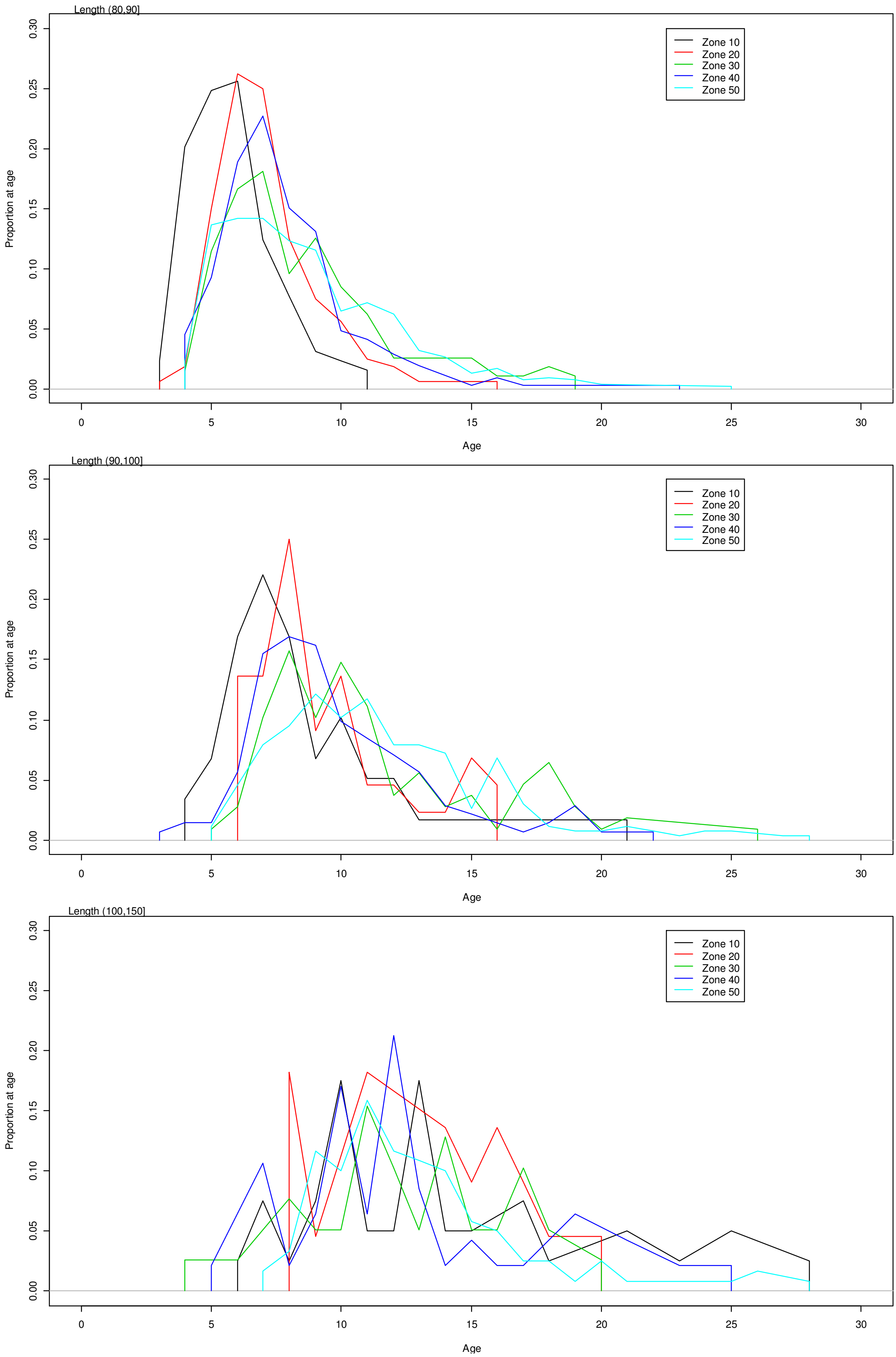

Figure 3 (ctd): Proportion-at-age by zone and length class (last 3 classes) for the trawl data.

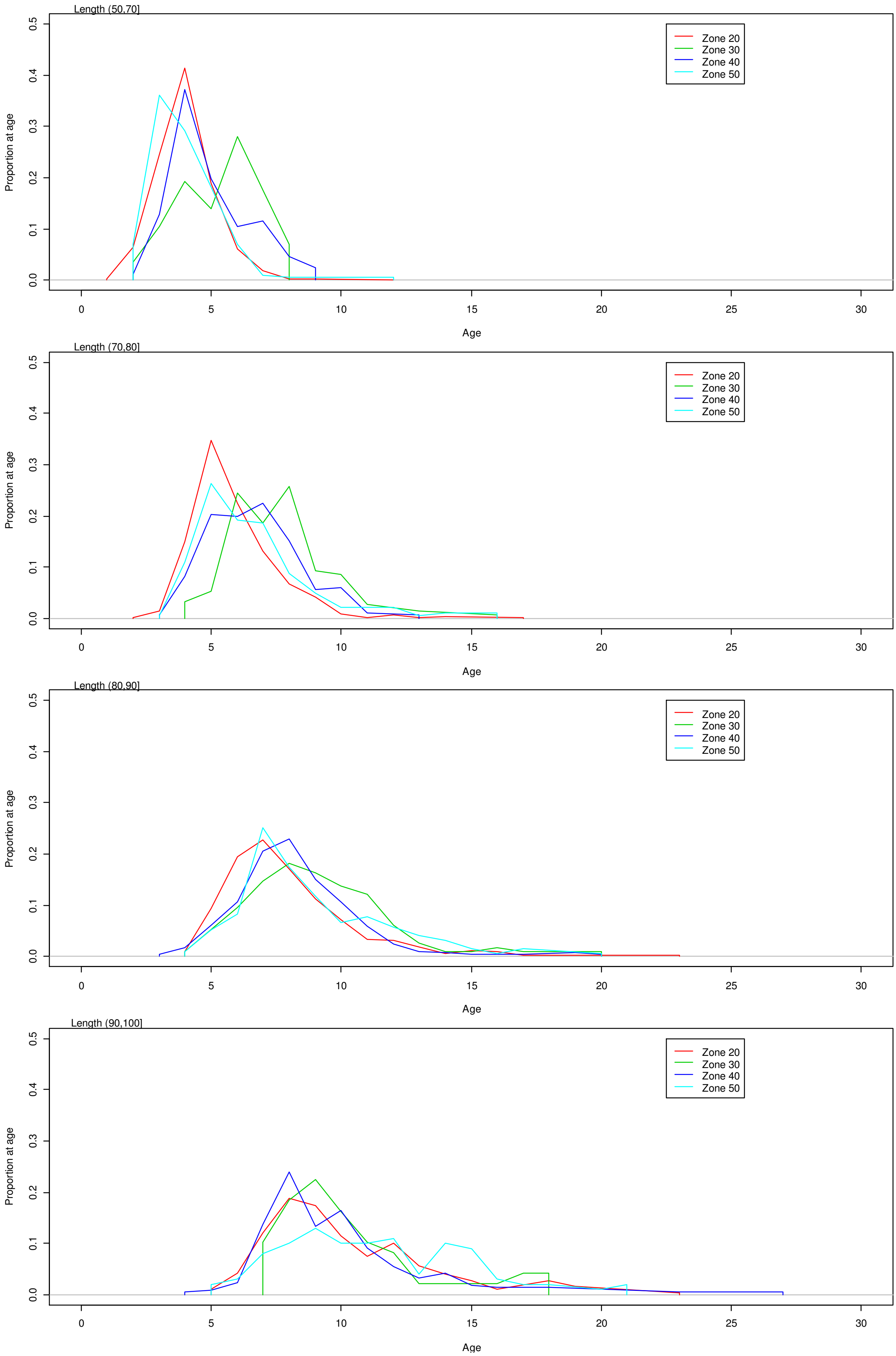

Figure 4: Proportion-at-age by zone and length class (middle 4 classes) for the non-trawl data.

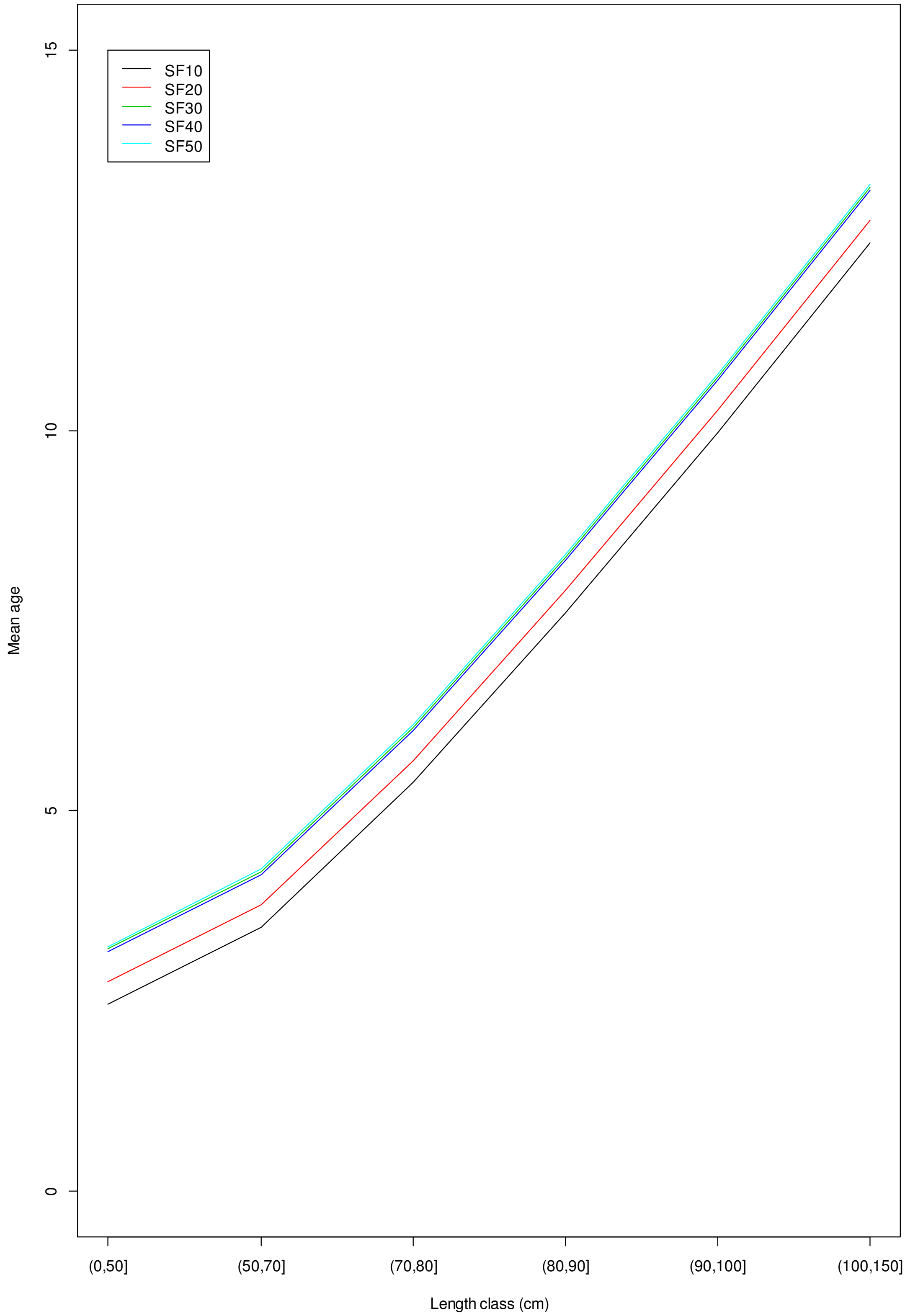

Figure 5: Predicted mean age by length class for a linear model explaining age by year, month, sex, gear, zone, length class. Standardized to July 2000, Zone 10, trawl, unknown sex.