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2014/0818 June 2016

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

PART
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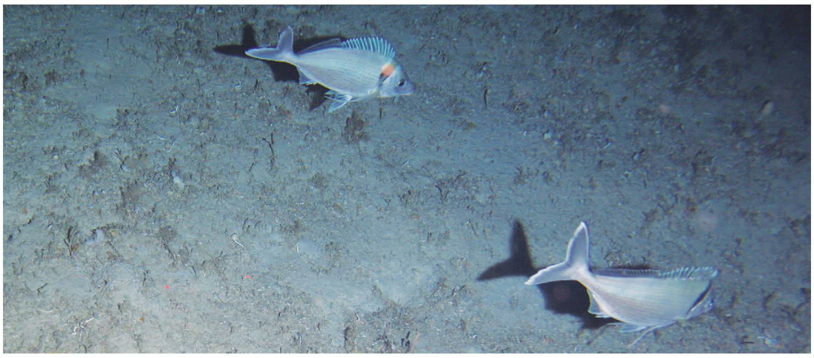

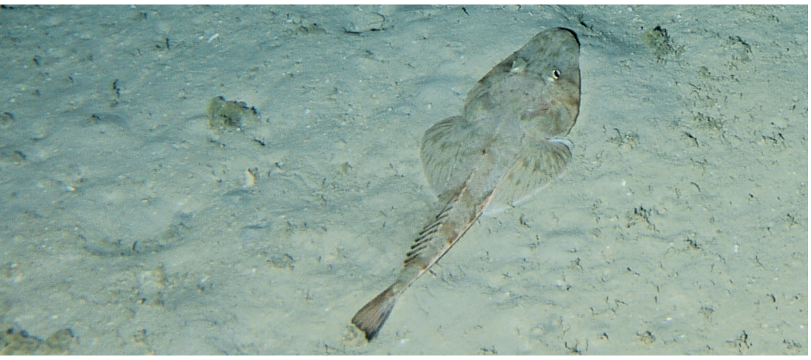

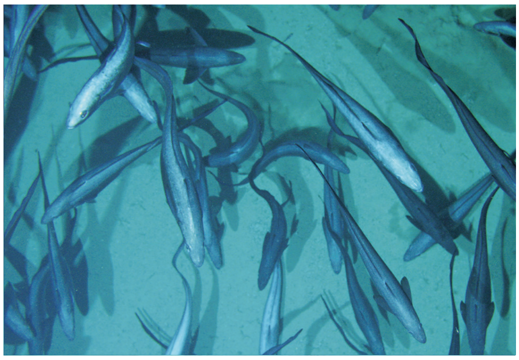

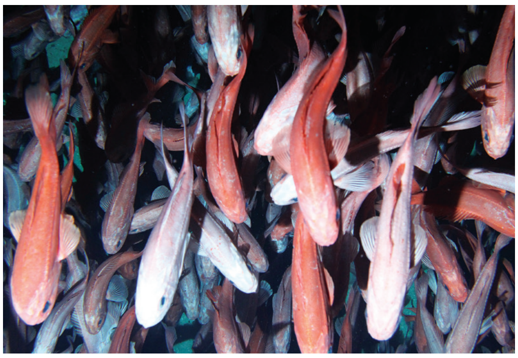

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Cover photographs

Front cover, jackass morwong, orange roughy, blue grenadier, and flathead.

Report structure

Part 1 of this report describes the Tier 1 assessments of 2015. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2015.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

Part 1: Tier 1 assessments

G.N. Tuck
June 2016
Report 2014/0818

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015 Part 1

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7. Silver Warehou (*Seriolella punctata)* stock assessment based on data up to 2014

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7.1 Summary

This chapter presents a quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the Southern and Eastern Scalefish and Shark Fishery (SESSF) using data up to 31 December 2014. The last full assessment was presented in Day *et al.* (2012). The 2015 assessment updates all data inputs (catch, discard, length, ageing error, age and catch rate data) and is performed using the stock assessment package Stock Synthesis (SS-V3.24U).

Changes to the last stock assessment include: using discards in the assessment; splitting the trawl fleet into eastern and western components; separating length frequencies into onboard and port collected components; time blocking retention to allow for changes in discarding practice since 2002; including FIS abundance indices; weighting length frequencies by shots and trips rather than fish measured; and using a new tuning method.

Results show reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again in a relatively short time period (potentially requiring a further Tier 1 update if it is placed on a multi-year TAC).

This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. In comparison, the last assessment estimated the 2013 depletion to be 47%, with corresponding RBCs of 2,544t, with a long-term yield of 2,618t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020. However, if landed catches continue at levels well below the TAC, then the depletion is likely to remain between 35% and 45% for the next 5 years.

7.2 Introduction

7.2.1 *The Fishery*

Silver warehou occur throughout the SESSF in depths to 500m. They are predominantly caught by trawl, although some non-trawl (gillnet) catches occur (Morison *et al.*, 2007). Annual catches (landings by fleet) and discard rates of silver warehou by calendar year are shown in Table 7.1. Large catches of silver warehou were first taken in the 1970's (Smith, 1994) and landed catches increased to 3,800t in 2002. Landed catches declined to less than 2,000t from 2007 onwards, with further declines to less than 1,000t since 2012. Discard tonnage and length frequency are very variable and appear market driven. Silver warehou have also been captured off western Tasmania as bycatch of the winter spawning blue grenadier fishery.

For 2013 and 2014, the agreed TAC has been 2,329t. This agreed TAC was set following the last assessment in 2012 (Day *et al.*, 2012), with the agreed TAC for 2015 set at 2,417t.

7.2.2 *Stock Structure*

A recent stock-structure study indicated that a single stock exists east and west of Bass Strait (Morison *et al*. 2007). A common stock had previously been assumed for management purposes and is assumed for the assessment presented here. However, differences were suspected in standardised catch rates, length and age distribution east and west of longitude 147^{o} E, so in this assessment the data was split into two fleets, an eastern fleet (SESSF zones 10, 20 and 30) and a western fleet (SESSF zones 40 and 50) (Thomson *et al.* 2015).

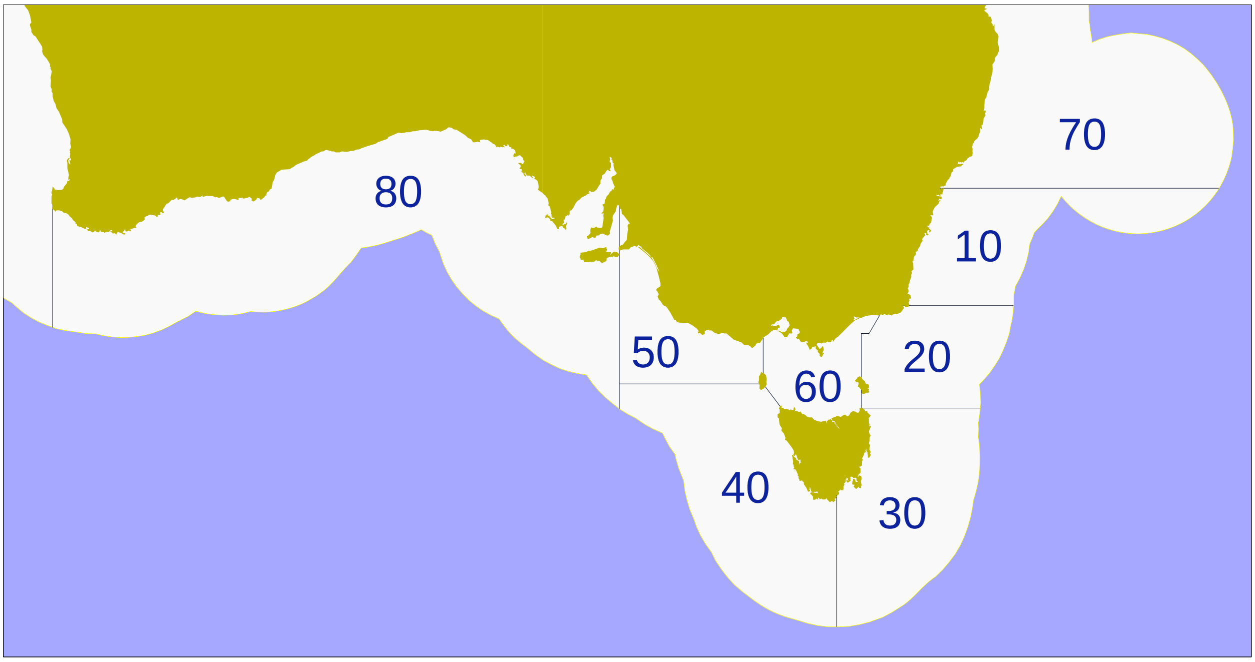


Figure 7.1. Map of the SESSF showing statistical zones.

7.2.3 *Previous Assessments*

The previous full quantitative assessment for silver warehou was performed in 2012 (Day *et al.*, 2012) using Stock Synthesis (SS-V3.24f, Methot, 2012). The 2012 assessment indicated that the spawning stock biomass levels in 2013 were around 47% of virgin biomass.

This assessment produced reasonably good fits to the catch rate data. However, Day *et al.* (2012) noted that "*when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again (requiring a further Tier 1 update if it is placed on a multi-year TAC) in a relatively short time period*". This prediction turned out to be true as the stock did indeed breakout (Figure 7.2).

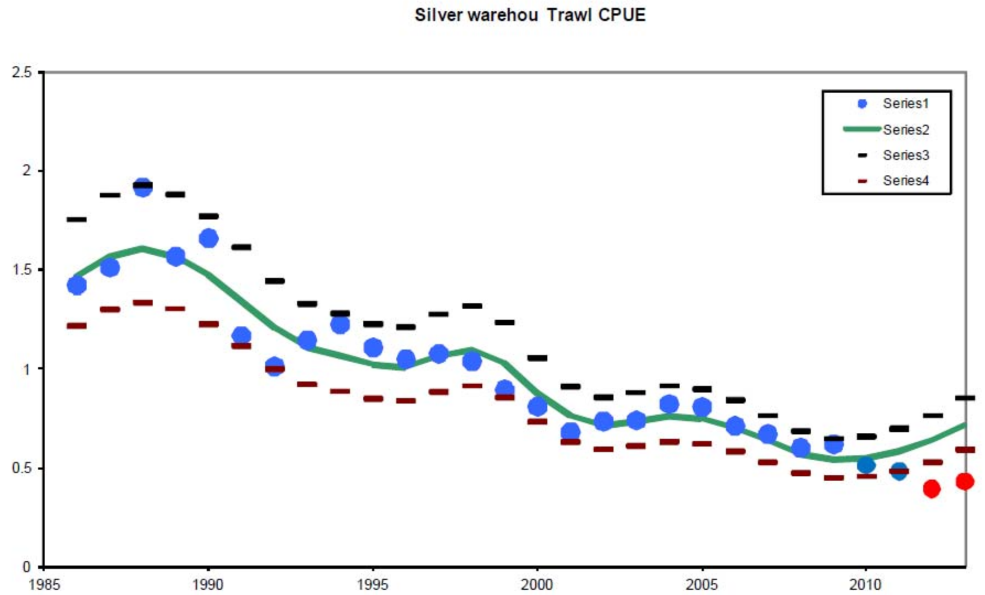


Figure 7.2. “Breakout” for spotted warehou (taken from Klaer *et al.* 2014) showing estimated stock abundance (green line with prediction interval) and observed standardised CPUE (blue and red spots).

Day *et al.* (2012) also warned that “*If recent recruitments (2008-2011), which are not currently estimated by the model, are assumed to be poor and at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40%. Under this scenario, setting a multi-year TAC could result in depletion levels falling below 30% by 2015.*” This comment is also still very relevant as the 2008-2011 recruitments have all now been estimated, with the recruitment estimates for 2008 and 2009 around the very low levels of recruitment in the period 2002-2005 and the recruitment estimates for 2010 and 2011 both below average. Furthermore, recruitment estimates for 2006 and 2007 which were estimated in the 2012 assessment, have been revised using additional data which is now available, and have changed from being around average recruitment levels in the 2012 assessment to well below average in the current assessment. The depletion is estimated in the current assessment to be 29% in 2013.

An earlier assessment for silver warehou was performed in 2009 (Tuck and Fay, 2009) using Stock Synthesis (version SS-V3.03a, Methot, May 2009) and this assessment indicated that the spawning stock biomass levels in 2010 were around 48% of virgin biomass. Fits to the length, age, and catch-rate data were reasonable. The fit to the catch rate index was a substantial improvement compared to Tuck and Punt, (2007), with changes to the estimates of mortality and growth. Exploration of model sensitivity showed that the model outputs are sensitive to the value assumed for natural mortality, *M*.

Before the 2009 assessment, other Stock Synthesis based assessments for silver warehou were performed in: 2008 (Tuck, 2008) with a depletion estimate for 2007/8 of 53%; 2007 (Tuck and Punt, 2007) with a depletion estimate for 2007/8 of 49%. Even earlier assessments include Taylor and Smith, (2004) and Thomson, (2002).

7.2.4 *Modifications to the previous assessments*

While the assessment model framework is largely unchanged from the previous assessment, conducted in 2012, with Stock Synthesis updated from version SS-V3.24f to version SS-V3.24U, there are a number of modifications to the data and structure used.

1. Catch, discard, length frequency, and age at length data for 2012, 2013 and 2014 have been added.
2. Discarding is being estimated and discard length frequency data have been included in the assessment.
3. Five more years of recruitment are being estimated (note that this is two more than the number of years of data that have been added). Recruitment is estimated to 2012, two years prior to the most recent data
4. Length frequency data have been split into onboard and port collected components (sharing a single selectivity pattern).
5. The single trawl fleet has been split into east and west (of 147^{o}) fleets, each with its own estimated selectivity pattern and discards (retention function).
6. Catch rate data has been split into eastern and western fleets with additional data added for 2012, 2013 and 2014 (Sporcic *et al.*, 2015).
7. The ageing error matrix has been updated.
8. Retention function has been time blocked, reflecting changes in the discarding practices in the periods 1980-2001 and 2002-2014.
9. Data collected from non-trawl vessels have been excluded from the dataset (this makes a negligible difference).
10. Inclusion of the FIS abundance indices for east and west fleets.
11. A new tuning procedure has been used to balance the weighting of each of the data sources that contribute to the overall likelihood function (this is a forerunner of an even newer tuning protocol for tuning expected to be agreed on during a workshop in the USA in October 2015).

These modifications are described in detail in Thomson *et al.* (2015), especially the more significant changes including the treatment of discards, the east and west fleets, the modified tuning procedure and a bridging analysis from the previous assessment.

Table 7.1. Landed catch by fleet, total landed catch, discard rate, standardised catch rate and the agreed TAC for silver warehou

Year	East trawl catch (t)	West trawl catch (t)	Total landed catch (t)	Discard rate	Catch rate east	Catch rate west	Agreed TAC (t)
1979							
1980	30	29	59				
1981	59	59	118				
1982	89	88	177				
1983	118	118	236				
1984	148	147	295				
1985	180	180	360				
1986	437	571	1008		1.7230	1.3771	
1987	263	485	749		1.6346	1.5718	
1988	788	578	1366		2.1414	1.8137	
1989	343	578	920		1.8205	1.5865	
1990	865	260	1126		2.2066	1.0381	
1991	652	711	1363		1.3229	1.1201	
1992	1307	558	1865		1.4036	0.8677	2000
1993	1008	772	1779	0.014	1.3843	1.1638	2000
1994	1387	682	2069	0.016	1.5213	1.0742	2500
1995	1725	1117	2842	0.092	1.3576	0.8413	2500
1996	1402	1282	2684	0.011	1.1338	0.9624	2500
1997	1100	1348	2448	0.084	1.1127	1.1480	2500
1998	942	1448	2389	0.191	0.9391	1.3627	3500
1999	1010	1985	2996	0.012	0.8109	1.1308	4000
2000	820	2954	3774	0.025	0.6641	1.1134	4000
2001	849	2901	3750	0.142	0.6209	0.8437	4400
2002	740	3075	3815	0.079	0.7208	0.8979	4400
2003	686	2667	3353	0.157	0.6770	0.9380	4488
2004	600	3131	3731	0.205	0.7761	1.0205	4039
2005	432	2070	2502	0.130	0.7222	1.1156	4400
2006	403	1744	2147	0.038	0.6092	0.9824	4400
2007	329	1661	1990	0.039	0.4841	1.0064	3088
2008	473	1035	1508	0.030	0.5602	0.7988	3227
2009	463	907	1370	0.023	0.6416	0.6928	3000
2010	341	948	1289	0.012	0.4674	0.6296	2566
2011	257	972	1229	0.246	0.4029	0.6085	2566
2012	215	634	849	0.140	0.3620	0.4537	2566
2013	204	442	646	0.043	0.4532	0.4311	2329
2014	103	278	381	0.044	0.3260	0.4091	2329

7.3 Methods

7.3.1 The Data and Model Input

7.3.1.1 Biological Parameters

A single sex model (i.e. both sexes combined) was used, as the length composition data for silver warehou are not available by sex.

The values of the von Bertalanffy growth parameters were estimated within the model-fitting procedure because Stock Synthesis accepts age-at-length data as an input. Estimating the parameters of the von Bertalanffy growth curve within the assessment is more appropriate because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

This assessment follows that of Day *et al*. (2012) and Tuck and Fay (2009) in using the base-case value of natural mortality of M=0.3yr^{-1}. The base case vale of the steepness of the stock-recruitment relationship, h, is 0.75 Sensitivities to this value for M and h are considered.

Silver warehou become sexually mature at a length of about 37 cm. Fecundity is assumed to be proportional to spawning biomass. The parameters of the length-weight relationship are the same as those used in previous assessments (a=6.5 x 10^{-6}, b=3.27). These values come from Taylor and Smith (2004) and were provided by David Smith (unpublished data).

7.3.1.2 Fleets

The base case assessment for silver warehou is based on a trawl fleet split into and eastern trawl fleet (SESSSF zones 10, 20 and 30) and a western trawl fleet (SESSF zones 40 and 50), with time-invariant logistic selectivity estimated separately for each fleet. Retention was time blocked.

In all previous assessments, discards were added to the landed catch due to difficulties in distinguishing between sized based discarding and market based discarding. This assumption ignored the size-related discarding of small fish that was occurring along with market related discarding of fish of all sizes, as evidenced by the greater proportion of small fish in the discarded length frequencies from 2002 onwards relative to the retained LFs from 2002 onwards (Thomson *et al.* 2015). This suggests that market based discarding reduced dramatically from 2002 onwards. Parameters for estimating retention were estimated separately for the eastern and western trawl fleets. Separate retention (discard) functions were estimated for the 1980-2001 and 2002-2014 periods. This enables a retention function to be fitted allowing for this apparent change in discarding practice from 2002 onwards. This also resulted in improvements to the fits to the length residuals, which were previously noted to behave differently before and after 2002 (Day *et al.* 2012).

While there is some non-trawl catch, it is small and the results of previous assessments (e.g. Thomson, 2002) were insensitive to the inclusion of the non-trawl catches.

7.3.1.3 Catches

The model uses a calendar year for all catch data. Landings of silver warehou prior to the start of SEF1 record-keeping in 1985 are not considered to have been large. However, a linear increase in catch from 1979 to the first year of SEF1 catches was used as an estimate of pre-SEF1 catch, following Punt *et al.* (2005). Total landings data (including both Commonwealth and state landings) were reliably available from 1985-2014 (Klaer 2009, Upston and Klaer 2012, Upston and Klaer 2014). Annual landed catches by fleet used in this assessment are shown in Table 7.1 and Figure 7.3 and Figure 7.4.

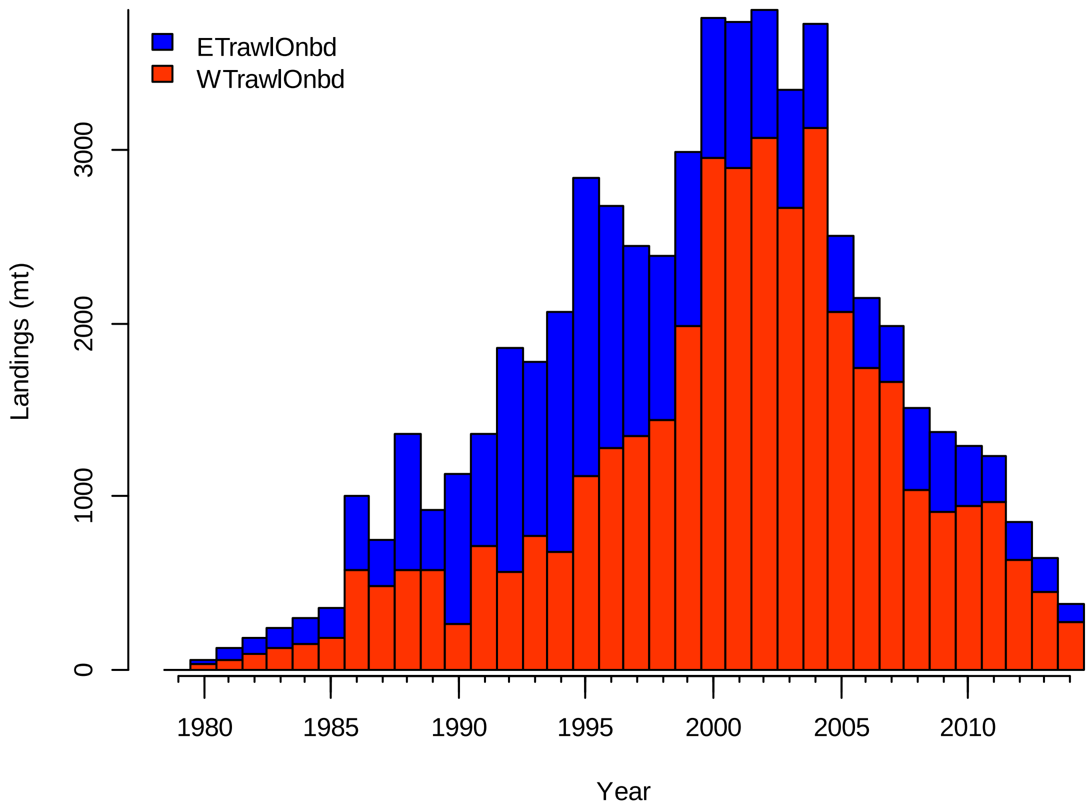


Figure 7.3. Total landed catch by fleet (stacked) of silver warehou in the SESSF from 1979-2014 as used in this assessment.

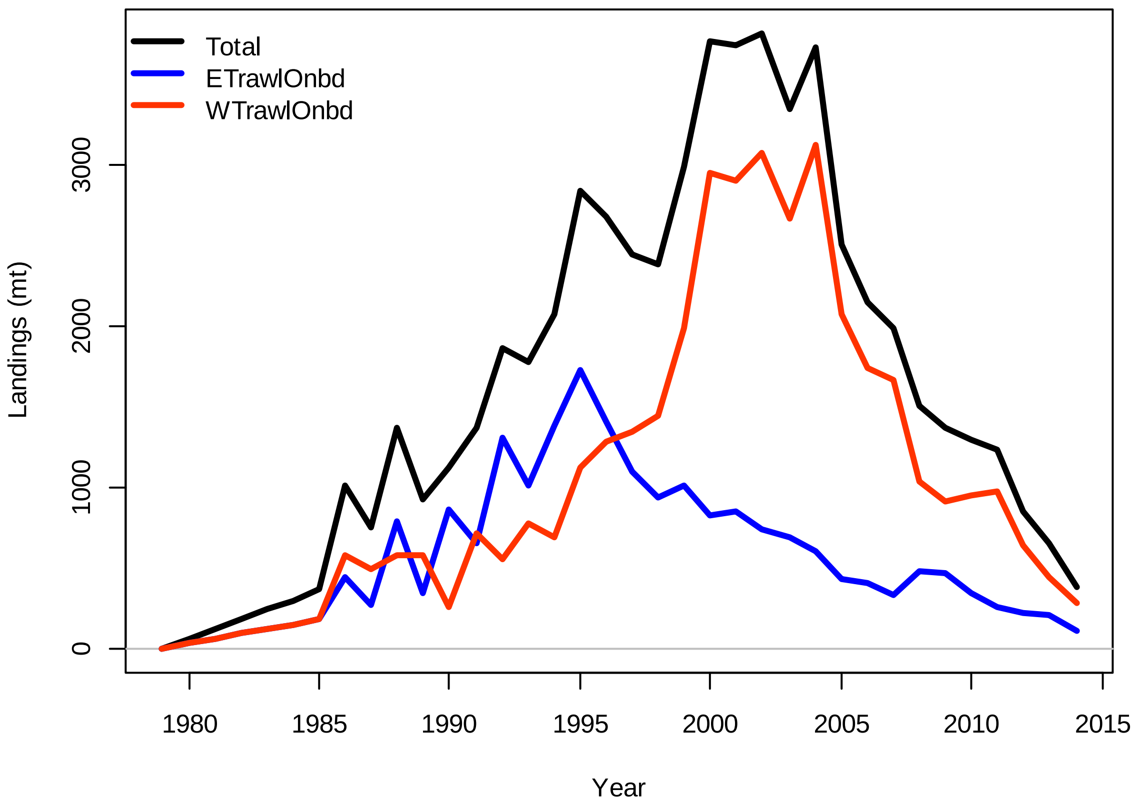


Figure 7.4. Total landed catch by fleet (stacked) of silver warehou in the SESSF from 1979-2014 as used in this assessment.

7.3.1.4 Discard Rates

Information on the discard rate of silver warehou is available from the ISMP for 1993-2014. These data are summarised in Table 7.1. Discard rates vary amongst years, with higher values of around 20-25% (1998, 2004, 2011), moderate values of around 8-16% (1995, 1997, 2001-3, 2005, 2010, 2012) and low values less than 5% for all other years.

Thomson (2002) states that members of the fishing industry had indicated that discarding of silver warehou occurs when market prices are low and is therefore not related to the size of the fish caught. However, examination of the ISMP data on the length frequency of catches and discards shows that there are times when discarding of silver warehou also appears to be size-related (Day *et al.* 2012, Tuck and Fay, 2009). In the 2012 assessment there was no known pattern indicating when discarding was market-driven and when it was size-related, so the mass of fish that were estimated to have been discarded by the trawl fleet was added to the landed. Thomson *et al.* (2015) provide evidence to support a change in discarding practice, from a mixture of market and sized based discarding to just size based discarding from 2002 onwards. Observations were then used to estimate discard rates for each fleet (Figure 7.5) and hence discarded catches for each fleet (Figure 7.6, Figure 7.7), with a change in discarding practice (and estimated retention) assumed from 2002 onwards.

In addition, a number of factory trawlers have operated since 1997 in the spawning fishery for blue grenadier. These trawlers have fishmeal plants which apparently absorb all fish that might otherwise have been discarded. Thus, the factory vessels effectively have zero discard rates (Thomson, 2002b). The discard rates therefore apply to the 'wet boats' only. The overall discard rate for the year is therefore computed by adjusting the 'wet boat' discard rates by the proportion of the catch not taken by factory vessels. This follows the same procedure for dealing with discards as used by Tuck and Fay (2009) and Day *et al.* (2012). However, there is recent evidence that there may be some discarding by factory vessels and it may be possible to incorporate this into future assessments.

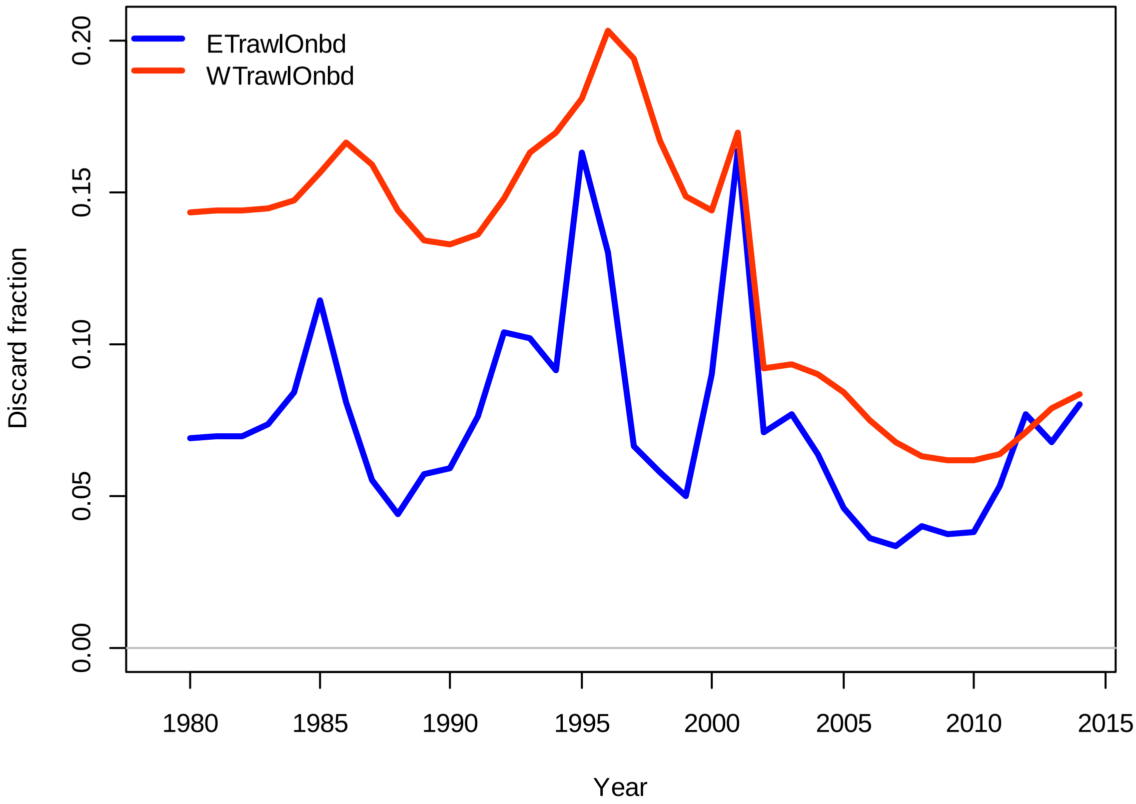


Figure 7.5. Model estimates of discard fractions per fleet for silver warehou in the SESSF from 1979-2014.

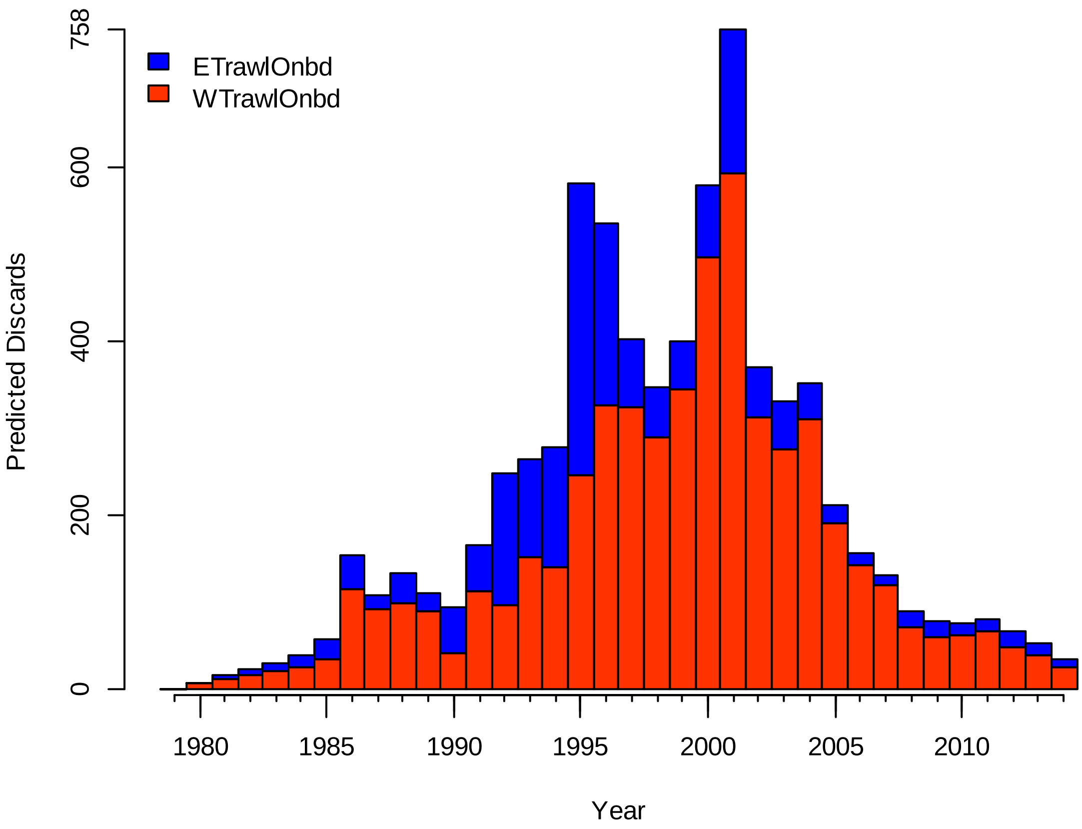


Figure 7.6. Estimated discards (stacked) of silver warehou in the SESSF from 1979-2014.

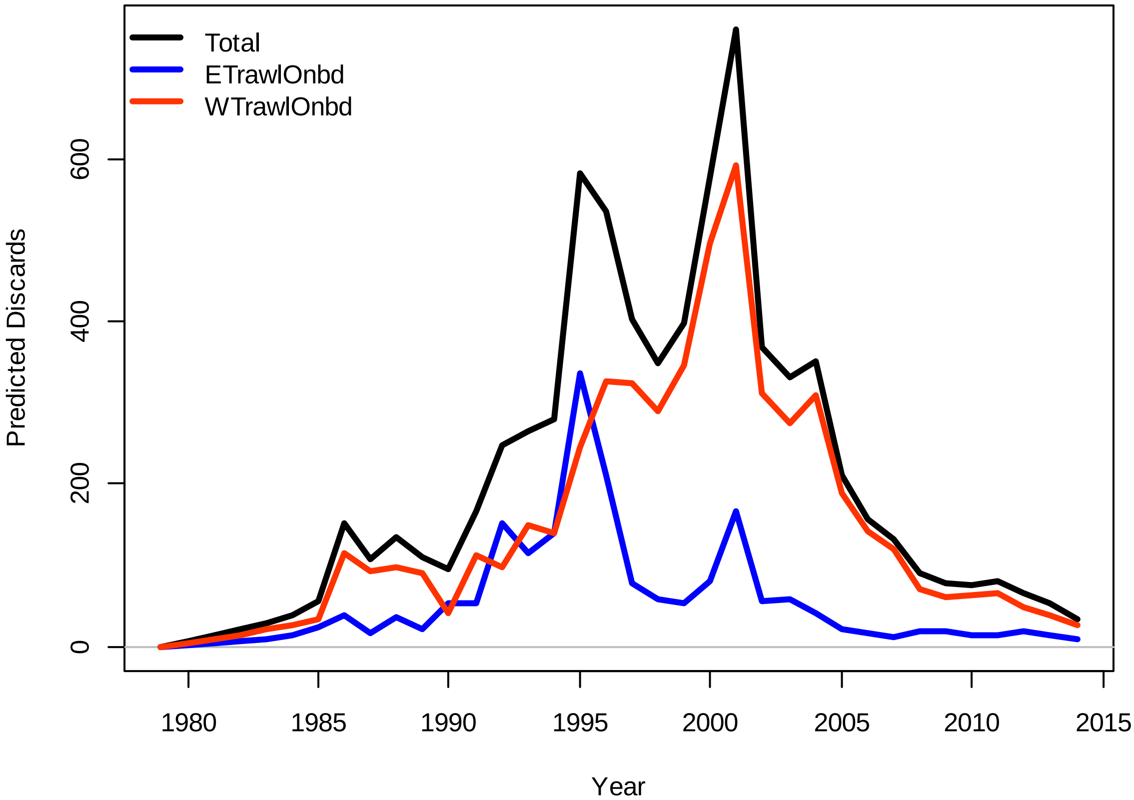


Figure 7.7. Estimated discards of silver warehou in the SESSF from 1979-2014.

7.3.1.5 Catch Rate Indices

Catch and effort data from the SEF1 logbook database from the period 1986 to 2011 were standardised using GLMs to obtain indices of relative abundance (Sporcic, 2015, Sporcic *et al.*, 2015) with the results listed in Table 7.1. Data used in this standardisation were restricted to trawl shots in depths between 0 and 600m from zones 10, 20 and 30 for the eastern trawl fleet and zones 40 and 50 for the western trawl fleet.

7.3.1.6 Length Composition Data

In 2010 the RAGs decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas in previous assessments only port data have been used (Tuck and Fay, 2009). In 2012, the port and onboard length composition data was combined to give one length distribution for each year of data. For the 2015 assessment, port and onboard length composition data were both used separately, with the gear selectivity estimated jointly from both port and onboard data from each fleet (eastern and western trawl).

The 2012 assessment weighted length samples by the number of fish measured. For onboard data, the number of shots, is considered to be more representative of the information content in the length frequencies than the number of fish measured. For port data, the number of shots is not available, but the number of trips can be used instead. In the 2015 assessment, the initial sample size associated with each length frequency in the assessment is the number of shots or trips. However, data was excluded for years with less than 100 individual fish measured, as this was considered to be unrepresentative. Sample sizes for retained length frequencies, including both the number of individuals measured and numbers of shots or trips, are listed in Table 7.2 for each fleet and year for the period 1991-2015.

Table 7.2. Number of retained lengths, shots and trips included in the base case assessment by fleet 1991-2014.

year	fleet	(retained)						
	east onboard # samples	east port # samples	west onboard # samples	west port # samples	east onboard # shots	east port # trips	west onboard # shots	west port # trips
1991		273				4		
1992		1648		1769		9		15
1993		1087		1431		6		11
1994		215		1802		4		22
1995		500		4651		5		37
1996	293	1014	122	6023	4	10	1	53
1997	1585	1762	1883	8874	19	18	33	82
1998	2959	6386	2671	9704	34	63	43	89
1999	2449	6347	1952	7742	32	68	19	75
2000	1642	8239	3584	5424	17	48	46	47
2001	1446	7958	4610	6978	23	60	47	61
2002	2554	12979	4047	9064	37	85	26	83
2003	2005	5431	5019	3359	34	37	44	28
2004	2147	4868	3679	2638	33	34	33	23
2005	2028	9007	6617	3319	25	46	60	28
2006	1847	7994	3763	855	33	49	32	9
2007	173	728		491	12	5		2
2008	440	971	198		18	6	8	
2009	370	2135	853	163	10	27	41	2
2010	1391	1139	1285		30	22	37	
2011	371	1288	1140		17	40	61	
2012	807	1252	991		31	40	31	
2013	730	1720	1523	141	29	45	49	1
2014	142	1391	900	152	4	26	17	2

Discarded length frequencies were only available for onboard samples as discarded fish are not landed in port. Sample sizes for discarded length frequencies including both the number of individuals measured and numbers of shots are listed in Table 7.3 for each fleet and year for the period 1994-2015.

7.3.1.7 Length Composition Data Split by Depth

There appear to be differences in length of silver warehou as a function of depth caught. While it was suggested that the catch and length frequency data could be stratified into deep (deeper than 200m) and shallow (shallower than 200m), a preliminary exploration examined whether this variation had already been incorporated through splitting the trawl fleet into eastern and western components. This was achieved by examining all onboard otter trawl retained length frequencies and aggregating them over all years, then splitting these initially into either eastern or western samples, then shallow or deep samples and finally combinations of all four of these variables. The results of this exploration are shown in Figure 7.8 and Figure 7.9.

Table 7.3. Number of discarded lengths and shots included in the base case assessment by fleet 1994-2014.

year	fleet	(discarded)		
	east onboard	west onboard	east onboard	west onboard
	# samples	# samples	# shots	# shots
1994	456	224	5	2
1995		930		8
1996		1421		10
1997	234	232	3	18
1998		1998		39
1999		477		6
2000	223	283	4	17
2001	888	1371	15	25
2002	1805	1257	34	8
2003	1364	191	23	3
2004	3319	1111	52	16
2005	1332	658	19	15
2006	140		13	
2007				
2008	150		9	
2009	127		2	
2010	131		6	
2011	159	132	9	23
2012	471		13	
2013	109	178	13	8
2014	163		2	

Figure 7.8 demonstrates a strong relationship between length frequencies caught in the west and those caught in deeper water, and a similar relationship between those caught in the east and in shallow waters, with larger fish generally caught in the west and in deeper water. When these are separated further (Figure 7.9), the majority of the length frequencies come from the deep water in the west, with the next largest group being from the east in shallower water. There are smaller numbers of fish caught in the east in deep water and even fewer in the west in shallow water. These aggregated length frequencies suggest that while there may be some differences in length frequencies between fish caught shallower or deeper than 200m, most of this variation is already captured by splitting the fleet into an eastern and western fleet.

A further exploration would be required to see if there were benefits in splitting this data by depth as well as region, but this brief examination suggests that the benefits would be marginal. Small sample sizes may mean that there would also be problems using all data if it was split both by region and depth, especially for shallow caught fish in the west, but also for deep caught fish in the east. Length frequency data were split by region (east/west) in this assessment, but were not split by depth.

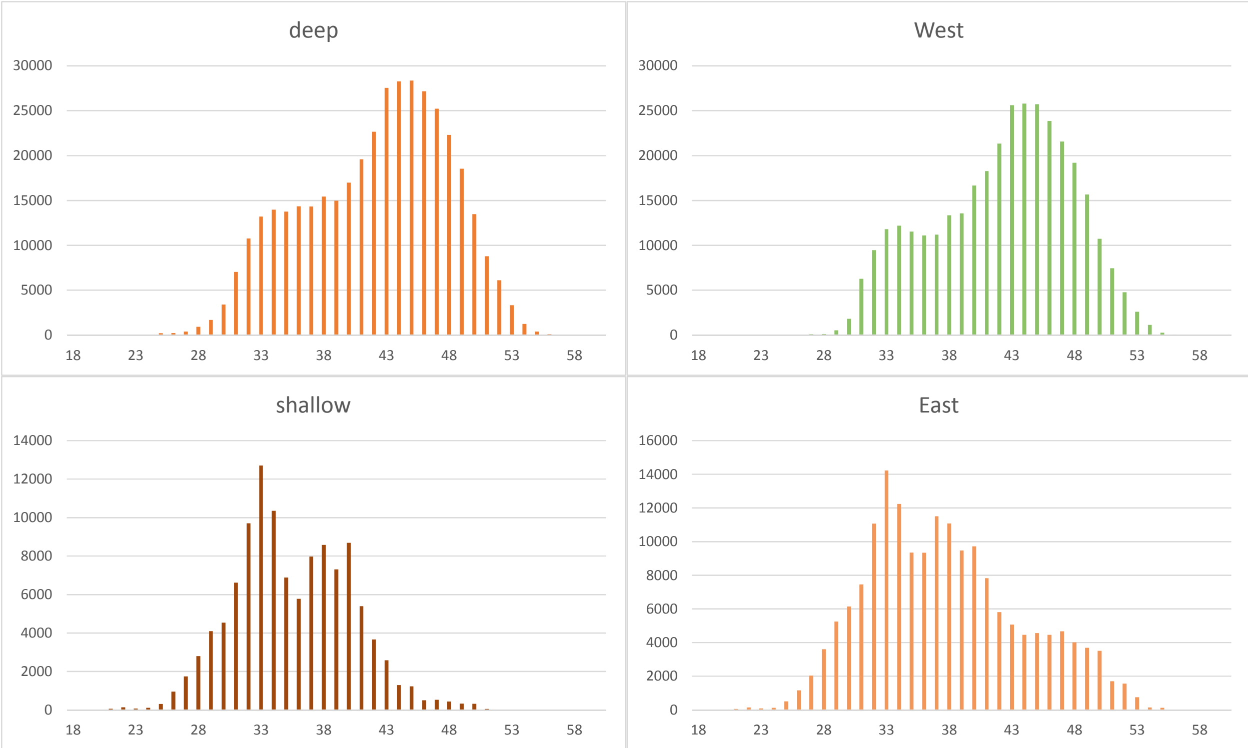


Figure 7.8. Retained otter trawl onboard length frequencies aggregated over all years either by depth (left column) or by location (right column).

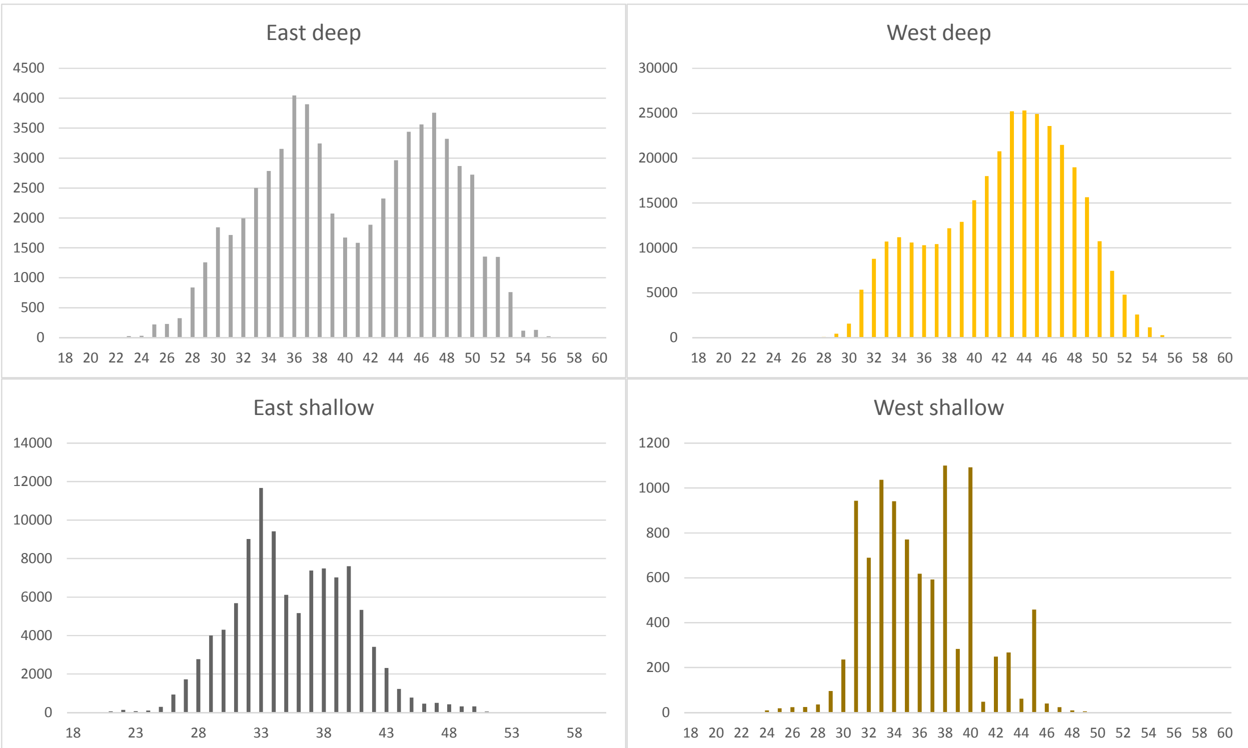


Figure 7.9. Retained otter trawl onboard length frequencies aggregated over all years by depth and by location.

7.3.1.8 Age Composition Data

Age-at-length measurements, based on sectioned otoliths provided by the CAF, were available for the years 1998 and 1993 to 2014 (Table 7.4). An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2015) using data supplied by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd and a variant of the method of Richards *et al.* (1992) (Table 7.5).

Table 7.4. Number of samples in the conditional age-at-length data in the base case assessment 1988-2014.

year	**age-at-length samples**
1988	132
1993	334
1994	359
1995	451
1996	515
1997	566
1998	585
1999	782
2000	406
2001	997
2002	722
2003	424
2004	305
2005	477
2006	395
2007	306
2008	547
2009	821
2010	822
2011	852
2012	989
2013	472
2014	306

Table 7.5. Number of samples in the conditional age-at-length data in the base case assessment 1988-2014.

Age	**Std dev.**	**Age**	**Std dev.**
0	0.148461	12	0.96479
1	0.148461	13	1.03015
2	0.230629	14	1.09417
3	0.311106	15	1.15687
4	0.389927	16	1.21828
5	0.467124	17	1.27842
6	0.542732	18	1.33732
7	0.616783	19	1.39502
8	0.68931	20	1.45152
9	0.760344	21	1.50686
10	0.829915	22	1.56106
11	0.898054	23	1.61415

The implied age distributions are obtained by transforming length frequency data to age data by using the information contained in the conditional age-at-length data from each year.

7.3.1.9 Fishery Independent Survey (FIS) estimates

Abundance indices for silver warehou for the FIS surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey *et al.* (2015) for the eastern and western fleets combined. Indices from the FIS were re-estimated for the east (SESSF zones 10, 20 and 30) and the west (SESSF zones 40 and 50) with coefficients of variation calculated for each fleet (Table 7.6). The length composition data from the FIS have not been included in this assessment and the FIS is assumed to have the same selectivity as the respective trawl fleets.

Table 7.6. FIS derived abundance indices for silver warehou with corresponding coefficient of variation (cv).

	East		West	
year	**abundance**	**cv**	**abundance**	**cv**
2008	148.99	0.21	110.74	0.18
2010	55.56	0.18	25.92	0.18
2012	218.73	0.28	25.56	0.18
2014	14.71	0.21	32.20	0.15

7.3.1.10 Input data summary

The data used in this assessment is summarised in Figure 7.10, indicating which years the various data types were available.

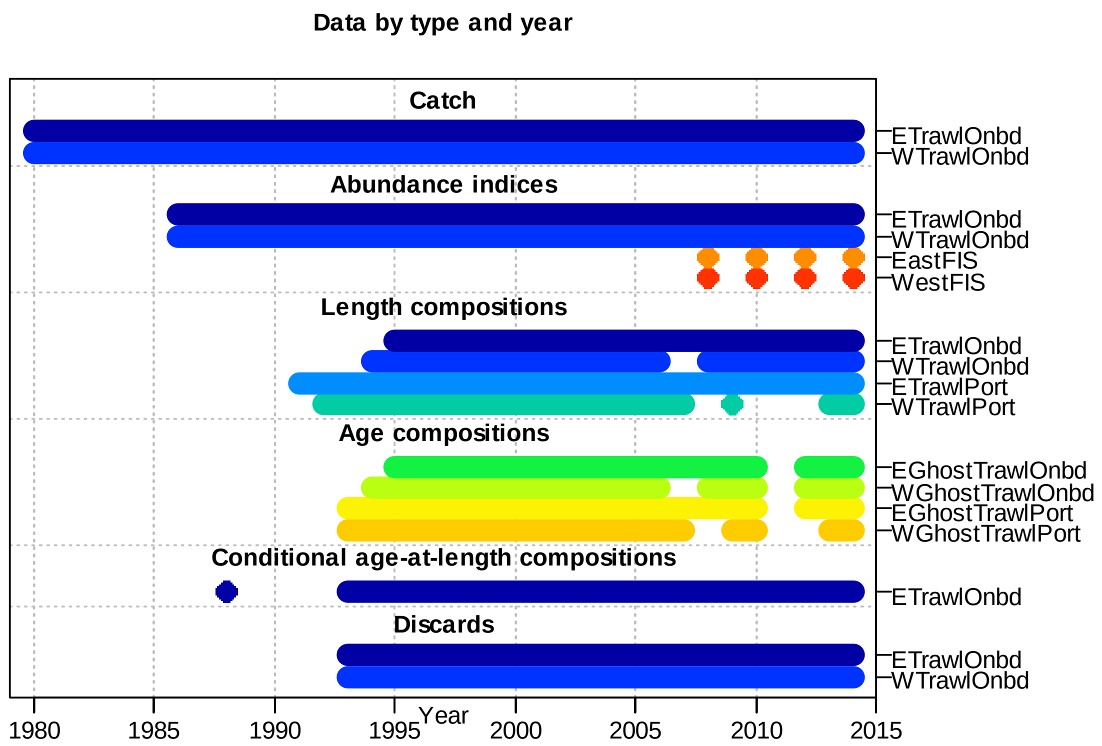


Figure 7.10. Summary of input data used for the silver warehou assessment.

7.3.2 *Stock assessment method*

7.3.2.1 Population dynamics model and parameter estimation

In 2012, a single-sex single-fleet stock assessment for silver warehou was conducted using the software package Stock Synthesis (version SS-V3.24f, Methot 2012). Stock Synthesis is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for silver warehou. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS2 user manual (Methot, 2009, Methot, 2012) and is not reproduced here. This year, the model was translated to the latest version of Stock Synthesis (version SS-V3.24U, Methot 2015). A comparison of parameter estimates and population trajectories showed a very close match across the two versions of Stock Synthesis.

Some key features of the base case model are:

(a) Silver warehou constitute a single stock with in the area of the fishery.

(b) The eastern (SESSF zones 10, 20 and 30) and western (SESSF zones 40 and 50) trawl fleets were modelled separately with separate catches, catch rates, length frequencies and selectivity

(c) The population was at its unfished (virgin) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1979.

(d) The CVs of the CPUE indices for the trawl fleets are tuned by adding 0.19 to the initial CVs used (set uniformly to 0.1).

(e) Selectivity for the trawl fleets is length-specific, logistic and time-invariant. The two parameters of the selectivity function were estimated within the assessment for each fleet.

(f) Retention is estimated separately for two time blocks (1980-2001 and 2002-2014) for each fleet. The slope and intercept parameters were estimated for each fleet, but the asymptote was fixed at 100%.

(g) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The base-case value for M is 0.30 yr^{-1}.

(h) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at virgin spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1980 to 2012. Deviations are not estimated prior to 1980 because there are insufficient data prior to 1980 to permit reliable estimation of recruitment residuals. Deviations are not estimated after 2012 as there would be insufficient numbers of fish recruited to the fishery or seen in the discards to reliably estimate recruitments from 2013 (the age at which 50% of fish have been recruited to the trawl fishery is approximately four). This final year for estimating recruitment deviations is confirmed by observing the increase in asymptotic standard error estimate of the recruitment deviation produced by Stock Synthesis.

(i) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is tuned (set equal to 0.52 prior to tuning) according to current agreed practice.

(j) A plus-group is modelled at age 23 years.

(k) Any length frequency data with less than 100 individual fish measured in a year were excluded as unrepresentative. The number of shots was used as the sample size for onboard length frequencies and the number of trips for port based length frequencies, with a cap at 100 shots (although in practice this cap was not needed for this assessment). These sample sizes were then further tuned so that the input sample size was equal to the effective sample size calculated by the model.

(l) Onboard and port length frequencies were fitted separately, with a common selectivity estimated from these two sources of length frequency data.

(m) Growth of silver warehou is assumed to be time-invariant, in that there is no change over time in mean size-at-age, with the distribution of size-at-age being estimated along with the remaining growth parameters within the assessment. No differences in growth related to gender are modelled, because the stock is modelled as a single-sex

This forms the base case model.

7.3.2.2 Calculating the RBC

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al.,* 2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006- 2012. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the quality and quantity of data for that stock. Silver warehou is assessed as a Tier 1 stock and it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. For the 2013 TACs AFMA has directed that the 20:40:40 (B_{lim}:B_{msy}:F_{targ}) form of the rule will be used up to where fishing mortality reaches F_{48}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2008) has determined that for most SESSF stocks where the proxy values of B_{40} and B_{48} are used for B_{MSY} and B_{MEY} this form of the rule is equivalent to a 20:35:48 strategy.

7.3.2.3 Sensitivity tests

A number of standard sensitivity tests are used to examine the sensitivity of the results of the 2012 primary base case to some of the assumptions and data inputs:

(a) $M = 0.25$ and 0.35 yr^{-1}.

(b) $h = 0.65$ and 0.85

(c) 50% maturity occurs at length 34 and 40cm.

(d) $\sigma_R = 0.45$ and 0.65.

(e) Recruitment deviations estimated to 2006 and 2008.

(f) Double and halve the weighting on the CPUE series.

(g) Double and halve the weighting on the length composition data.

(h) Double and halve the weighting on the age-at-length data.

(i) Double the reported catch form 1998 to 2002.

The last sensitivity, doubling the reported catch from 1998 to 2002, came about following a suggestion from industry at the September 2015 Slope RAG meeting, to explore the impact of any possible mis-reporting of silver warehou landings in this period.

7.3.2.4 Summary statistics

The results of the base-case analysis and the sensitivity tests are summarized using the following quantities:

(a)	SB_0	the average unexploited spawning biomass,
(b)	SB_{2016}	the spawning biomass at the start of 2016,
(c)	SB_{2016}/SB_0	the depletion level at the start of 2016, i.e. the 2016 spawning biomass expressed as a percentage of the virgin spawning biomass
(d)	$-lnL$	the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data),
(e)	2016 RBC 20:35:48	the 2016 RBC calculated using the 20:35:48 harvest rule.
(f)	Long term RBC 20:35:48	the long term RBC calculated using the 20:35:48 harvest rule.

7.4 The 2015 assessment of silver warehou

7.4.1 The base case

7.4.1.1 Transition from the 2009 base case to the 2015 base case

The assessment models presented in Day *et al.* (2012) used data up to 2011. The major changes in the 2015 assessment are: updating the version of Stock Synthesis; the addition of new data for 2012, 2013 and 2014 (including new catch, discard, CPUE, length frequency and age-at-length data); separating catch, catch rate and length data into eastern and western trawl fleets (each with their own selectivity pattern); estimating discards and including discard length frequencies, (estimating sized based discarding and allowing a change in retention from 2002 onwards to reflect a change in discarding practice); the separation of on board and port length frequencies (and estimating a joint selectivity); using shots and trips to weight the sample sizes of length frequencies; adding abundance time series from the east and west FIS for 2008, 2010, 2012 and 2014; the estimation of five more years of recruitment (an additional two years due to separate treatment of discards); and the implementation of a new tuning procedure.

These revisions, with a bridging analysis, were considered by Thomson *et al*. (2015) and showed relatively minor changes to the assessment outcomes. The most significant change was a revision downwards to the estimates of the last two recruitments estimated in the 2012 assessment (2006 and 2007), with the following five estimated recruitments (2008-2012) all lower than the standard projections used in the 2012 assessment. This results in a more depleted stock, despite the reduction in landed catches since 2012.

The model estimate of depletion for the start of 2015 is 35% and 40% for the start of 2016 (projected assuming 2014 catches in 2015). The 2012 assessment provided a base case with a 2013 spawning stock biomass of 47% of virgin stock biomass. With the revised recruitment time series, the 2015 assessment estimates the 2013 spawning stock biomass to have been 29%.

The selectivity patterns indicate that much smaller fish are caught in the east compared with the west, which strongly supports the separation of the data in to east and west fleets. Separating port and onboard length frequencies, using trips and shots to weight these length frequencies and the revised tuning procedure did not have major changes to the assessment outcomes or the estimated biomass trajectory. While conflicts between the age data and the CPUE and length data resulted in an inability to fully tune the age data in previous assessments (Day et al. 2012, Tuck and Fay 2009), with the structural changes to the 2015 assessment and the revised tuning procedure, this is no longer a problem and there is no need to continue to down-weight the age data in the 2015 assessment. A further scenario was explored for the 2015 base case where the age data was further down weighted, as in the 2012 assessment, but this was abandoned when this did not improve the fit to the CPUE series.

In the 2012 assessment, it was noted that there was some conflict between the length and age data and that the length residuals behave differently before and after 2002, with patterns in these residuals indicating some possible issues with the fits to the length data. Attempts were made to address this using cohort dependent growth in 2012, although this resulted in poorer fits to the CPUE series. Separating the trawl fleets into east and west, treating discards separately and allowing a change in discarding practice from 2002 appears to have adequately addressed this problem with the length residuals. In addition, it was noted in previous assessments that there had been a recent decline in both the catch and the CPUE in previous assessments. That decline in catch and in CPUE has continued with additional data to the end of 2014.

7.4.1.2 Tuning the 2015 base case

The proposed primary base case model needed to be tuned, following the addition of new data and this tuning was done according the following procedure (André Punt pers comm.):

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data)
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the length frequencies and Francis B (the larger of the Francis A and B factors, Francis (2011) - iterate to convergence
3. Adjust the recruitment variance (σ_R) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time);
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors- iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor, just once (no iterating);
6. Repeat steps 3 and 4.

7.4.1.3 Parameter estimates of the base case model

Figure 7.11 shows the estimated growth curve for silver warehou. All growth parameters are estimated. The estimates of the growth parameters are: (a) L_{min}=15.19cm, (b) L_{max}=50.21cm, (c) K=0.3096 yr^{-1}, and (d) cv of growth = 0.0896. This growth curve is very similar to the growth curve estimated in the 2012 assessment.

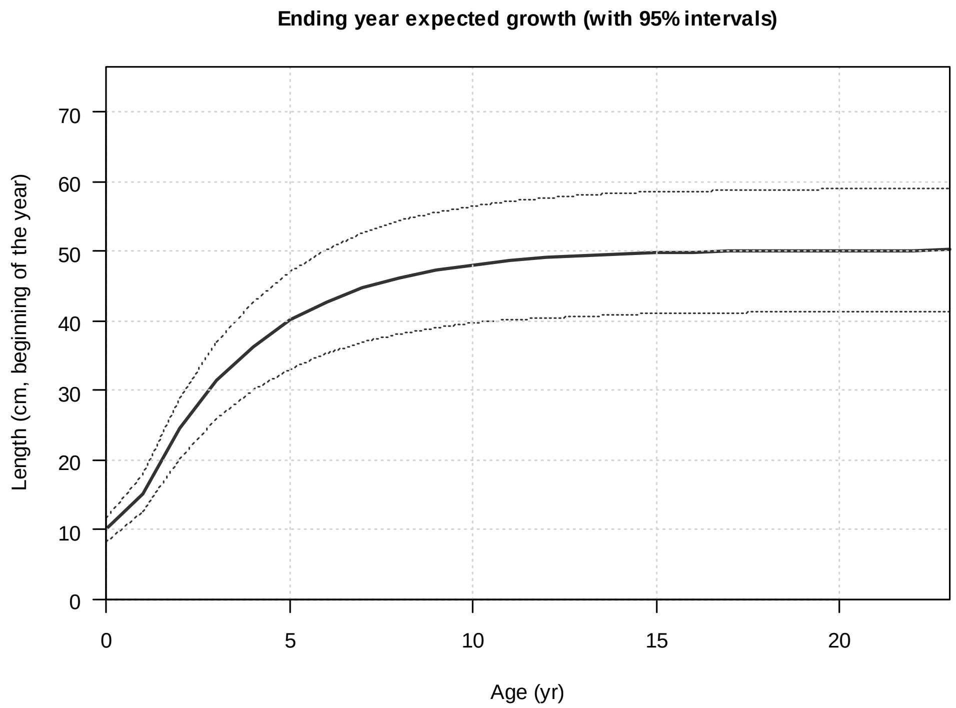


Figure 7.11. The model estimated growth function for silver warehou for the base case.

Figure 7.12 shows the estimated time varying retention and selectivity curves for the east and west trawl fleets for silver warehou. The parameters that define this selectivity function including the length at 50% selection and the spread. The estimates of these parameters for the base-case analysis are 24.66cm and 3.65cm respectively for the east and 39.59cm and 11.18cm for the west. The estimates for the parameters that define in the time block 2002-2014 are 27.44cm and 2.46cm respectively for the east and 28.30cm and 5.88cm for the west. The estimate of the parameter that defines the initial numbers (and biomass), $ln(R_0)$, is 9.626 for the base case.

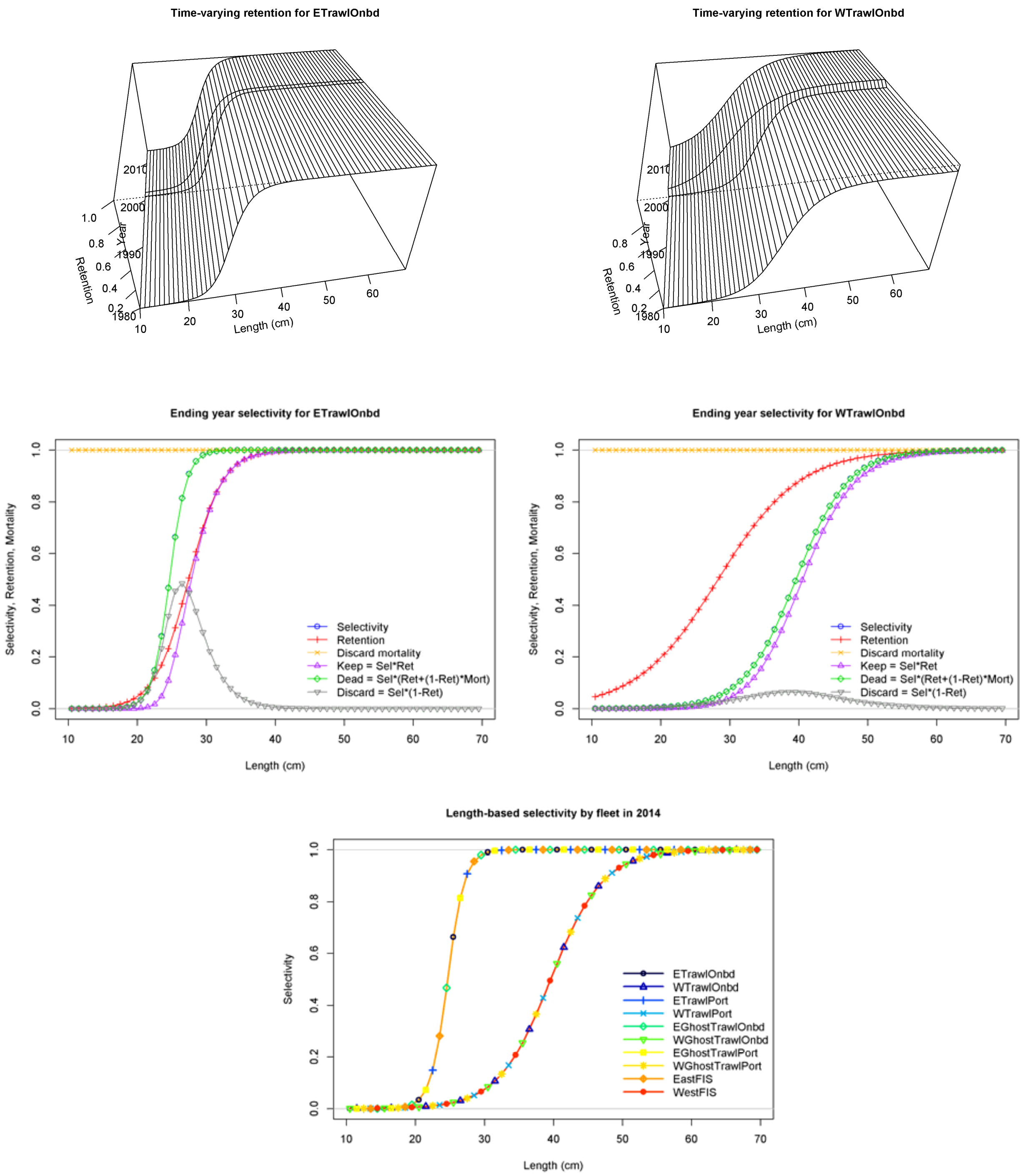


Figure 7.12. Estimated retention function (discard pattern) with two time blocks (1980-2001, and 2002-2014) for east (top left) and west (top right) trawl fleets. Selectivity and discard patterns for east (middle left) and west (middle right) fleets, and east and west selectivity patterns plotted together (bottom).

7.4.1.4 *Fits to the data for the base case model*

The fits to the catch rate indices (Figure 7.13) for the base case are reasonable for the west trawl fleet and adequate for the east trawl fleet, although in both cases the pattern seen in the previous two assessments where the trends in the data and the fit for the last three data points (2012, 2013 and 2014) suggest some conflict and again the potential for this species to break out in the near future. The data over this period suggests a downwards trend, and yet the model shows an increasing trend, with the model prediction very close to the upper 95% confidence bound in 2014 indicating a good chance of a breakout between the modelled predicted CPUE values and the observed CPUE values in the future.

The fits to the FIS indices are poor, but the FIS indices are confounded by very large variation between years, possibly relating to some FIS survey years having large shots of silver warehou which are absent in other years. The only way to fit these indices adequately is to increase the variance.

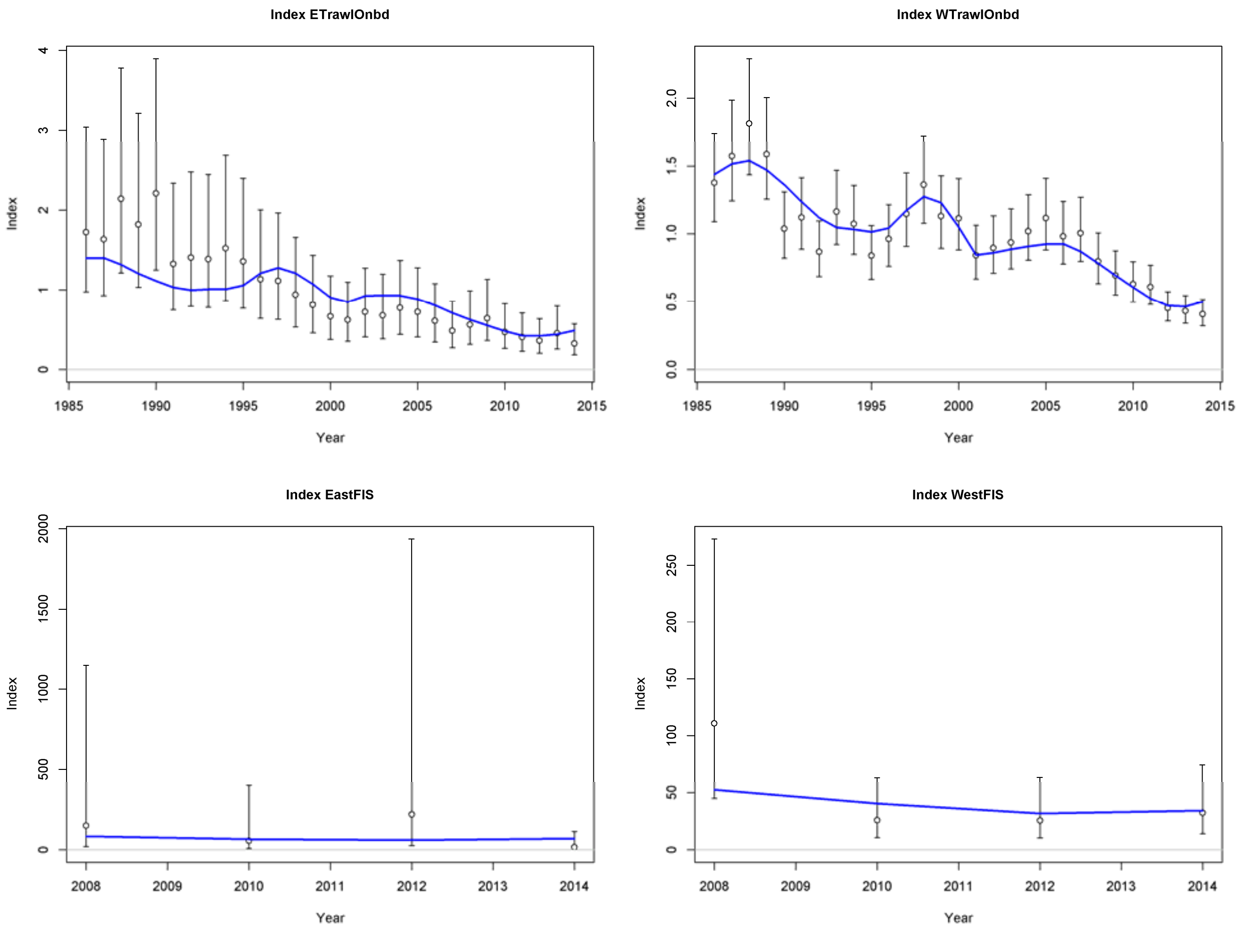


Figure 7.13. Observed (circles) and model-predicted (blue line) catch-rates for silver warehou for the east and west trawl fleet versus year for the base case analysis and for the east and west FIS. The vertical lines indicate approximate 95% confidence intervals for the data.

The base-case is able to fit the aggregated retained and discarded length-frequency distributions adequately in most cases (Figure 7.14, top). The eastern trawl retained fits are not as good as the western trawl, and the western trawl discard length frequencies are quite variable and hence difficult to fit well. Figure 7.14 demonstrates the difference in sizes of silver warehou caught between the eastern and western fleets.

The aggregated fits to the implied age composition are shown in Figure 7.14 (bottom). These age-compositions are not fitted directly, but are essentially fits to the length distributions with the length data transformed to age using a conversion from length to age obtained through the conditional age-at-length data. The fits to the implied age-compositions provide a means of checking the adequacy of the model and the model fits the observed age data very well.

Annual fits and residuals are included in Appendix A. While the annual fits are not as good as the aggregated fits, the length frequency data appears to be very variable, especially for the eastern trawl fleet. This has become more pronounced in this assessment with the separation of length frequencies by fleet and into port and onboard components within fleets. The resulting length frequencies have more inherent variability and smaller samples sizes. This may reflect spatial and temporal differences in collection of this data between years and hence this length frequency data may not be as representative as we would like. Equally, this variation may have been smoothed over by aggregating these length frequencies in the 2012 assessment. Similar comments apply to the implied fits to age, with better fits in the west, then the east, but given this implied fit to age is derived from length frequency data, it is not surprising to see similar trends.

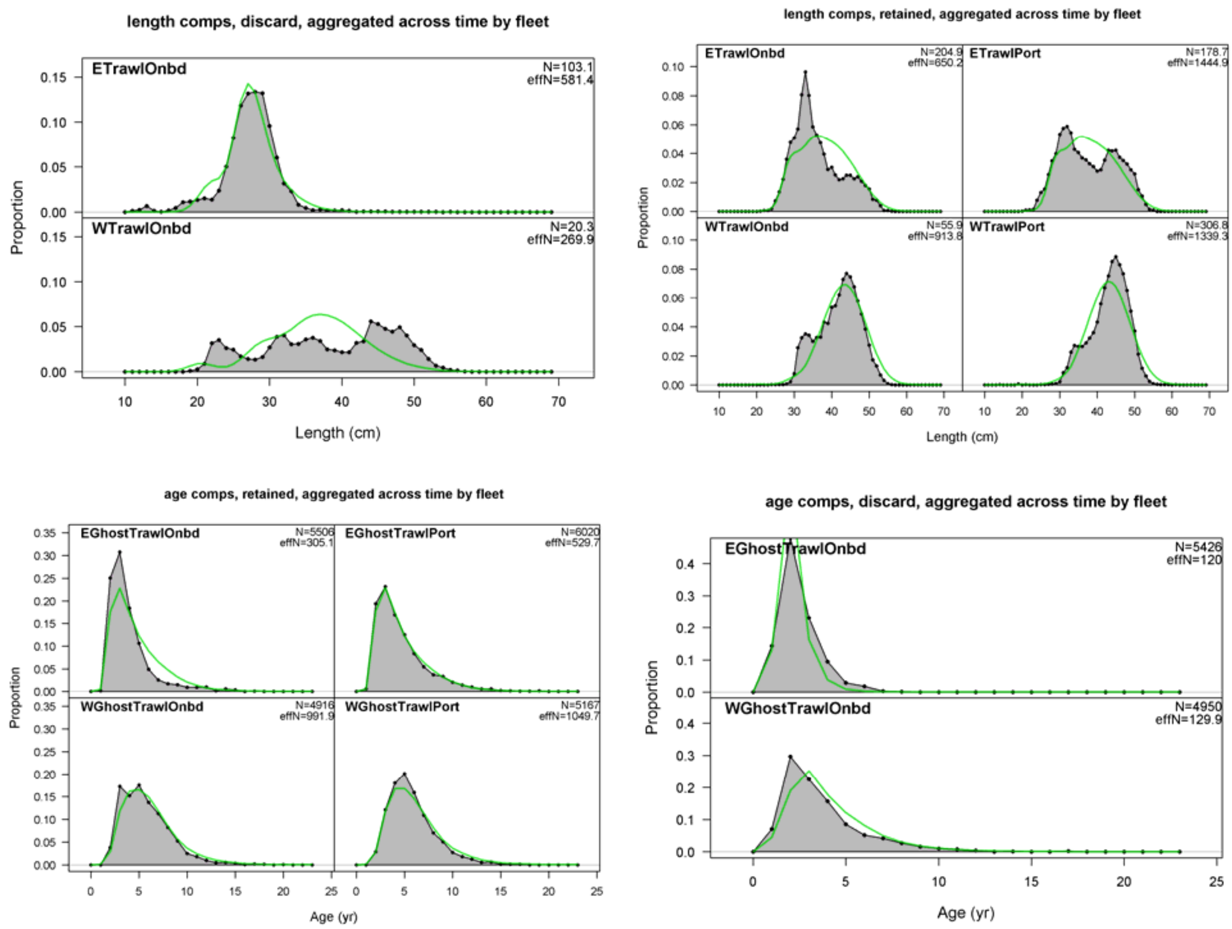
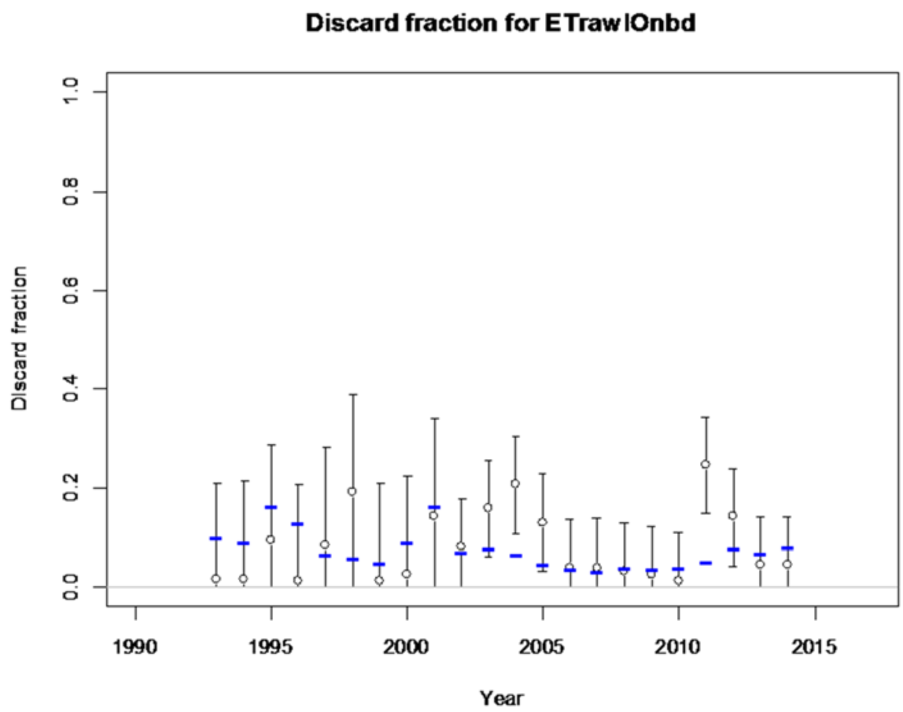


Figure 7.14. Aggregated length and implied age compositions for the onboard and port data sources in both the east and west. Observed data are grey and the fitted value is the green line. Note that the model is conditioned on the age at length data, not on the age compositions themselves.

The fits to the discard fractions (Figure 7.15) are reasonable given the variability in the data, with some very low data points (around 1%) and ranging up to 25%.



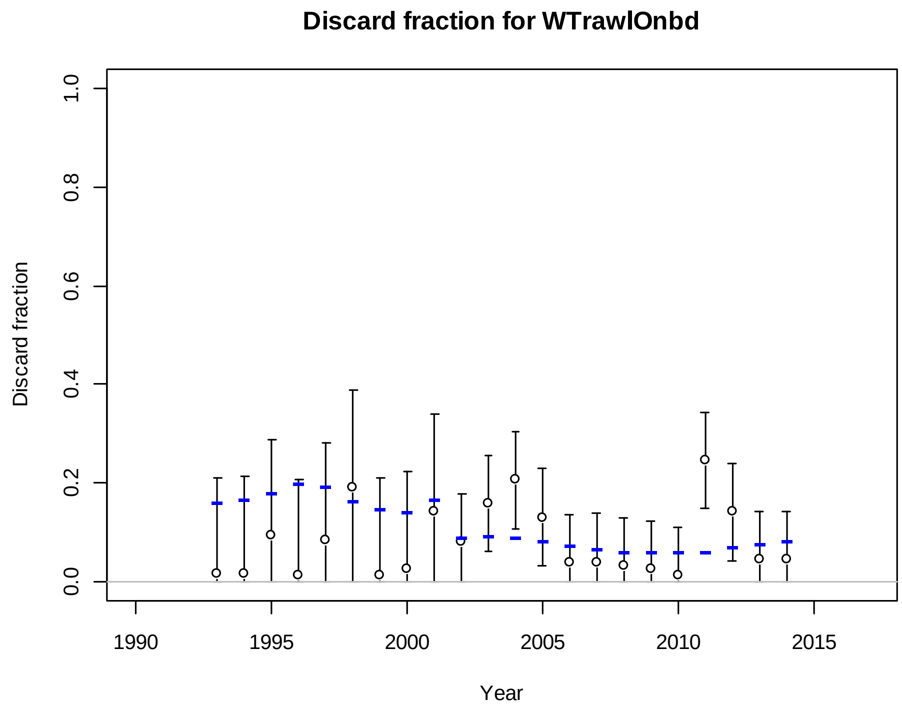


Figure 7.15. Observed (circles) and model-estimated (blue lines) discard estimates versus year, with approximate 95% asymptotic intervals for the Eastern trawl fleet (top) and western trawl fleet (bottom). Note that the observed values fitted were the same for each fleet, the discard data was not separated into eastern and western fleets.

7.4.1.5 Assessment outcomes for the base case model

Figure 7.16 shows the relative spawning stock depletion with the limit and target reference points at 20% and 48% respectively. The increase in stock size in the late 1980s followed by a subsequent decline is a result of the large recruitment in 1983 with below average recruitment in the early and late 1980s. The stock size continues to fluctuate as recruitment varies between periods of good and poor recruitment and as the catch also varies. However there is clearly an overall decline in stock size since the late 1980s. The increase in stock size towards the end of the series should be treated with some caution as this is a result of the model imposed average recruitment from 2013 onwards, when recruitment is unable to be estimated. As data becomes available to inform these recruitment events in future assessments, the increase in stock size from 2012 may need to be revised.

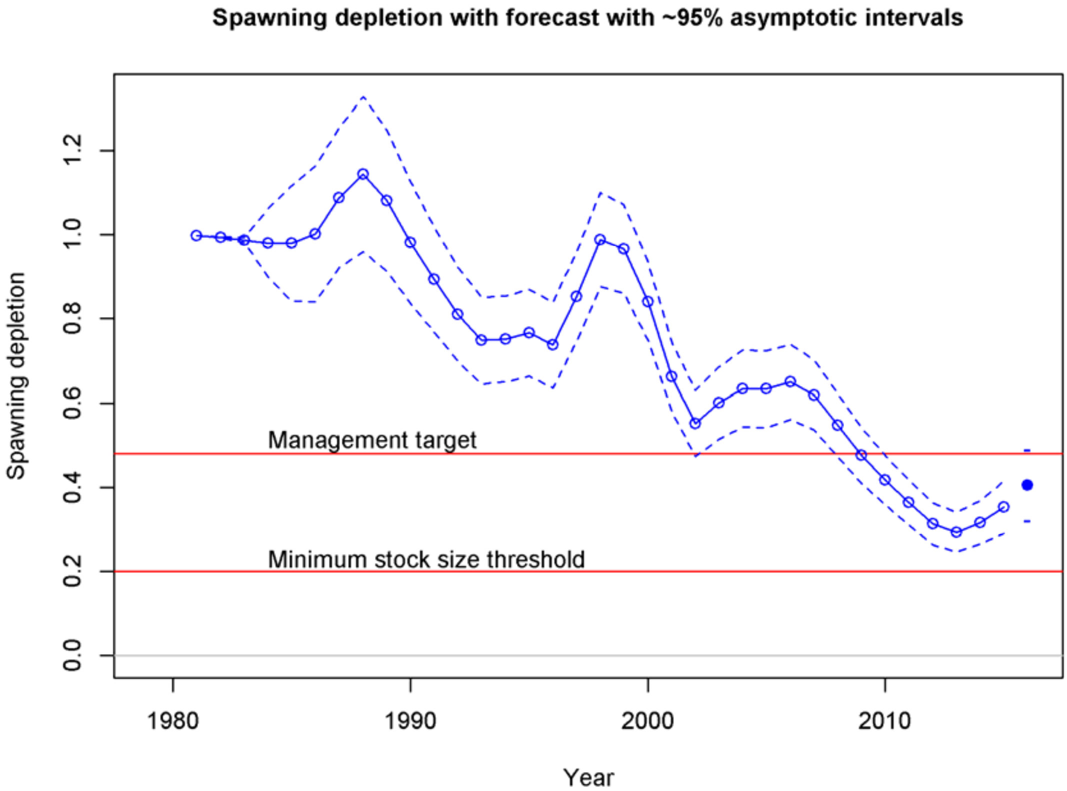


Figure 7.16. Time-trajectory of spawning biomass depletion (with 95% confidence intervals) corresponding to the MPD estimates for silver warehou.

The time-trajectories of recruitment deviations are shown in Figure 7.17 and the bias adjustment and standard errors of recruitment deviation estimates are shown in Figure 7.18. Note that nine of the last ten estimated recruitment events have been below average, with the last recruitment estimate only just above average, and likely to be revised when additional data is added.

The current (2016) spawning stock biomass is estimated to be 40% of unfished stock biomass (i.e. 2016 spawning biomass relative to unfished spawning biomass).

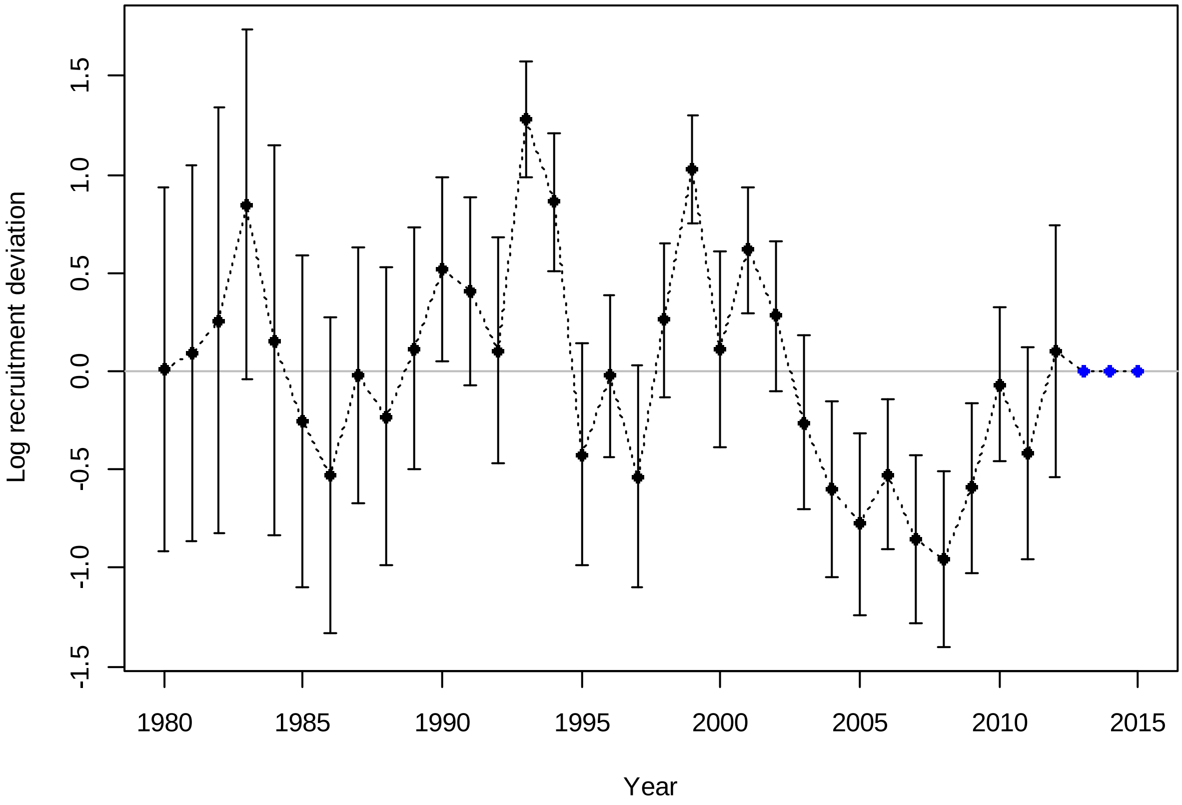


Figure 7.17. Recruitment estimates for the base case for silver warehou. Time trajectories of estimated log recruitment deviations, with approximate error distributions.

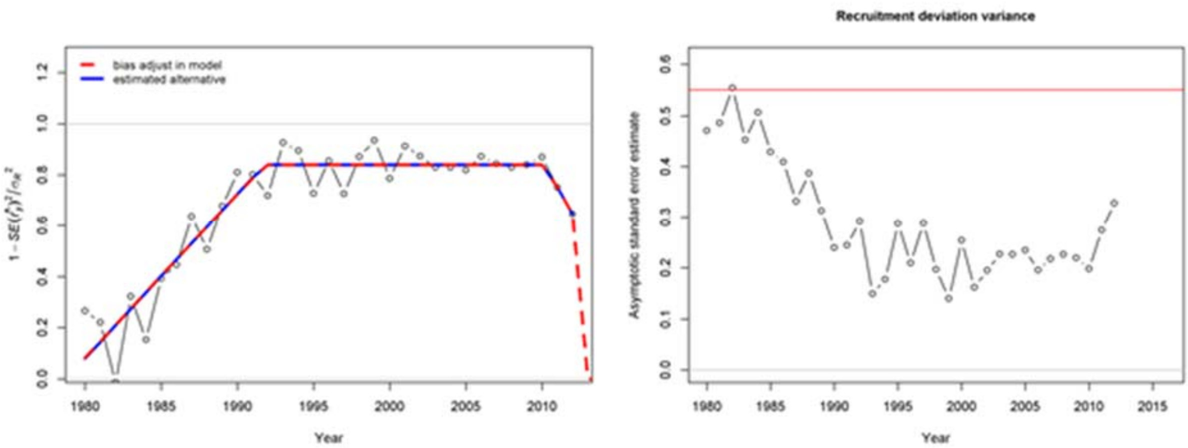


Figure 7.18. Bias adjustment (left) and standard errors of recruitment deviation estimates (right) for the base case for silver warehou.

Table 7.7. Summary of fixed and estimated parameters for the primary base case model.

Feature	Details	
Natural mortality (*M*)	fixed	0.3
Steepness (*h*)	fixed	0.75
σ_R in	fixed	0.55
length-weight scale, *a*	fixed	0.0000065
length-weight power, *b*	fixed	3.27
length at 50% maturity (cm)	fixed	37
maturity slope	fixed	-6
Recruitment deviations	estimated	1980-2012, bias adjustment ramp 1980-1992
CV growth	estimated	0.0896
Growth *K*	estimated	Female 0.310
Growth l_{min}	estimated	Female age 2 15.19
Growth l_{max}	estimated	Female 50.21
length at 50% selectivity (cm)	estimated	24.66 (east) 39.59 (west)
selectivity spread (cm)	estimated	3.65 (east) 11.18 (west)
ln(R_0)	estimated	9.626

7.4.2 *Sensitivities and alternative models*

Results of the sensitivity tests are shown in Table 7.8 and Table 7.9. The results are most sensitive to the assumed value for natural mortality (*M*) and recruitment variance (σ_R). However, even with *M*=0.35, the improved fits to the survey, discard and age data give an improvement to the overall likelihood of only five units. Similarly with σ_R =0.65, the improved fits to the recruitment give a similar improvement to the overall likelihood of only five units. Changes to the other fixed parameters produce little change to the overall likelihood and only minor changes to the depletion estimates.

Changing the weighting on various data sources has relatively minor impacts on the depletion estimates. The likelihood cannot be compared directly in these cases, but Table 7.9 shows the relative differences between the different components of the total likelihood, attributable to these changes.

This also suggests some conflict between the age and length data as increasing the weight on the age data results in poorer fits to the length data and vice versa.

Table 7.8. Summary of results for the base case and sensitivity tests (log-likelihood (-ln L) values that are comparable are in bold face). Spawning stock biomass includes both male and female biomass in the total.

Model	-ln L	SB_0	SB_{2016}	SB_{2016}/SB_0	2016 RBC (t)	long term RBC (t)
base case	**894**	**23381**	**9464**	**40**	**1958**	**2281**
M=0.25	**901**	22299	7651	34		
M=0.35	**889**	27497	12730	46		
h=0.65	**893**	23844	9322	39		
h=0.85	**894**	23064	9586	42		
50% maturity at 34cm	**894**	25770	11305	44		
50% maturity at 40cm	**894**	20251	7425	37		
σ_R = 0.45	901	22948	9702	42		
σ_R = 0.65	889	24088	9339	39		
est. recruitment to 2011	894	23302	9451	41		
est. recruitment to 2013	894	23442	9464	40		
double weight on CPUE	921	23380	8759	37		
halve weight on CPUE	878	23744	10509	44		
double weight on lengths	1183	22179	9640	43		
halve weight on lengths	737	24819	9661	39		
double weight on age	1389	24376	9738	40		
halve weight on age	638	22700	9311	41		
double catch 1998-2002	906	35182	16095	46		

Table 7.9. Summary of likelihood components for the base case and sensitivity tests. Likelihood components are unweighted and all cases below the primary base case are shown as differences from the base case. A negative value either in the total or individual components of likelihood indicates an improvement in fit compared to the primary base case. A positive value indicates deterioration in the fit.

Model	Likelihood TOTAL	Survey	Discard	Length	Age	Recruitment	parm_priors
base case	893.56	32.98	38.74	301.95	503.75	15.85	0.30
M=0.25	7.68	1.70	1.95	2.60	1.01	0.41	0.31
M=0.35	-4.91	-1.63	-1.64	-1.90	-0.11	0.38	0.29
h=0.65	-0.44	-0.15	0.13	0.24	-0.20	-0.46	0.30
h=0.85	0.38	0.12	-0.10	-0.17	0.15	0.38	0.30
50% maturity at 34cm	0.05	-0.01	0.00	0.01	0.01	0.05	0.30
50% maturity at 40cm	-0.14	0.01	0.00	-0.07	0.04	-0.13	0.30
σ_R = 0.45	7.68	1.40	-0.36	0.97	0.31	5.37	0.30
σ_R = 0.65	-4.88	-0.79	0.24	-0.56	-0.20	-3.57	0.30
est. recruitment to 2011	0.00	0.00	-0.01	0.02	0.00	-0.01	0.30
est. recruitment to 2013	0.00	0.00	0.00	0.01	-0.01	0.01	0.30
double weight on CPUE	1.60	-3.88	3.00	1.39	-0.70	1.77	0.31
halve weight on CPUE	1.42	5.11	-2.04	-1.01	0.90	-1.52	0.29
double weight on lengths	9.62	2.05	8.14	-22.76	19.78	2.42	0.29
halve weight on lengths	8.09	-0.91	-5.70	27.97	-12.70	-0.55	0.29
double weight on age	6.76	0.33	1.56	19.30	-15.48	1.08	0.28
halve weight on age	4.78	1.29	-0.78	-12.94	17.01	0.20	0.30
double catch 1998-2002	11.89	4.64	2.42	7.12	-3.74	1.45	0.30

7.4.3 *Application of the harvest control rules in 2015*

An estimate of the catch for the 2015 calendar year is needed to run the model forward to calculate the 2016 spawning biomass and depletion. Given that recent TACs have been considerably under-caught, the catch in 2015 is assumed to equal that of 2014 (namely 381t).

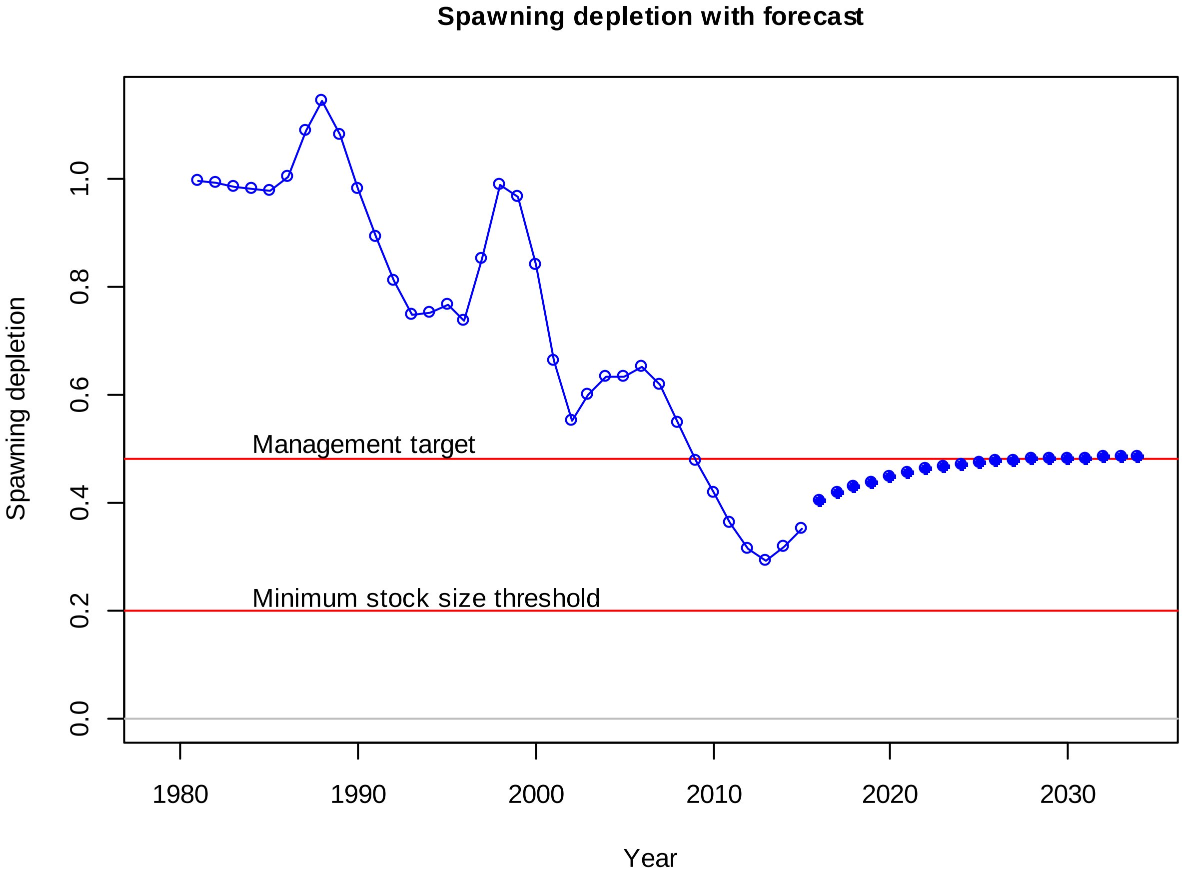


Figure 7.19. The projection of relative spawning biomass (bottom) under the 20:35:48 rule for silver warehou.

The depletion in 2016 under the base-case parameterisation is estimated to be 40.5%. An application of the Tier 1 harvest control rule with a target depletion of 48% leads to the 2016 and long-term RBCs of 1958t and 2281t (Table 7.8). An example of the time-series of RBCs and corresponding spawning biomass corresponding to the calculated RBCs for the 20:35:48 harvest control rule is shown in Figure 7.19. This figure assumes that the full RBC is caught in projected years and that recruitment is deterministically drawn from the stock-recruitment curve. Table 7.10 shows the annual RBCs and depletion estimates under the 20:35:48 harvest control rule.

Model estimated discard rates for 2016-2018 are required for calculation of the TAC from the RBC, and these can be obtained from Stock Synthesis output files. Under the assumption of average recruitment from 2013 onwards and assuming that the RBC is caught in full each year, the estimated discard mass for these years follow: 162t in 2016; 166t in 2017; and 169t in 2018.

Table 7.10. Summary of the annual RBCs and corresponding depletion for the base case under the 20:35:48 harvest control rule.

Year	RBC(t)	Depletion
2015	381	35.2
2016	1958	40.5
2017	2005	41.9
2018	2050	42.9
2019	2091	43.8
2020	2128	44.7
2021	2161	45.5
2022	2187	46.1
2023	2208	46.6
2024	2225	47.0
2025	2238	47.3
2026	2248	47.6
2027	2256	47.8
2028	2263	47.9
2029	2268	48.1
2030	2272	48.2
2031	2275	48.2
2032	2277	48.3
2033	2279	48.3
2034	2281	48.4

7.4.4 *Scenarios with low recruitment for 2013-2020*

7.4.4.1 Poor and very poor recruitment scenarios

To explore the potential impact of setting a multi-year TAC without updating this assessment, scenarios were run where the recruitment in the period from 2012-2020 was assumed to be poor. When the harvest control rules are applied and forward projections are made, recruitment deviations from 2012 onwards are set to zero, as there is insufficient information to estimate recruitment in this period. This essentially assumes average recruitment for the given level of spawning biomass for the period 2012 onwards.

Given that nine of the last ten recruitment events are estimated to be below average (Figure 7.17) and that the last recruitment estimated (2012) is only just above average and could be revised down in the future with additional data, and given that catches and catch rates have been declining for the last ten years, it seems unlikely that catches will return to the projected RBC levels given in Table 7.10. Indeed, it is possible that recruitment may remain below average for the next few years.

To explore the possible impact of continued poor recruitment, two additional recruitment scenarios were examined where recruitment was assumed to be poor in the period 2013-2020. In this case, the standard forward projections, assuming average recruitment, could produce RBCs that, if caught, could result in a lower spawning biomass than the target level. The first recruitment scenario, referred to as “poor recruitment” took the mean of the log recruitment deviations in the base case estimated from 2007-2011, giving a value of -0.576. This represented a recent period of five poor recruitment events. The second recruitment scenario, referred to as “very poor recruitment” took the mean of the log recruitment deviation from the worst three of these years, 2007-2009, giving a value of -0.799. The recruitment estimates from the poor and very poor recruitment scenarios are shown in Figure 7.20.

A similar scenario was explored in the 2012 assessment (Day *et al.* 2012), where log recruitment deviations were averaged over the period 2002-2005 giving a recruitment deviation of -0.627 projected forward for the period 2008-2011. This 2012 poor recruitment scenario falls between the two recruitment scenarios considered here, but was only projected for four years in 2012.

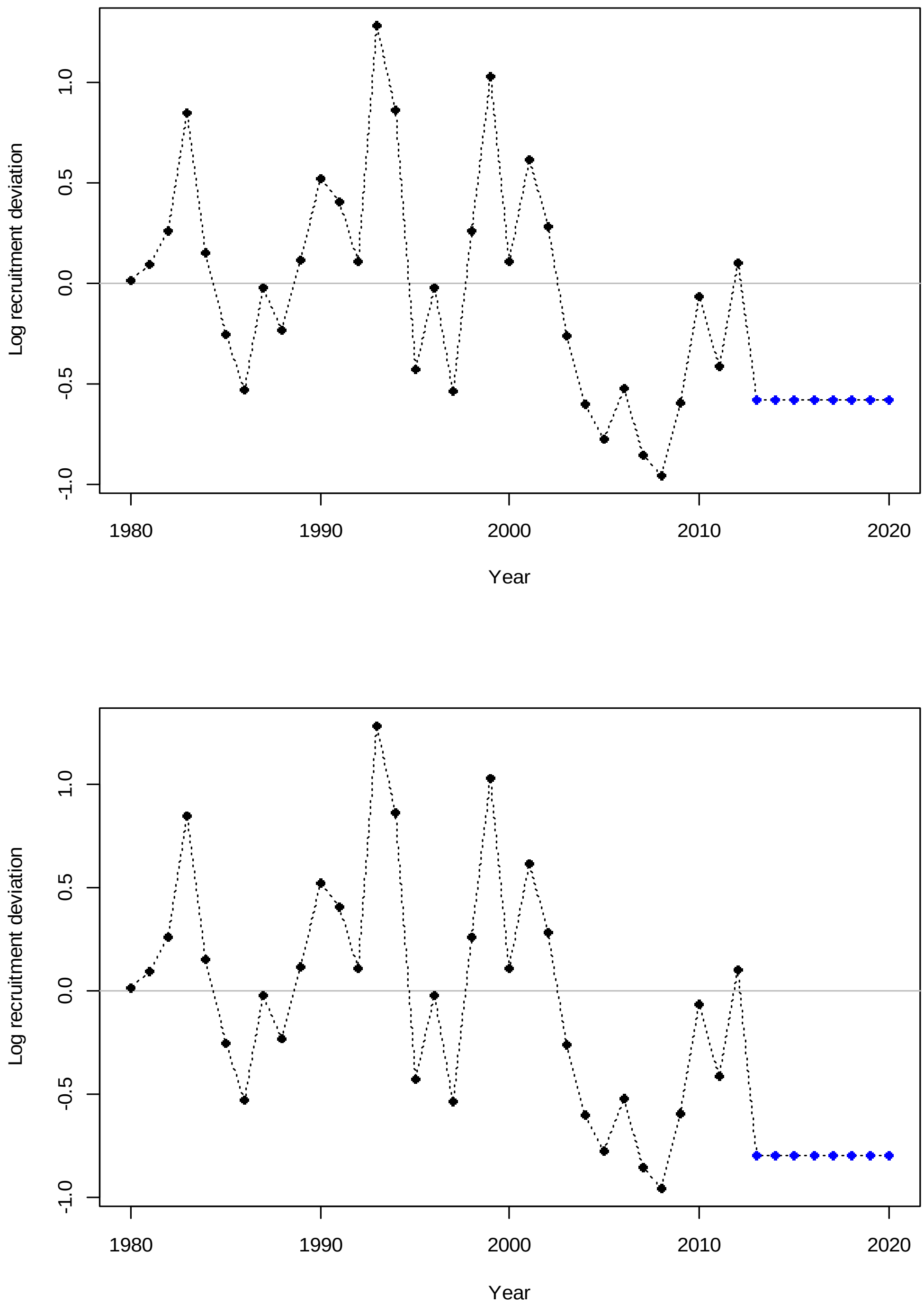


Figure 7.20. Time trajectories of log recruitment deviations estimates for the scenario with poor recruitment (top) and very poor recruitment (bottom).

7.4.4.2 Fixed catch projection to 2020

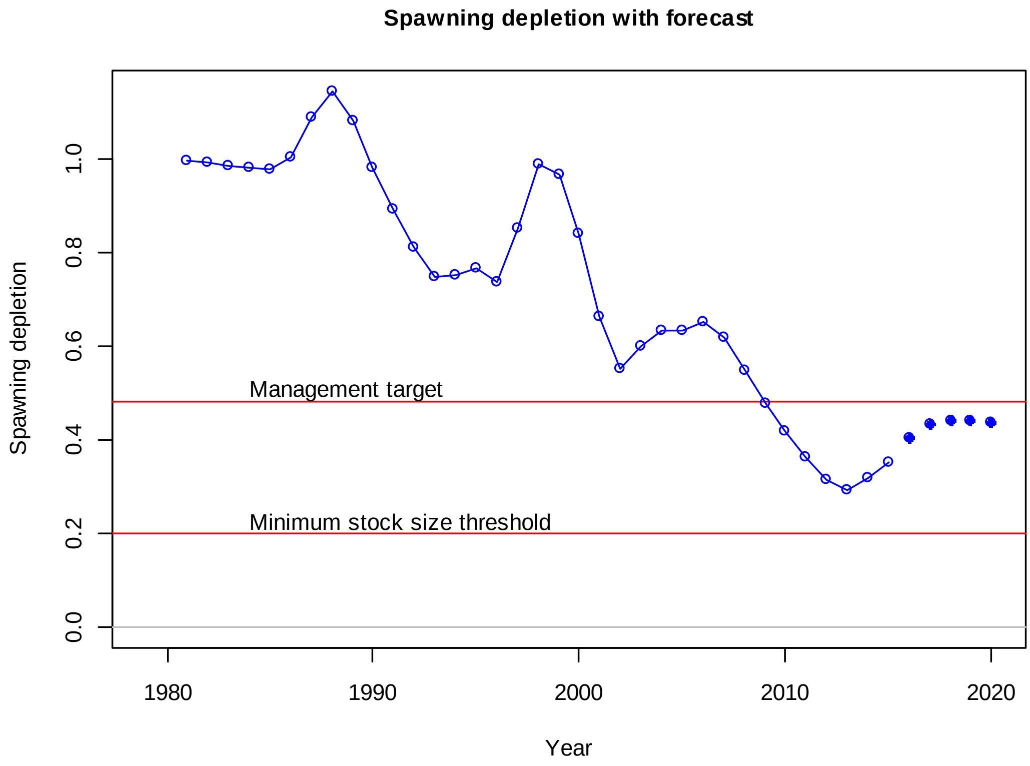
For the two poor recruitment scenarios, the dynamics were projected forward for five additional years, initially with a fixed catch level, set at the 2014 catch, 381t. Note that with discards being estimated, there are additional removals, and while the forecast catch is set to 381t, the actual landed catch is a little higher due to the interaction with discards. Spawning depletion scenarios and actual depletion levels are shown in Figure 7.21, Table 7.11 and Table 7.12. Neither recruitment scenario sees the stock approaching the target biomass by 2020, and the very poor recruitment scenario sees a decline in spawning biomass to a depletion below 40% in 2020.

Table 7.11. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 381t.

Year	Catch	Depletion
2015	381	35.2
2016	381	40.2
2017	384	43.3
2018	386	44.0
2019	387	43.9
2020	386	43.7

Table 7.12. Depletion levels assuming very poor recruitment from 2013-2020 and a fixed catch of 381t.

Year	Catch	Depletion
2015	381	35.2
2016	382	40.2
2017	385	42.4
2018	388	41.7
2019	389	40.2
2020	388	38.7



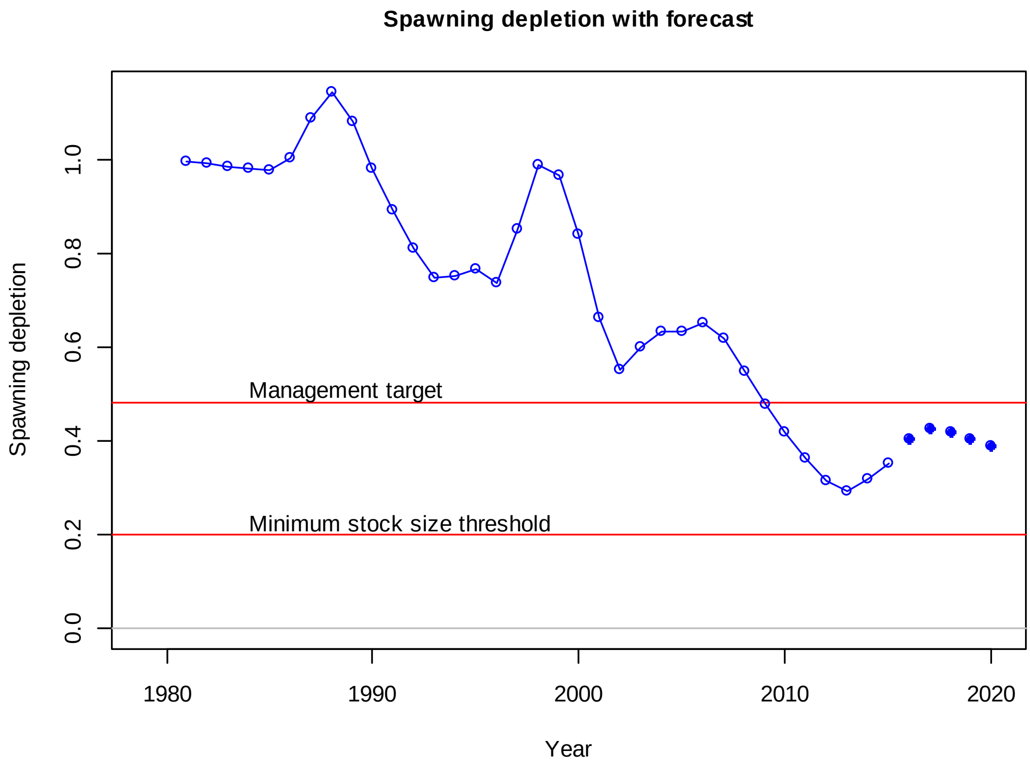


Figure 7.21. The poor (top) and very poor (bottom) recruitment scenario projections of relative spawning biomass with fixed catch of 381t (2014 catch).

7.4.4.3 Additional fixed catch projections to 2020

At the October RAG meeting, some additional fixed catch projections were run for the poor recruitment scenario (recruitment deviations set to -0.576 from 2012-2020), to examine the impact of fixed catches of 1958t, 1206t and 600t. As in the other fixed catch scenarios, with discards being estimated, there are additional removals, and while the forecast catch is set to at 1958t, 1206t and 600t respectively, the actual landed catch is a little higher due to the interaction with discards.

The actual depletion levels resulting from these fixed catches under the poor recruitment scenario are listed in Table 7.13, Table 7.14 and Table 7.15. Note that in all cases, the spawning biomass is projected to increase initially, with a subsequent decline in spawning biomass through to 2020.

Table 7.13. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 1958t.

Year	Catch	Depletion
2015	381	35.2
2016	1960	40.2
2017	1977	37.6
2018	1989	33.0
2019	1990	28.3
2020	1980	24.4

Table 7.14. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 1206t.

Year	Catch	Depletion
2015	381	35.2
2016	1209	40.2
2017	1219	40.3
2018	1225	38.2
2019	1226	35.7
2020	1223	33.6

Table 7.15. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 600t.

Year	Catch	Depletion
2015	381	35.2
2016	601	40.2
2017	605	42.5
2018	608	42.5
2019	609	41.7
2020	608	41.0

7.5 Conclusion

This document presents an updated assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 31 December 2014. A full stock assessment for silver warehou was last performed in 2012 by Day *et al.* (2012) using the stock assessment package Stock Synthesis. Changes from the 2012assessment include: (a) migration to the latest version of Stock Synthesis (SS-V3.24U), (b) updates of all catch, discard, length, age and catch rate data and the last year of estimation of recruitment (2012), two years prior to the last year of data (2014), (c) discarded length frequencies incorporated and discarding being estimated by the model, (d) the single trawl fleet split into east and west fleets, each with its own estimated selectivity pattern and discards (retention function), (e) length frequencies being split into onboard and port collected components (sharing a single selectivity pattern) for each fleet, (f) the retention function has been time blocked, reflecting changes in the discarding practices in the periods 1980-2001 and 2002-2014, (g) inclusion of FIS abundance fleets and (h) weighting length frequencies by shots and trips and (i) adopting new model tuning practices.

The fit to the last two CPUE data points suggest that the model may again be overly optimistic at the end of the time series and that this stock could “break out” again in a relatively short time period. Breaking out occurs when the CPUE trends fall outside of the 95% confidence bounds projected from the stock assessment (Klaer, 2012). The 2014 data point is already very close to the lower 95% confidence bound from the stock assessment without any projection. Additional data will help identify if the initial signs of stronger recruitments in 2010 and 2012 are confirmed or not. The last two recruitment events estimated by the 2012 assessment in 2006 and 2007 were revised downwards with the additional data available in this assessment, so revisions of promising recruitment events towards the end of the recruitment series have occurred in the past.

The continued decline in catches and catch rates indicate considerable concern for this species, and the results of this assessment suggest that it is now below the target biomass, and is only likely to return to this biomass if future recruitment returns to average. Nine out of the last ten years of below average recruitment suggest that relying on average recruitment for the stock to recover may be overly optimistic. Poor future recruitment scenarios illustrate the potential dangers to the stock if the calculated RBC is actually caught, although these impacts are reduced if the current low catch levels are maintained.

Future development of the stock assessment for silver warehou could include a depth structured model, although indications are that the east west split already incorporates most of the variability in depth. Incorporating cohort dependent growth to allow for apparent temporal differences in growth seen in the fits to age-at-length data could also be considered. Length frequency distributions from the FIS could also be a useful additional data source, as the annual variation in both onboard and port length frequency data suggests that this data may not be entirely representative.

This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. In comparison, the last assessment estimated the 2013 depletion to be 47%, with corresponding RBCs of 2,544t, with a long-term yield of 2,618t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020. However, if landed catches continue at levels well below the TAC, then the depletion is likely to remain between 35% and 45% for the next 5 years.

7.6 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller and Miriana Sporcic (CSIRO) pre-processed the data. Athol Whitten provided very useful R code for organising plots and provided the latest version of Stock Synthesis. Malcolm Haddon and Judy Upston are thanked for helpful discussions of this work.

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7.8 Appendix A Base case fits

7A.1 Length fits

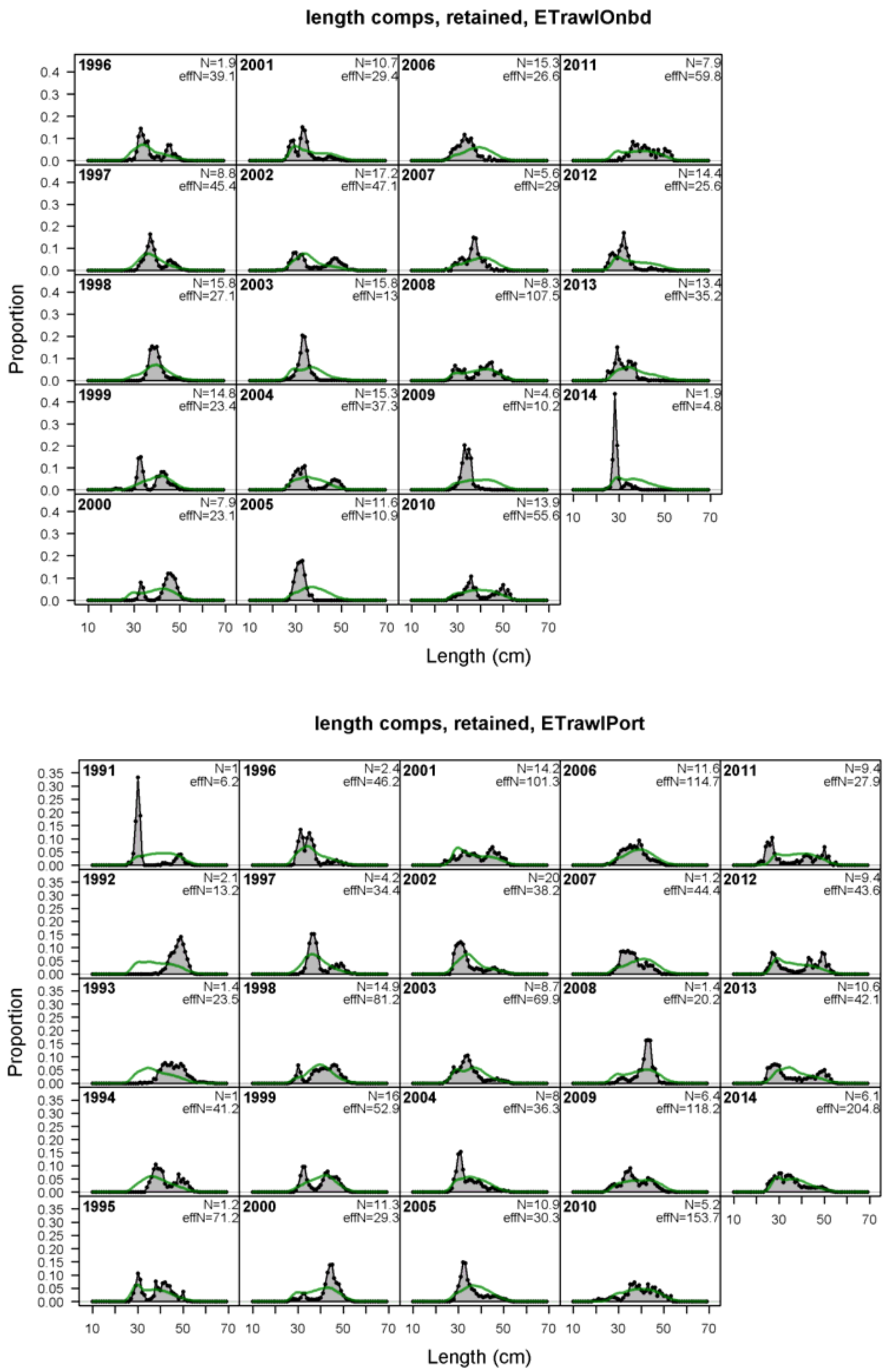
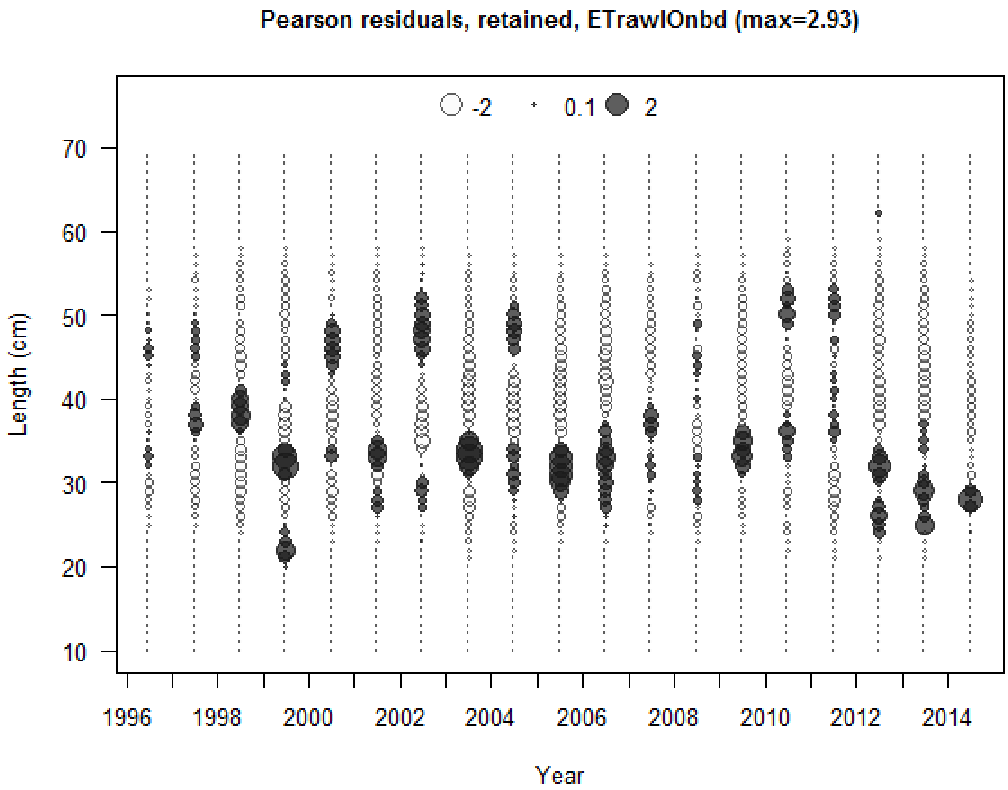


Figure 7A.1 The observed (shaded) and model-predicted (green line) fits to the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



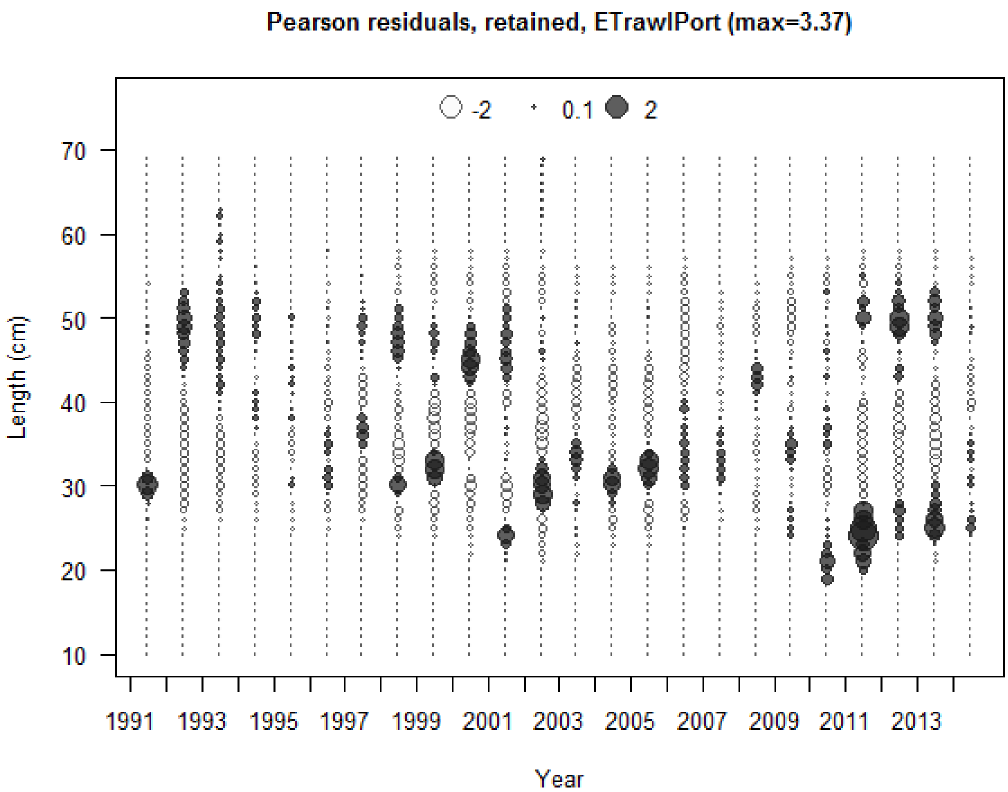
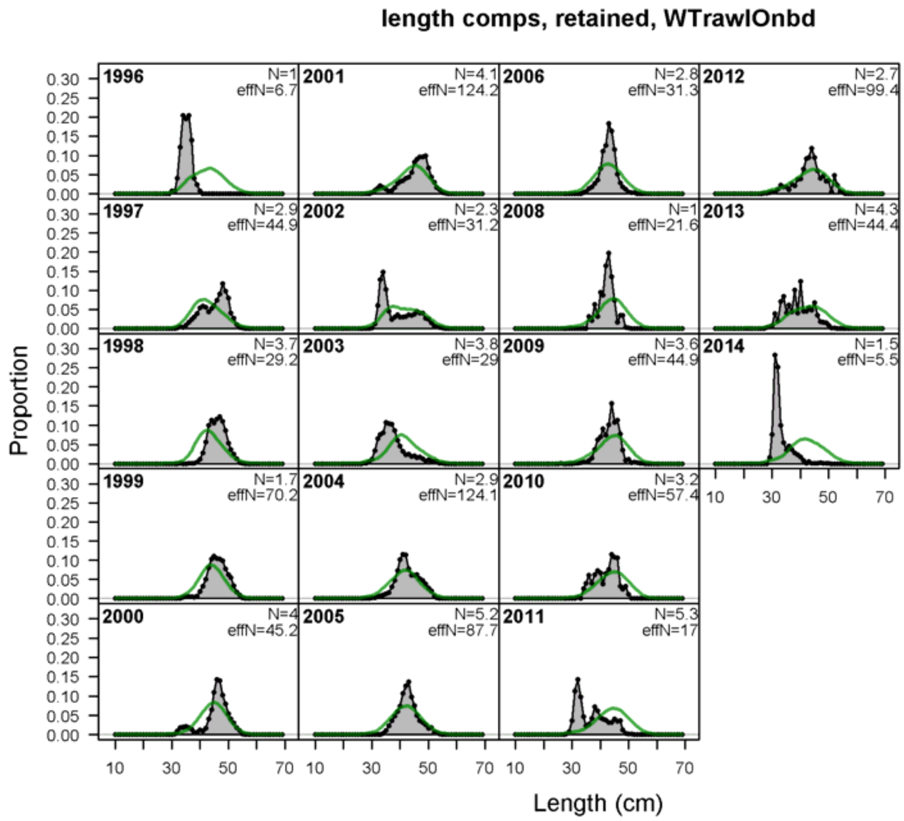


Figure 7A.2 The residual pattern for the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



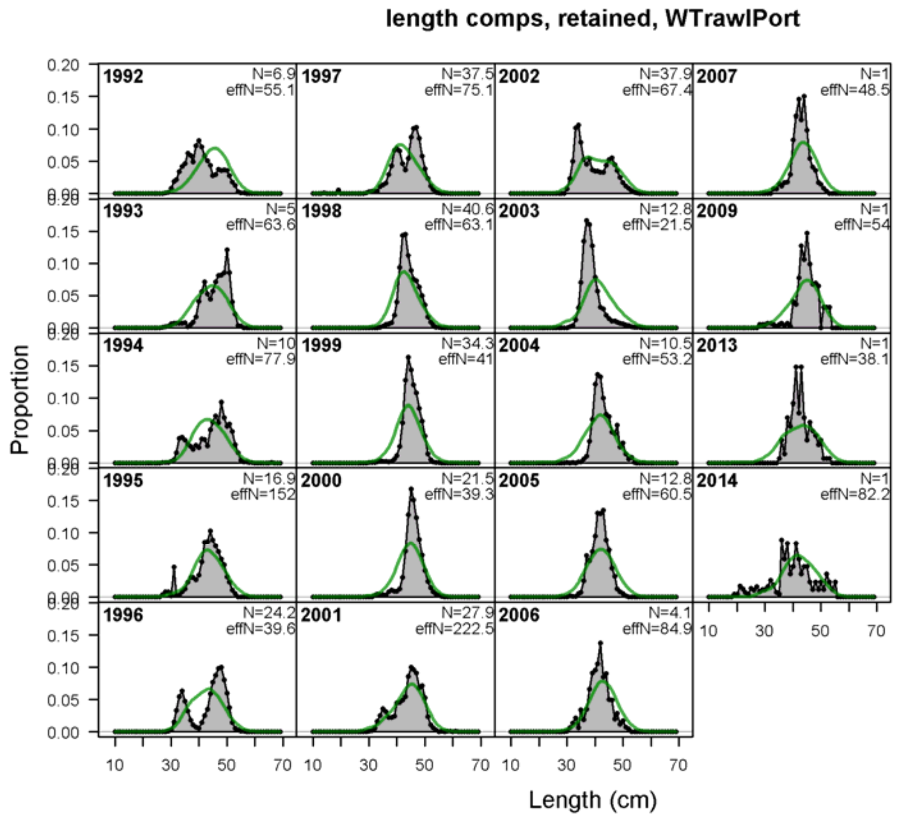


Figure 7A.3 The observed (shaded) and model-predicted (green line) fits to the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).

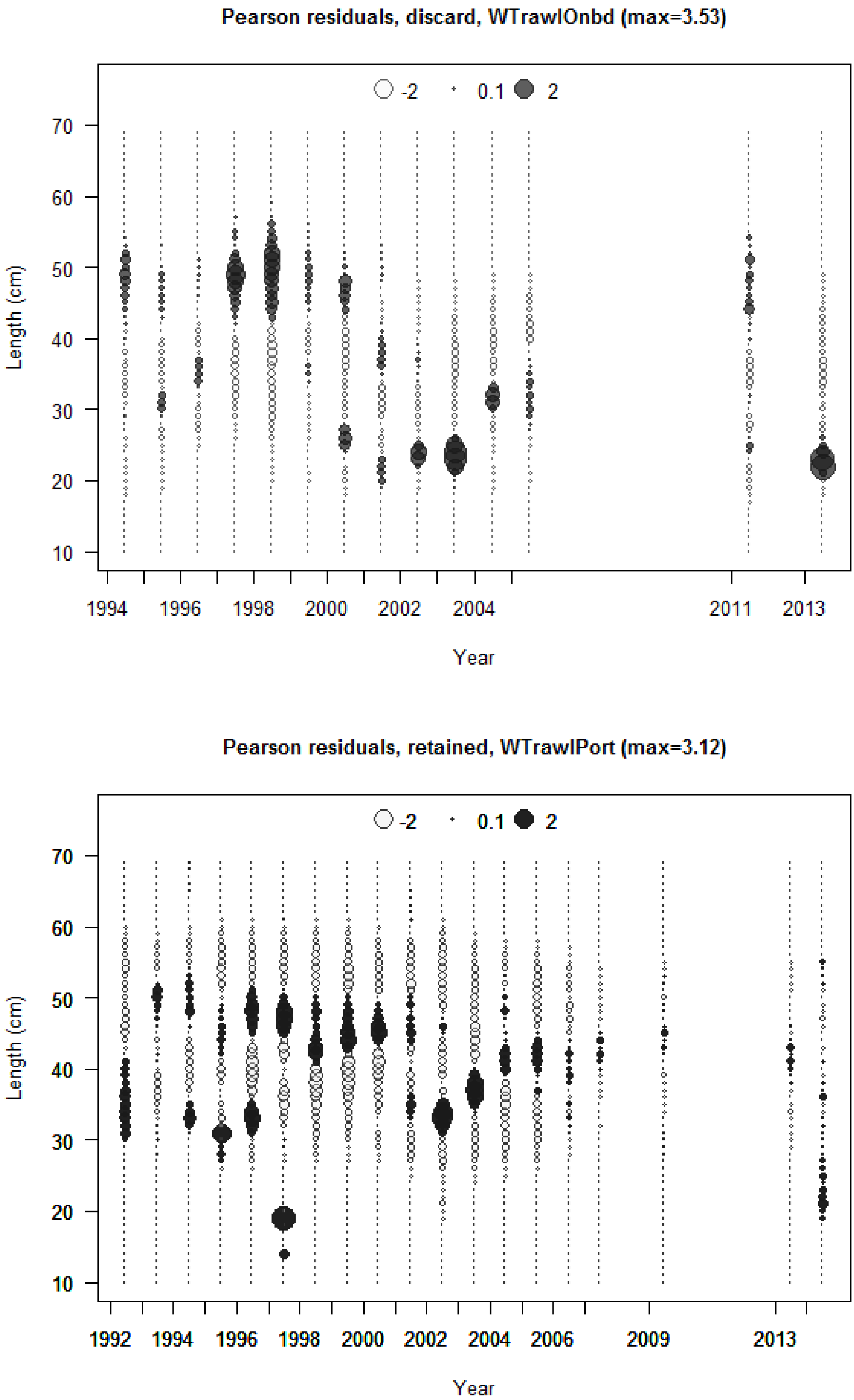


Figure 7A.4 The residual pattern for the retained length composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).

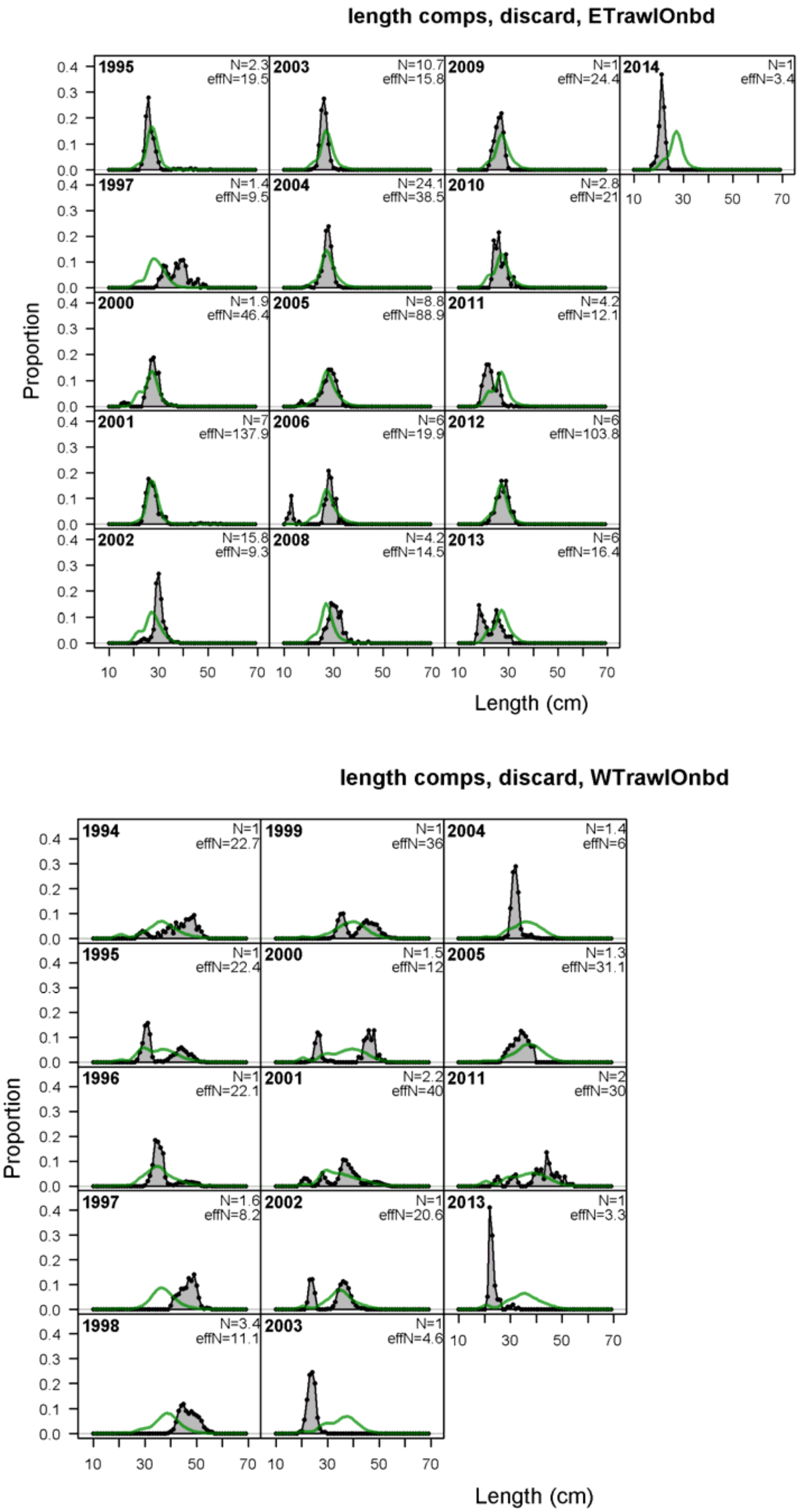
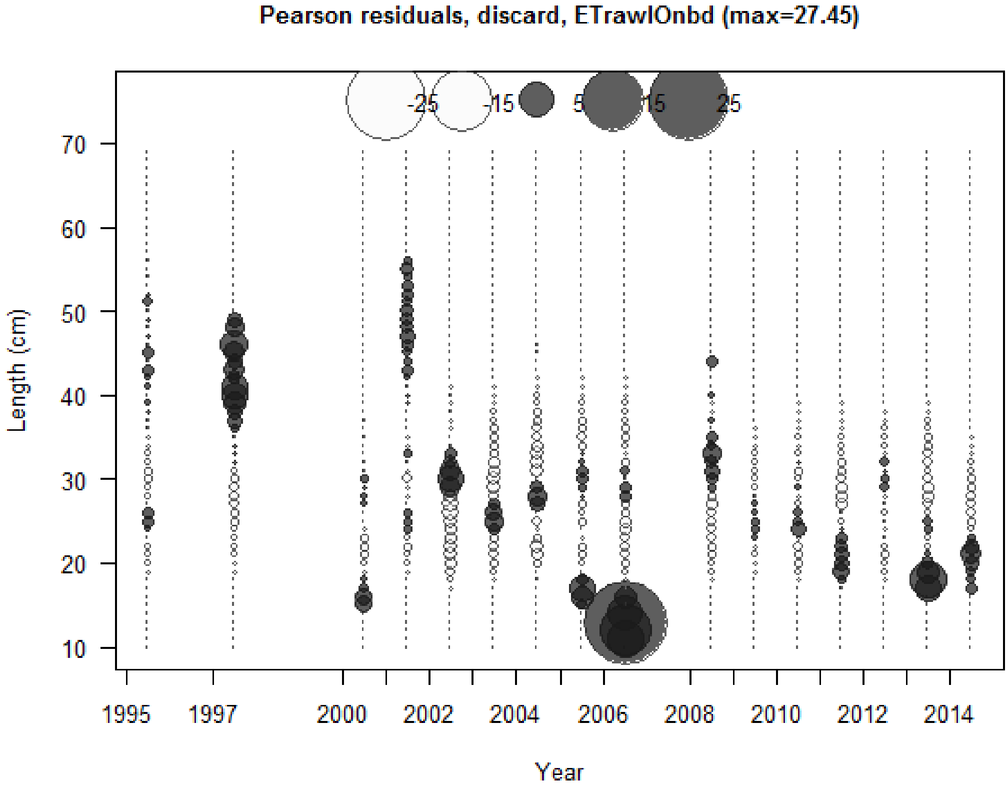


Figure 7A.5 The observed (shaded) and model-predicted (green line) fits to the discarded length composition data for silver warehou for the eastern trawl fleet onboard (top) and western trawl fleet onboard (bottom).



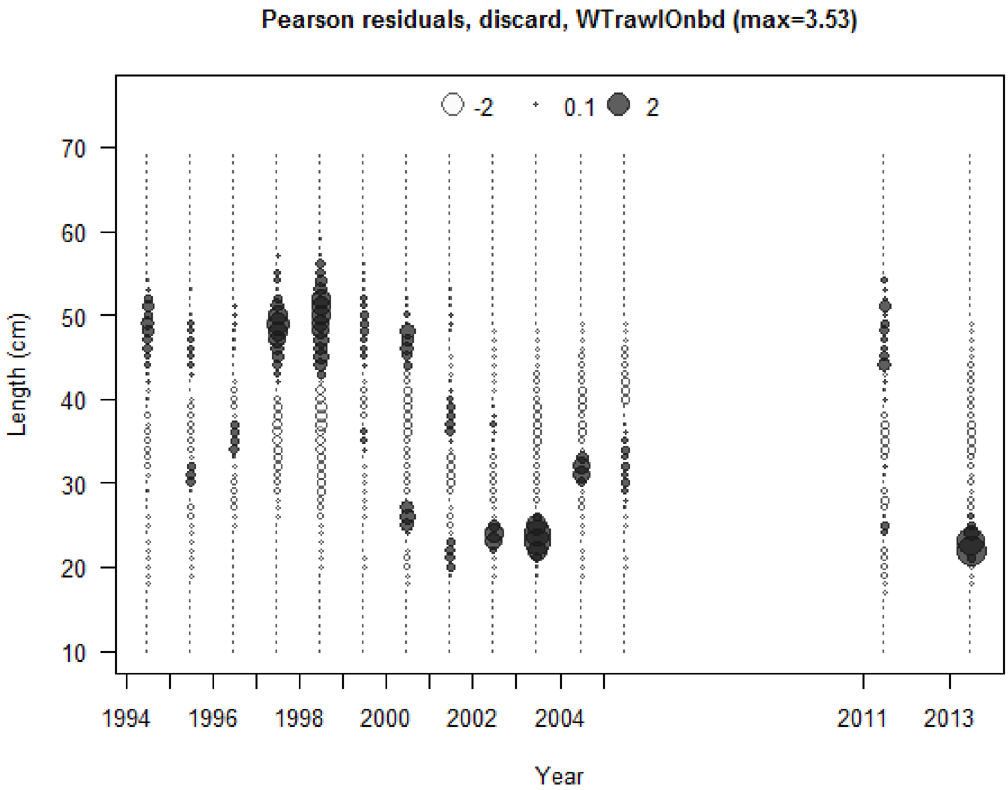


Figure 7A.6 The residual pattern for the discarded length composition data for silver warehou for the eastern trawl fleet onboard (top) and western trawl fleet onboard (bottom).

7A.2 Age fits

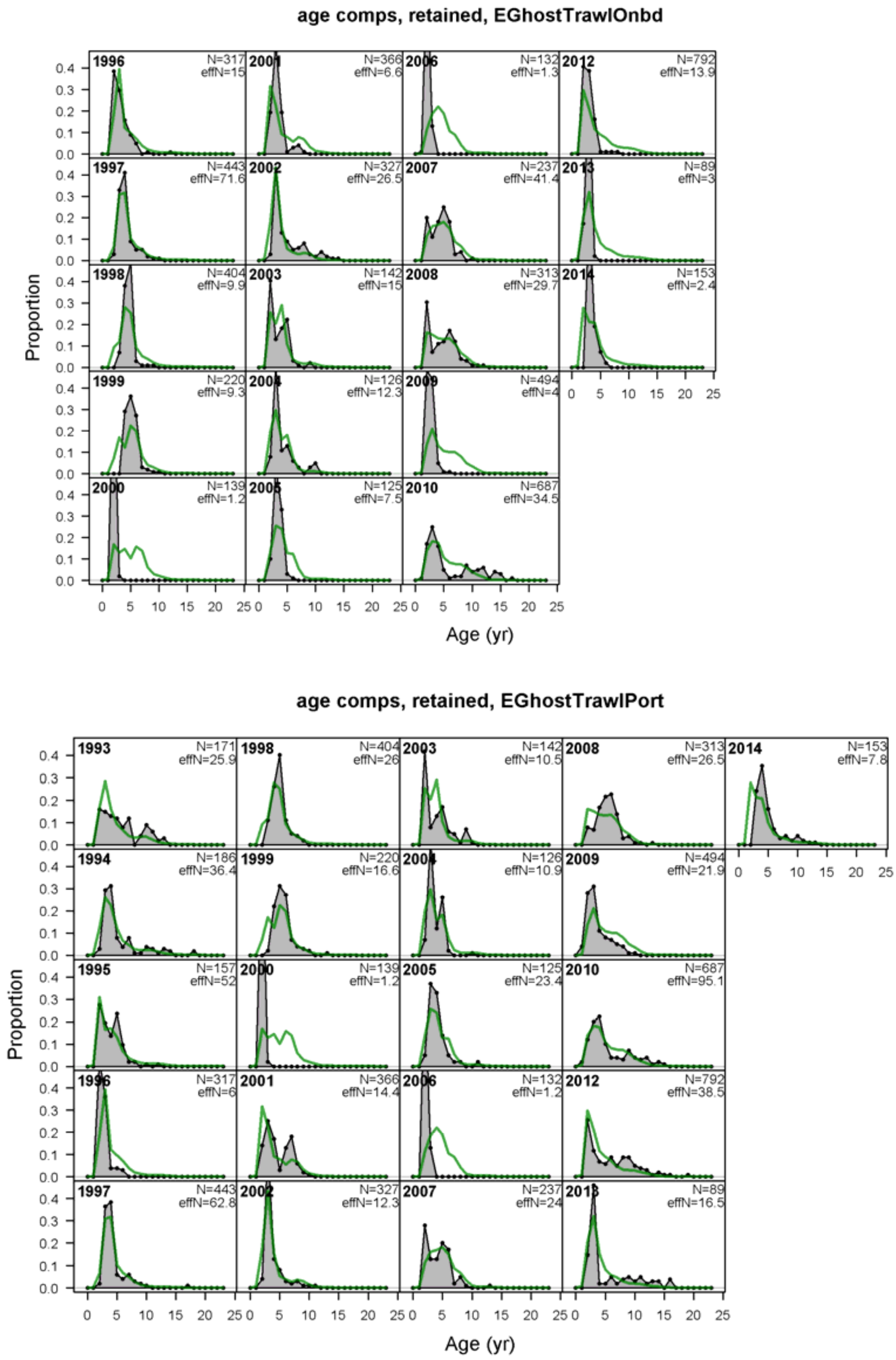
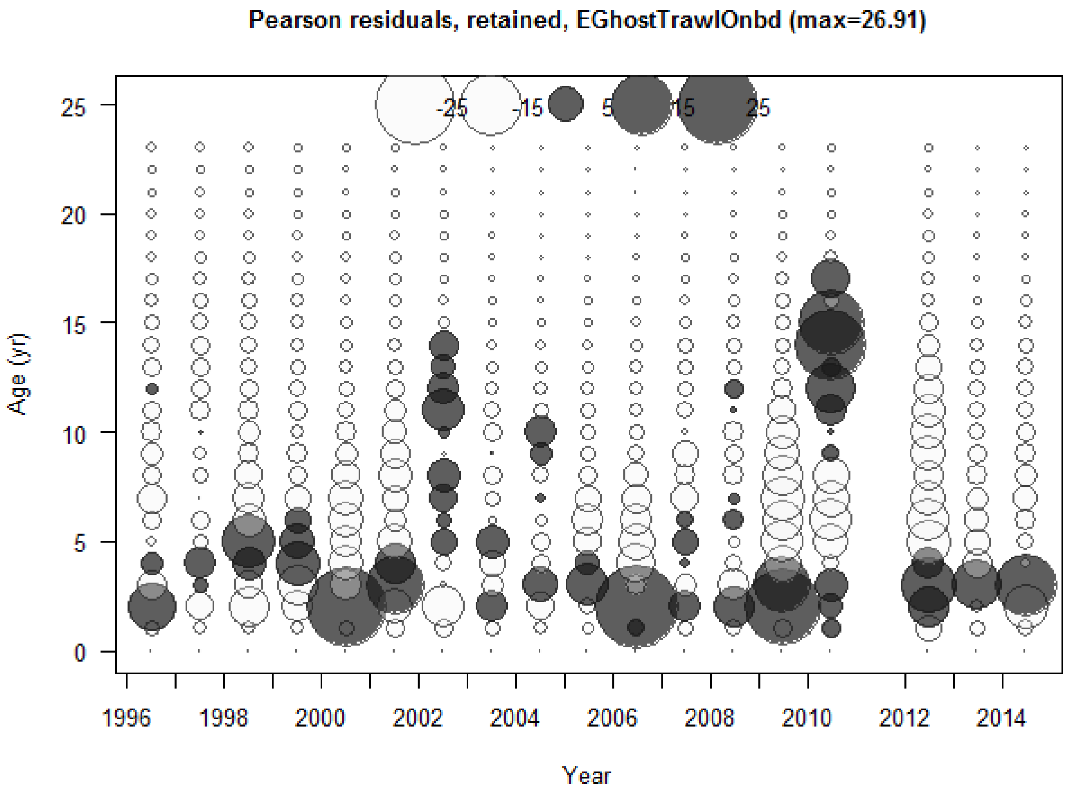


Figure 7A.7 The observed (shaded) and model-predicted (green line) implied fits to the age composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



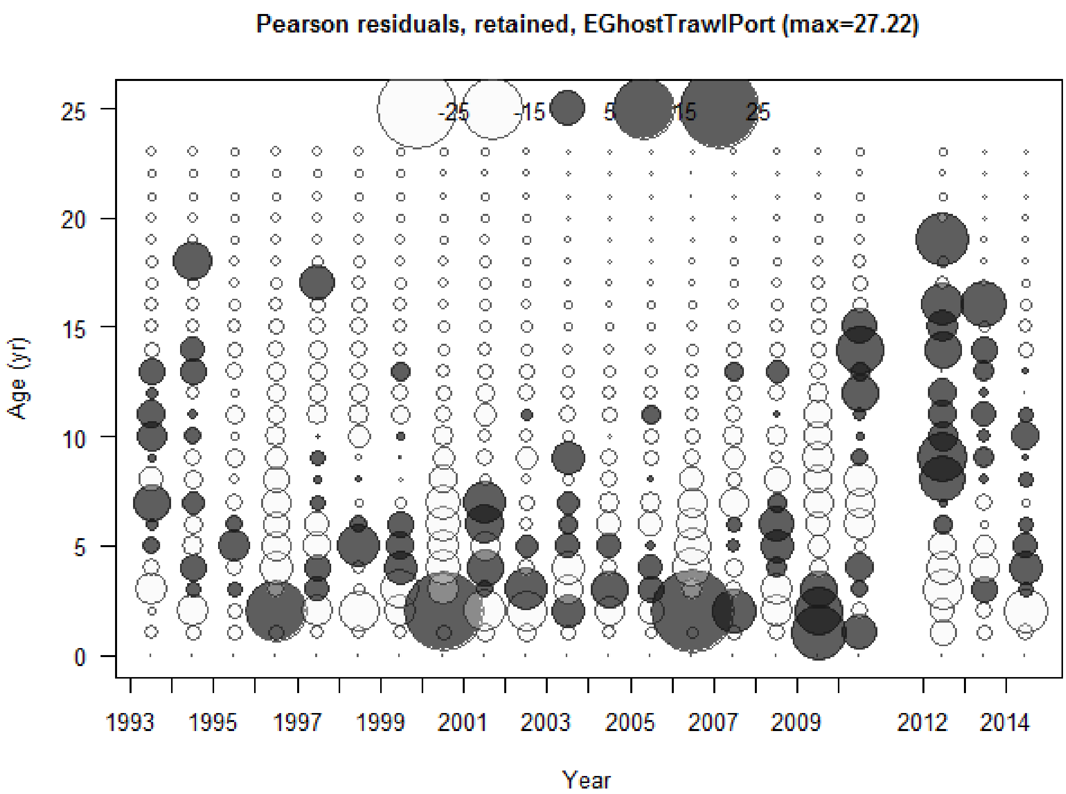


Figure 7A.8 The residual pattern for the age composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).

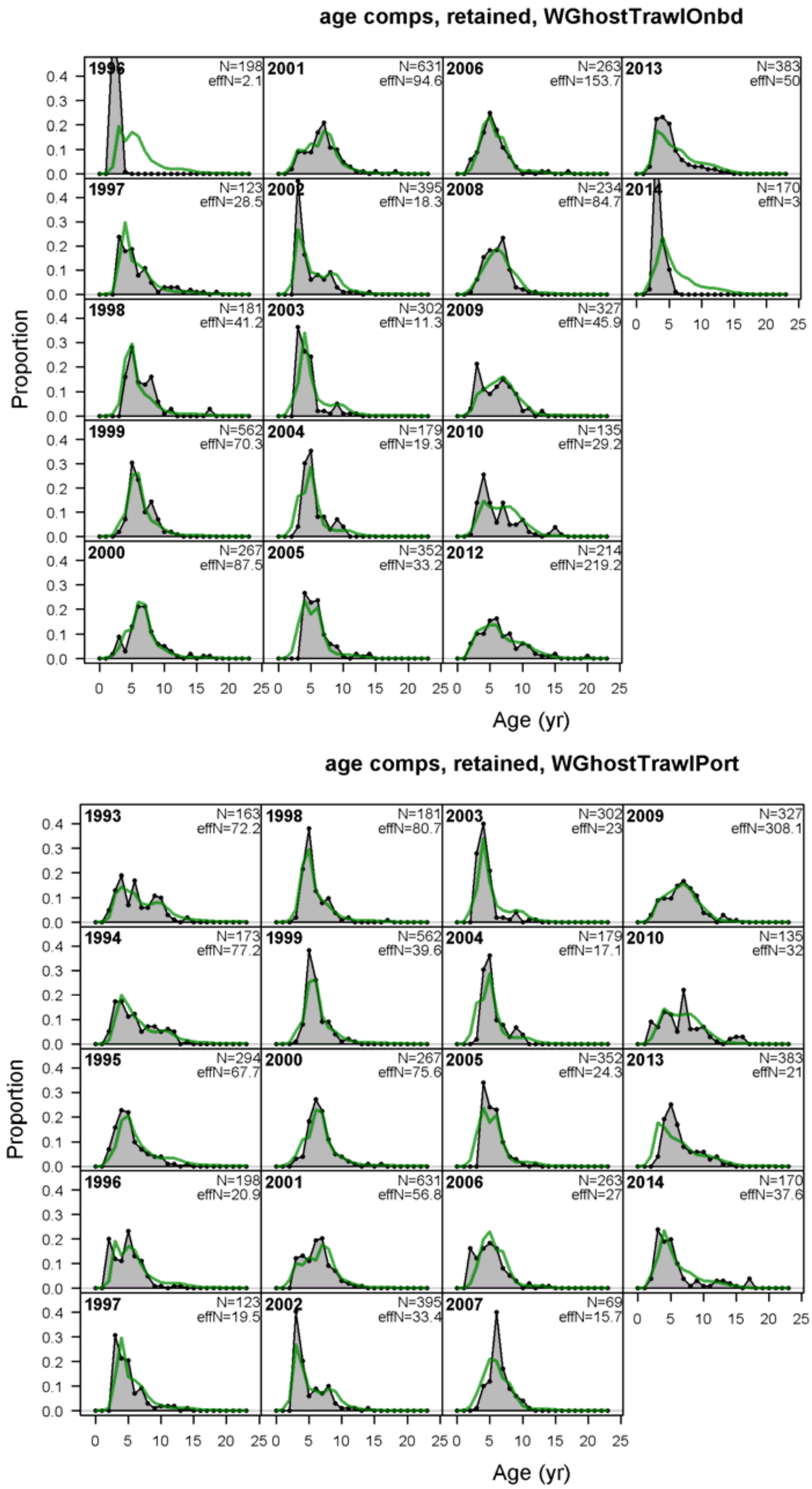
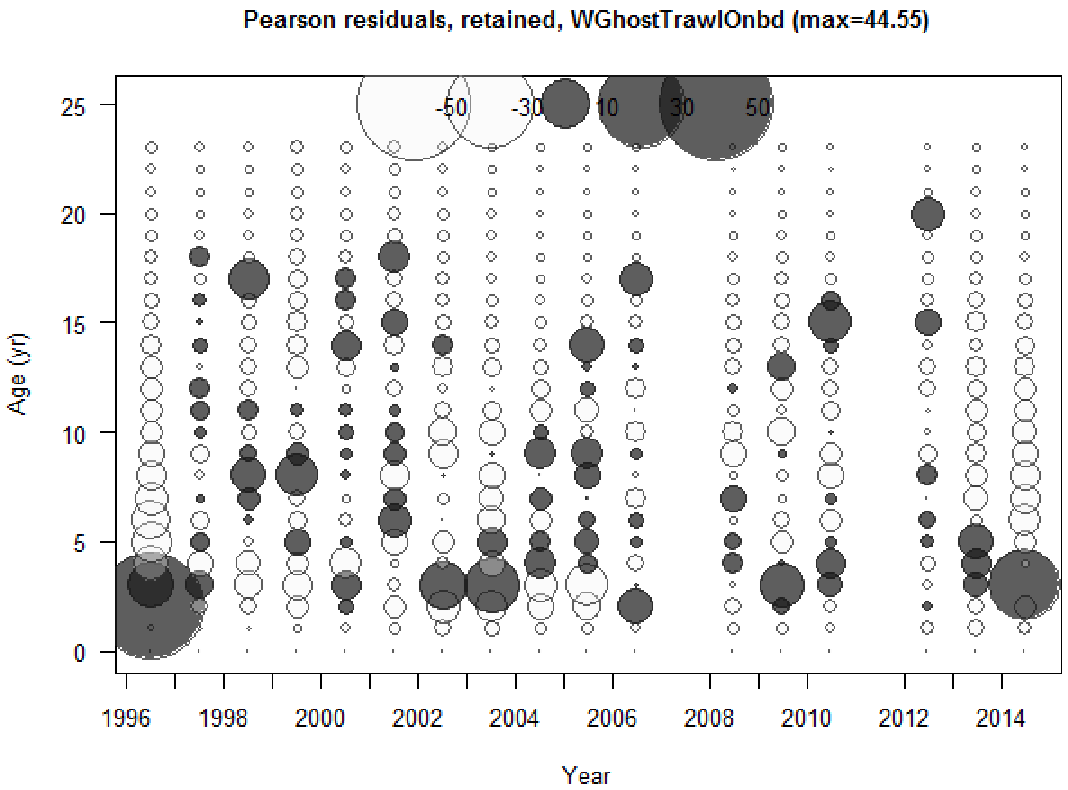


Figure 7A.9 The observed (shaded) and model-predicted (green line) implied fits to the age composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).



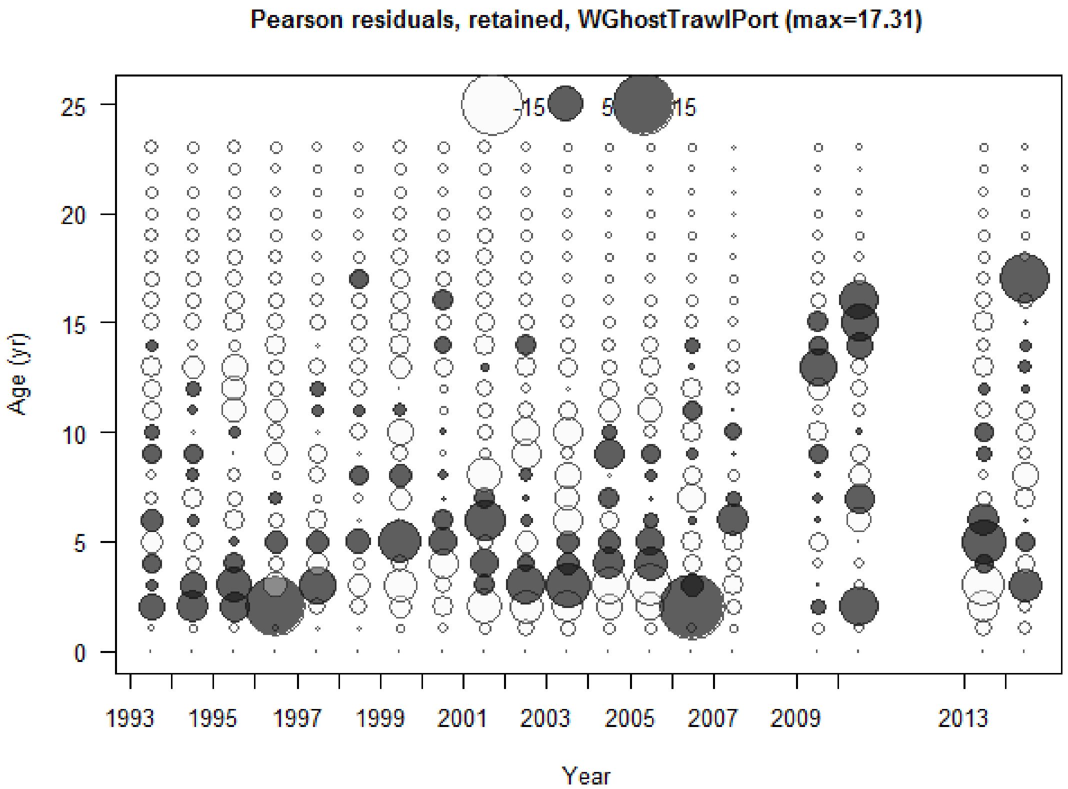


Figure 7A.10 The residual pattern for the age composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).

7A.3 Age-at-length fits

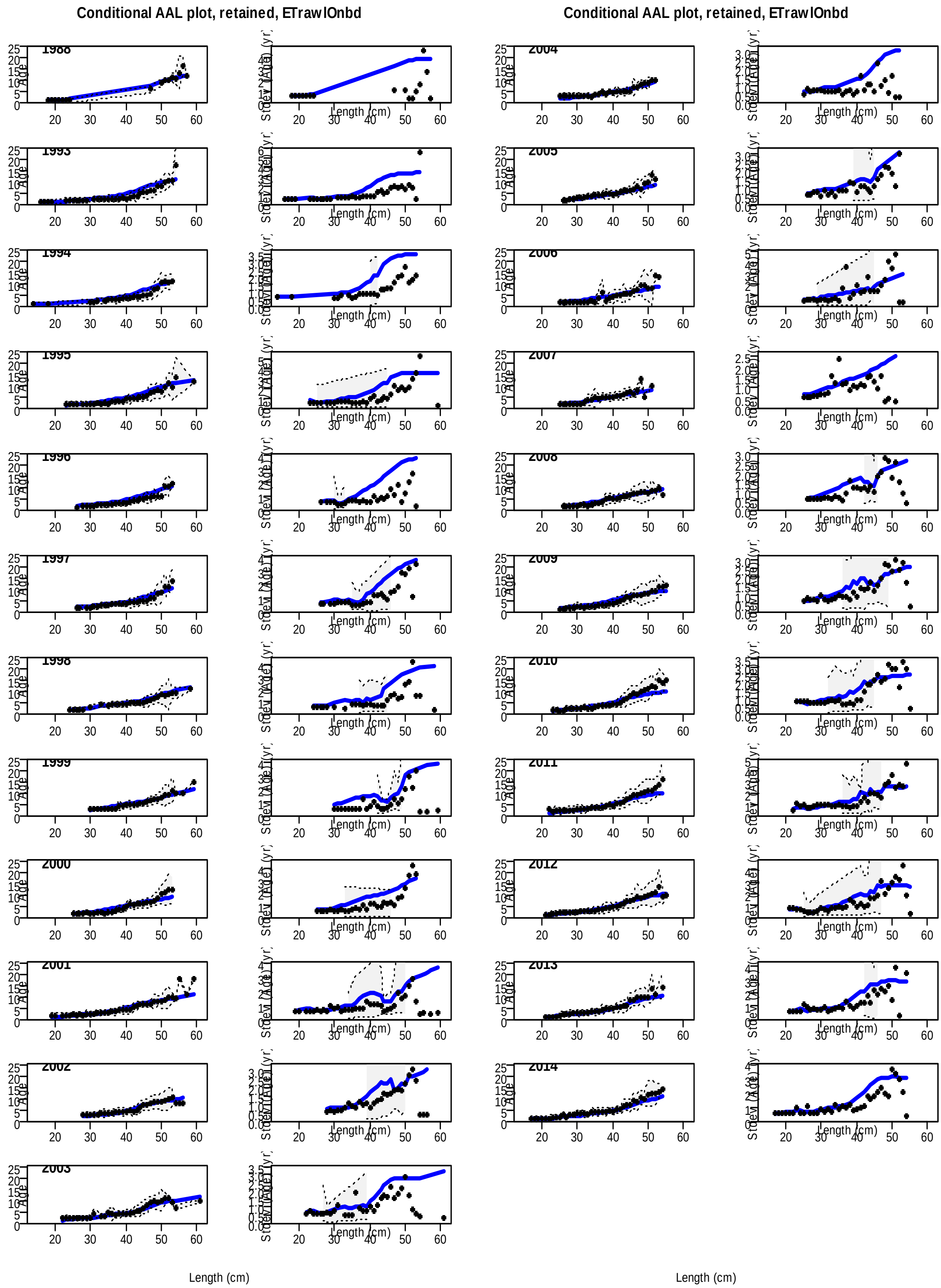
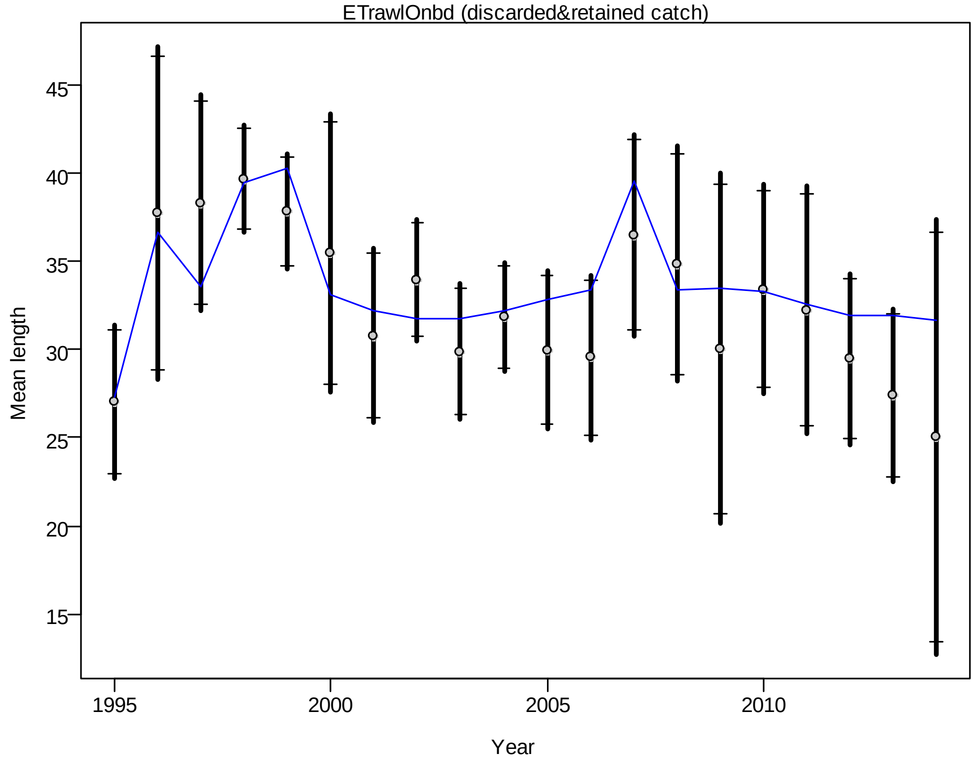


Figure 7A.11 Fits to the conditional age-at-length. Observed in black, expected in blue lines. Second and fourth columns are standard deviations.

7A.4 Length fit diagnostics (Francis mean length fits from method TA1.8)



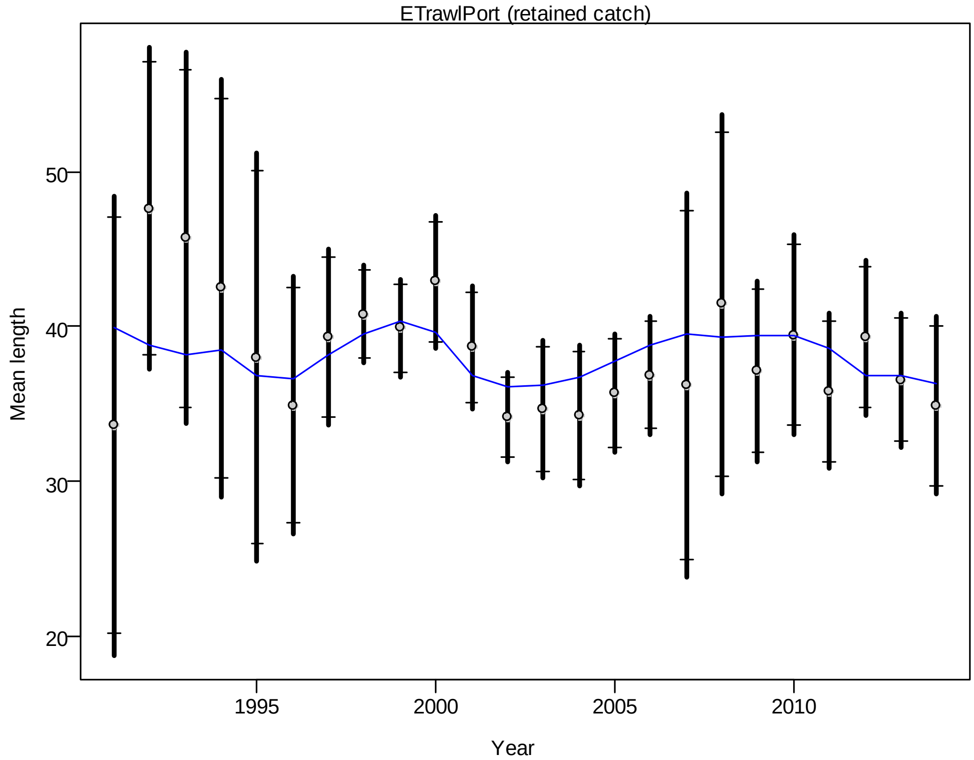


Figure 7A.12 Francis weighting – length fits diagnostics. Eastern trawl fleet onboard (top) and port (bottom).

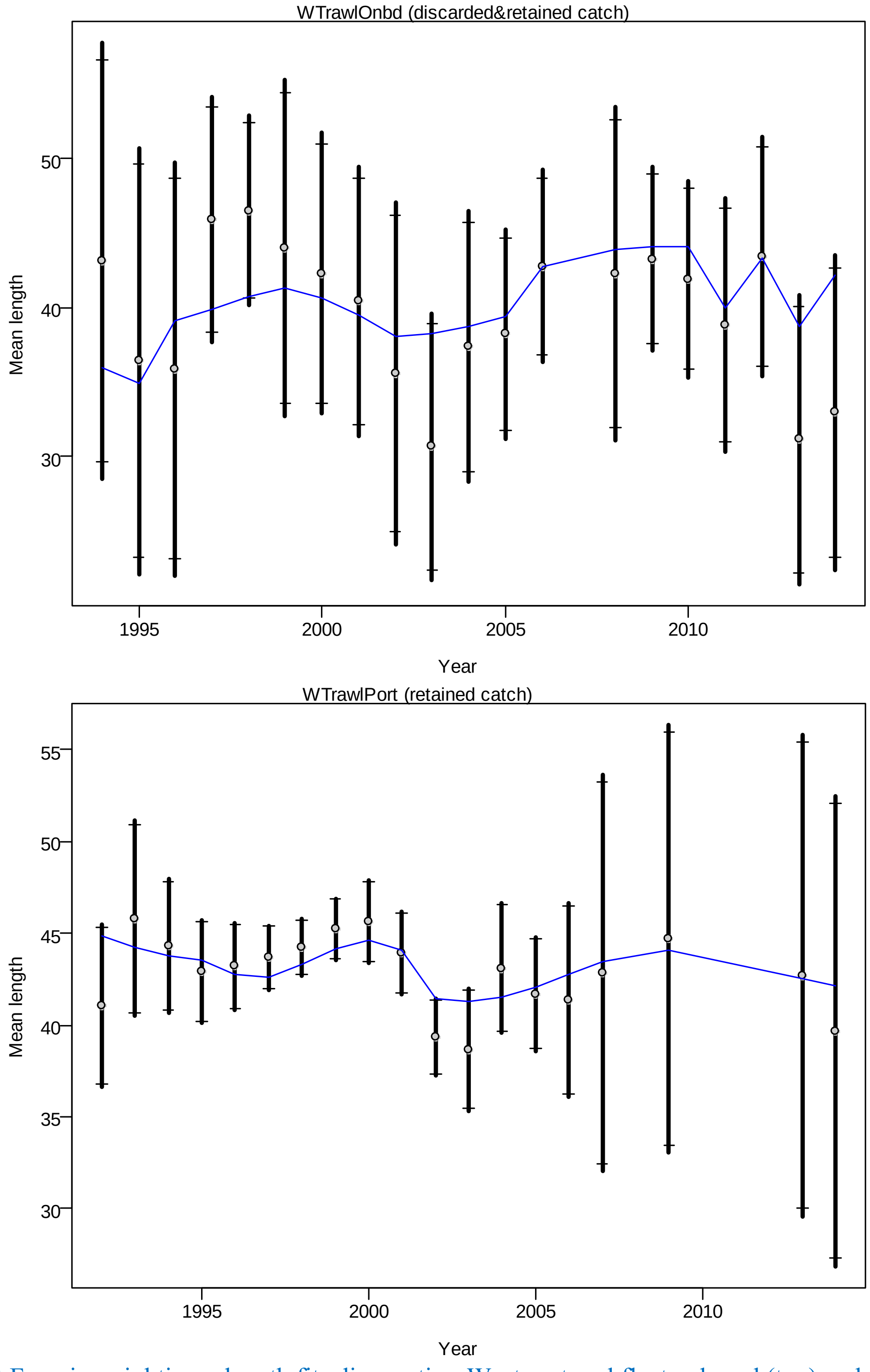


Figure 7A.13 Francis weighting – length fits diagnostics. Western trawl fleet onboard (top) and port (bottom).

7A.5 Age fit diagnostics (Francis mean age fits from method TA1.8)

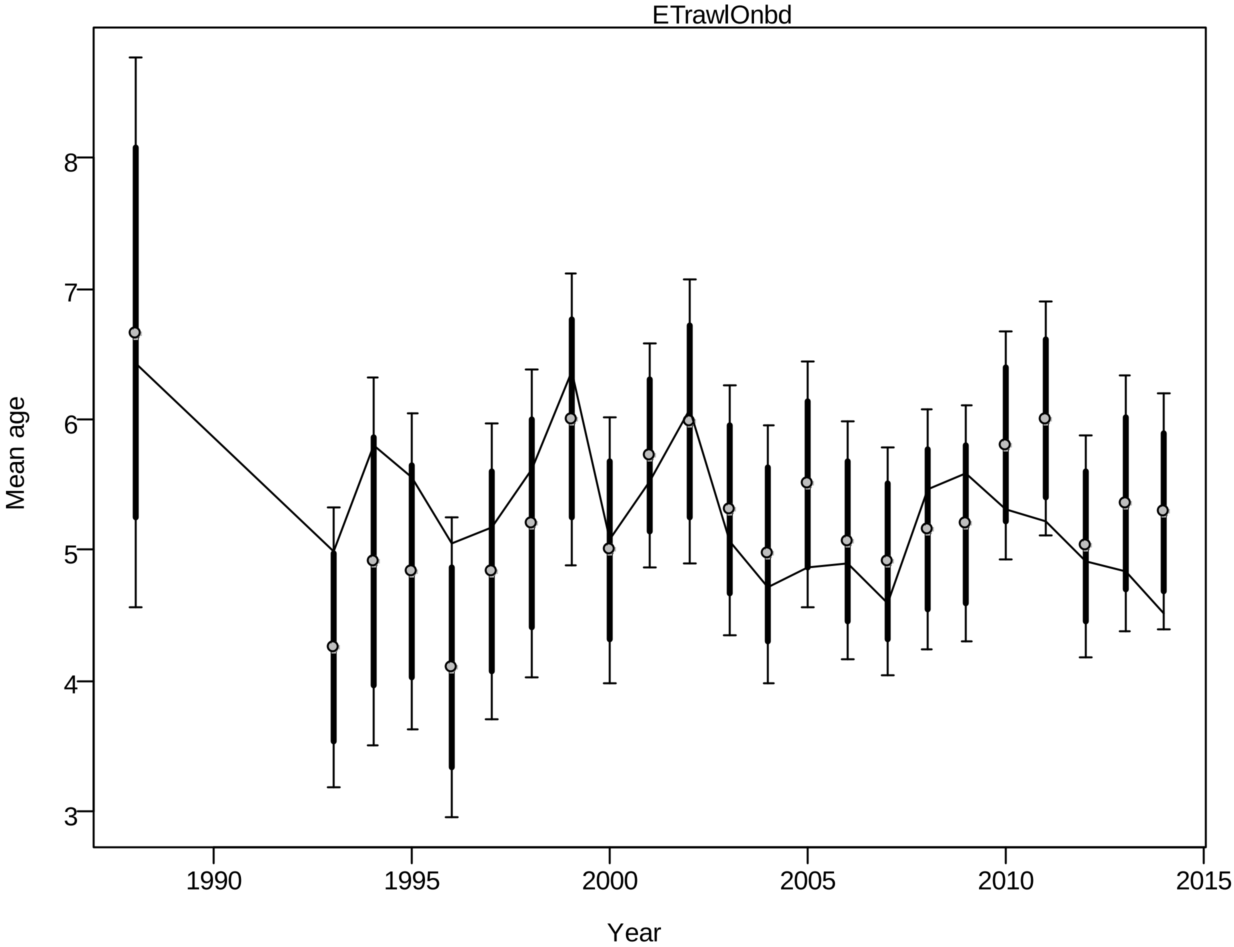


Figure 7A.14 Francis weighting – age fits diagnostics.