Cite as:
Day, J. (2009) School whiting (*Sillago flindersi*) stock assessment based on data up to 2008. pp 190 - 249 *in* Tuck, G.N. (ed.) 2010. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2009*. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 334p.

Tuck, Geoffrey N. (Geoffrey Neil).
Stock assessment for the southern and eastern scalefish and shark fishery: 2009.

ISBN 978-1-921605-65-9

Preferred way to cite this report

Tuck, G.N. (ed.) 2010. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2009. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 334 p.

Acknowledgements

All authors wish to thank the science, management and industry members of the slope, shelf, deepwater, GAB and shark resource assessment groups for their contributions to the work presented in this report. Authors also acknowledge support from Fish Ageing Services (for fish ageing data) and AFMA (for the on-board and port length-frequencies, and in particular John Garvey, for the log book data). Leonie Wyld and Louise Bell are also greatly thanked for their assistance with the production of this report and Tim Ryan and Bruce Barker for the cover photographs of SESSF fish.

Cover photographs

Front cover, blue grenadier and orange roughy.

Report structure

Part 1 of this report describes the Tier 1 assessments of 2009. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2009.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2009

Part 1: Tier 1 assessments

G.N. Tuck
August 2010
Report 2008/872

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2009 Part 1

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11. School whiting (*Sillago flindersi*) stock assessment based on data up to 2008[6]

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11.1 Summary

This document presents an assessment of school whiting (*Sillago flindersi*) in the SESSF using data up to 31 December 2008. This is an update to the previous stock assessment for school whiting (Day 2008b) which used data from 1947 through until 2007. Changes from the 2008 assessment include: (a) revised historical catch, length and age data for the period 1994-2007, (b) the addition of updated length frequencies, catches and catch-rates for data collected in 2008, (c) the estimation of recruitment up to 3 years before the most recent data and (d) the estimation of the natural mortality parameter, *M*.

The updated base-case assessment estimates that the 2010 spawning stock biomass is 50% of unfished stock biomass, which is just above the target biomass. Fits to the length, age, and catch-rate data are reasonable. Exploration of model sensitivity shows that the model outputs are most sensitive to the last year that recruitment is estimated and are also sensitive to the length at 50% maturity.

The RBC for the updated base-case model for 2009 is 1,723t under the 20:35:48 harvest control rule, while the long-term yields under this harvest control rules is 1,660 t.

Depletion across all sensitivities varied between 41% (when recruitment is only estimated to 2004) and 77% (when recruitment is estimated to 2006). If the final year of recruitment estimates is fixed at 2005, the values of depletion estimated range from 40% (50% maturity at 14 cm) and 58% (50% maturity at 18 cm). While the model is very sensitive to the last year that recruitment is estimated, there are strong arguments to set this final recruitment date at 2005, as used for the base case.

The major changes to the assessment are due to: recruitment estimation to three years before the most recent data used in the assessment; the updates and revisions to the data used in the assessment from 1994-2007; the new 2008 data; and estimating the natural mortality parameter, *M*.

This report examines the impact of revised historical data from 1994-2008 on the 2008 base case, performing forward retrospectives starting from the 2008 base case. These forward retrospectives showed that these revisions resulted in a reduction in the estimate of 2009 spawning biomass, although inclusion of the 2008 data, including the 2008 catch data, increased this estimate of 2009 spawning biomass. Backward retrospectives

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[6] Paper presented to the Shelf Resource Assessment Group on 9-10 November, 2009

suggest that there is some conflict between the 2007 and 2008 non-catch data sets, with the 2007 data supporting a higher spawning biomass and the 2008 non catch data supporting a lower spawning biomass.

The 2009 base case estimates a strong recruitment event in 2005, the last year in which recruitment is estimated. However this recruitment should be treated with some caution as there is some uncertainty about this estimate. The use of data collected from 2009 onwards in any future assessment will reduce the uncertainty of this recruitment estimate and may result in revisions to the estimates of the 2005 recruitment event and the 2010 biomass.

School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very rapid impact on the fish stock. As a result there will always be some uncertainty about the status of the stock. Further exploration of some biological parameters, such as age and length at maturity may help reduce this uncertainty, but the high mortality rate and short expected life time for this species mean that rapid changes are always possible and projections will always be subject to uncertainty relating to the most recent recruitment events, which may be poorly informed until the cohorts involved fully enter the fishery.

11.2 Introduction

11.2.1 The fishery

School whiting (*Sillago flindersi*) occur in the eastern regions of the SESSF and Bass Strait (zones 10, 20, 30 and 60) and are commonly found on sandy substrates to depths of about 60m. School whiting are benthic feeders and they mainly spawn during summer. They grow rapidly, reach a maximum age of about six years and become sexually mature at about two years of age.

In the SESSF full recruitment to the fishery occurs at around three years of age. Selectivity of 50% is only achieved for three year old fish for the Danish seine fishery and for four year olds for the otter trawl fishery. Selectivity for two year olds is less than 20% and for one year olds is less than 2%. The majority of the catch from 1947-1995 has been taken using Danish seine (mainly in zone 60 of the SESSF - Bass Strait) although the fraction of the catch taken by otter trawl has increased recently, and has averaged more than 65% of the total catch since 1998. In contrast to the Danish seine catches, catches by otter trawl occur predominantly in SESSF zone 10, with most of this catch taken by state registered trawlers. Much of the school whiting caught by the Lakes Entrance Danish seine fleet since 1993 has been sent to an export market, although issues with quality of whiting caught in the summer months have reduced catches for the export market during this time.

Annual catches (landings and discards) of school whiting used in the 2009 preliminary assessment are shown in Table 11.1 and also in Figure 11.1 and Figure 11.2 (separated by fleet) and in Figure 11.3 (separated by jurisdiction). Large catches of school whiting were first taken in the 1980’s (Smith, 1994) and catches increased to over 2,000 t in 1986. Catches have remained over 1,200t since then, with over 1,600 t caught in 2007 (including discards). Discard percentages are variable and appear market driven. From 1986-1996, more than 50% of the catch was taken by Commonwealth registered vessels. Catches of school whiting taken by state registered vessels have comprised more than 50% of the total catch for every year since 1997 (Figure 11.3).

The TAC for calendar years 2005 and 2006 was 1,500 t and in 2007 this was reduced to 750t, maintained at 750t in 2008 and increased to 1125t in 2009. The landed catches were 1,463t in 2004, 1,469t in 2005, 1,551t in 2006, 1,636t in 2007 and 1,303t caught in 2008, with an average of nearly 70% of this catch from state waters in this five year period. The state catches were 1001t in 2004, 1008t in 2005 and 1,080t in 2006, 1,125t in 2007 and 852t in 2008 with an average of over 900 t of state catch over the last 10 years.

11.2.2 Stock structure

School whiting is assumed to be a single stock off the east coast of Australia and in Bass Strait, which is largely encompassed by the SESSF but does continue further north above Barrenjoey Point to Ballina. Stout whiting (*Sillago robusta*) is caught off northern New South Wales and the range of these two species overlaps between Ballina and Clarence River, with the northern limit for school whiting at Ballina. NSW catches of stout whiting and school whiting were split equally between the two whiting species in this region where they both occur.

11.2.3 Previous assessments

A full stock assessment for school whiting was last performed in 2008 using data up to 2007 (Day 2008b). This assessment was an update of the 2007 assessment (Day 2007), which in turn extended earlier assessments of school whiting, including a partial stock assessment for school whiting (Cui *et al.* 2004) using data from 1991 through until 2003 and an even earlier assessment (Punt 1999). Given a lack of reliable age- and length-composition data, the 2004 assessment just used data from the Commonwealth logbook, and ignored catches taken under state jurisdictions and all catches before 1991. As a result, Cui *et al.* (2004) were only able to give information about biomass levels relative to 1991. Cui *et al.* (2004) looked at the probabilities of falling below the 1991 spawning biomass and half the 1991 spawning biomass for 5 different levels of future catch and predicted large recruitments in 2002 and 2003, albeit with high uncertainty. As a result the 2003 estimate of spawning biomass was higher than the 1991 spawning biomass, but was also highly uncertain.

The 2007 stock assessment (Day 2007) used much more data than the earlier assessments, including catch data from 1947-2006, conditional age-at-length data, length data, discards, ageing error and estimated the growth parameters within the assessment. This assessment estimated a 2008 spawning stock biomass of 35% of unfished stock biomass, but warned that there was some uncertainty about the status of the stock and that with a short lived species this estimate is sensitive to estimates of recruitment.

The 2008 stock assessment (Day 2008b) incorporated additional data for 2007 and also incorporated a number of revisions to both sample sizes and the distributions of length frequencies for the Danish seine and the otter trawl fleets in the period 1994-2006, due to improvements in the data extraction process. This assessment estimated a 2009 spawning stock biomass of 82% of unfished stock biomass, and again warned that there was some uncertainty about the status of the stock and that with a short lived species this estimate is sensitive to estimates of recruitment. The 2008 assessment showed that six of the last seven estimated recruitment events were above average and warned that "if these recent strong recruitment events are not supported by future data, the evidence for a recent strong recovery in the stock may need to be moderated".

11.2.4 Modifications to the previous assessments

The modifications to the 2008 assessment largely relate to updates to the data input to the assessment, but also include the estimation of natural mortality, *M*, which was unable to be estimated in the previous assessment. New catch, length and conditional age-at-length data is available from 2008. In addition to this new data for 2008, there is a new standardised CPUE series and there are new estimates for ageing error, with separate error estimates for whole and sectioned otolith readings. Like the 2008 assessment, the 2009 assessment uses the package Stock Synthesis (version SS-V3.03a, Methot 2009) and updates the 2008 assessment with new data. To avoid very large spurious recruitments at the end of the recruitment time series, recruitment was only estimated up to three years before the most recent available data used in this assessment, compared to the cut off of two years before the most recent data in the previous assessment.

11.2.4.1 Data-related issues

a) Port-based length-frequency data up to 2008 have been included in the assessment.
b) The catch-rate time series has been calculated for the Victorian Danish seine fleet (Haddon, 2009).
c) State catches have been added to catches from the appropriate fleets with an additional 331t of catch added to the 2007 NSW state catch.
d) Age-reading error (Table 11.2 and Table 11.3) has been accounted for when fitting to the conditional age-at-length data, with separate age-reading errors for whole and sectioned otoliths.
e) Catch, discard, length-composition, age-at-length, and catch rate data have been added for 2008.
f) Minor updates to the allocation of the Commonwealth catch have been made with a total of around 130t of catch moved from the Victorian Danish seine fleet to the otter trawl fleet in the period 1994-2007 with the biggest changes from 2000-2002.
g) Updates to discard, length-composition and age-at-length data have been incorporated for the period 1994-2007. Updates were made to the 2006 and 2007 Danish seine conditional age-at-length data and to the 2006 otter trawl conditional age-at-length data. For the Danish seine fleet, there were minor changes to the retained length frequency sample sizes and distributions in 1994 and 2002, minor changes to the distributions in 2000 and 2001, and an additional 1467 samples for the length frequency distribution in 2007 (leading to more than double the number of samples and a change to the distribution). For the retained length frequencies from the otter trawl fleet there were minor changes to the distribution in 1999 and there were an additional 285 samples in 2007 (leading to a 30% increase in the number of samples and a change to the distribution). New discard length frequency distributions were obtained for the Danish seine fleet in 1994, with changes to the discarded length frequency sample sizes and distributions for the Danish seine fleet in 1999 and 2001. New

discarded length frequency sample sizes and distributions were obtained for the otter trawl fleet in 2001, 2003, 2004 and 2005 with minor changes to the distributions in 1997 and 2002.

11.2.4.2 Model-related issues

a) Three growth parameters (L_{min}, L_{max} and cv_L) are estimated within the model, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths. The fourth growth curve parameter, *K*, had to be fixed to get a reasonable growth curve and to avoid very high correlations between *K* and L_{max}.
b) Natural mortality, *M*, is now estimated within the model.
c) Estimation of recruitment residuals has been limited to those cohorts for which length-composition data are available and estimated only until 2005, three years before the most recent available data.

11.3 Methods

11.3.1 The data and model inputs

11.3.1.1 Biological parameters

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

As with the 2008 assessment, age-at-length data was used as an input, and three of the four parameters of the von Bertalanffy growth equation were estimated within the model fitting procedure. This is more appropriate than pre-specifying these values because it accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

Previous work has suggested a range of values for the mortality parameter *M*, for school whiting ranging from 0.37 (Bax and Knuckey, 2001), 0.5 (Klaer and Thomson 2006), and 0.9 (Cui *et al.* (2004), Punt *et al.* (2005)). A sensitivity analysis across a range of values of *M* was conducted in the 2007 assessment (Day 2007) and used to construct a likelihood profile for *M*. This resulted in selecting *M*=0.6 for the base case in 2007 and this same value was used for the base case for the 2008 assessment. For the 2009 assessment, *M* was able to be estimated within the model. The base-case value for the steepness of the stock-recruitment relationship, *h*, is 0.75.

School whiting become sexually mature at a length of about 16 cm, when the fish are around two years of age. Fecundity is assumed to be proportional to spawning biomass. The parameters of the length-weight relationship are obtained from Klaer and Thomson (2006) ($a=1.32 \times 10^{-5}$, $b=2.93$).

11.3.1.2 Fleets

As was the case in the 2008 assessment, this assessment for school whiting is based on three fleets: two Danish seine fleets (with NSW and Victorian fleets treated separately) and a single otter trawl fleet. Time-invariant logistic selectivity is assumed for all three fleets.

1. Victorian Danish seine – Danish seine based around Lakes Entrance in eastern Victoria and Bass Strait and Eastern Tasmania (1947 – 2008). Length frequency data are available for this fleet from Victorian Fisheries in 1991 and from ISMP records in the years 1994-2008.

2. Otter trawl – otter trawlers from NSW, eastern Victoria and Bass Strait (1947 – 2008). Length frequency data are available for this fleet for two years from the Sydney fish market, 1983 and 1988, and from ISMP records from 1997-2008. In addition there are length frequency data from 1971 and 1974 for otter trawl from the northern limit of the school whiting range.

3. NSW Danish seine – Danish seine fleet operating in state waters in NSW (1957 – 1994). Length frequency data are available for this fleet from the Sydney fish market from 1983 -1989.

11.3.1.3 Landed catches

The model uses a calendar year for all catch data. Landings data came from a number of sources. Early Victorian school whiting catches are available from 1947-1978 (Wankowski, 1983) and later Victorian state catches, from 1979-2006, were provided by Matt Koopman. Information enabling these Victorian state catches to be separated by fleet was not available so it was assumed that 3% of these catches were from the otter trawl fleet and 97% were from Danish seine for the whole period. Matt Koopman supplied a catch history separated into state and Commonwealth catches for the period 1957-2006. None of these catches were separated by fleet.

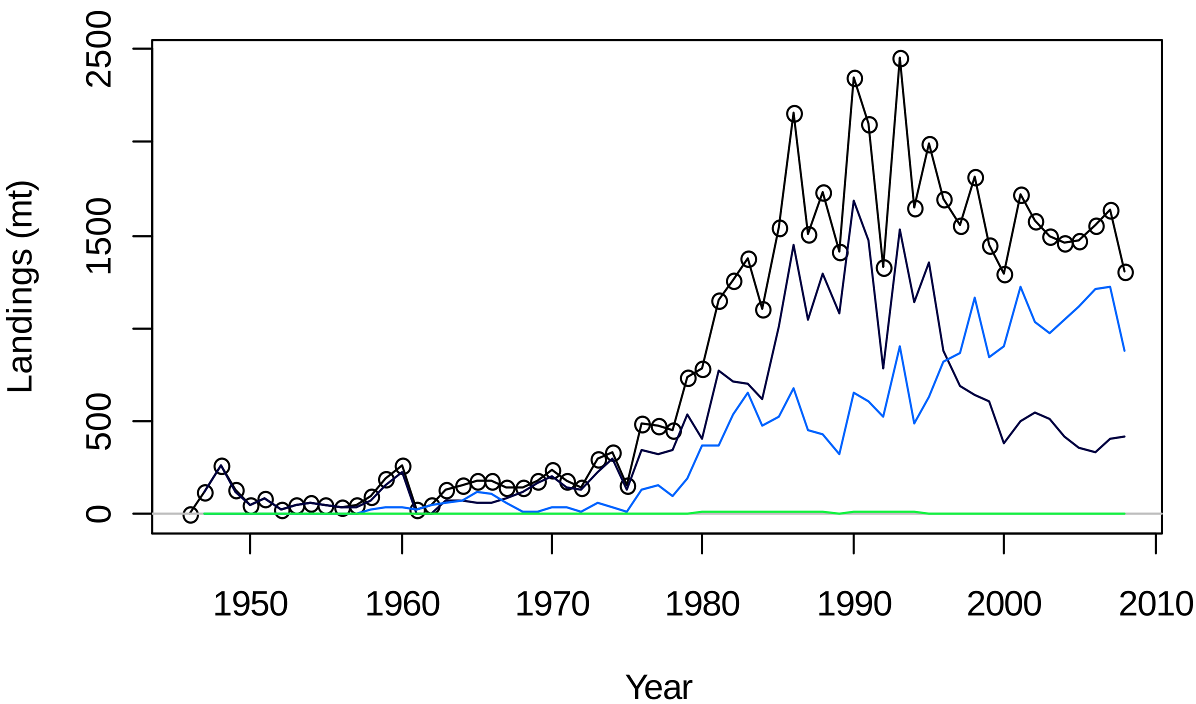


Figure 11.1. The total landed catch of school whiting in the SESSF from 1947-2008 (black with circles) as used in the 2009 assessment. These catches are also separated by fleet: the Victorian Danish seine fleet (navy blue, catches around 500t for the last 10 years); the otter trawl fleet (royal blue, catches around 1000t for the last 10 years) and the NSW Danish seine fleet (green, very small catches in the 1980s and the early 1990s with no recent catch).

The original data for the NSW component of this catch for the period from 1957-1992 is from Pease and Grinberg (1995). Corrections were made to these catches to remove the stout whiting component from the catch, with these corrections based on how far north the catch was landed along the NSW coast. Due to limited availability of catch data in the period 1957-1984, 66% of the NSW catches reported by Pease were assigned to school whiting in this period. The corrected NSW state catches of school whiting were incorporated into the NSW state catch history provided by Matt Koopman. The total NSW state catch was then allocated in the ratio of 97% to the otter trawl fleet and 3% to the NSW Danish seine fleet from 1957-1994. From 1995 to 2008 all of the NSW state catch was assumed to be otter trawl. Tasmanian state catches were available from 1995-2008 and all of this catch was assigned to the "Victorian Danish seine" fleet.

Commonwealth catches from 1985-2008 were separated into otter trawl and Danish seine (assumed to be the "Victorian Danish seine" fleet). These data came from the log book records and was supplied by Neil Klaer.

Annual landed catches for the three fleets used in this assessment (Victorian Danish seine, otter trawl and NSW Danish seine) are shown in Figure 11.1, Figure 11.2 and listed in Table 11.1. The same catch history split into state and Commonwealth components is shown Figure 11.3.

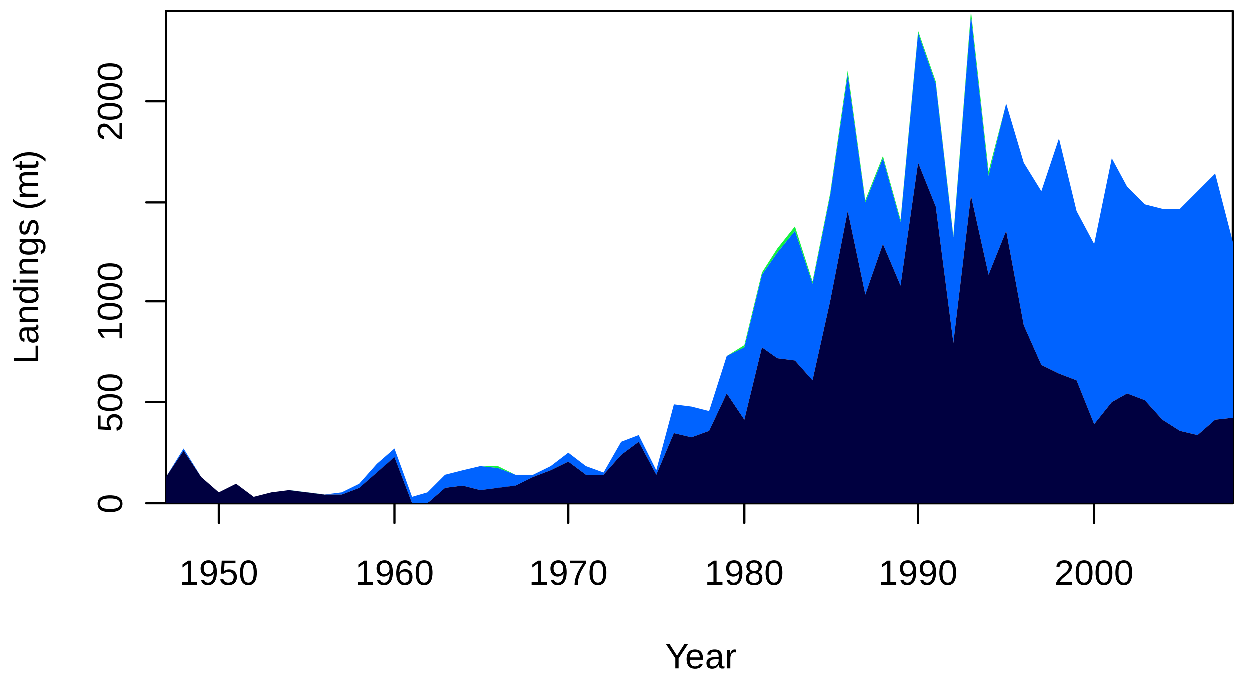


Figure 11.2. The total landed catch of school whiting in the SESSF from 1947-2008 as used in the 2009 assessment. These catches are also separated by fleet: the Victorian Danish seine fleet (navy blue, catches around 500t for the last 10 years); the otter trawl fleet (royal blue, catches around 1000t for the last 10 years) and the NSW Danish seine fleet (green, very small catches in the 1980s and the early 1990s with no recent catch).

The state catch is a significant proportion of the total catch for school whiting (Figure 11.3). From 1986-1996 the state catch averaged around 30% of the total catch, but from 1997-2008, the state catch has increased and the Commonwealth catch has decreased and as a result the state catch has averaged around 60% of the total catch in this period. The difference between catches in state and Commonwealth jurisdictions does not affect this assessment directly, but it does affect how catches are allocated to the different fleets, and it will have an impact on the allocation of the RBC. The NSW trawl fleet makes up around 90% of the state catches in the period 1986-2008. The Commonwealth catch starts in 1985 and the Victorian Danish seine fleet comprises around 80% of the Commonwealth catch since 1986. Note that the Commonwealth catch has been less than the state catch since 1997.

Information on the discard rate of school whiting is available from the ISMP for 1994-2008. These data are summarised in Table 11.1, with the discard length frequencies shown in Figure 11.4 and Figure 11.5. Discard rates vary amongst years, and have been as high as 40% (in 1996). Members of the fishing industry have indicated that discarding of small school whiting can vary rapidly in response to demands from the export market.

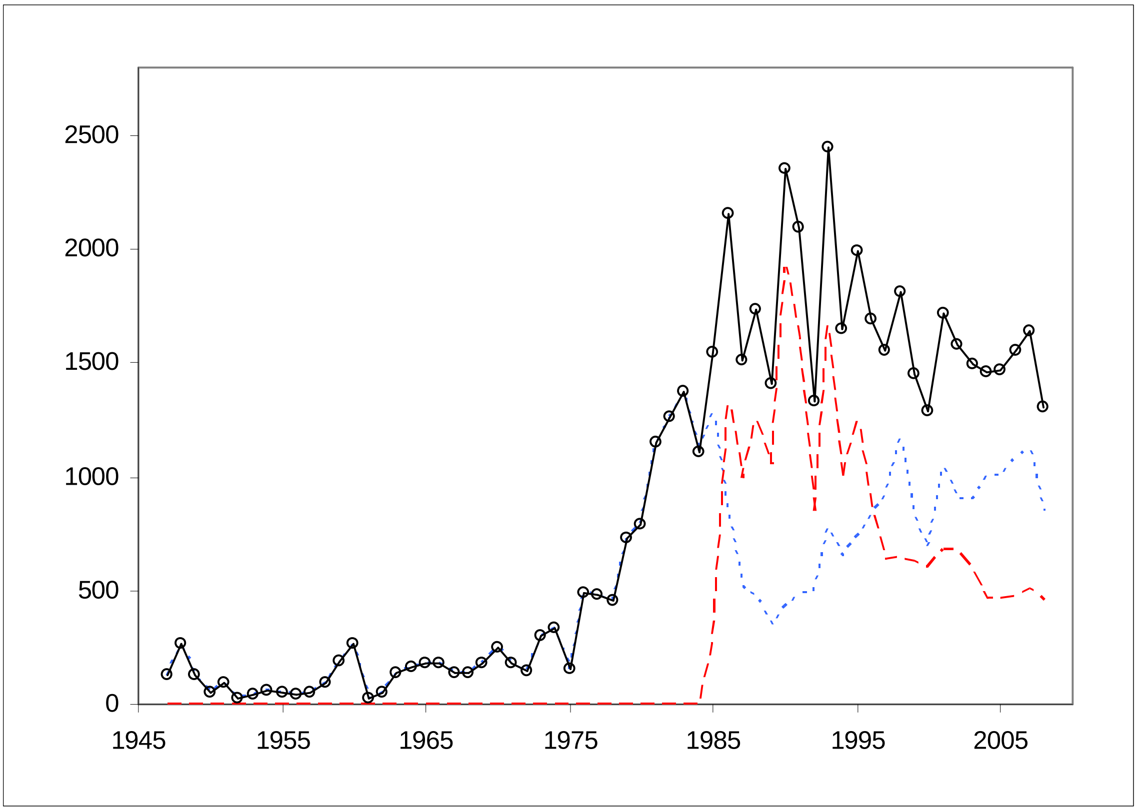


Figure 11.3. The total landed catch of school whiting in the SESSF from 1947-2008 (black line with circles) and this same catch separated into state catches (dotted line, blue) and Commonwealth catches (dashed line, red). The Commonwealth catch was larger than the state catch in the period 1986-1996. The state catches (blue) comprise the whole catch until 1985. The Commonwealth catch starts in 1985.

11.3.1.4 Catch rate indices

Catch and effort data from the SEF1 logbook database from the period 1986-2008 were standardised using GLMs to obtain indices of relative abundance (Haddon, 2009; Table 11.1). The restrictions used in selecting data for analysis were: (a) vessels had to have been in the trawl fishery for three or more years, (b) the catch rate had to be larger than zero, (c) catches in zone 60 only (d) catches in less than 100m depth and (e) effort is considered as catch per shot rather than as catch per hour, to allow for missing records of total time for each shot for data early in the fishery.

11.3.1.5 Length composition data

Length composition information for the retained component of the catch by the Victorian Danish seine fleet is available from port sampling for the period 1994-2008 (Figure 11.6). Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch from this fleet for 3 years only in this same period (Figure 11.4), with the 1994 discard data being made available for the first time for this assessment. An additional year (1991) of Victorian Fisheries length frequency data for the retained catch from the Victorian Danish seine fleet was also used (Anonymous, 1992). With the exception of the 2007 retained length frequencies and the three years of discarded length frequencies, the length frequency sample sizes and distributions for the Victorian Danish seine fleet were similar to those used in the 2008 assessment, despite differences in the data extraction process.

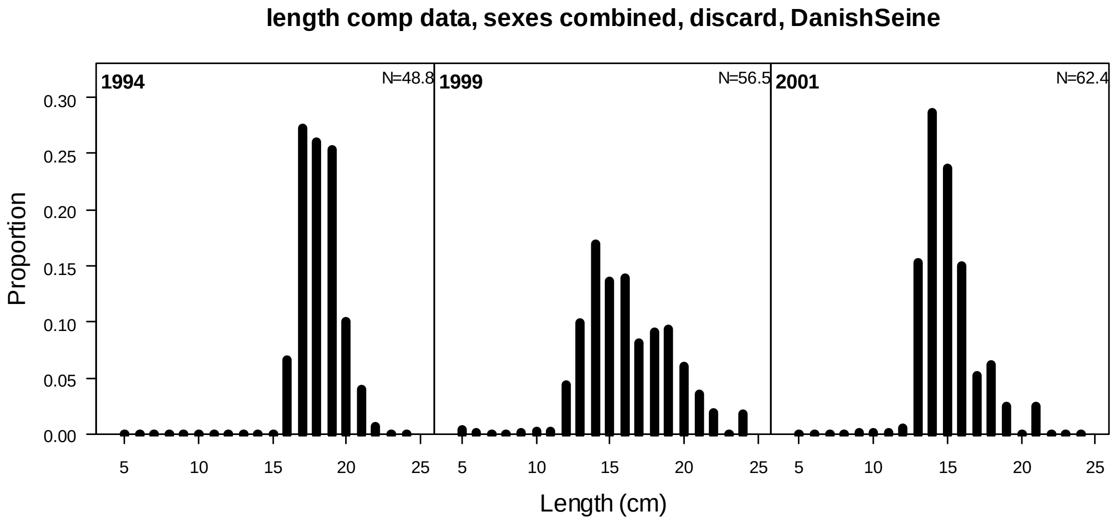


Figure 11.4. The discard length frequencies for school whiting for the Victorian Danish seine fleet.

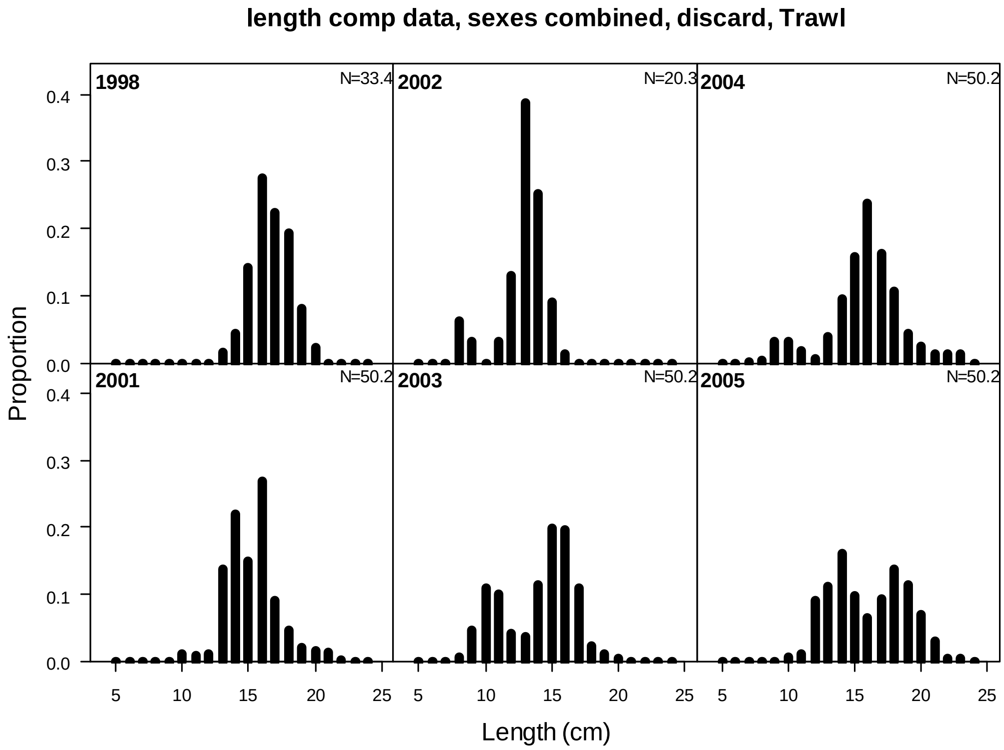


Figure 11.5. The discard length frequencies for school whiting for the otter trawl fleet.

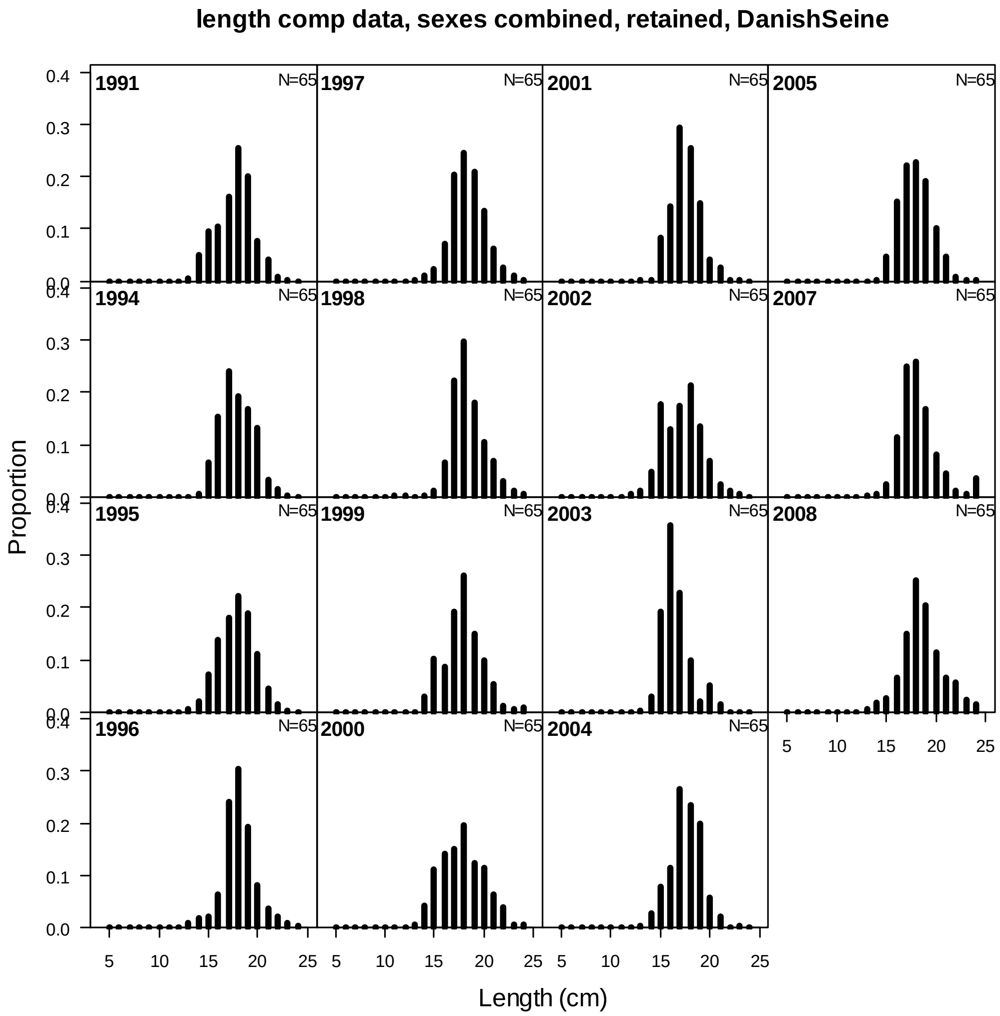


Figure 11.6. The retained length frequencies for school whiting for the NSW Danish seine fleet.

Length composition information for the retained component of the catch by the Commonwealth trawl fleet is available from port sampling for 1997-2008 (Figure 11.7) and in 1983 and 1988 from NSW state otter trawl (Kevin Rowling, pers. comm. 2006). Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch (Figure 11.5). With the exception of the 2007 retained length frequencies and discarded length frequencies in 2001, 2003, 2004 and 2005, the length frequency sample sizes and distributions for the otter trawl fleet were similar to those used in the 2008 assessment, despite the differences in the data extraction process.

Length composition information for the retained component of the catch by the NSW Danish seine fleet is available from Sydney fish market measurements for the period 1983-1989 (Figure 11.8).

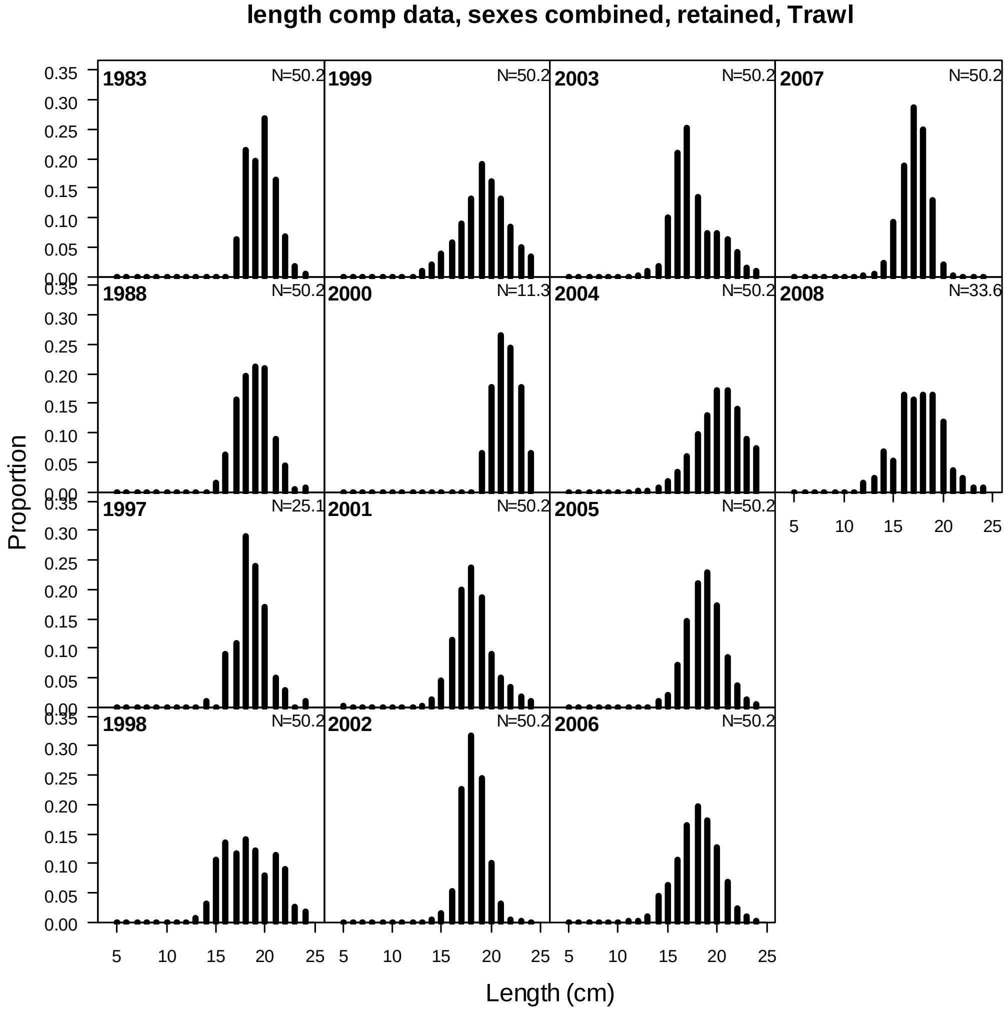


Figure 11.7. The retained length frequencies for school whiting for the otter trawl fleet.

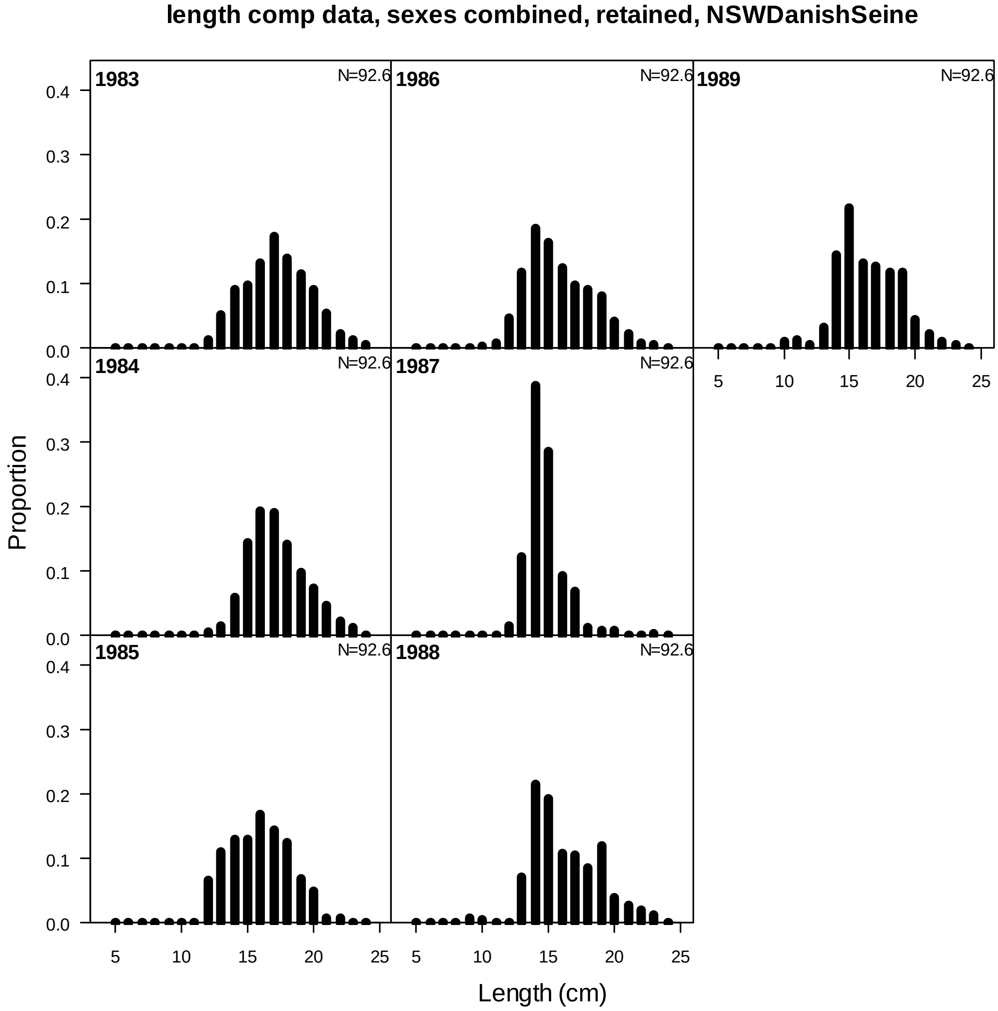


Figure 11.8. The retained length frequencies for school whiting for the Victorian Danish seine fleet.

11.3.1.6 Age composition data

Age-at-length measurements, based on whole otoliths provided by the CAF, are available from 1994-2006 for the Victorian Danish seine fleet and from 2001-2006 for the otter trawl fleet. Age-at-length measurements based on sectioned otoliths were used for the Victorian Danish seine fleet for 2007 and 2008 only. An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2009) using data supplied by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd and a variant of the method of Richards *et al*. (1992).

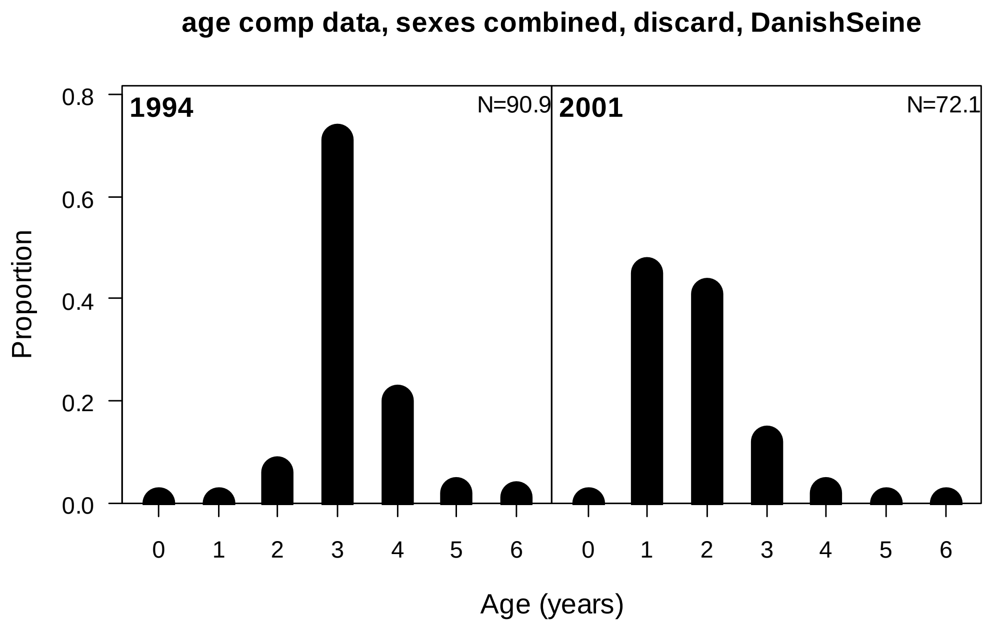


Figure 11.9. The implied discarded age frequencies for school whiting for the Victorian Danish seine fleet.

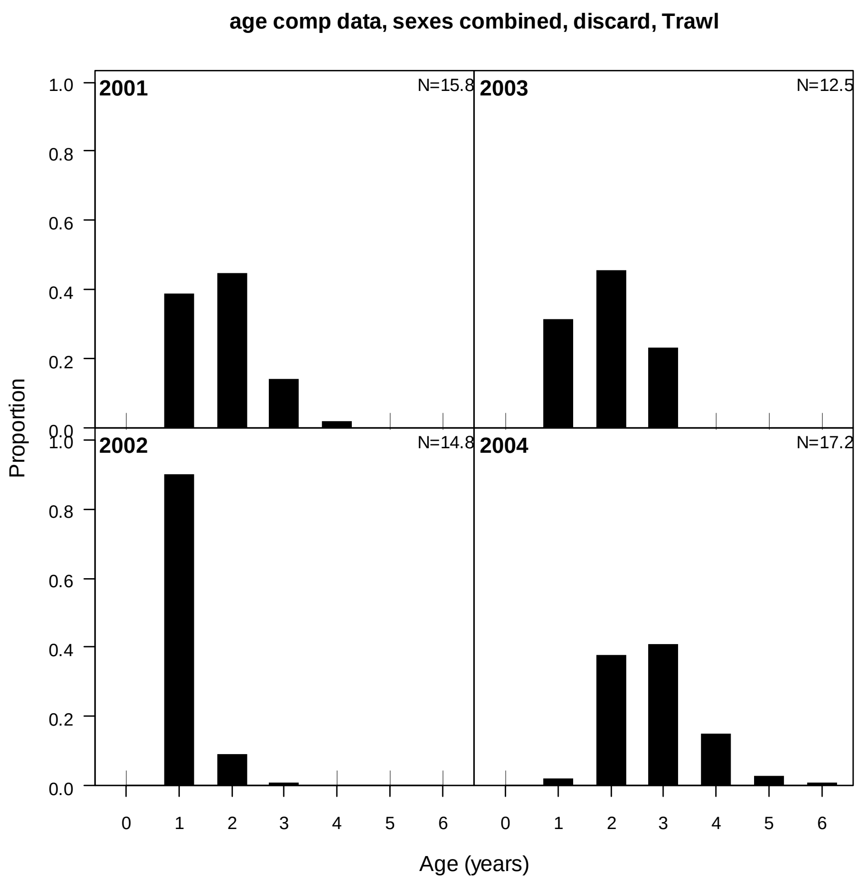


Figure 11.10. The implied discarded age frequencies for school whiting for the Commonwealth otter trawl fleet.

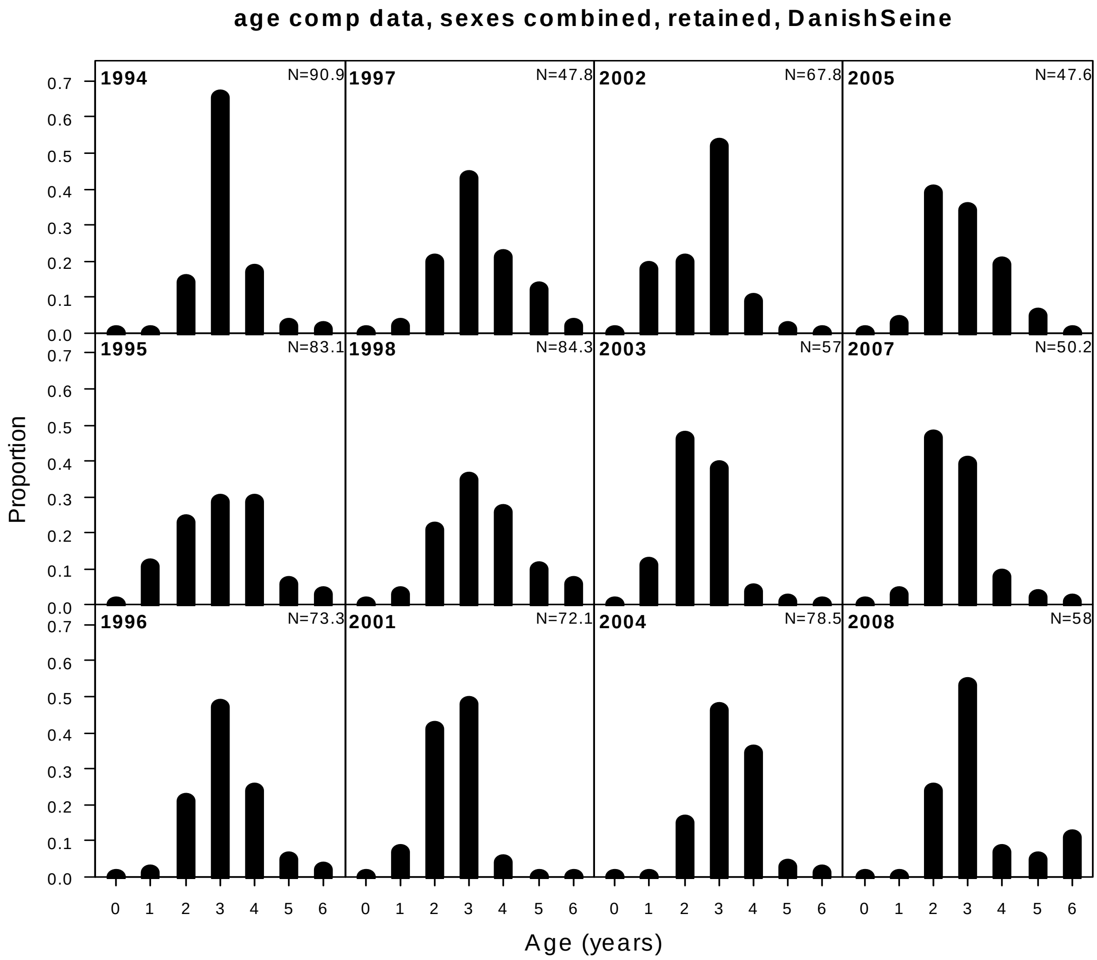


Figure 11.11. The implied retained age frequencies for school whiting for the Victorian Danish seine fleet.

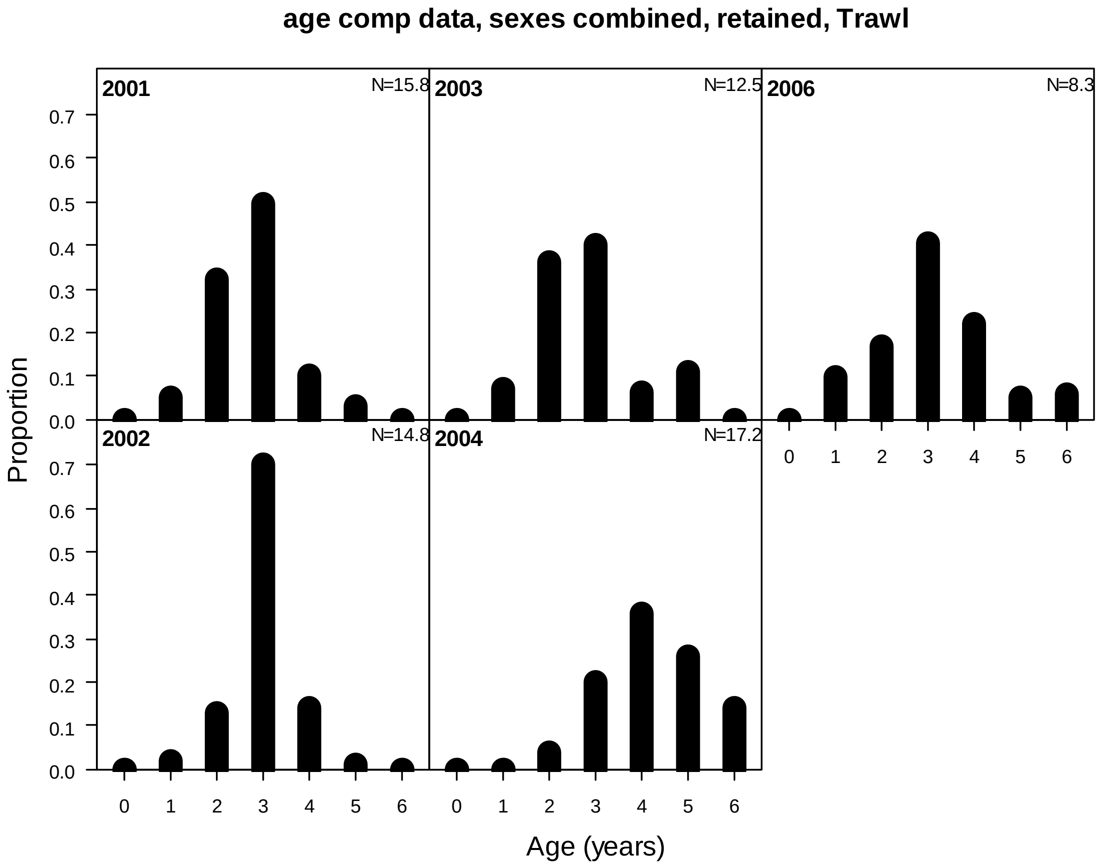


Figure 11.12. The implied retained age frequencies for school for the otter trawl fleet.

The implied age distributions for retained and discarded fish 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. Implied age distributions can be generated for discards in 1994 and 2001 for the Victorian Danish seine fleet (Figure 11.9) and for 2001-4 for the otter trawl fleet (Figure 11.10). Implied age distributions can be generated for the retained catch in the years 1994-1998, 2001-2005 and 2007-2008 for the Victorian Danish seine fleet (Figure 11.11) and for 2001-4 for the otter trawl fleet (Figure 11.12).

11.3.2 Stock assessment method

11.3.2.1 Population dynamics model and parameter estimation

A single-sex stock assessment for school whiting was conducted using the software package Stock Synthesis (version SS-V3.03a, Methot 2009). 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 school whiting. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are fully described in the user manual (Methot, 2009) and are not reproduced here. Some key features of the base-case model are:

a) School whiting constitute a single stock within the area of the fishery (Smith and Wayte, 2005).
b) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1947. This corresponds to a break in fishing during World War II, and given the facts that the species is short lived and was only lightly exploited prior to World War II, this seems a reasonable assumption.
c) The CVs of the CPUE indices for the Victorian Danish seine fleet were tuned to match the model-estimated standard errors (by adding 0.26 to the CVs provided with the CPUE standardisation (Haddon 2009)).
d) Three fishing fleets are modelled.
e) Selectivity was assumed to vary among fleets, but the selectivity pattern for each separate fleet was modelled as length-specific, logistic and time-invariant. The two parameters of the selectivity function for each fleet were estimated within the assessment.
f) Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for the two fleets where discard information was available (Victorian Danish seine and otter trawl). Retention for the NSW Danish seine fleet was implicitly assumed to be independent of length as no length frequency composition data is available on discards for this fleet.
g) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M was estimated within the model in this assessment.
h) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited 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 1981 to 2005. Deviations are not estimated prior to 1981 or after 2005 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.
i) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 0.359 in the base case so that the standard deviations of estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_r.
j) A plus-group is modelled at age six years.
k) Growth of school whiting 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.
l) The sample sizes for length and age frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before this retuning of length frequency data was performed by fleet, any sample sizes with a sample size greater than 200 were individually down-weighted to a maximum sample size of 200. This is because the appropriate sample size for length frequency data is probably more related to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured were used.

11.3.2.2 Calculating the RBC

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006- 2009 (Smith *et al.*, 2008). 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 basis used for assessing stock status or exploitation level for that stock. School whiting is assessed as a Tier 1 stock as 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 2010 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 (2008a) 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, which is the same strategy used to set the 2009 TACs.

11.3.2.3 Sensitivity tests

A series of forward sensitivity analyses were conducted, which initially reproduced the 2008 assessment in the latest version of the software (SS-V3.03a), then gradually updated the data in the 2008 assessment, taking account of revisions to the historical data (1994-2007). This included piecewise and independent additions of individual components of the 2008 data, addition of all new 2008 data, projection through to the end of 2009, Finally the mortality parameter, *M*, was estimated and the model was retuned to produce the new 2009 base case. These analyses were conducted to find which components of the revised data or the new data made major changes to the assessment outcomes when comparing the 2008 and 2009 assessments. In this analysis, updates to individual components of the data are always performed by starting from a previous base case or starting point, so that the effects of each change are evident rather than seeing cumulative changes. Once all components have been added one at a time, all components are then updated in a single step, before the next set of data revisions or updates begins. This first set of sensitivity analyses concludes with the 2009 base case being produced. This full process includes:

a) Update the 2008 assessment by only adding the revised catch data from 1994-2007.
b) Update the 2008 assessment by only adding the revised CPUE data from 1994-2007.
c) Update the 2008 assessment by only adding the revised length data from 1994-2007.
d) Update the 2008 assessment by only adding the revised age data from 1994-2007.
e) Update the 2008 assessment by only adding the revised discard data from 1994-2007.
f) Update the 2008 assessment by adding all the revised data from 1994-2007. This is the revised 2008 base case.
g) Update the 2008 assessment by only adding the revised catch data from 1994-2007 and with recruitment estimated to 2004.
h) Update the 2008 assessment by only adding the revised CPUE data from 1994-2007 and with recruitment estimated to 2004.
i) Update the 2008 assessment by only adding the revised length data from 1994-2007 and with recruitment estimated to 2004.
j) Update the 2008 assessment by only adding the revised age data from 1994-2007 and with recruitment estimated to 2004.
k) Update the 2008 assessment by only adding the revised discard data from 1994-2007 and with recruitment estimated to 2004.
l) Update the 2008 assessment by adding all the revised data from 1994-2007 and with recruitment estimated to 2004. This is the modified revised 2008 base case.
m) Update the modified revised 2008 base case by only adding the new catch data from 2008.
n) Update the modified revised 2008 base case by only adding the new CPUE data from 2008.

o) Update the modified revised 2008 base case by only adding the new length data from 2008.
p) Update the modified revised 2008 base case by only adding the new age data from 2008.
q) Update the modified revised 2008 base case by only adding the new discard data from 2008.
r) Update the modified revised 2008 base case by adding all the new data from 2008.
s) Project the new 2008 catch data to 2009, estimate *M* and retune the model to produce the 2009 base case.

A number of standard sensitivity tests are used to examine the sensitivity of the results of the 2009 base case to some of the assumptions and data inputs:

a) *h* = 0.65 and 0.85 yr-1.
b) 50% maturity occurs at length 14 and 18cm.
c) The von Bertalanffy *k* parameter = 0.2 and 0.3.
d) σ_r = 0.259 and 0.459.
e) Recruitment deviations estimated to 2004 and 2006.
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.

In addition to these sensitivities a number of model and data exploration options were investigated. These models were ruled out as possible base case models for a range of different reasons:

i) Include the low discard rates data or years with low discard sample size: the years previously omitted with discarding rates (<4%):1995, 2003 and 2004 for Danish seine and 1997, 2001, 2002, 2006 and 2007 for otter trawl. (Including these data results in unrealistically low model estimates of discarding rates).
j) Add 1971 and 1974 length frequency data from northern NSW (these length frequencies were from the northern end of the range and including them produced spurious recruitment events).

Following these sensitivity analyses, a range of traditional backward sensitivity analyses were conducted on the 2009 base case, where the effect of recent years of data, or components of the last year of data can be seen on the assessment.

a) Remove all 2008 data except for catch data.
b) Remove all 2007-2008 data except for catch data.
c) Remove all 2006-2008 data except for catch data.
d) Remove 2008 CPUE data.
e) Remove 2008 length data.
f) Remove 2008 age data.

The results of these various sensitivity analyses and model and data exploration options are summarised in figures showing spawning biomass and recruitment time series and in a series of tables listing the following quantities:

a) SB_0 the average unexploited spawning biomass,
b) SB_{2010} the spawning biomass at the start of 2010 (or 2009 when appropriate),

c) SB_{2010}/SB_0 the depletion level at the start of 2010 (or 2009 when appropriate), i.e. the 2010 (or 2009) spawning biomass expressed as a percentage of the unexploited 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) *2010 RBC 20:35:48* the 2010 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,

11.4 Results and discussion

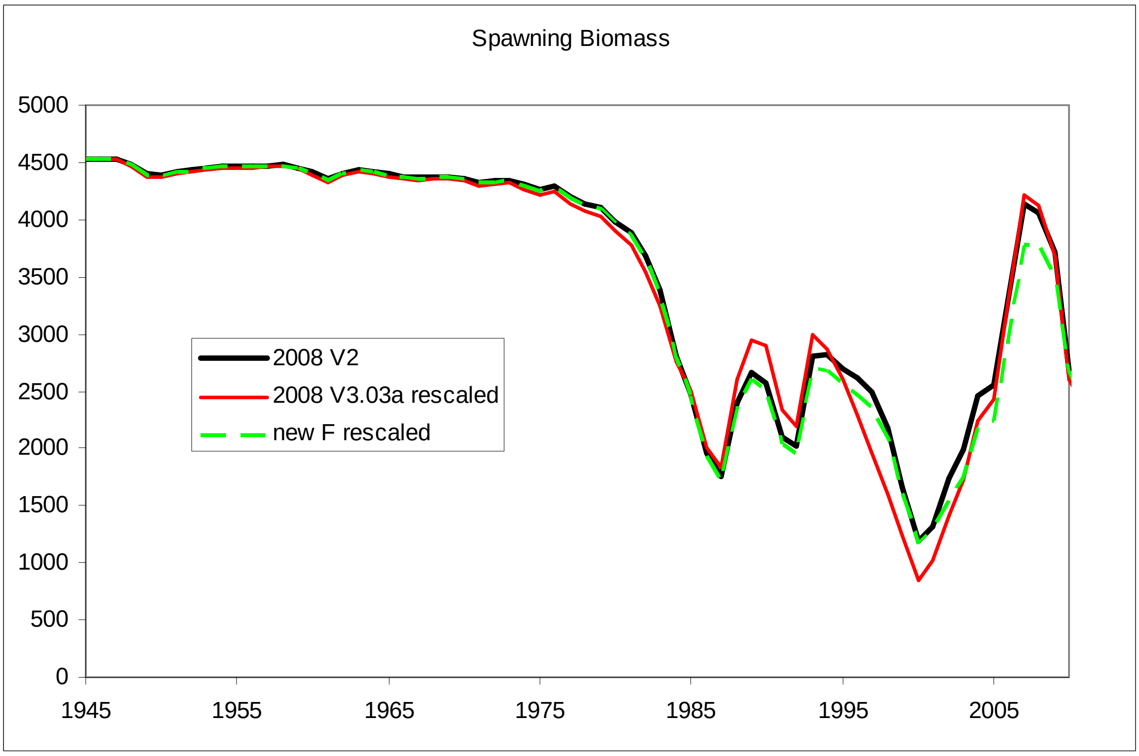
11.4.1 The 2008 forward retrospectives

11.4.1.1 Conversion from SS-V2.00h to SS-V3.03a

As a first step in updating this assessment, the same data set used in the 2008 assessment using SS-V2.00h was transferred to an updated version of Stock Synthesis, SS-V3.03a. Identical results were obtained for the 2009 depletion estimate (82% in each case) using SS-V2.00h and SS-V3.03a (Table 11.5) and the spawning biomass and recruitment time series are shown in Figure 11.13. SS-V3.03a has an option to use an improved estimation technique for fishing mortality using a continuous hybrid estimation procedure rather than Pope's approximation. The depletion rates and time series using this improved hybrid method are also shown in Table 11.5 and Figure 11.13, with a slight decrease in the estimate for the 2009 spawning biomass, with depletion changing from 82% to 77%. While there are minor differences in the time series for spawning biomass and depletion (Figure 11.13), these estimates are close enough to the 2008 SS-V2.00h base case to give confidence in the transition to SS-V3.03a.

11.4.1.2 2008 base case, revised data to 2007: recruitment deviations to 2005

Before considering the effects of including the new data from 2008 in this assessment, the effects of revisions to the historical data (1994-2007) were examined by modifying the data used in the 2008 assessment. This class of retrospectives is referred to as "forward retrospectives", where the impact of the revised historical data on the 2008 assessment can be examined. Revised historical data can include additional data through the incorporation of additional length or age samples not previously included in the assessment dataset or changes to some distributions resulting from changes to processing of the data.



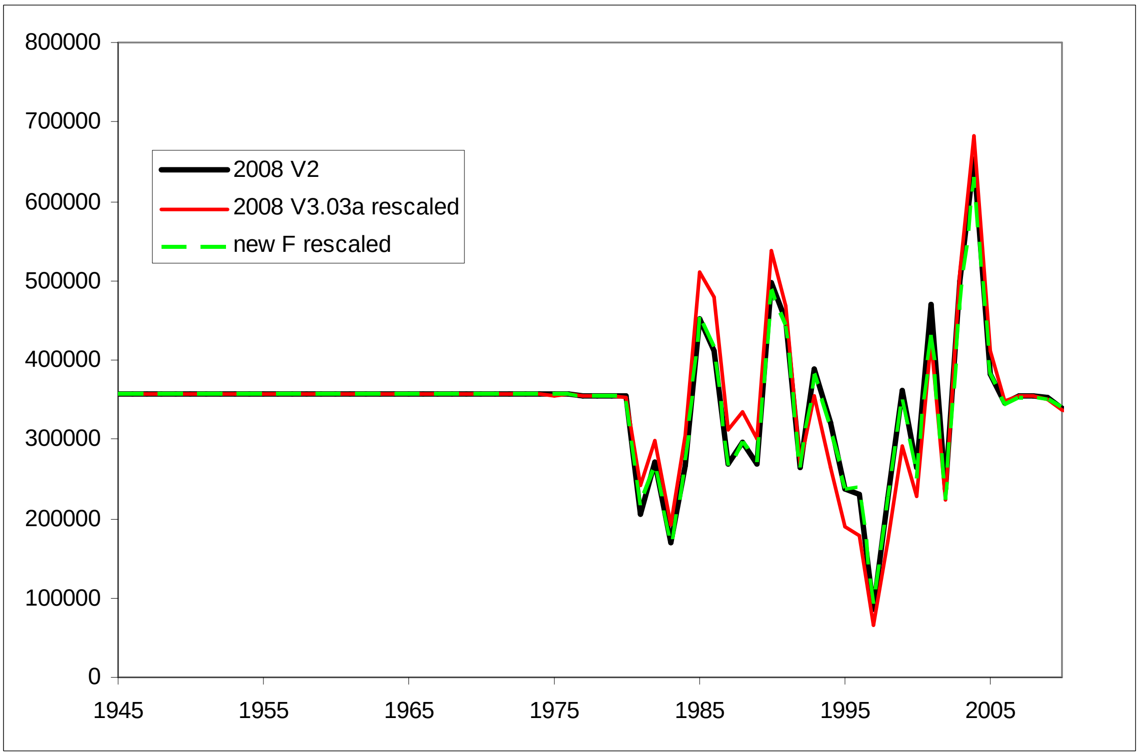
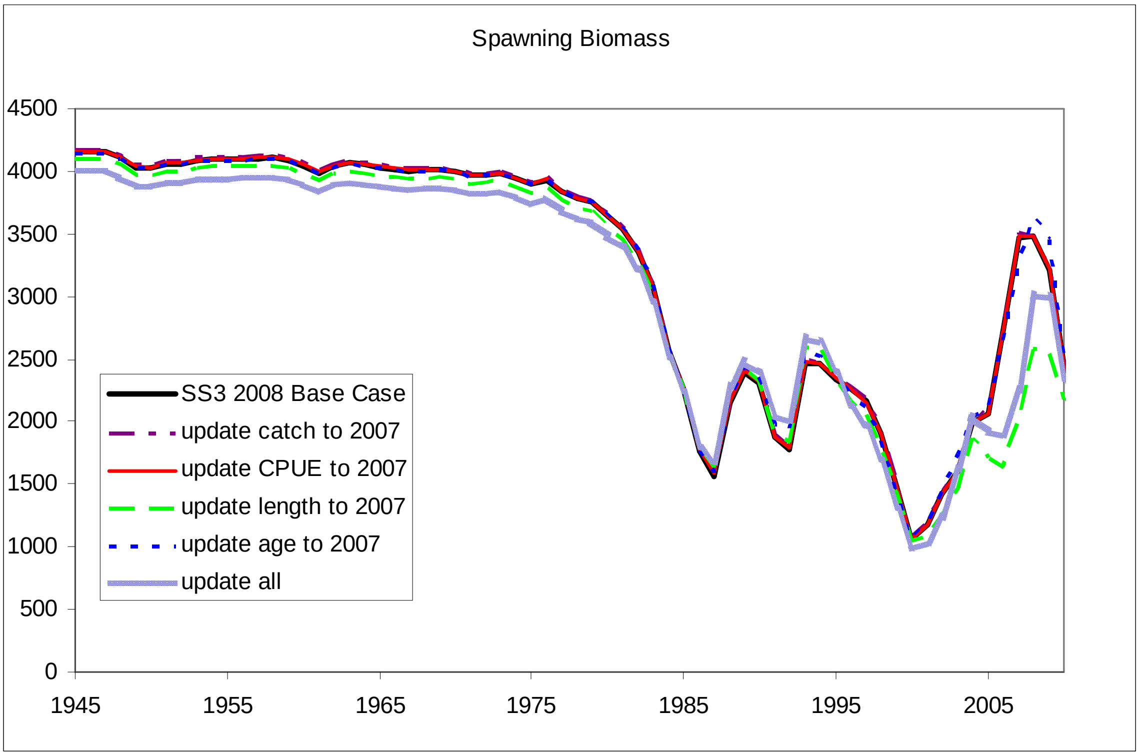


Figure 11.13. The 2008 assessment results for SS-V2.00h (bold line, black) compared to SS-V3.03a 2008 assessment (recruitment estimated to 2005) with the hybrid method for estimating fishing mortality (dashed line, green) and without the hybrid method for estimating fishing mortality (solid line, red), for spawning biomass (top) and recruitment (bottom). The estimated results are similar for all three models.

Revisions to historical data include changes to the catch data, the CPUE series, the discard data (1994, 1997, 1999, 2001-5) age data (2006-7) and length data (1994, 1999-2002, 2007). Revisions to the historical data in the 2008 school whiting assessment had a considerable impact on the assessment results, when compared to the results from the 2007 assessment, so it was possible that revisions this year would have a similar impact on the assessment outcomes from 2008 to 2009. To explore this possibility, the 2008 SS-V3.03a base case was updated by adding one component at a time of the revised data for 1994-2007. These effects were examined by updating the data for each component in turn, excluding any new data from 2008 in each case, and then restoring the original data used in the 2008 assessment before updating the next component of the data. This sequential and independent update of this historical data allows the effects of the revisions in each component of the data to be examined separately. This analysis shows which revisions to the historical data have the largest effect on the new assessment, before the new data for 2008 is added.

The changes to the catch series and the updated CPUE series had minimal effect on the predicted spawning biomass and recruitment series (Figure 11.14) and on the depletion rates (Table 11.6), with the new results following the results of the 2008 SS-V3.03a base case very closely in each case. The updated length frequency and age data produced larger changes to the results to the base case for recent recruitment events, especially for the years 2003, 2004 and 2005 (Figure 11.14). The updated length frequency and age data also produced larger changes to the spawning biomass time series and to the depletion rate (Table 11.6), which changed from 77% in the 2008 SS3 base case to 62% with the revised length frequency data and 83% for the revised age data. The updated discard rate data had a minor impact on the depletion rate (Table 11.6).

When all of these changes to the 1994-2007 data are added to the 2008 SS-V3.03a base case simultaneously, the combined effect on depletion is to balance out these changes and gives a similar estimate of depletion to the 2008 SS3 base case (75% compared to 77%). The time series of spawning biomass is slightly altered with the 2007/2008 peak shifted to 2008/2009 and reduced slightly in magnitude. In contrast, the recruitment pattern looks very different to the 2008 SS3 base case, with a very high recruitment estimate for 2005, the last year in which recruitment deviations are estimated. Larger variations in recruitment from the base case to the case where all data is updated occur in 1997 (28% increase, mostly due to the length data), 2000 (28% increase, mostly due to the age data), 2003 (41% decrease, mostly due to the length data), 2004 (47% decrease, due to both length and age data) and 2005 (72% increase, due to both length and age data). This produces an estimate of 2005 recruitment which is an outlier, with this recruitment event 35% larger than the previous highest recruitment event (1990). This large recruitment event is estimated to occur in the last year for which recruitment deviations are allowed. There is limited data to inform such a recruitment event and it is likely that this large recruitment estimate is spurious and is being “fitted” to improve likelihood components of other aspects of the model, rather than as a response to evidence of a strong recent recruitment event in the length or age data.



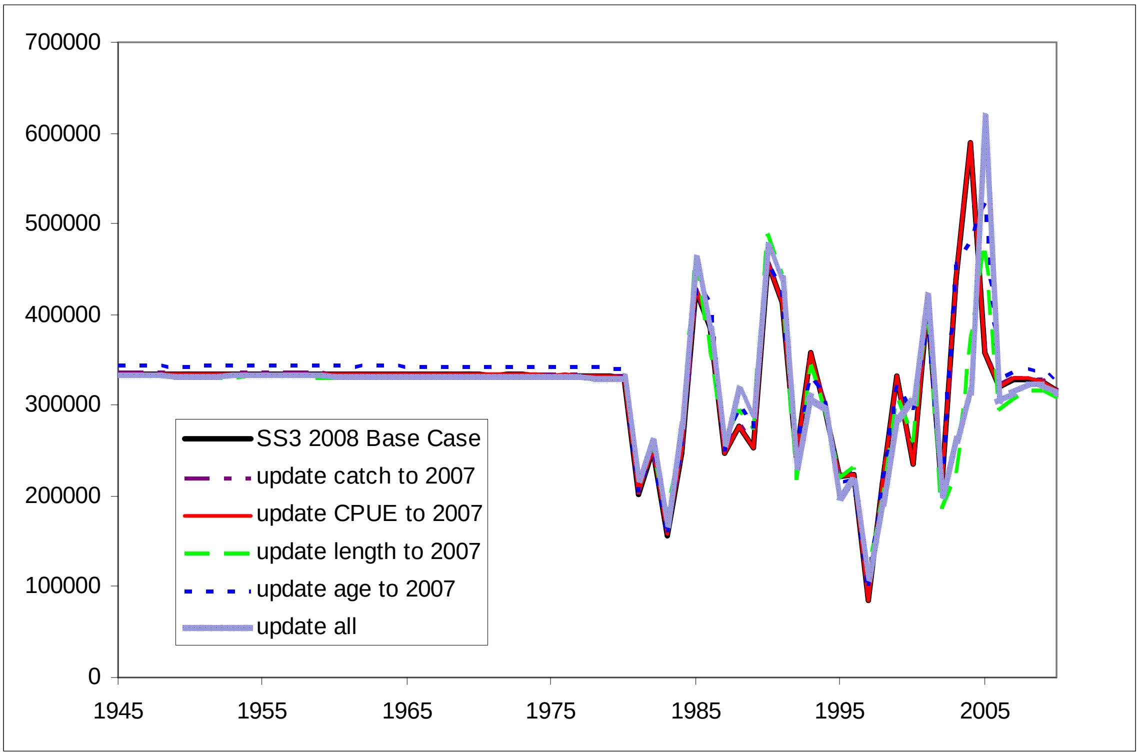


Figure 11.14. The 2008 SS-V3.03a assessment results (with recruitment estimated to 2005) with updates using one component of the updated data at a time, using updated data only from the period 1994-2007. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 -2015, showing the 2008 SS-V3.03a assessment (bold line, black), updated catch data only (dot-dashed line, purple), updated CPUE data only (solid line, red), updated length data (dashed line, green), updated age data (dotted line, blue) and all data to 2007 updated (shaded line, lilac).

The estimated selectivity of two year old fish is less than 20% for fish caught by the Danish seine fleet and less than 10% for the otter trawl fleet, compared to selectivities of over 50% (Danish seine) and 30% (otter trawl) for three year old fish. In the 2008 assessment, the 2005 recruitment event can only be informed by the presence of two year old fish caught in 2007, as these recruits would only be detected in the length and age data from 2007. The 2005 recruitment estimate is the last recruitment to be estimated in the 2008 assessment and for the 2008 base case the 2005 recruitment was not unusually high. While the 2004 recruitment was large, as estimated in the 2008 base case, this recruitment occurred in the penultimate year of recruitment estimates and was informed by two years of data rather than just one year of data.

11.4.1.3 Modified 2008 base case, revised data to 2007: recruitment deviations to 2004 only

When the revised historical catch data is incorporated into the 2008 base case, with recruitment deviations estimated to 2005, this allows a “spurious” large recruitment to be estimated in 2005. Because there is limited evidence for such a high recent recruitment, the same revisions to the historical data were considered for a modified version of the 2008 base case, where recruitment deviations were estimated to 2004 only. This modification to the 2008 base case resulted in more believable results without the “spurious” 2005 recruitment. The historical changes to the data in the period 1994-2007 are explored for this modified 2008 base case scenario to examine the effects of the revisions of different components of the data for this new scenario.

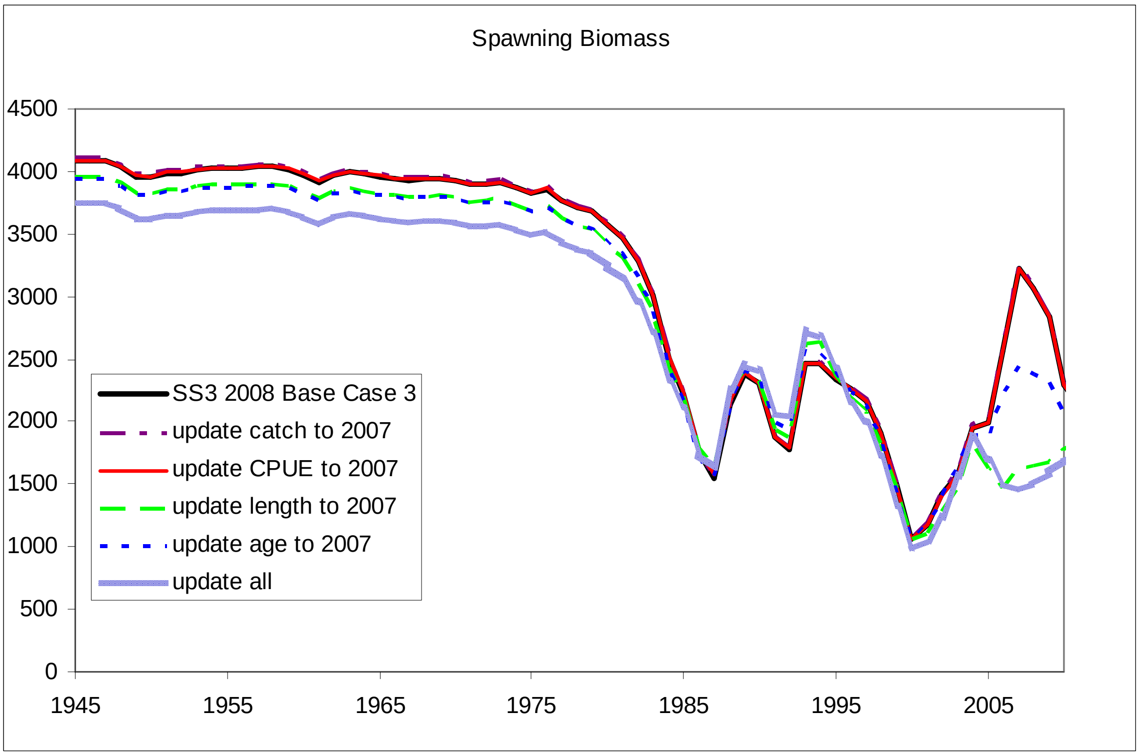
As with the standard 2008 base case retrospectives, the changes to the catch series and the updated CPUE series had minimal impact on the predicted spawning biomass and recruitment series (Figure 11.15) and on the depletion rates (Table 11.7) for the modified 2008 SS3-V3.03a base case, with the new results following the results of the standard 2008 SS3-V3.03a base case very closely in each case. In contrast, the revised length frequency and age data resulted in changes to the spawning biomass time series from 2005-2010 and to the 2009 depletion rate (Table 11.7), which changed from 69% in the modified 2008 base case to 42% with the revised length frequency data and 59% for the revised age data. The updated discard rate data had a minor effect on the depletion rate (Table 11.7).

In contrast to the standard 2008 SS3-V3.03a base case forward retrospectives with recruitment estimated to 2005, when all of these changes to the 1994-2007 data are added to the modified 2008 SS3-V3.03a base case simultaneously, the combined effect on depletion is to amplify the changes from the length and age data. This results in a 2009 depletion estimate of 42% (compared to 69% for the standard 2008 SS3-V3.03a base case). The time series of spawning biomass diverges from 2004 onwards, with the standard SS3-V3.03a 2008 base case showing a strong increase from 2004-2007 and the modified SS3-V3.03a 2008 base case with all 1994-2007 data revised showing a strong decrease from 2004-2007.

These changes to the spawning biomass time series are driven by changes to the recruitment series. As with the spawning biomass series, the changes in recruitment are amplified when all of the 1994-2007 data is revised simultaneously. When comparing the recruitment series for the modified SS3-V3.03a 2008 base case with the standard

SS3-V3.03a 2008 base case base case with all 1994-2007 data revised, the largest changes occur in the years 1997 (26% increase, mostly due to the length data), 2000 (24% increase, mostly due to the age data), 2003 (50% reduction, mostly due to the length data) and 2004 (58% reduction, due to both length and age data). These changes in recruitment estimates are largely driven by revisions to the length distribution data for both fleets in 2007 and to the age data for both fleets in 2006 and 2007.

When recruitment is only estimated to 2004, in the modified 2008 assessment, and the1994-2007 data is revised, the large recruitment event that was estimated in 2004 disappears (Figure 11.15), and this results in a reduced estimate of spawning biomass in 2009. Note that the changing the last year of recruitment estimation means the last large recruitment event is then in the final year of the estimated recruitment time series and when the 1994-1997 data is revised, this large recruitment in 2004 disappears.



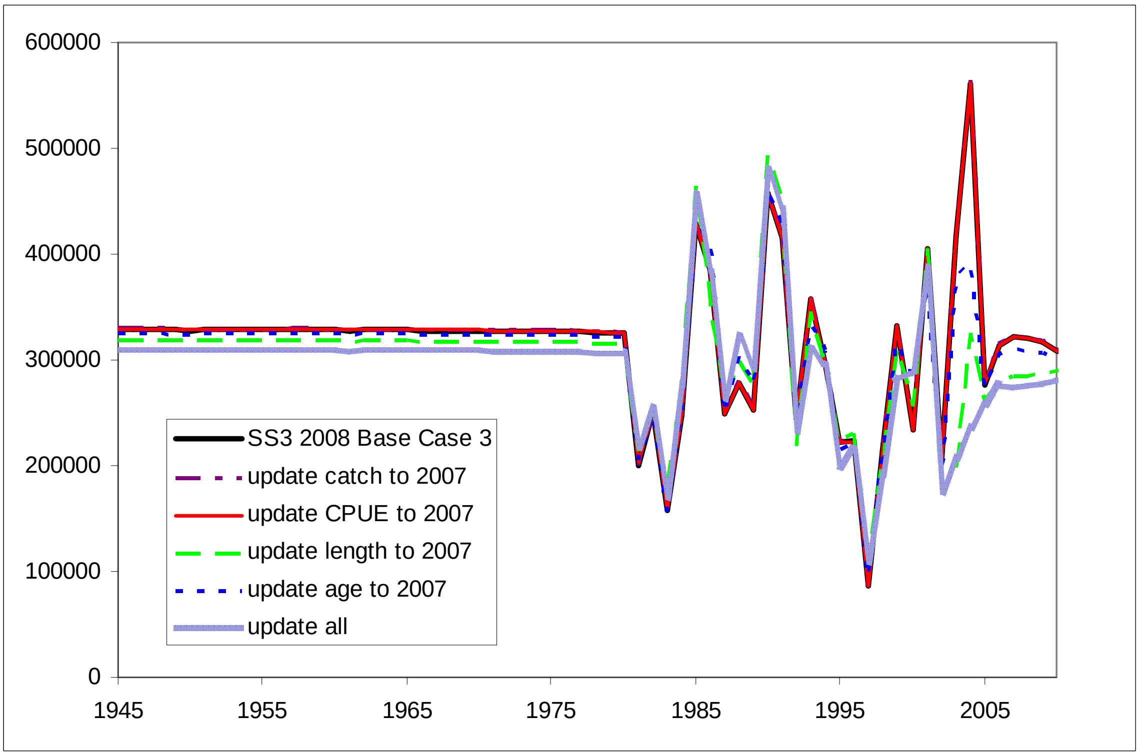
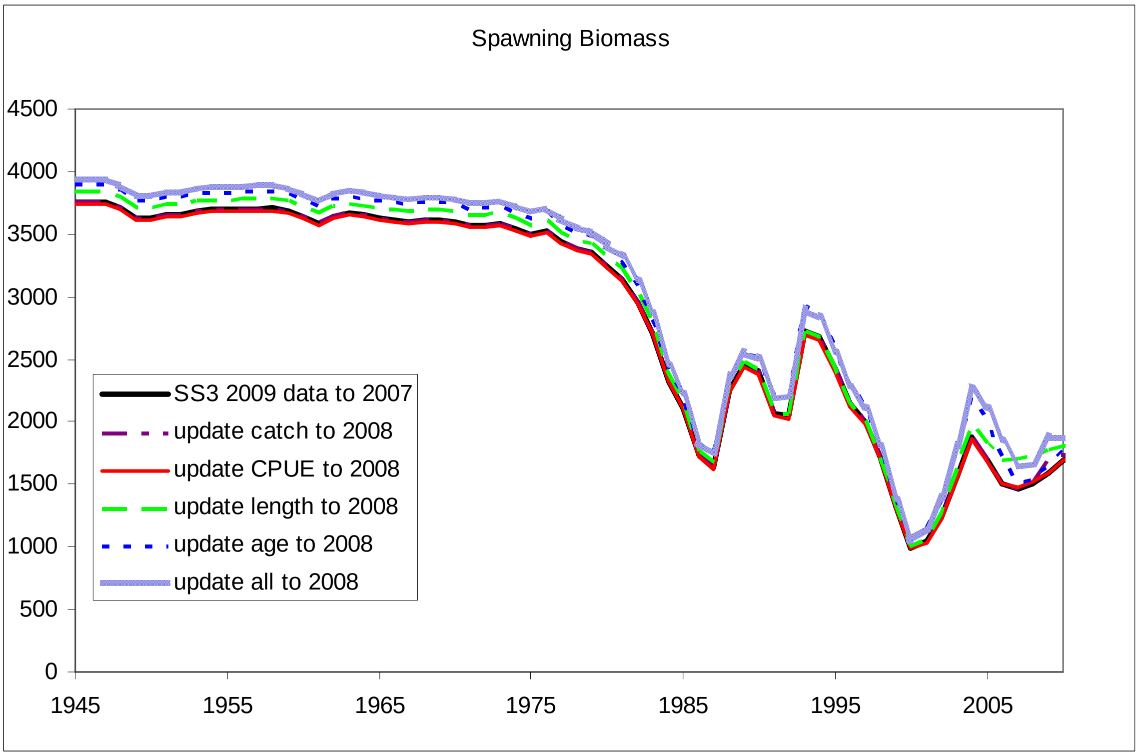


Figure 11.15. The modified 2008 SS-V3.03a assessment results (with recruitment estimated to 2004 only) with updates using one component of the updated data at a time, using updated data only from the period 1994-2007. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 - 2015, showing the modified 2008 SS3 assessment (bold line, black), updated catch data only (dot-dashed line, purple), updated CPUE data only (solid line, red), updated length data (dashed line, green), updated age data (dotted line, blue) and all data to 2007 updated (shaded line, lilac).

11.4.1.4 Projected modified 2008 base case, revised data to 2007 plus new 2008 data: recruitment deviations to 2004 only

To continue the comparison of the modified 2008 SS3-V3.03a base case, using the same model structure, the 2008 data was added one component at a time (catch, CPUE, length, age) to examine the effect of each component of the new data. All the new 2008 data was added as the final step, giving a projected modified 2008 SS3-V3.03a base case. For this to be valid, the comparison needs to be made to the 2009 spawning biomass and 2009 depletion, and even though there is now some data from 2008, and hence recruitment is still only estimated to 2004.

As with the previous retrospectives, the 2008 CPUE data point had a relatively small effect on the predicted spawning biomass and recruitment series (Figure 11.16) and on the depletion rates (Table 11.8). The new 2008 age data also resulted in minimal changes. In general, the new results follow the results of the modified 2008 SS3-V3.03a base case quite closely, with the depletion changing from 42% to 48%. The new length frequency data and the new catch data contribute most to the increased estimate of spawning biomass. There was no additional 2008 discard rate data.



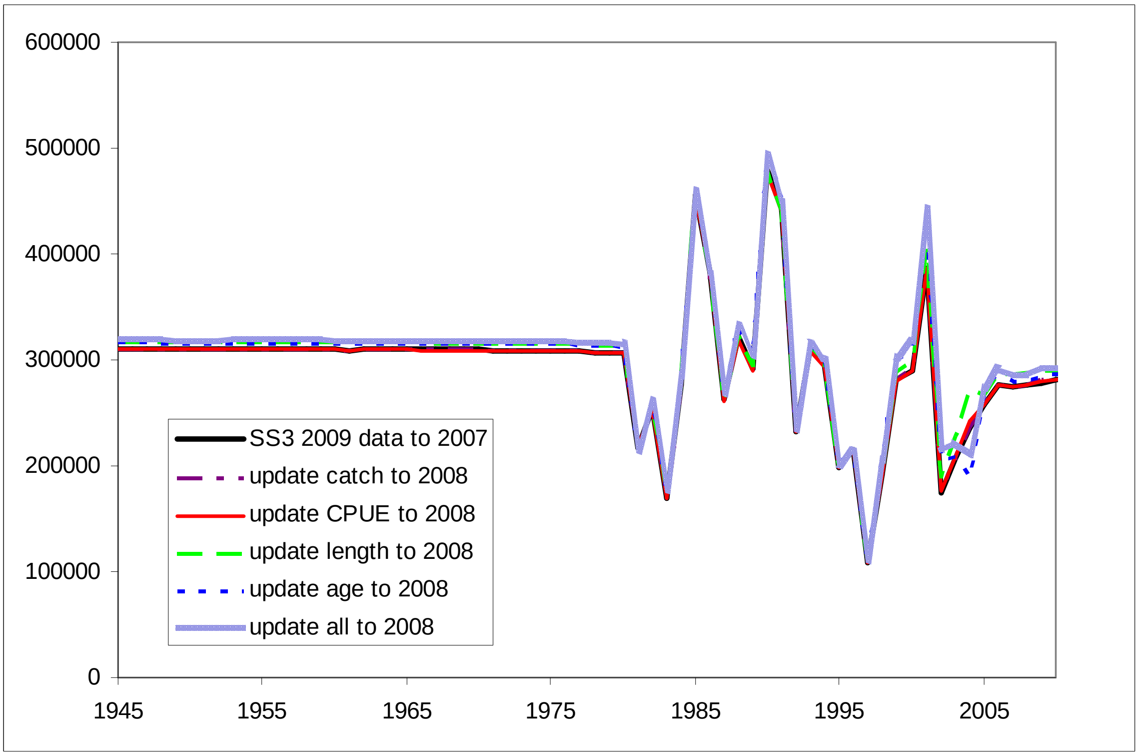
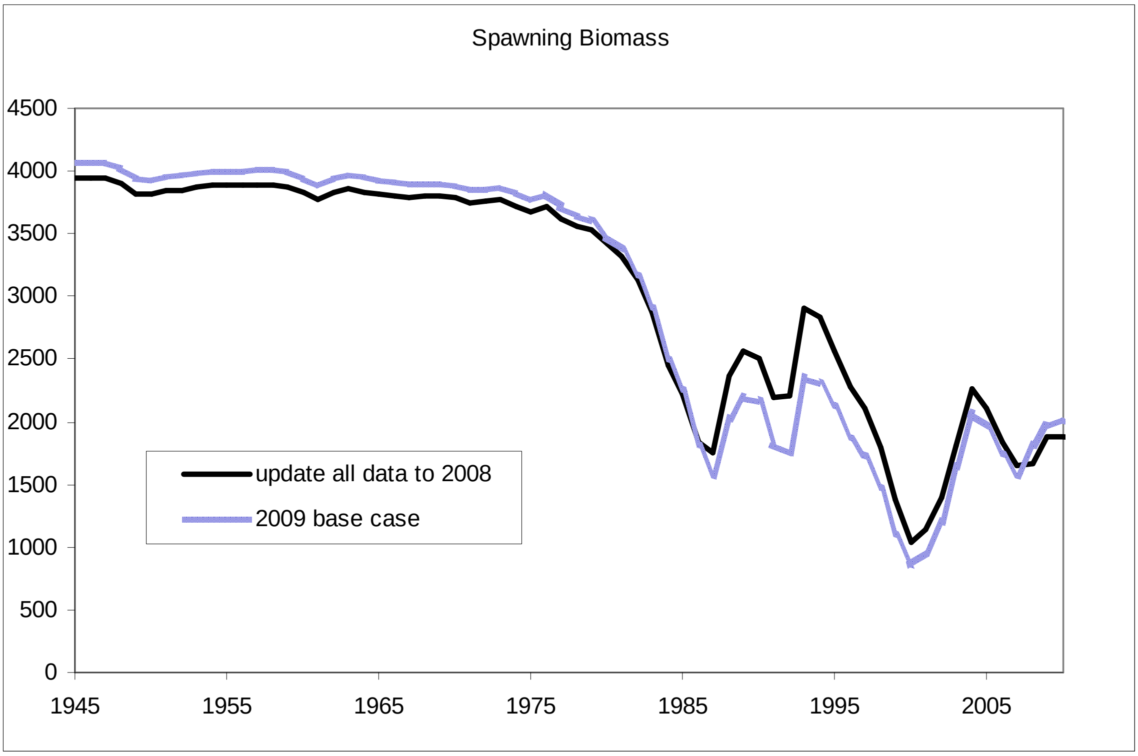


Figure 11.16. The projected modified 2008 SS-V3.03a assessment results (with recruitment estimated to 2004 only) with updates to the 2008 data including one component of the 2008 data at a time, and then updating all of the 2008 data. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 -2010, showing the projected modified 2008 SS-V3.03a assessment using revised data to 2007 (bold line, black), updated 2008 catch data only (dot-dashed line, purple), updated 2008 CPUE data only (solid line, red), updated 2008 length data (dashed line, green), updated 2008 age data (dotted line, blue) and all data to 2008 updated (shaded line, lilac).

11.4.1.5 Projected modified 2008 base case: all new data to 2008, recruitment estimated to 2005, mortality estimated and the 2009 base case

To complete the transition from the 2008 base case to the 2009 base case, recruitment deviations are estimated to 2005, three years before the last data used in the assessment, and the new (2008) catch data is projected to 2009. In addition to these changes, the mortality parameter, M, is estimated and the new 2009 base case is fully retuned, so that input and output values are consistent for: σ_r; the variance on the CPUE index; and effective sample sizes for length and age samples.

One significant change at this step is allowing recruitment to be estimated to 2005, one more year of estimated recruitment than the previous forward retrospectives presented here, and in particular for the 2008 SS3-V3.03a base case. This results in a large recruitment being estimated for 2005 which has an impact on the spawning biomass time series (Figure 11.17) and is partly responsible for a change in the 2010 depletion from 47% to 50% (Table 11.9). The other significant change at this step is allowing mortality to be estimated. This results in an estimate of the mortality parameter of M=0.51, which is lower than the fixed value of 0.6 used in previous assessments. This lower estimate for M also results in a change to productivity and a reduction in the mean recruitment. The two recruitment series in (Figure 11.17) show similar relative trends for all years except 2005, but they differ in absolute magnitude. The relative difference in these two recruitment series for the year 2005 is due to the fact that the 2008 updated recruitment series assumes mean recruitment in 2005 and the 2009 base case allows recruitment to be estimated in 2005, and this 2005 estimate is well above the average recruitment.



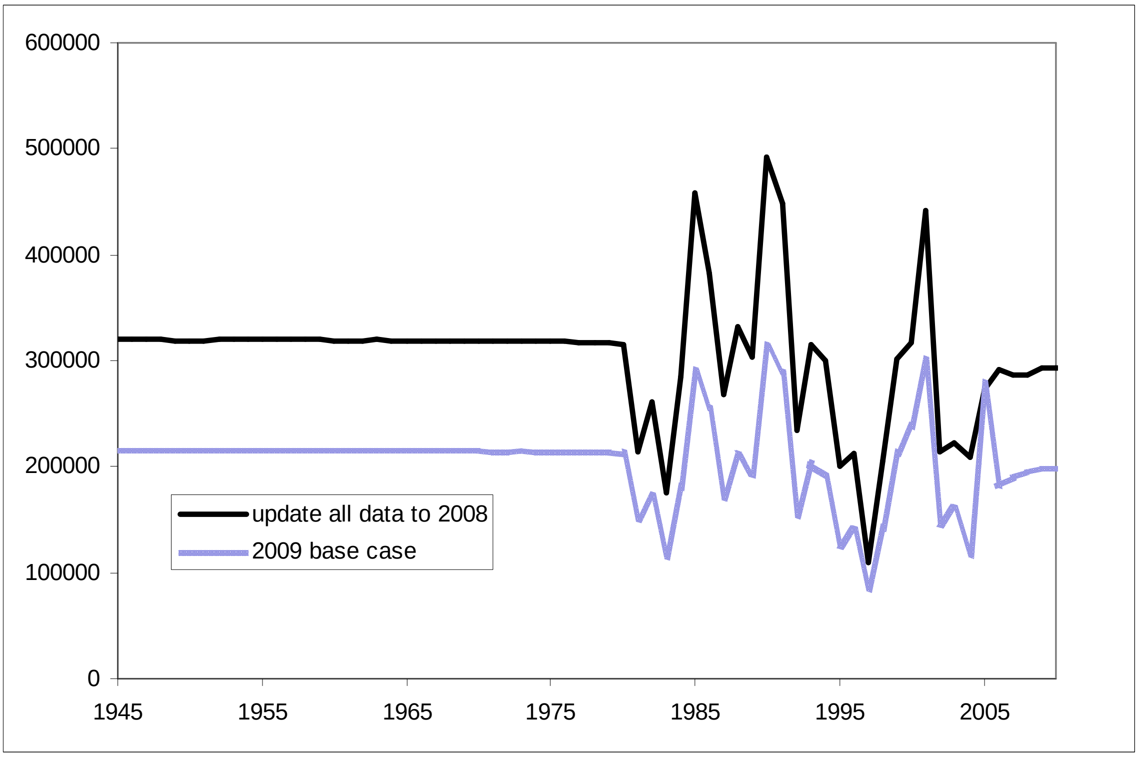


Figure 11.17. The projected modified 2008 SS3 assessment results with all of the 2008 data updated compared to the new 2009 base case. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 -2010, showing the projected modified 2008 SS3 assessment (bold line, black) with all data to 2008 updated and recruitment estimated to 2004 only, and the 2009 base case (shaded line, lilac), with all data to 2008 updated, recruitment estimated to 2005 (one additional year), the updated 2008 catch projected to 2009, mortality estimated and with the full model retuned.

The final recruitment estimate in 2005 (Figure 11.17), should be treated with caution as there is limited age and length frequency data to inform this recruitment event. Future data is likely to modify the estimate of recruitment in 2005. As a result, if a future assessment produces a reduction to this estimate of 2005 recruitment, the spawning biomass estimate for 2010 will also be reduced. Hence the estimate for the 2010 spawning biomass should also be treated with some caution. While this is the best estimate we have for the 2010 spawning biomass, the incorporation of future data could see this estimate revised downwards.

11.4.2 The base-case analysis

11.4.2.1 Parameter estimates

Figure 11.18 shows the estimated growth curve for school whiting for the base case. As with the 2008 assessment, it is only possible to estimate three out of the four growth parameters. The estimates of the growth parameters are: (a) L_{min}=9.55cm, (b) L_{max} =25.0cm and (c) cv of growth = 0.073, with the fourth parameter, von Bertalanffy k, fixed at 0.25yr^{-1}.

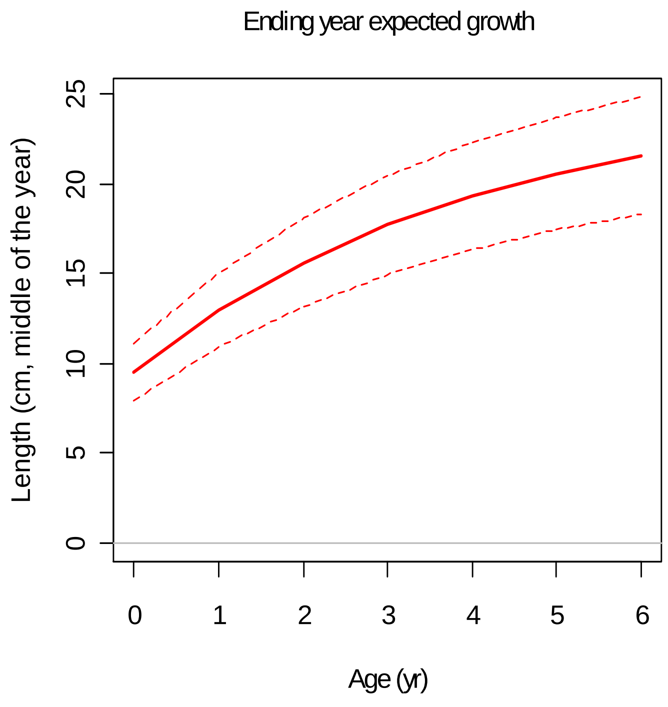


Figure 11.18. The model estimated growth function for school whiting for the base case analysis.

The parameters that define the selectivity function are the length at 50% selection and the spread. The selectivity functions for each of the three fleets are shown in Figure 11.19 for the base case. The estimates of these parameters for the Victorian Danish seine fleet are 17.4cm and 2.61cm, for otter trawl are 19.4cm and 3.81cm and for NSW Danish seine are 14.1cm and 1.79cm. The selectivity functions for each of the three fleets are shown in Figure 11.19. Note that these fitted selectivities show that otter the trawl fleet catches larger fish than either of the two Danish seine fleets and that the

NSW Danish seine fleet catches smaller fish than the Victorian Danish seine fleet. Retention for the NSW Danish seine fleet was implicitly assumed to be independent of length as no length frequency composition data is available on discards for this fleet. The estimate of the parameter that defines the initial numbers (and biomass), $ln(R_0)$, is 12.3 for the base case.

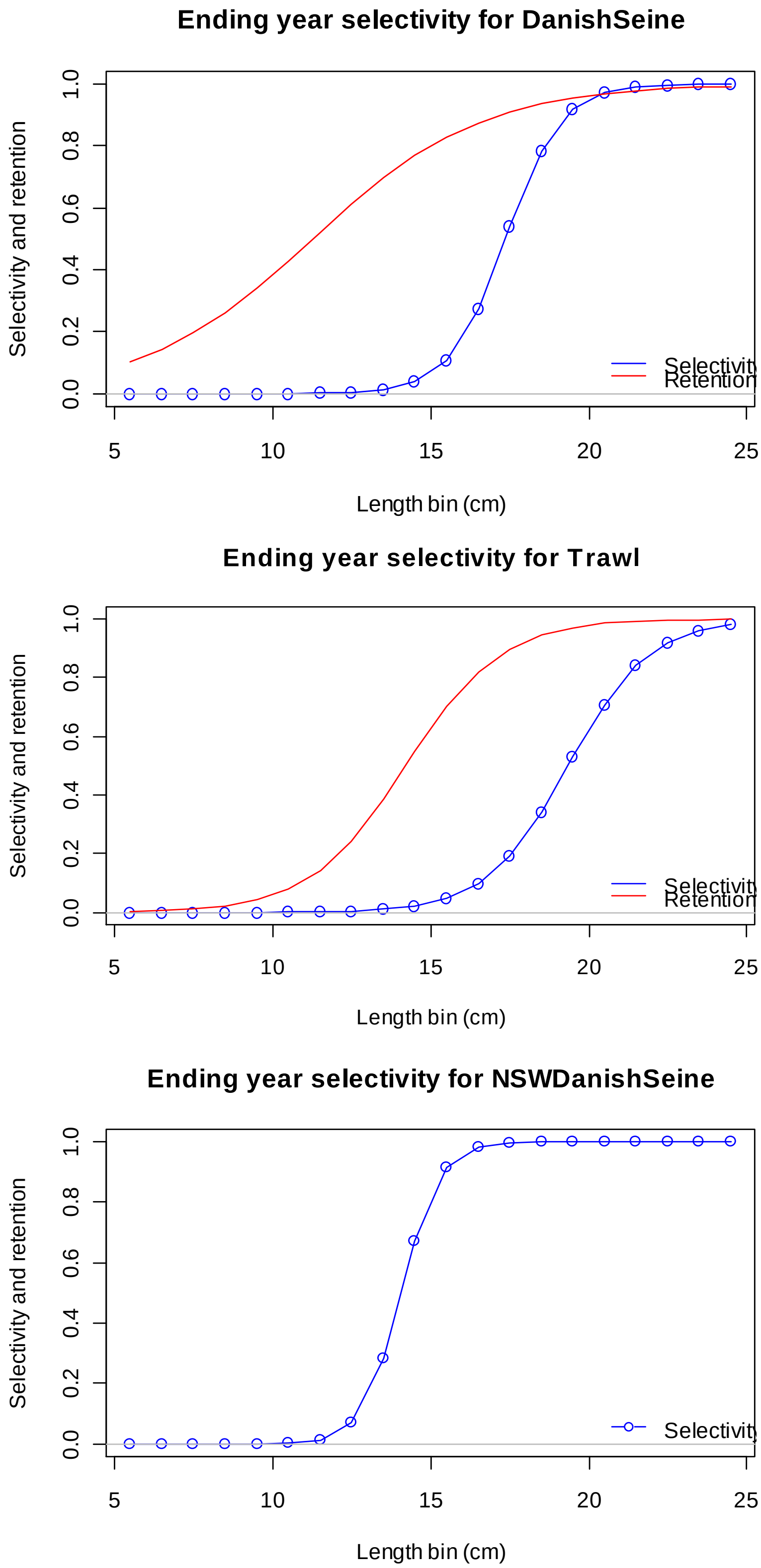


Figure 11.19. The model estimated selectivity (blue line with circles) and retention (red line) patterns for Victorian Danish seine (top), otter trawl (middle) and NSW Danish seine (bottom) fleets respectively for the base case analysis.

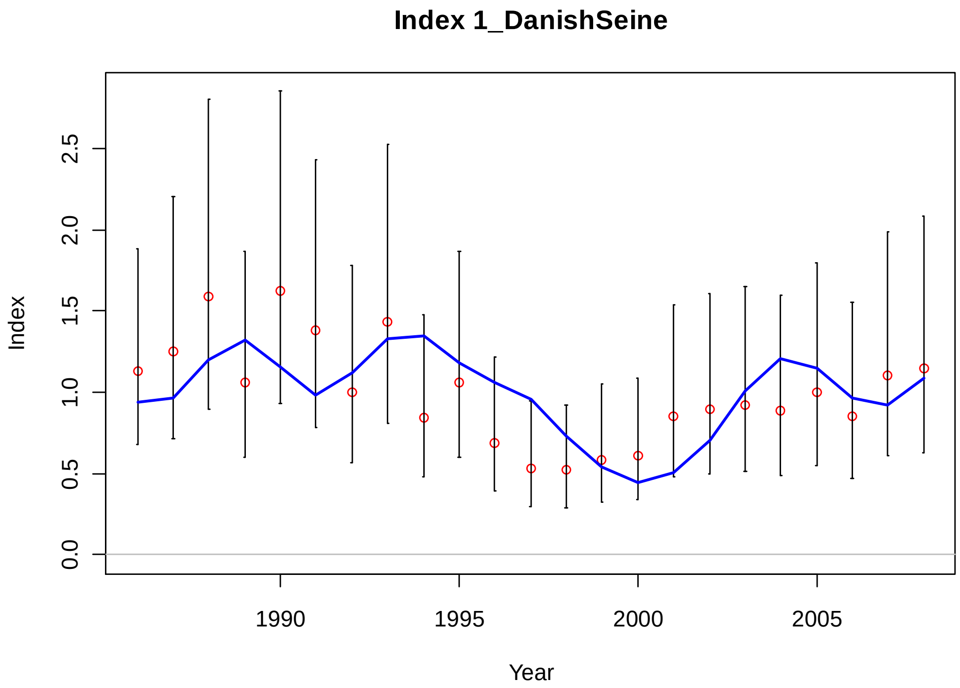


Figure 11.20. Observed (red circles) and model-predicted (blue lines) catch-rate for the Victorian Danish seine fleet versus year for the base case analysis. The vertical lines indicate approximate 95% confidence intervals for the data.

Fits to the data

The fits to the catch rate indices for the base case (Figure 11.20) are tolerable, showing a relatively stable oscillating pattern until the mid 1990s followed by a period of consistent decline and then a period of recovery from 2000 through until 2004 with a slight decline through to 2007 and an increase to 2008. The predicted CPUE is consistently higher than the observed CPUE for five consecutive years from 1994 to 1998, then lower for four years, 1999-2002 and then higher for another four years, 2003-2006. Note that the first ten years of catch rate data is quite variable, which makes it difficult to achieve a good fit to these catch rate indices.

The fits to the discard rate data (Figure 11.21 and Figure 11.22) are reasonable for the Victorian Danish seine and otter trawl fleets for the base case. To achieve reasonable levels of predicted discards, five years of very low (<4%) discard rate data was excluded (1995, 2003 and 2004 for Victorian Danish seine and 2001, 2002 and 2006 for otter trawl). If these very low discard rates are included in the model, the fitted discard rates match these very low rates well but give very poor fits to all other years with discard rates >4%. Including these low discard rates results in much lower overall predicted discard rates compared to the mean of the discard rates over all years with discard data for each fleet. To achieve predicted discard rates which have a better match to the overall discard rates, these five data points were excluded. In addition to these years with very low discard rates, discard data for the otter trawl fleet were excluded in 1997 and 2007 (with discard rates over 10% in each case) as these data come from sample sizes of less than ten, resulting in very uncertain estimates of the discard rate for this fleet in these years. Fits to the age and length composition data for discarded catches are shown in Section 11.8, Appendix .

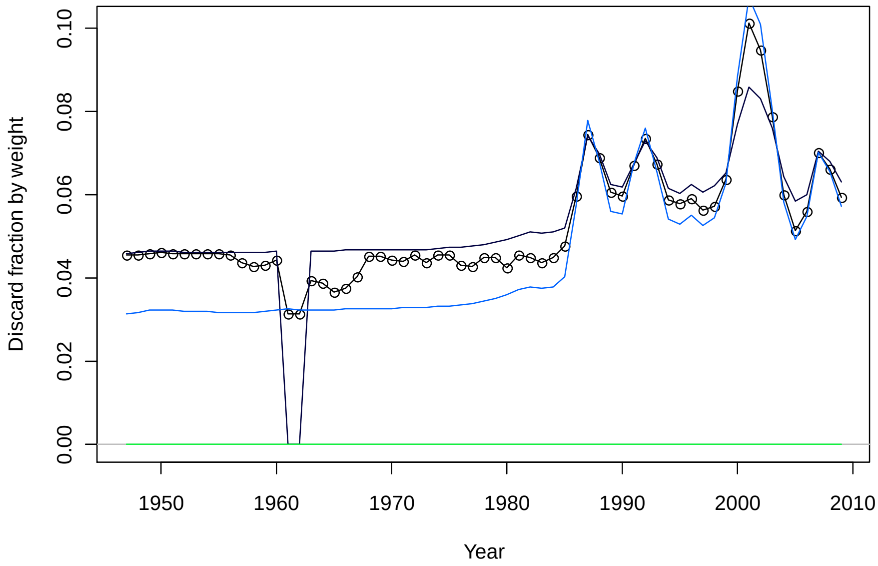


Figure 11.21. Model estimated discards by fraction of weight, including total discards (black with circles) and fleet specific discards, with Victorian Danish seine, (navy blue, initially over 4% up to the mid 1980s), otter trawl (royal blue, between 3% and 4% up to the mid 1980s) and NSW Danish seine (green, no discard data available for this fleet). Estimates of discarding range between 5% and 10% from the mid 1980s to present.

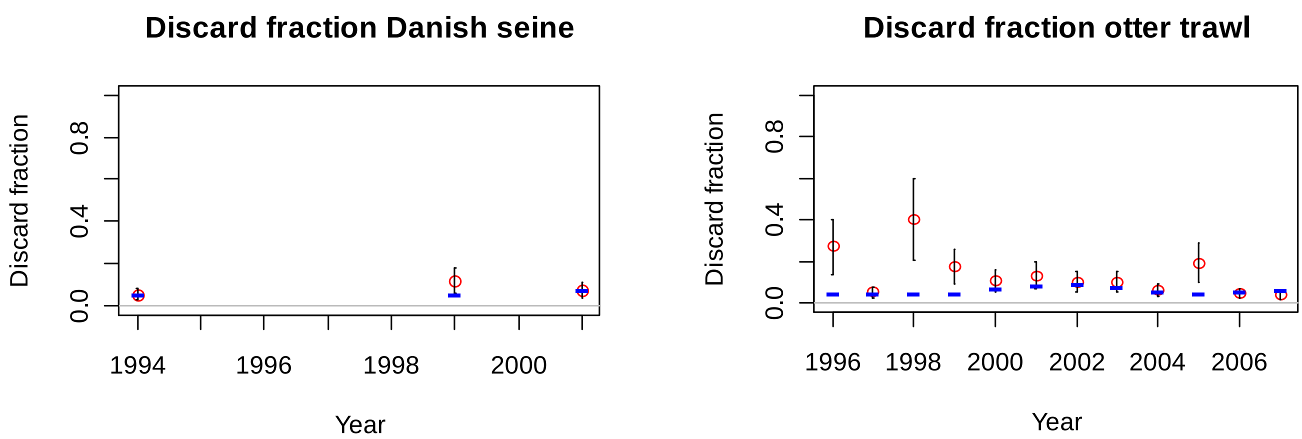
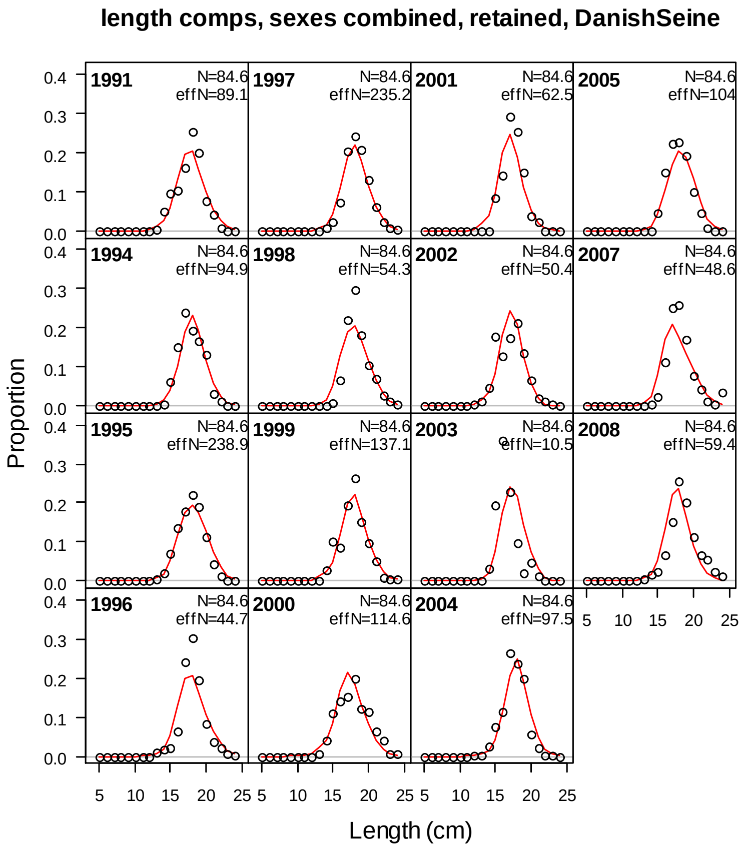
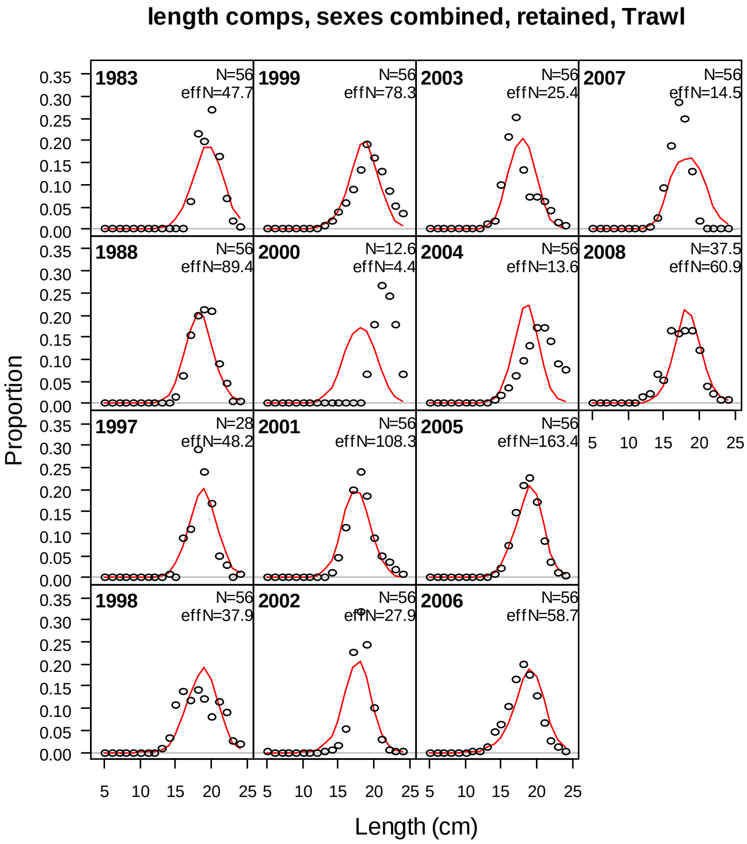


Figure 11.22. Observed (red circles) and model-predicted (blue dashes) discard rates versus year for the Victorian Danish seine (left) and otter trawl (right) fleets for the base case analysis. The vertical lines indicate approximate 95% confidence intervals for the data.

The base-case analysis is able to fit the retained length-frequency distributions adequately (Figure 11.23). The worst length frequency fits for the Victorian Danish seine fleet are for the years 2003, 1996, 2007 and 2008 with the best fits in 1995, 1997, 1999 and 2000. The modified 2007 data for the Victorian Danish seine fleet has reduced the size of the outlier in the largest length class, when compared to the data used in the 2008 assessment. The fits to the length frequency data for the otter trawl fleet are worst in the years 2000, 2004 and 2007, yet in contrast the fits in each following year, 2001, 2005 and 2008, are some of the best fits for this fleet. This suggests some inconsistency in the data, possibly due to unrepresentative sampling and a very low sample size in 2000, where the model cannot fit these changes in length distribution in one year. The fits to the length frequency data for the NSW Danish seine fleet in the 1980s are good given that this data is somewhat noisy. The fits are especially good for the years 1986, 1985 and 1983, and worst for the years 1987 and 1988.





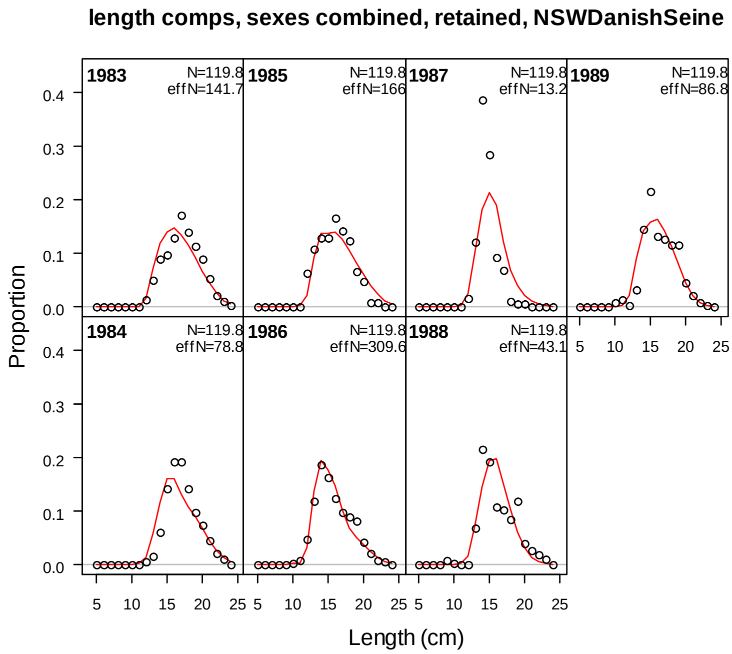


Figure 11.23. The observed and model-predicted fits to the length composition data for Victorian Danish seine (top), otter trawl (middle) and NSW Danish seine (bottom) data for school whiting for the base case analysis.

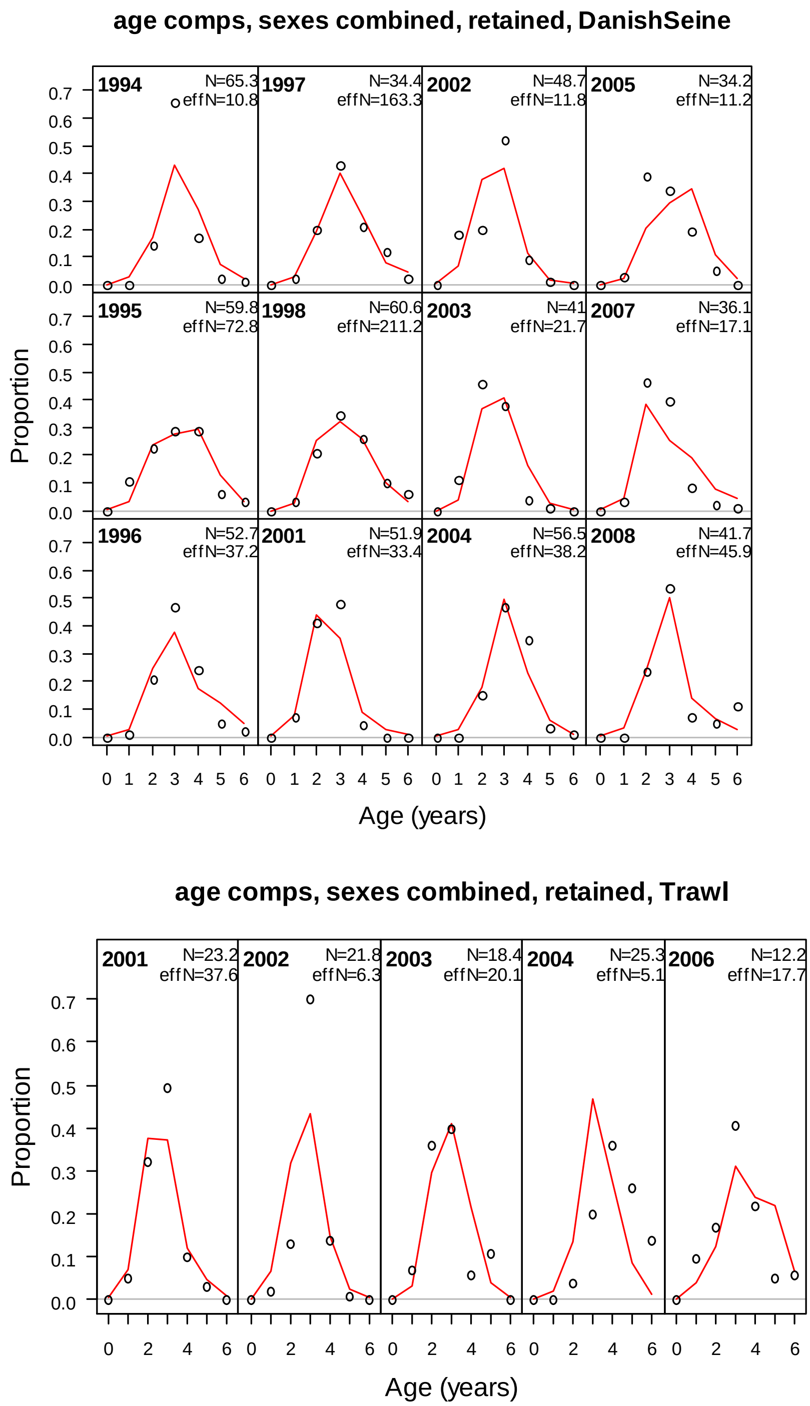


Figure 11.24. The observed and model-predicted implied fits to age for Victorian Danish seine (top) and otter trawl (bottom) data for school whiting for the base case analysis.

The implied fits to the age-composition data are shown in Figure 11.24 for the base case. It should be noted that 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 fairly well. The 2008 Victorian Danish seine age composition data is the only year where there are more fish in the 6+ group then in the 5 year old group, and the model is unable to fit this.

11.4.2.2 Assessment outcomes

The current spawning stock biomass is estimated to be 50% of unfished stock biomass (i.e. 2010 spawning biomass relative to unfished spawning biomass). The left panel of Figure 11.25 shows the time trajectory of combined male and female spawning stock biomass corresponding to the base-case analysis, and the right hand panel shows the relative spawning stock depletion with the limit and target reference points at 20% ands 48% respectively. The stock declines slowly from the beginning of the fishery in 1947, before a sharp decline in the 1980s corresponding to an increase in catch. The recoveries in the late 1980s, early 1990s and again in the early 2000s is driven by high recruitment events (Figure 11.26, left panel). After these good recruitment events, the stock can decline following poor recruitments and continued harvesting (e.g. the period of seven consecutive years of average or below average recruitment from 1992-1998) and as a result the stock shows considerable short term sensitivity to recruitment. Above average recruitment from 1999-2001 allowed a recovery in the stock from a depletion of 20% in 2000 to a depletion of over 50% by 2004. While the most recent years of recruitment are generally informed by less data and hence could potentially change after the inclusion of extra data in a future assessment, the last four years of estimated recruitment indicate a decline to a depletion of around 40% in 2007 followed by an increase to around the target of 48% by the end of 2009.

The recent recruitment history (Figure 11.26 and Figure 11.27) estimated in this assessment contrasts strongly with the previous assessment (Day 2008b), which showed above average recruitment for the last seven years of estimated recruitment from 1999-2005. The previous assessment (Day 2008b) foreshadowed possible changes, stating that “there is greater uncertainty on the recruitment estimates for recruitment event in the years 2003-2005 than for earlier recruitment events. If these recent strong recruitment events are not supported by future data, the evidence for a recent strong recovery in the stock may need to be moderated”. As foreshadowed, moderation of the prediction of a strong recent recovery was required this year, partly due to the information contained in the 2008 data, but also due to changes to the historical length frequency data, especially the 2007 data, and changes to the historical age-at-length data, especially the 2006 and 2007 data.

It is also worth noting that there have been changes to the data collection procedures for the collection of the 2007 and 2008 data, and it seems likely that the last two years of data may not be as representative of the stock as data collected in earlier years. In light of this information, estimates of the most recent recruitment should be treated with some caution. Hopefully these issues have now been addressed and future data collection will be more representative of the fishery as a whole.

Revisions to the 2007 length frequency data and 2006 and 2007 age-at length data result in very different depletion estimates when compared to the 2008 assessment, so future revisions to the most recent data used in this assessment may also have an impact in revising the results of this assessment. When the 95% confidence intervals are considered for the estimated2010 depletion rate, the range for this depletion estimate is somewhere between 40% and 60% (Figure 11.28).

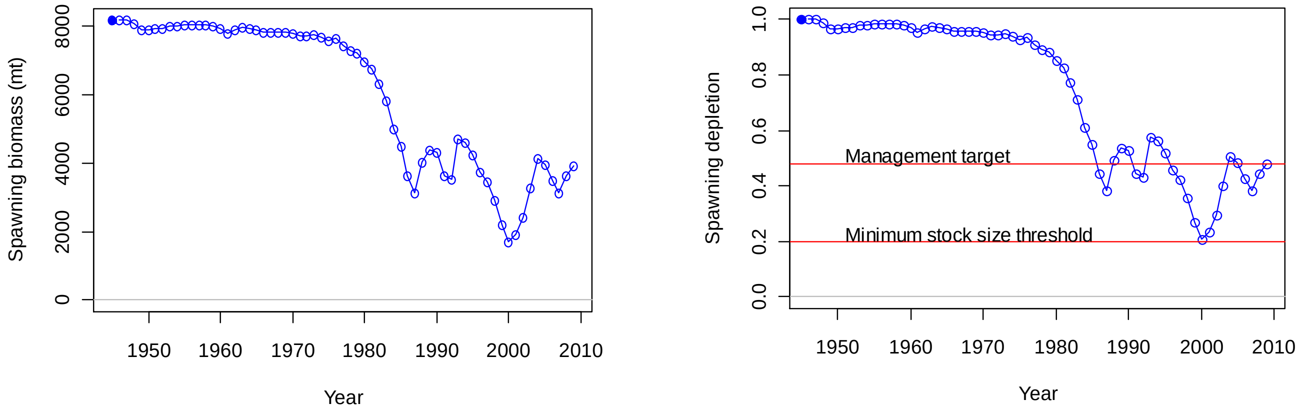


Figure 11.25. Time-trajectories of combined male and female spawning biomass and spawning biomass depletion corresponding to the MPD estimates for the base-case analysis.

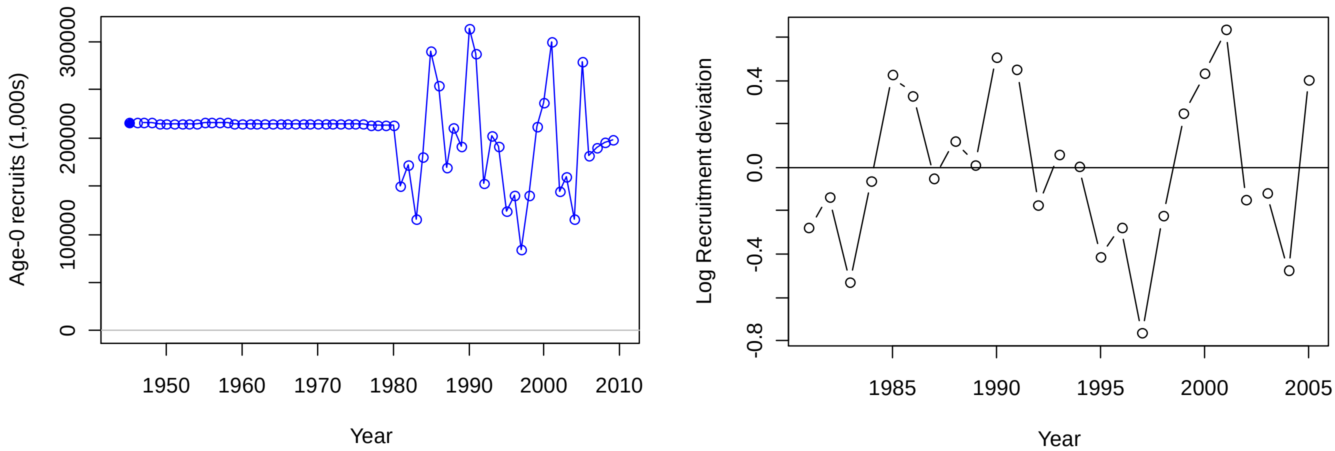


Figure 11.26. Time-trajectories of recruitment (left) and recruitment deviations (right) for the base-case analysis.

11.4.2.3 Application of the harvest control rule

An estimate of the catch for biological year 2009 is needed to run the model forward to calculate the 2010 spawning biomass and depletion. For the base case analysis, based on the 2008 catch data, the Victorian Danish seine catch in 2009 is assumed to be 423t and the otter trawl catch is assumed to be 880t, with no catch for the NSW Danish seine fleet. The total retained catch is then 1,303t. The depletion in 2010 under the base-case parameterisation is estimated to be 50%. An application of the Tier 1 harvest control rules under the target level scenarios used in 2009 (Day 2008a), leads to the following 2010 and long-term RBCs:

Control Rule	2010 RBC	Long-term RBC
20:35:48 (base case)	1,723t	1,660t

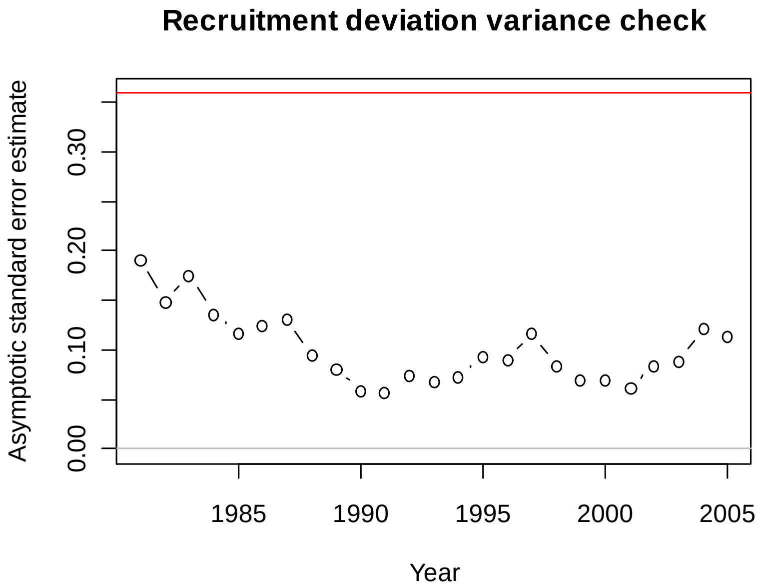


Figure 11.27. The standard error estimate on the recruitment deviation for each of the estimated recruitment parameters. Note that the standard error is reasonable for all values. In particular this standard error is neither too high at the beginning nor the end of the recruitment estimate series.

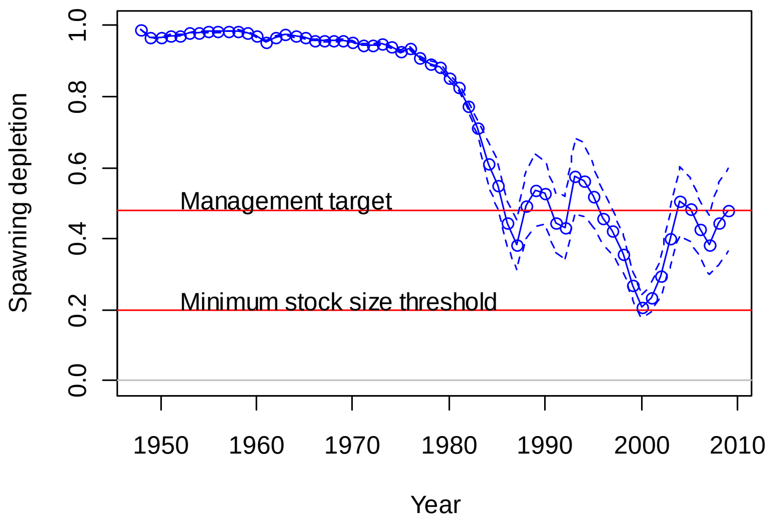


Figure 11.28. The spawning depletion time series with 95% confidence intervals for the base case. Note the tight confidence bounds on the low depletion estimate in 2000. These confidence intervals suggest that the 2010 depletion estimate could range between 40% and 60%.

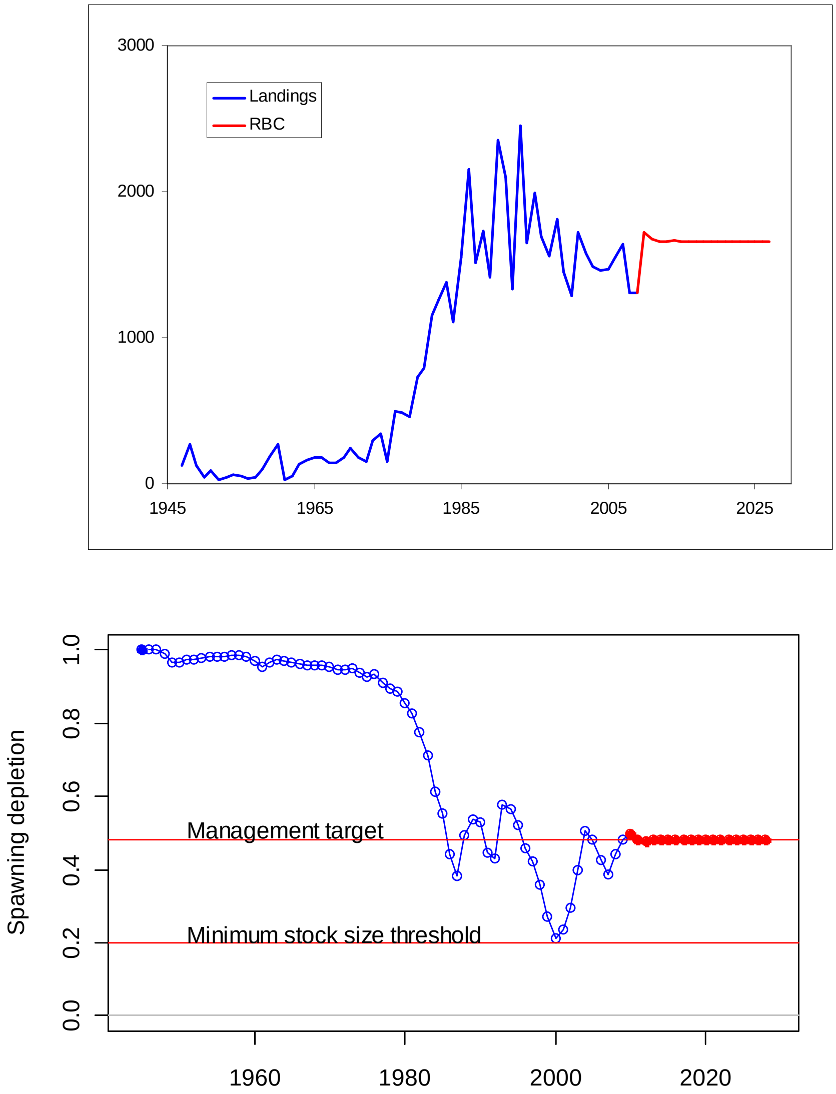


Figure 11.29. The projection of RBCs (top) and its corresponding relative spawning biomass (bottom) under the 20:35:48 rule for school whiting for the base case analysis.

An example of the time-series of RBCs and corresponding spawning biomass for the 20:35:48 harvest control rule is shown for the base case in Figure 11.29. Approximate 95% asymptotic confidence intervals for the spawning biomass are shown in Figure 11.28. These give an indication of the uncertainty in the estimates of the spawning biomass.

11.4.3 Sensitivity tests

11.4.3.1 Conventional sensitivity tests

Results of the sensitivity tests are shown in Table 11.10. As was found with the sensitivities in the 2008 assessment, these results are not very sensitive to the assumed values for steepness, *h*, von Bertalanffy *k* and σ_r (relative to the base-case). As with previous assessments, the estimates of initial spawning biomass are very sensitive to the age at 50% maturity. School whiting become sexually mature at two years of age (Smith and Wayte, 2005), which corresponds to a length of around 16cm. Three year olds are about 18cm long and school whiting reach 14cm at about 1½ years old. One year old fish are around 11-12 cm and are unlikely to be sexually mature. Other reports of length at maturity for school whiting range from 15cm in northern NSW (Kevin Rowling, pers comm. based on an unpublished research by Grey and Barnes) and 17cm in Victoria (Hyndes and Potter, 1997, based on data from Hobday and Wankowski (1986)). The base case value for length at 50% maturity has been left at 16cm.

In contrast to the results of the sensitivity analyses in the 2008 assessment, the 2009 base case was not very sensitive to including the additional low discard rates values. Including the 1970s length frequency data resulted in a reduction in the spawning biomass estimate rather than a large increase.

The 2009 base case is very sensitive to the last year recruitment is estimated. If recruitment is estimated to 2006, the depletion is estimated to be 77%, but as already discussed, this model results in a large spurious recruitment in 2006, a recruitment event that is not well supported by data. If recruitment is only estimated to 2004, the depletion estimate changes to 41%, due to the higher than average estimated 2005 recruitment returning to average value when it is no longer estimated.

This assessment is not sensitive to the weighting placed on the CPUE series with the depletion ranging from 50% to 49% when this weighting is doubled and halved. The assessment is slightly more sensitive to the weightings on the length and age data, with a depletion of 47% if the weighting on length data is halved and a depletion of 46% if the weighting on the age data is doubled. This indicates that there is some conflict in the length and age data, with the length data supporting a higher spawning biomass than the age data. The length and age data weightings were set according to standard practice in SESSF stock assessments, using iterative reweighting of this data to match input and output effective sample sizes.

The base case depletion rate for the 2007 assessment was 35%, which compares to a base case in 2008 of 82% and a base case in 2009 of 50%. This variation in assessment results requires some careful exploration of the data to explain why the assessment results can change so dramatically. In addition to the forward retrospective analyses already described, this exploration also includes a number of backward retrospective analyses where the three most recent years of data were removed one at a time from the 2009 base case assessment so that the effect of the most recent data can be examined. This approach shows whether a change in the assessment is strongly influenced by data from any particular year out of the three most recent years of data.

11.4.3.2 Backward retrospective analyses: whole years excluded

The backward retrospective analyses start from the 2009 base case and, for each sensitivity analysis, successively exclude recent non-catch data, a year at a time. In each case in this section, the comparisons are made between the 2009 base case and the respective sensitivity analysis.

The exclusion of the 2008 non-catch data results in an increase in the 2010 RBC values (due to a change in the depletion from 50% to 59%) and a small decrease in the size of the estimated recruitment events from 1999 2002 (relative reductions between 5% and 20% in each of these years) and larger increases in the size of the estimated recruitment events in 2004 and 2005 (greater than 40% relative increase in 2004 and 30% relative increase in 2005). The next retrospective excludes all of the 2007 non-catch data as well as the 2008 data and in this case the 2010 depletion is 34% with reductions to the recruitment estimates in the period 2001-2004 (average relative reduction of 20% per year in this period). When all the 2006 non-catch data is also excluded, there is a relative increase of 120% in recruitment in 2004 and a relative decrease of 40% in 2005. With all three years of data excluded, the spawning biomass time series and the 2010 depletion estimate resembles the base case more closely than the cases when only one or two years of data is excluded and the 2010 depletion is estimated to be 52%.

Inclusion of the most recent data suggests that there is a strong recovery in spawning biomass from 2000 to 2004. The 2009 base case spawning biomass trajectory falls midway between the trajectory where the 2008 data is excluded (with a higher 2010 biomass) and the trajectory where both the 2007 and 2008 data is excluded (with a lower 2010 biomass). Inclusion of the 2008 data reduces the estimate of the 2005 recruitment. These changes to the spawning biomass and recruitment series from this retrospective analysis are illustrated in Figure 11.30 and Table 11.11.

Note that the recruitment series shown in Figure 11.30 have different base line values for recruitment, which makes comparison of the absolute values difficult. The changes in recruitment described in the text above are relative changes. To make these figures comparable to the 2009 base case, the new recruitment series are normalised to match the 2009 base case recruitment in 1947 at the start of the recruitment series, and the 2009 base case recruitment series is compared to the normalised recruitment series for each sensitivity analysis.

The base case analysis features a large recruitment event in 2005. When the 2008, 2007 and 2006 data are excluded successively, the estimates of this recruitment event vary. This suggests that all three years of data influence the spawning biomass time series approaching 2010, but with no consistent pattern, or without one year of data having a substantially different impact to the other years. The 2006 and 2007 data appear to pull the spawning biomass in opposite directions, with the addition of the 2008 data returning the prediction closer to the result obtained only using data up to 2005. The 2008 data appears to be no more influential on the model results than the 2007 or the 2006 data.

It appears that there are conflicting signals evident in the 2007 and 2008 data, but the inclusion of the 2008 data moderates the estimated size of the large recruitment in 2005. This also results in a lower estimate of 2010 spawning biomass.

As always, for a short lived species like school whiting, large recruitment events at the end of the recruitment time series should be treated with caution as they are not supported by successive years of informative data. Earlier recruitment events are much better supported by the data, as a good cohort can be observed (or confirmed) over a period of several years. In the 2007 and 2008 assessments (Day 2007, Day 2008b) a decision was made to stop estimating recruitment residuals for the last two years of data only. This decision was revised in this assessment.

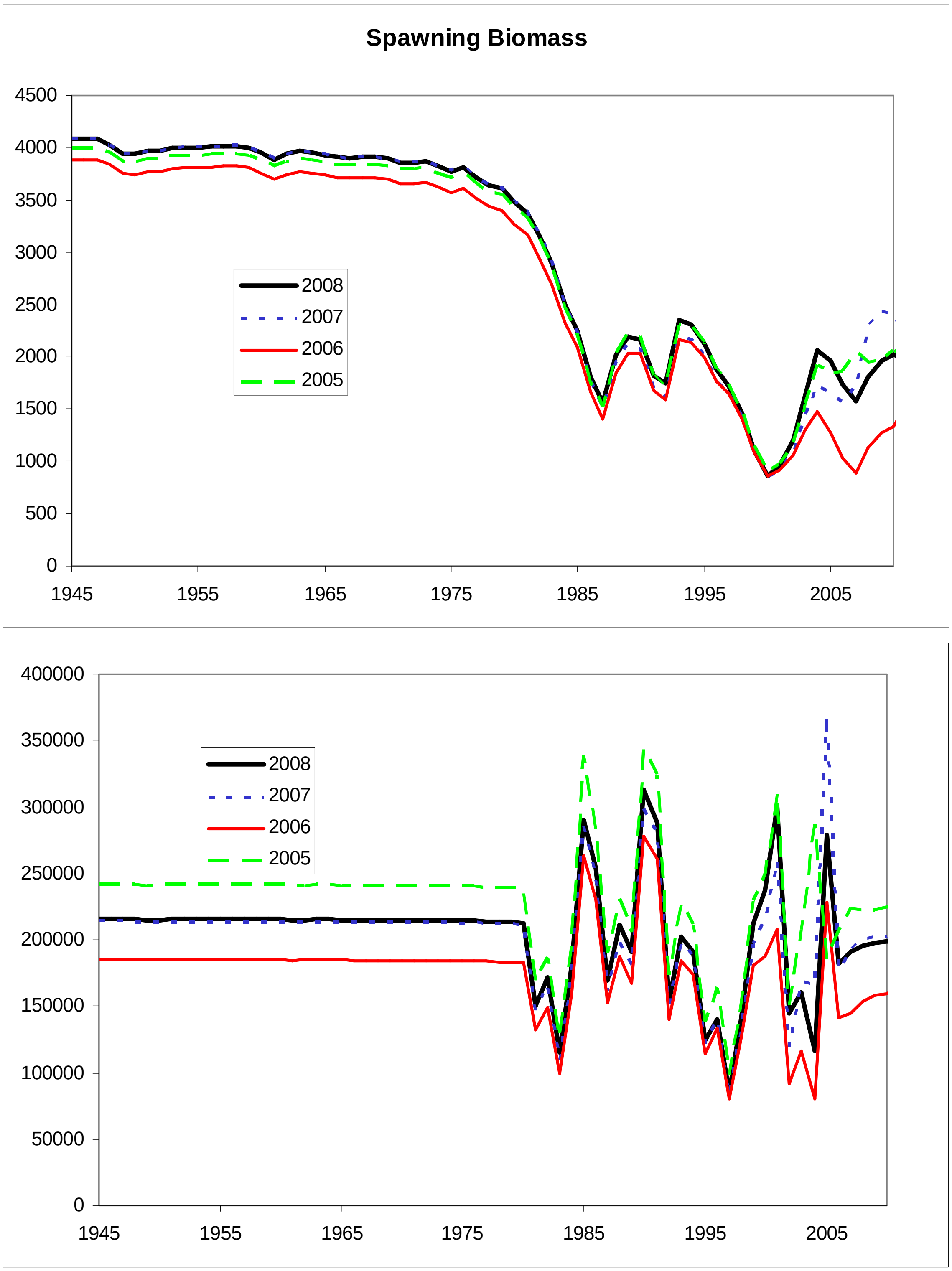


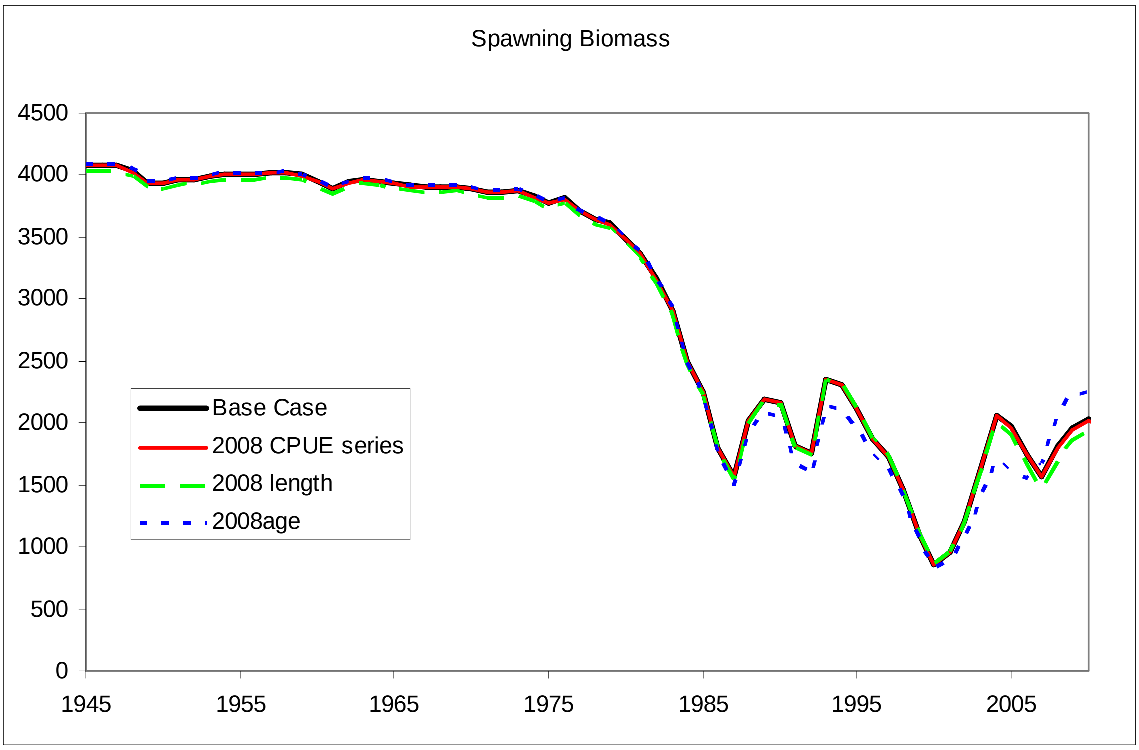
Figure 11.30. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 - 2015 using all the data to the end of 2008 (bold line, black), data to 2007 (solid line, red), data to 2006 (dashed line, green) and data to 2005 (dotted line, blue).

11.4.3.3 Backward retrospective analyses: individual components of the 2008 data excluded

The remaining backward retrospective analyses start from the 2009 base case and, for each sensitivity analysis, individual components of the 2008 non-catch data are excluded, with replacement. In each case in this section, the comparisons are made between the 2009 base case and the respective sensitivity analysis. This allows an investigation of the separate influence of the 2008 CPUE, length and age data on the 2009 base case, with impacts on estimates of spawning biomass and recruitment shown in Figure 11.31 and in Table 11.11.

Excluding the 2008 CPUE and length data alone result in minimal changes to the initial spawning biomass, the recruitment series and to the depletion rates. However, excluding the 2008 age data has more impact, with larger changes to the recruitment series and a change in the depletion rate from 50% for the base case to 55%. Without the 2008 age data, larger recruitments are estimated in 2004 (relative increase of 43%) and 2005 (relative increase of 18%) and smaller recruitments in 2000 and 2001 (relative decreases of 12% and 16% respectively). In contrast, the other components of the 2008 data have little impact on the recruitment or spawning biomass estimates.

The 2008 age data contains information that changes recent recruitment estimates, especially the most recent estimated recruitment in 2005, and this also results in a reduction in the estimate of the 2010 spawning biomass.



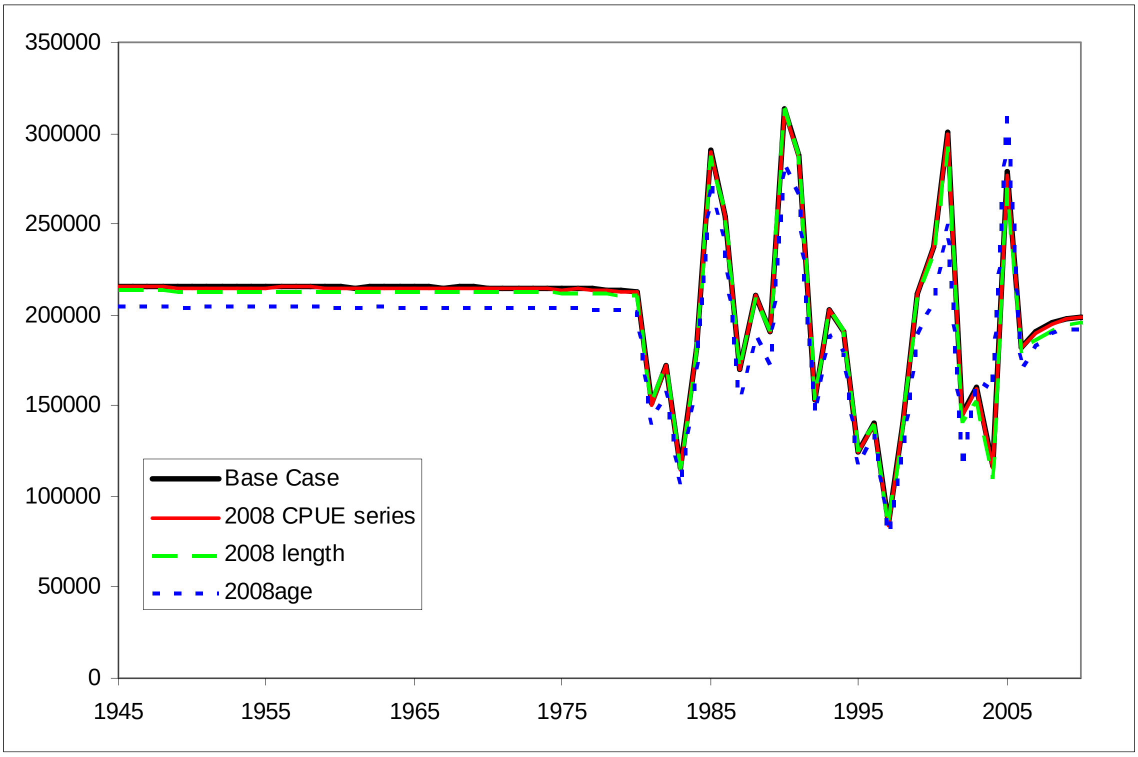


Figure 11.31. The 2009 assessment results with final year updates with one component of the data removed at a time, using data to 2008. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945-2015, showing the 2009 assessment (bold line, black), CPUE data to 2006 only (solid line, red), length data to 2006 only (dashed line, green) and age data to 2006 only (dotted line, blue).

11.4.4 Discussion

This document presents an assessment of school whiting (*Sillago flindersi*) in the SESSF using data up to 31 December 2008. This is an update to the previous stock assessment for school whiting (Day 2008b) which used data from 1947 through until 2007. Changes from the 2008 assessment include: (a) revised historical catch, length and age data for the period 1994-2007, (b) the addition of updated length frequencies, catches and catch-rates for data collected in 2008, (c) the estimation of recruitment up to 3 years before the most recent data and (d) the estimation of the natural mortality parameter, *M*.

The updated base-case assessment estimates that the 2010 spawning stock biomass is 50% of unfished stock biomass, which is just above the target biomass. Fits to the length, age, and catch-rate data are reasonable. Exploration of model sensitivity shows that the model outputs are most sensitive to the last year that recruitment is estimated, are also sensitive to the length at 50% maturity and are a little sensitive to the weightings used for length and age data. While the model is very sensitive to the last year that recruitment is estimated, there are strong arguments to set this final recruitment date at 2005, as used for the base case. This ensures that the length and age data from 2008 provides some information on the last recruitment estimate in 2005.

Depletion across all sensitivities varied between 41% (when recruitment is only estimated to 2004) and 77% (when recruitment is estimated to 2006). If the final year of recruitment estimates is fixed at 2005, the values of depletion estimated range from 40% (50% maturity at 14 cm) and 58% (50% maturity at 18 cm).

The major changes to the assessment are due to: recruitment estimation to three years before the most recent data used in the assessment; the updates and revisions to the data used in the assessment from 1994-2007; the new 2008 data; and estimating the natural mortality parameter, *M*.

The RBC for the updated base-case model for 2009 is 1,723t under the 20:35:48 harvest control rule, while the long-term yields under this harvest control rules is 1,660 t.

There were minor changes to the revised catch series over the period 1994-2007, with the major change being an additional 331t of reported catch in NSW state waters in 2007. In addition to this change there was a combined reduction of 7t in Commonwealth catch from 2006-2007 and a reallocation of Commonwealth catch between Danish seine and otter trawl fleets with a total of around 130t being switched from the Danish seine fleet to the otter trawl fleet in a 14 year period from 1994-2007. In contrast to the 2008 assessment, the revisions to the historical catch series had a very minor impact on this assessment.

In addition to the revised catch data there were minor modifications to the 2006 and 2007 conditional age-at-length data and minor changes to the length frequency distributions in the period 1994-2002. There were more substantial changes to length frequency distributions in 2007 with an additional 1467 samples for the Victorian Danish seine fleet and additional 285 samples for the otter trawl fleet. Unless the additional data comes from biased sources, the expectation is that there would be little change to the length frequency distributions in individual years, so additional length frequency data would not be expected to result in large changes to an assessment. In this case there are some changes to these distributions, and this results in changes to the assessment outcomes.

Forward retrospectives showed that these revisions resulted in a reduction in the estimate of 2009 spawning biomass, although inclusion of the 2008 data, including the 2008 catch data, increased this estimate of 2009 spawning biomass. Backward retrospectives suggest that there is some conflict between the 2007 and 2008 non-catch data sets, with the 2007 data supporting a higher spawning biomass and the 2008 non catch data supporting a lower spawning biomass.

The 2009 base case estimates a strong recruitment event in 2005, the last year in which recruitment is estimated. However this recruitment should be treated with some caution as there is some uncertainty about this estimate. The use of data collected from 2009 onwards in any future assessment will reduce the uncertainty of this recruitment estimate and may result in revisions to the estimates of the 2005 recruitment event and the 2010 biomass.

School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very rapid impact on the fish stock. As a result there will always be some uncertainty about the status of the stock. Further exploration of some biological parameters, such as age and length at maturity may help reduce this uncertainty, but the high mortality rate and short expected life time for this species mean that rapid changes are always possible and projections will always be subject to uncertainty relating to the most recent recruitment events, which may be poorly informed until the cohorts involved fully enter the fishery.

11.5 Acknowledgements

The members of the SESSF stock assessment group – Neil Klaer, Gavin Fay, André Punt, Sally Wayte, Robin Thomson, Geoff Tuck, Rich Little, and Malcolm Haddon – are thanked for their generous advice and comments during the development of this assessment. Thanks also to the providers of data for this assessment – Neil Klaer for the provision of stock assessment data (in a very useful format), Kevin Rowling (NSW Fisheries) for providing NSW length frequency compositions, Malcolm Haddon for the calculation of the catch-rate indices and Kyne Krusic-Golub (Fish Ageing Services Pty Ltd) for the provision of ageing data. Thanks also to other members of Shelf RAG for their helpful discussion and input to the assessment process throughout the year.

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11.7 Tables

Table 11.1. The annual catch for all three fleets, the proportion discarded for two fleets and the standardised catch rate and coefficient of variation (Haddon, 2009) for the Vic. Danish seine fleet for school whiting.

2009 final version updated

Year	Vic Danish seine	Otter trawl	NSW Danish seine	Vic Danish seine discard proportion	Trawl discard proportion	Catch rate	Catch rate c.v.
1947	122	4	0				
1948	262	8	0				
1949	125	4	0				
1950	47	1	0				
1951	89	3	0				
1952	26	1	0				
1953	46	1	0				
1954	59	2	0				
1955	49	2	0				
1956	39	1	0				
1957	41	7	0				
1958	76	22	1				
1959	154	38	1				
1960	230	37	1				
1961	0	23	1				
1962	0	52	2				
1963	73	61	2				
1964	78	79	2				
1965	59	117	4				
1966	69	107	3				
1967	81	57	2				
1968	128	12	0				
1969	164	18	0				
1970	204	40	1				
1971	143	36	1				
1972	135	14	0				
1973	233	64	2				
1974	301	37	1				
1975	139	17	0				
1976	351	138	4				
1977	322	157	5				
1978	352	104	3				
1979	538	188	5				
1980	412	367	11				
1981	772	368	11				
1982	714	535	16				
1983	705	650	19				
1984	614	476	14				
1985	1005	525	15				
1986	1451	684	20			1.1334	0
1987	1041	457	13			1.2539	0.0291
1988	1293	427	12			1.5897	0.0297
1989	1079	324	8			1.0619	0.0286
1990	1691	651	10			1.6270	0.0267
1991	1477	609	12			1.3816	0.0284
1992	791	530	12			1.0046	0.0325
1993	1529	905	15			1.4332	0.0287
1994	1138	495	15	0.0536		0.8407	0.0288
1995	1359	632	0	0.0024		1.0610	0.0293
1996	880	815	0		0.2705	0.6907	0.0296
1997	688	868	0		0.0540	0.5334	0.0319
1998	645	1169	0		0.3986	0.5217	0.0327
1999	610	839	0	0.1199	0.1740	0.5881	0.0381
2000	388	902	0		0.1054	0.6084	0.0380
2001	502	1218	0	0.0759	0.1308	0.8569	0.0392
2002	545	1033	0		0.1032	0.8979	0.0375
2003	510	980	0	0.0087	0.1031	0.9232	0.0369
2004	417	1047	0	0.0000	0.0642	0.8877	0.0396
2005	356	1113	0		0.1924	0.9986	0.0412
2006	339	1213	0		0.0452	0.8574	0.0430
2007	410	1226	0		0.0406	1.1024	0.0420
2008	423	880	0		0.0000	1.1469	0.0456

Table 11.2. The standard deviation of age reading error for whole otoliths (used until 2006).

age	st. dev.
0.5	0.294347
1.5	0.294347
2.5	0.294355
3.5	0.294465
4.5	0.295919
5.5	0.315190
6.5	0.570463

Table 11.3. The standard deviation of age reading error for sectioned otoliths (used for 2007 and 2008).

age	st. dev.
0.52356	0.294347
1.69764	0.294347
2.71059	0.294355
3.58451	0.294465
4.33850	0.295919
4.98900	0.315190
5.55022	0.570463

Table 11.4. Estimated and pre-specified parameters of the model.

Estimated parameters	Number of parameters
Unexploited recruitment	1
Recruitment deviations 1981 – 2005	25
Growth	3
Selectivity	6
Retention	4

Pre-specified parameters	Values
Recruitment variability, σ_r	0.259, 0.359, 0.459
Maturity inflection	14, 16, 18
Steepness, *h*	0.65, 0.75, 0.85
Maturity slope	-2
Length-weight scale, a	1.32×10^{-5}
Length-weight power, b	2.93

Table 11.5. Summary of results for the 2008 SS2 base case, with 2009 depletion values and 2009 RBC values, and conversion of this base case from SS2 to SS3-V3.03a using Popes approximation (middle line) and then the new continuous hybrid method of estimating fishing mortality (bottom row). The depletion rate is identical for the top two rows, even though the absolute values of the initial biomass change.

Model	female SB_0	SB_{2009}	SB_{2009}/SB_0	2009 RBC 20:35:48	longterm RBC 20:35:48	-ln L
2008 base-case (M=0.6, h=0.75, σ_R=0.42)	**4,528**	**3,714**	**0.82**	**3,785**	**2,070**	**1,370.35**
SS3 base case (M=0.6, h=0.75, σ_R=0.42)	3,829	3,120	0.82	3,403	1,782	1,372.93
SS3 base case - continuous F	4,157	3,213	0.77	3,344	2,007	1,361.05

Table 11.6. Summary of results for the modified 2008 SS-V3.03a assessment, with 2009 depletion values and 2009 RBC values, and updates to the 2008 assessment, including revised data from 1994-2007. The 2008 SS-V3.03a base case is initially modified by adding revised data from each component separately, so that the effects of each component of the data can be explored (lines 2-6). The last line of this table shows the results of adding all the revised data from 1994-2007 to the 2008 SS-V3.03a base case. In all cases recruitment is estimated until 2005 only, 2 years before the most recent data used in these analyses.

Model rec devs to 2005	female SB_0	SB_{2009}	SB_{2009}/SB_0	2009 RBC 20:35:48	longterm RBC 20:35:48	-ln L
2008 SS-V3.03a base case (2005 rec)	4,157	3,213	0.77	3,344	2,007	1,361.05
2008 base case - catch data updated to 2007	4,177	3,207	0.77	3,324	2,013	1,361.05
2008 base case - CPUE data updated to 2007	4,162	3,219	0.77	3,349	2,009	1,361.30
2008 base case - length data updated to 2007	4,099	2,555	0.62	2,554	1,961	1,320.16
2008 base case - age data updated to 2007	4,147	3,449	0.83	3,655	2,079	1,329.08
2008 base case - discards updated to 2007	4,115	3,091	0.75	3,227	1,991	1,362.63
2008 base case - all data updated to 2007	4,008	3,001	0.75	3,171	2,020	1,306.41

Table 11.7. Summary of results for the modified 2008 SS-V3.03a assessment, with 2009 depletion values and 2009 RBC values, and updates to the 2008 assessment, including revised data from 1994-2007. The 2008 SS-V3.03a base case is initially modified by only estimating recruitment to 2004 and then further modified by adding revised data from each component separately, so that the impacts of each component of the data can be explored (lines 2-6). The last line of this table shows the results of adding all the revised data from 1994-2007 to the 2008 SS-V3.03a base case. In all cases recruitment is estimated until 2004 only, 3 years before the most recent data used in these analyses.

Model rec devs to 2004	female SB_0	SB_{2009}	SB_{2009}/SB_0	2009 RBC 20:35:48	longterm RBC 20:35:48	-ln L
2008 SS-V3.03a base case (2004 rec)	4,086	2,839	0.69	2,947	1,969	1,361.54
2008 base case - catch data updated to 2007	4,107	2,838	0.69	2,934	1,975	1,361.52
2008 base case - CPUE data updated to 2007	4,091	2,841	0.69	2,948	1,971	1,361.80
2008 base case - length data updated to 2007	3,957	1,681	0.42	1,664	1,879	1,323.15
2008 base case - age data updated to 2007	3,934	2,316	0.59	2,448	1,967	1,332.89
2008 base case - discards updated to 2007	4,031	2,754	0.68	2,884	1,952	1,362.61
2008 base case - all data updated to 2007	3,756	1,585	0.42	1,646	1,882	1,314.00

Table 11.8. Summary of results for the modified 2008 SS-V3.03a assessment, with 2009 depletion values and 2009 RBC values, and updates to the 2008 assessment including additional data from 2008. The initial 2008 SS-V3.03a assessment includes all revised data to 2007 initially and is then modified by adding revised data from each component separately, so that the effects of each component of the data can be explored (lines 2-5). The last line of this table shows the results of adding all the additional data from 2008 to the 2008 SS-V3.03a assessment. In all cases recruitment is estimated until 2004 only, 4 years before the most recent data used in most of these analyses.

Model rec devs to 2004 all data updated to 2007	female SB_0	SB_{2009}	SB_{2009}/SB_0	2009 RBC 20:35:48	longterm RBC 20:35:48	-ln L
2008 SS-V3.03a base case (new 2007 data)	3,756	1,585	0.42	1,646	1,882	1,314.00
2008 base case - 2008 catch data added	3,756	1,693	0.45	1,761	1,882	1,314.00
2008 base case - 2008 CPUE data added	3,740	1,596	0.43	1,666	1,883	1,314.61
2008 base case - 2008 length data added	3,837	1,774	0.46	1,844	1,915	1,335.15
2008 base case - 2008 age data added	3,896	1,650	0.42	1,683	1,914	1,393.56
2008 base case - all data to 2008 added	3,944	1,876	0.48	1,903	1,926	1,414.36

Table 11.9. Summary of results the modified 2008 SS-V3.03a assessment, with 2010 depletion values and 2010 RBC values with full updates to the 2008 SS-V3.03a assessment, and a 2009 SS-V3.03a assessment updates base case. The 2008 SS-V3.03a base case includes all revisions to the historical data (to 1994-2007) and all new 2008 data, but with recruitment estimated only to 2004. The 2009 SS-V3.03a base case estimates recruitment to 2005, estimates mortality, *M*, and is retuned.

Model rec devs to 2004 all data updated to 2008	female SB_0	SB_{2010}	SB_{2010}/SB_0	2010 RBC 20:35:48	longterm RBC 20:35:48	-ln L
2008 SS-V3.03a base case (new 2008 data)	3,944	1,873	0.47	1,905	1,926	1,414.36
2009 base case - new data, rec to 2005, est M	4,078	2,026	0.50	1,723	1,660	1,594.38

Table 11.10. Summary of results for the base-case analysis and the sensitivity tests (log-likelihood (-ln L): values that are comparable are in bold face).

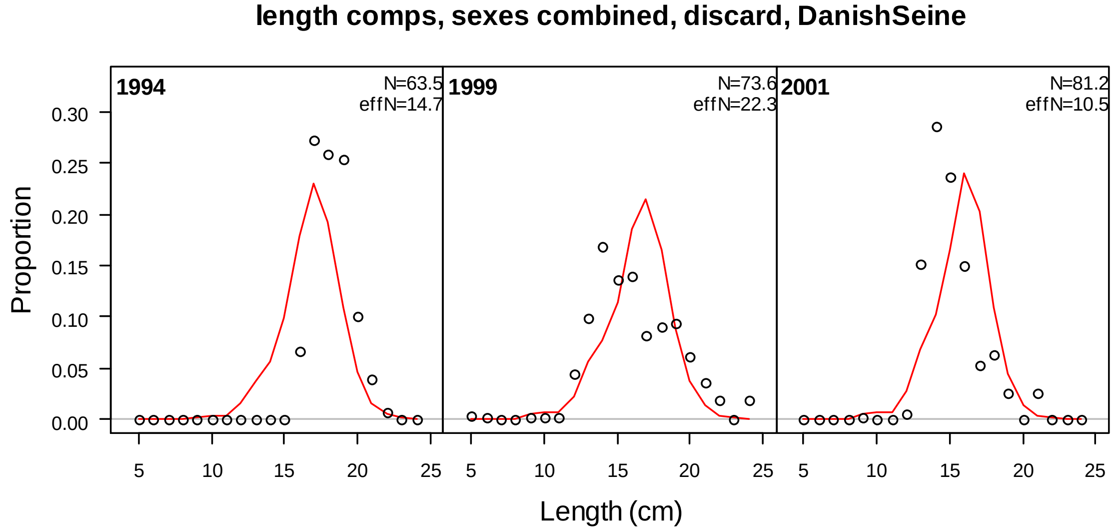
Model	female SB_0	SB_{2009}	SB_{2010}/SB_0	2010 RBC 20:35:48	longterm RBC 20:35:48	-ln L
base-case (h=0.75, σ_R=0.359)	**4,078**	**2,026**	**0.50**	**1,723**	**1,660**	**1,594.38**
h = 0.65	4,280	2,070	0.48	1,672	1,653	**1,595.03**
h = 0.85	3,933	1,992	0.51	1,757	1,663	**1,594.01**
50% maturity at 14 cm	4,937	2,843	0.58	2,373	1,866	**1,594.38**
50% maturity at 18 cm	3,035	1,228	0.40	1,263	1,467	**1,594.49**
VBK = 0.2	4,014	2,058	0.51	1,819	1,699	**1,579.96**
VBK = 0.3	4,133	1,988	0.48	1,634	1,626	**1,620.25**
σ_R= 0.259	4,002	1,946	0.49	1,606	1,583	1,604.87
σ_R=0.459	4,203	2,120	0.50	1,872	1,776	1,589.29
Estimate recruitment to 2004	4,012	1,645	0.41	1,364	1,604	1,600.27
Estimate recruitment to 2006	4,240	3,244	0.77	2,857	1,781	1,587.88
Double weighting on CPUE	4,111	2,073	0.50	1,766	1,676	1,605.10
Halve weighting on CPUE	4,054	2,002	0.49	1,705	1,654	1,588.37
Double weighting on LF data	4,053	2,055	0.51	1,748	1,643	2,042.10
Halve weighting on LF data	4,118	1,918	0.47	1,588	1,636	1,361.31
Double weighting on age data	4,050	1,862	0.46	1,550	1,617	2,673.70
Halve weighting on age data	4,105	2,109	0.51	1,809	1,682	1,044.03
Include all discards	3,971	1,966	0.50	1,667	1,612	1,632.90
Add 1970s lfs	4,160	1,876	0.45	1,434	1,527	1,666.52

Table 11.11. Summary of results for the 2009 base-case analysis, and retrospective analyses where either components of the 2008 data are excluded or whole years of data are omitted to allow the impacts of different components of the recent data to be considered.

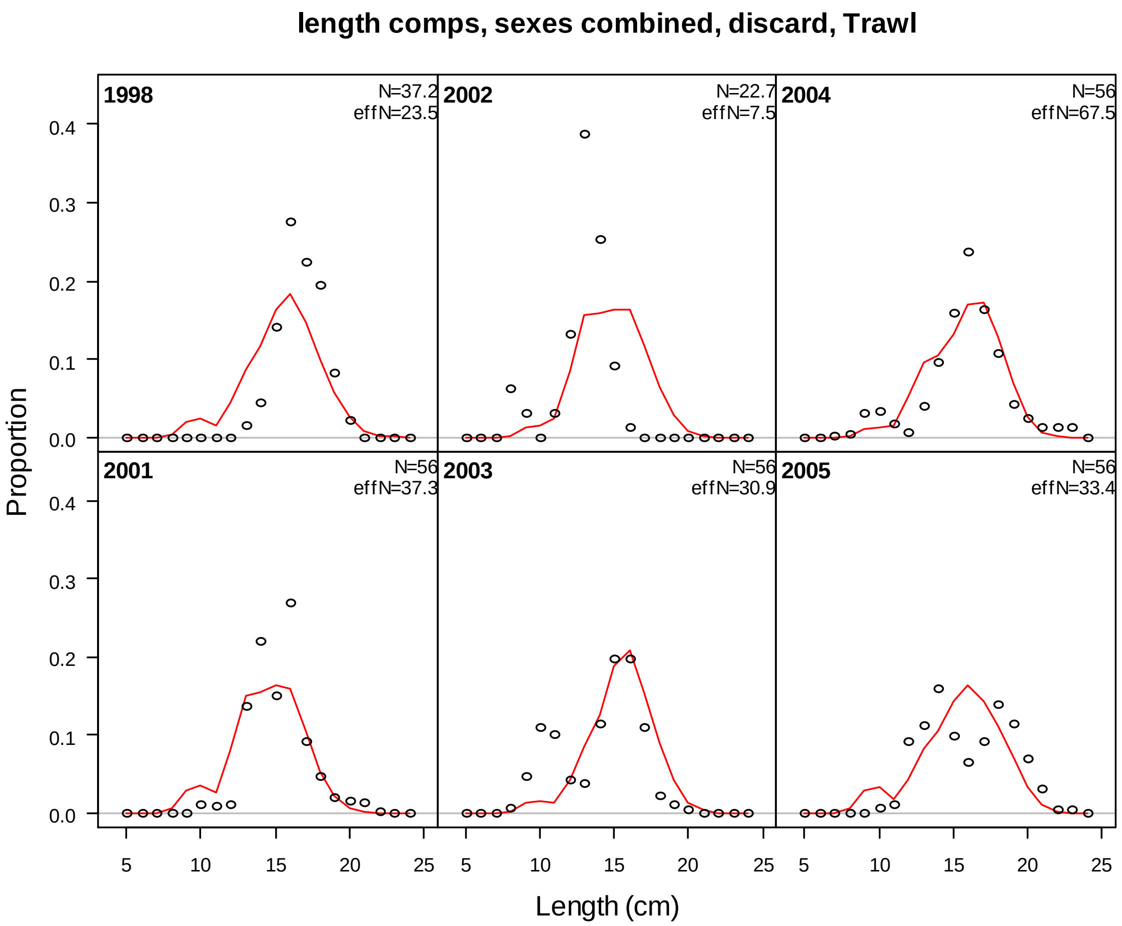
Model	female SB_0	female SB_{2010}	SB_{2010}/SB_0	2010 RBC 20:35:48	longterm RBC 20:35:48	-ln L
base-case (h=0.75, σ_R=0.379)	**4,078**	**2,026**	**0.50**	**1,723**	**1,660**	**1,594.38**
Remove 2008 data except for catch data	4,081	2,404	0.59	2,091	1,675	1,467.93
Remove 2007/8 data except for catch data	3,886	1,331	0.34	1,038	1,535	1,413.78
Remove 2006/7/8 data except for catch data	4,004	2,062	0.52	1,870	1,734	1,356.40
2008 CPUE removed	4,076	2,013	0.49	1,710	1,658	1,594.36
2008 length data removed	4,038	1,925	0.48	1,639	1,646	1,580.59
2008 age data removed	4,091	2,243	0.55	1,910	1,649	1,482.27

11.8 Appendix: discard age and length composition fits

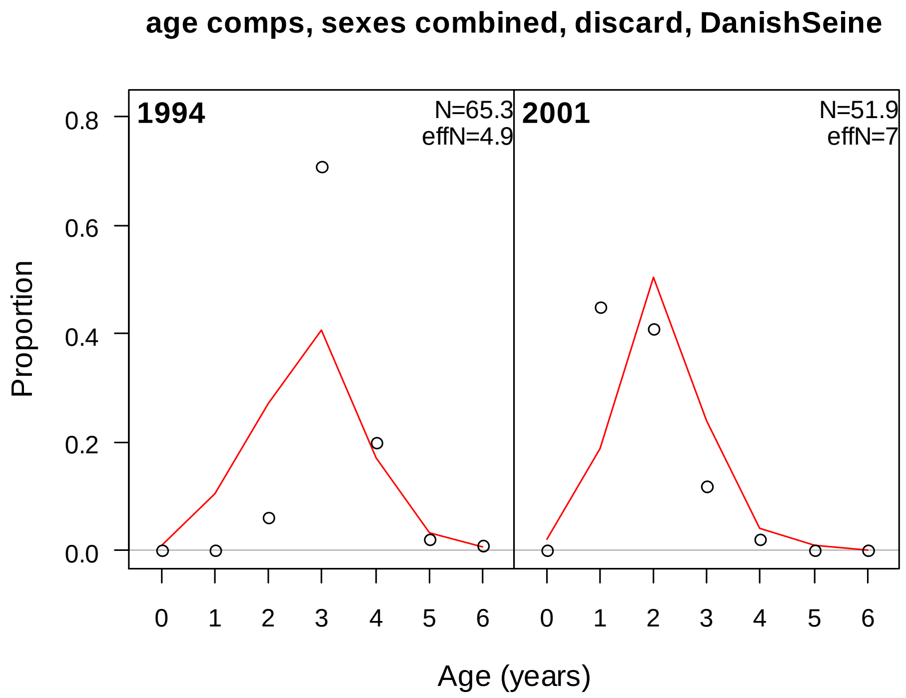
Discard length fits – Victorian Danish seine



Discard length fits – otter trawl



Discard implied age fits – Victorian Danish seine



Discard implied age fits – otter trawl