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Stock assessment of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN 5&6) for the 2014–15 fishing year

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EXECUTIVE SUMMARY

Roberts, J. (2016). Stock assessment of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN 5&6) for the 2014–15 fishing year.

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An updated Bayesian assessment is presented for the LIN 5&6 (Sub-Antarctic) stock, using the general-purpose stock assessment program CASAL v2.30. This assessment incorporated all relevant biological parameters, the commercial catch histories, updated CPUE series, and series of catch-at-age data from the commercial trawl and line fisheries. The model structure allows the input of catch histories and relative abundance indices attributable to different fishing methods and seasons.

The current status of the LIN 5&6 stock was estimated to be around 85–90% B_0, though the stock biomass is uncertain due to a lack of contrast in the principal abundance index. The assessment incorporated uncertainty in M by allowing CASAL to estimate parameters that give the M-at-age ogive, with alternative functional forms describing the shape of this relationship. The resulting ogives were biologically plausible. Six models were examined, and all produced similar estimates of current stock status and similar M ogives. The model using free trawl survey q's (as opposed to nuisance q's) was adopted as the base model. This model suggests that B_0 was about 290 000 t and was very unlikely to be lower than 180 000 t; B_{2014} was approximately 250 000 t (86% of B_0). Other model runs gave quite different estimates of stock biomass, although similar estimates of stock status. Current stock size of LIN 5&6 is estimated to be well above the management target of 40% B_0, and is likely to increase slightly over the next 5 years at the most recent catch level or to decrease slightly at the level of the TACC. The assessment projections are indicative of some surplus ling production being available.

In recent years, a greater proportion of the ling catch has come from LIN 5, which has a smaller fished area than LIN 6. An analysis of the summer trawl survey biomass index in different regions, found no evidence for a long-term biomass trend in any region, such as could arise from spatial variation in fishing pressure within the stock area.

1. INTRODUCTION

This document reports part of the results of Ministry of Fisheries Project DEE201002LIND. The specific project objectives were to carry out a descriptive analysis of the commercial catch and effort data, update the standardised catch and effort analyses from the ling fisheries, and conduct a stock assessment, including estimating biomass and sustainable yields, for LIN 3&4 and LIN 5&6 in 2013–14. Only the assessment for LIN 5&6 is reported in the main body of this document. The updated CPUE index series was completed by Ballara & Horn (2015) and indices used in this assessment are presented in Appendix A. The assessment of LIN 3&4 was reported by McGregor (2015).

Ling are managed as eight administrative QMAs, although five of these (LIN 3, 4, 5, 6, and 7) (Figure 1) currently produce about 95% of landings. Research has indicated that there are at least five major biological stocks of ling in New Zealand waters (Horn 2005): the Chatham Rise, the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Platform, the west coast of the South Island, and Cook Strait. In the stock assessment process, the same five biological stocks of ling are recognised, and are defined as follows: Chatham Rise (LIN 3 and LIN 4), Sub-Antarctic – incorporating Campbell Plateau and Stewart-Snares shelf (LIN 5, and LIN 6 west of 176º E), Bounty Plateau (LIN 6 east of 176º E), west coast South Island (LIN 7 west of Cape Farewell), and Cook Strait (those parts of LIN 2 and LIN 7 between latitudes 41° and 42° S and longitudes 174° and 175.4° E, equating approximately to Statistical Areas 016 and 017). These stocks are referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively. The most recent assessment for LIN 5&6 was reported on by Horn et al. (2013).

The current assessment for the Sub-Antarctic ling stock (LIN 5&6) used CASAL v2.30, a generalised age- or length-structured fish stock assessment model (Bull et al. 2012). This assessment incorporates two trawl survey biomass series, catch-at-age data from both research survey series and from commercial line and trawl fisheries and two line fishery CPUE series.

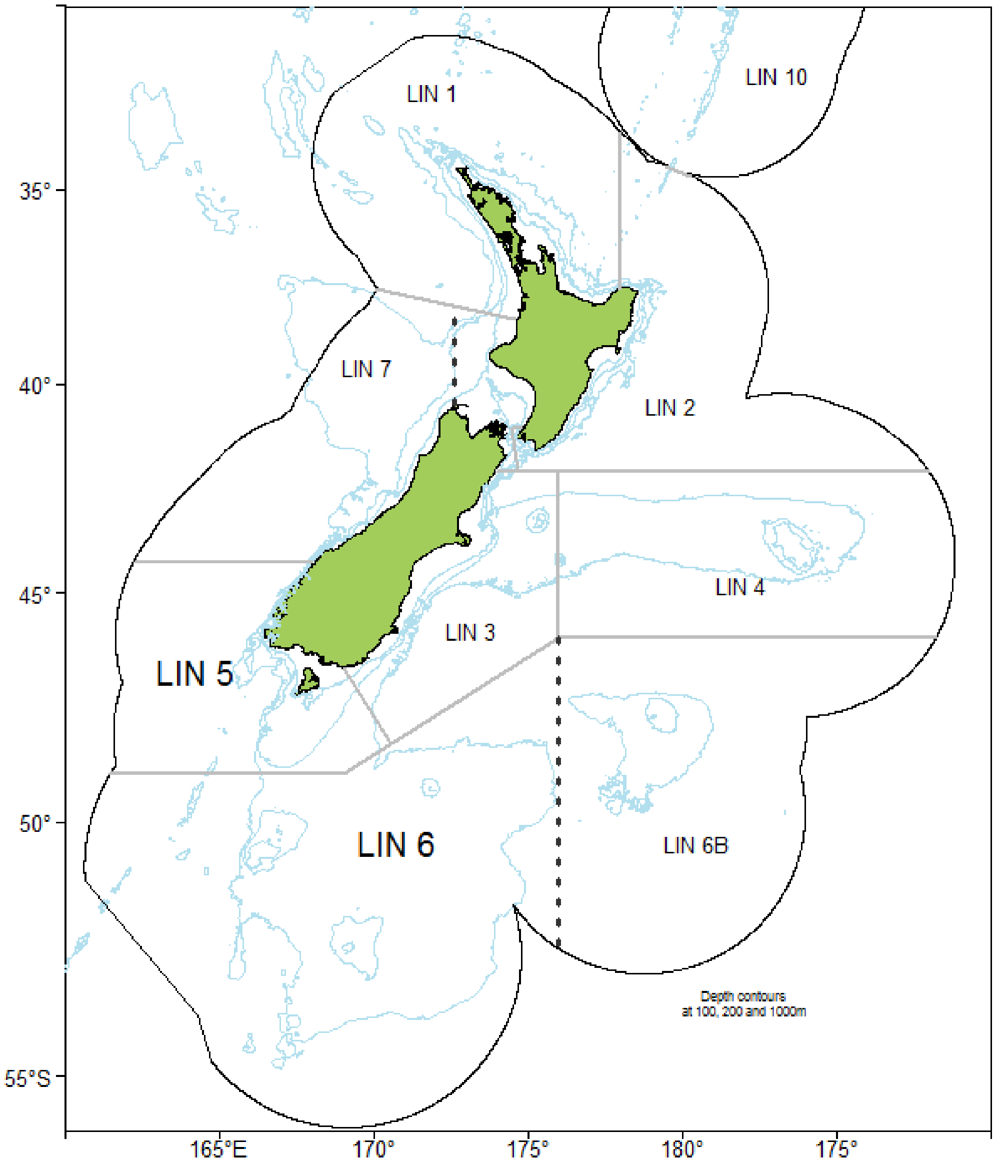


Figure 1: Area of Fishstocks LIN 3, 4, 5, 6, and 7. Adjacent ling fishstock areas are also shown, as is the 1000 m isobath. The boundaries used to separate biological stock LIN 6B from the rest of LIN 6, and the west coast South Island section of LIN 7 from the rest of LIN 7, are shown as dashed lines.

2. REVIEW OF THE FISHERY

Reported landings and estimated catch histories of ling in LIN 5&6 are summarised in Table 1 and Table 2. The trawl fishery has operated since the mid-1970s and has taken the majority of the estimated ling catch in all years since. The annual catch of the two line fisheries (spawn and non-spawn) has varied with year, taking an increased proportion of the total estimated catch in the late-1970s and the 1990s. The TACC is set separately for LIN 5 and LIN 6. Landings in LIN 5 have been close to the TACC in nearly all seasons since 1986–87. The LIN 6 TACC has not been met since 2003–04 and less than 50% has been taken since 2008–09. From 1 October 2004, TACCs for LIN 5 and 6 were increased by about 20% to 3600 t and 8500 t, respectively. This followed an assessment (Horn 2004) indicating that the level of exploitation during the 1990s had little impact on the size of the Sub-Antarctic stock. The TACC for LIN 5 was then increased again to 3955 t for the 2013–14 fishing year, following the assessment by Horn et al. (2013).

Table 1: Reported landings (t) of ling by FMA from 1983–84 to 2013–14 and TACCs (t) from 1986–87 to 2013–14.

FMA Fishing year	LIN 5		LIN 6	
	Landings	TACC	Landings	TACC
1983–84*	2 605	–	869	–
1984–85*	1 824	–	1 283	–
1985–86*	2 089	–	1 489	–
1986–87#	1 859	2 500	956	7 000
1987–88#	2 213	2 506	1 710	7 000
1988–89#	2 375	2 506	340	7 000
1989–90#	2 277	2 706	935	7 000
1990–91#	2 285	2 706	2 738	7 000
1991–92#	3 863	2 706	3 459	7 000
1992–93#	2 546	2 706	6 501	7 000
1993–94#	2 460	2 706	4 249	7 000
1994–95#	2 557	3 001	5 477	7 100
1995–96#	3 137	3 001	6 314	7 100
1996–97#	3 438	3 001	7 510	7 100
1997–98#	3 321	3 001	7 331	7 100
1998–99#	2 937	3 001	6 112	7 100
1999–00#	3 136	3 001	6 707	7 100
2000–01#	3 430	3 001	6 177	7 100
2001–02#	3 294	3 001	5 945	7 100
2002–03#	2 936	3 001	6 283	7 100
2003–04#	2 899	3 001	7 032	7 100
2004–05#	3 584	3 595	5 506	8 505
2005–06#	3 522	3 595	3 553	8 505
2006–07#	3 731	3 595	4 696	8 505
2007–08#	4 145	3 595	4 502	8 505
2008–09#	3 232	3 595	2 977	8 505
2009–10#	3 034	3 595	2 414	8 505
2010–11#	3 856	3 595	1 335	8 505
2011–12#	3 649	3 595	2 047	8 505
2012–13#	3 610	3 595	3 102	8 505
2013–14#	3 935	3 955	3 221	8 505

* FSU data.
# QMS data.

Table 2: Estimated catch histories (t) for LIN 5&6. Landings have been separated by fishing method (trawl or line, "line home" refers to the non-spawning line fishery). 2014 values are required for the current assessment and were assumed based on recent landings trends.

Year	trawl	line home	line spawn	Year	trawl	line home	line spawn
1972	0	0	0	1995	5 348	2 355	338
1973	500	0	0	1996	6 769	2 153	531
1974	1 120	0	0	1997	6 923	3 412	614
1975	900	118	192	1998	6 032	4 032	581
1976	3 402	190	309	1999	5 593	2 721	489
1977	3 100	301	490	2000	7 089	1 421	1 161
1978	1 945	494	806	2001	6 629	818	1 007
1979	3 707	1 022	1 668	2002	6 970	426	1 220
1980	5 200	0	0	2003	7 205	183	892
1981	4 427	0	0	2004	7 826	774	471
1982	2 402	0	0	2005	7 870	276	894
1983	2 778	5	1	2006	6 161	178	692
1984	3 203	2	0	2007	7 504	34	651
1985	4 480	25	3	2008	6 990	329	821
1986	3 182	2	0	2009	5 225	276	432
1987	3 962	0	0	2010	4 270	864	313
1988	2 065	6	0	2011	4 404	567	169
1989	2 923	10	2	2012	4 384	934	376
1990	3 199	9	4	2013	6 234	135	340
1991	4 534	392	97	2014	4 900	550	330
1992	6 237	566	518				
1993	7 335	1 238	474				
1994	5 456	770	486				

3. RESEARCH RESULTS

3.1 Catch-at-age

The latest catch-at-age distributions for LIN 5&6 were created as part of Project MID201001D and were reported by Horn & Sutton (2014). These include age composition estimates for the commercial longline (spawning fishery), commercial longline (non-spawning fishery) and commercial trawl fisheries.

3.2 Catch-at-length

The initial formulation of series of numbers-at-length for ling from various trawl and longline fisheries was described by Horn (2002). These series have been included in some previous stock assessment models where a lack of age data precludes their input as catch-at-age. However, considerable volumes of catch-at-age data are now available and catch-at-length data are no-longer used as model inputs for this stock.

3.3 CPUE index

The updated CPUE index series was completed by Ballara & Horn (2015) and indices used in this assessment are presented in Appendix A.

4. MODEL INPUTS, STRUCTURE, AND ESTIMATION

4.1 Model input data

Estimated commercial landings histories are listed in Table 1. Landings up to 1972 are assumed to be zero, although it is very likely that small quantities of ling were taken before then. The split between methods since 1983 was based on reported estimated landings per month, pro-rated to equal total reported landings. Landings before 1983 were split by method based on anecdotal information of fishing patterns at the time, as no quantitative information is available.

Estimates of biological parameters and assumed values for model parameters used in the assessments are given in Table 3. Growth and length-weight relationships were revised most recently by Horn (2005). The maturity ogive represents the proportion of fish (in the virgin stock) that are estimated to be mature at each age (Horn 2005). The proportion spawning was assumed to be 1.0 in the absence of data to estimate this parameter. A stock-recruitment relationship (Beverton-Holt, with steepness 0.84) was assumed. Variability in the von Bertalanffy age-length relationship was assumed to be normal with a constant CV of 0.12. The values of stock-recruitment steepness and CV associated with the age-length relationship were agreed by the Deepwater Working Group.

Table 3: Biological and other input parameters used in the ling assessment.

1. Weight = a (length)^b **(Weight in g, total length in cm)**

Female		Male	
a	*b*	*a*	*b*
0.00128	3.303	0.00208	3.190

2. von Bertalanffy growth parameters (n, sample size)

Male				Female			
n	*k*	t_0	L_∞	*n*	*k*	t_0	L_∞
2 884	0.188	–0.67	93.2	4 093	0.124	–1.26	115.1

3. Maturity ogives (proportion mature at age)

Age	3	4	5	6	7	8	9	10
Male	0.00	0.00	0.10	0.30	0.50	0.80	1.00	1.00
Female	0.00	0.00	0.05	0.10	0.30	0.50	0.80	1.00

4. Miscellaneous parameters

Stock-recruitment steepness	0.84
Recruitment variability *CV*	0.60
Ageing error *CV*	0.06
Proportion by sex at birth	0.50
Proportion spawning	1.00
Maximum exploitation rate (U_{max})	0.60

A summary of all observations used in this assessment and the associated time series is given in Table 4. The updated CPUE indices (Ballara & Horn 2015) were used as relative biomass indices, with associated CVs estimated from the generalised linear model used to estimate relative year effects. Two series of research trawl survey indices were available – from the Summer and Autumn trawl surveys (Table 5). Biomass estimates from the trawl surveys were used as relative biomass indices, with associated CVs estimated from the survey analysis. The CVs available for these estimates of relative abundance allow for sampling error only. An additional process error CV of 0.15 was added to the trawl survey biomass index and the longline CPUE index, following the recommended method of Francis (2011).

Table 4: Summary of the data series used for the assessment modelling, including source years (Years).

Data series	Years
Trawl survey biomass (*Tangaroa*, Nov-Dec)	1992–94, 2001–10, 2012–13
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
CPUE (longline, spawning fishery)	1991–2012
CPUE (longline, non-spawning fishery)	1991–2012
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08, 2010
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1999, 2001, 2003, 2005, 2009–12
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–13

Table 5: Series of relative biomass indices (t) from *Tangaroa* (TAN) trawl surveys (with coefficients of variation, CV) available for the assessment modelling.

Trip code	Date	Biomass (t)	CV (%)
TAN9105	Nov-Dec 1991	24 090	7
TAN9211	Nov-Dec 1992	21 370	6
TAN9310	Nov-Dec 1993	29 750	12
TAN0012	Dec 2000	33 020	7
TAN0118	Dec 2001	25 060	7
TAN0219	Dec 2002	25 630	10
TAN0317	Nov-Dec 2003	22 170	9
TAN0414	Dec 2004	23 790	12
TAN0515	Dec 2005	19 700	9
TAN0617	Dec 2006	19 640	12
TAN0714	Dec 2007	26 490	8
TAN0813	Dec 2008	22 840	10
TAN0911	Dec 2009	22 710	10
TAN1117	Nov-Dec 2011	23 180	12
TAN1215	Nov-Dec 2012	27 010	11
TAN9204	Mar-Apr 1992	42 330	6
TAN9304	Apr-May 1993	33 550	5
TAN9605	Mar-Apr 1996	32 130	8
TAN9805	Apr-May 1998	30 780	9

Data from trawl surveys could be inputted either as (i) biomass and proportions-at-age, or (ii) numbers-at-age. Francis et al. (2003) presented an argument against the use of numbers-at-age data for hoki from trawl surveys. For the ling assessment the preference was for a), i.e., entering trawl survey biomass and trawl survey proportions-at-age data as separate input series. The CVs applied to each data set would then give appropriate weight to the signal provided by each series. Lognormal errors, with known CVs, were assumed for all relative biomass observations.

Catch proportions-at-age were estimated using the NIWA catch-at-age software (Bull & Dunn 2002). Ageing error for the observed proportions-at-age data was assumed to have a discrete normal distribution with a CV of 0.06. As in the previous assessment (Horn et al. 2013), the age composition data for the trawl survey and commercial fisheries were sexed in all model runs.

The assumed errors for the catch-age-age data were multinomial, and were lognormal for all other data. The effective sample sizes for the proportion-at-age estimates were estimated following method TA1.8 as described in Appendix A of Francis (2011). This method finds a weighting, w, which is such that

$$w = 1/Var_y\left[(\bar{O}_y - \bar{E}_y)/\sqrt{(v_y/\tilde{N}_y)}\right]$$

where

$Var_k[x_k] = \sum_y (x_k - \bar{x})^2/(n-1)$,
$\bar{x}$ is the sample mean,
O_y and E_y and the observed and expected values at year y, respectively,
$\tilde{N}_y$ is the effective sample size at year y, prior to re-weighting,
v_y is the variance of the expected age or length distribution.

The initial effective sample sizes were estimated from a multinomial model fitted to a regression of log(proportion) against log(CV), where the CV was estimated by bootstrapping from the sample data (Bull & Dunn 2002). The initial effective sample sizes are then multiplied by the weighting w to get the multinomial effective sample sizes (Table 6).

Table 6: Multinomial effective sample sizes (EFS) assumed for the age composition data sets. The initial EFS are estimated from the sample data, and the reweighted EFS have been scaled following the technique of Francis (2011).

Summer trawl survey proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1990	277	50
1992	499	90
1993	450	82
1994	451	82
2001	510	92
2002	491	89
2003	469	85
2004	427	77
2005	398	72
2006	419	76
2007	386	70
2008	401	73
2009	352	64
2010	374	68
2012	415	75
2013	396	72

Autumn trawl survey proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1992	436	70
1993	473	76
1996	414	66
1998	403	65

Fishery longline spawn proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
2000	471	72
2001	230	35
2002	357	54
2003	419	64
2004	439	67
2005	170	26
2006	315	48
2007	271	41
2008	85	13
2010	165	25

Fishery trawl proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1992	442	39
1993	310	27
1994	221	20
1996	337	30
1998	254	23
2001	450	40
2002	320	28
2003	500	44
2004	334	30
2005	381	34
2006	428	38
2007	322	29
2008	335	30
2009	440	39
2010	424	38
2011	411	36
2012	368	33
2013	427	38

Fishery longline non-spawn proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1999	789	95
2001	302	36
2003	218	26
2005	272	33
2009	207	25
2010	179	22
2011	251	30
2012	321	39

4.2 Model structure

The stock assessment model partitions the Sub-Antarctic population into sexes and age groups 3–25, with a plus group at age 25. There are three fisheries (trawl, longline spawn and longline non-spawn) in the stock. The model's annual cycle for the stock is described in Table 7.

As in the previous assessment, natural mortality (M) was estimated. A double-exponential functional form was adopted for all runs, except for a sensitivity run for which M was constant with respect to age. Sex-specific age-based selectivity ogives were estimated separately for the two trawl survey series, the trawl fishery and the two line fisheries. A double normal parameterisation was used for the trawl fishery ogives and a logistic selectivity was used for the trawl surveys and line fisheries, with a sensitivity run using a double normal selectivity for the trawl and non-spawning line fisheries. The parameterisations of the double normal and logistic curves were given by Bull et al. (2012). Selectivities were assumed constant across years, i.e., there was no allowance for annual variation in selectivity.

The maximum exploitation rate was assumed to be 0.6. The choice of the maximum exploitation rate has the effect of determining the minimum possible virgin biomass allowed by the model. This value was set relatively high as there was little external information from which to determine it.

Table 7: Annual cycles of the LIN 5&6 stock models, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M^1	Age[2]	Description	$\%Z^3$
1	Dec–Aug	Recruitment	0.75	0.4	Trawl survey (summer)	0.1
		Non-spawning fisheries (trawl & line)			Trawl survey (autumn)	0.5
					Line (non-spawn) CPUE	0.7
					Line (non-spawn) catch-at-age	
					Trawl catch-at-age	
2	Sep–Nov	Increment ages	0.1	0.0	Line (spawn) CPUE	0.5
					Line (spawn) catch-at-age	

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction (used for determining length-at-age) that was assumed to have occurred by the start of that time step.
3. %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

4.3 Model estimation

Model parameters were estimated with Bayesian estimation implemented using the CASAL v2.30 software. Only the mode of the joint posterior distribution (MPD) was estimated in preliminary runs. For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Full details of the CASAL algorithms, software, and methods were detailed by Bull et al. (2012).

Year class strengths were assumed known (and equal to 1) when inadequate (i.e., fewer than three data points) or no catch-at-age data were available for that year. Otherwise, year class strengths were estimated under the assumption that the estimates from the model must average 1. The Haist parameterisation for year class multipliers is used here (see Bull et al. (2012) for details).

5. MODEL ESTIMATES

5.1 The base model and sensitivity runs

An array of model runs was examined relative to a reference model, which differed in terms of their parameterisation, types of observations used and the relative weighting of different observation types (Table 8). The reference model run (reference run) was configured as the 2011–12 assessment (Horn et al. 2013), with the exception that: multinomial errors were assumed for the composition at age estimates (previously they were lognormal); a steepness of 0.84 was used (previously 0.90); and a process error of 0.15 was added to the trawl survey biomass index (previously 0.01). Details of the reference model configuration are given in Table 8. As with the previous assessment, the reference run model was fitted to the trawl survey biomass index and not the longline CPUE (Horn et al. 2013), as the trawl survey was deemed by the Middle Depth Fisheries Assessment Working Group to be more likely to represent abundance.

The Deepwater Working Group agreed that the base model run (base run) should use free q's instead of nuisance q's for the trawl survey series and was the same as the reference run in every other regard. Four other sensitivities were investigated: estimating constant M with respect to age (mortality run); using a double-normal selectivity ogive for all except the spawning longline fishery, which retained a lognormal selectivity ogive (domed run); halved multinomial weightings associated with age composition estimates (multinomial run); and fitting to spawning and non-spawning longline fishery CPUE (CPUE run).

Table 8: Key assumptions for MPD model runs, showing estimated B_0 (t) and B_{2014} (% B_0).

Key run assumptions	B_0 (t)	B_{2014} (% B_0)
1. Reference run	313 000	89
• No fishery abundance indices		
• Selectivity logistic ogive for trawl survey and line fisheries		
• Selectivity double normal for trawl fishery		
• Nuisance q's for trawl survey		
• Double exponential M		
• Steepness = 0.84		
• Sigma-r = 0.6		
2. Base run (free q's)	307 000	89
• Same as reference run, but free q's for the trawl survey		
3. Domed run	324 000	88
• Same as reference run, but logistic selectivity ogive for longline spawn only		
4. Multinomial run	325 000	88
• Same as reference run, but multinomial weightings halved		
5. Mortality run	350 000	88
• Same as reference run, but constant M with respect to age		
6. CPUE run	384 000	86
• Same as reference run, but fitted to commercial CPUE		

5.2 MPD runs

All MPD model runs produced a similar biomass trajectory: an overall slight decline from the early 1970s to the late 1990s, followed by a rebuilding phase to the present (Figure 2). The slight biomass decline about 1980 corresponded with a period of moderate catches followed by a period of low catches throughout the 1980s (Table 2) which, along with the recruitment of some strong year classes in the mid-1970s to early-1980s (Figure 3), resulted in a slight rebuild of biomass to 1990. Throughout the 1990s, catches increased to peak in 1997 and recruiting year classes were generally weak, resulting in a steady decline in the biomass trajectory to its minimum in the late-1990s. During the 2000s there was a steady rebuild in biomass particularly in the early part of the decade when three very strong year classes (e.g. 1993–1995) would have recruited into the fishery (Figure 3).

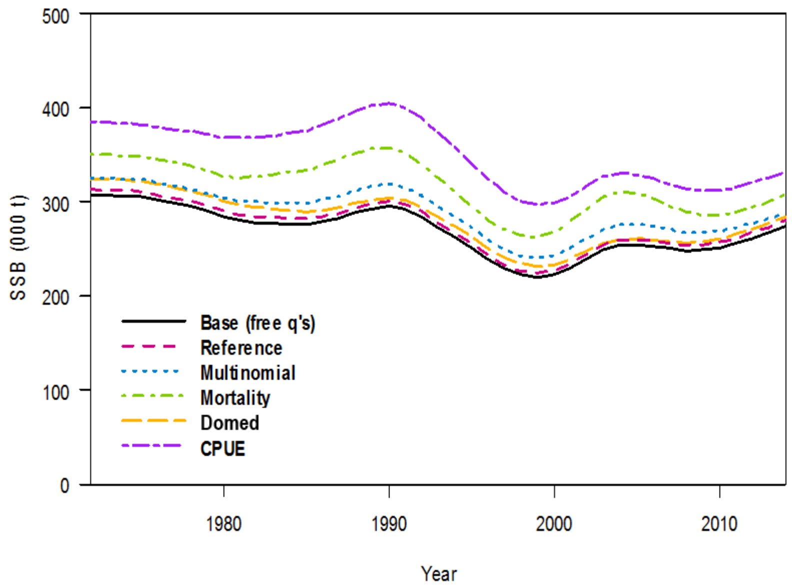


Figure 2: Estimated biomass for all MPD model runs.

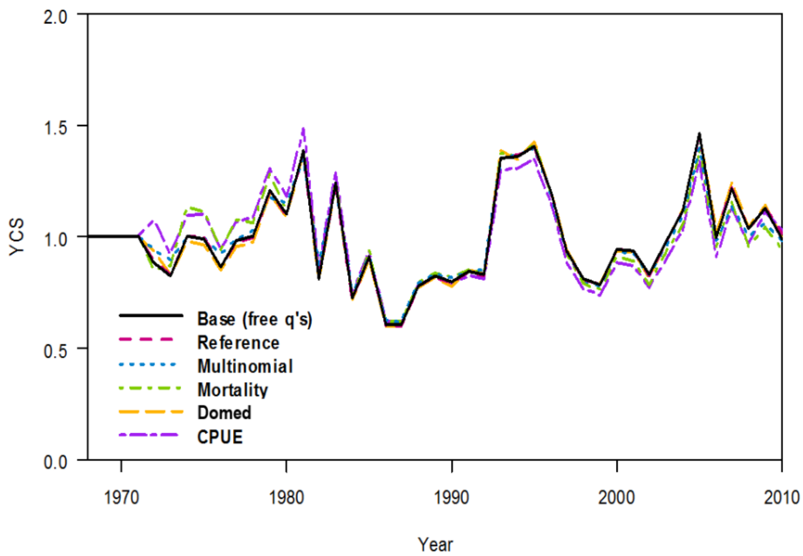


Figure 3: Estimated YCS for all MPD model runs.

Proportion-at-age distributions were compiled by year from the autumn and summer trawl surveys, the trawl fishery and the two longline fisheries. The summer survey observations and fits are shown in Figure 4 and Figure 5. The fits to the composition data were reasonably good for the Base run (using free *q*'s). Weak or strong year classes (e.g. 1991 and 1994) could be identified in most survey years (Figure 6), although they were not easily differentiated at ages 15 and older, for which the relative catch proportion at age was low (Figure 4 and Figure 5).

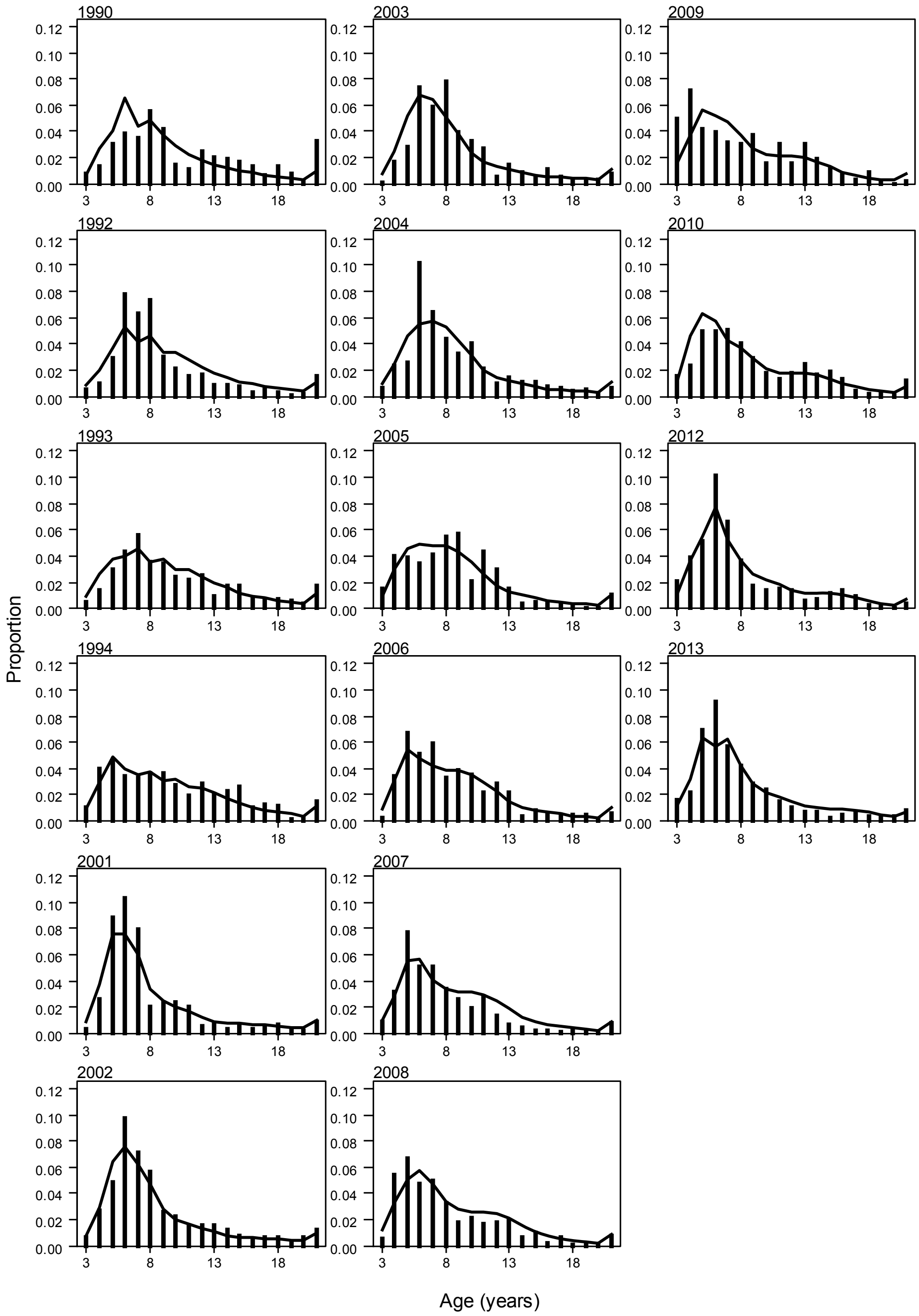


Figure 4: Base run (free *q*'s) fit (line) to observed proportion-at-age (bars) for male ling in the summer trawl surveys.

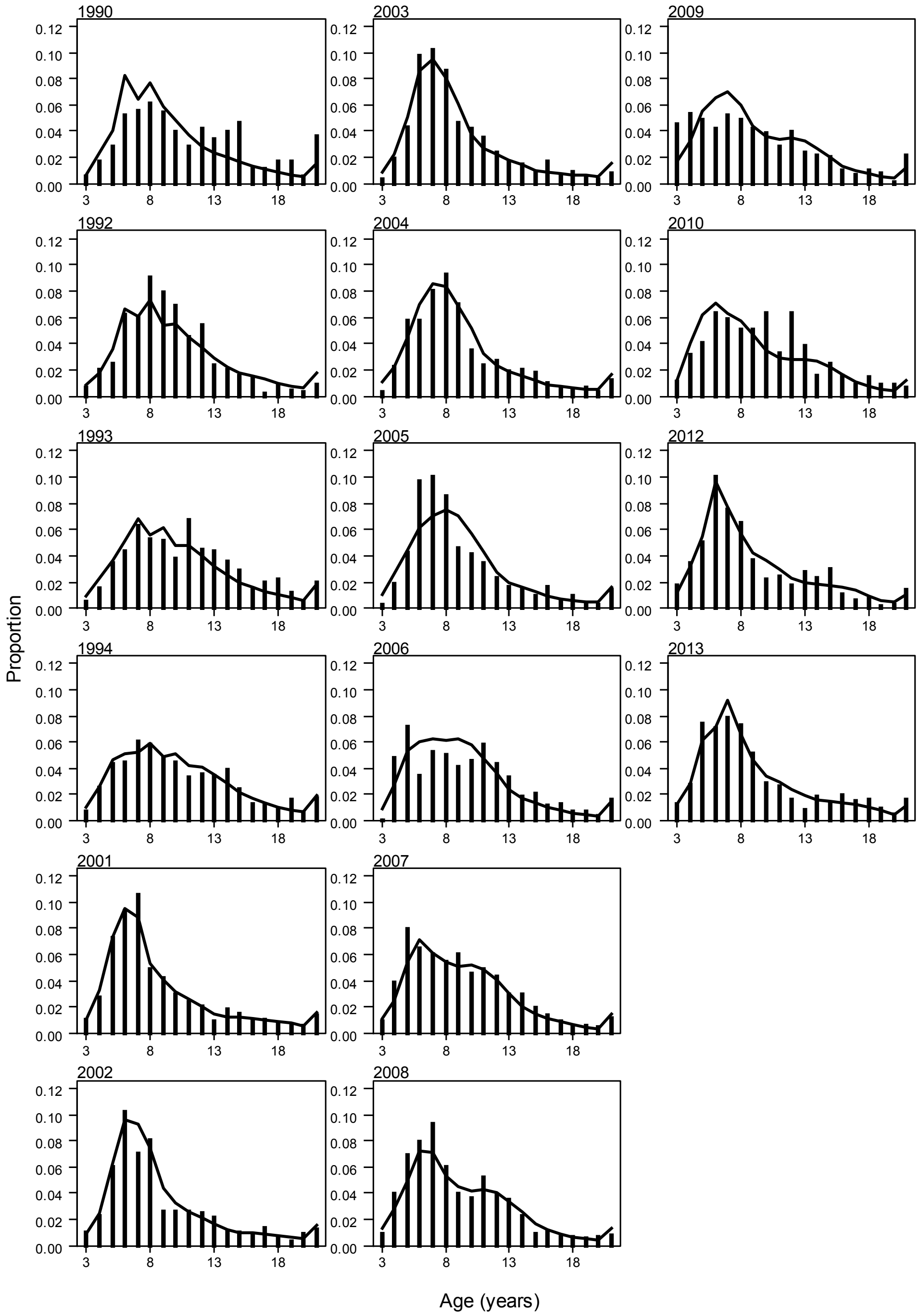
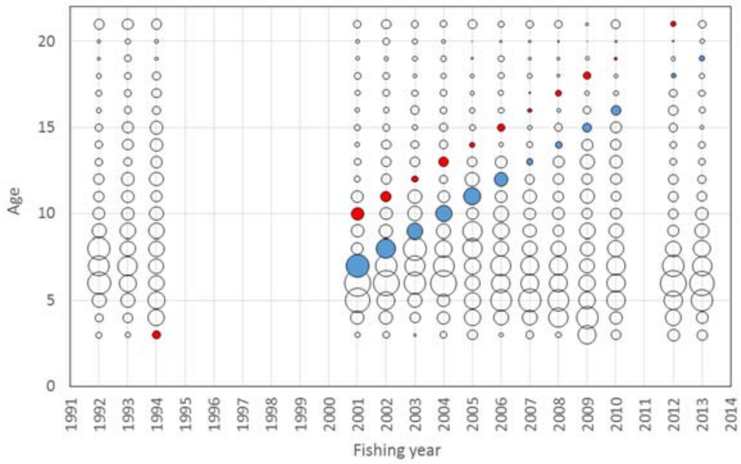


Figure 5: Base run (free *q*'s) fit (line) to observed proportion-at-age (bars) for female ling in the summer trawl surveys.



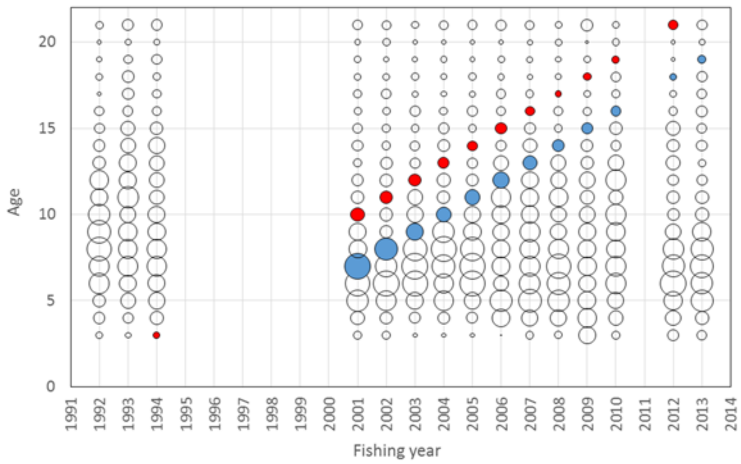


Figure 6: Bubble plot of observed proportion-at-age by year for male (top) and female ling (below) in the summer trawl surveys. The two highlighted year classes are 1991 (red) and 1994 (blue).

The estimated biomass trajectory is also influenced by the series of relative abundance indices. If we assume that the relative abundance series is an accurate and unbiased index of relative abundance, then a good model will fit the series well. Two trawl survey biomass series are available for the LIN 5&6 stock (see Table 5.) and fits to the two series are shown in Figure 7. The autumn series is relatively short but appears to be well fitted. The summer series is not well-fitted overall, although it is reasonable when 1994 and 2001 are disregarded. Estimates of trawl survey q were very similar whether nuisance q's (e.g. the Reference model) or free q's (the Base model) were used – these were 0.13 for the autumn survey and 0.09 for the summer survey for both model runs.

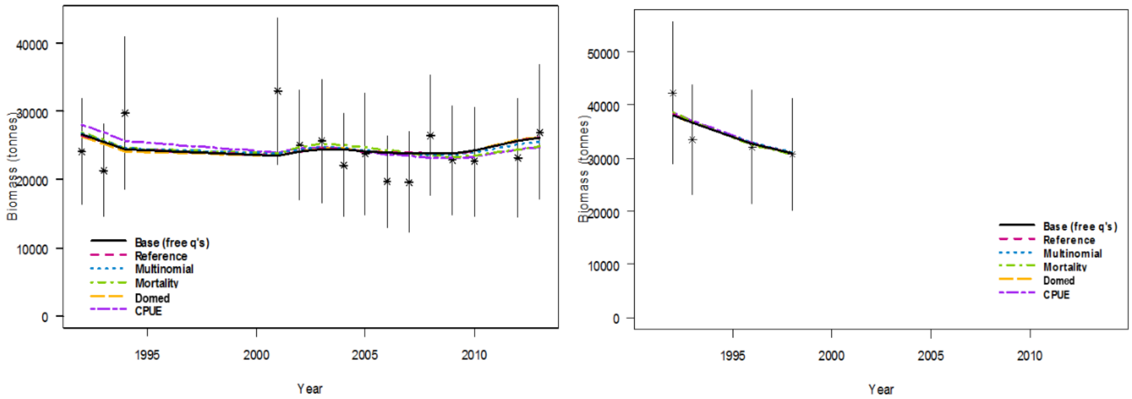


Figure 7: MPD model fit (lines – all 6 MPD runs) to observed relative biomass (points – error bars are the 95% confidence intervals) for the summer (left) and autumn (right) research trawl survey.

The estimated instantaneous natural mortality (*M*) ogive from the base model run was biologically plausible with a minimum at age 14 (slightly higher than the estimated age at 100% maturity of 11 years) and a range from 0.14 to 0.34 (Figure 8). The various selectivity ogives that are estimated in the initial model will be confounded with the ogive for *M*. Specifying logistic ogives for all except the trawl fishery assumes that selectivity does not decline with age in either the line fisheries or the trawl surveys, though no information is available to verify such an assumption. However, line fisheries consistently catch larger ling than trawl fisheries and there is no reason to believe that the oldest (largest) ling are less likely to be captured than younger fish, so the logistic ogives are probably logical for these fisheries. The trawl surveys comprehensively cover the range of depths where ling are most abundant, so applying logistic ogives to these series assumes that older (larger) fish are not better at avoiding the trawl than younger fish. The ogives estimated from the initial model (Figure 9 and Figure 10) are logical in that age at full selectivity increases from the trawl surveys (60 mm mesh codend), to the commercial trawl fishery (60–100 mm mesh codends), to the line fisheries.

The Mortality run assumed a constant *M* with respect to age and estimated a value of 0.21, which was within the range of estimates for all other model runs (Figure 8), though poorer fits to at-age observations were obtained with this configuration (Table 9).

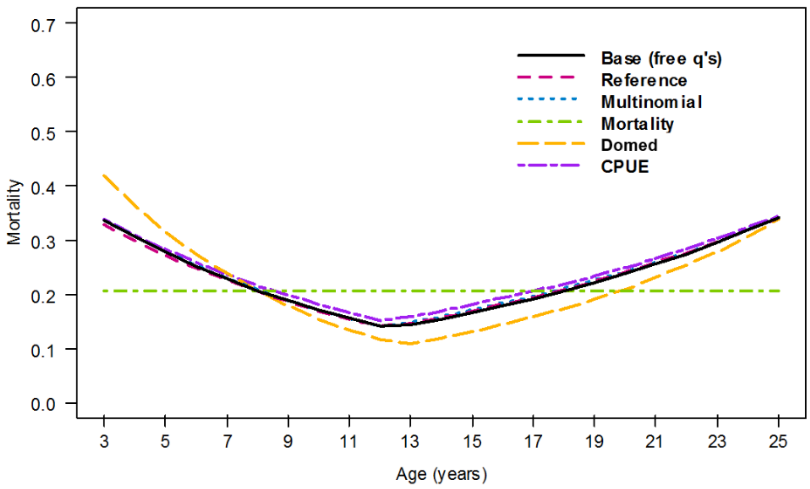


Figure 8: Estimated ogive for *M* for both sexes combined for all MPD model runs, over an age range of 3 to 25 years.

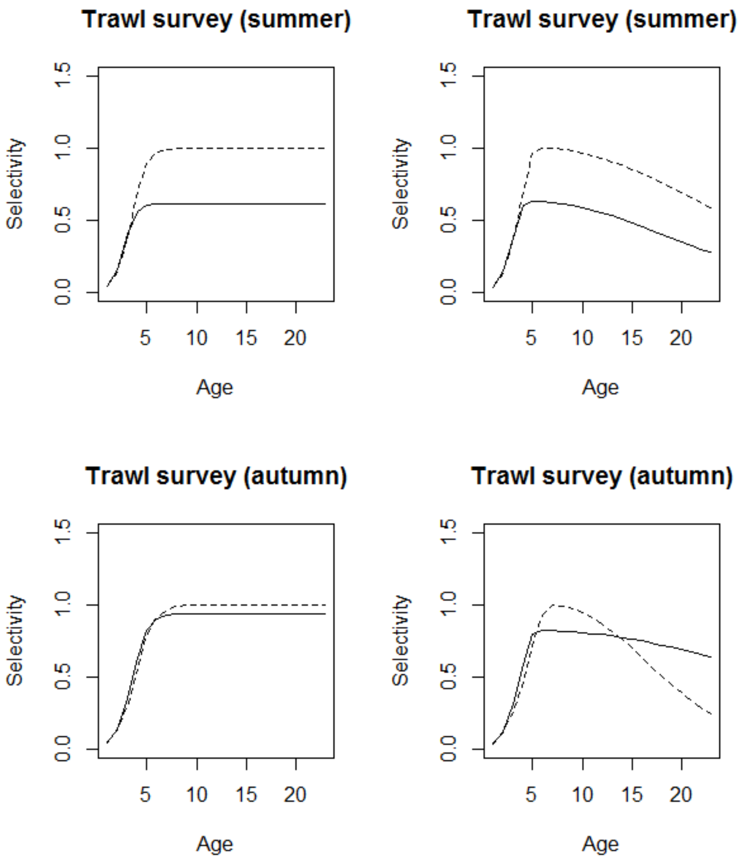


Figure 9: Estimated ogive for selectivity-at-age male (solid line) and female (dashed line) ling for the summer and autumn trawl survey for the base (free *q*'s) (left) and domed (right) model runs.

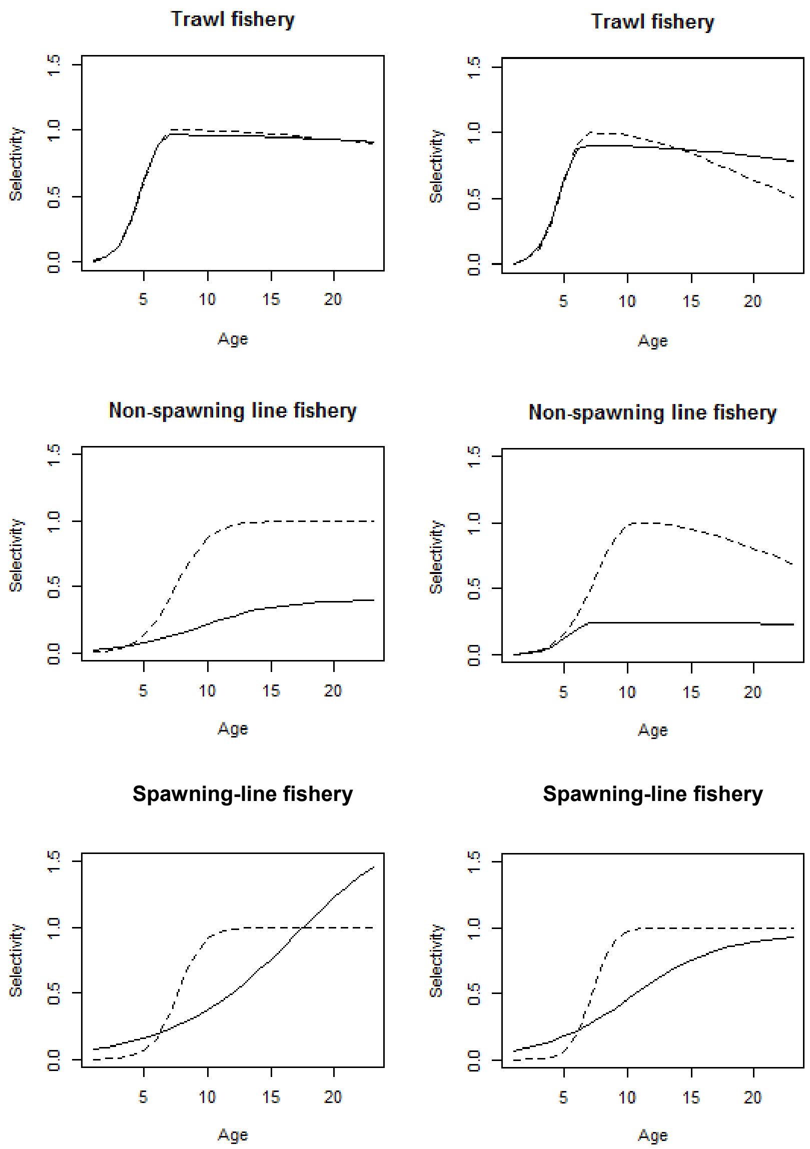


Figure 10: Estimated ogive for selectivity-at-age male (solid line) and female (dashed line) ling for the trawl fishery (top), non-spawning line fishery (middle) and spawning line fishery (bottom) for the base (free *q*'s) (left) and domed (right) model runs.

The effect of allowing the trawl and non-spawning line fishery ogives to be domed was examined in the Domed model (i.e. a logistic selectivity was used for the spawning longline fishery only). This had the effect of reducing the estimated selectivity of females from after age 10 (Figure 10). Again, the selectivity ogives for the Domed run would be confounded with the estimated ogive for M, although the range of M estimates for ages 3–25 (0.11–0.36) was not greatly different from those of the Reference or Base model runs (both 0.14 to 0.34) (Figure 8). The domed trawl survey ogives indicated that fish become less vulnerable to the trawl with increasing age. This would suggest that there was a cryptic biomass of older-aged fish in the stock area, though the survey q values for the Domed model (0.14 and 0.10 for the autumn and summer trawl surveys, respectively) were not greatly different from the Reference model (0.12 and 0.09), indicating that the reduced vulnerability of fish at alder ages would not have translated to a large cryptic biomass.

The overall fit for the model allowing domed trawl survey and non-spawning line fishery ogives was slightly better than for the Reference model, particularly for the trawl survey and non-spawning line fishery at-age data (Table 9), though the gain in likelihood values (3 relative to the Reference and Base models) was not deemed sufficient to warrant an MCMC run.

Table 9: Negative log likelihood of all data series for MPD fits of Base, Reference, Mortality and Domed model runs.

Data series	Reference	Base (free *q*'s)	Mortality	Domed
Survey biomass (autumn)	-6.8	-6.8	-6.8	-6.8
Survey biomass (summer)	-20.8	-20.8	-20.8	-20.9
Survey age (autumn)	176.1	176.1	176.6	175.1
Survey age (summer)	697.0	696.9	700.4	695.9
Line fishery age (non-spawn)	248.9	248.9	249.3	247.5
Line fishery age (spawning)	335.7	335.7	337.2	336.4
Trawl fishery age	546.3	546.2	549.0	545.4
Priors and penalties	-4.0	-3.9	-4.1	-3.6
Total	1972.4	1972.3	1980.7	1969.1

Two CPUE series are available for the LIN 5&6 stock, one from each of the two line fisheries (see Appendix A). No obvious sources of bias are apparent for either of the series, but because they are fishery-dependent series they are considered to be less reliable as indices of relative abundance than trawl survey biomass. Fits to the two CPUE series when they were included in the initial model are shown in Figure 11. Although the CPUE series were quite spiky, model fits were reasonable and there was no obvious trend in the residuals.

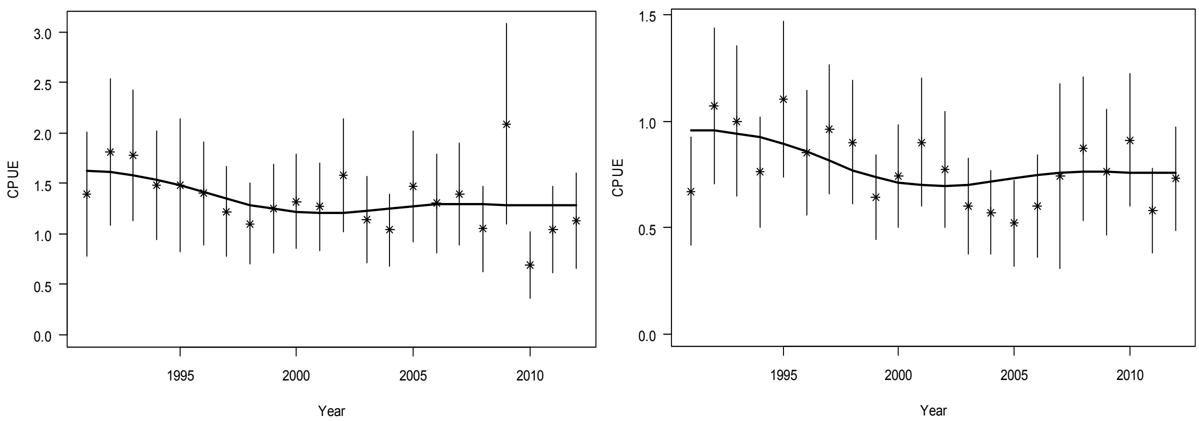


Figure 11: MPD model fit (line) to observed CPUE series (points – error bars are the 95% confidence intervals) for the spawning (left) and non-spawning (right) line fisheries.

All six models produced very similar estimates of stock status (B_{2014}), ranging from 86% to 89% of B_0 (89% B_0 for the base run), although B_0 was quite variable across model runs (ranging from 307 000 t – 384 000 t) (Table 8). Estimated annual fishing pressures did not exceed 0.07 for any model run (Figure 12).

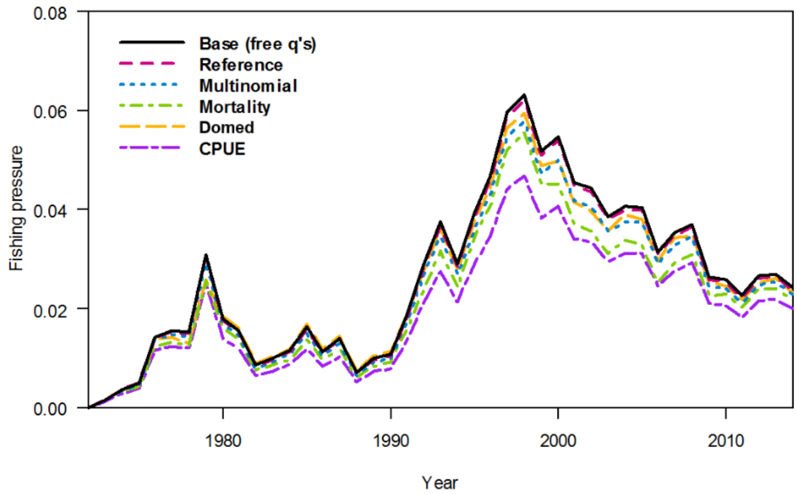


Figure 12: Estimated total fishing pressures for all MPD model runs.

Following the investigations above with MPD model fits, the Deepwater Working Group concluded that the best base model for MCMC estimation was the model using free *q*'s for the trawl survey series. Three additional models were also fully investigated. Descriptions of all four models are as follows:

- Reference model — catch history, trawl survey abundance, all available at-age data series, logistic selectivity ogives for the line fisheries and the trawl survey series, double-normal ogives for the trawl fishery, and *M* estimated as a double-exponential ogive, nuisance *q*'s for the trawl survey series, the standard deviation of log-YCS was 0.6.
- Base model (free *q*'s) — as for the Reference model except free *q*'s for the trawl survey series.
- Mortality — as for the Reference model except constant *M* with respect to age
- Sigma-r — as for the Reference model except the standard deviation of log-YCS was 1.0.

5.3 MCMC runs

5.3.1 Model estimation

Model parameters were estimated with Bayesian estimation implemented using the CASAL software. For final runs, the full posterior distribution was sampled using Monte Carlo Markov Chain (MCMC) methods, based on the Metropolis-Hastings algorithm. MCMCs with a total chain length of 1×10^7 iterations, a burn-in length of 2.5×10^6 iterations and with every 2500th sample kept from the final 7.5×10^6 iterations (i.e., a final sample of length 3000 was taken from the Bayesian posterior).

5.3.2 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 10. Most priors were intended to be uninformed, and were specified with wide bounds. The exception was the choice of informative priors for the *Tangaroa* trawl survey *q*, which were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was penalised. A penalty was applied to the estimates of year class strengths to encourage estimates that average to 1.

Table 10: Assumed prior distributions and bounds for estimated parameters in the assessment. Parameter values are the mean (in natural space) and CV for lognormal.

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	50 000	800 000
Year class strengths	Lognormal	1.00	0.70	0.01	100
Trawl survey *q*	Lognormal	0.13	0.70	0.02	0.30
CPUE *q*	Uniform-log	–	–	$1e^{-8}$	$1e^{-3}$
Selectivities	Uniform	–	–	0.00	5-200*
M (x_0, y_0, y_1, y_2)	Uniform	–	–	3,0.01,0.01,0.01	15,0.6,1,1

* A range of maximum values were used for the upper bound

5.3.3 MCMC estimates

Model estimates of biomass, year class strengths, and *M* were derived using the fixed parameters (see Table 3) and the model input parameters described earlier. The Reference model and Base model (free *q*'s) and two sensitivity models were investigated. MCMC estimates of the posterior distributions are presented below. In addition, MCMC estimates of the median posterior and 95% percentile credible intervals are reported for the key output parameters. A visual inspection of the chains for B_0 suggested reasonably good mixing for the Reference and Sigma-r runs and least convergence for the Base (free *q*'s) and Mortality runs (Figure 13). For the Base run, there was some variation in the distributions of estimates of B_0 comparing the first, middle, and last thirds of the chain. However, the chains for B_{2014} (%B_0) were reasonable for all model runs (Figure 14) and, for the Base run, the Working Group considered that there was acceptable agreement between the three chain portions (Figure 15). As such, the degree of convergence under the Base model was deemed adequate by the Deepwater Working Group for the purposes of this stock assessment.

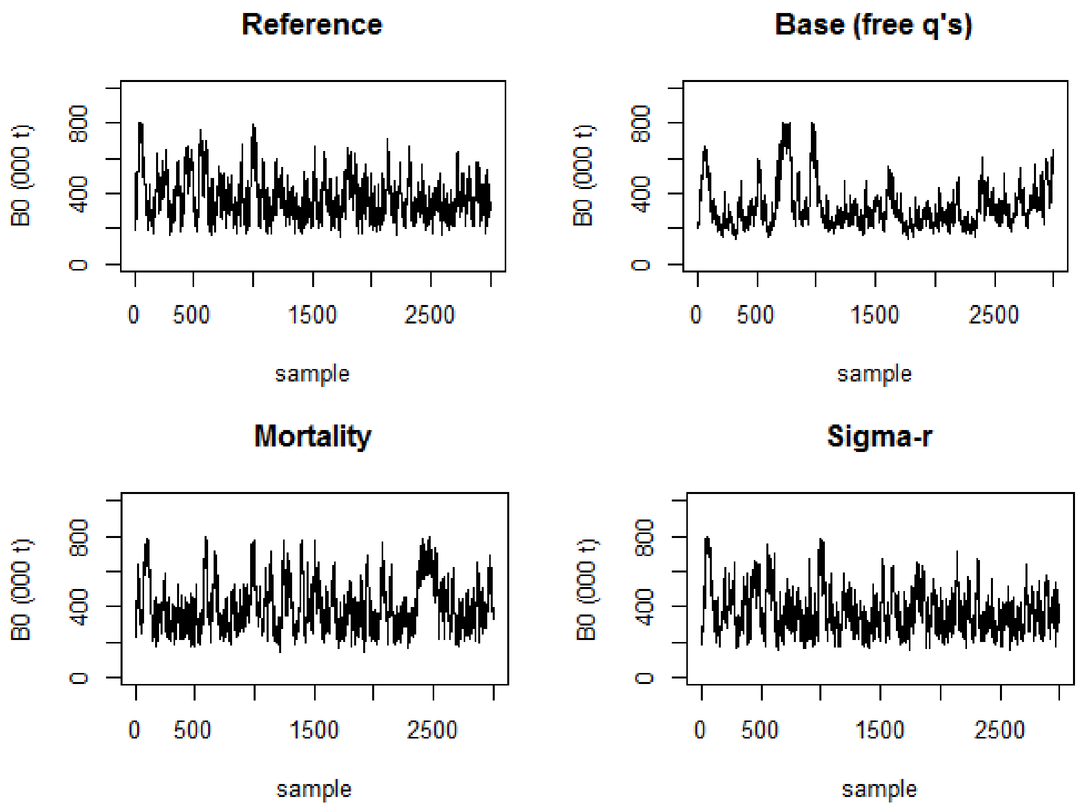


Figure 13: Trace diagnostic plot of the MCMC chain for estimates of B_0 for the Reference, Base (free *q*'s), Mortality and Sigma-r runs.

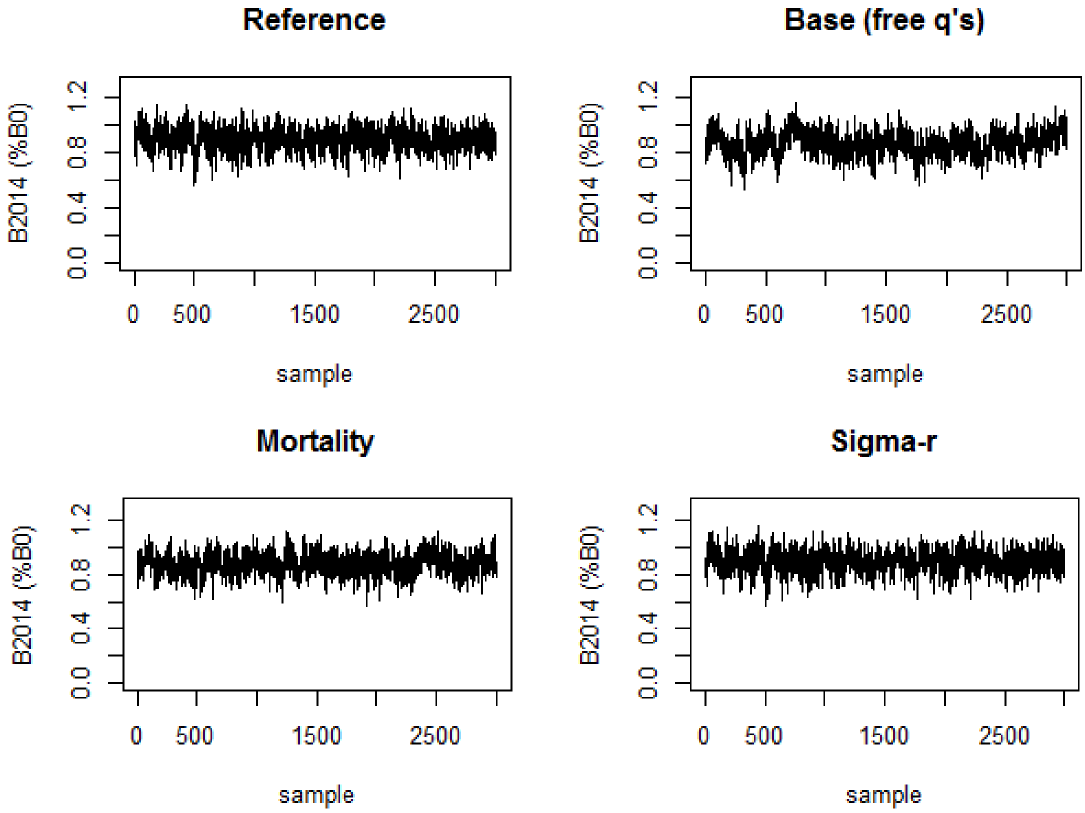


Figure 14: Trace diagnostic plot of the MCMC chain for estimates of B_{2014} (%B_0) for the Reference, Base (free *q*'s), Mortality and Sigma-r runs.

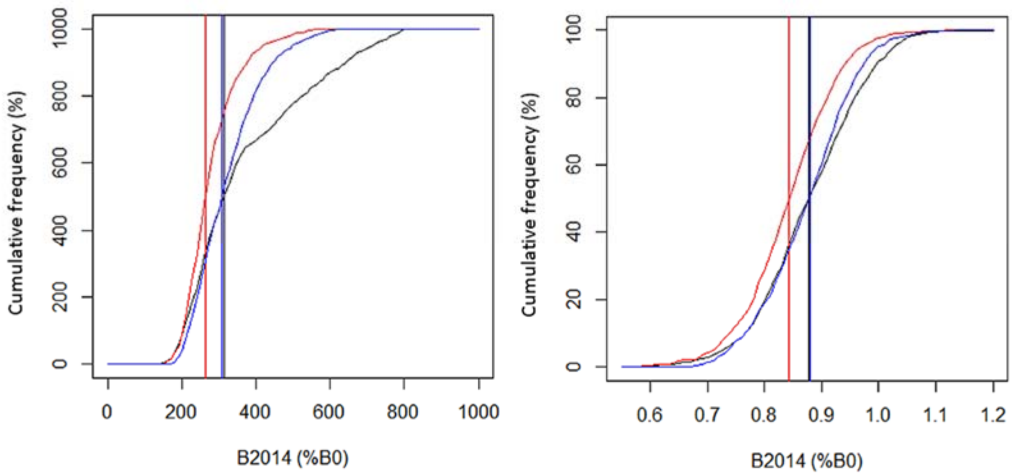


Figure 15: MCMC diagnostic plot showing the cumulative frequencies of B_0 (left) and B_{2014} (%B_0) (right) for the first (black), middle (red), and last (blue) third of the MCMC chain for the Base model run (free *q*'s).

Instantaneous natural mortality (*M*) was estimated as an ogive independent of sex and was almost identical for the Reference and Base model runs (Figure 16). The ogive had a minimum of about 0.14 at 13 years, rising to about 0.3 at 25 years, and a relatively narrow 95% credible interval across most ages. The estimation of *M* will be confounded with the estimation of survey and fishery selectivities such that we cannot be confident that the true ogive has been determined here (Figure 16). An *M* of 0.21 (95% credible intervals 0.19 – 0.23) was obtained from the Mortality run (constant *M* with respect to age). As expected, estimates of M for this run were positively correlated with B_0. The chain indicated that convergence was achieved (Figure 17).

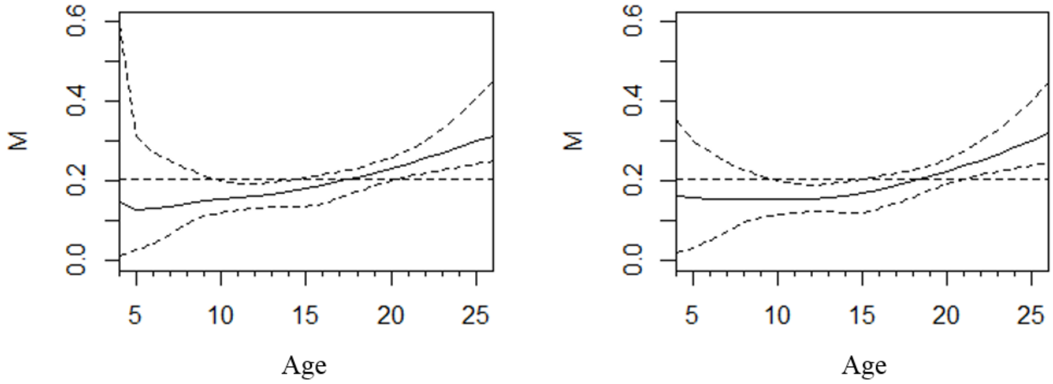


Figure 16: Estimated posterior distributions of the natural mortality ogive for the Reference model (left) and Base model (right) runs with double exponential natural mortality. Solid line is the median; dashed lines are 95% credible intervals and median estimate (0.21) for the Mortality model run (assuming constant *M* with respect to age).

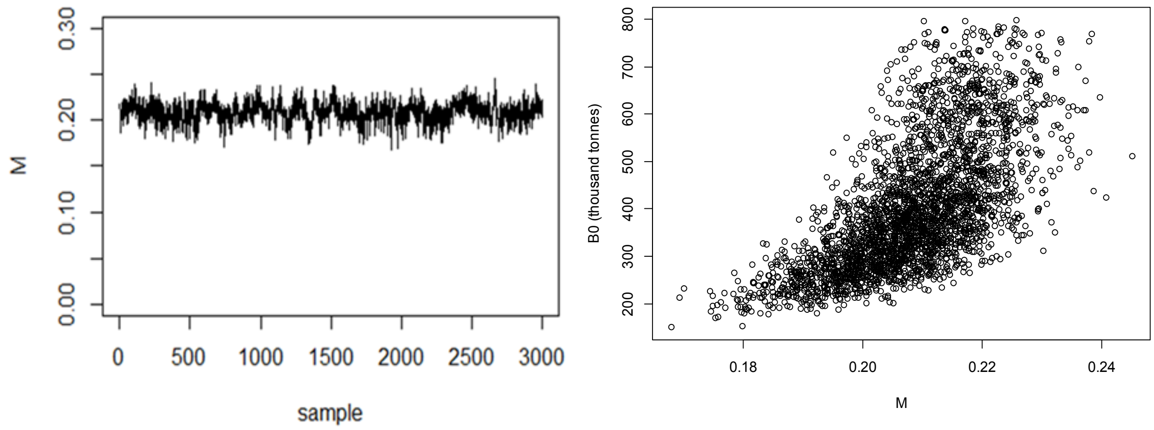


Figure 17: Trace plot of estimated *M* (left) and correlation between estimated *M* and B_0 (right) for the Mortality model run.

Resource survey and fishery selectivity ogives were relatively tightly defined. The survey ogive suggested that ling were fully selected by the research gear at about age 7–9 (Figure 18). Estimated fishery selectivities indicated that ling were fully selected by the trawl fishery at about age 9 years, and by the line fisheries at about age 12–16 (Figure 19). The poorly defined ogives for males in the line fisheries (particularly at ages 15 and over) are explained by the low relative catch proportion of males (and therefore few age frequency observations) in line fisheries (e.g. Figure 20).

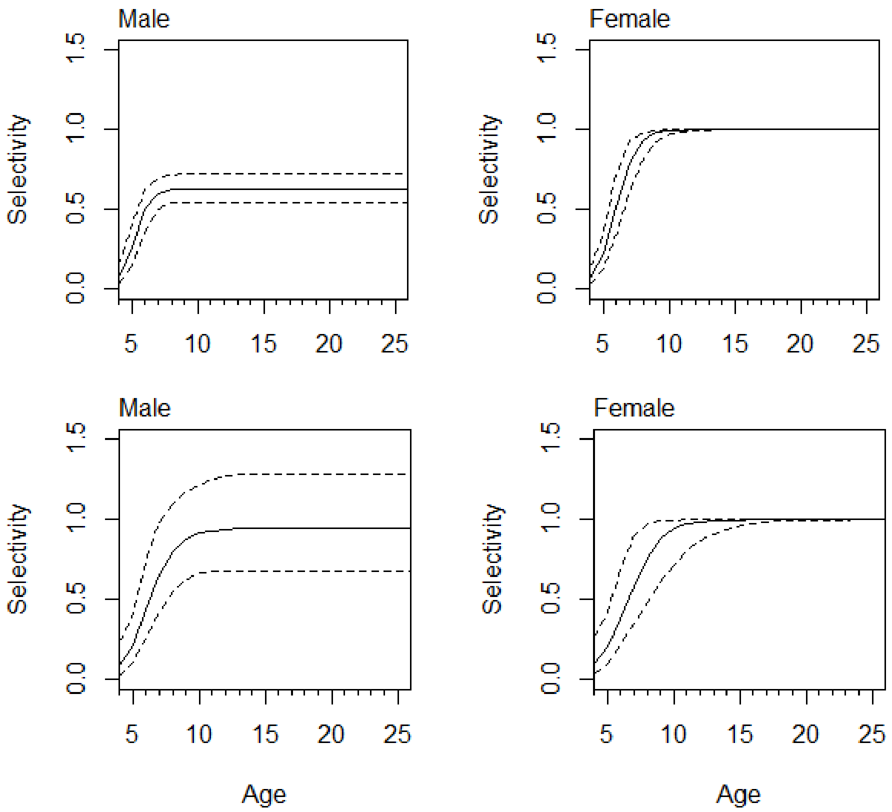


Figure 18: Estimated posterior distributions of selectivity ogives for the base model (free *q*'s) run for the summer (top) and autumn trawl survey (bottom). Dashed lines show the 95% credible intervals and the solid line the median.

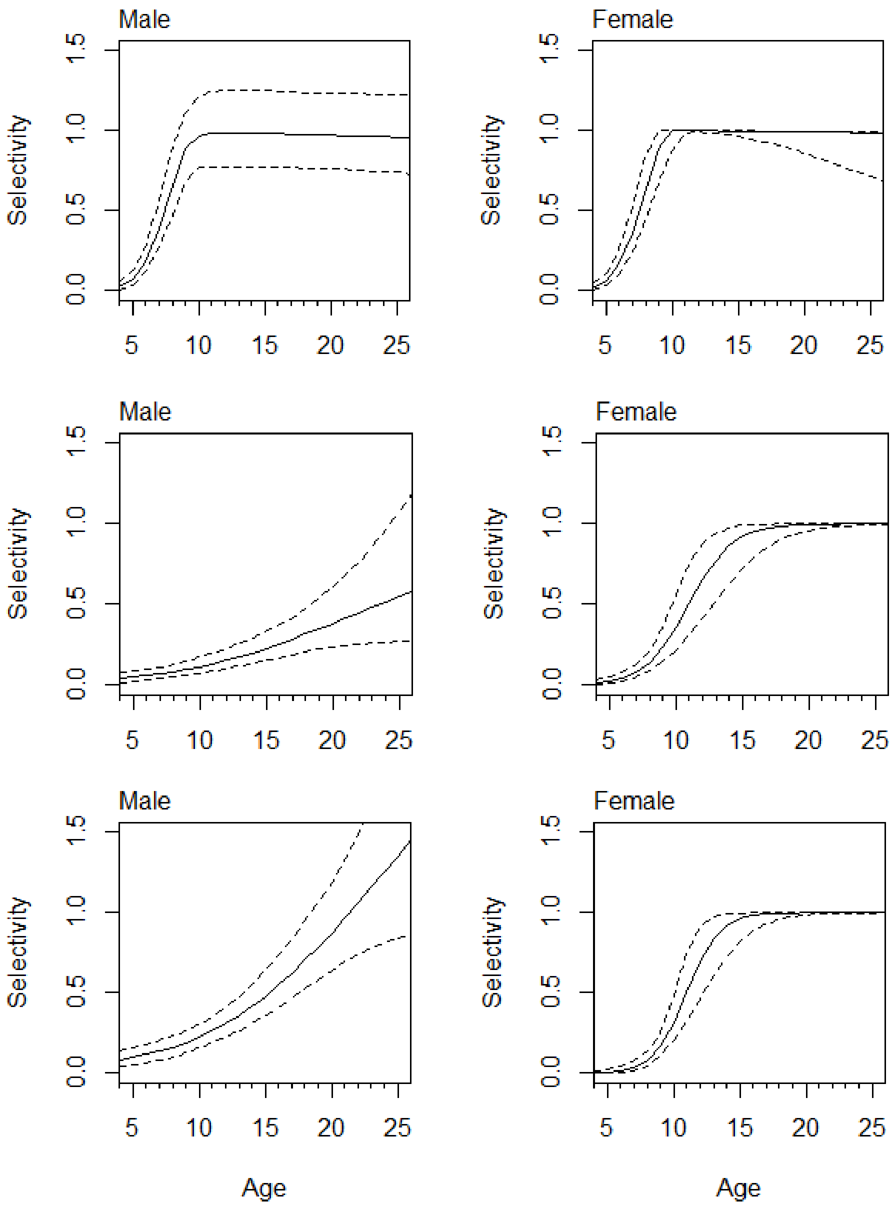


Figure 19: Estimated posterior distributions of selectivity ogives for the base model (free *q*'s) run for the trawl fishery (top), non-spawning line fishery (middle) and spawning line fishery (bottom). Dashed lines show the 95% credible intervals and the solid line the median.

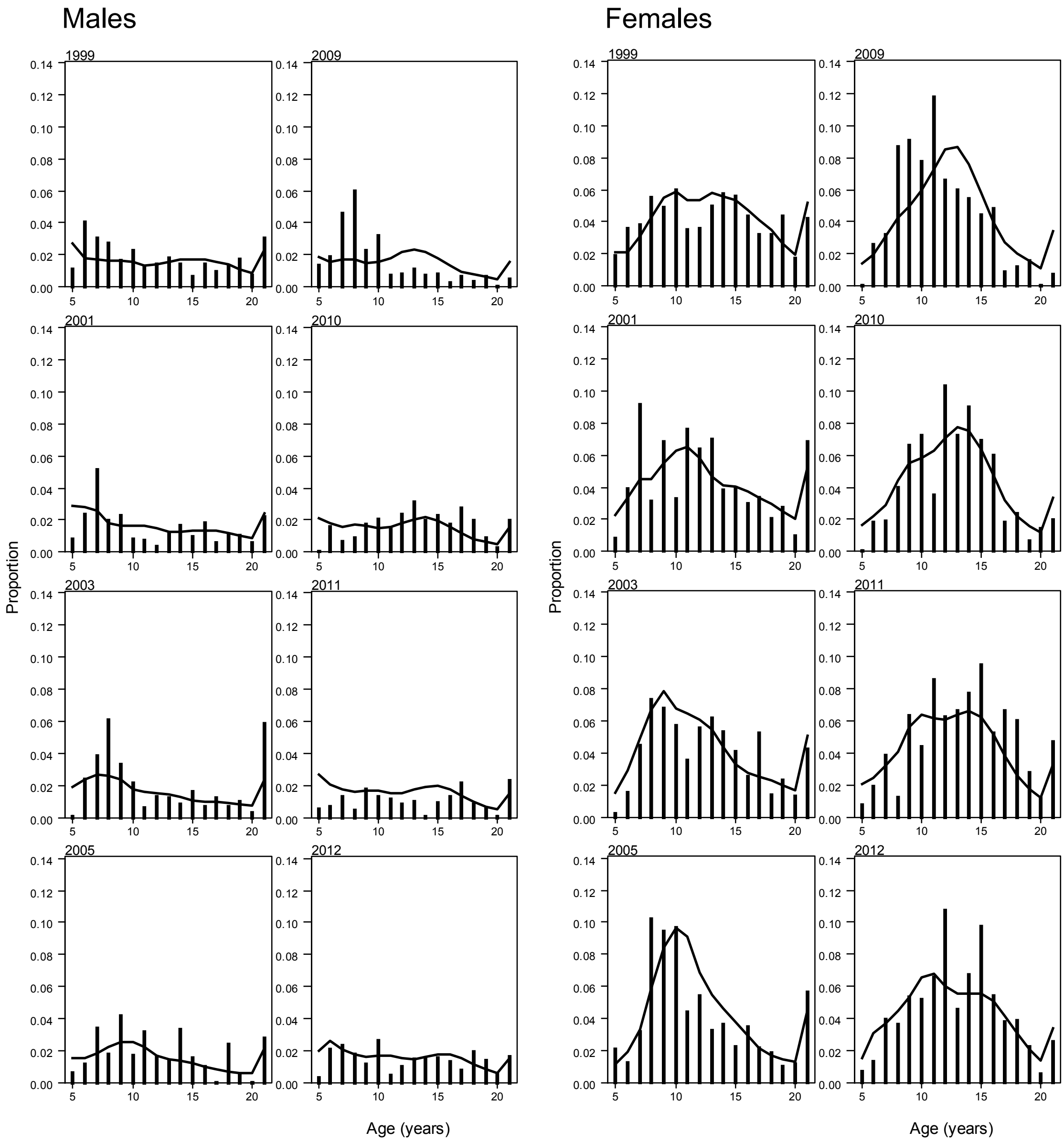


Figure 20: Base run fit (line) to observed proportion-at-age (bars) for female ling in the non-spawning line fishery.

Posterior distributions of year class strength (YCS) estimates were almost identical for the Reference and Base (free *q*'s) model runs (Figure 21). YCS was not well estimated and had wide credible bounds for years where only older fish were available to determine age class strength (i.e., before 1980) or where there are few data (i.e., after 2006); intermediate YCSs appear well estimated. Since 1980, year class strengths were around or below average, except for between 1993 and 1996, and in 2005 when YCS estimates were above average. Estimated annual YCS were not widely variable, with all medians being between 0.5 and 1.5 of the average (Figure 21).

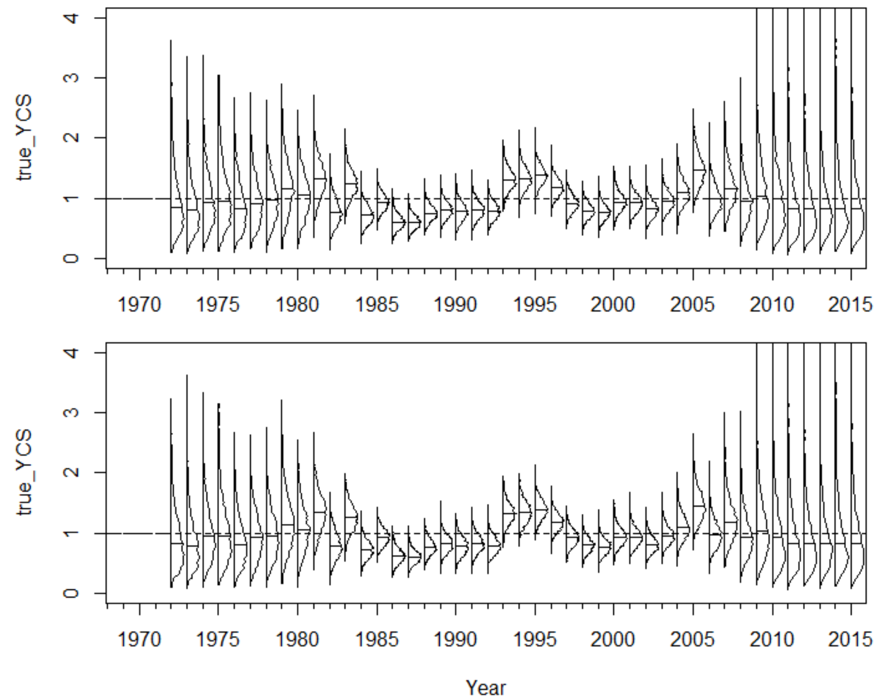


Figure 21: Estimated posterior distributions of year class strength for the reference run (top) and base (free q's) run (bottom).

Estimated median catchability coefficients (q, with 95% credible intervals) for the reference model run (using nuisance q's) were 0.08 (0.04–0.15) and 0.11 (0.06–0.21) for the summer and autumn surveys, respectively (Figure 22). As expected, the summer survey q is lower than the autumn value. The base model run using free q's gave increased estimates of q for both the summer and autumn surveys – 0.10 (0.04–0.19) and 0.13 (0.05–0.24), respectively.

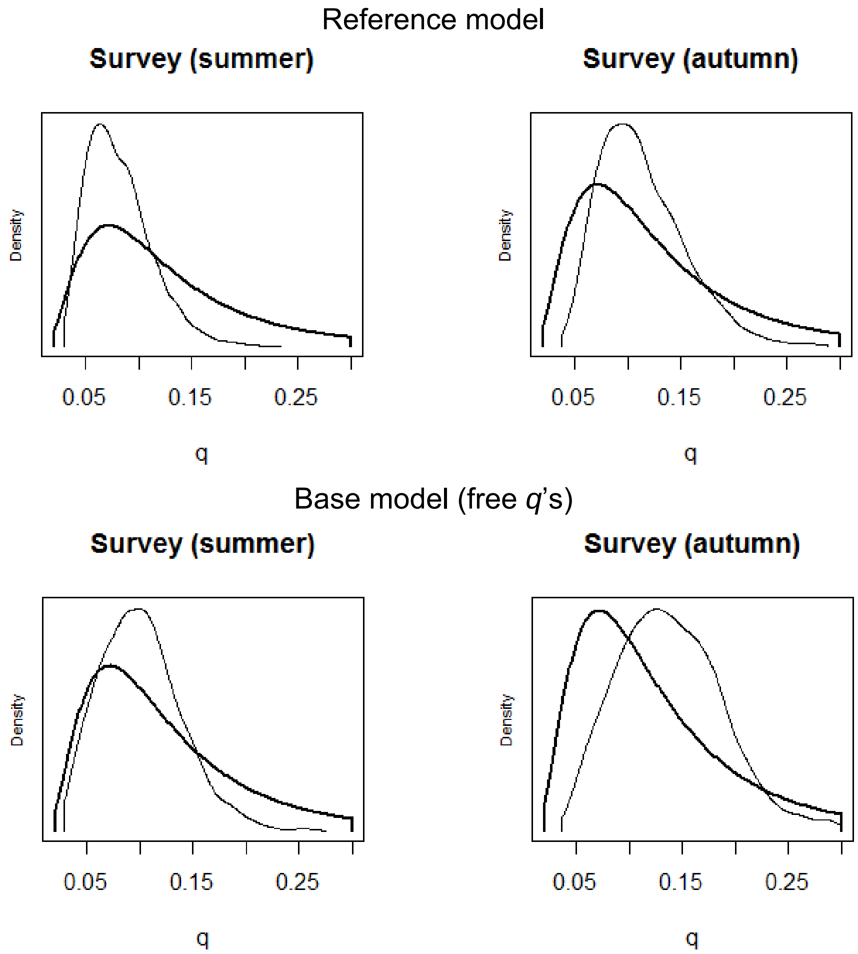


Figure 22: Estimated posterior distributions (thin lines) of the trawl survey *q* and distributions of priors (thick lines), for the autumn and summer trawl survey series for the reference model and base model (free *q*'s) runs.

Estimated biomass for the Sub-Antarctic stock declined slightly throughout the 1980s owing to fishing, but more steeply throughout the 1990s owing to increased fishing pressure and the recruitment of the relatively weak years classes spawned throughout the 1980s (Figure 21 and Figure 24). Biomass has since increased following a reduction in fishing pressure and the recruitment of average to strong year classes. Bounds around the median biomass estimates are wide. Current stock size is estimated to be about 87% of B_0 (95% credible interval 69–103%) (Figure 23 and Table 11). Estimated current biomass was 85–90% of B_0 (Figure 23 and Table 11). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.06) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches (Figure 24).

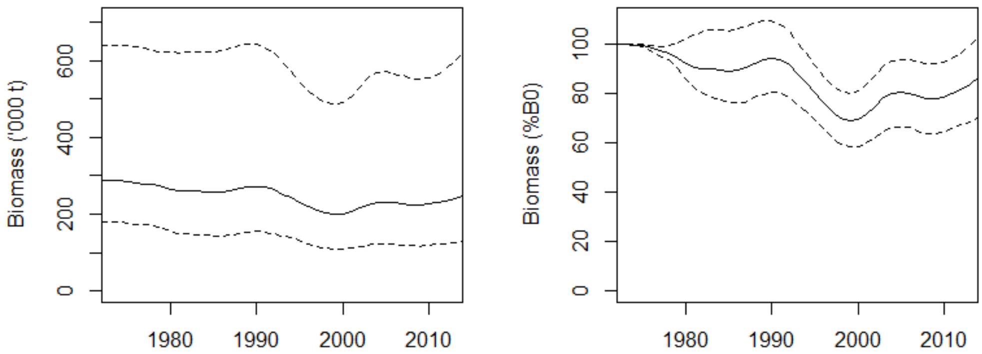


Figure 23: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0 for base run (free q's).

Table 11: Bayesian median and 95% credible intervals of B_0, B_{2014}, and B_{2014} as a percentage of B_0 for the reference, base (free *q*'s) and mortality model runs.

Model run	B_0	B_{2014}	B_{2014} (% B_0)
Reference	354 000 (204 000 – 673 000)	317 000 (155 000 – 655 000)	89 (72 – 104)
Base (free *q*'s)	289 000 (179 000 – 665 000)	251 000 (127 000 – 651 000)	86 (69 – 103)
Mortality	374 000 (214 000 – 715 000)	329 000 (160 000 – 689 000)	87 (72 – 102)

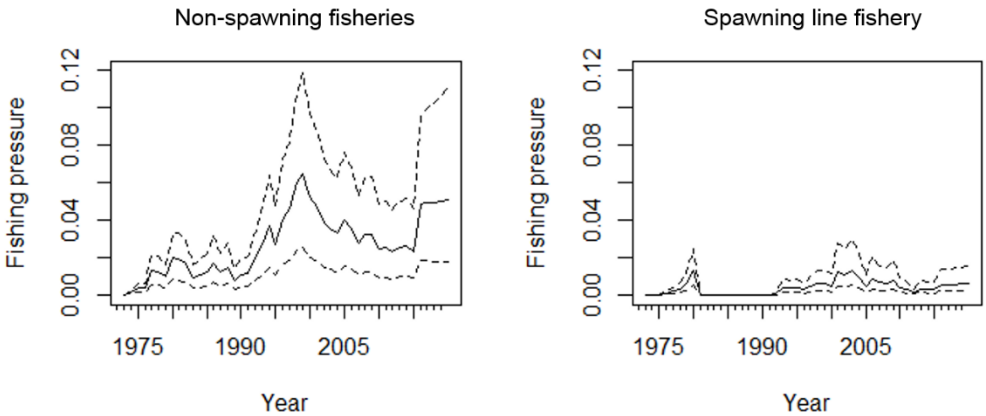


Figure 24: Estimated fishing pressures for non-spawning fisheries (left) and spawning line (right) fisheries. Dashed lines show the 95% credible intervals and the solid line the median.

5.1.1 Biomass projections

Biomass projections were made under two assumed future catch scenarios. The first, lower catch scenario (4800 t by the trawl fishery, 300 t by the spawning line fishery and 600 t by the non-spawning line fishery) is the mean catch level reported from the last five years. The second, higher catch scenario (10 200 t by the trawl fishery, 650 t by the spawning line fishery and 1250 t by the non-spawning line fishery) assumes that the TACC is taken. The lognormal distribution was used when assigning YCS for years 2011 onwards.

Projections with all four model runs suggested that biomass in 2019 will be between 89 – 95 %B_0 under current catch scenarios. If the TACC was caught, the biomass in 2019 would be 82 – 88 % B_0 (Table 12 and Figure 25).

Table 12: Bayesian median and 95% credible intervals of projected B_{2019} (t) and B_{2019} as a percentage of B_0 for the four MCMC model runs, under two alternative future annual catch scenarios.

Future catch	Model run	B_{2019}	B_{2019} (% B_0)
5 700	Reference	338 000 (161 000 – 716 000)	94.7 (73.2 – 122.5)
	Base (free *q*'s)	265 000 (132 000 – 707 000)	90.8 (69.8 – 118.9)
	Mortality	376 000 (214 000 – 710 000)	89.4 (68.7 – 115.4)
	Sigma-r	337 000 (159 000 – 733 000)	94.0 (71.2 – 130.6)
12 100	Reference	314 000 (136 000 – 692 000)	87.7 (62.9 – 117.0)
	Base (free *q*'s)	241 000 (106 000 – 683 000)	82.3 (57.1 – 113.2)
	Mortality	372 000 (214 000 – 688 000)	83.2 (59.5 – 110.4)
	Sigma-r	312 000 (133 000 – 709 000)	87.0 (61.1 – 125.1)

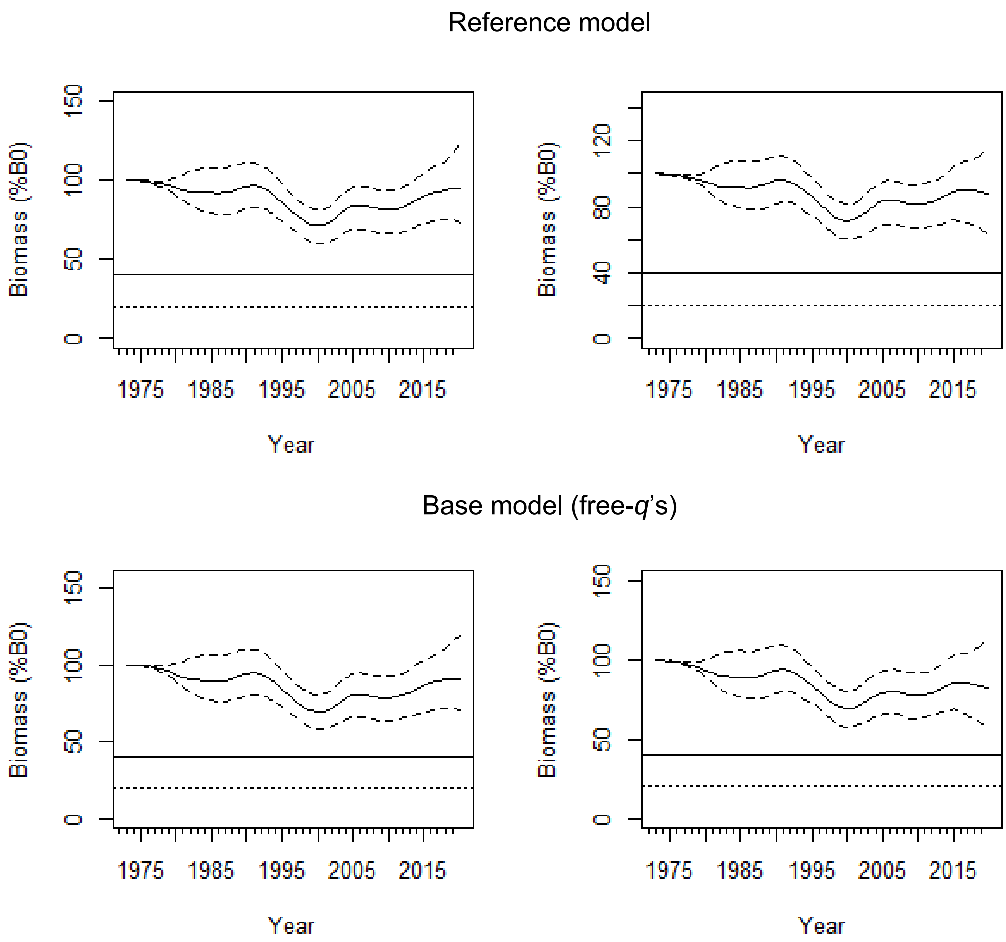


Figure 25: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for biomass as a percentage of B_0, projected to 2019 under the reference and base (free-q's) models, with future catches assumed to be 5900 t (left panel) or 12 100 t (right panel) annually.

5.1.2 Management biomass targets

Probabilities that current and projected biomass will drop below selected management reference points (i.e., target, 40% B_0; soft limit, 20% B_0; hard limit, 10% B_0) are shown, for the Base model run in Table 13. It appears very unlikely (i.e., < 1%) that B_{2019} will be lower than the target level of 40% B_0, even for the high future catch scenario.

Table 13: Probabilities that current (B_{2014}) and projected (B_{2019}) biomass will be less than 40%, 20% or 10% of B_0. Projected biomass probabilities are presented for two scenarios of future annual catch (i.e., 5700 t, and 12 100 t).

Biomass	Model run	Management reference points		
		40% B_0	20% B_0	10% B_0
B_{2014}	Reference	0.000	0.000	0.000
	Base (free *q*'s)	0.000	0.000	0.000
	Mortality	0.000	0.000	0.000
	Sigma-r	0.000	0.000	0.000
B_{2019}, 5 700 t catch	Reference	0.000	0.000	0.000
	Base (free *q*'s)	0.000	0.000	0.000
	Mortality	0.000	0.000	0.000
	Sigma-r	0.000	0.000	0.000
B_{2019}, 12 100 t catch	Reference	0.000	0.000	0.000
	Base (free *q*'s)	0.000	0.000	0.000
	Mortality	0.000	0.000	0.000
	Sigma-r	0.000	0.000	0.000

6. DISCUSSION

Previous assessments have produced relatively uncertain results because there is little contrast in any of the abundance series (i.e., trawl surveys or line fishery CPUE). This led to conclusions that the stock had been only lightly fished and that the absolute biomass was poorly known. This latest assessment also produced imprecise estimates of B_0 (95% credible intervals of 127 000 – 651 000 tonnes under the base model run) and optimistic estimates of stock status for all model runs (85–90% of B_0 and very unlikely to be less than 70% of B_0).

Model estimates indicate that minor variations in stock biomass have occurred over the assessment period, which may be explained by periods of strong and weak YCS and changes in fishing pressure. One example of this includes the shallow trough in biomass in the late-1990s and subsequent recovery in response to reduced catches and the recruitment of some relatively strong year classes (Table 2, Figure 2 and Figure 3). However, catches at the recent level are likely to be sustainable in the long term (assuming no exceptional decline in future recruitments). Projections indicated that catches at the TACC may lead to slight decline in biomass, although the probability of B_{2019} being below 60% was very small when assuming either the low or high future annual catch scenarios (5700 t or 12 100 t, respectively).

Previous modelling of Sub-Antarctic ling have shown the assessments to be relatively sensitive to small changes in M and that the true value of M probably varies between stocks (Horn 2008). In this assessment, the derived ogives from all model runs were very similar when using the double-exponential functional form. The selectivity and M ogives will be confounded, such that the estimated M ogive may not be a true representation of this biological parameter, though the estimates obtained were biologically sensible, with M being greater for very old and very young fish (0.34 at ages 3 and 25), and lowest at around age 13–14 years (0.14). A value of 0.21 was obtained when assuming constant M with respect to age (though this gave poorer fits to the at-age observations). We suggest that future assessments explore the consequences of exploring sex-specific M.

The Sub-Antarctic biological stock is spread across two administrative fish stocks (LIN 5 and LIN 6). Although it is likely that the current TACCs allow the harvest of biomass in proportion to its abundance in each area, the actual proportion of the available ling biomass harvested from LIN 5 each year is probably greater, because the LIN 6 TACC is usually under-caught, whilst the LIN 5 TACC is often fully caught. An analysis of the Summer trawl survey biomass index of ling in different regions (including a region that includes most of the fished grounds within LIN 5), found no evidence for a long-term biomass trend in any region, such as could arise from spatial variation in fishing pressure within the stock area (see Appendix B). This suggests that the current method for allocating the TACC to LIN 5 and LIN 6 is appropriate, though it is recommended that future assessments continue to monitor survey biomass estimates in LIN 5.

7. ACKNOWLEDGMENTS

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APPENDIX A. Commercial fishery CPUE indices used in the 2013–14 stock assessment for Sub-Antarctic ling (LIN 5&6)

The commercial CPUE indices used in this assessment were reported separately by Ballara & Horn (2015) and are presented in (Table A1) below.

Table A1: Commercial fishery CPUE indices and associated CVs for the Sub-Antarctic spawning and non-spawning longline fisheries, used in the 2013–14 stock assessment for Sub-Antarctic ling (LIN 5&6); as reported by Ballara & Horn (2015).

	Spawning longline fishery		Non-spawning longline fishery	
Year	Index	CV	Index	CV
1990/91	1.39	0.17	0.67	0.12
1991/92	1.81	0.14	1.07	0.09
1992/93	1.78	0.11	1.00	0.10
1993/94	1.48	0.11	0.76	0.09
1994/95	1.48	0.17	1.10	0.08
1995/96	1.40	0.11	0.85	0.09
1996/97	1.22	0.11	0.96	0.06
1997/98	1.10	0.11	0.90	0.07
1998/99	1.25	0.10	0.64	0.05
1999/00	1.32	0.10	0.74	0.07
2000/01	1.27	0.09	0.90	0.08
2001/02	1.58	0.10	0.77	0.10
2002/03	1.14	0.12	0.60	0.12
2003/04	1.04	0.09	0.57	0.09
2004/05	1.47	0.12	0.52	0.13
2005/06	1.30	0.12	0.60	0.14
2006/07	1.39	0.11	0.74	0.26
2007/08	1.05	0.14	0.87	0.13
2008/09	2.09	0.19	0.76	0.13
2009/10	0.69	0.19	0.91	0.09
2010/11	1.04	0.15	0.58	0.09
2011/12	1.13	0.15	0.73	0.08

APPENDIX B. Trawl survey biomass indices of Sub-Antarctic ling by geographical region

The low degree of inter-annual variation in the Sub-Antarctic trawl survey biomass index for ling suggests that biomass of ling has remained relatively constant throughout the time series of the summer survey used in the assessment (1991–2012). However, the combined survey strata cover a large area, including the Stewart-Snares Shelf and Puysegur Bank (LIN 5) and the Campbell Plateau (LIN 6). Furthermore, fishing effort is not distributed evenly across the stock area, with a greater proportion of the overall ling catch taken in LIN 5, which is smaller than LIN 6, in all years since 2008–09 (Table 2). Should local depletions of ling occur, this may not lead to a detectable change in the Sub-Antarctic-wide survey biomass. As such, it would be desirable to know if the biomass of ling is likely to have changed across smaller regions of the survey area.

For this analysis, Sub-Antarctic trawl strata were grouped into three regions: North – approximating to LIN 5; Central – the northern Campbell Plateau; and South – the southern Campbell Plateau (See Figure B1 and Table B1). The summed biomass for each region was then reported for each survey (Table B2). No obvious year-trend was observed from the biomass estimates of either region, suggesting that the Sub-Antarctic survey trend is representative of the smaller regions through the time period of the survey (i.e., there is limited evidence for depletions in smaller regions).

Table B1: Stratum groupings used to generate regional biomass estimates.

Stratum	Name	Region	Area (km^2)
1	Puysegur Bank	North	2 150
2	Puysegur Bank	North	1 318
3a	Stewart-Snares	North	4 548
3b	Stewart-Snares	North	1 556
4	Stewart-Snares	North	21 018
5a	Snares-Auckland	Central	2 981
5b	Snares-Auckland	Central	3 281
6	Auckland Is.	Central	16 682
7	South Auckland	South	8 497
8	N.E. Auckland	Central	17 294
9	N. Campbell Is.	Central	27 398
10	S. Campbell Is.	South	11 288
11	N.E. Pukaki Rise	Central	23 008
12	Pukaki	Central	45 259
13	N.E. Camp. Plateau	South	36 051
14	E. Camp. Plateau	South	27 659
15	E. Camp. Plateau	South	15 179
Total			**288 417**

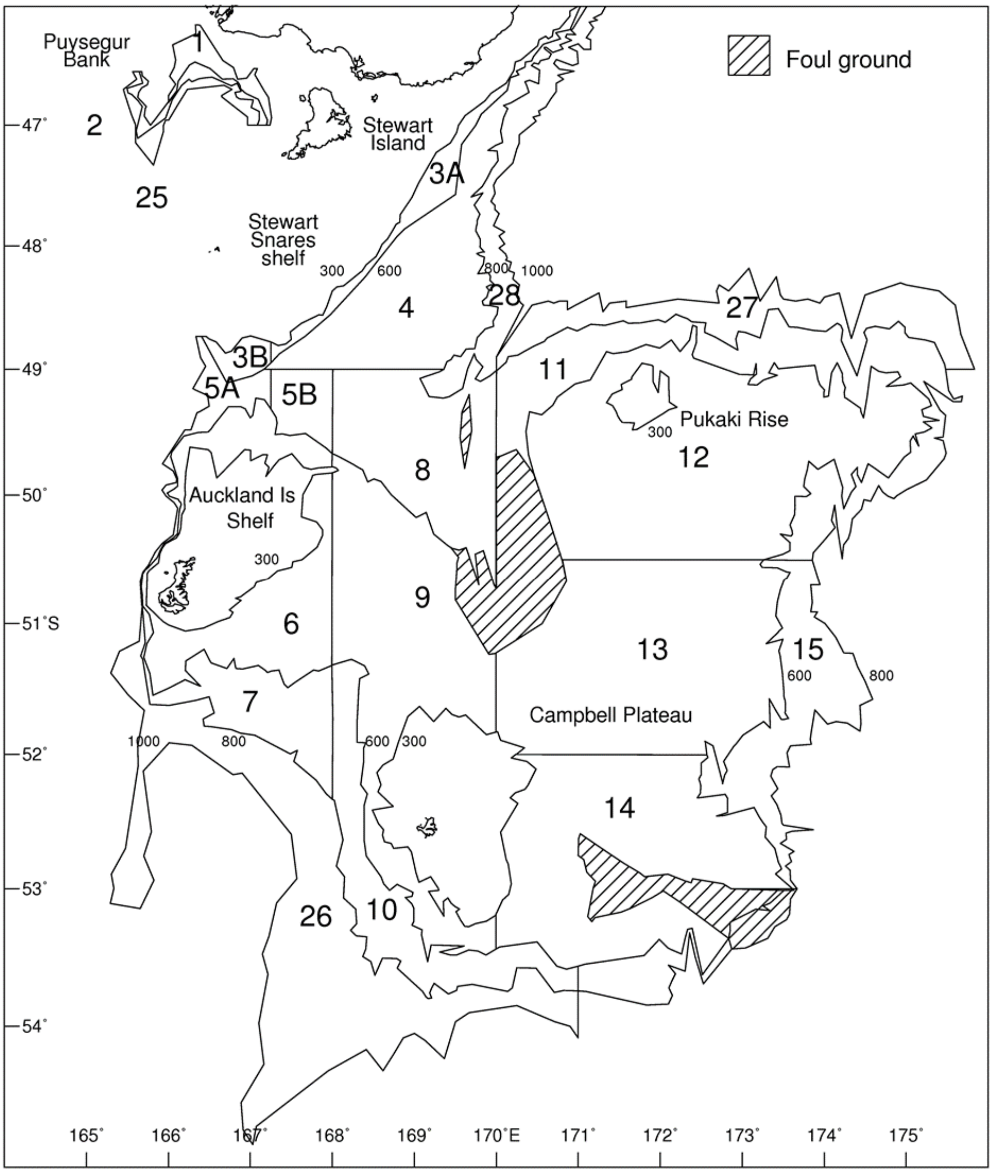

Figure B1: Stratum boundaries for the summer 2000–12 Sub-Antarctic trawl surveys.

Table B2: Combined biomass estimates by stratum region and survey year.

		Biomass index (t) by stratum region		
Survey year	**Survey name**	**North**	**Central**	**South**
1991	TAN9105	2 712	13 439	7 954
1992	TAN9211	3 120	11 849	6 407
1993	TAN9310	7 950	13 699	8 089
2000	TAN0012	3 944	19 675	9 393
2001	TAN0118	4 228	12 095	8 735
2002	TAN0219	6 908	12 175	6 547
2003	TAN0317	5 711	10 852	5 612
2004	TAN0414	7 823	9 725	6 196
2005	TAN0515	2 941	10 889	5 853
2006	TAN0617	2 591	10 502	6 185
2007	TAN0714	3 168	13 346	9 974
2008	TAN0813	5 280	10 195	7 356
2009	TAN0911	3 044	13 229	6 440
2011	TAN1117	5 334	12 440	5 403
2012	TAN1215	4 664	12 396	9 950