A 2011 stock assessment of bluenose (*Hyperoglyphe antarctica*)

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EXECUTIVE SUMMARY

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This document describes the first fully-quantitative stock assessment of bluenose. The assessment was developed in consultation with the Northern Inshore Working Group and presented to the 2011 Plenary.

The stock structure of bluenose is unknown. However, for the purposes of assessment, a single EEZ-wide stock was assumed. This assumption is supported by the similar pattern of decline in CPUE indices across several bluenose trawl and line fisheries and the long pre-settlement period of juveniles. Alternative stock structure assumptions are possible, but there is little information to support any specific alternative.

The stock assessment model was implemented in the Bayesian stock assessment program CASAL. Many preliminary runs were done using alternative combinations of parameters and data sets. However, the assessment consists of a final set of 18 runs for which the mode of the posterior distribution was calculated (i.e., MPD runs). The 18 runs consist of all combinations of 3 alternative values of natural mortality (M), 2 values of stock-recruitment steepness (h), and 3 alternative catch histories (the main uncertainty in the catch history is the spike in foreign catches just before the declaration of the EEZ). Deterministic projections were done to 2050 for the six runs using the base catch history.

The model was age-structured with two sexes, a single area, and two fisheries (line and trawl). The model was fitted to CPUE indices and length frequencies for each fishery, and to a single year of age frequencies from each fishery. Growth parameters, estimated in a recent age-validation study, were assumed known. Year class strengths were not estimated from the limited age data.

The fits to the CPUE indices were consistent with the assumed CVs of 20%. However, for both time series, a poor residual pattern was apparent, especially for the line CPUE. The line CPUE is flatter than the predicted values from 1990 to 2004, and then steeper than the predictions from 2005 to 2010. The fits to the length frequencies and age frequencies were adequate given their inconsistent nature (e.g., modes at different lengths in different years due to patchy sampling and/or selectivity changes).

The differences between the biomass trajectories from the 18 assessment runs are driven by the value of M with estimates of virgin biomass (B_0) ranging from just over 30 000 t with an M of 0.1 to around 60 000 t with an M of 0.06. Biomass trajectories, as a proportion of B_0, all show a similar trend with a continuous decline from the late 1980s to the present. The runs are in two groups with regard to current stock status (mid-spawning season in the 2010–11 fishing year). The 6 runs with M = 0.06 are above 20% B_0 while the 12 runs with M = 0.08 or M = 0.10 are below 20% B_0. The full range is from 14–27% $B_{0.}$

The results of the assessment are sensitive to the assumed value of M but not to h or the uncertainties in the early catch history. The projection results are sensitive to assumed values of M and h. Given the simplicity of the model relative to the real-world, and the sensitivity of results to unknown parameters, it is imprudent to put too much faith in the *precision* of the model estimates and predictions. However, semi-quantitatively, or approximately, the results are clear. The EEZ-wide stock is very likely to currently be below the (default) target of 40% B_0; catches at the current TACC (2335 t) will very likely cause the stock to decline further; and a step-down to annual catches in the range 550–900 t could allow the stock to rebuild to the target level within the recommended timeframe of the Harvest Strategy Standard (i.e., $2 \times T_{min}$).

1. INTRODUCTION

This document summarizes and provides details of the 2011 stock assessment of bluenose that was developed in consultation with the Northern Inshore Working Group and presented at the 2011 Plenary. Details of the assessment and work associated with the assessment are presented in five appendices: the derivation of the catch history (Appendix 1); an analysis of commercial length-frequency data looking for spatial and temporal patterns relevant to stock structure (Appendix 2); a review of data and literature relevant to stock structure (Appendix 3); model fits to length and age data (Appendix 4); and model input files for the stock assessment (Appendix 5).

2. METHODS

A single EEZ-wide stock was assumed for all model runs in the assessment. The available data and literature are consistent with this assumption but do not preclude multiple stocks. However, there are no obvious alternatives to the single-stock assumption. All model runs used a simple age-structured model which was implemented in the general purpose Bayesian stock assessment program CASAL (Bull et al. 2009).

A known catch-history was assumed in each run, although three alternatives were considered. Natural mortality and steepness (in the Beverton-Holt stock recruitment relationship) were also varied across model runs. Many preliminary runs were done using alternative combinations of parameters and data sets. However, the assessment consists of a final set of 18 runs for which the mode of the posterior distribution was calculated (i.e., MPD runs).

2.1 Data inputs

Catch history

The catch history in the model starts in 1935–36 when some bluenose were landed as groper or hapuku. The main uncertainty in the catch history is the foreign catch just prior to the declaration of the EEZ. The size of the spike in catches is very uncertain. Three alternative total catch histories were constructed: low, base, and high (Figure 1). Derivation of the early catch history is fully described in Appendix 1.

Two fisheries are used in the model, a “line” fishery and a “trawl” fishery (see below). The bluenose catches from 1935–36 to 1982–83 were assumed to be by line (except for foreign trawl-caught fish). From 1983–84 to 1988–89 there was an increasing proportion of trawl caught bluenose in BNS2 (Peter Horn, pers. comm.). All catch in those years was assumed to be by line except for BNS2 where the proportion of trawl-caught fish was assumed to be 40% in 1983–84 and to increase in steps of 10% each year to 90% in 1988–89 (from the characterization data, the proportion of trawl-caught fish in BNS2 in 1989–90 was 86%).

The catch histories for the line and trawl fisheries from 1989–90 to 2006–07 were derived from the bluenose characterizations done for the 2008 AMP review. The total catches from 2007–08 to 2009–10 are from the 2010 Plenary report. The split between line and trawl approximately matches the split in the 2006–07 year. The assumed catches in 2010–11 are rounded values close to those in 2009–10. See Table 1 for the three alternative catch histories. Note, the middle catch history is denoted as a “base” because it is a plausible reality, whereas the low and high catch histories were designed to be extreme so as to capture the full range of possibilities.

Table 1: The three alternative catch histories (t) used in the model runs. Trawl catch prior to 1970 was assumed to be zero. The fishing year is denoted by the second year (e.g., 1970 is 1969–70).

	Line				Line				Trawl		
	Low	Base	High		Low	Base	High		Low	Base	High
1936	0	75	150	1963	0	59	119	1970	0	0	0
1937	0	75	150	1964	0	66	133	1971	0	0	0
1938	0	75	150	1965	0	64	128	1972	0	45	78
1939	0	75	150	1966	0	61	123	1973	0	42	72
1940	0	56	112	1967	0	65	129	1974	0	68	117
1941	0	50	100	1968	0	57	113	1975	0	116	204
1942	0	50	100	1969	0	55	111	1976	0	112	211
1943	0	50	100	1970	0	70	140	1977	0	385	1 505
1944	0	50	100	1971	0	69	138	1978	0	0	0
1945	0	50	100	1972	0	59	118	1979	0	0	0
1946	0	69	138	1973	0	63	126	1980	0	0	0
1947	0	75	150	1974	0	69	137	1981	0	0	0
1948	0	81	162	1975	111	182	252	1982	0	0	0
1949	0	95	189	1976	618	692	767	1983	0	0	0
1950	0	89	177	1977	821	913	1 004	1984	324	324	324
1951	0	74	147	1978	1	81	161	1985	372	372	372
1952	0	71	142	1979	9	92	176	1986	605	605	605
1953	0	70	141	1980	15	98	180	1987	667	667	667
1954	0	69	137	1981	235	300	365	1988	522	522	522
1955	0	66	132	1982	469	511	554	1989	623	623	623
1956	0	69	138	1983	730	755	780				
1957	0	69	138	1984	951	956	962				
1958	0	75	149	1985	1 013	1 013	1 013				
1959	0	68	137	1986	982	982	982				
1960	0	62	124	1987	744	744	744				
1961	0	60	121	1988	752	752	752				
1962	0	59	118	1989	797	797	797				

	No variation	
	Trawl	Line
1990	763	777
1991	577	1 192
1992	549	1 414
1993	733	1 573
1994	860	1 459
1995	904	1 382
1996	811	1 503
1997	1 060	1 765
1998	779	1 728
1999	904	1 871
2000	1 022	1 712
2001	1 082	1 638
2002	1 345	1 443
2003	1 331	1 671
2004	957	2 133
2005	1 114	1 900
2006	710	1 765
2007	424	2 001
2008	500	2 000
2009	300	1 746
2010	300	1 759
2011	300	1 700

CPUE indices

Catch and effort data from all bluenose QMAs from 1989-90 to 2009-10 were analyzed by Starr & Kendrick (in prep.) to construct QMA-specific and EEZ-wide CPUE time series. Their trawl (tow-by-tow) and line ("trip strata") EEZ-wide time series were used in the assessment as relative biomass indices (Figure 2).

Length frequencies

Logbook and Ministry of Fisheries Scientific Observer Programme (SOP) length samples were used to construct annual length frequencies for the line and trawl fisheries for each year when there were more than 500 fish measured (line: 1993–2008; trawl: 1995–2004). For each sample, the length frequency was scaled to the numbers of fish in the sampled catch. These catch-number weighted samples were then combined with no further scaling or stratification. The annual length frequencies (and a model fit) are shown in Appendix 4. The length samples were also used in a spatial and temporal analysis of mean length (see Appendix 2 for that analysis, sample sizes, and other details of the data).

Age frequencies
Two age frequencies were fitted in each run: Palliser Bank, single fishing-year 1985–86 (Peter Horn, pers. comm.; 6 sampling periods during the year with separate age-length keys in each period, 1610 otoliths altogether), and BOP and East Northland combined across areas for the fishing year 2000–01 (Horn & Sutton, 2010; approximately 1000 otoliths used in total).

2.2 The model, fixed parameters, and assessment runs

The CASAL input files for the "middle" run are given in Appendix 5 for those who wish to check the full details of the model structure and assumptions.

Model structure
The model assumed a single New Zealand stock of bluenose, partitioned into two sexes and 80 age groups (1–80 years with a plus group), and did not have maturity in the partition. The model had a single time-step, single area, two year-round fisheries (line and trawl), and mid-fishing-year spawning. The stock was assumed to be in deterministic equilibrium at virgin biomass (B_0) in 1935. The maximum allowable exploitation rate in each fishery was set to 60%.

The line and trawl CPUE indices were fitted as relative biomass indices. CVs of 20% were assumed for each year. This assumption incorporates some process error as the estimated CVs for the CPUE indices were unrealistically low (as is typical for indices estimated using a GLM approach).

The annual length frequencies for line and trawl were fitted in each run and assumed to be multinomial (with sample sizes proportional to the number of fish measured). The two age frequencies were also used in each run and assumed to be multinomial (ageing error was assumed to be "normal" with a CV of 10%). The effective sample sizes for the composition data were calculated so that the SDNRs were approximately equal to 1 for the "middle" run (see below).

Fixed and estimated parameters
In the final assessment runs, YCS were assumed deterministic and only B_0 (uniform-log prior), the nuisance *q*s (for the two CPUE time series, uniform-log priors), the fishing selectivities (both double normal, uniform priors), and the CV of length at age (uniform prior) were estimated. Natural mortality (M) and steepness (h) were varied (see Assessment runs below).

Fixed parameters were:

	Male	Female	Source
Length-weight (cm, g)			
a	0.00963	0.00963	Plenary report
b	3.173	3.173	
von Bertalanffy growth			
t_0	–0.5	–0.5	Horn et al. 2010
L_∞	72.2	92.5	
K	0.125	0.071	
Maturity (logistic)			
a_{50}	15	17	Horn & Sutton 2010
$a_{95} - a_{50}$	5	10	Horn & Sutton 2010

Assessment runs

The final set of 18 runs, which constitute the assessment presented to the Plenary, consisted of all combinations of a “grid” of MPD fits:

- catch history: low, base, high
- M: 0.06, 0.08, 0.10
- h: 0.75, 0.9

The M values cover what the Northern Inshore Working Group considered a plausible range. The default assumption of h = 0.75 was used and h = 0.9 was included as a sensitivity.

Iterative re-weighting was used to determine weights for the “middle” run (base catch, M = 0.08, h = 0.75). The CVs were unaltered from the initial assumption of 20%. These CVs and the sample-sizes, determined from the re-weighting, were fixed for all other runs. Convergence was checked for two runs (base catch and mid M, with h = 0.75, h = 0.90). An MCMC run was also done for the middle run. This was to check that the MPD estimates were not very different from the medians of the posterior distributions for B_0 and stock status. All runs had the same simple model structure so this was only checked for the single run.

3. RESULTS

The fishing selectivities, for both trawl and line, were estimated to be domed. However, the shapes of the fishing selectivities, especially for the line fishery, were confounded with M (Figure 3). The CV of length at age was estimated at 6% for all of the runs.

The fits to the CPUE indices were consistent with the assumed CVs of 20%. However, for both time series, a poor residual pattern was apparent, especially for the line CPUE (Figure 4). The line CPUE is flatter than the predicted values from 1990 to 2004, and then steeper than the predictions from 2005 to 2010. The fits to the length frequencies and age frequencies were adequate given their inconsistent nature (e.g., modes at different lengths in different years due to patchy sampling and/or selectivity changes). The fits to the middle run are given in Appendix 4.

The trawl and line fisheries show different trends in exploitation rates with the trawl fishery peaking from 2002 to 2005 and the line fishery increasing from 1980 to 2011 (Figure 5).

The differences between the biomass trajectories from the 18 assessment runs are driven by the value of M (Figures 6 and 7) with estimates of B_0 ranging from just over 30 000 t with an M of 0.1 to around 60 000 t with an M of 0.06.

Biomass trajectories, as a proportion of B_0, all show a similar trend with a continuous decline from the late 1980s to the present (Figure 7). The runs presented are in two groups with regard to current stock status. The 6 runs with M = 0.06 are above 20% B_0 while the 12 runs with M = 0.08 or M = 0.10 are below 20% B_0 (Figure 7, Table 2). These results should not be interpreted as there being a 66% probability that the stock is below 20% B_0. It is the range of the results that is important. The proportion of runs above or below 20% B_0 can be arbitrarily altered by including additional runs at different M values.

Table 2: Estimates of B_0, B_{2011} and stock status (B_{2011}/B_0) for the final 18 runs. The range is given for the six runs at each value of M. B_0 and B_{2011} are mid-spawning season (after half the annual catch has been removed).

M	B_0 (000 t)	B_{2011} (000 t)	B_{2011}/B_0
0.06	60–60	15–16	0.24–0.27
0.08	42–42	6.3–7.0	0.15–0.17
0.10	33–34	4.8–5.0	0.14–0.15

The MCMC run for the middle run confirmed that the MPD and median of the posterior were similar for B_0 and stock status (Figure 8).

Assuming trawl and line catches remain in the same proportions as assumed for 2010–11, deterministic B_{MSY} was estimated as 25% B_0 when h=0.75 and 15–18% B_0 for h=0.9.

Projections

Deterministic projections to 2050 were carried out for a range of future constant catches, maintaining the current ratio between catches from the line and trawl fisheries. Projections were carried out for the models fitted with the base catch history only as the different catch history scenarios had little effect on model estimates.

Catches at the level of the current TACC (2325 t, excluding Kermadec) or the current catch (2059 t) are predicted to cause the stock to decline to very low abundance over the next 20 years (Figure 9). For a stock below the soft limit of 20% B_0, the time required for SSB to rebuild to 40% B_0 in the absence of catch is called T_{min}. Although the point estimates for some runs with low M are above 20% B_0 the time required to rebuild to 40% B_0 was calculated for each run and is denoted as T_{min}. The estimates of T_{min} range from 10 to 13 years (Table 3) and the maximum catches that allow a rebuild to 40% B_0 within twice T_{min} range from 570–840 t (Table 4).

Table 3: The number of years before SSB reaches 40% B_0 when no future catch is taken. The duration, in a whole number of years, is defined as "T_{min}" and is shown for the six runs with the base catch history and combinations of M and h.

	h	
M	0.75	0.90
0.06	13	12
0.08	13	12
0.10	11	10

Table 4: The maximum catch (t) that allows SSB to rebuild to at least 40% B_0 within twice T_{min} for the six runs with base catch history.

	h	
M	0.75	0.90
0.06	600	720
0.08	570	770
0.10	600	840

4. DICUSSION AND CONCLUSIONS

The use of a single EEZ-wide stock in the assessment was discussed at length by the Northern Inshore Working Group and the Plenary. Stock structure is unknown. However, what data there are do not rule out a single stock although the real situation is undoubtedly more complex than the single-stock dynamics assumed in the model. Data and studies relevant to stock structure are presented in Appendix 4. The three pieces of evidence in favour of a single stock are the coincident decline of the QMA-specific CPUE time series (Starr & Kendrick in prep.), the long larval phase of bluenose and the juvenile occupation of surface waters (Baelde 1996, Last et al. 1993, Duffy et al. 2000), and the long migrations of some tagged fish (Horn 2003). It is difficult to justify any stock hypothesis because of the lack of data.

The natural division of the population into east and west coast stocks is one alternative. There is some support for this on the basis of the tag returns (no fish tagged on the east coast were captured on the west coast), and the different trends over time of the mean lengths of bluenose caught on the WCSI and the top of the North Island (Appendix 2). Also, the CPUE time series from QMAs 7 and 8 is the flattest of the QMA-specific CPUE series. This stock hypothesis should perhaps be considered as a sensitivity analysis for the next assessment.

The results of the assessment are sensitive to the assumed value of M but not to the uncertainties in the early catch history. The projection results are sensitive to assumed values of M and h. Given the simplicity of the model relative to the real-world, and the sensitivity of results to unknown parameters, it is imprudent to put too much faith in the *precision* of the model estimates and predictions. However, semi-quantitatively, or approximately, the results are clear. The EEZ-wide stock is very likely to currently be below the (default) target of 40% B_0; catches at the current TACC (2335 t) will very likely cause the stock to decline further; and a step-down to annual catches in the range 550–900 t could allow the stock to rebuild to the target level within the recommended timeframe of the Harvest Strategy Standard (i.e., $2 \times T_{min}$).

5. ACKNOWLEDGEMENTS

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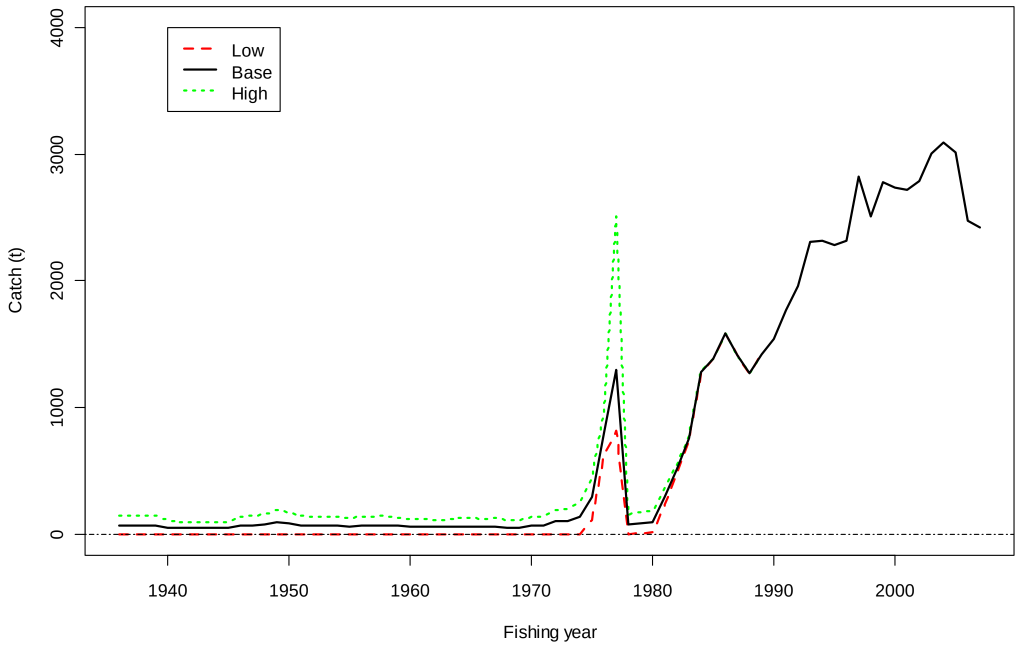

Figure 1: The three alternative catch histories used in the assessment model runs.

Figure 2: The line and trawl CPUE indices fitted in the assessment model runs.

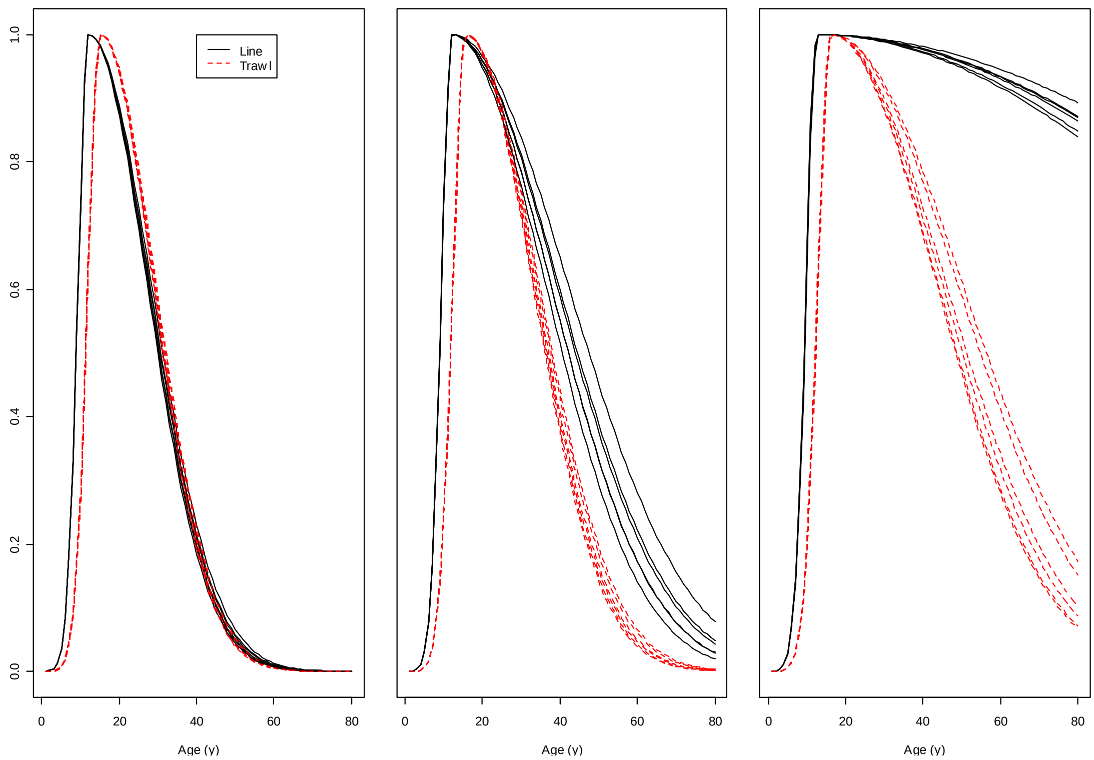

Figure 3: Estimated fishing selectivities for the trawl and line fisheries for the final 18 MPD runs. Each plot shows the results for six runs with the same value of M (0.06, 0.08, 0.10, increasing from left to right).

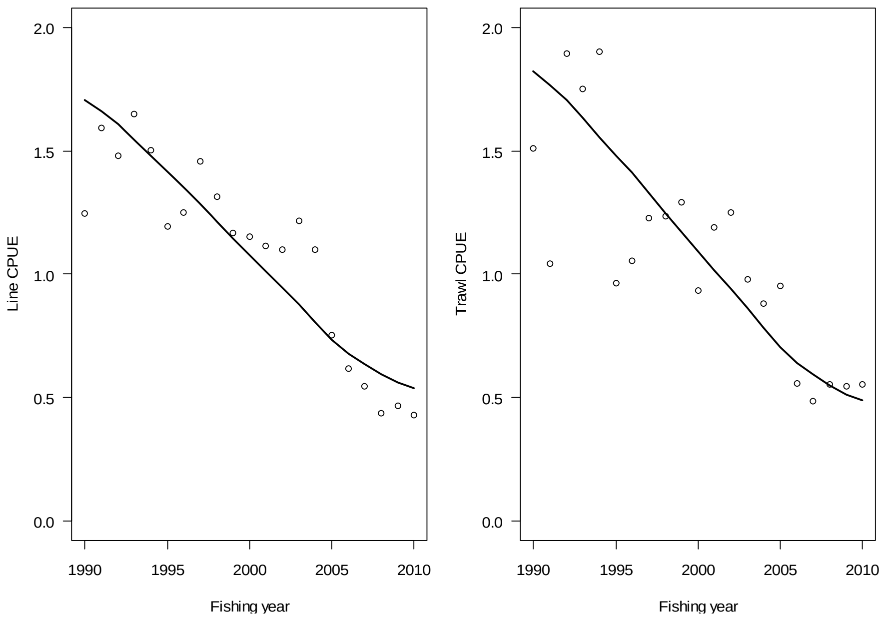

Figure 4: The model fits to the line and trawl CPUE for the run with base catch, mid M (0.08), and h=0.75. The fits for the other runs are almost identical.

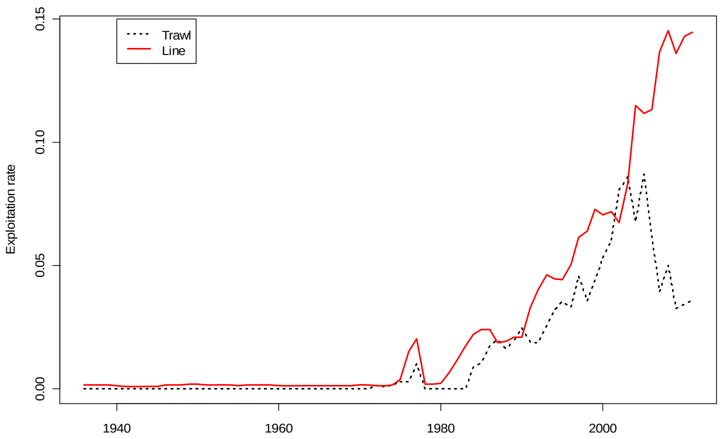

Figure 5: Exploitation rates (catch divided by beginning-of-year selected biomass) for the trawl and line fisheries for the run with base catch, mid M (0.08), and h = 0.75.

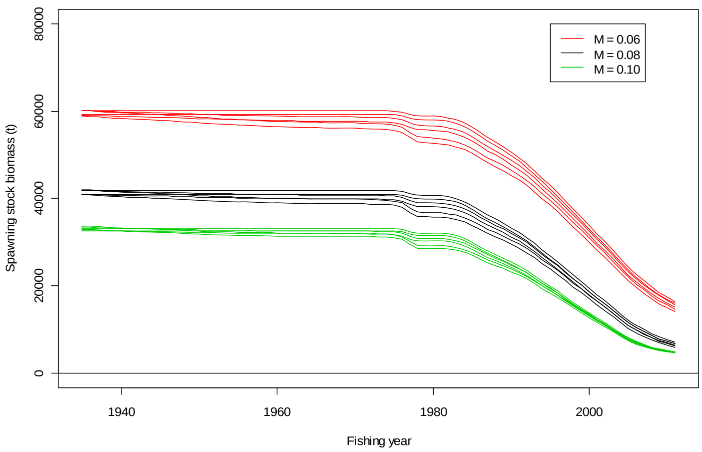

Figure 6: Biomass trajectories (t) for the final set of 18 MPD runs.

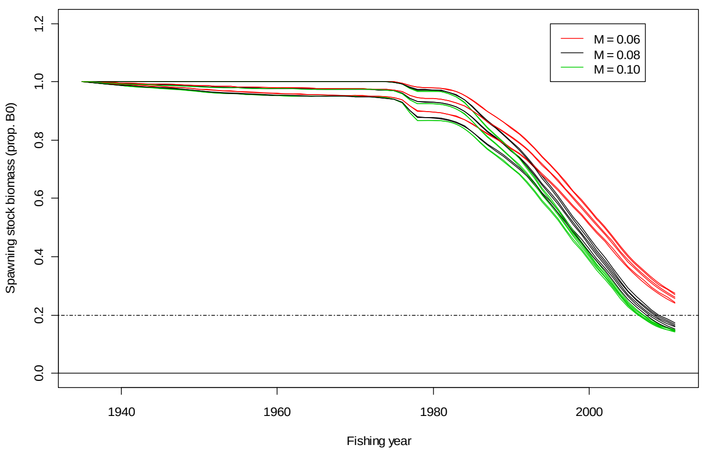

Figure 7: Biomass trajectories (proportion of B_0) for the final set of 18 MPD runs.

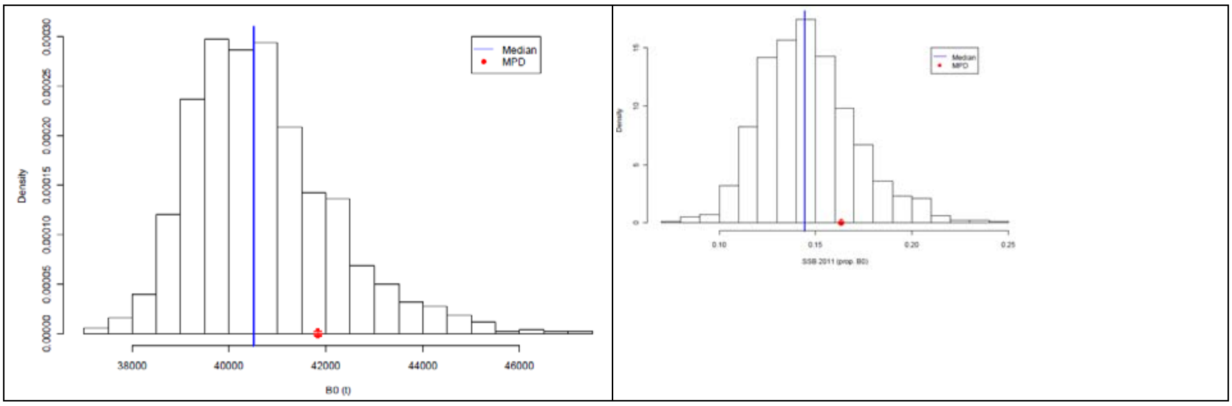

Figure 8: MCMC posteriors for B_0 and B_{2011}/B_0 for base catch, mid M (0.08), h = 0.75.

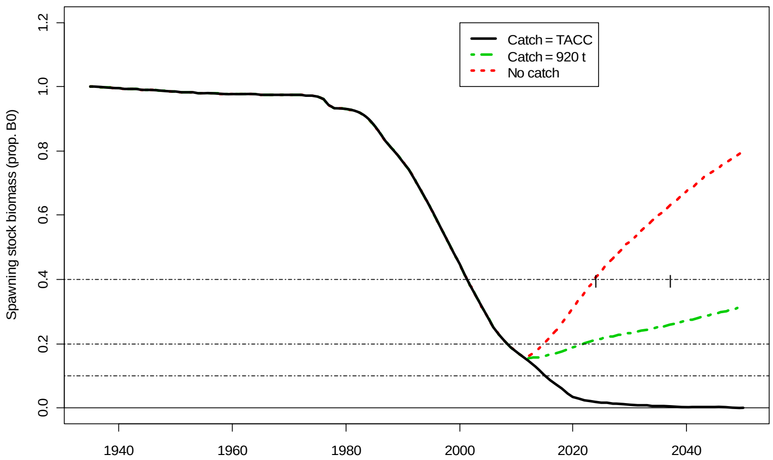

Figure 9: Projected SSB at different catch levels for the run with base catch, mid M (0.08), and h = 0.75. The two short vertical lines at 40% B_0 mark 2011 + T_{min} and 2011 + 2 T_{min}.

APPENDIX 1: Derivation of the catch history

Data sources and data

Prior to 1989–90 there is substantial uncertainty with regard to total landings of bluenose. From 1989–90 to 2009–10 the total landings are well determined from QMS data.

Landing estimates in the Plenary reports go back to the calendar year 1981. Horn (1988), notes that prior to 1981 "most bluenose was landed under various names and coded as groper or hapuku". He notes that catches by foreign/chartered vessels from 1978 to 1986 were low and also refers to Paul & Robertson (1979) with regard to landings of bluenose by foreign vessels from 1971 to 1977. There is no mention of foreign-caught bluenose in the 2010 Plenary report (and the landing tables do not include it).

The 2010 Plenary report for groper (HPB) lists New Zealand landings from 1948 to 1983 (including foreign catches from 1974) and notes "the first recorded landings of about 1500 t in 1936 were generally typical of the range of catches (1000-2000 t) from then until 1978". A restriction of effort and reduced catch in the war years is also noted.

The foreign/chartered catches recorded in Table 2 of Horn (1988) are relatively small, with the catch in 1985–86 of 80.9 t being the largest. The domestic catches from 1981 to 1986 (Table 1, Horn, 1988) increased from 300 t in 1981 to 1500 t in 1986.

The foreign catches from 1972 to 1977 were probably substantial but are very uncertain. No catches of bluenose were explicitly recorded by any of the foreign fishing nations, but they undoubtedly caught some bluenose with trawl and bottom longline. Paul & Robertson (1979) and later Horn (1988) suggest that the blue warehou catch recorded by the Japanese bottom longline fleet is actually bluenose. Also, Horn (1988) says that "any foreign trawl-caught bluenose were probably included with butterfish or warehou". Paul & Robertson note that "butterfish is a recognized international name for warehou". The relevant data from tables 4–8 of Paul & Robertson (1979) are given in Table A1.1. The peak year for foreign catches of BNS was probably 1977 when Japanese, Korean, and Russian vessels were all fishing (Table A1.1).

Table A1.1: Recorded catch (t) of species/species-group, which probably includes bluenose, for foreign fleets in calendar years 1972 to 1977.

	1972	1973	1974	1975	1976	1977
Japanese trawl (butterfishes)	0	0	2 343	9 085	15 580	11 135
Japanese line (blue warehou)	0	0	0	111	618	821
Korean trawl (other species)	0	0	0	0	0	9 692
Korean line (other species)	0	0	0	0	0	655
Russian trawl (warehou)	6 500	6 000	7 400	200	2200	6 300

Early catches of warehou by foreign fleets are documented in a number of FARDs (Livingston 1988, Bagley & Hurst 1997, Bagley et al. 1998). Tabulated catches by the old fishery management areas C–H were used in calculations to extract approximate bluenose catches from the total "warehou" catches (which most likely include bluenose).

Methods

The catch history is assumed to start in 1936 on the basis that some of the HPB landings include BNS. HPB landings are assumed to be 1500 t from 1936 to 1947 except from 1940–1945 when they are taken to be 1000 t (because of reduced effort during the war years).

BNS catches from 1936 to 1970 are calculated by applying a percentage (see Table A1.2) to the recorded and assumed HPB landings. From 1971 to 1977, the 1936–1970 percentage is applied to the HPB landings and estimated foreign catches are added on (see below). From 1978 to 1986 the BNS foreign/chartered catch estimates are added to the recorded domestic landings and a trending proportion of HPB landings. After 1986, the recorded landings in the 2010 Plenary report are used.

Missing foreign/chartered reported catch from April 1980-March 1981 is estimated by linear interpolation of the average monthly catches in the 1980 and 1982 April-March fishing years. The HPB, foreign/chartered, and domestic catches are converted to October-September fishing years by assuming equal monthly catches in the recorded time periods. The foreign species-group catches are not adjusted from calendar year to fishing year (e.g., 1976 is taken to be 1975–76).

Table A1.2: The components of the catch history for the three time periods: a percentage of HPB landings; a percentage of foreign recorded catches under species group/misnomer; the recorded foreign/chartered BNS catches; and the QMS BNS landings. The total catch in each period is derived from totaling across components within the columns.

	1936–1970	1971–1977	1978–1986
HPB % (low, base, high)	0, 5, 10	0, 5, 10	0, 5 down to 0 (1984), 10 down to 0 (1984)
Foreign % (low, base, high; Paul & Robertson 1979, Livingston 1988)	NA	Japanese line (blue warehou): 100, 100, 100; Korean line (others):0, 0 ,0; Japanese trawl (warehou): see Table A1.4; Russian trawl (warehou) and Korean trawl (others): see Table A1.5.	NA
Foreign BNS (Horn, 1988)	NA	NA	April 1978 to September 1986
QMS BNS	NA	NA	1981 to 1986

The calculations to estimate the foreign catch of bluenose from 1971 to 1977 are complex as they depend on area, year, and country specific calculations and assumptions. For the April-March fishing years 1978–79, 1979–80, 1981–82 and 1982–83 the percentage of bluenose in the total catch of bluenose and warehou was calculated directly from available data for the old fishery management areas C–H. For the 1983–84 to 1985–86 fishing years this percentage was calculated assuming that the total warehou catch contained 10% of white warehou in those years (the catch data on white warehou are quite limited – see Bagley & Hurst 1997). The figure of 10% was a rough estimate given that the median white warehou percentage across areas for the April-March fishing years 1978–79, 1979–80, 1981–82 and 1982–83 was 8%. The bluenose catch appears to have been very poorly reported in the April-March fishing years 1978–79, 1979–80, 1981–82 (see Table A1.3).

Table A1.3: The percentage of bluenose in the total catch of bluenose and warehou for the old fishery management areas C–H for fishing years with available data. The first four fishing years are April-March and the last three are October-September.

Fishing year	C	D	E	F	G	H
1978–79	0.2	0.0	0.0	0.0	0.0	1.1
1979–80	0.1	0.3	0.0	0.0	0.1	0.0
1981–82	0.0	0.1	0.0	0.2	0.9	0.0
1982–83	0.4	1.0	0.1	1.3	2.3	1.4
1983–84	0.9	0.6	0.0	0.2	10.7	0.0
1984–85	0.1	0.8	0.0	1.4	1.2	0.0
1985–86	0.3	1.3	1.5	0.6	2.7	0.0

For each area, the median percentage across the fishing years 1982–83 to 1985–86 was used as a baseline percentage; the high scenario used 1% for areas where bluenose is not often caught by trawl and 5% for areas where it is; and the low scenario assumed a percentage of zero (Table A1.4). These percentages were assumed to apply to the total Japanese warehou catches for the April-March fishing years 1975–76 to 1977–78 (Livingston 1988, Table 2). The percentages were applied to give an estimate for the Japanese trawl catch of bluenose in the October-September fishing years 1974–75 to 1976–77.

Table A1.4: For the low, high, and base scenarios, the estimated percentage of bluenose in the total catch of bluenose and warehou for each of the old fishery management areas C–H. These were applied to area-specific data available for April-March fishing years 1975–76 to 1977–78 (Livingston 1988).

Scenario	C	D	E	F	G	H
Low	0.00	0.0	0.00	0.00	0.0	0.0
Base	0.35	0.9	0.05	0.95	2.5	0.0
High	1.00	5.0	1.00	1.00	5.0	5.0

For the Russian and Korean trawl fleets, the ratio of the bluenose catch estimates to the total warehou catches in the fishing years 1975–76 to 1977–78 were calculated and rounded to 1 decimal place (Table A1.5). These were applied to the Russian catches in 1972–1977 and the Korean catch in 1977 (the 1975–76 ratio was used for calendar years 1972–1975; 1976–77 for 1976; and 1977–78 for 1977).

Table A1.5: For the low, high, and base scenarios, the calculated ratio of bluenose to total warehou catch expressed as a percentage, in the April-March fishing years 1975–76 to 1977–78. These were applied to year-specific data available for calendar years 1972–77 (Russian trawl) and 1977 (Korean trawl) (Paul & Robertson 1979).

	Low	Base	High
1975–76	0.0	0.7	1.2
1976–77	0.0	0.8	1.5
1977–78	0.0	1.0	4.0

Results

The base assumptions created a local peak in catches in the October-September fishing year 1976–77 of 1200 t compared to the known peak in catches in 2003–04 of 3100 t (see Figure 1). The alternative "low" and "high" assumptions gave catch histories with local peak values of 800 t and 2 300 t respectively (see Figure 1).

For the local peak, the Japanese line catch is the main contribution except in the high scenario (Table A1.6). For the high scenario, the Japanese line and trawl catches are both approximately 800 t and the combined trawl catches of Korea and Russia are approximately 600 t (Table A1.6).

Table A1.6: Estimated foreign catches of BNS (t) in 1976–77 under the low, high, and base scenarios.

	Low	Base	High
Japanese line	821	821	821
Japanese trawl	0	226	865
Korean trawl	0	97	388
Russian trawl	0	63	252
Total	821	1 207	2 326

APPENDIX 2: Linear modeling of mean fish length

Bluenose have been sampled by Ministry of Fisheries observers through the Scientific Observer Programme (SOP) and also through fishing industry logbook programmes.

Methods

Length frequencies for bluenose and associated station data were extracted from the relevant databases and analysed with regard to mean length. A total of 7253 records were used in the analysis; 52% were from the SOP and 48% from logbooks. There were a few records prior to the fishing year 1992–93 but these were not used. The bulk of the data are from 1992–93 to 2007–08 (Table A2.1).

Linear models were used in the analysis with mean length (at each station) as the response variable. The explanatory variables were: fishing year, month, target species, fishing method (BLL = all line methods except dahn line, DAL = dahn line, TWL = trawl methods), area (10 areas were defined), and depth (only available for 47% of the records).

The bulk of the dahn line data were in the 1990s (when there was an exploratory fishery in the Kermedec area) and in 2009–10 only trawl data are available (Table A2.1). The logbook data are, on the whole, from inshore fishing vessels in line fisheries, whereas the SOP data are mainly from larger vessels in trawl fisheries and have a broader coverage (Figure A2.1). Ten areas were defined, by eye, on the basis of the clustering of stations when aggregated across all years (Figure A2.2).

The data become rather sparse when they are partitioned according to the explanatory variables (Tables A2.2–3). In terms of areas, the most reliable signals come from the top of the North Island (the location of the main logbook programme) and the west coast South Island (SOP sampling in the hoki fishery during winter) (Tables A2.2–3).

Four models were used:

Simple: length ~ fyear + target + month + area + method
Simple+depth: length ~ fyear + target + month + area + method + depth
Seasonal: length ~ fyear + target + area + area:month + method
Temporal: length ~ area*fyear + target + method

All variables were categorical except depth which was fitted as a 3rd order polynomial. The "*" denotes a full interaction term (e.g., area*fyear = area + fyear + area:fyear). The ":" is an interaction between the terms (e.g., for area:month a coefficient is estimated for each month within each area).

Table A2.1: The total number of mean-length records used in the analysis by method and fishing year (1993 = 1992/93; BLL = bottom long line, DAL = dahn line, Trawl = midwater of bottom trawl).

	BLL	DAL	Trawl
1993	26	248	30
1994	6	62	46
1995	74	44	187
1996	194	5	266
1997	773	101	153
1998	511	165	284
1999	460	6	388
2000	364	0	397
2001	203	0	257
2002	126	0	179
2003	150	5	127
2004	253	0	148
2005	162	13	116
2006	196	11	127
2007	185	0	43
2008	97	0	11
2009	7	0	22
2010	0	0	24

Table A2.2: The total number of mean-length records used in the analysis by area and month (BttmS = bottom South Island, Ckst = Cook Strait, CrE = east Chatham Rise, CrW = west Chatham Rise, Ecni = east coast North Island, Ker = Kermadec area, OffNW = offshore north west of North Island, Tar = off Taranaki, TopN = top of North Island, Wcsi = west coast South Island).

	BttmS	Ckst	CrE	CrW	Ecni	Ker	OffNW	Tar	TopN	Wcsi
1	11	1	19	25	7	26	26	83	282	85
2	22	0	4	15	24	39	13	136	257	49
3	59	0	12	10	12	0	3	86	220	28
4	33	2	19	5	32	43	5	33	241	24
5	34	15	19	61	46	77	5	40	170	25
6	18	6	8	18	62	7	19	28	167	68
7	10	22	0	5	22	25	38	33	155	596
8	9	37	8	4	59	61	42	48	167	693
9	15	39	22	24	7	77	95	32	177	166
10	100	0	20	80	60	4	30	38	186	9
11	44	0	14	47	117	44	50	61	216	17
12	11	0	8	40	57	56	24	59	274	15

Table A2.3: The total number of mean-length records used in the analysis by area and fishing year (1993 = 1992/93; BttmS = bottom South Island, Ckst = Cook Strait, CrE = east Chatham Rise, CrW = west Chatham Rise, Ecni = east coast North Island, Ker = Kermadec area, OffNW = offshore north west of North Island, Tar = off Taranaki, TopN = top of North Island, Wcsi = west coast South Island).

	BttmS	Ckst	CrE	CrW	Ecni	Ker	OffNW	Tar	TopN	Wcsi
1993	9	0	15	4	16	131	121	0	0	8
1994	5	0	1	6	12	0	66	0	0	24
1995	1	0	2	5	65	44	0	61	13	114
1996	26	1	2	34	13	5	8	123	56	197
1997	0	0	8	24	58	101	18	142	566	110
1998	26	4	8	48	20	174	15	73	413	179
1999	32	25	5	57	106	4	18	63	346	198
2000	43	12	4	35	70	0	11	68	300	218
2001	46	21	18	45	34	0	0	3	182	111
2002	42	8	3	28	33	0	5	8	103	75
2003	26	7	20	10	11	0	29	12	87	80
2004	21	4	14	12	1	0	12	64	154	119
2005	18	10	12	4	8	0	2	34	84	119
2006	42	18	5	5	25	0	36	25	69	109
2007	20	2	3	1	17	0	3	1	110	71
2008	6	7	25	9	5	0	0	0	22	35
2009	1	3	1	2	7	0	0	0	7	8
2010	2	0	7	5	4	0	6	0	0	0

Results

The models had adjusted R^2 ranging from 30–34%, with the simple+depth model having the largest R^2. On an AIC basis, the interactions were significant (with AICs for Simple, Seasonal, Temporal being respectively: 51 366, 51 213, 51 134).

The Simple model had similar predicted mean lengths over all years (Figure A2.3) and months (Figure A2.4). Mean lengths were different depending on fishing method with dahn line catching the largest fish, then other line methods, and trawl the smallest (Figure A2.5). There were strong target-species and area effects (Figures A2.6–7) with larger bluenose associated with deeper-water species (Figure A2.6). When depth was included in the simple model, it was significant and again showed larger fish being caught deeper (Figure A2.8). There is a question as to whether there are real area effects or whether area and depth are confounded. However, there is a good spread of depths within each area (Figure A2.9) so confounding should not be a problem. Indeed, the area effects are very similar whether depth is included in the model or not (Figure A2.10).

The Seasonal model results are less conclusive than those of the simple model because of the sparse data in some areas and months. The two most interesting trends are a lack of large fish at the bottom of the South Island from January to April, with the top of the North Island having a peak in the mean length of bluenose in April (Figure A2.11).

The Temporal model results also suffer from a lack of data. There may have been changes in the mean length of bluenose over the years for the top of the North Island, with a reduction in the length of fish (Figure A2.12). However, there appears to have been little change in the mean length for the west coast South Island (Figure A2.12).

The analysis results have few stock structure implications as such. However, they do suggest that there is a size-structuring of fish in the EEZ – with some areas showing consistently smaller or larger fish than others. There are also indications of seasonal changes in availability, which is suggestive of seasonal migrations (the lack of large fish at the bottom of the South Island in January to April ties in well with the annual spawning cycle of the fish; as does the increase in the size of fish in January to April at the top of the North Island). The different time-trends in the mean length of bluenose on the west coast South Island and the top of the North Island is weakly suggestive of different stocks.

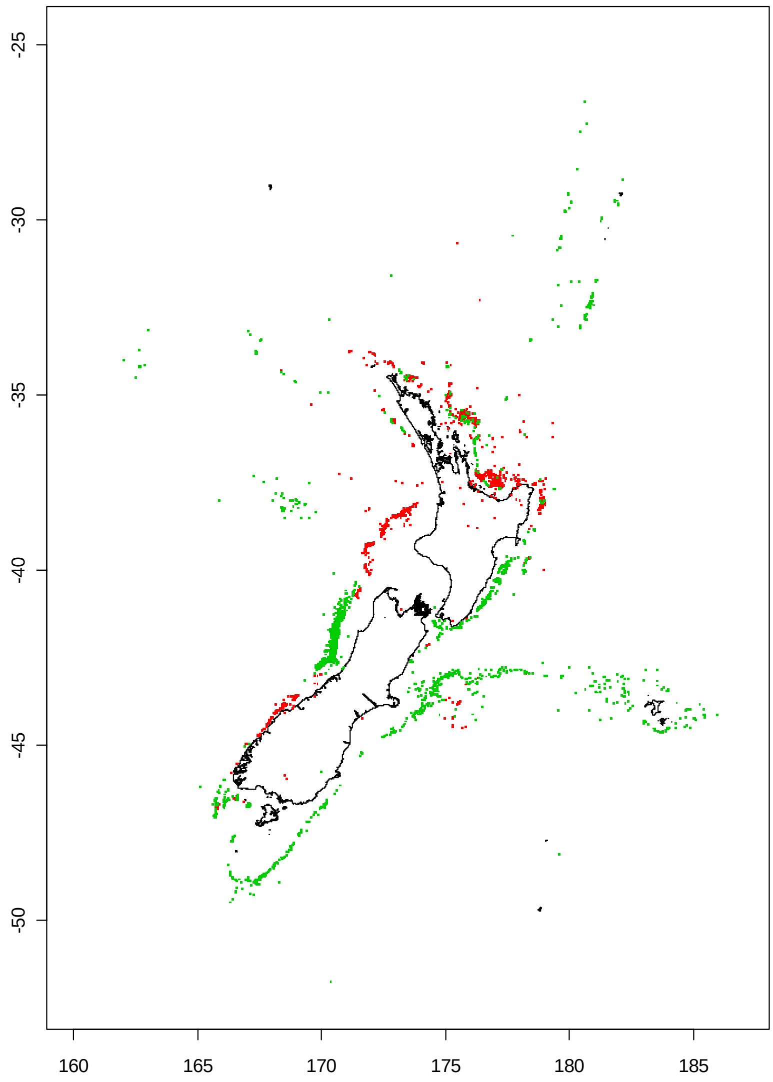

Figure A2.1. Station record locations for bluenose length samples (SOP in green, logbook programmes in red).

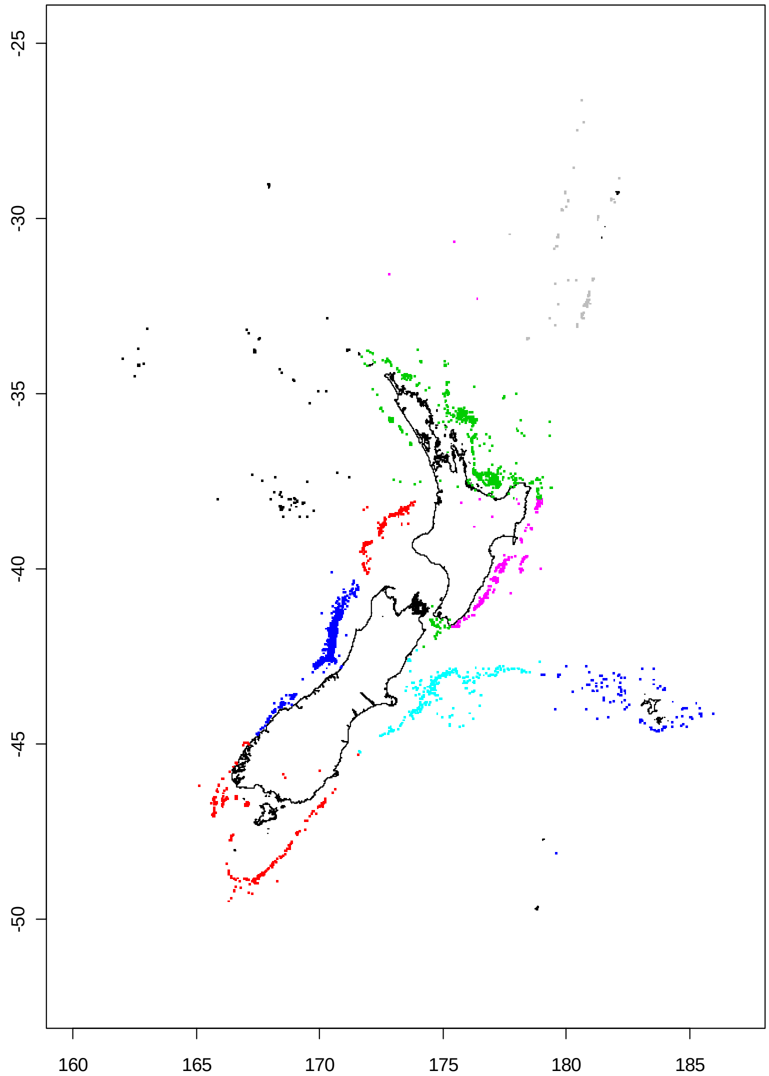

Figure A2.2. Station record locations for bluenose length samples colour-coded to show the 10 areas defined for the analysis (BttmS: red, Ckst: green, CrE: blue, CrW: turquoise, Ecni: pink, Ker: grey, OffNW: black, Tar: red, TopN: green, Wcsi: blue).

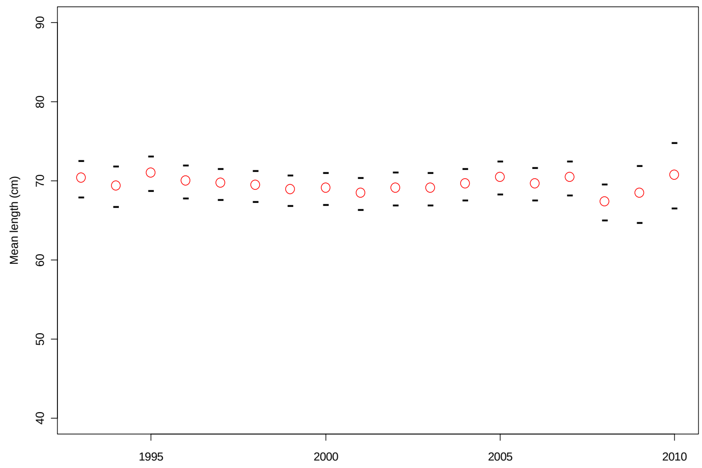

Figure A2.3. Simple model: predicted mean length for each fishing year with 95% confidence intervals.

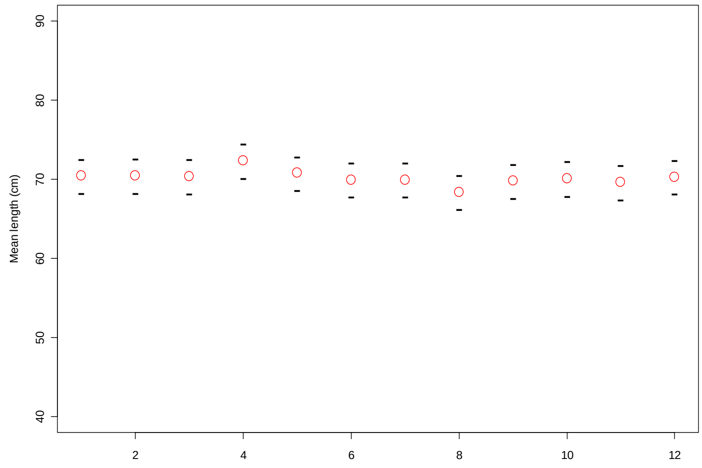

Figure A2.4. Simple model: predicted mean length for each month with 95% confidence intervals.

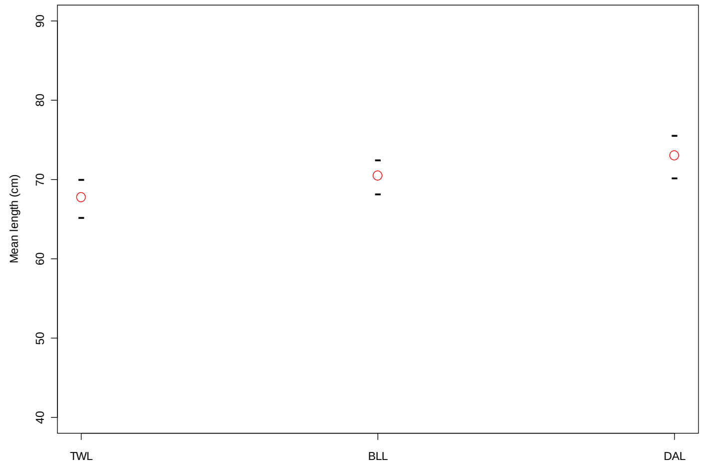

Figure A2.5. Simple model: predicted mean length for each fishing method with 95% confidence intervals.

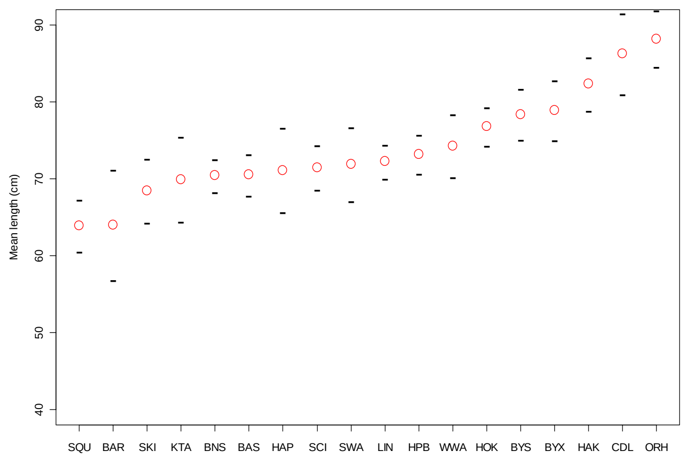

Figure A2.6. Simple model: predicted mean length of bluenose for each target species with 95% confidence intervals.

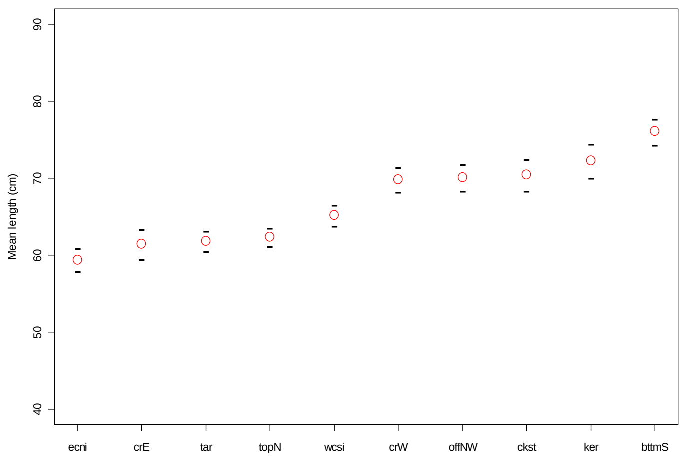

Figure A2.7. Simple model: predicted mean length for each area with 95% confidence intervals.

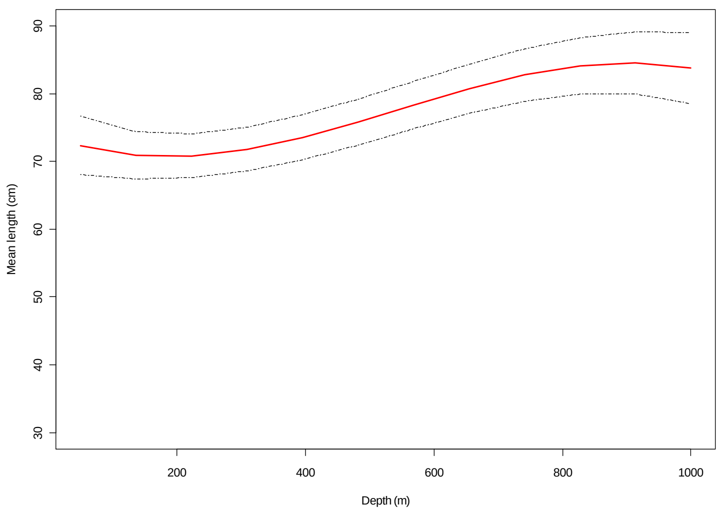

Figure A2.8. Simple model: predicted mean length at depth with 95% confidence intervals.

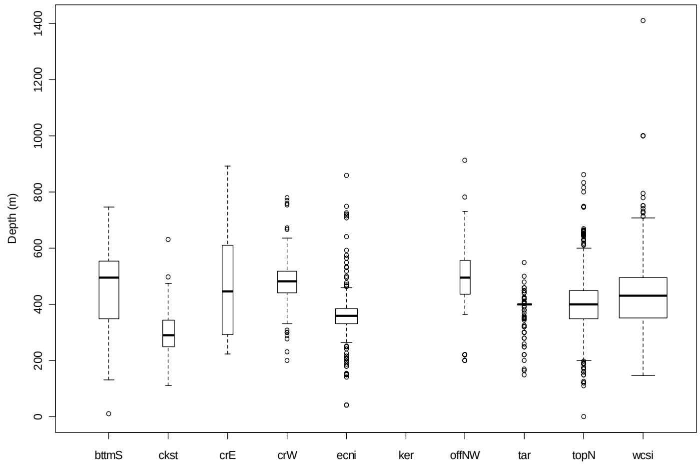

Figure A2.9. Box and whiskers plot of depth within area (the box covers 75% of the distribution; the median is marked by the horizontal line within the box).

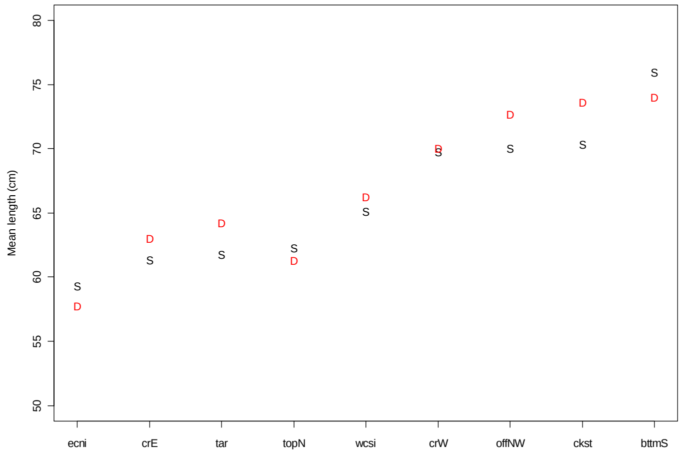

Figure A2.10. Simple model: predicted mean length for each area with (D) and without (S) depth in the model.

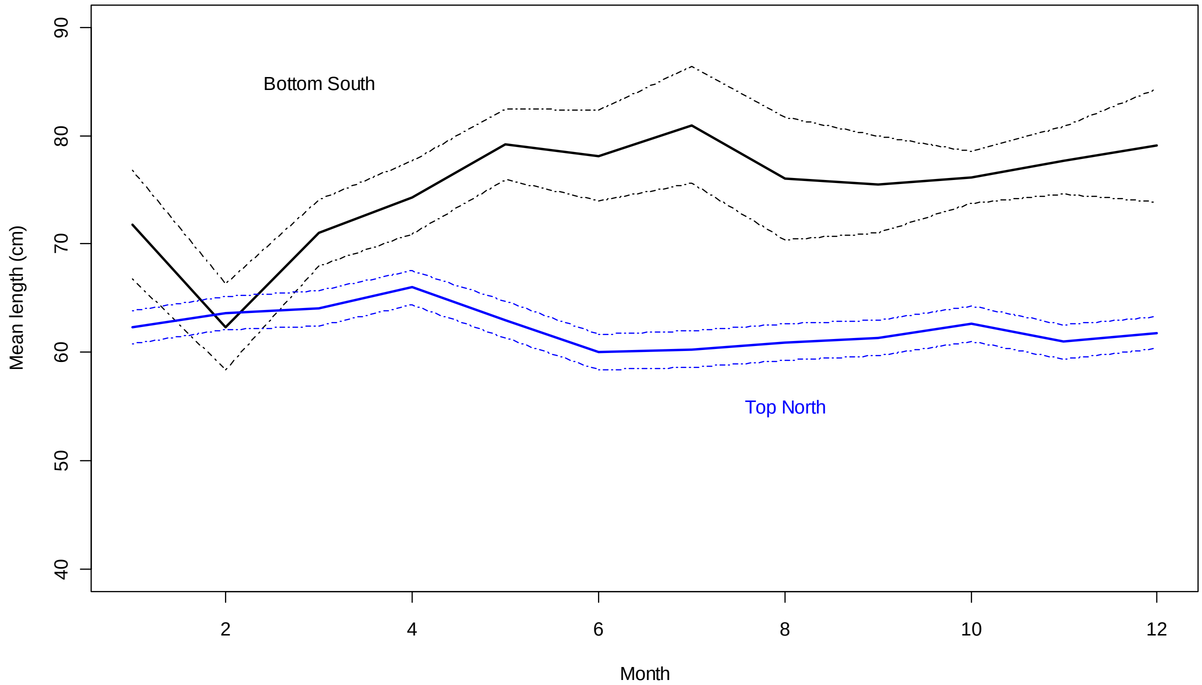

Figure A2.11. Seasonal model: predicted mean length, with 95% confidence intervals, for BttmS and TopN in each month.

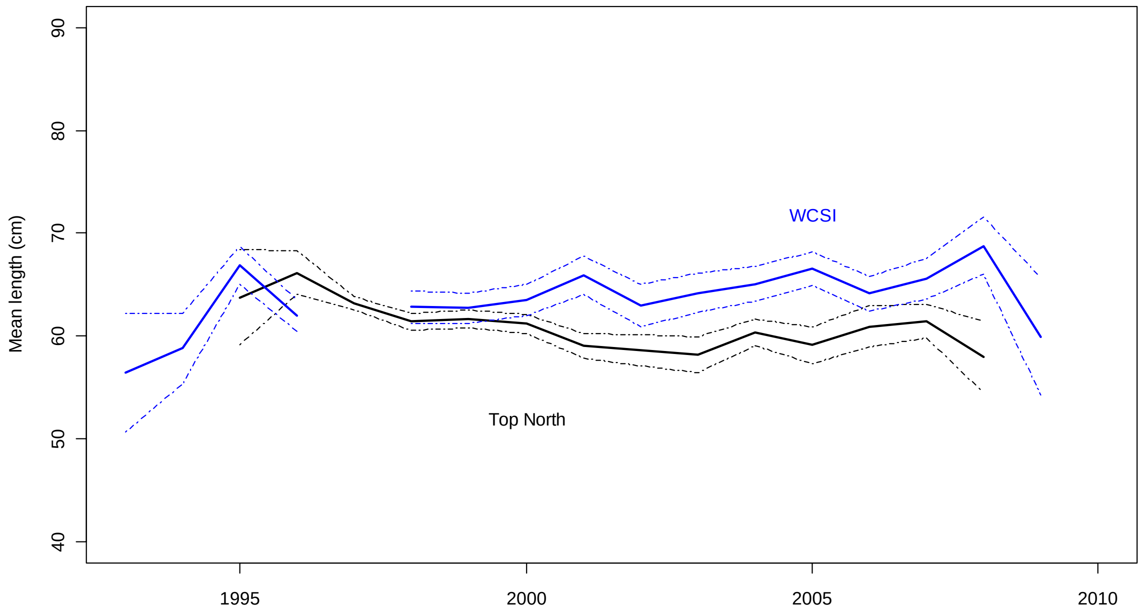

Figure A2.12. Temporal model: predicted mean length, with 95% confidence intervals, for Wcsi and TopN in each fishing year.

Appendix 3: Data and research relevant to stock structure

Spatial distribution

Hyperoglyphe antarctica is widely distributed in the southern oceans, recorded from New Zealand, southern Australia, Tasmania, New Caledonia, South Africa and Tristan da Cunha (McDowall, 1982). In New Zealand, it is present throughout the entire EEZ but most catches occur off the north and east coasts of the North Island.

Depth distribution

The depth distribution of bluenose extends from near-surface waters to about 1200 m (Figure A3.1). Research trawl surveys record the main depth range as 250–750 m, with a peak at 300–400 m, although they regularly occur to about 800 m (Anderson et al. 1998).

The depth distribution of bluenose changes with size, with small juveniles known to occur at the surface under floating objects (Last et al. 1993, Duffy et al. 2000). Larger juveniles probably live in coastal and oceanic pelagic waters for one or two years. Fish 40–70 cm in length are caught between 200 m and 600 m, while larger fish, particularly those larger than 80 cm, are more often caught deeper than 600 m.

Abundance

There are no fishery independent abundance indices for bluenose. CPUE series for the two major fisheries (bottom longline and trawl) have been updated in 2011 for all stocks (Starr & Kendrick in prep.). Figure A3.2 shows the relative CPUE time series for bottom longline between the 1990 and 2010 fishing years, for all stocks. The general trend one can observe on this figure is a relatively constant CPUE in the early years (1990 until the early 2000s) followed by a decline until 2007 and a slowing down in the decrease in the most recent years.

The peak in BNS 3 around 2000 tends to make the analysis of the recent years difficult. Figure A3.3 is the same as Figure A3.2 but without BNS 3. It confirms the initial analysis that there is a concurrent declining trend in standardised CPUE over areas for 5–6 years, around the mid 2000s, the decline reaching a plateau in the last years.

Starr & Kendrick (in prep.) have analysed the relative standardised CPUE indices for the trawl fishery by doing two types of amalgamation: tow-by-tow (OR) and trip stratum (TS) (trip, statistical area, method of capture and target species). For the first years of the trawl OR time series (Figure A3.4) only the trawl CPUE index for BNS 2 is available and is quite variable. Similarly to the bottom longline CPUE time series, the trawl (OR) CPUE indices for BNS 2, BNS 3 and the two stocks combined show a plateau in the middle of the time series, a decline in the first part of the 2000s and a lower plateau in the most recent years.

The trawl TS CPUE time series also starts with data for BNS 2 only which shows a general increase until 1994, followed by a steep decline over a year (Figure A3.5). Since 1995, the time series is relatively constant but with a slight declining trend, particularly over the last years. The BNS 3 time series starts in 1996 and shows a general declining trend over the years (Figure A3.5).

When all time series are taken into consideration (i.e. bottom longline and trawl), it is possible to observe concurrent declining trends in standardised CPUE over areas and gear types on the order of 40–50% for a period of 5–6 years.

Age

Over the years, more than 32 000 otoliths have been collected through the Ministry of Fisheries observer programme, market samples, trawl surveys and the SeaFIC logbook programme (Horn and Sutton 2010). Otoliths have been collected in all FMAs between 1978–79 and 2009–10 but only for some years for each FMA. Most otoliths were collected by observers except in FMA 2 where most otoliths prior to 2000–01 were from market samples. Most of the observer sampling was concentrated in FMA 7 (west coast South Island) due to the hoki target trawl fishery in which bluenose can occur as a bycatch. Of the otoliths collected, a subsample from BNS 1 and BNS 2 has been used to age bluenose and to determine whether the available data could provide more information on the spatial and temporal stock structure of bluenose in BNS 1 and BNS 2.

For BNS 1, 2414 otoliths collected between 1996–97 and 2005–06 through the SeaFIC logbook programme were used to age fish from three areas – south-east Bay of Plenty, Statistical Area 004 and Statistical Area 008 (Horn & Sutton 2010). Horn and Sutton estimated proportion-at-age distributions by year, and tried to identify patterns of strong and weak year classes within and between sampled areas (Figure A3.6). For the Bay of Plenty, while some year-classes showed some strong (e.g., 1981 in four out of five samples) or weak (e.g., 1998, only recorded in the two most recent samples) signals, others were contradictory (e.g., 1988 being both strong and weak in different samples). For Statistical Area 004, the 1979 year class could be considered to be a relatively strong year class, similarly the 1982 and 1979 year classes in Area 008. Nevertheless, there were no clear patterns of strong or weak year classes between years, either within or between sampled areas. Despite the potential existence of strong and weak year classes, the small sample size in most years and the difficulty of ageing bluenose have undoubtedly minimised the possibilities of observing such patterns. As a consequence, this analysis did not strengthen our understanding of bluenose stock structure.

For BNS 2, 1983 otoliths collected through market samples from the midwater trawl fishery on Palliser Bank from April 1984 to November 1986 were analysed for the Northern Inshore Working Group (Horn, pers. comm.) (Figure A3.7). Horn observed important temporal differences between samples in the age composition but did not find any seasonal trend in age composition. Fish of all ages are present in all samples except in April 1984 when old fish are not common and in November 1985 and 1986 when young fish seem to be rare.

Maturity and spawning
Previous analysis of gonad maturity stage proportions for BNS 1, BNS 7 and BNS 8 concluded that spawning probably extends from January to April (Horn & Massey 1989). Baelde (1996) appears to find a similar spawning time for Tasmania and indicates that there is considered to be a single stock in southern Australia.

For this assessment, macroscopic gonad stage data for females from observer sampling and for males and females from logbook data were analysed. Data were collected between 1986 and 2010 over the six QMA areas (BNS 1, BNS 2, BNS 3, BNS 7, BNS 8 and BNS 10) using the standard 5-stage scale:

- stage 1: immature/resting,
- stage 2: maturing,
- stage 3: ripe/spermiated,
- stage 4: running,
- stage 5: spent.

The data were groomed to make sure fishing events were not considered twice. The observer data correspond to almost 9 500 females observed and the logbook data correspond to more than 33 000 fish.

In order to identify potential spawning grounds, a map was created for each source of data (observer data and logbook data). Only the three stages (stages 3, 4 and 5) showing evidence of spawning have been included on the maps additionally to the events reporting bluenose length data (Figure A3.8). Dots are not proportional to the number of observations but the larger dots correspond to the ripening and running stages as these are the stages which provide information on potential spawning grounds. If several fish with the same gonad stage have been identified in one fishing event, there is only one dot on the map. If several stages have been identified during a fishing event, a dot for each stage is plotted irrespective of the number of observations per gonad stage.

On the left panel of Figure A3.8 it is possible to see that the data from the observer programme are quite patchy but an extensive area is covered, including the Kermadec area. The latter is due to some experimental fishing occurring in the mid 1990s mainly targeting hapuku and bass. Ripening and running females have been observed along all the coasts of New Zealand and there is no area standing out as a potential spawning ground. The right panel of the same figure (data from the logbook programme) shows more concentrated data along the west coast and the north coast of New Zealand. Similarly, there is no distinctive area that can be identified as a specific spawning ground. The relatively low number of observations on the east coast can be explained by the fact that there was no logbook programme for bluenose in BNS 2 and the level of participation in BNS 3 was low. Without any clear spawning grounds identified, it is difficult to conclude whether there is a single bluenose stock or multiple stocks.

In addition to a spatial analysis, a temporal analysis was conducted. Gonad stages were plotted by month for each source of data (Figure A3.9 for the observer data and Figure A3.10 for the logbook programme data). For the observer data (n = 9 170), only female maturity stages are available but for the logbook programme, gonad stages for both sexes combined (n = 29 780) have been plotted as well as for males (n = 17 465) and females (n = 12 123) separately. The same colours as on Figure A3.8 have been used for the later stages (orange for stage 3 (f3), red for stage 4 (f4) and purple for stage 5 (f5)) and green and blue correspond to stage 1 (f1) and stage 2 (f2) respectively. The thickness of the columns is proportional to the number of observations for a given month over the 12 months. For example in Figure A3.9, July, August and September are the three months with most of the observations. Within a given month, the length of a coloured bar is proportional to the number of observations for a given stage. For example in Figure A3.9, most of females observed were considered as immature or resting (stage 1).

Figure A3.9 does not show a clear seasonal pattern in terms of spawning season, although there does appear to be more stage 3 and 4 fish in December. During the other months, stage 3 and 4 fish are very infrequent and the proportion of stage 5 fish increases relatively slowly over the months. Most of the fluctuation is due to immature/resting (stage 1) and maturing (stage 2) fish. The proportion of spent fish (stage 5) is relatively high in November but the proportion of stage 4 fish in the two previous months is almost zero. This appears to be inconsistent.

Contrary to Figure A3.9, there is a clear seasonal pattern in Figure A3.10. It is possible to observe an increase in the proportion of stage 3 and 4 fish starting in December and reaching a peak in March for stage 3 and in April for stage 4. The highest proportion of stage 5 fish is in April with a slow decrease in the following months. This pattern is similar for both sexes combined and for males and females separately. This clear pattern confirms the results previously found (Horn & Massey 1989) that the spawning season for bluenose in New Zealand waters is probably spread between January and April.

In order to have a better understanding of the spatial and seasonal character of the spawning of bluenose, the information from Figures A3.8, A3.9 and A3.10 have been combined and the maturity stages by month and QMA are plotted for both the observer data and the logbook data in Figures A3.11 and A3.12. It is important to note that there are no data in the observer dataset for March in BNS 1 or BNS 10, or for the months January to April or November to December for BNS 7. There are also some months of sampling missing in the logbook programme dataset. May is missing in BNS 2 and February and April to June in BNS 3. There are a number of months of data missing for BNS 3 but there is only a small amount of data collected in this QMA (214 observations out of 26 609, or less than 1% of the total logbook programme data).

As in Figure A3.9, there is no clear seasonal pattern in spawning in Figure A3.11. Most of the information observed in Figure A3.9 comes from the signal in BNS 10 (Figure A3.11), which corresponds to approximately 20% of the data coming from the observer dataset. But as BNS 10 only corresponds to 20% of the latter dataset, it is hard to conclude that BNS 10 could be a specific spawning area, despite the fact that there is a non negligible proportion of females with gonads in stage 3 and 4.

Figure A3.12 suggests that most of the signal observed in Figure A3.10 comes from BNS 1 as almost 70% of the logbook data have been collected in this area. But the trends observed in BNS 2 and BNS 8 are quite similar to the pattern observed in BNS 1, with an increase in the proportion of stages 3 and 4 in the first months of the calendar year followed by a decline until the beginning of the second part of the year. BNS 7 shows a slightly different pattern with an earlier peak of stages 3 and 4 – January – with a decline in the first months of the year, and not from the middle of the year. Information collected in BNS 3 can barely be analysed due to the low number of records and the fact that there are no data for four months of the year (especially as given two of these are during the supposed spawning season) and most of the data were collected during the second half of the calendar year.

Tagging data

In late 1987, 1971 bluenose were tagged at six commercial fishing grounds between Gisborne and Cape Palliser (BNS 2) (Horn 2003). Over the eight and a half following years, forty four tagged bluenose were recaptured for which the tagging and recapture sites were known (Table A3.1). Of these 44 fish, 22 were recaptured within the first two months, 15 were recaptured between two and twelve months after being tagged, 3 during the second year and 4 fish were finally recaptured after more than two years at liberty (after two years and two months, two years and eight months, eight years and two months and eight years and four months respectively). Most of the fish were recaptured in the same fishing ground in which they were tagged but four of them covered extensive distances, over 450 km, with movements to both the north and the south of the tagging area.

Table A3.1: Movements of bluenose obtained by tag returns. Data grouped by time at liberty. Locations indicate the release and recapture grounds. Values in parentheses indicate numbers of fish and, in the “>24 months” category, the time between release and recapture (from Horn 2003).

Time at liberty	No.	Movements
0-2 months	22	Palliser to Palliser (4)
		Paoanui to Paoanui (18)
2-12 months	15	Palliser to Palliser (9)
		Paoanui to Paoanui (1)
		Madden to Madden (1)
		Madden to Motukura (1)
		Motukura to Madden (1)
		Madden to White Island (1)
		Paoanui to Conway Rise (1)
12-24 months	3	Palliser to Palliser (2)
		Tuaheni to Tuaheni (1)
> 24 months	4	Palliser to Palliser (1, 2.2 years)
		Motukura to Mayor Island (1, 2.8 years)
		Madden to North Cape (1, 8.2 years)
		Tuaheni to Tuaheni (1, 8.4 years)

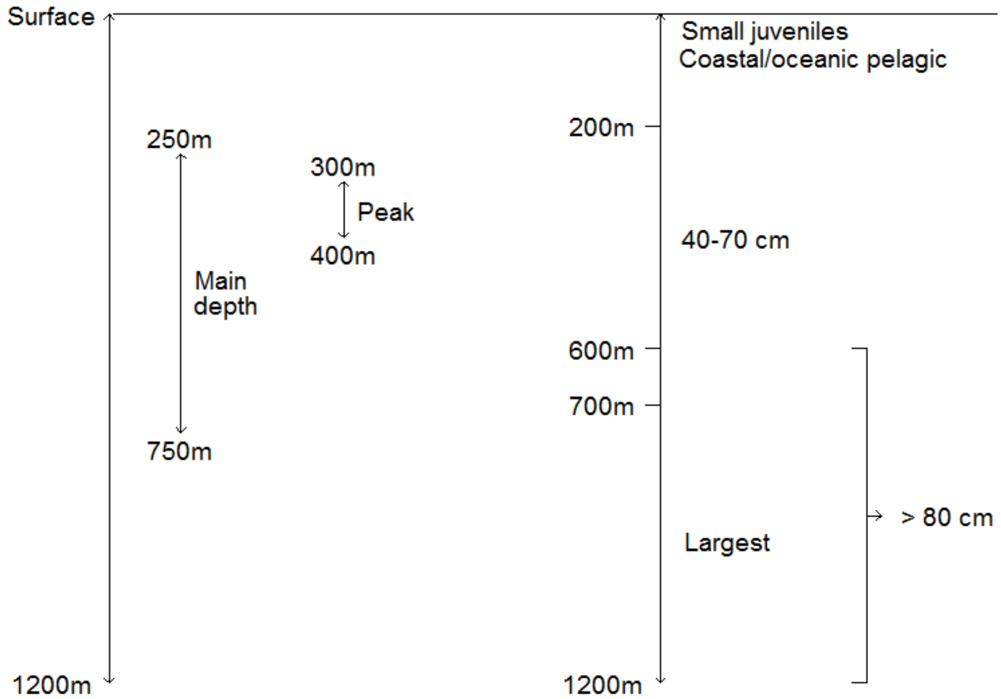

Figure A3.1: Schema of the depth distribution of bluenose in New Zealander waters. The left part corresponds to the fished population. The right part corresponds to the whole population.

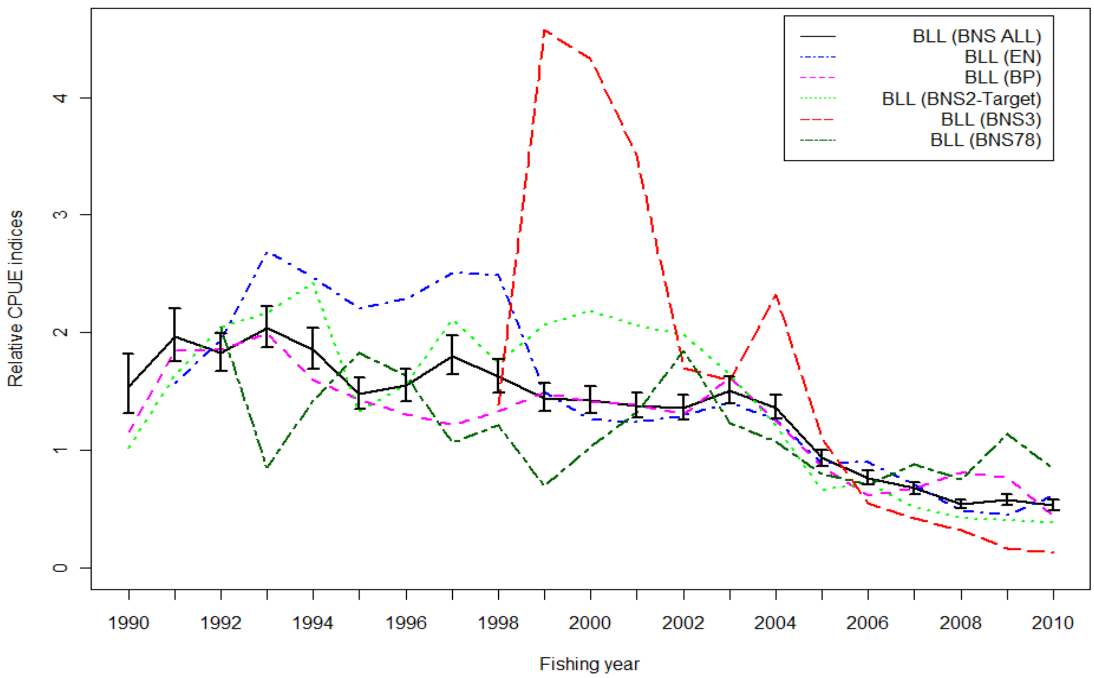

Figure A3.2: Bluenose bottom longline standardised CPUE indices. Each series is scaled so that the geometric mean is equal to 1.0 from 1997–98 to 2009–10. Vertical bars: lower and upper boundaries of the 95% confidence interval for the CPUE all stocks combined.

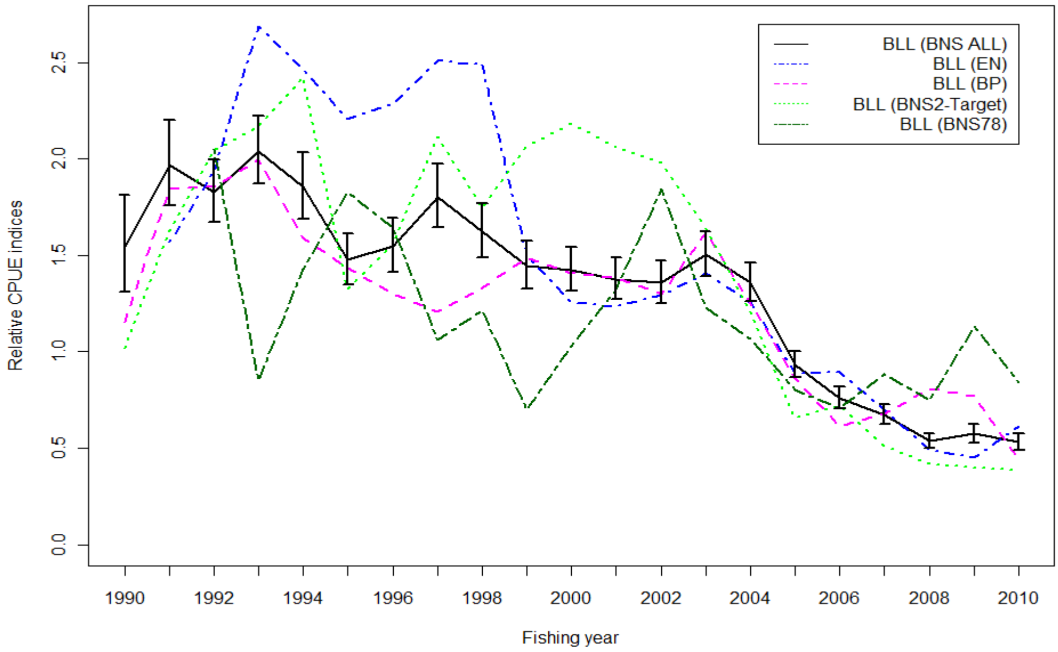

Figure A3.3: Bluenose bottom longline standardised CPUE indices, excluding BNS 3. Each series is scaled so that the geometric mean is equal to 1.0 from 1997–98 to 2009–10. Vertical bars: lower and upper boundaries of the 95% confidence interval for the CPUE combined.

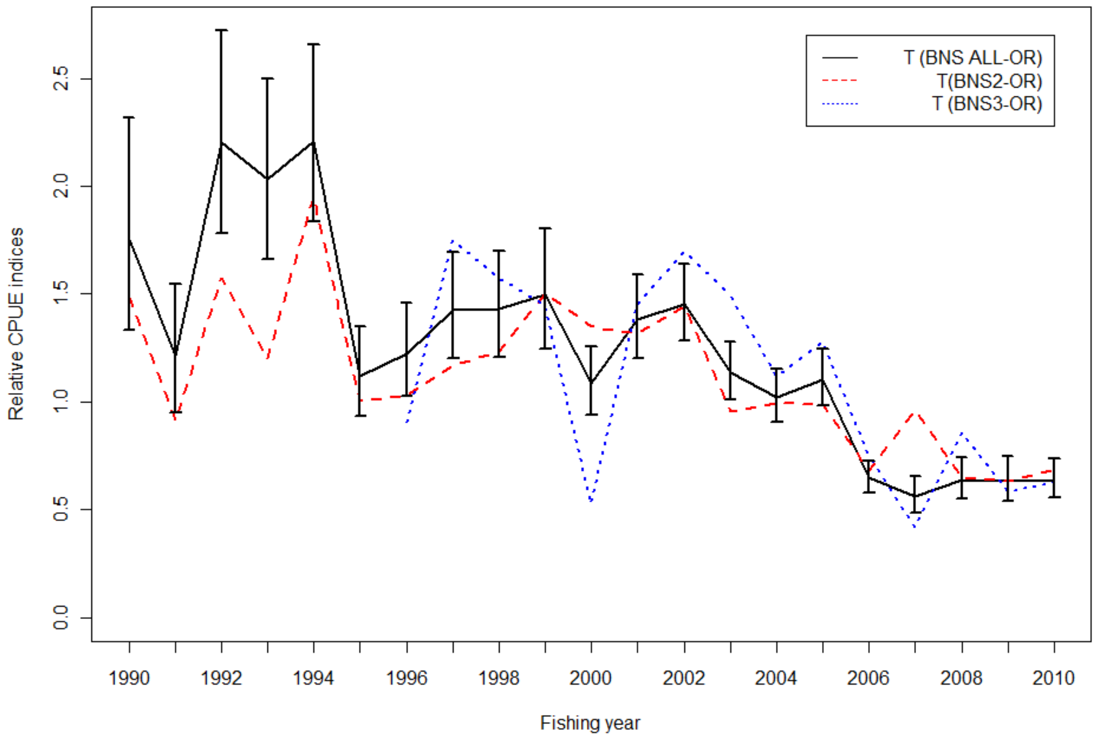

Figure A3.4: Bluenose trawl (original tow-by-tow amalgamation) standardised CPUE indices. Each series is scaled so that the geometric mean is equal to 1.0 from 1995–96 to 2009–10. Vertical bars: lower and upper boundaries of the 95% confidence interval for the CPUE combined.

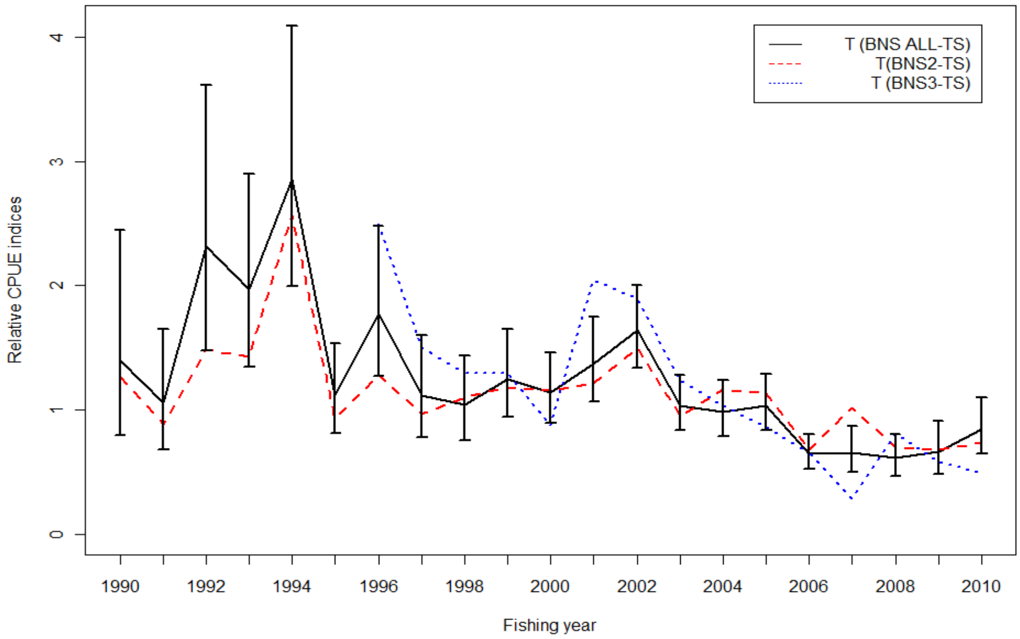

Figure A3.5: Bluenose trawl (trip stratum amalgamation) standardised CPUE indices. Each series is scaled so that the geometric mean is equal to 1.0 from 1995–96 to 2009–10. Vertical bars: lower and upper boundaries of the 95% confidence interval for the CPUE combined.

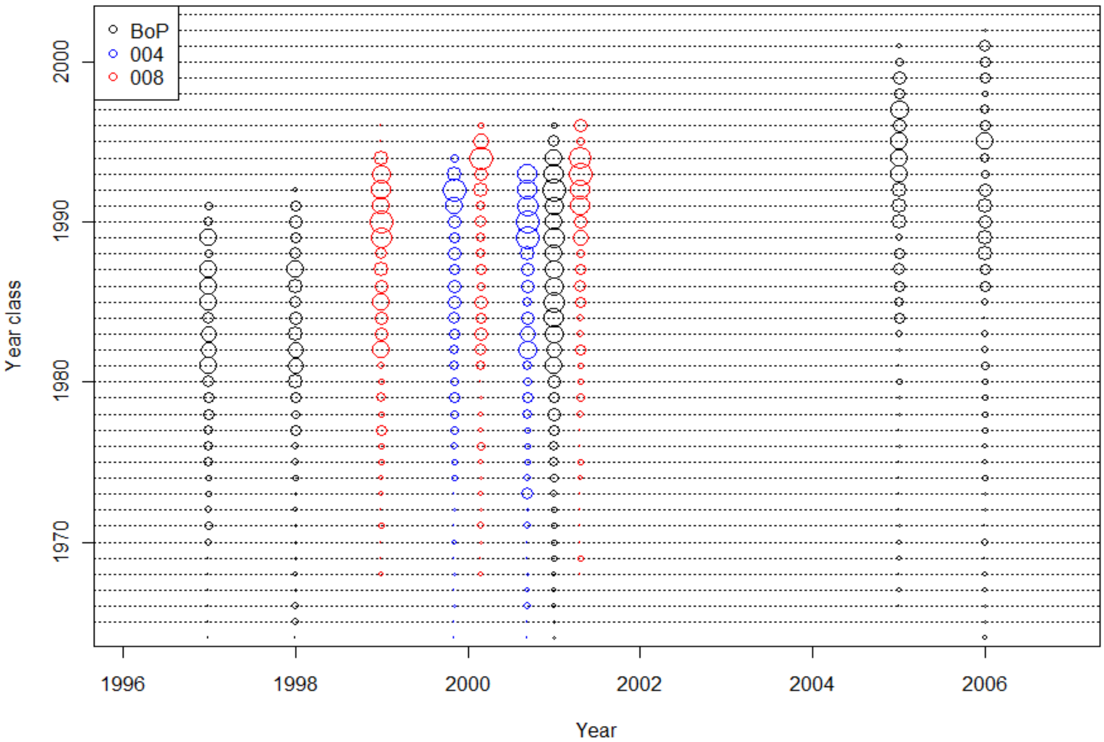

Figure A3.6: Age frequency distribution (sex combined) by fishing year for the south-eastern Bay of Plenty, Statistical Area 004 and Statisitical Area 008 between 1997and 2006. Black circles: Bay of Plenty, blue circles: Statistical Area 004, red circles: Statisical Area 008.

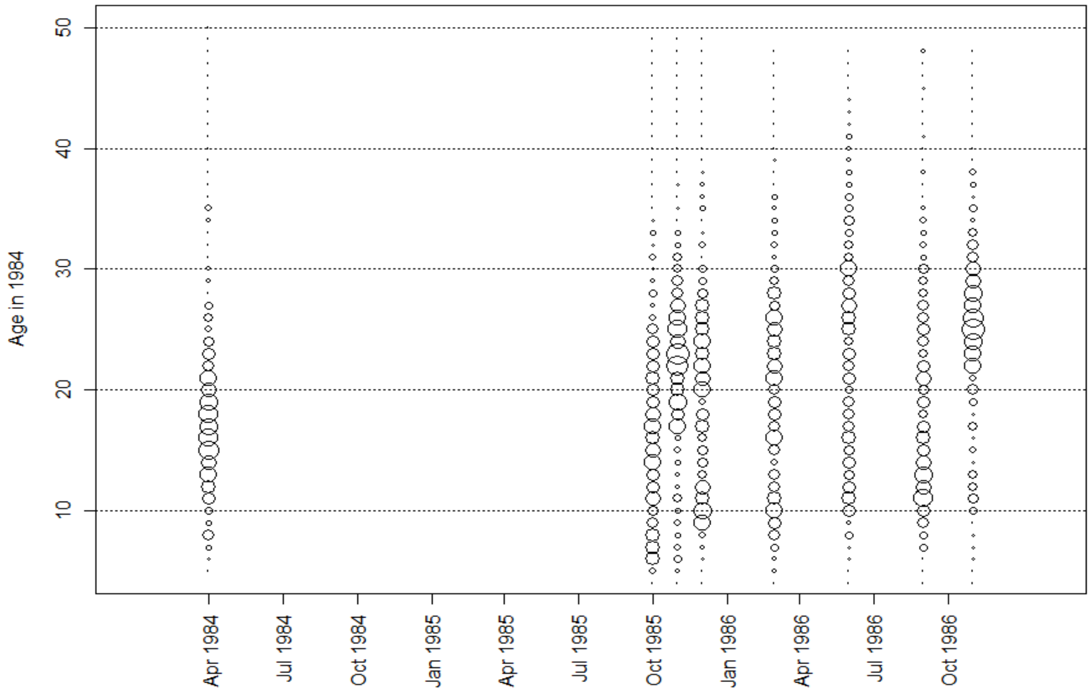

Figure A3.7: Percentage age frequency (sex combined) for Palliser Bank in months sampled between 1984 and 1986.

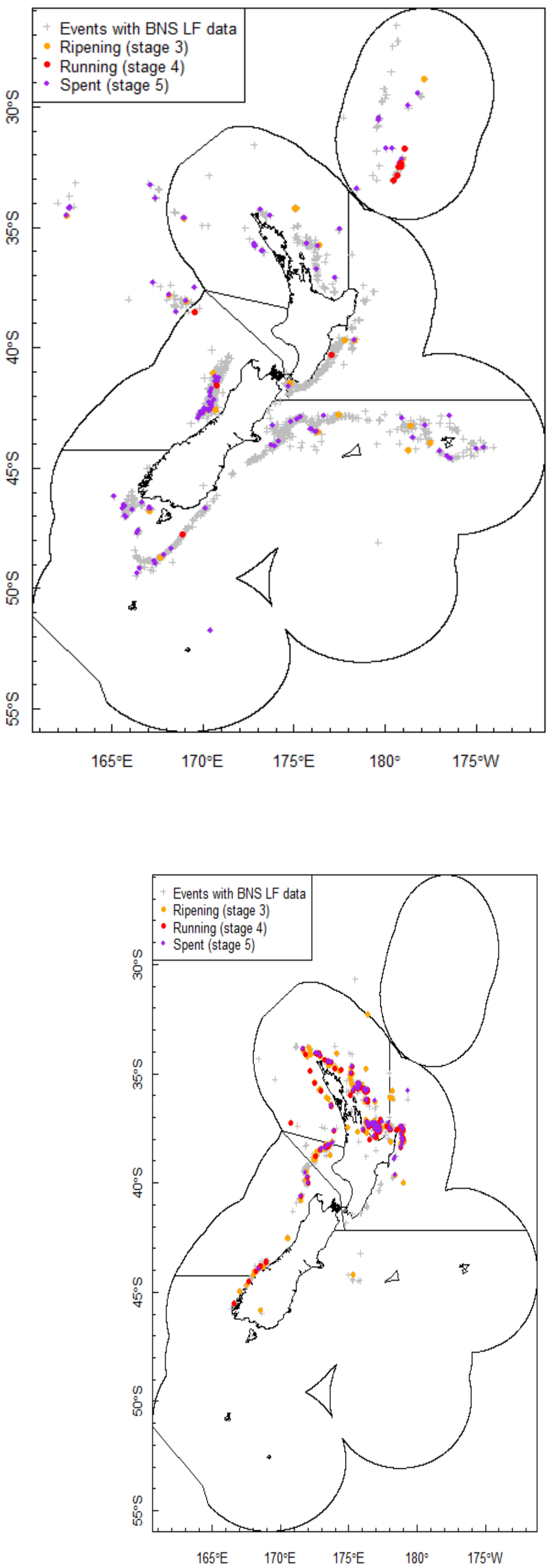

Figure A3.8: Location of spawning fish. Left panel: observer data for spawning females. Right panel: logbook data for spawning fish (males and females). Grey crosses: events with BNS length data, orange dots: fish with gonads in stage 3, red dots: fish with gonads in stage 4, purple dots: fish with gonads in stage 5. The size of the dots is not proportional to the number of observations.

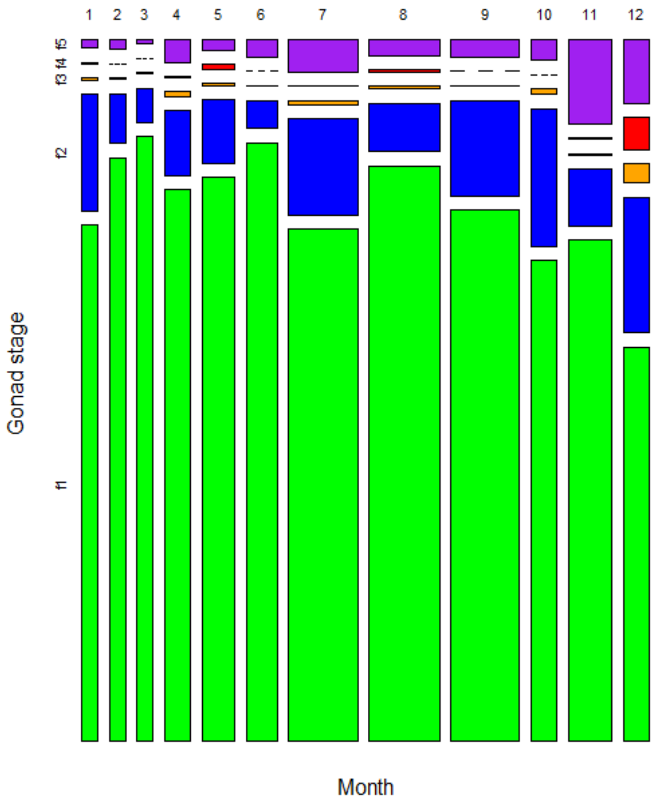

Figure A3.9: Observer data – relative proportion of female maturity stages by month. Total number of observations: 9170. Data per month have been summed over the years. F1 to F5: gonad stage 1 to gonad stage 5.

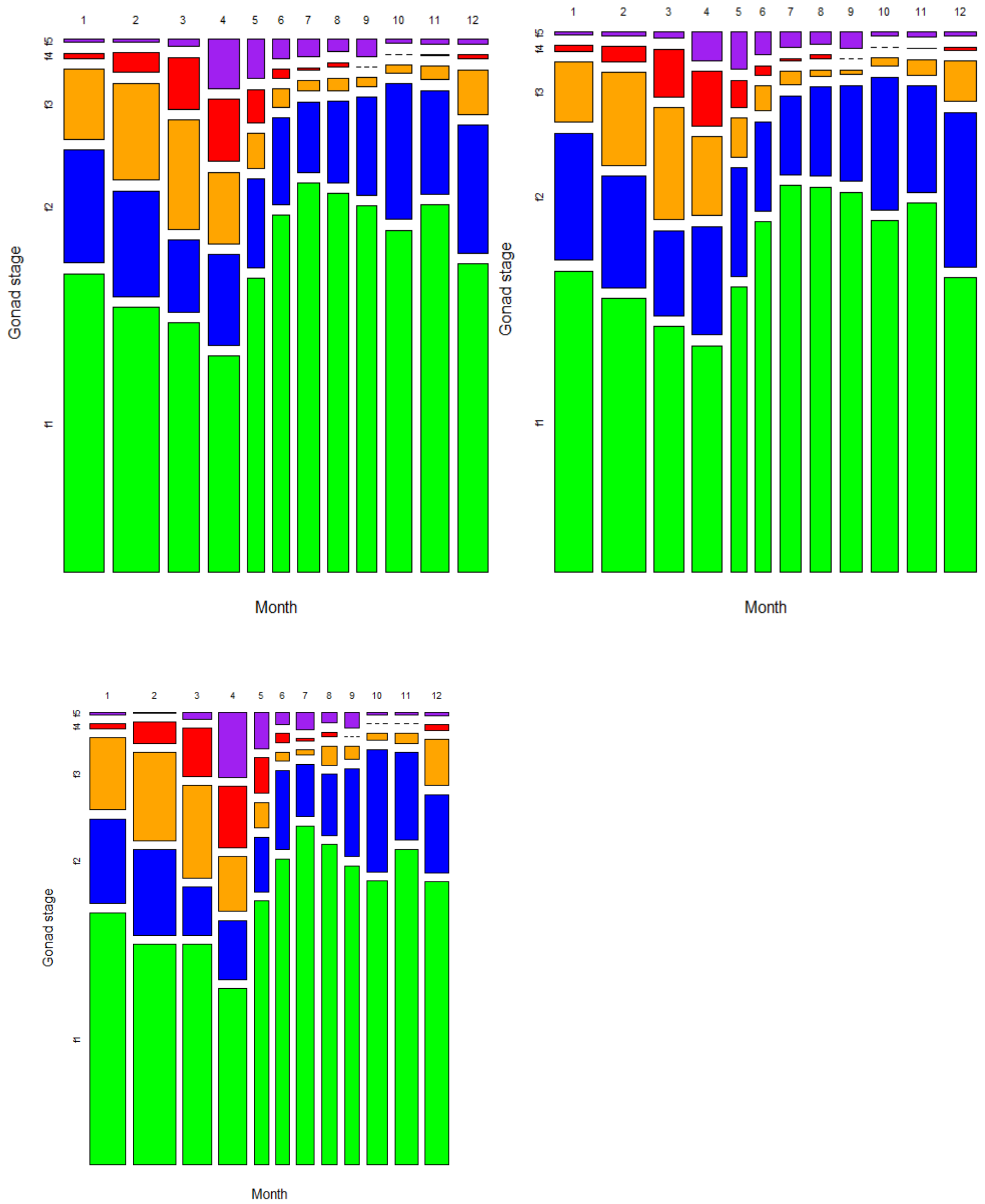

Figure A3.10: Logbook programme data. Relative proportion of fish maturity stages by month. Top left: all fish (n = 29 780), top right: males (n = 17 465), bottom left: females (n = 12 123). Data per month have been summed over the years. F1 to F5: gonad stage 1 to gonad stage 5.

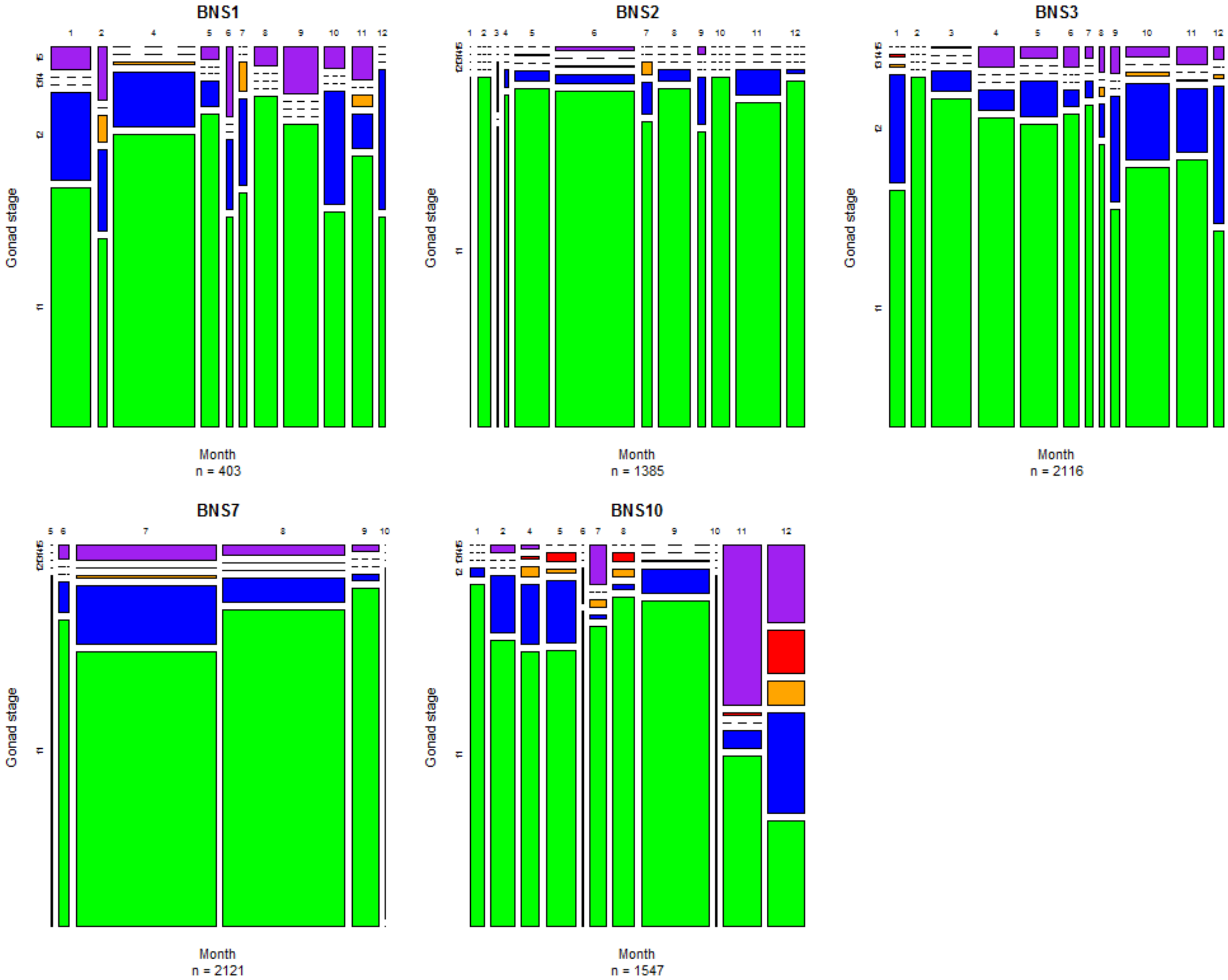

Figure A3.11: Observer data. Relative proportion of female maturity stages by month and by QMA. F1 to F5: gonad stage 1 to gonad stage 5.

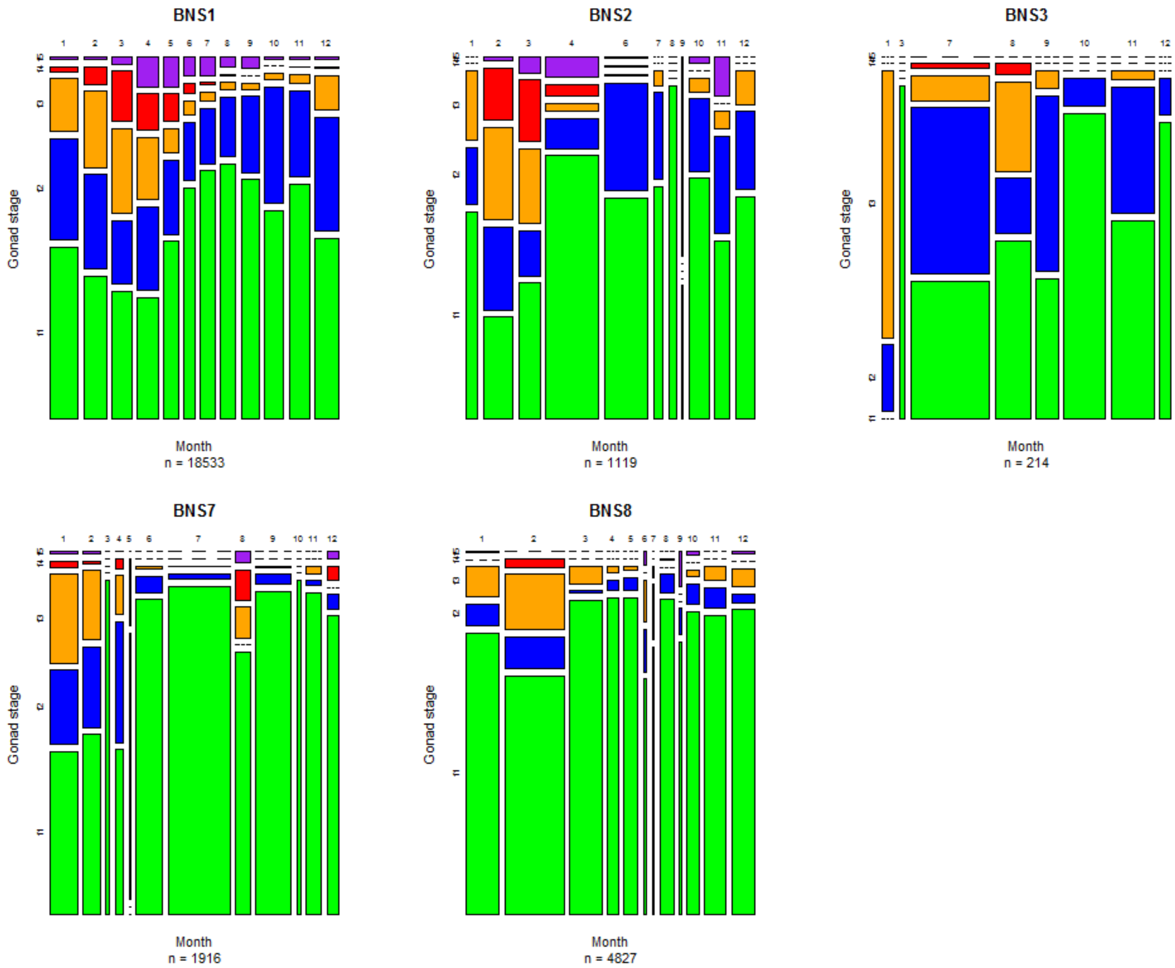

Figure A3.12: Logbook programme data. Relative proportion of fish maturity stages by month and by QMA. F1 to F5: gonad stage 1 to gonad stage 5.

Appendix 4: Fits to length and age frequencies

The following plots show the fits to the age and length frequencies for the middle run (base catch history, M=0.08, h=0.75). The length frequencies are adequately fitted given that the main modes are quite variable from year to year (Figures A4.1-2). The consistently poor fit to the left-hand edge of the length frequencies suggests that there is a strong length-selection in the fisheries. Unfortunately, the model is age structured and cannot accommodate such a sharply defined length selection (using length-based selection does not help because the model must convert the length parameters to equivalent age parameters). The age data (Figure A4.3) can be fitted better if year class strengths are estimated, but the data are unlikely to be representative of the line or trawl fisheries as a whole, and so the year class strength estimates could be misleading. The data are included to help with the estimation of selectivity.

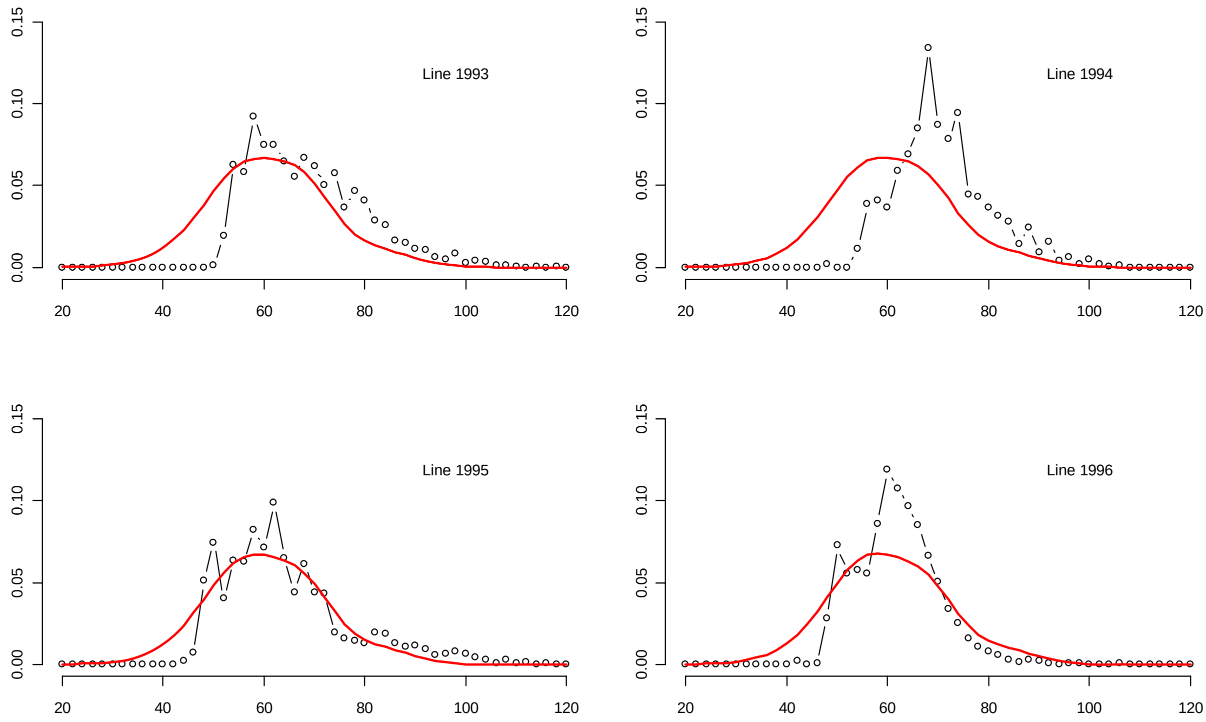

Figure A4.1: Observed and fitted length frequencies for the line fishery 1993–2008. The fitted values, shown by the continuous red line, are for the middle run. Length on the x-axis is in cm.

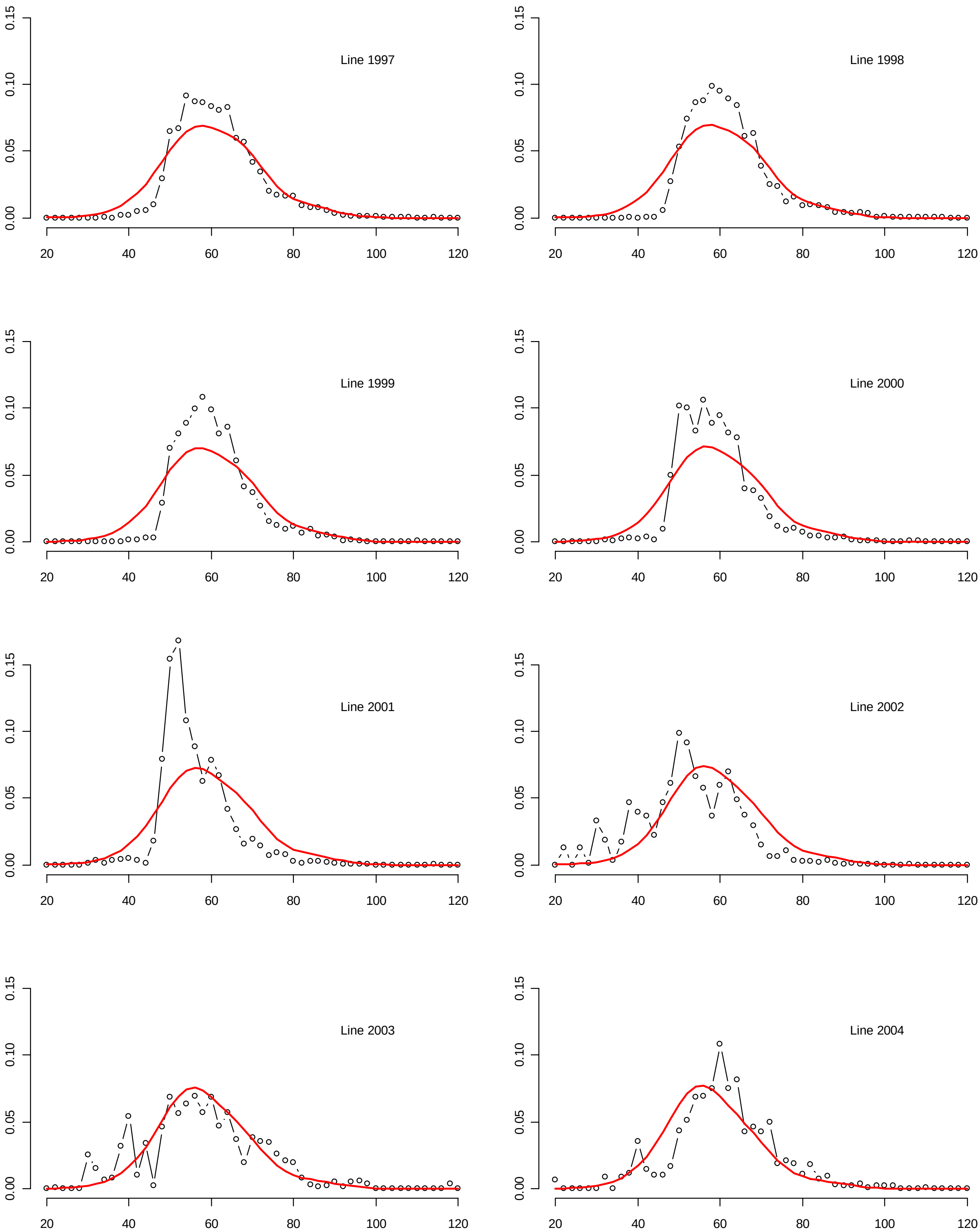

Figure A4.1 (ctd.): Observed and fitted length frequencies for the line fishery 1993–2008. The fitted values, shown by the continuous red line, are for the middle run. Length on the x-axis is in cm.

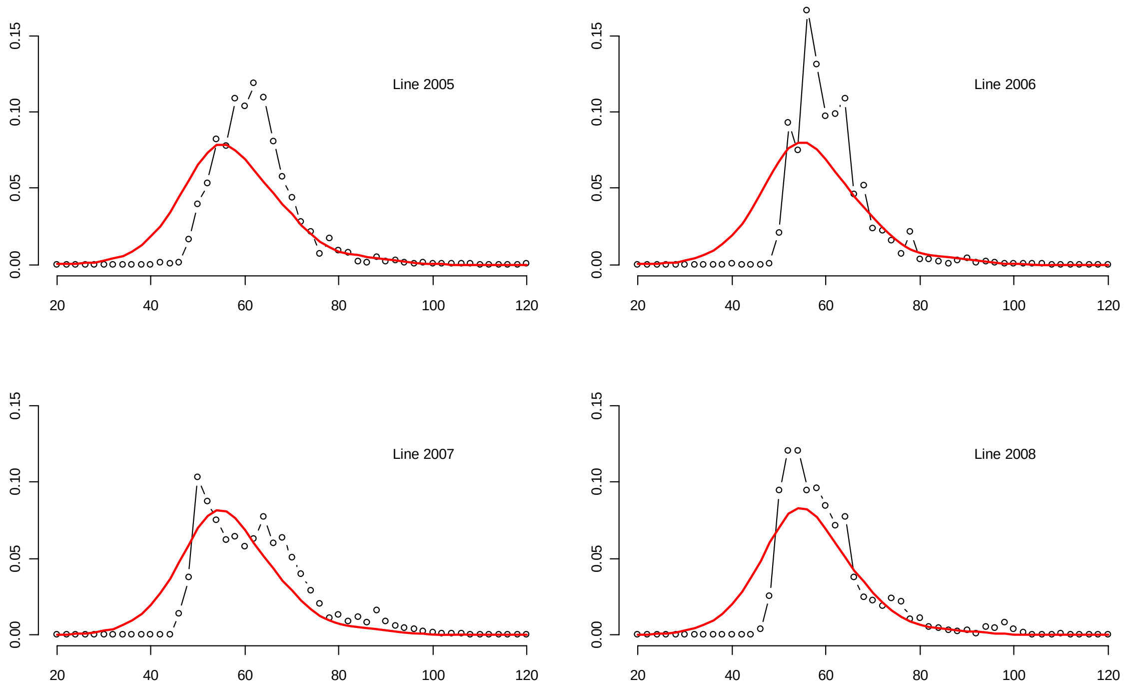

Figure A4.1 (ctd.): Observed and fitted length frequencies for the line fishery 1993–2008. The fitted values, shown by the continuous red line, are for the middle run. Length on the x-axis is in cm.

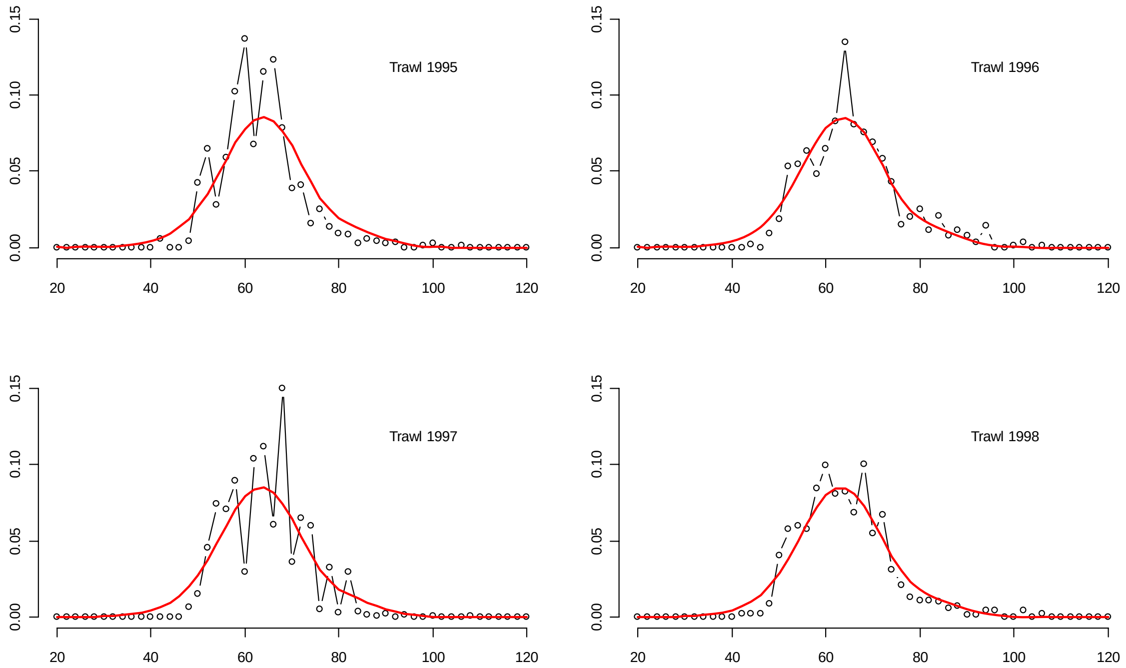

Figure A4.2: Observed and fitted length frequencies for the trawl fishery 1995–2004. The fitted values, shown by the continuous red line, are for the middle run. Length on the x-axis is in cm.

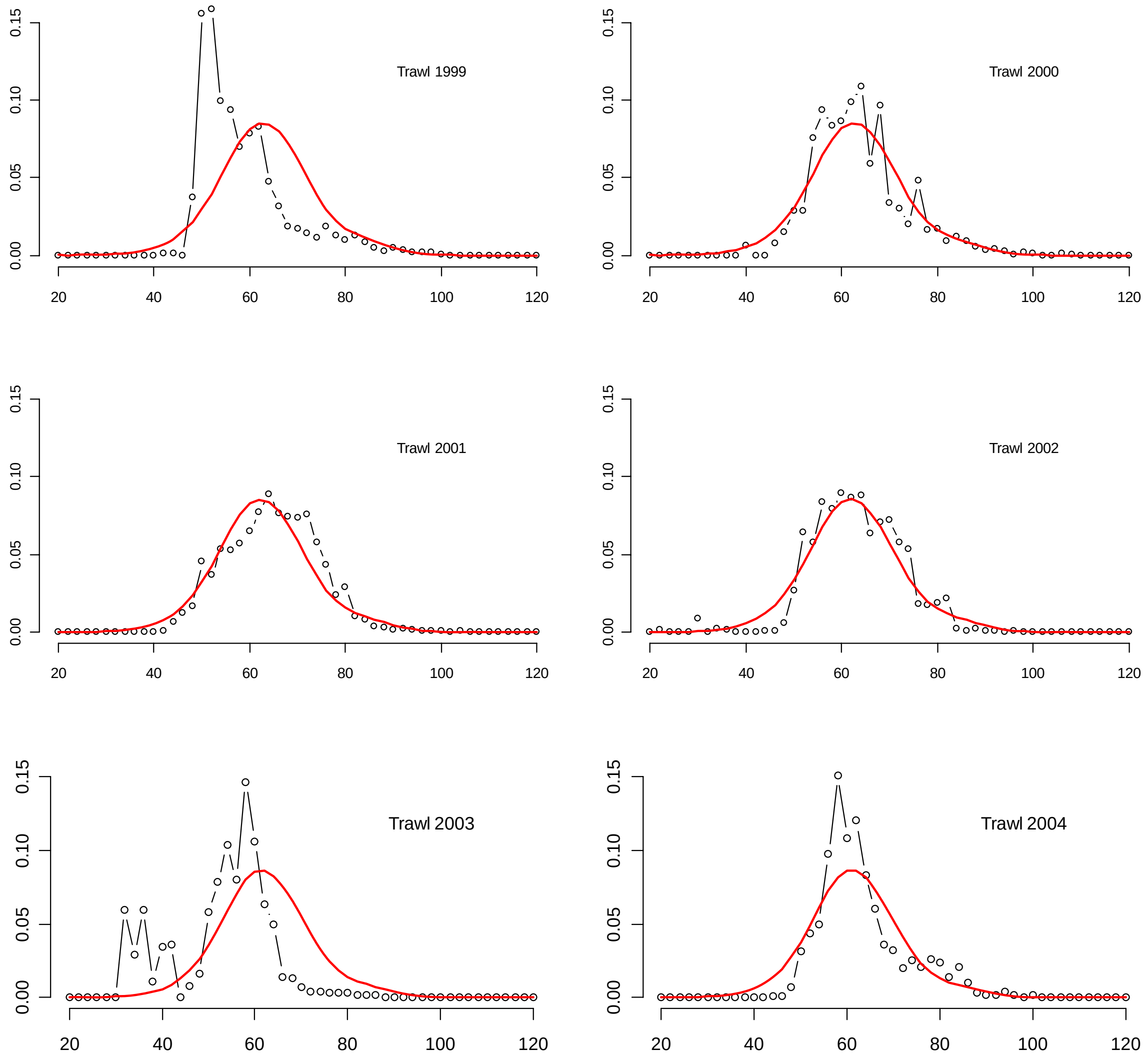

Figure A4.2 (ctd.): Observed and fitted length frequencies for the trawl fishery 1995–2004. The fitted values, shown by the continuous red line, are for the middle run. Length on the x-axis is in cm.

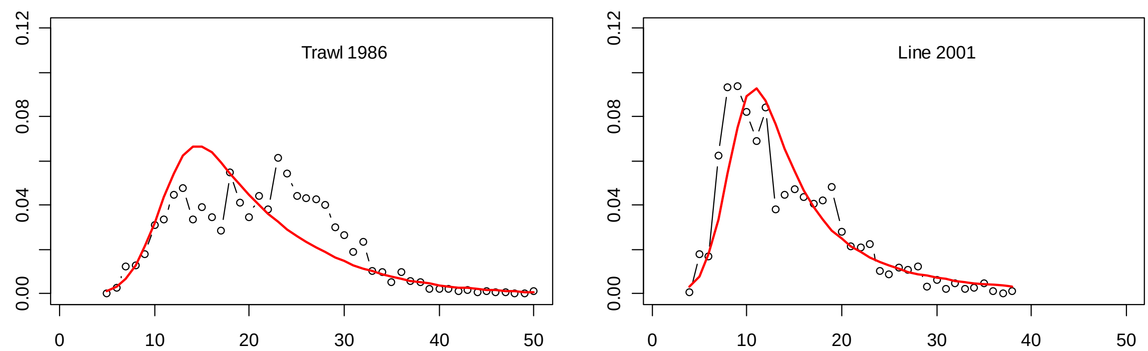

Figure A4.3: Observed and fitted age frequencies. The fitted values, shown by the continuous red line, are for the middle run. Age on the x-axis is in years.

Appendix 5: CASAL input files

The following files were used for the MPD and MCMC run: catch = base, M = 0.08, h = 0.75. For other MPD runs, the appropriate parameters and/or catch history were changed in population.csl.

population.csl

```
@size_based 0
@min_age 1
@max_age 80
@plus_group 1
@sex_partition 1
@mature_partition 0
@n_areas 1
@area_names home
@n_stocks 1

@initial 1936
@current 2011
@final   2016

@annual_cycle
time_steps 1
recruitment_time 1
recruitment_areas home
spawning_time 1
spawning_part_mort 0.5
spawning_areas home
spawning_ps 1
aging_time 1
growth_props 0.0
M_props 1.0
baranov 0
fishery_names trawl line
fishery_times 1 1
fishery_areas home home
n_migrations 0
maturation_times 1

@y_enter 1
@standardise_YCS 1
@recruitment
YCS_years 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947
1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
2008 2009 2010
YCS          1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1
SR BH
steepness 0.75
p_male 0.5
sigma_r 0.6
first_free 1940
last_free 1997
```

```
@randomisation_method none

@maturity_props
male logistic 15 5
female logistic 17 10

@natural_mortality
male 0.08
female 0.08

@fishery trawl
years 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949
1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964
1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
2010 2011
catches  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 45.5 42 68.201 116.183 111.771 385.4475 0 0 0 0 0 0 324 372.5 605.4
667.1 522.4 622.8 763.4964 577.146 549.4659 733.4205 860.3949 904.2976
810.814 1059.699 778.9319 903.5404 1022.308 1081.995 1344.832 1331.13
957.2068 1113.771 709.6602 423.8427 500 300 300 300
selectivity trawl_sel
U_max 0.6
F_max 0.6
future_years   2012 2013 2014 2015 2016
future_catches  300  300  300  300  300

@fishery line
years 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949
1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964
1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
2010 2011
catches 75 75 75 75 56.25 50 50 50 50 50 68.75 75 81.1875 94.65 88.7
73.7125 71.075 70.4875 68.6875 65.9875 68.775 68.7875 74.55 68.275 62.2375
60.4 59.025 59.4375 66.3 63.9625 61.4375 64.55 56.6625 55.4875 70.2375
69.2125 58.825 63.2 68.6375 181.7375 692.475 912.725 80.625 92.1375
97.82083 299.8479 511.4937 755.2354 956.3813 1013.05 981.5 743.9 751.6
797.2 776.6607 1191.947 1414.430 1573.325 1459.099 1381.559 1502.719
1765.302 1727.673 1871.110 1711.520 1637.806 1442.682 1670.612 2132.76
1899.505 1765.167 2001.273 2000 1746 1759 1700
selectivity line_sel
U_max 0.6
F_max 0.6
future_years   2012 2013 2014 2015 2016
future_catches 1700 1700 1700 1700 1700

@selectivity_names trawl_sel line_sel

@selectivity trawl_sel
all double_normal    10 5 10

@selectivity line_sel
all double_normal    10 5 10

@initialization
B0 100000
```

```
@size_at_age_type von_Bert
@size_at_age_dist normal
@size_at_age
k_male 0.125
t0_male -0.5
Linf_male 72.2
k_female 0.071
t0_female -0.5
Linf_female 92.5
cv 0.10


@size_weight
a 9.63e-9
b 3.173
verify_size_weight 40 0.8 4
```

estimation.csl

```
@estimator Bayes
@max_iters 300
@max_evals 1000

@MCMC
start 0
length 1300000
keep 1000
burn_in 300
systematic 1
adaptive_stepsize 1
adapt_at 10000 50000 100000 150000

@relative_abundance line_CPUE
biomass 1
q line_cpue
years 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
2004 2005 2006 2007 2008 2009 2010
step 1
proportion_mortality 0.5
area home
ogive line_sel
1990  1.247441814
1991  1.590947955
1992  1.477727473
1993  1.649550216
1994  1.500194891
1995  1.193148238
1996  1.250706938
1997  1.457456864
1998  1.314037285
1999  1.168289555
2000  1.152326268
2001  1.113044069
2002  1.098104608
2003  1.216502307
2004  1.100227489
2005  0.753376718
2006  0.614730612
2007  0.545121426
```

```
2008  0.434553641
2009  0.464832065
2010  0.429294754
cv 0.2
cv_process_error 0
dist lognormal

@relative_abundance trawl_CPUE
biomass 1
q trawl_cpue
years 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
2004 2005 2006 2007 2008 2009 2010
step 1
proportion_mortality 0.5
area home
ogive trawl_sel
1990  1.510256596
1991  1.042574728
1992  1.894356836
1993  1.750991576
1994  1.899914374
1995  0.963911837
1996  1.053177411
1997  1.2284709
1998  1.232794605
1999  1.290068485
2000  0.933782045
2001  1.190904953
2002  1.249063247
2003  0.977561748
2004  0.878536218
2005  0.951121731
2006  0.557849976
2007  0.484998026
2008  0.551232474
2009  0.545266918
2010  0.550689277
cv 0.2
cv_process_error 0
dist lognormal



@catch_at lf_line
years 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
2007 2008
fishery line
at_size 1
sexed 0
plus_group 0
sum_to_one 1
class_mins 19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49
51  53  55  57  59  61  63  65  67  69  71  73  75  77  79  81  83  85  87
89  91  93 95  97  99 101 103 105 107 109 111 113 115 117 119 121
1993 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.000833034 0.01907067 0.06234897
0.05787144 0.09205867 0.07474554 0.07462903 0.06442023 0.05551416
0.06665473 0.06177136 0.05009846 0.05755423 0.03631356 0.04637422
0.04059342 0.02823511 0.02532275 0.01646804 0.01509342 0.01095231
0.01054003 0.005978919 0.004740671 0.008281408 0.002961299 0.003867287
0.003174747 0.001295687 0.001050167 0.0007580613 0 0.0001366856 0
0.0001470798 0
```

1994 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.002088497 0 0 0.01118551 0.0386302
0.04073961 0.03668246 0.0587458 0.06882336 0.0844908 0.1339844 0.08683745
0.07804843 0.094172 0.04425235 0.04293688 0.03625063 0.03115765 0.02785656
0.01417502 0.02453844 0.009071525 0.01535035 0.004280811 0.006553846
0.001712733 0.004409622 0.001821751 0.0003476381 0.0008556447 0 0 0 0 0 0 0
1995 0 0 0 0 0 0 0 0 0 0 0 0 0.001951494 0.006970228 0.05123687 0.0747149
0.04020342 0.0635675 0.06250192 0.0825977 0.071601 0.09895632 0.06510201
0.04441395 0.06159359 0.04387734 0.0431837 0.01933916 0.01585675 0.01469333
0.01314635 0.01921609 0.01862644 0.01324993 0.01091688 0.01166447
0.009225448 0.006070978 0.006858778 0.007866656 0.006880516 0.004725787
0.002802254 0.0008428806 0.002679879 0.0004551937 0.001804038 0
0.0006062384 0 0
1996 0 0 0 0 0 0 0 0 0 0 0 0.002439013 0 0.0005101933 0.02847421 0.07256657
0.05578062 0.05787344 0.05574118 0.08573875 0.1192315 0.1078919 0.09660355
0.08516509 0.0667029 0.0502352 0.03425016 0.02550657 0.01602009 0.01089069
0.007679021 0.005706875 0.003067761 0.001881337 0.003181110 0.002389083
0.0008685203 0.0003567525 0.0005825793 0.0008078353 1.271716e-05
0.0002179089 0 0.001043853 0.0003524023 0 0.0002179089 0 0 0 1.271716e-05
1997 0 0 0 0 0 0 3.912111e-05 0.0001877923 0 0.001841102 0.002232748
0.004817867 0.005361016 0.009550732 0.02959137 0.06483232 0.0671129
0.09111494 0.0871997 0.0864397 0.08344914 0.08045222 0.08244177 0.05983338
0.05656332 0.04126666 0.03461616 0.02007929 0.01723191 0.01629499
0.01610065 0.008948374 0.00783506 0.007987189 0.005295748 0.003342567
0.002106076 0.001466373 0.001252883 0.0009473101 0.000973236 0.0002775681
0.0002653043 0.0002289464 0.0002619671 4.44539e-05 0 0.0001161277 0 0 0
1998 0 0 0 0 0 0 0 0 0 0.0002080367 0 0.0001360276 0.0004181825 0.005271027
0.02719975 0.05340558 0.07430036 0.0864845 0.087711 0.09841176 0.09516996
0.08887776 0.08438755 0.06132509 0.06345817 0.03899578 0.02464859
0.02353183 0.01172220 0.01549702 0.00940414 0.00957537 0.009239372
0.007488616 0.004109825 0.004288218 0.003448511 0.004120912 0.003227495
0.0003192350 0.0008565428 0.0007052956 0.0003669328 0.0007811777
0.0002715160 0.0002517235 0.0001212468 0.0002637077 0 0 0
1999 0 2.035576e-05 0 0 0 0 0 0 4.071151e-05 0.000187939 0.001472152
0.001735844 0.003038184 0.003071571 0.02890338 0.07013204 0.0805171
0.08845659 0.09940573 0.1084639 0.09899896 0.081137 0.08617487 0.06066383
0.04134431 0.03652042 0.026575 0.01542838 0.01220077 0.009315495 0.01170378
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0.001180376 0.0008083183 0.0002325269 0.0002784671 0.0002243698 0
0.0003653545 0.0003667486 0.000791085 6.081429e-05 0 0 0 0
2000 0 0 0 0 0 0 0.001645453 0.0006195374 0.002462247 0.003064009
0.002035381 0.003528527 0.001246496 0.009441382 0.04973815 0.1016881
0.1004298 0.0826693 0.1059320 0.08914305 0.09482094 0.08131894 0.07784081
0.0399449 0.03808148 0.0325412 0.01853448 0.01185210 0.008537929 0.01048621
0.007076915 0.004310271 0.004258643 0.002828536 0.002965858 0.003710454
0.001597613 0.001032728 0.001025803 0.0009886237 0.0002874664 0.000177379
0.0001392196 0.000729877 0.000644862 0.0003366853 0.0002651314 0 0 0 0
2001 0 0 0 0 0 0.001200278 0.003460784 0.001172576 0.003429272 0.003692143
0.004412721 0.003136546 0.001343542 0.01792959 0.07926287 0.1540561
0.1679265 0.1079745 0.0883399 0.06255923 0.07859732 0.06660509 0.04183325
0.02669441 0.01524119 0.01941711 0.01379246 0.007254297 0.009138866
0.007622425 0.002658743 0.001523725 0.002608082 0.002400284 0.002174176
0.001004692 0.0004872101 0.000323458 9.013154e-05 0.0005214016 1.267249e-05
0 0 0 0 0 0 0.0001024305 0 0 0
2002 0 0.01254557 0 0.01254557 0.001014284 0.03304973 0.01873846
0.003269959 0.01726231 0.04661792 0.03907993 0.03685197 0.02194842
0.04677307 0.06071196 0.09819849 0.09160194 0.0662933 0.0575858 0.03659285
0.05949228 0.06965559 0.04843567 0.03716772 0.02909325 0.01493039
0.00624949 0.00595732 0.01041636 0.003593370 0.002699171 0.002292237
0.002108238 0.003219974 0.00100714 0.0007224421 0.000948807 0.0002818598
0.0003093084 0.0003519134 0 0 0 0.0003859575 0 0 0 0 0 0 0

```
2003 0 0.0009967001 0 0 0 0.0253126 0.01487488 0.006519233 0.00835565
0.03188688 0.0540221 0.01043772 0.03420224 0.002075497 0.04624752
0.06865826 0.05656626 0.06335071 0.06936536 0.05727059 0.06840694
0.04677754 0.05728594 0.03691287 0.01986714 0.03832593 0.03548033
0.03474119 0.02570534 0.02097603 0.01984831 0.007846012 0.002980477
0.001823910 0.002167627 0.005398813 0.001279773 0.004979329 0.005712703
0.003750032 0 0 0 0 0 0 0 0 0 0 0.003735815 0
2004 0.006495217 0 0 0 0 0 0.009025305 0 0.009025305 0.01127712 0.03551906
0.01417183 0.01013894 0.01026870 0.01698568 0.04299337 0.05157036
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0.003394647 0.0006677748 0.002448124 0.002385301 0.002059969 0 0 0
0.0007220154 0 0 0 0 0
2005 0 0 0 0 0 0 0 0 0 0 0 0 0.001374136 0.0003919997 0.0009593593 0.01625565
0.0392564 0.0534077 0.08169088 0.07756105 0.1089275 0.1032241 0.1187824
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0.01721544 0.009283102 0.007614942 0.001532345 0.001341824 0.00447502
0.001994104 0.002627414 0.001116653 0.000555307 0.0009772627 0.0003271633
0.0001457229 0.0002812737 0.0007337297 0.0002479523 0 0 0 0 0 0.0001056350
2006 0 0 0 0 0 0 0 0 1.118206e-05 0 0.0001358196 0 0 0 0.0004356601
0.02089889 0.0924201 0.07464896 0.1665842 0.1312537 0.09719674 0.09858058
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0.004167773 0.001501069 0.001808627 0.001333887 0.0005952916 0.0005992896
0.0002018768 9.962319e-05 0.0002585633 0 0 0 0 0 0 0
2007 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.01372076 0.03743546 0.1030029 0.08709071
0.07538374 0.0620374 0.06411771 0.05755508 0.06313634 0.07717764 0.05973588
0.06378247 0.05062632 0.03956377 0.02898915 0.02039481 0.01102126
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0.005763921 0.004451052 0.003437062 0.002257977 0.001204630 0.000918174
0.0005841044 0.0007674782 0 0 0 1.330027e-05 0.0002959331 1.330027e-05 0
2008 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.003411721 0.0255222 0.09457644 0.1207092
0.1207135 0.0946572 0.09570498 0.08473751 0.07118058 0.07757383 0.03784860
0.02427679 0.02235321 0.01903186 0.02376668 0.02203408 0.009871937
0.01098032 0.004785387 0.004065826 0.003256392 0.002226485 0.003036518
0.001084377 0.004871237 0.004265542 0.007898112 0.003363144 0.001601792 0 0
0 0.0005945635 0 0 0 0 0
dist multinomial
N_1993   10
N_1994    2
N_1995    4
N_1996    7
N_1997   32
N_1998   19
N_1999   20
N_2000   14
N_2001   14
N_2002    8
N_2003    4
N_2004    3
N_2005    4
N_2006    6
N_2007    8
N_2008    8

@catch_at lf_trawl
years 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
fishery trawl
at_size 1
sexed 0
```

```
plus_group 0
sum_to_one 1
class_mins 19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49
51  53  55  57  59  61  63  65  67  69  71  73  75  77  79  81  83  85  87
89  91  93 95  97  99 101 103 105 107 109 111 113 115 117 119 121
1995 0 0 0 0 0 0 0 0 0 0 0 0 0.005386854 0 0 0.004395466 0.04199339 0.0645052
0.02791055 0.05898416 0.1018713 0.1369029 0.067774 0.1153757 0.1226970
0.07824038 0.03888739 0.04109890 0.01585228 0.02495305 0.01320923
0.008759512 0.008558257 0.002305707 0.005695989 0.004088632 0.002808990
0.003484397 0 0 0.0009930459 0.002342325 0 0 0.0009253303 0 0 0 0 0 0 0
1996 0 0 0 0 0 0 0 0 0 0 0 0 0 0.001533445 0 0.009428641 0.01818692
0.05292114 0.05475225 0.06317558 0.0482625 0.06484054 0.08293471 0.1347730
0.0807305 0.07530848 0.06927263 0.05837092 0.04329575 0.01508776 0.02009997
0.02493512 0.01156858 0.02076003 0.007934844 0.01116985 0.007974544
0.003535176 0.01380494 0 0 0.0008078236 0.003354132 0 0.001180252 0 0 0 0 0
0 0
1997 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.006785822 0.01504600 0.04525421 0.074516
0.07069951 0.0894621 0.02937663 0.1041428 0.1119376 0.06046075 0.1497293
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0.02963404 0.003817985 0.001459142 0.0008977748 0.002379543 0 0.001601162 0
0 0.00082926 0 0 0 0.0004947163 0 0 0 0 0 0
1998 0 0 0 0 0 0 0 0 0 0 0 0.001934453 0.002173173 0.002297901 0.008470545
0.0403711 0.05762125 0.05974484 0.05747124 0.08453248 0.0993494 0.080777
0.08258507 0.06894717 0.1000575 0.05510098 0.06750686 0.03088648 0.02106523
0.01326274 0.01120687 0.01076367 0.01027152 0.00617681 0.007101847
0.001623326 0.001493930 0.004442368 0.004571129 0.0002114182 0.0004091064
0.004587499 0.0001164878 0.002528844 0.0001164878 0.0001155826 0 0 0
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1999 0 0 0 0 0 0 0 0 0 0 0 0.001312261 0.001155765 0 0.03756868 0.1553176
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0 0 0 0 0 0 0 0 0
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0.004073925 0.002896561 0.0004200243 0.001595957 0.0008503987 0 0
0.001029484 0.0001894501 0 0 0 0 0 0
2001 0 0 0 0 0 0 0 0 0 0 0 0.001088462 0.006698544 0.01261797 0.01687603
0.04561997 0.03687700 0.05313648 0.05282115 0.05734986 0.06497931
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0.002844199 0.001390611 0.001993638 0.001306159 0.0008394371 0.0008073965
0.0006838156 0 0.0004439613 0 0 0 0 0 0 0 0
2002 0 0.001437519 0 0 0 0.00904225 0 0.002142891 0.001437519 0.0003907263
0 0 0.0005205232 0.0005205232 0.005705558 0.02694496 0.06408431 0.05801856
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2003 0 0 0 0 0 0 0.05971417 0.02909296 0.05971417 0.01133514 0.03459166
0.0359807 0 0.007843138 0.01603625 0.05787173 0.0786105 0.1035397
0.08014267 0.1462817 0.1058573 0.06336534 0.04955728 0.01423265 0.01312190
0.007054365 0.003896355 0.004075708 0.003353946 0.003359487 0.003522022
0.002212726 0.001747447 0.001737301 0.000576918 0.0006860638 0.0002453034
0.0001992933 0.0001842165 2.980161e-05 0.0001937511 3.629777e-05 0 0 0 0 0
0 0 0 0
```

```
2004 0 0 0 0 0 0 0 0 0 0 0.000304247 0.000304247 0.001407648 0.0009044065
0.007322961 0.03180188 0.04374591 0.04990059 0.09708846 0.1507301 0.108393
0.1200567 0.08300504 0.06018672 0.03575333 0.03189492 0.02027619 0.025169
0.02076878 0.0259457 0.02368006 0.01421261 0.02100907 0.01039054
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0.0001001850 0 0 0 0 0 0 0 0 0
dist multinomial
N_1995   17
N_1996   21
N_1997   13
N_1998   81
N_1999   35
N_2000   59
N_2001   77
N_2002  100
N_2003   57
N_2004  104

@catch_at pb_trawl
years 1986
fishery trawl
sexed 0
plus_group 0
sum_to_one 1
min_class 5
max_class 50
1986 0.0003 0.0030 0.0125 0.0129 0.0180 0.0311 0.0336 0.0449 0.0477 0.0334
0.0394 0.0346 0.0288 0.0548 0.0412 0.0348 0.0443 0.0381 0.0616 0.0541
0.0442 0.0433 0.0426 0.0404 0.0302 0.0265 0.0187 0.0233 0.0103 0.0100
0.0055 0.0098 0.0059 0.0055 0.0021 0.0023 0.0021 0.0014 0.0020 0.0007
0.0013 0.0007 0.0005 0.0002 0.0003 0.0011
dist multinomial
N 200
ageing_error true

@catch_at bopen_line
years 2001
fishery line
sexed 0
plus_group 0
sum_to_one 1
min_class 4
max_class 38
2001 6e-04 0.0178 0.0168 0.0622 0.0933 0.0938 0.0822 0.0688 0.0841 0.0384
0.0449 0.0475 0.0438 0.0406 0.042 0.048 0.0281 0.0214 0.0209 0.0223 0.0105
0.0086 0.0119 0.0107 0.0126 0.0032 0.0061 0.0022 0.0049 0.0022 0.0025
0.0046 0.0011 0 0.0012
dist multinomial
N 200
ageing_error true

@q_method nuisance

@estimate
parameter q[line_cpue].q
lower_bound 1e-8
upper_bound 1e-3
prior uniform-log

@estimate
parameter q[trawl_cpue].q
```

```
lower_bound 1e-8
upper_bound 1e-3
prior uniform-log

@estimate
parameter initialization.B0
lower_bound 10000
upper_bound 500000
prior uniform-log


@estimate
parameter selectivity[line_sel].all
lower_bound 1  1  1
upper_bound 20 50 200
prior uniform

@estimate
parameter selectivity[trawl_sel].all
lower_bound 1  1  1
upper_bound 20 50 200
prior uniform

@estimate
parameter size_at_age.cv
lower_bound 0.02
upper_bound 0.20
prior uniform

@vector_average_penalty
label YCS_average_1
vector recruitment.YCS
k 1
multiplier 6

@ageing_error
type normal
c 0.1

@catch_limit_penalty
label clptrawl
fishery trawl
log_scale 1
multiplier 10000

@catch_limit_penalty
label clpline
fishery line
log_scale 1
multiplier 10000
```