Stock Assessment of
Shortspine Thornyhead in 2013

by

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Executive Summary

Stock

This assessment applies to shortspine thornyhead (*Sebastolobus alascanus*) off of the west coast of the United States from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south. Shortspine thornyheads have been reported as deep as 1,524 m, and this assessment applies to their full depth range although survey and fishery data are only available down to 1,280 m. This resource is modeled as a single stock because genetic analyses do not indicate significant stock structure within this range. This is the same stock assumption made in the most recent assessment of shortspine thornyhead in 2005 (Hamel, 2005).

Catches

Landings of shortspine are estimated to have risen to a peak of 4,815 mt in 1989, followed by a sharp decline during a period of trip limits and other management measures imposed in the 1990s. Since the institution of separate trip limits for shortspine and longspine thornyheads, the fishery had more moderate removals of between 1,000 and 2,000 mt per year from 1995 through 1998. Landings fell below 1,000 mt per year from 1999 through 2006, then rose to 1,531 in 2009 and have declined since that time. Recreational fishery landings of thornyheads were negligible, so only commercial landings were included in the model. Trawl landings represent only bottom trawl gear and non-trawl landings include all other gears, the majority of which is longline, with some catch by pot gear. Both trawl and non-trawl landings are divided into North (the waters off Washington and Oregon) and South (the waters off California) fleets although they are assumed to be fishing on the same unit stock. Discard rates (landings divided by total catch) for shortspine have been estimated as high as 43% per year, but are more frequently below 20%. Discard rates in the trawl fisheries declined over the period where they are available from West Coast Groundfish Observer Program (WCGOP) from 2003–2011 and dropped to less than 1% in 2011, the only estimate available under catch shares system that began that year.

Table a: Recent Landings

Year	Landings (mt)				
	Trawl N	Trawl S	Non-trawl N	Non-trawl S	Total
2003	270	364	11	155	800
2004	295	323	11	129	757
2005	255	250	11	139	654
2006	296	248	15	144	703
2007	562	285	16	143	1006
2008	902	330	20	175	1427
2009	948	383	29	172	1531
2010	770	355	22	206	1353
2011	424	288	24	237	974
2012	381	323	36	155	894

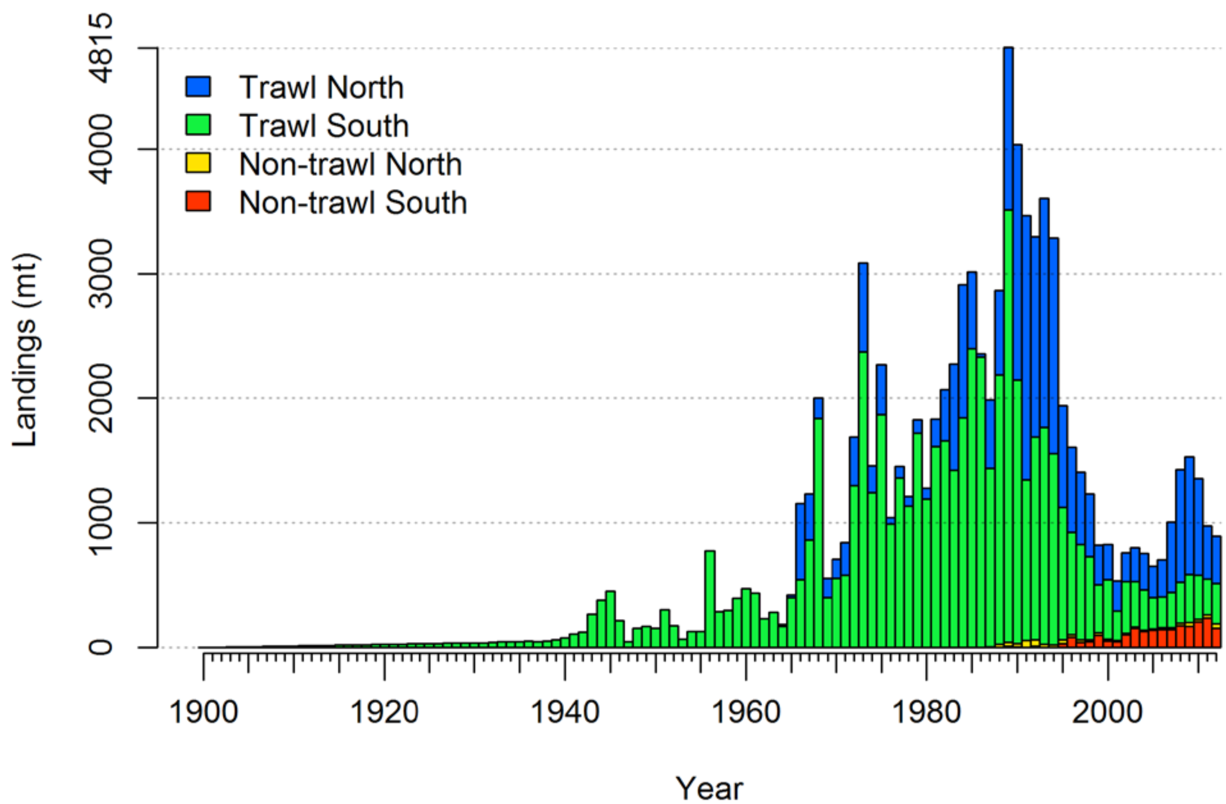

Figure a: Landings History

Data and assessment

The most recent assessment for shortspine thornyhead was conducted in 2005 (Hamel, 2005). Stock status was determined to be above the target biomass and catches did not attain the full management limits so reassessment of thornyheads has not been a higher priority.

This new assessment used Stock Synthesis (SS, Methot, 2012) Version 3.24o used in other recent west coast assessments. Additional sensitivities were conducted using Version 3.24q, which has more flexible options to model maturity at length, a change that was made to explore new data for shortspine thornyheads (R. Methot, pers. comm.).

The data are divided into four fisheries: trawl and non-trawl gears, which are each divided into North (the waters off Washington and Oregon) and South (the waters off California) and five surveys: the Alaska Fisheries Science Center (AFSC) triennial shelf survey from 55-366 meters (1980-2004), the deeper range of triennial shelf survey from 366-500 meters for the later years (1995-2004), the AFSC slope survey (1997, 1999-2001), the Northwest Fisheries Science Center (NWFSC) slope survey (1998-2002) and the NWFSC combined shelf-slope survey (2003-2012).

Most of the data used in the previous assessment has been newly extracted and processed, including length compositions from each fishing fleet and survey, indices of abundance derived from new GLMM analyses of survey data, discard rates from both a 1980s Oregon State University observer study (Pikitch et al., 1988) and the current West Coast Groundfish Observer Program (WCGOP), and the time series of catch from 1981-2012. Data retained from the previous assessment without reanalysis are the estimated historic catch for the years up to 1980 and discard rates from the Enhanced Data Collection Project (EDCP) study in the 1990s. Shortspine ovaries were collected in 2011 and 2012 from the NWFSC shelf-slope survey which allowed an exploration of alternative maturity assumptions from those used in the previous assessment. However, additional sampling and further analysis of maturity patterns is needed before revising the assumptions about maturity used in the assessment.

As in the previous assessment, no age data are used in this analysis and growth parameters are fixed at the same values used in 2005. Parameters for steepness of the stock-recruit relationship and natural mortality are likewise fixed in this assessment. There are 223 estimated parameters in the assessment. The log of the unfished equilibrium recruitment, $\log(R_0)$, controls the scale of the population, annual deviations around the stock-recruit curve (163 parameters) allow for more uncertainty in the population trajectory, and selectivity and retention of the 4 fishing fleets and 5 surveys, including estimates of changes in retention over time (58 parameters). Finally, there is a single parameter which represents additional variability in one of the surveys that is added to the estimate of sampling error for that index.

Stock biomass

Unfished equilibrium spawning biomass (B_0) is estimated to be 189,765 mt, with a 95% confidence interval of 57,435 – 322,095 mt. The B_0 estimate represents an increase from the 130,646 mt estimate for B_0 in the previous assessment although this previous estimate falls well within the uncertainty interval around the current estimate. Spawning biomass is estimated to have remained stable until the mid-1970s and then declined from the 1970s to about 80% in the 1990s, followed by a slower decline under the lower catch levels in the 2000s. The estimated spawning biomass in 2013 is 140,753 mt, which represents a stock status or "depletion" (represented as spawning biomass in 2013, B_{2013}, divided by B_0) of 74.2%. The depletion estimated for 2005 is 76.4%, which is higher than the 62.9% estimated for 2005 in the previous assessment. The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.45$, which is less than the $p^* = 0.72$ default minimum used in adjustments to OFL values for Category 2 stock assessments.

Table b: Recent trend in beginning of the year biomass and depletion

Year	Spawning biomass (1000 mt)	~95% confidence interval	Estimated depletion	~95% confidence interval
2003	146.0	16.1 – 275.8	76.9%	61.3% – 92.5%
2004	145.5	15.5 – 275.5	76.7%	60.8% – 92.5%
2005	145.0	15.0 – 275.1	76.4%	60.4% – 92.5%
2006	144.7	14.5 – 274.8	76.2%	60.0% – 92.4%
2007	144.3	14.1 – 274.6	76.1%	59.7% – 92.4%
2008	143.8	13.4 – 274.2	75.8%	59.2% – 92.4%
2009	143.1	12.6 – 273.7	75.4%	58.4% – 92.4%
2010	142.3	11.6 – 273.0	75.0%	57.7% – 92.3%
2011	141.6	10.8 – 272.5	74.6%	57.0% – 92.3%
2012	141.2	10.2 – 272.1	74.4%	56.5% – 92.3%
2013	140.8	9.7 – 271.8	74.2%	56.1% – 92.3%

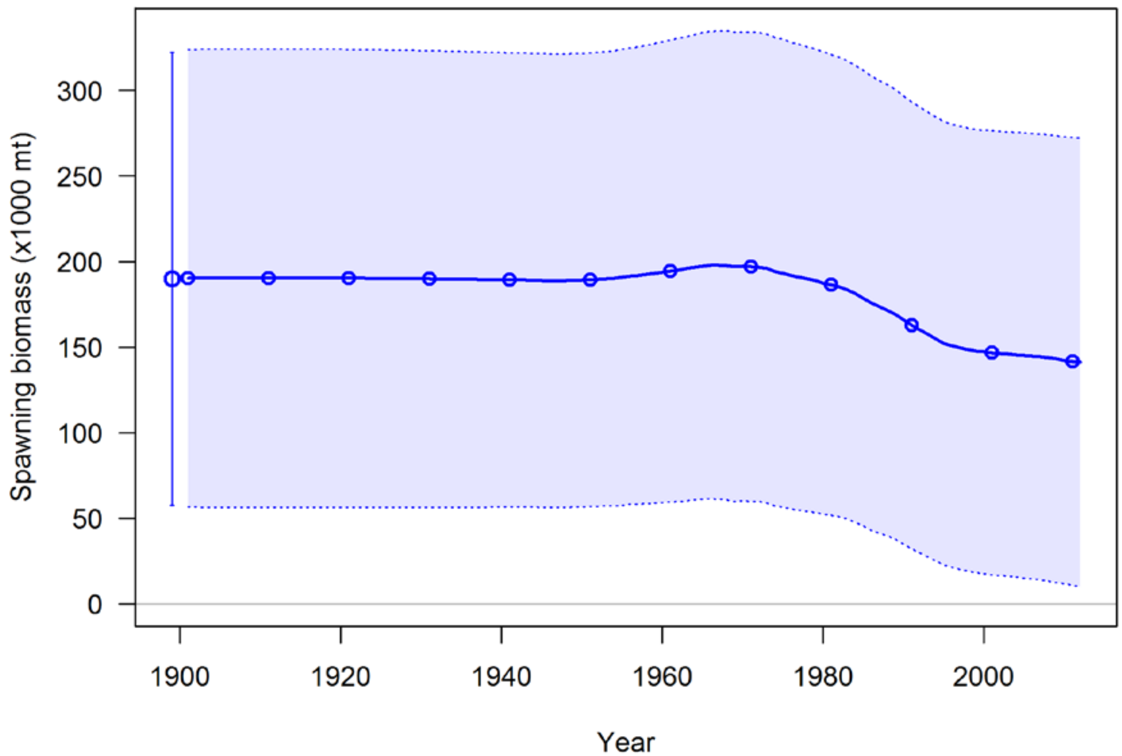

Figure b: Biomass trajectory

Recruitment

This assessment assumed a Beverton-Holt stock recruitment relationship. Steepness (the fraction of expected equilibrium recruitment associated with 20% of equilibrium spawning biomass) was kept at the value of 0.6 that was assumed in the previous assessment, although the results were relatively insensitive to alternative assumptions about steepness. The scale of the population is estimated through the log of the initial recruitment parameter (R_0). Recruitment deviations were estimated for the years 1850 through 2012, where the values estimated in the years 1850 through 1900 are used to estimate a non-equilibrium age-structure in 1901, which is the first year of the population projection. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates.

Table c: Recent recruitment

Year	Estimated recruitment (millions)	+-~95% confidence interval
2003	20.6	7.3 - 57.9
2004	22.5	7.9 - 64.1
2005	27.2	9.3 - 79.5
2006	32.7	10.9 - 98.5
2007	33.0	10.8 - 100.8
2008	30.9	10.1 - 94.3
2009	30.2	9.9 - 92.4
2010	30.5	9.9 - 93.5
2011	27.4	9.0 - 83.7
2012	28.8	9.3 - 89.3

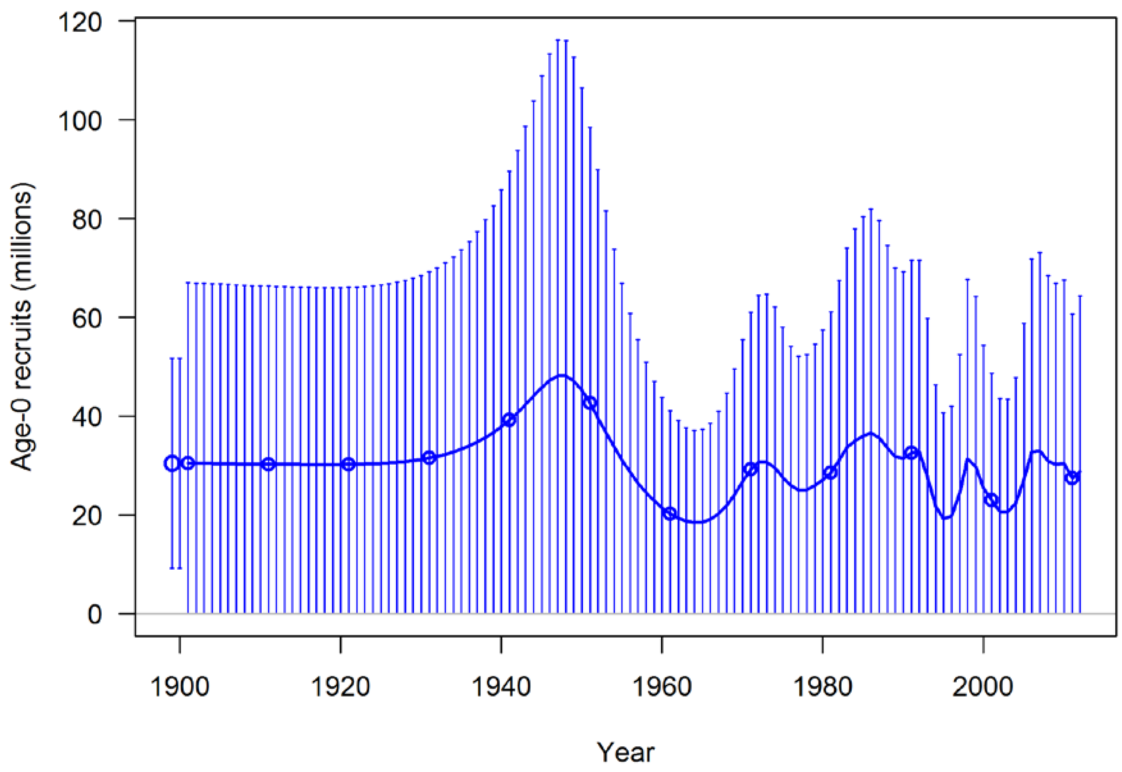

Figure c: Recruitment

Exploitation status

The summary harvest rate (total catch divided by age-1 and older biomass) closely follows the patterns of landings. The harvest rates are estimated to have never exceeded 2% and have remained below 1% in the past decade. Expressing exploitation rates in terms of spawning potential ratio (SPR) indicates that the exploitation slightly exceeded the target reference point associated with $SPR_{50\%}$ for a single year in 1985 and then for the period 1989-1994. However, the stock status is estimated to have never fallen below the $B_{40\%}$ management target.

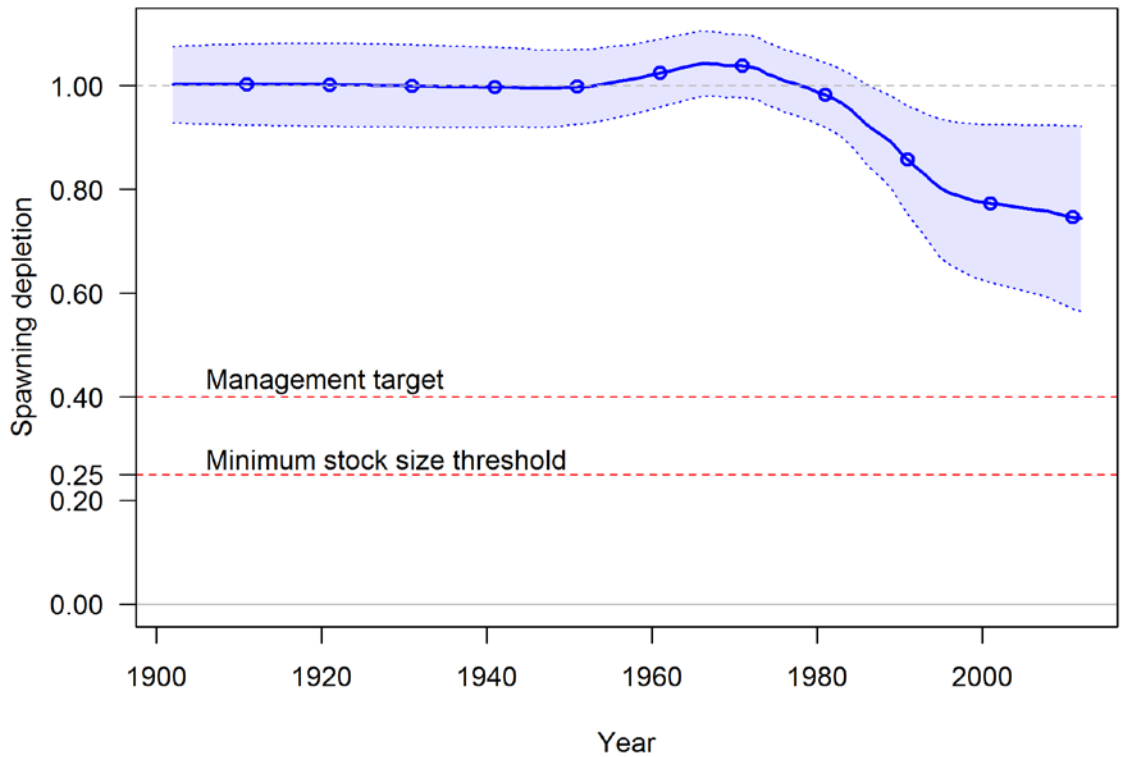

Figure d. Estimated relative depletion with approximate 95% asymptotic confidence intervals (shaded area) for the base case assessment model.

Table d. Recent trend in spawning potential ratio (entered as 1-SPR) and summary exploitation rate (catch divided by biomass of age-1 and older fish).

Year	Estimated 1–SPR (%)	~95% confidence interval	Harvest rate (proportion)	~95% confidence interval
2001	13.0%	2.2% - 23.8%	0.0024	0.0002 - 0.0045
2002	17.4%	3.4% - 31.4%	0.0034	0.0003 - 0.0064
2003	18.4%	3.6% - 33.2%	0.0036	0.0004 - 0.0068
2004	17.6%	3.3% - 31.8%	0.0034	0.0003 - 0.0064
2005	15.5%	2.7% - 28.3%	0.0029	0.0003 - 0.0056
2006	16.6%	3.0% - 30.2%	0.0032	0.0003 - 0.0060
2007	21.8%	4.6% - 39.0%	0.0042	0.0004 - 0.0081
2008	29.7%	7.6% - 51.8%	0.0061	0.0005 - 0.0116
2009	31.4%	8.2% - 54.5%	0.0065	0.0005 - 0.0126
2010	28.3%	6.7% - 49.8%	0.0058	0.0004 - 0.0112
2011	20.3%	3.7% - 36.9%	0.0041	0.0003 - 0.0078
2012	18.7%	3.1% - 34.2%	0.0037	0.0002 - 0.0072

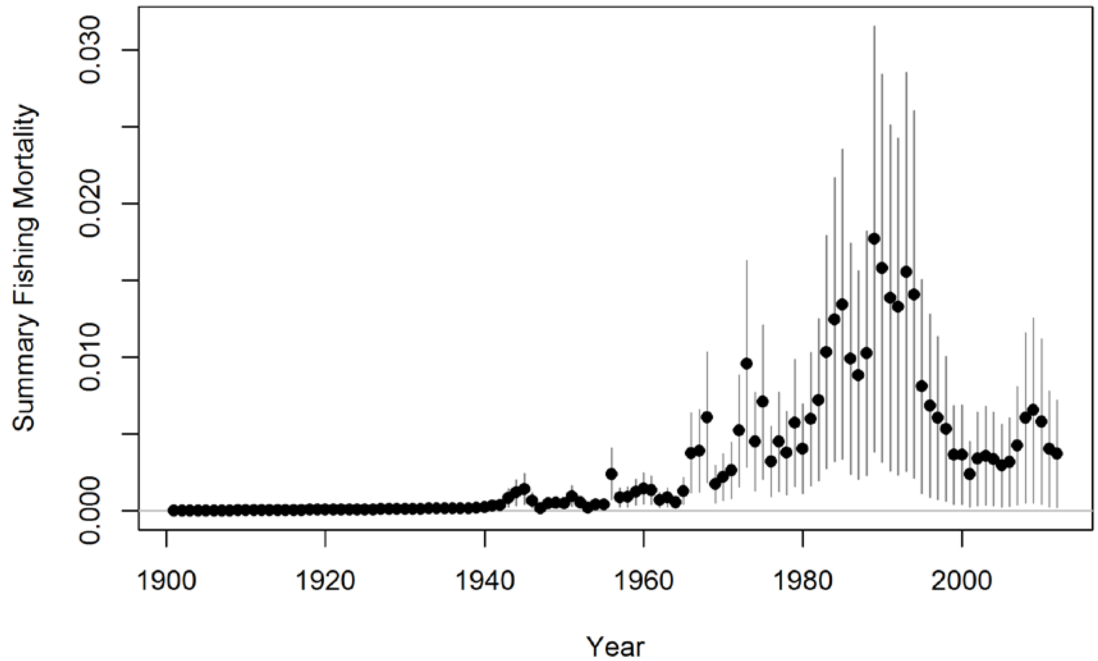

Figure e. Time-series of estimated summary harvest rate (total catch divided by age-1 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines).

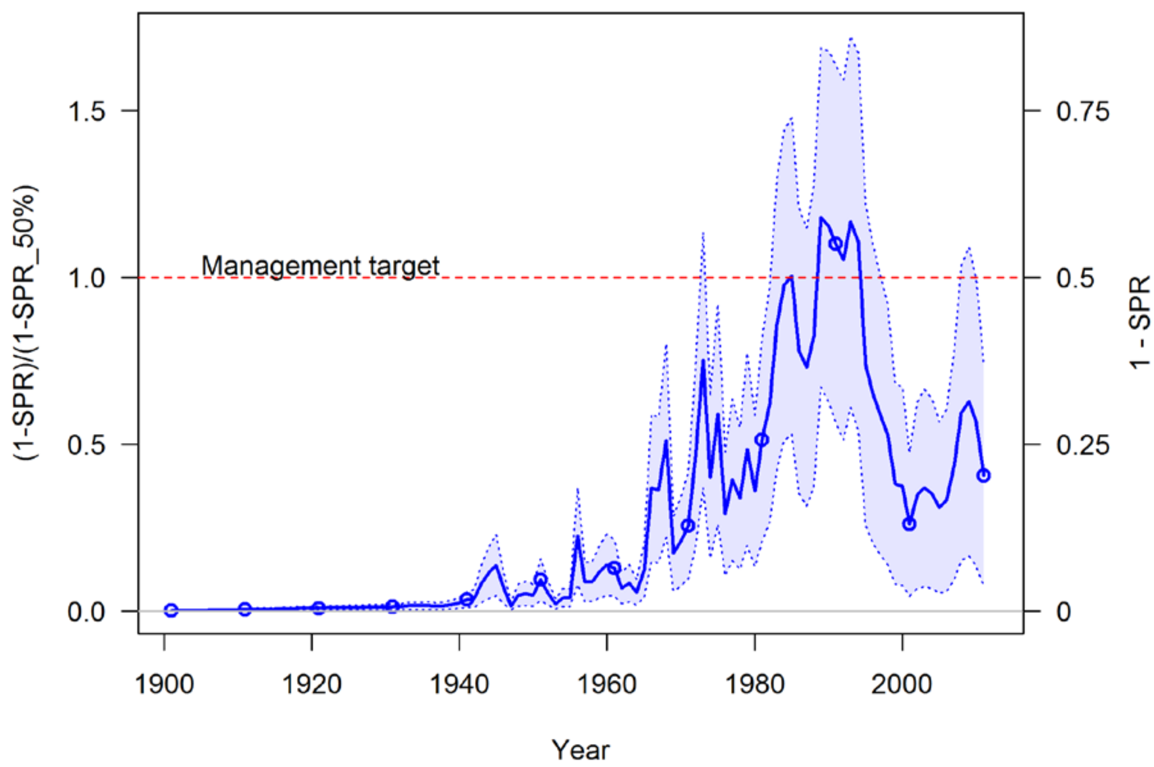

Figure f. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. Both one minus SPR (right y-axis) and the ratio of this quantity to the associated target (1 - $SPR_{50\%}$) (left y-axis) are shown. These quantities are chosen so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

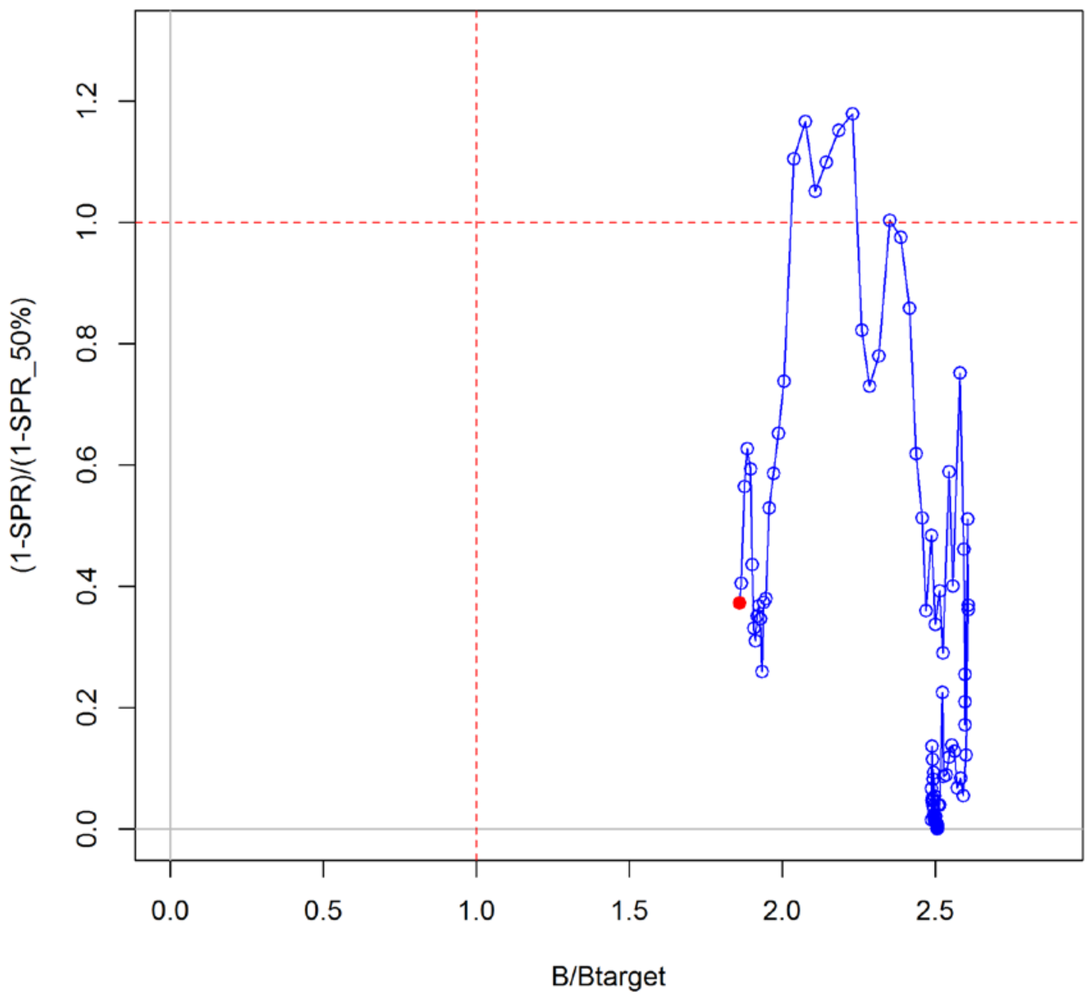

Figure g. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 50% of the unfished spawning biomass. The red point indicates the year 2012.

Ecosystem considerations

Shortspine and longspine thornyheads have historically been caught with each other and with Dover sole and sablefish, making up a "DTS" fishery. Other groundfishes that frequently co-occur in these deep waters include a complex of slope rockfishes, rex sole, longnose skate, roughtail skate, Pacific grenadier, giant grenadier, Pacific flatnose as well as non-groundfish species such as Pacific hagfish and a diverse complex of eelpouts. Shortspine thornyheads typically occur in shallower water than the shallowest longspine thornyheads, and migrate to deeper water as they age. When shortspines have reached a depth where they overlap with longspines, they are typically larger than the largest longspines. Shortspine thornyhead stomachs have been found to include longspine thornyheads, suggesting a predator-prey linkage between the two species.

Thornyheads spawn gelatinous masses of eggs which float to the surface. This may represent a significant portion of the upward movement of organic carbon from the deep ocean (Wakefield, 1990). Thornyheads have been observed in towed cameras beyond the 1280 meter limit of the current fishery and survey, but their distribution, abundance, and ecosystem interactions in these deep waters are relatively unknown.

Reference points

Reference points were calculated using the estimated catch distribution among fleets in the last year of the model (2012), and the estimated values are dependent on this assumption. In general, the population is at a healthy status relative to the reference points. Sustainable total yield (landings plus discards) was estimated at 2,034 mt when using an $SPR_{50\%}$ reference harvest rate and ranged from 633 – 3,435 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished spawning output ($B_{40\%}$) was 75,906 mt. The most recent catches (landings plus discards) have been lower than the estimated long-term yields calculated using an $SPR_{50\%}$ reference point, but not as low as the lower bound of the 95% uncertainty interval. However, this is due to the fishery not fully attaining the full ACL. The OFL and ACL values over the past 6 years have been approximately 2,400 mt and 2,000 mt, respectively. Both of those values are lower than the OFL and ACL values predicted in short-term forecasts, which are around 3,200 mt and 2,700 mt respectively for 2015–2016.

Table e. Summary of reference points and management outputs for the base case model.

Quantity	Estimate	~95% confidence interval
Unfished Spawning biomass (mt)	189,765	(57,435 – 322,095)
Unfished age 1+ biomass (mt)	331,047	(100,196 – 561,898)
Unfished recruitment (R0, millions)	30.4	(15.2 – 61.1)
Depletion (2013)	74.2%	(56.1% – 92.3%)
Spawning Biomass (2013)	140,753	(9,673 – 271,833)
SD of log Spawning Biomass (2013)	0.45	–
Reference points based on $B_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	75,906	(22,974 – 128,838)
SPR resulting in $B_{40\%}$ ($SPR_{SB40\%}$)	50.0%	–
Exploitation rate resulting in $B_{40\%}$	0.015	(0.015 – 0.016)
Yield with $SPR_{50\%}$ at $B_{40\%}$ (mt)	2,034	(633 – 3,435)
Reference points based on SPR proxy for MSY		
Spawning biomass	75,906	(22,974 – 128,838)
SPR_{proxy}	50.0%	–
Exploitation rate corresponding to SPR_{proxy}	0.015	(0.015 – 0.016)
Yield with SPR_{proxy} at SB_{SPR} (mt)	2,034	(633 – 3,435)
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	64,600	(19,517 – 109,683)
SPR_{MSY}	45.0%	(44.9% – 45.2%)
Exploitation rate corresponding to SPR_{MSY}	0.018	(0.018 – 0.019)
MSY (mt)	2,062	(642 – 3,482)

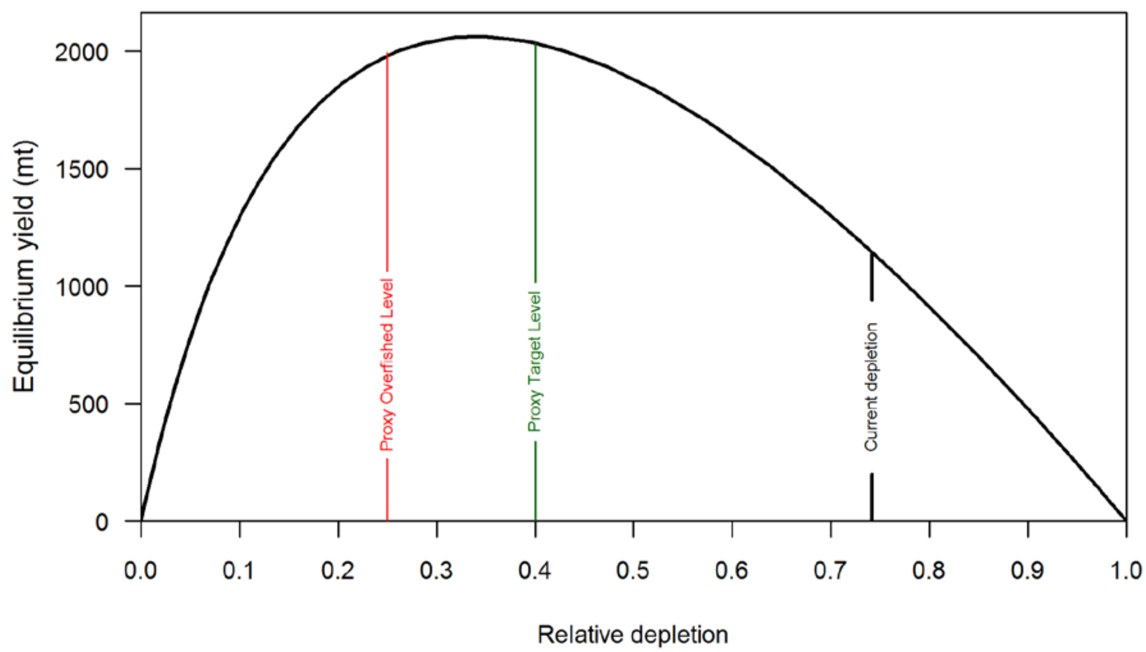

Figure h. Equilibrium yield curve (derived from reference point values reported in Table i) for the base case model. Values are based on 2012 relative catch among fleets. The depletion is relative to unfished spawning biomass.

Management performance

Catches for shortspine thornyheads have not fully attained the catch limits in recent years. Increases in ACLs in 2007 was associated with higher catch levels in 2006–2010, but in 2011 and 2012, catches were about half of the allowed limit. The fishery for shortspine thornyhead may be limited more by the ACLs on sablefish with which they co-occur and by the challenging economics of deep sea fishing, than by the management measures currently in place.

Table f. Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the commercial landings plus the model estimated discarded biomass.

Year	OFL (mt)	ACL (mt)	Commercial Landings (mt)	Estimated Total Catch (mt)
2001	880	751	532	602
2002	1,004	955	762	855
2003	1,004	955	800	903
2004	1,030	983	757	846
2005	1,055	999	654	739
2006	1,077	1,018	703	792
2007	2,476	2,055	1,006	1,058
2008	2,476	2,055	1,427	1,507
2009	2,437	2,022	1,531	1,619
2010	2,411	2,001	1,353	1,431
2011	2,384	1,978	974	994
2012	2,358	1,957	894	911

Unresolved problems and major uncertainties

The absence of a reliable ageing method provides a significant hindrance to estimating growth and natural mortality of shortspine thornyhead. New maturity data made available for this assessment indicate puzzling patterns of maturity, with higher rates of maturity in the north than in the south and a higher fraction of mature fish in the samples with length 20–30 cm than in the samples from 30–40cm. The relative distribution of different sizes of shortspine thornyheads, with smaller fish occurring shallower and further the north, suggests an ontogenetic migration pattern to deeper and more southern waters, with a potentially J-shaped pattern of migration. Understanding the rates and patterns of thornyhead migration and any potential interaction or confounding with spatial patterns of fishing would be valuable for understanding better appropriate ways to model this stock.

The indices of abundance are all relatively flat, providing little information about the scale of the population (other than providing evidence that it has not been declining). The current NWFSC index has the largest number of data points of any available index on the west coast, and each additional year of this index will be valuable for understanding any changes in size composition or abundance. However, in the absence of large changes in shortspine catch, the population is estimated to remain similar to its current state.

Projections and Decision table

The standard deviation of the log of spawning biomass in 2013 is σ = 0.45. The SSC assigned this shortspine thornyhead assessment to Category 2, which is associated with a minimum value of σ = 0.72 for adjustment of quotas based on scientific uncertainty (a process referred to by the notation "*p**"). The Pacific Fisheries Management Council chose a *p** value of 0.40 for shortspine thornyheads, which leads to a multiplication of the OFL by 83.3%, which is the 40% quantile of a log-normal distribution with σ = 0.72. Twelve-year projections were conducted with a total catch assumed equal to the ACL calculated by applying this adjustment to the estimated OFL for each year. The retention function and allocation of catch among fleets was assumed to match the average values for 2011–2012 (the only years in which the trawl fishery was operating under IFQs). This allocation between fleets was 43% for Trawl North, 32% for Trawl South, 3% for Non-trawl North, and 22% for Non-trawl South. Catch for 2013–2014, the limits on which have already been set, were assumed to equal the averages over 2011–2012, which correspond to a total catch of 952 mt and landings of 933 mt after applying the estimated retention function to the age structure of the population in 2013. The 933 mt value is identical to the average of the retained catch for the years 2011–2012, suggesting that the choice to model forecast catches in terms of total catch rather than landings has little influence on the forecast results.

This default harvest rate projection applied to the base model indicated that the stock status would slowly decline from 74.2% in 2013 to 68.1% in 2024, still far above the 40% biomass target and 25% minimum stock size threshold. The associated OFL values over the period 2015–2024 would average 3,080 mt and the average ACL would be 2,566. These values are above recent catch limits, which have not been fully attained in recent years. In these projections, the stock status was always above 40%, so the 40-10 adjustment in the control rule had no impact on the projections.

Table g. Projection of potential OFL, landings, and catch, summary biomass (age-1 and older), spawning biomass, and depletion for the base case model projected with status quo catches in 2013 and 2014, and catches at the *p adjustment (83.3%) from the OFL from 2015 onward. The 2013 and 2014 OFL's are values specified by the PFMC and not predicted by this assessment. The OFL for 2015 and onward is the calculated total catch determined by F_{SPR}.**

Year	Predicted OFL (mt)	ACL Catch (mt)	Landings (mt)	Age 1+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2013	2,333	1,836	933	243,824	140,753	74.2%
2014	2,333	1,836	933	243,316	140,342	74.0%
2015	3,203	2,668	2,616	242,845	139,977	73.8%
2016	3,173	2,643	2,592	240,549	138,660	73.1%
2017	3,144	2,619	2,568	238,299	137,389	72.4%
2018	3,116	2,596	2,545	236,097	136,157	71.8%
2019	3,089	2,573	2,522	233,944	134,954	71.1%
2020	3,063	2,551	2,500	231,842	133,773	70.5%
2021	3,038	2,531	2,480	229,790	132,614	69.9%
2022	3,014	2,511	2,460	227,790	131,477	69.3%
2023	2,991	2,492	2,441	225,841	130,366	68.7%
2024	2,970	2,474	2,423	223,943	129,282	68.1%

Additional projections were conducted for the base model and low and high states of nature (columns) under three catch streams (rows). The uncertainty in spawning biomass associated with the base model was very broad, so states of nature were chosen based on this range. The low state of nature was chosen from a profile over the equilibrium recruitment parameter as a model which had an estimate of 2013 spawning biomass closest to the 12.5th percentile of the spawning biomass distribution in the base model. This represents the middle of the lower 25% of probabilities in the base model. The high state of nature was not chosen in the same way, however, as 87.5th percentile of the base model did not encompass the range of models seen in sensitivity analyses as plausible alternatives. Instead, the high state of nature was taken as the model in the profile over the equilibrium recruitment that had a change in negative log-likelihood equal to 1.2 units, which is an alternative way to calculate the approximate center of the upper 25% of probable possibilities. This high state better reflected the asymmetry in uncertainty about the scale of the population (with more information about the lower range than the upper range of probable population sizes).

The catch streams chosen for the decision table were represented as total catch rather than landed catch, but discard rates were low under IFQs, so the difference in between total catch and landings is small. The low catch stream was assumed to have total catch equal to the average over the years 2011–2012, the years in which the trawl fishery was operating under IFQs was used as a low catch stream. This was a total catch of 952 mt divided among the fleets by the fraction. The high catch stream was chosen based on applying the SPR = 50% default harvest control rule to the base model, including a *p** = 0.40 offset which reduced the catch to 83.3% of the OFL. The middle catch stream was chosen to stabilize the stock status at approximately 60% of the unfished equilibrium (based on an exploratory 100-year forecast). This was achieved by using an SPR = 65% with a 94.2% adjustment to the OFL (based the *p** = 0.45 and sigma = 0.475 associated with the Category 1 classification which was the default at the time of the assessment review). The average total catch for the years 2015–2024 was 952 mt for the low catch stream, 1,795 for the middle catch stream, and 2,566 for the high catch stream.

The stock status remained above 40% in all years, regardless of the state of nature or management decision. The most pessimistic forecast scenario, combining the low state of nature with the high catch stream, resulted in a projected stock status of 41.6%, just above the target value. All other projections led to a higher projected status, with a maximum of 89.1% for the combination of the high state of nature and low catch. Forecasts under the base case led to estimated status ranging from 2024 spawning depletion values of 68.1% in the high catch stream to 72.9% in the low catch stream.

No projections were done to explore changes in ratio of trawl to non-trawl or north to south. Due to differences in selectivity and retention among the fleets, these projections could be expected to provide slightly different results, although the general pattern of the projections suggesting stocks above target levels as described above is unlikely to change as a result of alternative ratios among the fleets.

Table h. Summary table of 12-year projections beginning in 2015 for alternate states of nature based on an axis uncertainty. Columns range over low, mid, and high state of nature, and rows range over different assumptions of catch levels.

			State of nature					
			Low		Base case		High	
Relative probability of log(R_0)			0.25		0.5		0.25	
Management decision	Year	Total catch (mt)	Spawning biomass (1000 mt)	Depletion	Spawning biomass (1000 mt)	Depletion	Spawning biomass (1000 mt)	Depletion
Status quo catches	2015	952	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	952	54.1	53.2%	139.7	73.6%	405.1	88.8%
	2017	952	53.7	52.8%	139.4	73.5%	405.1	88.9%
	2018	952	53.3	52.4%	139.2	73.3%	405.2	88.9%
	2019	952	52.9	52.0%	139.0	73.2%	405.4	88.9%
	2020	952	52.6	51.7%	138.8	73.1%	405.5	88.9%
	2021	952	52.2	51.4%	138.6	73.1%	405.7	89.0%
	2022	952	51.9	51.0%	138.5	73.0%	405.8	89.0%
	2023	952	51.6	50.8%	138.4	72.9%	406.0	89.0%
	2024	952	51.4	50.5%	138.2	72.9%	406.1	89.1%
Catch associated with SPR = 65%, stabilizing population around 60% of B_0	2015	1,828	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	1,819	53.6	52.7%	139.2	73.3%	404.6	88.7%
	2017	1,812	52.7	51.8%	138.4	72.9%	404.1	88.6%
	2018	1,804	51.8	50.9%	137.6	72.5%	403.7	88.5%
	2019	1,797	50.9	50.0%	136.9	72.1%	403.3	88.5%
	2020	1,790	50.0	49.1%	136.2	71.8%	402.9	88.4%
	2021	1,784	49.1	48.3%	135.5	71.4%	402.6	88.3%
	2022	1,778	48.3	47.5%	134.9	71.1%	402.2	88.2%
	2023	1,773	47.5	46.7%	134.2	70.7%	401.8	88.1%
	2024	1,768	46.7	45.9%	133.6	70.4%	401.5	88.1%
OFL (associated with SPR = 50%), including *p** offset (83.3%)	2015	2,668	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	2,643	53.1	52.2%	138.7	73.1%	404.1	88.6%
	2017	2,619	51.7	50.8%	137.4	72.4%	403.1	88.4%
	2018	2,596	50.3	49.4%	136.2	71.8%	402.2	88.2%
	2019	2,573	48.9	48.1%	135.0	71.1%	401.4	88.0%
	2020	2,551	47.5	46.7%	133.8	70.5%	400.5	87.8%
	2021	2,531	46.2	45.4%	132.6	69.9%	399.7	87.7%
	2022	2,511	44.9	44.1%	131.5	69.3%	398.8	87.5%
	2023	2,492	43.6	42.8%	130.4	68.7%	398.0	87.3%
	2024	2,474	42.3	41.6%	129.3	68.1%	397.2	87.1%

Table i. Summary table of the results.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Commercial landings (mt)	800	757	654	703	1,006	1,427	1,531	1,353	974	894	NA
Estimated Total catch (mt)	903	846	739	792	1,058	1,507	1,619	1,431	994	911	NA
OFL (mt)	1,004	1,030	1,055	1,077	2,476	2,476	2,437	2,411	2,384	2,358	2,333
ACL (mt)	955	983	999	1,018	2,055	2,055	2,022	2,001	1,978	1,957	1,836
1-SPR	18%	18%	16%	17%	22%	30%	31%	28%	20%	19%	NA
Exploitation rate (catch/ age 1+ biomass)	0.0036	0.0034	0.0029	0.0032	0.0042	0.0061	0.0065	0.0058	0.0041	0.0037	NA
Age 1+ biomass (1000 mt)	252.0	251.2	250.6	250.0	249.5	248.7	247.4	246.1	245.0	244.3	243.8
Spawning Biomass (1000 mt)	146.0	145.5	145.0	144.7	144.3	143.8	143.1	142.3	141.6	141.2	140.8
~95% Confidence Interval	16.1 – 275.8	15.5 – 275.5	15.0 – 275.1	14.5 – 274.8	14.1 – 274.6	13.4 – 274.2	12.6 – 273.7	11.6 – 273.0	10.8 – 272.5	10.2 – 272.1	9.7 – 271.8
Recruitment (millions)	20.6	22.5	27.2	32.7	33.0	30.9	30.2	30.5	27.4	28.8	NA
~95% Confidence Interval	7.3 – 57.9	7.9 – 64.1	9.3 – 79.5	10.9 – 98.5	10.8 – 100.8	10.1 – 94.3	9.9 – 92.4	9.9 – 93.5	9.0 – 83.7	9.3 – 89.3	NA
Depletion (%)	76.9%	76.7%	76.4%	76.2%	76.1%	75.8%	75.4%	75.0%	74.6%	74.4%	74.2%
~95% Confidence Interval	61.3% – 92.5%	60.8% – 92.5%	60.4% – 92.5%	60.0% – 92.4%	59.7% – 92.4%	59.2% – 92.4%	58.4% – 92.4%	57.7% – 92.3%	57.0% – 92.3%	56.5% – 92.3%	56.1% – 92.3%

Research and data needs

Research and data needs for future assessments include the following:

1) More investigation into maturity of shortspine is necessary to understand the patterns in maturity observed in the samples collected in 2011 and 2012.
2) Information on possible migration of shortspine thornyheads would be valuable for understanding stock dynamics. Analysis of trace elements and stable isotopes in shortspine otoliths may provide valuable information on the extent of potential migrations. Possible connections between migration and maturity could likewise be explored.
3) A greater understanding of catchability of thornyheads would help define the scale of the populations. This could include a survey using a towed camera to assess the abundance in water beyond the 1280 m range of the trawl surveys. Further exploration of perceived differences in catchability between towed cameras and trawl nets could also be explored. Understanding the relative catchability of shortspine and longspine thornyhead, which are difficult to distinguish in camera observations, would have to be a component of such investigations. Differences in selectivity between the AFSC Slope survey and the NWFSC surveys may be the result of behavioral interactions with different footropes. Understanding these interactions would also improve understanding of catchability.
4) Age data would be valuable for future stock assessments. Otoliths have been collected in good quantities from the NWFSC survey, but at this time the ageing methods are not believed to be reliable. Additional research on ageing methods for thornyheads would be valuable.
5) A greater understanding of the connection between thornyheads and bottom type could be used to refine the indices of abundance. Thornyheads are very well sampled in trawlable habitat, but the extrapolation of density to a survey stratum could be improved by accounting for the proportion of different bottom types within a stratum and the relative density of thornyheads within each bottom type.
6) A comprehensive catch reconstruction for shortspine and longspine thornyheads should be completed to estimate landings for each species prior to 1981 in each of the three states.
7) Exploration of simpler assessment methods for thornyheads and evaluation of whether such methods would provide a more robust management strategy than the current approach. It is likely that any significant reduction in the size of the shortspine thornyhead population would be apparent in the NWFSC Combo Survey index. A method for setting and/or adjusting catch limits based on either absolute values or trends in the survey has the potential to be much less labor intensive than the current assessment approach.
8) More tows or visual surveys south of 34.5 deg. N. lat. including the large Cowcod Conservation Area. Because the southern Conception Area is a large potential habitat for thornyheads, more sampling effort would help refine the estimations of their abundance in this area.

1 Introduction

1.1 Distribution

Shortspine thornyhead (*Sebastolobus alascanus*) are found in the waters off of the West Coast of the United States from northern Baja California to the Bering Sea. They are found from 20 to over 1,500 meters in depth. The majority of the spawning biomass occurs in the oxygen minimum zone between 600 and 1,400 meters, where longspine thornyheads are most abundant (Jacobson and Vetter 1996, Bradburn et al. 2011). The distribution of the smallest shortspine thornyheads suggests that they tend to settle at around 100–400 meters and are believed to have ontogenetic migration down the slope, although large individuals are found across the depth range.

Shortspine thornyhead do not appear to be distributed evenly across the West Coast, with higher densities (kg/ha) of thornyheads in shallower areas (under 500 meters) off of Oregon and Washington, and higher densities in deeper areas off of California (Figure 4–Figure 9). The mean latitude of the largest shortspine is slightly further north than of the medium sizes, suggesting the possibility of either a J-shaped migration, differential patterns of recruitment, or regional differences in exploitation history (Figure 9).

Although their densities vary, shortspine thornyheads are present in almost all trawlable areas below 500 m. They are caught in 91% of the trawl survey hauls below 500 m and 94% of the commercial bottom trawl hauls below 500 m. In camera-tows, thornyheads are seen to be spaced randomly across the sea floor (Wakefield 1990), indicating a lack both of schooling and territoriality.

1.2 Stock structure

Genetic studies of stock structure do not suggest separate stocks along the west coast. Siebenaller (1978) and Stepien (1995) found few genetic differences among shortspine thornyheads along the Pacific coast. Stepien (1995), however, did suggest that there may be a separate population of shortspine thornyhead in the isolated area around Cortes Bank off San Diego, California. Stepien (1995) also suggested that juvenile dispersion might be limited in the area where the Alaska and California currents split. This occurs towards the northern boundary of the assessment area, near 48° N.

Stepien et al. (2000), using a more discerning genetic material (mtDNA), found evidence of a pattern of genetic divergence corresponding to geographic distance. However, this study, which included samples collected from southern California to Alaska, did not identify a clear difference between stocks even at the extremes of the range. No such pattern was seen in longspine thornyhead, which suggests that the shorter pelagic stage (~1 yr vs. ~2 yrs) of shortspine may contribute to an increased genetic separation with distance.

1.3 Life History

Shortspine thornyheads along the West Coast spawn pelagic, gelatinous masses between December and May (Wakefield, 1990; Erickson and Pikitch, 1993; Pearson and Gunderson, 2003). Juveniles settle at around 1 year of age (22- 27 mm in length), likely in the range of 100-200 m (Vetter and Lynn 1997), and migrate down the slope with age and size, although large individuals are found across the depth range.

Estimates of natural mortality for shortspine thornyhead range from 0.013 (Pearson and Gunderson 2003) to 0.07 (Kline 1996). However, Pearson and Gunderson's estimate is based upon a regression model, using the gonadosomatic index as a proxy. Butler et al. (1995) estimated M to be 0.05 based upon a maximum lifespan of over 100 years for shortspine thornyhead. Butler et al. also suggested that M is lower for older, larger shortspine thornyhead residing in the oxygen minimum zone due to lack of predators. All estimates of M for thornyheads are highly uncertain.

Shortspine thornyhead grow very slowly, but may continue growing throughout their lives, reaching maximum lengths of over 70 cm. Females appear to reach larger sizes than do males. Maturity in females has been estimated as occurring near 18 cm, at 8-10 years of age (Pearson and Gunderson 2003), although new information suggests that patterns of maturity may be more complex.

1.4 Ecosystem Considerations

Shortspine and longspine thornyheads have historically been caught with each other and with Dover sole and sablefish, making up a "DTS" fishery. Other groundfishes that frequently co-occur in these deep waters include a complex of slope rockfishes, rex sole, longnose skate, roughtail skate, Pacific grenadier, giant grenadier, Pacific flatnose as well as non-groundfish species such as Pacific hagfish and a diverse complex of eelpouts. Shortspine thornyheads typically occur in shallower water than the shallowest longspine thornyheads, and migrate to deeper water as they age. When shortspines have reached a depth where they overlap with longspines, they are typically larger than the largest longspines. Shortspine thornyhead stomachs have been found to include longspine thornyheads, suggesting a predator-prey linkage between the two species.

Thornyheads spawn gelatinous masses of eggs which float to the surface. This may represent a significant portion of the upward movement of organic carbon from the deep ocean (Wakefield, 1990). Thornyheads have been observed in towed cameras beyond the 1280 meter limit of the current fishery and survey, but their distribution, abundance, and ecosystem interactions in these deep waters are relatively unknown.

1.5 Fishery Information

The history of fishing for thornyheads has seen fluctuations due to a combination of increasing depth range of the fisheries, variable markets, and changes in fisheries management.

There were few markets for thornyheads in the early part of the century. Landings were minimal until the 1930's when thornyheads started to be landed as incidental catch from the sablefish fishery off California. In the early years, there was relatively little trawling in the depths where the majority of thornyheads occur. The first significant market for thornyheads began in northern California in the early 1960's. At first, larger (30-35 cm) thornyhead were sold as "ocean catfish". The minimum size decreased to 25 cm by the early 1980's. In the late 1980's a market for small thornyheads (~20 cm) developed because of the depletion of a related species (*Sebastolobus machrochir*) off of Japan. The fishery started moving into deeper waters with the demand for smaller (and thus longspine) thornyheads increased over time. This can be seen as the proportion of shortspine in the total thornyhead landings decreased from around 90% in 1981 to 40% in 1994 (before regulation lowered it even more in 1995) (Figure 3).

Landings of shortspine thornyheads off the coast of California peaked around 3,500 mt in 1989, and have exceeded those from further north in most years. In the northern area off of Oregon and Washington, the fishery became significant in the early 1980's, with landings peaking in 1991 at around 2200 mt.

Non-trawl landings of shortspine thornyheads were relatively low prior to the mid-1990s, at which point the non-trawl (mostly longline) landings in California began to increase steadily from less than 5 mt in 1994 to 237 mt in 2011. This increase, combined with decreases in trawl landings in California, has made these two components similar in magnitude in that area. The increase in non-trawl landings has been driven by the development of live-fish markets for thornyheads, and the ex-vessel prices associated with the non-trawl landings are much higher than those for the trawl fishery. Nominal prices for line-caught shortspines increased steadily from $0.69/lb in 1993 to $3.81/lb in 2008, and have remained near or above that level, since. Trawl prices, on the other hand were $0.46/lb and $0.72/lb at the beginning and end of that same period, though they were commonly in the $0.80–1.06/lb range in the interim, when Japanese demand was stronger. Non-trawl landings of shortspine in Washington and Oregon have not seen a similar increase, and have remained below the estimated peak of 54 mt in 1991 since that time.

The foreign fishery off of the West Coast is estimated to have caught approximately 7,400 mt of shortspine thornyhead during the 11 year period from 1966-1976 (Rogers, 2003), which is on the order of the estimate of domestic catch (~8,600 mt) during that same period.

Management measures contributed to a decline in coastwide landings from an estimated peak of 4,815 in 1989 to between 1,000 and 2,000 mt per year from 1995 through 1998. Landings fell below 1,000 mt per year from 1999 through 2006, then rose to 1,531 in 2009 and have declined since that time (Table 1).

1.6 Summary of Management History

Beginning in 1989, both thornyhead species were managed as part of the deepwater complex with sablefish and Dover sole (DTS). In 1991, the Pacific Fishery Management Council (PFMC) first adopted separate ABC levels for thornyheads and catch limits were imposed on the thornyhead group. Harvest guidelines (HG) were instituted in 1992 along with an increase in the minimum mesh size for bottom trawl fisheries. In 1995 separate landing limits were placed on shortspine and longspine thornyheads and trip limits became more restrictive. Trip limits (predominantly 2-month limits on cumulative vessel landings) have often been adjusted during the year since 1995 in order to not exceed the HG or OY for that year. At first, the HG for shortspine thornyhead was set higher than the ABC (1,500 vs. 1,000 mt in 1995-1997) in order to allow a greater catch of longspine thornyhead, which was considered relatively undepleted. In 1999 the OY was set at less than 1,000 mt and remained close to that level through 2006. As a result of the 2005 shortspine assessment, catch limits increased to about 2,000 mt per year and have remained near that level to the present.

Since early 2011, trawl harvest of each thornyhead species has been managed under the PFMC's catch share, or individual fishing quota (IFQ), program. Whereas the trip limits previously used to limit harvest restricted only the amount of fish each vessel could land, individual vessels fishing under the catch-share program are now held accountable for all of the quota-share species they catch.

1.7 Management Performance

Landings of shortspine thornyhead have been below the catch limits since 1999. Estimated total catch, including discards, has likewise remained below the limit during this period (Table 2).

1.8 Fisheries off Canada, Alaska, and/or Mexico

The Alaska Fishery Science Center conducts assessments of thornyheads as a mixed stock complex, including shortspine and longspine thornyheads. The 2011 assessment reports that "It is unlikely that thornyheads are overfished or approaching overfished condition", however noting that fishing in the Western Gulf of Alaska approaches the ABC for the complex (Murphy and Ianelli, 2011).

2 Assessment

2.1 Data

An overview of the data sources available for each combination of fleet and year is provided in Figure 15.

2.1.1 Biology

Natural mortality and longevity

Butler et al. (1995) estimated the lifespan of shortspine thornyhead to exceed 100 years, and suggested that M was likely less than 0.05. M may decrease with age as shortspine migrate ontogenetically down the slope to the oxygen minimum zone, which is largely devoid of predators for fish of their body size. The previous assessment fixed the natural mortality parameter at 0.05. For this assessment, a prior on natural mortality was developed based on a maximum age of 100 years which had a mean of 0.0505 and a standard deviation on a log scale of 0.5361 (Hamel, pers. comm.). For the base case, natural mortality was fixed at the mean of this prior distribution.

Length-weight relationship

The length-weight relationship for shortspine thornyhead was calculated from 10,787 fish collected in the NWFSC trawl survey over the years 1999-2012. Males and females showed very similar patterns so a single relationship was used for both sexes. Unsexed fish were excluded from the analysis. The unsexed fish were primarily small fish which have little influence on the conversion of numbers to biomass in the model, but including them in the estimation resulted in a reduction of fit to the larger fish. This may have been caused by less relative precision in the scale for weights below 0.05 kg. The estimated mean weight at length (Figure 11) is

$$W(L) = 4.771\text{E-}6 \cdot L^{3.263},$$

where L is length in cm and W is weight in kg. This is very similar to the values from Jacobson (1990) used in the previous assessment,

$$W(L) = 4.9\text{E-}6 \cdot L^{3.264}.$$

Length at age

No new age data or information on growth or length at age has been developed since the previous assessment. Therefore, growth parameters were fixed at the same values used in 2005. These parameters were based on the Kline (1996) data, while accounting for differences in maximum size between the sexes by setting the length at age 100 for males to be 90% of that of females. The Von Bertalanffy K parameter is set to 0.018, a choice that fit the data well, while accounting for biases towards larger individuals among the younger ages (Hamel, 2005). Length at age 2 is set to 7 cm for both males and females, and average length at age 100 is 75 cm and 67.5 cm respectively.

Maturation and fecundity

Pearson and Gunderson (2003) estimated length at 50% maturity to be 18.2 cm on the West coast. With most females maturing between 17 and 19 cm. This was represented in the previous assessment by the logistic function,

$$M(L) = (1 + e^{-2.3\cdot(L-18.2)})^{-1},$$

where L is the length in cm.

Shortspine thornyhead ovaries were collected for maturity analysis on the NWFSC trawl survey in 2011 (N = 130) and 2012 (N = 160). Histological analysis of these samples (M. Head, pers. comm.) indicated puzzling patterns of spawning, with a higher fraction of fish spawning within most size bins in the north than in the south, and a higher fraction of spawning fish in the samples with length 20-30 cm than in the larger fish in the 30-40cm range (Figure 10, Figure 12). In general it is difficult to differentiate immature thornyheads from mature thornyheads that were not spawning (Pearson and Gunderson, 2003), so in this assessment “maturity” is used to indicate fish that were both mature and showed indication of spawning, and “immature” may refer to fish that are resting. Atresia was observed in relatively few samples. One hypothesis that could explain the spatial patterns in spawning would be different migration directions associated with mature and immature fish. Alternatively, environmental conditions could have influenced the growth and maturity in different locations and depths.

The complexity of the observed patterns of maturity suggest that the 290 samples collected in 2011 and 2012 were not adequate to estimate a new maturity curve to be used as representative of the shortspine thornyhead population throughout the assessment period, and more ovaries are expected to be collected in the 2013 survey. Ovaries from winter months, when the survey is not operating, may also be needed to understand the ability to accurately estimate maturity throughout the year. For the base model, the maturity curve was retained from the previous assessments. Sensitivity analyses were conducted using alternative maturity curves based on the new samples. In the most extreme sensitivity, the empirical estimates of maturity in each 2cm length bin were used in the alternative model. An intermediate pattern was also developed by multiplying the logistic maturity ogive used in the previous assessment by a maximum fraction of mature or spawning fish which was assumed to increase linearly from 50% at 20 cm to 100% at 70cm,

$$f(L) = 0.3 + 0.01 \cdot L.$$

The maturity ogive used in this alternative was the product of the linear and logistic functions,

$$M(L) = (0.3 + 0.01 \cdot L) \cdot (1 + e^{-2.3 \cdot (L-18.2)})^{-1}.$$

Sizes beyond 70cm were assumed to be 100% mature.

These base model and alternative maturity curves are shown in Figure 12. The spawning output of each size used in the calculation of spawning biomass is the product of the length-weight relationship and the maturity ogive under the assumption that fecundity of mature, spawning fish is proportional to weight (Figure 13). The slow but steady rate of growth for shortspine thornyheads, with growth still occurring at age 100, reduces the importance of assumptions about maturity because older individuals will have significantly higher spawning output due to their much larger size, regardless of the fraction spawning.

2.1.2 Catch History

PacFIN data from 1981-present was used to estimate landings in the north and south (Table 1, Table 2, Figure 1). All landings reported for the shortspine and nominal shortspine categories were considered shortspine, whereas landings placed in the thornyheads category were split between longspine and shortspine by the ratio of specified longspine and shortspine landings for the entire coast. The values of this ratio from 1981-2012 are shown in Figure 3. The fraction of unspecified thornyheads in the landings was around 20% in the 1980s, but has averaged 2% of the landings from 1988 onward (Figure 3).

Catches prior to 1981 were set equal to those used in the previous model, rather than to the reconstructed history provided by CDFW and ODFW for most West Coast assessments. The California catch reconstruction did not split unspecified thornyheads into the two species. Furthermore, the recordings of longspine thornyhead prior to 1981 (e.g. 0.2 mt in 1977) are so low that the ratio of specified catch is not likely to be representative of the true ratio. The impact on the shortspine assessment of assuming all pre-PacFIN catch was shortspine is smaller than the impact of this assumption on the longspine assessment, but using the catch reconstruction for one species and the values from the previous assessment for another would risk double counting catch. Therefore, the catch from the previous assessments, both of which had a thorough independent review, were used for both species in the current assessments for the years prior to 1981. A sensitivity analysis indicated that the differences in these alternative assumptions about historical catch had very little impact on the model results (Figure 62, Figure 63).

2.1.3 Discards and retention

Discard rates were estimated from three periods. The first estimates for the years 1985–1987 were calculated from Oregon State University observer study (Pikitch et al., 1988), which included data from only the Trawl North fleet. The second set covered the years 1995–1999 using the Enhanced Data Collection Project (EDCP), which again only included data from the Trawl North fleet. The third, and most precise set of estimates covered the years 2002–2011 using the ongoing West Coast Groundfish Observer Program (WCGOP), which included samples from all four fleets used in the base model.

Discard rates and associated uncertainty were newly calculated from the early discard study (J. Wallace, pers. comm.) and the WCGOP data (J. Jannot, pers. comm.). The EDCP discard rates and uncertainty intervals were retained from the previous assessment as the raw data were not obtained in time to do a reanalysis of these rates. For the other three fleets, discard rates were only available for the years 2002–2011 from the WCGOP database.

2.1.4 Fishery Length Compositions

Fishery size-composition data were obtained from PacFIN for 1978-2012. The number of fish sampled by port samplers from different trips has not been proportional to the amount of landed catch in these trips. Sampling effort has also varied among the states. In order to account for non-proportional sampling and generate more representative length-frequency distributions, the observed length data were expanded using the following algorithm:

1. Length data were acquired at the trip level by sex, year and state.
2. The raw numbers in each trip were scaled by a per-trip expansion factor calculated by dividing the total weight of trip landings by the total weight of the species sampled.
3. A per-year, per-state expansion factor was computed by dividing the total weight of state landings by the total weight of the species sampled for length in the state.
4. The per-trip expanded numbers were multiplied by the per-state expansion factor and summed to provide the coastwide length-frequency distributions by year.

Only randomly collected samples were used. The sample sizes associated with the length compositions from the fishing fleets are shown in Table 3 (landings) and Table 4 (discards). The length samples from the Trawl North fleet in the years 1994 and 1995 showed a very different pattern than the surrounding years (and different from each-other). The sample sizes for these years was lower than most other years, so the observed differences are more likely due to non-representative than changes in the fishery or population. Therefore these two years were not included in the base model. This change made very little difference in model results.

In camera-tows, thornyheads are seen to be spaced randomly across the sea floor (Wakefield 1990), indicating a lack both of schooling and territoriality. This likelihood contributes to the conclusion in a bootstrapping analysis by Stewart and Hamel (2013), that “thornyheads had the highest average effective sample size per haul…and also the greatest independence among fish within tows”. Based on these findings, the input samples sizes for both fishery and survey length compositions were calculated from the number of fish sampled in each year, independent of the number of hauls from which these fish were collected. The input sample sizes were set to $N_{input} = N_{sampled}{}^{0.6}$, which is an approximation to the pattern found by Stewart and Hamel (2013; their figure 4D). The input sample sizes were further tuned in the manner suggested by Stewart and Hamel (2013). This involved adjusting the input sample size so that the arithmetic mean of the input length composition sample sizes for each fleet was similar to the harmonic mean of the estimated effective sample sizes for that fleet (Table 7). The tuning was not updated after changes to the model were made in the review panel, but the resulting differences in adjusted input and effective samples sizes were viewed by the reviewers as small enough to remain present in the final base model.

All length data from commercial fisheries included in the model with sexes combined. This avoids the possibility of bias due to difficulty in sex determination of thornyheads (also see notes below on sex ratios in survey data).

2.1.5 Age Compositions

No age composition data was used for this assessment, because thornyheads have proven very difficult to age (P. MacDonald, pers. comm.). Even in directed studies such as those done by Kline (1996) and Butler et al. (1995) there are large inter-reader differences and a second reading by the same ager can produce a markedly different result. Kline (1996) reported only about 60% of the multiple reads were within 5 years of each other and inter-reader differences were as large as 24 years for a sample of 50 otoliths. No production ageing of thornyheads is undertaken at this time for the west coast, although shortspine thornyhead otoliths are routinely collected in the NWFSC trawl survey.

2.1.6 NMFS Surveys

Four trawl surveys have been conducted on the U.S. west coast over the past four decades. The Alaska

Fisheries Science Center (AFSC), conducted a triennial groundfish trawl survey on the continental shelf, from 1977 to 2001, although the 1977 survey had incomplete coverage and is not believe to be comparable to the later years. A final survey was conducted in 2004 by the NWFSC using the same survey design. In 1995, the timing of the survey shifted so that instead of occurring between mid-July and late September, it was conducted from early June through mid-August. The years 1980–1992 had a maximum depth of 366 m, while from 1995 onward, the maximum depth was extended to 500 m. The shallow limit of the survey was 55 m in all years, but for purposes of computing indices, only tows deeper than 100 m were used as shortspines are rarely seen at less than this depth.

For some species the shift in timing between the 1992 and 1995 surveys would be expected to influence their catchability, availability, or distribution. However, thornyheads are believed to be sedentary enough that the change in timing would not be as influential. However, the increase in depth is expected to significantly increase the range of shortspine thornyhead habitat covered by the survey. In order to preserve a time-series of maximum length while eliminating the influence of the increase depth range, the triennial survey was split into two time series, separated by the 366 m depth contour. The first, here referred to as "AFSC Triennial Shelf Survey 1", consists of 9 data points, every third year spanning the range 1980–2004 covering the depths 100–366 m. The second, "AFSC Triennial Shelf Survey 2", consists of 4 data points spanning the years 1995–2004 and covering the depths 366–500 m. This second time series is recognized as providing little information about stock status due to the limited number of points and limited depth range, but there is no compelling reason to exclude it from the assessment.

Starting in the late 1990s, two slope surveys were conducted on the west coast, one using the research vessel Miller Freeman, "AFSC Slope Survey", which ended in 2001, and the other a cooperative survey using commercial fishing vessels, conducted by the Northwest Fisheries Science Center, "NWFSC Slope Survey" which covered the years 1998–2002. The AFSC Slope Survey was a source of valuable information on the depth distribution and overlap of shortspine and longspine thornyheads in the 1980s, but the early years had very limited latitudinal range. This survey also had a different net and larger roller gear than the NWFSC Slope Survey.

In 2003, the design of the NWFSC Slope Survey was modified and the survey was expanded to cover the shelf and slope between 50 m and 1280 m. This combination shelf-slope survey, "NWFSC Combo Survey", has been conducted every year from 2003 to the present with consistent design. Data for the years 2003–2012 were available for this assessment. The NWFSC Combo Survey now represents the largest number of survey observations, the largest depth range, and the most consistent groundfish sampling program in the history of west coast fisheries. Continuing this time series in a consistent manner is vital for improving estimates of current stock status and detecting any future changes in size distribution or abundance of west coast groundfish.

The results from these four (nominally five) fishery-independent surveys are used in this assessment (Figure 18; Table 6). Indices of abundance for all of the surveys were derived using a delta-generalized linear mixed model (GLMM) following the methods of Thorson and Ward (2013). The surveys were stratified by latitude and depth, and vessel-specific differences in catchability (via inclusion of random effects for the NWFSC surveys and fixed effects for the AFSC and Triennial survey) were estimated for each survey time series. The Delta-GLMM approach explicitly models both the zero and non-zero catches and allows for skewness in the distribution of catch rates. Gamma error structures were assumed for the positive tows although log-normal error produced essentially identical results. Model convergence was evaluated using the effective sample size of all estimated parameters (typically >500 of more than 1000 kept samples would indicate convergence).

The stratification for the surveys was as follows. A single stratum was used for each of the AFSC Triennial Shelf Survey time series, as these had a narrow depth range. The AFSC Slope Survey was split into two strata: shallower and deeper than 500 m. The NWFSC Slope Survey was divided into 6 strata, with breaks dividing a southern, central, and northern strata at 40.5º N and 43º N, each of which was further divided with a break at 550 m. The NWFSC Combo Survey was divided into 7 strata, with two southern strata below 34.5º N, one covering 183–550 m and the other covering 550–1280 m. Two central strata between 34.5º N and 40.5º N, had the same depth ranges. North of 40.5º N, three strata were used, covering the ranges 100–183 m, 183–550 m and the other covering 550–1280 m. The depth breaks at 183 m and 550 m are associated with changes in sampling intensity of the survey and are recommended to be used. South of 40.5º N, there are very few shortspine thornyheads shallower than 183 m so no shallow stratum was used in these latitudes.

The frequency of occurrence of both shortspine and longspine thornyheads in trawl surveys and fishery is extremely high. 91% of the tows in the NWFSC Combo Survey below 500 m have at least one shortspine thornyhead in the catch (and 97% have at least one longspine). This is similar to the rate for commercial trawl fisheries, which is greater than 94% (a value that doesn't include for trips in which shortspines were landed but not recorded by the observer as associated with a particular tow). The distribution of catch rates among the frequent tows that included shortspine thornyheads showed no evidence of extreme catch events, a pattern which is consistent with the conclusion of Wakefield (1990), that thornyheads in camera-tows are seen to be spaced randomly across the sea floor. Together, the high frequency of occurrence and the low variability in catch between tows lead to model-based (GLMM) index estimates that are very similar to the design-based (raw) estimates (Table 6).

Length-composition data were available for each year of each survey. However, the length data for the triennial survey were collected from a single tow in both 1980 and 1983, so these samples were not included in the model. In all cases, the length compositions were calculated by weighting length compositions in each tow by the estimated catch per unit effort (in terms of numbers rather than biomass) and then weighting the length composition in each chosen stratum.

The number of survey hauls and shortspine thornyheads sampled available for this assessment is described in Table 5. All samples were included in the model with sexes combined with the exception of the NWFSC Combo survey for the years 2005–2012, as this period had a much lower rate of unsexed fish (averaging 16% per year compared to 67% in 2004), suggesting that sexes determination was being done in a more systematic way. This improvement in sex determination was likely informed by the comparison of visual estimates with laboratory analysis described in Fruh et al. (2010) which was based associated with data collected during the 2003 NWFSC Combo survey. The sex ratio of all samples with sex determined collected in 2005 and onward was 50.04%.

2.1.7 Changes in data from the 2005 assessment

Most of the data used in the previous assessment has been newly extracted and processed, including length compositions from each fishing fleet and survey, indices of abundance derived from new GLMM analyses of survey data, discard rates from both the 1980s Pikitch study and the current West Coast Groundfish Observer Program (WCGOP), and the time series of catch from 1981-2012. Data retained from the previous assessment without reanalysis are the estimated historic catch for the years up to 1980 and the discard rates from the EDCP study in the 1990s.

New data for this assessment include the maturity data collected from the NWFSC survey in 2011 and 2012 for use in a sensitivity analysis, the additional WCGOP observations of discards and length compositions from retained and discarded fish. For the 2005 assessment, the NWFSC Combo Survey had just begun in its current configuration, so the data from 2003–2004 were used as an extension of the NWFSC Slope Survey. The NWFSC Combo Survey now has 10 years of observations and was treated as an independent survey for this assessment. Length compositions were developed from this survey and observations of weight-at-length were used in revising the weight-length relationship used in the assessment.

2.1.8 Environmental and Ecological Data

No ecological or environmental information was used in this assessment.

2.2 Model

2.2.1 Overview

The most recent assessment for shortspine thornyhead was conducted in 2005 (Hamel, 2005). Stock status was determined to be above the target biomass and catches did not attain the full management limits so reassessment of thornyheads has not been a higher priority. The current assessment model adds new data from the past 8 years, refines the indices of abundance, separates trawl and non-trawl data and uses a different functional form for selectivity, but otherwise does not diverge in any large way from the previous assessment. This is both testament to the high quality of the work conducted by Hamel (2005) and the absence of any information to suggest that the model structure and assumptions made in 2005 were incorrect.

This new assessment used Stock Synthesis (SS, Methot, 2012) Version 3.24o used in other recent west coast assessments. Additional sensitivities were conducted using Version 3.24q, which has more flexible options to model maturity at length, a change that was made to explore new data for shortspine thornyheads (R. Methot, pers. comm.).

2.2.2 Fishing fleets and surveys

The commercial landings and other data were divided into four fisheries: trawl and non-trawl gears, which are each divided into North (the waters off Washington and Oregon) and South (the waters off California).

Five surveys were represented in the model: a shallower subset of the Alaska Fisheries Science Center (AFSC) triennial shelf survey from 100-366 meters (1980-2004), the deeper range of triennial shelf survey from 366-500 meters for the later years (1995-2004), the AFSC slope survey (1997, 1999-2001), the Northwest Fisheries Science Center (NWFSC) slope survey (1998-2002) and the NWFSC combined shelf-slope survey (2003-2012).

2.2.3 Parameters

2.2.3.1 Overview

There are 223 estimated parameters in the assessment. The log of the unfished equilibrium recruitment, log(R_0), controls the scale of the population, annual deviations around the stock-recruit curve (163 parameters) allow for more uncertainty in the population trajectory, and selectivity and retention of the 4 fishing fleets and 5 surveys, including estimates of changes in retention over time (58 parameters). Finally, there is a single parameter which represents additional variability in one of the surveys that is added to estimated sampling error for that index.

2.2.3.2 Growth, mortality, and recruitment

Growth parameters are fixed at the same values used in 2005 (Table 8, Figure 14). With no age data in the model, the ability to estimate a growth curve is limited, and there was no apparent lack of model fit that indicated that growth was mis-specified. A likelihood profile exploring alternative growth parameters was conducted to estimate the influence of this assumption (Figure 56).

For this assessment, a prior distribution on natural mortality was developed based on a maximum age of 100 years which had a mean of 0.0505 and a standard deviation on a log scale of 0.5361 (Hamel, pers.

comm., Figure 45). For the base case, natural mortality was fixed at the mean of this prior distribution. A likelihood profile exploring alternative natural mortality parameters was conducted (Figure 54).

As in the previous shortspine thornyhead assessment, a Beverton-Holt stock recruitment relationship was assumed with steepness (the fraction of expected equilibrium recruitment associated with 20% of equilibrium spawning biomass) fixed at 0.6. A likelihood profile exploring alternative steepness parameters was conducted and the model results were found to be relatively insensitive to the assumed value (Figure 52).

The scale of the population is estimated through the log of the initial recruitment parameter (R_0). Recruitment deviations were estimated for the years 1850 through 2012, where the values estimated in the years 1850 through 1900 are used to estimate a non-equilibrium age-structure in 1901, which is the first year of the population projection and first year of catch data. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates. The σ_R parameter which controls the variability in recruitment deviations was fixed at 0.5 as in the previous assessment. Methot and Taylor (2011) suggested that σ_R^2 could be tuned to match the sum of the variance of the estimate recruitment deviations and the square of the average standard error of these estimates. Applying this method to the estimated values and their uncertainty for the base model provided a value of 0.526, which was seen as similar enough to the assumed value of $\sigma_R = 0.5$ that no additional tuning was applied. A sensitivity to alternative values of σ_R was conducted including the alternative model with no deviations in recruitment around the stock-recruit curve. These alternative models had similar overall patterns to the base case (Figure 60).

2.2.3.3 Selectivity and retention

Gear selectivity parameters used in this assessment were specified as a function of size with the additional assumption that age 0 fish were not selected, regardless of their size. Separate size-based selectivity curves were fit to each fishery fleet and survey.

The selectivity curves for all fisheries and surveys were allowed to be dome-shaped and modeled with double-normal selectivity. The double-normal selectivity curve was used in a configuration that has four parameters, including: 1) peak, which is the length at which selectivity is first fully selected, 2) width of the plateau on the top, 3) width of the ascending part of the curve, 4) width of the descending part of the curve. For some fleets, the plateau of fully selected lengths was estimated to be of negligible width. In these cases, the 2nd parameter described above often hit the lower bound. Having these parameters against the bound did not appear to lead to convergence problems for any other parameter, and previous attempts to fix these parameters at the lower bound led to the use of incorrect values and necessitated a presentation of errata to the review panel. Therefore, all selectivity parameters remained estimated whether they hit a bound or not.

Retention curves are defined as a logistic function of size. These are controlled by four parameters: (1) inflection, (2) slope, (3) asymptotic retention, and (4) male offset to inflection. Male offset to retention was fixed at 0 (i.e. no male offset was applied). The parameters for inflection and asymptotic retention were modeled as time-varying quantities via use of time blocks, where the definition of the time blocks was chosen to match the data available for each fleet. Although the North Trawl fleet had observed discard rates going back to 1985, there was not clear evidence in the data for a change in retention prior to the 2000s. Therefore, both North Trawl and South Trawl fleets were broken into three periods: (1) 1901–2006, (2) 2007–2010, (3) 2011–2012. The first break was based on observation of a strong reduction in discard rates for both North and South Trawl in this year, while the later break was associated with the beginning of the IFQ program.

The Non-trawl North fleet showed little change in discard rates and has been associated with low levels of landings and small sample sizes of the composition data. Therefore, a single retention function was used for all years for this fleet. Retention for the Non-trawl South fleet was divided into two periods: (1) 1901–2006, and (2) 2007–2012. Like the trawl fleets, this fleet had a reduction in discards in 2007, but the non-trawl catch of thornyheads was not subject to the changes associated with the IFQ program and therefore did not exhibit a further reduction in discards in 2011.

Alternative retention blocking, including breaks in 1989 and 1996 were explored as well as having blocks for every 2-year period starting in 2005. However, the more parsimonious set of blocks chosen for the base model had a very similar fit to the data with many fewer parameters. Selectivity would be expected to shift when larger mesh sizes were adopted by the trawl fishery in the early 1990s. However, exploration of time-varying selectivity did not lead to plausible estimates. In general, changes in markets, gear, and fishery distribution are likely to have occurred far more frequently than what is captured in the base model. However, for the years prior to the WCGOP program, there is little data to accurately capture a larger set of such changes within the assessment model. This suggests that the continued collection of large numbers of length observations from both fishery discards and landings will be valuable to understand any future changes in fishery dynamics and the impact that they may have on thornyhead populations.

The changes between blocks are represented as random walks with normal prior distributions that cause the retention parameters to remain constant across blocks in the absence of additional information suggesting changes over time.

This model depends on the assumptions that thornyheads are long-lived, slow-growing, and relatively sedentary groundfish. They are assumed to represent a single stock within the area considered for this assessment. If the assumptions about growth, natural mortality, or stock structure turn out to be far from the true life history and ecology of shortspine thornyheads, this assessment will be highly inaccurate.

2.3 Model Selection and Evaluation

A variety of model configurations were explored on the way to choosing the base model presented here. The following assumptions were considered but not retained:

- Asymptotic selectivity rather than dome-shaped selectivity. This was associated with poor fits to the length compositions.
- Splitting the AFSC Triennial Survey into an early and a late period with different depth ranges in each, rather than a long shallow time series and a shorter deeper time series. This was associated with large changes in the estimated catchability between the two time periods in spite of similar length compositions.
- Modeling the retention and selectivity as having more frequent changes as described above.

2.3.1 Model Convergence

The ADMB search for maximum likelihood estimates indicated a well-converged model. The base model had a small maximum gradient component of (0.00006) and a positive definite Hessian matrix, both of which are associated with converged models.

Runs with 100 alternative sets of starting parameter values jittered from the base model found no model with a better likelihood (Table 15). Out of the 100 model runs, only 27 returned to the best estimates associated with the base model. This may be an indication that the data do not provide very strong information population dynamics of shortspine thornyheads and a wide range of model estimates can have a somewhat similar likelihood. It may also be related to selectivity parameters hitting bounds as described above.

2.3.2 Stock assessments in Alaska

The stock assessment for shortspine thornyheads in the Gulf of Alaska (Murphy and Ianelli, 2011) is classified as “Tier 5” under the North Pacific Fishery Management Council system. This assessment is based on a swept area biomass estimate from a groundfish trawl survey. The use of this approach is essentially assuming a catchability of 1.0, depending on the interpretation of selectivity (which is not estimated in the assessment). The estimated biomass is 78,795 mt, which is slightly higher in magnitude to the index values estimated from the NWFSC Combo Survey (44,137–58,430). Murphy and Ianelli use a value of $M = 0.03$ to calculate an OFL value of 2,360 mt.

2.4 Response to STAR Panel Recommendations

The STAR panel report associated with the previous shortspine thornyhead assessment in 2005 outlined a number of research and modeling recommendations (Barnes et al. 2005). These are listed below along with notes on what progress has been made toward meeting these recommendations..

1. *Better age information is needed for this stock. As well as more samples, research is needed on how to age this species accurately.*
   Response: no progress has been made toward improved ageing methods for thornyheads. This has been retained as a research recommendation but reduced in priority in recognition that progress in the near future is unlikely.

2. *A survey using a towed camera to assess the abundance in deeper water. The proportion of the stock and its size range in deeper water is unknown.*
   Response: use of towed cameras as well as cameras mounted on AUV and ROV devices has continued in various locations on the west coast. But no systematic survey has been developed, likely due to both the costs involved and the need to work out technical challenges. It is uncertain whether the water beyond 1280 m (700 fathoms), where trawling is currently prohibited would be a high priority if and when the finances and technology were available to conduct such a survey. Better understanding of the density of thornyheads in deeper water has been retained as a research recommendation along with other issues related to the catchability of the populations.

3. *More tows or visual surveys south of 34.5 deg. N. lat. including the area closed for cowcod. Because the southern Conception Area is a large potential habitat for thornyheads, more effort is required to define their distribution in this area.*
   Response: the NWFSC Combo survey has provided much more detail on the abundance and distribution of thornyheads south of Point Conception than any previous survey. However, this survey has not entered the Cowcod Conservation Area. More detailed maps of bottom type and estimates of associations of thornyheads with different sediment types could improve the estimation of thornyheads within the Cowcod Conservation Area even in the absence of additional survey data.

4. *Length frequencies for discards are needed. As well, SS2 should be enhanced to include a more sophisticated description of the discard fraction at length.*
   Response:the WCGOP program has provided excellent information on discards length frequencies and discard rates. This data has been particularly detailed in 2011 due to the increase to full observer coverage of the trawl fishery under the IFQ program. The IFQ program has also led to very low discard rates, which reduces the impact of discarded fish on the dynamics of the population. The options for modeling retention in Stock Synthesis have been enhanced since 2005 and at this point are likely to have more than enough flexibility to capture patterns in the data available.

5. *A critical evaluation of the significance at q's for surveys of absolute abundance when they are far from 1, especially those greater than 1.*
   Response:the interpretation of catchability remains a vexing problem for many west coast groundfish species along with almost every other fish stock assessment around the world. This assessment differed from the previous one in freely estimating the catchability for all surveys. This led to a larger, more realistic portrayal of the uncertainty in population size. Thornyheads are particularly well sampled by trawl surveys, however, and it would be expected that catchability of shortspine and longspine thornyhead might be somewhat comparable if the interaction between selectivity and catchability could be better understood. Research into survey catchability remains a high priority research recommendation.

2.5 Base-Model Results

2.5.1 Spawning biomass and depletion

Unfished equilibrium spawning biomass (B_0) is estimated to be 189,765 mt, with a 95% confidence interval of 57,435 – 322,095 mt. The B_0 estimate represents an increase from the 130,646 mt estimate for B_0 in the previous assessment although this previous estimate falls well within the uncertainty interval around the current estimate. Spawning biomass is estimated to have remained stable until the mid-1970s and then declined from the 1970s to about 80% in the 1990s, followed by a slower decline under the lower catch levels in the 2000s (Table 11, Figure 36). The estimated spawning biomass in 2013 is 140,753 mt, which represents a stock status or "depletion" (represented as spawning biomass in 2013, B_{2013}, divided by B_0) of 74.2% (Figure 37). The depletion estimated for 2005 is 76.4%, which is higher than the 62.9% estimated for 2005 in the previous assessment. The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.45$, which is greater than the 0.36 minimum assumed for use in p^* adjustments to OFL values.

The parameter with the greatest influence on population scale is log(R_0), which was estimated at 10.32 in the base model (in units of 1000s of fish on a log scale). This corresponds to R_0 = 30.4 million age 0 recruits at unfished equilibrium. A full list of parameter estimates for the base model is provided in Table 8–Table 10.

2.5.2 Selectivity and retention

Selectivity was estimated as dome-shaped for all fleets, with the highest degree of dome-shape occurring in the AFSC Triennial Shelf Survey (1 and 2) and for the AFSC Slope Survey. It is not clear why the AFSC Slope Survey, which includes deep waters in which larger shortspines occur, would have such a high degree of dome-shape. However, the footrope and roller gear used by this survey may play a role in the catchability of thornyheads. The length compositions observed for these three fleets with strongly dome-shaped selectivity show a much smaller proportion of large fish than the other fleets.

The estimated selectivity patterns for the four components of the fishery seem reasonable (Table 9, Figure 16). The Trawl North fleet selects smaller fish than the other components, which is consistent with the higher presence of small fish off the coasts of Washington and Oregon where this fleet is designated. Both non-trawl fleets select fewer small fish than the trawl fleets, which is consistent with the expectation that the hooks used in longline gear (which makes up the majority of non-trawl catch) would not select the smallest shortspines. The degree of dome-shape of the fisheries may be somewhat confounded with the assumptions about natural mortality and growth. However, some extent of dome-shaped selectivity is expected to occur for both fisheries and surveys due to the ontogenetic migration of shortspines to deeper water, combined with the lower rates of fishing effort in the deepest waters and the presence of shortspines beyond the deepest extent of the fishery.

Retention is generally estimated to peak at about 40 cm in the early period of the fishery and then shift toward higher retention of smaller fish in the most recent years (Figure 17). The trawl fleets were estimated to have 100% retention of the largest fish while the non-trawl fleets were estimated to have an asymptote slightly below 100%, indicating that a small fraction of all sizes is discarded. This is consistent with the understanding that the landings from non-trawl fisheries are primarily occurring in the live-fish fishery, which represents a relatively small fraction of the fleet operating primarily in Southern California.

2.5.3 Recruitment

This assessment assumed a Beverton-Holt stock recruitment relationship. Steepness (the fraction of expected equilibrium recruitment associated with 20% of equilibrium spawning biomass) was kept at the value of 0.6 that was assumed in the previous assessment, although the results were relatively insensitive to alternative assumptions about steepness. The scale of the population is estimated through the log of the initial recruitment parameter (R_0). Recruitment deviations were estimated for the years 1850 through 2012, where the values estimated in the years 1850 through 1900 are used to estimate a non-equilibrium age-structure in 1901, which is the first year of the population projection. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates (Figure 38, Figure 39).

Recruitment deviations were modeled as recommended by Methot and Taylor (2011). This involved estimating the uncertainty associated with the recruitment deviates and using this uncertainty to adjust the lognormal recruitment distributions to account for differences between the median and mean. The values used in this bias adjustment (Figure 40) were estimated by a function in the R4SS software package (Taylor et al., 2013). With no age data and relatively little signal in the length data about variability in recruitment, the bias adjustment was very small. As noted in the section on parameters above, the model did not show evidence that the assumed variability in recruitment, $\sigma_R = 0.5$, was inconsistent with the data, so this value was retained from the previous assessment.

2.5.4 Fit to data

2.5.4.1 Indices of abundance

The base model had reasonable fits to all indices of abundance (Figure 18). The AFSC Triennial Shelf Survey 1, which had the longest time series, had the lowest index values during the middle period of the survey (1986–1992) and highest estimate in the final year. The expected index values from the base model showed a slow decline from 1980–1995 and a slight increase over the period 1995–2004. This index was the only one where a parameter was used to estimate additional variance beyond what was estimated by the GLMM. The additional parameter increased the mean CV from 16% to 26%. This additional variance caused the variance of the index residuals to be of similar magnitude to the index uncertainty. This index was associated with the shallowest depth range (100–366 m) and samples primarily smaller fish. The additional variance may be accounting for processes such as variability in the settlement of young shortspines in or outside the survey range. It also may be caused by variability in survey design that is not captured in the GLMM analysis.

All other indices were relatively flat and the model expectations fell within the 95% intervals of all observations with no additional variance component estimated.

2.5.4.2 Discard fractions

The base model had relatively good fit to the estimated discard fractions (Figure 19). The three time blocks chosen for the Trawl North fleet allowed it to capture the decreasing discard fractions in recent years. The fleet with the least good fit to the discard fractions was Trawl South where in spite of the presence of a time block allowing separate retention prior to 2007, the estimated discard rates were similar before and after this break point and the discard fractions from WCGOP for the years 2002–2006 are significantly higher than the model expectation. This is likely the result of the length data of the discarded fish not showing a similar change. The net result is that the total mortality estimated within the model (the combination of retained and discarded catch shown in Figure 1 and Figure 2) may be slightly lower than the actual mortality experienced by the population. This is likely to have a relatively minor impact on the over results, however.

2.5.4.3 Mean body weight

Mean weight of discarded fish followed the same trend as discard fraction. However, there was greater variability in the mean weight estimates from the data so the base model estimates did not fit the data as closely. In general, the base model's expected mean individual weight is slightly lower than the observed values (Figure 20).

2.5.4.4 Length compositions

In general, none of the sources of length composition data for shortspine thornyhead showed large changes over the time periods for which data were available (Figure 21–Figure 24). The trawl fleets showed a slight shift toward smaller fish, but this appears to have been fit well by increased retention of small fish rather than estimates of large removals of the larger fish (Figure 25–Figure 29). Time-varying selectivity was not included in the model, as there was no clear lack of fit that suggested that this process was occurring. The years and fleets that had the greatest lack of fit to the length data were typically those with the smallest sample sizes. The Trawl South fleet, however, showed relatively large variability between years over the past decade, with some years showing a bimodal distribution.

The fit to the length compositions of the discarded fish was of similar quality as discards of retained fish. Discards in the trawl fisheries were characterized by a size composition with a mode around 20 cm and few fish greater than 40cm, while the non-trawl fisheries had few fish below 20 cm in either discards or retained, and the discards showed a long tail of larger fish extending above 60 cm (Figure 25).

Fits to the survey length compositions were generally adequate (Figure 30–Figure 31). The survey data from 2005–2012, in which the length data was separated by sex, showed that the slightly larger proportion of females at lengths greater than 50cm was fit reasonably well the assumptions about differences in growth between the two sexes. The split-sex data are represented in the model as a single vector stretching across the length bins for both sexes in each year with observations. In this context, a mismatch between the sex-ratios of the data and the expected sex-ratios in the model would appear as a mis-fit to the length compositions. However, no such mis-fit was apparent.

In general, the effective sample sizes of the length data were higher than the input sample sizes and the Pearson residuals did not show any obviously bad patterns (Figure 32–Figure 35).

2.6 Uncertainty and Sensitivity Analyses

The scale of the population is very imprecisely estimated, with a CV around the 2013 spawning biomass of 47.5%. This large amount of uncertainty occurred in spite of a large number of simplifying assumptions and fixed parameters that were made in the absence of data that would allow a more complex model or one with more estimated quantities.

However, sensitivity analyses provide a valuable exploration of alternative scenarios and the robustness of the base model results to alternative assumptions about population dynamics. In general, the alternative model runs from likelihood profiles, sensitivities and retrospective analyses showed that the stock status of shortspine thornyheads is currently above the $B_{40\%}$ target biomass (Table 16, Figure 64).

2.6.1 Likelihood profiles

Likelihood profiles were conducted to look at the sensitivity of the model to assumptions about steepness (h), natural mortality (M), and growth (by varying the parameter controlling the length at age 100).

A likelihood profile over the log(R_0) parameter was conducted to explore the influence of different data sources on the scale of the population and stock status (Figure 46–Figure 51). This indicated that there is some tension between data sources, but generally very little information in any data source about the scale of the population. The abundance indices, which are all relatively flat, were best fit by large populations with little depletion. The discard data and length compositions were best fit at lower R_0 values, although the length data had very similar likelihood contribution over a broad range of population sizes. At low R_0 values, the total likelihood is dominated by the recruitment likelihood. This is driven by the penalty associated with the estimation of an increasingly large recruitment event in the early years that serves to increase spawning biomass above B_0 in the 1960s which serves to offset the impact of a fishery on a lower initial population.

Examination of likelihood contributions by each fleet (Figure 47, Figure 48) indicated that the length data for the Trawl South fleet was fit best at high biomass and the other fleets at lower biomass. The AFSC Triennial Survey 1 had a larger contribution to the changes in likelihood than any other index, and it's best fit occurred at high biomass where the fishery had little impact on the population. This is consistent with the large time-period spanned by this index and its coverage of the years in which the fishery was at its peak. The NWFSC Combo Survey has better depth and latitudinal coverage, more consistent design, more tows per year and more years of observations, but it has occurred during a period of lower fishing intensity in which the population is less likely to have experienced any large changes in abundance. Therefore, this survey will likely be more influence in future years, especially if catches for thornyheads increase to a point that the population exhibits larges changes in abundance that what has been estimated in this assessment.

The likelihood profile over log(R_0) allows a consideration of the relationship between stock status and catchability of the NWFSC Combo Survey (Figure 51). As expected, larger populations are associated with lower catchability values. Interpretation of catchability is generally difficult. However, comparisons between camera sleds and trawl surveys (Lauth et al., 2004) and the presence of fish beyond the deepest extent of the survey both suggest that catchability is likely to be less than 1.0. The base model catchability for this survey is 0.43 and catchability estimates less than 1.0 are associated with spawning biomass that is above 50% of B_0. The catchability values are dependent on the estimated selectivity, so interpretation of these values can be difficult.

Likelihood values and model results were relatively insensitive to changes in steepness (Figure 52, Figure 53). The change in negative log likelihood over the range of $h = 0.3–0.9$ was less than 1.5 units with the largest contribution coming from the discard fractions. No other likelihood component had a change of greater than 1 unit. The lowest B_0 and depletion values were associated with the least productive population, with $h = 0.3$, but there was little qualitative difference between any of these cases. The influence of h on population dynamics for shortspine thornyhead is likely the result of the relatively high stock status associated with most model configurations. That is, assumptions about the stock-recruit relationship are less influential when the population remains relatively close to B_0 and the expected recruitments in each year therefore remain closer to the equilibrium recruitment, R_0, regardless of the steepness value.

Likelihood values and model results were much more sensitive to changes in natural mortality (Figure 54, Figure 55). A range of $M = 0.02 – 0.08$ was explored (relative to a base model value of 0.0505), but the models with $M = 0.07$ and 0.08 did not converge so results are only reported for values in the range 0.02 – 0.06. The change in negative log likelihood over these M values was over 30 units, with the largest change occurring in the likelihood contribution for the fit to the length composition data. The lowest negative log likelihood was associated with $M = 0.02$. The B_0 values estimated in this profile ranged from 126,245 mt to 1,691,150 mt and the depletion in 2013 ranged from 41.8% to 95.6%. The lowest B_0 and depletion values were associated with $M = 0.03$. The lowest mortality value considered, $M = 0.02$, had slightly higher estimated stock status and equilibrium biomass.

A likelihood profile over the parameter for mean length at age 100 indicated that the fit to the length composition data was improved slightly with a lower rate of growth. However, the difference in negative log likelihood between the base model with this parameter fixed at 75 cm and the best fit alternative with the parameter at 70 cm was only 0.12 units (Figure 56), which did not suggest compelling reason to change the assumptions about growth in the base model away from the values used in the previous assessment. In all cases, the mean length at age 100 for males was set to 90% of the value for females. The smaller growth parameter was associated with a higher stock status, while the higher value had a very similar status to the base model (Figure 57).

2.6.2 Sensitivity analyses

Several sensitivity analyses were conducted for quantities that aren't amenable to likelihood profiles. In the first two, the maturity ogive was changed to one of two the alternative maturity curves associated with the ovaries collected in 2011 and 2012 (Figure 12). In these cases, the scale of the spawning biomass changed slightly (Figure 58), but the spawning depletion showed almost no difference between maturity assumptions (Figure 59). The lack of sensitivity to alternative maturity assumptions is likely due to the relatively high stock status and short history of fishing pressure. Under these circumstances, there has been no opportunity for reductions in recruitment associated with declining spawning biomass to feed back into lower numbers growing into maturity. Furthermore, the steady growth assumed for shortspine thornyheads causes the increase in spawning contribution due to increase in body mass to be more significant than the effect of either of the alternative assumptions about fecundity (Figure 13).

The next sensitivity analyses looked at the impact of assuming a higher or lower value for σ_R, the parameter controlling the variability of recruitment around the stock-recruit curve. The base model assumed a value of $\sigma_R = 0.5$ as was used in the previous assessment. Alternatives explored were $\sigma_R = 0.25$ and $\sigma_R = 0.75$ as well as deterministic recruitment (no deviations from the stock-recruit curve, equivalent to $\sigma_R = 0$). In all cases, the estimated spawning biomass time series was similar to the base model (Figure 60). The cases with $\sigma_R > 0$ had lower variability between years than the uncertainty within each of the estimated deviations (Figure 61).

The final sensitivity analysis examined the effect of using an alternative timeseries of catch for the years prior to 1981 (Figure 62, discussed under Catch History above). The model was found to be very insensitive to the differences in early catch, with equilibrium spawning biomass and 2013 depletion estimates changing by less than 1% (Figure 63).

2.6.3 Retrospective analyses

Retrospective analysis indicates that removing the most recent years of data a large impact on the estimates of spawning biomass (Figure 65). This is consistent with the results of the likelihood profile over R_0 (Figure 46) which showed that the data provide very little information about the scale of the population. In this context, small changes in the data have the potential to cause large changes in the best estimates of R_0 and hence population scale. However, all estimates of spawning biomass in the retrospective analysis fell within the wide 95% uncertainty interval around the base model spawning biomass timeseries (Figure 65).

An examination of the fit to the NWFSC Combo survey by the models in the retrospective analysis (Figure 66) did not reveal any patterns which indicate that the survey index was the primary cause of differences between these models. Therefore, removal of the most recent years of length composition data may be presumed to be the primary cause of the changes in the retrospective analysis.

Most models in the retrospective analysis had lower estimates of spawning biomass, but removing the most recent 2 years of data led to higher estimates.

2.6.4 Comparison to previous assessment

Comparing the time series of spawning biomass and depletion from the 2005 assessment with the base model indicates that the 95% confidence interval around the base model spawning biomass includes the values from the 2005 assessment, but the lower uncertainty associated with the 2005 assessment (which had fixed catchability for one of the surveys) does not encompass the base model estimates (Figure 67). The spawning depletion values in the current assessment are slightly higher than the previous assessment for the overlapping years, but both show the population at a high stock status (Figure 68).

2.6.5 Axis of uncertainty and states of nature

The uncertainty in spawning biomass associated with the base model was very broad (Figure 36), so the $\log(R_0)$ parameter, which controls the scale of the population, was chosen as the axis of uncertainty, and states of nature were chosen based on this range. The low state of nature was chosen from a profile over the equilibrium recruitment parameter as a model which had an estimate of 2013 spawning biomass closest to the 12.5th percentile of the spawning biomass distribution in the base model This represents the middle of the lower 25% of probabilities in the base model. The high state of nature was not chosen in the same way, however, as 87.5th percentile of the base model did not encompass the range of models seen in sensitivity analyses as plausible alternatives. Instead, the high state of nature was taken as the model in the profile over the equilibrium recruitment that had a change in negative log-likelihood equal to 1.2 units, which is an alternative way to calculate the approximate center of the upper 25% of probable possibilities. This high state better reflected the asymmetry in uncertainty about the scale of the population (with more information about the lower range than the upper range of probable population sizes).

3 Reference Points

Reference points were calculated using the estimated catch distribution among fleets in the last year of the model (2012), and the estimated values are dependent on this assumption. In general, the population is at a healthy status relative to the reference points (Figure 44). Sustainable total yield (landings plus discards) was estimated at 2,034 mt when using an $SPR_{50\%}$ reference harvest rate and ranged from 633 – 3,435 mt based on estimates of uncertainty (Table 12). The spawning biomass equivalent to 40% of the unfished spawning output ($B_{40\%}$) was 75,906 mt. The most recent catches (landings plus discards) have been lower than the estimated long-term yields calculated using an $SPR_{50\%}$ reference point, but not as low as the lower bound of the 95% uncertainty interval. However, this is due to the fishery not fully attaining the full ACL. The OFL and ACL values over the past 6 years have been approximately 2,400 mt and 2,000 mt, respectively. Both of those values are lower than the OFL and ACL values predicted in short-term forecasts, which are around 3,200 mt and 2,700 mt respectively for 2015–2016 (Table 13). This is reflected in the timeseries of low harvest rates (Figure 41), low 1-SPR values (Figure 42), and the phase plot showing the history of being above the target biomass and below the target fishing intensity reference points (Figure 43).

4 Harvest Projections and Decision Tables

The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.45$. The SSC assigned this shortspine thornyhead assessment to Category 2, which is associated with a minimum value of $\sigma = 0.72$ for adjustment of quotas based on scientific uncertainty (a process referred to by the notation “p*”). The Pacific Fisheries Management Council chose a p* value of 0.40 for shortspine thornyheads, which leads to a multiplication of the OFL by 83.3%, which is the 40% quantile of a log-normal distribution with σ = 0.72. Twelve-year projections were conducted with a total catch assumed equal to the ACL calculated by applying this adjustment to the estimated OFL for each year. The retention function and allocation of catch among fleets was assumed to match the average values for 2011–2012 (the only years in which the trawl fishery was operating under IFQs). This allocation between fleets was 43% for Trawl North, 32% for Trawl South, 3% for Non-trawl North, and 22% for Non-trawl South. Catch for 2013–2014, the limits on which have already been set, were assumed to equal the averages over 2011–2012, which correspond to a total catch of 952 mt and landings of 933 mt after applying the estimated retention function to the age structure of the population in 2013. The 933 mt value is identical to the average of the retained catch for the years 2011–2012, suggesting that the choice to model forecast catches in terms of total catch rather than landings has little influence on the forecast results.

This default harvest rate projection applied to the base model indicated that the stock status would slowly decline from 74.2% in 2013 to 68.1% in 2024 (Table 13), still far above the 40% biomass target and 25% minimum stock size threshold. The associated OFL values over the period 2015–2024 would average 3,080 mt and the average ACL would be 2,566. These values are above recent catch limits, which have not been fully attained in recent years. In these projections, the stock status was always above 40%, so the 40-10 adjustment in the control rule had no impact on the projections.

Additional projections were conducted for the base model and low and high states of nature (columns) under three catch streams (rows) to form a decision table (Table 14). The uncertainty in spawning biomass associated with the base model was very broad, so states of nature were chosen based on this range. The low state of nature was chosen from a profile over the equilibrium recruitment parameter as a model which had an estimate of 2013 spawning biomass closest to the 12.5th percentile of the spawning biomass distribution in the base model. This represents the middle of the lower 25% of probabilities in the base model. The high state of nature was not chosen in the same way, however, as 87.5th percentile of the base model did not encompass the range of models seen in sensitivity analyses as plausible alternatives. Instead, the high state of nature was taken as the model in the profile over the equilibrium recruitment that had a change in negative log-likelihood equal to 1.2 units, which is an alternative way to calculate the approximate center of the upper 25% of probable possibilities. This high state better reflected the asymmetry in uncertainty about the scale of the population (with more information about the lower range than the upper range of probable population sizes).

The catch streams chosen for the decision table were represented as total catch rather than landed catch, but discard rates were low under IFQs, so the difference in between total catch and landings is small. The low catch stream was assumed to have total catch equal to the average over the years 2011–2012, the years in which the trawl fishery was operating under IFQs was used as a low catch stream. This was a total catch of 952 mt divided among the fleets by the fraction. The high catch stream was chosen based on applying the SPR = 50% default harvest control rule to the base model, including a p^* = 0.40 offset which reduced the catch to 83.3% of the OFL. The middle catch stream was chosen to stabilize the stock status at approximately 60% of the unfished equilibrium (based on an exploratory 100-year forecast). This was achieved by using an SPR = 65% with a 94.2% adjustment to the OFL (based the p^* = 0.45 and sigma = 0.475 associated with the Category 1 classification which was the default at the time of the assessment review). The average total catch for the years 2015–2024 was 952 mt for the low catch stream, 1,795 for the middle catch stream, and 2,566 for the high catch stream.

The stock status remained above 40% in all years, regardless of the state of nature or management decision. The most pessimistic forecast scenario, combining the low state of nature with the high catch stream, resulted in a projected stock status of 41.6%, just above the target value. All other projections led to a higher projected status, with a maximum of 89.1% for the combination of the high state of nature and low catch. Forecasts under the base case led to estimated status ranging from 2024 spawning depletion values of 68.1% in the high catch stream to 72.9% in the low catch stream.

No projections were done to explore changes in ratio of trawl to non-trawl or north to south. Due to differences in selectivity and retention among the fleets, these projections could be expected to provide slightly different results, although the general pattern of the projections suggesting stocks above target levels as described above is unlikely to change as a result of alternative ratios among the fleets.

5 Regional Management Considerations

Currently both shortspine and longspine thornyheads have a management boundary at Pt. Conception, 34º27' N latitude. There is no evidence of stock structure associated with this line and the amount of data associated with fishery to the south of this boundary is unlikely to justify any effort to develop a spatial model with explicit accounting for this boundary. The choice to implement this boundary as a management line was made during a period when the surveys did not extend south of Pt. Conception and the assessment did not include this region. Thus, estimated quotas were not applicable to the southern area.

At this point, however, the NWFSC Combo survey has been consistently sampling between the Mexican border and Pt. Conception (though not in the Cowcod Conservation Area), and the assessment is applied to all thornyheads within the boundaries of the west coast of the continental United States. Therefore, there no longer appears to be any scientific basis for maintaining separate quotas north and south of the 34º27' N latitude boundary.

If this boundary is maintained for social or political reasons, the best method for apportioning the quotas between areas is the fraction of the population observed in the trawl survey. The fraction of the total estimated biomass south of 34º27' N in the NWFSC Combo Survey is 34.6% based on the median GLMM results. This is very similar to 34.3% of the raw, swept area biomass. The survey trends associated with the two subsets of the coast are similarly flat (Figure 69). Due to the smaller size of the southern area with fewer survey stations, the uncertainty in the south is higher, with a mean CV of 19.3% compared to a 7.6% CV in the north. These estimates include extrapolation of observed densities south of 34º27' N into the large, unobserved, Cowcod Conservation Area (indicated by the absence of tows centered around 33º N, 119º W in Figure 5). The uncertainty associated with that extrapolation is difficult to quantify at this point. However, the uncertainty in the fraction of the population north or south of Pt. Conception is likely lower than the uncertainty in the size of the total coastwide population. Therefore, if separate quotas are to be maintained, it does not appear necessary to include a higher buffer for scientific uncertainty in the southern quota on the scale of what has been done in the past.

6 Research Needs

Research and data needs for future assessments include the following:

1) More investigation into maturity of shortspine is necessary to understand the patterns in maturity observed in the samples collected in 2011 and 2012.
2) Information on possible migration of shortspine thornyheads would be valuable for understanding stock dynamics. Analysis of trace elements and stable isotopes in shortspine otoliths may provide valuable information on the extent of potential migrations. Possible connections between migration and maturity could likewise be explored.
3) A greater understanding of catchability of thornyheads would help define the scale of the populations. This could include a survey using a towed camera to assess the abundance in water beyond the 1280 m range of the trawl surveys. Further exploration of perceived differences in catchability between towed cameras and trawl nets could also be explored. Understanding the relative catchability of shortspine and longspine thornyhead, which are difficult to distinguish in camera observations, would have to be a component of such investigations. Differences in selectivity between the AFSC Slope survey and the NWFSC surveys may be the result of

behavioral interactions with different footropes. Understanding these interactions would also improve understanding of catchability.

4) Age data would be valuable for future stock assessments. Otoliths have been collected in good quantities from the NWFSC survey, but at this time the ageing methods are not believed to be reliable. Additional research on ageing methods for thornyheads would be valuable.
5) A greater understanding of the connection between thornyheads and bottom type could be used to refine the indices of abundance. Thornyheads are very well sampled in trawlable habitat, but the extrapolation of density to a survey stratum could be improved by accounting for the proportion of different bottom types within a stratum and the relative density of thornyheads within each bottom type.
6) A comprehensive catch reconstruction for shortspine and longspine thornyheads should be completed to estimate landings for each species prior to 1981 in each of the three states.
7) Exploration of simpler assessment methods for thornyheads and evaluation of whether such methods would provide a more robust management strategy than the current approach. It is likely that any significant reduction in the size of the shortspine thornyhead population would be apparent in the NWFSC Combo Survey index. A method for setting and/or adjusting catch limits based on either absolute values or trends in the survey has the potential to be much less labor intensive than the current assessment approach.
8) More tows or visual surveys south of 34.5 deg. N. lat. including the large Cowcod Conservation Area. Because the southern Conception Area is a large potential habitat for thornyheads, more sampling effort would help refine the estimations of their abundance in this area.

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9 Tables

Table 1: Estimated landings history for shortspine thornyhead. Note that fleets are only shown for range of years in which they had non-zero landings.

Year	Catch (mt)	
	Trawl S	Total
1901	2	2
1902	2	2
1903	4	4
1904	5	5
1905	6	6
1906	8	8
1907	9	9
1908	10	10
1909	11	11
1910	13	13
1911	14	14
1912	15	15
1913	17	17
1914	17	17
1915	19	19
1916	20	20
1917	21	21
1918	23	23
1919	24	24
1920	25	25
1921	26	26
1922	28	28
1923	29	29
1924	30	30
1925	32	32
1926	32	32
1927	34	34
1928	35	35
1929	36	36
1930	38	38
1931	39	39
1932	40	40
1933	49	49
1934	49	49
1935	49	49
1936	51	51
1937	47	47
1938	53	53
1939	63	63
1940	76	76

Year	Catch (mt)		
	Trawl N	Trawl S	Total
1941	-	109	109
1942	-	122	122
1943	-	269	269
1944	-	380	380
1945	-	453	453
1946	-	216	216
1947	-	48	48
1948	-	152	152
1949	-	168	168
1950	-	153	153
1951	-	305	305
1952	-	176	176
1953	-	68	68
1954	-	128	128
1955	-	128	128
1956	-	776	776
1957	-	286	286
1958	-	296	296
1959	-	398	398
1960	-	472	472
1961	-	437	437
1962	-	230	230
1963	-	285	285
1964	12	172	184
1965	20	400	420
1966	612	543	1,155
1967	369	864	1,233
1968	168	1,835	2,003
1969	155	400	555
1970	149	557	706
1971	260	582	842
1972	389	1,297	1,686
1973	712	2,377	3,089
1974	215	1,244	1,459
1975	405	1,867	2,272
1976	52	992	1,044
1977	91	1,359	1,450
1978	76	1,136	1,212
1979	109	1,720	1,829
1980	87	1,192	1,279

Year	Catch (mt)				
	Trawl N	Trawl S	Non-trawl N	Non-trawl S	Total
1981	242	1,623	-	1	1,830
1982	554	1,655	-	1	2,069
1983	1,493	1,562	-	1	2,279
1984	1,681	1,961	-	1	2,914
1985	1,346	2,560	-	2	3,016
1986	458	2,422	-	3	2,362
1987	558	1,953	4	3	1,984
1988	696	2,163	23	2	2,868
1989	1,340	3,506	29	10	4,815
1990	1,918	2,228	27	3	4,036
1991	2,157	1,306	54	2	3,467
1992	1,669	1,625	52	9	3,299
1993	2,037	1,774	24	1	3,609
1994	1,835	1,538	20	3	3,287
1995	815	1,064	28	32	1,940
1996	686	831	21	81	1,608
1997	580	771	23	40	1,406
1998	505	669	17	47	1,232
1999	319	398	18	99	824
2000	282	490	14	53	824
2001	236	241	13	46	532
2002	231	428	10	104	762
2003	270	374	11	155	800
2004	295	319	11	129	757
2005	255	252	11	139	654
2006	296	247	15	144	703
2007	562	279	16	143	1,006
2008	902	325	20	175	1,427
2009	948	382	29	172	1,531
2010	770	357	22	206	1,353
2011	424	287	24	237	974
2012	381	323	36	155	894

Table 2. Recent trend in commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the commercial landings plus the model estimated discarded biomass.

Year	OFL (mt)	ACL (mt)	Commercial Landings (mt)	Estimated Total Catch (mt)
2001	880	751	532	602
2002	1,004	955	762	855
2003	1,004	955	800	903
2004	1,030	983	757	846
2005	1,055	999	654	739
2006	1,077	1,018	703	792
2007	2,476	2,055	1,006	1,058
2008	2,476	2,055	1,427	1,507
2009	2,437	2,022	1,531	1,619
2010	2,411	2,001	1,353	1,431
2011	2,384	1,978	974	994
2012	2,358	1,957	894	911

Table 3: Summary of sampling effort of landings data (number of hauls and fish sampled) used to create length compositions. The samples from the Trawl North in 1994 and 1995 appeared to be outliers associated with small sample sizes taken from hauls that were not representative of the population and were excluded from the base model.

Year	Trawl N		Trawl S		Non-trawl N		Non-trawl S	
	Hauls	Samples	Hauls	Samples	Hauls	Samples	Hauls	Samples
1978			861	1,188				
1979	268	447	488	649				
1980	175	268	243	298				
1981	119	180	75	88				
1982	133	180	341	405				
1983			961	1,230				
1984			1,958	2,755				
1985			2,311	3,176			3	3
1986			739	978			9	9
1987			289	343			46	54
1988			91	140			8	8
1989			505	741			18	18
1990	299	510	392	517			22	24
1991	785	1,060	390	532				
1992	733	1,227	339	448			48	75
1993	225	293	649	993			3	3
1994	20	40	819	1,367			36	46
1995	19	24	1,260	2,248			23	36
1996	265	497	1,188	2,062			15	26
1997	1,036	2,322	1,101	1,720			27	36
1998	543	757	659	1,130			71	130
1999	621	819	524	821			883	1,852
2000	498	660	695	1,027	3	3	228	444
2001	990	1,632	841	1,413	21	30	59	102
2002	1,216	2,313	1,565	2,320	9	10	447	1,026
2003	1,537	2,461	1,130	1,909			373	834
2004	1,074	1,509	628	1,073	1	1	93	132
2005	1,094	1,649	912	1,393			353	620
2006	1,120	1,573	2,268	3,109	2	2	306	594
2007	1,708	2,432	1,297	1,893	77	115	149	278
2008	1,933	2,631	1,458	2,212	152	251	732	1,786
2009	1,986	2,854	1,201	2,137	106	130	565	1,168
2010	1,981	2,980	1,057	1,720	161	210	588	1,136
2011	1,600	2,381	1,583	2,950	284	515	1,550	2,762
2012	1,608	2,262	1,385	2,423	323	538	1,119	1,881

Table 4: Summary of sampling effort of discard data (fish sampled, hauls not reported here) used to create length compositions.

Year	Trawl N		Trawl S		Non-trawl N		Non-trawl S	
	Hauls	Samples	Hauls	Samples	Hauls	Samples	Hauls	Samples
1985		208						
1986		2,551						
1987		435						
2005						7		
2006		708		247		112		200
2007		1,124		338		245		273
2008		1,712		326		67		177
2009		2,423		495		50		108
2010		1,281		201		73		200
2011		1,446		441		236		183

Table 5: Summary of sampling effort of survey data (number of hauls and fish sampled) used to create length compositions. Samples from the 1980 and 1983 (AFSC Triennial Shelf Survey 1) were excluded from the base model as they represented only a single tow in each case. Sex-specific numbers are not shown, but for the years 2005 and onward, the NWFSC Combo samples included a total of 17,599 females, 17,572 males, and 6,715 unsexed shortspine thornyheads.

Year	AFSC Triennial Shelf Survey 1		AFSC Triennial Shelf Survey 2		AFSC Slope Survey		NWFSC Slope Survey		NWFSC Combo Survey	
	Hauls	Samples	Hauls	Samples	Hauls	Samples	Hauls	Samples	Hauls	Samples
1980	1	153								
1983	1	78								
1986	10	246								
1989	54	1,877								
1992	29	1,254								
1995	145	4,027	145	7,235						
1997					171	7,454				
1998	161	4,515	161	6,109			210	7,827		
1999					188	6,752	300	10,042		
2000					196	7,017	288	7,932		
2001	198	4,255	198	6,220	196	6,072	294	8,076		
2002							371	11,761		
2003									289	7,685
2004	137	3,400	137	5,108					213	6,692
2005									314	8,046
2006									332	6,198
2007									367	5,499
2008									361	4,712
2009									340	4,195
2010									358	3,841
2011									347	4,697
2012									349	4,678

Table 6: Final design and model (GLMM)-based abundance indices for shortspine thornyhead.

	AFSC Triennial Shelf Survey 1		
Year	Design	Model	log_SD
1980	2,627	2,660	0.144
1983	3,406	3,415	0.118
1986	1,628	1,636	0.133
1989	2,015	2,010	0.139
1992	2,069	2,064	0.177
1995	3,483	3,480	0.152
1998	3,056	3,076	0.152
2001	3,690	3,698	0.142
2004	4,128	4,117	0.181

	AFSC Triennial Shelf Survey 2		
Year	Design	Model	log_SD
1995	3,494	3,523	0.122
1998	2,809	2,815	0.126
2001	3,353	3,384	0.124
2004	3,485	3,504	0.129

	AFSC Slope Survey		
Year	Design	Model	log_SD
1997	27,068	27,148	0.084
1999	25,525	25,641	0.082
2000	31,912	31,971	0.083
2001	31,377	31,567	0.081

	NWFSC Slope Survey		
Year	Design	Model	log_SD
1998	27,512	27,416	0.086
1999	28,213	28,311	0.079
2000	30,673	30,897	0.081
2001	26,192	26,376	0.080
2002	32,562	32,404	0.080

	NWFSC Combo Survey		
Year	Design	Model	log_SD
2003	51,666	52,474	0.103
2004	53,181	53,885	0.105
2005	48,162	48,155	0.091
2009	58,273	58,430	0.096
2010	46,229	46,489	0.090
2011	48,095	48,556	0.089
2009	58,273	58,430	0.096
2010	46,229	46,489	0.090
2011	48,095	48,556	0.089
2012	53,426	53,045	0.101

Table 7: Summary of input and effective sample sizes and sample size adjustments.

Fleet	Arithmetic mean of adjusted input N	Harmonic mean of effective N	Sample size adjustment	Ratio of harmonic to adjusted input N
Trawl North	38.8	37.5	0.56	0.97
Trawl South	66.0	70.8	0.98	1.07
Non-trawl North	9.1	8.8	0.54	0.97
Non-trawl South	13.2	13.4	0.40	1.02
AFSC Triennial Shelf Survey 1	75.4	78.9	0.68	1.05
AFSC Triennial Shelf Survey 2	121.9	150.8	0.65	1.24
AFSC Slope Survey	199.6	473.1	1.00	2.37
NWFSC Slope Survey	121.5	136.6	0.51	1.12
NWFSC Combo Survey	176.6	573.3	1.00	3.25

Table 8: Parameters related to biology, stock-recruit relationship and index variance. Only log(R_0) and the Extra SD parameter (shown in bold) are estimated so the prior distribution on *M* had no impact on model results.

Parameter	Value	Min	Max	Prior		
				Type	Mean	SD (of log)
Natural mortality (*M*)	0.0505	0.01	0.15	Log-normal	0.0505	0.5361
Length at age 2	7.0					
Length at age 100 (females)	75.0					
Length at age 100 (males)	67.5					
von Bertalanffy K	0.018					
Length CV at age 2	0.125					
Length CV at age 100	0.125					
Weight-Length a	4.7707×10^{-6}					
Weight-Length b	3.2630					
log(R_0)	**10.32**	7	13			
Steepness (*h*)	0.6					
σ_R	0.5					
Extra SD for AFSC Triennial Shelf Survey 1	**0.113**	0.01	0.50			

Table 9: Parameters related to selectivity and retention for each fishing fleet. Estimated quantities are indicated in bold.

	Prior					Fleet			
Parameter	Type	Mean	SD	Min	Max	Trawl N	Trawl S	Non-trawl N	Non-trawl S
Double-normal 1 (peak)				10	60	**23.53**	**28.05**	**40.81**	**30.93**
Double-normal 2 (plateau width)				-7	7	**-7.00**	**-0.30**	**-7.00**	**-2.12**
Double-normal 3 (ascending slope)				-5	10	**3.77**	**4.25**	**4.55**	**3.41**
Double-normal 4 (descending slope)				-5	10	**6.78**	**4.85**	**6.29**	**5.72**
Double-normal 5 (optional initial)						-999	-999	-999	-999
Double-normal 6 (optional final)						-999	-999	-999	-999
Retention curve inflection				5	70	**28.11**	**23.74**	**21.75**	**26.18**
Retention curve slope				0.1	40	**3.43**	**2.42**	**4.87**	**2.87**
Retention curve asymptote				0.0001	1	**1.00**	**1.00**	**0.94**	**0.95**
Retention curve male-offset						0.00	0.00	0.00	0.00
Retention inflection offset 2007-2010	Normal	0	5	-10	10	**-0.23**	**-0.04**	-	-
Retention inflection offset 2011-2012	Normal	0	5	-10	10	**-0.53**	**-0.18**	-	-
Retention inflection offset 2007-2012	Normal	0	5	-10	10	-	-	-	**-0.23**
Retention asymptote offset 2007-2010	Normal	0	0.2	-0.5	0.5	**0.00**	**0.01**	-	-
Retention asymptote offset 2011-2012	Normal	0	0.2	-0.5	0.5	**0.00**	**0.00**	-	-
Retention asymptote offset 2007-2012	Normal	0	0.2	-0.5	0.5	-	-	-	**0.03**

Table 10: Parameters related to selectivity and retention for each survey. Estimated quantities are indicated in bold.

			Survey				
Parameter	Min	Max	AFSC Triennial Shelf Survey 1	AFSC Triennial Shelf Survey 2	AFSC Slope Survey	NWFSC Slope Survey	NWFSC Combo Survey
Double-normal 1 (peak)	10	60	**22.90**	**21.36**	**20.61**	**22.63**	**24.73**
Double-normal 2 (plateau width)	-7	7	**-7.00**	**-7.00**	**-7.00**	**-7.00**	**-7.00**
Double-normal 3 (ascending slope)	-5	10	**3.67**	**3.82**	**3.43**	**4.06**	**4.52**
Double-normal 4 (descending slope)	-5	10	**4.04**	**4.50**	**4.26**	**6.77**	**6.77**
Double-normal 5 (optional initial)			-999	-999	-999	-999	-999
Double-normal 6 (optional final)			-999	-999	-999	-999	-999

Table 11: Time-series of total biomass, summary (age 1+) spawning biomass, spawning output, depletion (stock status), recruitment, and exploitation rate estimated in the model.

Year	Total biomass (1000 mt)	Summary biomass (age 1+, 1000 mt)	Spawning biomass (1000 mt)	Depletion	Age-0 recruits (millions)	Total catch (mt)	1 - SPR	Relative exploitation rate
1901	331.9	331.8	190.2	100.2%	30.5	2	0.0%	0.000
1902	331.9	331.9	190.2	100.2%	30.4	2	0.0%	0.000
1903	331.9	331.9	190.2	100.2%	30.4	4	0.1%	0.000
1904	331.9	331.9	190.2	100.3%	30.4	5	0.1%	0.000
1905	331.9	331.9	190.3	100.3%	30.4	6	0.1%	0.000
1906	331.9	331.9	190.3	100.3%	30.3	8	0.1%	0.000
1907	331.9	331.9	190.3	100.3%	30.3	9	0.1%	0.000
1908	332.0	331.9	190.3	100.3%	30.3	10	0.2%	0.000
1909	332.0	331.9	190.3	100.3%	30.2	11	0.2%	0.000
1910	332.0	331.9	190.3	100.3%	30.2	13	0.2%	0.000
1911	331.9	331.9	190.3	100.3%	30.2	14	0.2%	0.000
1912	331.9	331.9	190.3	100.3%	30.2	15	0.2%	0.000
1913	331.9	331.9	190.3	100.3%	30.2	18	0.3%	0.000
1914	331.9	331.9	190.3	100.3%	30.2	18	0.3%	0.000
1915	331.9	331.9	190.3	100.3%	30.2	20	0.3%	0.000
1916	331.9	331.8	190.2	100.2%	30.2	21	0.3%	0.000
1917	331.8	331.8	190.2	100.2%	30.1	22	0.3%	0.000
1918	331.8	331.8	190.2	100.2%	30.1	24	0.4%	0.000
1919	331.8	331.7	190.2	100.2%	30.2	25	0.4%	0.000
1920	331.7	331.7	190.2	100.2%	30.2	26	0.4%	0.000
1921	331.7	331.6	190.1	100.2%	30.2	27	0.4%	0.000
1922	331.6	331.6	190.1	100.2%	30.2	29	0.4%	0.000
1923	331.6	331.5	190.1	100.2%	30.3	30	0.5%	0.000
1924	331.5	331.5	190.1	100.2%	30.3	31	0.5%	0.000
1925	331.5	331.4	190.0	100.1%	30.4	33	0.5%	0.000
1926	331.4	331.4	190.0	100.1%	30.5	33	0.5%	0.000
1927	331.3	331.3	189.9	100.1%	30.6	35	0.5%	0.000
1928	331.2	331.2	189.9	100.1%	30.8	36	0.5%	0.000
1929	331.2	331.1	189.9	100.0%	31.0	37	0.6%	0.000
1930	331.1	331.1	189.8	100.0%	31.2	39	0.6%	0.000
1931	331.0	331.0	189.8	100.0%	31.5	40	0.6%	0.000
1932	331.0	330.9	189.7	100.0%	31.9	41	0.6%	0.000
1933	330.9	330.8	189.7	99.9%	32.3	50	0.8%	0.000
1934	330.8	330.8	189.6	99.9%	32.7	50	0.8%	0.000
1935	330.7	330.7	189.6	99.9%	33.3	50	0.8%	0.000
1936	330.7	330.6	189.5	99.9%	33.9	53	0.8%	0.000
1937	330.6	330.6	189.5	99.8%	34.7	48	0.7%	0.000
1938	330.6	330.5	189.4	99.8%	35.6	55	0.8%	0.000
1939	330.5	330.5	189.4	99.8%	36.6	65	1.0%	0.000
1940	330.5	330.5	189.3	99.8%	37.8	78	1.2%	0.000

Table 11 continued

Year	Total biomass (1000 mt)	Summary biomass (age 1+, 1000 mt)	Spawning biomass (1000 mt)	Depletion	Age-0 recruits (millions)	Total catch (mt)	1 - SPR	Relative exploitation rate
1941	330.5	330.5	189.3	99.8%	39.2	112	1.7%	0.000
1942	330.5	330.5	189.3	99.7%	40.7	126	1.9%	0.000
1943	330.5	330.5	189.2	99.7%	42.3	277	4.1%	0.001
1944	330.4	330.4	189.1	99.7%	44.1	392	5.8%	0.001
1945	330.2	330.2	189.0	99.6%	45.7	467	6.8%	0.001
1946	330.0	330.0	188.8	99.5%	47.2	223	3.3%	0.001
1947	330.2	330.1	188.8	99.5%	48.1	50	0.8%	0.000
1948	330.5	330.5	188.9	99.5%	48.1	157	2.4%	0.000
1949	330.9	330.9	189.0	99.6%	47.1	174	2.6%	0.001
1950	331.3	331.3	189.2	99.7%	45.2	158	2.4%	0.000
1951	331.9	331.8	189.4	99.8%	42.6	315	4.7%	0.001
1952	332.3	332.3	189.6	99.9%	39.7	182	2.7%	0.001
1953	333.0	333.0	189.9	100.1%	36.7	70	1.1%	0.000
1954	333.9	333.9	190.4	100.3%	33.8	133	2.0%	0.000
1955	334.9	334.9	190.9	100.6%	31.1	133	2.0%	0.000
1956	335.9	335.9	191.5	100.9%	28.6	806	11.3%	0.002
1957	336.3	336.2	191.8	101.1%	26.4	297	4.3%	0.001
1958	337.2	337.2	192.4	101.4%	24.5	308	4.5%	0.001
1959	338.2	338.2	193.1	101.8%	22.8	414	5.9%	0.001
1960	339.1	339.1	193.8	102.1%	21.4	491	6.9%	0.001
1961	340.0	339.9	194.5	102.5%	20.2	455	6.4%	0.001
1962	340.8	340.8	195.2	102.8%	19.3	239	3.4%	0.001
1963	341.9	341.9	195.9	103.3%	18.7	297	4.2%	0.001
1964	342.8	342.8	196.7	103.6%	18.4	193	2.8%	0.001
1965	343.8	343.8	197.4	104.0%	18.5	440	6.1%	0.001
1966	344.5	344.5	197.9	104.3%	19.1	1,299	18.5%	0.004
1967	344.2	344.1	197.9	104.3%	20.2	1,336	18.1%	0.004
1968	343.7	343.6	197.7	104.2%	21.9	2,097	25.6%	0.006
1969	342.2	342.2	197.0	103.8%	24.1	596	8.6%	0.002
1970	342.3	342.3	197.1	103.9%	26.7	749	10.5%	0.002
1971	342.1	342.0	197.1	103.8%	29.2	903	12.8%	0.003
1972	341.5	341.5	196.8	103.7%	30.6	1,784	23.1%	0.005
1973	340.0	339.9	195.9	103.2%	30.7	3,260	37.6%	0.010
1974	336.7	336.7	194.1	102.3%	29.5	1,521	20.0%	0.005
1975	335.2	335.1	193.2	101.8%	27.7	2,373	29.5%	0.007
1976	332.6	332.6	191.7	101.0%	25.9	1,074	14.5%	0.003
1977	331.4	331.4	190.9	100.6%	25.0	1,492	19.7%	0.005
1978	329.6	329.6	189.8	100.0%	25.1	1,247	16.9%	0.004
1979	328.0	328.0	188.8	99.5%	26.0	1,880	24.2%	0.006
1980	325.7	325.7	187.5	98.8%	27.1	1,316	18.0%	0.004

Table 11 continued

Year	Total biomass (1000 mt)	Summary biomass (age 1+, 1000 mt)	Spawning biomass (1000 mt)	Depletion	Age-0 recruits (millions)	Total catch (mt)	1 - SPR	Relative exploitation rate
1981	323.9	323.9	186.4	98.3%	28.6	1,933	25.7%	0.006
1982	321.4	321.3	185.0	97.5%	31.1	2,319	31.0%	0.007
1983	318.4	318.4	183.4	96.6%	33.6	3,288	43.0%	0.010
1984	314.3	314.3	181.2	95.5%	35.0	3,916	48.8%	0.012
1985	309.5	309.4	178.5	94.1%	36.0	4,156	50.2%	0.013
1986	304.4	304.4	175.7	92.6%	36.6	3,010	39.0%	0.010
1987	300.6	300.5	173.5	91.4%	35.6	2,652	36.5%	0.009
1988	297.1	297.1	171.5	90.4%	33.6	3,049	41.1%	0.010
1989	293.3	293.3	169.2	89.2%	31.8	5,191	59.0%	0.018
1990	287.2	287.2	165.7	87.3%	31.5	4,541	57.6%	0.016
1991	281.8	281.8	162.6	85.7%	32.5	3,907	55.0%	0.014
1992	277.1	277.0	160.0	84.3%	32.7	3,684	52.6%	0.013
1993	272.7	272.6	157.5	83.0%	27.7	4,239	58.3%	0.016
1994	267.7	267.7	154.7	81.5%	21.8	3,769	55.3%	0.014
1995	263.3	263.3	152.2	80.2%	19.2	2,129	36.9%	0.008
1996	260.7	260.7	150.8	79.5%	19.8	1,787	32.6%	0.007
1997	258.6	258.6	149.6	78.8%	24.5	1,561	29.3%	0.006
1998	256.8	256.8	148.6	78.3%	31.4	1,371	26.5%	0.005
1999	255.2	255.2	147.7	77.8%	29.8	928	19.0%	0.004
2000	254.2	254.2	147.2	77.6%	25.4	925	18.7%	0.004
2001	253.3	253.3	146.7	77.3%	22.9	602	13.0%	0.002
2002	252.8	252.8	146.4	77.1%	20.6	855	17.4%	0.003
2003	252.0	252.0	146.0	76.9%	20.6	903	18.4%	0.004
2004	251.3	251.2	145.5	76.7%	22.5	846	17.6%	0.003
2005	250.6	250.6	145.0	76.4%	27.2	739	15.5%	0.003
2006	250.1	250.0	144.7	76.2%	32.7	792	16.6%	0.003
2007	249.5	249.5	144.3	76.1%	33.0	1,058	21.8%	0.004
2008	248.7	248.7	143.8	75.8%	30.9	1,507	29.7%	0.006
2009	247.5	247.4	143.1	75.4%	30.2	1,619	31.4%	0.007
2010	246.1	246.1	142.3	75.0%	30.5	1,431	28.3%	0.006
2011	245.0	245.0	141.6	74.6%	27.4	994	20.3%	0.004
2012	244.4	244.3	141.2	74.4%	28.8	911	18.7%	0.004

Table 12: Summary of reference points and management outputs for the base case model.

Quantity	Estimate	~95% confidence interval
Unfished Spawning biomass (mt)	189,765	(57,435 – 322,095)
Unfished age 1+ biomass (mt)	331,047	(100,196 – 561,898)
Unfished recruitment (R0, millions)	30.4	(15.2 – 61.1)
Depletion (2013)	74.2%	(56.1% – 92.3%)
Spawning Biomass (2013)	140,753	(9,673 – 271,833)
SD of log Spawning Biomass (2013)	0.45	–
Reference points based on $B_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	75,906	(22,974 – 128,838)
SPR resulting in $B_{40\%}$ ($SPR_{SB40\%}$)	50.0%	–
Exploitation rate resulting in $B_{40\%}$	0.015	(0.015 – 0.016)
Yield with $SPR_{50\%}$ at $B_{40\%}$ (mt)	2,034	(633 – 3,435)
Reference points based on SPR proxy for MSY		
Spawning biomass	75,906	(22,974 – 128,838)
SPR_{proxy}	50.0%	–
Exploitation rate corresponding to SPR_{proxy}	0.015	(0.015 – 0.016)
Yield with SPR_{proxy} at SB_{SPR} (mt)	2,034	(633 – 3,435)
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	64,600	(19,517 – 109,683)
SPR_{MSY}	45.0%	(44.9% – 45.2%)
Exploitation rate corresponding to SPR_{MSY}	0.018	(0.018 – 0.019)
MSY (mt)	2,062	(642 – 3,482)

Table 13: Projection of potential OFL, landings, and catch, summary biomass (age-1 and older), spawning biomass, and depletion for the base case model projected with status quo catches in 2013 and 2014, and catches at the *p adjustment (83.3%) from the OFL from 2015 onward. The 2013 and 2014 OFL's are values specified by the PFMC and not predicted by this assessment. The OFL for 2015 and onward is the calculated total catch determined by F_{SPR}.**

Year	Predicted OFL (mt)	ACL Catch (mt)	Landings (mt)	Age 1+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2013	2,333	1,836	933	243,824	140,753	74.2%
2014	2,333	1,836	933	243,316	140,342	74.0%
2015	3,203	2,668	2,616	242,845	139,977	73.8%
2016	3,173	2,643	2,592	240,549	138,660	73.1%
2017	3,144	2,619	2,568	238,299	137,389	72.4%
2018	3,116	2,596	2,545	236,097	136,157	71.8%
2019	3,089	2,573	2,522	233,944	134,954	71.1%
2020	3,063	2,551	2,500	231,842	133,773	70.5%
2021	3,038	2,531	2,480	229,790	132,614	69.9%
2022	3,014	2,511	2,460	227,790	131,477	69.3%
2023	2,991	2,492	2,441	225,841	130,366	68.7%
2024	2,970	2,474	2,423	223,943	129,282	68.1%

Table 14: Summary table of 12-year projections beginning in 2015 for alternate states of nature based on an axis uncertainty. Columns range over low, mid, and high state of nature, and rows range over different assumptions of catch levels.

			State of nature					
			Low		Base case		High	
Relative probability of log(R_0)			0.25		0.5		0.25	
Management decision	Year	Total catch (mt)	Spawning biomass (1000 mt)	Depletion	Spawning biomass (1000 mt)	Depletion	Spawning biomass (1000 mt)	Depletion
Status quo catches	2015	952	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	952	54.1	53.2%	139.7	73.6%	405.1	88.8%
	2017	952	53.7	52.8%	139.4	73.5%	405.1	88.9%
	2018	952	53.3	52.4%	139.2	73.3%	405.2	88.9%
	2019	952	52.9	52.0%	139.0	73.2%	405.4	88.9%
	2020	952	52.6	51.7%	138.8	73.1%	405.5	88.9%
	2021	952	52.2	51.4%	138.6	73.1%	405.7	89.0%
	2022	952	51.9	51.0%	138.5	73.0%	405.8	89.0%
	2023	952	51.6	50.8%	138.4	72.9%	406.0	89.0%
	2024	952	51.4	50.5%	138.2	72.9%	406.1	89.1%
Catch associated with SPR = 65%, stabilizing population around 60% of B_0	2015	1,828	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	1,819	53.6	52.7%	139.2	73.3%	404.6	88.7%
	2017	1,812	52.7	51.8%	138.4	72.9%	404.1	88.6%
	2018	1,804	51.8	50.9%	137.6	72.5%	403.7	88.5%
	2019	1,797	50.9	50.0%	136.9	72.1%	403.3	88.5%
	2020	1,790	50.0	49.1%	136.2	71.8%	402.9	88.4%
	2021	1,784	49.1	48.3%	135.5	71.4%	402.6	88.3%
	2022	1,778	48.3	47.5%	134.9	71.1%	402.2	88.2%
	2023	1,773	47.5	46.7%	134.2	70.7%	401.8	88.1%
	2024	1,768	46.7	45.9%	133.6	70.4%	401.5	88.1%
OFL (associated with SPR = 50%), including *p** offset (83.3%)	2015	2,668	54.6	53.6%	140.0	73.8%	405.1	88.9%
	2016	2,643	53.1	52.2%	138.7	73.1%	404.1	88.6%
	2017	2,619	51.7	50.8%	137.4	72.4%	403.1	88.4%
	2018	2,596	50.3	49.4%	136.2	71.8%	402.2	88.2%
	2019	2,573	48.9	48.1%	135.0	71.1%	401.4	88.0%
	2020	2,551	47.5	46.7%	133.8	70.5%	400.5	87.8%
	2021	2,531	46.2	45.4%	132.6	69.9%	399.7	87.7%
	2022	2,511	44.9	44.1%	131.5	69.3%	398.8	87.5%
	2023	2,492	43.6	42.8%	130.4	68.7%	398.0	87.3%
	2024	2,474	42.3	41.6%	129.3	68.1%	397.2	87.1%

Table 15: Change in likelihood associated with model estimates using 100 alternative starting values for all parameters.

Difference in likelihood from base model	Number of occurrences	Difference in likelihood from base model	Number of occurrences
0	27	12.01	1
0.54	34	21.83	1
0.57	11	24.13	1
1.21	12	26.25	1
2.78	1	31.28	1
2.79	1	31.59	1
2.92	1	40.07	1
2.97	1	77.46	1
3.38	1	140.89	1
3.53	1	267.70	1

Table 16: Summary of results for likelihood profiles and sensitivity analyses. Likelihood values are change relative to base model with larger values indicating a worse fit.

Quantity	Base model	Low state of nature log(R_0) = 9.7	High state of nature log(R_0) = 11.2	Low steep. h=0.4	High steep. h=0.8	Low mort. M=0.04	High mort. M=0.06	Alt. maturity 1	Alt. maturity 2	No recruit var.	Low recruit var. σ_R=0.25	High recruit var. σ_R=0.75	Alt. early catch
Likelihood values relative to base model													
Total likelihood	0.00	3.65	1.17	-0.92	-0.61	-7.29	7.46	-0.03	-0.06	53.91	9.96	-4.25	-0.63
Survey indices	0.00	2.18	-0.41	0.27	-0.09	1.74	-0.34	-0.01	-0.02	1.88	0.00	0.52	-0.01
Length data	0.00	-1.41	0.57	-0.01	-0.02	-5.86	4.80	-0.02	-0.04	59.56	14.63	-4.87	0.05
Discard fractions	0.00	-1.00	1.30	-0.51	0.22	-0.57	0.49	0.02	0.05	-2.70	-0.84	0.13	0.00
Quantities of interest													
Unfished Spawning biomass (1000 mt)	189.8	101.7	455.9	167.9	201.3	126.8	1691.2	159.5	141.3	129.6	198.2	153.8	190.9
Unfished recruitment (R0, millions)	30.4	16.3	73.1	26.9	32.3	10.9	442.4	30.6	30.8	20.8	31.8	24.7	30.6
Depletion (2013)	74.2%	54.6%	88.9%	69.6%	76.2%	53.6%	95.6%	74.2%	73.8%	59.8%	74.1%	69.0%	74.6%
Catchability for NWFSC Combo Survey	0.43	1.04	0.15	0.52	0.40	1.21	0.03	0.43	0.42	0.69	0.40	0.58	0.43

10 Figures

10.1 Catch history

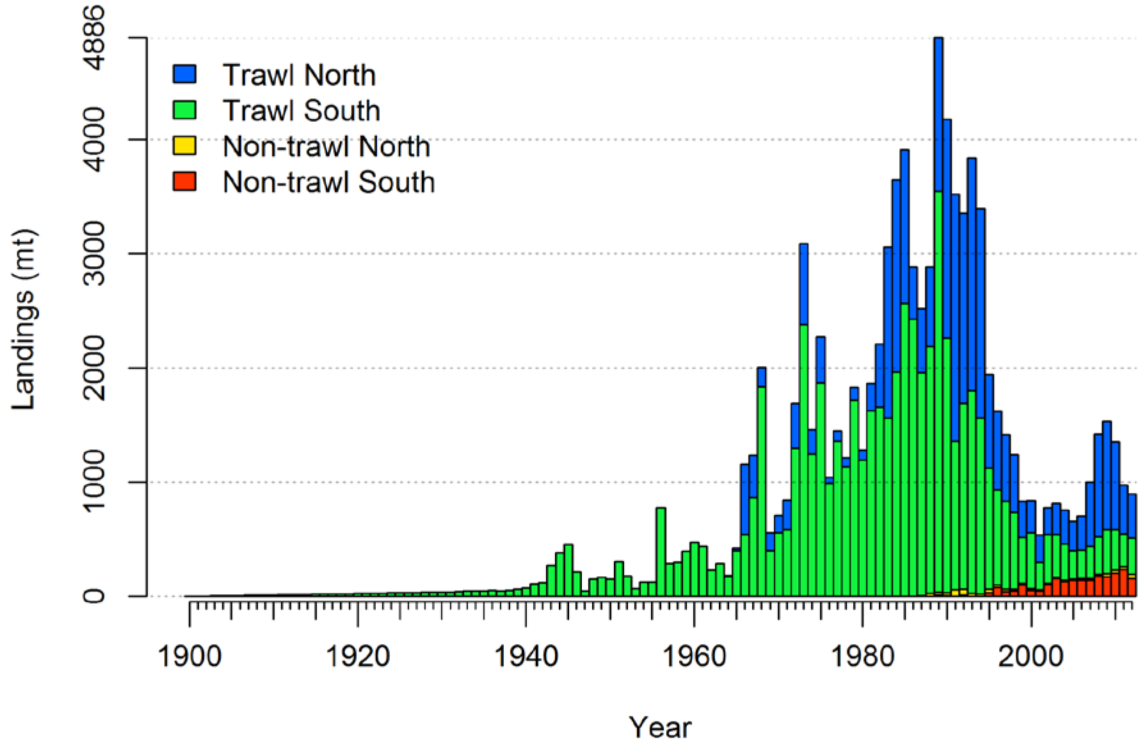

Figure 1: Estimated landings history for shortspine thornyhead.

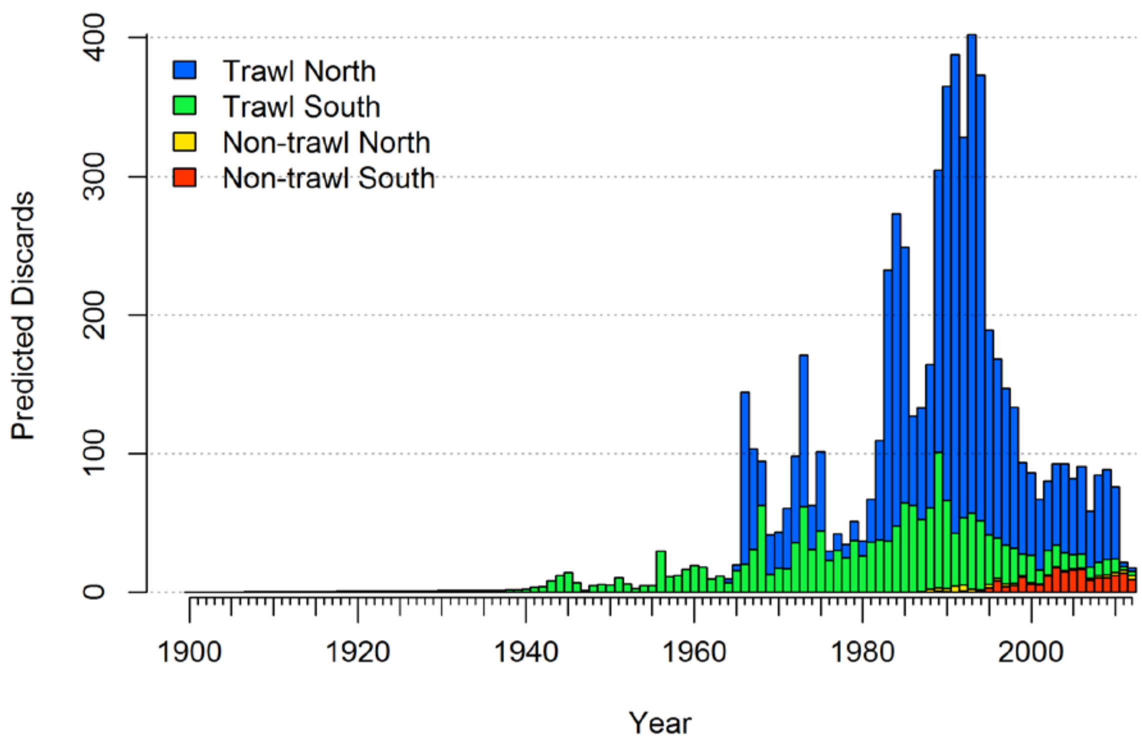

Figure 2: Predicted discards based estimated retention and selectivity for each fleet.

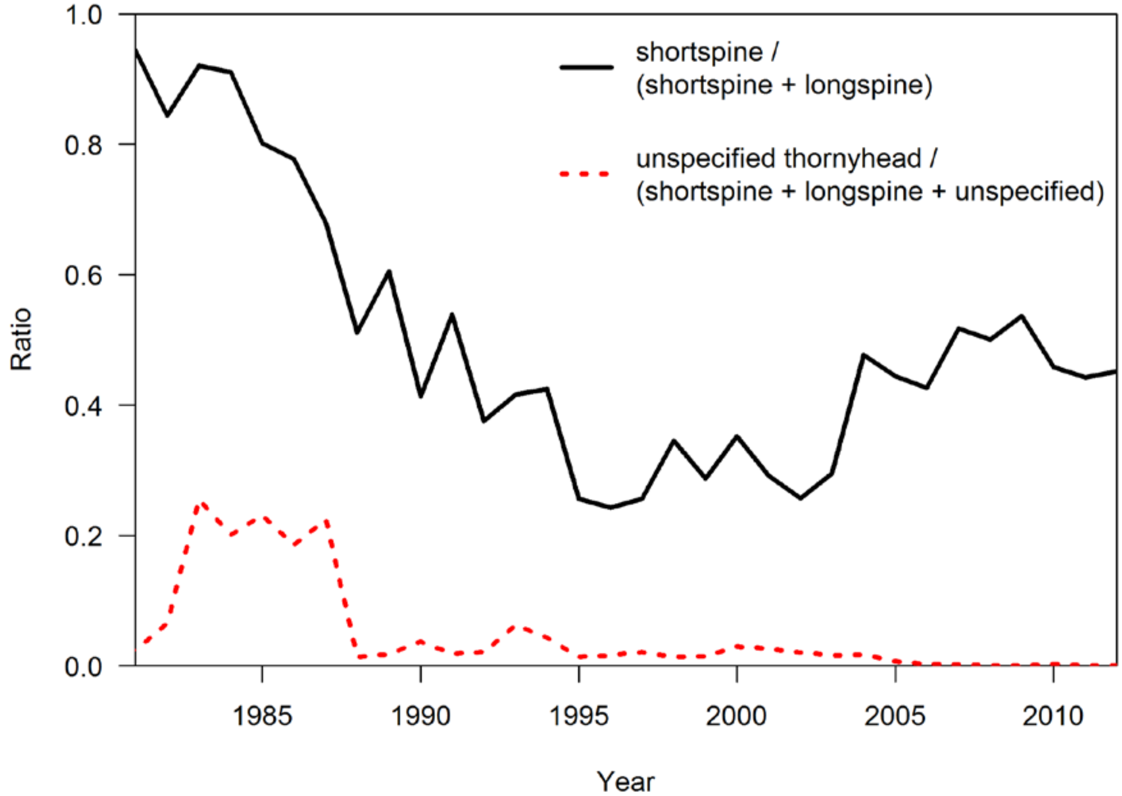

Figure 3: Ratio of shortspine to combined thornyheads in the subset of the landings for which the species was identified (solid black line), and the ratio of unspecified landings to total landings of both thornyhead species (dotted red line). The ratio of specified thornyheads was used to apportion the unspecified landings into estimates of the landings for each species.

10.2 Distribution, Ecology and Life history

Figure 4: Occurrence and abundance of shortspine thornyhead found in the NWFSC annual survey (2003-2012) north of 40°10’ N latitude.

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Figure 5: Occurrence and abundance of shortspine thornyhead found in the NWFSC annual survey (2003-2012) south of 40º10' N latitude.

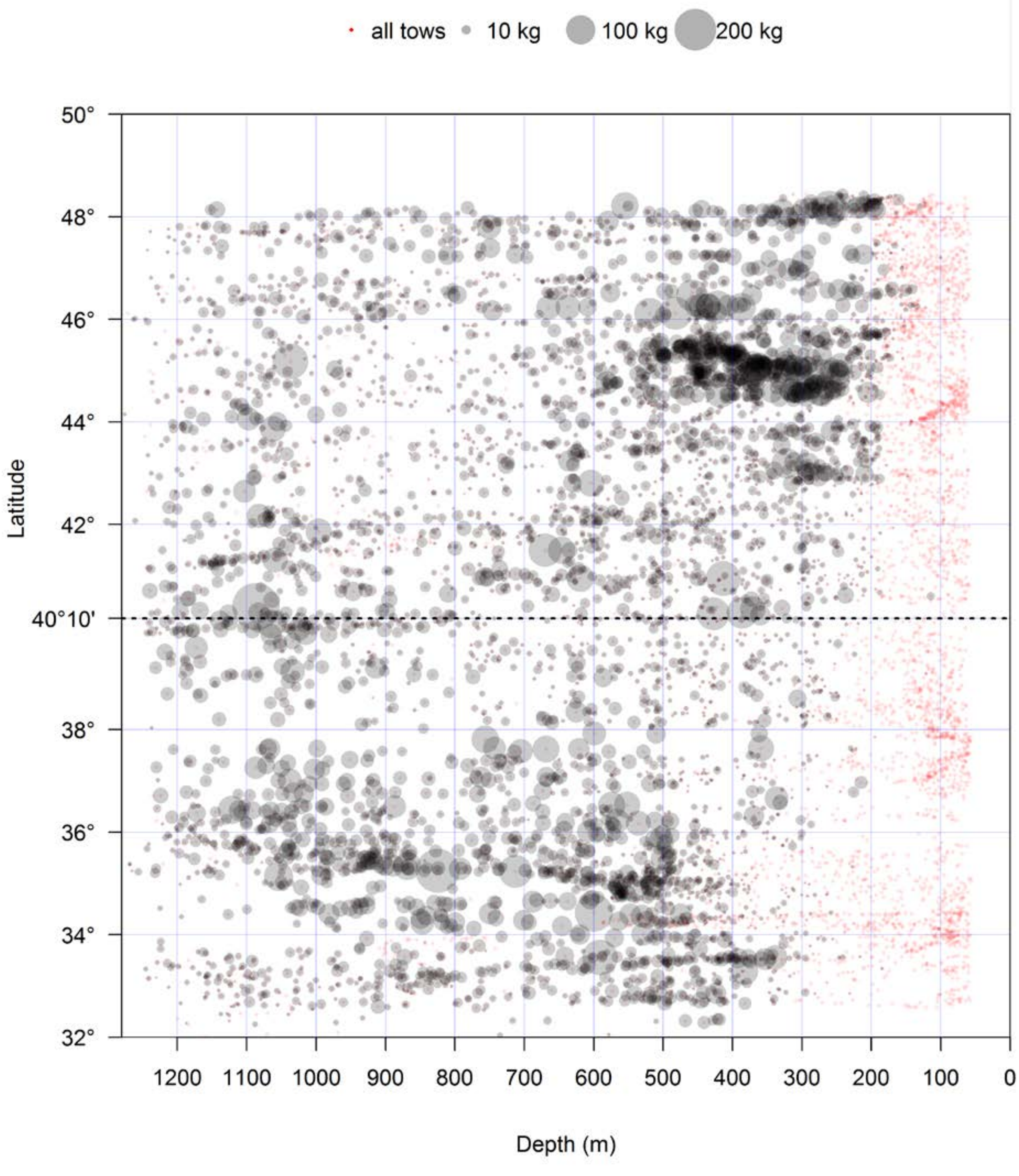

Figure 6: Spatial distribution of shortspine thornyhead in NWFSC shelf-slope survey data (2003 – 2012). Red points indicate location of all tows. Grey points indicate location of shortspine thornyheads with area of circle proportional to biomass of catch with scale indicated in key at the top. Swept area is not accounted for in this figure, but tows typically cover similar area.

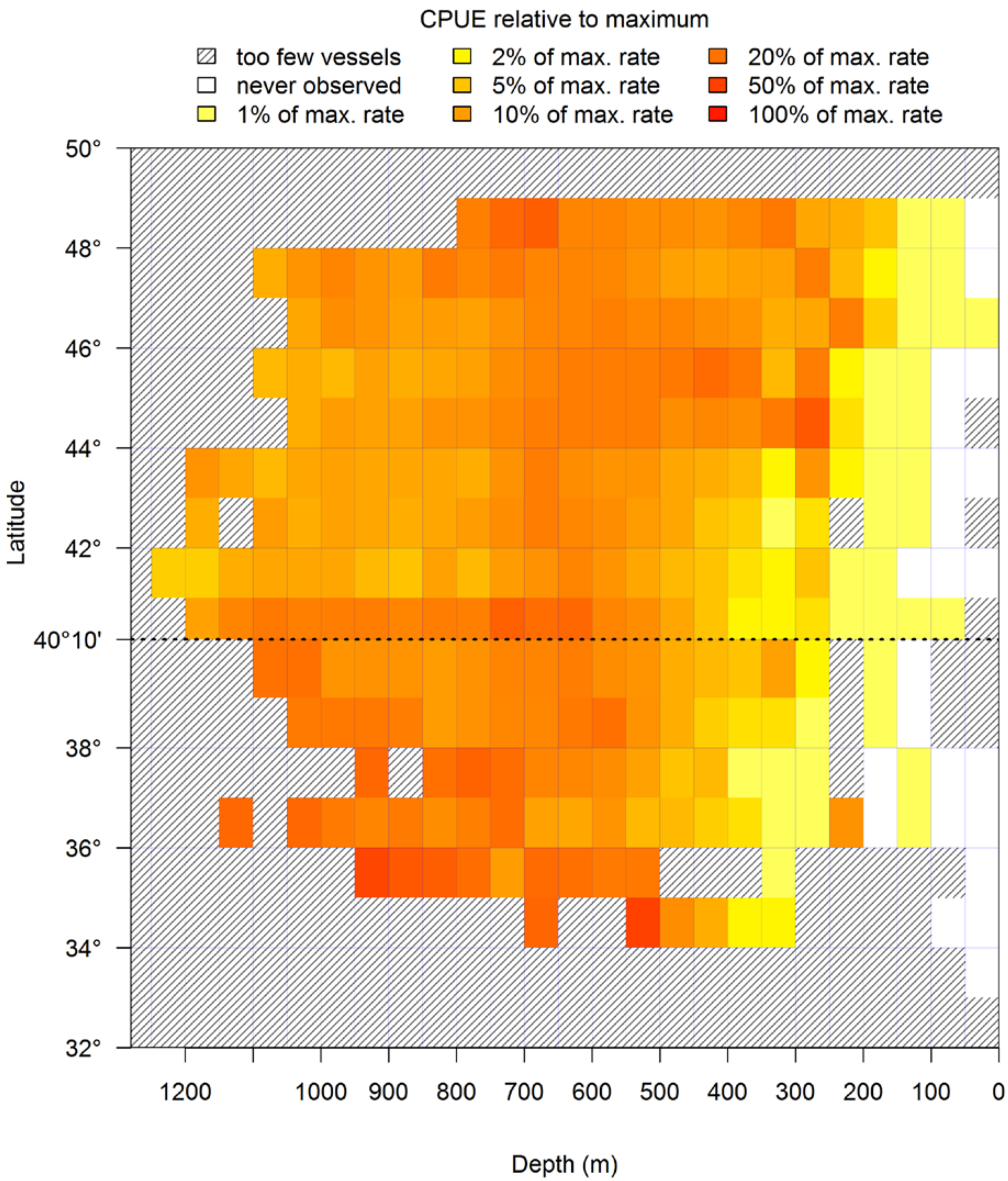

Figure 7: Spatial distribution of shortspine thornyhead in WCGOP trawl data (2002 – 2011). Colors represent CPUE relative to the maximum. Darkest red = highest CPUE; lightest yellow = lowest CPUE. Data for hatched boxes could not be displayed because of confidentiality (only 1 or 2 vessels carrying observers fished in the area) or because no vessels carrying observers fished in the area. White areas are places where 3 or more vessels fished and carried observers, but the species in question was not caught. CPUE represented here is the sum of the observed catch across all years divided by the sum of the trawl durations during observed hauls within each cell.

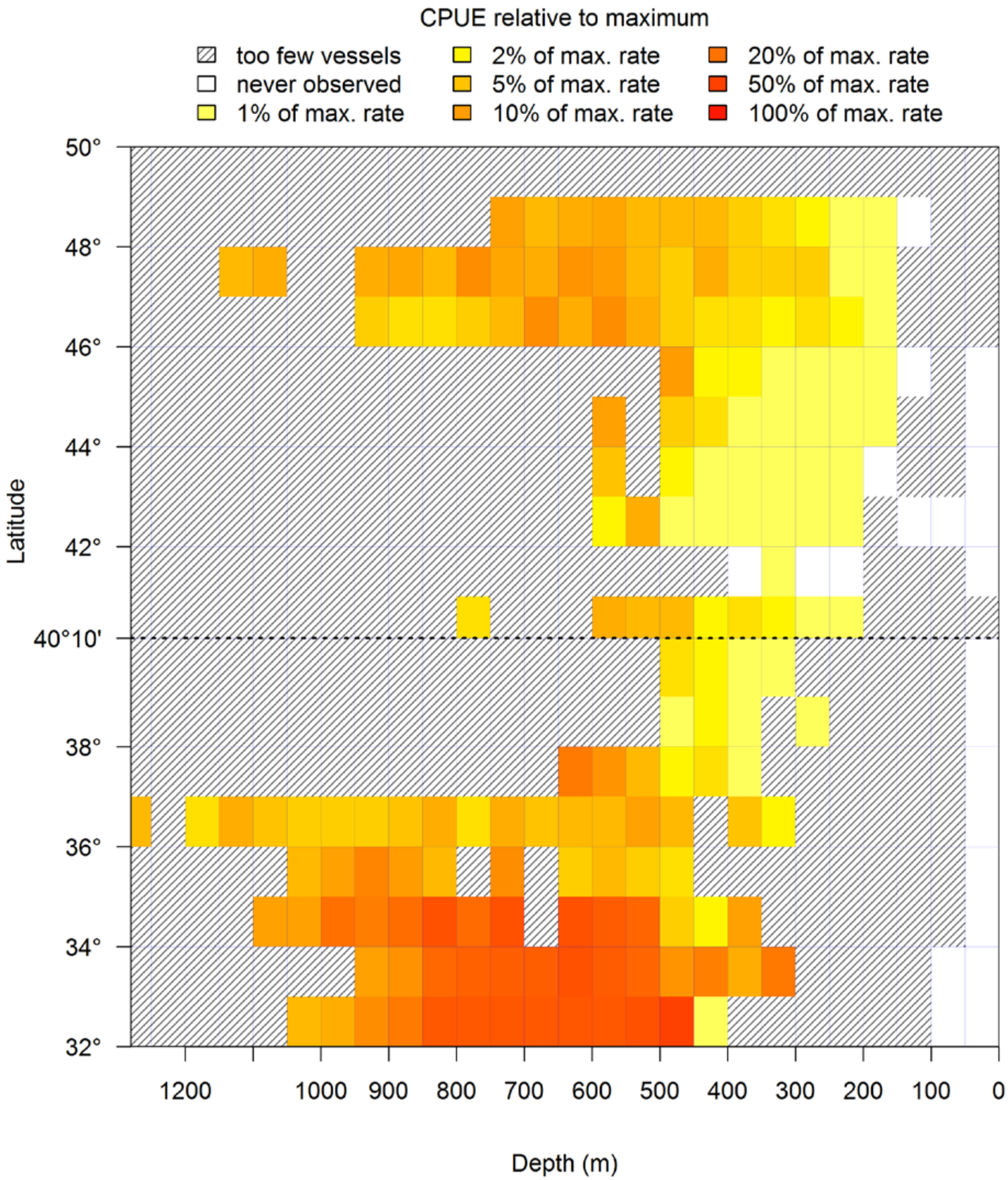

Figure 8: Spatial distribution of shortspine thornyhead in WCGOP hook and line fishery data (2002 – 2011). Colors represent CPUE relative to the maximum. Darkest red = highest CPUE; lightest yellow = lowest CPUE. Data for hatched boxes could not be displayed because of confidentiality (only 1 or 2 vessels carrying observers fished with hook and line in the area) or because no vessels carrying observers fished in the area. White areas are places where 3 or more vessels fished and carried observers, but the species in question was not caught. CPUE represented here is the sum of the observed catch across all years divided by the sum of the number of hooks set hauls within each cell.

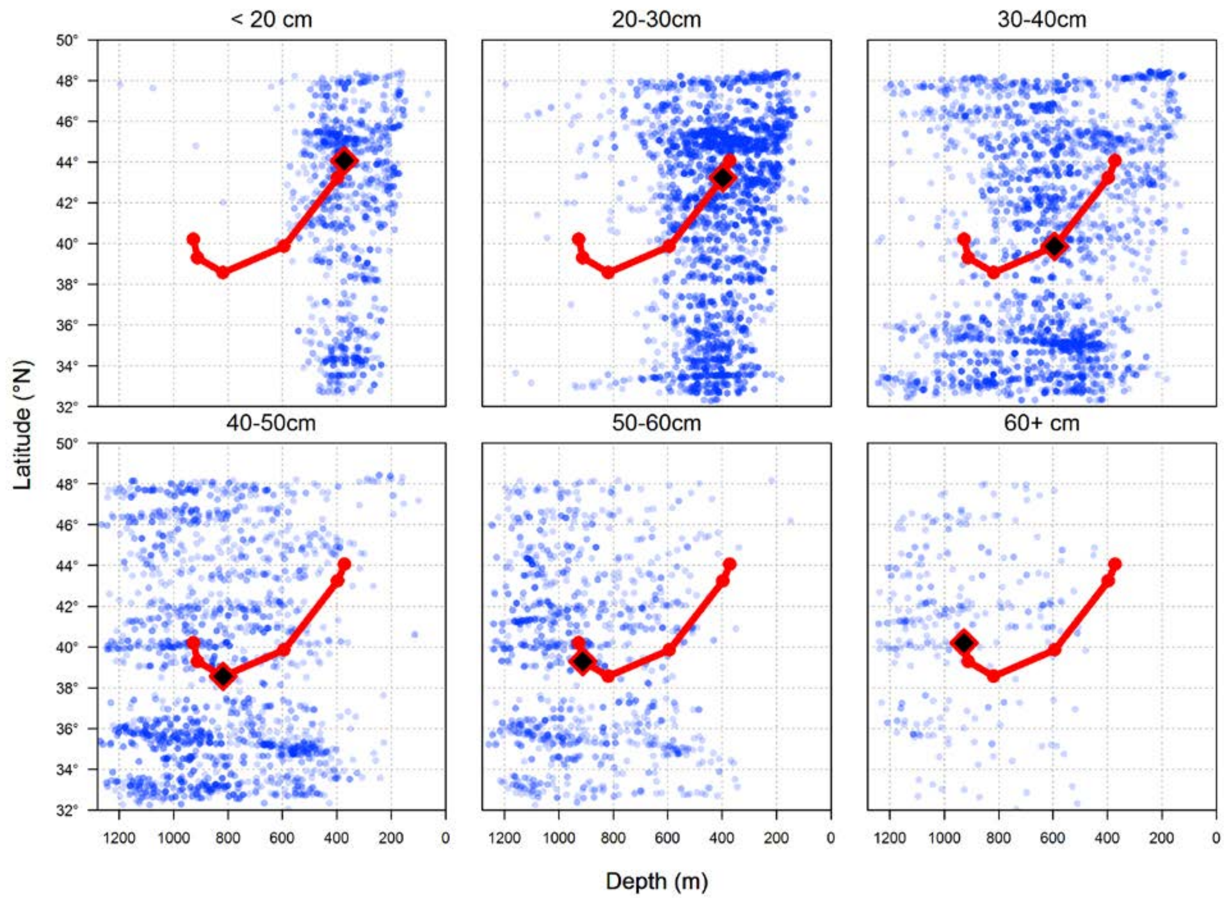

Figure 9: Distribution of different size groups of shortspine thornyheads. Blue points represent location of samples in each size bin. Black diamonds indicate the weighted average of depth and latitude for each bin, and the red lines show the connected series of average values across bins.

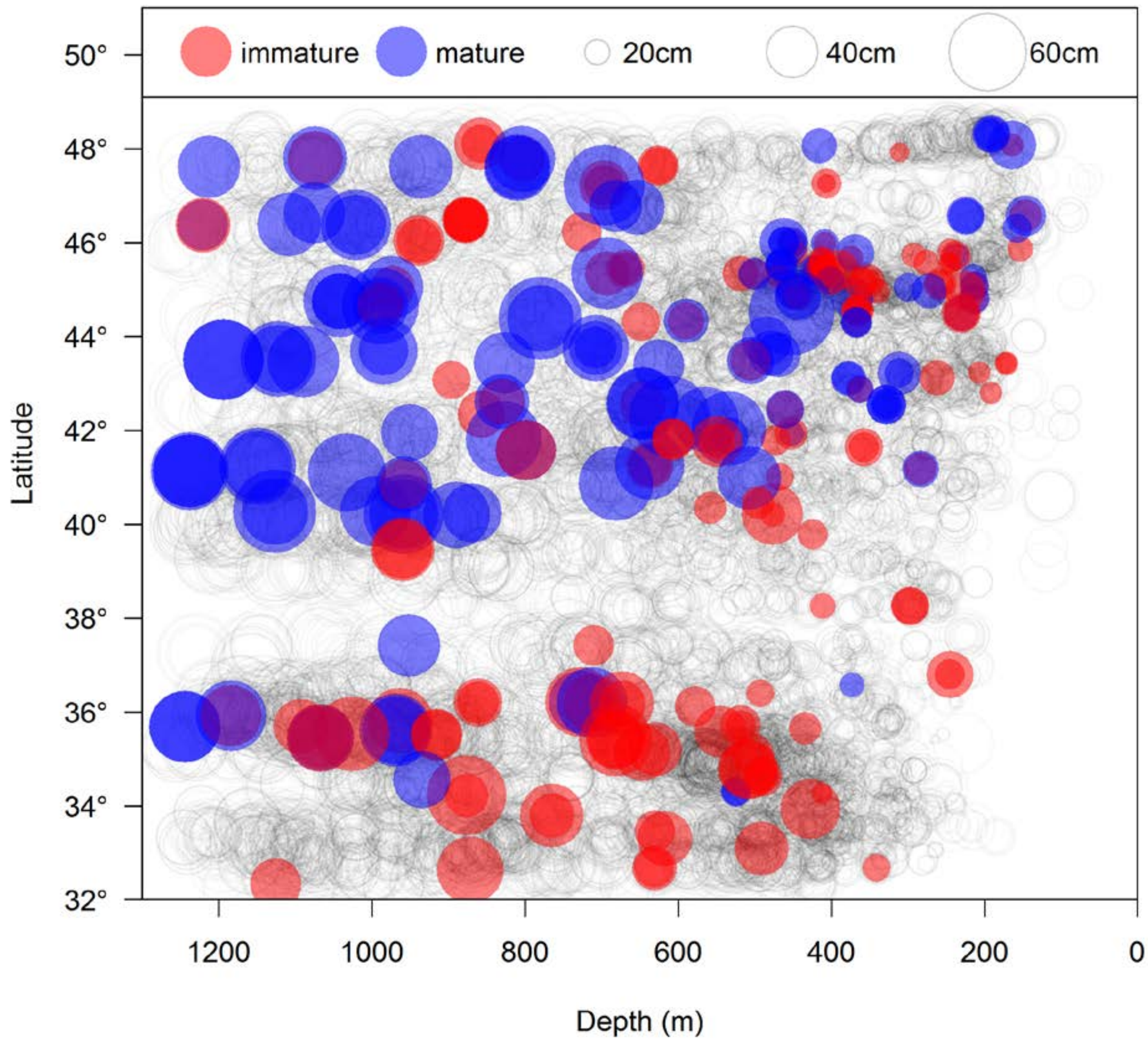

Figure 10: Distribution of mature and immature shortspine thornyheads based on ovaries collected in the NWFSC Combo Survey in 2011 and 2012. Due to difficulty in determining maturity of individuals that are not spawning, immature samples may include fish that were skipping spawning. Open circles indicate all length samples. Filled circles represent locations where ovaries were collected. Circle Diameter of circles is proportional to observed length.

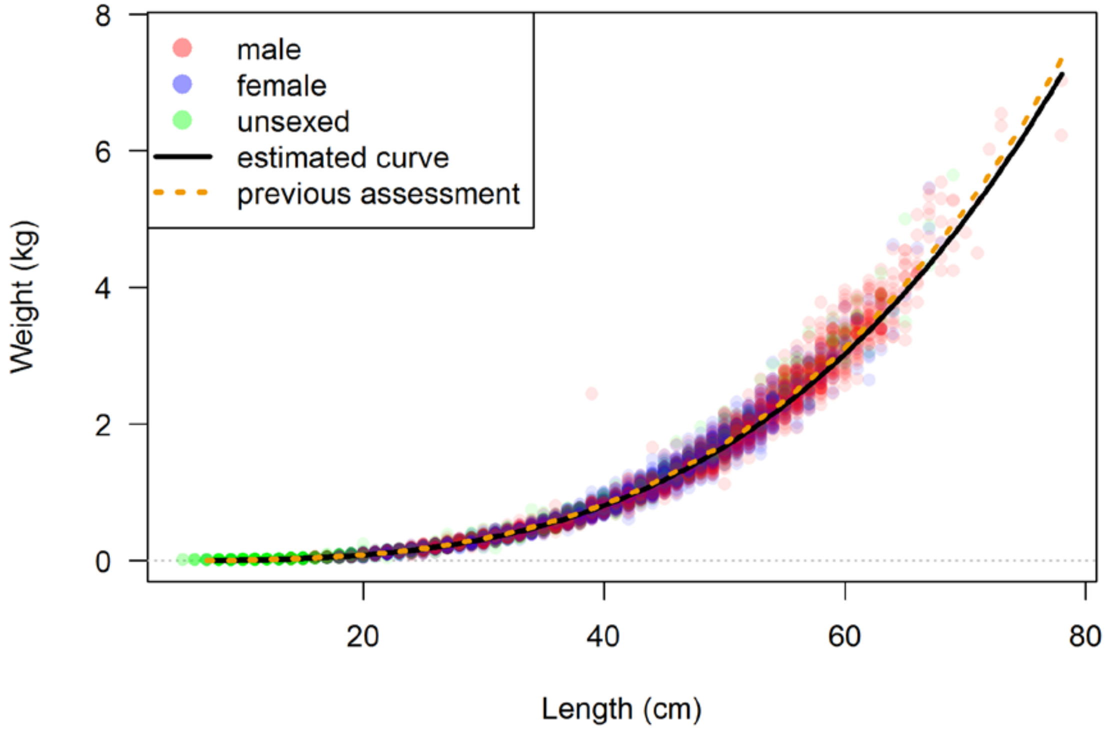

Figure 11: Weight at length observations and estimation mean relationship used in the assessment.

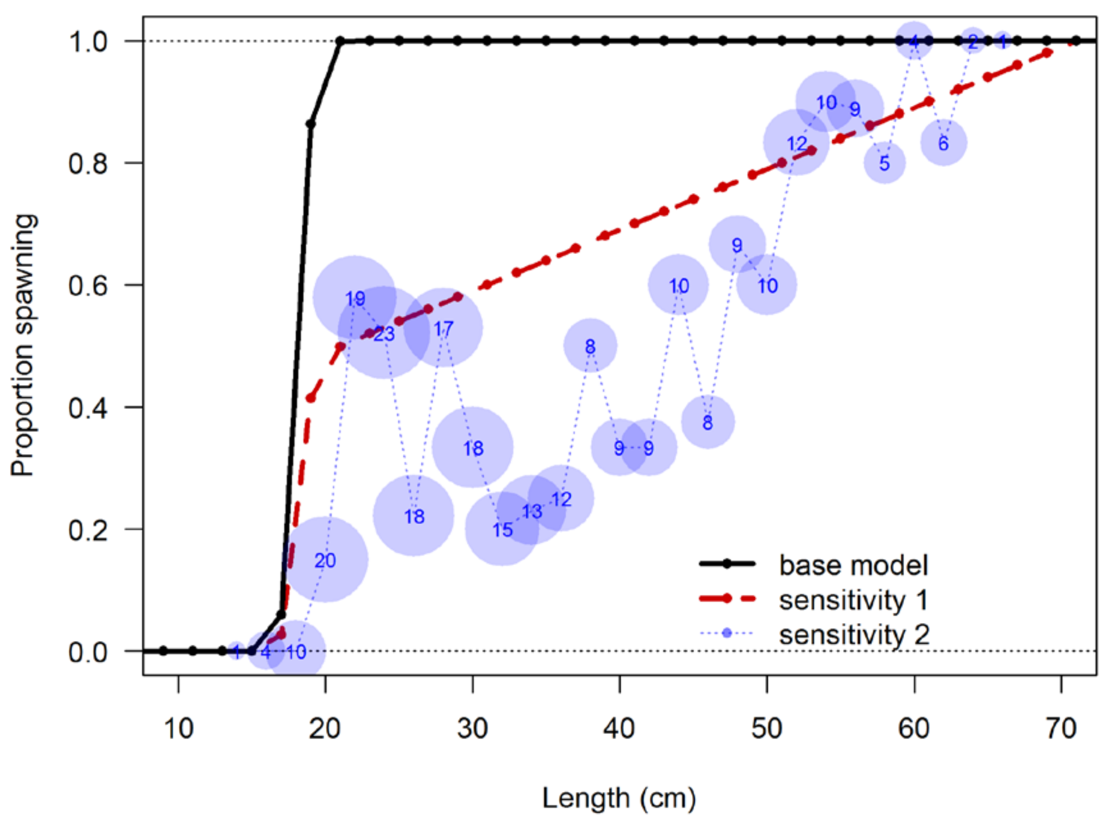

Figure 12: Recently collected data on proportion spawning by length bin (circles) with sample size indicated by area of circle and number within. Maturity schedules for the base model and sensitivity analyses are shown by the solid and dashed lines.

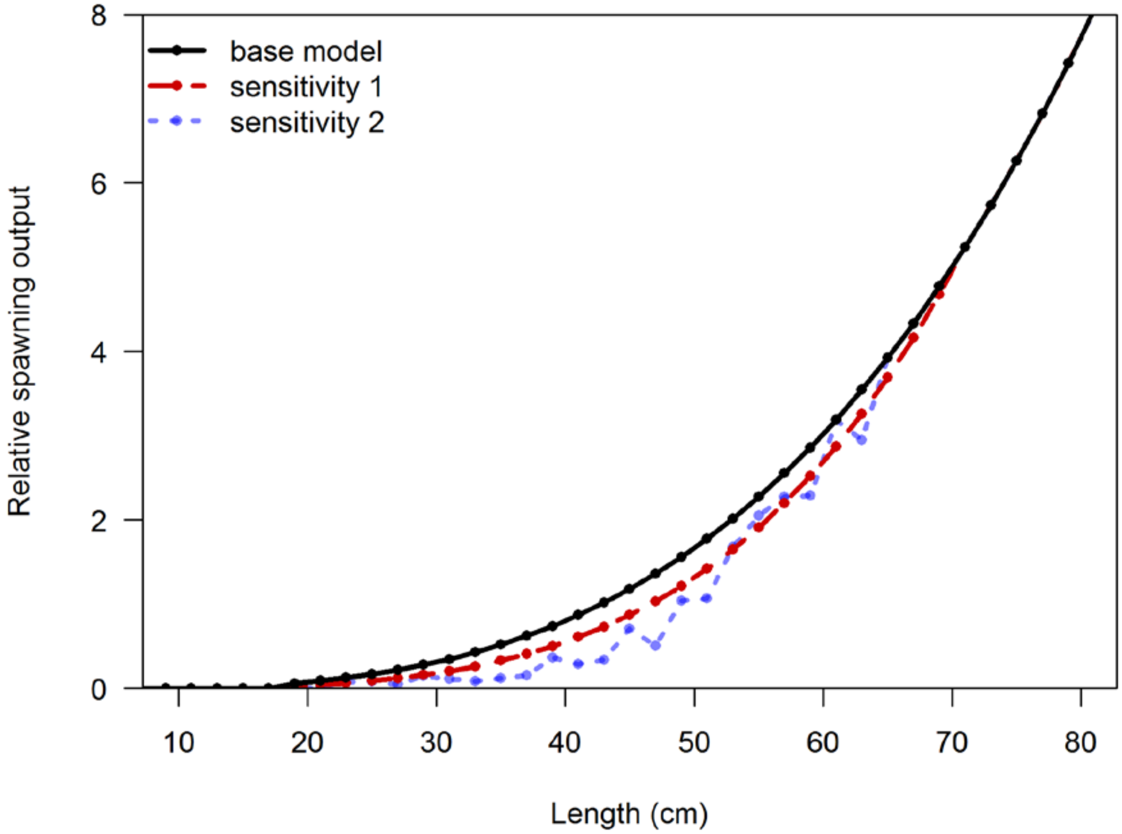

Figure 13: Spawning output as a function of length for the base model and the sensitivity analyses. This is the product of fraction spawning and fecundity (assumed proportional to weight).

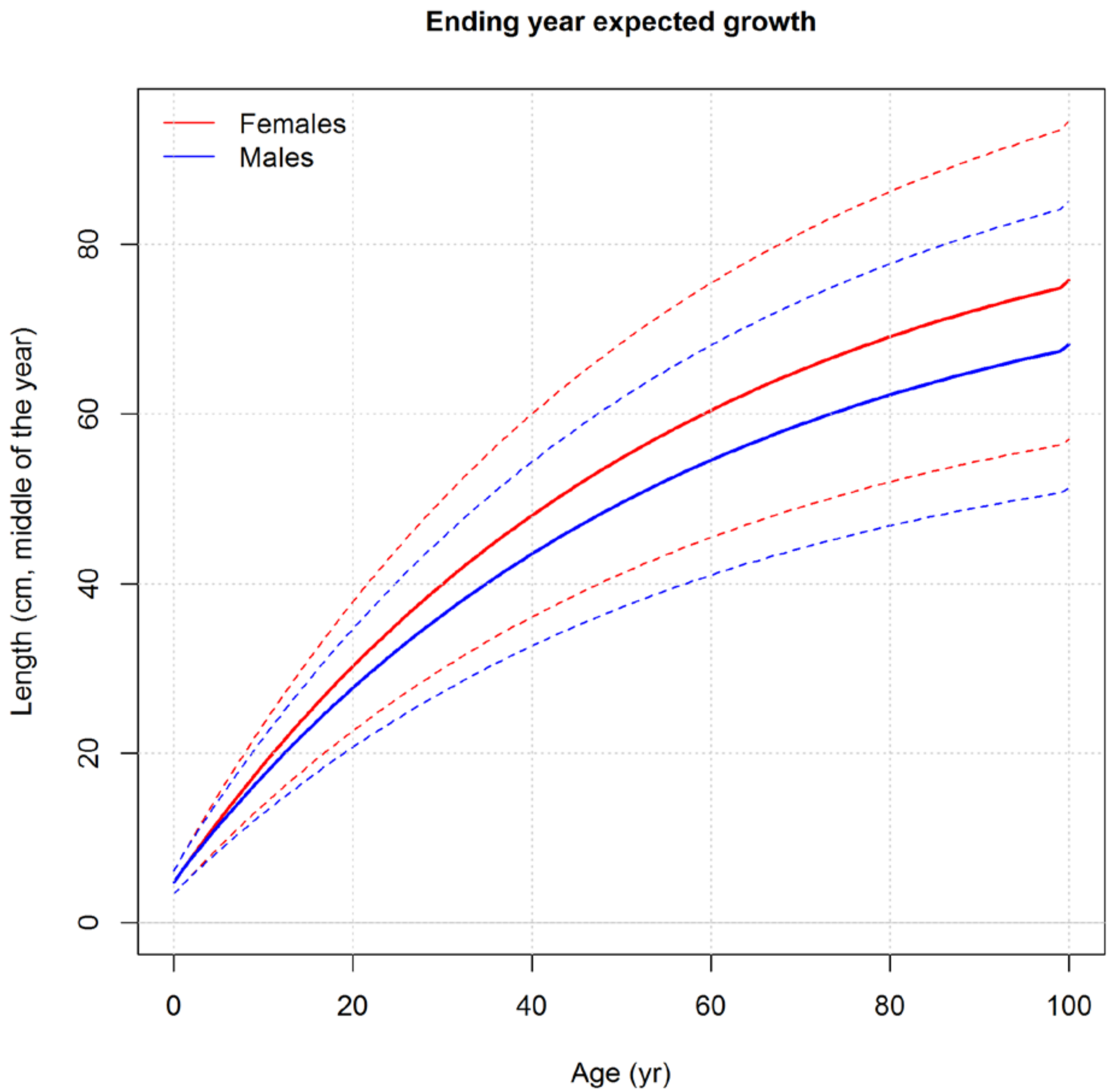

Figure 14: Growth curves (solid lines) and 95% variability in length-at-age used in the model.

10.3 Data and model fits
10.3.1 Data summary

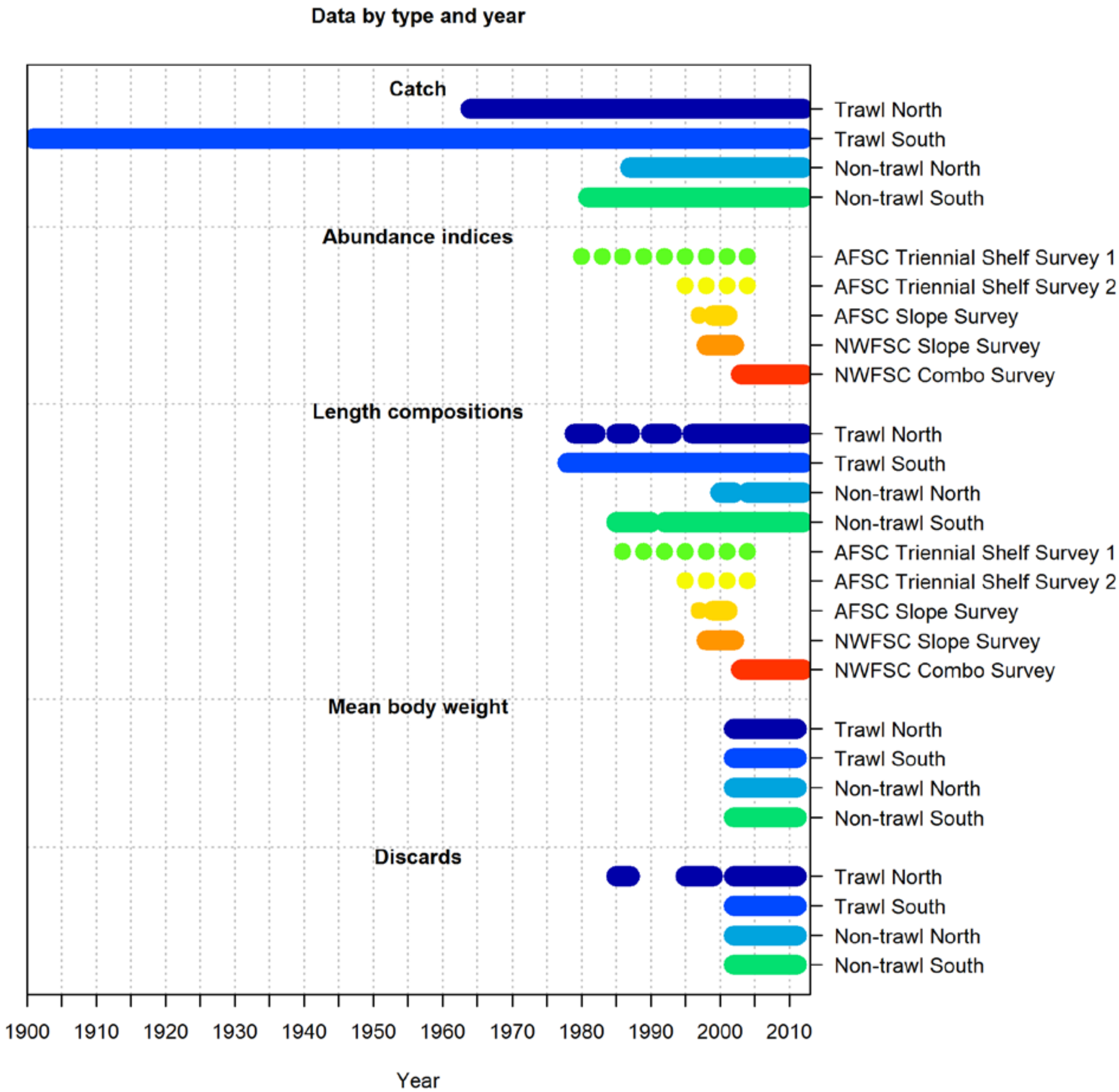

Figure 15: Chart of data availability by year for each fleet.

10.3.2 Selectivity and retention

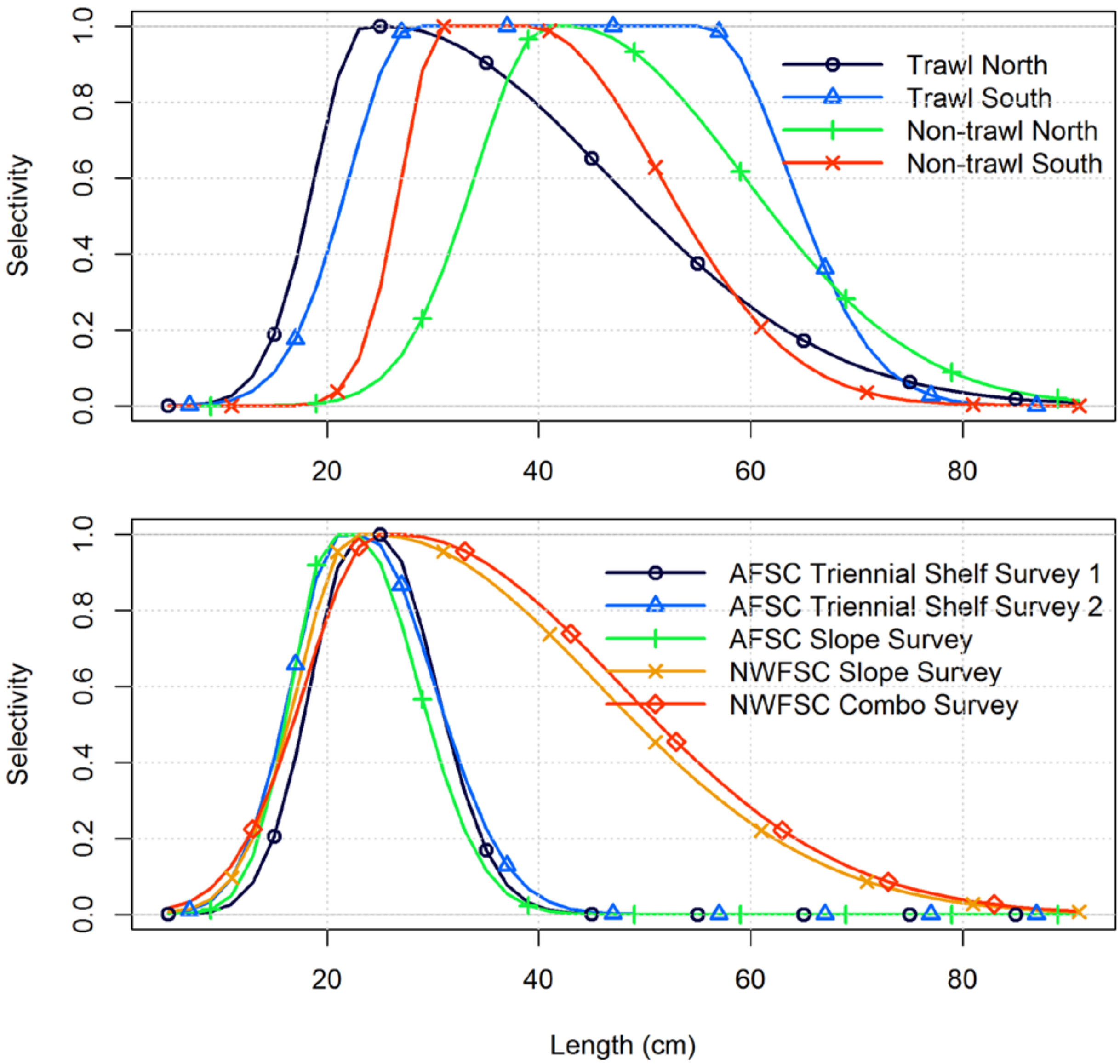

Figure 16: Selectivity for each fishing fleet (upper panel) and survey (lower panel).

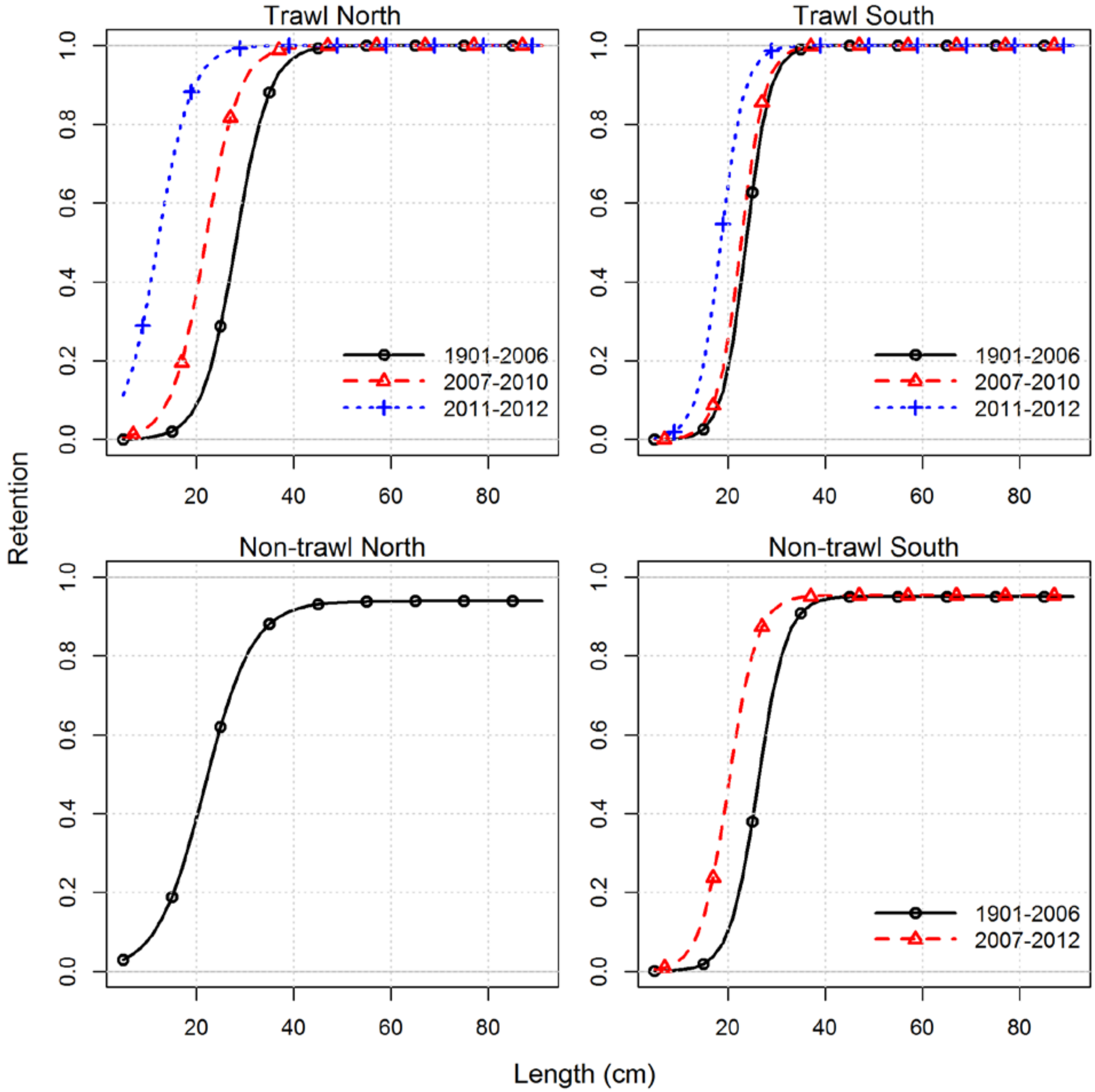

Figure 17: Retention functions for each fleet in the base model indicating increased retention of smaller fish in more recent years.

10.3.3 Indices and discard data

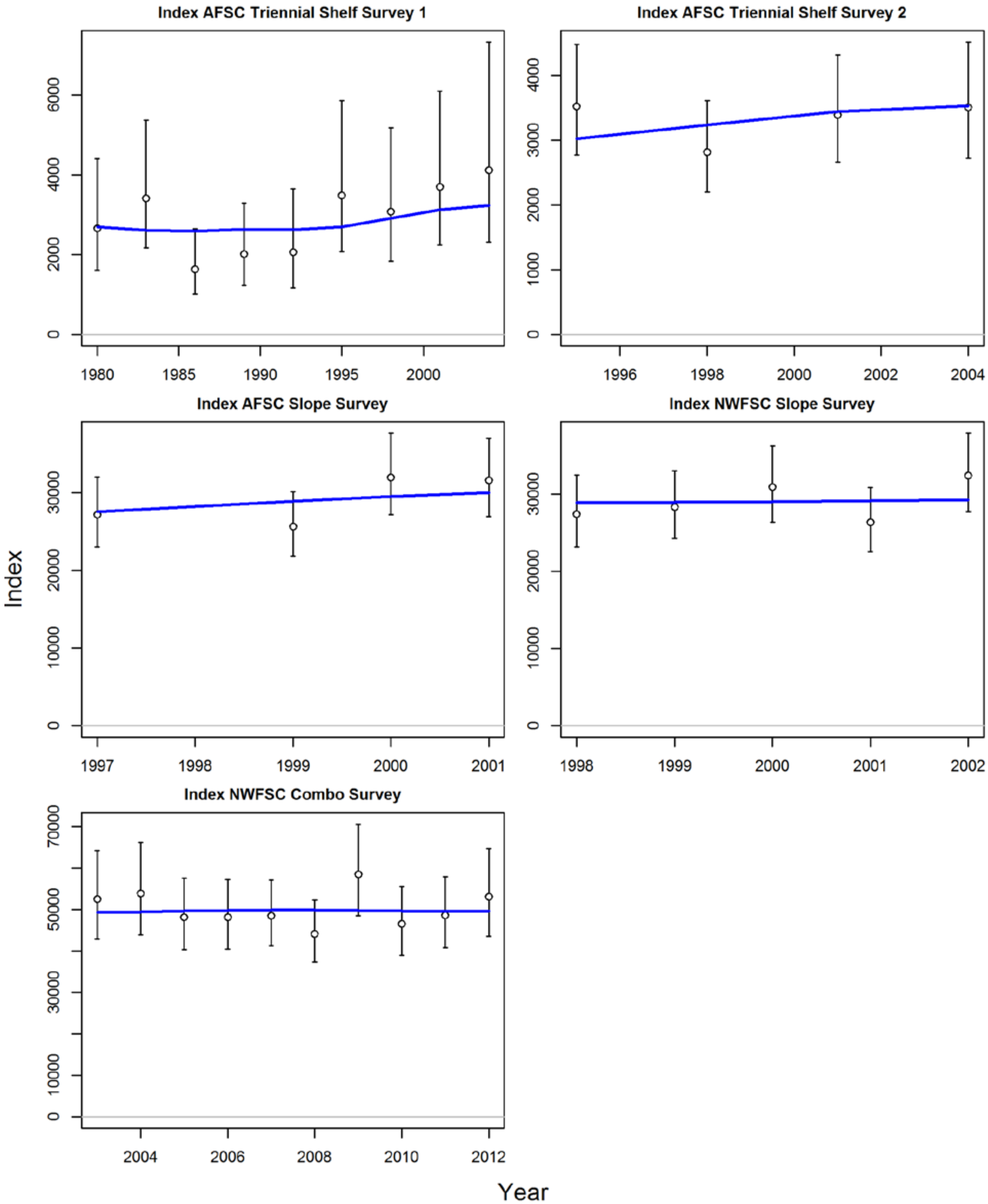

Figure 18: Indices of abundance used in the assessment (open circles) shown with 95% intervals (black vertical lines) and model fits (blue lines).

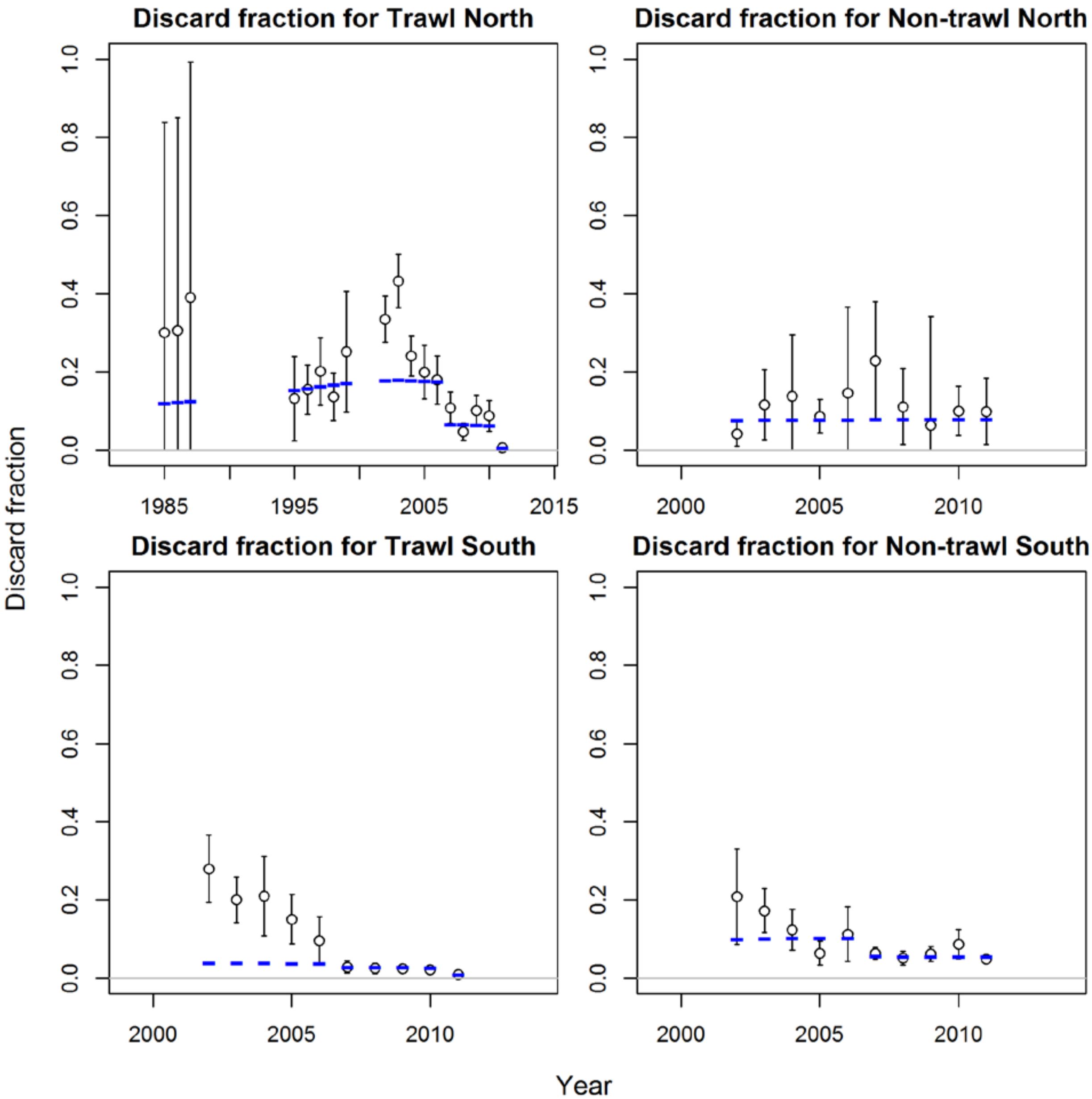

Figure 19: Discard fractions estimated for each fleet (open circles) shown with 95% intervals (black vertical lines) and model fits (blue lines).

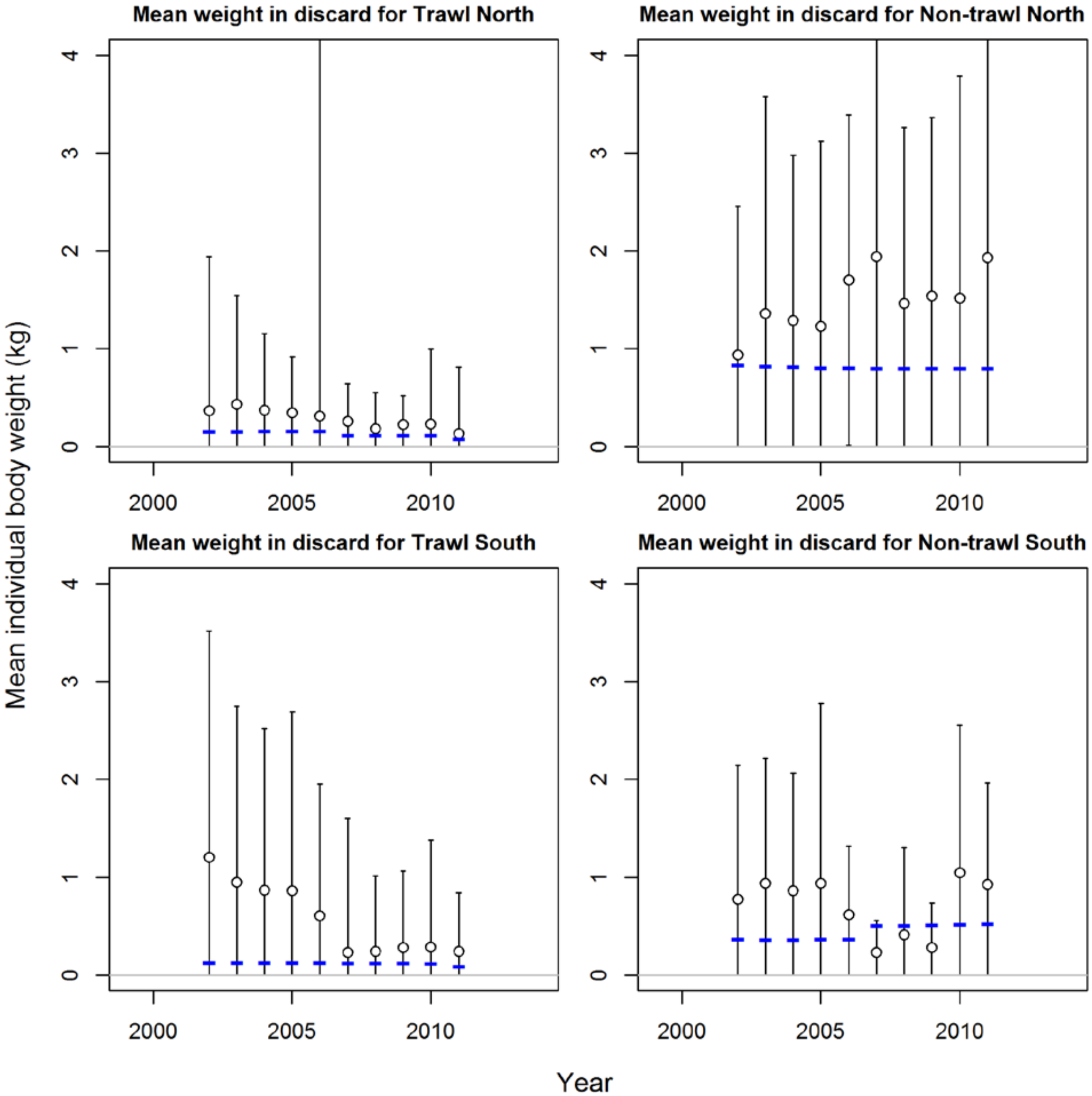

Figure 20: Mean weight of discard data for each fleet (open circles) shown with 95% intervals (black vertical lines) and model fits (blue lines).

10.3.4 Length compositions

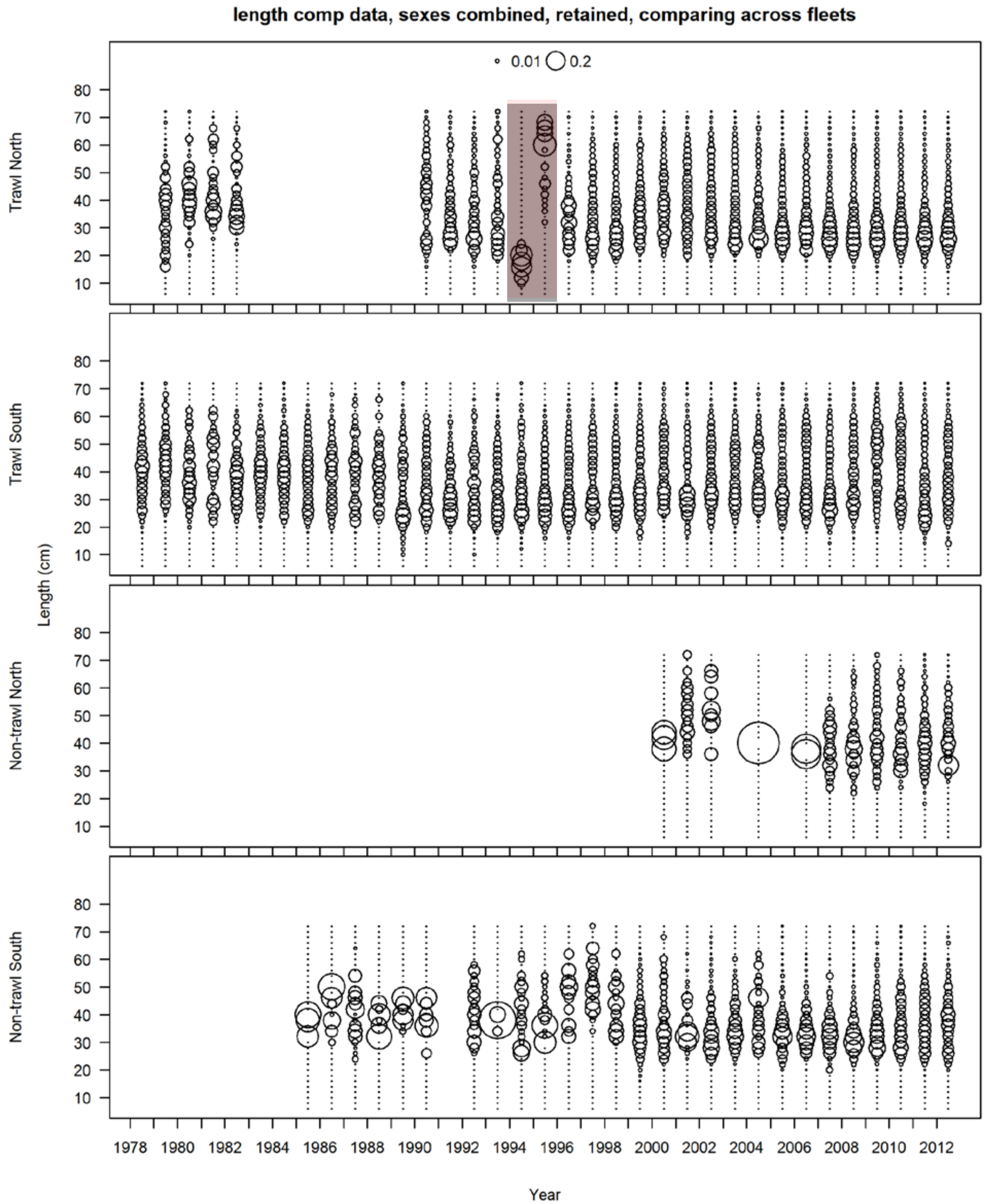

Figure 21: Fishery length compositions calculated from landed catch. Bubble sizes indicate proportion in each length bin. Sexes are combined. Shaded section in top panel indicates observations from 1994–95 that were considered outliers and removed from base model.

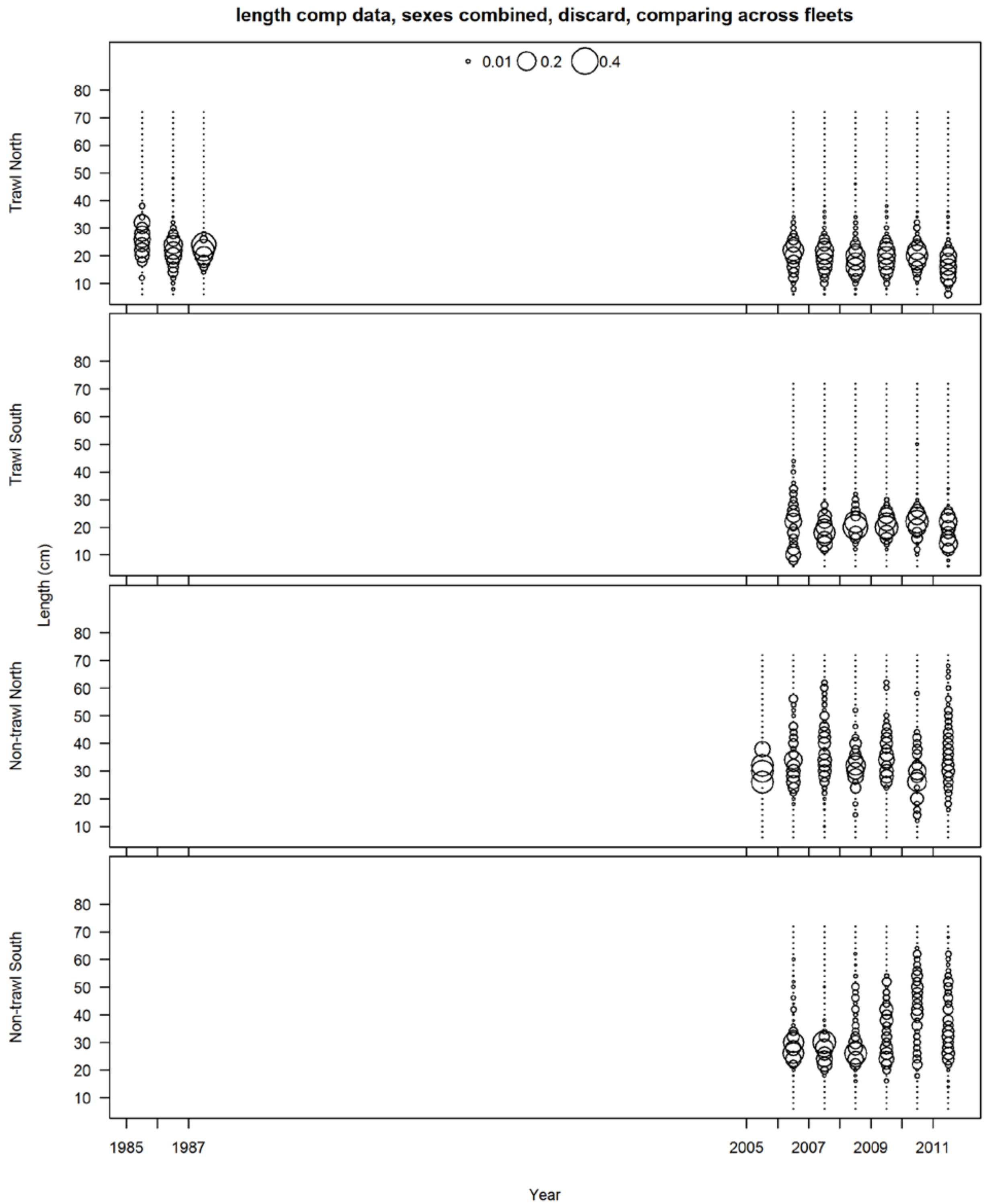

Figure 22: Fishery length compositions calculated from discards. Sexes are combined.

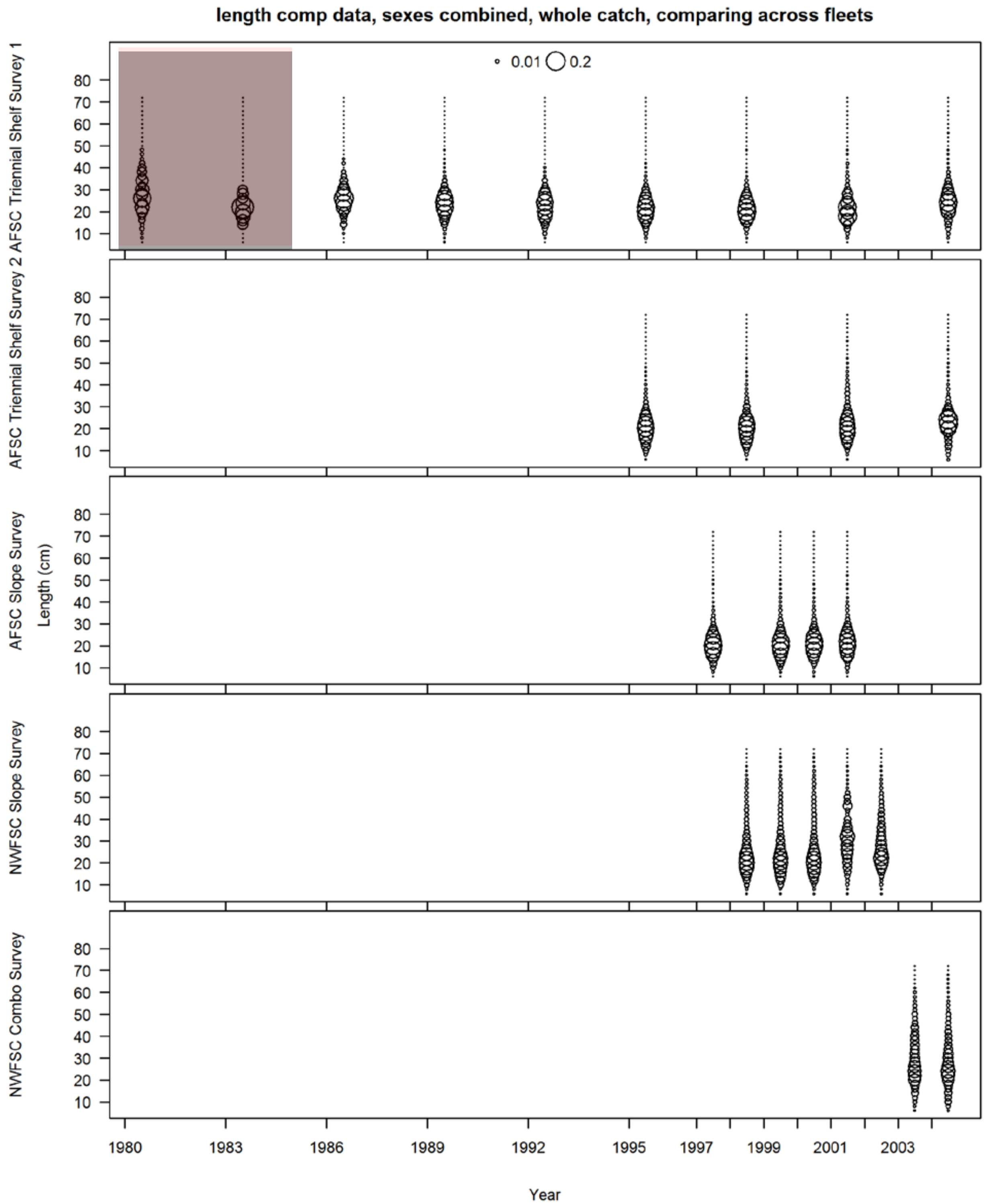

Figure 23: Survey length compositions for years with combined sex data. Shaded region in top panel indicates observations that were associated with only a single tow and removed from the base model.

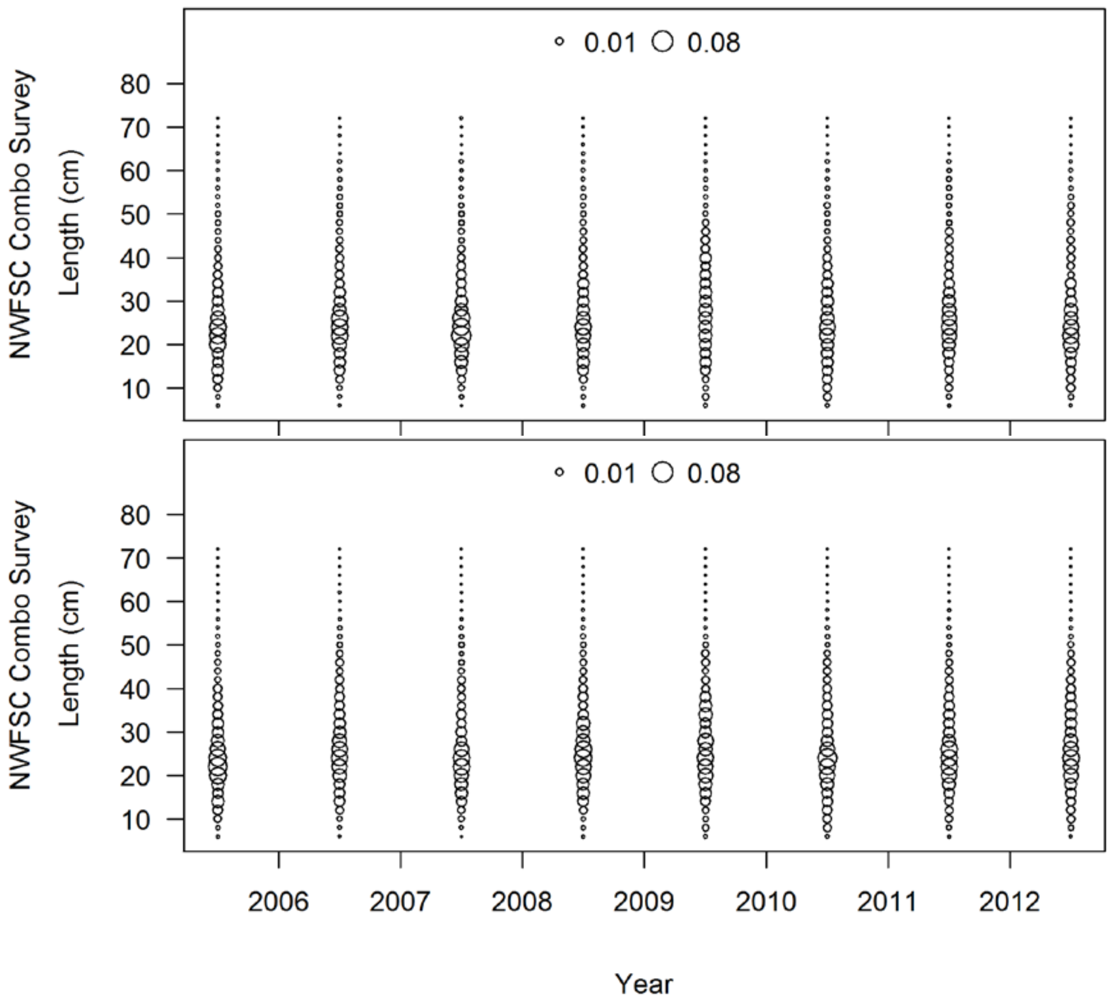

Figure 24: Survey length compositions for females (top) and males (bottom) for the NWFSC Combo Survey.

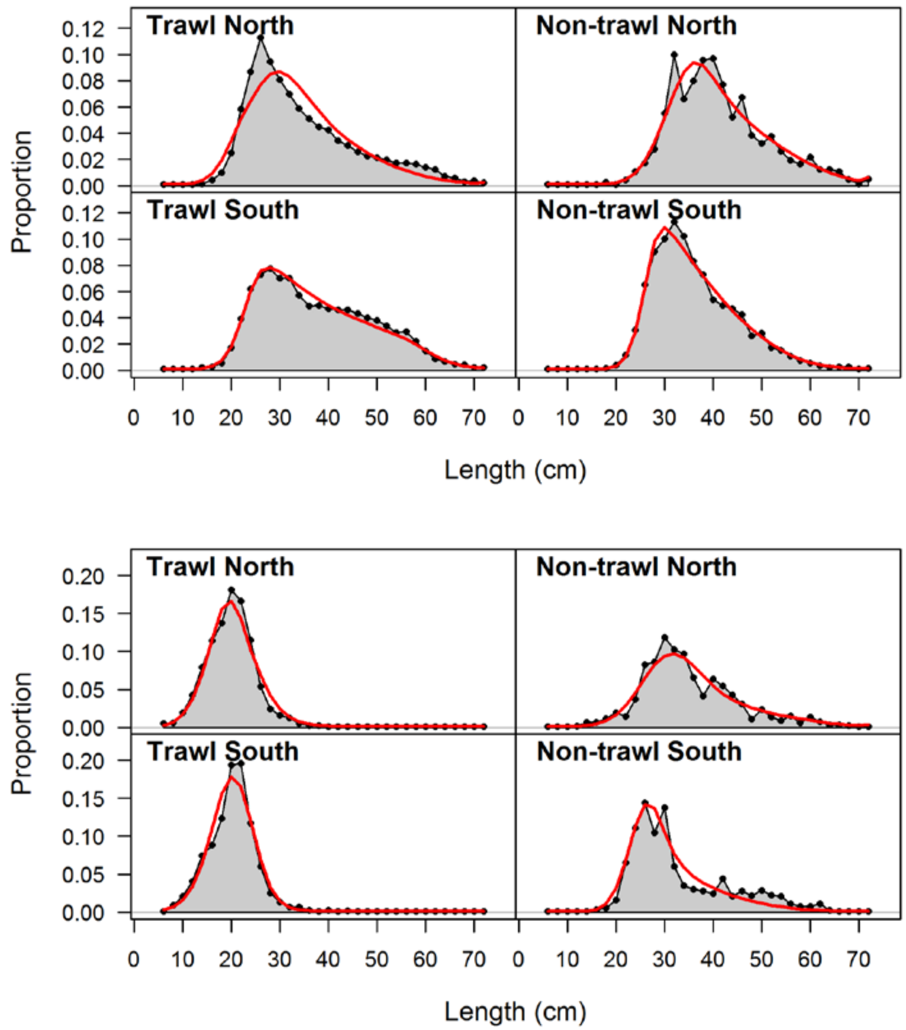

Figure 25: Fits to fishery length compositions aggregated across all years for each fleet. Top panels show retained catch and bottom panels show discarded catch. Grey polygons indicate aggregated observed length compositions and red lines indicate aggregated model fit.

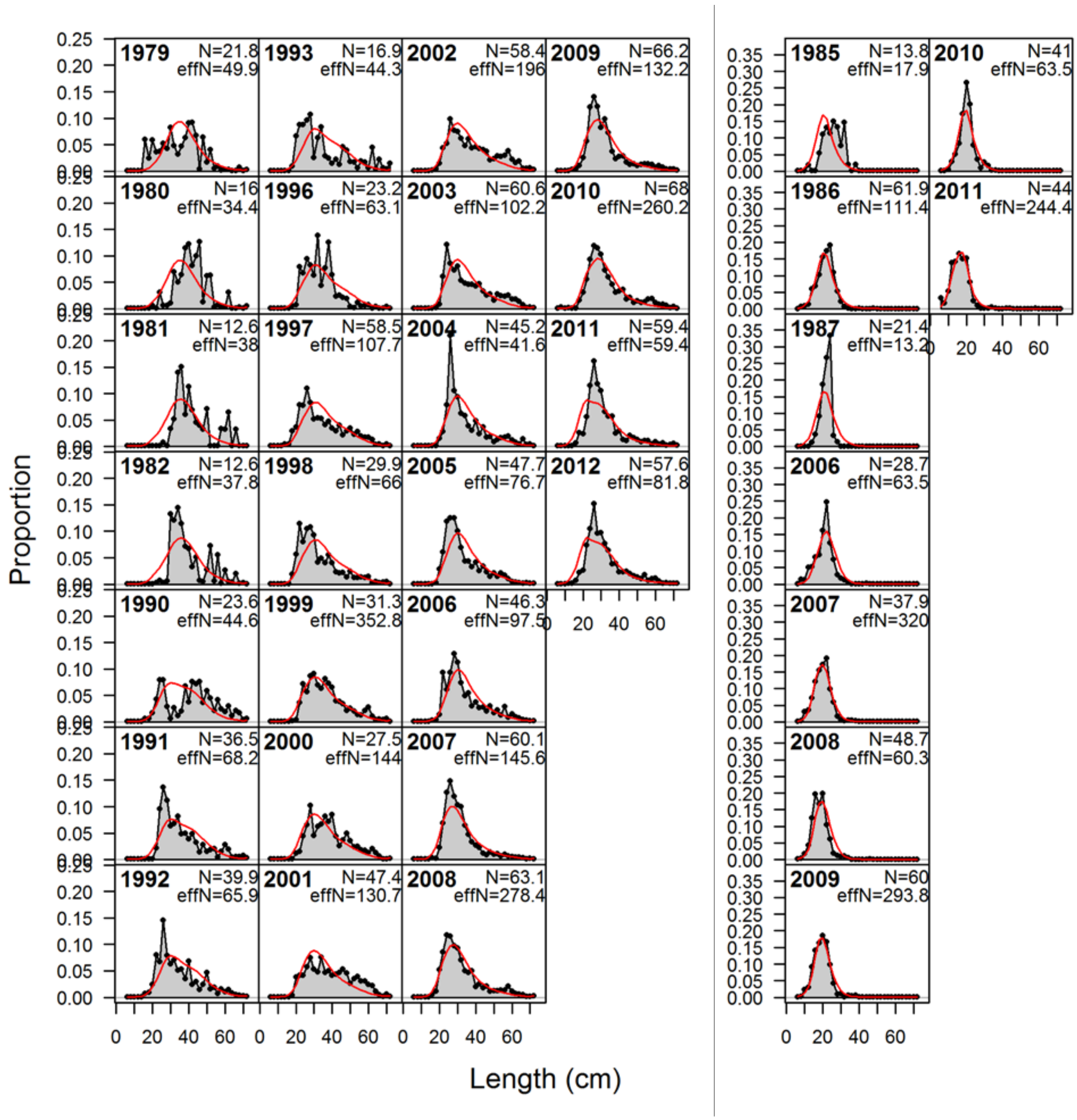

Figure 26: Fits to fishery length compositions for the Trawl North fishery. Retained catch is shown for the years 1979–2012 in the panels on the left (with outliers in 1994–95 removed). Discards are shown for the years 1985–1987 and 2006–2011 in the panels on the right. Grey polygons indicate observed length compositions and red lines indicate model fit. Numeric values labeled "N" and "effN" indicate the input sample sizes and the estimated effective sample sizes associated with each composition.

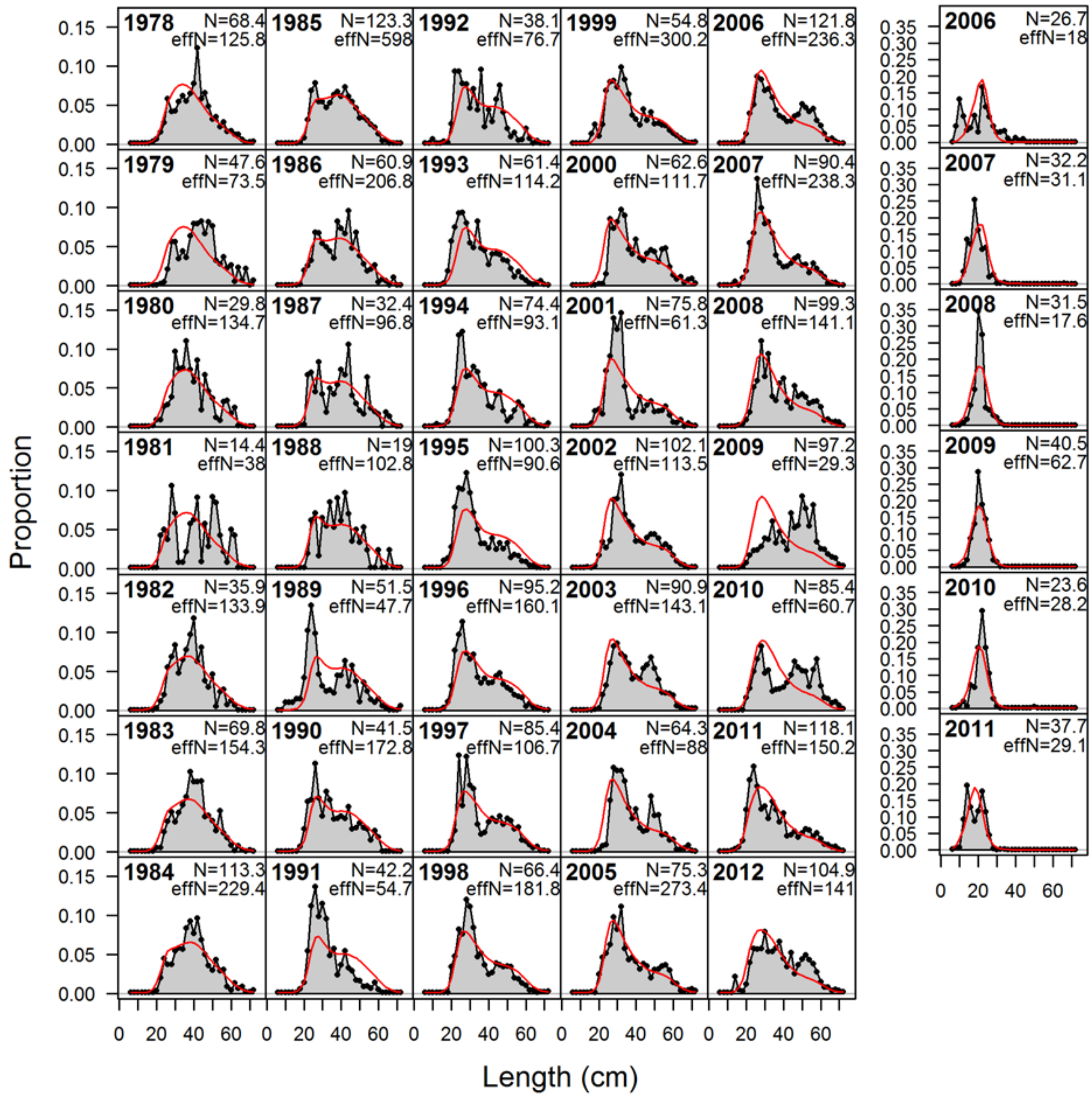

Figure 27: Fits to fishery length compositions for the Trawl South fishery. Retained catch is shown for the years 1978–2012 in the panels on the left. Discards are shown for the years 2006–2011 in the panels on the right. Plot details are provided under Figure 26.

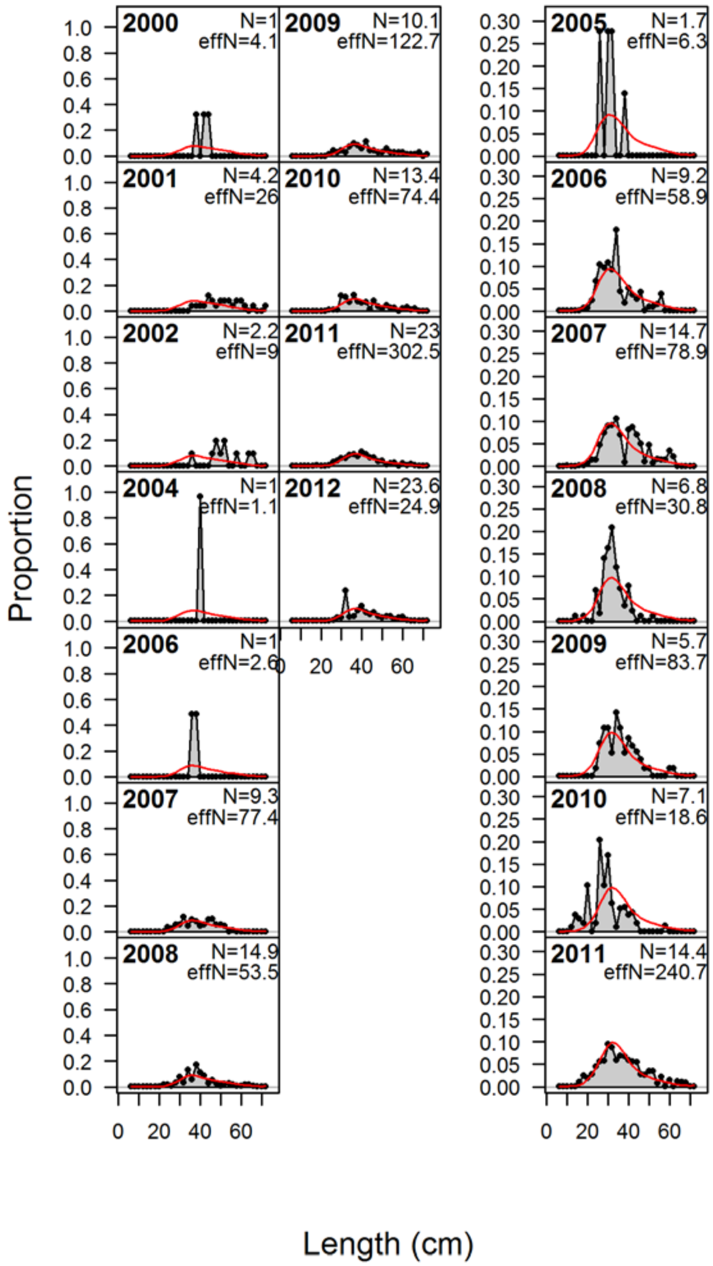

Figure 28: Fits to fishery length compositions for the Non-Trawl North fishery. Retained catch is shown for the years 2000–2012 (no data for 2003 or 2005) in the panels on the left. Discards are shown for the years 2005–2011 in the panels on the right. Plot details are provided under Figure 26.

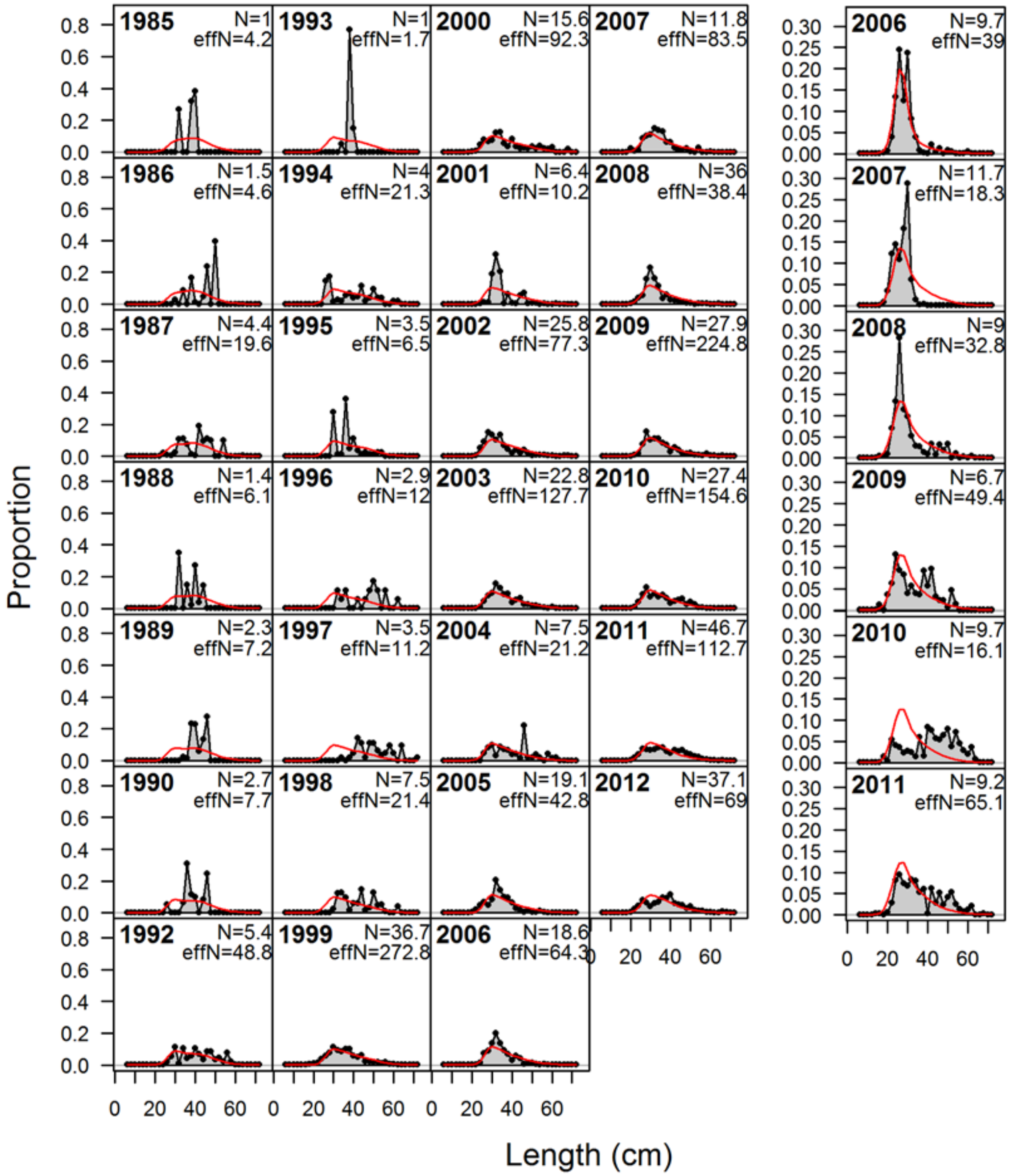

Figure 29: Fits to fishery length compositions for the Non-Trawl North fishery. Retained catch is shown for the years 1985–2012 (no data for 1991) in the panels on the left. Discards are shown for the years 2006–2011 in the panels on the right. Plot details are provided under Figure 26.

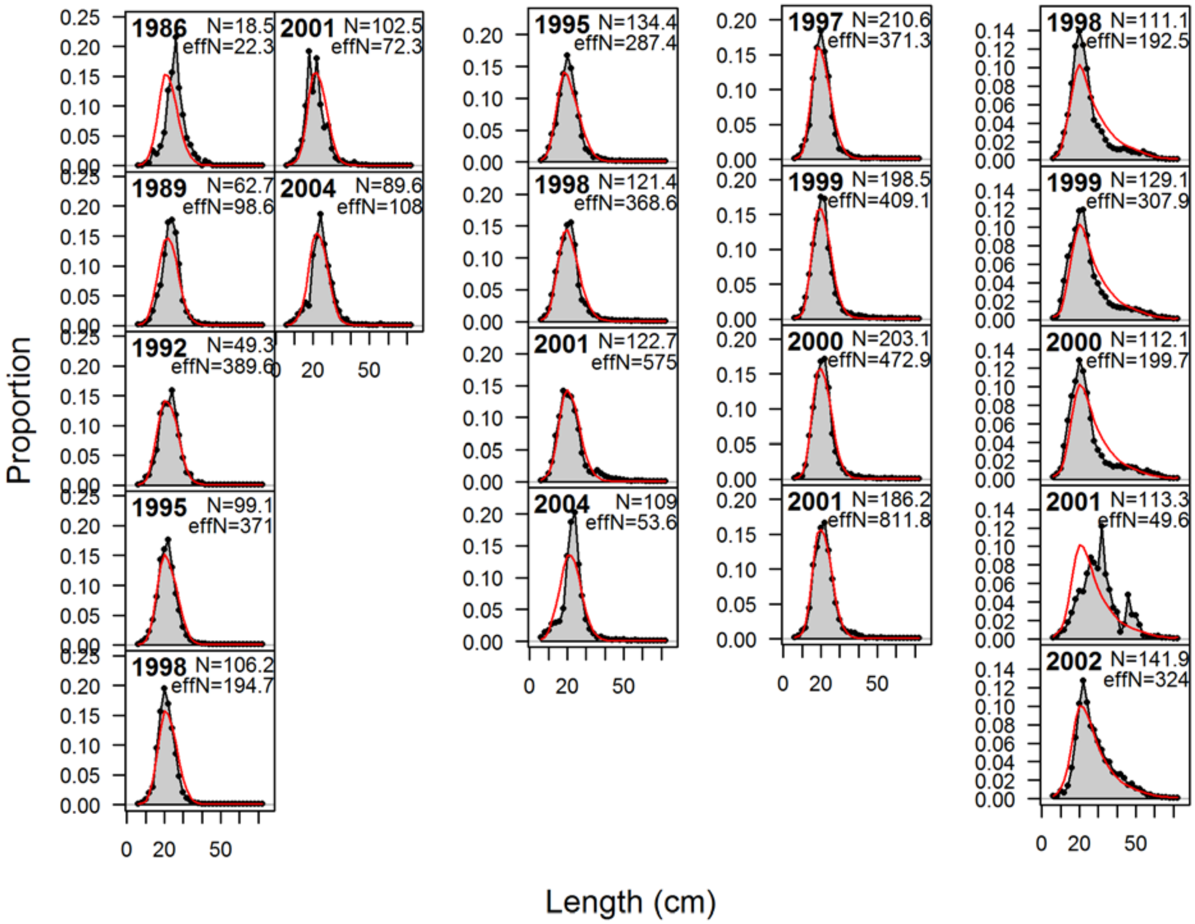

Figure 30: Fits to survey length compositions for the AFSC Triennial Survey 1 (far left, 1986–2004, samples from 1980 and 1983 not shown), AFSC Triennial Survey 2 (center-left, 1995–2004), AFSC Slope Survey (center-right, 1997–2001) and NWFSC Slope Survey (far right, 1998–2002). Plot details are provided under Figure 26.

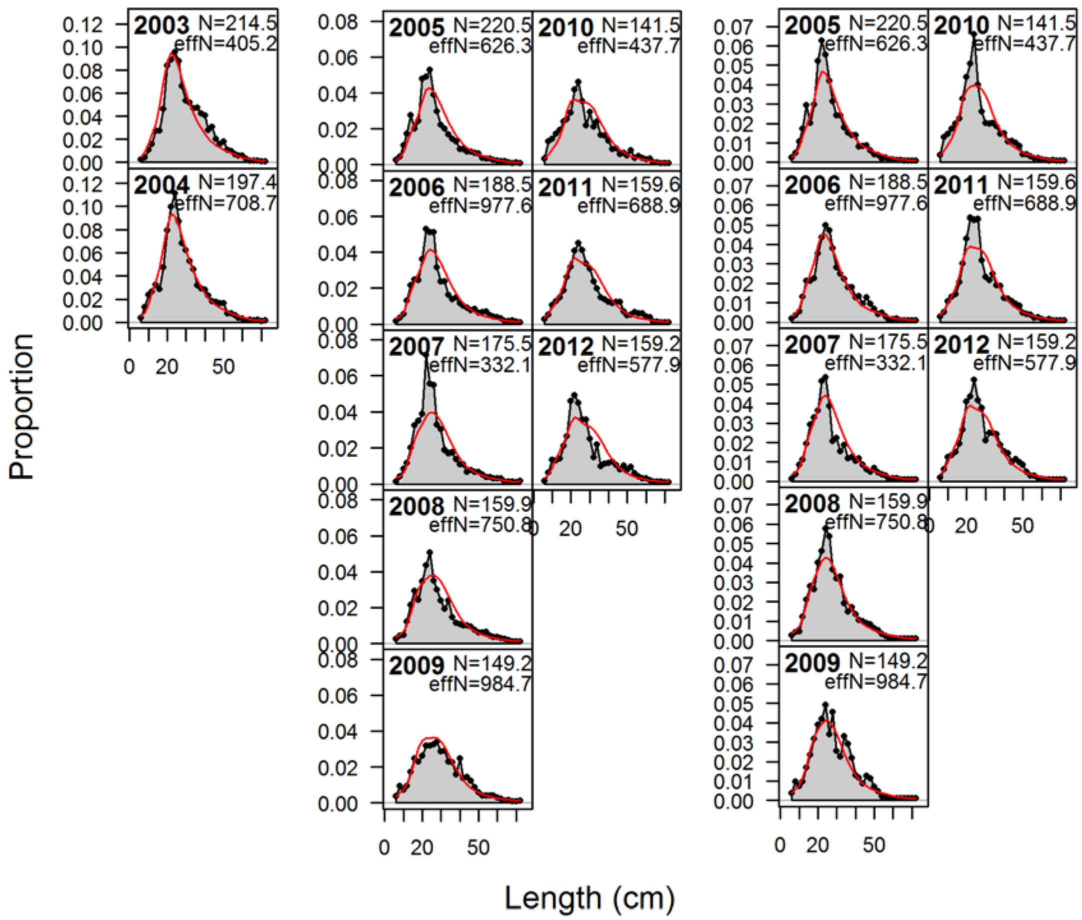

Figure 31: Fits to survey length compositions for combined sexes (left) females (center) and males (right) for the NWFSC Combo Survey.

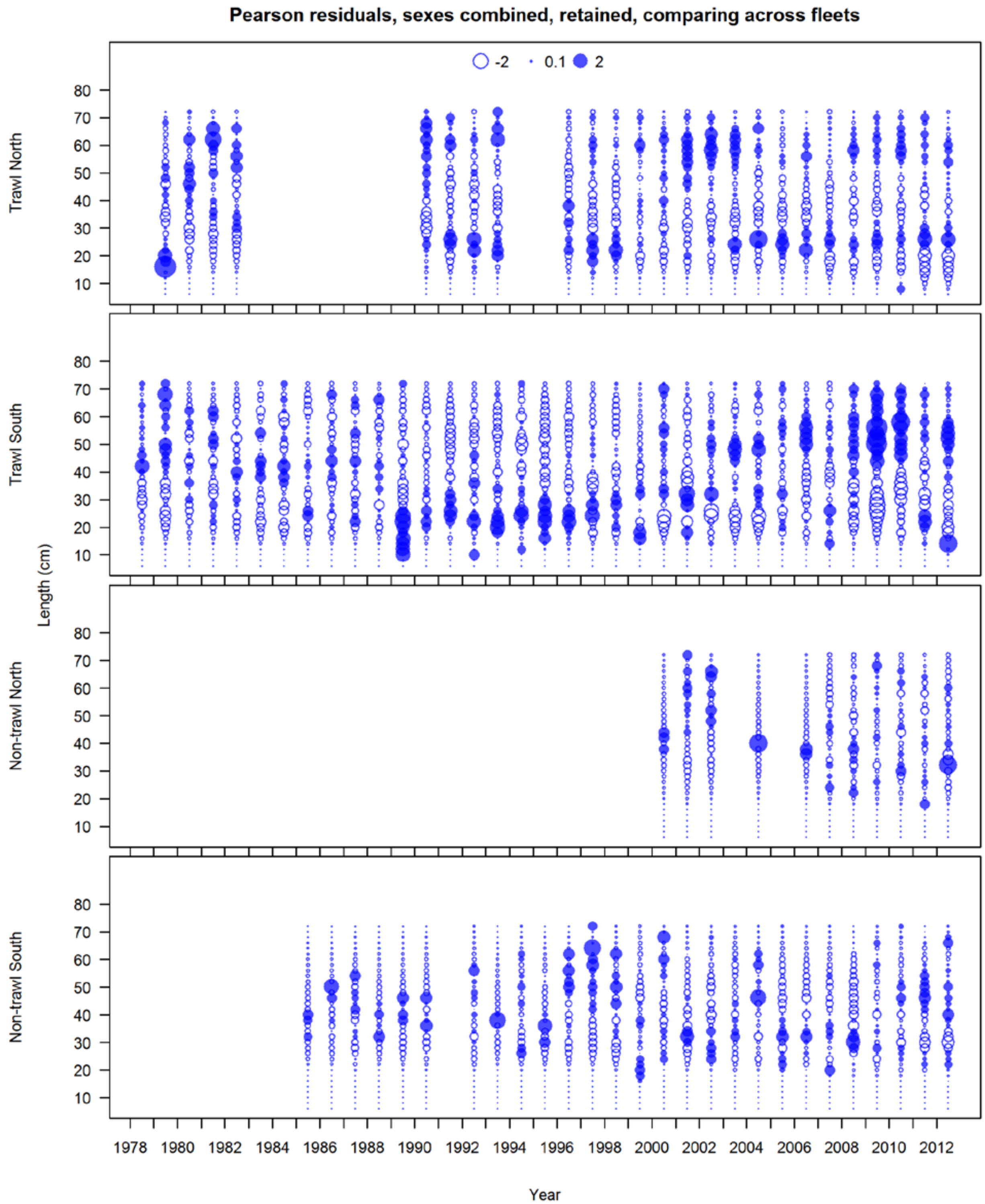

Figure 32: Pearson residuals for fits to fishery length compositions calculated from landed catch. Bubble sizes indicate proportion in each length bin. Sexes are combined. Closed circles represent observations that are larger than the expectation.

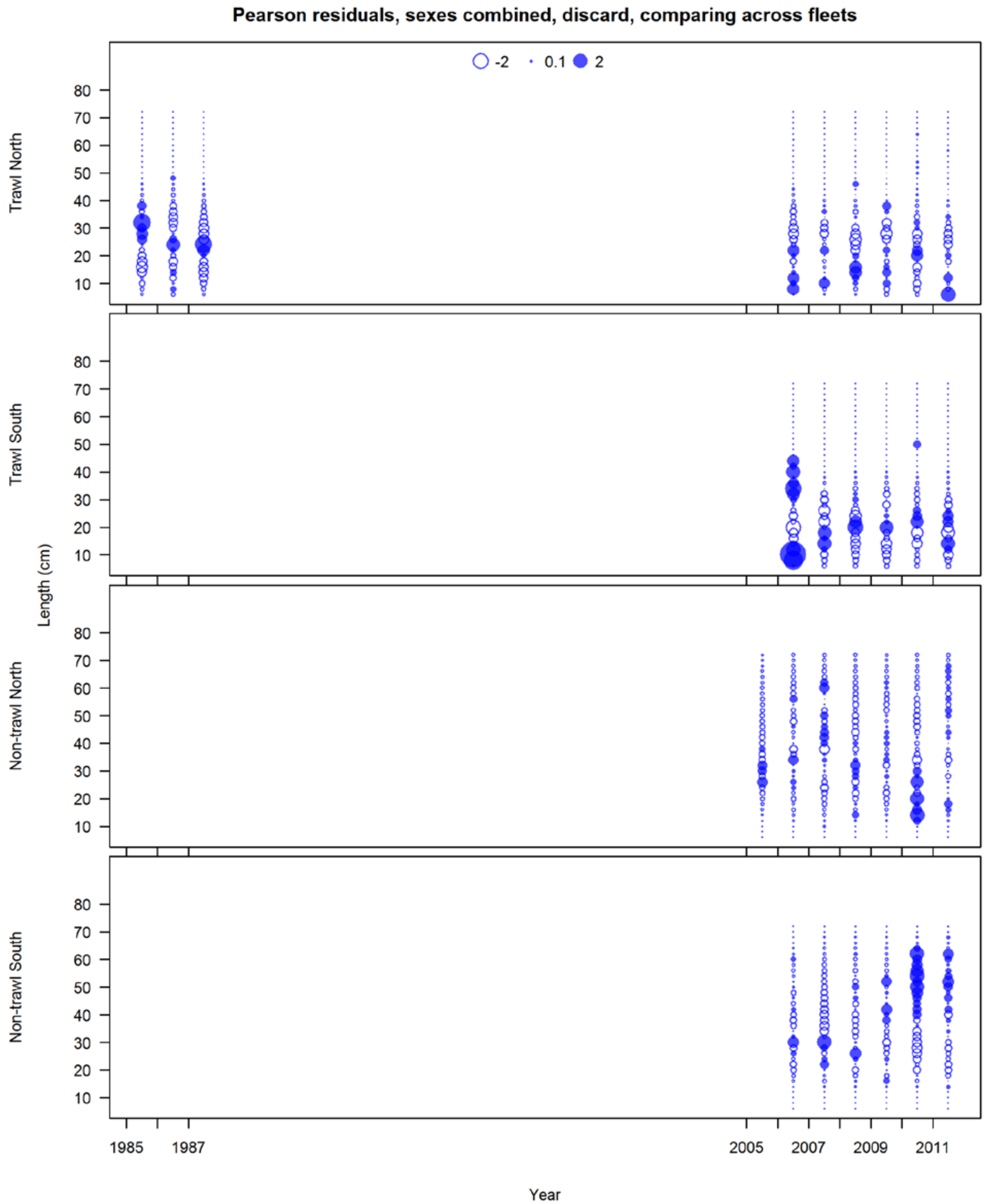

Figure 33: Pearson residuals for fits to fishery length compositions calculated from discards. Sexes are combined. Closed circles represent observations that are larger than the expectation.

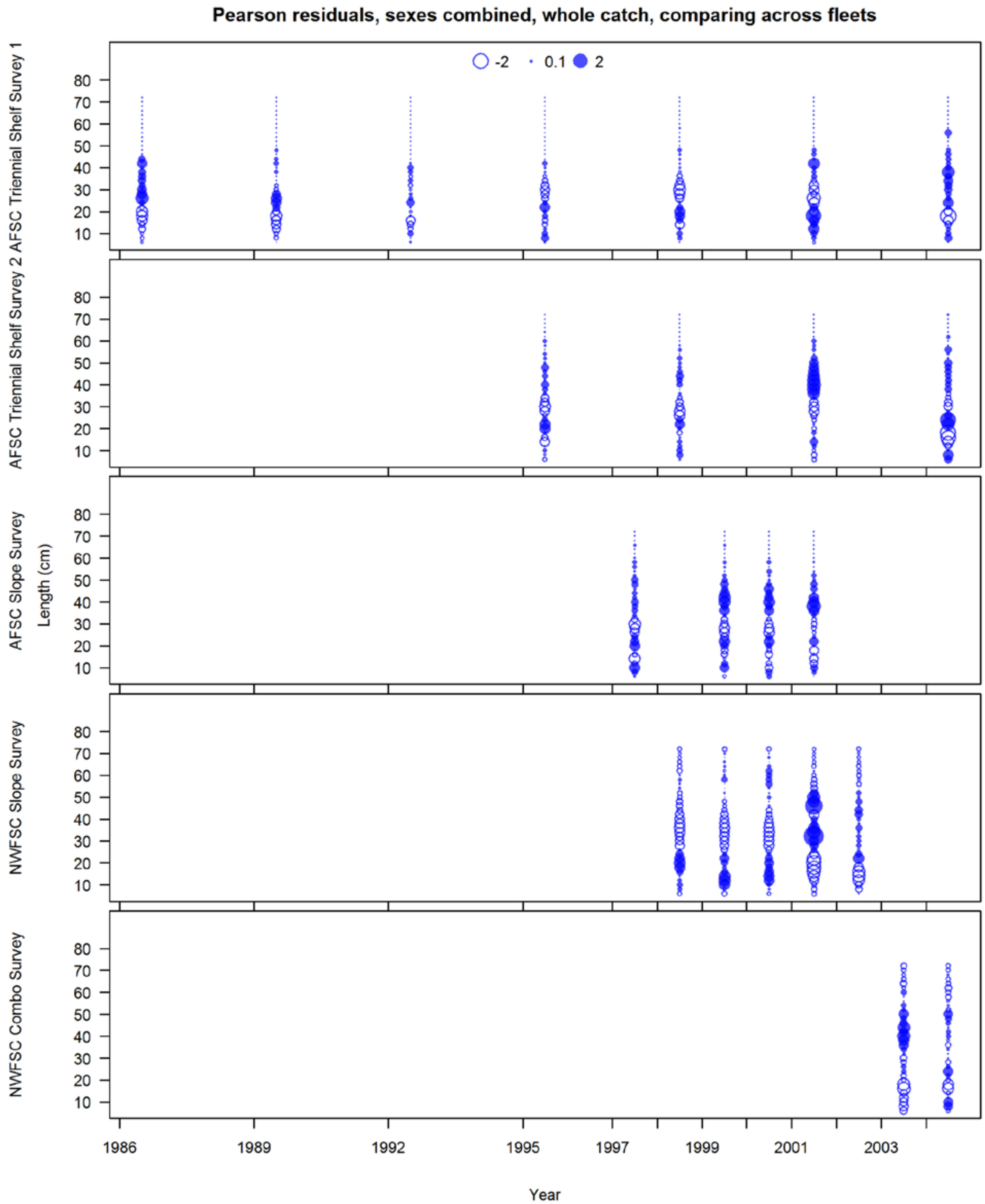

Figure 34: Pearson residuals for fits to survey length compositions for years with combined sex data. Closed circles represent observations that are larger than the expectation.

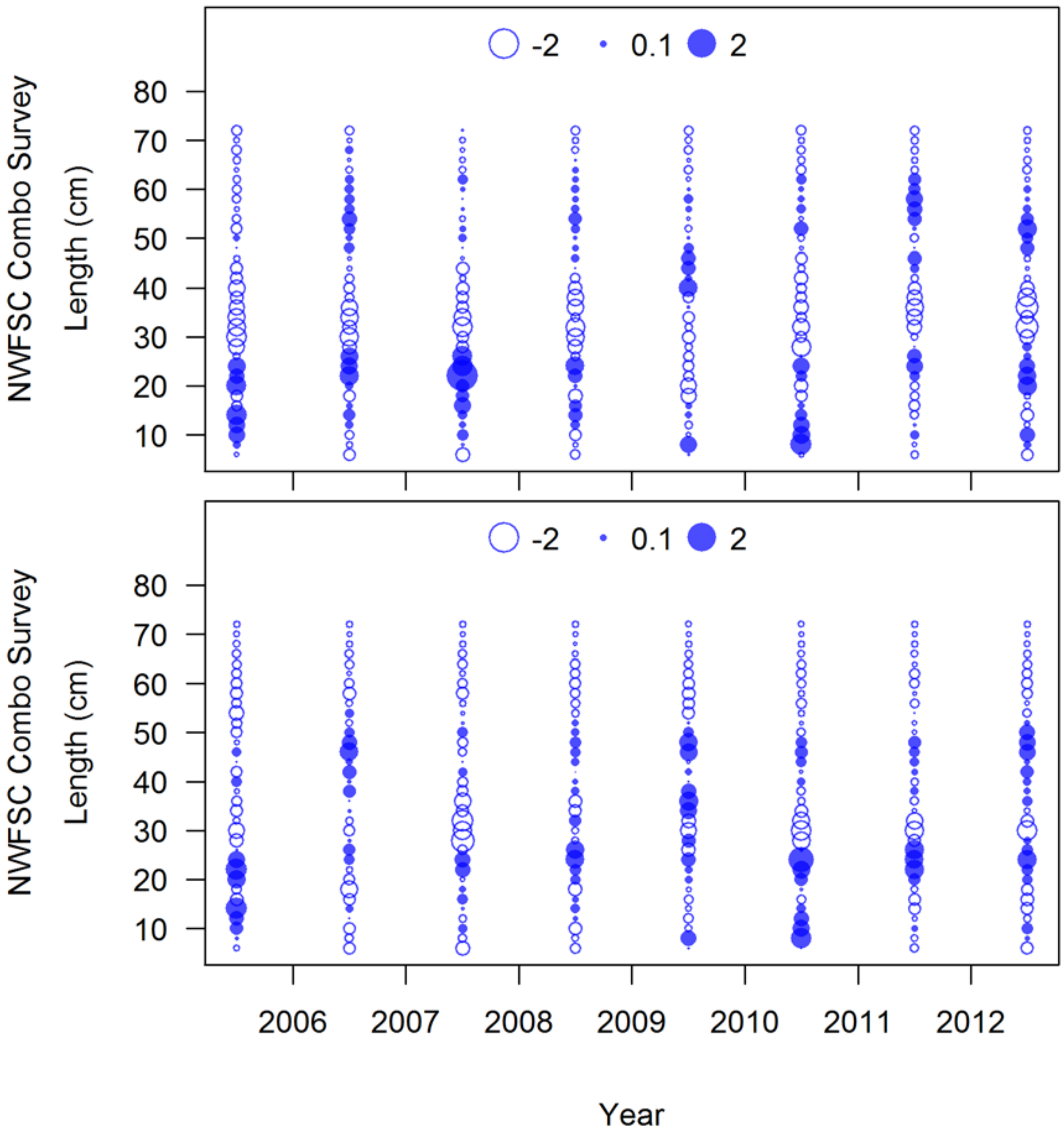

Figure 35: Pearson residuals for fits to survey length compositions for females (top) and males (bottom) for the NWFSC Combo Survey. Closed circles represent observations that are larger than the expectation.

10.4 Model results

10.4.1 Base model results

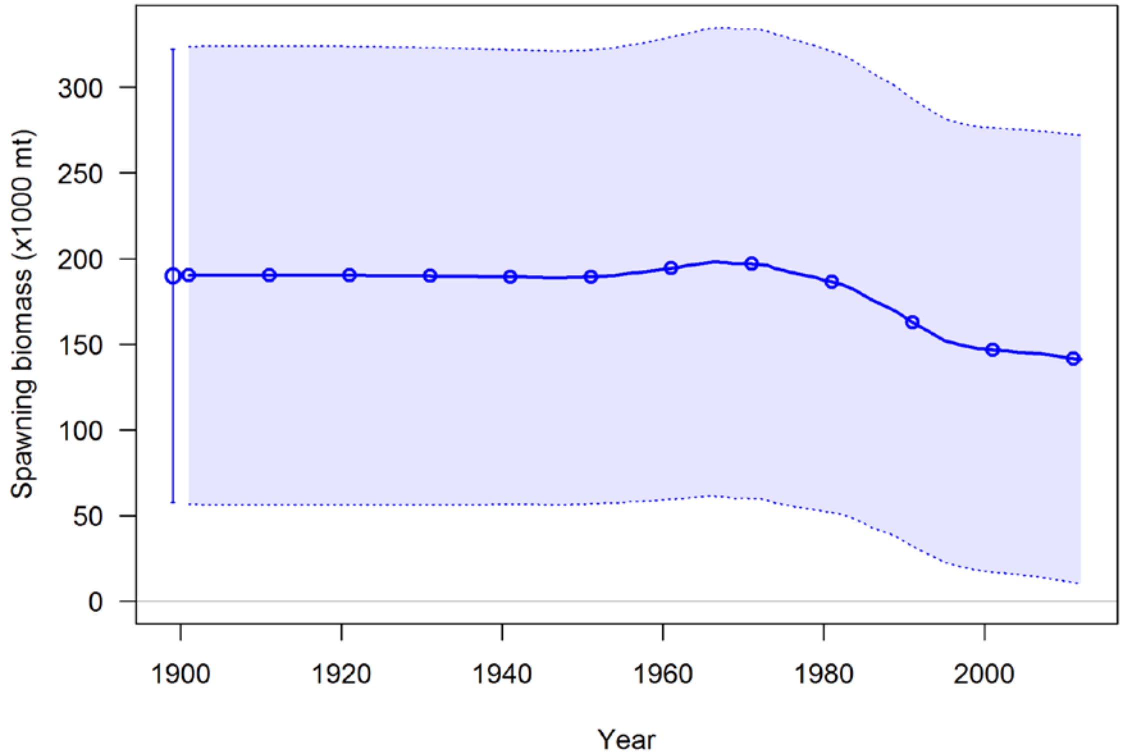

Figure 36: Trajectory of spawning biomass. The disconnected point at the left represents the unfished equilibrium estimate and its associated uncertainty.

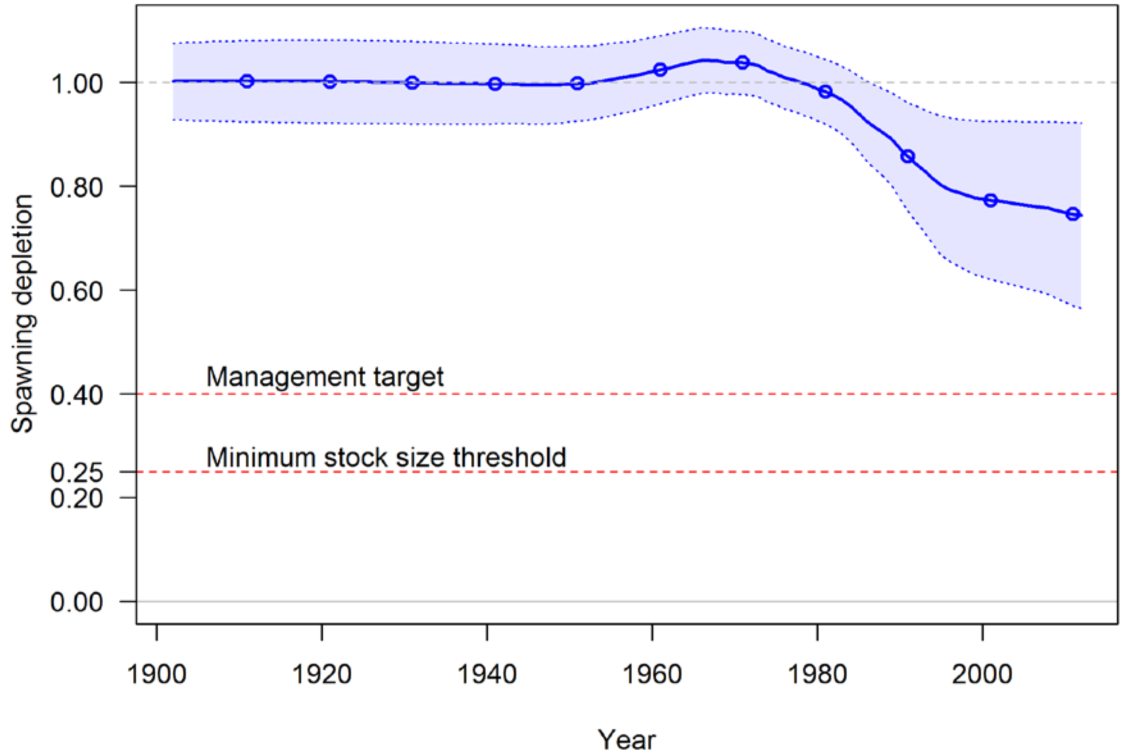

Figure 37: Estimated relative depletion with approximate 95% asymptotic confidence intervals (shaded area) for the base case assessment model.

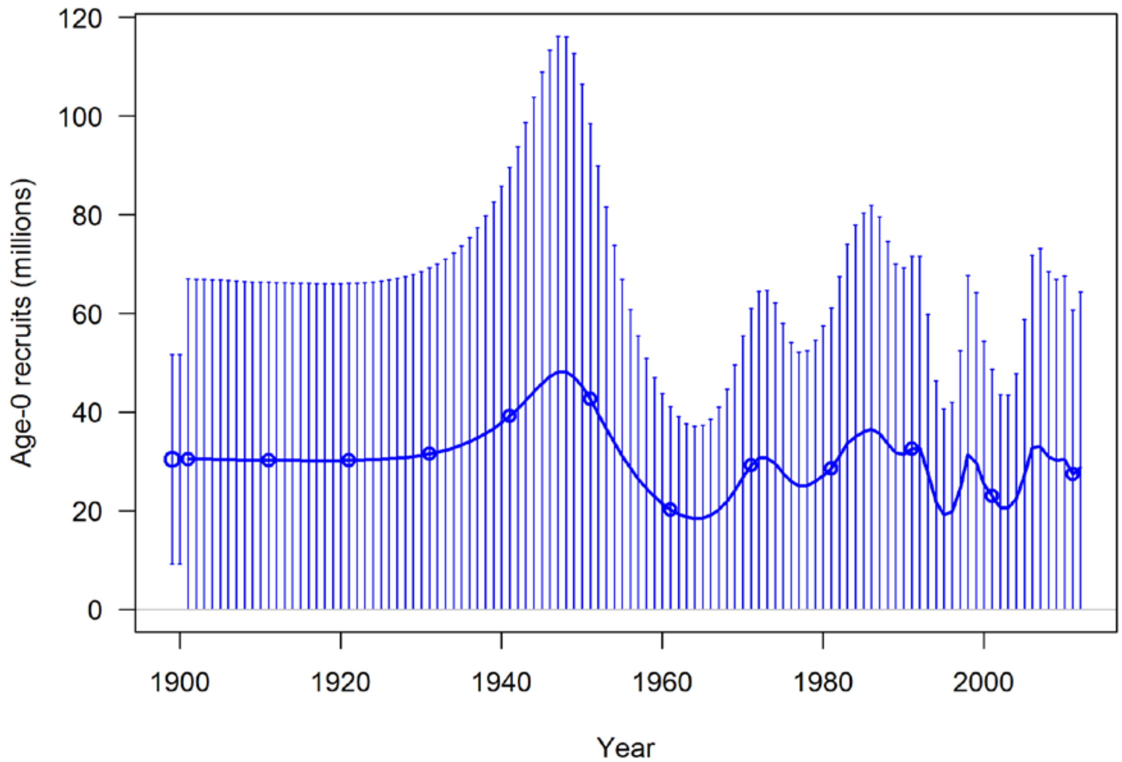

Figure 38: Time series of recruitment. The disconnected point at the left represents the unfished equilibrium estimate and its associated uncertainty.

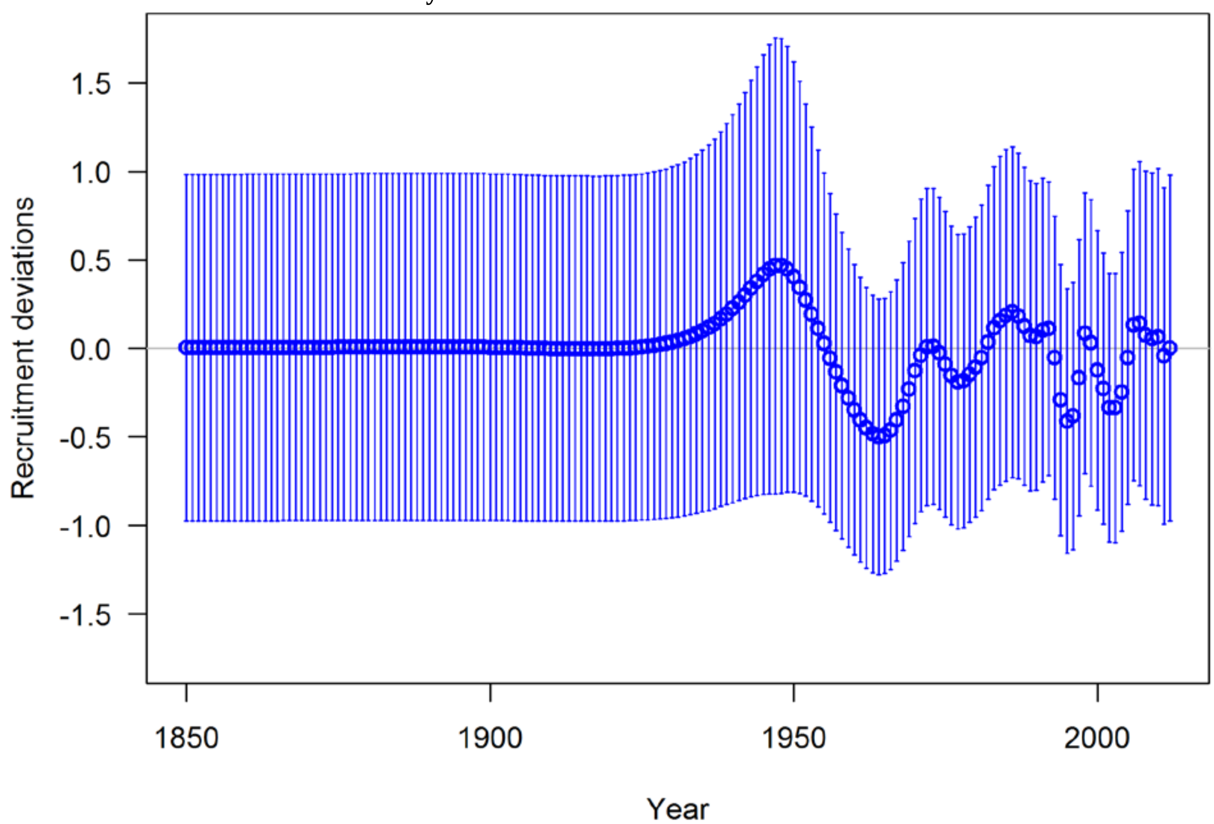

Figure 39: Time series of recruitment deviations with 95% intervals. Circles represent the difference between estimated recruitment and the expectation associated with the stock-recruit relationship on a log scale.

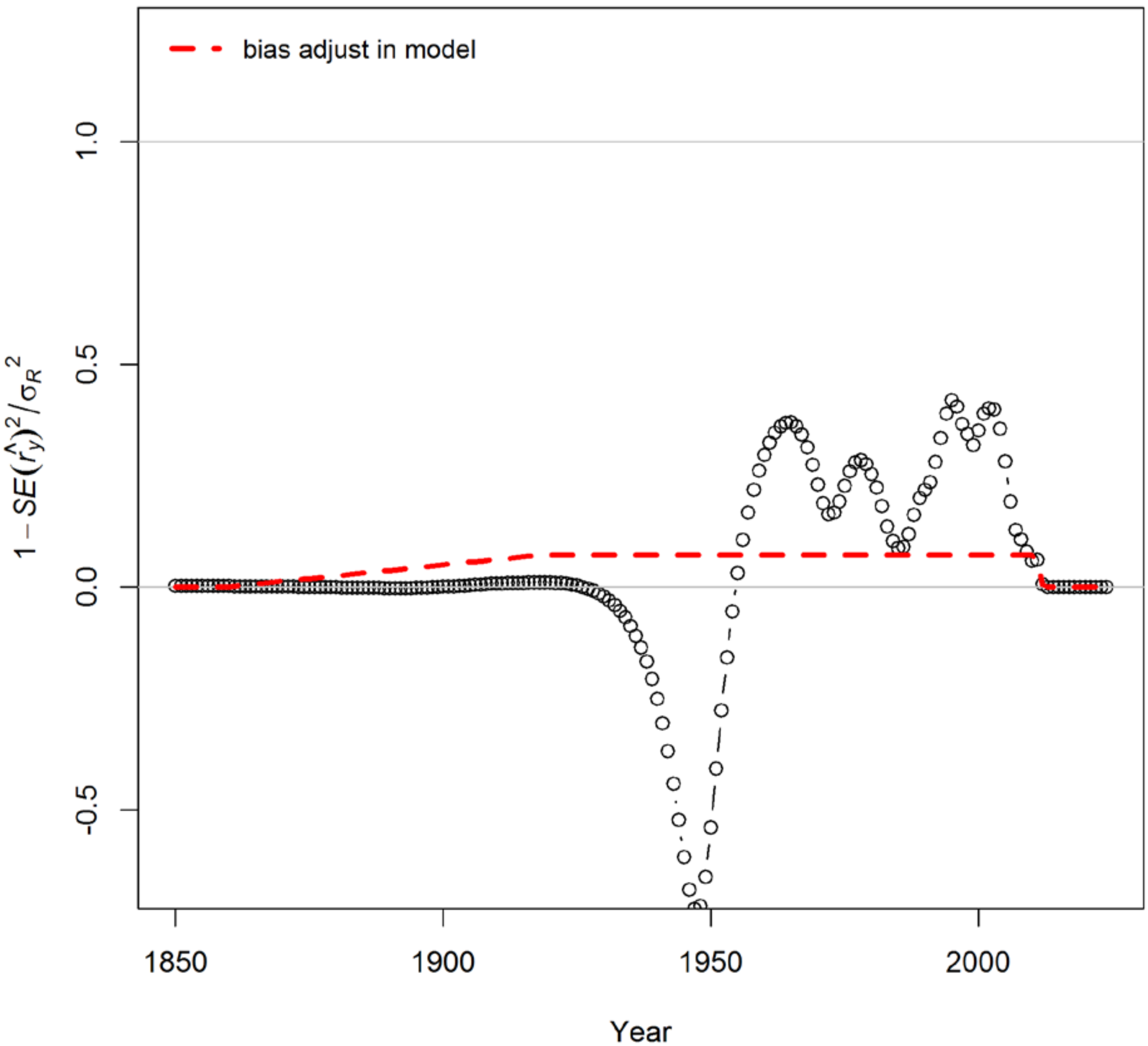

Figure 40: Transformed recruitment deviation uncertainty estimates used to adjust for differences between median and mean of the lognormal distribution of recruitment.

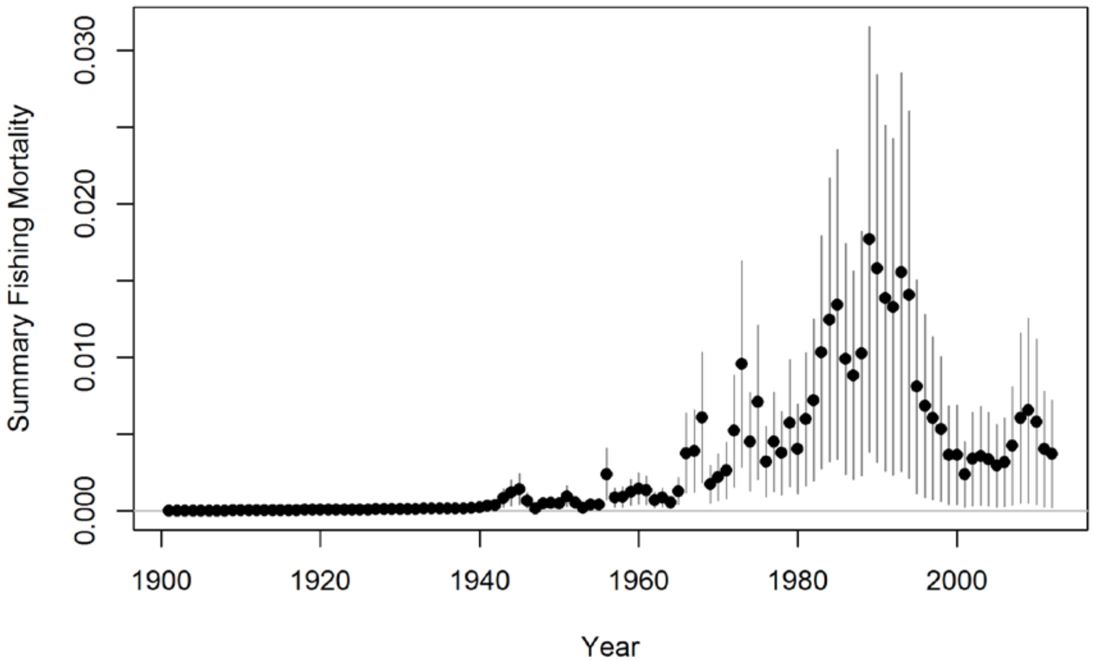

Figure 41: Time-series of estimated summary harvest rate (total catch divided by age-1 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines).

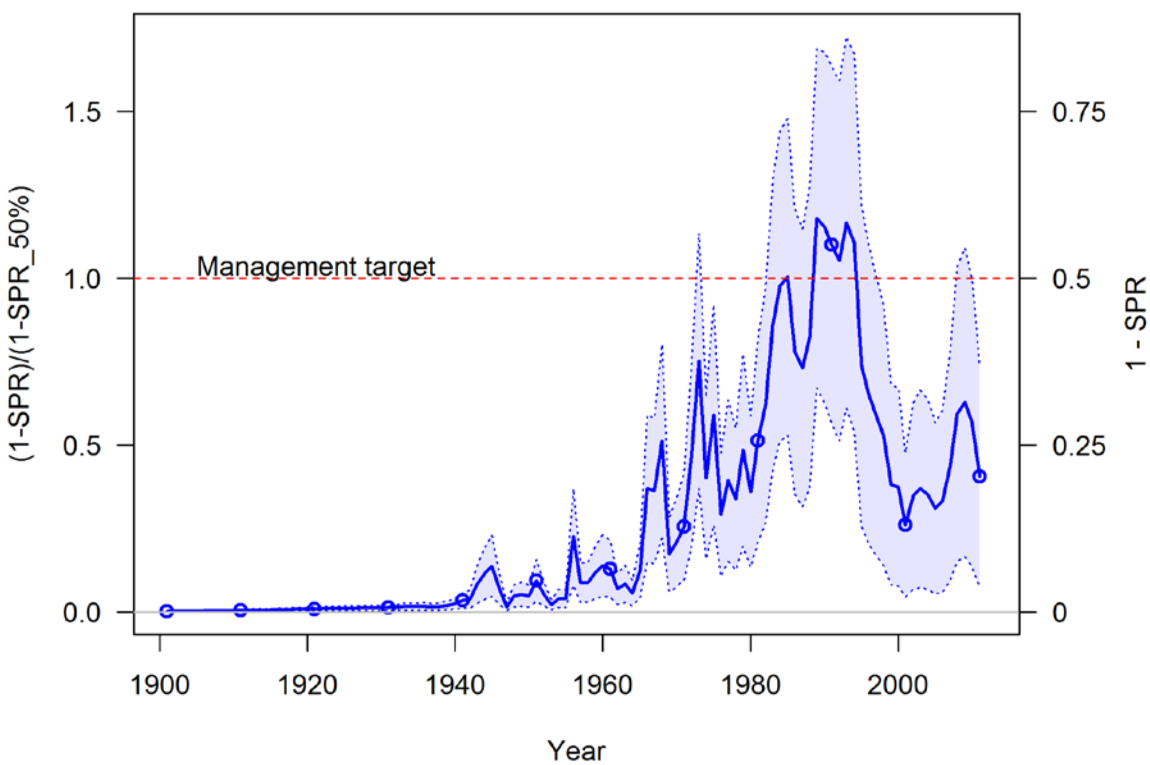

Figure 42: Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. Both one minus SPR (right y-axis) and the ratio of this quantity to the associated target (1 - $SPR_{50\%}$) (left y-axis) are indicated. These quantities are chosen so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

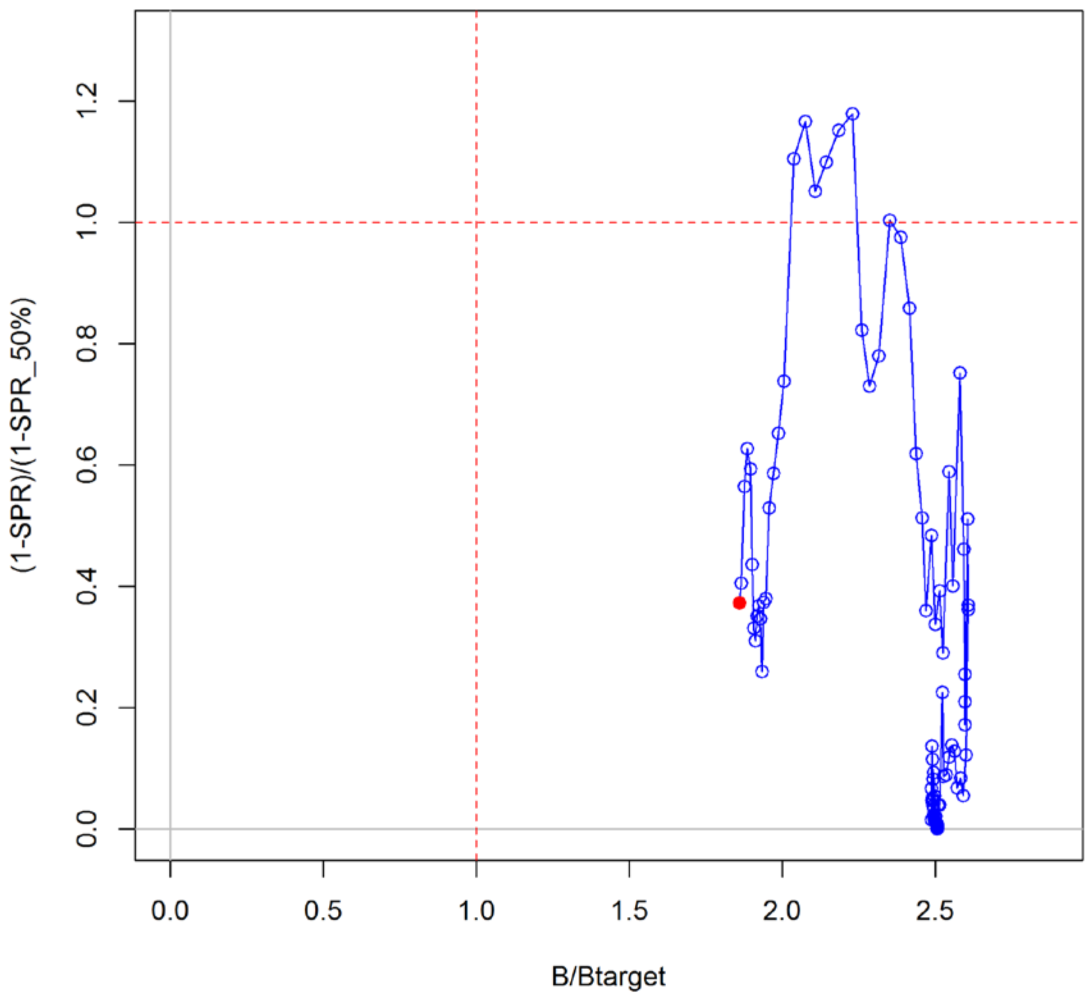

Figure 43: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 50% of the unfished spawning biomass. The red point indicates the year 2012.

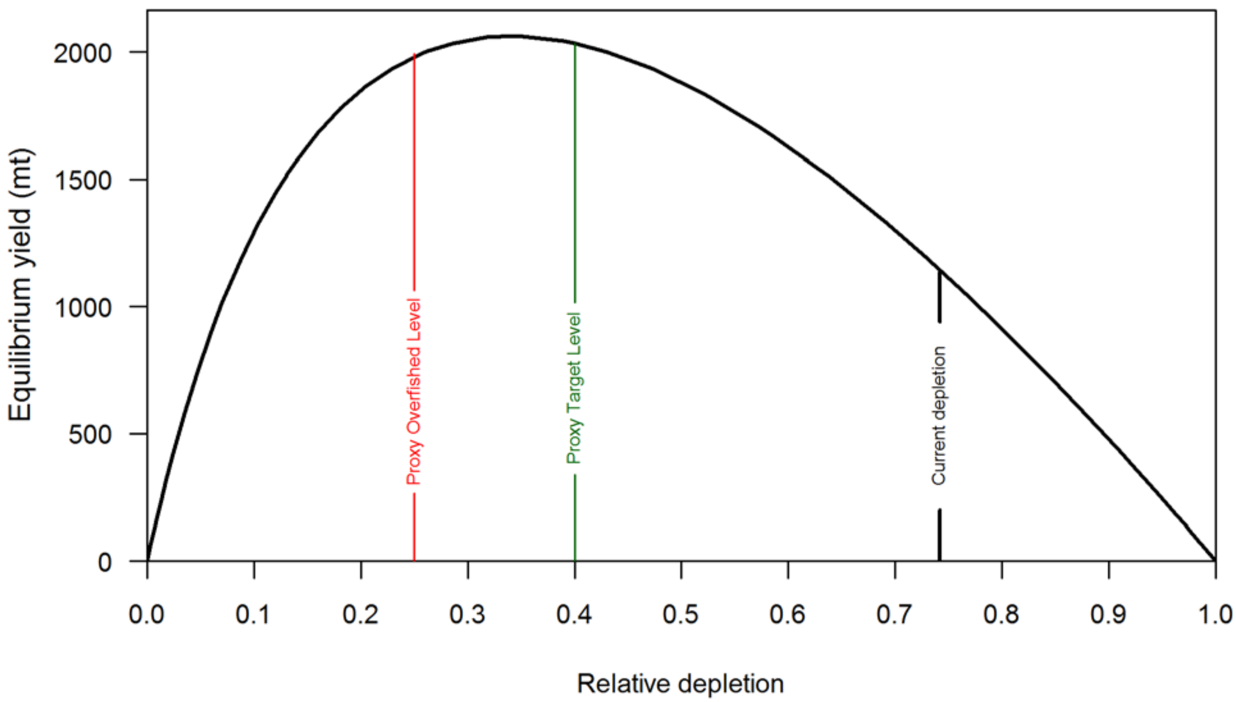

Figure 44: Equilibrium yield curve (derived from reference point values reported in Table 12) for the base case model. Values are based on 2012 relative catch among fleets. The depletion is relative to unfished spawning biomass.

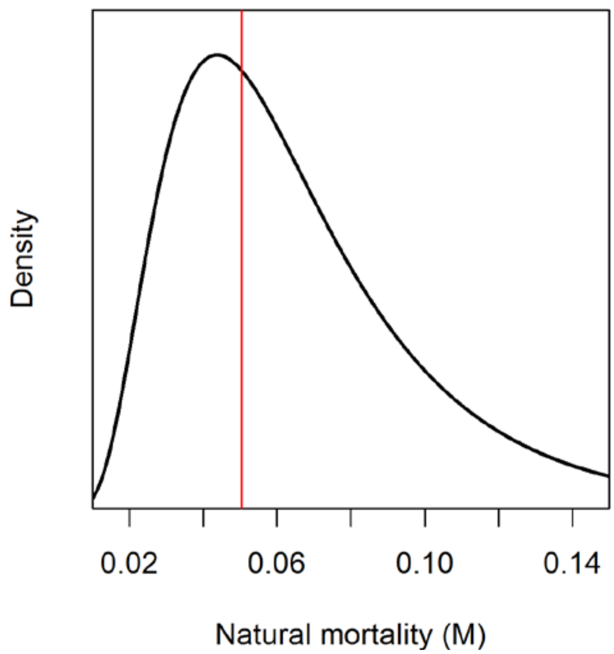

Figure 45: Prior distributions for natural mortality (*M*). The base model has natural mortality fixed at the mean of the distribution indicated by the red vertical line (*M* = 0.0505).

10.4.2 Likelihood profiles, sensitivities, and retrospective analyses

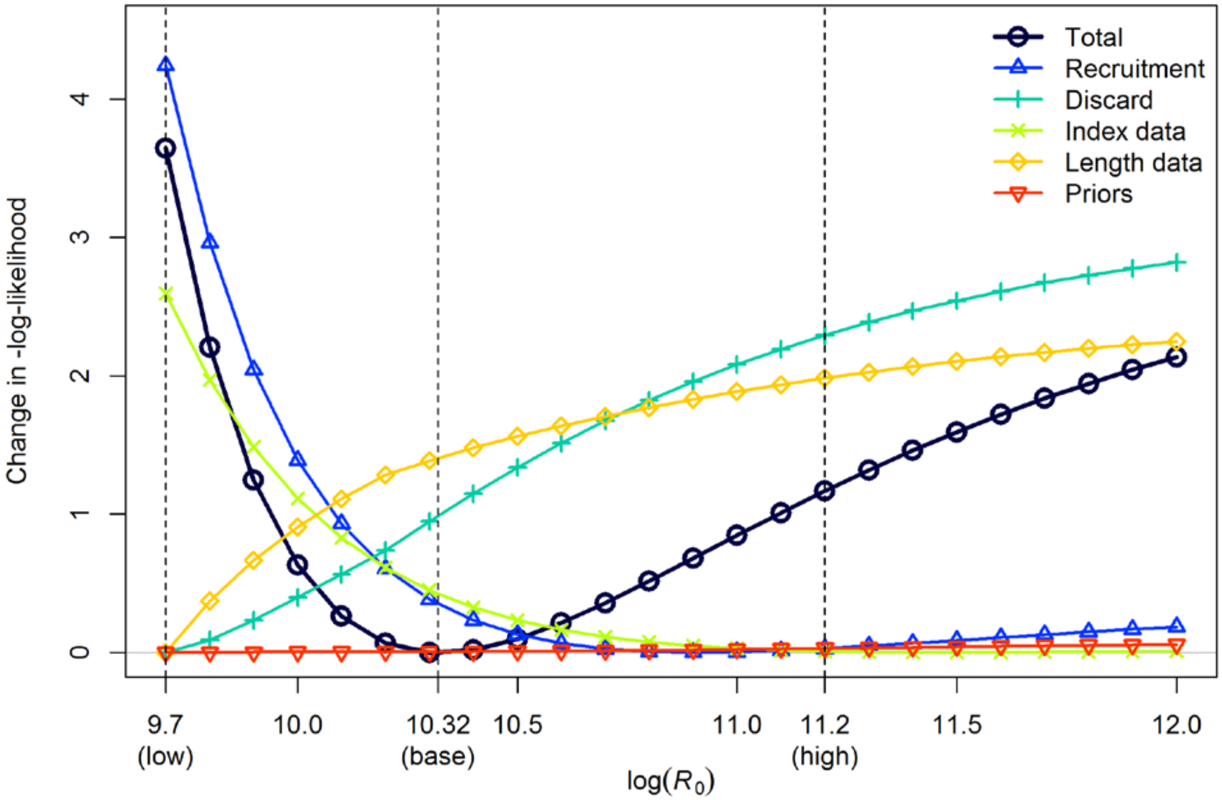

Figure 46: Likelihood profile over the log of equilibrium recruitment, log(R_0). Vertical lines and axis labels indicate the base model with log(R0) estimated at 10.32 and the low and high states of nature used in the decision table (Table 14).

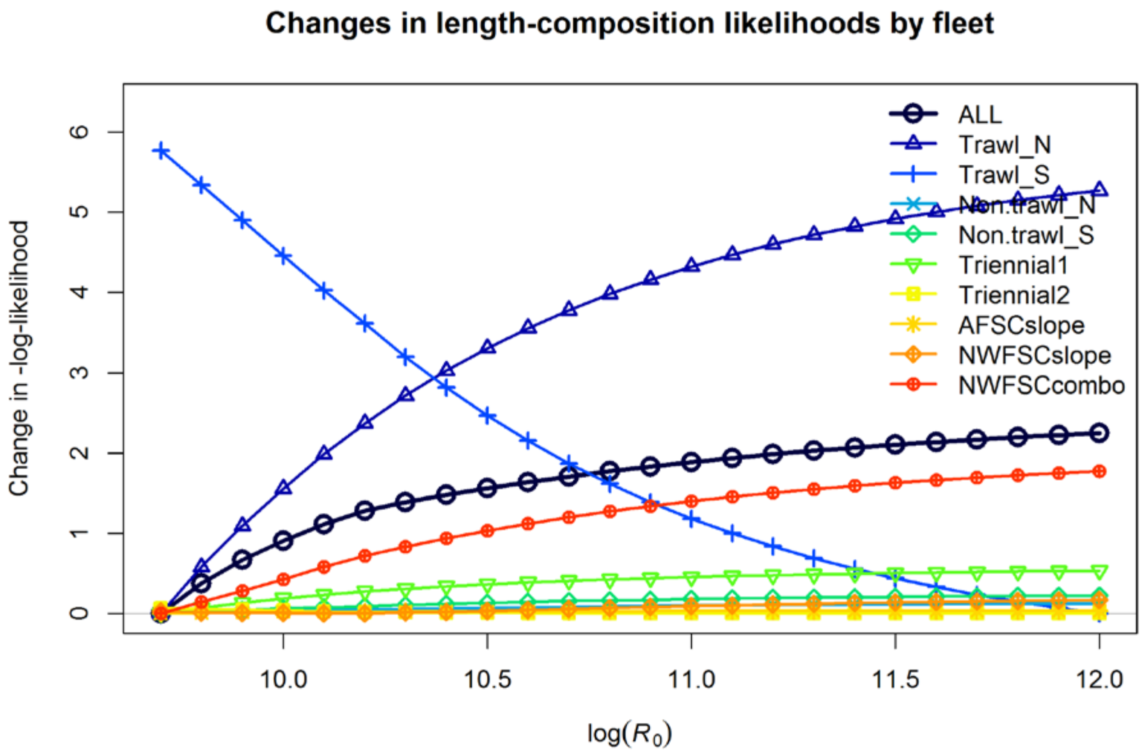

Figure 47: Likelihood contributions by fleet to the length data likelihood component (orange line with diamonds in Figure 46) of the likelihood profile over the log of equilibrium recruitment, log(R_0).

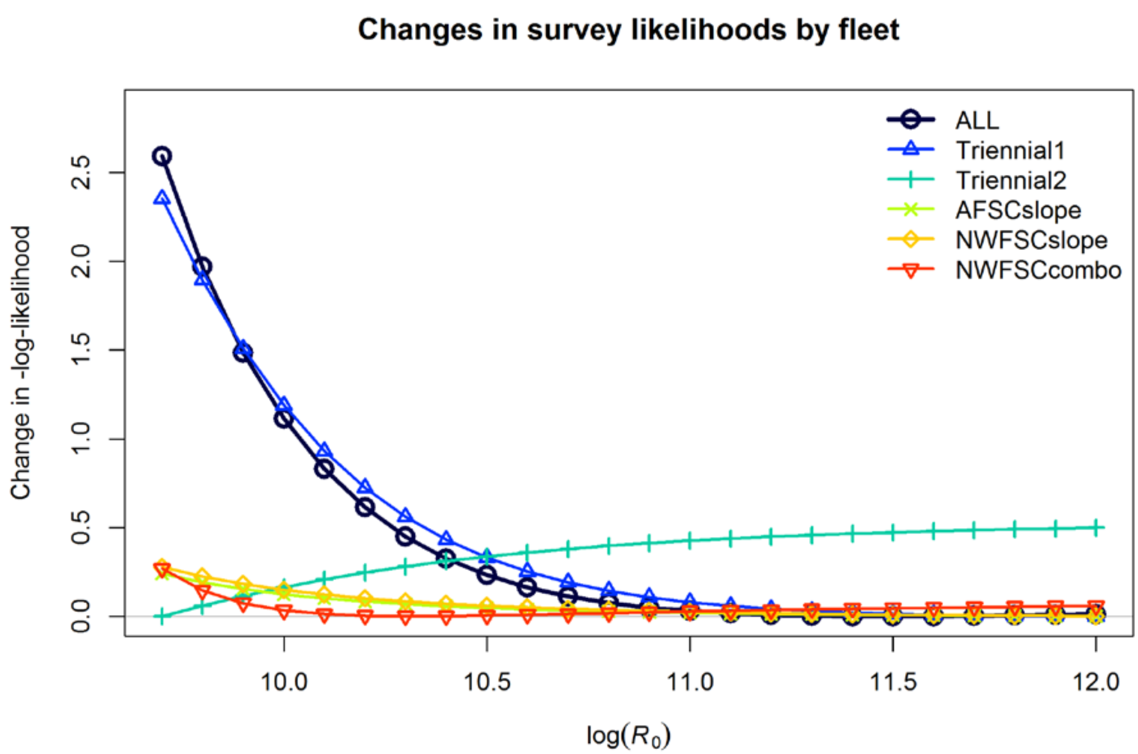

Figure 48: Likelihood contributions by fleet to the survey data likelihood component (light green line with Xs in Figure 46) of the likelihood profile over the log of equilibrium recruitment, log(R_0).

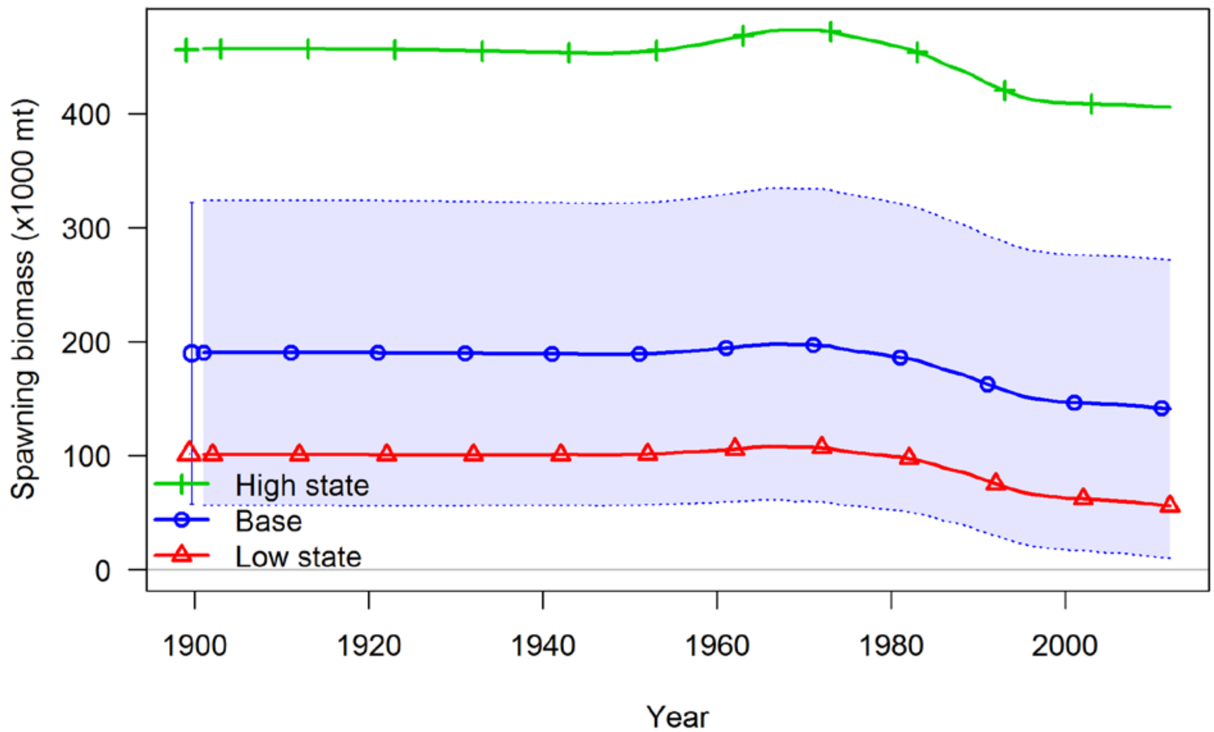

Figure 49: Time series of spawning biomass for low and high states of nature taken from the log(R_0) profile. The base model has log(R0) estimated at 10.32 while the low and high states of nature have log(R0) = 9.7 and 10.2 respectively. Uncertainty is only shown for the base model as the fixed log(R_0) values in the other cases limits the portrayal of uncertainty.

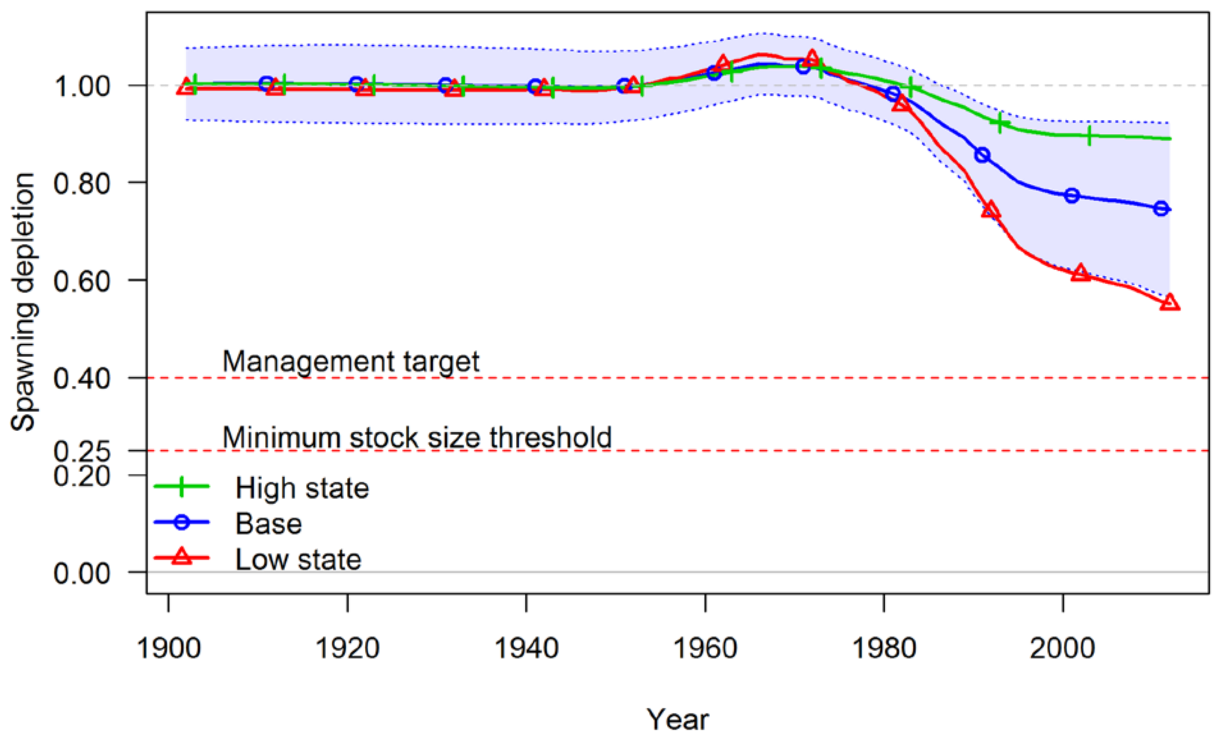

Figure 50: Time series of spawning depletion for low and high states of nature as described in the caption for Figure 49 above.

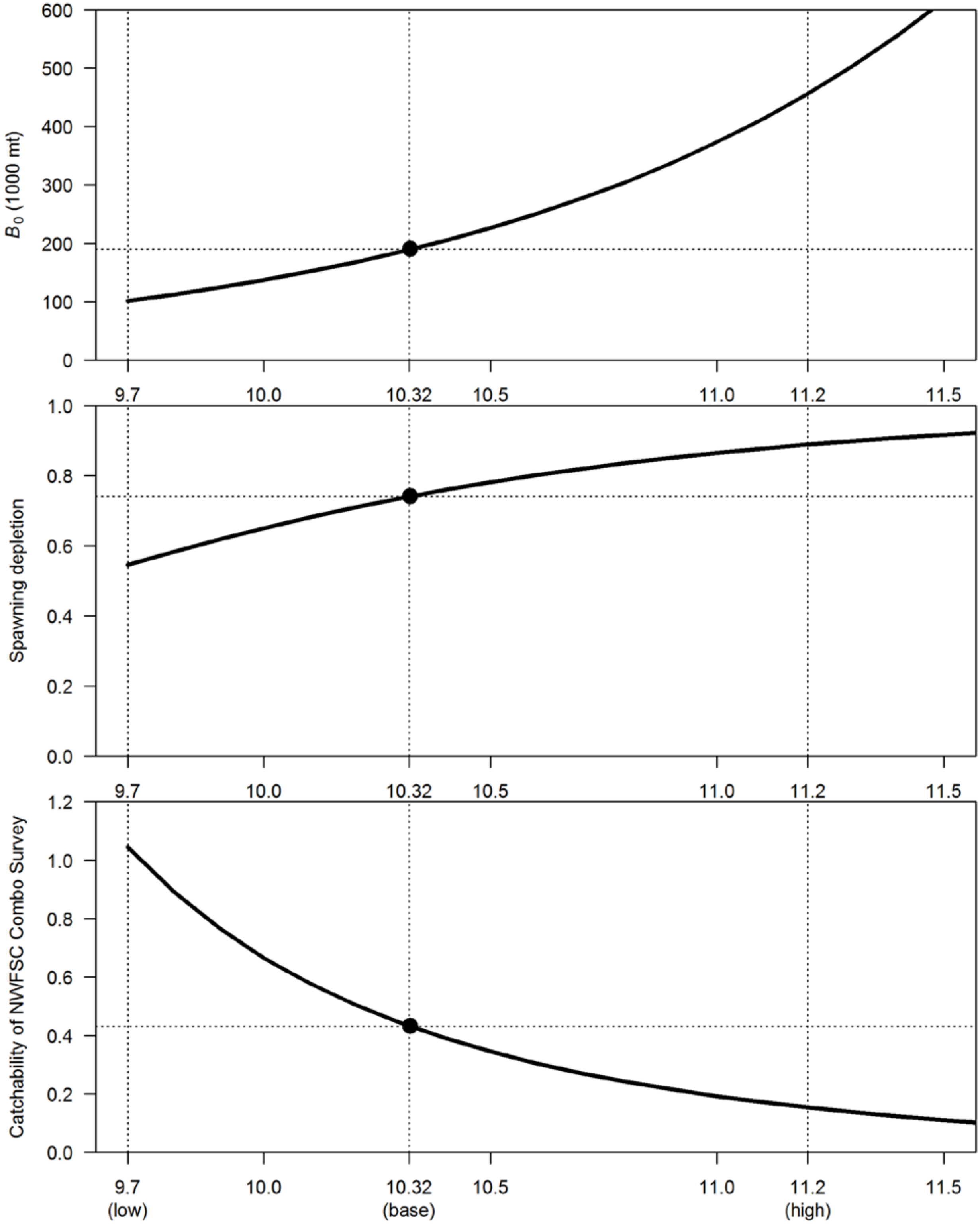

Figure 51: Relationship between log(R_0) and equilibrium spawning biomass (top), depletion (middle), and catchability of the NWFSC Combo Survey (bottom).

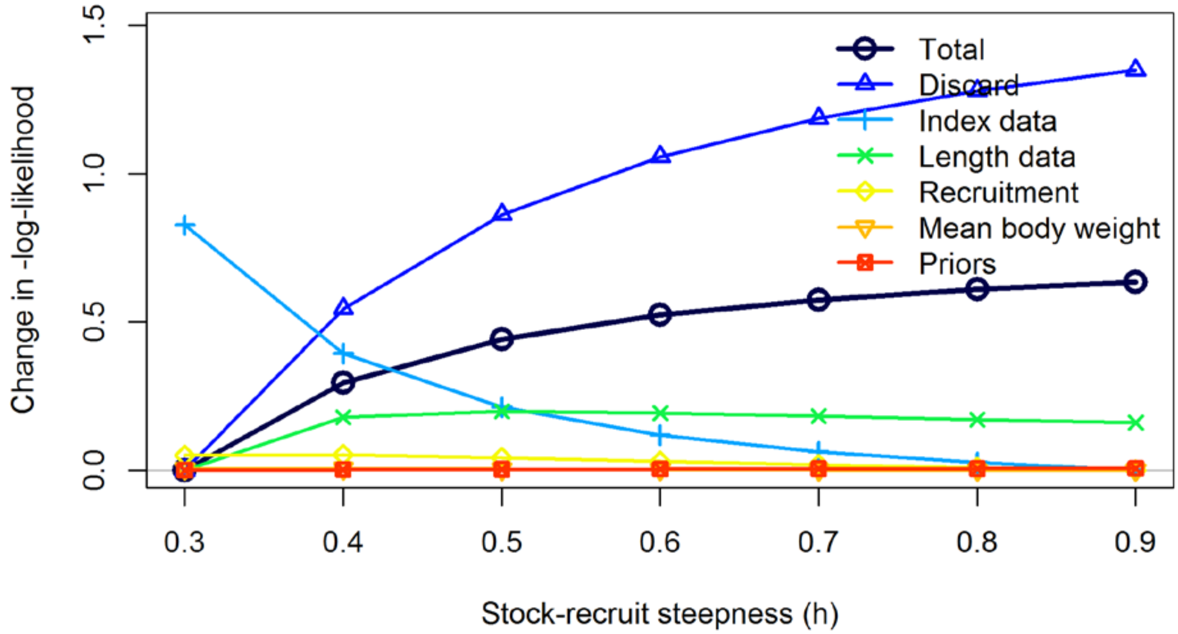

Figure 52: Likelihood profile over steepness (*h*). The base model has steepness fixed at *h* = 0.6.

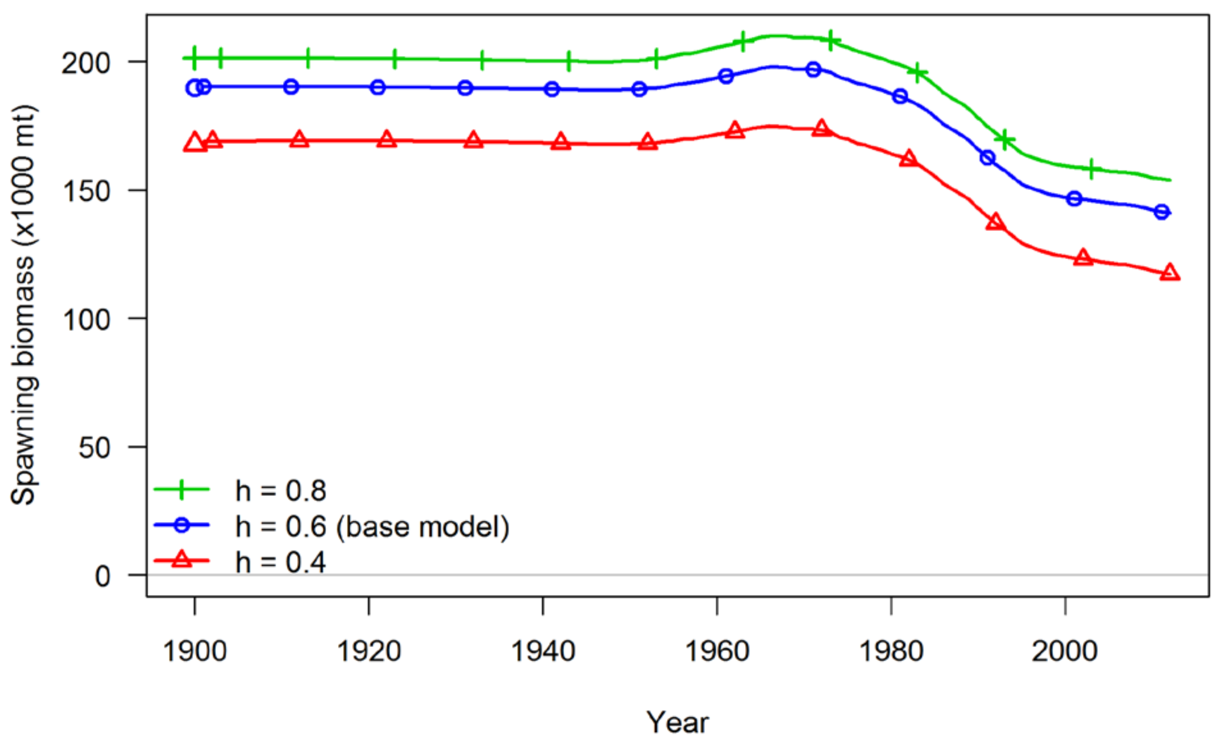

Figure 53: Time series of spawning biomass associated with lower and higher steepness values from the likelihood profile above.

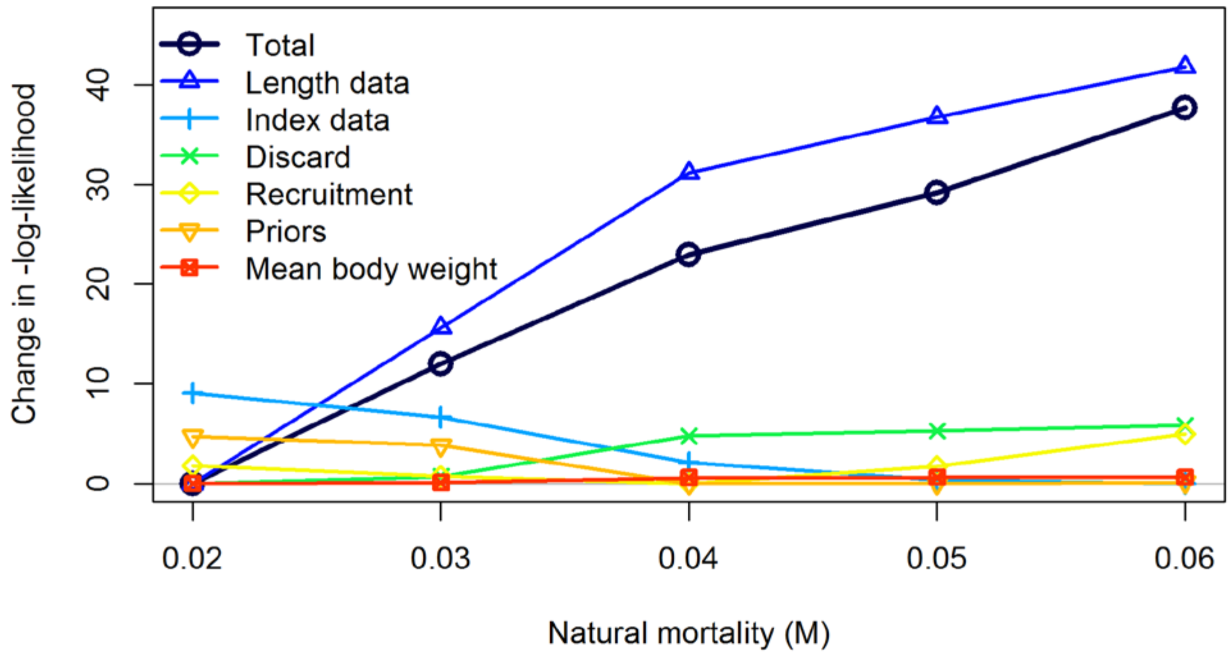

Figure 54: Likelihood profile over natural mortality (*M*). The base model has mortality fixed at *M* = 0.0505. Models with M = 0.07 and greater did not converge with starting values used for base model.

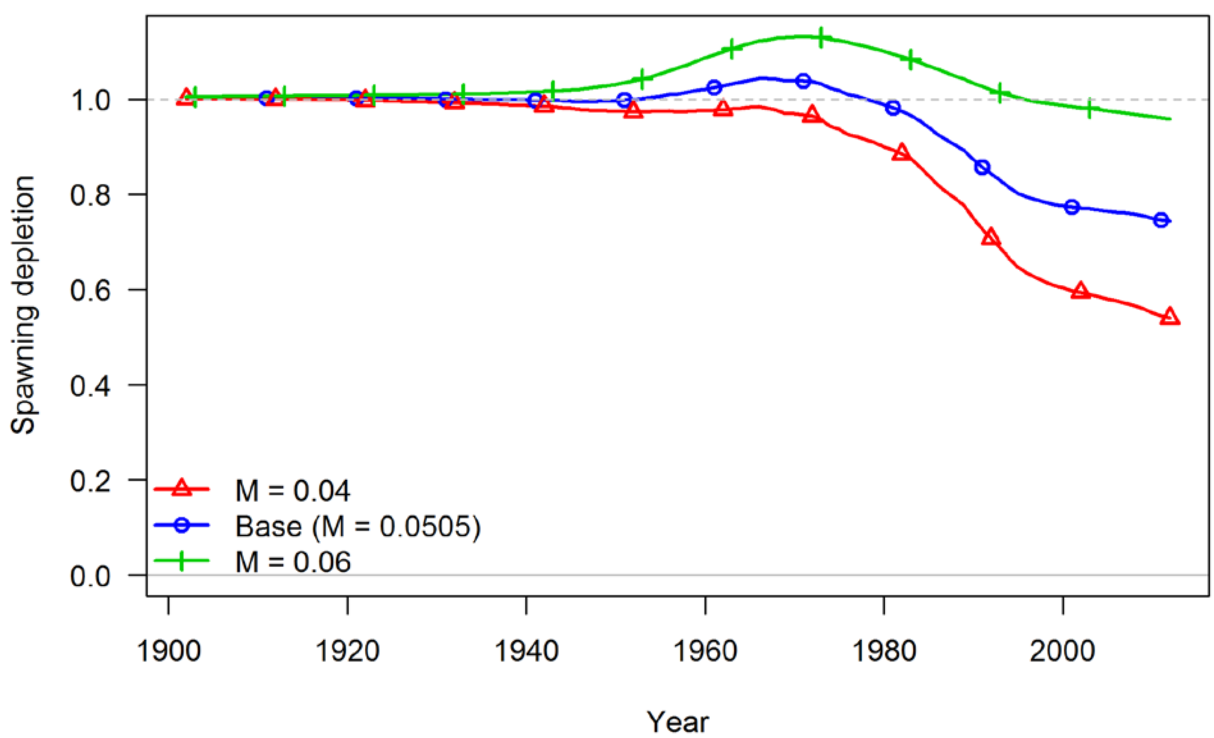

Figure 55: Time series of spawning depletion associated with two alternative *M* values bracketing the value used in the base model.

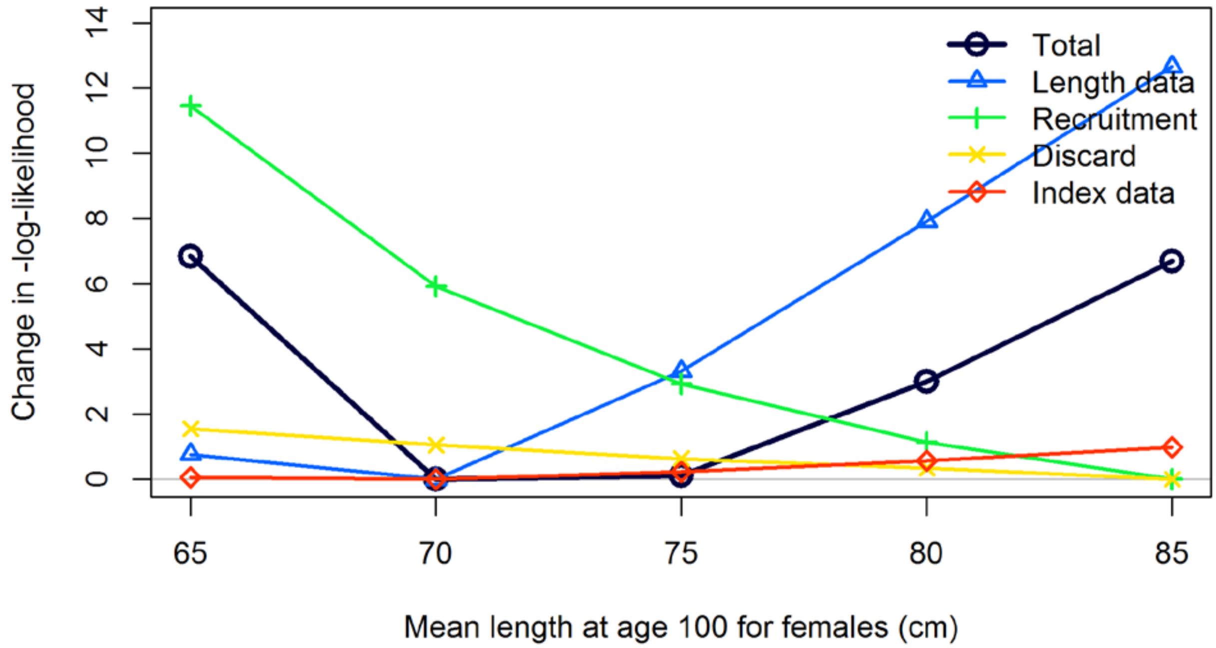

Figure 56: Likelihood profile over length at age 100 for females. The base model has this value fixed at 75 cm. In all cases the length at age 100 for males is set to 90% of the value for females.

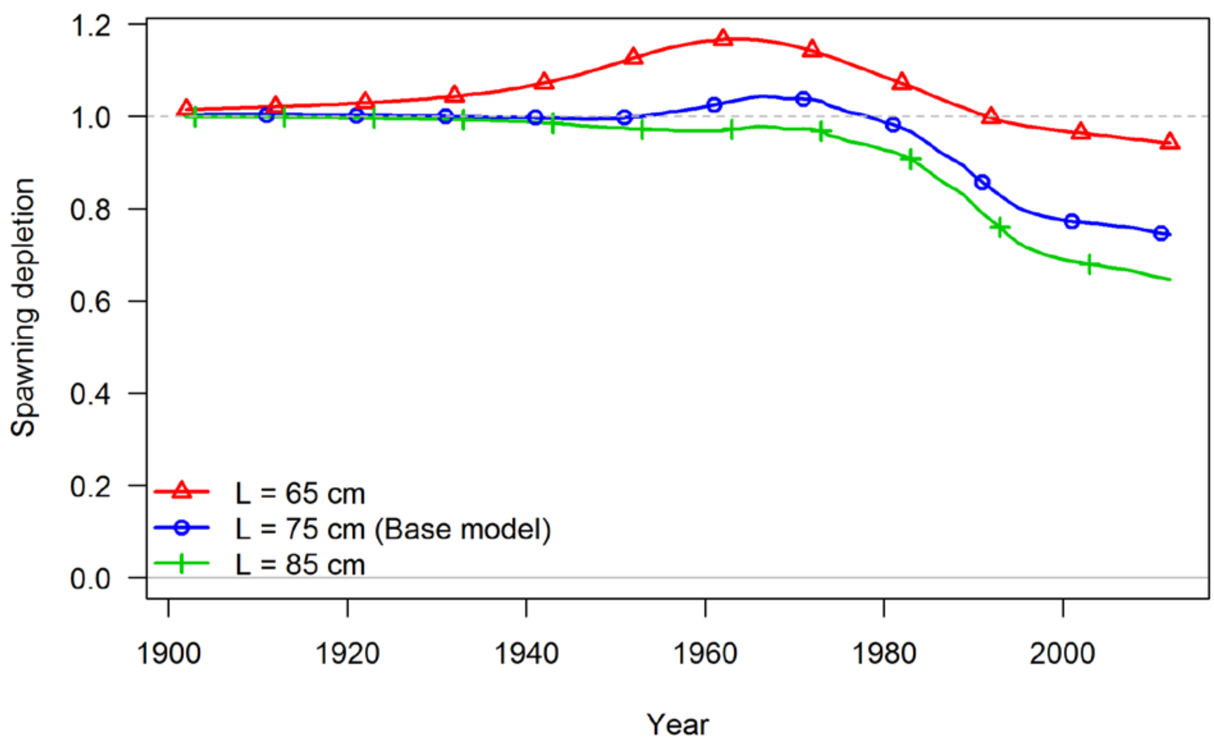

Figure 57: Time series of spawning depletion for models with alternative values for length at age 100.

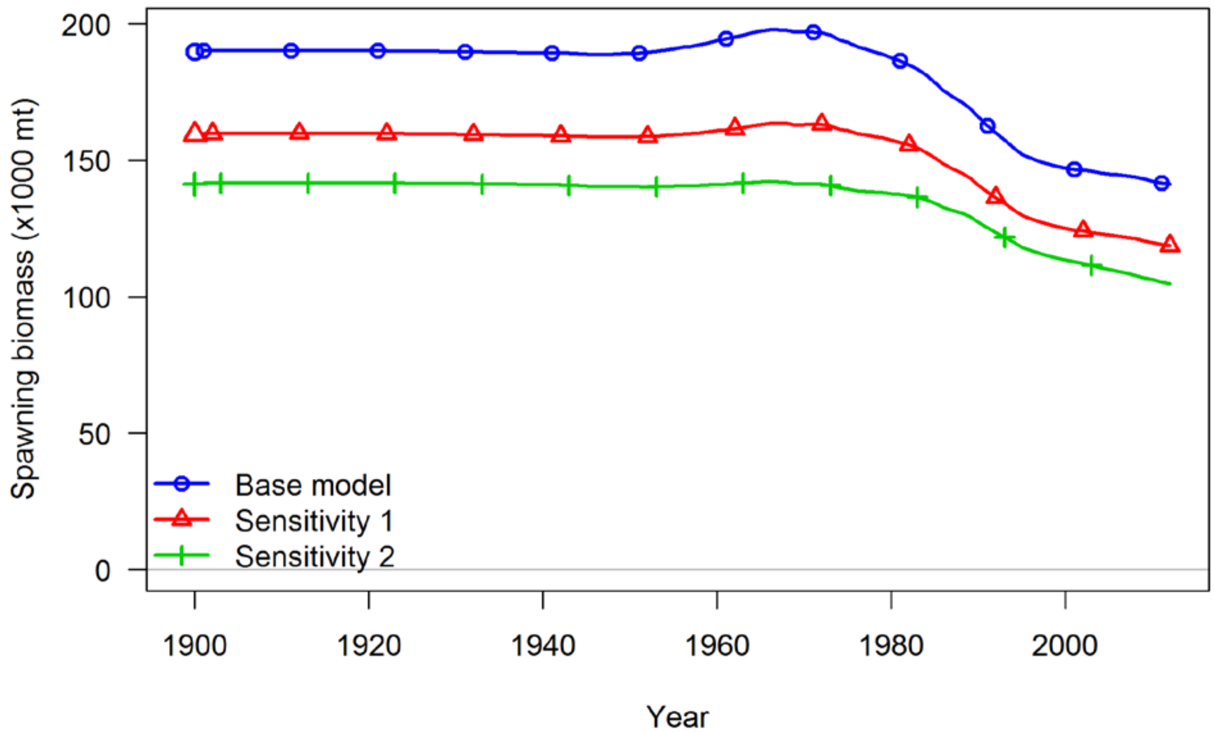

Figure 58: Time series of spawning biomass associated with alternative assumptions about maturity. Maturity ogives are shown in Figure 12.

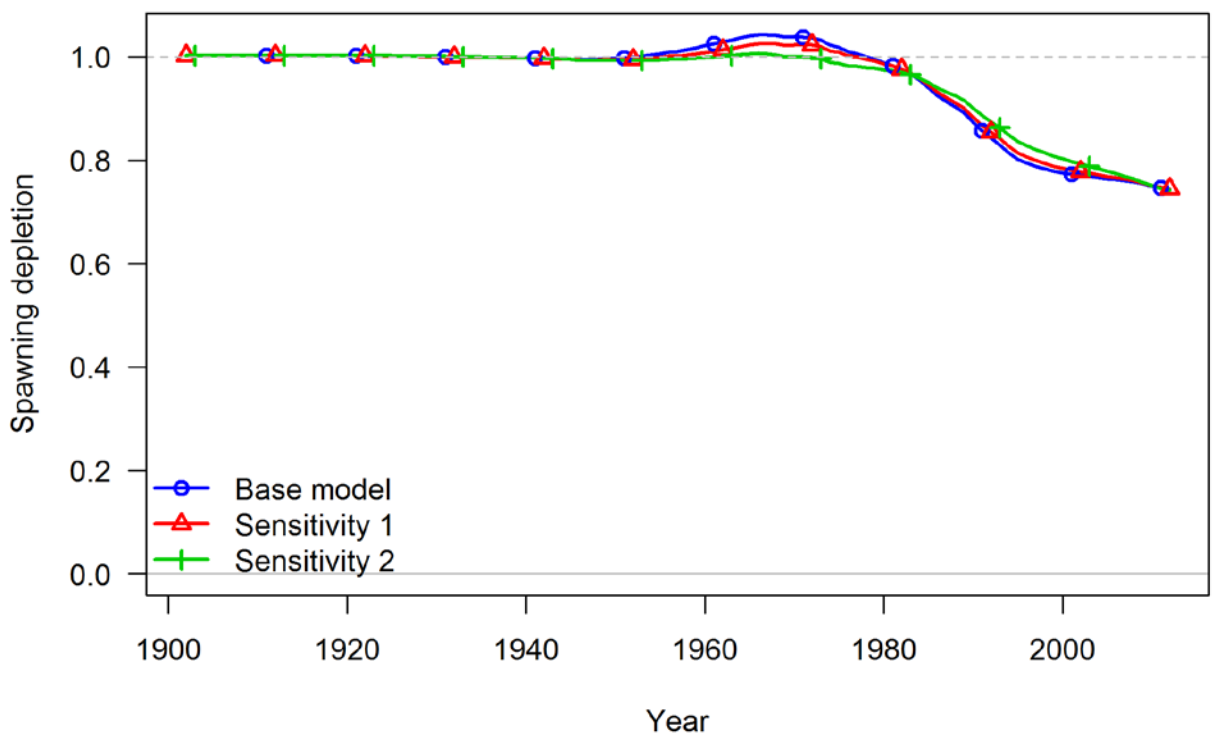

Figure 59: Time series of depletion associated with alternative assumptions about maturity. Maturity ogives are shown in Figure 12.

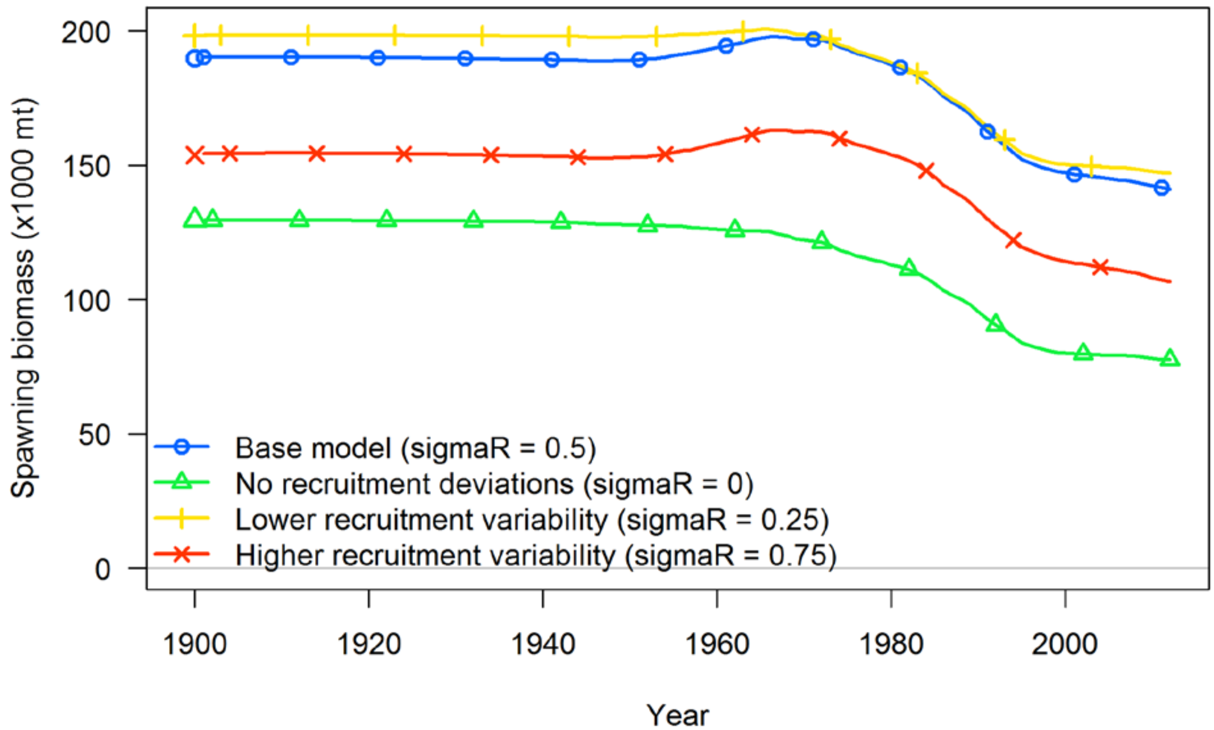

Figure 60: Time series of spawning biomass associated with alternative values for σ_R, the parameter controlling variability in recruitment around the stock-recruit curve.

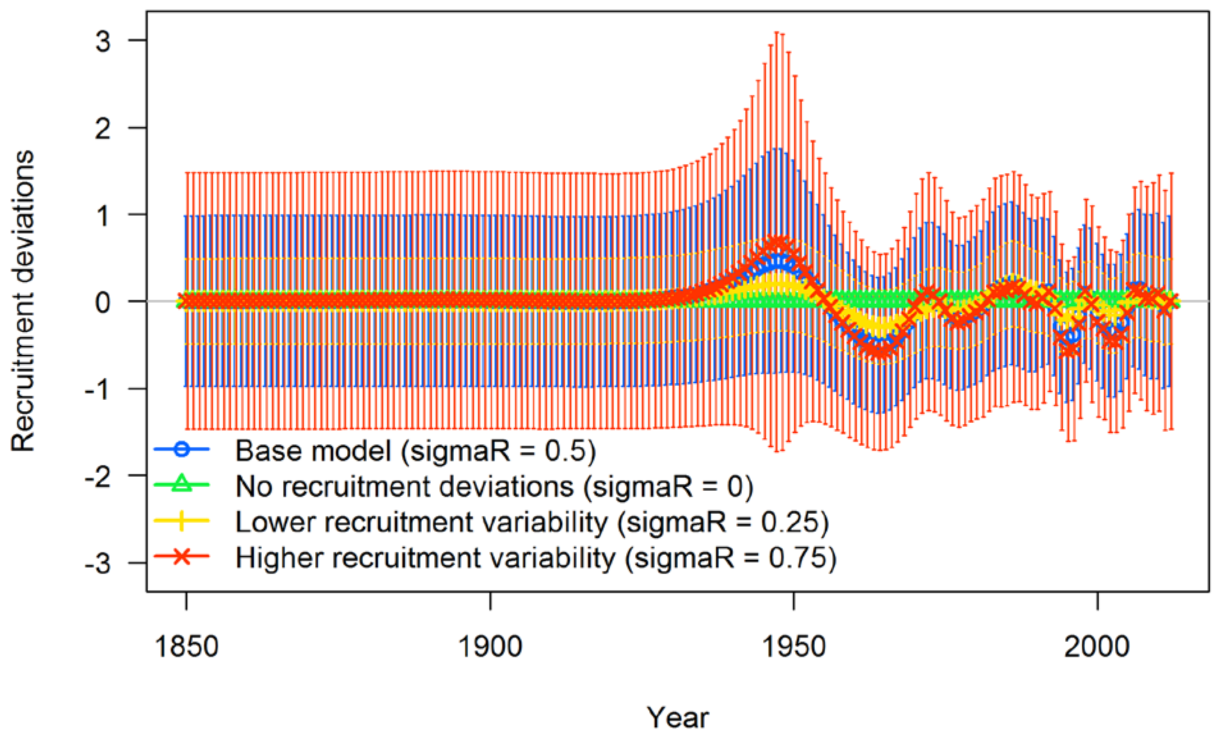

Figure 61: Time series of estimated recruitment deviations with 95% intervals around the stock-recruit curve associated with alternative values for σ_R.

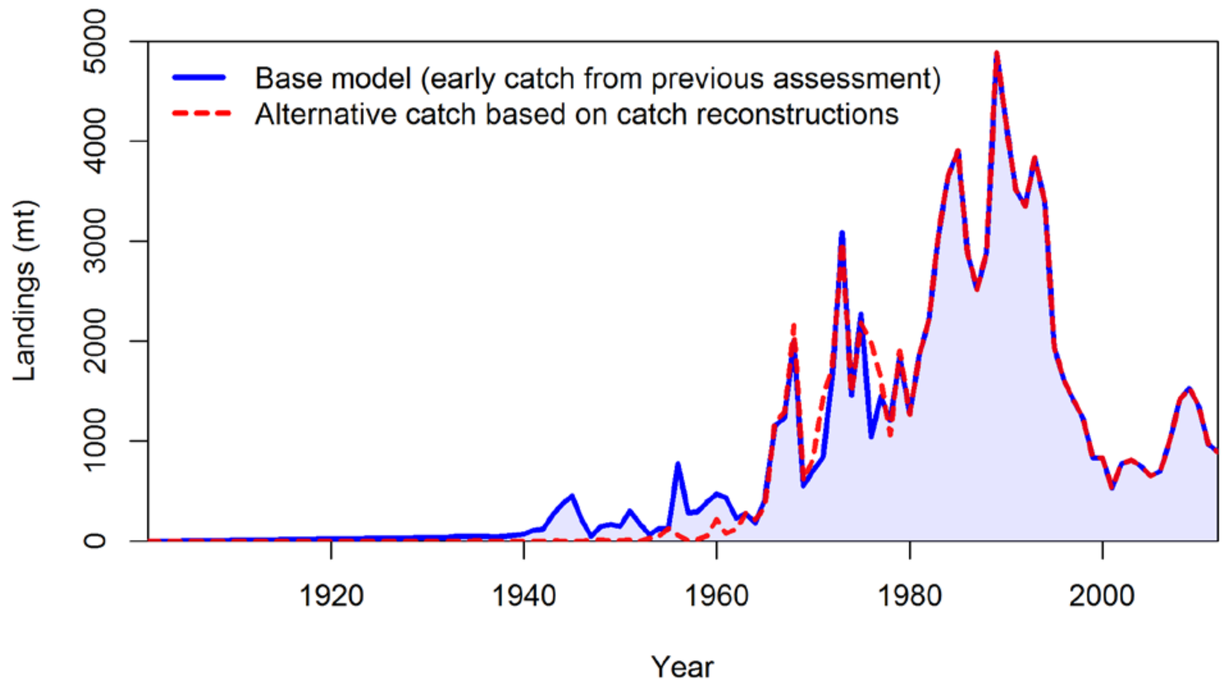

Figure 62: Time series of catch used in the base model show along with alternative catch assembled from available catch reconstructions. Catch reconstruction estimates may include some longspine thornyheads.

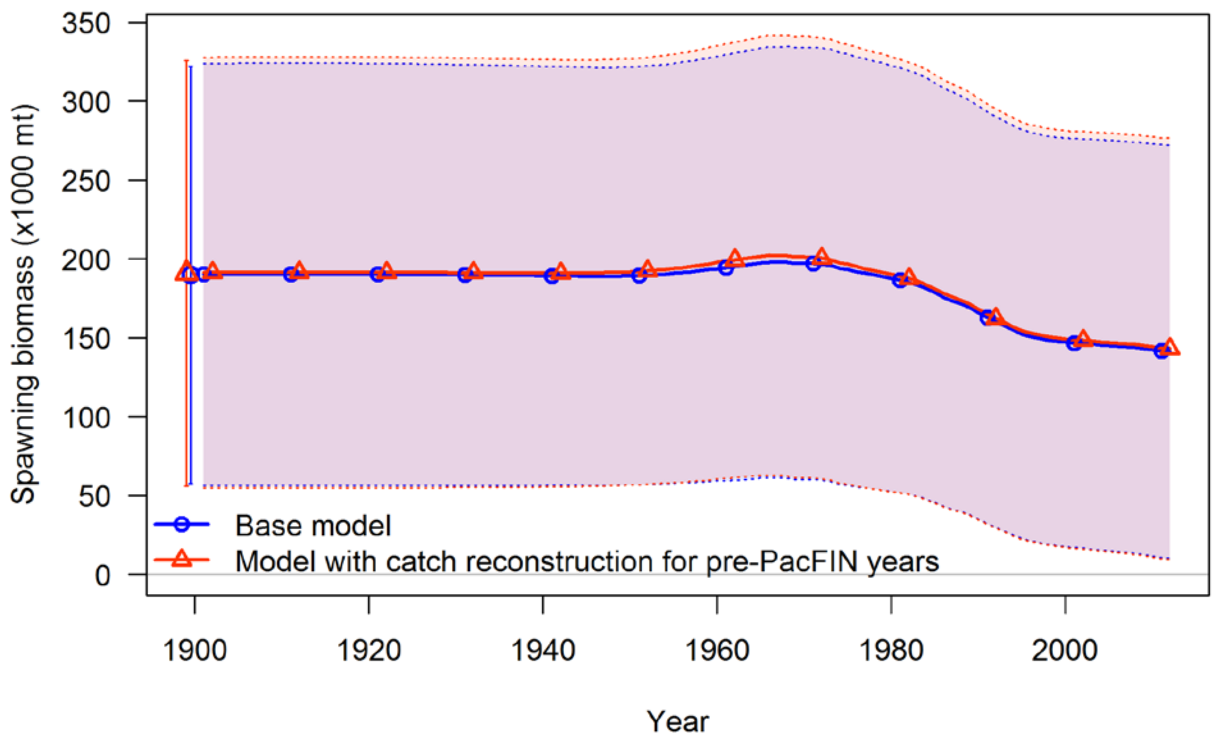

Figure 63: Time series of spawning biomass and 95% uncertainty intervals associated with alternative catch histories.

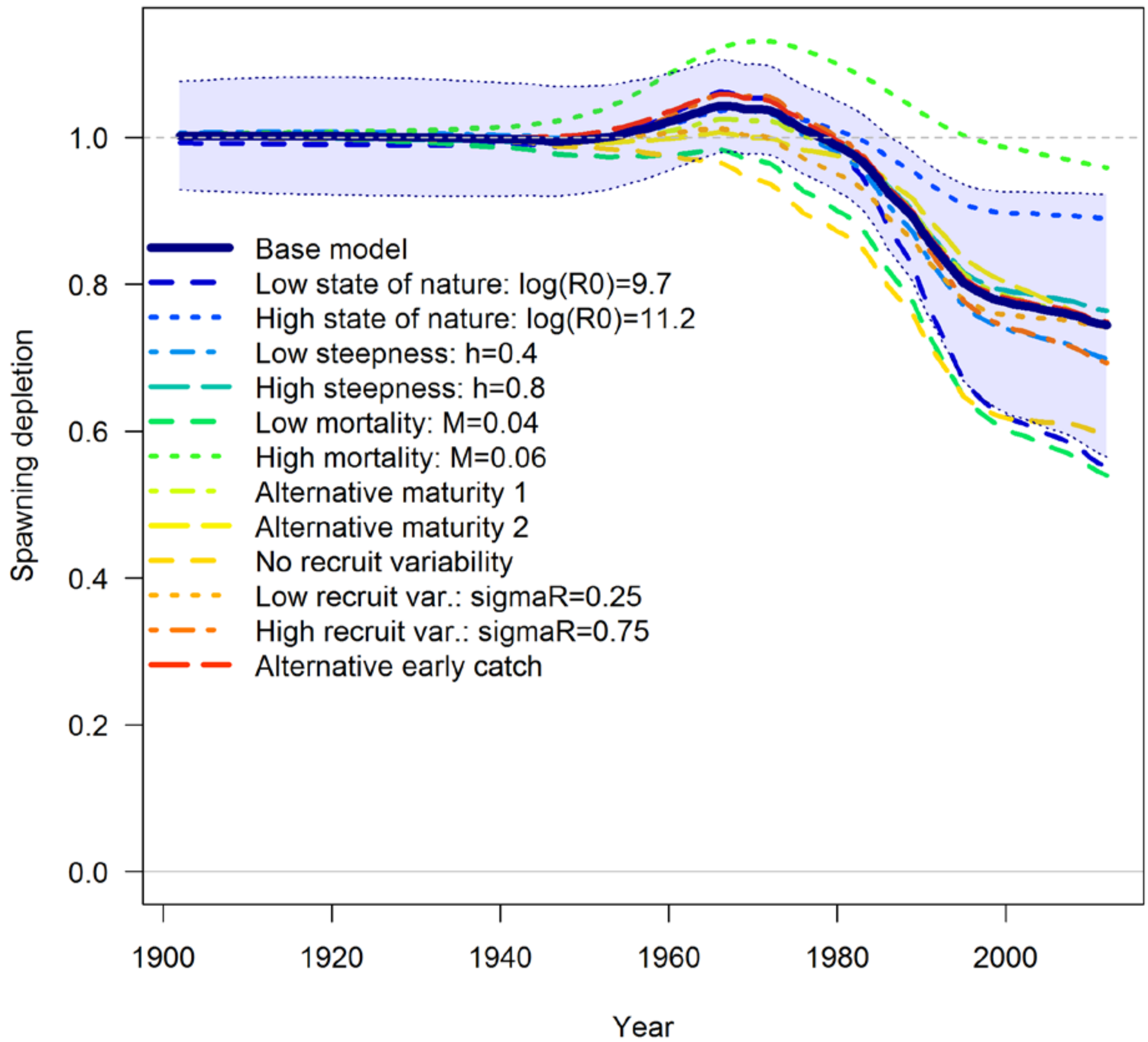

Figure 64: Summary of spawning depletion estimates for a large set of alternative models compared to the base model with 95% uncertainty intervals (blue shaded region).

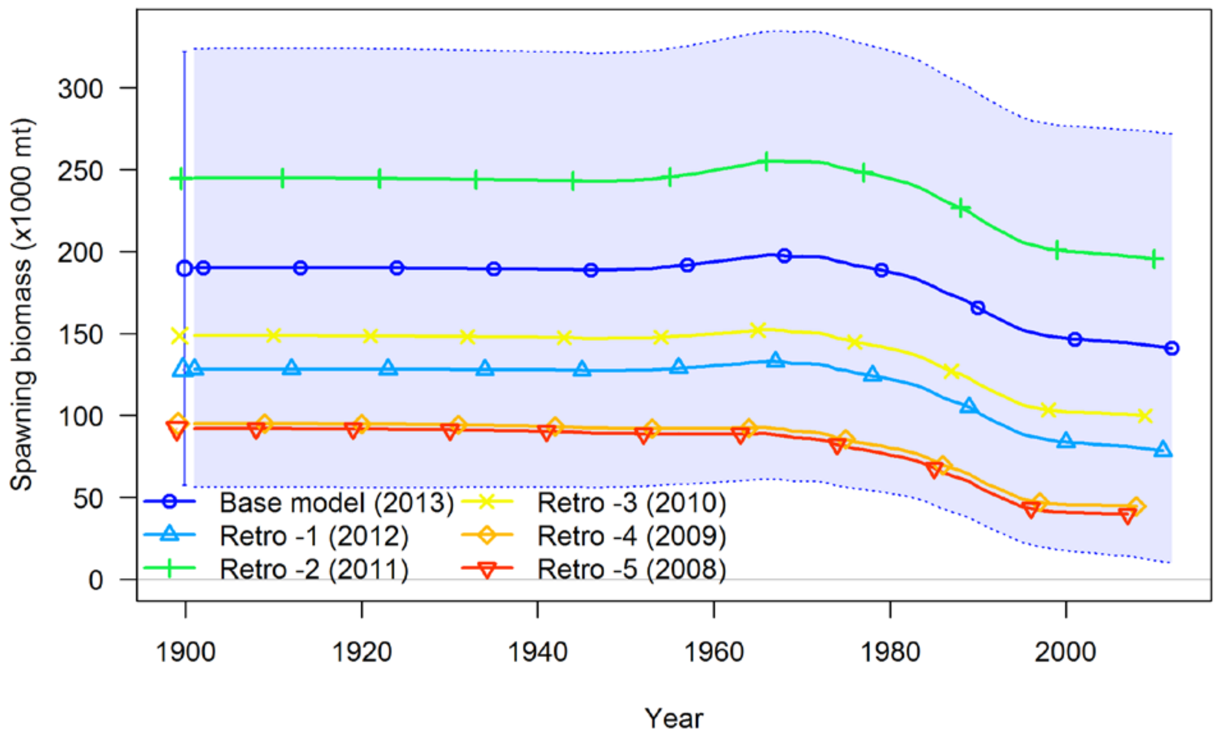

Figure 65: Time series of spawning biomass in retrospective analysis. The shaded blue region is the 95% interval around the base model, which encompasses the models with 1–5 years of data removed.

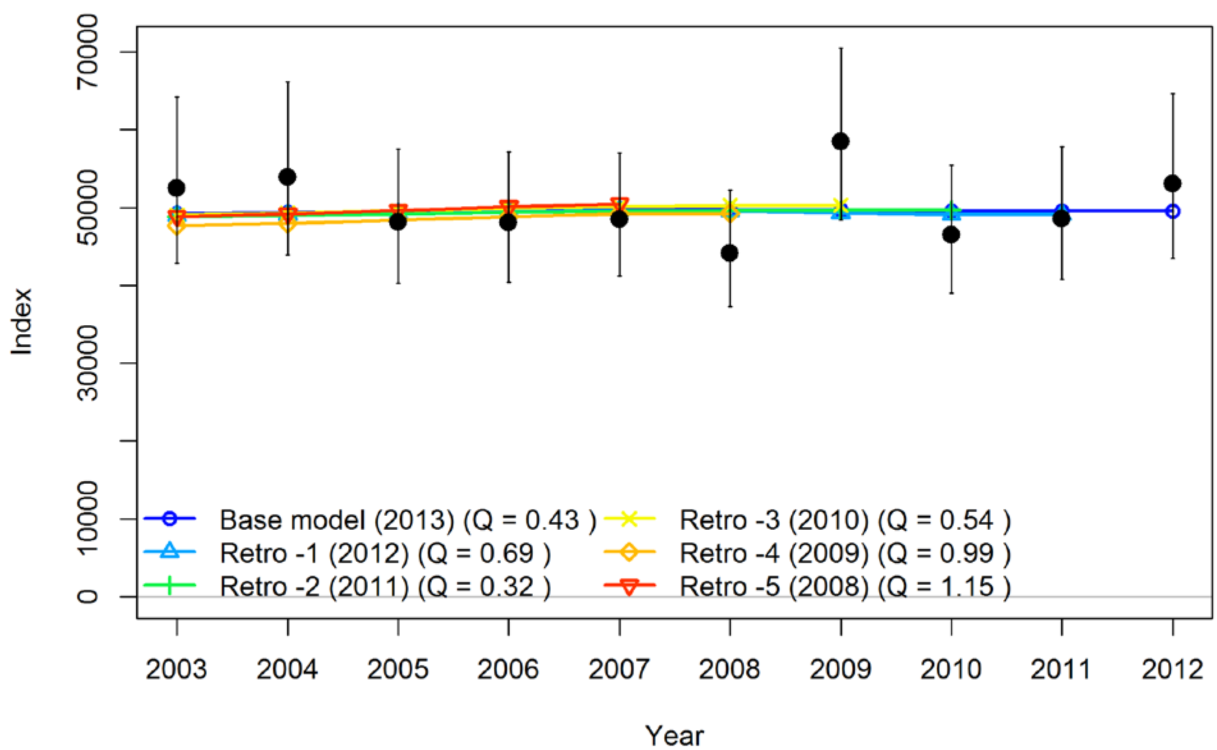

Figure 66: Fit to NWFSC Combo survey for models in the retrospective analysis. Catchability (Q) values are shown in legend.

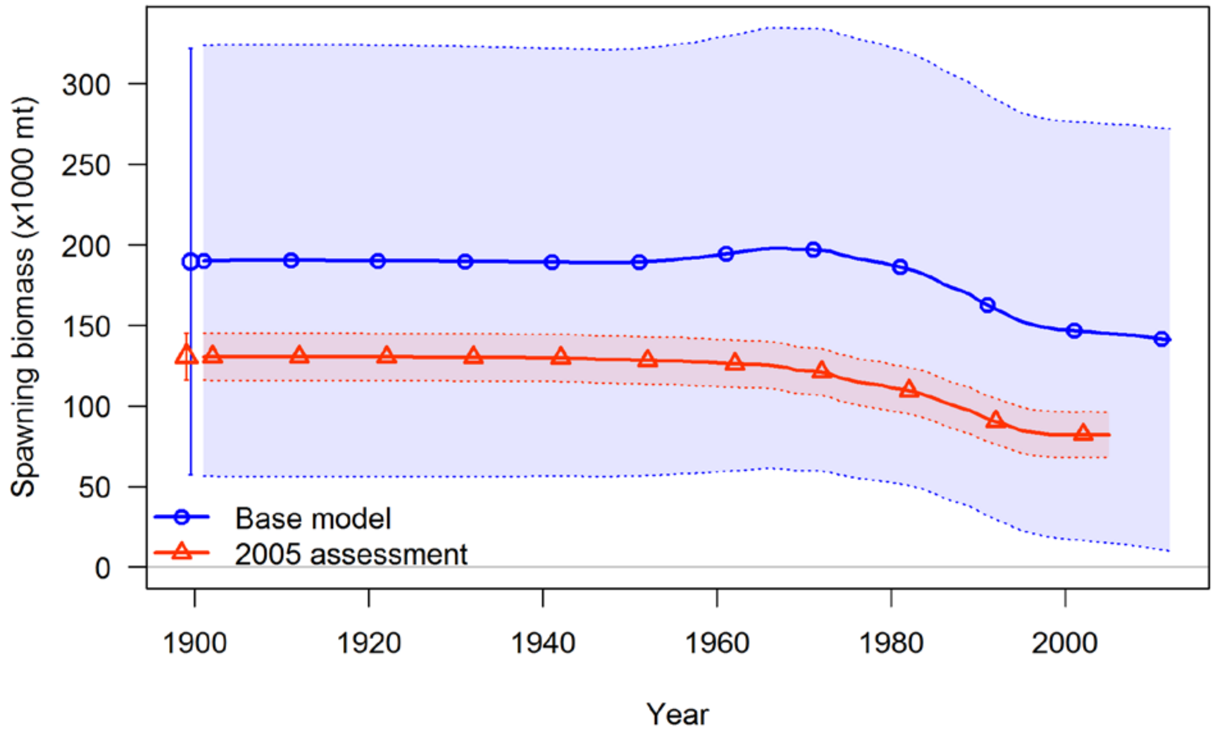

Figure 67: Comparison of spawning biomass time series and 95% confidence intervals from 2005 assessment and base model.

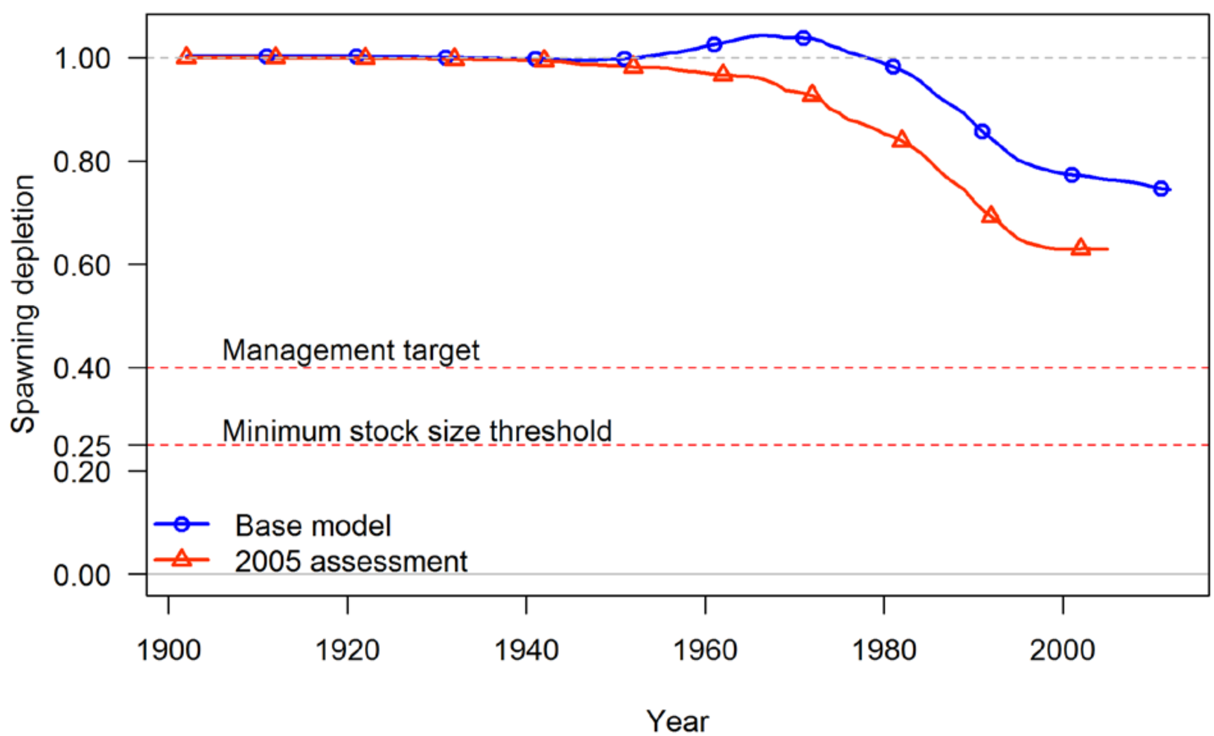

Figure 68: Comparison of spawning depletion time series from 2005 assessment and base model.

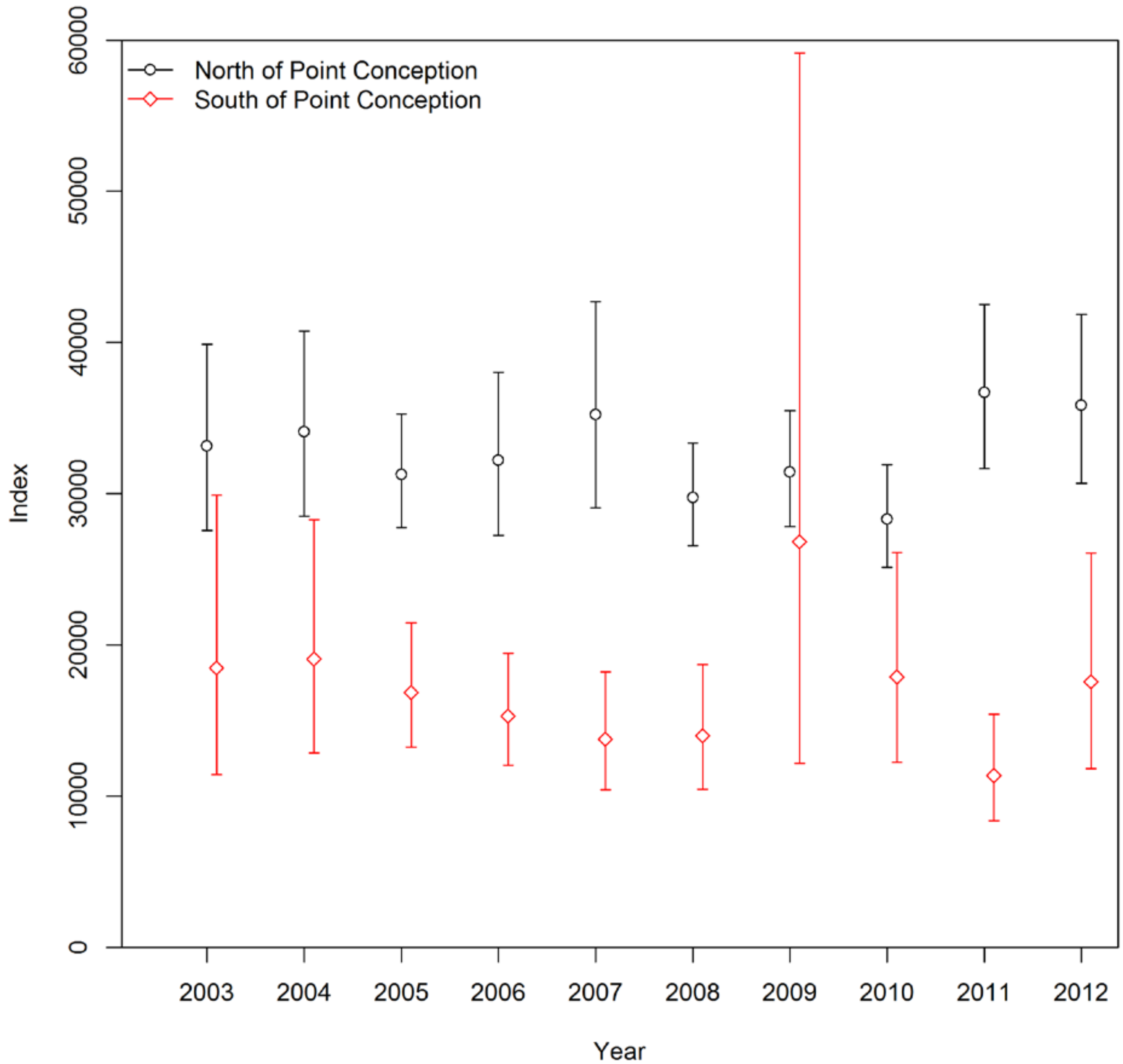

Figure 69: Subsets of the design-based indices from the NWFSC Combo Survey associated with the strata north and south of Point Conception. The mean value of the southern portion in 34.3% of the total (similar to 34.6% for the GLMM results).

Appendix A. Estimated numbers at age

Table 17: Estimated numbers at age of females

	Age(s)																		
Year	0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1901	15.2	14.5	13.8	13.1	12.5	11.9	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1902	15.2	14.5	13.8	13.1	12.5	11.9	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1903	15.2	14.5	13.8	13.1	12.5	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1904	15.2	14.5	13.8	13.1	12.4	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1905	15.2	14.4	13.7	13.1	12.4	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1906	15.2	14.4	13.7	13.1	12.4	11.8	11.2	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1907	15.1	14.4	13.7	13.1	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1908	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1909	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1910	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1911	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.1	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1912	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.1	9.7	74.1	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1913	15.1	14.4	13.7	13.0	12.3	11.8	11.2	10.6	10.1	9.6	74.0	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1914	15.1	14.4	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	74.0	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1915	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.9	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1916	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.9	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1917	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.8	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1918	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.8	44.8	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1919	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.7	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1920	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.7	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1921	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.6	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1922	15.1	14.4	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.5	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1923	15.1	14.4	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.5	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1924	15.2	14.4	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1925	15.2	14.4	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1926	15.3	14.5	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1927	15.3	14.5	13.7	13.0	12.4	11.7	11.1	10.6	10.1	9.6	73.3	44.5	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1928	15.4	14.6	13.8	13.1	12.4	11.8	11.2	10.6	10.1	9.6	73.3	44.5	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1929	15.5	14.6	13.9	13.1	12.4	11.8	11.2	10.6	10.1	9.6	73.3	44.4	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1930	15.6	14.7	13.9	13.2	12.5	11.8	11.2	10.6	10.1	9.6	73.3	44.4	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1931	15.8	14.8	14.0	13.2	12.5	11.9	11.2	10.7	10.1	9.6	73.3	44.4	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1932	15.9	15.0	14.1	13.3	12.6	11.9	11.3	10.7	10.1	9.6	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1933	16.1	15.1	14.2	13.4	12.7	12.0	11.3	10.7	10.2	9.6	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1934	16.4	15.3	14.4	13.5	12.8	12.0	11.4	10.8	10.2	9.7	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1935	16.6	15.6	14.6	13.7	12.9	12.1	11.4	10.8	10.2	9.7	73.4	44.2	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1936	17.0	15.8	14.8	13.9	13.0	12.2	11.5	10.9	10.3	9.7	73.5	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3
1937	17.4	16.1	15.0	14.1	13.2	12.4	11.6	11.0	10.3	9.8	73.6	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3
1938	17.8	16.5	15.3	14.3	13.4	12.5	11.8	11.1	10.4	9.8	73.8	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3

Table 17: Estimated numbers at age of females (continued)

Year	Age(s) 0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1939	18.3	16.9	15.7	14.6	13.6	12.7	11.9	11.2	10.5	9.9	74.0	44.1	26.8	16.2	9.8	5.9	3.6	2.2	3.3
1940	18.9	17.4	16.1	14.9	13.9	12.9	12.1	11.3	10.6	10.0	74.3	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1941	19.6	18.0	16.6	15.3	14.2	13.2	12.3	11.5	10.8	10.1	74.7	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1942	20.3	18.6	17.1	15.7	14.5	13.5	12.5	11.7	10.9	10.2	75.1	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1943	21.2	19.3	17.7	16.3	15.0	13.8	12.8	11.9	11.1	10.4	75.6	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1944	22.0	20.1	18.4	16.8	15.5	14.2	13.1	12.2	11.3	10.6	76.2	44.1	26.6	16.2	9.8	5.9	3.6	2.2	3.3
1945	22.9	20.9	19.1	17.5	16.0	14.7	13.5	12.5	11.6	10.8	76.9	44.1	26.6	16.1	9.8	5.9	3.6	2.2	3.3
1946	23.6	21.7	19.9	18.2	16.6	15.2	14.0	12.9	11.9	11.0	77.7	44.1	26.5	16.1	9.8	5.9	3.6	2.2	3.3
1947	24.0	22.4	20.7	18.9	17.3	15.8	14.5	13.3	12.2	11.3	78.8	44.1	26.5	16.1	9.7	5.9	3.6	2.2	3.3
1948	24.1	22.9	21.3	19.7	18.0	16.4	15.0	13.8	12.6	11.6	80.0	44.2	26.4	16.0	9.7	5.9	3.6	2.2	3.3
1949	23.6	22.9	21.7	20.3	18.7	17.1	15.6	14.3	13.1	12.0	81.5	44.4	26.4	16.0	9.7	5.9	3.6	2.2	3.3
1950	22.6	22.4	21.8	20.7	19.3	17.8	16.3	14.9	13.6	12.4	83.2	44.5	26.4	16.0	9.7	5.9	3.6	2.2	3.3
1951	21.3	21.5	21.3	20.7	19.6	18.3	16.9	15.5	14.1	12.9	85.2	44.7	26.4	16.0	9.7	5.9	3.6	2.2	3.3
1952	19.8	20.3	20.4	20.3	19.7	18.7	17.4	16.1	14.7	13.4	87.4	44.9	26.4	15.9	9.7	5.9	3.6	2.2	3.3
1953	18.3	18.9	19.3	19.4	19.3	18.7	17.8	16.6	15.3	14.0	90.0	45.2	26.4	15.9	9.7	5.9	3.6	2.1	3.3
1954	16.9	17.4	17.9	18.3	18.5	18.3	17.8	16.9	15.7	14.5	92.9	45.6	26.4	15.9	9.7	5.9	3.6	2.1	3.3
1955	15.5	16.0	16.6	17.0	17.4	17.6	17.4	16.9	16.0	15.0	96.1	46.1	26.4	15.9	9.7	5.9	3.5	2.1	3.3
1956	14.3	14.8	15.3	15.8	16.2	16.5	16.7	16.6	16.1	15.3	99.4	46.6	26.4	15.9	9.6	5.9	3.5	2.1	3.3
1957	13.2	13.6	14.0	14.5	15.0	15.4	15.7	15.9	15.7	15.3	102.5	47.1	26.4	15.8	9.6	5.8	3.5	2.1	3.3
1958	12.3	12.6	12.9	13.4	13.8	14.2	14.6	15.0	15.1	15.0	105.5	47.9	26.4	15.8	9.6	5.8	3.5	2.1	3.3
1959	11.4	11.7	11.9	12.3	12.7	13.1	13.5	13.9	14.2	14.3	107.8	48.7	26.5	15.8	9.6	5.8	3.5	2.1	3.3
1960	10.7	10.9	11.1	11.4	11.7	12.1	12.5	12.9	13.2	13.5	109.2	49.7	26.6	15.8	9.6	5.8	3.5	2.1	3.3
1961	10.1	10.2	10.3	10.5	10.8	11.1	11.5	11.9	12.2	12.6	109.5	50.8	26.6	15.7	9.5	5.8	3.5	2.1	3.3
1962	9.7	9.6	9.7	9.8	10.0	10.3	10.6	10.9	11.3	11.6	108.6	52.1	26.8	15.7	9.5	5.8	3.5	2.1	3.3
1963	9.4	9.2	9.1	9.2	9.3	9.5	9.8	10.1	10.4	10.7	106.6	53.7	26.9	15.7	9.5	5.8	3.5	2.1	3.3
1964	9.2	8.9	8.7	8.7	8.8	8.9	9.1	9.3	9.6	9.9	103.5	55.4	27.1	15.7	9.5	5.8	3.5	2.1	3.3
1965	9.3	8.8	8.5	8.3	8.3	8.3	8.4	8.6	8.8	9.1	99.5	57.3	27.4	15.7	9.5	5.8	3.5	2.1	3.3
1966	9.6	8.8	8.3	8.0	7.9	7.9	7.9	8.0	8.2	8.4	94.6	59.2	27.7	15.7	9.4	5.8	3.5	2.1	3.3
1967	10.1	9.1	8.4	7.9	7.6	7.5	7.5	7.5	7.6	7.8	88.8	60.8	27.9	15.7	9.4	5.7	3.5	2.1	3.3
1968	11.0	9.6	8.6	8.0	7.5	7.3	7.1	7.1	7.1	7.2	82.8	62.3	28.2	15.6	9.4	5.7	3.5	2.1	3.3
1969	12.1	10.4	9.1	8.2	7.6	7.2	6.9	6.8	6.7	6.8	76.7	63.2	28.5	15.6	9.3	5.7	3.5	2.1	3.2
1970	13.4	11.5	9.9	8.7	7.8	7.2	6.8	6.6	6.4	6.4	71.2	63.9	29.1	15.6	9.3	5.7	3.5	2.1	3.2
1971	14.6	12.7	10.9	9.4	8.3	7.4	6.8	6.5	6.2	6.1	66.1	64.0	29.7	15.6	9.3	5.6	3.5	2.1	3.2
1972	15.3	13.9	12.1	10.4	8.9	7.9	7.1	6.5	6.1	5.9	61.4	63.3	30.4	15.7	9.2	5.6	3.4	2.1	3.2
1973	15.3	14.6	13.2	11.5	9.9	8.5	7.5	6.7	6.2	5.8	57.2	61.8	31.1	15.7	9.2	5.6	3.4	2.1	3.2
1974	14.8	14.6	13.8	12.5	10.9	9.4	8.1	7.1	6.4	5.9	53.5	59.2	31.7	15.6	9.1	5.5	3.4	2.1	3.2
1975	13.8	14.0	13.9	13.2	11.9	10.4	8.9	7.7	6.7	6.0	50.8	56.6	32.6	15.7	9.0	5.5	3.4	2.1	3.2
1976	13.0	13.2	13.3	13.2	12.5	11.3	9.9	8.5	7.3	6.4	48.7	53.4	33.4	15.7	9.0	5.5	3.4	2.1	3.2

Table 17: Estimated numbers at age of females (continued)

	Age(s)																		
Year	0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1977	12.5	12.3	12.5	12.7	12.5	11.9	10.8	9.4	8.0	6.9	47.7	50.3	34.4	15.9	9.0	5.4	3.4	2.1	3.2
1978	12.6	11.9	11.7	11.9	12.1	11.9	11.3	10.2	8.9	7.6	47.5	46.9	35.2	16.0	8.9	5.4	3.3	2.1	3.2
1979	13.0	11.9	11.3	11.1	11.3	11.5	11.3	10.7	9.7	8.5	48.3	43.5	35.8	16.2	8.9	5.4	3.3	2.1	3.2
1980	13.5	12.4	11.3	10.7	10.6	10.8	10.9	10.8	10.2	9.2	50.0	40.2	36.0	16.5	8.9	5.4	3.3	2.0	3.2
1981	14.3	12.9	11.8	10.8	10.2	10.1	10.2	10.4	10.2	9.7	52.7	37.3	36.0	16.8	8.9	5.3	3.3	2.0	3.2
1982	15.5	13.6	12.2	11.2	10.3	9.7	9.6	9.7	9.8	9.7	55.7	34.5	35.4	17.1	8.9	5.3	3.3	2.0	3.2
1983	16.8	14.8	12.9	11.6	10.6	9.7	9.2	9.1	9.2	9.3	58.5	32.1	34.5	17.4	8.8	5.3	3.2	2.0	3.2
1984	17.5	16.0	14.1	12.3	11.1	10.1	9.3	8.8	8.6	8.7	60.5	29.8	33.0	17.8	8.8	5.2	3.2	2.0	3.2
1985	18.0	16.7	15.2	13.4	11.7	10.5	9.6	8.8	8.3	8.1	61.7	27.9	31.2	18.1	8.8	5.2	3.2	2.0	3.1
1986	18.3	17.1	15.8	14.5	12.7	11.1	10.0	9.1	8.3	7.8	62.2	26.5	29.1	18.4	8.8	5.1	3.2	2.0	3.1
1987	17.8	17.4	16.3	15.1	13.7	12.1	10.5	9.5	8.6	7.9	62.6	25.6	27.1	18.7	8.8	5.1	3.1	2.0	3.1
1988	16.8	16.9	16.5	15.5	14.3	13.1	11.5	10.0	9.0	8.2	62.9	25.4	25.1	19.0	8.8	5.0	3.1	1.9	3.1
1989	15.9	16.0	16.1	15.7	14.7	13.6	12.4	10.9	9.5	8.5	62.9	25.5	23.0	19.2	8.9	5.0	3.1	1.9	3.1
1990	15.7	15.1	15.2	15.3	14.9	14.0	12.9	11.8	10.3	9.0	62.3	25.9	20.9	19.0	8.8	4.9	3.0	1.9	3.1
1991	16.3	15.0	14.4	14.4	14.6	14.2	13.3	12.2	11.1	9.7	61.7	26.7	18.9	18.6	8.9	4.9	3.0	1.9	3.1
1992	16.4	15.5	14.2	13.7	13.7	13.8	13.5	12.6	11.6	10.5	61.9	27.8	17.3	18.1	9.0	4.8	3.0	1.9	3.0
1993	13.8	15.6	14.7	13.5	13.0	13.0	13.1	12.8	11.9	10.9	62.9	28.9	15.9	17.5	9.1	4.8	2.9	1.8	3.0
1994	10.9	13.2	14.8	14.0	12.8	12.3	12.4	12.4	12.1	11.2	64.3	29.6	14.6	16.6	9.2	4.7	2.9	1.8	3.0
1995	9.6	10.3	12.5	14.1	13.3	12.2	11.7	11.7	11.8	11.4	66.3	30.0	13.6	15.7	9.4	4.7	2.9	1.8	3.0
1996	9.9	9.1	9.8	11.9	13.4	12.6	11.6	11.1	11.1	11.1	69.3	30.4	13.0	14.7	9.6	4.7	2.8	1.8	3.0
1997	12.2	9.4	8.7	9.3	11.3	12.7	12.0	11.0	10.5	10.5	72.1	30.7	12.6	13.7	9.8	4.7	2.8	1.8	3.0
1998	15.7	11.6	8.9	8.3	8.9	10.7	12.1	11.4	10.5	10.0	74.2	30.9	12.5	12.7	10.0	4.8	2.8	1.8	2.9
1999	14.9	14.9	11.1	8.5	7.9	8.4	10.2	11.5	10.8	9.9	75.5	31.1	12.6	11.8	10.1	4.8	2.8	1.8	2.9
2000	12.7	14.1	14.2	10.5	8.1	7.5	8.0	9.7	10.9	10.3	76.7	31.5	13.1	10.8	10.1	4.9	2.8	1.7	2.9
2001	11.5	12.1	13.5	13.5	10.0	7.7	7.1	7.6	9.2	10.3	77.9	31.9	13.8	10.0	10.1	4.9	2.8	1.7	2.9
2002	10.3	10.9	11.5	12.8	12.8	9.5	7.3	6.7	7.2	8.8	78.6	32.7	14.6	9.3	10.0	5.0	2.8	1.7	2.9
2003	10.3	9.8	10.4	10.9	12.2	12.2	9.0	6.9	6.4	6.9	77.3	33.9	15.4	8.7	9.7	5.1	2.8	1.7	2.9
2004	11.2	9.8	9.3	9.9	10.4	11.6	11.6	8.6	6.6	6.1	74.0	35.4	16.1	8.1	9.4	5.3	2.8	1.7	2.9
2005	13.6	10.7	9.3	8.9	9.4	9.9	11.0	11.0	8.2	6.3	69.8	37.2	16.7	7.7	8.9	5.4	2.8	1.7	2.9
2006	16.4	12.9	10.2	8.8	8.4	8.9	9.4	10.4	10.5	7.7	65.8	39.1	17.1	7.4	8.5	5.6	2.8	1.7	2.8
2007	16.5	15.6	12.3	9.7	8.4	8.0	8.5	8.9	9.9	9.9	63.6	41.0	17.3	7.2	7.9	5.7	2.8	1.7	2.8
2008	15.5	15.7	14.8	11.7	9.2	8.0	7.6	8.0	8.5	9.4	63.8	42.2	17.5	7.2	7.4	5.8	2.8	1.7	2.8
2009	15.1	14.7	14.9	14.1	11.1	8.7	7.6	7.2	7.6	8.0	63.6	42.9	17.7	7.2	6.8	5.9	2.8	1.7	2.8
2010	15.2	14.4	14.0	14.2	13.4	10.6	8.3	7.2	6.9	7.2	62.1	43.3	17.8	7.5	6.3	5.9	2.9	1.6	2.8
2011	13.7	14.5	13.6	13.3	13.5	12.7	10.0	7.9	6.8	6.5	59.9	43.7	17.9	7.8	5.8	5.9	2.9	1.6	2.8
2012	14.4	13.0	13.8	13.0	12.6	12.8	12.1	9.5	7.5	6.5	57.2	44.1	18.3	8.3	5.4	5.8	3.0	1.6	2.8
2013	14.4	13.7	12.4	13.1	12.3	12.0	12.2	11.5	9.1	7.1	55.6	43.3	19.0	8.7	5.0	5.7	3.0	1.6	2.7

Table 18: Estimated numbers at age of males

Year	Age(s) 0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1901	15.2	14.5	13.8	13.1	12.5	11.9	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1902	15.2	14.5	13.8	13.1	12.5	11.9	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1903	15.2	14.5	13.8	13.1	12.5	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1904	15.2	14.5	13.8	13.1	12.4	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1905	15.2	14.4	13.7	13.1	12.4	11.8	11.3	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1906	15.2	14.4	13.7	13.1	12.4	11.8	11.2	10.7	10.2	9.7	74.3	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1907	15.1	14.4	13.7	13.1	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1908	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.1	16.3	9.8	5.9	3.6	2.2	3.3
1909	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1910	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.2	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1911	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.2	9.7	74.1	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1912	15.1	14.4	13.7	13.0	12.4	11.8	11.2	10.7	10.1	9.7	74.1	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1913	15.1	14.4	13.7	13.0	12.3	11.8	11.2	10.6	10.1	9.6	74.0	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1914	15.1	14.4	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	74.0	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1915	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	74.0	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1916	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.9	44.8	27.0	16.3	9.9	5.9	3.6	2.2	3.3
1917	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.8	44.8	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1918	15.1	14.3	13.6	13.0	12.3	11.7	11.2	10.6	10.1	9.6	73.8	44.8	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1919	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.7	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1920	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.7	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1921	15.1	14.3	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.6	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1922	15.1	14.4	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.5	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1923	15.1	14.4	13.6	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.5	44.7	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1924	15.2	14.4	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1925	15.2	14.4	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1926	15.3	14.5	13.7	13.0	12.3	11.7	11.1	10.6	10.1	9.6	73.4	44.6	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1927	15.3	14.5	13.7	13.0	12.4	11.7	11.1	10.6	10.1	9.6	73.3	44.5	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1928	15.4	14.6	13.8	13.1	12.4	11.8	11.2	10.6	10.1	9.6	73.3	44.5	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1929	15.5	14.6	13.9	13.1	12.4	11.8	11.2	10.6	10.1	9.6	73.3	44.4	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1930	15.6	14.7	13.9	13.2	12.5	11.8	11.2	10.6	10.1	9.6	73.3	44.4	27.0	16.3	9.8	5.9	3.6	2.2	3.3
1931	15.8	14.8	14.0	13.2	12.5	11.9	11.2	10.7	10.1	9.6	73.3	44.4	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1932	15.9	15.0	14.1	13.3	12.6	11.9	11.3	10.7	10.1	9.6	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1933	16.1	15.1	14.2	13.4	12.7	12.0	11.3	10.7	10.2	9.6	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1934	16.4	15.3	14.4	13.5	12.8	12.0	11.4	10.8	10.2	9.7	73.3	44.3	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1935	16.6	15.6	14.6	13.7	12.9	12.1	11.4	10.8	10.2	9.7	73.4	44.2	26.9	16.3	9.8	5.9	3.6	2.2	3.3
1936	17.0	15.8	14.8	13.9	13.0	12.2	11.5	10.9	10.3	9.7	73.5	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3
1937	17.4	16.1	15.0	14.1	13.2	12.4	11.6	11.0	10.3	9.8	73.7	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3
1938	17.8	16.5	15.3	14.3	13.4	12.5	11.8	11.1	10.4	9.8	73.8	44.2	26.8	16.3	9.8	5.9	3.6	2.2	3.3

Table 18: Estimated numbers at age of males (continued)

Year	Age(s) 0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1939	18.3	16.9	15.7	14.6	13.6	12.7	11.9	11.2	10.5	9.9	74.1	44.2	26.8	16.2	9.8	5.9	3.6	2.2	3.3
1940	18.9	17.4	16.1	14.9	13.9	12.9	12.1	11.3	10.6	10.0	74.3	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1941	19.6	18.0	16.6	15.3	14.2	13.2	12.3	11.5	10.8	10.1	74.7	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1942	20.3	18.6	17.1	15.7	14.5	13.5	12.5	11.7	10.9	10.2	75.1	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1943	21.2	19.3	17.7	16.3	15.0	13.8	12.8	11.9	11.1	10.4	75.6	44.1	26.7	16.2	9.8	5.9	3.6	2.2	3.3
1944	22.0	20.1	18.4	16.8	15.5	14.2	13.1	12.2	11.3	10.6	76.2	44.1	26.6	16.2	9.8	5.9	3.6	2.2	3.3
1945	22.9	20.9	19.1	17.5	16.0	14.7	13.5	12.5	11.6	10.8	76.9	44.1	26.6	16.1	9.8	5.9	3.6	2.2	3.3
1946	23.6	21.7	19.9	18.2	16.6	15.2	14.0	12.9	11.9	11.0	77.8	44.1	26.5	16.1	9.8	5.9	3.6	2.2	3.3
1947	24.0	22.4	20.7	18.9	17.3	15.8	14.5	13.3	12.2	11.3	78.8	44.1	26.5	16.1	9.7	5.9	3.6	2.1	3.3
1948	24.1	22.9	21.3	19.7	18.0	16.4	15.0	13.8	12.6	11.6	80.1	44.3	26.4	16.0	9.7	5.9	3.6	2.1	3.3
1949	23.6	22.9	21.7	20.3	18.7	17.1	15.6	14.3	13.1	12.0	81.5	44.4	26.4	16.0	9.7	5.9	3.6	2.1	3.3
1950	22.6	22.4	21.8	20.7	19.3	17.8	16.3	14.9	13.6	12.4	83.2	44.5	26.4	16.0	9.7	5.9	3.5	2.1	3.3
1951	21.3	21.5	21.3	20.7	19.6	18.3	16.9	15.5	14.1	12.9	85.2	44.8	26.4	16.0	9.7	5.9	3.5	2.1	3.3
1952	19.8	20.3	20.4	20.3	19.7	18.7	17.4	16.1	14.7	13.4	87.5	45.0	26.4	15.9	9.7	5.9	3.5	2.1	3.3
1953	18.3	18.9	19.3	19.4	19.3	18.7	17.8	16.6	15.3	14.0	90.1	45.3	26.4	15.9	9.7	5.9	3.5	2.1	3.3
1954	16.9	17.4	17.9	18.3	18.5	18.3	17.8	16.9	15.7	14.5	93.0	45.7	26.4	15.9	9.7	5.9	3.5	2.1	3.3
1955	15.5	16.0	16.6	17.0	17.4	17.6	17.4	16.9	16.0	15.0	96.1	46.1	26.4	15.9	9.7	5.9	3.5	2.1	3.3
1956	14.3	14.8	15.3	15.8	16.2	16.5	16.7	16.6	16.1	15.3	99.4	46.7	26.4	15.9	9.6	5.8	3.5	2.1	3.3
1957	13.2	13.6	14.0	14.5	15.0	15.4	15.7	15.9	15.7	15.3	102.6	47.2	26.4	15.8	9.6	5.8	3.5	2.1	3.3
1958	12.3	12.6	12.9	13.4	13.8	14.2	14.6	15.0	15.1	15.0	105.6	47.9	26.4	15.8	9.6	5.8	3.5	2.1	3.3
1959	11.4	11.7	11.9	12.3	12.7	13.1	13.5	13.9	14.2	14.3	107.9	48.8	26.5	15.8	9.6	5.8	3.5	2.1	3.3
1960	10.7	10.9	11.1	11.4	11.7	12.1	12.5	12.9	13.2	13.5	109.3	49.8	26.6	15.8	9.5	5.8	3.5	2.1	3.2
1961	10.1	10.2	10.3	10.5	10.8	11.1	11.5	11.9	12.2	12.6	109.6	50.9	26.7	15.7	9.5	5.8	3.5	2.1	3.2
1962	9.7	9.6	9.7	9.8	10.0	10.3	10.6	10.9	11.3	11.6	108.7	52.2	26.8	15.7	9.5	5.8	3.5	2.1	3.2
1963	9.4	9.2	9.1	9.2	9.3	9.5	9.8	10.1	10.4	10.7	106.7	53.7	27.0	15.7	9.5	5.8	3.5	2.1	3.2
1964	9.2	8.9	8.7	8.7	8.8	8.9	9.1	9.3	9.6	9.9	103.6	55.5	27.2	15.7	9.5	5.8	3.5	2.1	3.2
1965	9.3	8.8	8.5	8.3	8.3	8.3	8.4	8.6	8.8	9.1	99.6	57.4	27.4	15.7	9.5	5.7	3.5	2.1	3.2
1966	9.6	8.8	8.3	8.0	7.9	7.9	7.9	8.0	8.2	8.4	94.7	59.3	27.7	15.7	9.4	5.7	3.5	2.1	3.2
1967	10.1	9.1	8.4	7.9	7.6	7.5	7.5	7.5	7.6	7.8	88.9	60.9	28.0	15.7	9.4	5.7	3.5	2.1	3.2
1968	11.0	9.6	8.6	8.0	7.5	7.3	7.1	7.1	7.1	7.2	82.9	62.4	28.3	15.6	9.3	5.7	3.5	2.1	3.2
1969	12.1	10.4	9.1	8.2	7.6	7.2	6.9	6.8	6.7	6.8	76.9	63.3	28.6	15.5	9.3	5.6	3.4	2.1	3.2
1970	13.4	11.5	9.9	8.7	7.8	7.2	6.8	6.6	6.4	6.4	71.4	64.1	29.1	15.6	9.2	5.6	3.4	2.1	3.2
1971	14.6	12.7	10.9	9.4	8.3	7.4	6.8	6.5	6.2	6.1	66.3	64.2	29.7	15.6	9.2	5.6	3.4	2.1	3.2
1972	15.3	13.9	12.1	10.4	8.9	7.9	7.1	6.5	6.1	5.9	61.6	63.5	30.4	15.6	9.2	5.6	3.4	2.1	3.2
1973	15.3	14.6	13.2	11.5	9.9	8.5	7.5	6.7	6.2	5.8	57.4	61.9	31.1	15.6	9.1	5.5	3.4	2.1	3.2
1974	14.8	14.6	13.8	12.5	10.9	9.4	8.1	7.1	6.4	5.9	53.7	59.4	31.7	15.6	9.0	5.5	3.4	2.0	3.2
1975	13.8	14.0	13.9	13.2	11.9	10.4	8.9	7.7	6.7	6.1	51.0	56.8	32.6	15.6	9.0	5.4	3.3	2.0	3.2
1976	13.0	13.2	13.3	13.2	12.5	11.3	9.9	8.5	7.3	6.4	49.0	53.7	33.4	15.7	8.9	5.4	3.3	2.0	3.1

Table 18: Estimated numbers at age of males (continued)

	Age(s)																		
Year	0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
1977	12.5	12.3	12.5	12.7	12.5	11.9	10.8	9.4	8.0	6.9	47.9	50.5	34.4	15.8	8.9	5.4	3.3	2.0	3.1
1978	12.6	11.9	11.7	11.9	12.1	11.9	11.3	10.2	8.9	7.6	47.7	47.1	35.2	16.0	8.9	5.3	3.3	2.0	3.1
1979	13.0	11.9	11.3	11.1	11.3	11.5	11.3	10.8	9.7	8.5	48.5	43.8	35.8	16.2	8.9	5.3	3.3	2.0	3.1
1980	13.5	12.4	11.3	10.7	10.6	10.8	10.9	10.8	10.2	9.2	50.3	40.5	36.1	16.4	8.8	5.3	3.2	2.0	3.1
1981	14.3	12.9	11.8	10.8	10.2	10.1	10.2	10.4	10.2	9.7	52.9	37.6	36.0	16.7	8.8	5.2	3.2	2.0	3.1
1982	15.5	13.6	12.2	11.2	10.3	9.7	9.6	9.7	9.8	9.7	55.9	34.8	35.5	17.0	8.8	5.2	3.2	2.0	3.1
1983	16.8	14.8	12.9	11.6	10.6	9.7	9.2	9.1	9.2	9.3	58.8	32.4	34.5	17.4	8.8	5.2	3.2	2.0	3.1
1984	17.5	16.0	14.1	12.3	11.1	10.1	9.3	8.8	8.6	8.7	60.9	30.1	33.0	17.7	8.7	5.1	3.1	1.9	3.0
1985	18.0	16.7	15.2	13.4	11.7	10.5	9.6	8.8	8.3	8.2	62.2	28.2	31.2	18.0	8.7	5.0	3.1	1.9	3.0
1986	18.3	17.1	15.8	14.5	12.7	11.1	10.0	9.1	8.3	7.9	62.8	26.7	29.1	18.2	8.6	5.0	3.0	1.9	3.0
1987	17.8	17.4	16.3	15.1	13.7	12.1	10.5	9.5	8.6	7.9	63.3	25.9	27.1	18.6	8.6	4.9	3.0	1.9	3.0
1988	16.8	16.9	16.5	15.5	14.3	13.1	11.5	10.0	9.0	8.2	63.5	25.6	25.1	18.9	8.7	4.9	3.0	1.9	3.0
1989	15.9	16.0	16.1	15.7	14.7	13.6	12.4	10.9	9.5	8.5	63.6	25.8	23.1	19.0	8.7	4.8	2.9	1.8	2.9
1990	15.7	15.1	15.2	15.3	14.9	14.0	12.9	11.8	10.3	9.0	63.1	26.2	20.9	18.8	8.7	4.7	2.9	1.8	2.9
1991	16.3	15.0	14.4	14.4	14.6	14.2	13.3	12.3	11.2	9.8	62.6	27.1	19.0	18.4	8.7	4.7	2.8	1.8	2.9
1992	16.4	15.5	14.2	13.7	13.7	13.8	13.5	12.6	11.6	10.5	62.8	28.2	17.3	17.9	8.8	4.6	2.8	1.8	2.9
1993	13.8	15.6	14.7	13.5	13.0	13.0	13.1	12.8	11.9	11.0	63.9	29.3	15.9	17.2	8.9	4.6	2.8	1.7	2.8
1994	10.9	13.2	14.8	14.0	12.8	12.3	12.4	12.5	12.1	11.3	65.3	30.0	14.6	16.4	9.0	4.5	2.7	1.7	2.8
1995	9.6	10.3	12.5	14.1	13.3	12.2	11.7	11.7	11.8	11.5	67.4	30.5	13.6	15.4	9.1	4.5	2.7	1.7	2.8
1996	9.9	9.1	9.8	11.9	13.4	12.6	11.6	11.1	11.1	11.2	70.4	31.0	13.0	14.5	9.3	4.5	2.7	1.7	2.8
1997	12.2	9.4	8.7	9.3	11.3	12.7	12.0	11.0	10.6	10.6	73.2	31.3	12.6	13.5	9.5	4.5	2.6	1.6	2.7
1998	15.7	11.6	8.9	8.3	8.9	10.8	12.1	11.4	10.5	10.0	75.2	31.5	12.5	12.5	9.6	4.5	2.6	1.6	2.7
1999	14.9	14.9	11.1	8.5	7.9	8.4	10.2	11.5	10.8	9.9	76.5	31.8	12.7	11.6	9.8	4.6	2.6	1.6	2.7
2000	12.7	14.1	14.2	10.5	8.1	7.5	8.0	9.7	10.9	10.3	77.6	32.2	13.1	10.7	9.8	4.6	2.6	1.6	2.7
2001	11.5	12.1	13.5	13.5	10.0	7.7	7.1	7.6	9.2	10.4	78.7	32.7	13.9	9.9	9.8	4.7	2.6	1.6	2.7
2002	10.3	10.9	11.5	12.8	12.8	9.5	7.3	6.7	7.3	8.8	79.3	33.5	14.7	9.2	9.7	4.8	2.6	1.6	2.7
2003	10.3	9.8	10.4	10.9	12.2	12.2	9.0	6.9	6.4	6.9	77.9	34.7	15.6	8.6	9.4	4.9	2.6	1.6	2.6
2004	11.2	9.8	9.3	9.9	10.4	11.6	11.6	8.6	6.6	6.1	74.5	36.2	16.4	8.0	9.1	5.0	2.6	1.6	2.6
2005	13.6	10.7	9.3	8.9	9.4	9.9	11.0	11.0	8.2	6.3	70.2	38.0	16.9	7.6	8.7	5.2	2.6	1.6	2.6
2006	16.4	12.9	10.2	8.8	8.4	8.9	9.4	10.4	10.5	7.8	66.2	40.0	17.4	7.3	8.2	5.3	2.6	1.6	2.6
2007	16.5	15.6	12.3	9.7	8.4	8.0	8.5	8.9	9.9	9.9	63.9	41.8	17.7	7.2	7.7	5.5	2.6	1.5	2.6
2008	15.5	15.7	14.8	11.7	9.2	8.0	7.6	8.1	8.5	9.4	64.1	43.0	17.9	7.1	7.2	5.6	2.6	1.5	2.6
2009	15.1	14.7	14.9	14.1	11.1	8.7	7.6	7.2	7.6	8.0	63.9	43.6	18.0	7.2	6.6	5.7	2.7	1.5	2.6
2010	15.2	14.4	14.0	14.2	13.4	10.6	8.3	7.2	6.9	7.2	62.4	44.0	18.1	7.4	6.1	5.7	2.7	1.5	2.5
2011	13.7	14.5	13.6	13.3	13.5	12.7	10.0	7.9	6.8	6.5	60.2	44.4	18.3	7.8	5.6	5.7	2.7	1.5	2.5
2012	14.4	13.0	13.8	13.0	12.6	12.8	12.1	9.5	7.5	6.5	57.6	44.6	18.7	8.3	5.2	5.6	2.8	1.5	2.5
2013	14.4	13.7	12.4	13.1	12.3	12.0	12.2	11.5	9.1	7.1	56.0	43.8	19.4	8.8	4.9	5.4	2.9	1.5	2.5

Appendix B. SS data file

```
# Shortspine Thornyhead data file
# Ian Taylor and Andi Stephens, 2013
#
#  uses SSv3.24o (April 10, 2013)
#
### Global model specifications ###
#
1901    # Start_year
2012    # End_year
1       # N seasons per year
12      # Months per season
1       # Spawning season - spawning will occur at beginning of this season
4       # N fishing fleets
5       # N surveys
1       # N areas
#
# Fishery/Survey Names
#
Trawl_N%Trawl_S%Non-trawl_N%Non-trawl_S%Triennial1%Triennial2%AFSCslope%NWFSCslope%NWFSCcombo
#
# Further specifications
#
0.5  0.5  0.5  0.5 0.5 0.5 0.5 0.5 0.5 # Timing of each fishery/survey
1    1    1    1   1   1   1   1   1   # Area of each fleet
1    1    1    1             # Units for catch per fleet: 1=Biomass(mt), 2=Numbers(1000s)
0.01 0.01 0.01 0.01          # SE of log(catch) per fleet for equilibrium and continuous options
2                            # Number of genders
100                          # Number of ages
#
### Catch section ###
#
# Initial equilibrium catch (landings + discard) by fishing fleet
0  0  0  0
#
# Nyears Catch
# Nyears Catch
112
#NTrawl STrawl  NOther  SOther  Year Season
0       2       0       0       1901    1
0       2       0       0       1902    1
0       4       0       0       1903    1
0       5       0       0       1904    1
0       6       0       0       1905    1
0       8       0       0       1906    1
0       9       0       0       1907    1
0       10      0       0       1908    1
0       11      0       0       1909    1
0       13      0       0       1910    1
0       14      0       0       1911    1
```

0	15	0	0	1912	1
0	17	0	0	1913	1
0	17	0	0	1914	1
0	19	0	0	1915	1
0	20	0	0	1916	1
0	21	0	0	1917	1
0	23	0	0	1918	1
0	24	0	0	1919	1
0	25	0	0	1920	1
0	26	0	0	1921	1
0	28	0	0	1922	1
0	29	0	0	1923	1
0	30	0	0	1924	1
0	32	0	0	1925	1
0	32	0	0	1926	1
0	34	0	0	1927	1
0	35	0	0	1928	1
0	36	0	0	1929	1
0	38	0	0	1930	1
0	39	0	0	1931	1
0	40	0	0	1932	1
0	49	0	0	1933	1
0	49	0	0	1934	1
0	49	0	0	1935	1
0	51	0	0	1936	1
0	47	0	0	1937	1
0	53	0	0	1938	1
0	63	0	0	1939	1
0	76	0	0	1940	1
0	109	0	0	1941	1
0	122	0	0	1942	1
0	269	0	0	1943	1
0	380	0	0	1944	1
0	453	0	0	1945	1
0	216	0	0	1946	1
0	48	0	0	1947	1
0	152	0	0	1948	1
0	168	0	0	1949	1
0	153	0	0	1950	1
0	305	0	0	1951	1
0	176	0	0	1952	1
0	68	0	0	1953	1
0	128	0	0	1954	1
0	128	0	0	1955	1
0	776	0	0	1956	1
0	286	0	0	1957	1
0	296	0	0	1958	1
0	398	0	0	1959	1
0	472	0	0	1960	1
0	437	0	0	1961	1
0	230	0	0	1962	1

0	285	0	0	1963	1
12	172	0	0	1964	1
20	400	0	0	1965	1
612	543	0	0	1966	1
369	864	0	0	1967	1
168	1835	0	0	1968	1
155	400	0	0	1969	1
149	557	0	0	1970	1
260	582	0	0	1971	1
389	1297	0	0	1972	1
712	2377	0	0	1973	1
215	1244	0	0	1974	1
405	1867	0	0	1975	1
52	992	0	0	1976	1
91	1359	0	0	1977	1
76	1136	0	0	1978	1
109	1720	0	0	1979	1
87	1192	0	0	1980	1
242.3	1622.8	0	0.5	1981	1
553.7	1655.4	0	0.5	1982	1
1492.8	1562.1	0	0.5	1983	1
1681.4	1961.2	0	0.5	1984	1
1345.9	2559.9	0	1.7	1985	1
457.7	2422.3	0	2.6	1986	1
558.3	1953.0	4.2	3.2	1987	1
696.4	2163.1	23.1	2.1	1988	1
1340.4	3506.4	29.3	9.9	1989	1
1917.7	2227.5	27	3.3	1990	1
2157.0	1306.4	53.8	1.5	1991	1
1669.2	1625.1	51.9	9.3	1992	1
2037.1	1773.9	24.4	1.1	1993	1
1835.3	1537.8	20.3	2.9	1994	1
815.0	1064.2	28.1	32.4	1995	1
686.2	830.9	21.2	80.6	1996	1
579.5	771.3	23	40.2	1997	1
504.7	668.9	17	47.3	1998	1
318.9	398.1	17.6	99.3	1999	1
281.9	489.8	13.9	53.3	2000	1
236.2	241.2	12.6	45.6	2001	1
231.4	428.2	10.4	104.1	2002	1
270.2	374.4	10.7	155.2	2003	1
294.6	319.4	10.5	128.8	2004	1
254.7	252.4	10.7	138.9	2005	1
295.7	246.8	15.4	143.7	2006	1
562.4	278.9	16.2	142.5	2007	1
902.0	325.3	19.8	175.4	2008	1
947.7	382.1	28.5	172.2	2009	1
770.3	356.7	22.2	206.1	2010	1
424.3	286.5	24.3	237	2011	1
380.5	322.5	35.7	155.1	2012	1

#

```
#
### Abundance Indices ###
#
32 # N observations
#
# Units:  0=numbers; 1=biomass; 2=F
# Errtype:  -1=normal; 0=lognormal; >0=T
#_Fleet Units  Errtype
1       1      0    #_NorthTrawl
2       1      0    #_SouthTrawl
3       1      0    #_NorthOther
4       1      0    #_SouthOther
5       1      0    #_Triennial1
6       1      0    #_Triennial2
7       1      0    #_AFSCslope
8       1      0    #_NWFSCslope
9       1      0    #_NWFSCcombo


### AFSC triennial survey
### Shallow/Deep alternative: Shallow triennial for all years
#Year Seas    Fishery Value   sd_log
1980  1       5       2660    0.14397
1983  1       5       3415    0.11794
1986  1       5       1636    0.13302
1989  1       5       2010    0.13880
1992  1       5       2064    0.17697
1995  1       5       3480    0.15198
1998  1       5       3076    0.15184
2001  1       5       3698    0.14188
2004  1       5       4117    0.18055

### Shallow/Deep alternative: Deep triennial only for 1995+
#Year Seas    Fishery Value   sd_log
1995  1       6       3523    0.12239
1998  1       6       2815    0.12634
2001  1       6       3384    0.12357
2004  1       6       3504    0.12889

### AFSC slope survey
#Year   Seas    Fishery Value   sd_log
1997    1       7       27148   0.08413
1999    1       7       25641   0.08243
2000    1       7       31971   0.08342
2001    1       7       31567   0.08090

### NWFSC slope survey
### calculations are in \GLMM_results\NWSurveys_2e5_iter\SSPN_Early\
#Year   Seas    Fishery Value   sd_log
1998    1       8       27416   0.08592
1999    1       8       28311   0.07894
```

```
2000    1       8       30897   0.08111
2001    1       8       26376   0.08015
2002    1       8       32404   0.07977

### NWFSC combo survey
### calculations are in \GLMM_results\NWSurveys_2e5_iter\SSPN_Late\
#Year   Seas    Fishery Value   sd_log
2003    1       9       52474   0.10313
2004    1       9       53885   0.10477
2005    1       9       48155   0.09085
2006    1       9       48076   0.08847
2007    1       9       48499   0.08276
2008    1       9       44137   0.08622
2009    1       9       58430   0.09584
2010    1       9       46489   0.09002
2011    1       9       48556   0.08926
2012    1       9       53045   0.10120
#
#
# N fleets with discard
4
#_Fleet Units Errtype
1       2      30
2       2      30
3       2      30
4       2      30
#
# N observations
48
### Pikitch data from John Wallace
### code is in c:/SS/Thornyheads/Data/Pikitch/Pikitch_discard_rates_code.R, which references stuff from John
#Year   Seas    Fishery Value           CV
1985    1       1       0.3007437       0.875096968
1986    1       1       0.3057904       0.871989114
1987    1       1       0.390653        0.755043223

### Discard rates from ECDP taken from 2005 shortspine assessment
#Year   Seas    Fishery Value           CV
1995    1       1       0.132           0.40
1996    1       1       0.155           0.20
1997    1       1       0.201           0.21
1998    1       1       0.136           0.22
1999    1       1       0.252           0.30

### WCGOP data based on code from Jason Jannot

#Year   Seas    Fishery Value           CV              #_note
2002    1       1       0.335245159     0.086828889     #_Bottom_Trawl_WAOR
2003    1       1       0.432544649     0.077544931     #_Bottom_Trawl_WAOR
2004    1       1       0.241343211     0.104530141     #_Bottom_Trawl_WAOR
2005    1       1       0.199355761     0.168445593     #_Bottom_Trawl_WAOR
```

```
2006	1	1	0.179544612	0.168130911	#_Bottom_Trawl_WAOR
2007	1	1	0.108599973	0.180051291	#_Bottom_Trawl_WAOR
2008	1	1	0.046659398	0.230100051	#_Bottom_Trawl_WAOR
2009	1	1	0.101435957	0.191825142	#_Bottom_Trawl_WAOR
2010	1	1	0.087443339	0.222646136	#_Bottom_Trawl_WAOR
2011	1	1	0.006739797	0.001		#_Bottom_Trawl_WAOR_catch-shares_fully_observed_has_assumed_tiny_CV
2002	1	2	0.279645087	0.151118174	#_Bottom_Trawl_CA
2003	1	2	0.201024932	0.141541966	#_Bottom_Trawl_CA
2004	1	2	0.209662602	0.237090534	#_Bottom_Trawl_CA
2005	1	2	0.151047698	0.205977662	#_Bottom_Trawl_CA
2006	1	2	0.095571796	0.314441499	#_Bottom_Trawl_CA
2007	1	2	0.028857912	0.266351701	#_Bottom_Trawl_CA
2008	1	2	0.025042737	0.244805907	#_Bottom_Trawl_CA
2009	1	2	0.024825575	0.186500398	#_Bottom_Trawl_CA
2010	1	2	0.02119381	0.223866125	#_Bottom_Trawl_CA
2011	1	2	0.008817099	0.001		#_Bottom_Trawl_CA_catch-shares_fully_observed_has_assumed_tiny_CV
2002	1	3	0.04212257	0.363439925	#_H&L_WAOR
2003	1	3	0.115775182	0.378023795	#_H&L_WAOR
2004	1	3	0.137199236	0.562925392	#_H&L_WAOR
2005	1	3	0.086555528	0.24160193	#_H&L_WAOR
2006	1	3	0.145679196	0.739064372	#_H&L_WAOR
2007	1	3	0.229120952	0.320967658	#_H&L_WAOR
2008	1	3	0.111293876	0.426373646	#_H&L_WAOR
2009	1	3	0.063697859	2.135161651	#_H&L_WAOR
2010	1	3	0.100494748	0.306851214	#_H&L_WAOR
2011	1	3	0.098921828	0.419172661	#_H&L_WAOR
2002	1	4	0.209165098	0.286389385	#_H&L_CA
2003	1	4	0.172752926	0.161447006	#_H&L_CA
2004	1	4	0.123425508	0.207194228	#_H&L_CA
2005	1	4	0.063810176	0.232701577	#_H&L_CA
2006	1	4	0.112808086	0.302538535	#_H&L_CA
2007	1	4	0.063235119	0.115288264	#_H&L_CA
2008	1	4	0.051092247	0.167925949	#_H&L_CA
2009	1	4	0.062246542	0.145575545	#_H&L_CA
2010	1	4	0.087162496	0.210516003	#_H&L_CA
2011	1	4	0.04912734	0.101605531	#_H&L_CA_combination_of_catch-shares_and_non-catch-shares
##
### Average weight of discards
# Value is from Wghtd_AVG_W
# CV is ratio of AVG_WEIGHT.SD/AVG_WEIGHT.MEAN
40	#N observations
30	#Degrees of freedom for Student's T distribution used to evaluate mean body weight deviations.
	# (Not conditional, must be here even if no mean body wt observations.)
#Year	Seas	Fleet	Partition	Value	CV		#	Gear		State
2002	1	1	1	0.364642072	2.118749079	#	ALL TRAWL	WA-OR
2003	1	1	1	0.431779002	1.264625597	#	ALL TRAWL	WA-OR
2004	1	1	1	0.372344756	1.025736743	#	ALL TRAWL	WA-OR
2005	1	1	1	0.343027331	0.814245184	#	ALL TRAWL	WA-OR
2006	1	1	1	0.310969633	12.62000381	#	ALL TRAWL	WA-OR
2007	1	1	1	0.256335672	0.743340316	#	ALL TRAWL	WA-OR
2008	1	1	1	0.181144246	1.006699102	#	ALL TRAWL	WA-OR
```

```
2009	1	1	1	0.228195667	0.621404079	#	ALL TRAWL	WA-OR
2010	1	1	1	0.230299418	1.63260079	#	ALL TRAWL	WA-OR
2011	1	1	1	0.132364976	2.519562237	#	ALL TRAWL	WA-OR
2002	1	2	1	1.203992327	0.939911162	#	ALL TRAWL	CA
2003	1	2	1	0.951036879	0.924020709	#	ALL TRAWL	CA
2004	1	2	1	0.866807099	0.931865538	#	ALL TRAWL	CA
2005	1	2	1	0.859717225	1.04266895	#	ALL TRAWL	CA
2006	1	2	1	0.606677363	1.088379327	#	ALL TRAWL	CA
2007	1	2	1	0.233209182	2.866227179	#	ALL TRAWL	CA
2008	1	2	1	0.240984699	1.573568927	#	ALL TRAWL	CA
2009	1	2	1	0.283314819	1.347244662	#	ALL TRAWL	CA
2010	1	2	1	0.289119393	1.843418882	#	ALL TRAWL	CA
2011	1	2	1	0.241109466	1.218321567	#	ALL TRAWL	CA
2002	1	3	1	0.935587086	0.796707154	#	OTHER GEAR	WA-OR
2003	1	3	1	1.362731591	0.794783992	#	OTHER GEAR	WA-OR
2004	1	3	1	1.289451512	0.640189562	#	OTHER GEAR	WA-OR
2005	1	3	1	1.230766218	0.75118062	#	OTHER GEAR	WA-OR
2006	1	3	1	1.70271943	0.485157236	#	OTHER GEAR	WA-OR
2007	1	3	1	1.941936392	0.603611928	#	OTHER GEAR	WA-OR
2008	1	3	1	1.4616857	0.603113256	#	OTHER GEAR	WA-OR
2009	1	3	1	1.538109678	0.581701899	#	OTHER GEAR	WA-OR
2010	1	3	1	1.515242478	0.733887181	#	OTHER GEAR	WA-OR
2011	1	3	1	1.929418253	0.866996647	#	OTHER GEAR	WA-OR
2002	1	4	1	0.773613445	0.866608059	#	OTHER GEAR	CA
2003	1	4	1	0.938616528	0.665412757	#	OTHER GEAR	CA
2004	1	4	1	0.863882591	0.680271218	#	OTHER GEAR	CA
2005	1	4	1	0.940173578	0.956812123	#	OTHER GEAR	CA
2006	1	4	1	0.617362917	0.555537579	#	OTHER GEAR	CA
2007	1	4	1	0.232538998	0.688254613	#	OTHER GEAR	CA
2008	1	4	1	0.411108216	1.06005575	#	OTHER GEAR	CA
2009	1	4	1	0.280832591	0.799593801	#	OTHER GEAR	CA
2010	1	4	1	1.044745397	0.706886658	#	OTHER GEAR	CA
2011	1	4	1	0.927216543	0.547415781	#	OTHER GEAR	CA
#
# Length data
2 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
# no additional input for option 1
# read binwidth, minsize, lastbin size for option 2
2  # width
4  # minsize
90 # maxsize
# read N poplen bins, then vector of bin lower boundaries, for option 3
-0.001 #_comp_tail_compression
0.001  #_add_to_comp
0 #_combine males into females at or below this bin number
34 #_N_LengthBins
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72
#
161   # number of observations
### multiplier for inputN = N^p :				p =	0.6	# this multiplier is applied to column "CC" which is 
number of fish
```

```
### PacFIN comps
# created by Andi's excellent code
# Fully expanded combined sexes from "SSPN_Fully_Expanded_Comps.csv"
### Trawl North
#_year  Season  Fleet   gender  partition       inputN  U6      U8      U10     U12     U14     U16     U18     U20     U22     U24
U26     U28     U30     U32     U34     U36     U38     U40     U42     U44     U46     U48     U50     U52     U54     U56     U58
U60     U62     U64     U66     U68     U70     U72     M6      M8      M10     M12     M14     M16     M18     M20     M22     M24
M26     M28     M30     M32     M34     M36     M38     M40     M42     M44     M46     M48     M50     M52     M54     M56     M58
M60     M62     M64     M66     M68     M70     M72
1979    1       1       0       2       38.9    0       0       0       0       0       626.405277      245.2673267     613.1683168
367.9009901     382.1549086     543.2271306     441.1096005     855.4398016     492.7851167     324.285983      485.330046
657.8250564     947.9139122     960.1600227     700.4440979     30.04661492     663.1640505     172.6142808     419.0054398
46.65726309     85.52705684     14.23926427     25.55222486     25.55222486     0       0       64.34140985     1.002304147
25.55222486     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
1980    1       1       0       2       28.6    0       0       0       0       0       0       0       21.21710526     0
122.6336634     21.21710526     21.21710526     40.11976048     282.4445531     203.8220521     260.5324311     467.6516855
496.4119063     331.7925783     407.8986385     517.7768373     48.12972771     251.4923642     256.4891968     10.22187005
28.28491771     11.22187005     11.79527632     122.6336634     1       1       10.22187005     0       20.4437401      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
1981    1       1       0       2       22.6    0       0       0       0       0       0       0       0       0       0
277.971774      0       1348.552644     2062.147007     5650.532506     6084.687444     2394.169716     4559.779356     2785.345084
1810.685872     1573.630928     1295.659154     2844.990843     12.12532049     24.25064097     12.14961973     1307.760175
1283.509534     2579.168689     12.12532049     1283.509534     12.12532049     24.29923945     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
1982    1       1       0       2       22.6    0       0       0       0       0       0       0       0       141.0262467
523.7816039     141.0262467     423.07874       10593.11699     9648.898821     11532.73854     9160.438533     5642.774642
5319.226579     2553.118058     4054.820602     465.1924954     334.0209858     2170.362701     5783.838837     416.4581239
4423.16254      82.43713818     2077.45264      334.0209858     223.4633848     1525.550574     82.43713818     141.0262467     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
1990    1       1       0       2       42.1    0       0       0       0       0       1924.947776     1924.947776     5774.843327
14905.72696     27666.4423      27568.48558     9864.88148      1847.069815     9069.830075     3772.017591     6735.382671
23359.59467     13018.97501     26320.15453     25028.71237     26662.50566     12421.50806     20480.45837     15608.68916
7337.181167     14522.01441     8209.002571     6600.967396     10315.25531     3668.590584     7106.252976     5593.538359
1310.278071     1924.947776     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
1991    1       1       0       2       65.3    0       0       0       0       0       0       333.0456247     88.90879198
21413.24098     95250.41859     136595.7272     112333.1227     63427.36283     67626.86423     81490.72307     48402.43843
49514.35549     38630.29679     48288.54562     31287.06857     13839.40397     27694.53994     14511.73812     18100.01391
20159.8324      3823.740062     14620.92732     27283.52312     18611.36944     3510.248662     4349.627476     5017.623552
6831.453701     2482.803179     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
1992    1       1       0       2       71.3    0       0       0       0       0       4283.744261     5365.500935     15786.07435
54077.76801     45113.94088     99010.53391     53393.14192     42060.32429     47565.41457     34056.01912     35960.07155
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22932.44589     45892.84618     15861.34611     19599.85997     9312.347789     16244.28191     31189.5984      9706.523002
12366.41858     4476.463287     9724.578872     6652.978035     9464.414855     5092.78775      2658.936613     1706.325623
1145.240451     338.6720152     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
1993    1       1       0       2       30.2    0       0       0       0       0       0       5416.211353     39546.82712
52125.0825      52115.5363      57267.77154     63774.80354     14586.66515     37637.42123     49721.20008     16917.67653
14122.83002     8063.225695     12965.58343     6993.775095     27168.29731     23347.55616     10045.06738     9457.51208
2973.246148     11090.42812     9460.622373     2973.246148     26305.33322     1971.631769     13184.11758     3329.746643
1971.631769     8485.702754     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
# next two values turned off after investigation of outliers
1994    1       -1      0       2       9.1     0       0       12713.39147     38140.1744      0       76280.34879     63566.95733
88993.74026     25426.78293     12713.39147     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       0       0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0       0       0       0       0       0
1995    1       -1      0       2       6.7     0       0       0       0       0       0       0       0       0       0       0
0       0       622.5845188     0       622.5845188     622.5845188     622.5845188     1245.169038     622.5845188     2490.338075
622.5845188     0       1245.169038     0       0       622.5845188     11422.21299     0       5711.106497     5711.106497
5711.106497     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       0
1996    1       1       0       2       41.5    0       0       0       0       0       0       1654.26599      2424.662486
27660.50029     23466.08213     32985.46835     28967.09679     22002.39485     48447.13798     15307.46481     26874.7827
44070.24734     22224.84517     7997.711487     8774.533502     7183.915352     6620.098545     1305.839118     626.1648094
3929.045226     1612.34413      2042.524985     2150.031018     0       1198.299426     0       0       1198.299426     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
1997    1       1       0       2       104.6   0       0       0       0       635.1738665     640.5539514     5445.218045
7073.243147     15270.90073     14909.45973     21221.76311     15992.63334     9975.498658     10462.8571      10228.1183
7864.847433     9055.687749     6689.867269     5458.986106     7636.338759     4152.832393     5469.863328     6534.989123
4186.716302     5239.854646     3614.080987     3242.603434     3246.350192     2414.441641     556.5159002     733.1062255
88.80798926     734.472811      88.80798926     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
1998    1       1       0       2       53.4    0       0       0       0       0       0       6695.932686     21202.13222
43547.93777     30340.33423     39605.16146     40890.86669     35235.81211     15335.56476     18521.83533     15062.30927
20943.48222     15149.56165     8689.484335     7862.757955     8115.447606     4713.698503     8927.532915     4263.478204
4517.327663     4988.636735     4295.649537     5138.374729     735.1896078     1535.326124     794.5993269     968.8591766
1605.980917     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
1999    1       1       0       2       56      0       0       0       0       0       0       284.2626852     568.5253705
6696.922718     13356.3953      10408.70391     16148.00183     16960.76337     12954.29842     11622.35575     15145.2801
13471.35841     12133.86768     7330.49254      7065.859455     6246.046354     3751.049233     4582.173221     3657.343824
2418.061644     2243.937905     3873.707222     5021.455746     1872.267058     521.7329404     773.2022583     702.0059588
997.6469031     67.41086536     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
```

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6162.208956 9181.985259 14403.85118 6281.298891 8778.052288 9300.03407 11527.23672 10165.13913
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2437.368143 2381.868326 1670.981282 2820.286896 1674.2899 839.3506021 111.4432515 80.08084897
272.5284633 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
2001 1 1 0 2 84.7 0 0 0 0 0 15.11692596 232.9897173 3597.255614
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0 0 0 0
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0	0	0	0
2008	1	1	0	2	112.7	0	0	0	0	0	2822.675361	6806.953086	32787.88889
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2009	1	1	0	2	118.4	0	0	0	0	1400.678782	1890.520785	5985.91883
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1660.86691	2168.673576	695.2491494	0	0	0	0	0	0	0	0	0	0	0
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2010	1	1	0	2	121.5	0	1224.614098	0	421.0423793	0	343.6613544	7502.097021
15142.15131	27265.27503	46564.40952	59370.12095	56992.89354	51224.33344	36234.50581	29840.83268
22890.75901	15268.87761	16092.87463	18005.10015	8624.615266	10398.48301	5548.743737	6827.859089
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900.4421385	1456.237206	310.3441406	0	0	0	0	0	0	0	0	0	0	0
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2011	1	1	0	2	106.2	0	0	0	0	29.58870069	1549.342467	7094.992452
6580.115029	15553.78583	32332.15638	45614.79276	33375.86619	29712.39783	18346.75466	16075.69976
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0	0	0	0	0	0
2012	1	1	0	2	103	0	0	0	101.6627008	298.4610652	1614.624706	5402.386866
6556.107868	18404.02171	26479.75381	38529.81258	24178.10021	24556.81338	19413.08991	16107.16338
9530.474869	9807.949217	5800.608162	5812.669596	6041.480794	4768.641256	3671.403154	3171.190949
2502.780242	4287.013191	1705.043626	2416.527054	2644.553641	1266.201081	154.3935112	610.4114642
220.0680214	217.8908102	146.4815835	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0	0	0
2013	1	1	0	2	38.2	0	0	0	28.10654121	49.8528637	166.1263083	270.1858285
326.258699	604.4893471	1223.891687	1494.058926	802.3087505	845.2864681	635.2751607	468.2287912
278.2953003	261.3512914	404.2793402	67.78783308	294.8580716	352.1774391	181.8060228	116.7693402
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5.047468354	5.047468354	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
### Trawl South
#_year	Season	Fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
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M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1978	1	2	0	2	70	0	0	0	0	0	2.653061224	74.89361702	149.787234
415.266745	750.2559864	1596.723185	1146.187746	1152.170794	1497.752536	1701.891325	1511.512383
1775.748642	2138.145439	3400.89629	1604.914076	1795.025143	1315.726296	861.5114278	957.9346999
590.0853863	754.7092559	427.6076328	441.9237861	316.7417898	315.9829595	131.6872827	34.46327684
61.39516129	73.02586207	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
1979	1	2	0	2	48.7	0	0	0	0	0	0	0	0	30.42553191
68.57142857	400.9721065	1104.111577	1102.825377	673.3393267	865.8765705	707.5491286	1258.794053
1573.310434	1577.759227	1642.538269	1314.992865	1625.95247	1521.10635	623.3254729	543.0711951
711.7250716	429.5737057	512.353877	89.04903448	452.5417667	110.647171	413.6618597	0	122.6336634
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
1980	1	2	0	2	30.5	0	0	0	0	0	0	3.809108911	55.83333333
55.83333333	167.5	182.2761056	248.6780664	635.2327714	490.9139223	498.4393745	727.7940023	481.5778368
378.2163434	564.890827	138.2378517	439.1309098	297.8135841	241.6325568	74.04440303	50.24592157
210.2475965	219.9313501	108.1052632	160.4576634	3.809108911	3.809108911	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	0
1981	1	2	0	2	14.7	0	0	0	0	0	0	0	0	12713.39147
14880.08758	11175.59047	32040.9079	21380.17591	2166.696112	2166.696112	6263.721488	17160.82033
18977.11295	27521.56719	2280.73275	17274.85696	8430.4176	27707.51568	25426.78293	12713.39147
6263.721488	2166.696112	14994.12422	12713.39147	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	0	0	0
1982	1	2	0	2	36.7	0	0	0	0	0	0	0	1533.056215	8195.217329
14129.67695	40163.1434	50055.84707	61264.57	34761.71615	47438.75694	56366.94117	70860.85684
86194.29472	45737.53879	58542.19544	27179.26	21161.86951	33411.14745	3066.483002	16670.19815
19016.27457	4795.310206	8688.710194	4256.127999	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	0	0	0
1983	1	2	0	2	71.4	0	0	0	0	0	0	0	2607.346463	2597.923744
15005.34121	23325.71085	30736.07963	23297.28416	30261.50038	36257.04597	43069.71336	62553.95275
54914.13058	54988.18844	55510.03043	27109.81401	27989.10264	23824.05984	16061.6872	31687.59291
14510.1425	10578.93394	4603.616646	485.5920405	3919.319871	824.1270178	0	824.1270178	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	1	2	0	2	115.9	0	0	0	0	0	0	325.5856508	1840.942996
16355.94262	37205.07336	31274.4734	31016.06652	45573.14851	48929.65993	47754.9188	71074.85261
78912.88875	65117.04951	82122.85558	57879.87738	41933.92347	29750.89093	24289.60158	36141.31945
24077.69439	25120.05738	6838.602394	2863.900093	10716.21523	4976.131408	6481.97326	567.9836263
532.5744411	2586.413675	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0
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0	0
1996	1	2	0	2	97.4	0	0	0	0	0	1529.979353	5092.635853	15679.76176
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0	0	0	0											
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2004	1	2	0	2	65.8	0	0	0	0	0	0	0	157.3265332	938.9623961
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0	0	0	0											
2006	1	2	0	2	124.6	0	0	0	0	0	7.886967802	178.5083713	1369.222581	
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0	0	0	0											
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0	0	0	0											
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2009	1	2	0	2	99.5	0	0	0	20.35186895	20.35186895	61.05560685	372.4593859
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2011	1	2	0	2	120.8	0	0	14.33483846	59.98426112	469.9359486	801.4190182
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2012	1	2	0	2	107.3	0	0	0	43.34520692	2912.346741	564.3254348	263.1977886
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0	0	0	0	0	0
### Non-trawl North
#_year	Season	Fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
2000	1	3	0	2	1.9	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	103.6696704	0	103.6696704	103.6696704	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	0	0	0
0	0	0	0	0	0	0	0	0
2001	1	3	0	2	7.7	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	213.5257156	213.5257156	213.5257156	213.5257156	640.5771467	427.0514311
213.5257156	427.0514311	427.0514311	427.0514311	213.5257156	427.0514311	427.0514311	213.5257156	0
213.5257156	0	0	213.5257156	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
2002	1	3	0	2	4	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	103.6696704	0	0	0	0	103.6696704	207.3393409	103.6696704
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	1	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	2716.026494	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	0	0	0	0	0	0	0
0	0	0	0	0	0	0
2006	1	3	0	2	1.5	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	103.6696704	103.6696704	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	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
2007	1	3	0	2	17.2	0	0	0	0	0	0	0	0	0	230.5538952
161.2787921	338.07309	338.07309	729.9057773	284.3134926	584.142491	499.351882	284.3134926
353.5885958	584.142491	637.9020884	353.5885958	353.5885958	284.3134926	0	53.75959736	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
0	0	0	0	0	0
2008	1	3	0	2	27.5	0	0	0	0	0	0	0	0	115.0193601
115.0193601	43.57729975	185.4075621	473.9385626	195.34715	804.3940823	330.9070987	1040.05841
671.5968928	516.6606404	150.8209089	314.1407012	167.5873063	43.57729975	124.958948	160.6042867
97.19910431	43.57729975	43.57729975	90.21608471	115.0193601	46.63878496	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	0
2009	1	3	0	2	18.6	0	0	0	0	0	0	0	0	0	103.6696704
311.0090113	207.3393409	311.0090113	207.3393409	518.3483522	725.6876931	622.0180226	414.6786817
829.3573635	311.0090113	311.0090113	207.3393409	207.3393409	414.6786817	207.3393409	207.3393409
207.3393409	207.3393409	103.6696704	103.6696704	103.6696704	207.3393409	0	103.6696704	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
2010	1	3	0	2	24.7	0	0	0	0	0	0	0	0	0	83.45187317
54.4280004	54.4280004	850.228351	790.1436854	518.8758764	921.3435601	558.6355896	475.1837164
500.1517476	90.5679685	584.0397172	253.8519697	139.4806971	311.8997152	163.2840012	181.135937	0
137.8798736	221.3317467	54.4280004	137.8798736	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	0
2011	1	3	0	2	42.4	0	0	0	0	0	0	59.62168154	0	23.94272424
31.53973549	228.8542166	304.1401787	462.3179131	477.5119356	676.6507408	721.9591564	584.9186974
878.9295959	699.6360057	499.9107101	526.5436483	275.1061997	308.1844586	92.74165307	155.3925785
190.0510735	23.94272424	161.5405819	31.53973549	137.5978577	44.85620459	23.94272424	23.94272424
23.94272424	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
2012	1	3	0	2	43.5	0	0	0	0	0	0	0	0	0	0
66.6053925	242.0613033	253.19343	2310.573692	307.4200782	371.3589588	819.1632006	1144.496253
629.9911686	507.9286046	663.935428	341.3634289	259.0017509	379.1448574	359.9801523	105.9051111
254.1739052	301.1672901	75.81914983	16.65134812	0	16.65134812	0	19.50874616	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
### Non-trawl South
```

```
#_year	Season	Fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1985	1	4	0	2	1.9	0	0	0	0	0	0	0	0	0	0	0
0	0	3099.723146	0	0	3674.175085	4448.737314	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	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1986	1	4	0	2	3.7	0	0	0	0	0	0	0	0	0	0	0
0	348.82136	0	1058.092517	0	2083.096071	121.8639723	0	576.1313754	2964.655448	0
4915.75031	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	0	0	0	0	0	0	0	0	0
1987	1	4	0	2	11	0	0	0	0	0	0	0	0	0	366.9858758
183.4929379	91.74646896	458.7323448	1986.217815	2065.864433	1451.015389	223.2311591	60.76606204
3600.597026	1754.425278	2120.255993	1846.171747	0	0	1846.171747	0	0	0	0
91.74646896	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	0	0
1988	1	4	0	2	3.5	0	0	0	0	0	0	0	0	0	0	0
0	0	10048.23795	0	4289.812566	592.9905149	7861.969293	1024.734819	4126.628826	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
0	0	0	0	0	0	0	0	0	0	0	0
1989	1	4	0	2	5.7	0	0	0	0	0	0	0	0	0	0	0
0	0	0	415.5931108	293.2583695	4381.882177	4270.183994	1107.912869	2535.944344	5164.385854
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	0	0	0	0	0	0	0	0	0	0	0
1990	1	4	0	2	6.7	0	0	0	0	0	0	0	0	0	0
1658.714727	0	0	0	1969.723738	9686.894006	3656.987498	3172.723872	0	2653.943563
7737.664964	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	0	0	0	0	0	0	0	0	0	0	0
1992	1	4	0	2	13.3	0	0	0	0	0	0	0	0	0	0
404.2118419	1269.306432	2643.01733	202.105921	2425.06793	953.6555768	1285.149911	2456.754888
1600.800767	735.7061766	2020.856088	2020.856088	735.7061766	1067.200511	533.6002557	1802.906688
533.6002557	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	0	0	0	0	0
1993	1	4	0	2	1.9	0	0	0	0	0	0	0	0	0	0	0
0	0	0	323.1405685	0	4928.628915	940.3572126	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	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1994	1	4	0	2	9.9	0	0	0	0	0	0	0	0	0	0
6672.044768	7882.050117	608.0624901	1186.686866	868.361794	2516.423086	2928.076934	1744.42747
2055.04866	5210.170764	868.361794	1736.723588	4278.029279	1736.723588	1736.723588	0	0
868.361794	868.361794	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 0 0 0
1995 1 4 0 2 8.6 0 0 0 0 0 0 0 0 0 0 0
0 2467.788894 106.7797605 106.7797605 3199.135743 427.1190422 985.8985658 320.3392816 106.7797605
213.5595211 106.7797605 106.7797605 213.5595211 213.5595211 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 0 0 0 0 0
0 0
1996 1 4 0 2 7.1 0 0 0 0 0 0 0 0 0 0 0
0 0 1353.686658 676.8433291 1353.686658 0 0 676.8433291 0 676.8433291 1353.686658
2030.529987 1353.686658 0 1353.686658 0 0 676.8433291 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 0 0 0
1997 1 4 0 2 8.6 0 0 0 0 0 0 0 0 0 0 0
0 0 0 528.1530582 0 528.1530582 1409.737056 4229.211169 3347.627171 528.1530582
3347.627171 3347.627171 1937.890114 1056.306116 1409.737056 2819.474113 1409.737056 0 2819.474113
0 0 0 528.1530582 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
1998 1 4 0 2 18.6 0 0 0 0 0 0 0 0 0 0 0
0 369.9370345 2071.210889 2115.952537 1565.957653 279.9081102 1004.395418 1021.855573 2458.717205
266.2673641 506.4455382 2108.697681 792.880998 896.5506684 103.6696704 0 0 679.612284 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 0 0 0
1999 1 4 0 2 91.3 0 0 0 0 0 66.00327334 300.8065709 597.9896766
999.3725875 2550.521239 3739.433633 5268.98741 7770.93427 6163.155051 5660.254566 6936.781818
6899.225902 3926.463022 3250.327501 4070.749745 1506.297769 1458.558869 1137.923876 1082.463814
721.1689054 1093.776556 396.3646392 360.3738148 75.87100837 52.28216275 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 0 0
2000 1 4 0 2 38.8 0 0 0 0 0 0 0 49.06515175 225.2536512
1375.641477 2303.603233 1969.82795 2115.312636 3562.591645 3685.25519 1561.083382 942.2735005
2355.796909 987.3705256 610.7549346 740.4545638 604.1169988 952.9913985 643.8164378 1082.642157
643.8164378 528.7020433 885.1353376 0 0 0 528.7020433 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
2001 1 4 0 2 16 0 0 0 0 0 0 0 0 0 103.6696704
311.0090113 311.0090113 5547.536848 9272.215324 6112.363769 127.0789509 1909.327795 254.1579017
127.0789509 1655.169893 2036.406746 127.0789509 230.7486213 254.1579017 0 127.0789509 0 0
127.0789509 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 0 0 0
2002 1 4 0 2 64.1 0 0 0 0 0 0 0 51.66615963 440.5251727
4492.036889 8022.58685 13150.87951 11771.51885 9128.403533 11992.2681 6098.141662 3995.1944
1874.090342 3401.935321 1936.626017 3471.698543 1616.285664 477.334686 569.2460648 573.2956559
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2003 1 4 0 2 56.6 0 0 0 0 0 0 0 0 386.7527581
1205.020065 5118.212322 8756.975176 10609.31929 16973.24082 13892.56287 9710.540675 10202.13242

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4062.675471	5628.037472	7208.926612	2772.63333	2925.497136	1846.544761	1900.523004	859.683984
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0	0	0	0	0	0	0	0	0	0	0
2004	1	4	0	2	18.7	0	0	0	0	0	0	0	0	0	0
518.3483522	890.2069527	1036.696704	311.0090113	944.8363616	737.4970207	719.4675128	408.4585015
475.5282709	164.5192596	2371.331027	207.3393409	207.3393409	408.4585015	207.3393409	0	469.3080907
164.5192596	207.3393409	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	0	0	0
2005	1	4	0	2	47.4	0	0	0	0	0	0	0	414.6786817	2253.472943
5125.853818	7740.402906	5404.685358	9245.380828	23241.34456	16163.11486	10870.76333	10553.26754
7304.726034	3174.788386	1598.827119	487.5892192	1801.260524	669.8655628	280.2498783	1126.695649
311.0090113	103.6696704	0	176.5802079	0	0	176.5802079	0	176.5802079	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
2006	1	4	0	2	46.2	0	0	0	0	0	0	0	93.1990681	0
1355.312845	8062.489559	9960.385132	15233.22707	22512.44341	15032.85005	10226.43485	7880.794878
3222.537009	6132.647375	4619.730382	553.6024645	987.9101219	1360.706394	441.6825401	186.3981362
376.5242351	93.1990681	93.1990681	93.1990681	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	0	0	0
2007	1	4	0	2	29.3	0	0	0	0	0	0	0	1479.286451	338.9200764
792.8337411	5605.40579	6640.042391	7324.203145	9878.464333	9080.532761	8443.280318	4177.645527
3945.75774	1732.14741	539.9462002	815.8803063	1399.540551	103.6696704	0	1700.950519	0	0
103.6696704	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	0	0	0	0
2008	1	4	0	2	89.4	0	0	0	0	0	0	0	302.2391429	2298.591023
5787.895625	8250.199021	24276.18557	35691.60444	25183.38891	17716.4917	5322.618301	9250.617463
4154.533399	3446.12426	2895.377164	1514.775272	1244.84228	1072.556029	129.8414064	648.0169862
376.5301691	272.4511504	47.44727518	47.44727518	271.7430472	141.9016409	82.41891433	129.8661895
82.41891433	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0
2009	1	4	0	2	69.3	0	0	0	0	0	0	0	291.8866994	1438.377936
3402.817112	15987.13201	31657.98309	21196.2792	22748.48287	23043.08058	17686.70045	14461.75028
6141.960412	11259.26827	8356.059523	4388.694946	3548.094685	4399.859585	1928.053683	1883.798666
831.8850166	2998.550806	1033.041106	536.3867281	0	1010.822357	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	0
2010	1	4	0	2	68.1	0	0	0	0	0	0	0	103.6696704	1240.025016
5367.433716	11211.77927	16824.88995	9214.140245	11861.73219	9332.492298	10908.16293	8478.729608
4416.696579	5977.956454	7077.705238	7984.371554	3150.072777	5187.873027	3043.576963	978.6034828
890.9112303	311.0090113	103.6696704	207.3393409	103.6696704	0	258.680511	103.6696704	258.680511
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
2011	1	4	0	2	116.1	0	0	0	0	0	0	84.02163747	133.9433737
2336.444158	4829.976904	9371.501661	8688.910435	8154.603331	8974.57535	10455.69793	10098.81277
7436.426222	5874.132332	8478.76696	7295.513461	8310.057857	5712.798535	5019.107548	3528.883557
2993.673204	1591.195461	1061.357427	157.0272121	199.5732241	37.22329439	284.2237138	68.5709177
```

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43.48445872	66.2906176	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0
2012	1	4	0	2	92.2	0	0	0	0	0	15.6118345	15.6118345	385.3000756
1920.151565	3633.498363	6925.513865	5583.112419	3333.589209	5017.222926	5771.82751	8071.548645
7702.683417	9655.809044	5005.616069	4423.135415	4180.134399	2394.401436	3260.085873	1498.662284
1142.115479	1100.514776	458.7929234	228.6587279	41.13117937	23.41775176	701.2038859	280.8326764	0
15.6118345	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
### Length comps from Pikitch discard study, produced by John Wallace and process by code in file
c:/SS/Thornyheads/comps/WCGOP_discard_comps_calcs.R
# discards (partition 1)
#_year	season	fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1985	1	1	0	1	24.6	0	0	0	0.037037037	0	0	0.111111111	0.228148148
0.268148148	0.234074074	0.308148148	0.274074074	0.157037037	0.302222222	0.04	0	0.04	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
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	1	1	0	1	110.7	0	0.011196934	0.016371154	0.027992336	0.122199232	0.138701595
0.209066732	0.321333718	0.358829277	0.395181773	0.223827751	0.109103203	0.044104469	0.013699636
0.002797396	0	0	0.002797396	0	0	0	0.002797396	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	0	0	0	0
0	0	0	0	0	0
1987	1	1	0	1	38.3	0	0	0	0	0.022995126	0.07301728	0.184997785
0.385963669	0.551998228	0.686973859	0.067027027	0.027027027	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	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# utilized (partition 2) Setting these to have negative fleet number because they are less complete than the PacFIN comps from the
same years
1986	1	-1	0	2	84.5	0	0	0	0	0	0	0	0	0	0.022733002
0.294802768	0.541127103	0.24573112	0.324863838	0.199027435	0.124678584	0.079245034	2.49E-05
0.022732078	0.122252459	1.91E-06	8.08E-06	1.52E-05	0.022735008	6.34E-06	0	2.22E-06
4.43E-06	4.43E-06	1.91E-06	0	0	2.22E-06	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
1987	1	-1	0	2	43.1	0	0	0	0	0	0	0	0	0	0.139704291
0.344175983	0.488207717	0.27847097	0.156653444	0.137468446	0.12917418	0.112225027	0.072124053
0.055174901	0.033898305	0.016949153	0.03577353	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	0	0	0	0	0	0	0
0	0	0
```

```
### Length comps from WCGOP discard observations, calculated by Andi and processed by code in file
c:/SS/Thornyheads/comps/WCGOP_discard_comps_calcs.R
# zero values in columns for males
#_year	season	fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
2006	1	1	0	1	51.3	0.000933932	0.015161679	0.012005045	0.050769397	0.053931026
0.084047756	0.090596621	0.166508506	0.255341033	0.127799546	0.075849983	0.029087037	0.017532184
0.012596764	0.005744453	0	0	0.000361794	0	0.001085381	0.000361794	0	0	0	0
0	0	0	0.000286069	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	0	0	0
2007	1	1	0	1	67.7	0.001067326	0.001643666	0.031115581	0.036043099	0.073717228
0.124285788	0.159795053	0.17702998	0.195964989	0.101012841	0.061427015	0.017096874	0.006741339
0.001754351	0.004698943	0.004763693	0.001754351	0	8.79E-05	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	0	0	0	0
0	0	0	0	0	0	0	0	0
2008	1	1	0	1	87.1	0.001107168	0.002338281	0.016359105	0.043666045	0.128098353
0.202661027	0.172928682	0.204723937	0.107396943	0.063723615	0.018383228	0.011955122	0.008811853
0.010135815	0.005653147	0	0.000252333	0	0.000252333	0	0.001528746	0	0	0	0
0	0	2.43E-05	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	0	0	0	0
2009	1	1	0	1	107.3	0.000252304	0.001369352	0.022276413	0.030028139	0.094250058
0.145231947	0.16748135	0.190248263	0.170985004	0.100076117	0.042795192	0.008788839	0.011225837
0.000156292	0.004916114	0.004019242	0.005237976	0.000229954	0.000186802	0.000131301	0	0.000101375
1.21E-05	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	0	0	0	0	0	0	0	0	0	0
2010	1	1	0	1	73.2	0	0.000183245	0.003243669	0.028111525	0.051682189	0.084699148
0.177316396	0.273746854	0.20759716	0.079217725	0.035267762	0.010088923	0.026121325	0.017156476
0.001565449	0.001646141	0	0	0	0.000471203	0	0	0.000471203	0.000471203	0.000471203
0	0	0	0	0.000471203	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	0	0
2011	1	1	0	1	78.7	0.032543195	0.017293142	0.054742982	0.143047386	0.145733482
0.171153188	0.153781032	0.157166783	0.08188635	0.024466363	0.009600741	0.001082426	0.000830115
0.000987164	0.004217882	0.000874986	0	0	0.000112178	0.000112178	0	0	0	0	0
0	0.000368427	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	0	0	0	0	0
2006	1	2	0	1	27.3	0.0010017	0.049248688	0.13325481	0.080501719	0.037463569
0.043558037	0.082139376	0.031319811	0.17167437	0.109452562	0.078227243	0.049113088	0.029717846
0.032080361	0.035953599	0.010718187	0	0.012487856	0.003205439	0.008881737	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	0	0
0	0	0	0	0	0	0	0	0	0
```

2007 1 2 0 1 32.9 0 0 0.000268938 0.037493764 0.137677474 0.12373167
0.261339775 0.167770291 0.106131305 0.112209982 0.020747518 0.028057342 0.001774989 0.000268938
0.002259077 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0.000268938 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 0
2008 1 2 0 1 32.2 0 0 0 0.007054186 0.018218684 0.061902752 0.111101608
0.35467914 0.282040172 0.05439221 0.046347912 0.030936476 0.023550982 0.008942708 0.000277724 0
0 0 0 0.000277724 0 0 0 0 0.000277724 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 0 0 0 0
0 0 0
2009 1 2 0 1 41.4 0 0 0 0.005429989 0.020108646 0.087175105 0.133371075
0.29582215 0.192799489 0.14750025 0.082574819 0.019992076 0.014994351 0.000232051 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 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2010 1 2 0 1 24.1 0 0 0.007894996 0.02166063 0.005870638 0.071851023
0.064066248 0.187822418 0.302850225 0.188602769 0.108525731 0.030011383 0.006073074 0.001012179 0
0 0 0 0 0 0 0 0.003758688 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 0 0 0 0 0 0
0 0 0
2011 1 2 0 1 38.6 0.001946921 0.005690998 0.006346212 0.093801736 0.20062451
0.132293785 0.088690075 0.120623316 0.182580318 0.117206525 0.04420508 0.002620855 0.000374408
0.001198105 0.001797157 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 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
2005 1 3 0 1 3.2 0 0 0 0 0 0 0 0 0 0
0.285714286 0 0.285714286 0.285714286 0 0 0.142857143 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 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
2006 1 3 0 1 17 0 0 0 0 0 0 0.005870703 0.005870703
0.02348281 0.0686499 0.106977248 0.099560788 0.110443123 0.095105382 0.186179519 0.04520441
0.018786248 0.051324622 0.037572497 0.02714008 0.043053879 0 0.010063452 0.010063452 0.015656237
0.038994948 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 0 0 0 0 0 0
2007 1 3 0 1 27.1 0 0 0.001424816 0 0 0.001424816 0.001424816
0.005414302 0.014533127 0.014755754 0.047321713 0.076022858 0.092076017 0.093121124 0.108515493
0.072277857 0.008833861 0.08403406 0.088477041 0.072195206 0.05172105 0.010258678 0.048319631
0.006596185 0.015925632 0.014289895 0.014927202 0.034276007 0.021832857 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 0 0 0
2008 1 3 0 1 12.5 0 0 0 0 0.0117638 0 0.0117638 0 0
0.070582798 0.0176457 0.14436388 0.168222336 0.214358488 0.122992977 0.075545651 0.035291399
0.080413974 0.023527599 0 0.0117638 0 0 0.0117638 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 0 0 0 0
0 0 0 0
2009 1 3 0 1 10.5 0 0 0 0 0 0 0 0 0 0.01754386
0.076023392 0.111111111 0.111111111 0.052631579 0.14619883 0.111111111 0.052631579 0.087719298
0.070175439 0.055555556 0.038011696 0.01754386 0.01754386 0 0 0 0 0.01754386
0.01754386 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 0 0
2010 1 3 0 1 13.1 0 0 0 0.009515395 0.038061578 0.028546184 0.019030789
0.10466934 0 0.019030789 0.20933868 0.10466934 0.174457962 0.063508462 0.009515395 0.05233467
0.05551553 0.038061578 0.042819275 0.019030789 0 0 0 0 0 0 0.011894243 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 0 0 0 0 0
2011 1 3 0 1 26.5 0 0 0 0 0 0.00942247 0.024498423 0.018844941
0.027040994 0.045856022 0.057288218 0.059182087 0.096265306 0.089704161 0.059675645 0.070318853
0.068941074 0.060146769 0.056534822 0.056277725 0.027639246 0.027011082 0.035496796 0.035502287
0.007490268 0.02256622 0 0.013982155 0 0.011469496 0.0106788 0.008166141 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
2006 1 4 0 1 24 0 0 0 0 0 0 0.00152866 0.006216551
0.040237733 0.137142051 0.251804304 0.128980704 0.244229672 0.084687775 0.039962453 0.008050944
0.001974519 0.00076433 0.020827995 0.002687894 0.011872594 0 0.007477696 0.005299355 0.000955413
0 0 0.005299355 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 0 0 0 0 0
2007 1 4 0 1 29 0 0 0 0 0 0 0.008079789 0.036199841
0.126470582 0.148515314 0.111406714 0.186143627 0.29681398 0.063523855 0.014487897 0.002786134
0.004179201 0 0 0 0 0 0.001393067 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 0 0 0 0 0 0
0 0 0
2008 1 4 0 1 22.3 0 0 0 0 0 0.004679868 0.003509901 0.008336015
0.071046243 0.136886133 0.290517418 0.116777326 0.100909649 0.053050689 0.028042645 0.026762994
0.013162128 0.009323174 0.032576267 0.006581064 0.03115037 0.017988242 0.032466583 0 0.009652227
0 0.002193688 0 0.004387376 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 0 0 0
2009 1 4 0 1 16.6 0 0 0 0 0 0.011622839 0 0.036466657
0.063925614 0.133662647 0.096469563 0.086009008 0.039517652 0.058114194 0.039517652 0.037193084
0.094144995 0.058114194 0.09879413 0.032543949 0.023245678 0.023245678 0.005811419 0.047653639
0.013947407 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 0 0 0 0 0 0
2010 1 4 0 1 24 0 0 0 0 0 0 0.013968052 0.002971926
0.054980629 0.041904155 0.036851881 0.023973536 0.027957332 0.024228272 0.014336005 0.061179218
0.016076704 0.086369828 0.078211184 0.059084718 0.055957119 0.066613597 0.080737321 0.03930372
0.073364114 0.045937483 0.030016452 0.020209096 0.037743459 0.0080242 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 0 0

```
2011	1	4	0	1	22.8	0	0	0	0	0.002472025	0.002472025	0	0.004944049
0.028675486	0.083554434	0.097438973	0.075643955	0.069711096	0.085367252	0.082236021	0.05504375
0.062295022	0.002472025	0.064272642	0.028869952	0.052489324	0.024225842	0.04210682	0.05384409
0.025255852	0.013843338	0.006798068	0.012360123	0.021135811	0	0	0.002472025	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

### Length comps from AK triennial survey, calculated in file c:/SS/Thornyheads/comps/AK_survey_comps.R
###      note: combining males and females due to lack of trust is sex determination from this survey
# zero values in columns for males
### Shallow/Deep alternative: Shallow triennial for all years
# zero values in columns for males
#_year	season	fleet	gender	partition	Nsamp	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
## 1980	1	5	0	0	20.5	0	0.326797386	0.326797386	1.307189542	0.980392157	2.287581699
3.094033312	7.397744044	12.00716846	5.840185537	17.52055661	8.760278305	10.95034788	3.65011596
8.760278305	3.65011596	5.110162345	3.65011596	2.190069576	0.730023192	0.730023192	0.730023192	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	0	0	0	0	0	0	0	0	0	0
## 1983	1	5	0	0	13.7	0	0	0	0	6.41025641	7.692307692	12.82051282
14.1025641	26.92307692	12.82051282	6.41025641	7.692307692	5.128205128	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	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	1	5	0	0	27.2	0	0	0.423988083	0.408995349	2.467453146	1.950485296
3.315429313	5.633143805	12.90542178	16.07820742	22.18746142	13.38474179	8.760379785	4.735650502
3.497593867	1.946658371	1.151891483	0	0.765301949	0.387196642	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	0	0	0	0
0	0	0	0	0	0	0	0
1989	1	5	0	0	92.1	0.063954122	0.075106871	0.568128067	0.9662749	2.441352775
5.12658233	6.823767936	12.23061743	17.77825092	18.21727841	15.96489334	10.52257638	4.21251583
2.287042298	1.340242924	0.579139866	0.379572853	0.111159013	0.155771865	0.084279017	0	0.071492848
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	0	0	0	0	0	0	0	0	0	0
1992	1	5	0	0	72.3	0.031460261	0.200534546	1.282114112	1.662539687	3.88444415
5.985344078	12.3496482	14.0402569	13.99088707	16.32364135	12.06371113	8.59909058	4.696272698
2.115173891	1.725629577	0.318560247	0.427862322	0.302829202	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	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1995	1	5	0	0	145.5	0.024249528	0.496147078	1.05235154	2.243802985	4.201711386
8.217641106	14.7316106	16.45438075	18.17738699	13.38830499	8.842614359	5.896153768	3.050810693
1.587813445	0.810092011	0.389292621	0.227485565	0.097510714	0.110639874	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	0	0	0
0	0	0	0	0	0	0	0	0	0
1998	1	5	0	0	155.9	0.029825636	0.237628709	0.81746814	1.908443599	2.883653155
9.744713983	16.02256648	20.04595434	17.33504234	13.13747015	8.668105015	4.861663393	1.995817097
1.095531826	0.651459098	0.251197523	0.115247028	0.031430524	0.030049216	0.031430524	0.029138748
0.061370941	0	0	0	0	0.014792535	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	0	0	0	0	0
2001	1	5	0	0	150.4	0	0.299922432	0.848457183	2.582640027	4.299389123	10.29481135
19.67591978	12.7337098	18.47485517	10.53804784	6.550858741	6.93012039	2.823139297	1.244046789
0.850581015	0.734826875	0.310988803	0.149836032	0.453424995	0.038064379	0.092918161	0.073441819	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	0	0	0	0	0	0	0	0	0	0
2004	1	5	0	0	131.5	0.02798798	0.422514571	0.870510673	1.865749358	2.505487415
3.83377209	3.303566033	12.1258476	15.26888313	19.16243968	13.98166069	10.152021	7.228956775
3.961467949	2.413689575	0.968993244	1.026974482	0.220497045	0.108327345	0.127345173	0.135003546
0.085980724	0	0	0.019044475	0.183279447	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	0	0	0	0	0	0
### Shallow/Deep alternative: Deep triennial only for 1995+
# zero values in columns for males
#_year	season	fleet	gender	partition	Nsamp	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1995	1	6	0	0	206.9	0.112455446	0.668440799	2.200681798	4.401920823	6.085164281
10.87135676	14.18583461	17.21083961	15.11888439	11.05643533	7.370611555	4.103138889	2.064308079
1.457264992	0.712303265	0.803455616	0.514197789	0.377112836	0.108918348	0.120844056	0.060999759
0.161000176	0.033897284	0.044966264	0.051035572	0	0.025582417	0.059515293	0	0.018833974	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	0	0
1998	1	6	0	0	186.9	0.147521512	0.784045777	1.920244293	4.181413576	7.9362766
10.98733643	13.39728466	15.53374365	15.97249594	12.3419091	5.798747269	3.412499618	2.782394868
1.566631139	1.02947579	0.774626021	0.310723034	0.306440521	0.193947301	0.212340267	0.113026457
0.05699428	0.045868576	0.080436962	0.009980623	0.05232957	0.023478717	0.009262482	0	0
0.009262482	0	0.009262482	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
2001	1	6	0	0	188.9	0.091979539	0.349738679	1.210957508	3.110440774	7.239928032
10.36352239	14.50642672	13.93855775	13.65358246	11.28004613	8.294121614	4.533425082	2.491260158
1.538303615	1.217463152	1.796825067	1.238299904	0.861412357	0.632679885	0.43587965	0.357098887
0.292038303	0.234692992	0.13879367	0.017166563	0.054105974	0.043296339	0.077956807	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	0
0	0	0
2004	1	6	0	0	167.9	0.519770778	1.323687489	1.655067394	2.690494248	2.941535981
3.13513326	5.167696633	13.69057991	19.26990873	20.75598261	12.39785584	7.313428525	3.44528155
1.835766926	1.159000169	0.501843501	0.65503411	0.339819809	0.234305995	0.143474215	0.172657297
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0.161031251	0.19555598	0.020653615	0.041334214	0.154250483	0	0.011616667	0.046579196	0	0
0	0	0.020653615	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
### Length comps from AK slope survey, calculated in file c:/SS/Thornyheads/comps/AK_survey_comps.R
###	note: combining males and females due to lack of trust is sex determination from this survey
# zero values in columns for males
#_year	season	fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1997	1	7	0	0	210.6	0.030386654	0.369562218	1.804653004	2.757247317	4.942339502
11.89074365	16.48339926	18.9390944	15.88222381	12.16100635	6.225180361	3.646951966	1.443751181
1.166680808	0.845981201	0.478373068	0.218968131	0.185644309	0.054925958	0.074103429	0.02070116
0.097120933	0.109658155	0.030501764	0.015537486	0.044561245	0.044464033	0.015537486	0	0
0.02070116	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	0
1999	1	7	0	0	198.5	0.019095526	0.195653984	1.281515857	3.118860815	6.504941305
10.98437758	14.67758907	18.0146668	17.65895756	10.39036528	6.724947841	3.669172649	2.325368094
1.169345388	0.824962954	0.734027803	0.301482516	0.390871841	0.341922216	0.206555462	0.101443027
0.155621262	0.074859406	0.048615552	0	0.024986015	0.036850548	0	0	0	0.022943661	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	0
2000	1	7	0	0	203.1	0.123295768	0.43611988	0.355917511	2.021318246	6.217659489
10.37440467	15.10487062	17.25871678	17.64141568	13.3953186	6.563098983	3.97764435	2.256182198
1.386027972	0.772824157	0.690743879	0.304106406	0.383496035	0.200152614	0.115567782	0.212498183
0.061517877	0.020728465	0.019651226	0.05570012	0	0.041407781	0.009614732	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	0	0
0	0
2001	1	7	0	0	186.2	0.05596268	0.355900227	1.172479391	1.56290144	4.491634356
10.83139185	13.50069213	16.27651529	17.12002454	12.97070003	8.743981154	5.231906564	2.772091448
1.395948164	0.954810176	0.825242662	0.760772963	0.348527414	0.247568579	0.021965721	0.118374294
0.115576025	0.035173305	0.063087587	0.010542592	0	0.016229422	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	0	0	0	0
0
### Length comps from NWFSC surveys, calculated in file c:/SS/Thornyheads/comps/NWFSC_survey_comps.R
### sex determination seems to have been sorted out in 2005, so combining earlier years. Note that only one 2000 from early survey had
length measurements
#_year	Season	Fleet	gender	partition	inputN	U6	U8	U10	U12	U14	U16	U18	U20	U22	U24
U26	U28	U30	U32	U34	U36	U38	U40	U42	U44	U46	U48	U50	U52	U54	U56	U58
U60	U62	U64	U66	U68	U70	U72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
1998	1	8	0	0	216.8	0.077385619	0.562559509	1.452053501	2.942848139	4.93316692
8.47024576	12.5792311	14.24343412	12.69464717	10.06514512	6.881429906	4.344328936	3.726125238
3.087467881	2.131982052	1.505967871	1.195737446	1.078422416	1.061613175	1.205601824	0.978878903
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0.814347047     0.823087113     0.660923277     0.834741009     0.543072387     0.537254678     0.349862766     0.075708391
0.070804629     0.021934738     0.024332606     0.014952919     0.010705835     0.06709767      0.562559509     1.452053501
2.942848139     4.93316692      8.47024576      12.5792311      14.24343412     12.69464717     10.06514512     6.881429906
4.344328936     3.726125238     3.087467881     2.131982052     1.505967871     1.195737446     1.078422416     1.061613175
1.205601824     0.978878903     0.814347047     0.823087113     0.660923277     0.834741009     0.543072387     0.537254678
0.349862766     0.075708391     0.070804629     0.021934738     0.024332606     0.014952919     0.010705835
1999    1       8       0       0       251.8   0.081420433     0.327487784     2.04159955      4.251857901     6.950471531
8.190062058     9.924976613     12.01655931     12.19940723     9.32009787      6.355568216     4.772094952     3.969518824
2.925607606     2.481167198     1.702473341     1.483334535     1.279911178     1.240803927     1.249845675     1.229726221
1.005106678     1.058876913     0.940778584     0.717090165     0.559183367     0.673730904     0.380593842     0.186203292
0.2062691       0.161785847     0.081125386     0.035263966     0       0.066641218     0.327487784     2.04159955      4.251857901
6.950471531     8.190062058     9.924976613     12.01655931     12.19940723     9.32009787      6.355568216     4.772094952
3.969518824     2.925607606     2.481167198     1.702473341     1.483334535     1.279911178     1.240803927     1.249845675
1.229726221     1.005106678     1.058876913     0.940778584     0.717090165     0.559183367     0.673730904     0.380593842
0.186203292     0.2062691       0.161785847     0.081125386     0.035263966     0
2000    1       8       0       0       218.6   0.164528453     0.539098982     1.120001142     3.591558761     6.450336041
9.189806561     10.84458331     13.15235178     11.96461731     9.531239623     6.65871878      4.173857393     3.17118773
2.555598714     1.773805477     1.578028903     1.342395365     1.378107143     1.419331512     1.182996578     1.305916474
1.214968844     1.184044248     0.825487023     0.6627089       0.878333075     0.688085519     0.522117626     0.475394568
0.235418696     0.117982324     0.061125047     0.046268098     0       0.158357435     0.539098982     1.120001142     3.591558761
6.450336041     9.189806561     10.84458331     13.15235178     11.96461731     9.531239623     6.65871878      4.173857393
3.17118773      2.555598714     1.773805477     1.578028903     1.342395365     1.378107143     1.419331512     1.182996578
1.305916474     1.214968844     1.184044248     0.825487023     0.6627089       0.878333075     0.688085519     0.522117626
0.475394568     0.235418696     0.117982324     0.061125047     0.046268098     0
2001    1       8       0       0       221     0.08340262      0.252148515     0.773731016     0.926781316     1.733228858
2.867890298     4.333804124     5.254866118     5.179084321     7.185020564     8.958302658     8.408198152     7.738211704
12.49244624     7.107492284     5.399626842     3.436326789     2.906515555     0.673467244     1.542634205     4.811830371
2.614923301     2.541119193     1.485460042     0.302648374     0.238328498     0.170395556     0.174763086     0.249157643
0.06398497      0.046427554     0.024225372     0.010447152     0.013109467     0.05564037      0.252148515     0.773731016
0.926781316     1.733228858     2.867890298     4.333804124     5.254866118     5.179084321     7.185020564     8.958302658
8.408198152     7.738211704     12.49244624     7.107492284     5.399626842     3.436326789     2.906515555     0.673467244
1.542634205     4.811830371     2.614923301     2.541119193     1.485460042     0.302648374     0.238328498     0.170395556
0.174763086     0.249157643     0.06398497      0.046427554     0.024225372     0.010447152     0.013109467
2002    1       8       0       0       276.9   0.214600951     0.228894555     0.754943583     0.569936498     1.346196334
3.336462522     6.741876127     10.53227114     13.07223084     10.63398096     8.02123752      7.581790263     6.248759351
5.327210713     4.16801842      3.999473079     2.862267755     2.539138826     2.606058483     2.238744703     1.40861612
1.563226584     1.075733187     1.024466677     0.670017433     0.368746938     0.34996398      0.170734514     0.149206763
0.080530276     0.054164959     0.024651136     0.022898394     0.01295042      0.196543627     0.228894555     0.754943583
0.569936498     1.346196334     3.336462522     6.741876127     10.53227114     13.07223084     10.63398096     8.02123752
7.581790263     6.248759351     5.327210713     4.16801842      3.999473079     2.862267755     2.539138826     2.606058483
2.238744703     1.40861612      1.563226584     1.075733187     1.024466677     0.670017433     0.368746938     0.34996398
0.170734514     0.149206763     0.080530276     0.054164959     0.024651136     0.022898394     0.01295042
# first two years of combo survey have sexes combined
2003    1       9       0       0       214.5   0.143799623     0.303030821     1.00886991      1.552529703     2.733674168
2.711281081     4.653827445     8.573039547     9.114363609     9.799368709     8.99916528      6.765106372     5.44838546
5.255839708     4.753114027     4.788233596     4.284893607     4.133505529     2.806905142     3.052344575     1.972814648
1.519303603     1.734155933     1.02344612      0.900260813     0.601089829     0.474600672     0.502784002     0.211589304
0.051274318     0.056983885     0.05682642      0.00679627      0.00679627      0.143799623     0.303030821     1.00886991
1.552529703     2.733674168     2.711281081     4.653827445     8.573039547     9.114363609     9.799368709     8.99916528
6.765106372     5.44838546      5.255839708     4.753114027     4.788233596     4.284893607     4.133505529     2.806905142
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3.052344575	1.972814648	1.519303603	1.734155933	1.02344612	0.900260813	0.601089829	0.474600672
0.502784002	0.211589304	0.051274318	0.056983885	0.05682642	0.00679627	0.00679627
2004	1	9	0	0	197.4	0.284421675	1.275670187	2.330140848	2.62799238	3.27603371
2.865826962	4.779280901	8.13971663	10.18595315	11.3923255	8.916513857	6.994560536	6.370330491
5.37858658	4.61821747	3.211580902	2.917892446	2.779435509	2.289229678	1.760643759	1.689574398
1.579577814	1.61326729	0.69856653	0.68253191	0.534697668	0.263024676	0.202657342	0.0602913
0.085490799	0.066784004	0.081580911	0.008344963	0.039257227	0.232610946	1.275670187	2.330140848
2.62799238	3.27603371	2.865826962	4.779280901	8.13971663	10.18595315	11.3923255	8.916513857
6.994560536	6.370330491	5.37858658	4.61821747	3.211580902	2.917892446	2.779435509	2.289229678
1.760643759	1.689574398	1.579577814	1.61326729	0.69856653	0.68253191	0.534697668	0.263024676
0.202657342	0.0602913	0.085490799	0.066784004	0.081580911	0.008344963	0.039257227
# later years with split sexes
#_year	Season	Fleet	gender	partition	inputN	F6	F8	F10	F12	F14	F16	F18	F20	F22	F24
F26	F28	F30	F32	F34	F36	F38	F40	F42	F44	F46	F48	F50	F52	F54	F56	F58
F60	F62	F64	F66	F68	F70	F72	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24
M26	M28	M30	M32	M34	M36	M38	M40	M42	M44	M46	M48	M50	M52	M54	M56	M58
M60	M62	M64	M66	M68	M70	M72
2005	1	9	3	0	220.5	0.165219888	0.391179319	1.045602577	1.744514078	2.854431141
2.030474945	2.501615491	5.023090253	5.140685657	5.530326293	4.077813649	3.088587305	2.269765555
2.055897311	1.697043966	1.450142513	1.277907727	0.831412667	0.839880087	0.659158495	0.671067308
0.614036973	0.58218919	0.291063721	0.277940045	0.274412491	0.17445629	0.126233709	0.099647459
0.09690612	0.044320947	0	0.021195476	0	0.16521917	0.391180037	1.045601141	1.756255597
3.02607501	2.043752274	3.066169786	5.465771995	6.595070856	5.808356088	4.393535061	3.252502579
2.478873434	2.474638647	1.799214491	1.527226699	1.380543519	1.395905213	0.775420565	0.80424627
0.814236576	0.540910425	0.339159933	0.286172678	0.098164781	0.16385568	0.070062825	0.044982229
0.033917788	0.014760007	0	0	0	0
2006	1	9	3	0	188.5	0.088609235	0.273637597	0.489992025	1.290087237	2.202994339
2.565415979	2.514004341	3.755947566	5.54876593	5.376022352	5.381263848	3.253156349	2.435983711
2.424403619	1.648649453	1.375443411	1.487668968	1.137113304	0.97521508	0.864114847	0.721238783
0.802528861	0.590241441	0.608088203	0.632146096	0.416302435	0.360057185	0.287146035	0.230613992
0.070501172	0.073279885	0.11400732	0.023089168	0.016024939	0.088607414	0.273635776	0.489994756
1.298819422	2.159271503	2.170494696	2.323006117	3.683894977	4.545772833	5.221575302	4.933452347
3.969249234	2.910494339	2.548114581	2.271120131	1.824018786	1.822109559	1.251030488	1.337271627
0.896340442	1.272152161	0.910861308	0.619316859	0.333616628	0.424711408	0.196342601	0.038352055
0.059611206	0.084640556	0.008366182	0	0	0	0
2007	1	9	3	0	175.5	0.041957756	0.346588527	0.798602057	1.157670402	2.029950746
3.369944316	3.631248056	4.055623468	7.529969295	5.838477674	5.745110462	3.395262057	3.114022184
1.904980062	1.725892945	1.768435993	1.375584731	1.061050198	1.072485731	0.634821874	0.739621538
0.63156734	0.614996638	0.48410911	0.30246134	0.313108268	0.245315249	0.220483454	0.254688397
0.065265481	0.053218471	0.04496893	0.01908977	0.090175058	0.041957756	0.299378544	0.812375679
1.09340993	1.958280166	3.029341172	3.393736447	3.798788742	5.40020388	5.61558605	4.044513696
2.101054517	2.278060766	1.531974829	1.885222597	1.158286499	1.221089131	1.011862542	1.15271082
0.813507757	0.560827837	0.409468942	0.64368058	0.381011415	0.297846772	0.206243139	0.051149925
0.061828429	0.069853864	0	0	0	0	0
2008	1	9	3	0	159.9	0.16817772	0.377076712	0.407486527	1.195803317	2.179333577
3.005851658	2.487498475	3.573173933	4.556520695	5.3178613	3.638676135	3.082198519	2.459638423
1.952533404	2.445583023	1.444066077	1.135501517	1.042168085	0.972965172	0.957052691	0.903123377
0.707727369	0.552016011	0.533422148	0.586905685	0.375845063	0.281304961	0.266801862	0.194342093
0.157348432	0.091370672	0.021832466	0.010043415	0.013277214	0.168176759	0.377075751	0.407487488
1.215891107	2.164854497	2.880805668	2.707755153	4.204490073	4.809726383	6.047223225	5.640221864
3.794570031	3.312789711	3.433272259	1.937004252	1.492888179	1.725571829	1.339579593	1.021240621
```

```
0.952736155	0.86362895	0.773110441	0.574349976	0.46134859	0.242501295	0.159261235	0.096229056
0.035091426	0.022833541	0	0.021878581	0.021878581	0	0
2009	1	9	3	0	149.2	0.295651499	0.915246111	0.674950614	0.915792304	1.737411529
2.538219786	2.33402868	2.684946293	3.31468548	3.277824645	3.389802723	3.53407631	2.958254892
2.989421448	2.349559777	2.310315344	1.574624492	2.520985358	1.354723272	1.434656465	1.192884646
0.826152556	0.506570614	0.344472223	0.325176428	0.338157097	0.338464093	0.205611057	0.125503417
0.043037317	0.067196293	0	0	0.00955039	0.295650738	0.915246111	0.669151972	0.925724344
1.718016703	2.408323967	3.295179434	4.046206368	4.378415515	5.140702265	3.546911479	4.774173569
2.629668753	2.314746597	3.428446114	3.003521928	2.224738149	1.280536158	1.144481376	0.807227746
1.235870924	1.102947044	0.647991348	0.397715058	0.112110627	0.089399026	0.009945752	0.005573156
0.012415431	0.011009192	0	0	0	0
2010	1	9	3	0	141.5	0.240348547	1.267577937	1.445387287	1.748523674	1.967413409
2.445875264	2.633988443	2.978043129	4.34737625	4.839500733	3.694144767	2.236770008	3.029775272
2.149194257	2.4515024	1.684387393	1.614424552	1.312413422	0.839804434	0.878415361	0.541959981
0.610335921	0.438275906	0.740612054	0.308956158	0.40227785	0.28606489	0.220006506	0.247641506
0.026519926	0.029297428	0	0.00724289	0	0.300092421	1.281319486	1.445388136	1.748522826
2.019727698	2.314395802	3.376993578	4.580924033	5.340219094	6.951017534	4.175171123	2.685942921
2.071178102	2.032887101	2.042058883	1.899526269	1.453974377	1.494840911	1.02419985	1.073259718
0.97024944	0.786532063	0.338304502	0.34704519	0.244956502	0.114920526	0.135629167	0.062796326
0.01658694	0	0.007281926	0	0	0
2011	1	9	3	0	159.6	0.198108409	0.453811688	1.03588376	1.274100315	1.492426204
1.884473196	2.690469983	3.32425248	4.253313616	4.701386415	4.317007143	3.505980932	3.21026105
2.446197796	2.012238326	1.478631447	1.378161973	1.204883027	1.160268172	1.20043033	1.200103518
0.664024953	0.408783971	0.456026136	0.59207874	0.540211774	0.54119221	0.336394685	0.292211918
0.055236698	0.046648961	0.008898986	0	0.013098107	0.198105663	0.453812604	1.035882844	1.286054123
1.439100028	2.09283178	3.136656061	4.476446477	5.612590075	5.512855699	5.536084973	3.307778232
2.372318175	2.19354293	2.548681236	1.935508942	1.901164402	1.206895163	1.172171631	1.032336432
0.890587049	0.801416844	0.415662582	0.333862579	0.299231507	0.146385168	0.164804724	0.051389106
0.008287473	0.049943627	0.010414954	0	0	0
2012	1	9	3	0	159.2	0.098347569	0.570364482	1.331728727	1.318142849	1.433770593
2.126543885	2.72031459	4.7871209	5.14118312	4.672895712	3.708811807	3.68297547	2.541007705
1.506799288	2.231835456	0.967251732	1.097629646	1.168723583	1.234449654	1.024781899	0.751340843
0.999591572	0.721824127	0.904709863	0.553748331	0.359322009	0.255536159	0.238382894	0.10889826
0.044187466	0.029868788	0.042497521	0.010169143	0.025246003	0.098347569	0.577009632	1.23584566
1.328596925	1.526092003	1.960653391	2.742030051	4.28628077	4.582783347	5.495255165	4.351691614
3.951748709	2.141049243	2.571467646	2.555355039	2.494803605	1.898484063	1.558431025	1.457356128
0.934350214	1.136587617	0.964565342	0.797529386	0.41285084	0.203349295	0.206903582	0.068011263
0.029217046	0.015428932	0	0	0.007923253	0	0
#
0  #  N age' bins
0  #  number of ageerr matrices to generate
0  #  N age observations
2  #  Length bins range method
0  #  Combine males into females below this age bin number.
0  #  N size@age observations; values on row1; N on row2
0  #  environmental data  N variables
0  #  environmental data  N observations
0  #  No WtFrequency methods
0  #  No Tagging data
0  #  No Morph data
999  # end  of  file
```

Appendix C. SS control file

```
# Shortspine Thornyhead control file
# Ian Taylor and Andi Stephens, 2013
#
#  uses SSv3.24o (April 10, 2013)
#
1  # N growthmorphs
1  # N submorphs within growth patterns
#
3 # Block designs
2 2 1 # Blocks in each design
# design 1 (trawl north)
2007 2010 # design 1, block 1
2011 2012 # design 1, block 2
# design 2 (trawl south)
2007 2010 # design 2, block 1
2011 2012 # design 2, block 2
# design 3 (non-trawl south)
2007 2012 # design 3, block 1
#
# Natural mortality and growth parameters for each morph
0.5  #_fracfemale
1    #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
2    #_N_breakpoints
20 40 # age(real) at M breakpoints
1    # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=age_speciific_K; 4=not implemented
2    #_Growth_Age_for_L1
100  #_Growth_Age_for_L2 (999 to use as Linf)
0.1  #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0    #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)
1    #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity by GP; 4=read age-fecundity by GP; 5=read fec and wt
from wtatage.ss; 6=read length-maturity by GP
#_two alternative empirical age- or length- maturity by growth patterns (use option 6 above)
#0 0 0 0 0 0.001 0.060 0.863 0.998 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
#0 0 0 0 0 0     0.027 0.414 0.499 0.520 0.540 0.560 0.580 0.600 0.620 0.640 0.660 0.680 0.700 0.720 0.740 0.760 0.780 0.800 0.820
0.840 0.860 0.880 0.900 0.920 0.940 0.960 0.980 1 1 1 1 1 1 1 1 1 1 1
1    #_First_Mature_Age
1    #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L; (5)eggs=a+b*W
0    #_hermaphroditism option:  0=none; 1=age-specific fxn
3    #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
1    #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds; 3=standard w/ no bound check)
#
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
0.01    0.15    0.05050 -3.129   3      0.5361  -3      0       0       0       0       0       0       0       #F_natM_young (Owen
prior)
-3      3       0       0       -1      0.2     -3      0       0       0       0       0       0       0
#F_natM_old_as_exponential_offset(rel_young)
3       10      7       9       -1      2       -2      0       0       0       0       0       0       0       #F_Lmin
55      95      75      70      -1      5       -2      0       0       0       0       0       0       0       #F_Lmax
```

```
0.01    0.03    0.018   0.017   -1      0.8     -3      0       0       0       0       0       0       0       #F_VBK
0.05    0.25    0.125   0.1     -1      0.8     -3      0       0       0       0       0       0       0       #F_CV-young
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0       #F_CV-
old_as_exponential_offset(rel_young)
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0
#M_natM_young_as_exponential_offset(rel_morph_1)
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0
#M_natM_old_as_exponential_offset(rel_young)
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0
#M_Lmin_as_exponential_offset
-3      3       -0.1053605 -0.1 -1      0.8     -2      0       0       0       0       0       0       0
#M_Lmax_as_exponential_offset
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0
#M_VBK_as_exponential_offset
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0       #M_CV-
young_as_exponential_offset(rel_CV-young_for_morph_1)
-3      3       0       0       -1      0.8     -3      0       0       0       0       0       0       0       #M_CV-
old_as_exponential_offset(rel_CV-young)

#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
0       100     4.770654e-06 0  -1      0.8     -3      0       0       0       0       0       0       0       #Female_wt-len-1
0       100     3.262977     0  -1      0.8     -3      0       0       0       0       0       0       0       #Female_wt-len-2
0       100     18.2    22      -1      0.8     -3      0       0       0       0       0       0       0       #Female_mat-len-1
-3      100     -2.3    -0.4    -1      0.8     -3      0       0       0       0       0       0       0       #Female_mat-len-2
0       100     1       1       -1      0.8     -3      0       0       0       0       0       0       0
#Female_eggs/gm_intercept
0       100     0       0       -1      0.8     -3      0       0       0       0       0       0       0       #Female_eggs/gm_slope
0       100     4.770654e-06 0  -1      0.8     -3      0       0       0       0       0       0       0       #Male_wt-len-1
0       100     3.262977     0  -1      0.8     -3      0       0       0       0       0       0       0       #Male_wt-len-2

#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
0       0       0       0       -1      0       -4      0       0       0       0       0       0       0       #RecrDist_GP_1
0       0       0       0       -1      0       -4      0       0       0       0       0       0       0       #RecrDist_Area_1
0       0       0       0       -1      0       -4      0       0       0       0       0       0       0       #RecrDist_Seas_1
0       0       0       0       -1      0       -4      0       0       0       0       0       0       0       #CohortGrowDev
#
# Seasonal effects on biology parameters (0=none)
 0 0 0 0 0 0 0 0 0 0
#
#
#_Spawner-Recruitment
3 #_SR_function: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=survival_3Parm
#
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
7       13      10.3    10      -1      10      4       #_SR_LN(R0)
#0.2    1       0.6     0.6     -1      0.2     -4      #_SR_BH_steep (old model)
0.2     1       0.6     0.779   -2      0.152   -2      #_SR_BH_steep (Thorson prior turned off)
0       2       0.5     0.5     -1      0.8     -4      #_SR_sigmaR
-5      5       0       0       -1      1       -3      #_SR_envlink
-5      5       0       0       -1      1       -4      #_SR_R1_offset
-1      1       0       0       -1      100     -1      #_SR_autocorr
```

```
#
0     #_SR_env_link
0     #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1     #_do_recdev:  0=none; 1=devvector; 2=simple deviations
1850  # first year of main recr_devs; early devs can preceed this era
2012  # last year of main recr_devs; forecast devs start in following year
6     #_recdev phase
1     # (0/1) to read 13 advanced options
 0    #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -4   #_recdev_early_phase
 5   #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1    #_lambda for Fcast_recr_like occurring before endyr+1
 1859.5  #_last_early_yr_nobias_adj_in_MPD
 1918.4  #_first_yr_fullbias_adj_in_MPD
 2010.7  #_last_yr_fullbias_adj_in_MPD
 2012.1  #_first_recent_yr_nobias_adj_in_MPD
 0.072   #_max_bias_adj_in_MPD (1.0 to mimic pre-2009 models)
 0    #_period of cycles in recruitment (N parms read below)
 -5   #min rec_dev
 5    #max rec_dev
 0    #_read_recdevs
#_end of advanced SR options
#
#Fishing Mortality info
0.06 # F ballpark for annual F (=Z-M) for specified year
1999 # F ballpark year (neg value to disable)
1    # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
0.9  # max F or harvest rate, depends on F_Method
#
# init F setupforeachfleet
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
0       1       0.00    0.01    -1       99      -1
0       1       0.00    0.01    -1       99      -1
0       1       0.00    0.01    -1       99      -1
0       1       0.00    0.01    -1       99      -1
#
#_Q_setup
 # Q_type options:  <0=mirror, 0=float_nobiasadj, 1=float_biasadj, 2=parm_nobiasadj, 3=parm_w_random_dev, 4=parm_w_randwalk,
5=mean_unbiased_float_assign_to_parm
#_for_env-var:_enter_index_of_the_env-var_to_be_linked
#_Den-dep  env-var  extra_se  Q_type
 0 0 0 0 # 1 NorthTrawl
 0 0 0 0 # 2 SouthTrawl
 0 0 0 0 # 3 NorthOther
 0 0 0 0 # 4 SouthOther
 0 0 1 0 # 5 Triennial1
 0 0 0 0 # 6 Triennial2
 0 0 0 0 # 7 AFSCslope
 0 0 0 0 # 8 NWFSCslope
 0 0 0 0 # 9 NWFSCcombo
#
```

```
#LO  HI      INIT    PRIOR   PR_type SD      PHASE
0.01 0.5     0.05    0.05    -1      0.1     4 # additive value for triennial survey

## #LO  HI      INIT    PRIOR   PR_type SD      PHASE
## -3   3       -0.5    -0.5    -1      2       2       #_Q_for_triennial_early
## -3   3       -0.5    -0.5    -1      2       2       #_Q_for_triennial_late
## -3   3       0       0.01    -1      2       2       #_Q_for_AFSC_slope_survey
## -3   3       0       0.01    -1      2       2       #_Q_for_NWFSC_slope_survey
## -3   3       0       0.01    -1      2       -2      #_Q_for_NWFSC_combo_survey
#### -3   3       -0.2231 0.01    -1      2       -2      #_Q_for_NWFSC_combo_survey
#
# SELEX & RETENTION PARAMETERS
#Pattern  Retention(0/1)  Male(0/1)  Special
# Size selex
24  1  0  0  # North Trawl
24  1  0  0  # South Trawl
24  1  0  0  # North Other
24  1  0  0  # South Other
24  0  0  0  # Triennial1
24  0  0  0  # Triennial2
24  0  0  0  # AFSC Slope survey
24  0  0  0  # NWFSC Slope survey
24  0  0  0  # NWFSC combo survey
# Age selex
10  0  0  0  # North Trawl
10  0  0  0  # South Trawl
10  0  0  0  # North Other
10  0  0  0  # South Other
10  0  0  0  # Triennial1
10  0  0  0  # Triennial2
10  0  0  0  # AFSC Slope survey
10  0  0  0  # NWFSC Slope survey
10  0  0  0  # NWFSC combo survey
#
#LO  HI  INIT  PRIOR  PR type  SD  PHASE  env-variable  use dev  dev minyr  dev maxyr  dev stddev  Block Pattern
#Size-Selectivity for North Trawl (double normal)
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       1       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal

#Retention for North Trawl
```

```
5       70      23      27      -1      99      3       0       0       0       0       0       1       3       # infl_for_logistic
0.1     40      2       15      -1      99      3       0       0       0       0       0       0       0       #
95%width_for_logistic
0.0001  1       0.9     0.9     -1      99      3       0       0       0       0       0       1       3       # final
-3      3       0       0       -1      3       -4      0       0       0       0       0       0       0       # male_offset

#Size-Selectivity for South Trawl (double normal)
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       1       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal

#Retention for South Trawl
5       70      23      27      -1      99      3       0       0       0       0       0       2       3       # infl_for_logistic
0.1     40      2       15      -1      99      3       0       0       0       0       0       0       0       #
95%width_for_logistic
0.0001  1       0.9     0.9     -1      99      3       0       0       0       0       0       2       3       # final
-3      3       0       0       -1      3       -4      0       0       0       0       0       0       0       # male_offset

#Size-Selectivity for North non-trawl (double normal)
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal

#Retention for North non-trawl
5       70      23      27      -1      99      3       0       0       0       0       0       0       0       # infl_for_logistic
0.1     40      2       15      -1      99      3       0       0       0       0       0       0       0       #
95%width_for_logistic
0.0001  1       0.9     0.9     -1      99      3       0       0       0       0       0       0       0       # final
-3      3       0       0       -1      3       -4      0       0       0       0       0       0       0       # male_offset

#Size-Selectivity for South non-trawl (double normal)
```

```
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal
#Retention for South non-trawl
5       70      23      27      -1      99      3       0       0       0       0       0       3       3       # infl_for_logistic
0.1     40      2       15      -1      99      3       0       0       0       0       0       0       0       #
95%width_for_logistic
0.0001  1       0.9     0.9     -1      99      3       0       0       0       0       0       3       3       # final
-3      3       0       0       -1      3       -4      0       0       0       0       0       0       0       # male_offset

#Size-Selectivity for Triennial1
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       -7      -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal

#Size-Selectivity for Triennial2
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal
#Size-Selectivity for AK slope
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
```

```
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       -7      -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal
#Size-Selectivity for NW slope
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal
#Size-Selectivity for NW combo
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min dev_max dev_SD  Block   Block_Fxn
10      60      30      30      -1      5       2       0       0       0       0       0       0       0       #
SizeSel_3P_1_Type24_size_double-normal
-7      7       0       -0.5    -1      2       3       0       0       0       0       0       0       0       #
SizeSel_3P_2_Type24_size_double-normal
-5      10      3       1.75    -1      5       3       0       0       0       0       0       0       0       #
SizeSel_3P_3_Type24_size_double-normal
-5      10      5       0.1     -1      2       4       0       0       0       0       0       0       0       #
SizeSel_3P_4_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_5_Type24_size_double-normal
-999    15      -999    0       -1      5       -99     0       0       0       0       0       0       0       #
SizeSel_3P_6_Type24_size_double-normal
#
1 #_custom_sel-blk_setup (0/1)
#### BLOCK PARAMETERS FOR EACH FLEET
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
-10     10      0       0       0       5       4       #       Retain_1P_1_Trawl_N_BLK1delta_2007
-10     10      0       0       0       5       4       #       Retain_1P_1_Trawl_N_BLK1delta_2011
-0.5    0.5     0       0       0       0.2     4       #       Retain_1P_3_Trawl_N_BLK1delta_2007
-0.5    0.5     0       0       0       0.2     4       #       Retain_1P_3_Trawl_N_BLK1delta_2011
#
-10     10      0       0       0       5       4       #       Retain_2P_1_Trawl_S_BLK2delta_2007
-10     10      0       0       0       5       4       #       Retain_2P_1_Trawl_S_BLK2delta_2011
```

```
-0.5    0.5     0       0       0       0.2     4       #       Retain_2P_3_Trawl_S_BLK2delta_2007
-0.5    0.5     0       0       0       0.2     4       #       Retain_2P_3_Trawl_S_BLK2delta_2011
#
-10     10      0       0       0       5       4       #       Retain_4P_1_Non-trawl_S_BLK3delta_2007
-0.5    0.5     0       0       0       0.2     4       #       Retain_4P_3_Non-trawl_S_BLK3delta_2007
#
2 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds; 3=standard w/ no bound check)
#
0  # TG_custom
1 #_Variance_adjustments_to_input_values
#_fleet:
#1      2       3       4       5       6       7       8       9
0       0       0       0       0       0       0       0       0       #_add_to_survey_CV
0       0       0       0       0       0       0       0       0       #_add_to_discard_stddev
0       0       0       0       0       0       0       0       0       #_add_to_bodywt_CV
0.5595  0.9773  0.5422  0.4024  0.6812  0.6494  1       0.5126  1       #_mult_by_lencomp_N
1       1       1       1       1       1       1       1       1       #_mult_by_agecomp_N
1       1       1       1       1       1       1       1       1       #_mult_by_size-at-age_N
#
5  # max lambda phases: read this Number of values for each componentxtype below
1  # include (1) or not (0) the constant offset For Log(s) in the Log(like) calculation
#
3 # number of changes to make to default Lambdas (default value is 1.0)
# lambdas below are to mimic the old ballpark F approach of phasing out that component
#
# Like_comp codes:  1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch; 9=init_equ_catch;
# 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin; 17=F_ballpark
#like_comp fleet/survey  phase  value  sizefreq_method
17          999           2     0.1      999
17          999           3     0.01     999
17          999           5     0        999
#
0 # extra SD pointer
#
999  # end-of-file
```

Appendix D. SS starter file

```
# Shortspine Thornyhead starter file
# Ian Taylor and Andi Stephens, 2013
#
#  uses SSv3.24o (April 10, 2013)
#
SST_data.SS
SST_control.SS
0 # 0=use init values in control file; 1=use ss3.par
1 # run display detail (0,1,2)
1 # detailed age-structured reports in REPORT.SSO (0,1)
0 # write detailed info from first call to echoinput.sso (0,1)
0 # write parm values to ParmTrace.sso (0=no,1=good,active; 2=good,all; 3=every_iter,all_parms; 4=every,active)
0 # write to cumreport.sso (0=no,1=like&timeseries; 2=add survey fits)
1 # Include prior_like for non-estimated parameters (0,1)
0 # Use Soft Boundaries to aid convergence (0,1) (recommended)
3 # Number of datafiles to produce: 1st is input, 2nd is estimates, 3rd and higher are bootstrap
25 # Turn off estimation for parameters entering after this phase
0 # MCeval burn interval
1 # MCeval thin interval
0 # jitter initial parm value by this fraction
-1 # min yr for sdreport outputs (-1 for styr)
-2 # max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs
0 # N individual STD years
0.0001 # final convergence criteria (e.g. 1.0e-04)
0 # retrospective year relative to end year (e.g. -4)
1 # min age for calc of summary biomass
1 # Depletion basis:  denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
1 # Fraction (X) for Depletion denominator (e.g. 0.4)
1 # SPR_report_basis:  0=skip; 1=(1-SPR)/(1-SPR_tgt); 2=(1-SPR)/(1-SPR_MSY); 3=(1-SPR)/(1-SPR_Btarget); 4=rawSPR
1 # F_report_units: 0=skip; 1=exploitation(Bio); 2=exploitation(Num); 3=sum(Frates); 4=true F for range of ages
0 # F_report_basis: 0=raw; 1=F/Fspr; 2=F/Fmsy ; 3=F/Fbtgt
999 # check value for end of file
```

Appendix E. SS forecast file

```
# Shortspine Thornyhead forecast file
# Ian Taylor and Andi Stephens, 2013
#
#  uses SSv3.24o (April 10, 2013)
#
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0 for endyr, neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy
2 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)
0.5 # SPR target (e.g. 0.40)
0.4 # Biomass target (e.g. 0.40)
# Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter actual year, or values of 0 or -integer to be rel.
endyr)
 0 0 0 0 0 0
#  2010 2010 2010 2010 2010 2010 # after processing
1 # Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
#
1 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F (uses first-last relF yrs); 5=input annual F scalar
12 # N forecast years
0.20 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF  (enter actual year, or values of 0 or -integer to be rel. endyr)
 0 0 0 0
#  1180659524 1667592815 7631713 0 # after processing
1 # Control rule method (1=catch=f(SSB) west coast; 2=F=f(SSB) )
0.40 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40); (Must be > the no F level below)
0.10 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
#
# NOTE: 0.942 target below based on qlnorm(0.45, 0, sigma=0.4751487)
#       which is based on estimated SD of 2013 spawning biomass in base model
# UPDATE: better calculation provides new sigma 0.451 which leads to 0.945 below.
# UPDATE2: category 2 designation and P*=40% leads to qlnorm(0.40, 0, sigma=0.72): 0.833
#          category 2 designation and P*=45% leads to qlnorm(0.45, 0, sigma=0.72): 0.913
#          category 2 designation and P*=25% leads to qlnorm(0.25, 0, sigma=0.72): 0.615
0.833 # Control rule target as fraction of Flimit (e.g. 0.75)
3 #_N forecast loops (1=OFL only; 2=ABC; 3=get F from forecast ABC catch with allocations applied)
3 #_First forecast loop with stochastic recruitment
0 #_Forecast loop control #3 (reserved for future bells&whistles)
0 #_Forecast loop control #4 (reserved for future bells&whistles)
#-65534 #_Forecast loop control #5 (reserved for future bells&whistles)
0 #_Forecast loop control #5 (reserved for future bells&whistles)
2013  #FirstYear for caps and allocations (should be after years with fixed inputs)
0 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
2001 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
2011 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas(row) x fleet(col) below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
2 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio; 3=retainbio; 5=deadnum; 6=retainnum)
# max totalcatch by fleet (-1 to have no max) must enter value for each fleet
-1 -1 -1 -1
```

```
# max totalcatch by area (-1 to have no max); must enter value for each fleet
-1
# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an alloc group)
0 0 0 0
#_Conditional on >1 allocation group
# allocation fraction for each of: 0 allocation groups
# no allocation groups
0 # Number of forecast catch levels to input (else calc catch from forecast F)
2 # basis for input Fcast catch:  2=dead catch; 3=retained catch; 99=input Hrate(F) (units are from fleetunits; note new codes in
SSV3.20)
# Input fixed catch values
#Year Seas Fleet Catch(or_F)
2013  1    1     405.2 # average of 2011 and 2012
2013  1    2     307.2
2013  1    3      32.6
2013  1    4     207.5
2014  1    1     405.2 # average of 2011 and 2012
2014  1    2     307.2
2014  1    3      32.6
2014  1    4     207.5
999 # verify end of input
```