Stock Assessment and Status of Longspine Thornyhead (*Sebastolobus altivelis*) off California, Oregon and Washington in 2013

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Executive Summary

Stock

This assessment pertains to the longspine thornyhead (*Sebastolobus altivelis*) population located off the west coast of the continental USA, from the US/Canadian border in the north to the southern end of the Conception INPFC area (32.5° latitude). Longspine thornyheads have been reported from 200 meters (m) to as deep as 1,755 m, however 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 longspine thornyhead in 2005 (Fay, 2005).

Landings and Catch

Landings of longspine were modeled as a single coast-wide fishery. Very small amounts of longspine thornyhead are caught using gears other than trawl; this catch was combined with the trawl catch. Recreational fishery landings of thornyheads were negligible, so only commercial landings were included in the model.

The fishery for thornyheads increased gradually during the 1960s and 1970s, but did not expand significantly until the late 1980s with the development of a market for smaller thornyheads. At their peak in the early 1990s, annual landings were over 6,000 mt. Landings have declined in recent years in response to increased management restrictions. Landings in this assessment were estimated for the period 1964-2012.

Discard rates (landings divided by total catch) for longspine have been estimated as high as 46% per year, but are more frequently below 20%. Discard rates in the trawl fisheries observed by the West Coast Groundfish Observer Program (WCGOP) from 2003–2011 were less than 20%, except in 2009 when they were 28%. Discard rates have since dropped to less than 5% in 2011, the only estimate available under the catch shares program that began that year.

Table a: Recent Catches

Year	Catch (mt)
2003	1,886
2004	837
2005	792
2006	911
2007	956
2008	1,463
2009	1,375
2010	1,588
2011	972
2012	912

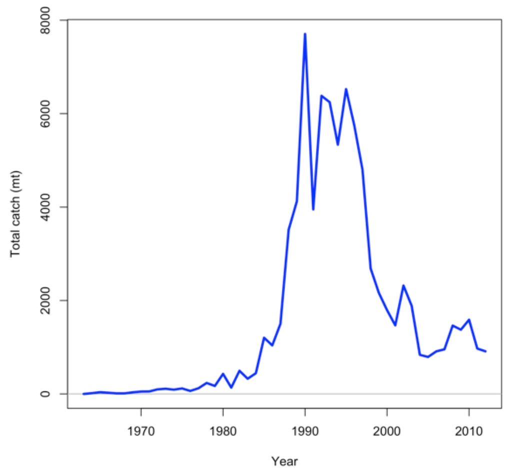

Figure a: Catch History

Data and assessment

This is the fifth stock assessment of West Coast longspine thornyhead. Previous stock assessments were conducted in 1990, 1992, 1994, 1997, and 2005. The most recent assessment, conducted by Gavin Fay in 2005, was the first to assess longspine thornyhead separately from shortspine thornyhead. Data sources included in the current assessment are:

1. Commercial landings (1964-2012) and length composition information (1978-2012) from California, Oregon and Washington obtained from the PACFIN database;
2. Commercial landings from the California Department of Fish and Wildlife (CDFW, 1934-1980);
3. Commercial landings from the Oregon Department of Fish and Wildlife (ODFW, 1932-1986);
4. Discard rates and length compositions from an Oregon State University observer study (Pikitch, 1985-87);
5. Discard rates from the Enhanced Data Collection Project (EDCP, 1995-99);
6. Discard rates, length compositions, and mean body weights from the West Coast Groundfish Observer Program (WGCOP, 2002-2011);
7. Biomass indices and length-composition information from the Alaska Fisheries Science Center (AFSC 1997, 1999-2001) and Northwest Fisheries Science Center (NWFSC, 1998-2002) FRAM slope surveys.
8. Biomass indices and length-composition information from the Northwest Fisheries Science Center (NWFSC, 2003-2012) combined shelf-slope survey.

These data were used to fit an age-structured population dynamics model using the length-age-structured model Stock Synthesis 3, version 24o (Methot 2005). Fixed parameters used in this assessment included a natural mortality rate (M) of 0.11, and Beverton-Holt steepness (*h*) of 0.6. Fishery and survey selectivities were estimated as asymptotic, with the exception of the AFSC slope survey, which is dome shaped.

For the majority of the data sources used in the previous assessment the data have 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 landings 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. As in the previous assessment, no age data is used in this analysis.

There are 103 estimated parameters in the assessment. The log of the unfished equilibrium recruitment, $\ln(R_0)$, controls the scale of the population. Annual deviations around the stock-recruit curve allow for uncertainty in the population trajectory, as well as in the selectivity and retention in the fishery and surveys.

Stock biomass

Total and spawning biomass of longspine thornyhead declined from the beginning of the modeled period, in 1964, until the late 1990s, with the rate of this decline being highest from the late 1980s until the mid to late-1990s due to peak catches during that period. Total biomass reached a low of 48,200 mt (compared to an unexploited level of 91,049 mt) in 1998, and spawning biomass reached a low of 18,184 mt (a depletion level of 46% of the unfished equilibrium level of 39,134). The stock, is currently only lightly exploited, and the current spawning biomass is estimated to be over 29,400 mt (a depletion of 75%), with a 95% confidence interval of 12,500 – 46,400 mt,.

The uncertainty in spawning biomass as output from the model is expressed as the standard deviation of the log of spawning biomass, which in 2013 is $\sigma = 0.29$, less than the $p^* = 0.72$ default minimum used in adjustments to OFL values for Category 2 stock assessments. Thus there is no evidence from the model that the default uncertainty assumption for this assessment is too low. The fact that it is well below the default assumption is not surprising given the necessarily fixed parameters in the model.

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
2001	18.5	8.2 - 28.8	47.20%	34.5% - 59.9%
2002	19.1	8.3 - 29.8	48.70%	35.3% - 62.1%
2003	19.4	8.1 - 30.1	49.50%	35.0% - 64.0%
2004	20.0	8.1 - 31.8	51.00%	35.5% - 66.5%
2005	21.1	86 - 33.5	53.80%	37.6% - 70.0%
2006	22.2	9.2 - 35.3	56.80%	40.0% - 73.7%
2007	23.4	9.8 - 37.1	59.90%	42.5% - 77.3%
2008	24.7	10.4 - 38.9	63.10%	45.0% - 81.1%
2009	25.7	10.9 - 40.5	65.70%	46.8% - 84.5%
2010	26.8	11.3 - 42.2	68.40%	48.8% - 88.0%
2011	27.7	11.7 - 43.7	70.80%	50.3% - 91.2%
2012	28.7	12.1 - 45.2	73.30%	52.2% - 94.5%
2013	29.4	12.5 - 46.4	75.20%	53.5% - 96.9%

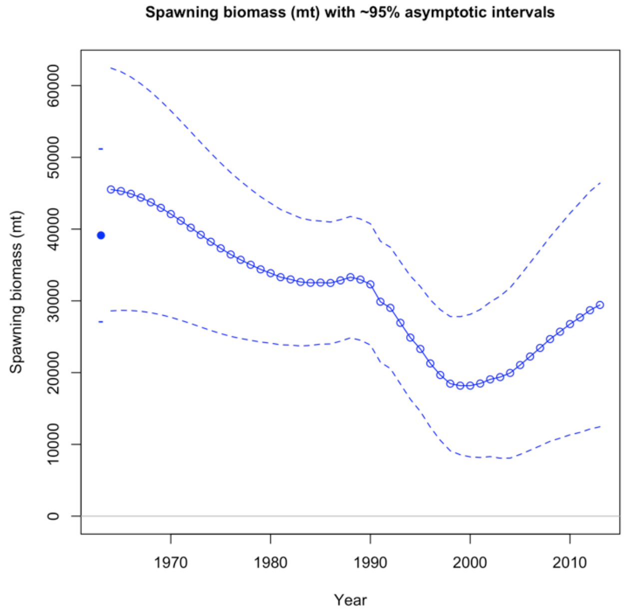

Figure b: Biomass trajectory

Recruitment

Expected annual recruitment was described by a Beverton-Holt function of spawning biomass. Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. The impact of recruitment variability on the biomass for longspine thornyhead is low due to the long-lived nature of the species. The bulk of the biomass for this stock is contained in a large number of old age-classes. In addition, no age data are available for this species (other than that used to estimate growth). Estimation of recruitment events is therefore difficult, and information is only available to estimate recruitment for recent years when size-composition data from the slope surveys are available (since 1997).

Table c: Recent recruitment

Year	Estimated recruitment (millions)	95% confidence interval
2001	196.4	95.1 - 405.7
2002	110.9	47.2 - 260.0
2003	256.3	13.4 - 490.6
2004	93.2	39.2 - 221.1
2005	118.0	54.7- 254.2
2006	101.1	47.4 - 216.0
2007	65.2	27.5 - 154.8
2008	72.4	31.2 - 167.7
2009	67.2	27.8 - 162.1
2010	68.5	27.5 - 170.5
2011	92.7	35.5 - 242.1
2012	132.6	41.6 - 422.6
2013	129.4	40.8 - 410.0

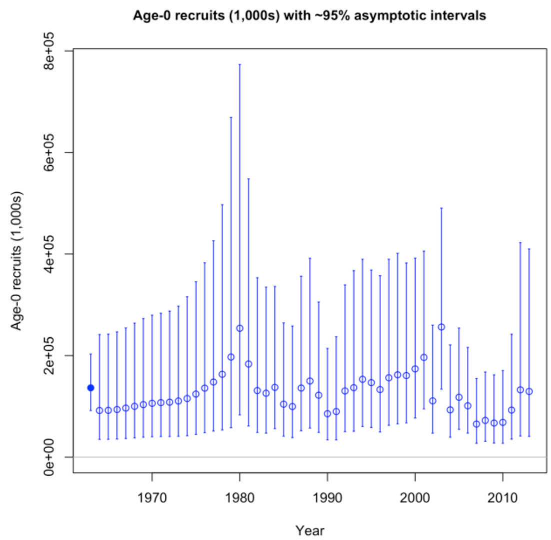

Figure c: Recruitment

Exploitation status

The 2013 spawning biomass of longspine thornyhead is estimated to be 75% of the unexploited equilibrium level. The stock is therefore well above the management target of $SB_{40\%}$. The current fishing mortality rate is also well below the F_{msy} proxy ($F_{50\%}$).

Table d. Recent trend in spawning potential ratio (entered as (1-SPR)/(1-$SPR_{50\%}$) and summary exploitation rate (catch divided by biomass of age-2 and older fish)

Year	Estimated (1-SPR) / (1-$SPR_{50\%}$)	~95% confidence interval	Harvest rate (proportion)	~95% confidence interval
2003	74.9%	46.6% - 103.2%	3.6%	1.5% - 5.7%
2004	41.4%	21.3% - 61.5%	1.6%	0.6% - 2.5%
2005	38.0%	19.3% - 56.8%	1.4%	0.6% - 2.2%
2006	40.7%	21.2% - 60.3%	1.5%	0.6% - 2.4%
2007	40.6%	21.2% - 60.0%	1.5%	0.6% - 2.4%
2008	54.0%	30.6% - 77.5%	2.3%	1.0% - 3.6%
2009	50.2%	27.8% - 72.5%	2.1%	0.9% - 3.3%
2010	54.2%	30.6% - 77.7%	2.4%	1.0% - 3.8%
2011	36.2%	18.5% - 53.8%	1.4%	0.6% - 2.3%
2012	33.2%	16.8% - 49.6%	1.3%	0.6% - 2.1%

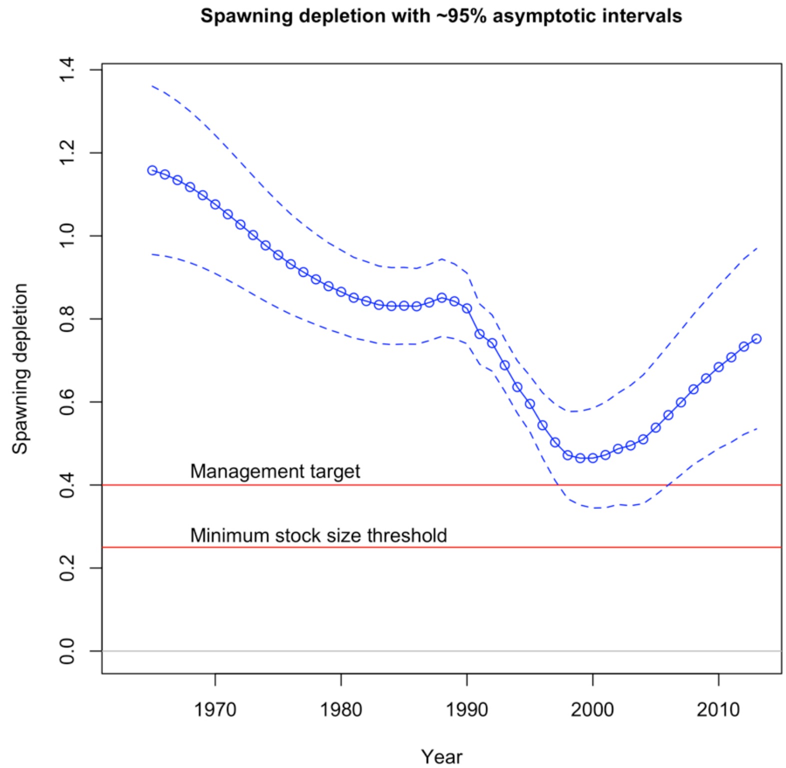

Figure d. Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

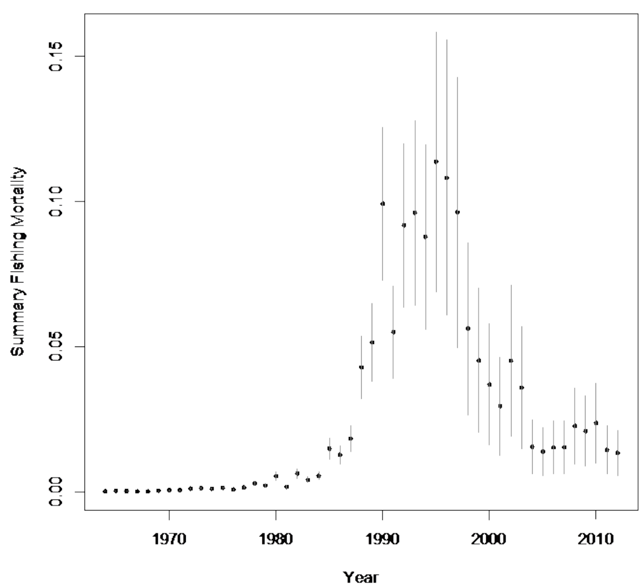

Figure e. Time-series of estimated summary harvest rate (total catch divided by age-2 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines).

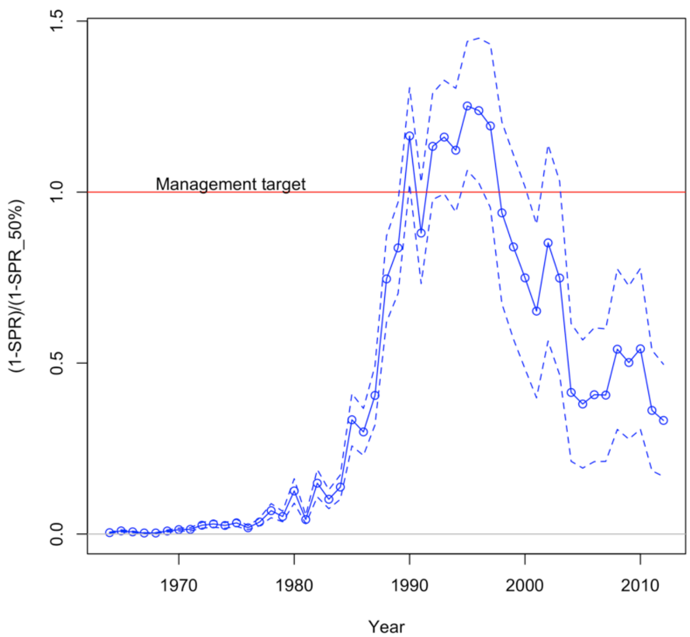

Figure f. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. The ratio shown in the figure is (1-SPR)/(1-$SPR_{50\%}$), which is twice (1-SPR). This ratio is chosen so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as the red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

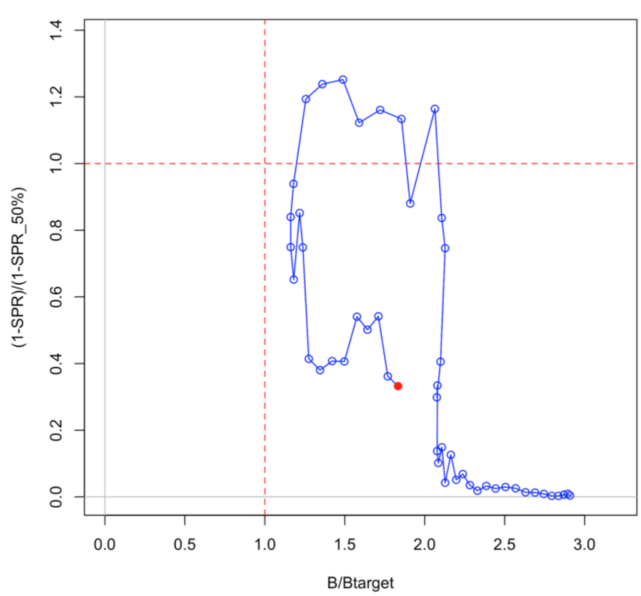

Figure g. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 1-$SPR_{50\%}$ (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished 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. Longspine thornyheads have been found in stomachs of shortspine thornyheads and sablefish, leading to the hypothesis that changes in abundance of these species could be linked through predation mortality. Because juvenile longspine thornyheads settle directly into adult habitat, there may be significant cannibalism, as well.

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. Longspine thornyheads are estimated to occur to a maximum depth of 1700 meters.

Unresolved problems and major uncertainties

The absence of a reliable ageing method provides a significant hindrance to estimating growth and natural mortality of longspine thornyhead. Uncertainty persists as to both the maximum age and asymptotic length of longspines, since various values of each have been reported in the literature. Additionally, the indices of abundance are all relatively flat, providing little information about the scale of the population. The Fay (2005) model estimated a much larger spawning biomass and a less-depleted stock (Figure 68), however that model did not provide estimates of uncertainty. 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 longspine catch, the current state of the population is likely to persist.

Reference points

Reference points were calculated using the estimated selectivity in the last year of the model (2012), and the estimated values are dependent on these assumptions. Sustainable total yield (landings plus discards) was estimated at 2,487 mt when using an $SPR_{50\%}$ reference harvest rate and ranged from 1,718- 3,256 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished spawning output ($B_{40\%}$) was 15,654 mt. The most recent catches (landings plus discards) have been lower than the lower confidence bound of potential long-term yields calculated using an $SPR_{50\%}$ reference point.

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

Quantity	Estimate	~95% confidence interval
Unfished Spawning biomass (mt)	39,134	(27,093 - 51175)
Unfished age 2+ biomass (mt)	91,049	(61,393 - 120,705)
Unfished recruitment (R0, millions)	136,529	(81,731 - 191,327)
Spawning biomass (2013)	29.4	(12.5 – 46.4)
SD of log Spawning Biomass (2013)	0.29	–
Depletion (2013)	75.2%	(53.5% - 96.9%)
Reference points based on $B_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	15,654	(10,837 – 20,471)
SPR resulting in $B_{40\%}$ ($SPR_{SB40\%}$)	50%	–
Exploitation rate resulting in $B_{40\%}$	0.06	(0.057 - 0.063)
Yield with $SPR_{50\%}$ at $B_{40\%}$ (mt)	2,487	(1,718 – 3,256)
Reference points based on SPR proxy for MSY		
Spawning biomass	15,654	(10,837 – 20,471)
SPR_{proxy}	50%	–
Exploitation rate corresponding to SPR_{proxy}	0.06	(0.057 - 0.063)
Yield with SPR_{proxy} at SB_{SPR} (mt)	2,487	(1,718 – 3,256)
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	13,108	(9,110 – 17,106)
SPR_{MSY}	44.6%	(44.4% - 44.8%)
Exploitation rate corresponding to SPR_{MSY}	0.071	(0.068 – 0.074)
MSY (mt)	2,529	(1,746 – 3,312)

Management performance

Catches for longspine thornyheads have not approached the catch limits in recent years. ACLs increased in 2007, however catch remained low. The fishery for longspine thornyhead may be limited by the ACLs on sablefish, with which they co-occur, and by the challenging economics of deep-sea fishing.

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

Year	OFL (mt)	ABC (mt)	Commercial Landings (mt)	Estimated Total Catch (mt)
2003	2,851	2,656	1,556	1,886
2004	2,851	2,656	689	837
2005	2,461	2,461	652	792
2006	2,461	2,461	750	911
2007	3,907	2696	810	956
2008	3,907	2696	1,243	1,463
2009	3,766	2626	1,171	1,375
2010	3,671	2560	1,359	1,588
2011	3,571	2495	926	972
2012	3,483	2430	871	912

Table g. Projection of potential OFL, landings, and catch, summary biomass (age-2 and older), spawning biomass, and depletion for the base case model projected with status quo catches in 2011 and 2012, and catches at the OFL from 2013 onward. The 2013 and 2014 OFL and ACL values are those specified by the PFMC and not predicted by this assessment. The OFL and ACL values in years later than 2014 is the calculated total catch determined by F_{SPR}.

Year	Predicted OFL (mt)	ACL Catch (mt)	Landings (mt)	Age 2+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2013	3,391	2,365	903	68,131	29,436	75%
2014	3,304	2,305	905	68,024	29,812	76%
2015	5,008	4,171	4,015	67,683	29,841	76%
2016	4,797	3,996	3,848	64,311	28,121	72%
2017	4,571	3,808	3,666	61,258	26,328	67%
2018	4,339	3,615	3,476	58,594	24,591	63%
2019	4,112	3,426	3,289	56,352	23,052	59%
2020	3,901	3,250	3,113	54,528	21,817	56%
2021	3,714	3,094	2,958	53,089	20,905	53%
2022	3,555	2,961	2,825	51,988	20,274	52%
2023	3,426	2,854	2,718	51,164	19,857	51%
2024	3,325	2,770	2,635	50,557	19,592	50%

Projections and Decision table

Axes of uncertainty for this assessment are the size of initial recruitment and the size of future catch. Initial recruitment is here represented by the log of the initial recruitment, LN(R_0). Table h displays the projected percent depletion and spawning biomass (in metric tonnes) for the base model using three values of LN(R_0), to represent three states of nature, and three catch streams.

The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.29$. The SSC assigned this longspine 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 longspine thornyheads, which leads to a multiplication of the OFL by 83.3%, which is the 40% quantile of a log-normal distribution with $\sigma = 0.72$.

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 was assumed to match the average values for 2011–2012 (the only years in which the trawl fishery was operating under IFQs). 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 942 mt and landings of 898 mt after applying the estimated retention function to the age structure of the population in 2013. The 942 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 75% in 2013 to 50% in 2024 (Table g), still above the 40% biomass target and 25% minimum stock size threshold. The associated OFL values over the period 2015–2024 would average 4,075 mt and the average ACL would be 3,395. 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 h). 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 the total catch, rather than landed catch, but discard rates were low under IFQs, so the difference 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. This was a total catch of 942 mt.

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 = 67% with a 83.3% adjustment to the OFL (based on the p* = 0.40 and sigma = 0.72). The average total catch for the years 2015–2024 was 942 mt for the low catch stream, 2,224 for the middle catch stream, and 3,394 for the high catch stream.

The stock status remained above 25% 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 31.58% in 2024. All other projections led to a higher projected status, with a maximum of 86.27% 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 50.06% in the high catch stream to 70.16% in the low catch stream.

Table h. Summary table of 12-year projections beginning in 2015 for alternate states of nature based on an axis of catch uncertainty. Columns range over low, mid, and high state of nature, and rows range over differing assumptions of catch levels. Depletion is the percentage of virgin spawning biomass represented by current spawning biomass. Spawning biomass is in metric tonnes.

			Low State $LN(R_0) = 11.5$		**Medium State $LN(R_0) = 11.8243$**		**High State $LN(R_0) = 12.3$**	
	Year	**Catch**	**Depletion (%)**	**Spawning Biomass**	**Depletion (%)**	**Spawning Biomass**	**Depletion (%)**	**Spawning Biomass**
Low Catch	2015	942	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	942	60.37%	18,734	75.57%	29,572	96.17%	54,924
	2017	942	59.22%	18,378	74.33%	29,090	94.66%	54,063
	2018	942	57.92%	17,974	72.84%	28,506	92.77%	52,982
	2019	942	56.83%	17,635	71.45%	27,960	90.84%	51,880
	2020	942	56.19%	17,437	70.43%	27,561	89.18%	50,932
	2021	942	56.05%	17,394	69.87%	27,343	87.94%	50,223
	2022	942	56.30%	17,472	69.72%	27,282	87.10%	49,745
	2023	942	56.82%	17,634	69.85%	27,333	86.57%	49,445
	2024	942	57.50%	17,845	70.16%	27,457	86.27%	49,272
Medium Catch	2015	2,453	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	2,420	58.17%	18,051	73.83%	28,893	94.99%	54,249
	2017	2,372	54.95%	17,052	70.97%	27,775	92.37%	52,757
	2018	2,315	51.76%	16,063	68.00%	26,611	89.48%	51,103
	2019	2,252	48.98%	15,200	65.28%	25,549	86.65%	49,490
	2020	2,189	46.87%	14,544	63.11%	24,698	84.22%	48,098
	2021	2,130	45.45%	14,103	61.56%	24,091	82.31%	47,007
	2022	2,078	44.60%	13,840	60.56%	23,698	80.90%	46,203
	2023	2,034	44.16%	13,704	59.96%	23,465	79.89%	45,630
	2024	2,001	43.99%	13,652	59.65%	23,344	79.18%	45,224
High Catch	2015	4,171	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	3,996	55.66%	17,274	71.86%	28,121	93.64%	53,481
	2017	3,807	50.25%	15,595	67.28%	26,328	89.86%	51,321
	2018	3,614	45.19%	14,025	62.84%	24,591	85.97%	49,098
	2019	3,425	40.86%	12,680	58.91%	23,052	82.32%	47,016
	2020	3,249	37.49%	11,633	55.75%	21,817	79.22%	45,245
	2021	3,093	35.05%	10,878	53.42%	20,905	76.79%	43,857
	2022	2,961	33.40%	10,365	51.81%	20,274	74.98%	42,825
	2023	2,853	32.30%	10,025	50.74%	19,857	73.68%	42,079
	2024	2,770	31.58%	9,799	50.06%	19,592	72.74%	41,545

Research and data needs

Research and data needs for future assessments include the following:

1) Age and growth information are needed 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.

   This could involve investigation of biochemical aging methods, for example an analysis of telomere length in relation to body length.

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. Further exploration of perceived differences in catchability (*q*) between towed cameras and trawl nets should also be explored.
3) More tows or visual surveys south of 34.5 deg. N. latitude. Because the southern Conception Area is a large potential habitat for thornyheads, more effort should be directed to describing their distribution in this area, for inclusion in future assessments.
4) An investigation of the possible discontinuity in the reconstructed thornyhead historical catches would be useful for future assessments.

Table i. Summary table of the results.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Commercial landings (mt)	1,556	689	652	750	810	1,243	1,171	1,359	926	871	NA
Estimated Total catch (mt)	1,886	837	792	911	956	1,463	1,375	1,588	972	912	NA
OFL (mt)	2,851	2,851	2,461	2,461	3,907	3,907	3,766	3,671	3,571	3,483	3,391
ACL (mt)	2,656	2,656	2,461	2,461	2,696	2,696	2,626	2,560	2,495	2,430	2,365
1-SPR	37.43	20.70	19.01	20.37	20.31	27.02	25.08	27.08	18.08	16.61	37.43
Exploitation rate (catch/ age 2+ biomass)	0.036	0.015	0.014	0.015	0.015	0.023	0.021	0.024	0.014	0.013	0.070
Age 2+ biomass (mt)	52.53	54.00	56.97	59.54	62.13	64.41	65.83	66.96	67.40	67.94	68.13
Spawning Biomass	19.4	20	21.1	22.2	23.4	24.7	25.7	26.8	27.7	28.7	29.4
~95% Confidence Interval	8.1 - 30.1	8.1 - 31.8	86 - 33.5	9.2 - 35.3	9.8 - 37.1	10.4 - 38.9	10.9 - 40.5	11.3 - 42.2	11.7 - 43.7	12.1 - 45.2	12.5 - 46.4
Recruitment	256.3	93.2	118.0	101.1	65.2	72.4	67.2	68.5	92.7	132.6	129.4
~95% Confidence Interval	13.4 - 490.6	39.2 - 221.1	54.7- 254.2	47.4 - 216.0	27.5 - 154.8	31.2 - 167.7	27.8 - 162.1	27.5 - 170.5	35.5 - 242.1	41.6 - 422.6	40.8 - 410.0
Depletion (%)	0.495	0.51	0.538	0.568	0.599	0.631	0.657	0.684	0.708	0.733	0.752
~95% Confidence Interval	35.0% - 64.0%	35.5% - 66.5%	37.6% - 70.0%	40.0% - 73.7%	42.5% - 77.3%	45.0% - 81.1%	46.8% - 84.5%	48.8% - 88.0%	50.3% - 91.2%	52.2% - 94.5%	53.5% - 96.9%

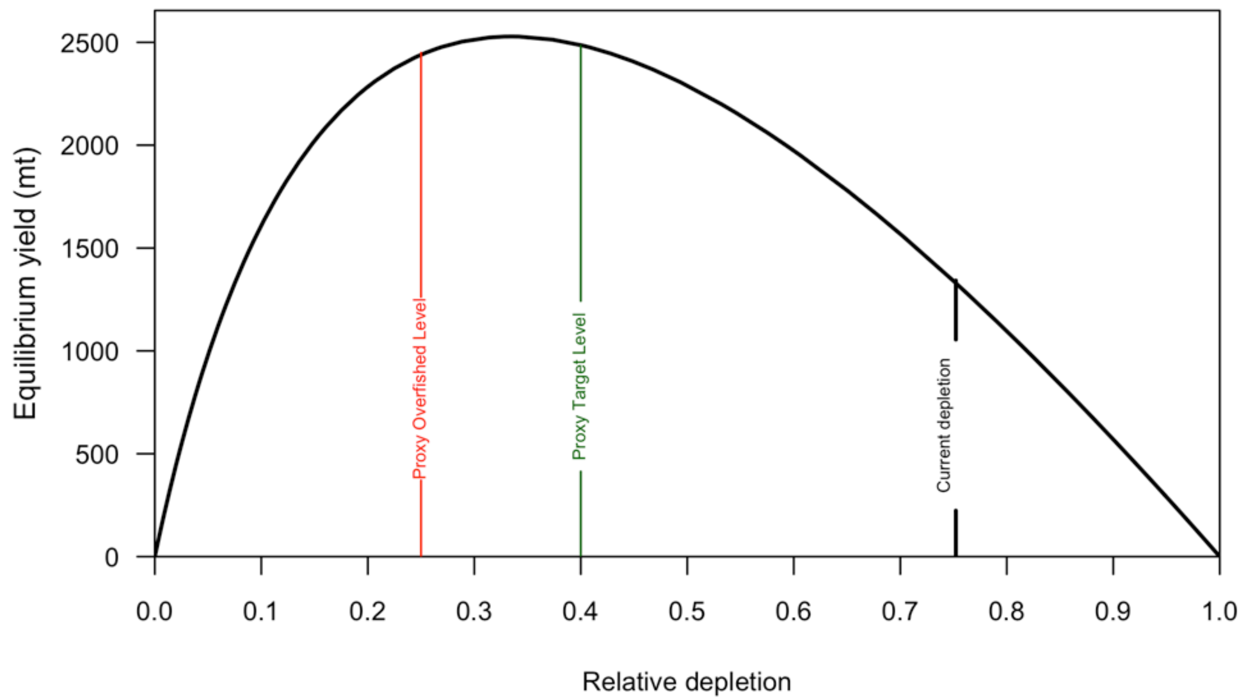

Figure h. Equilibrium yield curve (derived from reference point values reported in Table i) for the base case model. Values are based on 2010 fishery selectivity and distribution with steepness fixed at 0.6. The depletion is relative to unfished spawning biomass.

1 Introduction

This is an assessment of the longspine thornyhead (*Sebastolobus altivelis*) stock along the west coast of the continental USA. The analyses presented here follow the previous assessment (Fay 2005) by considering longspine thornyheads separate from shortspine thornyhead (*S.alascanus*), although the two species made up a single market category in the historical fishery, they are often difficult to separate in early landings data, and are similar in many respects (Jacobson and Vetter 1996, Bradburn et al., 2011).

Longspine thornyhead (*Sebastolobus altivelis*) is a rockfish species belonging to the genus *Sebastolobus* in the Scorpaenidae family. Its scientific name '*altivelis*' means "high sail", which describes the tall dorsal fin that distinguishes it from the shortspine thornyhead (*Sebastolobus alascanus*). Longspine thornyhead is a slow growing fish that lives in deep benthic waters, concentrating in the oxygen minimum zone (OMZ) and where water pressure is high. This species ranges from Cabo San Lucas, Baja California, to the Aleutian Islands.

1.1 Basic Information

Longspine thornyhead occur from the southern tip of Baja, California, to the Aleutian Islands (Jacobson and Vetter 1996, Orr et al. 1998). There appears to be no distinct geographic breaks in stock abundance along the west coast (Rogers *et al*. 1997, Fay 2005). Adult longspine thornyhead are bottom dwellers, and inhabit the deep waters of the continental slope throughout their range (see map, Figure 1 and 2.).

Bottom trawl surveys and camera sled observations show that longspine occur at depths greater than 600 m, with a distribution to about 1700 m depth (e.g., Love et al. 2005), and a peak in abundance and spawning biomass in the oxygen minimum zone (OMZ) at about 1000 m depth (Wakefield 1990; Jacobson and Vetter 1996). Longspine are better adapted to deep water than shortspine (Siebenaller 1978; Siebenaller and Somero 1982). Wakefield (1990) estimated that in Central California, 83% of the longspine population resides within an area of the continental slope bounded by 600 and 1,000 m depth.

Unlike shortspine thornyhead, the mean size of longspines is similar throughout the depth range of the species (Jacobson and Vetter 1996). Camera sled observations indicate that longspines do not school or aggregate, and are distributed relatively evenly over soft sediments (Wakefield 1990). Differences in density of individuals at depth do occur with latitude however, with higher densities of longspine in deep water (1000-1400 m) off Oregon than off central California (Jacobson and Vetter 1996).

The strong relationship between depth and size found in shortspine thornyhead (Jacobson and Vetter 1996) is not observed for longspines, with the distribution of longspines being relatively uniform with depth (Rogers et al. 1997). Unlike shortspines, longspine do not undergo an ontogenetic migration to deeper waters (Wakefield 1990.

1.2 Life History

Longspine thornyheads prefer muddy or soft sand bottoms in deep-water environments characterized by high pressure and low oxygen concentrations. These are low productivity (Vetter and Lynn 1997) and low diversity (Haigh and Schnute 2003) habitats where food availability is limited. Longspines have adapted to this environment with an extremely slow metabolism that allows it to wait up to 180 days between feedings (Vetter and Lynn 1997). They are not territorial, and do not school. They have no swim bladders; instead oil in the bones and spines provides floatation. Video observations from submersibles and ROVs indicate that thornyhead are sit-and-wait predators that rest on the bottom and remain motionless for extended periods (John Butler, NOAA Fisheries, Southwest Fisheries Science Center, CA, as cited in Jacobson and Vetter 1996).

1.2.1 Spawning and early life history

The spawning season for longspine thornyheads appears to be extended, and occurs over several months during February, March and April (Pearcy 1962; Best 1964; Moser 1974; Best 1964; Wakefield and Smith 1990). Both thornyhead species produce a bi- lobed jellied egg mass that is fertilized at depth and which then floats to the surface where final development and hatching occur (Pearcy 1962). An extended larval and pelagic juvenile phase follows, which is thought to be 18-20 months long (Moser 1974; Wakefield 1990). Juvenile longspine settle on the continental slope at depths between 600 and 1200 m (Wakefield 1990). Moser (1974) reports a mean length at settlement of 4.2-6.0 cm, although pelagic juveniles up to 69 mm in length have been collected in midwater trawls off Oregon (J. Siebenaller unpubl. data, as cited in Wakefield and Smith 1990).

Following settlement, longspine thornyhead are strictly benthic (Jacobson and Vetter 1996). No apparent pulse in recruitment during the year was observed by Wakefield and Smith (1990), perhaps due to the long spawning season, variation in growth rates, and variation in the duration of the pelagic period (Wakefield and Smith 1990). There is potential for cannibalism because juveniles settle directly on to the adult habitat (Jacobson and Vetter 1996).

1.2.2 Fecundity and maturity

Estimates for reproductive parameters of longspine thornyheads are difficult to obtain, due to difficulties in assessing maturity stage without histological examination (Pearson and Gunderson 2003). Estimates of the length at 50% maturity based on histological examinations are provided by Jacobson (1991, N=120) and Pearson and Gunderson (2003, N=239). Ianelli *et al.* (1994) used visual estimates of maturity stage to model maturity at length (N=3,738). Table 7 lists the parameter values provided by these studies. The length at which 50% of females are mature ranges from 18-22 cm, which corresponds to ages of approximately 12-15 years.

Adult females release between 20,000 and 450,000 eggs over a 4-5 month period (Best 1964; Moser 1974). Wakefield (1990) and Cooper *et al.* (2005) both found linear relationships between fecundity and somatic weight. The data analysed by Cooper *et al.* (2005) indicated that fecundity of longspine between 20 and 30 cm in length ranged from 20,000 to 50,000 eggs.

This assessment used the parameter values obtained by Pearson and Gunderson (2003) to determine the maturity at length, as these values were determined from histological samples, used individuals collected from locations throughout the west coast, and were based on a larger sample size than the histology estimates provided by Jacobson (1991).

1.2.3 Age and growth

There is considerable uncertainty regarding age and growth of thornyheads (Jacobson and Vetter 1996), although data indicate that longspine thornyhead are long lived. Age estimates of over 40 years have been obtained from otoliths using thin-section and break- and-burn techniques (Ianelli et al. 1994). High frequencies of large longspine thornyheads may be due to a strongly asymptotic growth pattern, with accumulation of many age groups in the largest size-classes (Jacobson and Vetter 1996).

Size-at-age data (Ianelli et al. 1994) indicate that longspine grow to a maximum size of about 30cm TL at ages of about 25-45 years, with little or no sexual dimorphism in length at age – longspines in British Columbia, Canada also display no sexual dimorphism (Starr and Haigh 2000). Orr et al. (1998) report a maximum length for longspines of 38 cm, although individuals of this size are rare in both trawl surveys and commercial landings. Growth increments on otoliths suggest that juveniles reach 80 mm after 1 year of life as demersal juveniles (Wakefield unpubl. data, as cited in Wakefield and Smith 1990), which would correspond to an age of 2.5 - 3 years old.

Estimates of mean length at age for longspine, based on the Von Bertalanffy growth curve, have been published by Jacobson (1991, N=192) and Kline (1996, N=478). The data used by Jacobson (1991) originated from fish in port samples of commercial landings in Oregon, and ages were obtained from sectioned otoliths (Jacobson 1991). Length and age data used by Kline came from California during 1990-1991. The length and age observation pairs for these two curves were analyzed together with additional data (Donna Kline, Moss Landing Marine Laboratory, pers. comm.) for the 2005 assessment to obtain a third growth curve based on a larger sample size (N=815). The parameter values and associated estimates of variability of length at age used for this assessment were those obtained from the analysis of the larger dataset, conducted for the 2005 (Fay) assessment (Table 7).

1.2.4 Natural mortality

The longevity of longspine thornyheads is uncertain. The species appears to be long- lived, although not as much so as shortspine. The maximum age reported by Jacobson et al. (1990) was 45 years, which, according to the authors, corresponds to a rate of natural mortality, M of 0.1 per year. In their 1994 assessment, Ianelli et al. used a range for M of 0.08 – 0.12 per year. Recently, Pearson and Gunderson (2003) obtained a much lower estimate of 0.015 per year for M from a prediction model based on a gonadal somatic index (GSI). This value for M would suggest that longevity of longspines is much greater than the maximum ages previously measured, and given the growth information presented above, that a large proportion of the population would be near the asymptotic length. Food habits data indicate that predation mortality on adult longspine thornyheads is lower than that on juveniles, and the low mortality rate calculated by Pearson and Gunderson (2003) for adults could reflect an age-dependent mortality determined by predation risk.

For this assessment, a prior on natural mortality was developed based on a maximum age of 100 years which had a mean of 0.1113 and a standard deviation on a log scale of 0.5206 (Hamel, pers. comm.). For the base case, natural mortality was fixed at the mean of this prior distribution.

1.3 Ecosystem Considerations

Longspine and shortspine thornyheads have different but overlapping depth ranges (Jacobson and Vetter 1996), and, due to the bathymetric demography of shortspines, it is frequently larger specimens of this species that are found with longspines. As such, the two species do not tend to be the same size at the same depth. However, there is some overlap in size at the shallower end of the longspine bathymetric distribution.

Settled longspine thornyheads are prey for both sablefish (*Anoplopoma fimbria*), and large shortspine, and longspine are common in stomach samples of both species (Laidig et al. 1997; Buckley et al. 1999). Size distribution data for longspines found in sablefish and shortspine stomachs indicate a high incidence of predation by these species on settled juvenile longspine, with longspine above 20cm rare in stomach data (Laidig et al. 1997, Buckley et al. 1999). These two species are predators of longspine thornyheads on the continental slope, suggesting that the rate of predation mortality could be lower for adult longspine than for juveniles. There may also be cannibalism, because juveniles settle directly on to the adult habitat (Jacobson and Vetter 1996).

Thornyheads are captured with Dover sole (*Microstomus pacificus*) and sablefish. The peak spawning biomass for these two species also occurs in the OMZ.

1.4 Fishery Information

Longspine thornyhead are exploited in the limited entry deep-water trawl fishery operating on the continental slope that also targets shortspine thornyhead, Dover sole and sablefish. A very small proportion of longspine landings are due to non-trawl gears (gillnet, hook and line), primarily in

California. Longspine and shortspine thornyhead make up a single market category. The thornyhead fishery developed in Northern California during the 1960s, with early landings being primarily from the Eureka INPFC area. The fishery then expanded north and south, and the majority of the landings of longspine thornyhead have since been in the Monterey, Eureka, and Columbia INPFC areas, with some increase in landings from the Conception and Vancouver INPFC areas in recent years.

Landings of longspine thornyhead averaged about 100 mt in the 1970s, rose steadily in the 80s, and peaked at 5,870 mt in 1990. Landings have decreased since, to annual landings of around 2,000-2,500 mt (Figure 4). Average landings over the last ten years have been just over 1,000 mt (Figure 4,Table 3).

The markets for longspine thornyheads along the west coast developed at different rates than for shortspine (Rogers *et al.* 1997). A primarily domestic market for thornyheads developed in the Eureka INPFC area in California during the early 1960s. Initially, thornyheads were sold with other rockfish under a variety of names. Large thornyheads (minimum size 12-14 inches) were trimmed and sold as ocean catfish, and also later sold filleted as Skin-on Perch. Due to size restrictions, there was little market for the smaller longspines, and these early fish were primarily shortspine. Smaller fish began to be taken by processors in Eureka during the late 1970s, and by the early 1980s, the minimum marketable size was 10 inches. This decrease in the minimum marketable size for thornyheads probably facilitated the development of the fishery for longspines.

An export market for thornyheads developed during the late 1980s because a similar species, *S. macrochir*, was depleted off Japan. As the Japanese market developed, processors began accepting fish as small as 7-8 inches, and landings of the smaller longspine thornyhead increased. As the market for smaller longspine developed, the trawl fishery moved into deeper water where longspine thornyheads are more common.

Trends toward deep-water fishing, higher prices, and increased landings for thornyheads occurred later in Oregon and Washington than in California (Rogers *et al.* 1997). A coastwide minimum marketable size of 10 inches was apparently in effect during 1990. However, this was replaced by a two-tiered price structure in 1991 (Pete Leipzig, Fishermen's Marketing Association, as cited by Jacobson, 1991). Marketing of thornyheads in Oregon as Skin-on Perch with a 10-inch minimum limit continued until about 1992 (Whitey Forsman, Pacific Coast, Warrenton OR, as cited by Rogers *et al*. 1997).

Exvessel prices for thornyheads increased substantially in 1994 and in 1995, although these have decreased since. The 1994 increase was likely a result of increased management restrictions on catches, and changes in the relative value of the Japanese yen and US dollar (Whitey Forsman, Pacific Coast, Warrenton OR, as cited by Rogers *et al.* 1997).

In 1997, processors coastwide imposed an 8-inch minimum size limit for thornyheads (Jay Bornstein, Bornstein Seafoods, Bellingham, WA; Whitey Forsman, Pacific Coast, Warrenton OR; Jerry Thomas, Eureka Fisheries, CA, all as cited by Rogers *et al.* 1997). Up to seven size categories had different prices, and longspines had lower prices than shortspines of the same size, due to both a lower condition factor (lower weight at length) and coloration differences in skin and flesh.

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).

1.5 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 were instituted in 1992, coincident with a change in mesh size from 3 to 4.5 inches. In 1995, separate landing limits were placed on shortspine and longspine thornyheads and trip limits became more restrictive. Trip limits (generally, limits on 20-month cumulative landings) have often been adjusted during the year since 1995 in order to not exceed the harvest guidelines or optimal yield for that year.

Although the depth range for longspine extends well beyond the depths at which shortspine are most abundant, no management options have been available for specifying higher longspine limits only in the zone where they could be caught with minimal coincident catch of shortspines. Since early 2011, trawl harvest of each thornyhead species has been managed under the PFMC's catch share, or individual quota, 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.

1.6 Management Performance

Landings of longspine thornyhead have been below the catch limits since 1999. Estimated total catch, including discards, has likewise remained below the limit during this period (Table 3).

1.7 Fisheries off Canada, and Alaska

The Alaska Fishery Science Center conducts assessments of thornyheads as a mixed-stock complex, including shortspine and longspine thornyheads. Broadfin thornyheads (*S. macrochir)* were formerly believed to have been caught with shortspines in the Gulf of Alaska, but this is now thought to have been misidentification of shortspines. 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).

Fisheries and Oceans Canada lists longspine thornyhead as a species of special concern under the Species at Risk Act (SARA), noting that the primary threat to the species is commercial fishing. The fishery is managed by Total Allowable Catches (TACs), Individual Vessel Quotas (IVQs) and 100% at-sea and dockside monitoring (Fisheries and Oceans Canada, 2012).

2 Assessment

2.1 Data

An overview of all data time-series used in this assessment is given in Figure 3.

2.1.1 Biology

Natural mortality and longevity

Lifespan for longspine thornyheads is believed to be in the range of 35-45 years (Jacobson and Vetter 1996, Ianelli et al., 1994). Previous assessments investigated M in the range 0.015-0.12 (Fay, 2005, Ianlli et al., 1994). For this assessment, a prior on natural mortality was developed based on a maximum age of 45 years, with a mean of 0.11131 and standard deviation on a log scale of 0.5208 (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 longspine thornyheads was retained from the previous assessment (Fay, 2005). Longspines are not believed to have dimorphic growth; therefore a single relationship was used for both males and females. The mean weight at length is given by: $W(L) = 4.30E\text{-}06\ L^{3.352}$ (Table 7, Figure 10).

Length at age

No new age data or information on growth or length at age has been developed since the previous assessment. The Von Bertalanffy K was previously set to 0.064; this is estimated to be 0.109 in the present model. The length at age 3 is set to 11 cm, and the average length at age 40 is estimated to provide the best fit to the data at 27.8 cm. Values are given in Table 6 and Table 7.

Maturation and fecundity

Pearson and Gunderson (2003) estimated length at 50% maturity for longspines to be 17.83 cm on the West coast, with most females maturing between 17 and 19 cm (Figure 11). This was represented in the previous assessment by the logistic function: $mat(L) = (1+e^{-1.79(L-17.826)})^{-1}$, where *L* is the length in cm (Table 7, Figure 12).

2.1.2 Catch History

PacFIN data from 1981-present for all gears was used to estimate landings in the fishery. All landings reported for the longspine and nominal longspine categories were considered longspine, whereas landings placed in the thornyheads category were divided between longspine and shortspine by the ratio of categorized longspine and shortspine landings for the entire coast. The values of this ratio from 1981-2012 are shown in Figure 5.

Catches prior to 1981 were set equal to those used in the Fay (2005) model, rather than to the reconstructed history provided by CDFW and ODFW for most West Coast assessments. The 2013 shortspine and longspine thornyhead assessments were prepared together. In the previous shortspine assessment, the numbers reported as domestic catch were much, much higher in the late 60s through the mid-70s than the total of the reconstructed catch, differing by hundreds of metric tons/year. Those higher landings had been in all previous assessments. In the longspine reconstructed catch, there was a distinct jump from very low levels to much higher levels that seemed unlikely (Figure 6).

In order to provide realistic catch streams, and consistency with previous peer-reviewed assessments, catches prior to 1981 were set equal to those used in the previous model. A sensitivity (Figures 58-59) using the historical catch reconstructed estimates (Ralston et al., 2010) was conducted during the STAR panel, and the recommendation from the panel (for both species) was to use past assessment estimates (see STAR panel report).

2.1.3 Discards/Retention

Discard rates (defined as the weight discarded divided by the total caught weight (i.e. discarded plus retained weight)) for longspine thornyhead likely changed with changes in market price-at-size and acceptable minimum size over the course of the fishery. Management restrictions in place from the mid-late 1990s may have also affected the discarding of longspine. Discard data are summarized in Table 2.

Data from the Pikitch study (Pikitch et al., 1988), conducted in Oregon, were provided for the years 1985-1987 (John Wallace, pers. comm.). These provide the single highest discard rate, 45% in 1987.

No longspine thornyhead length measurements were available to associate with the 1985-1987 discard rates estimate in the Pikitch discard study. However, an associated mesh size study that took place in the production fishery in 1988-1990 included length measurements for longspines. To make the data from the two studies more comparable, length-compositions from the mesh size study were created by weighting the longspine thornyhead length observations by using the ratio of mesh sizes by-tow seen in the production fishery based discard database to those seen in the mesh database (J. Wallace, pers. comm.). That is, samples from the mesh size study that were collected with mesh sizes less commonly seen in the fishery were given lower weight than the more common mesh sizes.

The discard estimates from the EDCP program were assumed to be equal to those in the previous assessment because the data necessary for recalculating these rates and the associated length compositions was not available in time to be included in the document. Helser *et al.* (2002) analyzed data from the Enhanced Data Collection Project (EDCP) to produce discard estimates for longspine by INPFC area for the years 1995-1999. Values during these years are in the range 10-20%.

Discard rates were also available from the West Coast Groundfish Observer Program (WCGOP) for the years 2002-2011. These ranged from 29% to 5%, though the average over this period was 17%. The lowest value in the range occurred in 2011, when the catch shares program (i.e., 100% observer coverage) was implemented.

2.1.4 Mean body weights

Information from the WCGOP was compiled to obtain estimates of mean body weight. No estimates of variance were associated with these data (Figure 16).

2.1.5 Length Compositions

Fishery length-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.

PacFIN length data for males, females and unsexed fish were combined, since the majority of the sampled fish were not sexed. Only randomly collected samples from PacFIN were used.

Length compositions from the Pikitch study were available for 1988-1990. Length compositions from the WCGOP covered the years 2005-2011, however there was only one sample lengthed in 2005, so that sample was disregarded. There were length compositions for each year of the AFSC and NWFSC surveys, however fish appear to have been reliably sexed only from 2005 onward. The NWFSC lengths for 2005-2012 are the only lengths entered by-sex in the model. Length composition sampling effort is summarized in Table 5. The ratio of females to males is .51 overall with little variation, so gender is not explicitly reported.

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”. This can be seen in the spatial distribution of WCGOP catch in Figure 9. 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).

2.1.6 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. No production ageing of thornyheads is undertaken at this time for the West Coast, although longspine thornyhead otoliths are routinely collected in the NWFSC trawl survey. The Alaska Fisheries Science Center does not attempt ageing thornyheads.

2.1.7 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. In 2004, the Northwest Fisheries Science Center (NWFSC) conducted the triennial survey. This survey contributes to many of the West Coast stock assessments, however it did not extend into longspine habitat and is not included here.

The AFSC began a slope survey in the 1980s, however the annual geographic coverage was very limited until 1996, and that data is not used in the current assessment. Starting in the late 1990s, two slope surveys that do inform this assessment were conducted on the West Coast, one using the research vessel Millar Freeman, the “AFSC Slope Survey”, which ended in 2001, and the other a cooperative survey using commercial fishing vessels, conducted by NWFSC, the “NWFSC Slope Survey” which covered the years 1998–2002.

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. Ninety-seven percent (97%) of all tows deeper than 500 m from this survey have longspine thornyheads in the catch (Figure 8). 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 and latitudinal range, and the most consistent groundfish sampling program in the history of west coast scientific data collection. 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 three fishery-independent surveys are used in this assessment (Table 4). 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 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 considered for the positive tows. Model convergence was evaluated using the effective sample size of all estimated parameters (typically >500 of more than 1000 kept samples indicates convergence).

2.1.8 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 landings from 1981-2012.

Catch (1981-2012) and length-composition data (1978-2012) were updated from PacFIN. This data was extracted on May 23, 2013. Catches prior to 1981 were set equal to those used in the previous model.

Biomass indices and length compositions for the AFSC slope survey (1997, 1999-2001) were used in this assessment. Biomass indices and length compositions for the NWFSC slope survey (1998-2002) were used in the assessment, as were biomass indices and length compositions for the NWFSC Combo survey (2003-2012) . The entire time series of each slope survey index was re-calculated using GLMM modeling software produced by Thorson and Ward (2013). The NWFSC length composition data were extracted on March 28, 2005.

2.1.9 Environmental and Ecological Data

No ecological or environmental information was used in this assessment.

2.2 History of Modeling Approaches Used for this Stock

This is the 5th stock assessment of west coast longspine thornyhead, but only the second in which it was assessed individually. Most assessments of thornyheads have treated longspine and shortspine thornyheads as a single stock. Previous assessments were conducted by Jacobson (1990, 1991), Ianelli *et al.* (1994), Rogers *et al.* (1997), and Fay (2005). The 1990 and 1991 assessments were very similar. Important features included reviews of available biological data, and analyses of trends in mean lengths from port samples and catch rates calculated from logbook data. Swept-area and video biomass estimates were used to estimate average biomass levels and exploitation rates in the Monterey to US-Vancouver management areas. The available data were used to conduct per-recruit analyses of yield, revenue, and spawning biomass, and to develop estimates of the then target level of $F_{35\%}$.

The 1994 assessment used coast-wide abundance estimates based on slope survey data, an updated analysis of the logbook data, and fishery length-composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The 1997 assessment by Rogers *et al.* used a length-based version of Stock Synthesis 1 to fit an age-structured model to data for the Monterey, Eureka, Columbia and Vancouver INPFC areas. Models were fitted to biomass estimates and length data from the AFSC slope surveys (1988-1996), a logbook CPUE index, discarded proportions by year, and length composition data from California and Oregon. Sensitivity to discard rates based on changes in prices and minimum size were explored.

The 2005 assessment fit an age-structured model to longspine thornyheads using Stock Synthesis 2, and identified the catchability of the slope surveys (Fay combined the then-brief NWFSC survey with the AFSC survey) as the primary source of uncertainty in the model. Sensitivity analyses involved the use of different combinations (inclusions and exclusions) of landings data sources and survey biomass estimates, as well as estimations of natural mortality and steepness. Model outcomes from this analysis were significantly more optimistic than those from 1997, likely due to assumptions regarding selectivity of the slope survey and to the inclusion of data from the INPFC Conception area.

It is worth noting that the use of the pre-1996 data was only feasible through combining data from multiple years into 'super-years', in order to achieve reasonable spatial coverage. This practice was used consistently whenever the AFSC slope survey was included in assessments up until 2005 or 2007. Given inter-annual changes in ocean conditions, that practice (and the inclusion of those early years) has been abandoned, now that longer, more-reliable survey time-series are available.

2.2.1 2005 STAR Panel recommendations

Many of the STAR Panel suggestions from 2005 are outside the scope of this assessment, as they involve investigations into otolith annuli signals, or using towed cameras to investigate habitat.

Including the length compositions of discards was among the recommendations that could be addressed; they are in the current model. Some analysis of Q values has been part of model selection for the base case. Q was found to be quite sensitive to changes in initial recruitment; see Figure 62.

The star panel suggested investigating the implications of having two natural mortality rates, blocked in the region above and below 15 or 20 cm. Initial investigation of this in a model with fixed early M (0.11131) and allowing M for older fish to be estimated as an offset resulted in an improved total likelihood (128.591 vs. 135.264 in the base model), but a seeming lack of convergence. Mortality of older fish was estimated at 81% of early M, or 0.09.

2.3 Software

This assessment uses the Stock Synthesis modeling framework developed by Dr. Richard Methot (NMFS, NWFSC). The most recent version (SSv3.24o, distributed on April 10, 2013) was used, since it included improvements in the output statistics for producing assessment results and several corrections to older versions.

2.4 General Model Specifications

This assessment focuses on the population of longspine thornyhead that occurs in coastal waters of the western United States, off Washington, Oregon and California. The population within this area is treated as a single coast-wide stock, given the lack of data suggesting the presence of multiple stocks. The modeling period begins in 1944, assuming that in 1943 the stock was in an unfished equilibrium condition.

Fishery removals are considered to occur within one commercial deepwater trawl fishery. Very little catch of longspine thornyhead occurs via other fishing methods, so all commercial landings were treated as one fishery.

Historical landings for the domestic fishery was reconstructed by state, and then combined into the coast-wide fleet. Selectivity and retention parameters are estimated for this fishery. The AFSC slope and NWFSC surveys are treated as separate fleets with independently estimated selectivity and catchability parameters reflecting differences in depth and latitudinal coverage, design and methods. Given the difference in latitudinal range, catchability (*q*) was estimated independently for the NWFSC slope and NWFSC shelf-slope surveys.

No seasons are used to structure removals or biological predictions; data collection is assumed to be relatively continuous throughout the year. Fishery removals in the model occur instantaneously at the mid-point of each year and recruitment on the 1st of January.

The base model is a sex-specific model and the sex ratio at birth is assumed to be 1:1. Growth is monomorphic; natural and fishing mortality are assumed to be the same for males and females at all ages.

Expected annual recruitment was described by a Beverton-Holt function of spawning biomass. Steepness (the fraction of expected equilibrium recruitment associated with 20% of equilibrium spawning biomass) was fixed to 0.6. The scale of the population is estimated through the log of the initial recruitment parameter (R_0).

Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. 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 13) were estimated by a function in the R4SS software package (Taylor et al., 2013). These values were determined in a model prior to the base model, but the differences that would result from a further iteration of the estimation process are expected to be small. The time series of the estimated asymptotic recruitment error for years with estimated recruitment deviations is shown in Figure 14.

The length composition data are summarized into 1-cm bins, ranging between 5 cm (representing fish under 6 cm) and 35+ cm.

Iterative re-weighting was used in the assessment to achieve consistency between the input sample sizes and the effective sample sizes for length composition samples based on model fit. This reduces the potential for particular data sources to have a disproportionate effect on total model fit.

Retention in the fishery was estimated separately for the periods 1964-1991, 1992-2006, 2007-2010, and 2011-12.

Likelihood components for the model were:

1. Indices (log-normal)
2. Length frequencies (multinomial)
3. Discard fraction (normal)
4. Mean body weight of discards (T-distribution with d.f. = 30)
5. Recruitment deviations (normal)
6. Priors (parameter-dependent)

2.4.1 Estimated and Fixed Parameters

In the assessment, there are parameters of three types, including life history parameters, stock-recruitment parameters and selectivity and retention parameters. These parameters were either fixed or estimated within the model. Reasonable bounds were specified for all estimated parameters. A full list of all biological parameters used in the assessment is provided in Table 6. Selectivity parameters are given in Table 9.

2.4.2 Life history and recruitment

The Von Bertalanffy rate parameter, K is estimated to be 0.109 in the present model, and the average length at age 40 is estimated to provide the best fit to the data at 27.8 cm. The length at age 3 is set to 11 cm, as in the Fay (2005) model. Previous and current values are given in Table 6 and Table 7.

For this assessment, a prior on natural mortality was developed based on a maximum age of 45 years, which had a mean of 0.11131 and a standard deviation on a log scale of 0.5208 (Hamel, pers. comm.). For the base case, natural mortality was fixed at the mean of this prior distribution.

This assessment assumed a Beverton-Holt stock recruitment relationship with a steepness of 0.6. Steepness is the fraction of expected equilibrium recruitment associated with 20% of equilibrium spawning biomass. The previous value was 0.75; however, no scientific justification was given for that value (Fay, 2005).

Most recent rockfish assessments use a steepness prior of 0.779, estimated from a meta-analysis of rockfish assessment results (Thorson, 2013). This value might be expected in the present assessment. However, rockfish ecology and reproduction are quite different from those of thornyheads, which (for example) do not give birth to live young but rather spawn floating egg masses.

Steepness in the shortspine thornyhead assessment was fixed at 0.6 both in the 2005 and 2013 models (Hamel, 2005, and Taylor and Stephens, in preparation). This value was justified based on consistency between the modeling approach and management targets, in addition to being within a range of biologically reasonable values. For consistency, therefore, steepness for the longspine model was also fixed at 0.6.

The scale of the population is estimated through the log of the initial recruitment parameter (R_0). Recruitment deviations were estimated for the years 1944 through 2012. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates.

2.4.3 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 the fishery and survey.

The AFSC slope survey was allowed to be dome-shaped, and was 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. The double-normal has an additional pair of parameters, which scale the initial and final selectivity values, but these were not used in the estimations.

For the fishery and NWFSC surveys, the peak selectivity was estimated to occur near the maximum size, indicating logistic selectivity. This was modeled using a 2-parameter function, in which the first parameter is the length at the inflection point at 50% selectivity, and the second parameter describes the width between that point and the 95% selectivity, controlling the steepness of the curve.

Retention curves are defined as a logistic function of size. These 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 defining the following four periods: 1964-1991, 1992-2006, 2007-10, and 2011-12. Blocks roughly correspond to changes in discarding which may have been driven by processor-imposed size-limits (Table 11), or to differences in management regimes. The changes between blocks are represented as random walks.

2.4.4 Key assumptions and structural choices

The structure of the base model was selected to balance model realism and parsimony. While the model was able to estimate natural mortality, uncertainty about the historical selectivity of the fishery led to concern about the estimated natural mortality rates. The *a priori* information about natural mortality from Hoenig's (1983) method led to the natural mortality rate being set at 0.11131.

The fishery selectivity curve is estimated to be asymptotic even when given the opportunity to be a dome-shaped (i.e. a double-normal form). We have, therefore, chosen to specify that fishery selectivity is asymptotic.

2.5 Base Model Results

A converged base model was found with appropriate gradient, covariance and Hessian properties. Additional exploration to conclude the base model was not settling on a local likelihood minimum was conducted by jittering staring values for all parameters at jitter values of 0.1 50 times. These jitter runs confirm the base case likelihood minimum over a moderate exploration of likelihood space.

2.5.1 Life History Parameters

The list of the all the parameters used in the assessment model and their values (either fixed or estimated) is provided in Table 6. Only the Von Bertalanffy K and Lmax, the length at the maximum age (40) were estimated in this model. K was estimated at 0.109, and Lmax at 27.8282. Both values are reasonable and consistent with what we know about the species. The growth curves and estimated mean weights are shown in Figure 15 and in Figure 16.

2.5.2 Discards

The base model balances the information in the discard fraction data with the length and mean weight data (Figure 16) to estimate the shape of the retention curve and, in the case of the trawl fleet, a time-varying asymptote for retention reflecting changes in management measures (Figure 17). Both the predicted discards (Figure 18) and the discard fraction estimated in the model (Figure 19) peak in 1990, when fishing was at its greatest.

The model does a reasonable job of fitting the length composition data for trawl discard, including balancing those data and the discard ratio data for 2006 and 2007, and matching the decline in average length of discards following the implementation of the catch shares fishery in 2011 (Figure 26 to Figure 28).

2.5.3 Abundance Indices

The base model did not indicate contradictions between the survey biomass indices and the estimated trends in selected biomass (Figure 20 to Figure 22). The fits to the all surveys were generally flat. This is not unexpected for the short time-series of the AFSC and NWFSC slope surveys. The NWFSC survey index shows shallow upward trend.

2.5.4 Length compositions

The model fit to length-frequency distributions, by year and aggregated across all years, Pearson residuals for the fits by fishery/survey, year and sex, and associated sample size comparisons are shown in Figure 23 to Figure 42. The quality of fit varies among years and fleets, which reflects the differences in quantity and quality of data. The Pearson residuals, which reflect the noise in the data both within and among years, did not exhibit any strong trends. Effective samples sizes varied from input sample sizes, but through iterative reweighting the difference between these were minimized.

Plots of observed and expected length compositions for the trawl and non-trawl landings aggregated across all years show acceptably good fits.

The survey length composition generally exhibits slightly smaller average length than the fishery.

2.5.5 Selectivities

Estimated selectivity curves for the fishery and surveys are shown in Figure 43. Estimated parameter values are given in Table 9. Full selectivity for longspine thornyhead in the fishery includes the asymptotic length (Figure 46). The time-varying retention is shown in Figure 44. Figure 45 compares the selectivity, retention and mortality curves for the fishery; it is worth noting that this figure is for year 2012, after the implementation of catch-shares, and shows that the small fish are being retained.

The NWFSC surveys both reach full selection by the maximum age of the fish (Figure 48 and Figure 49), which the model estimated to be 27.86 years (Table 6) (the large range of age bins in the model for plus-group fish allows for better growth modeling).

The AFSC slope survey selectivity is domed (Figure 43 and Figure 47) as it was in the previous assessment.

2.5.6 Derived outputs

The deviations from the estimated stock-recruitment function have a very large uncertainty, which is fairly consistent throughout the time-series (Figure 50 and Figure 51). Figure 52 shows the spawner-recruit time-series.

The estimated time series of spawning biomass, spawning depletion (relative to B_0) and fishing mortality are presented in Table 10 and Figure 53 to Figure 55. Trends in spawning biomass and spawning depletion track one another very closely. Exploitation never exceeded the management target except during peak fishing in the 1990s.

Figure 56 is a quadrant plot showing stock status over time relative to biomass and spawning potential ratio. The biomass has never been depleted below the management level of 0.4, and the exploitation has fallen since the 1990s so that the stock is currently neither depleted nor overfished.

The yield curve, Figure 57, shows the current stock status well above both the target and overfished levels. Longspine thornyhead appears to be well-recovered from the overfishing in the 1990s.

2.6 Profiles and sensitivity and retrospective analyses

Parameter uncertainty in the assessment is explicitly captured in the asymptotic confidence intervals estimated within the model and reported throughout this assessment for key parameters and management quantities. These intervals reflect the uncertainty in the model fits to the data sources in the assessment, but do not include the uncertainty associated with alternative model configurations and fixed parameters. To explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in model assumptions, a variety of sensitivity runs were performed.

2.6.1 Sensitivity to Historical Catch Reconstruction and Recruitment Deviations

The states of California and Oregon conducted reconstructions of the historical catch in the groundfish fishery, and those reconstructions have been used for many recent assessments for the pre-PacFIN era (prior to 1981). When compared with the catches used in the 2005 models, the reconstructed thornyhead catches were found to provide inconsistent or unrealistic values in some years. This impacted longspine thornyhead catches for the years 1969-1977 (Figure 58). Figure 59 and 68, and Table 12 demonstrate the relative insensitivity of the model to the alternate catch streams. The 2005 model values were used in this assessment.

The model was run without the estimation of recruitment deviations in order to investigate their impact on outcomes. This resulted in a generally higher scale for the biomass estimates, but a similar endpoint for depletion (Figure 61, Table 12).

2.6.2 Profiles

Profiles were conducted across values of initial recruitment, ln(R0), natural mortality (*M*) and steepness (*h*) in order to evaluate the sensitivity of the model to assumptions about these parameters.

The catchability (Q values) for the three surveys are shown for a range of values of ln(R0). Figure 62 shows that Q for the indices, which are all relatively flat, were best fit by large populations. However, the likelihood profile for ln(R0) (Figure 63) shows that values of initial recruitment much different from that estimated (ln(R0) = 11.82) are highly unlikely.

The likelihood profile over natural mortality, M (Figure 64), shows that the length data fit a lower mortality rate, near 0.05, than that fixed in the base case (0.11131). Other likelihood components are insensitive to changes in M over a range from 0.05 to 0.15.

Steepness (*h*) from the Beverton-Holt spawner-recruit relationship was fixed at 0.6 in the base case model. The likelihood profile over *h* (Figure 65) shows that while the length data in the model are fit best with a low value for *h*, the discard, the indices and the estimated recruitment are relatively insensitive to changes in *h*.

2.6.3 Retrospective analyses

The retrospective analyses for 2007–2011 are shown in Figure 66 and Figure 67. No strong patterns are obvious in these figures, indicating that the model is not strongly influenced by recent data. The base case model may be slightly more optimistic than the retrospectives.

2.6.4 Comparison to previous assessment

In comparing the current estimates of spawning biomass and depletion with those of the 2005 model (Figure 68), it should first be noted that estimates of uncertainty were not available for the earlier model. The much larger 2005 estimate of spawning biomass highlights the volatility of the scale of the biomass. However, both models estimate depletion at similar scales, and show the population at a high stock status.

2.6.5 Axis of uncertainty and states of nature

The uncertainty in spawning biomass associated with the base model was very broad (Figure 53) 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.

3 Reference Points

A summary of reference points for the base model is provided in Table 8. Reference points were calculated using the estimated selectivity in the last year of the model (2012), and the estimated values are dependent on these assumptions. Sustainable total yield (landings plus discards) was estimated at 2,487 mt when using an $SPR_{50\%}$ reference harvest rate and ranged from 1,718-3,256 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished spawning output ($B_{40\%}$) was 15,654 mt. The most recent catches (landings plus discards) have been lower than the lower confidence bound of potential long-term yields calculated using an $SPR_{50\%}$ reference point.

The stock is declared overfished if the current spawning output is estimated to be below 25% of unfished level. The management target for longspine thornyhead is defined as 40% of the unfished spawning output ($SB_{40\%}$), which is estimated by the model to be 15,654 mt (95% confidence interval: 10,837 – 20,471 mt), which corresponds to an exploitation rate of 0.06. This harvest rate provides an equilibrium yield of 2,487 mt (95% confidence interval: 1,718 – 3,256 mt).

Note that the reference points based on $B_{40\%}$ and those based on the SPR proxy for MSY are the same when h=0.6, as in this model, therefore the exploitation rate corresponding to an SPR of 50% (the proxy Fmsy), is 0.06, resulting in an equilibrium yield of 2,487 mt at $SB_{40\%}$ (95% confidence interval: 1,718 – 3,256 mt) at a biomass of 15,654 mt (95% confidence interval: 10,837 – 20,471 mt).

This assessment estimates that the 2012 SPR is 83%, while the SPR-based management fishing mortality target is 50%. Since 1964, the SPR has been above 50%, which means that overfishing of longspine thornyhead has not been occurring.

4 Harvest Projections and Decision Tables

Axes of uncertainty for this assessment are the size of initial recruitment and the size of future catch. Initial recruitment is here represented by the log of the initial recruitment, $LN(R_0)$. Table h displays the projected percent depletion and spawning biomass (in metric tonnes) for the base model using three values of $LN(R_0)$, to represent three states of nature, and three catch streams.

The standard deviation of the log of spawning biomass in 2013 is $\sigma = 0.29$. The SSC assigned this longspine 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 longspine thornyheads, which leads to a multiplication of the OFL by 83.3%, which is the 40% quantile of a log-normal distribution with $\sigma = 0.72$.

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 was assumed to match the average values for 2011–2012 (the only years in which the trawl fishery was operating under IFQs). 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 942 mt and landings of 898 mt after applying the estimated retention function to the age structure of the population in 2013. The 942 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 75% in 2013 to 50% in 2024 (Table g), still above the 40% biomass target and 25% minimum stock size threshold. The associated OFL values over the period 2015–2024 would average 4,075 mt and the average ACL would be 3,395. 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 h). 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 the total catch, rather than landed catch, but discard rates were low under IFQs, so the difference 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. This was a total catch of 942 mt.

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 = 67% with a 83.3% adjustment to the OFL (based on the p* = 0.40 and sigma = 0.72). The average total catch for the years 2015–2024 was 942 mt for the low catch stream, 2,224 for the middle catch stream, and 3,394 for the high catch stream.

The stock status remained above 25% 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 31.58% in 2024. All other projections led to a higher projected status, with a maximum of 86.27% 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 50.06% in the high catch stream to 70.16% in the low catch stream.

5 Regional Management Considerations

Currently both shortspine and longspine thornyheads have a management boundary at Pt. Conception, CA at 34º27' N latitude. There is no evidence of stock structure associated with this line and the amount of data associated with the fishery to the south of this boundary is unlikely to justify any effort to develop a spatial model with explicit accounting for this boundary. Therefore, the best method for apportioning the quotas between areas is the fraction of the population observed in the trawl survey (Figure 7). The fraction of the total estimated biomass south of 34º27' N in the NWFSC Combo Survey is 23.9% based on the median GLMM results. This is very similar to 23.8% the raw, swept area biomass.

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 2). The uncertainty associated with that extrapolation is difficult to quantify at this point. 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 16.6% compared to a 5.3% CV in the north.

6 Research Needs

Research and data needs for future assessments include the following:

1. Age and growth information are needed 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.
   This could involve investigation of biochemical aging methods, for example an analysis of telomere length in relation to body length.

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. Further exploration of perceived differences in catchability (*q*)between towed cameras and trawl nets should also be explored.
3. More tows or visual surveys south of 34.5 deg. N. latitude. Because the southern Conception Area is a large potential habitat for thornyheads, more effort should be directed to describing their distribution in this area, for inclusion in future assessments.
4. An investigation of the possible discontinuity in the reconstructed thornyhead historical catches would be useful for future assessments.

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9 Tables

Table 1: Trawl and Non-Trawl catch in metric tonnes. Unspecified thornyheads were divided between shortspine and longspines according to the ratio of identified catch, and these numbers represent the total. Values in bold (1964-1976 catch) were taken from the 2005 assessment, as the original sources for these numbers were no longer available.

Year	Trawl				Non-Trawl				Total
	WA	OR	CA	NA	WA	OR	CA	NA	
1964	0	0	0	**13**	0	0	0	0	**13**
1965	0	0	0	**30**	0	0	0	0	**30**
1966	0	0	0	**21**	0	0	0	0	**21**
1967	0	0	0	**10**	0	0	0	0	**10**
1968	0	0	0	**10**	0	0	0	0	**10**
1969	0	0	0	**29**	0	0	0	0	**29**
1970	0	0	0	**42**	0	0	0	0	**42**
1971	0	0	0	**44**	0	0	0	0	**44**
1972	0	0	0	**82**	0	0	0	0	**82**
1973	0	0	0	**93**	0	0	0	0	**93**
1974	0	0	0	**77**	0	0	0	0	**77**
1975	0	0	0	**99**	0	0	0	0	**99**
1976	0	0	0	**54**	0	0	0	0	**54**
1977	0	0	0	**102**	0	0	0	0	**102**
1978	0	0	197	0	0	0	0	0	197
1979	0	0	143	0	0	0	0	0	143
1980	0	0	357	0	0	0	0	0	357
1981	0	1	110	0	0	0	1	0	112
1982	0	26	382	0	0	0	1	0	408
1983	3	52	210	0	0	0	1	0	266
1984	4	68	288	0	0	0	0	0	360
1985	13	387	569	0	0	0	0	0	969
1986	12	194	619	0	0	0	1	0	827
1987	2	72	1,108	0	0	0	0	0	1,182
1988	11	86	2,639	0	0	0	0	0	2,736
1989	25	617	2,529	0	0	0	0	0	3,171
1990	36	1,748	4,083	4	0	0	0	0	5,870
1991	37	949	1,986	0	0	0	0	0	2,972
1992	238	1,968	3,274	0	0	0	0	0	5,481
1993	344	2,181	2,829	0	0	0	0	0	5,354
1994	423	1,752	2,388	0	0	0	0	0	4,563
1995	732	1,587	3,124	0	2	3	119	0	5,567
1996	419	1,516	2,803	1	0	0	141	0	4,881
1997	408	1,164	2,348	1	0	0	132	0	4,053
1998	196	629	1,401	0	0	1	26	0	2,252
1999	106	499	1,172	0	0	0	32	0	1,810

Table 1. Continued. Trawl and Non-Trawl Landings.

Year	Trawl				Non-Trawl				Total
	WA	OR	CA	NA	WA	OR	CA	NA	
2000	64	510	853	0	0	0	69	0	1,496
2001	83	393	673	17	0	0	55	0	1,221
2002	124	465	1,316	4	0	0	15	0	1,924
2003	104	384	1,049	1	0	0	18	0	1,556
2004	26	117	536	0	0	0	10	0	689
2005	4	78	551	3	0	0	16	0	652
2006	9	128	594	1	0	0	18	0	750
2007	43	177	570	1	0	0	20	0	810
2008	89	371	769	1	0	0	14	0	1,243
2009	61	449	634	4	0	0	22	0	1,171
2010	44	643	642	1	1	1	26	0	1,359
2011	26	354	519	0	0	1	25	0	926
2012	14	256	584	0	0	0	16	0	871

Table 2: Discard rates.

Source	Year	Value	CV
Pikitch	1985	0.221	0.946
	1986	0.222	0.943
	1987	0.458	0.421
EDCP	1995	0.100	0.200
	1996	0.120	0.200
	1997	0.130	0.200
	1998	0.170	0.200
	1999	0.200	0.200
WCGOP	2002	0.198	0.078
	2003	0.193	0.085
	2004	0.177	0.155
	2005	0.158	0.155
	2006	0.121	0.186
	2007	0.150	0.168
	2008	0.134	0.106
	2009	0.285	0.117
	2010	0.227	0.112
	2011	0.047	0.001

Table 3: 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)	ABC (mt)	Commercial Landings (mt)	Estimated Total Catch (mt)
2003	2,851	2,656	1,556	1,886
2004	2,851	2,656	689	837
2005	2,461	2,461	652	792
2006	2,461	2,461	750	911
2007	3,907	2,696	810	956
2008	3,907	2,696	1,243	1,463
2009	3,766	2,626	1,171	1,375
2010	3,671	2,560	1,359	1,588
2011	3,571	2,495	926	972
2012	3,483	2,430	871	912

Table 4: Final design and model (GLMM)-based abundance indices for longspine thornyhead.

	AFSC slope			NWFSC slope			NWFSC shelf-slope		
Year	Design	Model	log_SD	Design	Model	log_SD	Design	Model	log_SD
1995									
1996									
1997	103,403	103,712	0.07						
1998				72,692	72,770	0.09			
1999	100,313	100,499	0.07	84,620	84,076	0.09			
2000	99,337	99,184	0.07	87,038	87,669	0.09			
2001	100,571	100,456	0.07	85,590	85,285	0.08			
2002				88,957	89,069	0.09			
2003							139,366	140,537	0.08
2004							148,931	150,353	0.09
2005							132,760	134,201	0.09
2006							138,480	139,453	0.08
2007							138,959	139,599	0.08
2008							166,411	166,747	0.09
2009							172,436	173,041	0.09
2010							175,257	175,702	0.08
2011							160,828	161,373	0.09
2012							189,656	190,780	0.08

Table 5: Summary of sampling effort (number of hauls and fish sampled) used to create length compositions. The only sexed fish were sampled in the 2005-2012 NWFSC Combo Survey, where the ratio of females to males was .51 overall with little between-year variation, so gender is not explicitly reported.

Year	Commercial Trawl		Pikitch Study	WCGOP	AFSC Slope Survey		NWFSC Slope Survey		NW Shelf/Slope Survey	
	Hauls	Samples	Samples	Samples	Hauls	Samples	Hauls	Samples	Hauls	Samples
1978	246	449								
1979	212	398								
1980	74	138								
1981	15	23								
1982	77	120								
1983	200	297								
1984	377	809								
1985	623	1443								
1986	352	723								
1987	241	592								
1988	18	55								
1989	288	1234								
1990	1363	5381								
1991	1248	4631								
1992	1771	6839								
1993	888	4050								
1994	758	4025								
1995	1329	7931								
1996	1479	8770								
1997	1760	12158			134	33655				
1998	1120	5149					160	23879		
1999	1142	4558	524		146	23883	206	27118		
2000	982	4147	5777		159	20993	196	22652		
2001	1310	4832	705		160	27061	208	24399		
2002	1789	6833					276	34042		
2003	1466	5268							194	15432
2004	1099	3765							150	11171
2005	1069	3478							228	13530
2006	2018	5878		1154					236	9069
2007	1931	5130		2023					248	6196
2008	2356	7184		2547					258	3622
2009	2341	6522		3714					239	3098
2010	2386	7211		2312					258	3044
2011	2429	7226		4291					247	5012
2012	2310	6968							247	4798

Table 6: Biological parameterizations used in the longspine thornyhead model. Two of the growth parameters, K and the size-at-age for reference age 2 (40 years), were estimated, as was ln(R_0) (bold values).

Parameter	Value	Bounds	Prior Type	Prior Mean	Prior SD
Females and Males					
Natural mortality (M)	0.111313	0.01 - 03			
Length at Age 3	8.573	5 - 25			
Length at Age 40	**27.8282**	5 - 40	Full Beta	30	NA
VBGF K	**0.108505**	0.05 - 0.2	LogNormal	0.1	NA
Length CV at Amin	0.131	0.015 - 0.25			
Length CV at Amax	-0.892	-3 - 5			
Weight-Length a	4.30E-06	-3 - 3			
Weight-Length b	3.352	-3 - 8			
Length at 50% maturity	17.826	0.001 - 40			
Maturity slope	-1.79	-3 - 3			
Eggs/kg	1	-3 - 3			
Eggs/kg slope	0	-3 - 3			
Stock-recruit					
ln(R_0)	**11.8243**	3-31	LogNormal	9.3	NA
Steepness (h)	0.6	0.2 - 1			
σ_R	0.6	0 - 2			

Table 7: Biological parameterizations estimated in studies and used in the 2005 assessment.

Biological parameter	Source: Jacobson (1991)	Ianelli et al. (1994)	Kline (1996)	Pearson & Gunderson (2003)	2005 Assessment
Length-weight relationship					
a	4.30 e-06				
b	3.352				
Von Bertalanffy growth curve					
L_∞ (cm)	33.86		30.06		31.2
K	0.0585		0.072		0.064
t0	-0.38		-1.9		-2.02
	(N = 192)		(N = 478)		(N = 815)
Maturity at length					
L50 (cm)	18.8	22.1		17.8	
slope	-0.593	-0.766		-1.79	
	(N=120)	(N=3738)		(N = 239)	

Table 8: Summary of reference points and management outputs for the base case model.

Quantity	Estimate	~95% confidence interval
Unfished Spawning biomass (mt)	39,134	(27,093 - 51175)
Unfished age 2+ biomass (mt)	91,049	(61,393 - 120,705)
Unfished recruitment (R0, millions)	136,529	(81,731 - 191,327)
Spawning biomass (2013)	29.4	(12.5 – 46.4)
SD of log Spawning Biomass (2013)	0.29	–
Depletion (2013)	75.2%	(53.5% - 96.9%)
Reference points based on $B_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	15,654	(10,837 – 20,471)
SPR resulting in $B_{40\%}$ ($SPR_{SB40\%}$)	50%	–
Exploitation rate resulting in $B_{40\%}$	0.06	(0.057 - 0.063)
Yield with $SPR_{50\%}$ at $B_{40\%}$ (mt)	2,487	(1,718 – 3,256)
Reference points based on SPR proxy for MSY		
Spawning biomass	15,654	(10,837 – 20,471)
SPR_{proxy}	50%	–
Exploitation rate corresponding to SPR_{proxy}	0.06	(0.057 - 0.063)
Yield with SPR_{proxy} at SB_{SPR} (mt)	2,487	(1,718 – 3,256)
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	13,108	(9,110 – 17,106)
SPR_{MSY}	44.6%	(44.4% - 44.8%)
Exploitation rate corresponding to SPR_{MSY}	0.071	(0.068 – 0.074)
MSY (mt)	2,529	(1,746 – 3,312)

Table 9: Selectivity parameterizations used in the longspine thornyhead model.

					Prior		
Fishery/Survey	Parameter	Value	Min	Max	Type	Mean	SD
Fishery	Logistic 1	23.5035	6.5	25	Normal	20	1
	Logistic 2	9.03702	0.01	25	No prior		
Fishery Retention	Retention curve 1	9.03702	2	40	No prior		
	Retention curve 2	21.8443	1.00E-05	30	No prior		
	Retention curve 3	1.77623	1.00E-04	1	No prior		
	Retention curve 4	0	-10	5	No prior		
Retention Blocks	Retention 1992	0	-10	10	Normal	0	5
	Retention 2007	-0.103126	-10	10	Normal	0	5
	Retention 2011	-0.0295415	-10	10	Normal	0	5
	Retention 1992	-0.198137	-10	10	Normal	0	5
	Retention 2007	-0.0758172	-10	10	Normal	0	5
	Retention 2011	-0.164209	-10	10	Normal	0	5
AFSC Slope	Double-normal 1	19.705	6.5	34.5	No prior		
	Double-normal 2	-19.6327	-20	7	No prior		
	Double-normal 3	2.95146	-5	10	No prior		
	Double-normal 4	3.71387	-5	20	No prior		
	Double-normal 5	-999	-999	15	No prior		
	Double-normal 6	-999	-999	15	No prior		
NWFSC Slope	Logistic 1	20.0197	6.5	25	Normal	20	1
	Logistic 2	11.5486	-7	25	No prior		
NW Shelf/Slope	Logistic 1	20.5822	6.5	25	Normal	20	1
	Logistic 2	12.1119	0.01	25	No prior		

Table 10: Time-series of total biomass, summary (age2+) spawning biomass, spawning output, depletion (stock status), recruitment, and exploitation rate estimated in the model.

Year	Total biomass (mt)	Summary biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Exploitation rate
1964	103,038	102,727	45,523	1.16%	91,951	0
1965	101,936	101,627	45,311	1.16%	92,226	0
1966	100,568	100,256	44,925	1.15%	93,824	0
1967	99,004	98,686	44,394	1.13%	96,575	0
1968	97,292	96,963	43,737	1.12%	100,060	0
1969	95,467	95,127	42,969	1.10%	103,521	0
1970	93,558	93,207	42,103	1.08%	106,054	0
1971	91,622	91,264	41,170	1.05%	107,320	0
1972	89,718	89,356	40,203	1.03%	108,223	0
1973	87,849	87,483	39,212	1.00%	110,524	0
1974	86,084	85,706	38,240	0.98%	115,486	0
1975	84,482	84,083	37,326	0.95%	124,280	0
1976	83,025	82,592	36,470	0.93%	135,917	0
1977	81,809	81,336	35,723	0.91%	147,919	0
1978	80,758	80,240	35,038	0.90%	163,136	0
1979	79,883	79,288	34,391	0.88%	197,156	0
1980	79,439	78,698	33,861	0.87%	253,856	0.01
1981	79,019	78,266	33,304	0.85%	183,459	0
1982	79,200	78,658	32,989	0.84%	131,160	0.01
1983	79,436	79,004	32,635	0.83%	125,812	0
1984	80,315	79,876	32,521	0.83%	137,379	0.01
1985	81,326	80,911	32,549	0.83%	104,401	0.01
1986	81,717	81,373	32,495	0.83%	99,695	0.01
1987	82,306	81,920	32,855	0.84%	136,067	0.02
1988	82,422	81,947	33,304	0.85%	149,910	0.04
1989	80,518	80,054	32,970	0.84%	121,979	0.05
1990	77,930	77,572	32,302	0.83%	85,500	0.1
1991	72,044	71,751	29,882	0.76%	89,848	0.06
1992	69,848	69,489	29,028	0.74%	130,450	0.09
1993	65,421	64,974	26,944	0.69%	136,737	0.1
1994	61,201	60,719	24,887	0.64%	153,347	0.09
1995	57,889	57,384	23,302	0.60%	146,754	0.11
1996	53,615	53,141	21,285	0.54%	133,141	0.11
1997	50,328	49,849	19,673	0.50%	156,349	0.1
1998	48,200	47,667	18,465	0.47%	162,173	0.06
1999	48,276	47,734	18,184	0.46%	160,700	0.05
2000	49,010	48,452	18,189	0.46%	173,860	0.04

Table 10. Continued.

Year	Total biomass (mt)	Summary biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Exploitation rate
2001	50,289	49,674	18,484	0.47	196,411	0.03
2002	51,927	51,388	19,064	0.49	110,856	0.05
2003	53,102	52,527	19,378	0.50	256,257	0.04
2004	54,632	54,001	19,958	0.51	93,155	0.02
2005	57,314	56,966	21,060	0.54	117,956	0.01
2006	59,908	59,536	22,244	0.57	101,145	0.02
2007	62,419	62,130	23,440	0.60	65,197	0.02
2008	64,637	64,408	24,674	0.63	72,369	0.02
2009	66,062	65,827	25,705	0.66	67,170	0.02
2010	67,184	66,957	26,771	0.68	68,454	0.02
2011	67,662	67,398	27,689	0.71	92,717	0.01
2012	68,304	67,937	28,698	0.73	132,555	0.01

Table 11: Summary of the history of fishery processor size-limits, spatial extent of the fishery, and management regime.

Era	Size Limit (in.)	Extent	Management
1960s	12 - 14	Eureka INPFC	
Late 70s - Early 80s	10		
Late 80s	8	OR, WA fishery	Deepwater complex (DTS)
1990 (peak landings)	10	Coastwide	
1991	10		Separate ABC, Trip limits
1992			Harvest Guidelines, mesh size change (3 – 4.5 in.)
1995			Landing and trip limits
1997	8		Post-1995 yearly adjustments
2011			Catch-shares

Table 12: Sensitivity results comparing the base model (Base), historical catch reconstruction (H C), and the model without recruitment deviations (No Rec Devs).

		Base	H C	No Rec Devs
Parameters	LN(R_0)	11.82	11.82	12.52
	AFSC Slope Q	3.18	3.18	1.44
	NWFSC Slope Q	3.01	3.03	1.78
	NWFSC Combo Q	4.58	4.6	2.8
Derived Quantities	SB_0	39,134	38,955	55,881
	2013 Depletion	0.752	0.753	0.756
Reference Points based on B40%	SSB	15,654	15,582	22,352
	Yield	2,486	2,475	3,552
Perfomance	Likelihood	318.26	318.147	422.429
	Gradient	0.000616	0.00051795	0.00195

Table 13. Projection of potential OFL, landings, and catch, summary biomass (age-2 and older), spawning biomass, and depletion for the base case model projected with status quo catches in 2011 and 2012, and catches at the OFL from 2013 onward. The 2011 and 2012 OFL's are values specified by the PFMC and not predicted by this assessment. The OFL in years later than 2012 is the calculated total catch determined by F_{SPR}.

Year	Predicted OFL (mt)	ACL Catch (mt)	Landings (mt)	Age 2+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2013	4,788	942	903	68,131	29,436	75%
2014	4,915	942	905	68,024	29,812	76%
2015	5,008	4,171	4,015	67,683	29,841	76%
2016	4,797	3,996	3,848	64,311	28,121	72%
2017	4,571	3,808	3,666	61,258	26,328	67%
2018	4,339	3,615	3,476	58,594	24,591	63%
2019	4,112	3,426	3,289	56,352	23,052	59%
2020	3,901	3,250	3,113	54,528	21,817	56%
2021	3,714	3,094	2,958	53,089	20,905	53%
2022	3,555	2,961	2,825	51,988	20,274	52%
2023	3,426	2,854	2,718	51,164	19,857	51%
2024	3,325	2,770	2,635	50,557	19,592	50%

Table 14. Summary table of 12-year projections beginning in 2015 for alternate states of nature based on an axis of catch uncertainty. Columns range over low, mid, and high state of nature, and rows range over differing assumptions of catch levels. Depletion is the percentage of virgin spawning biomass represented by current spawning biomass. Spawning biomass is in metric tonnes.

			Low State $LN(R_0) = 11.5$		Medium State $LN(R_0) = 11.8243$		High State $LN(R_0) = 12.3$	
	Year	**Catch**	**Depletion (%)**	**Spawning Biomass**	**Depletion (%)**	**Spawning Biomass**	**Depletion (%)**	**Spawning Biomass**
Low Catch	2015	942	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	942	60.37%	18,734	75.57%	29,572	96.17%	54,924
	2017	942	59.22%	18,378	74.33%	29,090	94.66%	54,063
	2018	942	57.92%	17,974	72.84%	28,506	92.77%	52,982
	2019	942	56.83%	17,635	71.45%	27,960	90.84%	51,880
	2020	942	56.19%	17,437	70.43%	27,561	89.18%	50,932
	2021	942	56.05%	17,394	69.87%	27,343	87.94%	50,223
	2022	942	56.30%	17,472	69.72%	27,282	87.10%	49,745
	2023	942	56.82%	17,634	69.85%	27,333	86.57%	49,445
	2024	942	57.50%	17,845	70.16%	27,457	86.27%	49,272
Medium Catch	2015	2,453	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	2,420	58.17%	18,051	73.83%	28,893	94.99%	54,249
	2017	2,372	54.95%	17,052	70.97%	27,775	92.37%	52,757
	2018	2,315	51.76%	16,063	68.00%	26,611	89.48%	51,103
	2019	2,252	48.98%	15,200	65.28%	25,549	86.65%	49,490
	2020	2,189	46.87%	14,544	63.11%	24,698	84.22%	48,098
	2021	2,130	45.45%	14,103	61.56%	24,091	82.31%	47,007
	2022	2,078	44.60%	13,840	60.56%	23,698	80.90%	46,203
	2023	2,034	44.16%	13,704	59.96%	23,465	79.89%	45,630
	2024	2,001	43.99%	13,652	59.65%	23,344	79.18%	45,224
High Catch	2015	4,171	61.07%	18,953	76.25%	29,841	96.99%	55,396
	2016	3,996	55.66%	17,274	71.86%	28,121	93.64%	53,481
	2017	3,807	50.25%	15,595	67.28%	26,328	89.86%	51,321
	2018	3,614	45.19%	14,025	62.84%	24,591	85.97%	49,098
	2019	3,425	40.86%	12,680	58.91%	23,052	82.32%	47,016
	2020	3,249	37.49%	11,633	55.75%	21,817	79.22%	45,245
	2021	3,093	35.05%	10,878	53.42%	20,905	76.79%	43,857
	2022	2,961	33.40%	10,365	51.81%	20,274	74.98%	42,825
	2023	2,853	32.30%	10,025	50.74%	19,857	73.68%	42,079
	2024	2,770	31.58%	9,799	50.06%	19,592	72.74%	41,545

10 Figures

10.1 Ecology

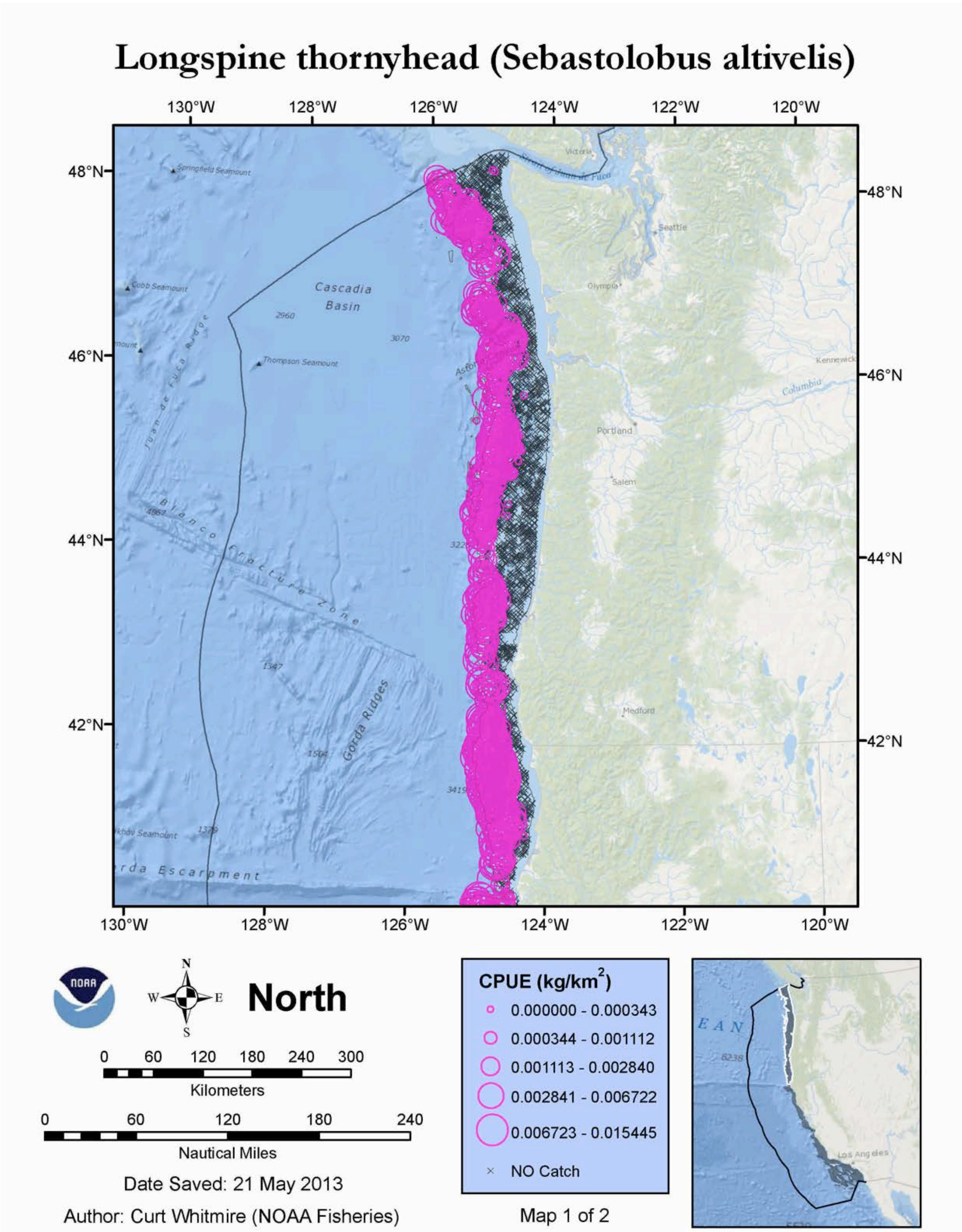


Figure 1: Occurrence and abundance of longspine thornyhead found in the NWFSC annual survey (2003-2012) north of 40°10' N latitude.

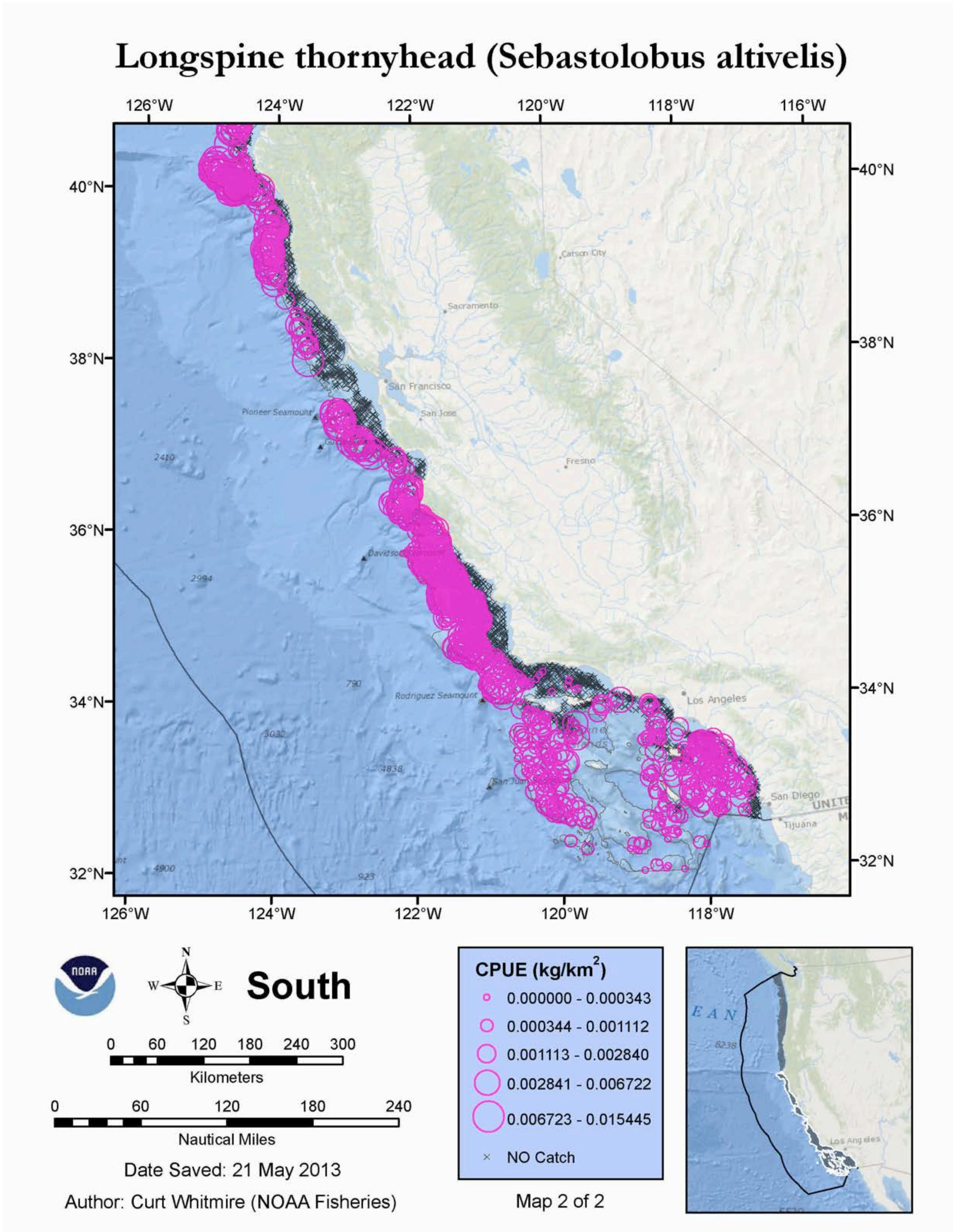


Figure 2: Occurrence and abundance of longspine thornyhead found in the NWFSC annual survey (2003-2012) south of 40°10' N latitude.

10.2 Data

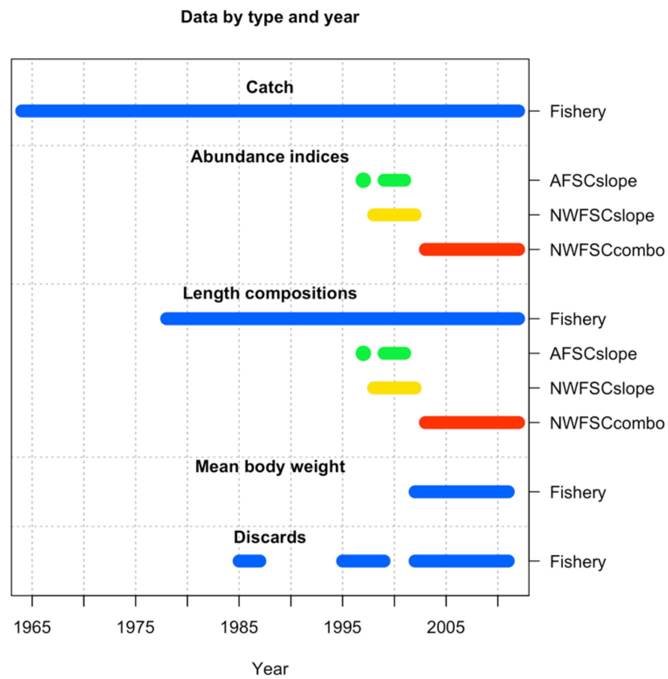


Figure 3: Data type and coverage in the base case model.

10.3 Landings

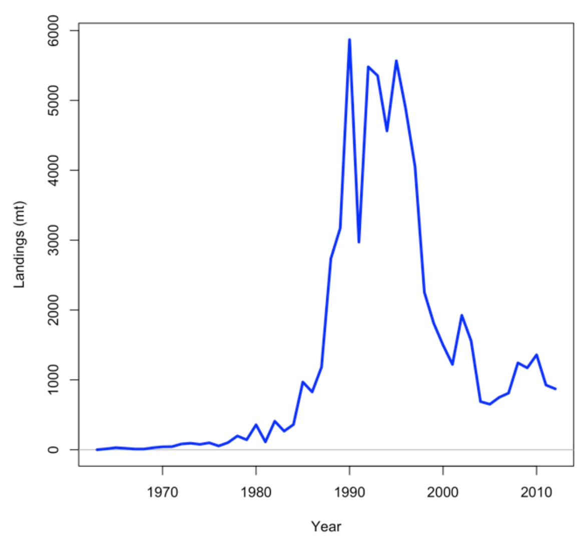


Figure 4: Total landings of longspine thornyheads, 1964-2012.

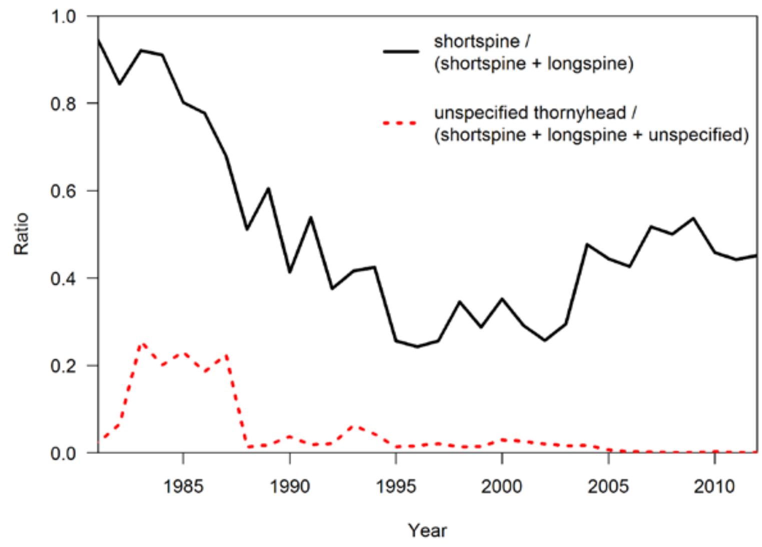


Figure 5: Ratio of shortspine to combined thornyheads in the subset of the landings for which the species was identified (solid black line), and the ratio of unspecified landings to total landings of both thornyhead species (dotted red line). The ratio of specified thornyheads was used to apportion the unspecified landings into estimates of the landings for each species. Longspine ratio is (1 – shortspine ratio).

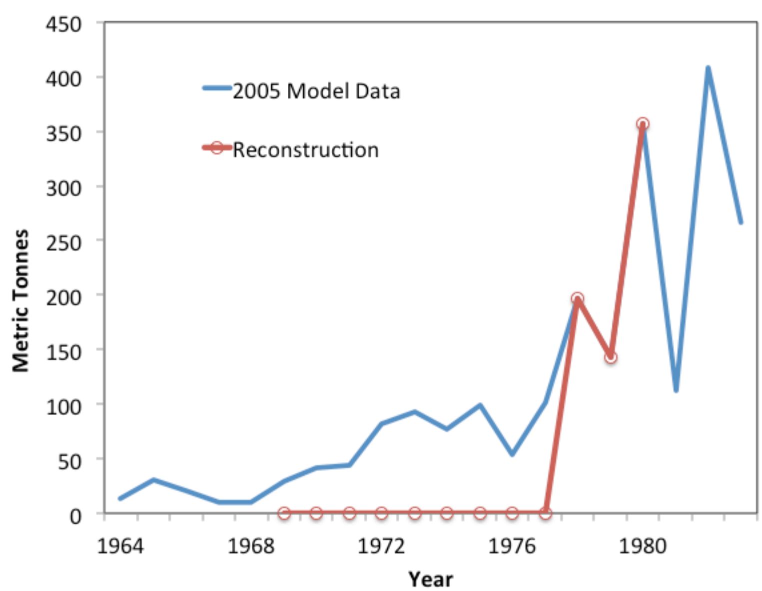


Figure 6: 2005 Model data (blue) and data compiled from California and Oregon historical catch reconstructions efforts (red, with open circles).

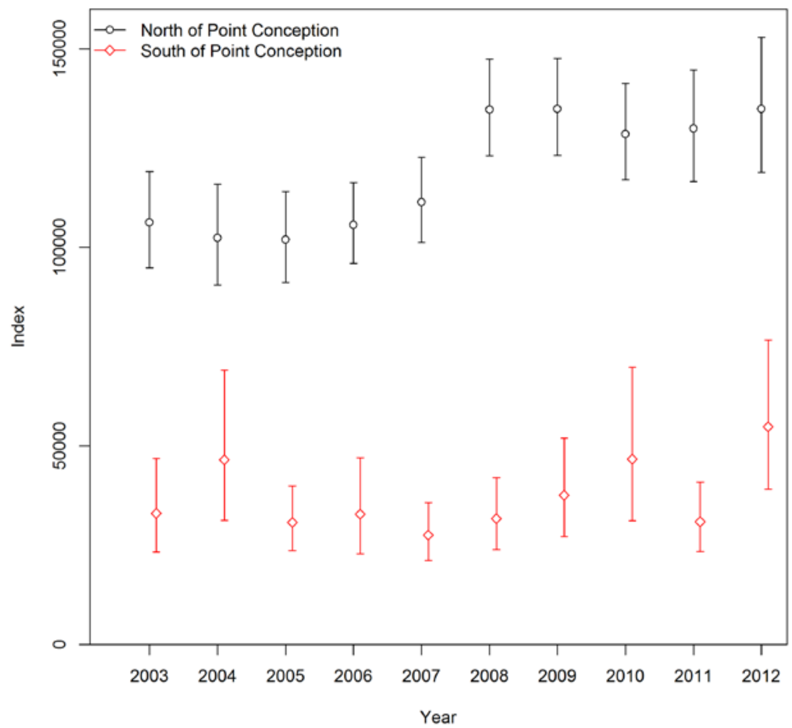


Figure 7: Subsets of the design-based indices from the NWFSC Combo Survey associated with the strata north and south of Point Conception. The mean value of the southern portion is 23.8% of the total (similar to 23.9% for the GLMM results). Due to the smaller size of the southern area with fewer survey stations, the uncertainty in the south is higher, with a mean CV of 16.6% compared to a 5.3% CV in the north.

10.4 Surveys

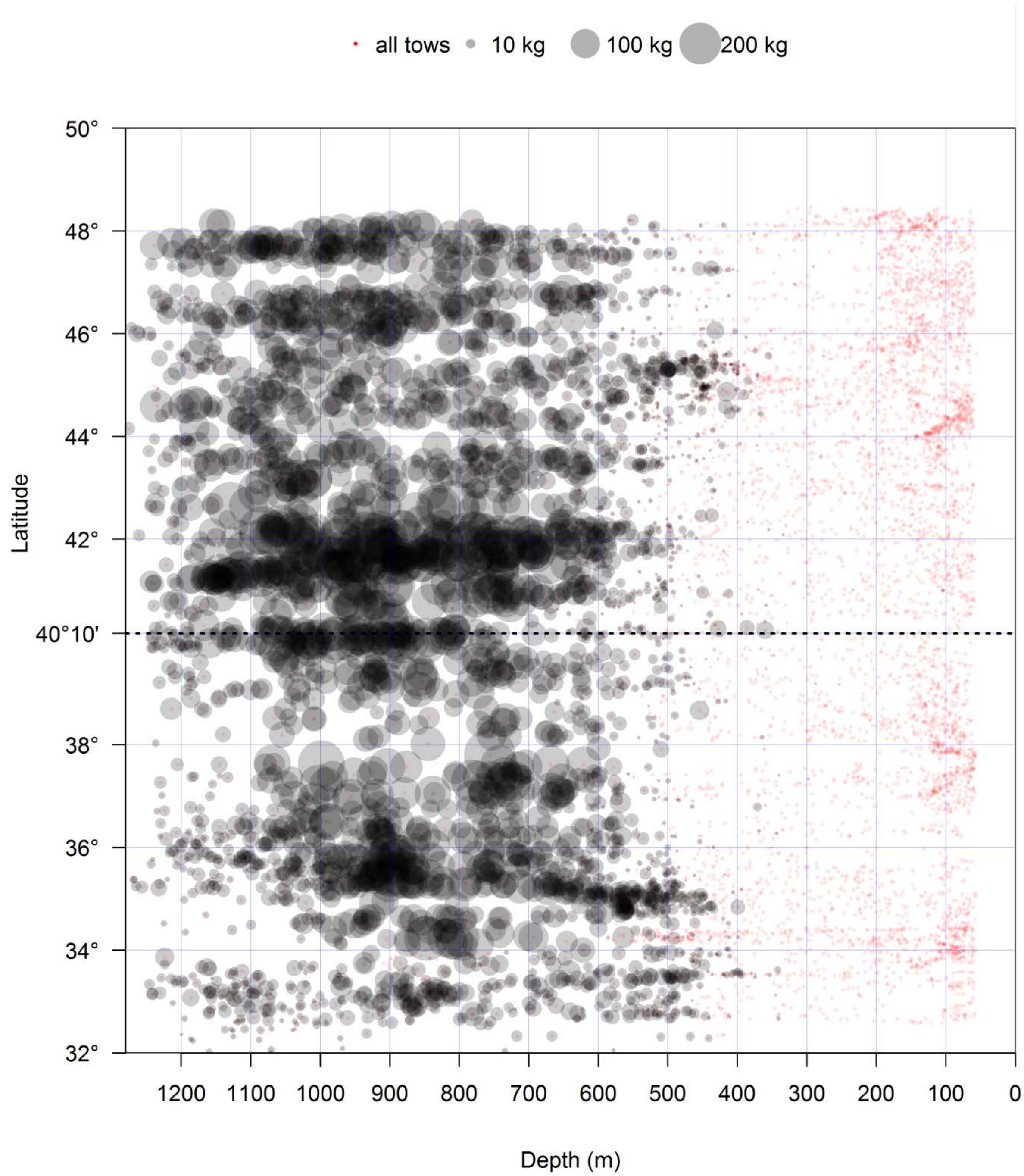


Figure 8: Spatial distribution of longspine thornyhead in NWFSC shelf-slope combo survey data (2003 – 2012). Red points indicate location of all tows. Grey points indicate location of longspine thornyheads with area of circle proportional to biomass of catch with scale indicated in the key at the top. Swept area is not accounted for in this figure, but tows typically cover similar area.

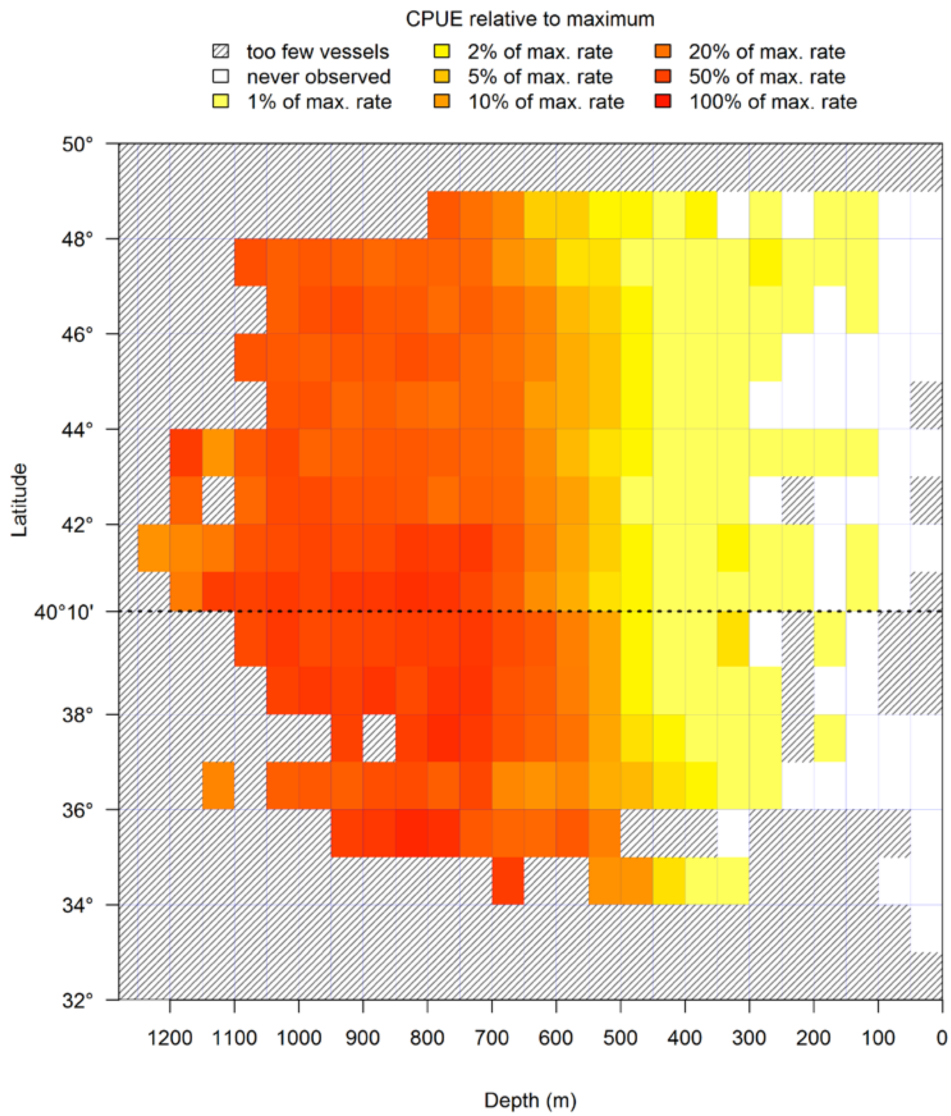


Figure 9: Spatial distribution of longspine thornyhead in WCGOP trawl data (2002 – 2011). Colors represent CPUE relative to the maximum. Darkest red = highest CPUE; lightest yellow = lowest CPUE. Data for hatched boxes could not be displayed because of confidentiality (only 1 or 2 vessels carrying observers 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.

10.5 Biology

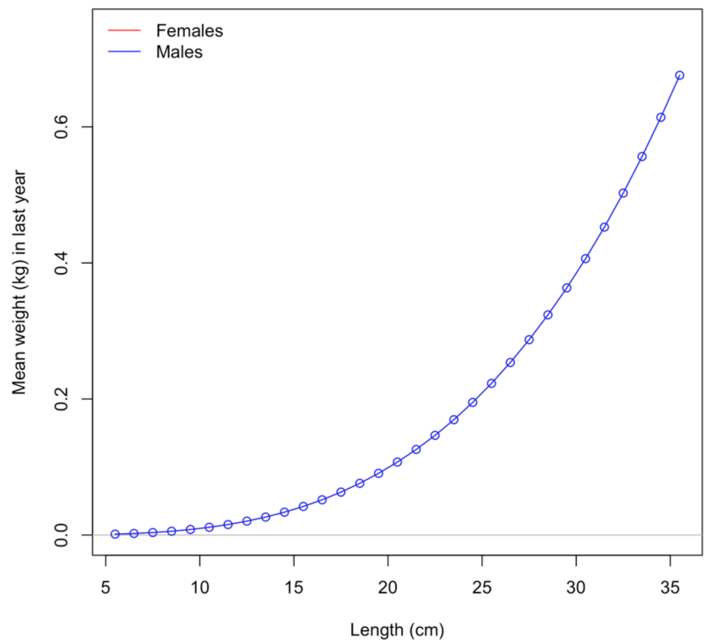


Figure 10: Length-weight relationship for female and male longspines assumed in the base case model.

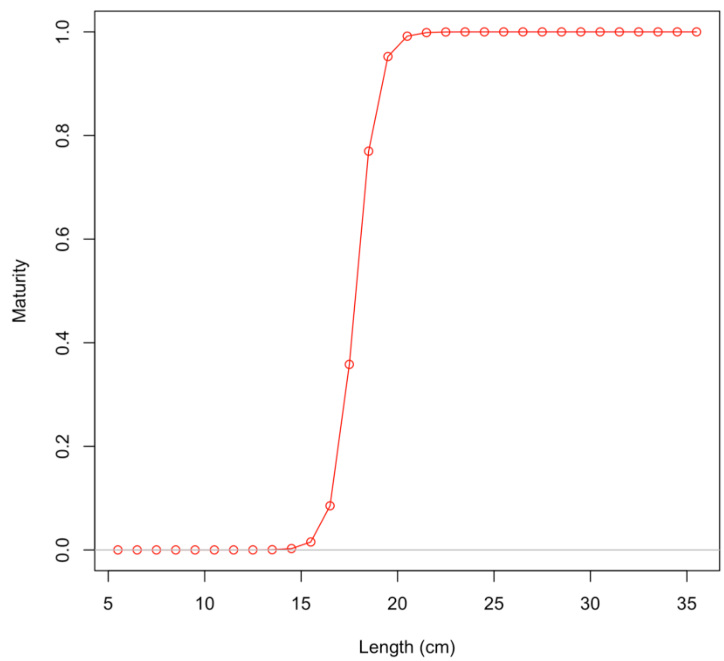


Figure 11: Female maturity ogive used in the longspine thornyhead base case model. Length at 50% maturity = 17.83.

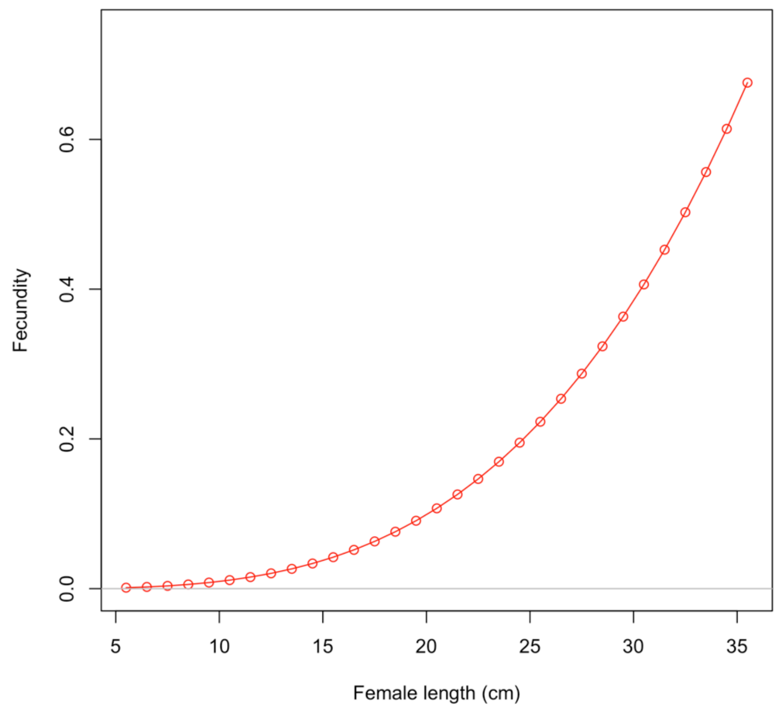


Figure 12: Fecundity at length relationship assumed in the longspine thornyhead base case model.

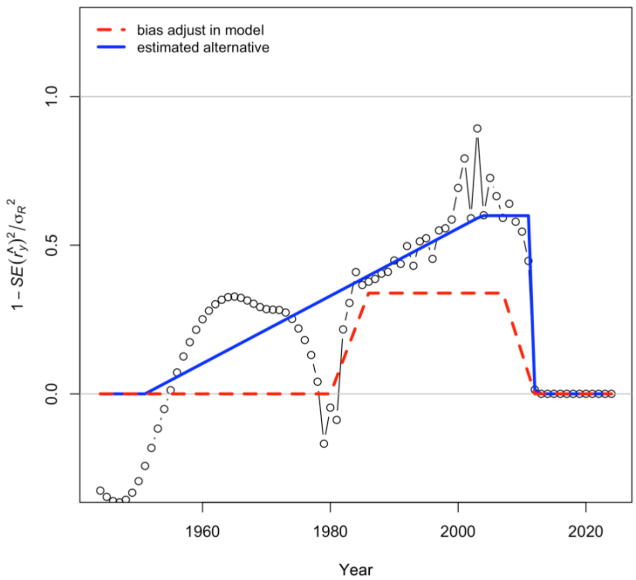


Figure 13: Time series of the applied bias0 adjustment in the base case model.

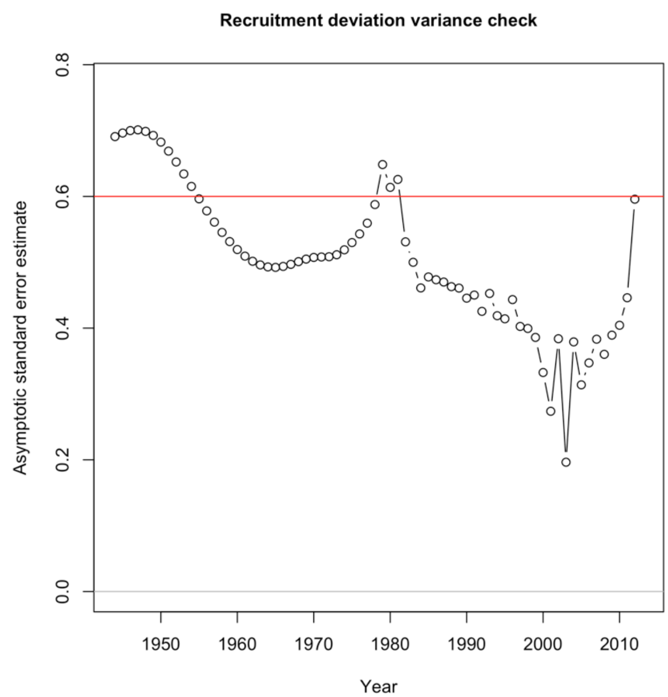


Figure 14: Time series of the estimated asymptotic recruitment error for years with estimated recruitment deviations from the base case assessment. Assumed model values are indicated by the red line.

10.6 Model results
10.6.1 Base model

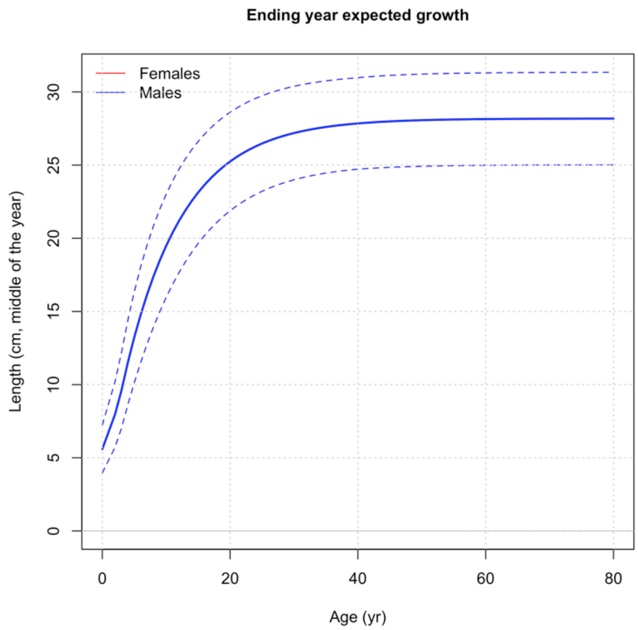


Figure 15: Estimated age and growth relationship for females and males in the base case model.

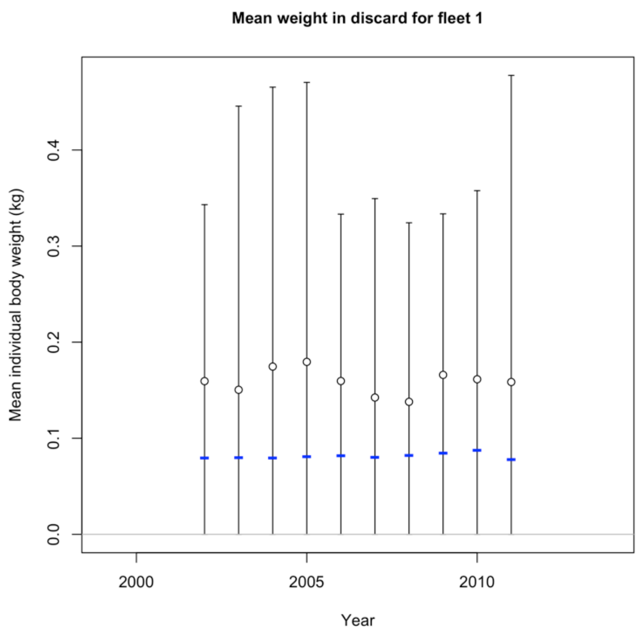


Figure 16: Base case model fit to longspine thornyhead mean individual body weight in the trawl fishery. Blue lines are model fit; error bars are observation error.

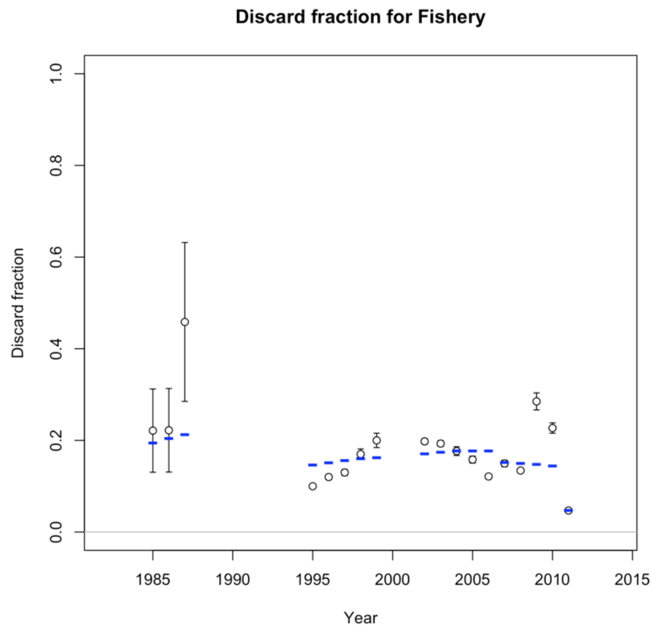


Figure 17: Base case model fits to discard fraction in the fishery.

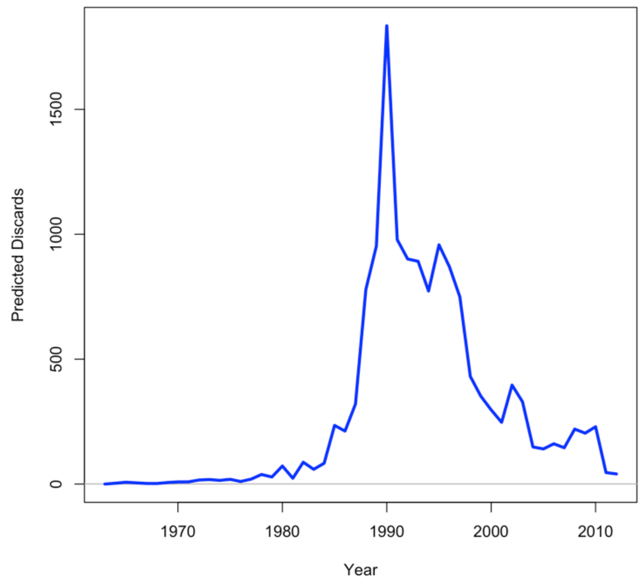


Figure 18: Base case model predicted discards of longspine thornyheads.

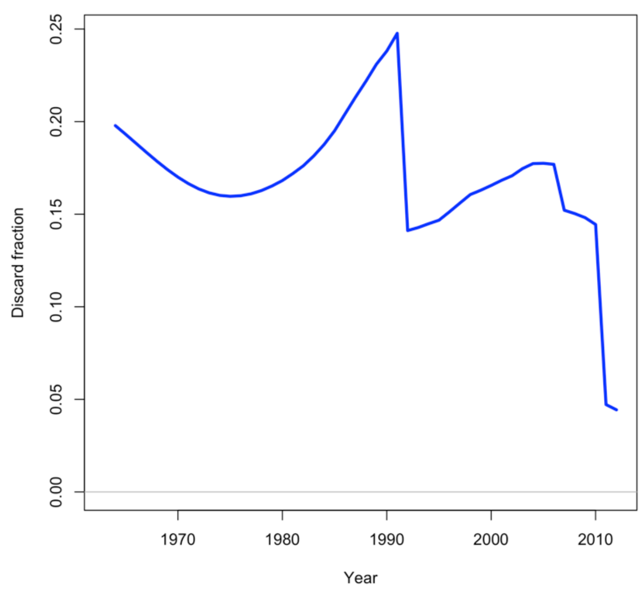
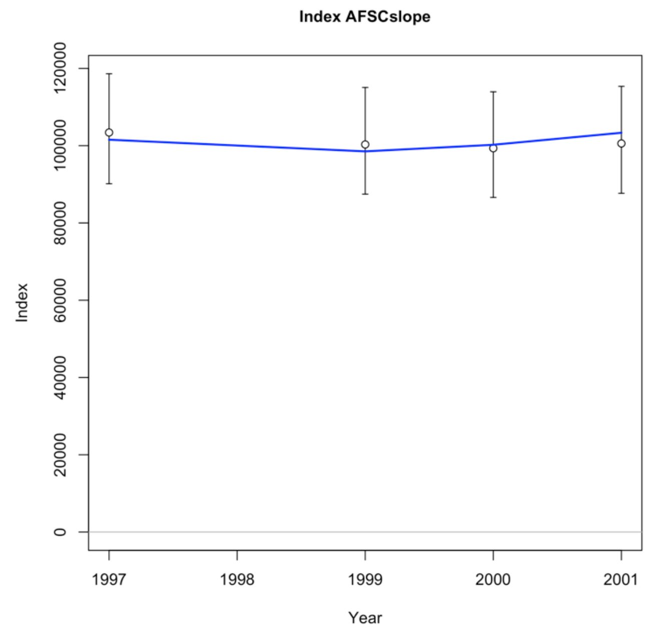


Figure 19: Discard fraction of longspine thornyheads used in the base case model.

10.6.2 Indices



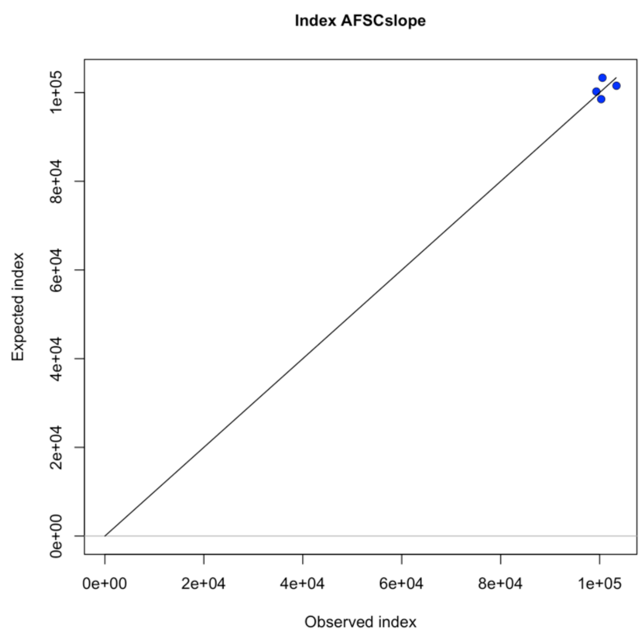
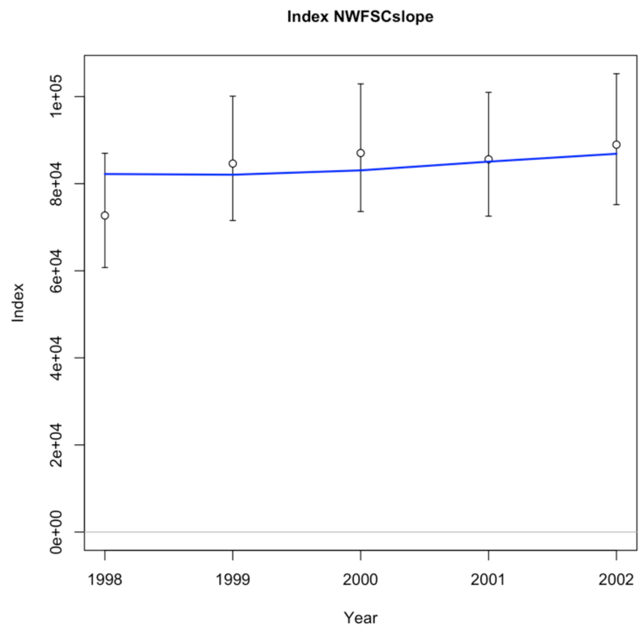


Figure 20: Top panel: Base case model fit (solid blue line) to the AFSC slope survey data (points with vertical lines indicating 95% CIs). Bottom panel: 1:1 observed to model expectations of survey values.



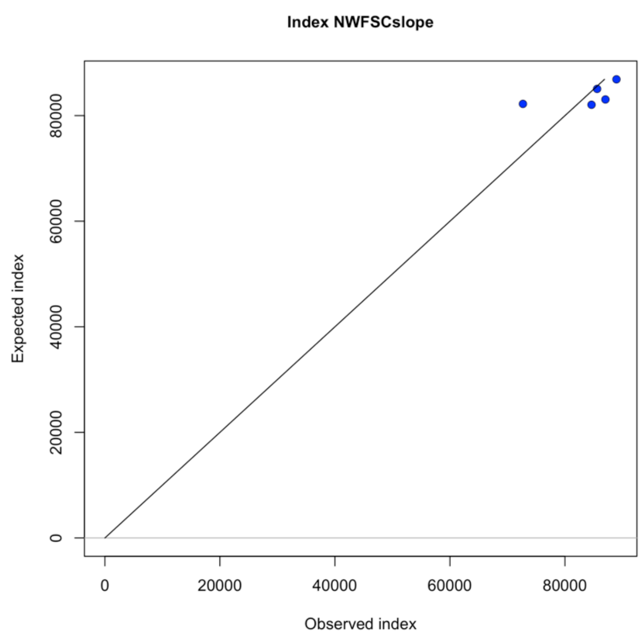


Figure 21: Top panel: Base case model fit (solid blue line) to the NWFSC slope survey data (points with vertical lines indicating 95% CIs). Bottom panel: 1:1 observed to model expectations of survey values.

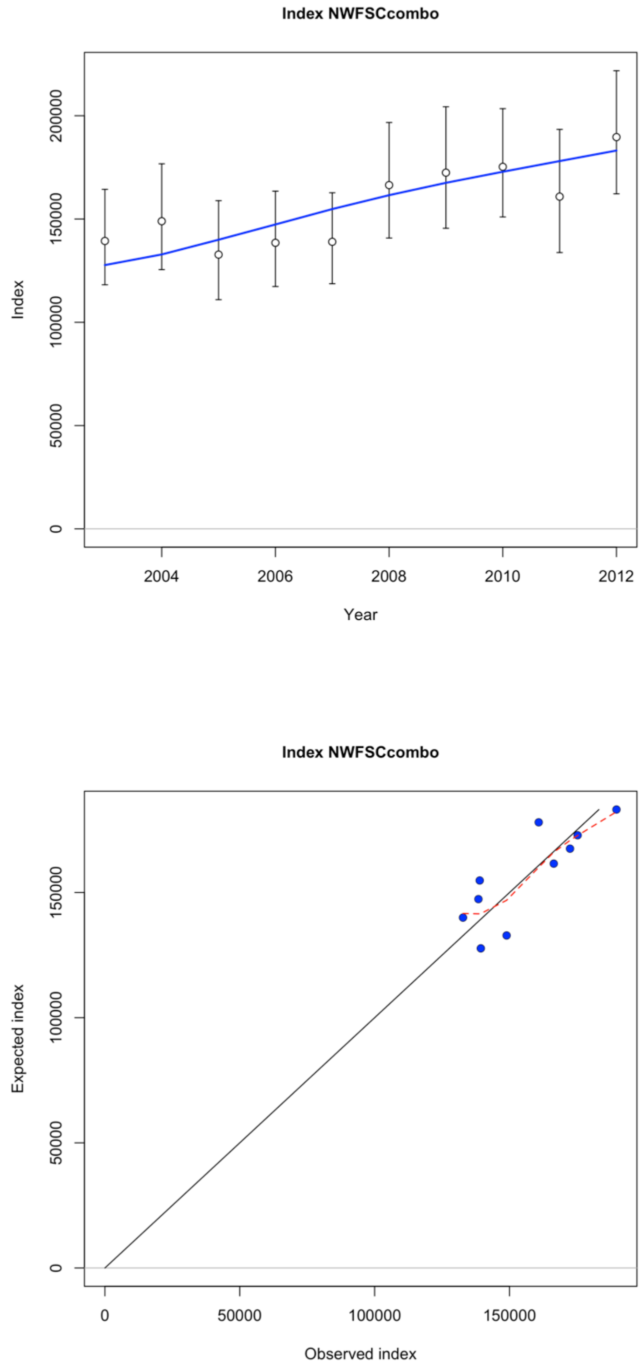


Figure 22: Top panel: Base case model fit (solid blue line) to the NWFSC combo survey data (points with vertical lines indicating 95% CIs). Bottom panel: 1:1 observed to model expectations of survey values

10.6.3 Length compositions

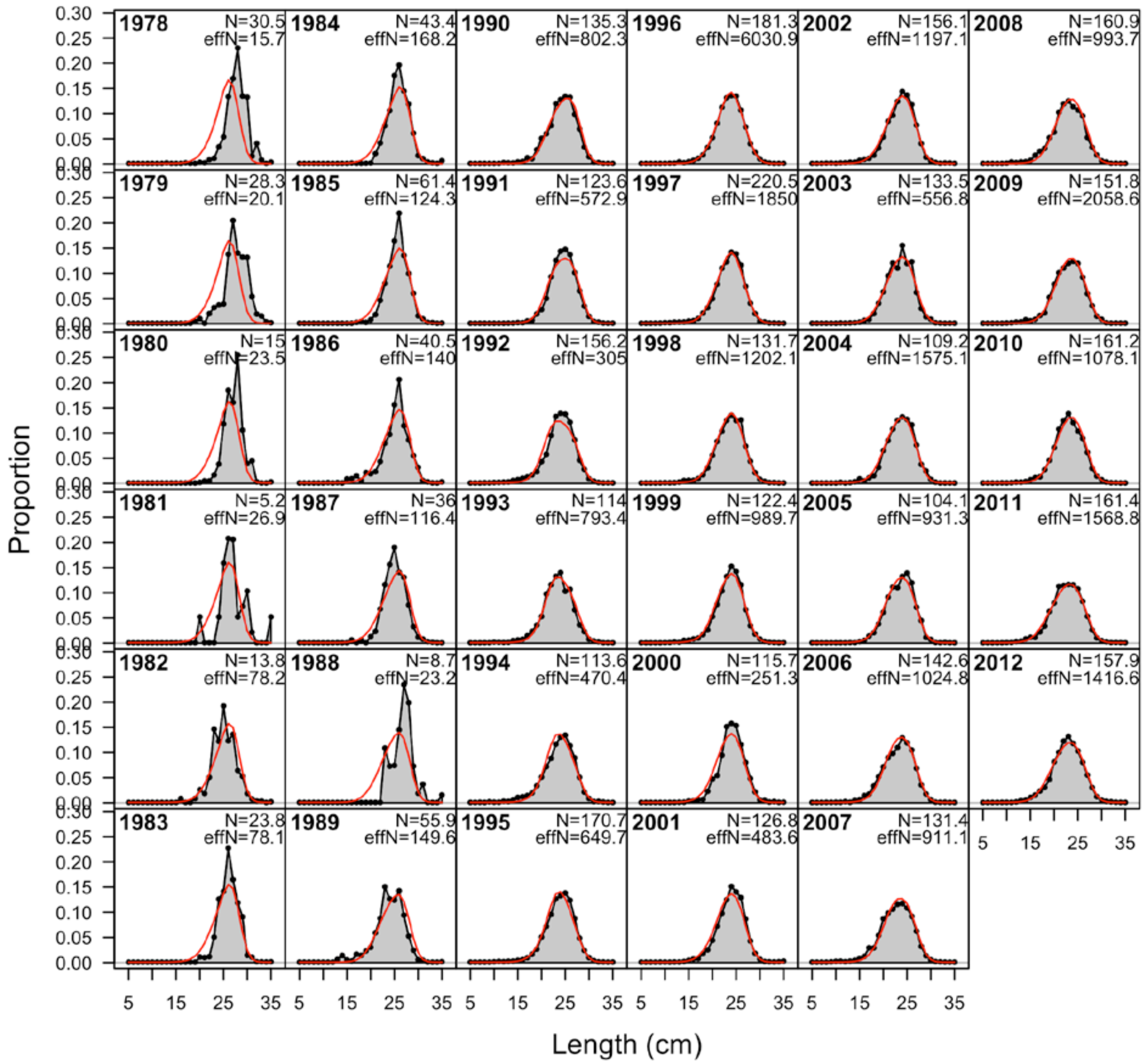


Figure 23: Base case fits to the fishery combined-sex length composition data.

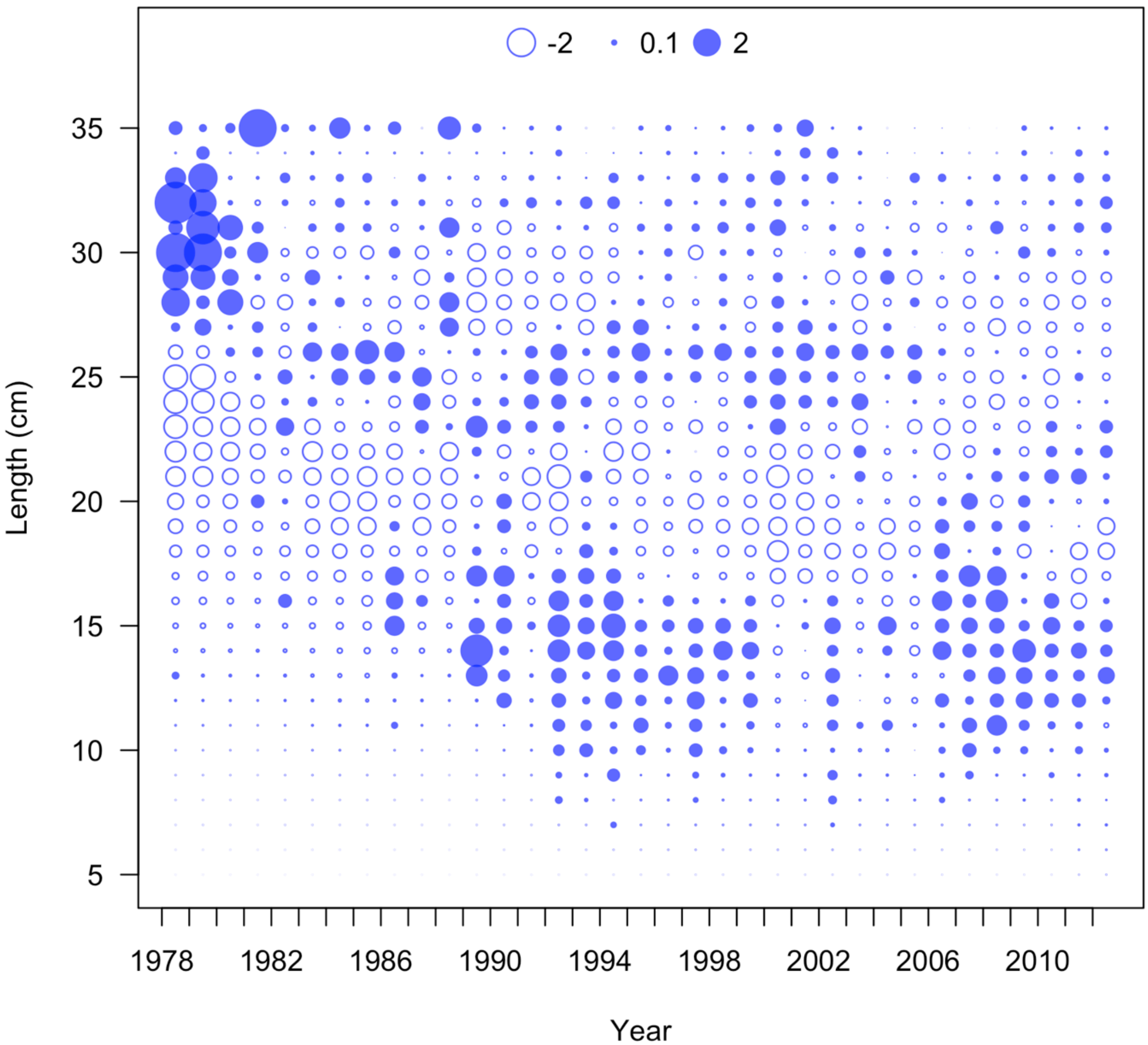


Figure 24: Residual plots to the fishery retained catch. Maximum is 4.57.

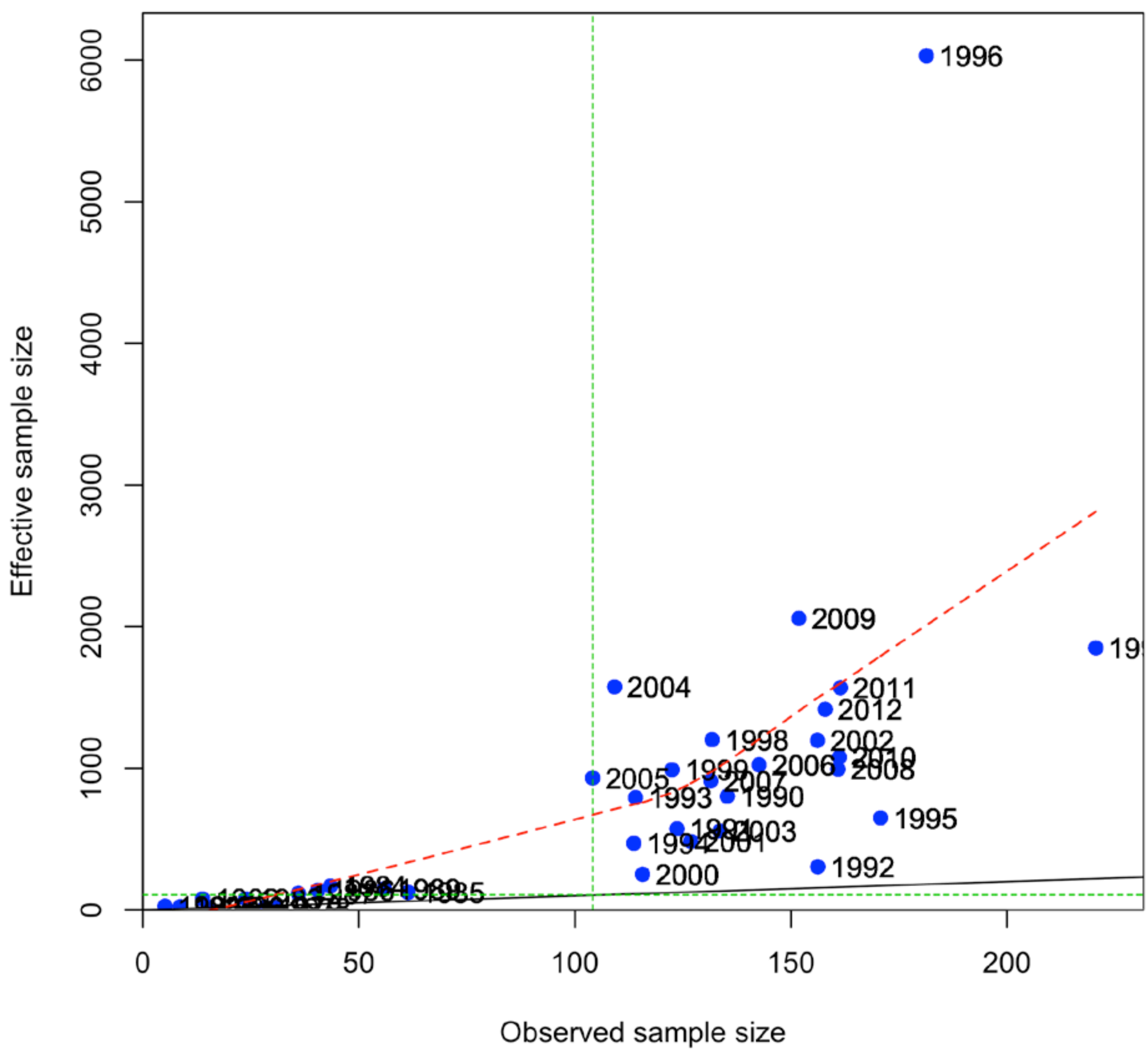


Figure 25: Observed vs. expected sample sizes for the retained catch. Red line is loess; vertical green line is the arithmetic mean of the observed sample size, horizontal green line is the harmonic mean of the effective sample size.

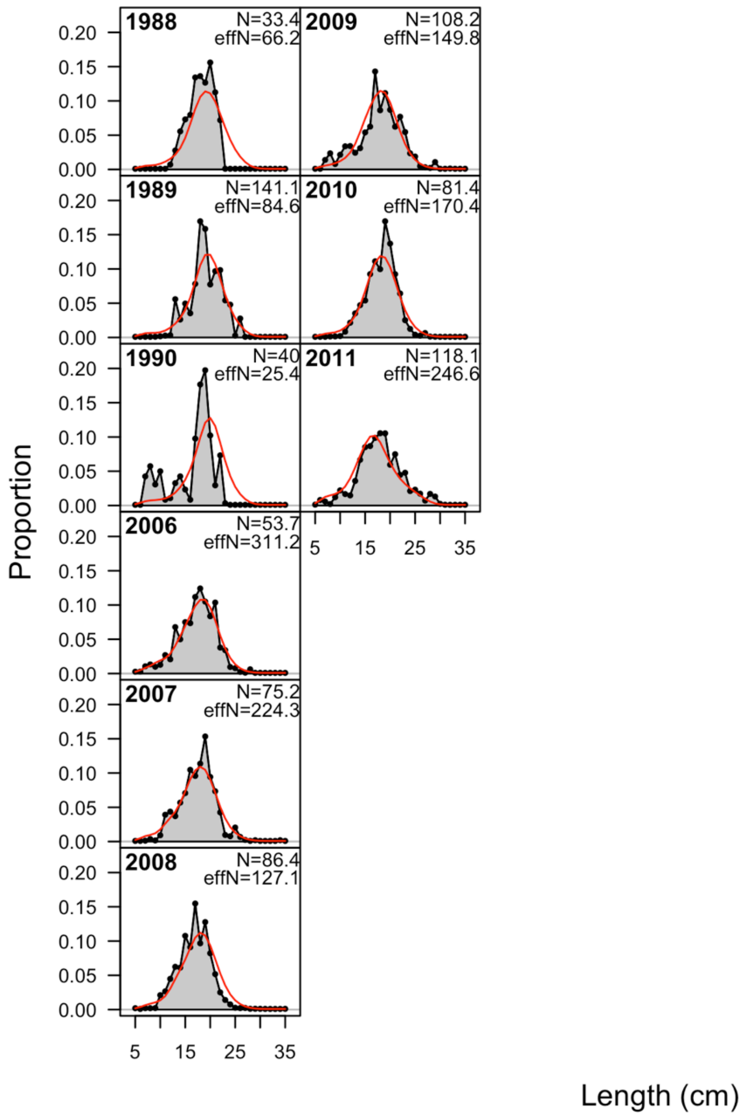


Figure 26: Base case fits to the fishery discards combined-sex length composition data.

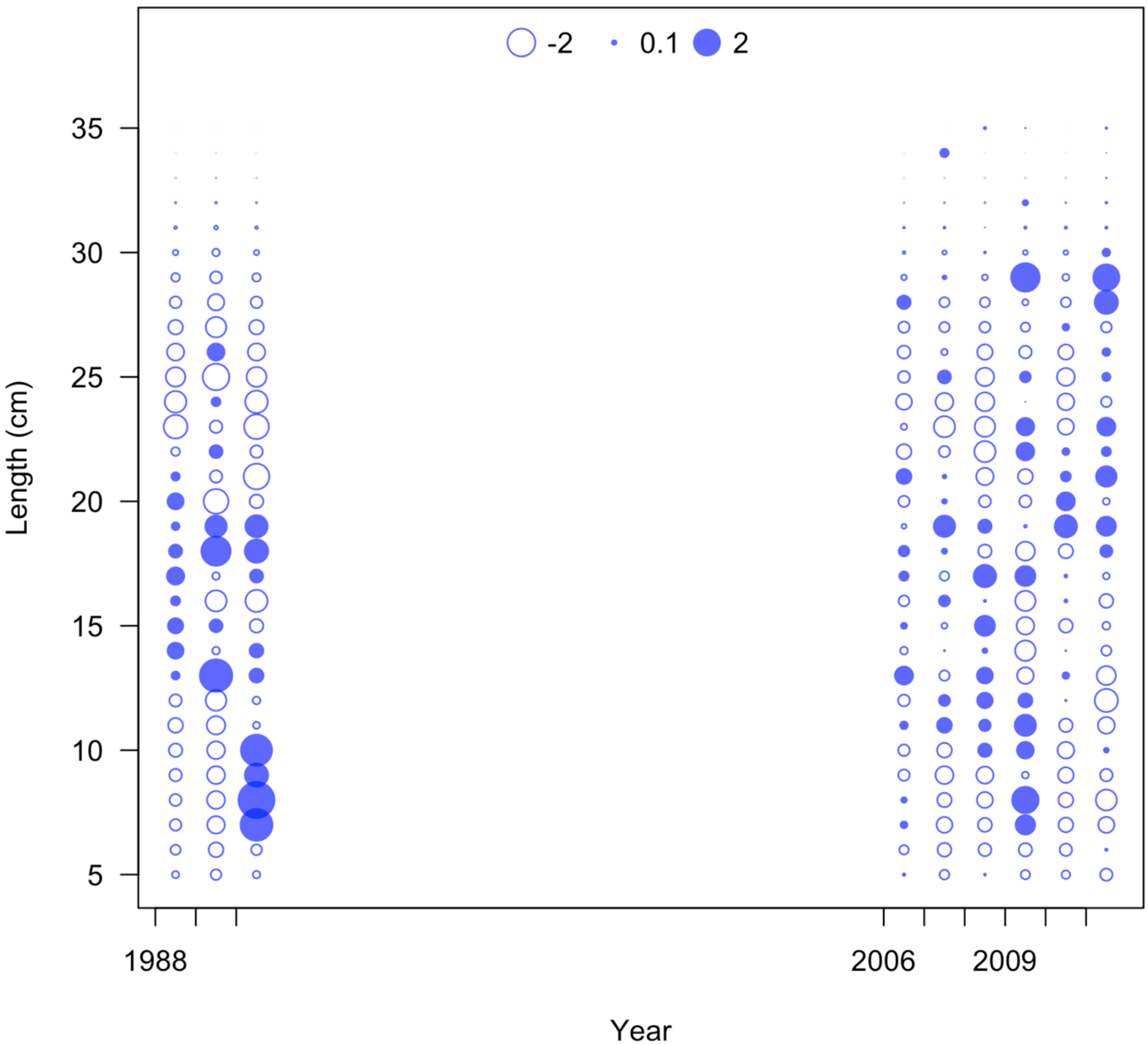


Figure 27: Residual fits to the fishery discard length compositions. Maximum is 3.7.

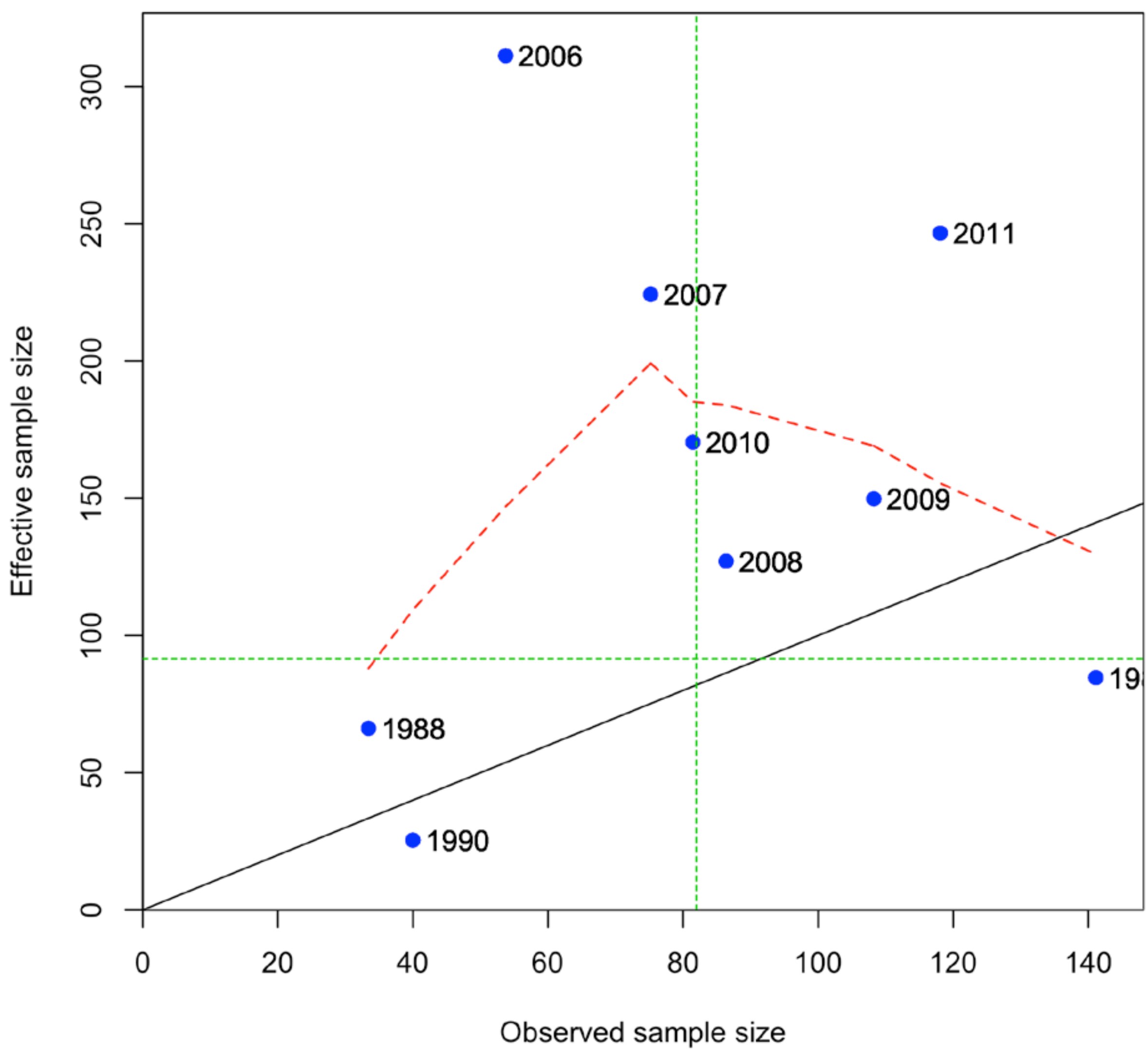


Figure 28: Observed vs. expected fishery discard length composition sample sizes. Red line is loess; vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

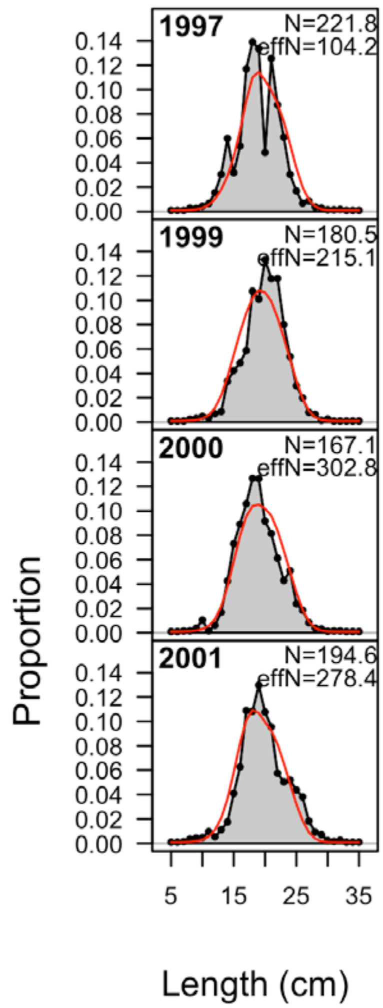


Figure 29: Base model fits to the AFSC slope combined-sex length compositions.

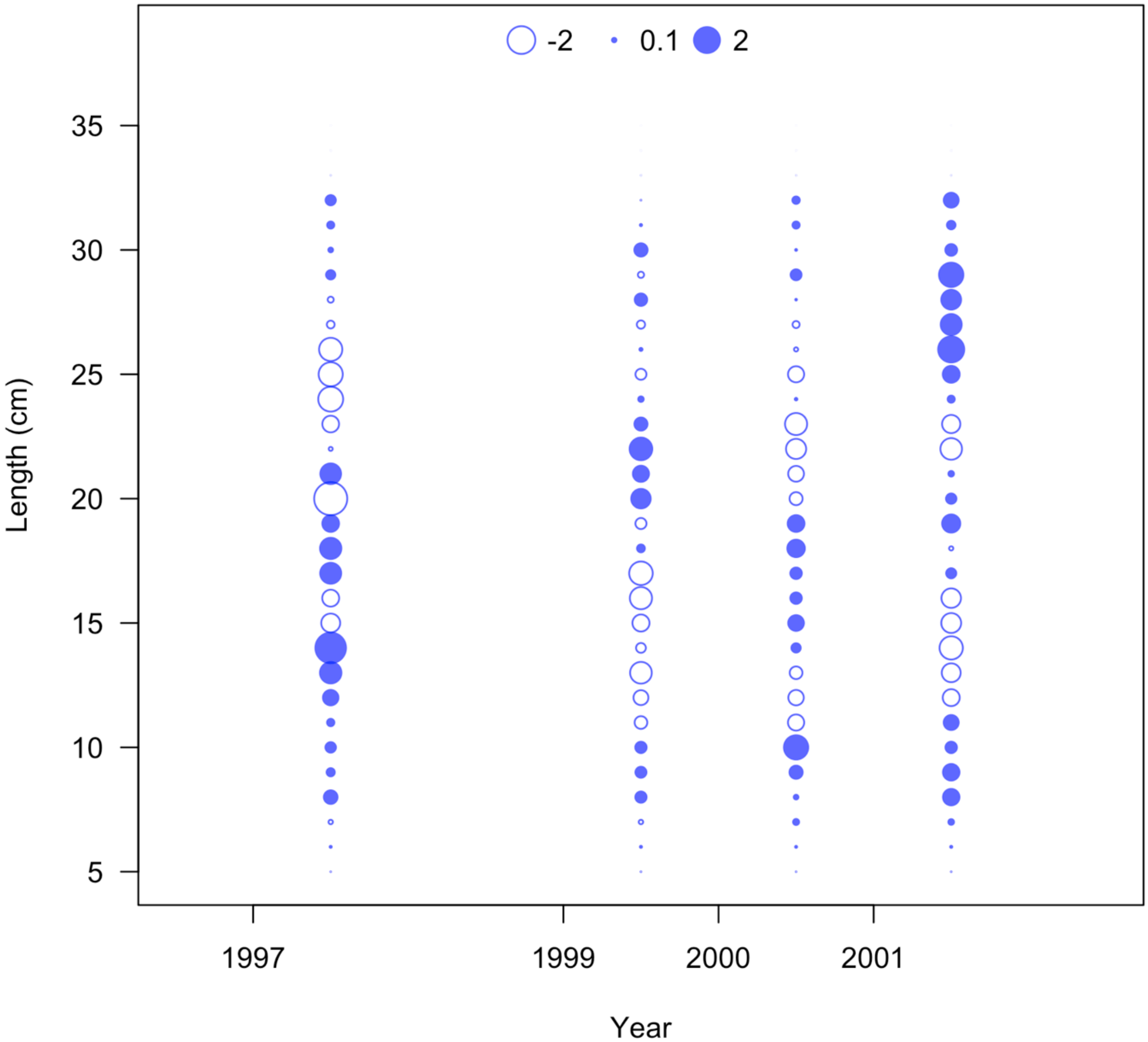


Figure 30: Residual fits to the AFSC slope length compositions. Maximum is 2.73.

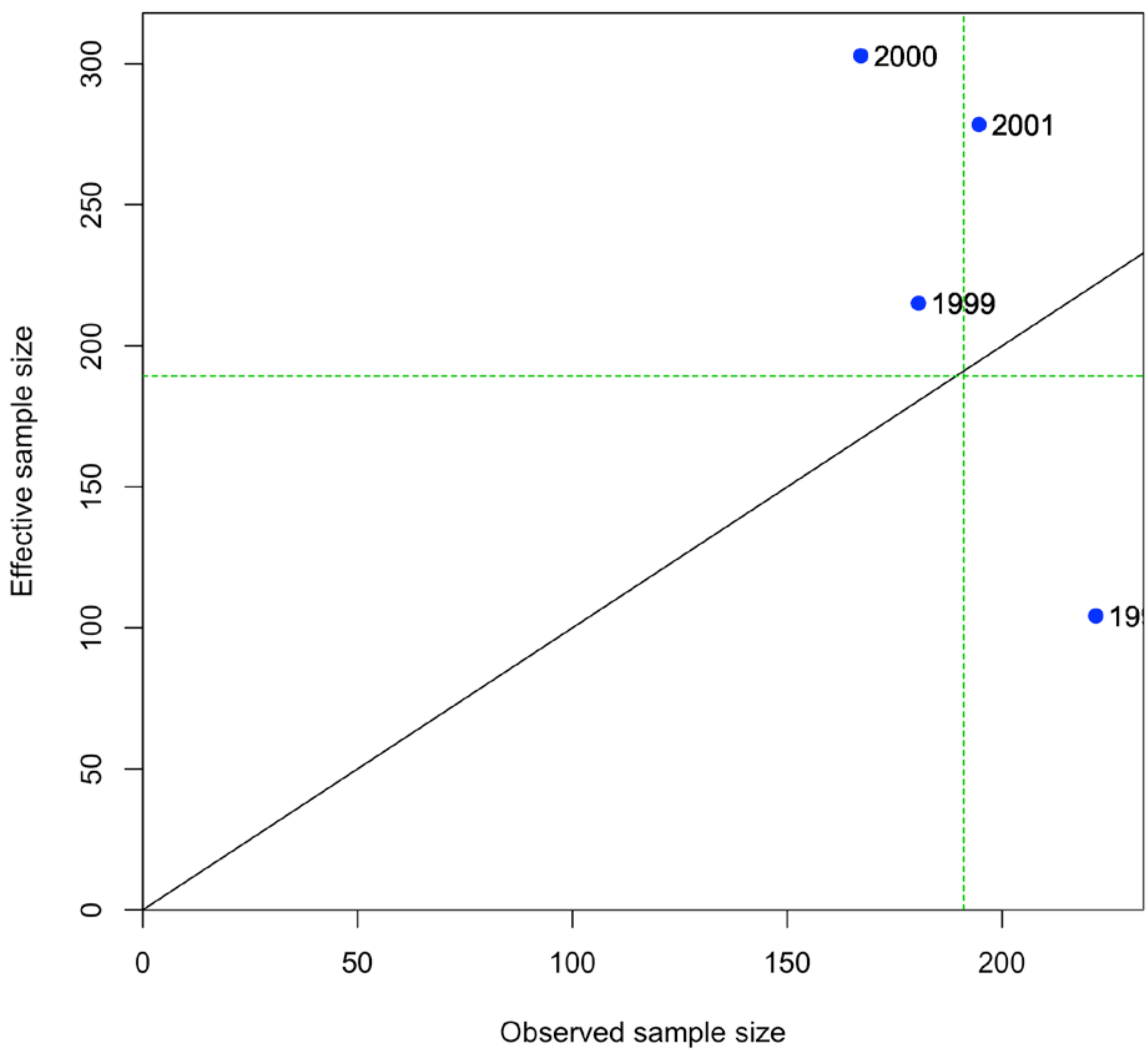


Figure 31: Observed vs. expected AFSC slope length composition sample sizes. Red line is loess; vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

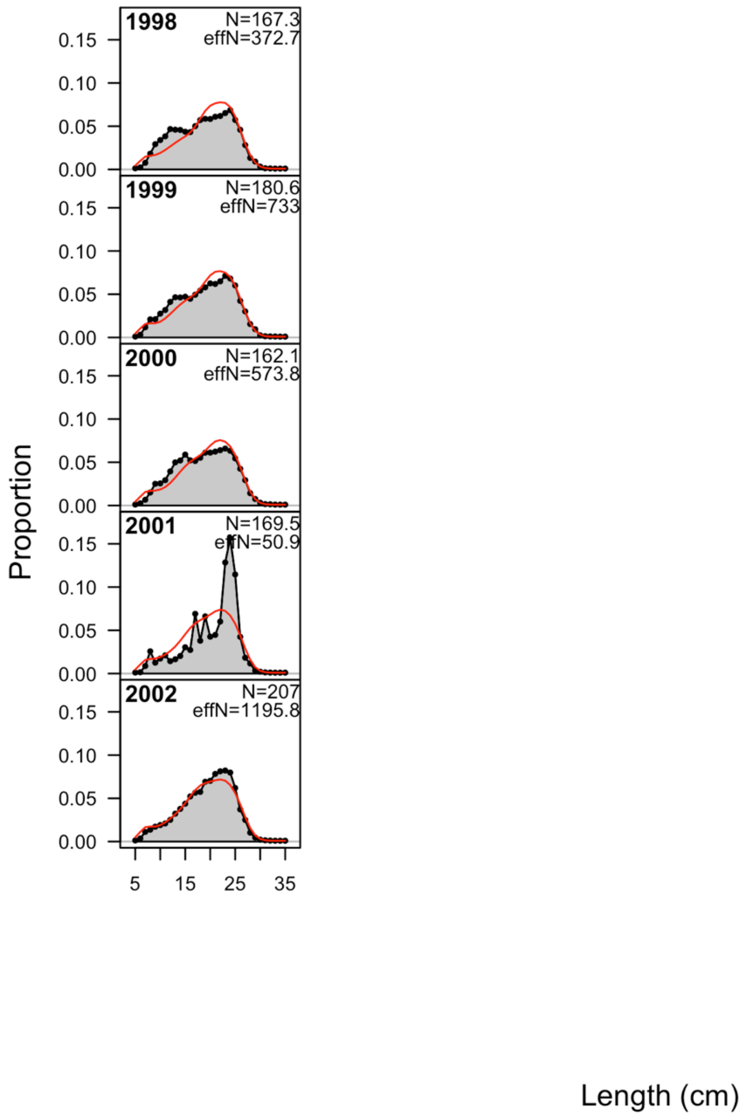


Figure 32: Base model fits to the NWFSC slope combined-sex length compositions.

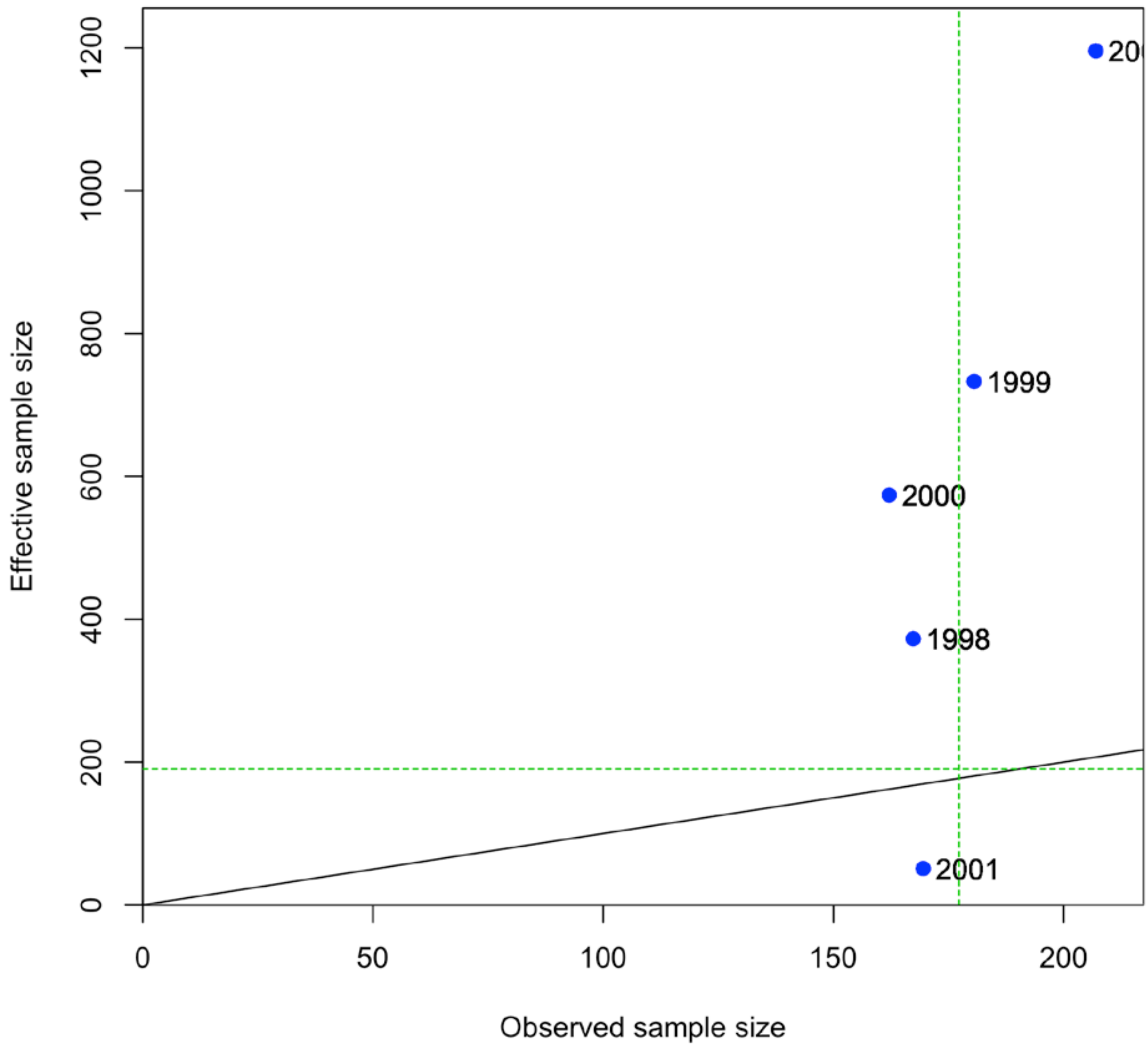


Figure 33: Observed vs. expected AFSC slope length composition sample sizes. Red line is loess; vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

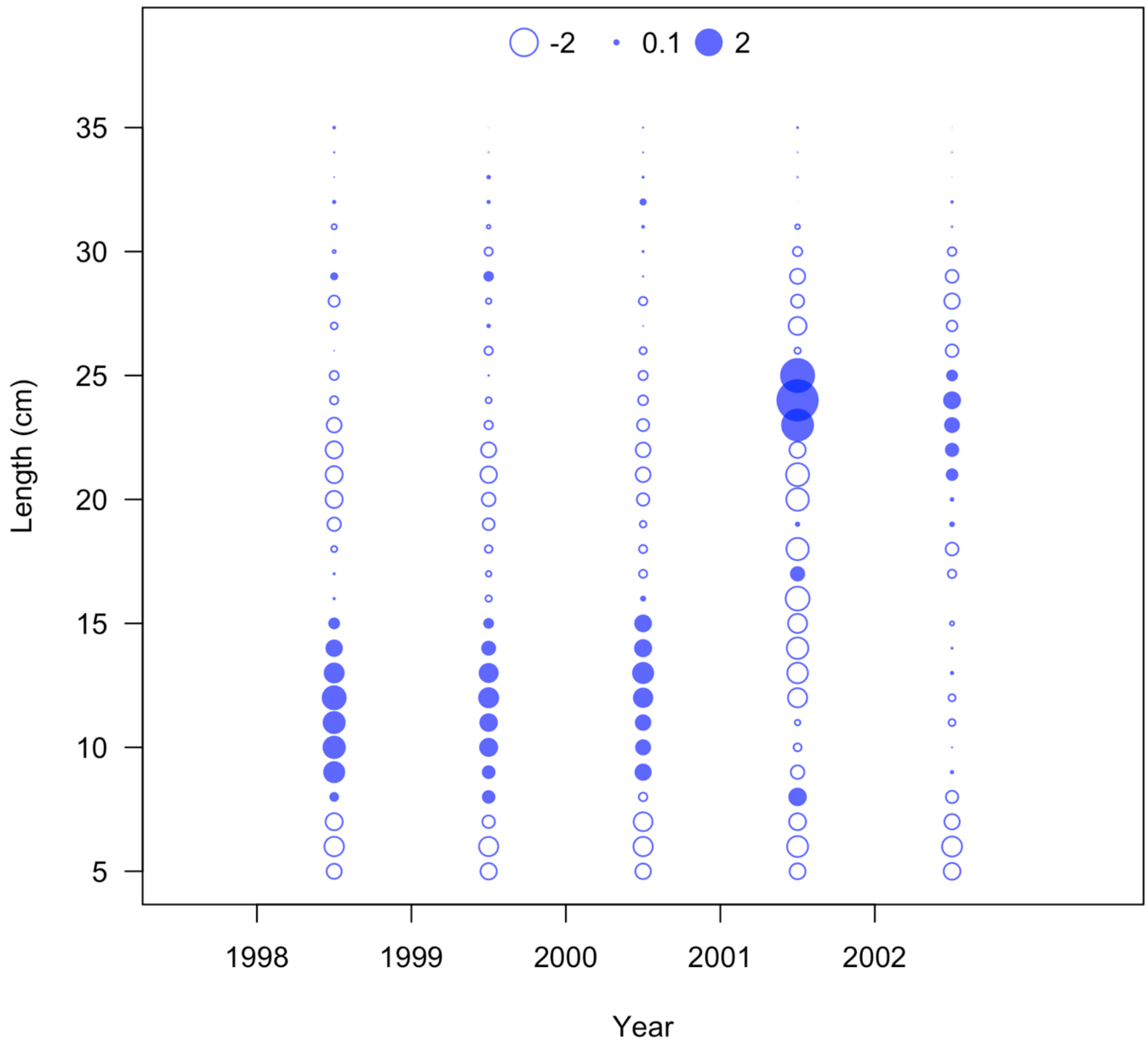


Figure 34: Pearson residuals for the NWFSC slope length compositions. Maximum is 4.65.

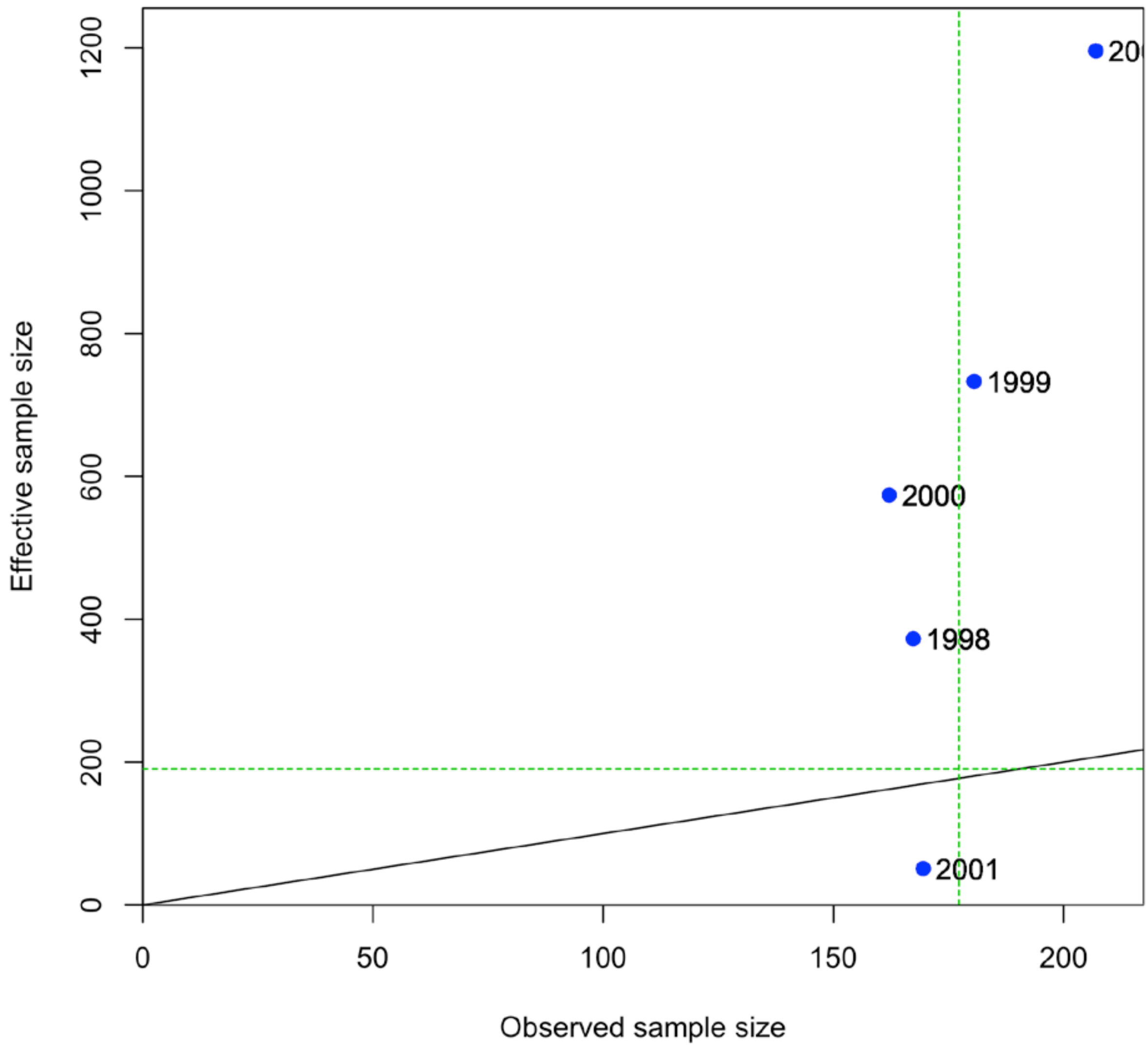


Figure 35: Observed vs. expected NWFSC slope length composition sample sizes. Vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

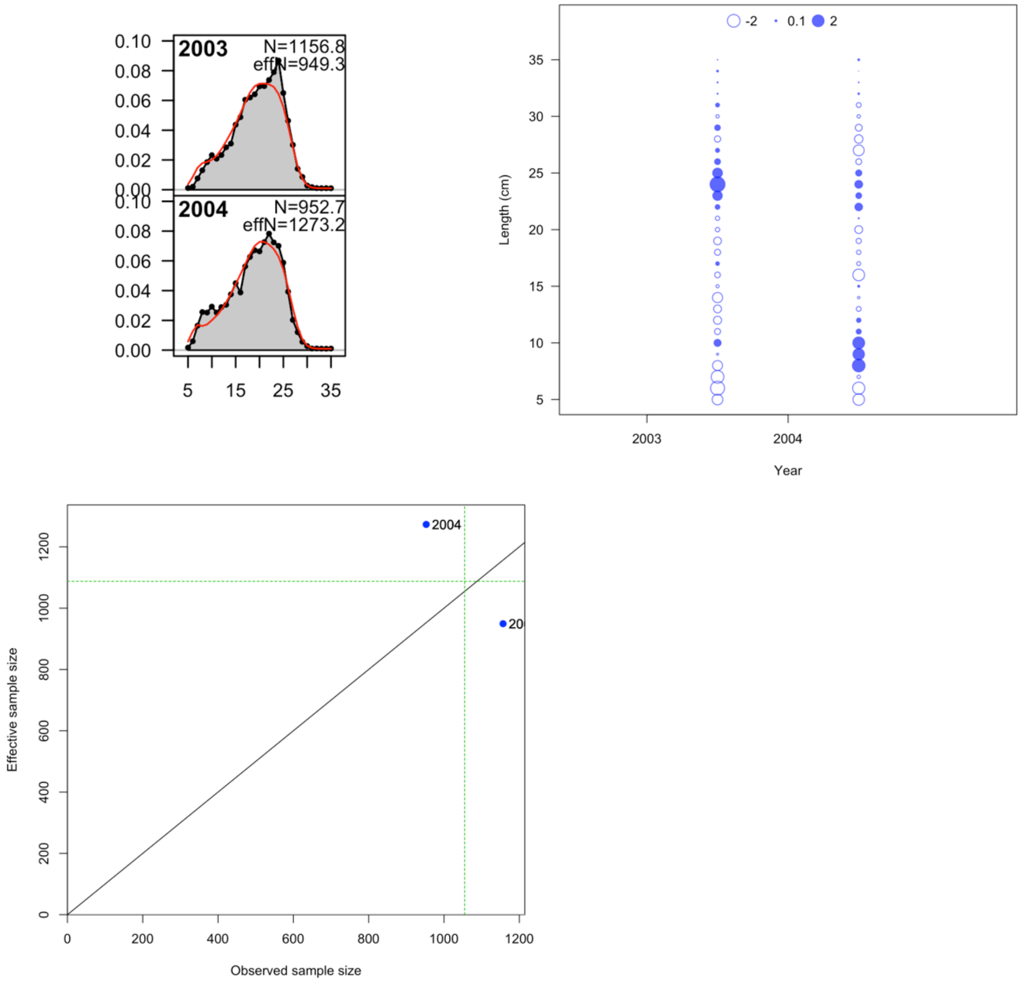


Figure 36: Combined-sex years (2003-04) base model fits to the NWFSC combo combined sex length compositions (top left), Pearson residuals (top right, maximum is 3.11), and effective sample sizes (bottom panel). The vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

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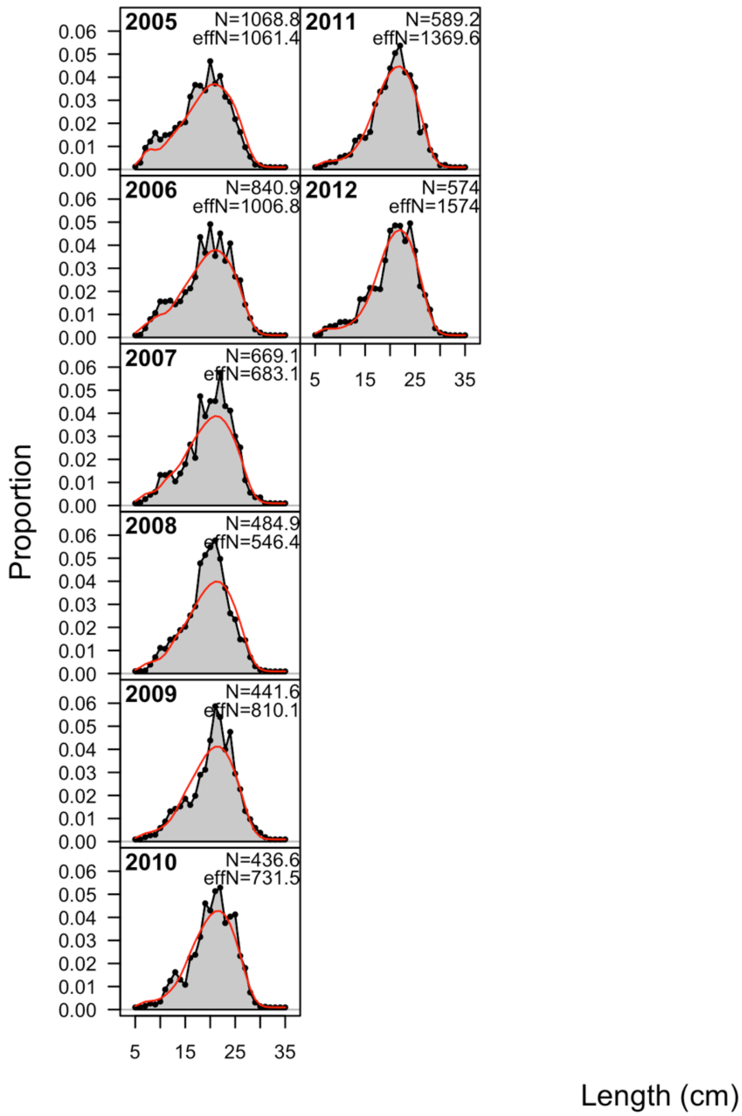

Figure 37: Base model fits to the later years of the NWFSC combo female length compositions.

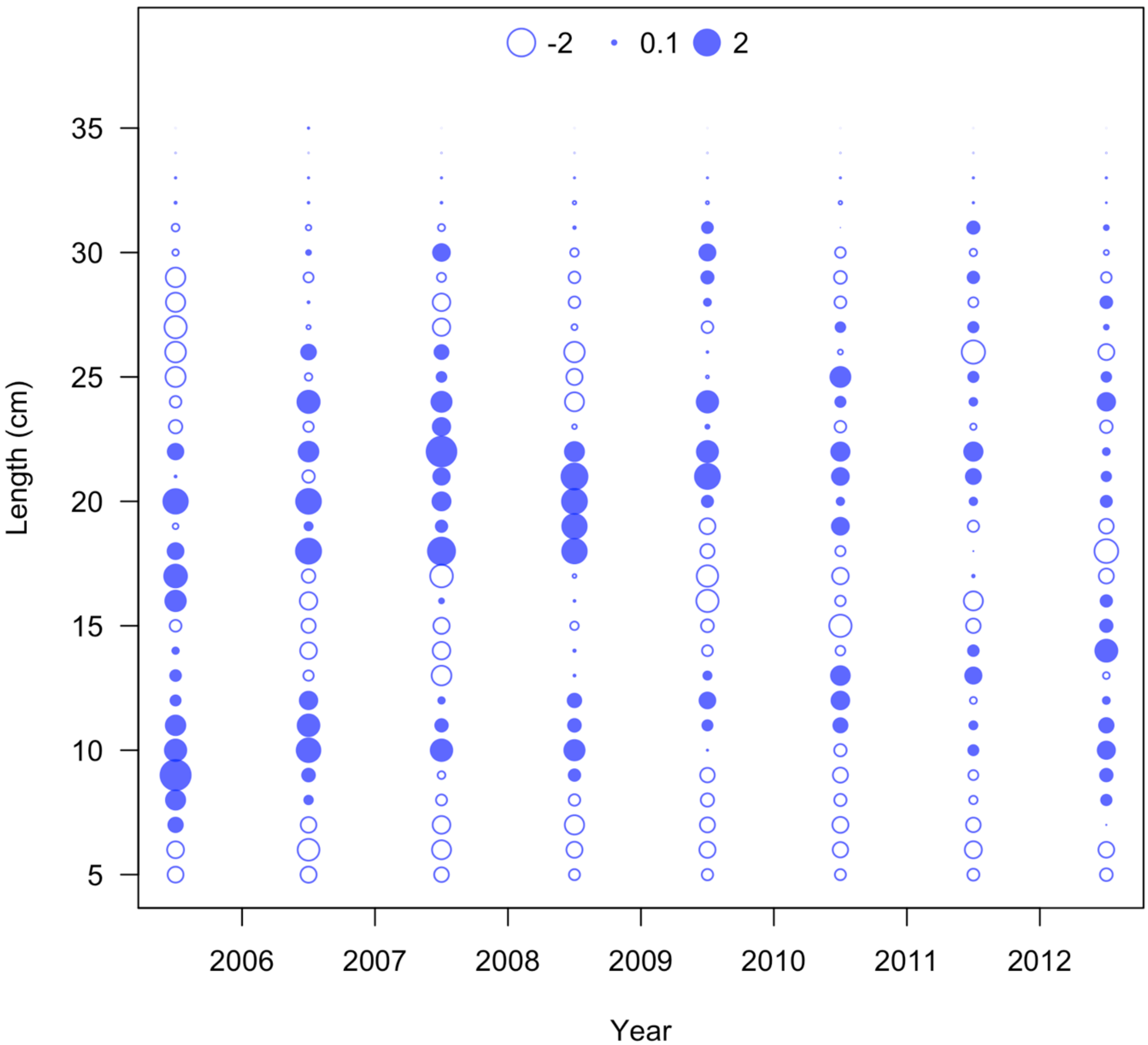

Figure 38: Pearson residuals for the later years of the NWFSC combo female length compositions. Maximum is 2.65.

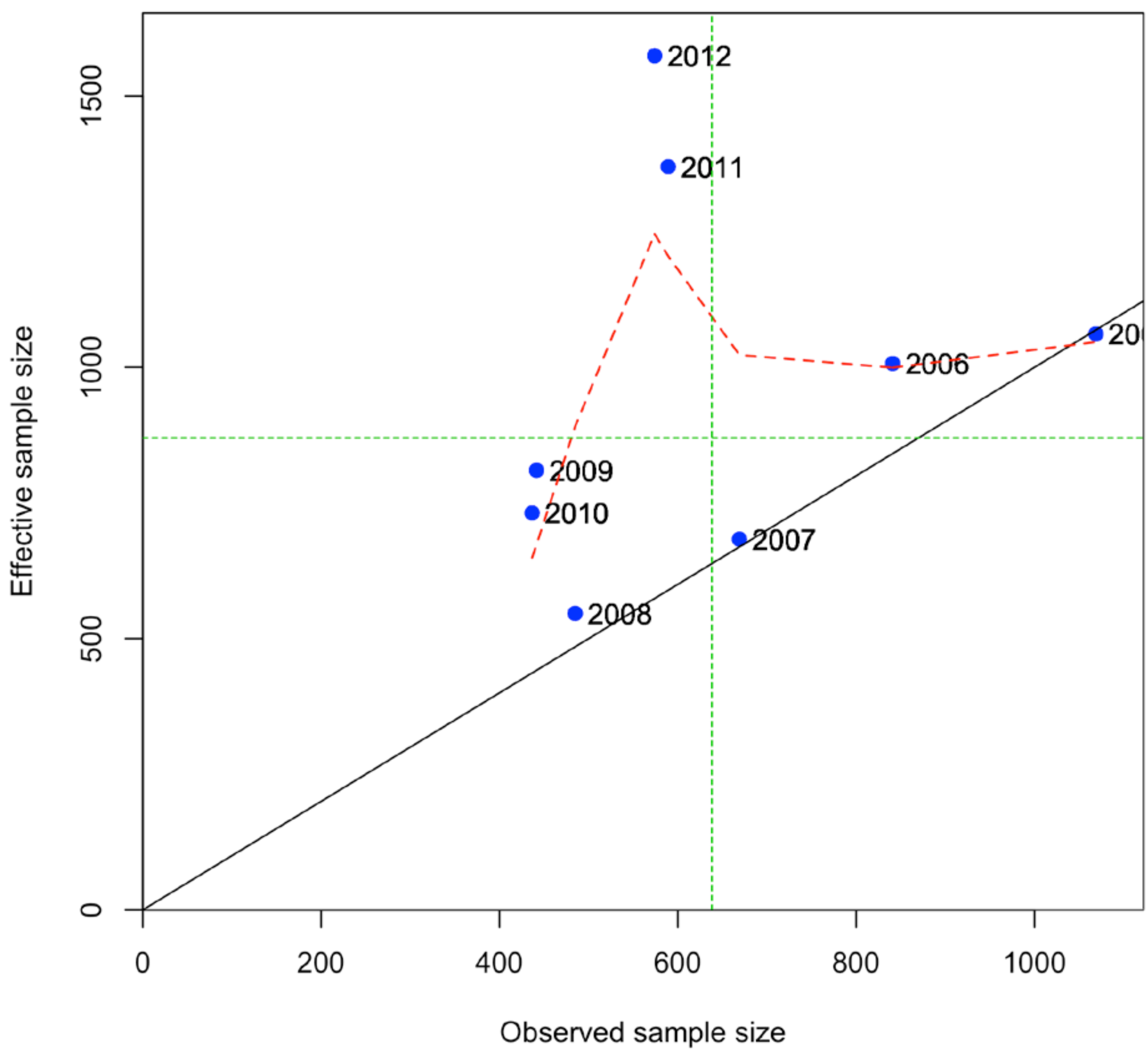

Figure 39: Observed vs. expected for the later years of the NWFSC combo female length composition sample sizes. Red line is loess; vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

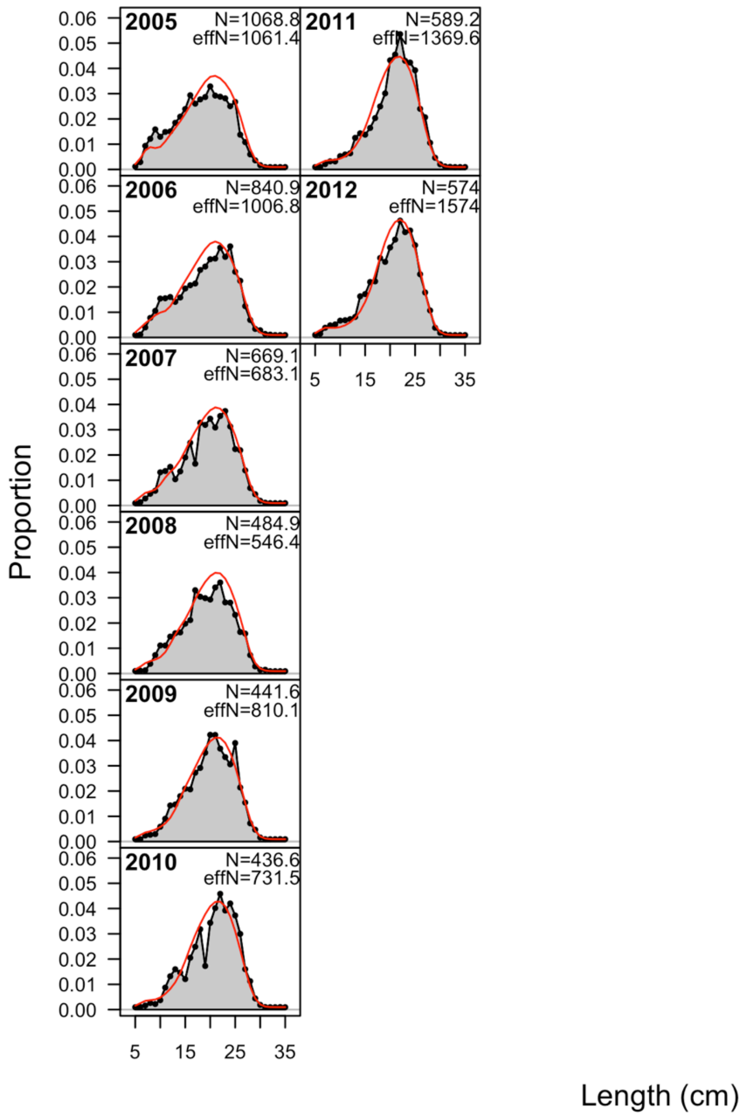

Figure 40: Base model fits to the later years of the NWFSC combo male length compositions.

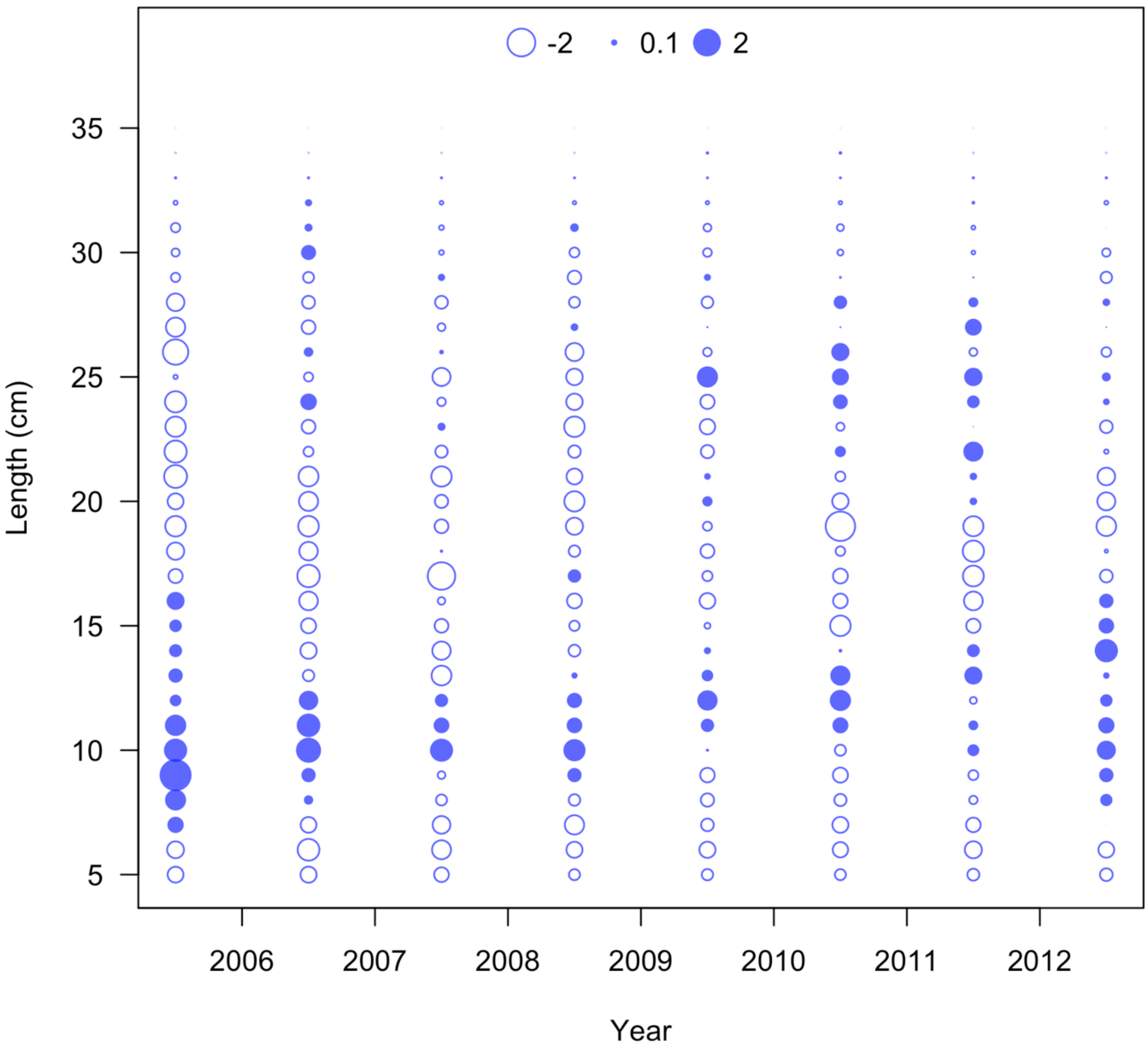

Figure 41: Pearson residuals for the later years of the NWFSC combo male length compositions. Maximum is 2.65.

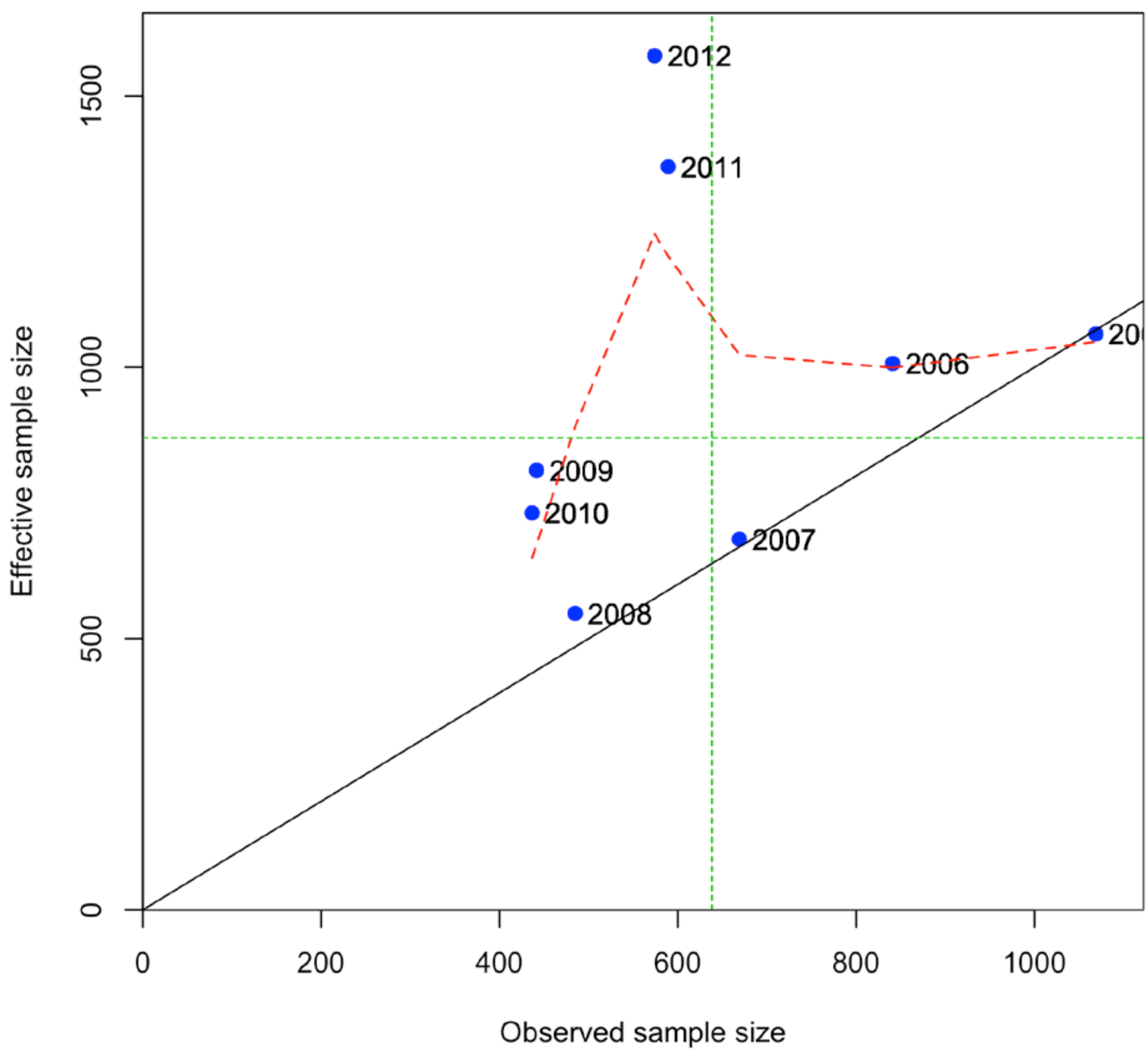

Figure 42: Observed vs. expected in the later years of the NWFSC combo male length compositions. Red line is loess; vertical green line is the arithmetic mean of observed sample size, horizontal green line is the harmonic mean of the effective sample size.

10.6.4 Selectivity

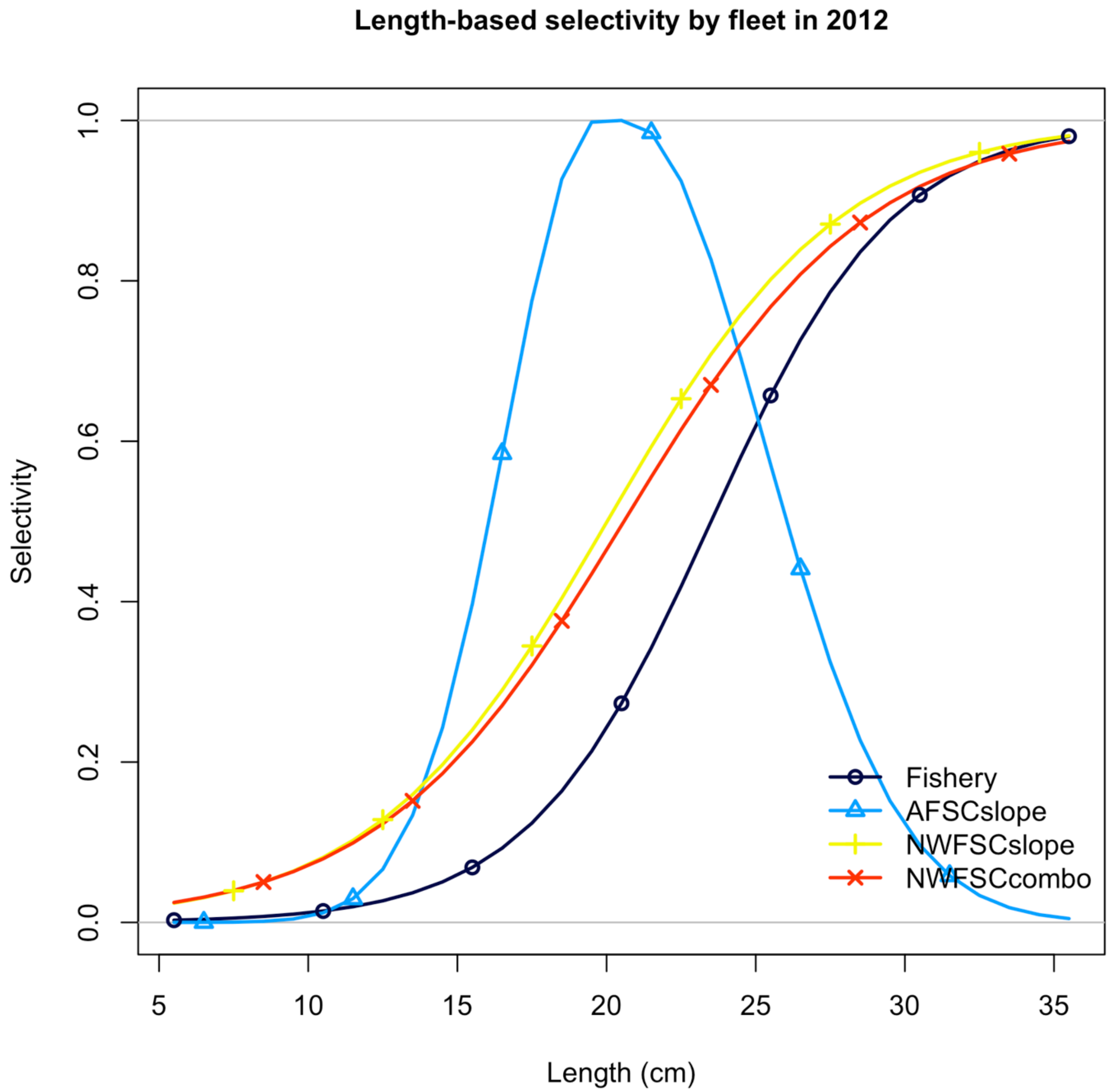

Figure 43: Estimated length-based selectivity by fishery and survey for longspine thornyhead.

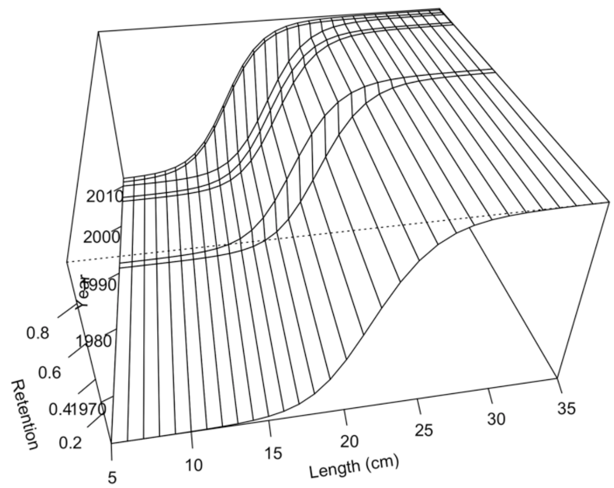

Figure 44: Estimates of the retention curves for each time block in the longspine thornyhead base case model.

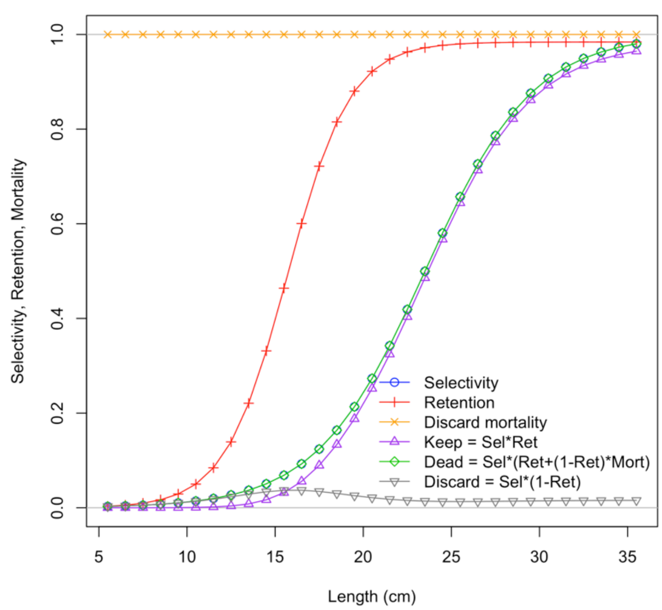

Figure 45: Selectivity, retention, and mortality curves for the fishery as estimated from the longspine thornyhead base case model. This is for 2012 only, after the implementation of catch-shares.

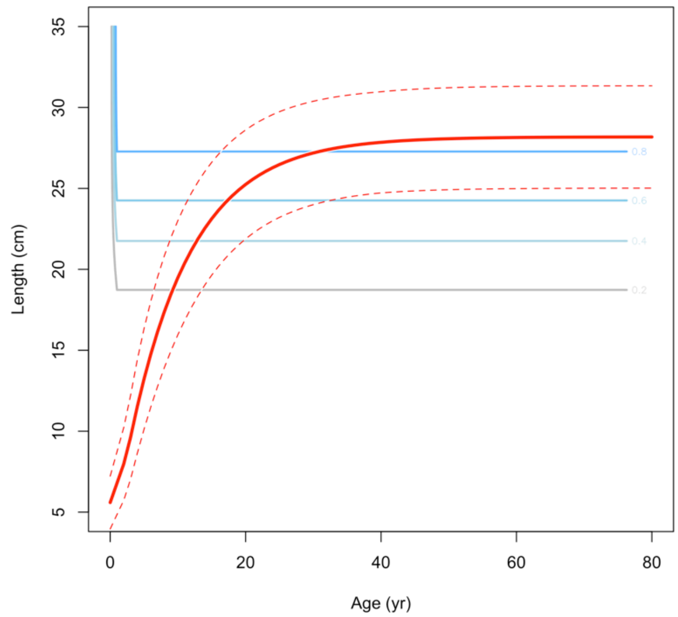

Figure 46: Age and growth (red lines) relative to selectivity curves (blue lines) for the fishery from the longspine thornyhead base case model.

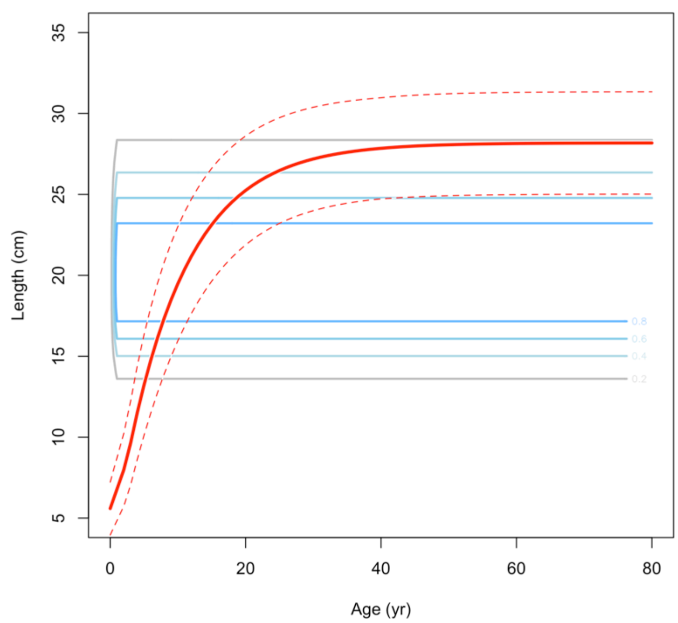

Figure 47: Age and growth (red lines) relative to selectivity curves (blue lines) for the AFSC slope from the longspine thornyhead base case model.

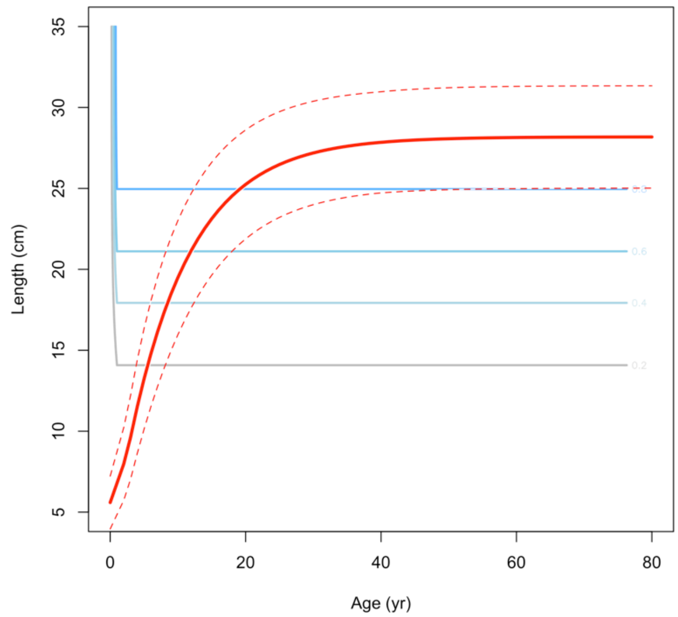

Figure 48: Age and growth (red lines) relative to selectivity curves (blue lines) for the NWFSC slope from the longspine thornyhead base case model.

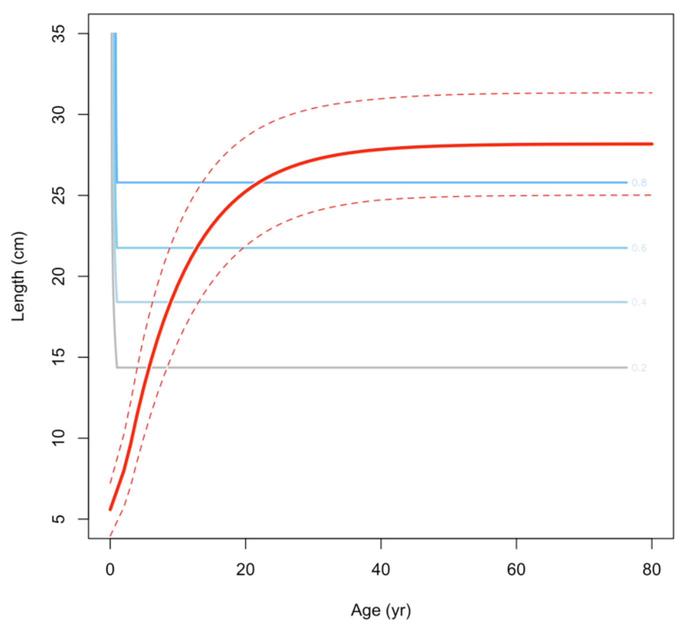

Figure 49: Age and growth (red lines) relative to selectivity curves (blue lines) for the NWFSC Combo from the longspine thornyhead base case model.

10.6.5 Recruitment

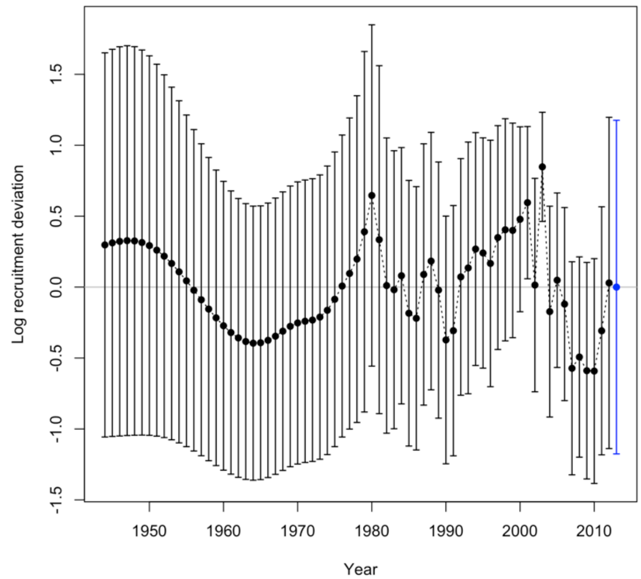

Figure 50: Time series of estimated recruitment deviations from the longspine thornyhead base case model. Vertical lines indicate the 95% CIs.

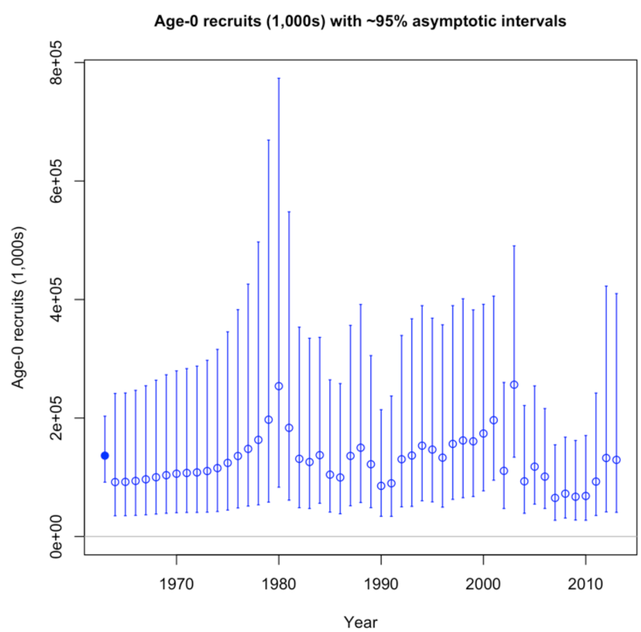

Figure 51: Time series of recruitment with asymptotic estimated 95% CIs for the longspine thornyhead base case model.

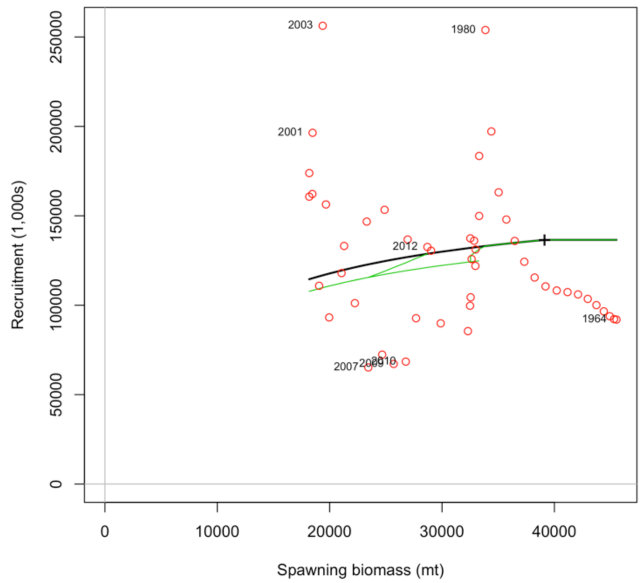

Figure 52: Spawner-recruit time series from the longspine thornyhead base case model. Reference years (beginning, ending, and high points) are labeled.

10.6.6 Biomass and status

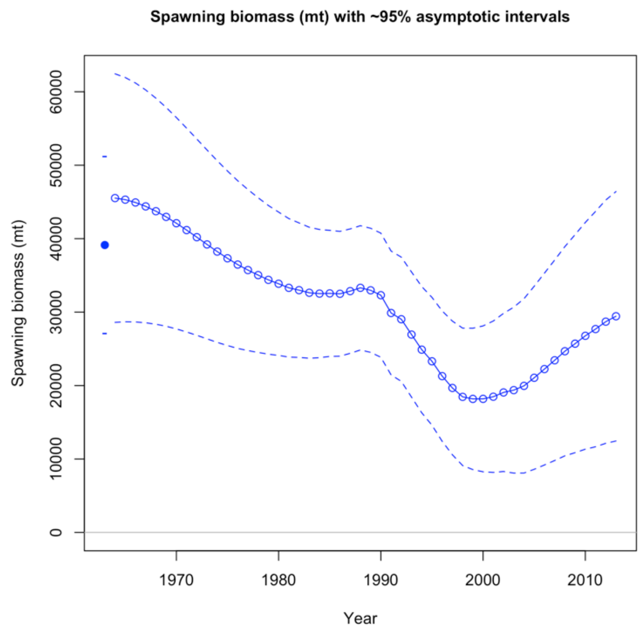

Figure 53: Time series of spawning biomass with asymptotic estimated 95% CIs for the base case model. The disconnected point at left represents the unfished equilibrium estimate and its associated uncertainty.

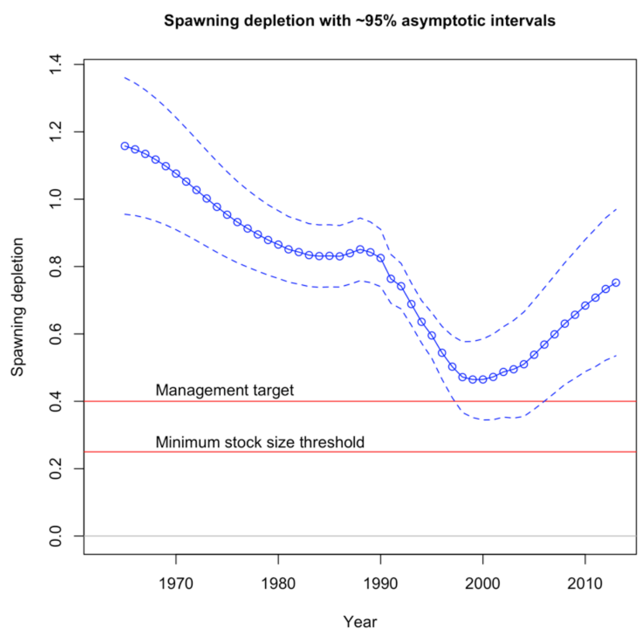

Figure 54: Time series of stock status (depletion) with asymptotic estimated 95% CIs for the longspine thornyhead base case model.

10.6.7 Management outputs

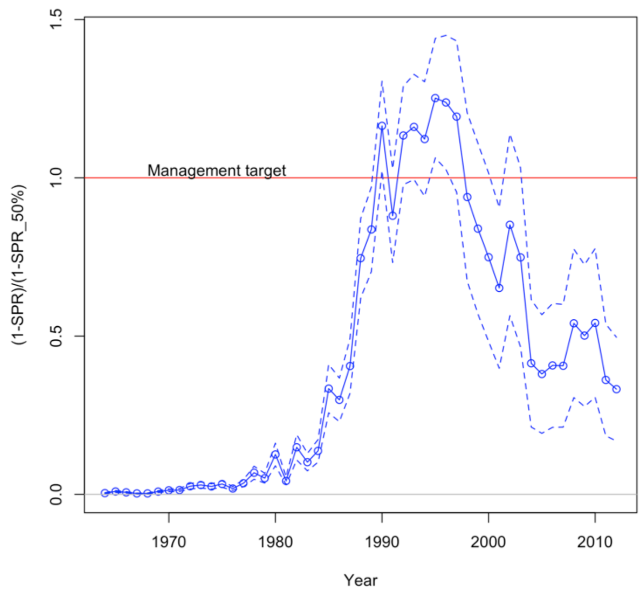

Figure 55: Time series of exploitation relative to the management target from the longspine thornyhead base case model. Symbols and line are the mean values. Broken lines indicate asymptotically estimated 95% CIs

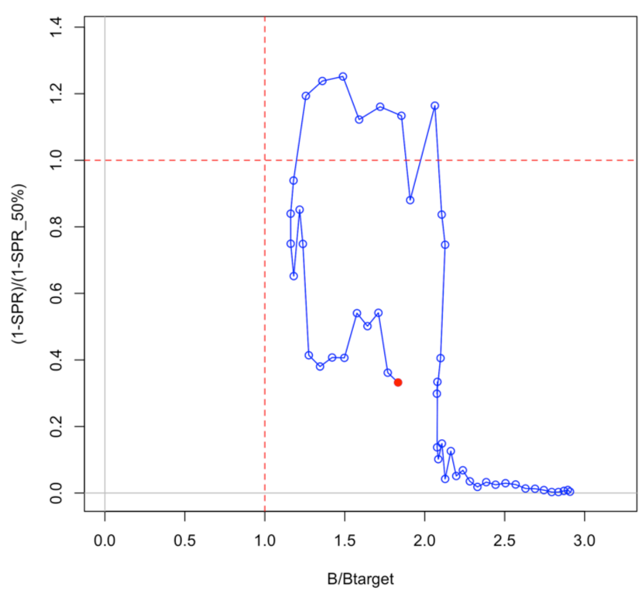

Figure 56: Quadrant plot showing the time series of stock status (x-axis) and exploitation metrics (y-axis) from the base case model. Red vertical broken line indicates biomass target; red horizontal broken line indicates exploitation target. Red dot is the current year.

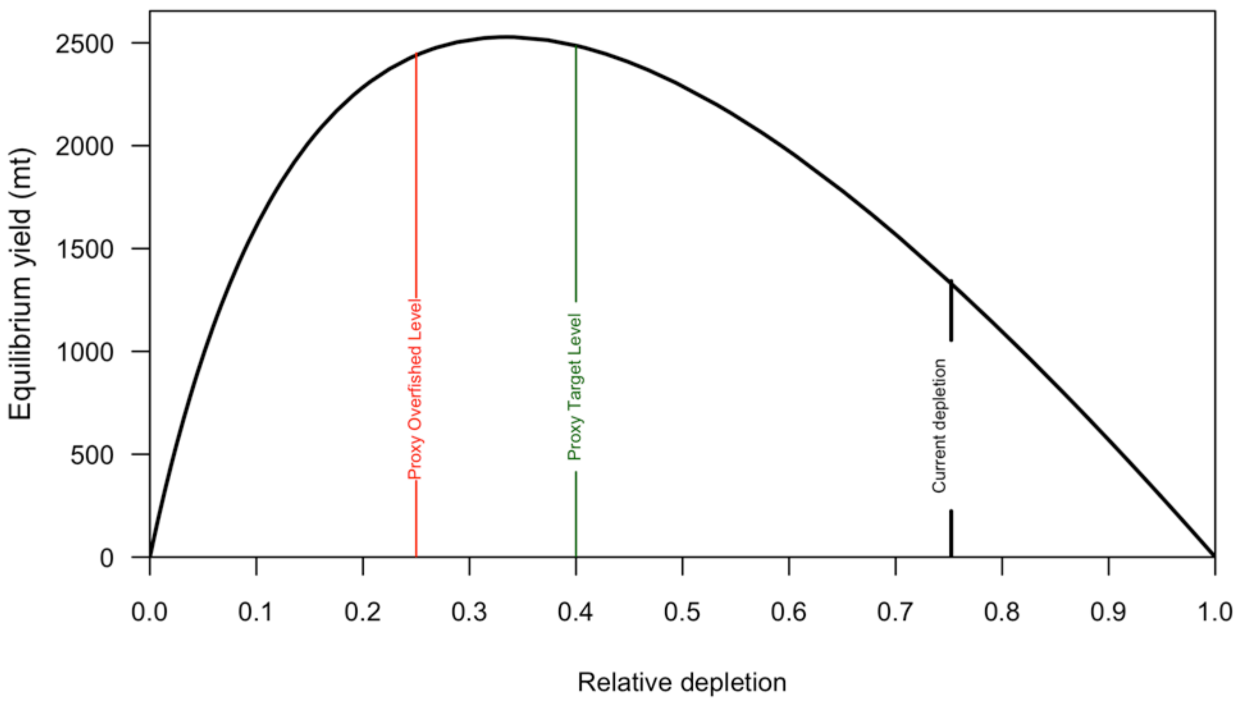

Figure 57: Equilibrium yield curve (derived from reference point values reported in Table 8) for the base case model. Values are based on 2012 fishery selectivity and allocation between fleets. The depletion is relative to unfished spawning biomass.

10.6.8 Sensitivity to Historical Catch Reconstruction

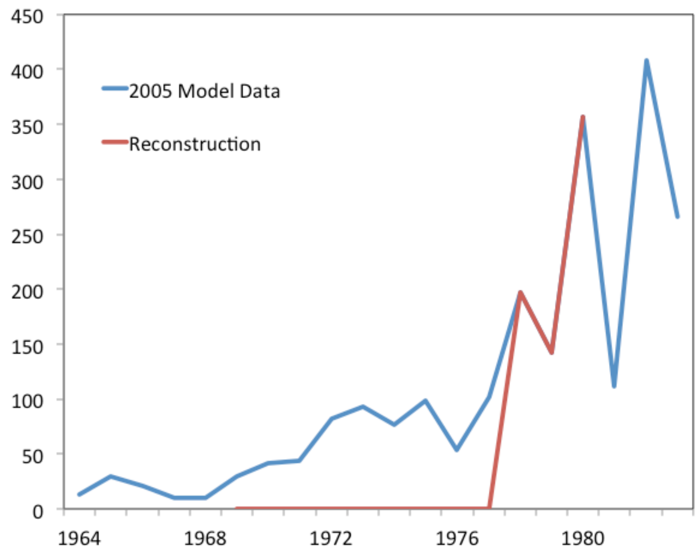

Figure 58: The California and Oregon historical reconstructed catch (in red) lies well below the values used in 2005 (blue) for the period 1969-1977.

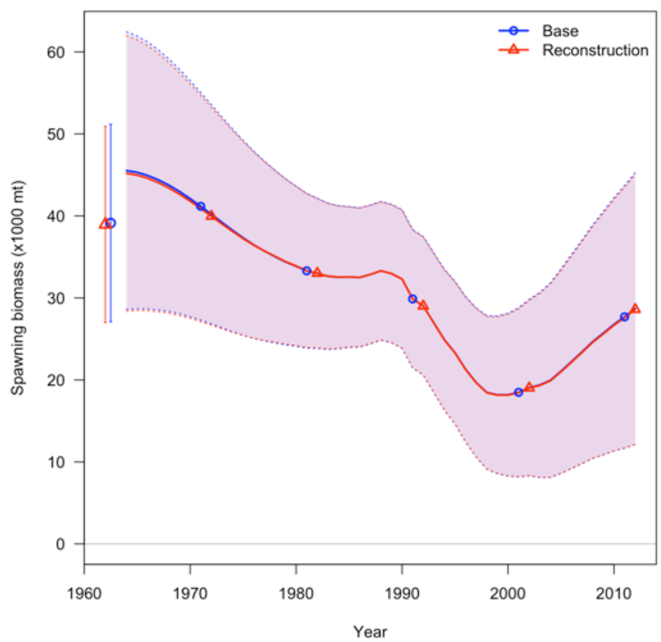

Figure 59: Biomass in the base model (blue circles) and model using the reconstructed catches (red triangles).

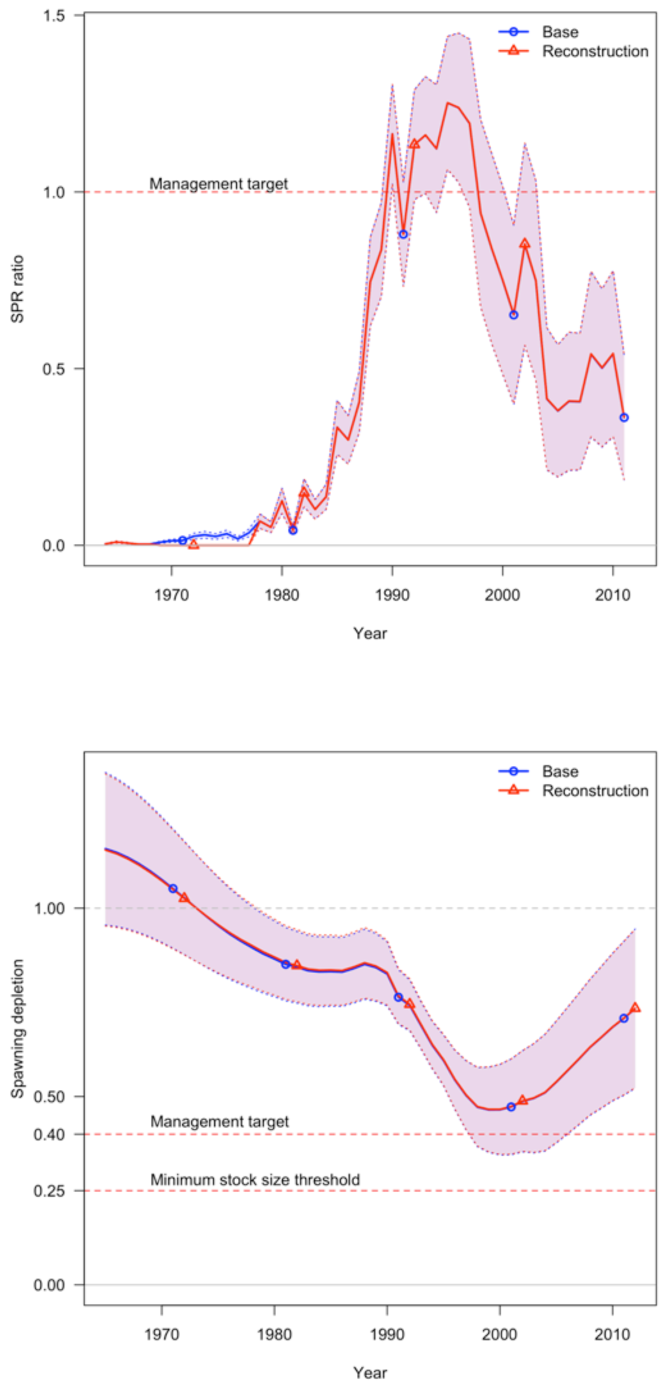

Figure 60: Stock status in terms of SPR target (top panel) and Spawning Depletion (bottom) for the base-case model and the model using the reconstructed catch.

10.6.9 Sensitivity to Recruitment Deviations

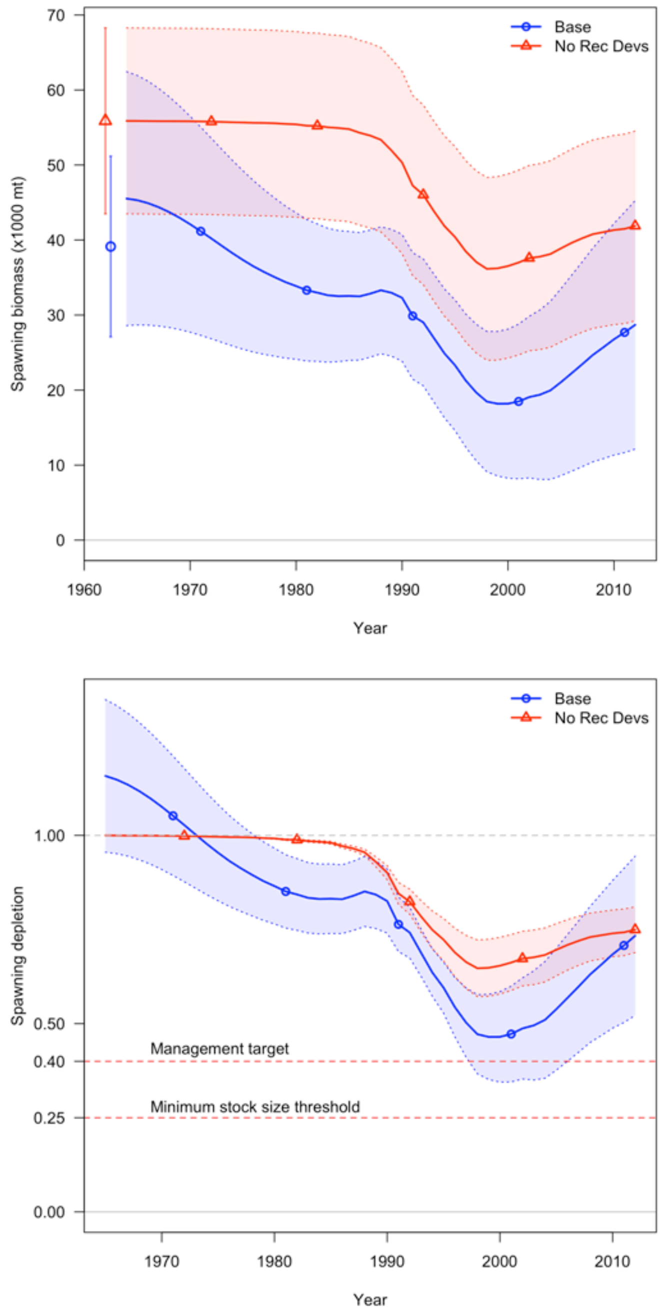

Figure 61: Stock status in terms of Spawning Biomass (top panel) and Spawning Depletion (bottom) for the base-case model and the model without estimated recruitment deviations.

10.6.10 Profiles

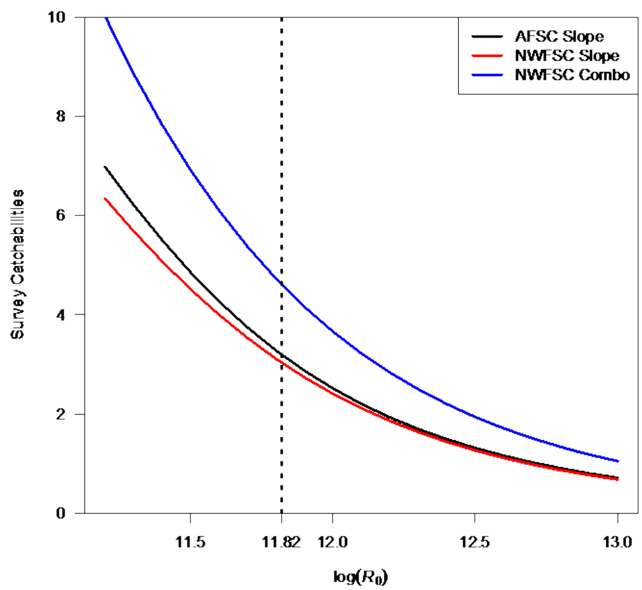

Figure 62: Survey catchability (Q values) profiled over ln(R_0). Base case value was estimated at 11.82.

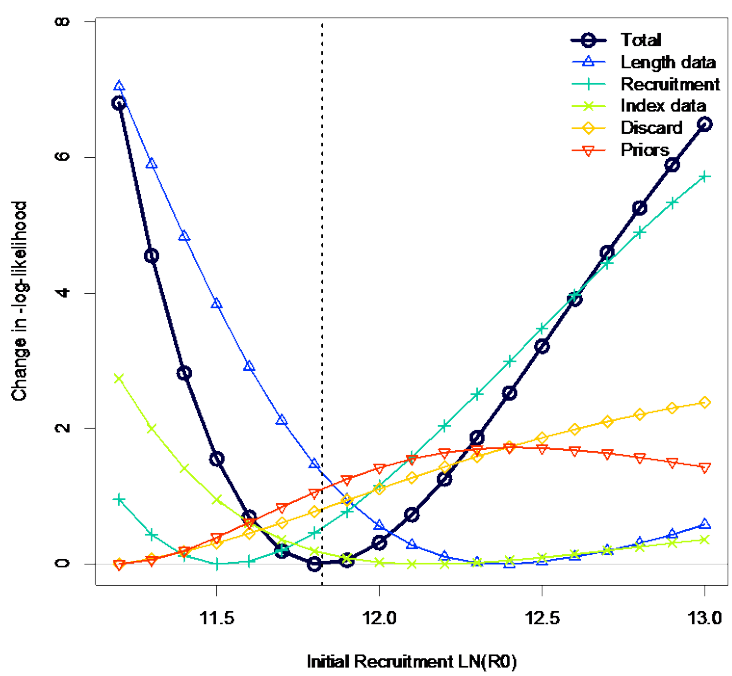

Figure 63: Change in –log-likelihood profiled over LN(R_0). Base case value was estimated at 11.82.

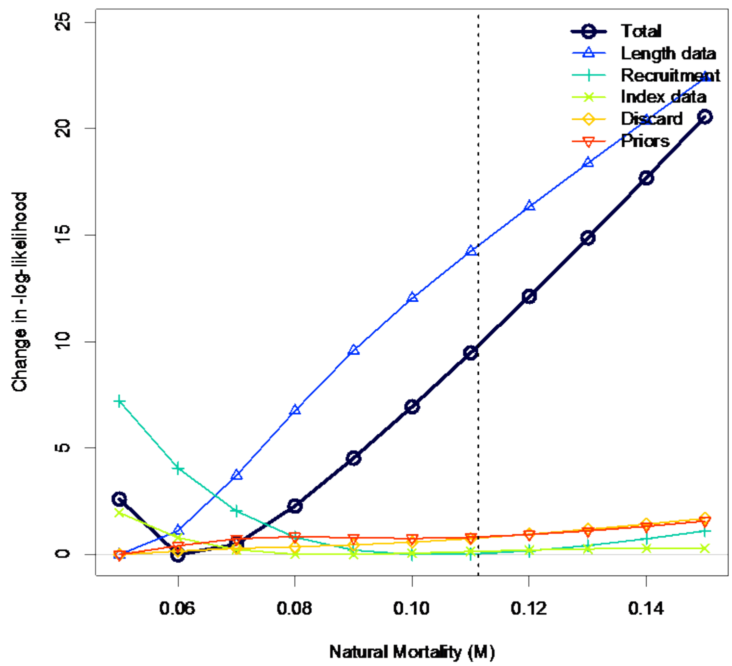

Figure 64: Change in -log-likelihood profiled over M. Base case value was fixed at 0.1113.

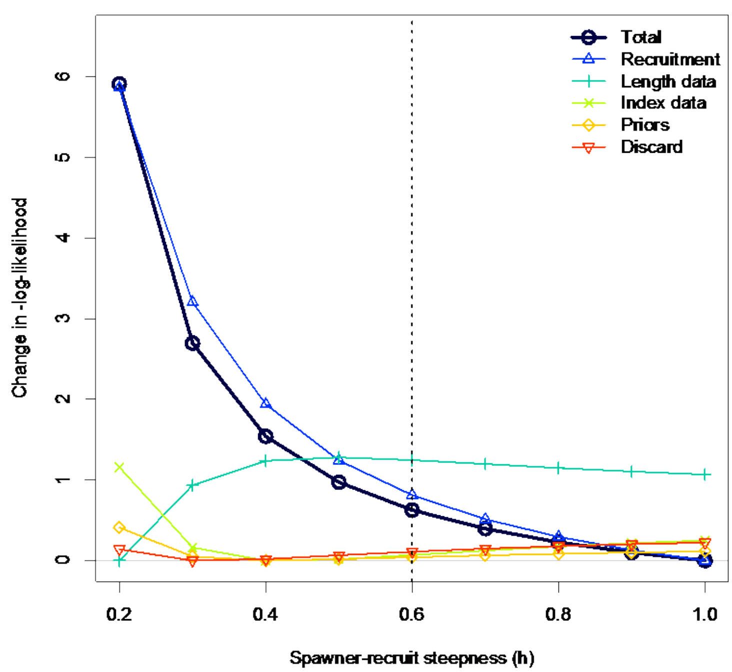

Figure 65: Change in -log-likelihood profiled over spawner-recruit steepness (h). Base case value fixed at 0.6.

10.6.11 Retrospective runs

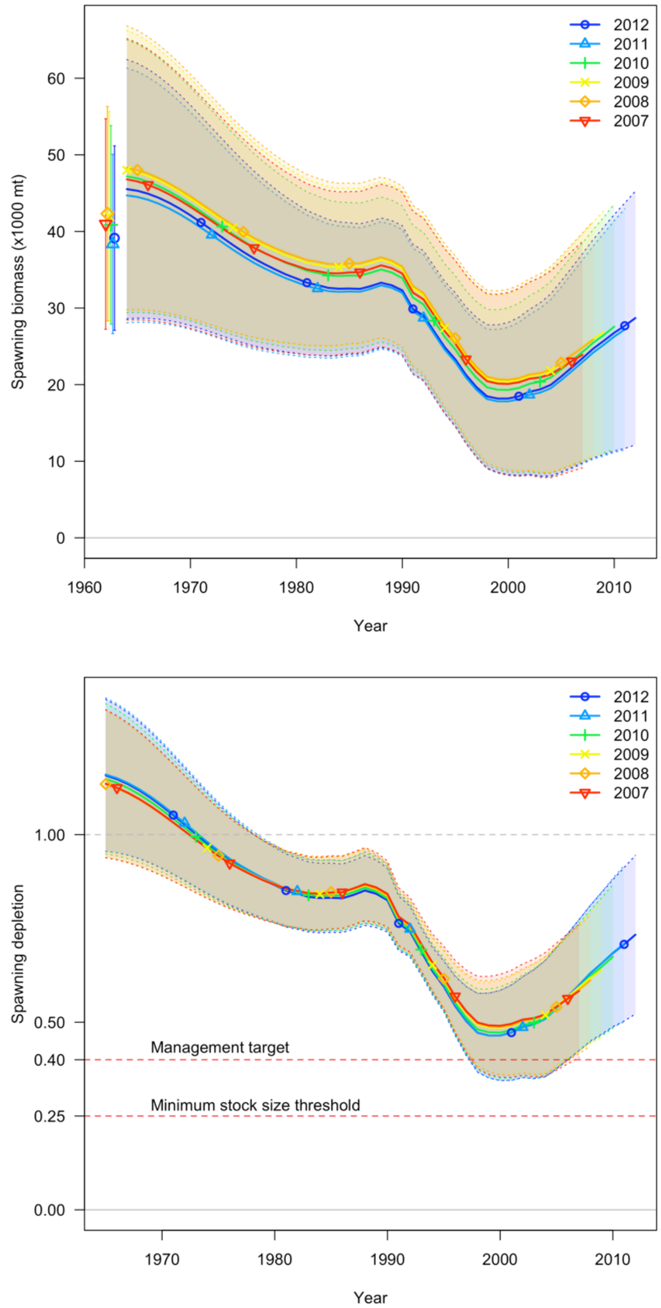

Figure 66: Spawning biomass (top) and depletion (bottom) for the base case and each retrospective run. Solid lines and symbols are median values; polygons are the 95% CI.

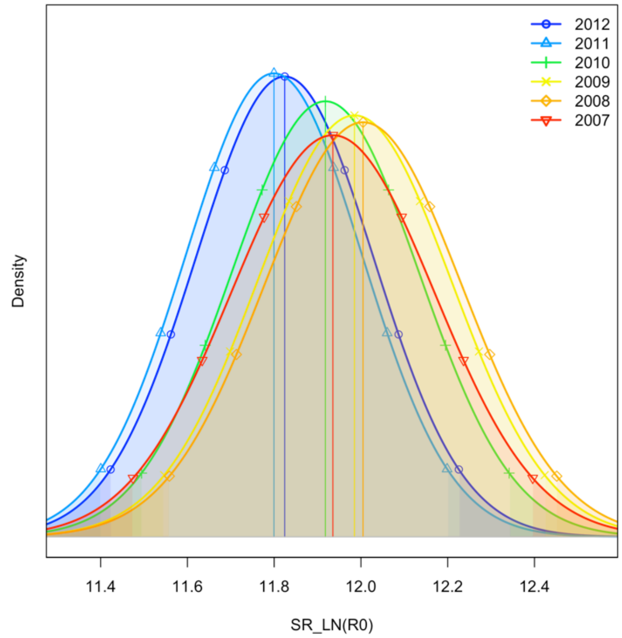

Figure 67: Value of initial recruitment across different retrospective years and the base case.

10.6.12 Comparison with 2005 results

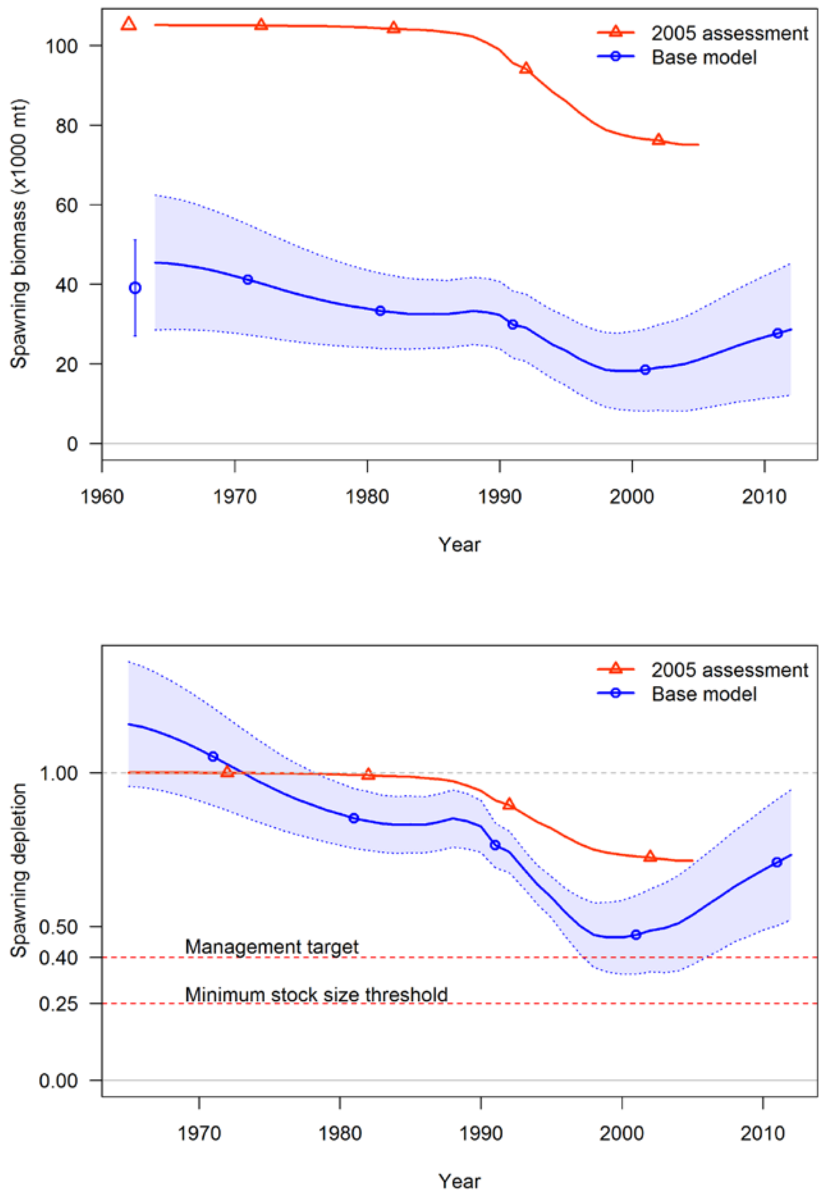

Figure 68: The base-case model (blue) and 2005 model (red) in terms of Spawning Biomass (top panel) and Depletion (bottom). Estimates of uncertainty were unavailable for the 2005 model.

Appendix A. Numbers at age

Table A.1. Numbers at age (millions) predicted by the base-case model.

Age (Yr)	0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-44	45+
1964	92.0	83.2	76.4	71.0	66.6	63.0	60.0	57.3	54.8	52.4	365.7	99.0	30.9	5.4	9.5
1965	92.2	82.3	74.5	68.3	63.5	59.6	56.4	53.7	51.2	49.0	353.9	103.9	30.9	5.4	9.5
1966	93.8	82.5	73.6	66.6	61.1	56.8	53.3	50.4	48.0	45.8	340.0	108.4	30.8	5.4	9.5
1967	96.6	83.9	73.8	65.8	59.6	54.7	50.8	47.7	45.1	42.9	324.7	112.5	30.8	5.4	9.5
1968	100.1	86.4	75.1	66.0	58.9	53.3	48.9	45.5	42.7	40.4	308.5	116.2	30.8	5.4	9.5
1969	103.5	89.5	77.3	67.2	59.1	52.7	47.7	43.8	40.7	38.2	292.0	119.3	30.8	5.4	9.5
1970	106.1	92.6	80.1	69.2	60.1	52.9	47.2	42.7	39.2	36.4	275.6	121.5	30.8	5.4	9.5
1971	107.3	94.9	82.9	71.7	61.9	53.8	47.3	42.2	38.2	35.0	259.9	122.9	30.8	5.4	9.5
1972	108.2	96.0	84.9	74.1	64.1	55.4	48.1	42.3	37.7	34.2	245.5	123.3	30.7	5.4	9.5
1973	110.5	96.8	85.9	75.9	66.3	57.3	49.5	43.0	37.8	33.7	232.6	122.7	30.7	5.4	9.4
1974	115.5	98.9	86.6	76.8	67.9	59.3	51.3	44.3	38.5	33.8	221.8	119.5	32.3	5.4	9.4
1975	124.3	103.3	88.5	77.5	68.8	60.8	53.1	45.9	39.6	34.4	213.2	115.5	33.9	5.4	9.4
1976	135.9	111.2	92.4	79.1	69.3	61.5	54.4	47.5	41.0	35.4	207.0	110.9	35.3	5.4	9.4
1977	147.9	121.6	99.5	82.7	70.8	62.0	55.0	48.6	42.5	36.7	203.4	105.8	36.6	5.4	9.4
1978	163.1	132.3	108.8	89.0	74.0	63.3	55.5	49.2	43.5	38.0	202.1	100.4	37.7	5.4	9.4
1979	197.2	146.0	118.4	97.3	79.6	66.2	56.7	49.6	44.0	38.9	202.6	94.7	38.6	5.3	9.3
1980	253.9	176.4	130.6	105.9	87.1	71.2	59.2	50.7	44.4	39.4	204.7	89.2	39.2	5.3	9.3
1981	183.5	227.1	157.8	116.8	94.8	77.9	63.7	52.9	45.3	39.6	207.0	83.6	39.4	5.3	9.2
1982	131.2	164.1	203.2	141.2	104.5	84.8	69.7	57.0	47.3	40.5	210.3	78.9	39.4	5.3	9.2
1983	125.8	117.3	146.8	181.8	126.3	93.5	75.8	62.3	50.9	42.3	213.6	74.3	38.9	5.2	9.1
1984	137.4	112.6	105.0	131.4	162.6	113.0	83.6	67.8	55.7	45.5	218.6	70.6	37.7	5.7	9.0
1985	104.4	122.9	100.7	93.9	117.5	145.4	101.0	74.7	60.6	49.7	225.7	67.5	36.2	6.1	9.0
1986	99.7	93.4	109.9	90.1	84.0	105.1	130.0	90.2	66.7	54.0	234.1	64.3	34.0	6.4	8.7
1987	136.1	89.2	83.6	98.3	80.6	75.1	93.9	116.1	80.5	59.4	245.5	62.2	31.8	6.7	8.5

Table A.1, Continued.

Age (Yr)	0	1	2	3	4	5	6	7	8	9	10-19	20-29	30-39	40-44	45plus
1988	149.9	121.7	79.8	74.7	87.9	72.0	67.1	83.8	103.5	71.6	259.1	60.4	29.4	6.5	8.6
1989	122.0	134.1	108.9	71.3	66.8	78.5	64.2	59.7	74.3	91.4	276.9	57.2	25.8	6.1	8.2
1990	85.5	109.1	119.9	97.3	63.7	59.6	69.9	57.0	52.8	65.5	308.2	53.8	22.3	5.5	7.7
1991	89.8	76.5	97.5	107.1	86.8	56.7	52.9	61.7	50.0	45.9	302.1	47.1	17.6	4.5	6.5
1992	130.4	80.4	68.4	87.2	95.7	77.5	50.5	46.9	54.6	44.0	290.4	44.6	15.1	3.9	6.0
1993	136.7	116.7	71.8	61.1	77.8	85.2	68.8	44.6	41.2	47.5	270.3	40.0	12.1	3.2	5.1
1994	153.3	122.3	104.3	64.2	54.5	69.3	75.6	60.7	39.1	35.8	255.5	36.0	9.7	2.5	4.3
1995	146.8	137.2	109.3	93.2	57.3	48.6	61.5	66.8	53.3	34.1	234.7	33.5	8.0	2.0	3.7
1996	133.1	131.3	122.6	97.7	83.1	51.0	43.0	54.1	58.3	46.0	210.4	30.2	6.3	1.5	2.9
1997	156.3	119.1	117.3	109.5	87.1	73.9	45.1	37.9	47.3	50.4	201.6	28.1	5.1	1.1	2.3
1998	162.2	139.9	106.5	104.8	97.7	77.5	65.6	39.8	33.1	41.0	200.4	27.1	4.2	0.9	1.9
1999	160.7	145.1	125.1	95.2	93.6	87.1	69.0	58.2	35.1	29.1	197.4	29.4	3.9	0.7	1.6
2000	173.9	143.8	129.7	111.8	85.0	83.5	77.6	61.3	51.5	31.0	183.7	34.4	3.7	0.6	1.5
2001	196.4	155.5	128.6	116.0	99.9	75.9	74.5	69.0	54.4	45.5	177.5	36.3	3.6	0.6	1.3
2002	110.9	175.7	139.1	115.0	103.7	89.2	67.7	66.3	61.3	48.1	188.1	36.3	3.6	0.5	1.2
2003	256.3	99.2	157.1	124.4	102.7	92.5	79.5	60.1	58.7	54.0	196.9	35.4	3.5	0.5	1.1
2004	93.2	229.3	88.7	140.5	111.1	91.7	82.5	70.7	53.3	51.8	210.4	36.0	3.5	0.4	1.0
2005	118.0	83.3	205.1	79.3	125.6	99.3	81.9	73.6	63.0	47.5	225.6	36.4	3.7	0.4	0.9
2006	101.1	105.5	74.6	183.4	70.9	112.3	88.8	73.1	65.6	56.1	235.3	36.9	4.0	0.4	0.9
2007	65.2	90.5	94.4	66.7	164.0	63.4	100.3	79.2	65.2	58.4	248.3	39.9	4.4	0.4	0.8
2008	72.4	58.3	80.9	84.4	59.6	146.6	56.6	89.5	70.6	58.0	260.3	43.9	5.0	0.4	0.8
2009	67.2	64.7	52.2	72.4	75.5	53.3	130.9	50.5	79.7	62.7	270.4	44.9	5.7	0.4	0.7
2010	68.5	60.1	57.9	46.7	64.7	67.5	47.6	116.7	45.0	70.8	286.3	43.0	7.0	0.4	0.7
2011	92.7	61.2	53.7	51.8	41.7	57.8	60.2	42.4	103.9	39.9	306.3	42.2	7.6	0.4	0.7
2012	132.6	82.9	54.8	48.1	46.3	37.3	51.7	53.8	37.8	92.5	295.5	46.0	7.9	0.5	0.6
2013	129.4	118.6	74.2	49.0	43.0	41.4	33.3	46.1	48.0	33.7	332.2	50.1	8.1	0.5	0.6

Appendix B. SS Data File

```
###########################################
# longspine thornyhead datafile 2013
###########################################
1964 # 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
1    # N fishing fleets
3    # N surveys
1    # N areas
#
# Fishery/Survey Names
#
Fishery%AFSCslope%NWFSCslope%NWFSCcombo
#
# Further specifications
#
0.5 0.5 0.5 0.5 # Timing of each fishery/survey
1 1 1 1      # Area of each fleet
1            # Units for catch per fleet: 1=Biomass(mt)  2=Numbers(1000s)
0.01         # SE of log(catch) per fleet for equilibrium and continuous options
2            # Number of genders
80           # N ages
#
### Catch section ###
#
# Initial equilibrium catch (landings + discard) by fishing fleet
0
# Single fishery: Commercial Trawl + a small amount of Other catch
# Nyears Catch
49
# Catch (mt) per fleet Year Season
13 1964 1 # 13 1964
30 1965 1 # 30 1965
21 1966 1 # 21 1966
10 1967 1 # 10 1967
10 1968 1 # 10 1968 Data from 2005 subbed for data from 2013 compilation .
29 1969 1 # 0.001361162 1969 1
42 1970 1 # 0.000453721 1970 1
44 1971 1 # 0.000453721 1971 1
82 1972 1 # 0.001361162 1972 1
93 1973 1 # 0.006805808 1973 1
77 1974 1 # 0.033121597 1974 1
99 1975 1 # 0.02722323  1975 1
54 1976 1 # 0.029945554 1976 1
102 1977 1 # 0.02722323  1977 1
196.9080349 1978 1
142.5617102 1979 1
357.24058   1980 1
111.9759881 1981 1
408.404017  1982 1
```

```
266.2773766  1983  1
360.4190546  1984  1
968.7333302  1985  1
826.8462204  1986  1
1181.688087  1987  1
2735.965568  1988  1
3171.021804  1989  1
5870.494222  1990  1
2971.941759  1991  1
5480.596298  1992  1
5353.908704  1993  1
4562.964115  1994  1
5566.973651  1995  1
4880.512721  1996  1
4053.096081  1997  1
2252.073967  1998  1
1809.718289  1999  1
1496.483279  2000  1
1220.99394   2001  1
1924.118701  2002  1
1556.46079   2003  1
688.8054141  2004  1
651.511277   2005  1
749.7898044  2006  1
810.2573874  2007  1
1243.354542  2008  1
1171.299471  2009  1
1358.880388  2010  1
926.0077125  2011  1
871.2645952  2012  1
#
#
### Abundance Indices ###
#
19 # N observations
#
# Units: 0 = numbers; 1=biomass; 2=F
# Errtype: -1=normal; 0 = lognormal; >0=T
# Fleet Units Errtype
#
1 1 0 # Fishery
1 1 0 # AFSC Slope
1 1 0 # NWFSC Slope
1 1 0 # NWFSC Combo
#
#AFSC Slope
#Year   Seas    Fishery Value   sd_log
1997    1       2       103403.46       0.07
1999    1       2       100312.67       0.07
2000    1       2       99337.47        0.07
2001    1       2       100570.80       0.07
#       1
#NWFSC Early (Slope)    1
1998    1       3       72691.60132     0.091559319
1999    1       3       84620.04893     0.085720483
2000    1       3       87038.26335     0.085497757
```

```
2001	1	3	85590.11609	0.084363494
2002	1	3	88957.39726	0.085767303
#	1
#NWFSC Late (Combo)	1
2003	1	4	139365.9881	0.084141453
2004	1	4	148930.7932	0.087330546
2005	1	4	132760.1457	0.091581854
2006	1	4	138479.7418	0.08465656
2007	1	4	138958.9279	0.080515143
2008	1	4	166410.8445	0.085368044
2009	1	4	172435.7467	0.086629996
2010	1	4	175257.335	0.076032812
2011	1	4	160827.9806	0.09402891
2012	1	4	189656.2745	0.079835471
#
#
# N fleets with discard
1
# Fleet Units Errtype
1 2 0
#
# N Observations
18
#
#
# Units: 0 = numbers; 1=biomass; 2=F
# Errtype: -1=normal; 0 = lognormal; >0=T
# Fleet Units Errtype
#
1 1 0 # Fishery
1 1 0 # AFSC Slope
1 1 0 # NWFSC Slope
1 1 0 # NWFSC Combo
#
#AFSC Slope
#Year	Seas	Fishery Value	sd_log
1997	1	2	103403.46	0.07
1999	1	2	100312.67	0.07
2000	1	2	99337.47	0.07
2001	1	2	100570.80	0.07
#	1
#NWFSC Early (Slope)	1
1998	1	3	72691.60132	0.091559319
1999	1	3	84620.04893	0.085720483
2000	1	3	87038.26335	0.085497757
2001	1	3	85590.11609	0.084363494
2002	1	3	88957.39726	0.085767303
#	1
#NWFSC Late (Combo)	1
2003	1	4	139365.9881	0.084141453
2004	1	4	148930.7932	0.087330546
2005	1	4	132760.1457	0.091581854
2006	1	4	138479.7418	0.08465656
2007	1	4	138958.9279	0.080515143
2008	1	4	166410.8445	0.085368044
2009	1	4	172435.7467	0.086629996
```

2010 1 4 175257.335 0.076032812
2011 1 4 160827.9806 0.09402891
2012 1 4 189656.2745 0.079835471
#
#
N fleets with discard
1
Fleet Units Errtype
1 2 0
#
N Observations
18
#
Year Seas Type Value CV
Pikitch data from John Wallace
code is in c:/SS/Thornyheads/Data/Pikitch/Pikitch_discard_rates_code.R
Year Seas Fishery Value CV
1985 1 1 0.2213098 0.946207082
1986 1 1 0.2220301 0.943095553
1987 1 1 0.4583943 0.420839875
#
EDCP discard rates taken directly from 2005 model
#Year Seas Fishery Value CV
1995 1 1 0.1 0.2
1996 1 1 0.12 0.2
1997 1 1 0.13 0.2
1998 1 1 0.17 0.2
1999 1 1 0.2 0.2
#
Discard rates from WCGOP program
#
Year Seas Fishery Value CV #_note
2002 1 1 0.197879077 0.077680068 #_Bottom_Trawl_whole_coast
2003 1 1 0.193096748 0.08500084 #_Bottom_Trawl_whole_coast
2004 1 1 0.176612635 0.155446156 #_Bottom_Trawl_whole_coast
2005 1 1 0.158121474 0.154715063 #_Bottom_Trawl_whole_coast
2006 1 1 0.121278141 0.186157304 #_Bottom_Trawl_whole_coast
2007 1 1 0.149661649 0.167588813 #_Bottom_Trawl_whole_coast
2008 1 1 0.134236906 0.105575198 #_Bottom_Trawl_whole_coast
2009 1 1 0.285072989 0.117006944 #_Bottom_Trawl_whole_coast
2010 1 1 0.226891516 0.111513558 #_Bottom_Trawl_whole_coast
2011 1 1 0.047029151 0.001 #_Bottom_Trawl_WAORCA_catch-shares_fully_observed_has_assumed_tiny_CV
#
Average weight of discards
Value is from Wghtd_AVG_W
CV is ratio of AVG_WEIGHT.SD/AVG_WEIGHT.MEAN
10 # N observations
30 # Degrees of freedom for StudentÍs 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
2002 1 1 1 0.159467638 0.563913943
2003 1 1 1 0.150435453 0.960761427
2004 1 1 1 0.174619516 0.81528541
2005 1 1 1 0.179495188 0.793306514

```
2006 1 1 1 0.159584003 0.532926081
2007 1 1 1 0.142406689 0.711785211
2008 1 1 1 0.137950633 0.66127181
2009 1 1 1 0.165980374 0.49431266
2010 1 1 1 0.161415023 0.595418723
2011 1 1 1 0.158557023 0.985295096
#
#
# Length data
#
# Bin type 1 means use databins
1
#2 # Use population bins
#1 5 45
#
# min proportion for compressing tails of observed composition frequencies
-1 # 0.000001
# constant added to expected proportions to make LogL calculation more robust
0.001 # 0.0000001
# Combine males into females at or
0
#
# Number of bins
31
# Lower edge of length bins
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
#
# N observations
67 # number of observations
# combined sexes
#fishyr fleet season gender partition inputN U5 U6 U7 U8 U9 U10 U11
 U12 U13
U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25 U26
 U27 U28 U29
U30 U31 U32 U33 U34 U35 M5 M6 M7 M8 M9 M10 M11
 M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
 M28 M29 M30
M31 M32 M33 M34 M35
1978 1 1 0 2 39 0 0 0 0 0 0 0
 0 50.68181818 0
0 0 55 0 0 114.2307692 57.11538462 385.1497816 510.2143888
 1640.817275
2617.604042 6589.730286 8377.036332 11396.93675 6637.688772 6537.743273
 723.1231007 1980.891978
361.6202825 0 140.9951613 0 0 0 0 0 0 0 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 1 0 2 36.3 0 0 0 0 0 0 0
 0 0 0 0
0 0 0 102.6044129 264.0361953 0 549.8311853 891.9810099
 1042.799398 1098.261383
3924.60401 5848.579247 3997.997709 3766.371378 3750.610406 1520.571192
 524.5142907 412.1744271
```

79.43103448 28.52678571 0 0 0 0 0 0 0 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 19.2 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 25 95.71428571 90.47391304 347.0307108 814.8161684
2547.488239
4003.524924 3476.909991 5535.209216 2280.994642 842.0596121 953.5945854
48.66666667 0 0
48.66666667 0 0 0 0 0 0 0 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 6.6 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 17059.03517 0 0 0 17059.03517 52605.21501
68950.19544
68236.14069 17059.03517 23960.64362 34118.07035 6901.608444 0 0 0
17059.03517 0 0
0 0 0 0 0 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 17.7 0 0 0 0 0 0 0
0 0 0 0
7144.020949 0 0 7144.020949 23501.62372 16357.60277 46324.0546
135242.8656 112756.6313
178162.7454 113653.904 125734.0167 58805.01545 48092.67996 16359.23009
6243.293724 2639.917537
2639.917537 0 1319.958769 0 0 0 0 0 0 0 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 1 0 2 30.5 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 8443.676032 7593.183447 9005.964431 40772.60066
102764.1699 115332.0042
185975.7863 134559.7328 96866.95488 73857.44924 11246.63258 8203.068227
656.3554428 604.890091
276.7123696 656.3554428 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0
1984 1 1 0 2 55.6 0 0 0 0 0 0 0
0 0 0 0
843.5464563 0 0 352.3884247 941.311648 23444.12465 48531.07924
89649.36723 125598.0953
208814.6484 233657.796 172030.8949 141348.9967 71979.1459 18840.81493
11554.47861 3675.310323
1304.071229 0 6682.404258 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0

0 0
1985 1 1 0 2 78.6 0 0 0 0 0 0 0
0 0 0 0
0 3925.015743 7354.713555 3986.371239 16115.32122 38952.8182 103734.0941
180400.944
258477.1389 373502.9099 498952.0544 307097.4789 225181.7541 135418.8254
33639.84783 19819.94653
4016.847241 2903.082439 0 1060.842471 0 0 0 0 0 0
0 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 2 51.9 0 0 0 0 0 0
1075.451335 0
1075.451335 0 12665.94033 13441.58125 22581.35717 7175.82429 31944.05067
28581.58813
34788.45595 65986.92793 122467.5827 149758.9173 240984.2258 319153.3672
176503.7639 132607.9474
84244.3876 47823.57746 7367.35628 3463.476758 299.8104127 0 3511.056202
0 0 0 0
0 0 0 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 46.1 0 0 0 0 0 0 0
0 642.8989408 0
0 11983.87766 0 11747.51813 0 26436.70751 49027.11203 145651.7643
250943.3067
337983.9426 411772.624 304207.7705 282631.7444 163023.7117 69461.60095
24181.08641 15638.09585
4779.132646 2552.013842 0 0 0 0 0 0 0 0 0
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 1 0 2 11.1 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 62163.65876 41442.43917 42251.61552
82884.87835
134687.9273 113966.7077 41442.43917 10360.60979 20721.21959 0 0 0
8539.211395 0 0
0 0 0 0 0 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 1 0 2 71.6 0 0 0 0 0 0 0
0 64033.98285
154052.318 51227.18628 27061.92586 183141.8098 155293.879 257777.7625
338872.4343 673322.8182
1005351.163 1729137.298 1451330.55 1423834.295 1638125.946 1077859.252
596590.7829 273251.3994
54537.82947 44309.53618 1270.043737 0 0 10746.22886 0 0 0
0 0 0 0
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 2 173.2 0 0 0 0 0 0
1477.109409 40813.42186

28462.75561 23257.22932 72932.13797 93864.69886 267401.5047 219365.5384
648160.0968 1174900.155
1393534.293 1772301.448 2799367.081 2986517.858 3132551.011 3093232.548
2298415.409 1611509.548
764870.937 316662.0896 45709.81248 41910.18534 1039.84184 1604.275915
1477.109409 0 0 0
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0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
1991 1 1 0 2 158.3 0 0 0 0 0 0 0
0 4222.951527
5314.525397 20951.14997 17118.45486 70821.84639 90160.07372 288546.4201
421510.5699 766494.4634
1436596.296 1943977.07 2226005.731 2285028.888 2122386.885 1564950.827
999998.5228 528837.0666
211619.4648 57055.84399 33448.75597 6263.126937 1374.966366 2823.275096 0
0 0 0 0
0 0 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 2 200 0 0 0 12125.59615 9278.235652
27053.26759
34540.22729 48191.84105 62213.88246 147732.4853 199725.4509 277042.5905
351251.771 475682.1087
659796.7461 1251779.707 1677835.839 2792117.153 3903103.864 4090726.91
4044998.568 3566507.033
2523581.643 1334541.95 802163.8073 248543.6437 108868.4056 29266.16466
5743.575251 9363.542216
6677.228081 0 0 0 0 0 0 0 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 2 146 0 0 0 3284.75426 3284.75426
31279.29195
22047.44923 14415.20574 19936.46098 85662.63933 112584.6997 141605.3065
288282.0968 468775.6628
727602.0421 1084248.157 2014419.5 2399998.717 2745279.731 2901407.402
2130414.536 2210807.349
1354150.107 737203.095 463048.9336 142311.4389 72157.82539 43835.66213
2751.687216 325.2283847 0
0 0 0 0 0 0 0 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 1 0 2 145.5 0 0 4715.875581 0 18863.50232
7177.4987
6957.821423 35342.24438 27428.31841 75454.35316 138570.6668 157225.8038
193618.5708 265407.3203
465429.1694 709658.1188 1002243.205 1234300.841 1631159.73 1827256.349
1883799.725 1588563.329
1247550.17 705182.5196 290063.2678 108902.0284 25311.28981 28921.14701
12735.95922 486.0787146 0
0 0 0 0 0 0 0 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 2 218.6 0 0 0 0 957.2707907
11947.03022 28156.24739
17943.75471 32551.29581 38692.12676 67062.36561 90439.8373 161872.6819
285514.7568 469443.3146
908489.1867 1290347.094 1729592.003 2292642.852 2400499.207 2504459.547
2239983.082 1582367.195
870621.3623 423942.1047 164878.6509 56969.9902 9636.191727 6147.87462
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0 0 0 0 0 0 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 2 232.2 0 0 0 0 0 3997.758363
7889.063283
11838.39013 66352.94054 28330.92114 75419.59049 134925.8675 215462.5696
359248.1332 666891.8056
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0 0 0 0 0 0 0 0 0 0 0 0 0
1997 1 1 0 2 282.4 0 0 0 3823.651858 5580.522928
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184997.601 386975.8161
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0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0
1998 1 1 0 2 168.7 0 0 0 0 2330.415034
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7594.945934 21378.96282 62491.53106 68961.09263 66858.97329 112615.8942
205956.8883 380764.6816
696425.2577 1047034.783 1302424.507 1574710.495 1704431.516 1571685.508
1588843.838 926546.2602
545628.2759 257903.7797 92781.02276 41064.99405 9221.743348 10249.08562
976.3075799 1967.787232 0
0 0 0 0 0 0 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 2 156.8 0 0 0 0 0 3428.423022
6516.782472 20589.063
12899.92128 46673.46392 52405.13515 76117.5389 94619.26915 163999.334
258325.5562 529658.5197
775840.8048 1049567.718 1343184.61 1548086.922 1443695.047 1172853.527
669983.8306 343210.5874
175068.2618 73758.05925 26221.07285 12657.72106 5961.036556 0 4426.887416
0 0 0 0
0 0 0 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 1 0 2 148.1 0 0 0 0 0 0 0
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3353.335501 3905.33348 23295.32268 26189.76405 43497.98511 46678.44203
170223.3671 359761.3226
413588.3197 725801.1307 1165372.033 1214001.282 1181237.598 889311.8143
613575.8458 368288.3324
161208.2814 38032.85417 37392.30457 6525.384113 13676.70545 2498.087872
4450.405684 0 0 0
0 0 0 0 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 2 162.4 0 0 0 0 852.7470191
875.2867392 0
1728.033758 1312.492027 8597.643967 24502.88307 43479.46956 47635.54941
113217.1994 162077.9768
288193.53 475224.3405 645366.8949 826025.3972 1001238.472 929782.4453
854052.9854 570727.9296
279033.9102 115561.4762 39354.52963 8220.217949 4723.028491 2924.756025
5824.396056 14175.28188 0
0 0 0 0 0 0 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 1 0 2 199.9 0 0 1620.45031 5432.287865
7423.578337 2305.854564
10265.69905 13625.03537 24563.64607 26634.96631 64714.7635 85396.59747
104113.8324 167876.6174
313340.483 537724.4654 852472.9504 975391.6968 1256124.074 1458408.491
1383634.71 1194457.004
775394.6639 402663.5826 125853.5113 55547.60999 19800.12677 2516.558783
9332.689328 8732.609036
720.0231411 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0
2003 1 1 0 2 171 0 0 0 0 0 0
4240.088489 2309.339183
5561.347221 9877.157644 19398.87196 50303.92462 66914.89021 167869.1839
346568.5612 546426.5654
824117.1752 1046466.773 959071.8115 1352534.294 1038915.537 1069788.351
534618.2039 256417.8267
111577.8299 70137.00268 8248.156441 3106.438207 0 1345.730581 1188.450463
0 0 0 0
0 0 0 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 1 0 2 139.8 0 0 0 0 0 0
3566.631494 0
2538.400456 7865.355239 25903.6341 13220.32649 31873.84844 45364.38875
96772.211 201291.4618
263403.733 334966.4925 389266.9723 410896.2879 394881.9785 360947.7102
235166.242 115320.9602
74815.24813 22291.53023 4697.22679 0 114.6875002 72.48746605 0 0
0 0 0 0
0 0 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 1 0 2 133.3 0 0 0 0 181.3436358
181.3436358 181.3436358 0
1478.305754 694.3497007 8210.987919 16476.19082 47343.90407 71617.27027
133303.1938 215822.9048
323126.5229 395396.6595 390457.1635 470615.4796 494187.2448 424771.1345
251158.8006 157532.1674
37866.76883 22786.84219 1927.823315 572.2874173 3127.144 46.66497468
46.66497468 0 0 0
0 0 0 0 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 1 0 2 182.6 0 0 0 1209.051664 996.2429925
1764.494557
1481.560642 7341.690664 1786.32549 21077.07441 24437.39196 58377.62075
71136.93699 140294.2037
219046.2267 302905.4985 380003.2815 416826.2191 468018.7275 550031.2302
507038.5115 446126.5945
289871.638 148643.7842 72001.71648 24209.02681 2503.208975 1290.220392
2258.822742 179.7028037
34.0428567 0 0 0 0 0 0 0 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 2 168.3 0 0 0 0 2589.863892
7407.666063 9041.88648
4371.052196 9760.072437 17945.04903 36416.42325 54667.8433 135829.8454
134848.5095 253347.4087
411443.4357 464289.324 501672.33 547347.7505 555078.9048 513669.3206
434146.4925 293156.7349
149117.4795 60608.08009 21798.41558 5472.336851 2926.691758 568.0477418 0
7.996355138 0 0
0 0 0 0 0 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 2 206 0 0 0 0 0 2764.723249
20879.01878
12118.20229 22606.19572 25379.81364 46685.95984 117082.1096 173682.6515
214327.3226 366076.3493
444049.1729 724272.6396 845228.0268 886488.1397 803625.2036 757548.3725
673315.4653 367977.9126
228945.9957 120514.788 37753.24657 21426.84103 1193.779855 2859.881103 0
8.006042714 0 0
0 0 0 0 0 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 2 194.4 0 0 0 334.0999246 0
2033.00511 3891.457846
9892.567458 12008.96905 30563.03219 21431.30905 33697.54653 66977.33737
90955.10456 225875.2312
339082.2899 439458.1535 480050.0002 519584.1741 537931.6591 519460.3827
399218.2974 256040.2343
152129.6821 60942.91159 34163.65674 3969.668918 670.7287783 1756.471964
972.8322645 918.4855542 0
0 0 0 0 0 0 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 2 206.4 0 0 0 0 1786.356311
1037.12074 3624.14391
12043.94053 11842.66598 21518.62456 48102.46622 78129.5837 88984.21125
193580.2489 329506.6382
513324.5767 783140.195 906893.315 1008261.898 877172.5559 754488.1192
647759.1358 443674.6564
211341.0433 100014.1385 48111.75246 13565.44929 3406.696966 3100.219655 0
658.3638399 0 0
0 0 0 0 0 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 2 206.7 0 0 0 0 723.8617691
3017.607365 3859.59461
13007.35201 17177.6583 41377.27955 59008.86777 57485.40446 117320.6567
179058.2388 338580.1406
429745.4045 611192.0395 620307.9812 630625.2012 627010.5657 582744.8072
448189.7471 285789.017
137748.7129 51923.44427 22050.52752 11238.71618 3240.448558 3907.830735
1863.058959 339.7293919 0
0 0 0 0 0 0 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 1 0 2 202.2 0 0 0 318.5351657 838.9022517
1306.836285 480.031548
5258.888362 19981.16716 24460.11102 46499.16734 69317.92492 106345.9661
141166.8174 214555.9324
378562.3166 468758.0214 573297.8829 617613.825 551200.4808 481491.2174
374378.4417 255700.5059
139495.6673 53296.62888 24055.18519 10304.0009 6425.600075 2144.150262
800.8795628 534.367309 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
2013 1 1 0 2 46.4 0 0 0 0 0 0 0
1717.122417
1909.737679 2960.914149 4949.293427 7009.147939 9122.240654 9359.429638
11316.82409 16483.48497
18156.41272 15205.40102 12674.84483 9737.98072 8309.406372 4805.573738
2703.507133 966.8874101
180.3786234 179.0566038 0 0 0 0 0 0 0 0 0
0 0 0 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
#_year season fleet gender partition inputN U5 U6 U7 U8 U9 U10 U11
U12 U13
U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25 U26
U27 U28 U29
U30 U31 U32 U33 U34 U35 M5 M6 M7 M8 M9 M10 M11
M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
M28 M29 M30
M31 M32 M33 M34 M35
1988 1 1 0 1 42.8 0 0 0 0 0 0 0
0.012656531

0.055068793   0.11255384   0.148637837   0.162276671   0.274830511   0.278742523
0.25922707   0.319720836
0.230063804   0.146221583   0   0   0   0   0   0   0   0   0
0   0   0   0
0   0   0   0   0   0   0   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   1   0   1   180.7   0   0.000238448   0   0   0.000238448
0.001615896   0.00369051
0.004767175   0.113197844   0.052158179   0.100076721   0.070929438   0.159300072
0.347618488   0.324813646
0.157573055   0.197544   0.200860201   0.109660317   0.096843329   0.003748341
0.055125891   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0
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   1   51.2   0   0   0.085657121   0.116329682
0.061345121   0.100993401
0.01533628   0.020121838   0.065287424   0.085657121   0.04600884   0.01533628
0.199381702   0.362181276
0.405084782   0.208808414   0.058717805   0.148967354   0.004785558   0   0   0
0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0
0   0
Overlap with PacFIN
1988   1   -1   0   2   135.6   0   0   0   0   0   0   0
0   0   0   0
0   0   0.00014464   7.23E-05   0.00043392   0.001977454   0.015412638
0.123313394   0.338030105
0.247302481   0.433234235   0.498505741   0.200772452   0.106316335   0.03294075
0.001326573   0.00014464   0
7.23E-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
1989   1   -1   0   2   437.3   0   0   0   0   0   2.15E-05
1.07E-05   3.22E-05
3.22E-05   0.000214565   0.000171652   0.000197617   0.000304923   0.003331268
0.009108738   0.026596131
0.063954435   0.100674878   0.138620444   0.198606417   0.284550243   0.356934888
0.362419851   0.226260991
0.145553224   0.055310824   0.020047373   0.006669116   0.000366197   9.67E-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
1990   1   -1   0   2   179.5   0   0   0   0   0   0   0
0   0
0.000513457   0.001540371   0.001540371   0.002053828   0.003594198   0.007697198
0.012976919   0.02015382

0.093529582 0.12703754 0.252371198 0.253848026 0.410396857 0.265215032
0.291650355 0.148638322
0.054975556 0.022677991 0.007679968 0.019111651 0.00279776 0 0 0
0 0 0 0
0 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 discards
#_year season fleet gender partition inputN U5 U6 U7 U8 U9 U10 U11
U12 U13
U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25 U26
U27 U28 U29
U30 U31 U32 U33 U34 U35 M5 M6 M7 M8 M9 M10 M11
M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
M28 M29 M30
M31 M32 M33 M34 M35
#2005 1 1 0 1 1 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 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 1 0 1 68.8 0.001741332 0.001907503 0.009867579
0.01273067 0.009236091
0.012120287 0.026722643 0.02043581 0.068880731 0.050510855 0.076334183
0.074775836 0.114199417
0.126963035 0.107176839 0.08523667 0.105776408 0.038076981 0.034121049
0.008860006 0.007050238
0.001522939 0.000304647 0.00535132 5.19E-05 4.50E-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
2007 1 1 0 1 96.3 0 0 0.000354873 0.002821058
0.000705898 0.008506643
0.039341112 0.044009857 0.037244917 0.057592368 0.071892935 0.10692387
0.097820934 0.116246651
0.157152875 0.096225226 0.07470993 0.042920636 0.008929009 0.007003372
0.020108407 0.005955308
0.001471442 6.05E-05 0.000997819 0 6.57E-06 0 0 0.000997819
0 0 0 0
0 0 0 0 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 1 110.6 0.001105738 0 0.001165885 0.001113835
0.001317688
0.020710282 0.026474975 0.045246942 0.063357808 0.06213943 0.109940117
0.092849609 0.158562094
0.09871086 0.130676193 0.083747937 0.052362581 0.024886679 0.013469754
0.006836322 0.001782374
0.001250495 0.00142682 0.000233649 0.000254855 0.000156152 7.06E-05 0
0 0

0.000150368 0 0 0 0 0 0 0 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 1 138.6 0 0 0.013357575 0.023271255
0.007174821 0.021108189
0.033845009 0.034220617 0.024085545 0.031042812 0.054737359 0.063432155
0.146384695 0.088035626
0.113837959 0.088735388 0.063278891 0.078328637 0.055287871 0.023287239
0.018383461 0.00393441
0.002378128 0.001258149 0.010126835 7.58E-06 0 0.000416635 0 5.68E-
06 3.75E-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
2010 1 1 0 1 104.3 0 0 0 0.000493606 0.000623113
0.001195655
0.007690074 0.021202663 0.035248331 0.047584206 0.054688432 0.094317153
0.113561001 0.101775657
0.17380651 0.140226915 0.09424215 0.065215649 0.025044451 0.011930148
0.003248901 0.001764644
0.005650563 0.000342233 0.000145253 0 2.69E-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
2011 1 1 0 1 151.2 0.00030884 0.007299507 0.004932291
0.001237584 0.011489519
0.021794153 0.016260896 0.014166736 0.0359562 0.067725428 0.086817202
0.088505627 0.100715037
0.107722635 0.10760128 0.060338546 0.076196391 0.04506025 0.048296126
0.020814651 0.022809649
0.016806521 0.006337889 0.016472284 0.012505895 0.001549359 0.000127367 7.96E-
06 4.46E-05
1.67E-05 8.29E-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
Length comps from AK slope survey
#_year season fleet gender partition inputN U5 U6 U7 U8 U9 U10 U11
U12 U13
U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25 U26
U27 U28 U29
U30 U31 U32 U33 U34 U35 M5 M6 M7 M8 M9 M10 M11
M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
M28 M29 M30
M31 M32 M33 M34 M35
1997 1 2 0 0 520.3 0 0 0 0.188238049 0.163862078
0.355955009
0.575084663 1.49045055 3.037827814 6.077630074 3.184339614 5.44945716
11.95621773 14.23896139
13.67447088 4.889904622 12.84905294 8.927045778 6.192713443 3.038768191
1.642770352 0.60005815

0.790656904 0.297744717 0.198806405 0.049130512 0.049130512 0.081722462 0
0 0 0 0
0 0 0 0 0 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 2 0 0 423.5 0 0 0 0.157368147 0.223246236
0.392789133
0.252217851 0.629366359 0.794151358 3.356655054 4.267412314 4.910379363
5.955449408 10.97601766
10.31178143 13.64064331 12.03313454 12.05555349 8.140102865 5.438543168
2.975394708 1.955767197
0.732826195 0.571746514 0.057363424 0.172090273 0 0 0 0 0
0 0 0 0
0 0 0 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 2 0 0 392 0 0 0.054417379 0.067784366
0.287612622 0.974303432
0.071534067 0.530955977 1.637381327 4.283729313 7.428000353 9.076911031
10.80902169 12.96267601
12.93727644 9.334150127 8.287934743 6.212004355 4.321296783 5.135851261
2.355084919 1.806081342
0.752042216 0.305879526 0.229315224 0.027751098 0.055502197 0.055502197 0
0 0 0 0
0 0 0 0 0 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 2 0 0 456.5 0 0 0.048025391 0.267450208
0.364152859 0.398656097
0.893366532 0.461135727 1.063404707 1.711097544 4.127943521 6.358083521
11.12876881 11.07563491
13.27523143 11.00782773 9.744408244 5.827647436 5.10114797 5.248820467
4.410595738 3.830553064
1.784386232 0.863045236 0.637936418 0.135990926 0.067995463 0.166693825 0
0 0 0 0
0 0 0 0 0 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
#_year Season Fleet gender partition inputN U5 U6 U7 U8 U9 U10 U11
U12 U13
U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25 U26
U27 U28 U29
U30 U31 U32 U33 U34 U35 M5 M6 M7 M8 M9 M10 M11
M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
M28 M29 M30
M31 M32 M33 M34 M35
1998 1 3 0 0 423.5 0.040095902 0.139823539 0.693941655
1.776716073 2.91212925
3.403125194 3.849204164 4.715554358 4.642959777 4.616458398 4.399956727
4.354866464 5.067788109
5.789014488 5.938952761 5.915990384 6.188022974 6.275559814 6.623662739
6.969699121 5.802884915
4.634402534 2.805676313 1.282313592 0.83915405 0.238510159 0.042581304
0.025201884 0.003422187

0.003501732 0.008829437 0 0 0 0 0 0 0 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 3 0 0 457 0.008110969 0.222703686 1.123893087
2.062806483 2.075232938
2.743532626 3.177178196 4.146741321 4.698014818 4.6759803 4.760950426
4.518884186 4.997476608
5.492150003 5.877266402 6.350830255 6.284917494 6.593958365 7.248777607
6.929541556 6.102847715
4.268292856 3.009091199 1.503381215 0.884214468 0.156254651 0.049163193
0.023013767 0.014793611 0
0 0 0 0 0 0 0 0 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 3 0 0 410.3 0.018639172 0.161420047 0.587728669
1.452839013 2.490374954
2.538029712 2.922931336 3.967866169 5.043304745 5.267076254 5.971619157
5.284498075 5.214062294
5.588041777 6.199083757 6.207419148 6.328299571 6.497800305 6.693738713
6.428665525 5.51486381
4.281181122 2.925664323 1.371472376 0.680167195 0.235616347 0.068323212
0.045843623 0.00773289
0.002735408 0.0029613 0 0 0 0 0 0 0 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 0 429 0.017771055 0.054686203 0.799430791
2.55205497 1.198545234
1.687053619 2.067356937 1.373842888 1.600723974 1.988286806 3.034438516
2.707954155 7.020351731
3.808336591 6.715423568 4.291183436 4.505762731 6.100295695 13.14294381
16.03297937 11.7160238
4.275645318 1.78360412 1.099250455 0.255771847 0.11828539 0.035607805
0.010174927 0.000965656 0
0.005248609 0 0 0 0 0 0 0 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 0 523.9 0.036836403 0.266378242 1.058771049
1.314498559 1.673912096
1.867333259 2.055824944 2.491282713 3.226137348 3.795345338 4.414418486
5.28307977 5.718795901
5.822866256 7.030160244 7.144500506 7.969261268 8.278632467 8.369427024
8.126222048 6.292781104
3.732977109 2.482392066 0.963029101 0.381827514 0.133722374 0.051133842
0.016802564 0.001650406 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0
first two years of combo survey have sexes combined

2003 1 4 0 0 325.9 0.016977298 0.10729549 0.685954667
1.245908999 1.812414002
2.294604174 2.049417247 2.306002954 2.836962205 3.096995047 4.408095077
4.927655468 6.13508316
6.291431807 6.514241881 7.05868904 7.079448637 7.502597158 8.043806064
8.848537121 6.603377687
4.681184539 3.00704544 1.353034361 0.788505413 0.189761584 0.084455676
0.013645784 0.005538015
0.008981887 0.00235212 0 0 0 0 0 0 0 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 4 0 0 268.4 0.075136828 0.513641998 1.592444219
2.537090666 2.503320792
2.913740372 2.504211668 2.882245288 3.042862318 3.765655242 4.539418494
3.896340736 5.702031811
6.357266043 6.824147993 6.744996533 7.386009732 7.970996425 7.363909018
7.126007053 5.960521235
3.953121145 1.990893296 1.145704392 0.479692695 0.183004845 0.013770245
0.017423088 0.00471061 0
0.009685218 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0
#_year Season Fleet gender partition inputN F5 F6 F7 F8 F9 F10 F11
F12 F13
F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26
F27 F28 F29
F30 F31 F32 F33 F34 F35 M5 M6 M7 M8 M9 M10 M11
M12 M13 M14
M15 M16 M17 M18 M19 M20 M21 M22 M23 M24 M25 M26 M27
M28 M29 M30
M31 M32 M33 M34 M35
2005 1 4 3 0 301.1 0.023834044 0.209429608 0.891503967
1.188157993 1.585361664
1.27425186 1.480040069 1.507411541 1.811418691 2.00380362 2.073663213
3.249457068 3.79426374
3.756947572 3.542267166 4.886348727 3.859849221 4.206661029 3.247162394
3.019972001 2.21710185
1.621131972 0.925147977 0.487363563 0.123309025 0.091124087 0.008163022
0.008713279 0 0 0
0.023833972 0.209429608 0.891503894 1.18815792 1.585361664 1.274251716
1.47875486 1.500990625
1.861407013 2.120323496 2.440414234 3.020655544 2.665979127 2.846801297
2.943514091 3.392601406
3.006101282 2.958022793 2.890876506 2.559877526 2.740229801 1.360608907
1.049024226 0.533703194
0.282193627 0.081521703 0 0 0 0 0
2006 1 4 3 0 236.9 0.003873379 0.025142815 0.325001932
0.739195599 1.025132917
1.559009414 1.549358764 1.600101453 1.427153547 1.56542852 1.990364678
2.160134853 2.675703349
4.523524682 3.792145038 5.116656746 3.654881451 4.689761834 3.430520275
4.234459015 2.704364777

2.536443857 1.41446536 0.792560718 0.27175922 0.125953411 0.016160268
0.008274891 0 0
0.003208503 0.003873304 0.02514274 0.322898254 0.722912322 1.016991241
1.536645885 1.549325291
1.602870308 1.399984057 1.581788349 1.95856342 2.096947367 2.168486897
2.740126549 2.881308245
3.190593835 3.217598213 3.674955175 3.2875282 3.731337342 2.6621493
2.283190622 1.216973921
0.637265768 0.260763357 0.202243965 0.046920495 0.019874314 0 0 0
2007 1 4 3 0 188.5 0 0.041310689 0.196127802 0.394162903
0.521143093
1.309597741 1.302679895 1.397163094 1.00954718 1.373847573 1.807053725
2.70927443 2.093343041
4.933775647 4.011022635 4.706956184 4.708156517 6.011515937 4.479277369
4.270923627 3.081429554
2.574648643 1.069345754 0.494798041 0.282514986 0.273704129 0.007960922
0.008972985 0 0 0
0 0.041310689 0.196127802 0.394163065 0.52114293 1.29650019 1.348995529
1.526704372 1.00408256
1.33400789 1.919215793 2.536998462 1.655405377 3.377763345 3.289383536
3.549875886 3.179268976
3.662508993 3.873419358 3.222988124 2.272080834 2.224312704 1.377575302
0.633816063 0.375067504
0.099239391 0.01779123 0 0 0 0
2008 1 4 3 0 136.6 0.006434331 0.021015627 0.037608431
0.308448936 0.652008535
1.078780953 1.039638754 1.462027734 1.556573719 1.897688512 2.056922412
2.575431554 2.991685016
4.97639675 5.357631767 5.720556927 6.028160978 5.182828492 3.83932443
2.672837007 2.3886907
1.472256075 1.436021887 0.657442427 0.237428129 0.072397227 0.035529872 0
0 0 0
0.006434331 0.021015627 0.037608431 0.308448808 0.675647513 1.081317273
1.077452499 1.454103567
1.593198938 1.628675784 1.994831463 2.145981223 3.402510797 3.129855195
3.069417321 3.009745178
3.518696867 3.727449112 2.891466972 2.880914203 2.366089753 1.646682024
1.579468611 0.675233299
0.198948236 0.057658777 0.059381015 0 0 0 0
2009 1 4 3 0 124.4 0 0.001470907 0.103846854 0.186975791
0.215530015
0.522796182 0.822698472 1.291686037 1.404210314 1.52238319 1.87569801
1.586033364 2.007498998
2.976083384 3.208986653 4.554169235 6.13032388 5.631803833 4.139272797
4.947430157 3.029746702
2.312959179 1.311789571 0.930161831 0.528311055 0.304420917 0.101451096
0.001071405 0 0 0
0 0.001470907 0.155148995 0.186975651 0.215529806 0.522796182 0.860247421
1.418928239
1.457720804 1.80880141 2.123185478 2.095509601 2.793901061 2.997678881
3.634663793 4.38814402
4.383347694 3.807123224 3.452089847 3.148431958 4.042236723 2.174019233
1.539844362 0.667484078
0.399316203 0.072093614 0 0 0 0.004500988 0
2010 1 4 3 0 123 0 0.011939107 0.070103392 0.176694214
0.135831163

0.269067363	0.824793102	1.223563841	1.623179184	1.283977019	1.047553635
	2.284455384	2.425440961
3.246306387	4.791873452	4.463005621	5.353375906	5.518588199	3.887824403
	4.180952674	4.279420462
2.372079047	1.813464533	0.692045568	0.227943231	0.052399523	0.029604825	0
	0	0	0	0
0.011939038	0.070103461	0.176694353	0.135831232	0.296096544	0.824793172
	1.301636204	1.596786409
1.45462781	1.1835718	2.078492408	2.543003009	3.280009143	1.734322205
	3.547219407	4.167239372
4.767395941	4.066574184	4.362432996	3.85786517	3.083109565	1.600073926
	1.094430923	0.369815107
0.098906837	0.006295331	0	0	0.005252259	0
2011	1	4	3	0	166	0	0.002176549	0.123885702	0.241919387
	0.237792034
0.458049235	0.529471711	0.5792734	1.230554293	1.40762895	1.35123436
	1.625081989	2.906427333
3.482005642	3.692117555	4.556533089	5.257471451	5.602344471	4.373089917
	4.240969689	3.680901861
1.602159869	1.892615347	0.802210007	0.526486235	0.097755553	0.109677274
	0.009109501	0	0	0
0	0.002176389	0.123885622	0.241919627	0.237792113	0.458049395	0.529471551
	0.579273479
1.227759064	1.420815791	1.361826268	1.644558692	2.058923404	2.549141701
	3.097934328	4.490814821
4.729045259	5.588419458	4.46926455	4.394541356	4.069333691	2.448065248
	2.092669638	1.019396222
0.392803831	0.118944476	0.024114652	0.01011697	0	0	0
2012	1	4	3	0	161.7	0.006334615	0.056531	0.311972555
	0.411345122	0.448239813
0.607996266	0.625949877	0.60297571	0.676480614	1.663470163	1.667461339
	2.182965997	2.149854946
2.128303432	3.445778854	4.820393509	5.058503455	5.044430401	4.333623282
	5.155798837	3.890119752
2.261115936	1.855058028	1.179622452	0.324257759	0.120892158	0.050201851
	0.008423679	0	0	0
0.006334548	0.056531067	0.309057261	0.411345055	0.448239813	0.607413949
	0.62594981	0.670384514
0.76372422	1.630237763	1.724707884	2.2327766	2.259741876	3.242326662
	3.079010978	3.683478789
4.015369633	4.812729514	4.328038362	4.398509457	3.782370682	2.557599128
	1.792935157	1.035062651
0.309145809	0.096584224	0.032293189	0	0	0	0
#	End Comps
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

```
##############################################
# Longspine Thornyhead control file
##############################################
#
1  # N growthmorphs
1  # N submorphs within growth patterns
#
#
2 # Block designs
3 3 # Blocks in each design
# design 1
1992 2006 # design 1, block 1
2007 2010 # design 1, block 2
2011 2012 # design 1, block 3
# design 2
1992 2006 # design 1, block 1
2007 2010 # design 1, block 2
2011 2012 # design 1, block 3
#
# Mortality and growth specifications
0.5     # Fraction female at birth
1       # M setup: 0=single Par,1=N_breakpoints,2=Lorenzen,3=agespecific;_4=agespec_withseasinterpolate
2       # Number of M breakpoints
11 12   # Ages at M breakpoints
1       # Growth model: 1=VB with L1 and L2, 2=VB with A0 and Linf, 3=Richards, 4=Read vector of L@A
3       # Age for growth Lmin
# Try changing to 45
40      # Age for growth Lmax or 999 = Linf
#
# Try changing to 0, since that's what they now do.
#
0.1     # SD constant added to LAA (0.1 mimics v1.xx for compatibility only)
#
0       # Variability about growth: 0=CV~f(LAA) [mimic v1.xx], 1=CV~f(A), 2=SD~f(LAA), 3=SD~f(A)
1       # Maturity option: 1=length logistic, 2=age logistic, 3=read age-maturity matrix by growth_pattern
2       # First age allowed to mature
1       # fecundity option
0       # hermaphro
3       # mg parm offset option:
#
#old key: 1=direct assignment, 2=each pat. x gender offset from pat. 1 gender 1, 3=offsets as SS2 V1.xx with M old
#new key: 1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
#
1       # mg parm adjust method 1=do V1.23 approach, 2=use logistic transform between bounds approach
#
#
# LO  HI  INIT  PRIOR  PR type  SD  PHASE  env-variable  use dev  dev minyr  dev maxyr  dev stddev
#
# Females
#
# Fixed prior, prior type, sd
# Try estimating VBK
0.001  0.3    0.11131269618101   -2.195436 3 0.52067   -4  0  0  0  0  0.5  0  0  #M1 natM young
```

```
-1.001  3      0        0        -1  99  -5  0  0  0  0  0.5  0  0  #M1 natM old as exponential offset(rel young)
5       25     8.573    10       -1  99  -2  0  0  0  0  0.5  0  0  #M1 Lmin
5       40     27       30       -1  99   2  0  0  0  0  0.5  0  0  #M1 Lmax
0.05    0.2    0.064    0.1      -1  99   3  0  0  0  0  0.5  0  0  #M1 VBK
0.015   0.25   0.131    0.1      -1  99  -6  0  0  0  0  0.5  0  0  #M1 CV-young
-3      5      -0.892   0        -1  99  -6  0  0  0  0  0.5  0  0  #M1 CV-old as exponential offset(rel young)
#
# Males
#
-3  3  0   0   -1  99  -4   0  0  0  0  0.5  0  0  #M1 natM young
-3  3  0   0   -1  99  -3   0  0  0  0  0.5  0  0  #M1 natM old as exponential offset(rel young)
-3  3  0   0   -1  99  -2   0  0  0  0  0.5  0  0  #M1 Lmin
-3  3  0   0   -1  99  -2   0  0  0  0  0.5  0  0  #M1 Lmax
-3  3  0   0   -1  99  -2   0  0  0  0  0.5  0  0  #M1 VBK
0  0  0  0  -1  99  -6  0  0  0  0  0.5  0  0  #M1 CV-young
-3  5  -0.892  0  -1  99  -6  0  0  0  0  0.5  0  0  #M1 CV-old as exponential offset(rel young)
#
# gender lines to read the wt-Len and mat-Len parameters
#
-3  3  4.3E-06  4.4E-06  -1  99 -3  0  0  0  0  0.5  0  0  #Female wt-len-1
-3  8  3.352  3.34694  -1  99 -3  0  0  0  0  0.5  0  0  #Female wt-len-2
0.001  40  17.826  20  -1  99 -3  0  0  0  0  0.5  0  0  #Female mat-len-1
-3  3  -1.79  -0.8  -1  99  -3  0  0  0  0  0.5  0  0  #Female mat-len-2
-3  3  1.  1.  -1  99  -3  0  0  0  0  0.5  0  0  #Female eggs/gm intercept
-3  3  0.  0.  -1  99  -3  0  0  0  0  0.5  0  0  #Female eggs/gm slope
#
# Male wt-len
-3  3  4.3E-06  4.4E-06  -1  99  -3  0  0  0  0  0.5  0  0  #Male wt-len-1
-3  8  3.352  3.34694  -1  99  -3  0  0  0  0  0.5  0  0  #Male wt-len-2
#
0  1  1  1  -1  50  -50  0  0  0  0  0  0  0  # Recruitment apportionment by growth pattern
0  1  1  1  -1  50  -50  0  0  0  0  0  0  0  # Rec app by Area
0  1  1  1  -1  50  -50  0  0  0  0  0  0  0  # Rec app by Season
0  1  1  1  -1  50  -50  0  0  0  0  0  0  0  # Cohort growth deviation
#
#
# Seasonal effects on biology parameters (0=none)
 0 0 0 0 0 0 0 0 0 0
#
# Spawner-Recruitment parameters
6  # SR fxn:  1=Beverton-Holt
#  LO  HI  INIT  PRIOR  Pr_type  SD    PHASE
3     31   12.   9.3     3      99     1  #Ln(R0)
0.2    1   0.6   0.6    -1       0.2   -4  #steepness
0      2   0.6   0.65   -1       99    -4  #SD recruitments
-5     5   0     0      -1       99    -3  #Env link
-5     5   0     0      -1       99    -4  #init eq
-1     1   0     0      -1       100   -1  # placeholder for Autocorrelation
#
0 # index of environmental variable to be used
0 # env target parameter: 0=none, 1=rec devs, 2=R0, 3=steepness
#
#  Recruitment residuals
1     #_do_recdev:  0=none; 1=devvector; 2=simple deviations
1944  # 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
```

3 #_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
1980 #_last_early_yr_nobias_adj_in_MPD
1986 #_first_yr_fullbias_adj_in_MPD
2007 #_last_yr_fullbias_adj_in_MPD
2012 #_first_recent_yr_nobias_adj_in_MPD
0.3388 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
0 #_period of cycles in recruitment (N parms read below)
-5 #min rec_dev
5 #max rec_dev
0 #_read_recdevs
#
Fishing mortality setup
0.06 # F ballpark for tuning early phases
1999 # F ballpark year
1 # F method: 1=Pope's; 2=Instan. F; 3=Hybrid (recommended)
0.9 # max F or harvest rate, depends on F_Method
#
Initial Fishing Mortality Parameters
0 1 0 0.01 -1 99 -1
#
Catchability Specification (Q_setup)
#_Den-dep env-var extra_se Q_type
0 0 0 0 # 1 Fishery
0 0 0 0 # 2 AFSC Slope
0 0 0 0 # 3 Early Slope
0 0 0 0 # 4 Late Slope
#
#
Selectivity Specification
Type Retent Moffset Special
Length
#24 1 0 0 # Comm. Trawl
#24 0 0 0 # Alaska SLope
#24 0 0 0 # Early Slope
#24 0 0 0 # Late Slope
1 1 0 0 # Comm. Trawl
24 0 0 0 # Alaska SLope
1 0 0 0 # Early Slope
1 0 0 0 # Late Slope
Age selex
10 0 0 0 # Comm. Trawl
10 0 0 0 # Alaska Slope survey
10 0 0 0 # Early Slope survey
10 0 0 0 # Late Slope survey
#
#
Size selectivity for commercial fishery
#
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_min dev_max dev_SD Block Block_Fxn
6.5 25 10 20 0 1 2 0 0 0 0 0 0 0 # SizeSel_3P_1_Type24_size_double-normal

```
.01     25      5     -0.5    -1      2    3   0    0    0    0    0    0    0   # SizeSel_3P_2_Type24_size_double-normal
# 6.5   34.5     20   20      -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     20       10   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 Commercial Fishery
#
2       40  10  19  -1  99  3    0  0  0  0  0.5  1  3  #infl for logistic
0.00001 30   3  10  -1  99  3    0  0  0  0  0.5  0  0  #95%width for logistic
0.0001  1.   .97  1  -1  99  4  0  0  0  0  0.5  2  3  #final
-10.    5  0.0 0.0  -1  99  -4   0  0  0  0  0.5  0  0
#
# Size selectivity for slope surveys (double normal)
#
#_LO    HI    INIT   PRIOR   PR_type SD  PHASE   env-var use_dev dev_min dev_max dev_SD  Block
Block_Fxn
 6.5   34.5     20   20      -1      5    2   0    0    0    0    0    0    0   # SizeSel_3P_1_Type24_size_double-normal
#-7     7       -2   -0.5    -1      2    3   0    0    0    0    0    0    0   # SizeSel_3P_2_Type24_size_double-normal
-20     7       -2   -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      20       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
#
#_LO    HI    INIT   PRIOR   PR_type SD  PHASE   env-var use_dev dev_min dev_max dev_SD  Block
Block_Fxn
 6.5    25      10    20      0      1    2   0    0    0    0    0    0    0   # SizeSel_3P_1_Type24_size_double-normal
.01     25      5     -0.5    -1      2    3   0    0    0    0    0    0    0   # SizeSel_3P_2_Type24_size_double-normal
# 6.5   34.5     20   20      -1      5    2   0    0    0    0    0    0    0   # SizeSel_3P_1_Type24_size_double-normal
#-7     10       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     20      10   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
#
#_LO    HI    INIT   PRIOR   PR_type SD  PHASE   env-var use_dev dev_min dev_max dev_SD  Block
Block_Fxn
 6.5    25      10    20      0      1    2   0    0    0    0    0    0    0   # SizeSel_3P_1_Type24_size_double-normal
.01     25      5     -0.5    -1      2    3   0    0    0    0    0    0    0   # SizeSel_3P_2_Type24_size_double-normal
# 6.5   34.5     20   20      -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     20      10   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      5       #       Retain_1P_1_Fishery_BLK1delta_1992
-10     10     0       0       0       5      5       #       Retain_1P_1_Fishery_BLK1delta_2006
-10     10     0       0       0       5      5       #       Retain_1P_1_Fishery_BLK1delta_2011
-0.3    0.3    0       0       0       0.2    5       #       Retain_1P_3_Fishery_BLK2delta_2006
```

-0.3 0.3 0 0 0 0.2 5 # Retain_1P_3_Fishery_BLK2delta_2006
-0.3 0.3 0 0 0 0.2 5 # Retain_1P_3_Fishery_BLK2delta_2011
#
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
#
#
Likelihood related quantities
variance/sample size adjustment by fleet
1 # Do variance adjustments
0 0 0 0 #_add_to_survey_CV
0 0 0 0 #_add_to_discard_stddev
0 0 0 0 #_add_to_bodywt_CV
#0.5805589 0.4230162 0.3483933 1 #_mult_by_lencomp_N
0.7808988 0.426327 0.39508358 3.549658
1 1 1 1 #_mult_by_agecomp_N
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 # N lambda changes
Like_comp Fleet Phase Value Size_Freq_Method
17 999 2 0.1 999
17 999 3 0.01 999
17 999 5 0 999
#
0 # Extra SC pointer
#
999 # End-of-file

Appendix D. SS Starter File

```
# Longspine Thornyhead starter file for SS v3.x

LST_data.SS       # Data file
LST_control.SS  # Control file

0          # Read initial values from .par file: 0=no,1=yes
1          # DOS display detail: 0,1,2
2          # Report file detail: 0,1,2
0          # Detailed checkup.sso file (0,1)
0          # Write parameter iteration trace file during minimization
2          # Write cumulative report: 0=skip,1=short,2=full
1          # Include prior likelihood for non-estimated parameters
0          # Use Soft Boundaries to aid convergence (0,1) (recommended)
1          # N bootstrap datafiles to create
25         # Last phase for estimation
1          # MCMC burn-in
1          # MCMC thinning interval
0          # Jitter initial parameter values by this fraction
-1         # Min year for spbio sd_report (neg val = styr-2, virgin state)
-2         # Max year for spbio sd_report (-1=endyr+1, -2=entire forecast)
0          # N individual SD years
0.0001     # Ending convergence criteria
0          # Retrospective year relative to end year (i.e. -4)
2          # Min age for summary biomass
1          # Depletion basis: denom is: 0=skip; 1=rel X*B0
1          # Fraction (X) for Depletion denominator (e.g. 0.4)
1          # (1-SPR)_reporting:  0=skip; 1=rel(1-SPR)
1          # F_std reporting: 0=skip; 1=exploit(Bio)
#0 45    #_min and max age over which average F will be calculated
0          # F_report_basis: 0=raw; 1=rel Fspr; 2=rel Fmsy ; 3=rel Fbtgt

999 # end of file marker
```

Appendix E. SS Forecast File

#V3.21d
#
#C LST 2013 forecast file
#
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: 0.913 target below based on qlnorm(0.45, 0, sigma=0.72)
based on a category 2 designation as decided by the SSC on 9/13/2013
0.913 # 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)
1 # 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)
Conditional input if relative F choice = 2
Fleet relative F: rows are seasons, columns are fleets
#_Fleet: FISHERY
0
max totalcatch by fleet (-1 to have no max) must enter value for each fleet
-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

```
#_Conditional on >1 allocation group
# allocation fraction for each of: 0 allocation groups
# no allocation groups
2 # 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     942 # average of 2011 and 2012
2014  1    1     942 # average of 2011 and 2012
999 # verify end of input
#
999 # verify end of input
```