Agenda Item E.8
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2017 Lingcod Stock Assessment

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Contents

Executive Summary

Stock

This assessment applies to lingcod (*Ophiodon elongatus*) off the West Coast of the United States, and is conducted as two separate single stock assessment models, Washington and Oregon in the north, and California in the south. Four fisheries are modeled in the north: commercial trawl (including limited landings in other net gears), commercial fixed gears, and WA and OR recreational fisheries. Three fisheries are modeled in the south: commercial trawl (including limited landings in other net gears), commercial fixed gears, and CA recreational fisheries. Both models start in1889, at the onset of landings.

Landings

Historical commercial catch reconstructions were provided by each state that extend through 1995, 1986, and 1980 for Washington, Oregon, and California, respectively. Recent landings, from 1981 forward, were obtained from PacFIN. However, WDFW and ODFW staff advised that the catch reconstructions be used rather than PacFIN for overlapping years as the reconstructions are regarded as more reliable. Commercial landings were aggregated into two fleets: 1) vessels using primarily trawl gear, but also including other net gear that caught a small fraction of the fish, and 2) vessels using fixed gear such as longline, troll, and hook and line (Tables a and b, Figures a and b). Commercial discards were modeled using discard rate and length composition data to estimate retention curves, while estimates of recreational discards were included in the total landings. Landings declined significantly during 1980 to 2000, with trawl landings dominating the catch in the north, and recreational landings dominating the catch in the south. More recently landings in both regions have been increasing, with the recreational component of the landings growing in the north, and the recreational landings continuing to dominate in the south.

Table a. Recent landings, north. All units are in metric tons.

Years	North Trawl Gear	North Fixed Gears	WA Recreational*	Oregon Recreational	Total Landings
2005	79.32	58.01	78.31	140.84	356.48
2006	115.58	78.63	62.18	107.61	364.01
2007	113.63	71.17	68.21	104.02	357.03
2008	118.79	92.78	70.81	89.34	371.72
2009	93.47	81.47	74.25	78.76	327.95
2010	77.76	47.22	91.43	93.94	310.35
2011	283.43	57.64	117.78	114.99	573.83
2012	373.23	64.87	122.32	155.25	715.68
2013	360.35	78.34	127.32	224	790.01
2014	217.53	82.2	141.58	176.09	617.41
2015	163.4	132.54	271.95	226.17	794.07
2016	262.74	98.31	349.69	154.66	865.4

* Note that the WA recreational landings are entered into SS as numbers of fish, as reported by WDFW, SS then internally converts these landings to weights. The quantities reported for WA landings are the model converted values in metric tons.

Table b. Recent landings, south.

Years	South Trawl Gears	South Fixed Gears	South Recreational	Total Landings
2005	20.23	40.77	387.79	448.78
2006	24.79	36.08	316.87	377.74
2007	42.74	36.47	190.73	269.94
2008	34	36.22	106.96	177.18
2009	31.71	25.04	133.44	190.19
2010	23.05	23.68	107.35	154.08
2011	6.67	26.22	230.24	263.13
2012	16.34	31.46	281.44	329.23
2013	23.61	41.19	432.99	497.78
2014	36.77	70.06	571.82	678.65
2015	42.17	106.32	715.36	863.85
2016	40.21	75.62	647.29	763.12

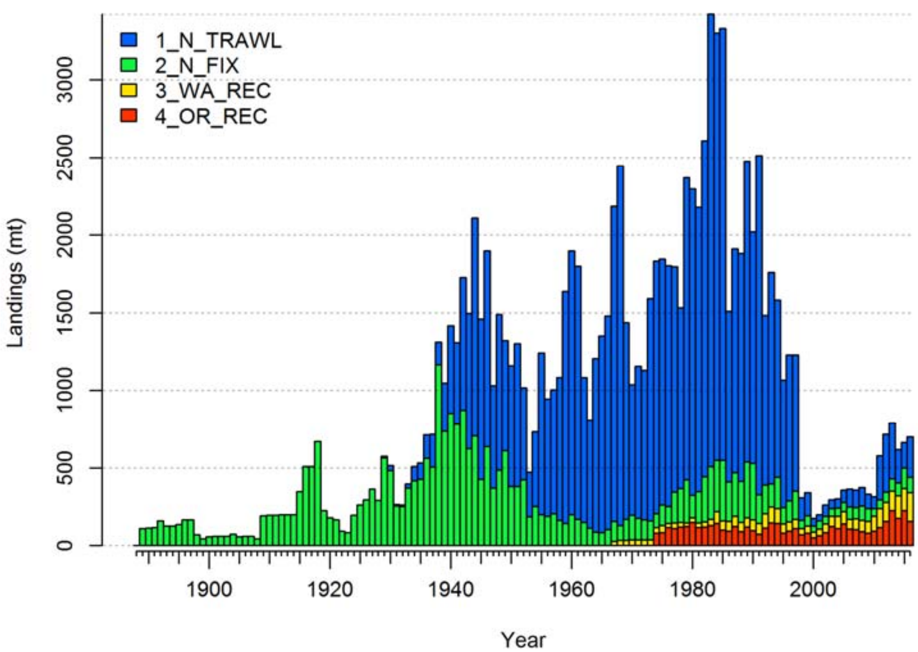

Figure a. North area landings.

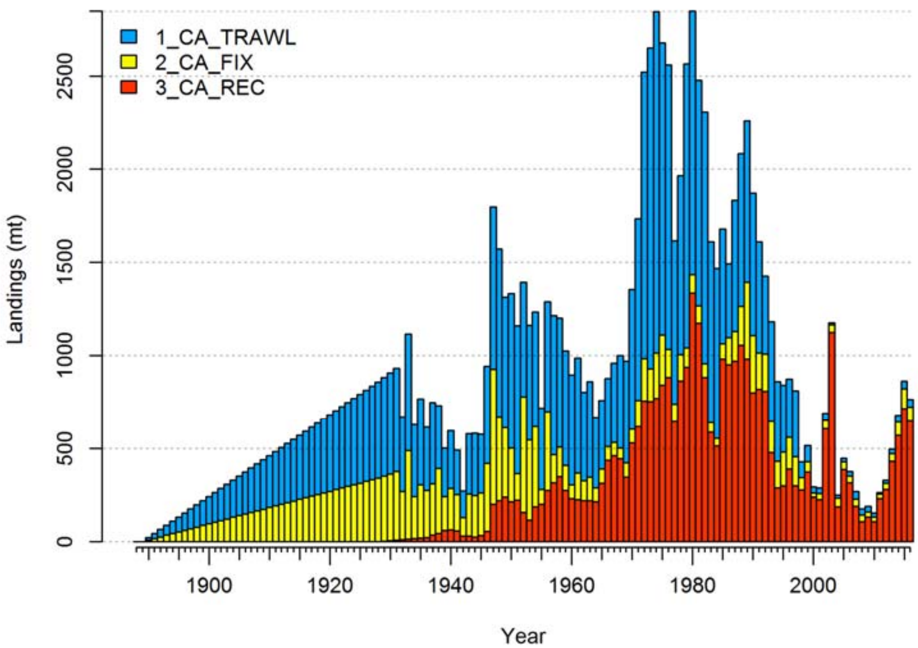

Figure b. South area landings

Data and Assessment

This assessment uses the Stock Synthesis (SS) fisheries stock assessment model, version 3.30.03.07. Lingcod has been modeled using various age-structured forward-projection models since the mid-1990s, with the most recent assessments conducted during 2005 (Jagielo et al. 2005) and 2009 (Hamel et al. 2009). Base model data sets include: landings data from each fleet; commercial discard data from the West Coast Groundfish Observer Program (WCGOP), NMFS Triennial bottom trawl survey, NWFSC bottom trawl survey, the NWFSC Hook and Line survey, PacFIN commercial logbook CPUE, OR nearshore commercial CPUE, both WA and OR recreational CPUE (North Only), commercial, recreational, and research length composition data, and survey age composition data (including CAAL data from the NWFSC bottom trawl survey). Concerns regarding biased sampling of commercial and recreational age composition data compared to the lengths lead to these data being removed from the base models. However, this issue can be addressed prior to the next assessment so that the lingcod age data can be included in the base models. In this assessment the impact of the current age data are show as model sensitivities. A research age and length composition data set from WDFW was also removed from the base model as the data set was limited and uninformative.

A wide range of sensitivity model runs for both the north and south stocks produce similar trajectories of stock decline and recovery, generally agreeing that both north and south lingcod stocks have increased since a low point during the 1990s. Of the key productivity parameters female natural mortality is fixed at the prior, male natural mortality is estimated, and stock-recruit steepness is fixed at 0.7, in keeping with the treatment of h for similar nest guarding species (e.g. Kelp Greenling). In the north, the base model is most sensitive to the inclusion of the fishery age data sets. Including only the Washington and Oregon conditional age-at-length data from the recreational fishery results in a lower estimate of unfished biomass but a similar estimate of stock status. Including only the marginal commercial age composition data results in a higher estimate of unfished biomass but similar stock status. In the south, the model is sensitive to removing the research data set collected by Lam et al., which results in a much higher unfished biomass estimate but a similar estimate of stock status. The south model is highly sensitive to the inclusion of the CA onboard observer index, which suggests a similar unfished stock size but a stock status that is well below the overfished threshold. Selectivity for all fleets and surveys were estimated using the composition data and are all estimated to be dome-shaped during recent years.

Stock Biomass

Tables c and d, and Figures c through f show the trends in spawning biomass and stock depletion. The north base model indicates that the lingcod female spawning biomass off of Washington and Oregon declined rapidly in the 1980s and 1990s, hitting a low during the mid-1990s, and has subsequently recovered to levels above the target reference point. The south base model indicates that the lingcod female spawning biomass off of California declined rapidly in the 1970s and early 1980s, reaching a low point during the 1990s, but that the southern stock has recovered above the minimum stock size threshold and remains in the precautionary zone (i.e. below the target reference point).

Stock status is currently estimated to be above the target reference point (40% of the estimated unfished spawning biomass) at 57.9% (47.9–67.8, 95% asymptotic interval) in the north and in the precautionary zone at 32.9% (12.0–53.9, 95% asymptotic interval) in the south. Unfished spawning biomass was measured at 37,947 mt (25,776–50,172 mt, 95% asymptotic interval) in the north and 20,462 mt (15,406–25,518 mt, 95% asymptotic interval) in the south. Spawning biomass at the beginning of 2017 was estimated to be 21,976 mt (12,517-31,434 mt, 95% asymptotic interval) in the north and 6,742 mt (1,775–11,709 mt, 95% asymptotic interval) in the south. The north stock is estimated to have been below the target reference point from approximately the 1980s through the early 2000s, while the south stock is currently estimated to be in the precautionary zone.

Table c. Recent trend in spawning biomass and stock depletion, north.

Years	Spawning Output	95% Asymptotic Interval	Estimated Depletion (%)	95% Asymptotic Interval
2005	14,711	8,479–20,943	38.7	31.5–46.0
2006	15,569	8,989–22,149	41	33.5–48.5
2007	15,833	9,111–22,556	41.7	34.1–49.3
2008	15,842	9,095–22,589	41.7	34.2–49.2
2009	15,627	8,940–22,314	41.2	33.8–48.5
2010	15,441	8,826–22,056	40.7	33.4–47.9
2011	15,912	9,150–22,674	41.9	34.7–49.1
2012	17,522	10,122–24,923	46.1	38.3–54.0
2013	19,235	11,116–27,355	50.7	42.1–59.2
2014	20,366	11,723–29,009	53.6	44.6–62.7
2015	20,939	12,019–29,858	55.1	45.8–64.5
2016	21,258	12,150–30,365	56	46.4–65.5
2017	21,976	12,517–31,434	57.9	47.9–67.8

Table d. Recent trend in spawning biomass and stock depletion, south.

Years	Spawning Output	95% Asymptotic Interval	Estimated Depletion (%)	95% Asymptotic Interval
2005	4,544	1,571–7,517	22.2	9.2–35.2
2006	4,834	1,551–8,117	23.6	9.4–37.9
2007	4,937	1,477–8,398	24.1	9.2–39.1
2008	4,866	1,376–8,355	23.8	8.7–38.8
2009	4,678	1,282–8,075	22.9	8.3–37.5
2010	4,407	1,169–7,646	21.5	7.7–35.4
2011	4,235	1,145–7,325	20.7	7.5–33.9
2012	4,199	1,180–7,219	20.5	7.7–33.4
2013	4,411	1,325–7,498	21.6	8.5–34.6
2014	4,853	1,515–8,192	23.7	9.6–37.8
2015	5,403	1,647–9,159	26.4	10.6–42.2
2016	6,040	1,696–10,383	29.5	11.2–47.8
2017	6,742	1,775–11,709	32.9	12.0–53.9

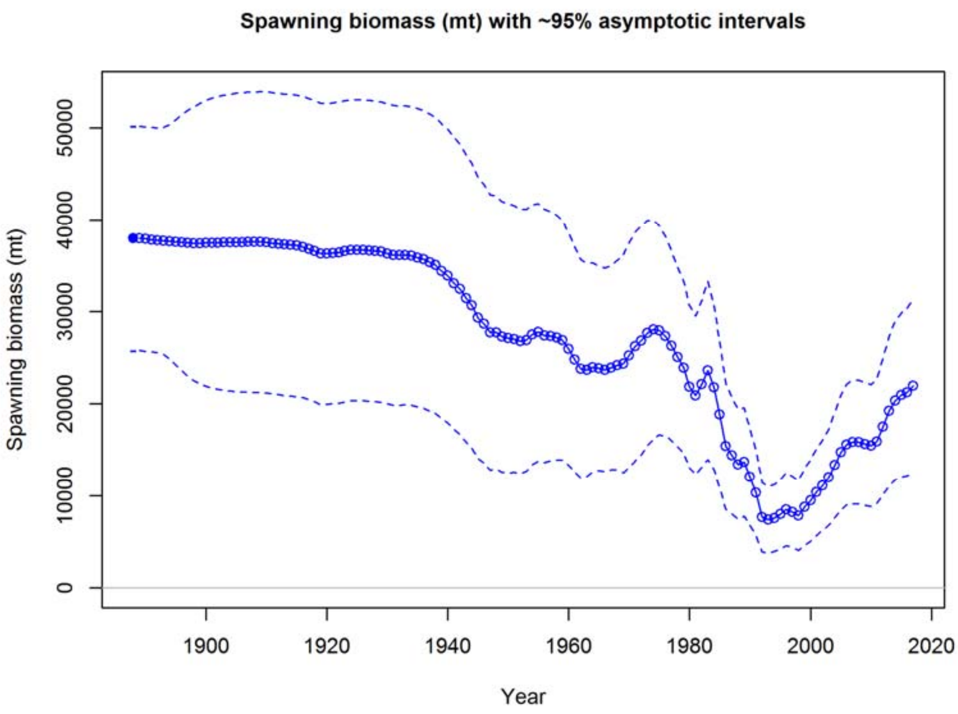

Figure c. Time series of spawning biomass, north.

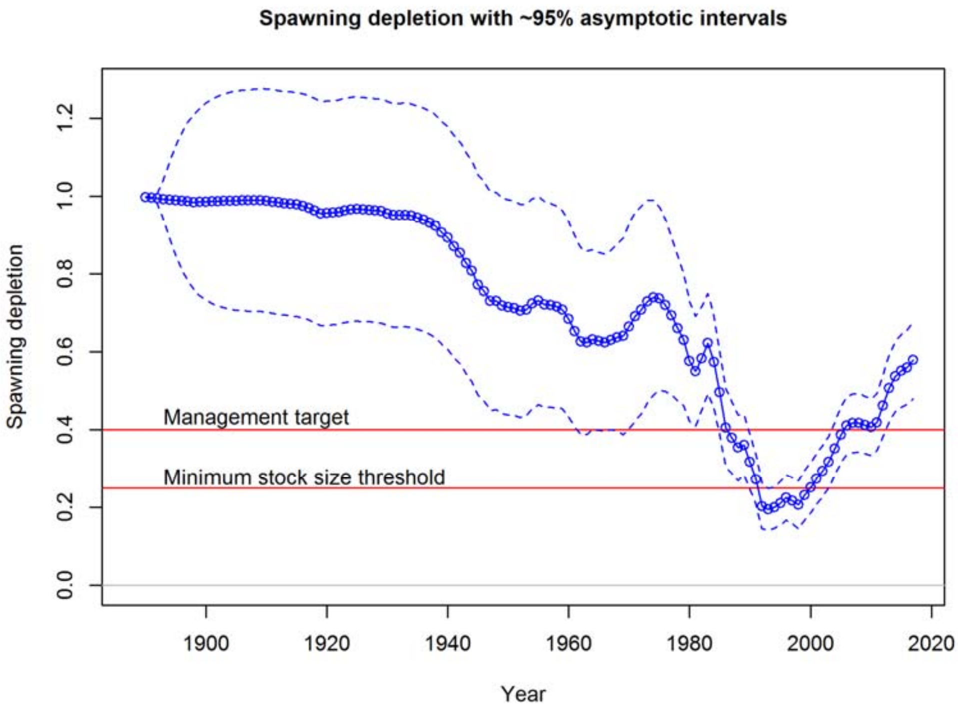

Figure d. Time series of stock depletion, north.

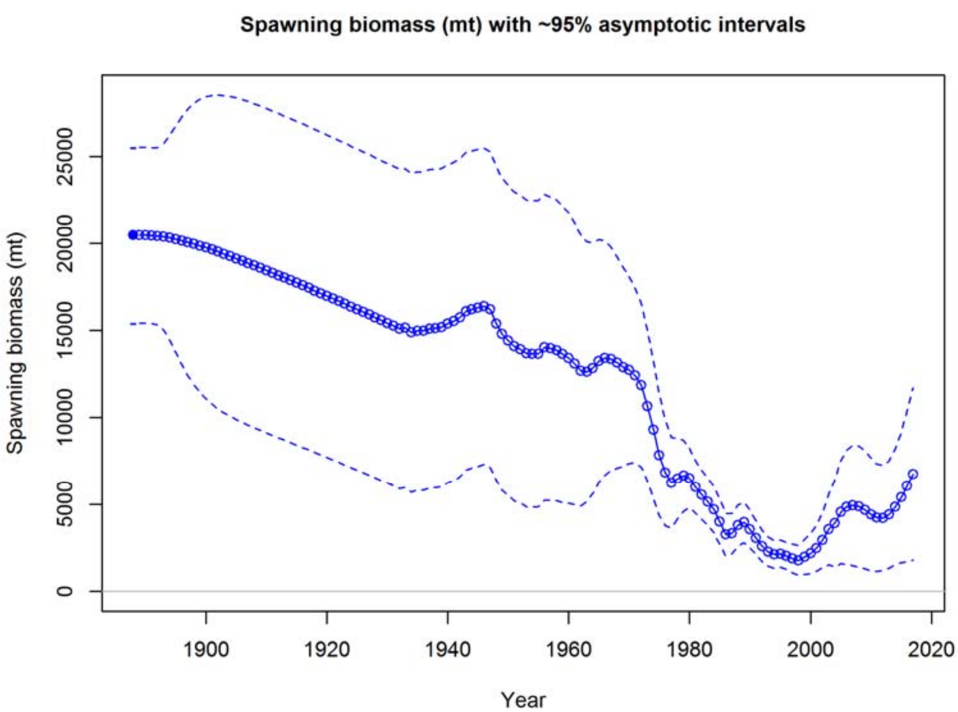

Figure e. Time series of spawning biomass, south.

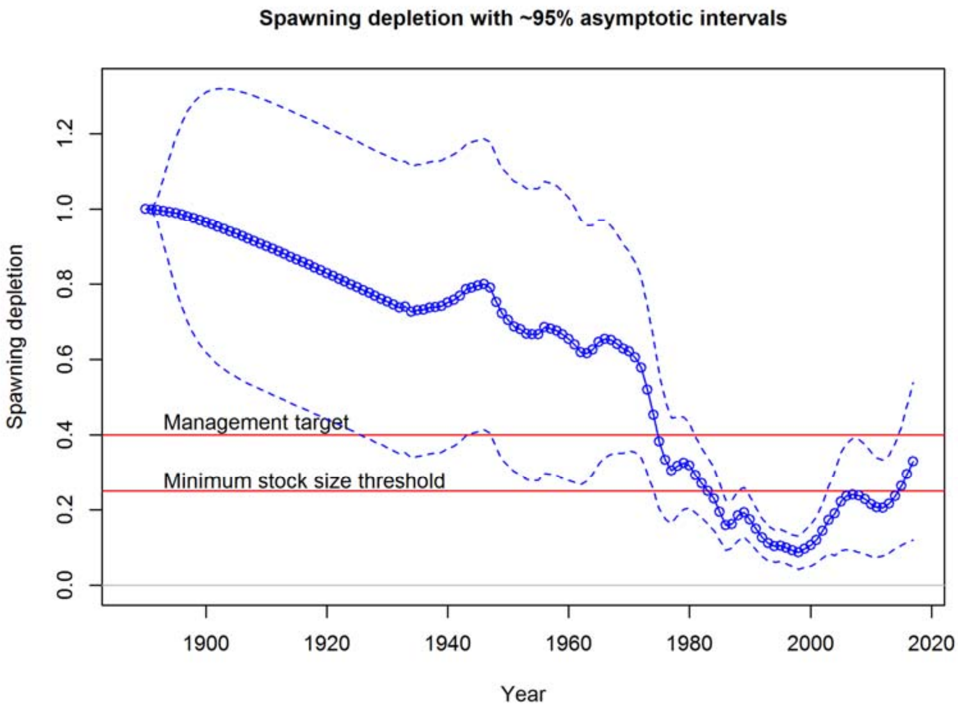

Figure f. Time series of stock depletion, south.

Recruitment

Recruitments in both the north and south were estimated from the model start through 2016 (Tables e and f, Figures g and h). Recruitments from 2017 forward are drawn exclusively from the stock-recruit curve, with corresponding levels of uncertainty. Large recruitment events in the north are estimated to have occurred during 1964-1965, 1969-1970, 1978-1980, 1985, 1990-1991, 2008, 2013 and 2015, while low recruitments were estimated to have occurred during 1986, 1996-1998, 2002-2007, 2011-2012, and 2014. Large recruitment events in the south are estimated to have occurred during 1961, 1973-1974, 1976-1977, and 1984-1985, while low recruitments were estimated to have occurred during 1981-1982, 1992-1993, 1995, 1997- 1998, 2002-2009, and 2014-2016. It is notable that lingcod in the south have not had a recruitment near historical high values since the mid-1980s.

Table e. Recent recruitment, north.

Years	Recruitment (1,000's)	95% Asymptotic Interval	Recruitment Deviations	95% Asymptotic Interval
2005	2,892	1,763–4,742	-0.803	-1.158–-0.447
2006	3,664	2,262–5,935	-0.579	-0.918–-0.241
2007	4,460	2,761–7,203	-0.387	-0.715–-0.058
2008	14,491	9,685–21,681	0.792	0.607–0.977
2009	6,292	3,961–9,996	-0.039	-0.346–0.267
2010	6,671	4,304–10,340	0.022	-0.238–0.281
2011	4,058	2,497–6,593	-0.482	-0.814–-0.150
2012	4,319	2,649–7,042	-0.44	-0.774–-0.107
2013	10,580	6,697–16,714	0.437	0.156–0.718
2014	4,851	2,528–9,307	-0.369	-0.929–0.191
2015	10,322	4,638–22,973	0.33	-0.422–1.082
2016	7,516	2,755–20,502	-0.041	-1.057–0.975
2017	8,037	2,813–22,958	0	-1.078–1.078

Table f. Recent recruitment, south.

Years	Recruitment (1,000's)	95% Asymptotic Interval	Recruitment Deviations	95% Asymptotic Interval
2005	637	329–1,236	-1.453	-1.977–-0.928
2006	454	223–922	-1.814	-2.407–-1.221
2007	792	429–1,461	-1.264	-1.712–-0.816
2008	1,799	1,071–3,021	-0.438	-0.752–-0.125
2009	1,928	1,146–3,244	-0.356	-0.675–-0.037
2010	3,807	2,272–6,379	0.345	0.068–0.623
2011	3,328	1,905–5,814	0.225	-0.095–0.546
2012	3,857	2,117–7,027	0.376	0.022–0.730
2013	5,174	2,805–9,541	0.652	0.284–1.019
2014	2,077	1,084–3,981	-0.294	-0.782–0.194
2015	1,823	834–3,986	-0.459	-1.151–0.233
2016	1,450	499–4,214	-0.854	-1.937–0.230
2017	4,007	1,056–15,200	0	-1.470–1.470

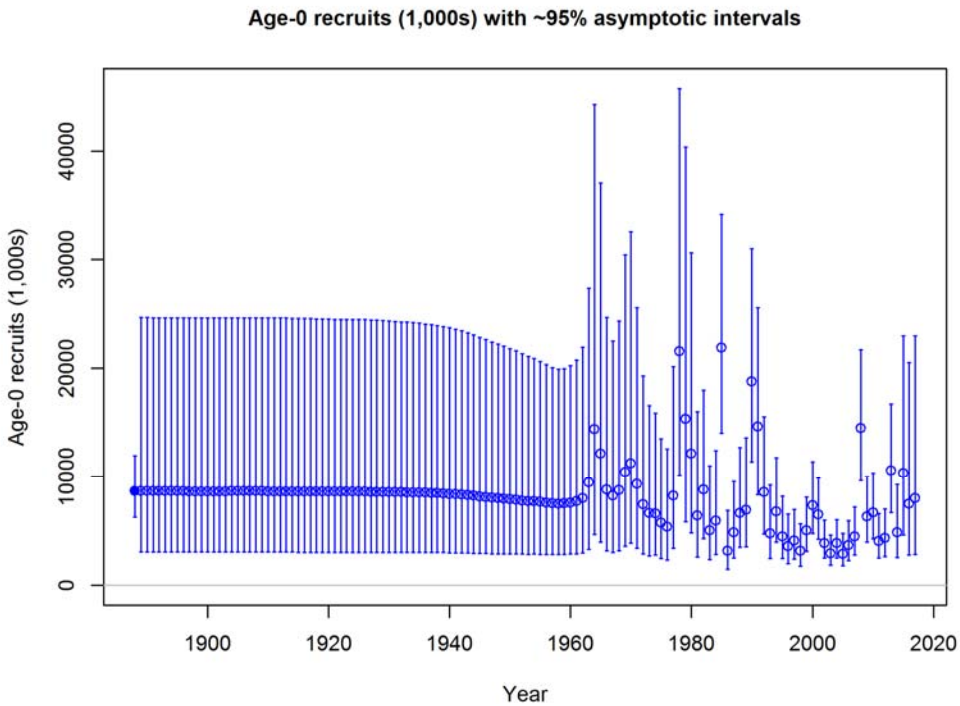

Figure g. Time series of estimated recruitment, north.

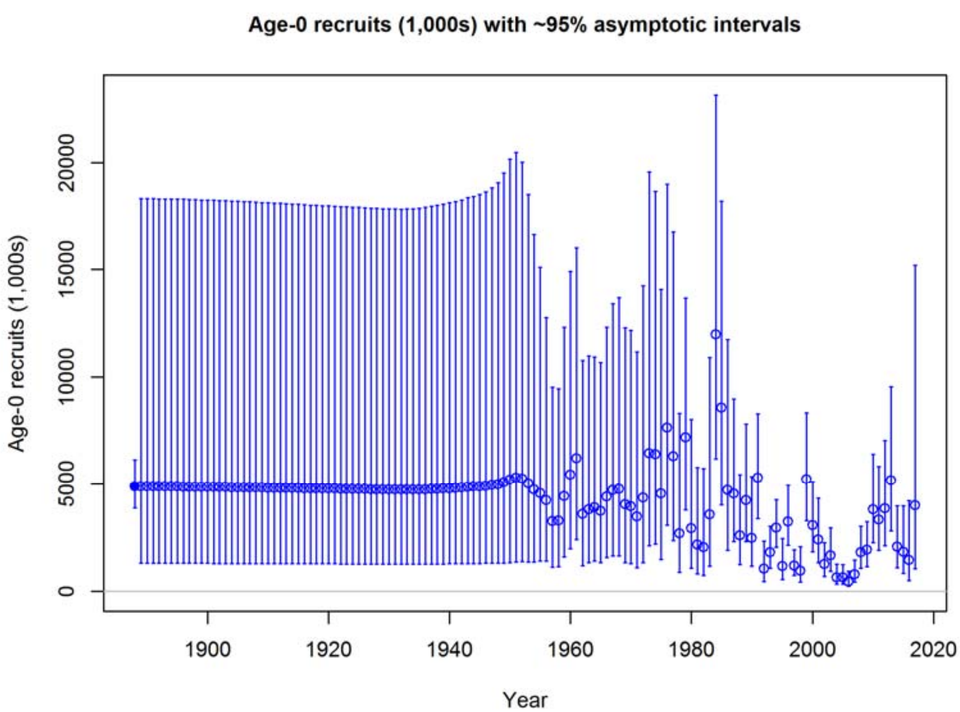

Figure h. Time series of estimated recruitments, south.

Exploitation Status

Historical harvest rates rose steadily through the 1990s, exceeding the target SPR harvest rate for several decades (Tables g and h, Figures i through l). Estimated harvest rates for the north and south models have not exceeded management target levels in recent years (Tables g and h, Figures i through l). However, in the south during the early 2000's it appears that harvest rates exceeded the management target for two years. In recent years, the spawning potential ratio (SPR) for lingcod in both areas has been above the proxy target of 45% (indicating fishing mortality rates are below the target). The full exploitation history in terms of both biomass and relative SPR, $(1\text{-SPR})/(1\text{-SPR}_{45\%})$, is portrayed graphically via a phase plot (Figures k and l).

Table g. Recent exploitation status, north. Harvest rate is catch/Age-3+ summary biomass.

Years	Estimated (1-SPR)/(1-SPR_45%) (%)	95% Asymptotic Interval	Harvest Rate (proportion)	95% Asymptotic Interval
2005	0.237	14.83–32.57	0.113	0.066–0.160
2006	0.2662	16.69–36.54	0.122	0.071–0.173
2007	0.2355	14.53–32.56	0.103	0.059–0.146
2008	0.2619	16.21–36.17	0.11	0.063–0.156
2009	0.2444	15.05–33.83	0.099	0.057–0.140
2010	0.193	11.89–26.71	0.08	0.046–0.113
2011	0.2818	17.82–38.55	0.12	0.071–0.169
2012	0.2914	18.47–39.81	0.136	0.080–0.192
2013	0.2865	18.08–39.22	0.139	0.082–0.196
2014	0.2183	13.48–30.17	0.107	0.063–0.152
2015	0.2324	14.35–32.14	0.115	0.067–0.163
2016	0.2504	15.46–34.62	0.115	0.067–0.163

Table h. Recent exploitation status, south. Harvest rate is catch/Age-3+ summary biomass.

Years	Estimated (1-SPR)/(1-SPR_45%) (%)	95% Asymptotic Interval	Harvest Rate (proportion)	95% Asymptotic Interval
2005	0.5096	22.71–79.22	0.304	0.109–0.499
2006	0.4724	20.21–74.26	0.247	0.082–0.413
2007	0.4123	17.02–65.43	0.188	0.057–0.318
2008	0.3333	13.36–53.31	0.129	0.037–0.222
2009	0.4269	18.50–66.88	0.146	0.040–0.252
2010	0.4179	18.62–64.95	0.123	0.033–0.214
2011	0.6601	33.62–98.40	0.205	0.059–0.351
2012	0.7041	37.01–103.81	0.255	0.078–0.432
2013	0.787	42.75–114.66	0.339	0.113–0.564
2014	0.8056	43.05–118.08	0.413	0.141–0.686
2015	0.8299	42.79–123.19	0.467	0.152–0.783
2016	0.6571	28.86–102.55	0.356	0.107–0.606

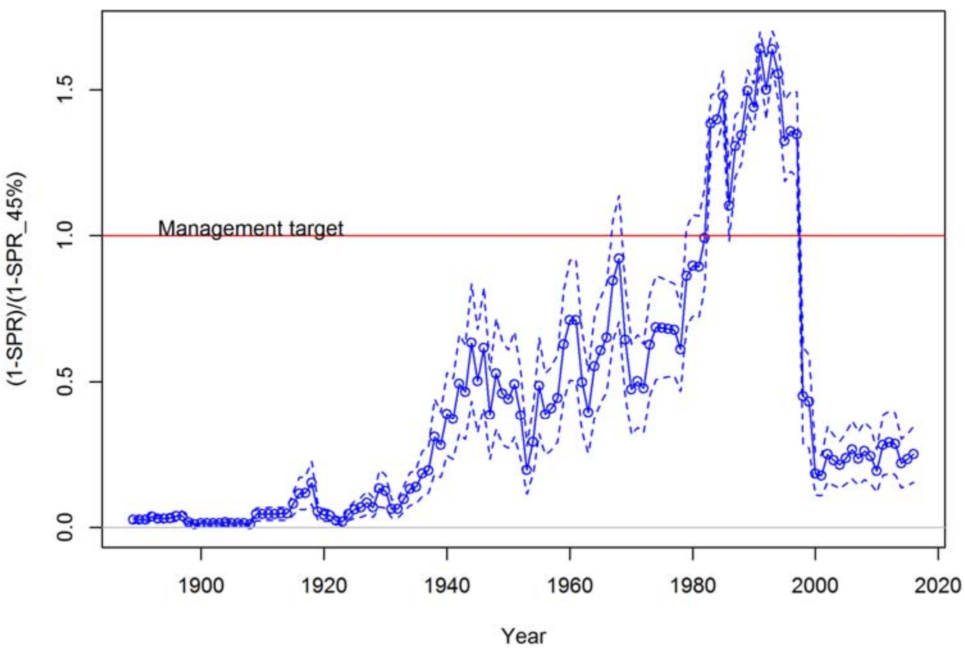

Figure i. Estimated spawning potential ratio (SPR), north. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

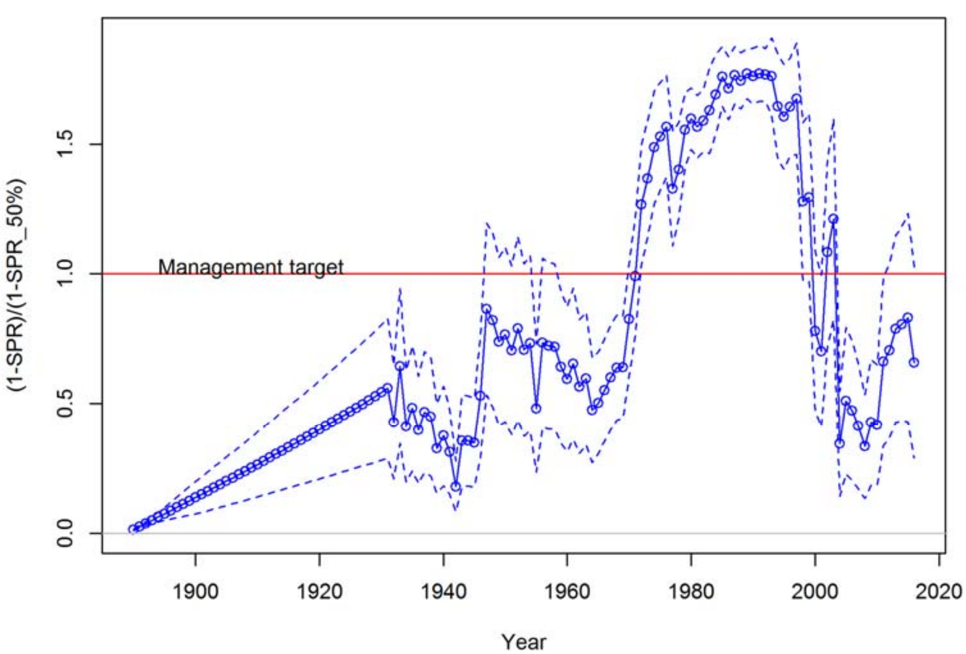

Figure j. Estimated spawning potential ratio (SPR), south. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

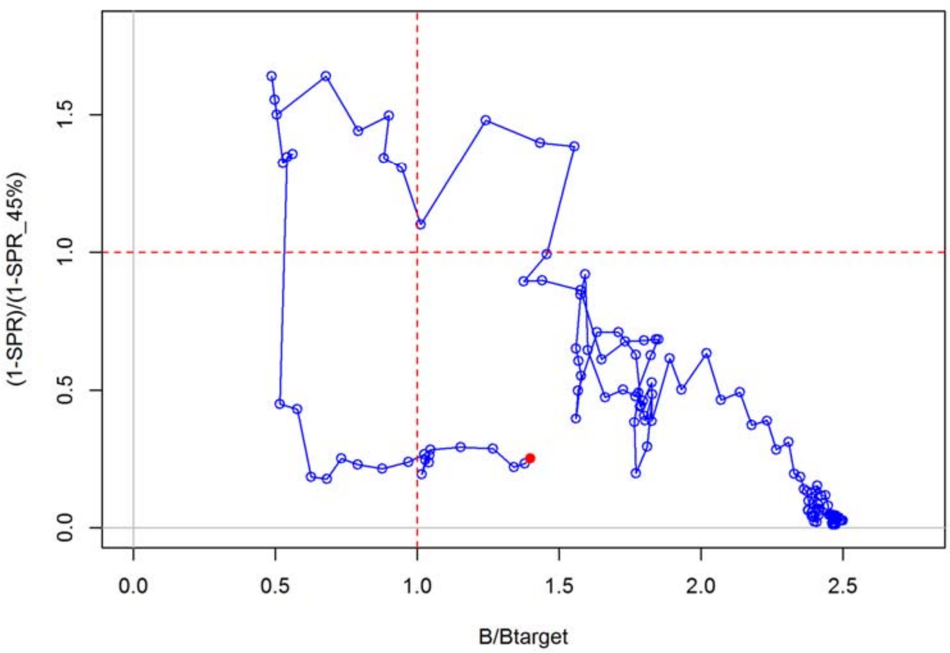

Figure k. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, north.

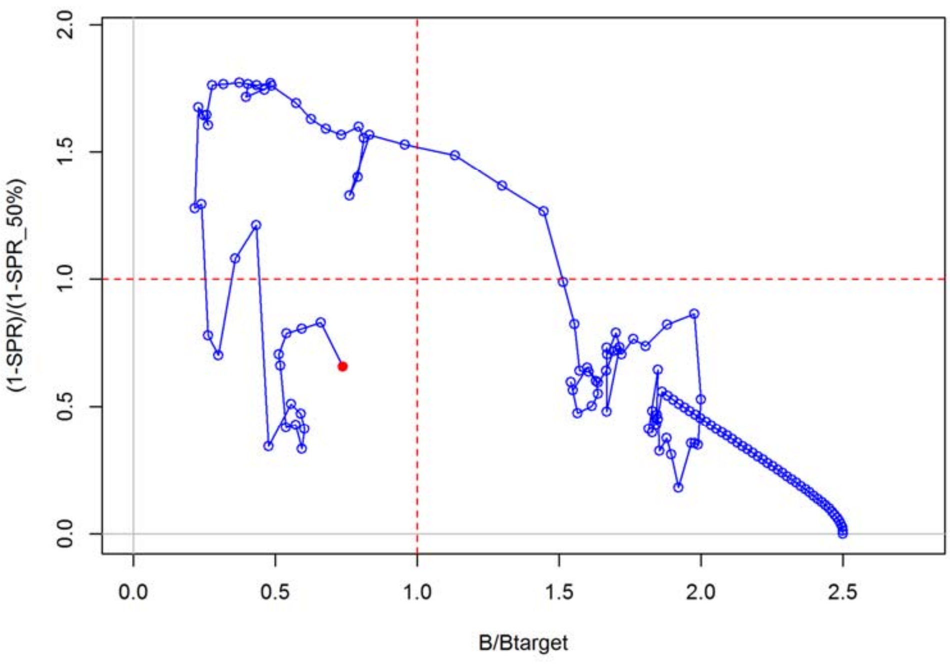

Figure l. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, south.

Ecosystem Considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. Lingcod often feed on target species of rockfish, particularly when these species are abundant (e.g., Beaudreau and Essington 2007).

However, there is a paucity of relevant data to provide quantitative information on this effect directly to the assessment. Recently available habitat information was used to select the data used in the onboard observer indices.

Reference Points

The north and south stocks are estimated to have been below the target reference point from approximately the 1980s through the early 2000s. Fishing intensity since approximately 2005 has been below the target for both the north and south stocks (Figures i - l). The phase plots show the interaction of fishing intensity and biomass targets (Figures k and l). The target stock size based on the biomass target (SB40%) is 15,190 10,311–20,069 mt, 95% asymptotic interval) in the north and 8,185 mt (standard deviation 569.7 mt) in the south, which gives catches of 2291.9 mt (standard deviation 58.1 mt) for the north and 1982.1 mt (6,162–10,207, 95% asymptotic standard deviation) for the south (Tables i and j). Equilibrium yield at the proxy FMSY harvest rate is 3,241 mt (2,215–4,268 mt, 95% asymptotic interval) and 1,658 mt (1,299–2,016 mt, 95% asymptotic interval) for the north and south, respectively (Tables i and j).

Table i. Reference points, north. Note that exploitation rate is Catch/(Age-3+ biomass).

	Estimate	95% Asymptotic Interval
Unfished Spawning Biomass (mt)	37,974	25,776–50,172
Unfished Age 3+ Biomass (mt)	56,005	38,126–73,884
Spawning Biomass (2017)	21,976	12,517–31,434
Unfished Recruitment (R0)	8,664	5,870–11,458
Depletion (2017)	57.87	47.94–67.80
Reference Points Based SB40%		
Proxy Spawning Biomass (SB40%)	15,190	10,311–20,069
SPR resulting in SB40%	0.464	0.464–0.464
Exploitation Rate Resulting in SB40%	0.126	0.123–0.129
Yield with SPR Based On SB40% (mt)	3,197	2,184–4,210
Reference Points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45)	14,582	9,898–19,266
SPR45	0.45	NA
Exploitation rate corresponding to SPR45	0.132	0.129–0.135
Yield with SPR45 at SBSPR (mt)	3,241	2,215–4,268
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	10,254	6,966–13,542
SPRMSY	0.348	0.345–0.351
Exploitation rate corresponding to SPRMSY	0.187	0.183–0.190
MSY (mt)	3,409	2,329–4,489

Table j. Reference points, south. Note that exploitation rate is Catch/(Age-3+ biomass).

	Estimate	95% Asymptotic Interval
Unfished Spawning Biomass (mt)	20,462	15,406–25,518
Unfished Age 3+ Biomass (mt)	31,547	24,121–38,973
Spawning Biomass (2017)	6,742	1,775–11,709
Unfished Recruitment (R0)	4,881	3,763–5,999
Depletion (2017)	32.95	12.02–53.88
Reference Points Based SB40%		
Proxy Spawning Biomass (SB40%)	8,185	6,162–10,207
SPR resulting in SB40%	0.464	0.464–0.464
Exploitation Rate Resulting in SB40%	0.125	0.116–0.135
Yield with SPR Based On SB40% (mt)	1,732	1,357–2,106
Reference Points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45)	9,003	6,779–11,228
SPR45	0.5	NA
Exploitation rate corresponding to SPR45	0.11	0.102–0.119
Yield with SPR45 at SBSPR (mt)	1,658	1,299–2,016
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	5,317	3,997–6,636
SPRMSY	0.339	0.334–0.344
Exploitation rate corresponding to SPRMSY	0.196	0.184–0.208
MSY (mt)	1,868	1,465–2,272

Management Performance

The 2009 stock assessment estimated lingcod to be at 61.9% and 73.7% of unfished spawning stock biomass in the north and south, respectively. Based on the 2009 stock assessment, the most recent 2017 and 2018 ACTs were set to 3066.4 and 2861.2 in the north and 1517.6 and 1392.8 in the south. Note that these values are based on reallocating 8% of the ACT north of 40-10 management line to the south. The value of 8% is based on the 5 year average biomass distribution in the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS). Recent coast-wide annual landings have not exceeded the ACL.

Table k. Recent trends in landings and total catch (mt) relative to management guidelines. Total dead catch represents the total landings plus the model estimated dead discard biomass. Note that the model estimated total dead catch may not be the same as the WCGOP estimates of total mortality, which are the "official" records for determining whether the ACL has been exceeded.

Years	Spatial Management Strata	Coast-wide OFL	North OFL	South OFL	Coast-wide ABC	North ABC	South ABC	North Landings	North Total Dead	South Landings	South Total Dead
2005	Coast-wide	2,922	NA	NA	2,414	NA	NA	356	502	449	462
2006	Coast-wide	2,716	NA	NA	2,414	NA	NA	364	544	378	390
2007	Coast-wide	6,706	NA	NA	6,706	NA	NA	358	459	270	289
2008	Coast-wide	5,853	NA	NA	5,853	NA	NA	374	480	177	191
2009	Coast-wide	5,278	NA	NA	5,278	NA	NA	331	424	190	202
2010	Coast-wide	4,829	NA	NA	4,829	NA	NA	315	343	154	160
2011	Split at 42º N	4,961	2438	2523	4,432	2,330	2,102	578	611	263	265
2012	Split at 42º N	4,848	2251	2597	4,315	2,151	2,164	717	748	329	334
2013	Lingcod Split at 40º10' N	4,668	3,334	1,334	4,147	3,036	1,111	790	813	498	505
2014	Lingcod Split at 40º10' N	4,438	3,162	1,276	3,941	2,878	1,063	619	632	679	690
2015	Lingcod Split at 40º10' N	4,215	3,010	1,205	3,834	2,830	1,004	662	677	864	877
2016	Lingcod Split at 40º10' N	4,027	2,891	1,136	3,665	2,719	946	702	723	763	774
2017	Lingcod Split at 40º10' N	5,051	3,549	1,502	4,584	3,333	1,251	NA	NA	NA	NA
2018	Lingcod Split at 40º10' N	4,683	3,310	1,373	4,254	3,110	1,144	NA	NA	NA	NA

Unresolved Problems and Major Uncertainties

A few outstanding issue remain for lingcod stock assessment on the west coast of the U.S. First, the commercial age data need to be resampled to ensure that they are representative of the sampled lengths. There is evidence of bias in some years with respect to age sampling. While this issue was not able to be fully resolved at the STAR panel, a resolution is possible for the next lingcod assessment. Future assessments should also investigate implementing a spatial model that is able to explore linkages between the north and south regions as lingcod are a single genetic stock but show differences in biological traits, such as growth and allometry, which may be attributable to physical and ecological differences across this large geographic expanse. There is evidence that the recreational lingcod fishery in California is landing fish from Mexican waters. Landings from Mexican waters need to be removed from the U.S. landings in future lingcod assessments. Finally, it would be useful to explore the availability of transboundary lingcod data (both Canada and Mexico) and how these data could be used in the PFMC stock assessment process. Both of these issues require communications and research activity outside of the PFMC stock assessment cycle. Time limitations during this assessment did not allow for exploration of Canadian lingcod data or inclusion in the assessment model. Mexico may also have relevant lingcod data but this has not been investigated.

Decision Table

The lingcod stock assessments are Category 1 stock assessments (subject to SSC approval), thus projections and decision tables are based on using P*=0.45 and sigma = 0.36, resulting in a multiplier on the OFL of 0.956. This is combined with the 40-10 harvest control rule to calculate OFLs, ABCs and ACLs. The total catches in 2017 and 2018 were assumed to equal the PFMC-adopted ACLs, and the average 2015-2017 exploitation rate was used to distribute catches among the fisheries. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviations for the 2017 spawning biomass from the base model. A fixed value of Ro was used to attain the 2017 spawning biomass values for the lower and upper states of nature, given by the base model mean +/- 1.15*standard deviation. The values for Ro were identified using likelihood profile model runs to produce a plot of Ro versus 2017 spawning biomass. The high catch stream in the decision table is given by the 40-10 control rule. At the request of the GMT representative on the STAR panel the moderate catch streams were set to 40% ACL attainment for the north and 70% ACL attainment in the south. Finally, the low catch stream was set to ~700 mt, a level similar to recent average catches.

Harvest projections are provided in Tables l and m. In the north, current medium-term projections of expected catch, spawning biomass and depletion from the base model project a declining trend through 2028 as recent large cohorts increase in age (note that all projections assume average recruitment from the stock-recruit curve) and the 40-10 control rule ACLs move the stock towards the target reference point. The stock is expected to remain above the target stock size of $SB_{40\%}$ through 2026, assuming average recruitment based on the stock-recruit curve. In the south, current medium term projection of expected catch, spawning biomass and depletion from the base model project a declining trend through the projection period, with the stock remaining just above the minimum stock size threshold $SB_{25\%}$ through the projection period. The lack of increasing stock sizes during the projections is due, in part, to a large number of poor recruitments since 2000 (11 out of 17 years) and a lack of recruitments near historical highs.

Decision tables are provided in Tables n and o. In the north, current medium-term forecasts based on the alternative states of nature project that the stock will fall below the target stock size in only case, in which the current control rule is applied to the low stock state of nature (bottom left corner of the table). All other decision table scenarios keep the stock at or above the target stock size. In the south, current medium-term forecasts based on the alternative states of nature project a range of outcomes from effective extirpation to increases above the target stock size. All of the low state of nature scenarios suggest that the stock is overfished and only in the constant catch scenario does the stock increase into the precautionary zone. The most pessimistic scenario, the application of the 40-10 rule to the low state of nature, suggests that the stock is extirpated from the south by 2024 (bottom left corner of the table). However, all catch scenarios under the high state of nature suggest that the stock will increase to above or near the target reference point. The constant and 75% ACL catches from the base case model allow the stock to increase towards, or exceed the target reference point.

Table l. Model projections, north.

Year	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	4,815.82	3,058.30	34,063.80	21,975.70	57.87
2018	4,711.84	2,844.79	33,998.90	21,239.20	55.93
2019	4,690.12	4,497.30	33,538.10	20,944.30	55.15
2020	4,458.62	4,275.36	31,723.50	19,737.80	51.98
2021	4,271.91	4,096.33	30,257.40	18,683.70	49.2
2022	4,126.12	3,956.53	29,105.30	17,821.00	46.93
2023	4,012.88	3,847.95	28,189.10	17,134.60	45.12
2024	3,923.16	3,761.93	27,451.10	16,586.10	43.68
2025	3,850.11	3,691.90	26,847.70	16,141.10	42.51
2026	3,789.18	3,633.48	26,347.50	15,774.10	41.54

Table m. Model projections, south.

Year	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	2,523.12	1,517.64	11,609.70	6,741.96	32.95
2018	2,322.09	1,392.80	10,976.00	6,664.33	32.57
2019	2,115.26	1,846.79	10,021.10	6,292.18	30.75
2020	1,940.77	1,604.91	9,403.82	5,630.36	27.52
2021	1,941.60	1,564.67	9,268.10	5,370.23	26.25
2022	1,998.58	1,605.35	9,332.59	5,334.50	26.07
2023	2,049.60	1,651.55	9,407.48	5,359.83	26.19
2024	2,079.88	1,679.93	9,449.77	5,380.20	26.29
2025	2,094.79	1,692.73	9,465.75	5,383.80	26.31
2026	2,101.99	1,697.75	9,470.86	5,379.30	26.29

Research and Data Needs

Most of the research needs listed below entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

1. Age validation of lingcod aging is needed to verify the level of age bias, if any.
2. A transboundary stock assessment and the management framework to support such assessments would be beneficial.
3. A survey in untrawlable habitat and/or a near shore survey would improve this stock assessment. Other survey techniques could include longline, combined lingcod/sablefish pot survey, or trap surveys.
4. Investigate environmental covariates for recruitment and time-varying growth and availability inshore.
5. The impact of nest-guarding on reproductive output should be investigated. The current assessment focuses on female spawning biomass as the limiting factor in reproductive output, but nest guarding by lingcod males and the availability of nesting habitat may also play roles. A cursory look at the proportion of sex ratio in the catch did not appear to indicate any serious changes for either north or south populations in recent years. However, we do not know what kind of change in sex ratio would indicate a serious change in reproductive success.

6. Investigation of the proportion of fish caught in Mexico and landed in U.S. ports as there is evidence that California recreational fisheries, primarily out of San Diego, are fishing in Mexican waters. These catches should be allocated appropriately between U.S. and Mexican waters.

Rebuilding Projections

Lingcod stocks in the California Current are not overfished and do not require rebuilding analyses.

Table n. Summary of model outputs, north. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviations for the 2017 spawning biomass from the base model. A fixed value of Ro was used to attain the 2017 spawning biomass values for the lower and upper states of nature, given by the base model mean +/- 1.15*standard deviation.

			State of nature					
			Low 2017 Spawning Biomass *Ln(Ro)=8.81*		Base case 2017 Spawning Biomass *Ln(R0) = 9.0669*		High 2017 Spawning Biomass *Ln(Ro)=9.8*	
Probability			0.25		0.5		0.25	
Manage-ment decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
~700mt Constant Catch	2019	695	14329	48.7	20944	55.2	51958	65.8
	2020	695	15227	51.8	22150	58.3	54488	69.0
	2021	697	16162	54.9	23337	61.5	56819	71.9
	2022	698	17084	58.1	24474	64.5	58968	74.6
	2023	698	17948	61.0	25527	67.2	60925	77.1
	2024	699	18741	63.7	26487	69.8	62686	79.3
	2025	699	19468	66.2	27357	72.0	64258	81.3
	2026	700	20129	68.4	28140	74.1	65649	83.1
	2027	700	20727	70.5	28840	76.0	66874	84.6
	2028	700	21267	72.3	29466	77.6	67952	86.0
40% of 40:10 Rule	2019	1785	14329	48.7	20944	55.2	51958	65.8
	2020	1698	14540	49.4	21455	56.5	53791	68.1
	2021	1642	14847	50.5	22009	58.0	55488	70.2
	2022	1575	15209	51.7	22585	59.5	57075	72.2
	2023	1533	15603	53.0	23171	61.0	58566	74.1
	2024	1499	16001	54.4	23741	62.5	59942	75.9
	2025	1472	16392	55.7	24287	64.0	61200	77.5
	2026	1449	16773	57.0	24803	65.3	62339	78.9
	2027	1430	17140	58.3	25287	66.6	63364	80.2
	2028	1413	17490	59.5	25740	67.8	64287	81.4
40:10 Rule	2019	4497	14329	48.7	20944	55.2	51958	65.8
	2020	4275	12863	43.7	19738	52.0	52084	65.9
	2021	4096	11601	39.4	18684	49.2	52171	66.0
	2022	3957	10538	35.8	17821	46.9	52295	66.2
	2023	3848	9682	32.9	17135	45.1	52518	66.5
	2024	3762	8963	30.5	16586	43.7	52799	66.8
	2025	3692	8339	28.3	16141	42.5	53118	67.2
	2026	3633	7779	26.4	15774	41.5	53455	67.7
	2027	3584	7266	24.7	15469	40.7	53800	68.1
	2028	3542	6788	23.1	15213	40.1	54149	68.5

Table o. Summary of model outputs, south. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviations for the 2017 spawning biomass from the base model. A fixed value of Ro was used to attain the 2017 spawning biomass values for the lower and upper states of nature, given by the base model mean +/- 1.15*standard deviation.

			State of nature					
			Low Ln(R0) = 8.122		Base case Ln(R0) = 8.493		High Ln(R0) = 8.742	
Management decision	Year	Catch (mt)	Spawning output (mt)	Depletion	Spawning output (mt)	Depletion	Spawning output (mt)	Depletion
Constant 700 mt catch	2019	700	2,725	19%	6,123	30%	8,894	34%
	2020	700	2,628	19%	6,144	30%	9,011	34%
	2021	700	2,739	20%	6,425	32%	9,441	36%
	2022	700	2,975	21%	6,908	34%	10,128	38%
	2023	700	3,248	23%	7,475	37%	10,930	41%
	2024	700	3,527	25%	8,067	40%	11,768	45%
	2025	700	3,810	27%	8,658	42%	12,600	48%
	2026	700	4,099	29%	9,238	45%	13,410	51%
	2027	700	4,395	31%	9,800	48%	14,186	54%
	2028	700	4,697	33%	10,340	51%	14,924	57%
75% ACL catch	2019	1,318	3,152	22%	6,572	32%	9,349	35%
	2020	1,154	2,707	19%	6,222	31%	9,092	34%
	2021	1,135	2,548	18%	6,214	30%	9,228	35%
	2022	1,173	2,524	18%	6,420	31%	9,634	37%
	2023	1,212	2,518	18%	6,696	33%	10,138	38%
	2024	1,237	2,489	18%	6,979	34%	10,662	40%
	2025	1,249	2,437	17%	7,250	36%	11,172	42%
	2026	1,255	2,372	17%	7,511	37%	11,666	44%
	2027	1,258	2,304	16%	7,765	38%	12,140	46%
	2028	1,261	2,232	16%	8,013	39%	12,596	48%
ABC 40-10 Rule	2019	1,757	2,725	19%	6,123	30%	8,894	34%
	2020	1,539	2,041	15%	5,512	27%	8,371	32%
	2021	1,513	1,685	12%	5,293	26%	8,292	31%
	2022	1,564	1,444	10%	5,291	26%	8,489	32%
	2023	1,616	1,179	8%	5,344	26%	8,775	33%
	2024	1,649	850	6%	5,388	26%	9,071	34%
	2025	1,665	NA	NA	5,412	27%	9,351	35%
	2026	1,673	NA	NA	5,425	27%	9,621	36%
	2027	1,678	NA	NA	5,435	27%	9,882	37%
	2028	1,681	NA	NA	5,445	27%	10,138	38%

Table p. Summary of model outputs, north. Note that exploitation rate is Catch/(Age-3+ biomass).

Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1-SPR	0.24	0.27	0.24	0.26	0.24	0.19	0.28	0.29	0.29	0.22	0.23	0.25	NA
Exploitation Rate	0.11	0.12	0.1	0.11	0.1	0.08	0.12	0.14	0.14	0.11	0.11	0.11	NA
Age 3+ Biomass (mt)	23,760	23,945	23,974	23,493	23,078	23,041	27,371	29,480	31,302	31,650	31,634	33,759	34,064
Spawning Biomass (mt)	14,711	15,569	15,833	15,842	15,627	15,441	15,912	17,522	19,235	20,366	20,939	21,258	21,976
95% Confidence Interval	8,479–20,943	8,989–22,149	9,111–22,556	9,095–22,589	8,940–22,314	8,826–22,056	9,150–22,674	10,122–24,923	11,116–27,355	11,723–29,009	12,019–29,858	12,150–30,365	12,517–31,434
Recruitment	2,892	3,664	4,460	14,491	6,292	6,671	4,058	4,319	10,580	4,851	10,322	7,516	8,037
95% Confidence Interval	1,763–4,742	2,262–5,935	2,761–7,203	9,685–21,681	3,961–9,996	4,304–10,340	2,497–6,593	2,649–7,042	6,697–16,714	2,528–9,307	4,638–22,973	2,755–20,502	2,813–22,958
Depletion (%)	38.7	41	41.7	41.7	41.2	40.7	41.9	46.1	50.7	53.6	55.1	56	57.9
95% Confidence Interval	31.5–46.0	33.5–48.5	34.1–49.3	34.2–49.2	33.8–48.5	33.4–47.9	34.7–49.1	38.3–54.0	42.1–59.2	44.6–62.7	45.8–64.5	46.4–65.5	47.9–67.8

Table q. Summary of model outputs, south. Note that exploitation rate is Catch/(Age-3+ biomass).

Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1-SPR	0.51	0.47	0.41	0.33	0.43	0.42	0.66	0.7	0.79	0.81	0.83	0.66	NA
Exploitation Rate	0.3	0.25	0.19	0.13	0.15	0.12	0.21	0.25	0.34	0.41	0.47	0.36	NA
Age 3+ Biomass (mt)	7,734	8,038	7,849	7,513	7,047	6,591	6,578	6,675	7,594	8,498	9,559	11,049	11,610
Spawning Biomass (mt)	4,544	4,834	4,937	4,866	4,678	4,407	4,235	4,199	4,411	4,853	5,403	6,040	6,742
95% Confidence Interval	1,571–7,517	1,551–8,117	1,477–8,398	1,376–8,355	1,282–8,075	1,169–7,646	1,145–7,325	1,180–7,219	1,325–7,498	1,515–8,192	1,647–9,159	1,696–10,383	1,775–11,709
Recruitment	637	454	792	1,799	1,928	3,807	3,328	3,857	5,174	2,077	1,823	1,450	4,007
95% Confidence Interval	329–1,236	223–922	429–1,461	1,071–3,021	1,146–3,244	2,272–6,379	1,905–5,814	2,117–7,027	2,805–9,541	1,084–3,981	834–3,986	499–4,214	1,056–15,200
Depletion (%)	22.2	23.6	24.1	23.8	22.9	21.5	20.7	20.5	21.6	23.7	26.4	29.5	32.9
95% Confidence Interval	9.2–35.2	9.4–37.9	9.2–39.1	8.7–38.8	8.3–37.5	7.7–35.4	7.5–33.9	7.7–33.4	8.5–34.6	9.6–37.8	10.6–42.2	11.2–47.8	12.0–53.9

Introduction

This assessment applies to lingcod (*Ophiodon elongatus*) off the West Coast of the United States, and is conducted as two separate single stock assessment models, Washington and Oregon in the north, and California in the south. This is the same approach implement in recent lingcod assessments. Four fisheries are modeled in the north: commercial trawl (including limited landings in other net gears), commercial fixed gears, and WA and OR recreational fisheries. Three fisheries are modeled in the south: commercial trawl (including limited landings in other net gears), commercial fixed gears, and CA recreational fisheries. Both models start during 1889, at the onset of landings. These areas were chosen due to latitudinal trends in weight-length and growth relationships observed in the Northwest Fishery Science Center (NWFSC) survey data, evidence that lingcod do not generally move across large areas (tagging data suggest the scale of movement is at 10's of kilometers), little stock connectivity at moderate (~10 km) to large (~1000 km) scales (Marko et al. 2007), and different fleet structures and sampling programs between the states. While there is evidence for a limited demographic connectivity at moderate to large scales (~100-1000 km) along the coast, analysis of genetic variation indicates that lingcod are genetically similar throughout their range (Marko et al. 2007).

Life History and Ecosystem Considerations

Lingcod (*Ophiodon elongatus*, family Hexagrammidae) are large opportunistic top predators in the nearshore demersal ecosystem of the northeast Pacific Ocean and are valued both commercially and recreationally in the U.S. groundfish fishery. They range from Kodiak Island, Alaska down to Baja California, Mexico, though abundance tapers off quickly south of Point Conception (Wilby 1937, Hart 1973). The historical center of abundance is off of British Columbia and Washington State (Hart 1973). While the NWFSC survey catches lingcod up to depths of approximately 450 m, they typically occur at depths of less than 200 meters. Lingcod are demersal on the continental shelf, display a patchy distribution and are most abundant in areas of hard bottom with rocky relief (Rickey 1991). Studies using DNA markers (Marko et al. 2007) have found that lingcod are genetically similar throughout their coastal range, suggesting extensive gene flow among populations throughout the West Coast. Through 2010 the lingcod stock was mangaged as a coast-wide population, during 2011 and 2012 lingcod were managed as having a Northern population (Washington and Oregon), and a Southern population (California), finally during 2013 to present northern and southern lingcod populations have been managed with a break at 40 degrees 10 minutes north latitude.

Lingcod are sexually dimorphic, with females typically growing slower than males but attaining larger sizes ($L\infty$ = 131 cm for females and $L\infty$= 93 cm for males sampled off of British Columbia) (Richards et al. 1990). Female lingcod reach maturity at larger sizes, between 3-5 years of age, while males are smaller, grow faster initially (before sexual maturation), and reach maturity earlier at 2 years (Miller and Geibel 1973, Cass et al. 1990). Growth rate and size at maturity has been seen to vary regionally, with lingcod off Washington waters growing slower and maturing at larger sizes (females at 64 cm, males at 52 cm) than lingcod from warmer waters in California (females 59 cm; males 40 cm) (Richards et al. 1990, Silberberg et al. 2001). Given that the age at maturity does not differ significantly between the regions, the observed geographic differences in size at maturation are likely attributed to spatial variation in growth rates.

In the late fall, male lingcod aggregate and become territorial in areas suitable for spawning, these areas are generally in shallower water with rocky high relief habitat. The proportion of male lingcod sampled from offshore trawl landings declines in the late fall, suggesting a pre-spawning departure of males from the trawl grounds (Miller and Geibel 1973 (California), Cass et al. 1990 (British Columbia), Jagielo 1994 (Washington)). Males are in spawning condition earlier in the year than females, and it appears that larger and older females spawn first (Cass et al. 1990). Mature females are rarely seen on the spawning grounds and appear to move into spawning areas for only a brief period to deposit eggs (Giorgi 1981). Spawning behavior has been reported from the intertidal zone to a depth of 126 m (Giorgi 1981, O'Connell 1993). Spawning typically begins in early December, with the observed timing of peak spawning activity ranging from January (Wilby 1937) to early March (La Riviere et al. 1981). However, recent maturity studies suggest that lingcod are batch spawners with ability to spawn year round, with, peak spawning taking place during October – December (pers. comm, Melissa Head, NWFSC). Mature females move in from deeper offshore areas (100-200 m) to shallow (10-40 m) rocky habitats to deposit eggs in favorable nesting sites (Wilby 1937). Mature males will initially select and guard optimal nesting areas, crevices or rocky outcrops with high flow, before the arrival of spawning females. After eggs are deposited, female lingcod will return to depth, leaving the male to guard the eggs until they hatch, usually between 5-7 weeks (Low and Beamish 1978, Miller and Geibel 1973). Nest guarding by males has been shown to be imperative for egg survival by protecting against opportunistic fish predators like perches (Embiotocidae), greenlings (Hexagrammidae), and sculpins (Cottidae) (Jewell 1968). Males appear to be more effective at guarding the nest from predation by vertebrates than by invertebrates (La Riviere et al. 1981, Low and Beamish 1928). In experiments where males were removed from nests, new males sometimes assumed a guardian role, but in one removal experiment, 4 of 7 nests were lost to predators within 22 days. (Low and Beamish, 1978). Ambient oxygen levels (Giorgi 1981), salinity and temperature affect egg survival as well (Cook et al. 2005).

Eggs hatch between January and June (Jewell 1968, Low and Beamish 1978). Upon hatching, the larvae are about 12 mm in total length and become epipelagic until they reach about 70 mm and settle to soft bottom habitats (Phillips and Barraclough 1977, Cass et al. 1990). Larvae in the Strait of Georgia first appear in the plankton in late February. Numbers peak in late April. Larvae were concentrated in the upper 3 m of the water column by day and disperse or migrate to deeper depths at night. Larvae begin to disappear from the upper water column by late May to early June and become demersal at about 70-80 mm and at about 3 months of age. Epipelagic larvae feed on small copepods and copepod eggs, shifting to larger copepods and fish larvae as they grow (Phillips and Barraclough 1977).

At about 3 months old, juveniles settle on sandy bottom areas near eelgrass or kelp beds. Juvenile lingcod will stay on the soft bottom until they grow to at least 350 mm in length, when they move into rocky areas with high relief as protection from large predators (Petrie and Ryer 2006). By age 1 or 2, lingcod move into rocky habitats similar to those occupied as adults, but shallower. Fishery and survey data indicate that male lingcod tend to be more abundant than females in shallow waters, and the size of both sexes increase with depth (Jagielo 1994). Newly settled juveniles have been sampled nearshore in June on sandy bottom areas near eelgrass or kelp beds (Buckley et al. 1984), and have been found at depth ranging from 20m in Canada (Phillips and Barraclough 1977) to 55 m in California (Miller and Geibel, 1973). In Washington, juveniles have been collected from the mouth of the Pysht River in the Strait of Juan de Fuca, from Grays Harbor and Willapa Bay, and from coastal waters nearshore to these embayments (Buckley et al. 1984, Jagielo 1994). Coley et al. (1986) found juvenile lingcod in Grays Harbor in October, over hard bottom shell-cobble habitat near rocks in 9-15 m of water.

Outside of spawning season, male and female lingcod are segregated by depth where females tend to inhabit deeper offshore waters and males in nearshore rocky reefs. Consequently, each sex is vulnerable to different types of fishing gear. The majority of nearshore males (66.3%) are caught using hook-and-line or spearfishing gear, and a majority of deep water females (62.4%) are caught by trawl gear (Miller and Geibel 1973). Miller and Geibel (1973) reported that juvenile lingcod in California are about 35 cm in length (1 year old) when they first move into nearshore rocky areas typical of adult habitat. Surveys off the west coast of Vancouver Island suggest that juveniles move from inshore areas to a wider range of flat bottom areas by September (Cass et al. 1990), and begin to move into habitats of similar relief and substrate as adult lingcod by age 2, but remain at shallower depths. Juvenile lingcod feed on small fishes including herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), flatfish (*Pleuronectidae*), shiner perch (*Cymatogaster aggregate*), and walleye pollock (*Theragra chalcogramma*), and an assortment of invertebrates including shrimp (*Neomysis macrops*) and prawns (*Pandalus danae*) (Cass et al. 1990).

Phillips and Barraclough (1977) estimated that young-of-the-year (YOY) growth was approximately 1.3 mm/day. Buckley et al. (1984) reported YOY growth from June to September in the Strait of Juan de Fuca also averaged 1.3mm/day. Samples from the mouth of the Pysht River averaged 96 mm in June, 135 mm in July, 173 mm in August and 200 mm in September (Jagielo 1994).

The movement and migration of lingcod has been extensively studied through tag-recapture methods and acoustic arrays. As adults, lingcod have a high degree of site fidelity and tend to stay within an 8 km home range. In Cape Flattery, Washington, Jagielo (1990) reported that 80.7% of tagged fish were recovered <8 km from their original release site though recaptures came from as far north as Queen Charlotte sound (195 km) and as far south as Cape Falcon (120 km). U.S. and Canadian tagging studies have demonstrated movement between coastal areas off Washington and southwest Vancouver Island. However, there is little interchange between these areas and the inland marine waters of Puget Sound and the Strait of Georgia (Cass et al. 1990, Jagielo 1990). Most fish recovered in tagging studies are found near the point of release, but some exceptional movements have been reported. Cass et al. (1990) found that 95% of fish recovered from a tagging study off the west coast of Vancouver Island were recaptured near the point of release. One fish tagged as a juvenile was recovered 510 km to the south in Oregon. . At Cape Flattery, Washington, Jagielo (1990) reported that only 19% of recoveries were further than 10km from the release point. However, recaptures came from as far north as Queen Charlotte sound (195 km) and as far south as Cape Falcon (120 km). Starr et al. (2005) in Alaska and Greenley (2009) in Central California used acoustic tags for tracking lingcod movement and both observed that while lingcod exhibit high site fidelity with an established location of residence, they frequently leave for brief periods of time (1-5 days) over short distances (2 km) to feed, then return home for a longer duration. Large females generally had shorter residency times, spending more time outside of their tagged site. Additional acoustic studies by Bishop et al. (2010) and Stahl et al. (2014) in Prince William Sound have reported that younger individuals (2-4 year olds, around 50 cm) disperse from nearshore reefs during spawning season, most likely due to displacement by older and larger spawning individuals. Overall, residency times appear vary by sex, size, season, and habitat of residence.

There are no clear stock delineations for lingcod in U.S. waters. No distinct breaks are seen in the fishery landings, catch distributions, or survey data. Genetic studies have found coastal lingcod populations to be genetically similar throughout their range (Jagielo et al. 1996). More recent analyses indicate limited genetic changes in the stock along the coast, but no distinct stock breaks. Marko et al. (2007) found surprisingly little connectivity between stocks at moderate (~10 km) to large (~1000 km) ranges, suggesting that regionally structured assessments are appropriate.

Lingcod are top order predators of the family Hexagrammidae. Among the Hexagrammidae, the genus Ophiodon is ecologically intermediate between the more littoral genera Hexagrammos, Agrammus and Oxylebius and the more pelagic Pleurogrammus (Rutenberg 1962). Lingcod are opportunistic predators, feeding on a variety of fishes (pelagic and demersal), cephalopods, and crustaceans (Wilby 1937). Juvenile lingcod in soft bottom habitats prey upon small fishes including herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), flatfish (*Pleuronectidae*), shiner perch (*Cymatogaster aggregata*), and an assortment of invertebrates including shrimp (*Neomysis macrops*) and prawns (*Pandalus danae*) (Cass et al. 1990). As juvenile lingcod begin to move into rocky habitats and exceed 30 cm TL, rockfishes (*Sebastes* spp.) become a more prominent component of their diet, making up 19% of total prey biomass by weight. Rockfish biomass in lingcod diet increases by three-fold for lingcod found inside marine reserves (Beaudreau and Essington 2007). Preliminary observations (B. Brown, Moss Landing Marine Laboratories, personal communication, 6 April 2017) from lingcod stomachs contents sampled from Washington to California in both nearshore and offshore habitats indicate a higher occurrence of bony fishes from Washington and Oregon waters, and a higher occurrence of cephalopods in lingcod from California waters with an overlapping region near southern Oregon.

This latitudinal shift in prey composition suggests differences in feeding behavior and the predatory role of lingcod in coastal environments.

Map

Figure 1a shows the geographic scope of the assessment and depicts boundaries for fisheries and data collection strata. Figure 1b shows the occurrence of lingcod in the NWFSC WCGBTS.

Historical and current fishery

Lingcod fisheries have a long history, with the earliest evidence of lingcod fishing coming from the remains of 51 archaeological sites representing the period between 6200 BC and 1830 AD on the central California coast from San Mateo to San Luis Obispo (Gobalet and Jones 1995). More recently, the commercial fishery off of California dates back more than a century, and the fishery off of Washington and Oregon dates back nearly as far. Recorded commercial and recreational take of lingcod began during the 1920s in southern California, then Oregon and Washington later during the 1940s.

Lingcod are harvested commercially by trawl and longline gear, and recreationally by hook-and-line and spear. The fishery steadily grew with the rise of the groundfish trawl industry, reaching peak landings during in the early 1980s. Landings decreased during the late 1980s due to population declines and the implementation of seasonal closures and size limits. During 1999 the lingcod fishery was declared overfished coast-wide. With the combination of a federal rebuilding plan implemented during 2003 and favorable ocean conditions for lingcod recruitment, the population was deemed recovered in 2005, four years ahead of the projected recovery time.

In California, the recreational lingcod fishery has substantial landings that have surpassed that of the CA commercial fleet since 1998. At the peak of the lingcod fishery during 1974, the landings were nearly equally divided between the commercial and recreational fleets. From 1980 to 2008, 95% to 97% of lingcod caught were taken by boat-based anglers (commercial passenger fishing vessel, CPFV, and private/rental boats). Private boat landings (including kayaks) were higher than those from CPFVs. A small fraction of landings are from spear fishers using SCUBA or free diving gear (Lynn 2008).

Catches of lingcod in Oregon and Washington have shifted from the commercial trawl fleet, accounting for 90% of landings during its mid-1980s peak, to a fishery evenly split between commercial and recreational in recent years. Between 1980 and 1996, the majority of lingcod were caught by the bottom trawl fishery (>75%), followed by troll and hook-and-line (between 10-20%), with a small fraction of additional landings from pots and traps, nets, and shrimp trawls (Jagielo et al. 1997). From 1999 to 2016, however, the recreational fishery has contributed about half of all lingcod landings, on average.

Management history and performance

Prior to 1977, lingcod stocks in the northeast Pacific were managed by the Canadian Government within its waters, and by the individual states in waters (out to three miles) off of the United States. With implementation of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) in 1976, primary responsibility for management of the groundfish stocks off Washington, Oregon and California shifted from the states to the Pacific Fishery Management Council (PFMC). The U.S. west coast ABC for lingcod was set at 7,000 mt, but catch was consistently below this level. In 1994, a harvest guideline (HG) of 4,000 mt was set. In 1995, both the ABC and HG were dropped to 2,400 mt based on a quantitative assessment (Jagielo et al. 2000). Trip limits on commercial Lingcod catch were first instituted in 1995, when a 20,000 lbs. /month limit was imposed, and a minimum size was imposed for recreational fisheries of 22 inches. During 1998 to present, individual year ABC and OY levels were set, commercial trip limits became much more restrictive (starting at 1,000 mt/2 months in 1998), and recreational bag limit were set at 2 (or 1) lingcod with minimum sizes ranging from 22 to 30 inches.

PFMC implemented an initial Lingcod Rebuilding Plan in 2000 with size and seasonal limitations in the recreational fishery and a change to limited entry and open access sectors in the commercial fishery. Coast-wide ABC was further reduced by 27.1% (700 mt, down from 960 mt). In the commercial fishery sector, harvest guidelines in 2000 were reduced by over 80% from 1998 limits. In order to achieve these low harvest goals, all commercial fishing for lingcod was closed for six months (January to April, and November to December). During the open period between April and November, all commercial vessels were limited to 400 pounds per month, and lingcod landed by non-trawl vessels south of Cape Mendocino had a minimum size limits of 26 inches long, and 24 inches long in all other areas. During the rebuilding period between 2000 and 2005, cumulative trip limits were very low at 800 lbs.' for every 2 months with frequent closures.

After 2006, the population had rebuilt, and ABC for trip limits began rising, with a bimonthly limit of 1,200 pounds. Concurrently, Marine Protected Areas (MPAs), Rockfish Conservation Area (RCA) and Cowcod Conservation Area (CCA) were implemented, prohibiting take of all groundfish within specified deaths, habitats, and locations.

During 2011, the limited entry trawl sector became a catch share program with 100% observer coverage, while prior to 2011 observer coverage was chosen by random stratified sampling. The Trawl Catch Share Program requires 100% at-sea observer coverage since all catch of Individual Fishing Quota (IFQ) species must be accounted for to allow fishers and managers to track and monitor their individual quotas.

The first recreational regulations for lingcod were set in 1994, with a bag limit of 3 fish in Washington and Oregon, 5 fish in California, and coast-wide size limit of 22 inches. In 1998, the bag limit in all three states dropped to 2 fish per day at 24 inches, where it largely remained until 2008. Regulations in California fluctuate frequently, where during the stock rebuilding period between 2000 and 2004 the California recreational bag limit dropped to 1 fish per day, and the size limit increased from 26 inches to 30 inches. In 2015, the bag limit has increased to 3 fish per day in California, 2 fish per day in Oregon and Washington, and a size limit of 22 inches. Most recently, the bag limit in California has decreased back to 2 fish per day.

Summaries of regulatory histories for both federal and state management actions are available as supplementary materials to this stock assessment. See table k in the executive summary for a history of OFLs, ACLs, landings, and catch (landings plus discards) for each area.

Fisheries off of Alaska, Canada, and Mexico

Lingcod fisheries in the Gulf of Alaska are managed in state waters by the State of Alaska Board of Fisheries and in federal waters by the North Pacific Management Council. The sport fishery is restricted by daily bag and possession limits. Commercial fisheries are restricted by catch and bycatch quotas. Lingcod are a non-target species in the subsistence fishery. No formal lingcod stock assessment has been done in Alaskan waters.

Lingcod in Canada are managed under the Pacific Integrated Goundfish Fishery by the Department of Fisheries and Oceans for take by First Nations and the commercial and recreational sectors. Beginning in 1997, the Canadian commercial groundfish trawl fishery implemented an IVQ (Individual vessel quota) program that now incorporates all commercially caught trawl and hook and line groundfish. Stocks in distinct management areas are regularly assessed, with the most recent lingcod assessment in outer British Columbia waters in 2011, and in the Strait of Georgia in 2014 (DFO, 2016). The 2011 assessment impliments a Bayesian surplus production model to assess lingcod stock status within four assessment areas. Overall the stock appears to have remained stable from 1927-1970, declined until 1980, increased until 1990 and has continued to decline since then.

However the stock is still estimate to be healthy with respect to reference points. The 2016 assessment implement a two-sex statistical catch-at-age model in a Bayesian model. Results suggest that spawning biomass in 2014 is greater than spawning biomass at the start of the current management regime during 2006, and that the stock is likely in a precautionary management zone.

Southern CA recreational fishers have reported fishing in Mexican waters and landing fish in U.S. ports. This is an issue that requires further investigation. There are no know Mexican stock assessments for lingcod.

2. Data

The following sources of data were used in building this assessment:

1. Fishery independent data including bottom trawl survey-based indices of abundance and biological data (age and length) from the NWFSC survey and AFSC Triennial survey.
2. Research length and age composition data from WDFW (north model only) and L. Lam (pers. Comm.)
3. Estimates of fecundity, maturity, length-weight relationships and ageing error from various sources.
4. Commercial landings, length, and age composition data.
5. Estimates of commercial discard length frequencies and fraction discarded in the fishery obtained from the West Coast Groundfish Observer Program (WCGOP).
6. Recreational landings, length, and age composition data.
7. Commercial and recreational fishery CPUE.

Data availability by source and year is presented in Figures 2 and 3 as well as in the more detailed data sections below. A description of each of the specific data sources follows.

Fishery Independent Data: NWFSC WCGBTS trawl survey

Three sources of information are produced from the West Coast Groundfish Bottom Trawl Survey (WCGBTS): an index of relative abundance, length-frequency distributions, and age-frequency distributions. Only years in which this survey included the continental shelf are considered (2003 forward), since lingcod are primarily a shelf species.

The WCGBTS is based on a random-grid design, covering the coastal waters from a depth of 55 m to 1,280 m (Keller et al. 2007). This design uses four industry chartered vessels per year, assigned to a roughly equal number of randomly selected grid cells and divided into two ‘passes’ of the coast that are executed from north to south. Two vessels fish during each pass, and are conducted from late May to early October each year. This design therefore incorporates both vessel-to-vessel differences in catchability as well as variance associated with selecting a relatively small number (~700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian border. Much effort has been expended on appropriate analysis methods for this type of data, culminating in the West Coast trawl survey workshop held in Seattle in November, 2006.

Data from the WCGBTS are analyzed using a spatio-temporal delta-model (Thorson et al. 2015), implemented as an R package titled *VAST* (Thorson and Barnett 2017) and publicly available online (https://github.com/James-Thorson/VAST). This method for constructing survey abundance indices was reviewed, endorsed, and recommended by the Pacific Fishery Management Council’s Scientific and Statistical Committee (SSC). *VAST* specifically includes spatial and spatio-temporal variation in both encounter probability and positive catch rates, a logit-link for encounter probability, and a log-link for positive catch rates. Vessel-year effects are included for each unique combination of vessel and year in the database, to account for the random selection of commercial vessels used during sampling (Helser et al. 2004, Thorson and Ward 2014). Spatial variation is approximated using 250 knots, and the bias-correction algorithm (Thorson and Kristensen 2016) in Template Model Builder (Kristensen et al. 2016) is used. Further details regarding model structure are available in the user manual (https://github.com/James-Thorson/VAST/blob/master/examples/VAST_user_manual.pdf). To confirm convergence of the model estimation algorithm, we confirm that the Hessian matrix is positive definite and that the absolute-value of the final gradient of the log-likelihood with respect to each fixed effect was <0.0001 for each fixed effect. We select among two alternative model configurations, i.e., treating positive catch rates as following a lognormal or gamma distribution. Following advice from the Science and Statistical Committee, we use the following three diagnostics for model fit:

1. The Quantile-Quantile plot, generated by comparing each observed datum with its predicted distribution under the fitted model, calculating the quantile of that datum, and comparing the distribution of quantiles with its expectation under a null model (i.e., a uniform distribution). This Q-Q plot shows no evidence that the model fails to capture the shape of dispersion shown in the positive catch rate data (Figure 4).
2. A comparison of predicted and observed proportion encountered when binning observations by their predicted encounter probability. This comparison shows no evidence that encounter probabilities are over-estimated for low-encounter-probability observations, or vice versa (Figure 5).
3. A visualization of Pearson residuals for encounter probability and positive catch rates associated with each knot. This comparison shows no evidence of residual spatial patterns for either model component (Figures 6 and 7).

VAST indices were calculated from separate model runs for the both north and south model areas, covering the extent of lingcod observations in the survey, the lognormal model was selected (Figure 8). CPUE was a function of year, latititude, longitude, and vessel-year. Note that a single area model run initially used to produce the indices was nearly identical to the separate area VAST model run. Trends for the north and south areas are similar. Additional tables with VAST model output and a comparison with the design based indices are available in Appendix I.

Length bins in 2 cm increments from 10 to 130 cm in the north and 4 to 130 cm in the south were used to summarize the length frequency of the survey catches in each year. The first bin includes all observations less than 10 cm and 4 cm for the north and south, respectively, and the last bin includes all fish larger than 130 cm. The observed length compositions were expanded to account for differences in catches among tows and spatial strata. Regional length frequency distributions were calculated in two steps: 1) expanding each length sample from a tow to represent the entire tow by dividing the total lingcod catch weight by the total weight of lingcod measured for length and multiplying the observed length frequencies by the expansion factor, the resulting length frequencies are then summed within a spatial stratum, and 2) length frequencies in each spatial stratum (from step 1) were expanded again to account for differences in catch among spatial strata by dividing the total weight of lingcod caught within a stratum by the total weight of lingcod caught within this stratum measured for length and multiplying the length frequency distributions from the first step with the second expansion factor, then summing these to produce annual length frequency distributions for each assessment. Figures 9 and 10 show the length frequency distributions for the WCGBTS north and south areas. Tables 2 and 3 show sample sizes.

Age-frequency data from the WCGBTS (Figures 11 and 12) were included in the model as conditional age-at-length distributions by sex and year. Individual length- and age-observations can be thought of as entries in an age-length key (matrix), with age across the columns and length down the rows. The approach consists of tabulating the sums within rows as the standard length-frequency distribution and, instead of also tabulating the sums to the age margin, the distribution of ages in each row of the age-length key is treated as a separate observation, conditioned on the row (length) from which it came. This approach has several benefits for analysis above the standard use of marginal age compositions. First, age structures are generally collected as a subset of the fish that have been measured. If the ages are to be used to create an external age-length key to transform the lengths to ages, then the uncertainty due to sampling and missing data in the key are not included in the resulting age-compositions used in the stock assessment. If the marginal age compositions are used with the length compositions in the assessment, the information content on sex-ratio and year class strength is largely double-counted as the same fish are contributing to likelihood components that are assumed to be independent. Using conditional age distributions for each length bin allows only the additional information provided by the limited age data (relative to the generally far more numerous length observations) to be captured, without creating a 'double-counting' of the data in the total likelihood. The second major benefit of using conditional age-composition observations is that in addition to being able to estimate the basic growth parameters (L_{minAge}, L_{maxAge}, K) inside the assessment model, the distribution of lengths at a given age, governed by two parameters for the standard deviation of length at a young age and the standard deviation at an older age, is also quite reliably estimated. This information could only be derived from marginal age-composition observations where very strong and well-separated cohorts existed and where they were quite accurately aged and measured; rare conditions at best. By fully estimating the growth specifications within the stock assessment model, this major source of uncertainty is included in the assessment results, and bias in the observation of length-at-age is avoided. Therefore, to retain objective weighting of the length and age data, and to fully include the uncertainty in growth parameters (and avoid potential bias due to external estimation where size-based selectivity is operating) conditional age-at-length compositions were developed using the WCGBTS age data.

Age distributions included bins from age 0 to age 20+, with the last bin including all fish of greater age. Note that these survey age data are used as CAAL and, therefore, are not expanded. You just used the numbers of fish without any adjustment. These data show the growth trajectory of females reaching a maximum size between 120-130 cm and males reaching a maximum size of about 80-90 cm. Tables 4 and 5 show sample sizes.

Fishery Independent Data: Triennial trawl survey

The Triennial Shelf Trawl Survey that was conducted every third year from 1977-2004 is the second source of fishery-independent data regarding the lingcod abundance (Dark and Wilkins 1994). However, the 1977 data were not used due to concerns about the first year of the survey's implementation. The sampling methods used in the survey over the 21-year period are most recently described in Weinberg et al. (2002). The basic design was a series of equally spaced transects from which searches for tows in a specific depth range were initiated. In general, all of the surveys were conducted in the mid-summer through early fall, although survey timing between years was variable. While the AFSC conducted all of the previous triennial surveys, the 2004 survey was conducted by the NWFSC Fishery Resource Analysis and Monitoring (FRAM) division following the AFSC survey protocols. Haul depths ranged from 91–457 m during the 1977 survey with no hauls shallower than 91 m. In all subsequent years the survey sampled depths from 55–366 m. Water hauls (Zimmermann et al., 2003), tows that were not on the bottom, and tows located in Canadian and Mexican waters were also excluded from the analyses for this assessment. Due to changes in survey timing, the triennial data have been split into early (1980-1992) and late (1995-2004) survey time series and treated independently, due to the changes in survey timing and the expected change in stock catchability because of the stock's seasonal onshore-offshore spawning movements.

Spatial variation is approximated using 250 knots, the bias-correction algorithm (Thorson and Kristensen 2016) in Template Model Builder (Kristensen et al. 2016) is used. Further details regarding model structure are available in the user manual (https://github.com/James-Thorson/VAST/blob/master/examples/VAST_user_manual.pdf). To confirm convergence of the model estimation algorithm, we confirm that the Hessian matrix was positive definite and that the absolute-value of the final gradient of the log-likelihood with respect to each fixed effect was <0.0001 for each fixed effect. We select among two alternative model configurations, i.e., treating positive catch rates as following a lognormal or gamma distribution. Following advice from the Science and Statistical Committee, we use the following three diagnostics for model fit:

1. The Quantile-Quantile plot, generated by comparing each observed datum with its predicted distribution under the fitted model, calculating the quantile of that datum, and comparing the distribution of quantiles with its expectation under a null model (i.e., a uniform distribution). This Q-Q plot shows no evidence that the model fails to capture the shape of dispersion shown in the positive catch rate data (Figures 13 and 14).
2. A comparison of predicted and observed proportion encountered when binning observations by their predicted encounter probability. This comparison shows no evidence that encounter probabilities are over-estimated for low-encounter-probability observations, or vice versa (Figures 15 and 16).
3. A visualization of Pearson residuals for encounter probability and positive catch rates associated with each knot. This comparison shows no evidence of residual spatial patterns for either model component (Figures 17-20).

VAST indices were calculated for the north and south areas using two separate model runs, using lognormal models (Figures 21 and 22). CPUE was a function of year, latititude, longitude, and vessel-year. The early Triennial survey shows a decline in relative abundance, while the late Triennial shows an increase in relative abundance. Note that a single area model run initially used to produce the indices was nearly identical to the separate area VAST model run. Additional tables with VAST model output are available in Appendix I.

Length bins in 2 cm increments from 10 to 130 cm in the north and 4 to 130 cm in the south were used to summarize the length frequency of the survey catches in each year. The first bin includes all observations less than 10 cm and the last bin includes all fish larger than 130 cm. Length data preparation follow the same methods as the NWFSC survey data. Figures 23-26 show the length frequency distributions for the Triennial survey. Tables 2 and 3 show sample sizes.

Age distributions included bins from age 0 to age 20+, with the last bin including all fish of greater age. Age data preparation follow the same methods as the NWFSC survey length data. The Triennial Shelf Trawl Survey age-frequency data were included in the model as marginal age compositions and are shown in Figures 27-28. Tables 4 and 5 show sample sizes.

Fishery Independent Data: NWFSC Hook and Line Survey

The lingcod index of abundance from the Hook and Line survey is based on numbers of fish caught in the Southern California Bight. This index uses survey data from 2004-2016 and was created following the methods described in Harms et al. (2010). The final index is averaged over all crew staff and sites. (Note that vessels are confounded with crew staff.) Two vessels were employed for the survey in 2004-12 and three vessels in 2013-16. Data from inside the Cowcod Conservation closed area was not used in this index as this area has not been consistently surveyed through time. A Bayesian delta GLM was used to estimate the number of lingcod are a function of year, site, staff, drop number, hook number, and sea state where sea state covariates (swell height, wave height, and the percentage of daylight passed at the time of each drop) are modeled as polynomial functions. The binomial model with a logit link was used to model the presence/absence of lingcod. The posterior median index values and their associated posterior log-SD are from a converged, 2.5 million draw MCMC. Figure 29 shows the index. Length compositions from this survey were used as numbers of fish and were not expanded.

Fishery Independent Data: WDFW Research Compositions

WDFW conducted mark-recapture experiments in the nearshore area at the Cape Flattery from 1986 - 1994. Though study results were published in several journal articles (Jagielo 1991, 1994, and 1999), original data were misplaced. Additional surveys were conducted in the following years using bottom fish troll gear. Biological data collected from these surveys are presented in Figures 30 and 31. These data were ultimately removed from the base model as they did not provide any additional information to the model.

Fishery Independent Data: Lam Research

In collaboration with the NWFSC and Moss Landing Marine Labs, lingcod in nearshore and offshore rocky reef habitats were collected between January 2016 and January 2017 via hook and line on chartered CPFVs. Sixteen latitudinally distinct sampling sites, or ports, were chosen from northern Washington to southern California. 85 to 120 individuals were caught per port (N=1784, 922 Males, 862 Females) using methods identical to those used by the onboard recreational lingcod fishery except that shorts were retained (individuals smaller than the legal-size limit of 22 inches) and areas closed to recreational harvest were occasionally utilized (CDFW Permit #SC-6477, ODFW Permit #20237, WDFW Permit ID Samhouri 16-138). This was to ensure an even distribution of size and age classes from each port for purposes of comparing lingcod von Bertalanffy growth curves by spatially explicit regions. A random stratified subsample by size and sex was selected per region for ageing and genetics analysis. These composition data are used as CAAL, and therefore are not expanded. The Lam research composition data are shown in Figures 32-35.

Fishery Independent Data: Other

The International Pacific Halibut Commission (IPHC) longline survey data were examined for its utility in building a fixed gear index of abundance. However, depth and hook size are not appropriate for lingcod so these data are not used.

A WDFW hook and line survey includes 5-7 years of sampling but methods changed over time as this was a pilot study so these data are not used.

Biological Data: Weight-Length

The weight-length relationship is based on the standard power function: $W = aL^b$ where *W* is weight in kilograms and *L* is length in centimeters. Hart (1967) reported the relationship between length and weight as $W = 0.000282406 \cdot L^{3.011}$. The length-weight relationship was estimated by Jagielo (1994) using available survey data and was fit to mean weight-at-length measured in the West Coast survey. Jagielo (1994) estimated the following relationship for males, $W = 0.000003953\ L^{3.2149}$, and females, $W = 0.00000176\ L^{3.3978}$, where W is weight (kg) and L is fork length (cm).

Between 2003 and 2015, lengths and weights were measured for 10789 lingcod. Spatial differences were investigated by fitting an overall exponential relationship between length and weight, and then comparing the residuals across latitude and depth using Tukey HSD pairwise multiple comparison tests. Although the parameter estimates for females and males appeared different, functionally the relationships were nearly identical. Residuals of the fit between length and weight showed significant differences among States, but not north and south of Point Conception, California. The relationship between length and weight did not change with depth.

The parameters were re-estimated using data from the NWFSC survey. New length and weight data from the NWFSC survey for this year's assessment estimate the following length-weight relationships for females, $W=0.00000276L^{3.28}$, and males, $W=0.00000161L^{3.42}$ in the north, and for females, $W=0.000003308L^{3.248}$, and males, $W=0.000002179L^{3.36}$ in the south (Figures 36-37).

Biological Data: Maturity and Fecundity

Richards et al. (1990) examined coast-wide trends in lingcod maturity and observed that male lingcod mature at a smaller size and younger age than female lingcod. They also noted that size at maturity increases with latitude (distance from the equator). Size at 50% maturity was estimated to be 63.6 cm for females and 57.1 cm for males (ages 3.9 and 3.5) off of Vancouver Island, whereas Miller and Geibel (1973) found size at 50% maturity to be 58.8 cm and 39.8 cm (and ages 5 and 2) for females and males off of California. Jagielo (1994) found ages of 50% maturity of 3.4 years for males and 4.6 years for females off Washington. The 2009 stock assessment used values estimated in the previous assessment, with 50% maturity occurring at 68 cm in the north and 60 cm in the south.

This assessment uses an updated functional maturity ogive for lingcod, collected in 2013 – 2016 from the WCGBTS, 2014 – 2016 Oregon Department of Fish and Wildlife (ODFW), 2016 Washington Department of Fish and Wildlife (WDFW), and the 2014, 2016 Southern California Bight Hook and Line Survey of untrawlable habitat (Figures 38 and 39). The estimated size at 50% maturity (cm) with 95% confidence intervals for lingcod is 56.693 (1.546) in the north (n=302) and 52.269 (1.940) in the south (n=222).

Fecundity was assumed to be proportional to weight. Hart (1967) found fecundity to be essentially proportional to length cubed.

Biological Data: Natural Mortality

Jagielo 1994 estimated *M* for male and female lingcod using three empirical models based on life history parameters (Hoenig 1983, Alverson and Carney 1975, and Pauly 1980). Estimates of *M* for male lingcod ranged from 0.23 to 0.39, while estimates for female lingcod range from 0.16 to 0.19. The averages of the estimates were 0.18 for females and 0.32 for males.

Starr et al. 2005 estimated natural mortality rates from a short term tag-recapture study and came up with ranges of 0.24-0.34 for females and 0.13-0.23 for males. However, these estimates do not take into account variation in *M* across the year (or between years), especially for males during nest-guarding.

Hamel (2015) developed a method for combining methods for calculating *M* via meta-analytic approaches to relating the natural mortality rate *M* to other life-history parameters such as longevity, size, growth rate and reproductive effort, to provide a prior on M. In that same issue of ICESJMS, Then et al. (2015), provided an updated data set of *M* values and covariates estimates of *M* and related life history parameters across a large number of fish species, from which to develop an *M* estimator for fish species in general. They concluded by recommending *M* estimates be based on maximum age alone, based on an updated Hoenig non-linear least squares (nls) estimator M=4.899A_max^(-.916). The approach of basing *M* priors on maximum age alone was one that was already being used for west coast rockfish assessments. However, in fitting the alternative model forms relating *M* to Amax, Then et al. did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of *M* to Amax. Therefore, it would be reasonable to fit all models under a log transformation. This was not done. Revaluating the data used in Then et al. (2015) by fitting the one-parameter Amax model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel 2015)), the point estimate for M is: M=5.4/Amax. Note that the data used by Then et al. (2015) include a wide range of genera.

The above is also the median of the prior. The prior is defined as a lognormal with mean ln(5.4/Amax) and SE = 0.4384343. Using a Maximum age of 21for females the point estimate and median of the prior for lingcod is 0.257.

Biological Data: Length at age

Lingcod display sexually dimorphic growth. Females grow faster than and reach larger sizes than males. Jagielo (1994) estimated growth using a fixed length at age 1 of 30 cm, and estimated L_∞ for males of 93.21 cm and females of 131.05 cm, and k of 0.1694 for males and 0.1137 for females. He also found that the average length for young-of-the-year (age 0) lingcod was 11.99 cm and for age 2 (48.1 cm) for Washington samples, and that growth trajectories diverge considerably by sex after age 3, as female lingcod tend to grow faster and live longer than male lingcod, while male lingcod mature at age 3.

Estimates of growth parameters were investigated and starting values for model inputs were updated using the WCBTS data. Spatial differences were investigated by fitting an overall von Bertalanffy relationship between age and length, and then comparing the residuals across latitude and depth using Tukey HSD pairwise multiple comparison tests. Although the parameters for females and males appeared different, functionally the relationships look similar. Residuals of the fit between age and length showed significant differences among States. Sampled fish were larger at higher latitudes (linear regression of latitude on length, coefficient = 2.087, $t = 54.75$, $df = 10787$, $p < 0.0001$). Unlike with the length-weight relationship, age and length fits did vary with depth. However, patterns were not statistically distinguishable between shallow (<85 m) and mid-shallow (85-110 m), or between mid-deep (140-183 m) and deep (>183 m).

Externally estimated lingcod von Bertalanffy growth parameters are: k=0.0173 and Linf=108.6 (females), and k=0.268 and Linf=79.3 (males) for the north, and k=0.191 and Linf=100.9 (female) and k=0.214 and Linf=86.3 (male) for the south. Internally estimate growth curves are shown in figures 40-41.

Biological Data: Ageing precision and bias

A new aging error analysis was derived using the double reads from the NWFSC Cooperative Aging Project (CAP) and Washington State labs using a program designed for that purpose (Punt et al. 2008). Within lab reads for WDFW and CAP had 336 and 811 samples, respectively. Between lab reads had 404 samples. The results used are shown in Figure 47. The software is publicly available at https://github.com/nwfsc-assess/nwfscAgeingEror. The variability in age readings was estimated under an assumption of a linear increase in standard deviation with age. The resulting estimate indicated a standard deviation in age readings increasing from 0.13 years at age 1 by about 1 year of uncertainty per 10 years of age to a standard deviation of 3.16 years at age 25 (Figure 42). Note that all ages are from fin rays.

McFarlane and King (2001) validated that the observed annuli are generally annual marks, via a mark-recapture study which used oxytetracycline (OTC) injections to leave a distinct mark on the otoliths that could be observed upon recapture of the fish and extraction of the otoliths, their results did find some error in ageing (>5% miss-aged) even for a single year at large, and under research settings, which generally have higher precision than under production ageing conditions. More work needs to be done to identify potential biases in production ageing of lingcod. One of the sources of error in ageing lingcod is that the first and second annuli can be re-absorbed as the fish ages. Beamish and Chilton (1977) developed a method that used mean annual diameter measurement to locate the position of the first and second annuli and thus minimize, but not eliminate, error due to this re-absorption. Recent unpublished work suggests that ages produced from fin rays and otoliths are similar.

Fishery Dependent Data: Commercial Landings

Historical commercial catch reconstructions were provided by each state that extend through 1995, 1986, and 1980 for Washington, Oregon, and California, respectively. Recent landings, from 1981 forward, were obtained from PacFIN. However, WDFW and ODFW staff advised that the catch reconstructions be used rather than PacFIN for overlapping years as the reconstructions are regarded as more reliable. While there is evidence for commercial landings in California prior to 1931, the historical catch reconstruction does not address this period. Therefore, in the south, a linear ramp was applied from the start of the model period to the first year of available reconstructed landings data. Current CA commercial landings do not include estimates of landing from OR and WA waters. Esimates of landings in CA from WA and OR waters provided late in the assessment process (pers. Comm. J. Field) were investigates as a model sensitivity run and did not impact the assessment. Commercial landings were aggregated into two fleets: 1) vessels using primarily trawl gear, but also including other net gear that caught a small fraction of the fish, and 2) vessels using fixed gear such as longline, troll, and hook and line. Table 1, and Figure 43 shows the commercial landings used in this assessment. Figure 43 also shows comparisons with commercial landings used in the 2009 assessment. Landings have declined significantly during the past two decades, with trawl landings dominating the catch in the north, and recreational landings dominating the catch in the south. More recently landings in both regions have been increasing, with the recreational component of the landings growing in the north, and the recreational landings continuing to dominate in the south.

WDFW's commercial catch reconstruction focused on pre-1980 landings, especially for time periods without fish ticket data (1889 - 1943). The two main challenges for historical Washington landing data are separating catches from Alaskan, Canadian, and Puget Sound waters; and determining catches by gear types. The main sources of information include the US Commission of Fish and Fisheries reports, WA Department of Fishery Statistical Bulletins, and the WDFW fish receiving ticket data.

Fishery Dependent Data: Commercial Discards

The WCGOP provided estimates of the discard ratios of darkblotched rockfish for the period between 2003 to present. The WCGOP data are collected by gear type, fishery (e.g., open access, limited entry) and species/management units. The discard ratios were computed as the total estimated discarded weight (in pounds) on observed trips divided by the estimated total catch (discarded and retained). To aggregate these ratios into the fleet modeled in this assessment, each state, fishery and gear combination was weighted by the total estimated catch (discarded and retained weight). Thus, the discard rates used for each fleet represent the weighted estimates from each contributing segment within that fleet. Uncertainty in these values was quantified via bootstrapping the individual observations and then aggregating to the total estimate, providing a distribution of the discard rate. From this distribution a standard error associated with year specific discard ratio estimate was provided.

Annual commercial fishery discard estimates (Figures 44-47) and length compositions for both the trawl and fixed gear fleets in the north and south (Figures 48-51) are provided by the West Coast Groundfish Observer Program (WCGOP) from 2003 forward. Differences in discard rates between the north (lower) and south (higher) as well as the trawl and fixed gear fleets are apparent. Prior to the beginning of the catch shares program discard rates were generally high. However, post catch shares discard rates in the north trawl fishery show a strong decrease while the south trawl fishery exhibits higher discard rates.

Analysis of discard mortality rates have been conducted as part of the PFMC process (via the Groundfish Management Team during April 2008) and reviewed/accepted by the Science and Statistical Committee (during March 2012). Discard mortality rates of 7% for fixed gears and 50% for trawl gears are applied in this assessment.

Fishery Dependent Data: Recreational Landings

Recreational landings for WA and OR were provided by the states. California recreational landings were obtained from John Field for the years 1928-1980, with 1981 – 2004 being taken from the 2009 assessment, and 2005 forward being provided by RecFIN (pers. comm R. Ames). Recreational catches include retained plus estimated discarded dead catch (catch types A and B1) and were aggregated across boat mode (“PC” = party/charter, “PR”=private/rental), year and area. Table 1 and Figures 52-53 show both commercial and recreational landings for this assessment.

Fishery Dependent Data: PacFIN Commercial Logbooks

Two commercial fishery catch-per-unit-effort (CPUE) indices derived from PacFIN logbook data were used in this assessment, north and south trawl indices. Significant changes in management beginning in 1998 result in a truncated index, ending during 1997 for both the north and south time series.

Logbook information went through several data quality filters, including filtering to attain the best possible consistent and representative data set through time to estimate a relative abundance trend. Erroneous tow locations outside of the EEZ, on land, or with extreme depths (e.g. in the abyssal plain) were removed from the data set. However, tows with reasonable depths but with map coordinates that correspond to deep areas, such as trenches or unreasonably shallow areas have been identified and removed, as these appear to be miss-reported. Likewise, tows with large differences between logbook reported and map depths have also been identified and removed. Only tows within the EEZ but not within Puget Sound were retained in the data set. This takes care of most of the tows reported to be on land, however there were erroneous tows west of the customary commercial groundfish fishing grounds but still inside the EEZ so another filtering step was needed. The following steps were used to define good tows in the rest of the logbook data based on location and reported depth: 1) polygons representing the customary groundfish fishing grounds (using data from 1981-2015) were identified using a convex hull function (‘ahull’ in the R alphahull package), and 2) points not in the hull were removed.

Many records in the PacFIN logbooks lack depth data. Estimated depths using GIS data were calculated for each tow using lat/long, with the ‘depthMeters’ function (R Imap package). Over all years, this increased the percentage of entries with a depth estimates from 85.7% to 99.7%. Note that for those tows recorded only by Fishing Block the centroid of the block is used for the beginning tow lat/long. In cases where depth was recorded in the logbooks, the GIS depth was used to double check reliable reporting of depth. To be retained in the data set 1) the depth reported in PacFIN must be within 500 meters of the GIS depth and 2) the reported depth, or the GIS depth if the reported depth is missing, must be smaller than 1,500 meters. These rules balance depth differences being generously large, since the GIS depth is based on the start of tow coordinates whereas the reported depth is a skipper estimated average depth over the tow, and depth difference being small enough to ferret out erroneous coordinates and depth.

For tows reported by fishing block before 1997, the above rules were not applied since the actual location and depth of a tow can be far different than the centroid of a block. For example, the centroid of a block may be outside of the polygons of the customary catch area, but the tow could be within a polygon. The reported depth, or GIS depth if no depth is recorded, must still be less than 1,500 meters (and greater than zero). Note that before 1997 there appears to be almost no erroneous reporting of blocks. However, from 1997 forward the recording of inaccurate data increased with the request for specific tow locations.

Finally, if a tow was identified as ‘midwater’ and the GIS bottom depth or the reported bottom depth was smaller than 1,646 meters (900 fathoms) then the tow was identified as good. Nine hundred fathoms is the default depth for midwater tows in the GIS estimated depth since it appears the reported depth may sometimes be the depth of the net (PacFIN has a placeholder to enter type of depth (net, bottom, etc.) but it is not used). This depth limit is based on recent year bottom depth limits for midwater tows. The midwater tow filter was used because there are clusters of tows identified in PacFIN as 'midwater' but whose species composition clearly show bottom dwelling species.

The resulting filtered dataset reduces the size of logbook dataset over all years by 6.04%. Finally, the data set for analysis for this assessment was limited to vessels that catch the top 90% of the lingcod catch over the duration of the logbook data, essentially removing vessels that rarely caught lingcod. Issues with management constraints on landing due to trip limits have not been explicitly addressed. However, the index has been truncated in 1997 to avoid the series of management measures that had strong impacts on the groundfish fishery beginning in 1998.

The PacFIN logbook data were analyzed using a single run of the spatio-temporal delta-model (Thorson et al. 2015), implemented as an R package titled *VAST* (Thorson and Barnett 2017) and publicly available online (https://github.com/James-Thorson/VAST). *VAST* specifically includes spatial and spatio-temporal variation in both encounter probability and positive catch rates, a logit-link for encounter probability, and a gamma-link for positive catch rates. Spatial variation is approximated using 100 knots, the bias-correction algorithm (Thorson and Kristensen 2016) in Template Model Builder (Kristensen et al. 2016) is used. Further details regarding model structure are available in the user manual (https://github.com/James-Thorson/VAST/blob/master/examples/VAST_user_manual.pdf). To confirm convergence of the model estimation algorithm, we confirm that the Hessian matrix is positive definite and that the absolute-value of the final gradient of the log-likelihood with respect to each fixed effect was <0.0001 for each fixed effect. We select among two alternative model configurations, i.e., treating positive catch rates as following a lognormal or gamma distribution. Following advice from the Science and Statistical Committee, we use the following three diagnostics for model fit:

1. The Quantile-Quantile plot, generated by comparing each observed datum with its predicted distribution under the fitted model, calculating the quantile of that datum, and comparing the distribution of quantiles with its expectation under a null model (i.e., a uniform distribution). This Q-Q plot shows that the model generally captures the shape of dispersion shown in the positive catch rate data (Figures 54).
2. A comparison of predicted and observed proportion encountered when binning observations by their predicted encounter probability. This comparison shows that encounter probabilities are acceptable (Figures 55).
3. A visualization of Pearson residuals for encounter probability and positive catch rates associated with each knot. This comparison shows generally small residuals with some spatial patterning, particularly for the southern California. (Figures 56-57).

Tow-by-tow catch rates (CPUE), calculated as pounds per hour, were fitted using VAST using year, vessel, month, depth, and PFMC area, and vessel-year as covariates Both gamma and lognormal models were explored, the gamma model better fit the data. Model diagnostics show adequate fit and general consistency with GLM model assumptions for the positive catch component. Similarly to past analyses (Jagielo 2000), the northern trawl logbook index trend shows a sharply declining stock since 1976, and the southern trawl logbook index indicates a declining stock since 1979 (Figure 58). Both stocks remain at low levels through the end of the time series in 1997. Additional tables with VAST model output are available in Appendix I.

Fishery Dependent Data: OR Fixed Gear Nearshore Commercial Logbook Index

The ODFW has required nearshore commercial fishers (both nearshore permitted vessels and open access vessels) to submit fishing logbooks since 2004. Responses from submitted logbooks have been entered into a central database. Fisher compliance is generally high, averaging around 80%, but has varied through time ranging from 65% in 2007 to 95% in recent years. Although required to provide all requested information in the logbook per fishing gear set, there has been substantial variation in the quantity and quality of information reported in logbooks.

Logbook information went through several data quality filters recommended by ODFW staff to attain the best possible consistent and representative data set through time to estimate a relative abundance trend. Individual observations of catch (kg) and effort (hook hour) were at the trip level, where multi-set trips were aggregated to the trip level. Gear type was restricted to hook-and-line (excluding longline gear) because this method accounted for a majority sets.

Covariates considered in the full model included month, vessel, port, depth, and people. All covariates were specified as categorical variables, except depth was a continuous variable. Depth was included to account for general differences in bathymetry and fishing depth restrictions. People were included in an attempt to control for the potential oversaturation of hooks at a given fishing location and the interaction that multi-crew trips (# fishers onboard) may have on fishing efficiency. The selection of covariates included in final models were evaluated using standard information criterion for relative goodness of fit (AIC), where a covariate remained in the model if model fit was improved relative to an otherwise identical model without the covariate.

CPUE was modeled using a delta-GLM approach, where the catch occurrence (binomial) component was modeled using a logit link function and the positive catch component was modeled according to a lognormal distribution with a log link function. CPUE was calculated for each trip, where total catch was defined as the sum total of all reported retained catch (in weight) and released catch (numbers converted to weight by applying a median catch weight) and total effort was defined by hook-hours (number of hooks used multiplied by the number of hours fished). A gamma distribution for the positive catch component was also evaluated, but graphical summary diagnostics of model adequacy favored the lognormal distribution.

Model selection procedures identified the full model with covariates month, vessel, port, depth and people as the best fit to the data, along with the categorical year factor of interest for the index. A bootstrap resampling routine was conducted to estimate the standard error (and CV) of the year effects. Standard model diagnostics show adequate fit and general consistency with GLM model assumptions for the positive catch component (Figure 59). Figure 60 shows the index.

Fishery Dependent Data: Commercial Biological Sampling

Sex specific commercial fishery landed length and age compositions (Figures 61-64) were obtained from PacFIN. Annual commercial length- and age-frequency distributions were developed for each state for which observations were available, following the same bin structure as was used for research observations. For each fleet, the raw observations were expanded to the sample level, to allow for any fish that were not measured, then to the trip level to account for the relative size of the landing from which the sample was obtained. Length and age data collected from commercial landings for each region are summarized by the number of port samples, where a port sample consists of fish sampled from a single fishing trip. The number of port samples is the input N for each year and area. Tables 2 to 4 show biological data sample sizes. Note that the early data contain a large proportion of unsexed fish, therefore all samples collection prior to 1993 are included in this assessment as sex combined compositions.

Fishery Dependent Data: WA Dockside Recreational Index

The WDFW provided recreational dockside fisheries data from 1981 to present. These data went through several data quality filters to identify the best subset of the available data that are likely to be consistent over the time series and provide a representative relative index of abundance once standardized. Analyses were conducted both with and without the Stephens and MacCall (2004) data filter. The Stephens-MacCall method is an objective approach for identifying trip records of catch and effort data when fishing locations are unknown, based on inference regarding the species composition of the catch, and identifying trips to habitats where the target species is likely to occur (Stephens and MacCall 2004). Since recreational fishing trips target a wide variety of species, standardization of the catch rates requires selecting trips that are likely to have fished in the target species habitat. The method of Stephens and MacCall (2004) was used to identify trips with a high probability of catching the target species, based on the species composition of the catch in a given trip. Coefficients from the Stephens-MacCall analysis (a binomial GLM) are positive for species that co-occur with the target species, and negative for species that are not caught with the target species. Covariates considered in the full model included year, month, boat type, area, and a covariate for management that captured management actions likely to impact the fisher (e.g. depth restrictions, bag limits, and size limits). All covariates were specified as categorical variables. The stepwise selection of covariates included in the final model was evaluated using standard information criterion for relative goodness of fit (AIC). Depth was not included in the analysis because it was not uniformly recorded through time; depth data collection began during 2003. The covariates for daily bag limits and allowable landing size of fish represent management changes.

CPUE was modeled using a delta-GLM approach, where the catch occurrence (binomial) component was modeled using a logit link function and the positive catch component was modeled after log-transformation of the response variable, according to a normal distribution with an identity link function. Data are collected at the trip level, with the number of fish landed and the number of anglers on each vessel being recorded. The amount of time fished by each angler is not recorded. Therefore, the units for CPUE are fish landed/angler-trip. A gamma distribution for the positive catch component was also explored, but model selection favored the lognormal model.

Model selection procedures selected the full model with covariates month, boat type, area, and management as important for both the catch occurrence and positive catch component models for all data sets, along with the categorical year factor used for the index of abundance. The management covariate accounts for changes in bag limits and allowable landing size. A bootstrap analysis (N=500) was used to estimate the standard errors (and CVs) of the year effects. Standard model diagnostics show adequate fit and general consistency with GLM model assumptions for the positive catch component (Figure 65). CPUE indices produced both with and without the Stephens-MacCall data filter produced highly similar indices so the index without Stephens-MacCall filtering was used in the stock assessment model (Figure 66).

Fishery Dependent Data: OR Ocean Recreational Boat Sampling (ORBS)

The OR Ocean Recreational Boat Sampling (ORBS) dockside sampling program has a more comprehensive coverage and greater sample sizes (i.e., 50-70 times more trips than the onboard observer program), but somewhat less confidence in the data elements compared to onboard observer programs, as only catch and the number of anglers were verified by biologists (all other trip details were angler reported). The onboard and dockside sampling programs are not fully independent as a single fishing trip can be sampled in both the onboard observer program and the dockside within ORBS. In order to provide estimates of total catch and effort for the Oregon sport fisheries, ORBS obtains catch rates from a portion of vessels via a dockside survey, and applies them to total effort counts. During the dockside survey, biologists intercept vessels returning from fishing trips and record catch, effort, and other trip-related details (e.g., grid area fished, target species, depth, port, etc.). Since catch and effort per sampled trip are both obtained, the dockside survey of ORBS was also used to develop an index of abundance for lingcod.

Modifications were made to trip hours from the original ORBS dataset to create a standardized unit of effort. Since trip hours in ORBS are not hours fished, but rather the total duration of the trip (as measured from the time the boat crossed into the ocean until the time they were interviewed at the dock), travel times had to be determined and subtracted from trip hours in order to get a standardized measure of fishing effort per trip.

Accordingly, a total distance function was created for each trip based on the river miles (distance along the navigable channel from the port to the bar (river mouth)) and ocean miles (i.e., straight distance from the river bar to the ocean grid fished, wrapping around obstructions if needed). Total distance was then converted to travel time based on generalized vessel speeds for private (i.e., 18 mph) and charter boats (i.e., 13 mph) following methods applied by Dick et al. (2015). It is important to note that the original trips hours minus travel hours still does not equal hours fished because it does account for time needed to move from drift to drift; however, since the number of resets between drifts would be expected to be related to fish abundance (as with catch rates), the modified trips hours was deemed a viable effort unit for the assessment. Some trips had erroneous trips hours (discrepancies between values entered on paper and then entered electronically later). These were the steps taken to correct the issue:

1. Trip hours is computed automatically by the data logger based on the time the interview is entered electronically
2. If samplers write their interviews on paper and enter them electronically later when they have time (as believed to have happened despite being instructed not to), then the trip hours are inflated.
3. To potentially remove these errors, we computed time intervals between interviews. Pulses of interviews a minute or two apart are very likely to have been from bunches of paper interviews entered at electronically in one sitting, as normal interviews are somewhat sporadic and take more than a minute to complete.
4. The ORBS dockside charter boat spans the years 2001-2016. As with the other trip-based CPUE data sets, analyses were completed with and without the Stephens-MacCall data filtering method that is used to identify trips with a high probability of catching the target species. Prior to using the Stephens-MacCall approach to select relevant trips, a number of other filters were applied to the data to minimize variability in CPUE estimates. Criteria for valid trips included vessels with trip hours <12. Trips targeting tuna and dive trips were excluded from the analysis.

CPUE was modeled using a delta-GLM approach, where the catch occurrence (binomial) component was modeled using a logit link function and the positive catch component was modeled after log-transformation of the response variable, according to a normal distribution with an identity link function. The units for CPUE are fish landed/angler-hours, with covariates being year, month, boat type, bag limits, minimum length regulations, and maximum length regulations. Both lognormal and gamma distributions for the positive catch component were explored, but model selection favored the lognormal model.

Model selection procedures selected the covariates year, month, and boat type as important for both the catch occurrence and positive catch component models for all data sets, along with the categorical year factor used for the index of abundance. A bootstrap analysis (N=500) was used to estimate the standard errors (and CVs) of the year effects. Standard model diagnostics show adequate fit and general consistency with GLM model assumptions for the positive catch component (Figure 67). CPUE indices produced both with and without the Stephens-MacCall data filter produced highly similar indices so the index without Stephens-MacCall filtering was used in the stock assessment model (Figure 68).

Note that the Oregon recreational fishery has been subject to a seasonal depth restriction since 2004, this was 40 fm until 2012 and changed to 30 fm after 2012.

Fishery Dependent Data: OR and CA Onboard Observer Recreational Indices

All data elements for the onboard observer indices were verified by a biologist, and thus there was a high degree of certainty in the catch, effort, and locations fished; however, there was limited spatial-temporal coverage and only charter boats were included (not private boats). The goal of the Observer Programs in California and Oregon is to collect data including charter boat fishing locations, catch and discard of observed fish by species, and lengths of discarded fish. Both states sample the Commercial Passenger Fishing Vessel (CPFV), i.e., charter boat or for-hire fleet. The onboard observer programs collect drift-specific information at each fishing stop on an observed trip. At each fishing stop recorded information includes start and end times, start and end location (latitude/longitude), start and/or end depth, number of observed anglers (a subset of the total anglers), and the catch (retained and discarded) by species of the observed anglers.

Data for the onboard observer indices for the recreational CPFV fleet are from four sampling programs. The CDFW conducted an onboard observer program in central California from 1987-1998 (Reilly et al. 1998). These data were previously used in the 2013 data moderate assessments (Cope et al. 2015), at the level of a fishing trip. Since the 2013 assessments, the original data sheets were acquired and data were key punched to the level of fishing stop. One caveat of these data is that locations were recorded at a finer scale than the catch data. We aggregated the relevant location information (time and number of observed anglers) to match the available catch information. Between April 1987 and July 1992 the number of observed anglers was not recorded for each fishing stop, but the number of anglers aboard the vessel is available. We imputed the number of observed anglers using the number of anglers aboard the vessel and the number of observed anglers at each fishing stop from the August 1992- December 1998 data (see Dick et al. 2015, Appendix E for details, p.E-1).

California implemented a statewide onboard observer program in 1999 (Monk et al. 2014). California Polytechnic State University (Cal Poly) has conducted an independent onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay (Stephens et al. 2006), but follows the protocols established in Reilly et al. (1998), and was modified to reflect sampling changes that CDFW has also adopted, e.g., observing fish as they are landed instead of at the level of a fisher's bag. Therefore, the Cal Poly data area incorporated in the same index as the CDFW data from 1999-2014. Cal Poly collects lengths of both retained and discarded fish.

We generated separate relative indices of abundance in California for the 1987-1998 and 1999-2016 datasets due to the number of regulation changes occurring throughout the time period, and the difference in sampling regimes between these periods. Regulatory changes implemented by CDFW during 1999 through 2001 resulted in removal of these years from the index. A regulation of three hooks during 2000 was reduced to (and remains at) two hooks during 2001.

The ODFW initiated an onboard observer program in 2001, which became a yearly sampling program in 2003 (Monk et al. 2013). Both California and Oregon provided onboard sampling data through 2016.

Prior to analyses preliminary data filters were applied. Trips/drifts from the CDFW 1988-1998 database meeting the following criteria were excluded from analyses:

1. Drift associated with a fishing location code that was not assigned to a reef.
2. Drifts identified as having possible erroneous location, observed anglers, or time data.
3. Trips encountering <50% groundfish species (number of fish).
4. Drifts/trips missing any of the following: year, month, district, depth, angler hours, number of lingcod kept or discarded, latitude or longitude, trip-level percentage of catch containing groundfish
5. Drifts with a value of zero for depth or angler hours
6. Drifts missing number of lingcod encountered (after determining whether this could be reconstructed from the number kept and discarded)
7. Drifts in depths 500 ft. (depth at which relatively few positive observations of lingcod occurred)

Trips/drifts from the CDFW 1999-2014, and Cal Poly databases meeting the following criteria were excluded from analyses:

1. Drifts identified as having possible erroneous location, observed anglers, or time data

2. Drifts/trips missing any of the following: year, month, district, depth, angler hours, number of lingcod kept or discarded, latitude or longitude, trip-level percentage of catch containing groundfish
3. Drifts with a value of zero for depth or angler hours
4. Drifts missing number of lingcod encountered (after determining whether this could be reconstructed from the number kept and discarded)
5. Drifts with locations outside of a polygon representing depths from 0-305mDrifts within Arcata Bay, Humboldt Bay, South Bay, or San Francisco Bay
6. Drifts occurring > 500m from a reef (distance at which relatively few positive observations of lingcod occurred), for northern or central California (where such habitat data were available)
7. Drifts occurring on a reef with < 3 cumulative positive encounters of lingcod over the period of the time series, for northern or central California (where such habitat data were available)
8. Drifts in southern California occurring outside the area of likely lingcod catch, determined by the convex hull of positive lingcod catch records (alpha = 0.28)
9. Trips encountering ≤ 50% groundfish species
10. Drifts in months with relatively few observations (January and February)
11. Drifts in depths 400 ft. (depth at which relatively few positive observations of lingcod occurred)
12. Drifts with fish times ≤ 2 minutes or 290 minutes

Trips/drifts from the ODFW database meeting the following criteria were excluded from analyses:

1. Drifts associated with a fishing location code that was not assigned to a reef
2. Drifts identified as having possible erroneous location, observed anglers, or time data
3. Trips encountering < 50% groundfish species (number of fish)
4. Halibut-targeted trips
5. Drifts/trips missing any of the following: year, month, county, depth, angler hours, number of lingcod kept or discarded, latitude or longitude
6. Drifts with a value of zero for depth or angler hours
7. Drifts missing number of lingcod encountered (after determining whether this could be reconstructed from the number kept and discarded)
8. Drifts where midwater groundfish made up 95% of the catch
9. Drifts occurring > 400m from a reef (distance at which relatively few positive observations of lingcod occurred)
10. Drifts occurring on a reef with < 3 cumulative positive encounters of lingcod over the period of the time series
11. Drifts with fish times ≤ 2 minutes
12. Drifts in months with relatively few observations (March and October)
13. Drifts in depths 200 ft. (depth at which relatively few positive observations of lingcod occurred)

CPUE was modeled using a delta-GLM approach, where the catch occurrence (binomial) component was modeled using a logit link function and the positive catch component was modeled after log-transformation of the response variable, according to a normal distribution with an identity link function. Data were analyzed at the drift level and catch was taken to be the sum of observed retained and discarded fish, i.e., the number of fish encountered per angler hour. Potential covariates for all indices were year, month, depth, area, and year-area interaction. Both lognormal and gamma distributions for the positive catch component were explored, but model selection favored the lognormal model in all cases. A bootstrap analysis (N=500) was used to estimate the standard errors (and CVs) of the year effects for all models. Standard model diagnostics show adequate fit and general consistency with GLM model assumptions for the positive catch component (Figures 69-71). The final models included all main effects. Although the model with the year-area interaction had the lowest AIC value, the index was unrealistically erratic and the CVs were very large. Figures 72-73 show the onboard recreational observer indices. Note that the base assessment model does not use both the OR onboard index as well as the OR dockside as they show similar trends. The dockside index is used due to the longer time series.

Fishery Dependent Data: Central CA Recreational Index

A central California (Point Conception to Point Mendocino) PSMFC recreational dockside boat survey index (1980-1997) was included in the 2009 south assessment (Hamel et al. 2009). Data after 1997 were not included due to a succession of changes in management regulations that may have affected the CPUE and length distribution of the catch. This index (Figure 74) is not included in the base model in this document and was explored in model sensitivity runs during the assessment process.

Fishery Dependent Data: Recreational Biological Sampling

Recreational fishery landed length and age compositions (Table 2 to 4 and Figures 75-79) were obtained directly from WDFW and ODFW, and from John Field and RecFIN for CA. Annual commercial length- and age-frequency distributions were developed for each state for which observations were available, following the same bin structure as was used for research observations. Many of these composition data lack information on the number of fish sampled out of those landed in a given trip, and therefore are used without expansion to the sample level. Unexpanded recreational composition data are commonly used in West Coast stock assessments for the above reason. Input N values were set at the number of fish sampled for each year and data set.

In Oregon the minimum size limits for lingcod have changed from 22 inches during 1995 to 1997 and 2006 to present, but were 24 inches during 1998 to 2006. It has also been reported that recreational fishers in Oregon sometimes release large, assumed to be female fish, so that they can spawn. However other anglers tend to target and retain these large fish.

4. Model

Data changes since 2009 assessment

Changes in data for this assessment include:

1. Expansion of the time period of the assessments back to 1889.
2. Splitting of the 2009 commercial fleet into trawl and fixed gear components.
3. Splitting the 2009 north recreational fleet into OR and WA.
4. Updated landings and length composition data
5. Use of conditional age-at-length data for only the NWFSC survey and the research study by L. Lam.
6. Re-analysis of the commercial fishery CPUE time series with VAST (last investigated during the late 1990s – early 2000s).
7. Addition of an OR commercial nearshore CPUE index.
8. Addition of a WA recreational dockside CPUE index.
9. Addition of an OR ORBS recreational dockside CPUE index.
10. Exploration of an OR charter boat onboard observer recreational CPUE index (in agreement with dockside sampling).
11. Exploration of early and late CA charter boat onboard observer recreational CPUE index (model sensitivity).

12. Addition of the NWFSC hook and line survey CPUE index and length data.
13. Addition of length and age composition data from L. Lam's research study.
14. Exploration of length and age data from a WDFW research study (removed from base model).
15. An updated prior on natural mortality (Hamel).
16. A new maturity relationship based on recent data collections.
17. Updated length weight relationships based on NWFSC survey data.
18. Re-analysis of double read age data for revised estimates of aging variability.
19. Re-analysis of the AFSC Triennial survey index with VAST.
20. Exploration of conditional age-at-length composition data for the WA and OR recreational fisheries (model sensitivity).
21. Exploration of marginal age composition for the commercial fleets (model sensitivity).

History of Modeling Approaches

There have been six assessments of lingcod since 1986 covering part or all of the West Coast of the United States.

Adams (1986) conducted a yield per recruit analysis. Jagielo (1994) conducted an age-structured assessment of the status of the lingcod stock between Cape Falcon in Northern Oregon to 49 ˚N (off of southwest Vancouver Island in British Columbia - PMFC areas 3A, 3B, and 3C, including Canada), using the Stock Synthesis program (Methot, 1990). Data included trawl and recreational catch from 1979-1993 with equilibrium catch before then, triennial shelf survey and trawl CPUE indices, and length and age composition data. The final spawning output levels were estimated to be about 20% of pristine levels, and catch level recommendations ranged between 2500 and 3000 mt based on F40% to F20%.

The 1997 assessment (Jagielo et al.1997) expanded the area south to Cape Blanco (42°50' N), and retained the northern boundary of 49°00'N and the use of the Stock Synthesis model. Depletion in spawning output in this model was below 10% for 1997.

Adams et al. (1999), conducted a length-based, age-structured population model implemented in AD Model Builder (ADMB, Fournier 1996) for the southern area which had not yet been assessed (Eureka, Monterey, and Conception INPFC areas).

Jagielo et al. (2000) conducted age structured models in ADMB for two areas of the US: US Vancouver-Columbia (no longer including Canadian waters) and Eureka, Monterey, Conception INPFC areas. Jagielo et al. (2003) conducted age structured assessments for the two areas using Coleraine. Finally, Jagielo et al. (2005) conducted age structured assessments for the two areas using Stock Synthesis 2 (SS2). They found that the northern stock had recovered substantially from a low point in the 1990s was at 87% depletion, while the southern area had not recovered as well as was at 24% depletion, with a 64% coast-wide depletion.

The 2009 stock assessment, completed in Stock Synthesis 2, divides the Northern (Washington and Oregon) and Southern (California) stocks by state line (Hamel et al. 2009). The point estimate for the spawning stock depletion at the start of 2009 was 61.9% for the North, 73.7% for the South, indicating the stock is recovered. The axis of uncertainty for the decision table provided to managers was natural mortality for the north, with the base model $M = 0.18$ for females and 0.32 for males. The "Low M" alternative uses $M = 0.16$ and 0.285 for females and males respectively, and the "High M" alternative uses $M = 0.20$ and 0.355. The axis of uncertainty for the South model was for the high alternative including age data, and for the low alternative excluding the dockside recreational CPUE index. The 2009 stock assessment removed all age data due to issues with outliers and possible aging bias. The north and south models were made as equivalent as possible by keeping fixed and estimated parameters are largely the same for the two assessments. Natural mortality (M) was fixed at 0.18 for females and 0.32 for males in both assessments, while stock-recruitment steepness (h) was fixed at 0.8.

GAP and GMT input

Two meetings were held to discuss data and modeling issues relevant to this 2017 lingcod stock assessment. The first was with GAP and GMT members during the March 2017 Pacific Fishery Management Council meeting held in Vancouver, WA. The second was at a pre-assessment workshop held during March 2017 at the PFMC offices in Portland, OR. GAP and GMT members were also active participants at the STAR panel review during June 2017.

Response to 2009 STAR Panel Recommendations

Issues with respect to data that were raised during the 2009 lingcod stock assessment are reviewed below. Actions take between the 2009 and current assessments are provided by each "a." below.

1. The need for age validation
    a. An age validation study has not been completed for lingcod.
2. Problems notes with NWFSC survey length and age sampling during the 2003 survey.
    a. Standard sampling protocols have been instituted for the NWFSC groundfish trawl survey and are reviewed annually.
3. The need for alternative survey methods for untrawlable habitat.
    a. No new surveys have been implemented.
4. Evaluate use of IPHC survey for lingcod
    a. This data set is not suitable for lingcod due to an inappropriate sampling depth range and hook size.
5. Evaluate usefulness of WA tagging data.
    a. This tagging data is from Puget Sound, outside of the scope of the assessment area, and the data reside on paper records that are not readily available for analyses.
6. Investigate reasons for outliers in length-at-age data.
    a. Length and age data have been restructured for this assessment and large outliers are no longer a problem. The models were able to fit the composition data well. However, the STAR panel identified concerns with bias sampling of ages with respect to lengths, leading to the removal of the fishery age data from the base model. The inclusion of the recreational age composition data as conditional-age-at-length is able to address the sampling bias, these data were included in the model as a sensitivity run. The amount of commercial age data prohibits the use of conditional compositions, the marginal age compositions are included as a model sensitivity. The sampling bias problem can be addressed for the next lingcod assessment.
7. Look at environmental covariates for recruitment, time-varying growth, and in-shore availability.
    a. No studies have been completed since the last assessment.

Issues with respect to the stock assessment modeling raised during the 2009 lingcod stock assessment are reviewed below. Actions take between the 2009 and current assessments are provided by each "a." below.

1. The definition of length at age is SS was unclear.
    a. SS documentation is now readily available.
2. Evaluate the assumption of fishery CPUE that is proportional to stock biomass.
    a. During model development the proportionality assumption was investigated for all indices. Assuming indices are not proportional to abundance results is similar or more favorable stock trends. However, this 2017 stock assessment maintains the assumption of proportionality as the indices generally provide similar information on stock trends and one could make argument for all if the indices to be not proportional to abundance.

3. Investigate the inability to estimate growth or poor growth estimation
    a. This assessment is able to reliable estimate male growth and female growth in the south but is not able to reliably estimate female L at maximum age in the north model where large fish that were observed historically are not present in the NWFSC conditional length-at-age data. This value is fixed.
4. Investigate the inability to fit the NWFSC survey data
    a. This assessment fits the NWFSC survey data.
5. Sensitivity to recruitment estimation start year
    a. This assessment is able to estimate recruitment from the model start and no longer shows an unrealistically large recruitment at the beginning of the main recruitment deviation period.
6. Consider the impact of male nest guarding on the definition of reproductive output
    a. Time did not permit for the investigation of this issue. The PFMC SSC may consider alternative definitions of reproductive output.
7. Undertake a Bi-national assessment.
    a. Lingcod are a transboundary stock with both Canada and Mexico. However, a legal mandate and management framework for using the advice of a transboundary stock assessment does not exist. Data sharing is currently happening at a scientific level with Canadian scientists.

Transition from 2009 to 2017 Stock Assessment Models

This assessment uses SS version V3.30.03.07, and implements two separate assessments for the north and south areas, as did the 2009 assessment. Similarly to the 2009 assessment the two areas are defined by state boundaries with the north area including Washington and Oregon, and the south area including California. The 2009 models were transitioned into SS version 3. 03.05, these transitioned models matched the time series of spawning biomass and stock depletion estimated in the 2009 stock assessment. The 2017 model implements model structural changes including:

1. Disaggregating both the commercial fleets into trawl and fixed gears and the north recreational fleet into WA and OR.
2. Plus and minus groups for the length bins that are larger and smaller, as well as a larger plus group for ages.
3. A broader set of time blocks are used to model selectivity for both commercial and recreational fisheries to better reflect management impacts.

Summary of data for fleets and areas

Commercial fishery removals were divided among four fleets and two assessment models:

1. north trawl gears
2. north fixed gears
3. south trawl gears
4. south fixed gears

Recreational fishery removals were divided into three fleets and two assessment models:

1. north WA
2. north OR
3. south CA

All available data are described in Figure 1.

Modeling software

This assessment used the Stock Synthesis V3.30.03.07modeling framework written by Dr. Richard Methot at the NWFSC (Methot and Wetzel, 2013).

Data weighting

Indices of relative abundance all had variance estimates generated as part of the analysis of raw catch data. These variances are converted to standard deviations in log space for use in the model; additional variances for the fishery indices of abundance were estimated inside the model. The number of trawl tows or port samples was used as the initial input sample sizes for length and marginal age compositional data for survey and fishery samples, respectively. The number of fish aged was used as the input sample size for the survey and L. Lam conditional age-at-length compositions, as well as for recreational composition data.

This assessment follows the iterative re-weighting approach to developing consistency between the input composition sample sizes (or standard errors) and the effective sample sizes based on model fit. This approach attempts to reduce the potential for particular data sources to have a disproportionate effect on total model fit, while creating estimates of uncertainty that are commensurate with the uncertainty inherent in the input data. Iterative re-weighting was applied to all compositional data. This consisted of comparing the mean input sample size for compositional data with the mean effective sample size based on model fit. A single iteration was completed using a multiplicative scalar to tune the input sample sizes for all length- or age-compositions for a given fleet or survey. Sensitivity to the two methods for model tuning of composition data were investigated as part of the pre-STAR model, the model was not sensitive to implementing either Francis (2011) or McAllister and Ianelli (1997). Each method provided similar results, therefore the model sensitivity section below focuses on other explorations. The base model in both the pre-STAR and post-STAR models uses the Francis (2011) method.

The value of σ_R was determined using an iterative procedure to ensure that the value of σ_R assumed by the assessment model and the empirical variance in recruitment were self-consistent. This involved setting σ_R to an initial value, fitting the model and calculating the variance of the recruitment deviations for the years for which recruitments are estimated in the model, then replacing the assumed value of σ_R by the calculated value. Very little iterative reweighting was necessary for σ_R.

Priors

Priors were applied only to Male natural mortality based on a meta-analysis completed by Hamel (2015). The prior female natural mortality was fixed at the prior based on a maximum observed age of 21, where M = 0.257.

General model specifications

Stock synthesis has a broad suite of structural options available. Where possible, the 'default' or most commonly used approaches are applied to this stock assessment. The assessment is sex-specific, including the estimation of separate growth curves, natural mortality, and selectivity for males and females. Therefore, the assessment only tracks female spawning biomass for use in calculating stock status.

This assessment consists of two independent models that cover the U.S. west coast with time-series of landings beginning in1889. The sex-ratio at birth is fixed at 1:1, although by allowing increased natural mortality for males, size-based selectivity, and dimorphic growth, the sex ratio will vary. The model starts at equilibrium, assuming an unfished initial age structure.

The internal population dynamics include ages 0-25, where age 25 is the 'plus-group'. As there is little growth occurring at age 25 and very few observations, the data use a plus group of age 20.

The following likelihood components are included in this model: catch, indices, discards, length compositions, age compositions, recruitments, parameter priors, and parameter soft bounds. See the SS technical documentation for details (Methot and Wetzel 2013).

Electronic model files including the data, control, starter, and forecast files are archived with the PFMC.

Estimated and fixed parameters

A full list of all estimated and fixed parameters is provided in Tables 6 and 7. Time-invariant, sex-specific growth is estimated in this assessment, with all SS growth parameters being estimated except for female length at maximum age in the north model. The log of the unexploited recruitment level for the Beverton-Holt stock-recruit function is treated as an estimated parameter. Annual recruitment deviations are estimated beginning in 1985, just prior to reliable length and age composition entering the models. Selectivities are estimated using the double normal pattern (SS pattern 24) for all fleets and surveys. Retention is estimated for the commercial fishing fleets and is fit with time blocks to account for management changes. The survey catchability parameters are calculated analytically (set as scaling factors) such that the estimate is median unbiased, which is comparable to the way q is treated in most groundfish assessments.

2017 Model

Key Assumptions and Structural Choices

All structural choices for stock assessment models are likely to be important under some circumstances. This assessment choices were generally made to 1) be as objective as possible and 2) follow generally accepted methods of approaching similar models and data. The relative effect on assessment results of each of these choices is often unknown; however, an effort is made to explore alternate choices through sensitivity analysis. Major choices in the structuring of this stock assessment model include two separate area models (north and south), splitting the triennial survey into an early and late time period, and estimates of selectivity curves for each fleet and retention curves for the commercial fleets. Length and age bins in this assessment are expanded from those used in the previous two assessments. In the north, length bins range from 10 to 130 in two cm increments, with the first bin containing all fish less than 10 cm and the maximum bin containing all fish ≥ 130 cm. In the south, length bins range from 4 to 130 in two cm increments, with the first bin containing all fish less than 4 cm and the maximum bin containing all fish ≥ 130 cm. Age bins for both models range from 0 to 20 in single year increments, with the upper bin serving as a plus group for all fish older than age 20.

Alternate Models Explored

Comparison of key model assumptions, include comparisons based on nested models (e.g., asymptotic vs. domed selectivity, constant vs. time-varying selectivity). Many variations on the base case models were explored during this analysis; only the most relevant and recent are reported in this document. Some of these are reported as sensitivity and retrospective analyses. Prior to the STAR panel, detailed exploration was made to evaluate:

1. Estimation of natural mortality with a prior.
2. Alternative fixed values for female natural mortality.
3. Alternative fixed values for h.
4. Tuning of composition sample sizes.
5. The period over which recruitment deviations are estimated.
6. Time varying, combined female and male versus sex specific selectivity, and asymptotic versus dome-shaped selectivity for fishing fleets and surveys.
7. The tuning of recruitment variability.

8. Commercial age data and aging error estimates.
9. Fishery dependent CPUE indices.
10. The impact of the 2016 NWFSC survey data and the 2016 research study data from L. Lam on derived model outputs.
11. Time blocking of retention parameters.
12. Estimation of the added standard deviation parameters for all indices of abundance.
13. Removal of individual index, length, and age data sets.
14. Alternative values for h
15. Estimation of growth parameters

Convergence

Convergence testing through use of over dispersed starting values often requires very extreme values to actually explore new areas of the multivariate likelihood surface. For this reason, a good target for convergence testing is to 'jitter' or randomly adjust starting values between reasonable upper and lower bounds by a factor. Jitter is a SS option that allows for the generation of a uniform random number equal to the product of the input value and the range between upper and lower parameter bounds for each parameter. These random numbers are then added to initial parameter values in the input files and the model minimization started at these new conditions. The SS jitter option was used to explore the identification of a global best estimate for the base models. In the north none of these trials found a different global minimum. A total of 100 jittered model runs, using a jitter value of 0.1 resulted in 76% of the model runs returning to the base case and the finding local minima with larger negative log-likelihood values. In the south, out of a total 300 jitter runs using combinations of jitter values of 0.1 and 0.15 as well as alternative start values for Ro, 4% of the model runs found a slightly better solution (0.22 likelihood units better), 2.7% went back to the base model likelihood, and there the rest went to local minima with larger negative log-likelihood values. A comparison of both models revealed that their results are virtually identical. The model run with the slightly better solution is presented in this document.

Base Model Results

All r4ss plot files (see the Auxilary files section of this document) for both the north and south base models are provided in supplementary materials. Parameters, both estimated and fixed are provided in tables 6 and 7. Note that fishery ages were removed from the base case model due to concerns with age sampling not being representative of length sampling, these data are used in model sensitivity runs below.

The base case model for the north model fit the indices, lengths and fishery independent ages well (Figures 80-109). Good fits to the indices were, in part, due to strong agreement among various indices, except for a few years during the 1990s when the recreational indices trended up while the commercial index remained low. Fits to the time aggregated length compositions were good except for a limited amount of miss-fitting to the Triennial survey compositions and the Lam research length compositions. The Triennial survey compositions are noisy due to lower sample sizes and most likely to the line transect nature of the survey design. The Lam research data were collected with age and growth studies in mind, and are therefore, not random samples, resulting in greater difficulty in fitting these data. The fits to the age compositions were also generally good, with the exception of some larger residuals in the Lam data.

North model selectivity curves were well estimated for all fleets, with the commercial and recreational fleets using time blocks to capture changes in management that drove corresponding changes in composition data. Figure 110 shows the end year selectivity for each fleet. Early selectivity patterns for the trawl, fixed gear commercial fleets are estimated to be asymptotic, while selectivity patterns for recent years being estimated as dome shaped. Estimated growth curves for females and males were reasonable (Figure 111), suggesting that on average females grow to a maximum size of about 120 cm and males grow to a maximum size of just over 80cm. Variability in growth was greater for females than for males.

Tables 1 and 8, along with Figures 112-116 shows the time trajectories of the estimates of total dead fish (landings plus estimated dead discards), spawning biomass, fishery exploitation rate, recruitment, and depletion in spawning output from the north model. Figures 117-119 show management quantities: equilibrium yield plots and time series of surplus production from the north model. This assessment estimated that the stock size was well over the management target, and has generally been on an upward trajectory since its low point during the 1990s. Large recruitment events in the north are estimated to have occurred during 1964-1965, 1969-1970, 1978-1980, 1985, 1990-1991, 2008, 2013 and 2015, while low recruitments were estimated to have occurred during 1986, 1996-1998, 2002-2007, 2011-2012, and 2014.

The base case model for the south model was able to fit the indices, lengths and fishery independent ages well with the exception of the CA recreational onboard observer index and recent length compositions (Figures 120-144). The model sensitivity run with the CA recreational observer index estimates a large added standard deviation and the length compositions shows strong residual patterns in recent years (Figure 132). Fits to the time aggregated length compositions were good except for a limited amount of miss-fitting to the Triennial Shelf Trawl Survey compositions, and the NWFSC Hook and Line survey length compositions. The Triennial survey compositions were noisy due to smaller sample sizes and most likely to the line transect nature of the survey design. The Hook and Line survey sample sizes were also lower and lingcod were less common in this survey. The fits to the age compositions were also generally good.

South model selectivity curves were well estimated for all fleets, with the commercial and recreational fleets using time blocks to capture changes in management that drove corresponding changes in composition data. Figure 144 shows the end year estimated selectivity curves. Early selectivity patterns for the trawl fleet and Triennial survey were estimated to be asymptotic. Fishery selectivity patterns for recent years were estimated as dome shaped. Estimated growth curves for females and males were reasonable (Figure 145), suggesting that on average females grow to a maximum size of about 120 cm and males grow to a maximum size of just over 80cm. Variability in growth was similar in both sexes.

Table 1 and 9, along with Figures 146-150, shows the time trajectories of the estimates of total dead fish (landings plus estimated dead discards), spawning biomass, fishery exploitation rate, recruitment, and depletion in spawning output from the south model. Figures 151-153 show management quantities: equilibrium yield plots and time series of surplus production from the south model. This assessment estimated that the stock is in the precautionary zone, and while it has generally been on an upward trajectory since its low point during the 1990s, the rate of increase is slower than in the north. Large recruitment events in the south are estimated to have occurred during 1961, 1973-1974, 1976-1977, and 1984-1985, while low recruitments were estimated to have occurred during 1981-1982, 1992-1993, 1995, 1997- 1998, 2002-2009, and 2014-2016. It is notable that lingcod in the south have not had a recruitment near historical high values since the mid-1980s.

Sensitivity Analyses

Sensitivity analyses were performed to determine the sensitivity of the model results to a range of different assumptions. For the most part, conclusions from the models remained generally consistent across the assumptions that were explored.

Results from the north base case sensitivity runs that showed the most extreme results are shown Figures 155-156. The sensitivity model runs all produced similar trajectories of stock decline and recovery. In the north, the model is most sensitive to the inclusion of the fishery age data sets. Including only the Washington and Oregon conditional age-at-length data from the recreational fishery results in a lower estimate of unfished biomass but a similar estimate of stock status. Including only the marginal commercial age composition data results in a higher estimate of unfished biomass but similar stock status. In pre-STAR model runs, not shown here, fixing *M* at either lower or higher values than the base model resulted in similar estimates of unfished spawning biomass, but stock status changed systematically with the assumed value of *M*: lower values of *M* resulted in lower stock status, although all values resulted in estimates of stock status that were over the management target reference point.

Results from the south base case sensitivity runs that showed the most extreme results are shown in Tables 10 and 11, and Figures 157-158. Many of the sensitivity model runs produced similar trajectories of stock decline and recovery. In the south, the model is sensitive to removing the research data set collected by Lam et al., which results in a much higher unfished biomass estimate but a similar estimate of stock status. The south model is highly sensitive to the inclusion of the CA onboard observer index, which suggests a similar unfished stock size but a stock status that is well below the overfished threshold. In the pre-STAR model runs, not shown here, fixing *M* at either lower or higher values than the base model resulted in similar estimates of unfished spawning biomass for all runs with stock status changing systematically with the assumed value of *M*: lower values of *M* resulted in lower stock status.

Retrospective Analyses

A retrospective analysis was conducted by comparing the base models with data through 2016 to models sequentially removing up to 5 years of data (Figures 159-162). The north model does not show a retrospective pattern. A retrospective pattern in the south model between 2016 and the rest of the years was identified (Figures 173-174), with investigations showing that this pattern is caused by the addition of the 2016 conditional age-at-length composition data from the Lam research study. Changes in the estimation of recruit devations also contributes to this retrospective pattern. The base model estimates that the most recent 3 years have had recruitment well below the long term average from the stock recruitment curve, while the preceeding 4 years were well above average.

Historical Assessment Analyses

Comparisons between the base model estimates for spawning biomass and stock depletion from the 2009 assessments suggest similar patterns of stock increases from a low point during the 1990s to present (Figures 163-164). However, the rate of the stock increase is slower and lower in magnitude than those estimated/projected in the 2009 assessment, particularly for the south. The 2017 south model shows a strong divergence from the 2009 assessment beginning during the early 2000s.

Likelihood profiles

Likelihood profiles for log unfished recruitment and female natural mortality were completed to investigate the uncertainty in these parameters. (Figures 165-168).

With the removal of the age data from the base models, there is no longer adequate information in the data to produce informative *M* or *h* profiles. North model likelihood profiles for log R_o show a strong conflict between the length and age data with respect to the value of unfished recruitment, with the length data suggesting a higher value and the age data suggesting a lower value. In the north the OR recreational index, NWFSC conditional age data, WA recreational lengths and Trawl commercial length data sets most strongly inform stock scale. In aggregate plausible values for log unfished recruitment range from about 8.7 to 9.8. South model likelihood profiles for log R_o show a strong influence of the recruitment estimates, with plausible values from about 8.3 to 8.7. In the south Lam research data, the indices (except the hook and line index), the late triennial length data, and the commercial trawl data most strongly inform stock scale.

Rebuilding Parameters

Both the north and south lingcod stocks are estimated to be above the minimum stock size threshold, therefore a rebuilding plan is not necessary.

Reference Points

The north and south stocks are estimated to have been below the target reference point from approximately the 1980s through the early 2000s. Fishing intensity since approximately 2005 has been below the target for both the north and south stocks. The phase plots show the interaction of fishing intensity and biomass targets. Stock status is currently estimated to be above the target reference point (40% of the estimated unfished spawning biomass) at 57.9% (47.9–67.8, 95% asymptotic interval) in the north and in the precautionary zone at 32.9% (12.0–53.9, 95% asymptotic interval) in the south. Unfished spawning biomass was measured at 37,947 mt (25,776–50,172 mt, 95% asymptotic interval) in the north and 20,462 mt (15,406–25,518 mt, 95% asymptotic interval) in the south. Spawning biomass at the beginning of 2017 was estimated to be 21,976 mt (12,517-31,434 mt, 95% asymptotic interval) in the north and 6,742 mt (1,775–11,709 mt, 95% asymptotic interval) in the south. The north stock is estimated to have been below the target reference point from approximately the 1980s through the early 2000s, while the south stock is currently estimated to be in the precautionary zone. The target stock size based on the biomass target (SB40%) is 15,190 10,311–20,069 mt, 95% asymptotic interval) in the north and 8,185 mt (standard deviation 569.7 mt) in the south, which gives catches of 2291.9 mt (standard deviation 58.1 mt) for the north and 1982.1 mt (6,162–10,207, 95% asymptotic standard deviation) for the south (Tables i and j). Equilibrium yield at the proxy FMSY harvest rate is 3,241 mt (2,215–4,268 mt, 95% asymptotic interval) and 1,658 mt (1,299–2,016 mt, 95% asymptotic interval) for the north and south, respectively.

Harvest Projections and Decision Tables

The lingcod stock assessments are Category 1 stock assessments (subject to SSC approval), thus projections and decision tables are based on using P*=0.45 and sigma = 0.36, resulting in a multiplier on the OFL of 0.956. This is combined with the 40-10 harvest control rule to calculate OFLs, ABCs and ACLs. The total catches in 2017 and 2018 were assumed to equal the PFMC-adopted ACLs, and the average 2015-2017 exploitation rate was used to distribute catches among the fisheries. Harvest projections are provided in Tables 12 and 13. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviations for the 2017 spawning biomass from the base model (a fixed value of Ro was used to attain the 2017 spawning biomass values for the lower and upper states of nature). A fixed value of Ro was used to attain the 2017 spawning biomass values for the lower and upper states of nature, given by the base model mean +/- 1.15*standard deviation. The values for Ro were identified using likelihood profile model runs to produce a plot of Ro versus 2017 spawning biomass. The high catch stream in the decision table is given by the 40-10 control rule. At the request of the GMT representative on the STAR panel the moderate catch streams were set to 40% ACL attainment for the north and 70% ACL attainment in the south. Finally, the low catch stream was set to ~700 mt, a level similar to recent average catches. Decision tables are provided in Tables 14 and 15.

In the north, current medium-term projections of expected catch, spawning biomass and depletion from the base model project a declining trend through 2028 as recent large cohorts increase in age (note that all projections assume average recruitment) and the 40-10 control rule ACLs move the stock towards the target reference point. The stock is expected to remain above the target stock size of $SB_{40\%}$ through 2026, assuming average recruitment based on the stock-recruit curve. In the south, current medium term projection of expected catch, spawning biomass and depletion from the base model project a declining trend through the projection period, with the stock remaining just above the minimum stock size threshold $SB_{25\%}$ through the projection period. The lack of increasing stock sizes during the projections is due, in part, to a large number of poor recruitments since 2000 (11 out of 17 years) and a lack of recruitments near historical highs.

In the north, current medium-term forecasts based on the alternative states of nature project that the stock will fall below the target stock size in only case, in which the current control rule is applied to the low stock state of nature (bottom left corner of the table). All other decision table scenarios keep the stock at or above the target stock size. In the south, current medium-term forecasts based on the alternative states of nature project a range of outcomes from effective extirpation to increases above the target stock size. All of the low state of nature scenarios suggest that the stock is overfished and only in the constant catch scenario does the stock increase into the precautionary zone. The most pessimistic scenario, the application of the 40-10 rule to the low state of nature, suggests that the stock is extirpated from the south by 2024 (bottom left corner of the table). However, all catch scenarios under the high state of nature suggest that the stock will increase to above or near the target reference point. The constant and 75% ACL catches from the base case model allow the stock to increase towards, or exceed the target reference point.

Regional Management Considerations

Regional management considerations are to some extent addressed by the two area assessments. Reallocation of catches from the south model area to the north model area based on the 40-10 management line can be done using the 5 year average percentage of survey biomass in the region from the 40-10 management line to the OR/CA border. This value was obtained using a VAST model run with the above spatial delineation for the management area, and is 8% of the coast wide survey biomass.

Research Needs

Most of the research needs listed below entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

1. Age validation of lingcod aging is needed to verify the level of age bias, if any.
2. A transboundary stock assessment and the management framework to support such assessments would be beneficial.
3. A survey in untrawlable habitat and/or a near shore survey would improve this stock assessment. Other survey techniques could include longline, combined lingcod/sablefish pot survey, or trap surveys.
4. Investigate environmental covariates for recruitment and time-varying growth and availability inshore.
1. The impact of nest-guarding on reproductive output should be investigated. The current assessment focuses on female spawning biomass as the limiting factor in reproductive output, but nest guarding by lingcod males and the availability of nesting habitat may also play roles. A cursory look at the proportion of sex ratio in the catch did not appear to indicate any serious changes for either north or south populations in recent years. However, we do not know what kind of change in sex ratio would indicate a serious change in reproductive success.
2. Investigation of the proportion of fish caught in Mexico and landed in U.S. ports as there is evidence that California recreational fisheries, primarily out of San Diego, are fishing in Mexican waters. These catches should be allocated appropriately between U.S. and Mexican waters.

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List of Auxiliary Files

Lingcod North Model:
\4_North_Base\Ling.dat
\4_North_Base\Ling.ctl
\4_North_Base\forecast.ss
\4_North_Base\starter.ss
\4_North_Base\natage_f.csv
\4_North_Base\natage_m.csv
r4ss plots folder: \4_North_Base\plots\

Lingcod South Model
\5_South_Base\Ling.dat
\5_South_Base\Ling.ctl
\5_South_Base\forecast.ss
\5_South_Base\starter.ss
\5_South_Base\natage_f.csv
\5_South_Base\natage_m.csv
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Table 1. Landings from 1889-2016. Note that the columns North and South "Total Dead" include model estimates of dead discarded fish.

Year	North Trawl Gears	North Fixed Gears	WA Recrea-tional	OR Recrea-tional	North Total Landings	North Total Dead	South Trawl Gears	South Fixed Gears	South Recrea-tional	South Total Landings	South Total Dead
1889	0.0	109.0	0.0	0.0	109.0	110.5	0.0	0.0	0.0	0.0	0.0
1890	0.0	112.7	0.0	0.0	112.7	114.2	13.2	8.7	0.0	22.0	25.1
1891	0.0	115.5	0.0	0.0	115.5	117.1	26.5	17.5	0.0	43.9	50.2
1892	0.0	158.4	0.0	0.0	158.4	160.5	39.7	26.2	0.0	65.9	75.4
1893	0.0	125.4	0.0	0.0	125.4	127.1	52.9	35.0	0.0	87.9	100.5
1894	0.0	125.4	0.0	0.0	125.4	127.1	66.1	43.7	0.0	109.8	125.6
1895	0.0	136.8	0.0	0.0	136.8	138.6	79.4	52.4	0.0	131.8	150.8
1896	0.0	164.5	0.0	0.0	164.5	166.7	92.6	61.2	0.0	153.7	175.9
1897	0.0	165.0	0.0	0.0	165.0	167.2	105.8	69.9	0.0	175.7	201.1
1898	0.0	71.0	0.0	0.0	71.0	71.9	119.0	78.6	0.0	197.7	226.3
1899	0.0	45.2	0.0	0.0	45.2	45.8	132.3	87.4	0.0	219.6	251.5
1900	0.0	57.3	0.0	0.0	57.3	58.1	145.5	96.1	0.0	241.6	276.7
1901	0.0	58.6	0.0	0.0	58.6	59.4	158.7	104.9	0.0	263.6	302.0
1902	0.0	59.9	0.0	0.0	59.9	60.7	171.9	113.6	0.0	285.5	327.2
1903	0.0	61.2	0.0	0.0	61.2	62.0	185.2	122.3	0.0	307.5	352.5
1904	0.0	73.3	0.0	0.0	73.3	74.2	198.4	131.1	0.0	329.5	377.8
1905	0.0	57.8	0.0	0.0	57.8	58.6	211.6	139.8	0.0	351.4	403.2
1906	0.0	59.1	0.0	0.0	59.1	59.9	224.8	148.6	0.0	373.4	428.5
1907	0.0	60.4	0.0	0.0	60.4	61.2	238.1	157.3	0.0	395.4	453.9
1908	0.0	44.9	0.0	0.0	44.9	45.5	251.3	166.0	0.0	417.3	479.3
1909	0.0	193.6	0.0	0.0	193.6	196.2	264.5	174.8	0.0	439.3	504.7
1910	0.0	194.9	0.0	0.0	194.9	197.5	277.7	183.5	0.0	461.2	530.2
1911	0.0	196.2	0.0	0.0	196.2	198.8	291.0	192.2	0.0	483.2	555.7
1912	0.0	197.5	0.0	0.0	197.5	200.1	304.2	201.0	0.0	505.2	581.2
1913	0.0	198.7	0.0	0.0	198.7	201.4	317.4	209.7	0.0	527.1	606.7
1914	0.0	200.0	0.0	0.0	200.0	202.7	330.6	218.5	0.0	549.1	632.3
1915	0.0	348.7	0.0	0.0	348.7	353.4	343.9	227.2	0.0	571.1	657.8
1916	0.0	508.4	0.0	0.0	508.4	515.3	357.1	235.9	0.0	593.0	683.5
1917	0.0	509.7	0.0	0.0	509.7	516.6	370.3	244.7	0.0	615.0	709.1
1918	0.0	669.4	0.0	0.0	669.4	678.6	383.5	253.4	0.0	637.0	734.8
1919	0.0	223.8	0.0	0.0	223.8	226.8	396.8	262.2	0.0	658.9	760.5
1920	0.0	177.5	0.0	0.0	177.5	179.9	410.0	270.9	0.0	680.9	786.2
1921	0.0	165.9	0.0	0.0	165.9	168.2	423.2	279.6	0.0	702.9	812.0
1922	0.0	93.2	0.0	0.0	93.2	94.5	436.5	288.4	0.0	724.8	837.8
1923	0.0	82.4	0.0	0.0	82.4	83.5	449.7	297.1	0.0	746.8	863.6
1924	0.0	195.8	0.0	0.0	195.8	198.5	462.9	305.8	0.0	768.7	889.5

1925	0.0	260.5	0.0	0.0	260.5	264.0	476.1	314.6	0.0	790.7	915.4
1926	0.0	294.8	0.0	0.0	294.8	298.8	489.4	323.3	0.0	812.7	941.4
1927	0.0	362.4	0.0	0.0	362.4	367.3	502.6	332.1	0.0	834.6	967.4
1928	0.0	290.6	0.0	0.0	290.6	294.6	515.8	340.8	0.0	856.6	993.4
1929	8.0	566.3	0.0	0.0	574.3	586.3	529.0	349.5	2.9	881.4	1022.4
1930	31.8	483.3	0.0	0.0	515.1	539.0	542.3	358.3	5.8	906.3	1051.4
1931	7.2	256.4	0.0	0.0	263.6	271.0	555.5	367.0	8.6	931.1	1080.5
1932	10.2	251.5	0.0	0.0	261.7	270.7	399.2	258.6	11.5	669.3	776.9
1933	27.8	368.8	0.0	0.0	396.7	417.0	626.9	474.1	14.4	1115.4	1287.1
1934	91.6	417.5	0.0	0.0	509.1	565.0	388.3	225.1	17.3	630.7	735.1
1935	106.7	426.9	0.0	0.0	533.6	598.1	459.7	286.3	20.2	766.1	890.5
1936	149.8	562.1	0.0	0.0	711.9	802.1	341.2	252.5	23.1	616.8	710.4
1937	212.5	504.6	0.0	0.0	717.1	841.4	438.4	273.8	35.8	747.9	866.4
1938	145.6	1166.1	0.0	0.0	1311.7	1408.4	337.0	350.4	43.3	730.7	826.4
1939	311.1	735.3	0.0	0.0	1046.4	1229.8	260.4	182.6	59.8	502.8	573.7
1940	564.0	853.0	0.0	0.0	1417.0	1745.9	312.4	222.2	62.8	597.4	682.3
1941	525.6	781.9	0.0	0.0	1307.5	1617.4	238.5	196.1	58.0	492.6	558.1
1942	855.8	870.3	0.0	0.0	1726.1	2231.8	141.6	100.1	30.8	272.6	310.7
1943	872.4	624.5	0.0	0.0	1496.9	2017.4	324.8	226.7	29.5	580.9	667.9
1944	1403.6	705.2	0.0	0.0	2108.8	2958.8	336.5	222.5	24.2	583.1	672.5
1945	1031.7	425.9	0.0	0.0	1457.6	2095.0	315.8	228.8	32.3	576.8	661.1
1946	1259.0	638.9	0.0	0.0	1897.9	2692.9	520.6	365.9	55.5	942.0	1080.5
1947	658.1	371.8	0.0	0.0	1029.9	1452.9	869.5	725.1	201.5	1796.1	2032.6
1948	1002.7	486.0	0.0	0.0	1488.7	2139.1	900.7	450.3	219.6	1570.6	1809.1
1949	708.9	612.3	0.0	0.0	1321.2	1788.7	700.4	373.0	239.4	1312.8	1502.2
1950	779.4	379.5	0.0	0.0	1158.9	1670.9	829.1	287.9	215.1	1332.0	1555.1
1951	919.9	380.4	0.0	0.0	1300.3	1905.7	792.7	143.9	222.3	1158.9	1371.8
1952	593.8	423.0	0.0	0.0	1016.8	1410.5	614.6	619.7	158.2	1392.6	1578.2
1953	288.2	184.0	0.0	0.0	472.2	662.1	614.6	430.5	116.7	1161.8	1344.0
1954	483.1	251.3	0.0	0.0	734.4	1049.1	614.6	429.7	187.9	1232.3	1415.8
1955	1041.1	199.2	0.0	0.0	1240.3	1909.8	436.6	79.5	201.2	717.2	838.9
1956	757.8	187.5	0.0	0.0	945.2	1431.5	591.8	423.5	274.3	1289.6	1461.8
1957	801.3	204.2	0.0	0.0	1005.4	1517.4	747.0	151.0	317.2	1215.2	1414.4
1958	920.1	161.7	0.0	0.0	1081.8	1667.3	692.2	160.3	348.9	1201.4	1380.1
1959	1493.7	144.2	0.0	0.0	1637.9	2589.8	615.6	133.6	275.1	1024.3	1176.5
1960	1699.8	197.4	0.0	0.0	1897.2	2993.3	591.3	74.6	229.9	895.8	1037.3
1961	1629.0	169.5	0.0	0.0	1798.4	2867.1	617.7	141.7	227.1	986.5	1141.1
1962	935.3	149.0	0.0	0.0	1084.4	1709.4	475.7	105.9	221.4	803.1	930.9
1963	697.9	111.4	0.0	0.0	809.3	1281.5	513.3	125.8	221.2	860.2	1005.9
1964	1118.4	88.0	0.0	0.0	1206.3	1973.5	378.9	75.1	214.6	668.6	774.7
1965	1265.6	83.9	0.0	0.0	1349.5	2245.7	368.2	77.5	313.5	759.2	857.6
1966	1376.6	102.2	0.0	0.0	1478.8	2522.0	364.0	74.2	438.3	876.5	969.6
1967	2030.0	127.1	29.2	0.0	2186.2	3873.3	426.7	69.5	462.9	959.1	1065.7

1968	2315.9	96.6	35.6	0.0	2448.1	4503.1	496.4	57.4	446.7	1000.5	1125.3
1969	1267.1	135.3	35.4	0.0	1437.7	2564.4	545.5	76.3	347.5	969.3	1111.2
1970	843.0	158.8	35.3	0.0	1037.1	1753.1	748.5	73.4	531.8	1353.8	1552.3
1971	981.5	138.3	35.4	0.0	1155.2	1947.2	973.1	140.3	618.9	1732.4	1993.7
1972	963.5	128.7	35.5	0.0	1127.8	1883.9	1539.4	226.9	756.4	2522.7	2935.6
1973	1431.6	123.7	35.6	0.0	1590.9	2737.6	1721.4	176.0	753.0	2650.4	3120.5
1974	1626.9	89.3	35.4	80.4	1832.0	3106.9	1833.7	244.0	768.5	2846.1	3399.0
1975	1584.9	133.1	41.7	84.8	1844.6	3035.6	1569.1	268.9	841.1	2679.1	3238.0
1976	1552.7	109.3	23.2	116.8	1802.0	2904.0	1527.2	152.1	881.3	2560.6	3186.9
1977	1451.1	198.8	31.3	110.2	1791.3	2766.8	875.3	92.5	646.7	1614.5	2005.8
1978	1163.4	218.9	26.1	118.9	1527.2	2273.5	957.6	144.3	862.1	1963.9	2408.9
1979	1948.6	276.0	22.4	121.7	2368.5	3614.7	1525.8	104.4	935.9	2566.1	3261.6
1980	1973.8	144.0	29.0	149.8	2296.6	3744.7	1413.5	98.6	1335.4	2847.5	3465.2
1981	1831.9	200.3	31.9	117.5	2181.6	3874.5	1212.2	92.1	1173.0	2477.3	2992.9
1982	2163.0	291.9	35.1	119.6	2609.7	4957.1	1350.8	74.1	882.0	2306.9	2849.3
1983	2914.1	337.8	43.2	129.0	3424.1	9221.2	967.3	52.2	589.0	1608.6	2173.4
1984	2752.5	330.4	71.9	143.9	3298.6	8012.9	910.3	42.0	514.0	1466.4	2024.6
1985	2781.0	388.8	55.1	98.9	3323.8	7601.0	614.0	82.4	981.0	1677.4	2264.8
1986	1098.1	252.4	56.6	92.4	1499.4	3165.8	394.3	146.1	950.0	1490.4	2046.8
1987	1442.9	279.2	60.0	122.9	1905.0	4478.0	703.2	159.4	969.0	1831.6	2711.8
1988	1467.5	263.8	57.0	90.5	1878.8	5004.3	819.0	211.0	1054.0	2083.9	2853.9
1989	1937.0	357.5	59.1	120.0	2473.6	6433.6	867.0	412.8	980.0	2259.9	2935.4
1990	1493.8	360.8	68.4	96.9	2019.9	4754.9	763.3	309.1	799.0	1871.4	2433.0
1991	2186.6	184.9	66.4	73.5	2511.4	6577.1	597.7	192.7	820.0	1610.4	2081.5
1992	1092.0	185.0	89.8	112.4	1479.2	4213.6	419.5	199.3	808.0	1426.8	1808.2
1993	1363.1	148.1	107.9	145.9	1764.9	7214.6	536.9	165.8	479.0	1181.7	1620.4
1994	1140.9	201.9	102.9	142.5	1588.1	5902.1	429.4	142.4	289.0	860.8	1177.3
1995	824.4	103.5	65.6	79.6	1073.0	3639.2	361.9	179.9	300.0	841.9	1085.2
1996	942.8	134.6	61.8	93.2	1232.3	3675.4	312.0	169.6	391.0	872.6	1092.0
1997	875.8	182.5	59.4	110.8	1228.5	3278.3	351.8	158.7	299.0	809.6	1073.5
1998	145.6	53.6	38.4	70.0	307.6	610.2	85.4	65.2	279.0	429.6	551.3
1999	149.5	65.1	45.5	79.7	339.8	627.0	89.5	52.7	375.0	517.2	638.2
2000	48.0	40.8	34.7	51.2	174.7	261.4	33.0	22.7	240.0	295.6	337.7
2001	39.6	53.3	43.5	61.8	198.1	268.2	28.6	34.1	226.0	288.6	328.2
2002	74.5	48.9	56.5	82.4	262.2	401.1	37.2	44.0	608.0	689.2	745.8
2003	56.3	49.4	66.5	122.5	294.6	410.9	12.4	38.8	1125.0	1176.3	1191.9
2004	60.3	53.3	79.0	108.7	301.4	426.5	16.7	45.7	188.0	250.4	265.8
2005	79.3	58.0	78.3	140.8	356.5	501.9	20.2	40.8	387.8	448.8	462.0
2006	115.6	78.6	62.2	107.6	364.0	544.3	24.8	36.1	316.9	377.7	390.5
2007	113.6	71.2	68.2	104.0	357.0	459.3	42.7	36.5	190.7	269.9	289.3
2008	118.8	92.8	70.8	89.3	371.7	480.2	34.0	36.2	107.0	177.2	190.8
2009	93.5	81.5	74.3	78.8	328.0	424.1	31.7	25.0	133.4	190.2	202.4
2010	77.8	47.2	91.4	93.9	310.4	342.7	23.1	23.7	107.4	154.1	159.8

2011	283.4	57.6	117.8	115.0	573.8	611.1	6.7	26.2	230.2	263.1	265.2
2012	373.2	64.9	122.3	155.3	715.7	747.5	16.3	31.5	281.4	329.2	333.9
2013	360.4	78.3	127.3	224.0	790.0	812.7	23.6	41.2	433.0	497.8	505.1
2014	217.5	82.2	141.6	176.1	617.4	632.3	36.8	70.1	571.8	678.7	689.9
2015	163.4	132.5	272.0	226.2	794.1	677.3	42.2	106.3	715.4	863.9	877.4
2016	262.7	98.3	349.7	154.7	865.4	722.7	40.2	75.6	647.3	763.1	773.7

* Note that the WA recreational landings are entered into SS as numbers of fish, as reported by WDFW, SS then internally converts these landings to weights. The quantities reported for WA landings are the model converted values in metric tons.

Table 2. Input length samples sizes for the north model.

Year	Fleet/Survey	Units	Input N
1986	Early Triennial	N tows	32
1989	Early Triennial	N tows	90
1992	Early Triennial	N tows	56
1995	Late Triennial	N tows	84
1998	Late Triennial	N tows	99
2001	Late Triennial	N tows	144
2004	Late Triennial	N tows	91
2003	NWFSC WCGBTS	N tows	90
2004	NWFSC WCGBTS	N tows	88
2005	NWFSC WCGBTS	N tows	98
2006	NWFSC WCGBTS	N tows	119
2007	NWFSC WCGBTS	N tows	116
2008	NWFSC WCGBTS	N tows	111
2009	NWFSC WCGBTS	N tows	103
2010	NWFSC WCGBTS	N tows	128
2011	NWFSC WCGBTS	N tows	139
2012	NWFSC WCGBTS	N tows	121
2013	NWFSC WCGBTS	N tows	99
2014	NWFSC WCGBTS	N tows	128
2015	NWFSC WCGBTS	N tows	116
2016	NWFSC WCGBTS	N tows	122
1971	Fixed Gears	N port samples	14
1978	Fixed Gears	N port samples	32
1979	Fixed Gears	N port samples	11
1980	Fixed Gears	N port samples	38
1981	Fixed Gears	N port samples	20
1982	Fixed Gears	N port samples	77
1983	Fixed Gears	N port samples	25
1986	Fixed Gears	N port samples	46
1987	Fixed Gears	N port samples	50
1988	Fixed Gears	N port samples	48
1989	Fixed Gears	N port samples	53
1990	Fixed Gears	N port samples	53
1991	Fixed Gears	N port samples	51
1992	Fixed Gears	N port samples	91
1993	Fixed Gears	N port samples	92
1994	Fixed Gears	N port samples	80
1995	Fixed Gears	N port samples	72
1996	Fixed Gears	N port samples	58
1997	Fixed Gears	N port samples	73

1998	Fixed Gears	N port samples	63
1999	Fixed Gears	N port samples	66
2000	Fixed Gears	N port samples	87
2001	Fixed Gears	N port samples	110
2002	Fixed Gears	N port samples	140
2003	Fixed Gears	N port samples	122
2004	Fixed Gears	N port samples	163
2005	Fixed Gears	N port samples	70
2006	Fixed Gears	N port samples	104
2007	Fixed Gears	N port samples	179
2008	Fixed Gears	N port samples	136
2009	Fixed Gears	N port samples	130
2010	Fixed Gears	N port samples	190
2011	Fixed Gears	N port samples	170
2012	Fixed Gears	N port samples	202
2013	Fixed Gears	N port samples	231
2014	Fixed Gears	N port samples	265
2015	Fixed Gears	N port samples	326
2016	Fixed Gears	N port samples	311
1965	Trawl Gears	N port samples	4
1966	Trawl Gears	N port samples	3
1967	Trawl Gears	N port samples	5
1968	Trawl Gears	N port samples	38
1969	Trawl Gears	N port samples	16
1970	Trawl Gears	N port samples	20
1971	Trawl Gears	N port samples	14
1972	Trawl Gears	N port samples	4
1973	Trawl Gears	N port samples	3
1974	Trawl Gears	N port samples	6
1975	Trawl Gears	N port samples	16
1978	Trawl Gears	N port samples	32
1979	Trawl Gears	N port samples	11
1980	Trawl Gears	N port samples	38
1981	Trawl Gears	N port samples	20
1982	Trawl Gears	N port samples	77
1983	Trawl Gears	N port samples	25
1984	Trawl Gears	N port samples	19
1985	Trawl Gears	N port samples	22
1986	Trawl Gears	N port samples	46
1987	Trawl Gears	N port samples	50
1988	Trawl Gears	N port samples	48
1989	Trawl Gears	N port samples	53
1990	Trawl Gears	N port samples	53

1991	Trawl Gears	N port samples	51
1992	Trawl Gears	N port samples	91
1993	Trawl Gears	N port samples	92
1994	Trawl Gears	N port samples	80
1995	Trawl Gears	N port samples	72
1996	Trawl Gears	N port samples	58
1997	Trawl Gears	N port samples	73
1998	Trawl Gears	N port samples	63
1999	Trawl Gears	N port samples	66
2000	Trawl Gears	N port samples	87
2001	Trawl Gears	N port samples	110
2002	Trawl Gears	N port samples	140
2003	Trawl Gears	N port samples	122
2004	Trawl Gears	N port samples	163
2005	Trawl Gears	N port samples	70
2006	Trawl Gears	N port samples	104
2007	Trawl Gears	N port samples	179
2008	Trawl Gears	N port samples	136
2009	Trawl Gears	N port samples	130
2010	Trawl Gears	N port samples	190
2011	Trawl Gears	N port samples	170
2012	Trawl Gears	N port samples	202
2013	Trawl Gears	N port samples	231
2014	Trawl Gears	N port samples	265
2015	Trawl Gears	N port samples	326
2016	Trawl Gears	N port samples	311
2004	Fixed Gears Discards	N tows	105
2005	Fixed Gears Discards	N tows	94
2006	Fixed Gears Discards	N tows	199
2007	Fixed Gears Discards	N tows	143
2008	Fixed Gears Discards	N tows	148
2009	Fixed Gears Discards	N tows	142
2010	Fixed Gears Discards	N tows	181
2011	Fixed Gears Discards	N tows	213
2012	Fixed Gears Discards	N tows	227
2013	Fixed Gears Discards	N tows	190
2014	Fixed Gears Discards	N tows	190
2015	Fixed Gears Discards	N tows	211
2004	Trawl Gears Discards	N tows	409
2005	Trawl Gears Discards	N tows	480
2006	Trawl Gears Discards	N tows	197
2007	Trawl Gears Discards	N tows	87
2008	Trawl Gears Discards	N tows	70

2009	Trawl Gears Discards	N tows	201
2010	Trawl Gears Discards	N tows	69
2011	Trawl Gears Discards	N tows	352
2012	Trawl Gears Discards	N tows	353
2013	Trawl Gears Discards	N tows	269
2014	Trawl Gears Discards	N tows	298
2015	Trawl Gears Discards	N tows	224
1979	WA Recreational	N fish	13
1980	WA Recreational	N fish	235
1981	WA Recreational	N fish	98
1982	WA Recreational	N fish	72
1983	WA Recreational	N fish	43
1986	WA Recreational	N fish	359
1987	WA Recreational	N fish	336
1988	WA Recreational	N fish	279
1989	WA Recreational	N fish	296
1990	WA Recreational	N fish	239
1991	WA Recreational	N fish	310
1992	WA Recreational	N fish	522
1993	WA Recreational	N fish	542
1994	WA Recreational	N fish	674
1995	WA Recreational	N fish	1,025
1996	WA Recreational	N fish	812
1997	WA Recreational	N fish	441
1998	WA Recreational	N fish	461
1999	WA Recreational	N fish	431
2000	WA Recreational	N fish	479
2001	WA Recreational	N fish	619
2002	WA Recreational	N fish	951
2003	WA Recreational	N fish	1,085
2004	WA Recreational	N fish	1,081
2005	WA Recreational	N fish	1,277
2006	WA Recreational	N fish	897
2007	WA Recreational	N fish	936
2008	WA Recreational	N fish	453
2009	WA Recreational	N fish	672
2010	WA Recreational	N fish	517
2011	WA Recreational	N fish	409
2012	WA Recreational	N fish	392
2013	WA Recreational	N fish	354
2014	WA Recreational	N fish	697
2015	WA Recreational	N fish	501
2016	WA Recreational	N fish	832

2001	OR Recreational	N fish	1164
1980	OR Recreational	N fish	108
1981	OR Recreational	N fish	54
1982	OR Recreational	N fish	254
1983	OR Recreational	N fish	101
1984	OR Recreational	N fish	241
1985	OR Recreational	N fish	345
1986	OR Recreational	N fish	140
1987	OR Recreational	N fish	250
1988	OR Recreational	N fish	286
1989	OR Recreational	N fish	295
1993	OR Recreational	N fish	948
1994	OR Recreational	N fish	955
1995	OR Recreational	N fish	434
1996	OR Recreational	N fish	564
1997	OR Recreational	N fish	596
1998	OR Recreational	N fish	446
1999	OR Recreational	N fish	451
2000	OR Recreational	N fish	314
2002	OR Recreational	N fish	2413
2003	OR Recreational	N fish	2908
2004	OR Recreational	N fish	1764
2005	OR Recreational	N fish	2912
2006	OR Recreational	N fish	4463
2007	OR Recreational	N fish	4934
2008	OR Recreational	N fish	5352
2009	OR Recreational	N fish	4531
2010	OR Recreational	N fish	5451
2011	OR Recreational	N fish	6154
2012	OR Recreational	N fish	6992
2013	OR Recreational	N fish	7105
2014	OR Recreational	N fish	5554
2015	OR Recreational	N fish	6388
2016	OR Recreational	N fish	4951
1996	WDFW Research	N fish	857
1997	WDFW Research	N fish	809
2001	WDFW Research	N fish	168
2002	WDFW Research	N fish	166
2003	WDFW Research	N fish	174
2016	Lam Research	N fish	744

Table 3. Input length samples sizes for the south model.

Year	Fleet/Survey	Units	Input N
1989	Early Triennial	N tows	72
1992	Early Triennial	N tows	32
1995	Late Triennial	N tows	55
1998	Late Triennial	N tows	64
2001	Late Triennial	N tows	102
2004	Late Triennial	N tows	90
2003	NWFSC WCGBTS	N tows	95
2004	NWFSC WCGBTS	N tows	82
2005	NWFSC WCGBTS	N tows	98
2006	NWFSC WCGBTS	N tows	52
2007	NWFSC WCGBTS	N tows	53
2008	NWFSC WCGBTS	N tows	79
2009	NWFSC WCGBTS	N tows	118
2010	NWFSC WCGBTS	N tows	107
2011	NWFSC WCGBTS	N tows	127
2012	NWFSC WCGBTS	N tows	129
2013	NWFSC WCGBTS	N tows	90
2014	NWFSC WCGBTS	N tows	135
2015	NWFSC WCGBTS	N tows	129
2016	NWFSC WCGBTS	N tows	108
2004	NWFSC Hook and Line	N fish	32
2005	NWFSC Hook and Line	N fish	37
2006	NWFSC Hook and Line	N fish	14
2007	NWFSC Hook and Line	N fish	26
2008	NWFSC Hook and Line	N fish	13
2009	NWFSC Hook and Line	N fish	19
2010	NWFSC Hook and Line	N fish	15
2011	NWFSC Hook and Line	N fish	31
2012	NWFSC Hook and Line	N fish	28
2013	NWFSC Hook and Line	N fish	94
2014	NWFSC Hook and Line	N fish	91
2015	NWFSC Hook and Line	N fish	85
2016	NWFSC Hook and Line	N fish	106
1978	Fixed Gears	N port samples	25
1979	Fixed Gears	N port samples	29
1982	Fixed Gears	N port samples	27
1983	Fixed Gears	N port samples	38
1985	Fixed Gears	N port samples	11
1986	Fixed Gears	N port samples	9

1987	Fixed Gears	N port samples	14
1988	Fixed Gears	N port samples	30
1989	Fixed Gears	N port samples	17
1993	Fixed Gears	N port samples	86
1994	Fixed Gears	N port samples	36
1995	Fixed Gears	N port samples	52
1996	Fixed Gears	N port samples	96
1997	Fixed Gears	N port samples	98
1998	Fixed Gears	N port samples	42
1999	Fixed Gears	N port samples	113
2000	Fixed Gears	N port samples	40
2001	Fixed Gears	N port samples	74
2002	Fixed Gears	N port samples	41
2003	Fixed Gears	N port samples	26
2004	Fixed Gears	N port samples	43
2005	Fixed Gears	N port samples	24
2006	Fixed Gears	N port samples	50
2007	Fixed Gears	N port samples	99
2008	Fixed Gears	N port samples	83
2009	Fixed Gears	N port samples	68
2010	Fixed Gears	N port samples	78
2011	Fixed Gears	N port samples	53
2012	Fixed Gears	N port samples	57
2013	Fixed Gears	N port samples	59
2014	Fixed Gears	N port samples	65
2015	Fixed Gears	N port samples	110
2016	Fixed Gears	N port samples	154
1978	Trawl Gears	N port samples	25
1979	Trawl Gears	N port samples	29
1980	Trawl Gears	N port samples	59
1982	Trawl Gears	N port samples	27
1983	Trawl Gears	N port samples	38
1984	Trawl Gears	N port samples	17
1985	Trawl Gears	N port samples	11
1986	Trawl Gears	N port samples	9
1987	Trawl Gears	N port samples	14
1988	Trawl Gears	N port samples	30
1989	Trawl Gears	N port samples	17
1993	Trawl Gears	N port samples	86
1994	Trawl Gears	N port samples	36
1995	Trawl Gears	N port samples	52
1996	Trawl Gears	N port samples	96
1997	Trawl Gears	N port samples	98

1998	Trawl Gears	N port samples	42
1999	Trawl Gears	N port samples	113
2000	Trawl Gears	N port samples	40
2001	Trawl Gears	N port samples	74
2002	Trawl Gears	N port samples	41
2003	Trawl Gears	N port samples	26
2004	Trawl Gears	N port samples	43
2005	Trawl Gears	N port samples	24
2006	Trawl Gears	N port samples	50
2007	Trawl Gears	N port samples	99
2008	Trawl Gears	N port samples	83
2009	Trawl Gears	N port samples	68
2010	Trawl Gears	N port samples	78
2011	Trawl Gears	N port samples	53
2012	Trawl Gears	N port samples	57
2013	Trawl Gears	N port samples	59
2014	Trawl Gears	N port samples	65
2015	Trawl Gears	N port samples	110
2016	Trawl Gears	N port samples	154
2004	Fixed Gears Discards	N tows	167
2005	Fixed Gears Discards	N tows	104
2006	Fixed Gears Discards	N tows	82
2007	Fixed Gears Discards	N tows	97
2008	Fixed Gears Discards	N tows	36
2009	Fixed Gears Discards	N tows	77
2010	Fixed Gears Discards	N tows	56
2011	Fixed Gears Discards	N tows	133
2012	Fixed Gears Discards	N tows	146
2013	Fixed Gears Discards	N tows	119
2014	Fixed Gears Discards	N tows	92
2015	Fixed Gears Discards	N tows	158
2004	Trawl Gears Discards	N tows	73
2005	Trawl Gears Discards	N tows	177
2006	Trawl Gears Discards	N tows	47
2007	Trawl Gears Discards	N tows	38
2008	Trawl Gears Discards	N tows	47
2009	Trawl Gears Discards	N tows	39
2010	Trawl Gears Discards	N tows	31
2011	Trawl Gears Discards	N tows	132
2012	Trawl Gears Discards	N tows	116
2013	Trawl Gears Discards	N tows	141
2014	Trawl Gears Discards	N tows	222
2015	Trawl Gears Discards	N tows	215

1987	CA Recreational, J. Field	N fish	284
1988	CA Recreational, J. Field	N fish	1072
1989	CA Recreational, J. Field	N fish	1070
1990	CA Recreational, J. Field	N fish	223
1991	CA Recreational, J. Field	N fish	359
1992	CA Recreational, J. Field	N fish	718
1993	CA Recreational, J. Field	N fish	566
1994	CA Recreational, J. Field	N fish	589
1995	CA Recreational, J. Field	N fish	952
1996	CA Recreational, J. Field	N fish	1091
1997	CA Recreational, J. Field	N fish	1290
1998	CA Recreational, J. Field	N fish	424
1975	CA Recreational, Southern CA	N fish	140
1976	CA Recreational, Southern CA	N fish	235
1977	CA Recreational, Southern CA	N fish	165
1978	CA Recreational, Southern CA	N fish	292
1986	CA Recreational, Southern CA	N fish	45
1987	CA Recreational, Southern CA	N fish	122
1988	CA Recreational, Southern CA	N fish	279
1989	CA Recreational, Southern CA	N fish	313
1959	CA Recreational, Monterey Bay	N fish	262
1960	CA Recreational, Monterey Bay	N fish	368
1961	CA Recreational, Monterey Bay	N fish	350
1962	CA Recreational, Monterey Bay	N fish	512
1963	CA Recreational, Monterey Bay	N fish	591
1964	CA Recreational, Monterey Bay	N fish	592
1966	CA Recreational, Monterey Bay	N fish	459
1967	CA Recreational, Monterey Bay	N fish	375
1968	CA Recreational, Monterey Bay	N fish	468
1969	CA Recreational, Monterey Bay	N fish	375
1970	CA Recreational, Monterey Bay	N fish	453
1971	CA Recreational, Monterey Bay	N fish	344
1972	CA Recreational, Monterey Bay	N fish	370
2004	CA Recreational, RecFIN	N fish	1426
2005	CA Recreational, RecFIN	N fish	4642
2006	CA Recreational, RecFIN	N fish	4477
2007	CA Recreational, RecFIN	N fish	3347
2008	CA Recreational, RecFIN	N fish	2695
2009	CA Recreational, RecFIN	N fish	2754
2010	CA Recreational, RecFIN	N fish	1908
2011	CA Recreational, RecFIN	N fish	4578
2012	CA Recreational, RecFIN	N fish	5770
2013	CA Recreational, RecFIN	N fish	7901

2014	CA Recreational, RecFIN	N fish	9017
2015	CA Recreational, RecFIN	N fish	12834
2016	CA Recreational, RecFIN	N fish	10337
1993	CA Recreational, MRFSS	N fish	664
1994	CA Recreational, MRFSS	N fish	406
1995	CA Recreational, MRFSS	N fish	397
1996	CA Recreational, MRFSS	N fish	787
1997	CA Recreational, MRFSS	N fish	166
1998	CA Recreational, MRFSS	N fish	341
1999	CA Recreational, MRFSS	N fish	721
2000	CA Recreational, MRFSS	N fish	242
2001	CA Recreational, MRFSS	N fish	153
2002	CA Recreational, MRFSS	N fish	848
2003	CA Recreational, MRFSS	N fish	1431
2016	Lam Research	N fish	1042

Table 4. Input age sample sizes for the north model.

Year	Fleet/Survey	Units	Input N
1995	Triennial Late	N tows	74
1998	Triennial Late	N tows	91
2001	Triennial Late	N tows	96
2004	Triennial Late	N tows	85
2003	NWFSC WCGBTS	N tows	81
2004	NWFSC WCGBTS	N tows	85
2005	NWFSC WCGBTS	N tows	96
2006	NWFSC WCGBTS	N tows	119
2007	NWFSC WCGBTS	N tows	91
2008	NWFSC WCGBTS	N tows	108
2010	NWFSC WCGBTS	N tows	99
2011	NWFSC WCGBTS	N tows	118
2012	NWFSC WCGBTS	N tows	97
2014	NWFSC WCGBTS	N tows	86
2013	NWFSC WCGBTS	N tows	96
2015	NWFSC WCGBTS	N tows	100
2016	NWFSC WCGBTS	N tows	90
1978	Fixed Gears	N tows	16
1979	Fixed Gears	N tows	11
1980	Fixed Gears	N tows	33
1981	Fixed Gears	N tows	19
1982	Fixed Gears	N tows	22
1983	Fixed Gears	N tows	18
1986	Fixed Gears	N tows	40
1987	Fixed Gears	N tows	47
1988	Fixed Gears	N tows	43
1989	Fixed Gears	N tows	40
1990	Fixed Gears	N tows	45
1991	Fixed Gears	N tows	49
1992	Fixed Gears	N tows	90
1993	Fixed Gears	N tows	89
1994	Fixed Gears	N tows	69
1995	Fixed Gears	N tows	68
1996	Fixed Gears	N tows	54
1997	Fixed Gears	N tows	43
1998	Fixed Gears	N tows	36
1999	Fixed Gears	N tows	34
2000	Fixed Gears	N tows	29
2001	Fixed Gears	N tows	40

2002	Fixed Gears	N tows	49
2003	Fixed Gears	N tows	63
2004	Fixed Gears	N tows	51
2005	Fixed Gears	N tows	35
2006	Fixed Gears	N tows	45
2007	Fixed Gears	N tows	57
2008	Fixed Gears	N tows	45
2009	Fixed Gears	N tows	37
2010	Fixed Gears	N tows	26
2011	Fixed Gears	N tows	35
2012	Fixed Gears	N tows	37
2013	Fixed Gears	N tows	44
2014	Fixed Gears	N tows	40
2015	Fixed Gears	N tows	14
2016	Fixed Gears	N tows	22
1978	Trawl Gears	N tows	16
1979	Trawl Gears	N tows	11
1980	Trawl Gears	N tows	33
1981	Trawl Gears	N tows	19
1982	Trawl Gears	N tows	22
1983	Trawl Gears	N tows	18
1984	Trawl Gears	N tows	11
1985	Trawl Gears	N tows	14
1986	Trawl Gears	N tows	40
1987	Trawl Gears	N tows	47
1988	Trawl Gears	N tows	43
1989	Trawl Gears	N tows	40
1990	Trawl Gears	N tows	45
1991	Trawl Gears	N tows	49
1992	Trawl Gears	N tows	90
1993	Trawl Gears	N tows	89
1994	Trawl Gears	N tows	69
1995	Trawl Gears	N tows	68
1996	Trawl Gears	N tows	54
1997	Trawl Gears	N tows	43
1998	Trawl Gears	N tows	36
1999	Trawl Gears	N tows	34
2000	Trawl Gears	N tows	29
2001	Trawl Gears	N tows	40
2002	Trawl Gears	N tows	49
2003	Trawl Gears	N tows	63
2004	Trawl Gears	N tows	51
2005	Trawl Gears	N tows	35

2006	Trawl Gears	N tows	45
2007	Trawl Gears	N tows	57
2008	Trawl Gears	N tows	45
2009	Trawl Gears	N tows	37
2010	Trawl Gears	N tows	26
2011	Trawl Gears	N tows	35
2012	Trawl Gears	N tows	37
2013	Trawl Gears	N tows	44
2014	Trawl Gears	N tows	40
2015	Trawl Gears	N tows	14
2016	Trawl Gears	N tows	22
1979	WA recreational	N fish	13
1980	WA recreational	N fish	226
1981	WA recreational	N fish	14
1982	WA recreational	N fish	19
1983	WA recreational	N fish	39
1986	WA recreational	N fish	342
1987	WA recreational	N fish	276
1988	WA recreational	N fish	250
1989	WA recreational	N fish	227
1990	WA recreational	N fish	207
1991	WA recreational	N fish	247
1992	WA recreational	N fish	499
1993	WA recreational	N fish	530
1994	WA recreational	N fish	449
1995	WA recreational	N fish	643
1996	WA recreational	N fish	461
1997	WA recreational	N fish	441
1998	WA recreational	N fish	416
1999	WA recreational	N fish	432
2000	WA recreational	N fish	394
2001	WA recreational	N fish	560
2002	WA recreational	N fish	650
2003	WA recreational	N fish	619
2004	WA recreational	N fish	570
2005	WA recreational	N fish	566
2006	WA recreational	N fish	398
2007	WA recreational	N fish	483
2008	WA recreational	N fish	430
2009	WA recreational	N fish	335
2010	WA recreational	N fish	385
2011	WA recreational	N fish	296
2012	WA recreational	N fish	234

2013	WA recreational	N fish	344
2014	WA recreational	N fish	688
2015	WA recreational	N fish	487
2016	WA recreational	N fish	768
1999	OR recreational	N fish	178
2000	OR recreational	N fish	264
2001	OR recreational	N fish	791
2002	OR recreational	N fish	859
2003	OR recreational	N fish	803
2004	OR recreational	N fish	647
2005	OR recreational	N fish	540
2006	OR recreational	N fish	799
2007	OR recreational	N fish	788
2008	OR recreational	N fish	740
2012	OR recreational	N fish	260
2014	OR recreational	N fish	259
2015	OR recreational	N fish	259
2016	OR recreational	N fish	260
1996	WDFW Research	N fish	511
1997	WDFW Research	N fish	498
2001	WDFW Research	N fish	100
2002	WDFW Research	N fish	100
2003	WDFW Research	N fish	100
2016	Lam Research	N fish	573

Table 5. . Input age sample sizes for the south model.

Year	Fleet/Survey	Units	Input N
2003	NWFSC WCGBTS	N tows	91
2004	NWFSC WCGBTS	N tows	76
2005	NWFSC WCGBTS	N tows	90
2006	NWFSC WCGBTS	N tows	52
2007	NWFSC WCGBTS	N tows	53
2008	NWFSC WCGBTS	N tows	77
2010	NWFSC WCGBTS	N tows	95
2011	NWFSC WCGBTS	N tows	96
2012	NWFSC WCGBTS	N tows	105
2013	NWFSC WCGBTS	N tows	68
2014	NWFSC WCGBTS	N tows	114
2015	NWFSC WCGBTS	N tows	103
2016	NWFSC WCGBTS	N tows	88
1993	Fixed Gears	N tows	22
1994	Fixed Gears	N tows	20
1998	Fixed Gears	N tows	14
2004	Fixed Gears	N tows	12
1993	Trawl Gears	N tows	22
1994	Trawl Gears	N tows	20
1995	Trawl Gears	N tows	12
1996	Trawl Gears	N tows	17
1997	Trawl Gears	N tows	43
1998	Trawl Gears	N tows	14
2001	Trawl Gears	N tows	14
2002	Trawl Gears	N tows	15
2003	Trawl Gears	N tows	13
2004	Trawl Gears	N tows	12
1995	Late Triennial	N tows	49
1998	Late Triennial	N tows	52
2001	Late Triennial	N tows	48
2004	Late Triennial	N tows	83
2016	Lam Research	N fish	414

Table 6. North base model parameters.

SS Parameter Name	Fixed Value or Estimate	Minimum Bound	Maximum Bound	Standard Deviation	Prior Type
NatM_p_1_Fem_GP_1	0.257	0.05	0.4	Fixed	Log_Norm
L_at_Amin_Fem_GP_1	17.2792	4	60	0.735161	No_prior
L_at_Amax_Fem_GP_1	110	40	130	Fixed	No_prior
VonBert_K_Fem_GP_1	0.128177	0.01	0.5	0.004204	No_prior
CV_young_Fem_GP_1	0.143666	0.01	0.5	0.0106661	No_prior
CV_old_Fem_GP_1	0.0606102	0.01	0.5	0.00990003	No_prior
Wtlen_1_Fem	0.00000276	-3	3	Fixed	No_prior
Wtlen_2_Fem	3.28	-3	5	Fixed	No_prior
Mat50%_Fem	56.7	-3	100	Fixed	No_prior
Mat_slope_Fem	-0.269	-5	5	Fixed	No_prior
Eggs/kg_inter_Fem	1	-3	3	Fixed	No_prior
Eggs/kg_slope_wt_Fem	0	-3	3	Fixed	No_prior
NatM_p_1_Mal_GP_1	0.304947	0.15	0.45	0.00660155	Log_Norm
L_at_Amin_Mal_GP_1	14.8756	10	60	1.02119	No_prior
L_at_Amax_Mal_GP_1	76.7131	40	110	0.98677	No_prior
VonBert_K_Mal_GP_1	0.301253	0.01	1	0.0154737	No_prior
CV_young_Mal_GP_1	0.156754	0.01	0.5	0.0140373	No_prior
CV_old_Mal_GP_1	0.0722656	0.01	0.5	0.00693014	No_prior
Wtlen_1_Mal	0.00000161	-3	3	Fixed	No_prior
Wtlen_2_Mal	3.42	-5	5	Fixed	No_prior
RecrDist_GP_1	0	-3	3	Fixed	No_prior
RecrDist_Area_1	0	-3	3	Fixed	No_prior
RecrDist_Bseas_1	1	0	999	Fixed	No_prior
CohortGrowDev	0	0	0	Fixed	No_prior
FracFemale_GP_1	0.5	0.000001	0.999999	Fixed	No_prior
SR_LN(R0)	9.0669	5	15	0.164548	No_prior
SR_BH_steep	0.7	0.2	1	Fixed	No_prior
SR_sigmaR	0.55	0	2	Fixed	No_prior
SR_regime	0	-5	5	Fixed	No_prior
SR_autocorr	0	0	2	Fixed	No_prior
LnQ_base_1_N_TRAWL(1)	-1.16572	-15	15	Fixed	No_prior
Q_extraSD_1_N_TRAWL(1)	0.0663834	0.001	2	0.0347138	No_prior
LnQ_base_2_N_FIX(2)	-7.08317	-15	15	Fixed	No_prior
Q_extraSD_2_N_FIX(2)	0.120872	0.001	2	0.054318	No_prior
LnQ_base_3_WA_REC(3)	-8.56169	-15	15	Fixed	No_prior
Q_extraSD_3_WA_REC(3)	0.261407	0.001	2	0.0416452	No_prior
LnQ_base_4_OR_REC(4)	-11.0514	-15	15	Fixed	No_prior
Q_extraSD_4_OR_REC(4)	0.216863	0.001	2	0.0339093	No_prior

LnQ_base_5_N_TRI_Early(5)	-0.733503	-15	15	Fixed	No_prior
LnQ_base_6_N_TRI_Late(6)	-0.645328	-15	15	Fixed	No_prior
LnQ_base_7_N_NWFSC(7)	-0.30414	-15	15	Fixed	No_prior
SizeSel_P1_1_N_TRAWL(1)	6.51E+01	14	120	1.45192	No_prior
SizeSel_P2_1_N_TRAWL(1)	-15	-20	4	Fixed	No_prior
SizeSel_P3_1_N_TRAWL(1)	6	-1	15	Fixed	No_prior
SizeSel_P4_1_N_TRAWL(1)	14	-1	15	Fixed	No_prior
SizeSel_P5_1_N_TRAWL(1)	-10	-5	9	Fixed	No_prior
SizeSel_P6_1_N_TRAWL(1)	-999	-5	9	Fixed	No_prior
Retain_P1_1_N_TRAWL(1)	86.3558	10	100	4.59286	No_prior
Retain_P2_1_N_TRAWL(1)	10.6771	0.1	12	1.22738	No_prior
Retain_P3_1_N_TRAWL(1)	8.24742	0.001	12	65.7569	No_prior
Retain_P4_1_N_TRAWL(1)	0.808175	-10	10	1.2112	No_prior
DiscMort_P1_1_N_TRAWL(1)	0	-1	1	Fixed	No_prior
DiscMort_P2_1_N_TRAWL(1)	0.0001	-1	1	Fixed	No_prior
DiscMort_P3_1_N_TRAWL(1)	0.5	0.001	1	Fixed	No_prior
DiscMort_P4_1_N_TRAWL(1)	0	-2	2	Fixed	No_prior
SzSel_Male_Peak_1_N_TRAWL(1)	-1.39219	-30	15	Fixed	No_prior
SzSel_Male_Ascend_1_N_TRAWL(1)	0.20461	-15	15	0.164678	No_prior
SzSel_Male_Descend_1_N_TRAWL(1)	-2.67287	-15	15	0.421588	No_prior
SzSel_Male_Final_1_N_TRAWL(1)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_1_N_TRAWL(1)	1	-15	15	Fixed	No_prior
SizeSel_P1_2_N_FIX(2)	86.0596	14	100	1.83103	No_prior
SizeSel_P2_2_N_FIX(2)	-15	-20	10	Fixed	No_prior
SizeSel_P3_2_N_FIX(2)	6.57729	-10	9	0.154424	No_prior
SizeSel_P4_2_N_FIX(2)	5.18328	-1	9	0.365862	No_prior
SizeSel_P5_2_N_FIX(2)	-999	-5	9	Fixed	No_prior
SizeSel_P6_2_N_FIX(2)	-999	-5	9	Fixed	No_prior
Retain_P1_2_N_FIX(2)	58.6395	10	100	0.412502	No_prior
Retain_P2_2_N_FIX(2)	6.84265	0.1	10	1.55369	No_prior
Retain_P3_2_N_FIX(2)	5.1616	0.001	6	20.1646	No_prior
Retain_P4_2_N_FIX(2)	-1.3	-2	6	Fixed	No_prior
DiscMort_P1_2_N_FIX(2)	0	-1	1	Fixed	No_prior
DiscMort_P2_2_N_FIX(2)	0.0001	-1	1	Fixed	No_prior
DiscMort_P3_2_N_FIX(2)	0.07	0.001	1	Fixed	No_prior
DiscMort_P4_2_N_FIX(2)	0	-2	2	Fixed	No_prior
SzSel_Male_Peak_2_N_FIX(2)	-28	-30	20	Fixed	No_prior
SzSel_Male_Ascend_2_N_FIX(2)	-1.40909	-15	15	0.249416	No_prior
SzSel_Male_Descend_2_N_FIX(2)	1.67931	-15	15	0.573604	No_prior
SzSel_Male_Final_2_N_FIX(2)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_2_N_FIX(2)	1	-15	15	Fixed	No_prior
SizeSel_P1_3_WA_REC(3)	72.581	35	100	1.12761	No_prior
SizeSel_P2_3_WA_REC(3)	-15	-20	10	Fixed	No_prior

SizeSel_P3_3_WA_REC(3)	4.9258	-1	9	0.140439	No_prior
SizeSel_P4_3_WA_REC(3)	6.27983	-1	9	0.15761	No_prior
SizeSel_P5_3_WA_REC(3)	-999	-5	9	Fixed	No_prior
SizeSel_P6_3_WA_REC(3)	-999	-5	9	Fixed	No_prior
SzSel_Male_Peak_3_WA_REC(3)	-8.64984	-15	15	1.22297	No_prior
SzSel_Male_Ascend_3_WA_REC(3)	-5.05E-01	-15	15	0.18074	No_prior
SzSel_Male_Descend_3_WA_REC(3)	-0.145975	-15	15	Fixed	No_prior
SzSel_Male_Final_3_WA_REC(3)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_3_WA_REC(3)	1	-15	15	Fixed	No_prior
SizeSel_P1_4_OR_REC(4)	58.66	35	100	0.436011	No_prior
SizeSel_P2_4_OR_REC(4)	-15	-20	4	Fixed	No_prior
SizeSel_P3_4_OR_REC(4)	4.62899	-4	9	0.210642	No_prior
SizeSel_P4_4_OR_REC(4)	8.10352	-1	9	1.06127	No_prior
SizeSel_P5_4_OR_REC(4)	-999	-5	9	Fixed	No_prior
SizeSel_P6_4_OR_REC(4)	-999	-5	9	Fixed	No_prior
SizeSel_P1_5_N_TRI_Early(5)	94.7887	14	120	5.00852	No_prior
SizeSel_P2_5_N_TRI_Early(5)	-15	-20	4	Fixed	No_prior
SizeSel_P3_5_N_TRI_Early(5)	7.06894	-1	9	0.15714	No_prior
SizeSel_P4_5_N_TRI_Early(5)	6	-1	9	Fixed	No_prior
SizeSel_P5_5_N_TRI_Early(5)	-999	-5	9	Fixed	No_prior
SizeSel_P6_5_N_TRI_Early(5)	-999	-5	9	Fixed	No_prior
SizeSel_P1_6_N_TRI_Late(6)	57.3908	14	110	9.90742	No_prior
SizeSel_P2_6_N_TRI_Late(6)	-15	-20	4	Fixed	No_prior
SizeSel_P3_6_N_TRI_Late(6)	6.16568	-1	9	0.685511	No_prior
SizeSel_P4_6_N_TRI_Late(6)	8	-1	15	Fixed	No_prior
SizeSel_P5_6_N_TRI_Late(6)	-999	-5	9	Fixed	No_prior
SizeSel_P6_6_N_TRI_Late(6)	-999	-5	9	Fixed	No_prior
SizeSel_P1_7_N_NWFSC(7)	61.2144	35	120	6.0047	No_prior
SizeSel_P2_7_N_NWFSC(7)	-15	-20	4	Fixed	No_prior
SizeSel_P3_7_N_NWFSC(7)	6.45783	-1	9	0.344327	No_prior
SizeSel_P4_7_N_NWFSC(7)	7.05119	-1	9	0.618844	No_prior
SizeSel_P5_7_N_NWFSC(7)	-999	-5	9	Fixed	No_prior
SizeSel_P6_7_N_NWFSC(7)	-999	-5	9	Fixed	No_prior
SizeSel_P1_8_N_Lam_Research(8)	82.4813	35	100	2.91143	No_prior
SizeSel_P2_8_N_Lam_Research(8)	-15	-20	4	Fixed	No_prior
SizeSel_P3_8_N_Lam_Research(8)	5.82225	-1	9	0.287732	No_prior
SizeSel_P4_8_N_Lam_Research(8)	5.55355	-1	9	0.691088	No_prior
SizeSel_P5_8_N_Lam_Research(8)	-999	-5	9	Fixed	No_prior
SizeSel_P6_8_N_Lam_Research(8)	-999	-5	9	Fixed	No_prior
SzSel_Male_Peak_8_N_Lam_Research(8)	-18.8698	-30	40	3.92398	No_prior
SzSel_Male_Ascend_8_N_Lam_Research(8)	-1.00808	-15	15	0.493042	No_prior
SzSel_Male_Descend_8_N_Lam_Research(8)	-1.52421	-15	15	0.915959	No_prior
SzSel_Male_Final_8_N_Lam_Research(8)	0	-15	15	Fixed	No_prior

SzSel_Male_Scale_8_N_Lam_Research(8)	1	-15	15	Fixed	No_prior
AgeSel_P1_1_N_TRAWL(1)	0.1	0	1	Fixed	No_prior
AgeSel_P2_1_N_TRAWL(1)	100	0	101	Fixed	No_prior
AgeSel_P1_2_N_FIX(2)	0.1	0	1	Fixed	No_prior
AgeSel_P2_2_N_FIX(2)	100	0	101	Fixed	No_prior
AgeSel_P1_3_WA_REC(3)	0.1	0	1	Fixed	No_prior
AgeSel_P2_3_WA_REC(3)	100	0	101	Fixed	No_prior
AgeSel_P1_4_OR_REC(4)	0.1	0	1	Fixed	No_prior
AgeSel_P2_4_OR_REC(4)	100	0	101	Fixed	No_prior
AgeSel_P1_5_N_TRI_Early(5)	0.1	0	1	Fixed	No_prior
AgeSel_P2_5_N_TRI_Early(5)	100	0	101	Fixed	No_prior
AgeSel_P1_6_N_TRI_Late(6)	0.1	0	1	Fixed	No_prior
AgeSel_P2_6_N_TRI_Late(6)	100	0	101	Fixed	No_prior
AgeSel_P1_7_N_NWFSC(7)	0.1	0	1	Fixed	No_prior
AgeSel_P2_7_N_NWFSC(7)	100	0	101	Fixed	No_prior
AgeSel_P1_8_N_Lam_Research(8)	0.1	0	1	Fixed	No_prior
AgeSel_P2_8_N_Lam_Research(8)	100	0	101	Fixed	No_prior
SizeSel_P4_1_N_TRAWL(1)_BLK3repl_1973	10	-1	15	Fixed	No_prior
SizeSel_P4_1_N_TRAWL(1)_BLK3repl_1983	6.78718	-1	15	0.222518	No_prior
SizeSel_P4_1_N_TRAWL(1)_BLK3repl_1993	6.25786	-1	15	0.215587	No_prior
SizeSel_P4_1_N_TRAWL(1)_BLK3repl_2003	6.27301	-1	15	0.171979	No_prior
SizeSel_P4_1_N_TRAWL(1)_BLK3repl_2011	8.3592	-1	15	0.587714	No_prior
Retain_P1_1_N_TRAWL(1)_BLK2repl_1998	82.1169	10	100	1.05352	No_prior
Retain_P1_1_N_TRAWL(1)_BLK2repl_2007	73.2902	10	100	3.23625	No_prior
Retain_P1_1_N_TRAWL(1)_BLK2repl_2010	59.9287	10	100	2.90061	No_prior
Retain_P1_1_N_TRAWL(1)_BLK2repl_2011	55.0591	10	100	0.89431	No_prior
Retain_P2_1_N_TRAWL(1)_BLK2repl_1998	7.58008	0.1	12	Fixed	No_prior
Retain_P2_1_N_TRAWL(1)_BLK2repl_2007	5.27153	0.1	12	1.27383	No_prior
Retain_P2_1_N_TRAWL(1)_BLK2repl_2010	4.28695	0.1	12	1.28567	No_prior
Retain_P2_1_N_TRAWL(1)_BLK2repl_2011	2.21665	0.1	12	0.301165	No_prior
Retain_P3_1_N_TRAWL(1)_BLK2repl_1998	7	0.001	12	Fixed	No_prior
Retain_P3_1_N_TRAWL(1)_BLK2repl_2007	1.81886	0.001	12	1.22386	No_prior
Retain_P3_1_N_TRAWL(1)_BLK2repl_2010	9.88871	0.001	12	40.5791	No_prior
Retain_P3_1_N_TRAWL(1)_BLK2repl_2011	11.4486	0.001	12	14.1079	No_prior
Retain_P2_2_N_FIX(2)_BLK1repl_1998	1.69917	0.1	10	0.427384	No_prior
Retain_P2_2_N_FIX(2)_BLK1repl_2011	1.44337	0.1	10	0.326083	No_prior
Retain_P3_2_N_FIX(2)_BLK1repl_1998	0.646927	0.001	6	0.0921431	No_prior
Retain_P3_2_N_FIX(2)_BLK1repl_2011	0.777991	0.001	6	0.118112	No_prior
SizeSel_P3_4_OR_REC(4)_BLK4repl_1999	2.0846	-4	9	0.261511	No_prior
SizeSel_P4_4_OR_REC(4)_BLK4repl_1999	6.78122	-1	9	0.120623	No_prior

Table 7. South base model parameters.

SS Parameter Name	Fixed Value or Estimate	Minimum Bound	Maximum Bound	Standard Deviation	Prior Type
NatM_p_1_Fem_GP_1	0.257	0.05	0.3	Fixed	Log_Norm
L_at_Amin_Fem_GP_1	18.0172	10	60	0.335569	No_prior
L_at_Amax_Fem_GP_1	93.4891	40	130	1.313	No_prior
VonBert_K_Fem_GP_1	0.129188	0.01	0.5	0.0101582	No_prior
CV_young_Fem_GP_1	0.149984	0.01	0.5	0.00896961	No_prior
CV_old_Fem_GP_1	0.0704911	0.01	0.5	0.00949212	No_prior
Wtlen_1_Fem	3.308E-06	-3	3	Fixed	No_prior
Wtlen_2_Fem	3.248	-3	5	Fixed	No_prior
Mat50%_Fem	52.3	-3	100	Fixed	No_prior
Mat_slope_Fem	-0.219	-5	5	Fixed	No_prior
Eggs/kg_inter_Fem	1	-3	3	Fixed	No_prior
Eggs/kg_slope_wt_Fem	0	-3	3	Fixed	No_prior
NatM_p_1_Mal_GP_1	0.318869	0.15	0.4	0.0144209	Log_Norm
L_at_Amin_Mal_GP_1	18.1283	10	60	0.407732	No_prior
L_at_Amax_Mal_GP_1	83.8504	40	110	2.618	No_prior
VonBert_K_Mal_GP_1	0.16	0.01	1	0.0207978	No_prior
CV_young_Mal_GP_1	0.136616	0.01	0.5	0.0102783	No_prior
CV_old_Mal_GP_1	0.0874206	0.01	0.5	0.0146184	No_prior
Wtlen_1_Mal	2.179E-06	-3	3	Fixed	No_prior
Wtlen_2_Mal	3.36	-5	5	Fixed	No_prior
RecrDist_GP_1	0	-3	3	Fixed	No_prior
RecrDist_Area_1	0	-3	3	Fixed	No_prior
RecrDist_Bseas_1	1	0	999	Fixed	No_prior
CohortGrowDev	0	0	0	Fixed	No_prior
FracFemale_GP_1	0.5	0.000001	0.999999	Fixed	No_prior
SR_LN(R0)	8.49309	5	15	0.11683	No_prior
SR_BH_steep	0.7	0.2	1	Fixed	No_prior
SR_sigmaR	0.75	0	2	Fixed	No_prior
SR_regime	0	-5	5	Fixed	No_prior
SR_autocorr	0	0	2	Fixed	No_prior
LnQ_base_1_CA_TRAWL(1)	-1.53461	-15	15	Fixed	No_prior
Q_extraSD_1_CA_TRAWL(1)	0.0459027	0.001	2	0.02565	No_prior
LnQ_base_4_CA_TRI_Early(4)	-0.16492	-15	15	Fixed	No_prior
LnQ_base_5_CA_TRI_Late(5)	0.222239	-15	15	Fixed	No_prior
LnQ_base_6_CA_NWFSC(6)	0.151513	-15	15	Fixed	No_prior
LnQ_base_7_CA_HookLine(7)	-11.6401	-15	15	Fixed	No_prior
SizeSel_P1_1_CA_TRAWL(1)	60.1518	14	100	2.26135	No_prior
SizeSel_P2_1_CA_TRAWL(1)	-15	-6	4	Fixed	No_prior
SizeSel_P3_1_CA_TRAWL(1)	7	-5	15	Fixed	No_prior

SizeSel_P4_1_CA_TRAWL(1)	13.0712	-5	15	36.8752	No_prior
SizeSel_P5_1_CA_TRAWL(1)	-999	-5	9	Fixed	No_prior
SizeSel_P6_1_CA_TRAWL(1)	-999	-5	9	Fixed	No_prior
Retain_P1_1_CA_TRAWL(1)	60.4119	10	100	3.39629	No_prior
Retain_P2_1_CA_TRAWL(1)	9	0.1	15	Fixed	No_prior
Retain_P3_1_CA_TRAWL(1)	2	0.001	1	Fixed	No_prior
Retain_P4_1_CA_TRAWL(1)	0	-2	2	Fixed	No_prior
DiscMort_P1_1_CA_TRAWL(1)	0	-1	1	Fixed	No_prior
DiscMort_P2_1_CA_TRAWL(1)	1.00E-04	-1	1	Fixed	No_prior
DiscMort_P3_1_CA_TRAWL(1)	0.5	0.001	1	Fixed	No_prior
DiscMort_P4_1_CA_TRAWL(1)	0	-2	2	Fixed	No_prior
SzSel_Male_Peak_1_CA_TRAWL(1)	-3.40204	-30	15	4.14287	No_prior
SzSel_Male_Ascend_1_CA_TRAWL(1)	3.16188	-15	15	0.921592	No_prior
SzSel_Male_Descend_1_CA_TRAWL(1)	-1.24978	-15	15	0.577689	No_prior
SzSel_Male_Final_1_CA_TRAWL(1)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_1_CA_TRAWL(1)	1	-15	15	Fixed	No_prior
SizeSel_P1_2_CA_FIX(2)	85.5639	14	100	1.26771	No_prior
SizeSel_P2_2_CA_FIX(2)	-15	-6	4	Fixed	No_prior
SizeSel_P3_2_CA_FIX(2)	7.53682	-5	15	0.696182	No_prior
SizeSel_P4_2_CA_FIX(2)	5.59902	-5	15	0.793539	No_prior
SizeSel_P5_2_CA_FIX(2)	-999	-5	9	Fixed	No_prior
SizeSel_P6_2_CA_FIX(2)	-999	-5	9	Fixed	No_prior
Retain_P1_2_CA_FIX(2)	51.6181	10	100	1.89667	No_prior
Retain_P2_2_CA_FIX(2)	2.36616	0.1	10	0.682729	No_prior
Retain_P3_2_CA_FIX(2)	1	0.001	1	Fixed	No_prior
Retain_P4_2_CA_FIX(2)	0	-2	2	Fixed	No_prior
DiscMort_P1_2_CA_FIX(2)	0	-1	1	Fixed	No_prior
DiscMort_P2_2_CA_FIX(2)	0.0001	-1	1	Fixed	No_prior
DiscMort_P3_2_CA_FIX(2)	0.07	0.001	1	Fixed	No_prior
DiscMort_P4_2_CA_FIX(2)	0	-2	2	Fixed	No_prior
SzSel_Male_Peak_2_CA_FIX(2)	-22	-30	20	Fixed	No_prior
SzSel_Male_Ascend_2_CA_FIX(2)	-1.66525	-15	15	0.283987	No_prior
SzSel_Male_Descend_2_CA_FIX(2)	0.284651	-15	15	0.375479	No_prior
SzSel_Male_Final_2_CA_FIX(2)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_2_CA_FIX(2)	1	-15	15	Fixed	No_prior
SizeSel_P1_3_CA_REC(3)	62.5	35	100	Fixed	No_prior
SizeSel_P2_3_CA_REC(3)	-15	-16	1	Fixed	No_prior
SizeSel_P3_3_CA_REC(3)	5.8	-1	15	Fixed	No_prior
SizeSel_P4_3_CA_REC(3)	7.2	-1	15	Fixed	No_prior
SizeSel_P5_3_CA_REC(3)	-999	-5	9	Fixed	No_prior
SizeSel_P6_3_CA_REC(3)	-999	-5	9	Fixed	No_prior
SizeSel_P1_4_CA_TRI_Early(4)	38.7654	10	100	4.40268	No_prior
SizeSel_P2_4_CA_TRI_Early(4)	-15	-6	4	Fixed	No_prior

SizeSel_P3_4_CA_TRI_Early(4)	5.39489	-1	15	0.532214	No_prior
SizeSel_P4_4_CA_TRI_Early(4)	14.2259	-1	15	18.5576	No_prior
SizeSel_P5_4_CA_TRI_Early(4)	-999	-5	9	Fixed	No_prior
SizeSel_P6_4_CA_TRI_Early(4)	-999	-5	9	Fixed	No_prior
SizeSel_P1_5_CA_TRI_Late(5)	24.9651	14	70	1.92705	No_prior
SizeSel_P2_5_CA_TRI_Late(5)	-15	-6	4	Fixed	No_prior
SizeSel_P3_5_CA_TRI_Late(5)	1.18281	-5	15	1.84467	No_prior
SizeSel_P4_5_CA_TRI_Late(5)	10.3673	-1	15	2.09671	No_prior
SizeSel_P5_5_CA_TRI_Late(5)	-999	-5	9	Fixed	No_prior
SizeSel_P6_5_CA_TRI_Late(5)	-999	-5	9	Fixed	No_prior
SizeSel_P1_6_CA_NWFSC(6)	2.70E+01	5	30	6.17249	No_prior
SizeSel_P2_6_CA_NWFSC(6)	-15	-12	4	Fixed	No_prior
SizeSel_P3_6_CA_NWFSC(6)	4.82267	-1	15	1.36051	No_prior
SizeSel_P4_6_CA_NWFSC(6)	7.91397	-1	15	0.355013	No_prior
SizeSel_P5_6_CA_NWFSC(6)	-999	-5	9	Fixed	No_prior
SizeSel_P6_6_CA_NWFSC(6)	-999	-5	9	Fixed	No_prior
SizeSel_P1_7_CA_HookLine(7)	65.7369	35	100	4.48331	No_prior
SizeSel_P2_7_CA_HookLine(7)	-15	-6	4	Fixed	No_prior
SizeSel_P3_7_CA_HookLine(7)	5.46627	-6	15	0.488622	No_prior
SizeSel_P4_7_CA_HookLine(7)	6.8853	-6	15	0.790743	No_prior
SizeSel_P5_7_CA_HookLine(7)	-999	-5	9	Fixed	No_prior
SizeSel_P6_7_CA_HookLine(7)	-999	-5	9	Fixed	No_prior
SzSel_Male_Peak_7_CA_HookLine(7)	-9.8533	-30	40	7.23756	No_prior
SzSel_Male_Ascend_7_CA_HookLine(7)	-0.101812	-15	15	0.779511	No_prior
SzSel_Male_Descend_7_CA_HookLine(7)	-1.98247	-15	15	1.18987	No_prior
SzSel_Male_Final_7_CA_HookLine(7)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_7_CA_HookLine(7)	1	-15	15	Fixed	No_prior
SizeSel_P1_8_CA_Lam_Research(8)	90.9412	35	100	0.0304565	No_prior
SizeSel_P2_8_CA_Lam_Research(8)	-15	-6	4	Fixed	No_prior
SizeSel_P3_8_CA_Lam_Research(8)	6.5544	-6	15	0.0778421	No_prior
SizeSel_P4_8_CA_Lam_Research(8)	-5.6	-6	15	Fixed	No_prior
SizeSel_P5_8_CA_Lam_Research(8)	-999	-5	9	Fixed	No_prior
SizeSel_P6_8_CA_Lam_Research(8)	-999	-5	9	Fixed	No_prior
SzSel_Male_Peak_8_CA_Lam_Research(8)	-27.4041	-30	40	Fixed	No_prior
SzSel_Male_Ascend_8_CA_Lam_Research(8)	-1.19576	-15	15	0.103804	No_prior
SzSel_Male_Descend_8_CA_Lam_Research(8)	9.66269	-15	15	0.238694	No_prior
SzSel_Male_Final_8_CA_Lam_Research(8)	0	-15	15	Fixed	No_prior
SzSel_Male_Scale_8_CA_Lam_Research(8)	1	-15	15	Fixed	No_prior
AgeSel_P1_1_CA_TRAWL(1)	0.1	0	1	Fixed	No_prior
AgeSel_P2_1_CA_TRAWL(1)	100	0	101	Fixed	No_prior
AgeSel_P1_2_CA_FIX(2)	0.1	0	1	Fixed	No_prior
AgeSel_P2_2_CA_FIX(2)	100	0	101	Fixed	No_prior
AgeSel_P1_3_CA_REC(3)	0.1	0	1	Fixed	No_prior

AgeSel_P2_3_CA_REC(3)	100	0	101	Fixed	No_prior
AgeSel_P1_4_CA_TRI_Early(4)	0.1	0	1	Fixed	No_prior
AgeSel_P2_4_CA_TRI_Early(4)	100	0	101	Fixed	No_prior
AgeSel_P1_5_CA_TRI_Late(5)	0.1	0	1	Fixed	No_prior
AgeSel_P2_5_CA_TRI_Late(5)	100	0	101	Fixed	No_prior
AgeSel_P1_6_CA_NWFSC(6)	0.1	0	1	Fixed	No_prior
AgeSel_P2_6_CA_NWFSC(6)	100	0	101	Fixed	No_prior
AgeSel_P1_7_CA_HookLine(7)	0.1	0	1	Fixed	No_prior
AgeSel_P2_7_CA_HookLine(7)	100	0	101	Fixed	No_prior
AgeSel_P1_8_CA_Lam_Research(8)	0.1	0	1	Fixed	No_prior
AgeSel_P2_8_CA_Lam_Research(8)	100	0	101	Fixed	No_prior
SizeSel_P3_1_CA_TRAWL(1)_BLK3repl_1973	7	-5	15	Fixed	No_prior
SizeSel_P3_1_CA_TRAWL(1)_BLK3repl_1983	7.52422	-5	15	1.06219	No_prior
SizeSel_P3_1_CA_TRAWL(1)_BLK3repl_1993	7.09913	-5	15	1.13626	No_prior
SizeSel_P3_1_CA_TRAWL(1)_BLK3repl_2003	3.37165	-5	15	0.940105	No_prior
SizeSel_P3_1_CA_TRAWL(1)_BLK3repl_2011	2.95757	-5	15	0.92669	No_prior
SizeSel_P4_1_CA_TRAWL(1)_BLK3repl_1973	14.405	-5	15	14.9785	No_prior
SizeSel_P4_1_CA_TRAWL(1)_BLK3repl_1983	6.27737	-5	15	0.370226	No_prior
SizeSel_P4_1_CA_TRAWL(1)_BLK3repl_1993	6.75968	-5	15	0.363754	No_prior
SizeSel_P4_1_CA_TRAWL(1)_BLK3repl_2003	6.43832	-5	15	0.27952	No_prior
SizeSel_P4_1_CA_TRAWL(1)_BLK3repl_2011	7.98343	-5	15	0.573227	No_prior
Retain_P1_1_CA_TRAWL(1)_BLK2repl_1998	66.6014	10	100	0.890228	No_prior
Retain_P1_1_CA_TRAWL(1)_BLK2repl_2007	67.3433	10	100	1.5386	No_prior
Retain_P1_1_CA_TRAWL(1)_BLK2repl_2010	56.4308	10	100	3.61753	No_prior
Retain_P1_1_CA_TRAWL(1)_BLK2repl_2011	56.5342	10	100	0.676295	No_prior
Retain_P2_1_CA_TRAWL(1)_BLK2repl_1998	3.5	0.1	10	Fixed	No_prior
Retain_P2_1_CA_TRAWL(1)_BLK2repl_2007	2.88695	0.1	10	1.10367	No_prior
Retain_P2_1_CA_TRAWL(1)_BLK2repl_2010	0.717526	0.1	10	2.02997	No_prior
Retain_P2_1_CA_TRAWL(1)_BLK2repl_2011	1.41886	0.1	10	0.399397	No_prior
SizeSel_P3_2_CA_FIX(2)_BLK1repl_1998	8.1	-5	15	Fixed	No_prior
SizeSel_P3_2_CA_FIX(2)_BLK1repl_2002	5.21908	-5	15	0.402242	No_prior
SizeSel_P3_2_CA_FIX(2)_BLK1repl_2003	6.72597	-5	15	0.112117	No_prior
SizeSel_P3_2_CA_FIX(2)_BLK1repl_2011	6.41842	-5	15	0.0960195	No_prior
SizeSel_P4_2_CA_FIX(2)_BLK1repl_1998	6.4	-5	15	Fixed	No_prior
SizeSel_P4_2_CA_FIX(2)_BLK1repl_2002	6.26952	-5	15	2.32721	No_prior
SizeSel_P4_2_CA_FIX(2)_BLK1repl_2003	4.75209	-5	15	0.396613	No_prior
SizeSel_P4_2_CA_FIX(2)_BLK1repl_2011	4.6785	-5	15	0.419886	No_prior
Retain_P1_2_CA_FIX(2)_BLK1repl_1998	61.3714	10	100	2.01447	No_prior
Retain_P1_2_CA_FIX(2)_BLK1repl_2002	30.3033	10	100	418.065	No_prior
Retain_P1_2_CA_FIX(2)_BLK1repl_2003	59.735	10	100	0.484091	No_prior
Retain_P1_2_CA_FIX(2)_BLK1repl_2011	59.5812	10	100	0.406052	No_prior
Retain_P2_2_CA_FIX(2)_BLK1repl_1998	2.46793	0.1	10	0.93287	No_prior
Retain_P2_2_CA_FIX(2)_BLK1repl_2002	2.06227	0.1	10	40.4422	No_prior

Retain_P2_2_CA_FIX(2)_BLK1repl_2003	0.9633	0.1	10	0.331465	No_prior
Retain_P2_2_CA_FIX(2)_BLK1repl_2011	1.03193	0.1	10	0.267353	No_prior
SizeSel_P1_3_CA_REC(3)_BLK4repl_1959	67.9434	20	100	5.37741	No_prior
SizeSel_P1_3_CA_REC(3)_BLK4repl_1975	69.8087	20	100	5.96763	No_prior
SizeSel_P1_3_CA_REC(3)_BLK4repl_1990	62.9961	20	100	1.31172	No_prior
SizeSel_P1_3_CA_REC(3)_BLK4repl_2004	62.6001	20	100	0.571921	No_prior
SizeSel_P3_3_CA_REC(3)_BLK4repl_1959	5.79739	-1	15	0.403138	No_prior
SizeSel_P3_3_CA_REC(3)_BLK4repl_1975	5.60189	-1	15	0.442773	No_prior
SizeSel_P3_3_CA_REC(3)_BLK4repl_1990	3.9863	-1	15	0.28373	No_prior
SizeSel_P3_3_CA_REC(3)_BLK4repl_2004	3.93701	-1	15	0.134673	No_prior
SizeSel_P4_3_CA_REC(3)_BLK4repl_1959	7.10632	-1	15	0.780214	No_prior
SizeSel_P4_3_CA_REC(3)_BLK4repl_1975	6.58471	-1	15	1.30567	No_prior
SizeSel_P4_3_CA_REC(3)_BLK4repl_1990	6.53554	-1	15	0.443927	No_prior
SizeSel_P4_3_CA_REC(3)_BLK4repl_2004	5.85501	-1	15	0.123925	No_prior

Table 8. Time series of population estimates from the north base case.

Year	Total Biomass (mt)	Spawning Biomass	Total Biomass 3+ (mt)	Deple-tion (%)	Age-0 Recruits	Total Landings (mt)	(1-SPR)/ (1-SPR_45%)	Relative Exploitation Rate
1889	58,746	37,974	56,005	100	8,664	110	0.025	0.002
1890	58,640	37,904	55,899	99.8	8,662	114	0.026	0.002
1891	58,540	37,834	55,799	99.6	8,660	117	0.027	0.002
1892	58,449	37,768	55,708	99.5	8,659	160	0.037	0.003
1893	58,327	37,682	55,587	99.2	8,656	127	0.029	0.002
1894	58,253	37,625	55,513	99.1	8,655	127	0.029	0.002
1895	58,189	37,576	55,450	99	8,654	139	0.032	0.002
1896	58,124	37,527	55,385	98.8	8,652	167	0.038	0.003
1897	58,041	37,466	55,302	98.7	8,651	167	0.038	0.003
1898	57,968	37,411	55,230	98.5	8,649	72	0.017	0.001
1899	57,997	37,424	55,259	98.6	8,650	46	0.011	0.001
1900	58,051	37,457	55,314	98.6	8,650	58	0.013	0.001
1901	58,089	37,482	55,352	98.7	8,651	59	0.014	0.001
1902	58,122	37,504	55,385	98.8	8,652	61	0.014	0.001
1903	58,150	37,524	55,412	98.8	8,652	62	0.014	0.001
1904	58,173	37,540	55,435	98.9	8,652	74	0.017	0.001
1905	58,180	37,547	55,442	98.9	8,652	59	0.013	0.001
1906	58,200	37,562	55,462	98.9	8,652	60	0.014	0.001
1907	58,217	37,574	55,479	98.9	8,653	61	0.014	0.001
1908	58,230	37,584	55,492	99	8,653	45	0.01	0.001
1909	58,255	37,603	55,517	99	8,653	196	0.045	0.004
1910	58,133	37,523	55,395	98.8	8,651	198	0.045	0.004
1911	58,020	37,446	55,282	98.6	8,648	199	0.045	0.004
1912	57,918	37,373	55,181	98.4	8,646	200	0.046	0.004
1913	57,827	37,307	55,090	98.2	8,644	201	0.046	0.004
1914	57,746	37,247	55,010	98.1	8,642	203	0.047	0.004
1915	57,675	37,194	54,940	97.9	8,640	353	0.08	0.006
1916	57,469	37,051	54,735	97.6	8,635	515	0.116	0.009
1917	57,130	36,816	54,397	97	8,628	517	0.117	0.009
1918	56,826	36,598	54,094	96.4	8,622	679	0.153	0.013
1919	56,403	36,298	53,673	95.6	8,613	227	0.053	0.004
1920	56,461	36,314	53,734	95.6	8,612	180	0.042	0.003
1921	56,573	36,376	53,848	95.8	8,612	168	0.039	0.003
1922	56,692	36,450	53,967	96	8,612	94	0.022	0.002
1923	56,871	36,569	54,146	96.3	8,612	84	0.019	0.002
1924	57,040	36,687	54,315	96.6	8,613	198	0.046	0.004
1925	57,078	36,720	54,353	96.7	8,610	264	0.061	0.005
1926	57,041	36,702	54,316	96.7	8,606	299	0.068	0.006

1927	56,968	36,658	54,244	96.5	8,601	367	0.084	0.007
1928	56,831	36,569	54,108	96.3	8,594	295	0.068	0.005
1929	56,774	36,530	54,053	96.2	8,588	586	0.133	0.011
1930	56,443	36,307	53,724	95.6	8,576	539	0.124	0.010
1931	56,186	36,124	53,470	95.1	8,565	271	0.064	0.005
1932	56,213	36,131	53,500	95.1	8,558	271	0.063	0.005
1933	56,241	36,146	53,531	95.2	8,550	417	0.097	0.008
1934	56,126	36,066	53,419	95	8,539	565	0.131	0.011
1935	55,877	35,888	53,173	94.5	8,525	598	0.139	0.011
1936	55,617	35,698	52,916	94	8,510	802	0.184	0.015
1937	55,185	35,387	52,489	93.2	8,492	841	0.195	0.016
1938	54,757	35,067	52,066	92.3	8,472	1,408	0.311	0.027
1939	53,825	34,422	51,141	90.6	8,441	1,230	0.283	0.024
1940	53,160	33,917	50,483	89.3	8,413	1,746	0.389	0.035
1941	52,086	33,107	49,420	87.2	8,373	1,617	0.371	0.033
1942	51,245	32,459	48,589	85.5	8,334	2,232	0.492	0.046
1943	49,924	31,454	47,282	82.8	8,281	2,017	0.464	0.043
1944	48,942	30,677	46,314	80.8	8,232	2,959	0.634	0.064
1945	47,189	29,334	44,580	77.2	8,159	2,095	0.502	0.047
1946	46,416	28,701	43,823	75.6	8,107	2,693	0.616	0.061
1947	45,170	27,752	42,599	73.1	8,039	1,453	0.386	0.034
1948	45,202	27,741	42,646	73.1	8,003	2,139	0.528	0.050
1949	44,597	27,294	42,062	71.9	7,947	1,789	0.46	0.043
1950	44,355	27,133	41,831	71.5	7,900	1,671	0.44	0.040
1951	44,233	27,049	41,727	71.2	7,853	1,906	0.491	0.046
1952	43,880	26,805	41,389	70.6	7,797	1,410	0.384	0.034
1953	43,989	26,910	41,512	70.9	7,748	662	0.196	0.016
1954	44,763	27,504	42,302	72.4	7,713	1,049	0.293	0.025
1955	45,070	27,781	42,624	73.2	7,661	1,910	0.486	0.045
1956	44,490	27,400	42,060	72.2	7,585	1,431	0.388	0.034
1957	44,346	27,330	41,932	72	7,528	1,517	0.408	0.036
1958	44,083	27,179	41,691	71.6	7,497	1,667	0.443	0.040
1959	43,656	26,903	41,281	70.8	7,522	2,590	0.628	0.063
1960	42,368	25,975	40,001	68.4	7,610	2,993	0.711	0.075
1961	40,802	24,808	38,423	65.3	7,750	2,867	0.71	0.075
1962	39,527	23,804	37,115	62.7	8,036	1,709	0.498	0.046
1963	39,551	23,697	37,072	62.4	9,466	1,282	0.395	0.035
1964	40,248	23,965	37,562	63.1	14,411	1,974	0.552	0.053
1965	40,921	23,834	37,557	62.8	12,128	2,246	0.607	0.060
1966	42,315	23,700	37,973	62.4	8,822	2,522	0.651	0.066
1967	43,976	23,934	40,419	63	8,231	3,873	0.846	0.096
1968	44,175	24,198	41,441	63.7	8,770	4,503	0.921	0.109
1969	43,314	24,325	40,671	64.1	10,435	2,564	0.644	0.063

1970	44,009	25,254	41,106	66.5	11,207	1,753	0.473	0.043
1971	45,464	26,221	42,121	69	9,315	1,947	0.502	0.046
1972	46,765	26,869	43,390	70.8	7,471	1,884	0.477	0.043
1973	47,866	27,706	45,077	73	6,652	2,738	0.626	0.061
1974	47,543	28,098	45,252	74	6,600	3,107	0.685	0.069
1975	46,189	27,974	44,102	73.7	5,746	3,036	0.683	0.069
1976	44,327	27,349	42,316	72	5,380	2,904	0.68	0.069
1977	42,150	26,318	40,347	69.3	8,249	2,767	0.677	0.069
1978	40,072	25,071	38,054	66	21,554	2,274	0.611	0.060
1979	39,617	23,935	36,002	63	15,340	3,615	0.862	0.100
1980	40,150	21,874	33,880	57.6	12,100	3,745	0.897	0.111
1981	42,192	20,898	37,662	55	6,425	3,874	0.894	0.103
1982	44,266	22,142	40,893	58.3	8,798	4,957	0.992	0.121
1983	44,311	23,613	42,130	62.2	5,062	9,221	1.384	0.219
1984	38,560	21,768	36,121	57.3	5,922	8,013	1.398	0.222
1985	32,771	18,857	31,023	49.7	21,909	7,601	1.479	0.245
1986	27,683	15,390	24,718	40.5	3,141	3,166	1.101	0.128
1987	28,390	14,369	23,019	37.8	4,866	4,478	1.306	0.195
1988	27,730	13,418	26,604	35.3	6,629	5,004	1.343	0.188
1989	25,794	13,688	24,141	36	6,928	6,434	1.497	0.267
1990	21,939	12,040	19,787	31.7	18,786	4,755	1.441	0.240
1991	20,403	10,314	17,348	27.2	14,615	6,577	1.64	0.379
1992	18,841	7,667	13,500	20.2	8,559	4,214	1.501	0.312
1993	20,771	7,391	16,772	19.5	4,749	7,215	1.639	0.430
1994	19,317	7,567	17,006	19.9	6,802	5,902	1.555	0.347
1995	17,686	8,006	16,085	21.1	4,476	3,639	1.324	0.226
1996	17,295	8,527	15,378	22.5	3,598	3,675	1.357	0.239
1997	16,180	8,234	14,860	21.7	4,079	3,278	1.347	0.221
1998	14,893	7,848	13,746	20.7	3,149	610	0.45	0.044
1999	15,971	8,772	14,746	23.1	5,024	627	0.432	0.043
2000	16,911	9,521	15,752	25.1	7,374	261	0.184	0.017
2001	18,409	10,371	16,641	27.3	6,482	268	0.177	0.016
2002	20,311	11,129	18,068	29.3	3,858	401	0.251	0.022
2003	22,225	12,015	20,392	31.6	2,927	411	0.229	0.020
2004	23,788	13,331	22,636	35.1	3,861	426	0.214	0.019
2005	24,752	14,711	23,760	38.7	2,892	502	0.237	0.021
2006	25,094	15,569	23,945	41	3,664	544	0.266	0.023
2007	24,955	15,833	23,974	41.7	4,460	459	0.235	0.019
2008	24,784	15,842	23,493	41.7	14,491	480	0.262	0.020
2009	25,227	15,627	23,078	41.2	6,292	424	0.244	0.018
2010	26,973	15,441	23,041	40.7	6,671	343	0.193	0.015
2011	29,373	15,912	27,371	41.9	4,058	611	0.282	0.022
2012	31,384	17,522	29,480	46.1	4,319	748	0.291	0.025

2013	32,650	19,235	31,302	50.7	10,580	813	0.286	0.026
2014	33,473	20,366	31,650	53.6	4,851	632	0.218	0.020
2015	34,564	20,939	31,634	55.1	10,322	677	0.232	0.021
2016	35,708	21,258	33,759	56	7,516	723	0.25	0.021
2017	37,110	21,976	34,064	57.9	8,037	4,838	1.058	0.142
2018	34,730	20,113	32,319	53	7,911	4,510	1.06	0.140
2019	32,939	18,809	30,415	49.5	7,811	4,080	1.035	0.134
2020	31,746	17,970	29,260	47.3	7,741	3,954	1.035	0.135
2021	30,793	17,268	28,336	45.5	7,677	3,855	1.035	0.136
2022	30,017	16,699	27,581	44	7,623	3,773	1.035	0.137
2023	29,376	16,235	26,959	42.8	7,577	3,704	1.035	0.137
2024	28,843	15,851	26,443	41.7	7,537	3,645	1.035	0.138
2025	28,397	15,532	26,011	40.9	7,502	3,594	1.035	0.138
2026	28,021	15,266	25,647	40.2	7,473	3,550	1.035	0.138

Table 9. Time series of population estimates from the south base case.

Year	Total Biomass (mt)	Spawning Biomass	Total Biomass 3+ (mt)	Deple-tion (%)	Age-0 Recruits	Total Catch (mt)	(1-SPR)/ (1-SPR_45%)	Relative Exploitation Rate
1889	33,103	20,462	31,547	1	4,881	0	0	0
1890	33,103	20,462	31,547	1	4,881	25.11434	0.0113753	0.000796084
1891	33,079	20,445	31,523	0.9991936	4,881	50.2302	0.0226774	0.00159343
1892	33,032	20,413	31,477	0.9976199	4,880	75.35	0.0339315	0.00239384
1893	32,964	20,366	31,409	0.9953376	4,879	100.4761	0.0451589	0.00319893
1894	32,877	20,306	31,323	0.9924102	4,877	125.6114	0.0563773	0.00401015
1895	32,774	20,235	31,221	0.988911	4,875	150.7582	0.0676002	0.00482875
1896	32,656	20,153	31,104	0.9849084	4,873	175.9185	0.0788381	0.0056558
1897	32,525	20,062	30,975	0.9804611	4,871	201.0939	0.0900989	0.00649219
1898	32,384	19,963	30,835	0.9756325	4,868	226.2857	0.101389	0.00733872
1899	32,233	19,858	30,685	0.9704765	4,866	251.4959	0.112712	0.00819603
1900	32,074	19,746	30,528	0.9650273	4,863	276.7246	0.124073	0.00906472
1901	31,909	19,630	30,363	0.9593387	4,859	301.972	0.135475	0.00994532
1902	31,737	19,509	30,193	0.953435	4,856	327.24	0.14692	0.0108383
1903	31,560	19,384	30,018	0.9473455	4,853	352.529	0.15841	0.0117441
1904	31,378	19,256	29,838	0.9410948	4,849	377.84	0.169947	0.0126632
1905	31,193	19,126	29,654	0.9347073	4,846	403.172	0.181532	0.0135959
1906	31,004	18,993	29,467	0.9281976	4,842	428.527	0.193168	0.0145428
1907	30,812	18,857	29,276	0.9215803	4,838	453.906	0.204855	0.0155042
1908	30,617	18,720	29,083	0.9148702	4,834	479.308	0.216595	0.0164805
1909	30,420	18,581	28,888	0.9080722	4,830	504.734	0.228389	0.0174722
1910	30,220	18,440	28,690	0.9012008	4,826	530.186	0.240239	0.0184798
1911	30,019	18,298	28,490	0.8942561	4,822	555.662	0.252144	0.0195036
1912	29,815	18,155	28,289	0.8872528	4,818	581.166	0.264107	0.0205442
1913	29,610	18,010	28,085	0.8801859	4,814	606.696	0.276128	0.0216021
1914	29,402	17,865	27,880	0.8730702	4,810	632.254	0.28821	0.0226778
1915	29,194	17,718	27,673	0.8659007	4,805	657.84	0.300352	0.0237717
1916	28,984	17,570	27,465	0.8586823	4,801	683.454	0.312557	0.0248846
1917	28,772	17,422	27,255	0.85142	4,797	709.099	0.324826	0.026017
1918	28,559	17,272	27,044	0.8441185	4,792	734.775	0.33716	0.0271694
1919	28,344	17,122	26,832	0.8367731	4,788	760.482	0.34956	0.0283426
1920	28,128	16,971	26,618	0.8293837	4,783	786.223	0.362027	0.0295372
1921	27,911	16,819	26,403	0.8219601	4,779	811.996	0.374564	0.0307538
1922	27,693	16,666	26,187	0.8144973	4,775	837.805	0.387172	0.0319934
1923	27,473	16,513	25,969	0.8069955	4,770	863.648	0.399851	0.0332565
1924	27,252	16,358	25,751	0.7994595	4,766	889.529	0.412604	0.034544
1925	27,030	16,203	25,531	0.7918892	4,761	915.448	0.425432	0.0358567
1926	26,807	16,048	25,310	0.7842848	4,757	941.406	0.438336	0.0371956

1927	26,583	15,891	25,087	0.7766412	4,753	967.406	0.451318	0.0385615
1928	26,357	15,734	24,864	0.7689684	4,749	993.448	0.464379	0.0399553
1929	26,130	15,577	24,640	0.7612613	4,744	1022.414	0.478661	0.041495
1930	25,900	15,417	24,411	0.7534418	4,741	1051.437	0.493064	0.0430723
1931	25,665	15,254	24,179	0.7455001	4,737	1080.503	0.507585	0.0446882
1932	25,427	15,089	23,943	0.7374461	4,733	776.896	0.388749	0.032448
1933	25,510	15,136	24,022	0.7397381	4,740	1287.099	0.585453	0.0535791
1934	25,106	14,864	23,623	0.7264059	4,733	735.088	0.374299	0.0311175
1935	25,268	14,963	23,781	0.7312589	4,743	890.498	0.437723	0.0374453
1936	25,286	14,970	23,798	0.7316303	4,750	710.433	0.361148	0.0298533
1937	25,484	15,097	23,991	0.7378028	4,763	866.409	0.424436	0.0361139
1938	25,529	15,124	24,033	0.7391566	4,772	826.374	0.408187	0.0343846
1939	25,609	15,171	24,109	0.7414193	4,783	573.684	0.295854	0.0237957
1940	25,937	15,383	24,429	0.7518095	4,802	682.25	0.340882	0.027928
1941	26,146	15,520	24,634	0.7585098	4,818	558.114	0.283457	0.0226565
1942	26,463	15,728	24,944	0.7686556	4,836	310.707	0.163307	0.012456
1943	27,006	16,084	25,477	0.7860735	4,861	667.871	0.322717	0.0262148
1944	27,169	16,194	25,637	0.7914396	4,876	672.488	0.323028	0.026231
1945	27,308	16,287	25,773	0.7959505	4,895	661.115	0.317173	0.0256513
1946	27,444	16,375	25,903	0.800261	4,921	1080.46	0.480497	0.0417114
1947	27,161	16,186	25,620	0.7910389	4,953	2032.583	0.784736	0.0793367
1948	25,963	15,390	24,428	0.7521565	4,988	1809.1	0.74593	0.074058
1949	25,063	14,781	23,526	0.7223642	5,071	1502.177	0.670542	0.0638524
1950	24,554	14,415	22,998	0.7044771	5,201	1555.107	0.695532	0.0676187
1951	24,101	14,076	22,517	0.6879096	5,281	1371.774	0.640971	0.0609225
1952	23,940	13,920	22,322	0.6803149	5,248	1578.187	0.718054	0.0707012
1953	23,669	13,674	22,029	0.6682485	5,022	1343.999	0.641201	0.0610102
1954	23,698	13,653	22,081	0.6672417	4,731	1415.765	0.664536	0.0641158
1955	23,656	13,647	22,116	0.666968	4,584	838.9273	0.437152	0.0379337
1956	24,122	14,027	22,654	0.6855002	4,248	1461.754	0.666775	0.0645242
1957	23,847	13,956	22,443	0.6820694	3,264	1414.437	0.655769	0.0630228
1958	23,406	13,843	22,169	0.6765518	3,279	1380.068	0.652431	0.0622515
1959	22,748	13,644	21,732	0.6668117	4,425	1176.486	0.582433	0.054135
1960	22,174	13,404	21,055	0.6550629	5,440	1037.3285	0.539564	0.0492682
1961	21,841	13,084	20,374	0.6394483	6,201	1141.105	0.593405	0.0560073
1962	21,716	12,683	19,957	0.6198556	3,591	930.927	0.513358	0.0466475
1963	21,971	12,625	20,256	0.6170064	3,822	1005.898	0.542328	0.0496584
1964	22,149	12,814	21,007	0.6262432	3,899	774.6593	0.43022	0.036877
1965	22,435	13,231	21,229	0.6466032	3,753	857.6251	0.456685	0.0403979
1966	22,473	13,407	21,260	0.6552388	4,399	969.559	0.500655	0.0456053
1967	22,306	13,343	21,071	0.6520866	4,708	1065.7111	0.545767	0.0505765
1968	22,062	13,128	20,655	0.6415791	4,756	1125.3459	0.578957	0.0544837
1969	21,858	12,872	20,380	0.6290973	4,052	1111.2499	0.581658	0.0545272

1970	21,734	12,717	20,308	0.621488	3,944	1552.3171	0.748668	0.0764399
1971	21,180	12,399	19,931	0.6059418	3,486	1993.724	0.899131	0.10003
1972	20,131	11,833	18,956	0.5783097	4,370	2935.56	1.15038	0.15486
1973	18,164	10,631	17,041	0.5195609	6,448	3120.505	1.24213	0.18312
1974	16,297	9,275	14,837	0.4532771	6,381	3398.981	1.35172	0.229082
1975	14,609	7,830	12,749	0.3826539	4,545	3237.958	1.39064	0.253984
1976	13,400	6,811	11,717	0.3328575	7,633	3186.869	1.42489	0.271998
1977	12,635	6,231	11,090	0.3045177	6,289	2005.8129	1.20636	0.180866
1978	13,333	6,477	11,215	0.316524	2,684	2408.875	1.27335	0.214794
1979	13,580	6,645	12,015	0.3247291	7,188	3261.627	1.41351	0.271468
1980	12,962	6,503	11,826	0.3177893	2,923	3465.162	1.45294	0.293014
1981	11,882	5,994	10,189	0.2929527	2,155	2992.9027	1.42397	0.293741
1982	10,849	5,550	10,077	0.2712199	2,040	2849.3257	1.44563	0.282761
1983	9,516	5,131	8,916	0.2507446	3,572	2173.3862	1.48081	0.243765
1984	8,438	4,691	7,781	0.2292639	11,962	2024.5862	1.5376	0.260205
1985	8,007	3,992	6,489	0.1950894	8,563	2264.8172	1.59982	0.349012
1986	8,117	3,248	5,388	0.1587366	4,724	2046.828	1.55916	0.379902
1987	8,901	3,310	6,947	0.1617554	4,541	2711.796	1.60546	0.390363
1988	9,001	3,785	7,784	0.1849724	2,589	2853.924	1.58466	0.366651
1989	8,422	3,958	7,405	0.1934121	4,233	2935.384	1.60983	0.396395
1990	7,295	3,564	6,509	0.1741546	2,485	2432.989	1.60189	0.373794
1991	6,279	3,059	5,342	0.1495086	5,284	2081.54	1.61064	0.389625
1992	5,595	2,593	4,757	0.1267099	1,035	1808.198	1.60601	0.380152
1993	5,074	2,271	4,039	0.1110089	1,802	1620.404	1.60092	0.401179
1994	4,545	2,116	4,218	0.1034362	2,950	1177.347	1.49533	0.279112
1995	4,355	2,153	3,788	0.1052141	1,161	1085.209	1.4595	0.286488
1996	4,142	2,030	3,479	0.0992332	3,250	1091.965	1.49327	0.313862
1997	3,967	1,877	3,479	0.0917529	1,184	1073.521	1.52335	0.308574
1998	3,788	1,770	3,066	0.0864992	946	551.316	1.1615	0.179831
1999	4,035	1,959	3,712	0.095757	5,225	638.1541	1.17601	0.171896
2000	4,448	2,156	3,806	0.1053725	3,066	337.6673	0.708607	0.0887114
2001	5,454	2,453	4,025	0.1199045	2,408	328.2299	0.636951	0.0815566
2002	6,668	2,938	5,761	0.1435751	1,254	745.8229	0.983129	0.129467
2003	7,426	3,544	6,768	0.1731992	1,658	1191.8754	1.10081	0.176108
2004	7,546	3,899	7,114	0.1905555	650	265.832	0.312373	0.0373655
2005	8,176	4,544	7,734	0.2220661	637	461.9585	0.4633	0.0597273
2006	8,244	4,834	8,038	0.2362335	454	390.455	0.429414	0.0485762
2007	8,036	4,937	7,849	0.2412981	792	289.3062	0.374777	0.0368606
2008	7,686	4,866	7,513	0.2377921	1,799	190.7518	0.303041	0.0253901
2009	7,385	4,679	7,047	0.2286467	1,928	202.3974	0.388123	0.0287225
2010	7,175	4,407	6,591	0.2153966	3,807	159.8474	0.379865	0.0242514
2011	7,353	4,235	6,578	0.206974	3,328	265.20846	0.600102	0.0403176
2012	7,847	4,199	6,675	0.2052239	3,857	333.9186	0.64006	0.0500258

2013	8,700	4,411	7,594	0.2155867	5,174	505.1492	0.715488	0.0665193
2014	9,840	4,853	8,498	0.2371944	2,077	689.9173	0.732401	0.0811837
2015	10,941	5,403	9,559	0.2640411	1,823	877.3937	0.754465	0.0917886
2016	11,689	6,040	11,049	0.2951632	1,450	773.7209	0.597323	0.0700261
2017	12,159	6,742	11,610	0.3294917	4,007	1517.6359	1.01489	0.130721371
2018	11,653	6,664	10,976	0.3256978	3,992	1392.8001	1.01136	0.126895053
2019	11,283	6,292	10,021	0.3075101	3,926	1846.7918	1.24644	0.184290327
2020	10,654	5,630	9,404	0.2751658	3,831	1604.9074	1.21406	0.170665474
2021	10,495	5,370	9,268	0.2624528	3,799	1564.6783	1.19829	0.168824063
2022	10,527	5,335	9,333	0.2607066	3,808	1605.3536	1.19596	0.172015871
2023	10,588	5,360	9,407	0.2619445	3,826	1651.5463	1.19762	0.175556717
2024	10,629	5,380	9,450	0.26294	3,840	1679.9327	1.19893	0.177774983
2025	10,647	5,384	9,466	0.263116	3,850	1692.7312	1.19917	0.17882695
2026	10,653	5,379	9,471	0.262896	3,856	1697.7526	1.19888	0.179260658

Table 10. Sensitivity table, north model

Label	Final Base	2009 M and h	Add Conditional Recreational Ages	Add Marginal Commercial Ages	Add Conditional Recreational and Commerical Marginal Ages	Ro8.81	Ro9.8	SigmaR 0.6	Female Length at Amax = 108	Female Length at Amax = 112
L_at_Amin_Fem_GP_1	17.28	16.92	16.11	17.42	16.43	17.15	17.37	17.28	16.92	17.63
VonBert_K_Fem_GP_1	0.13	0.13	0.14	0.13	0.14	0.13	0.13	0.13	0.14	0.12
NatM_p_1_Mal_GP_1	0.30	0.32	0.28	0.31	0.29	0.30	0.31	0.30	0.30	0.31
L_at_Amin_Mal_GP_1	14.88	12.05	15.52	15.24	15.39	15.13	14.59	14.87	14.76	14.99
L_at_Amax_Mal_GP_1	76.71	75.15	74.90	78.51	76.36	76.97	76.41	76.69	76.40	77.03
VonBert_K_Mal_GP_1	0.30	0.35	0.29	0.28	0.28	0.30	0.31	0.30	0.31	0.30
SR_LN(R0)	9.07	8.29	8.85	9.22	9.13	8.81	9.80	9.08	9.14	9.00
SR_BH_steep	0.70	0.80	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
SPRratio_2009	0.24	0.42	0.29	0.24	0.25	0.32	0.12	0.25	0.22	0.26
SPRratio_2017	0.96	1.31	1.04	0.91	0.92	1.14	0.54	0.97	0.90	1.01
F_2009	0.10	0.14	0.12	0.09	0.10	0.13	0.04	0.10	0.09	0.11
F_2017	0.64	0.90	0.74	0.59	0.60	0.87	0.28	0.65	0.58	0.69
Bratio_2009	0.41	0.35	0.41	0.38	0.39	0.39	0.45	0.40	0.42	0.41
Bratio_2017	0.58	0.51	0.58	0.55	0.56	0.54	0.64	0.56	0.59	0.57
SSB_Unfished_thousand_mt	37.97	43.16	32.06	44.29	42.23	29.42	79.02	38.32	39.52	36.80
TotBio_Unfished	58746	52676	49588	68085	64887	45659	121813	59289	62089	56099
SmryBio_Unfished	56005	51330	47401	64939	62034	43538	116108	56522	59131	53535
Recr_Unfished_millions	8.66	3.99	7.00	10.11	9.27	6.70	18.03	8.74	9.32	8.11
SSB_Btgt_thousand_mt	15.19	17.27	12.82	17.72	16.89	11.77	31.61	15.33	15.81	14.72
SPR_Btgt	0.46	0.44	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Fstd_Btgt	0.13	0.09	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.12
TotYield_Btgt_thousand_mt	3.20	2.05	2.73	3.66	3.51	2.49	6.60	3.23	3.46	2.98
SSB_SPRtgt_thousand_mt	14.58	17.84	12.31	17.01	16.22	11.30	30.34	14.72	15.18	14.13
Fstd_SPRtgt	0.13	0.09	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13
TotYield_SPRtgt_thousand_mt	3.24	2.02	2.77	3.71	3.56	2.53	6.69	3.27	3.51	3.02
SSB_MSY_thousand_mt	10.25	9.83	8.73	11.93	11.42	7.95	21.30	10.35	10.69	9.92
SPR_MSY	0.35	0.28	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Fstd_MSY	0.19	0.16	0.19	0.18	0.19	0.19	0.19	0.19	0.19	0.18
TotYield_MSY_thousand_mt	3.41	2.28	2.90	3.91	3.74	2.66	7.04	3.44	3.69	3.18
RetYield_MSY	3268.90	2205.54	2783.41	3738.00	3579.56	2551.33	6737.24	3299.97	3536.23	3047.87

Table 11. Sensitivity table, south model

Label	Final Base Model	Add Recreational Onboard Observer Index as Proportional to Biomass	Add Recreational Onboard Observer Index as Not Proportional to Biomass	Add Commercial Marginal Ages	SigmaR = 0.7	SigmaR = 0.8	No Lam Composition Data
L_at_Amin_Fem_GP_1	18.02	17.91	17.91	18.03	18.03	17.99	18.07
L_at_Amax_Fem_GP_1	93.49	92.70	92.36	93.09	93.59	93.28	96.51
VonBert_K_Fem_GP_1	0.13	0.14	0.14	0.13	0.13	0.13	0.12
NatM_p_1_Mal_GP_1	0.32	0.33	0.34	0.32	0.32	0.32	0.35
L_at_Amin_Mal_GP_1	18.13	17.99	17.95	18.12	18.15	18.10	18.13
L_at_Amax_Mal_GP_1	83.85	81.96	81.70	82.90	84.16	83.44	87.92
VonBert_K_Mal_GP_1	0.16	0.17	0.18	0.17	0.16	0.16	0.14
SR_LN(R0)	8.49	8.45	8.40	8.52	8.48	8.51	8.74
SPRratio_2009	0.43	0.66	0.90	0.41	0.38	0.49	0.32
SPRratio_2017	1.13	1.49	1.78	1.10	1.04	1.25	0.90
F_2009	0.15	0.27	0.43	0.14	0.13	0.18	0.09
F_2017	0.68	1.19	2.15	0.65	0.59	0.81	0.47
Bratio_2009	0.23	0.14	0.09	0.23	0.27	0.19	0.28
Bratio_2017	0.33	0.20	0.12	0.34	0.38	0.27	0.38
SSB_Unfished_thousand_mt	20.46	19.04	18.06	20.64	20.29	20.58	29.04
TotBio_Unfished	33103	29602	28010	33331	33083	33002	43779
SmryBio_Unfished	31547	28128	26588	31740	31542	31429	41828
Recr_Unfished_millions	4.88	4.66	4.46	5.00	4.82	4.94	6.22
SSB_Btgt_thousand_mt	8.19	7.62	7.22	8.25	8.12	8.23	11.62
SPR_Btgt	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Fstd_Btgt	0.13	0.13	0.13	0.13	0.12	0.13	0.12
TotYield_Btgt_thousand_mt	1.73	1.62	1.55	1.77	1.72	1.75	2.12
SSB_SPRtgt_thousand_mt	9.00	8.38	7.95	9.08	8.93	9.05	12.78
Fstd_SPRtgt	0.11	0.11	0.12	0.11	0.11	0.11	0.10
TotYield_SPRtgt_thousand_mt	1.66	1.55	1.48	1.69	1.64	1.67	2.02
SSB_MSY_thousand_mt	5.32	4.98	4.73	5.38	5.27	5.35	7.45
SPR_MSY	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Fstd_MSY	0.20	0.20	0.20	0.20	0.20	0.20	0.19
TotYield_MSY_thousand_mt	1.87	1.74	1.66	1.90	1.85	1.88	2.29
RetYield_MSY	1840	1719	1639	1874	1826	1856	2259

Table 12. Model projections, north.

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	4,815.82	3,058.30	34,063.80	21,975.70	57.87
2018	4,711.84	2,844.79	33,998.90	21,239.20	55.93
2019	4,690.12	4,497.30	33,538.10	20,944.30	55.15
2020	4,458.62	4,275.36	31,723.50	19,737.80	51.98
2021	4,271.91	4,096.33	30,257.40	18,683.70	49.2
2022	4,126.12	3,956.53	29,105.30	17,821.00	46.93
2023	4,012.88	3,847.95	28,189.10	17,134.60	45.12
2024	3,923.16	3,761.93	27,451.10	16,586.10	43.68
2025	3,850.11	3,691.90	26,847.70	16,141.10	42.51
2026	3,789.18	3,633.48	26,347.50	15,774.10	41.54
2027	3,737.61	3,584.04	25,929.20	15,468.60	40.73
2028	3,693.69	3,541.93	25,578.10	15,213.20	40.06

Table 13. Model projections, south.

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	2,523.12	1,517.64	11,609.70	6,741.96	32.95
2018	2,322.09	1,392.80	10,976.00	6,664.33	32.57
2019	2,115.26	1,846.79	10,021.10	6,292.18	30.75
2020	1,940.77	1,604.91	9,403.82	5,630.36	27.52
2021	1,941.60	1,564.67	9,268.10	5,370.23	26.25
2022	1,998.58	1,605.35	9,332.59	5,334.50	26.07
2023	2,049.60	1,651.55	9,407.48	5,359.83	26.19
2024	2,079.88	1,679.93	9,449.77	5,380.20	26.29
2025	2,094.79	1,692.73	9,465.75	5,383.80	26.31
2026	2,101.99	1,697.75	9,470.86	5,379.30	26.29
2027	2,105.91	1,699.87	9,473.01	5,373.57	26.26
2028	2,108.35	1,701.15	9,475.23	5,369.82	26.24

Table 14. North model decision table of 12-year projections for alternate states of nature (columns) and management options (rows). Relative probabilities of each state of nature are based on the asymptotic standard deviation of end year spawning biomass, using a fixed value of Ro to achieve the 2017 spawning biomass value.

			State of nature					
			Low 2017 Spawning Biomass *Ro=8.81*		Base case 2017 Spawning Biomass		High 2017 Spawning Biomass *Ro=9.8*	
Probability			0.25		0.5		0.25	
Manage-ment decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
~700 mt Constant Catch	2019	695	14329	48.7	20944	55.2	51958	65.8
	2020	695	15227	51.8	22150	58.3	54488	69.0
	2021	697	16162	54.9	23337	61.5	56819	71.9
	2022	698	17084	58.1	24474	64.5	58968	74.6
	2023	698	17948	61.0	25527	67.2	60925	77.1
	2024	699	18741	63.7	26487	69.8	62686	79.3
	2025	699	19468	66.2	27357	72.0	64258	81.3
	2026	700	20129	68.4	28140	74.1	65649	83.1
	2027	700	20727	70.5	28840	76.0	66874	84.6
	2028	700	21267	72.3	29466	77.6	67952	86.0
40% of 40:10 Rule	2019	1785	14329	48.7	20944	55.2	51958	65.8
	2020	1698	14540	49.4	21455	56.5	53791	68.1
	2021	1642	14847	50.5	22009	58.0	55488	70.2
	2022	1575	15209	51.7	22585	59.5	57075	72.2
	2023	1533	15603	53.0	23171	61.0	58566	74.1
	2024	1499	16001	54.4	23741	62.5	59942	75.9
	2025	1472	16392	55.7	24287	64.0	61200	77.5
	2026	1449	16773	57.0	24803	65.3	62339	78.9
	2027	1430	17140	58.3	25287	66.6	63364	80.2
	2028	1413	17490	59.5	25740	67.8	64287	81.4
40:10 Rule	2019	4497	14329	48.7	20944	55.2	51958	65.8
	2020	4275	12863	43.7	19738	52.0	52084	65.9
	2021	4096	11601	39.4	18684	49.2	52171	66.0
	2022	3957	10538	35.8	17821	46.9	52295	66.2
	2023	3848	9682	32.9	17135	45.1	52518	66.5
	2024	3762	8963	30.5	16586	43.7	52799	66.8
	2025	3692	8339	28.3	16141	42.5	53118	67.2
	2026	3633	7779	26.4	15774	41.5	53455	67.7
	2027	3584	7266	24.7	15469	40.7	53800	68.1
	2028	3542	6788	23.1	15213	40.1	54149	68.5

Table 15. South model decision table of 12-year projections for alternate states of nature (columns) and management options (rows). Relative probabilities of each state of nature are based on the asymptotic standard deviation of end year spawning biomass, using a fixed value of Ro to achieve the 2017 spawning biomass value.

			State of nature					
			Low Ln(R0) = 8.122		Base case Ln(R0) = 8.493		High Ln(R0) = 8.742	
Management decision	Year	Catch (mt)	Spawning output (mt)	Depletion	Spawning output (mt)	Depletion	Spawning output (mt)	Depletion
Constant 700 mt catch	2019	700	2,725	19%	6,123	30%	8,894	34%
	2020	700	2,628	19%	6,144	30%	9,011	34%
	2021	700	2,739	20%	6,425	32%	9,441	36%
	2022	700	2,975	21%	6,908	34%	10,128	38%
	2023	700	3,248	23%	7,475	37%	10,930	41%
	2024	700	3,527	25%	8,067	40%	11,768	45%
	2025	700	3,810	27%	8,658	42%	12,600	48%
	2026	700	4,099	29%	9,238	45%	13,410	51%
	2027	700	4,395	31%	9,800	48%	14,186	54%
	2028	700	4,697	33%	10,340	51%	14,924	57%
75% 40-10 catch	2019	1,318	2,725	19%	6,123	30%	8,894	34%
	2020	1,154	2,283	16%	5,774	28%	8,636	33%
	2021	1,135	2,136	15%	5,783	28%	8,789	33%
	2022	1,173	2,112	15%	6,006	29%	9,214	35%
	2023	1,212	2,089	15%	6,294	31%	9,736	37%
	2024	1,237	2,030	14%	6,583	32%	10,273	39%
	2025	1,249	1,943	14%	6,859	34%	10,797	41%
	2026	1,255	1,842	13%	7,126	35%	11,304	43%
	2027	1,258	1,732	12%	7,387	36%	11,794	45%
	2028	1,261	1,615	12%	7,644	37%	12,266	47%
40-10 Rule	2019	1,757	2,725	19%	6,123	30%	8,894	34%
	2020	1,539	2,041	15%	5,512	27%	8,371	32%
	2021	1,513	1,685	12%	5,293	26%	8,292	31%
	2022	1,564	1,444	10%	5,291	26%	8,489	32%
	2023	1,616	1,179	8%	5,344	26%	8,775	33%
	2024	1,649	850	6%	5,388	26%	9,071	34%
	2025	1,665	NA	NA	5,412	27%	9,351	35%
	2026	1,673	NA	NA	5,425	27%	9,621	36%
	2027	1,678	NA	NA	5,435	27%	9,882	37%
	2028	1,681	NA	NA	5,445	27%	10,138	38%

Figures

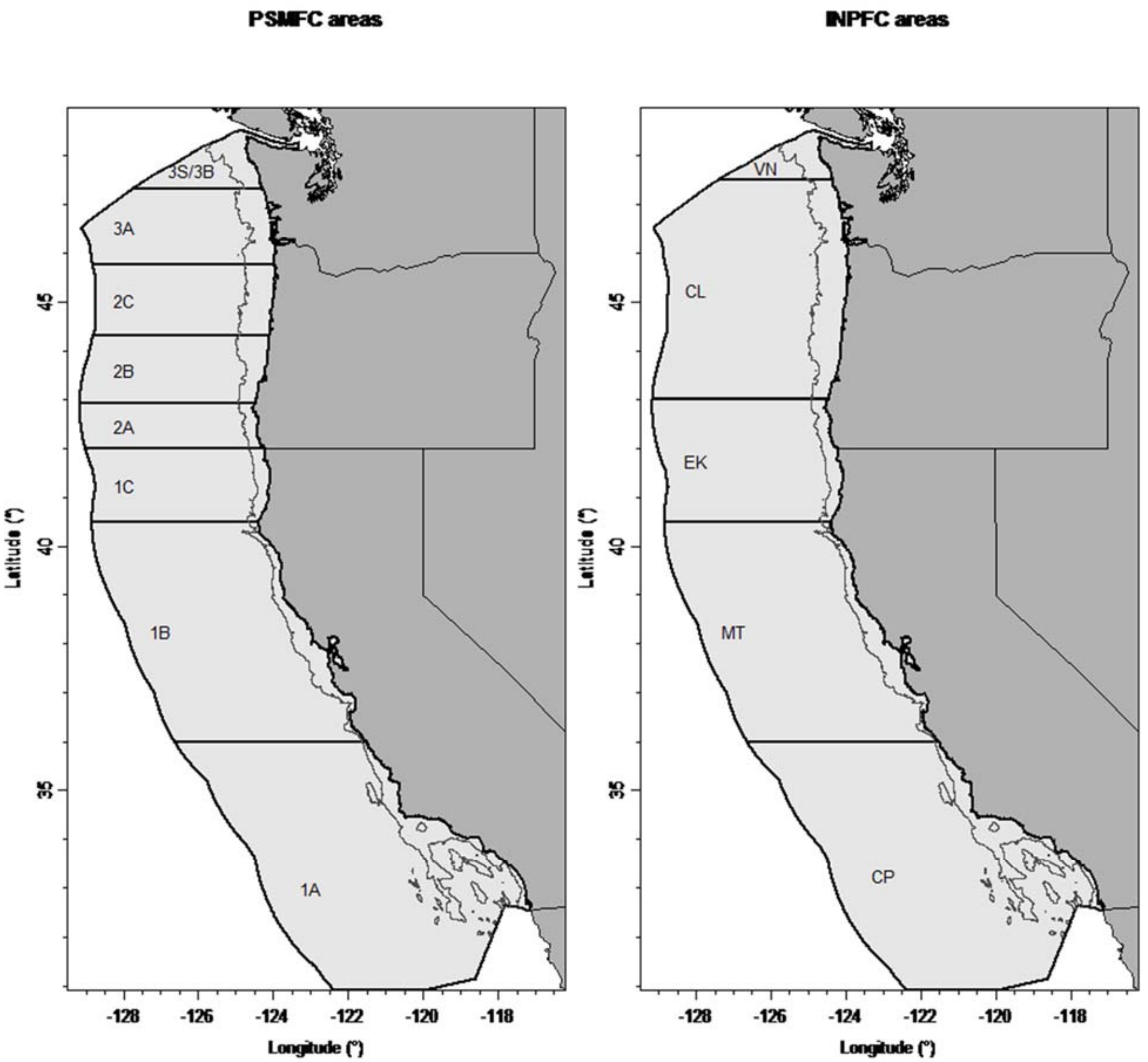


Figure 1. Map showing Pacific States Marine Fish Commission (PSMFC) and International North Pacific Fisheries Commission (INPFC) boundaries. The INPFC area abbreviations are Vancouver (VN), Columbia (CL), Eureka (EK), Monterrey (MT), and Concepcion (CP). The solid gray line off the coast is the 300 fathom depth contour.

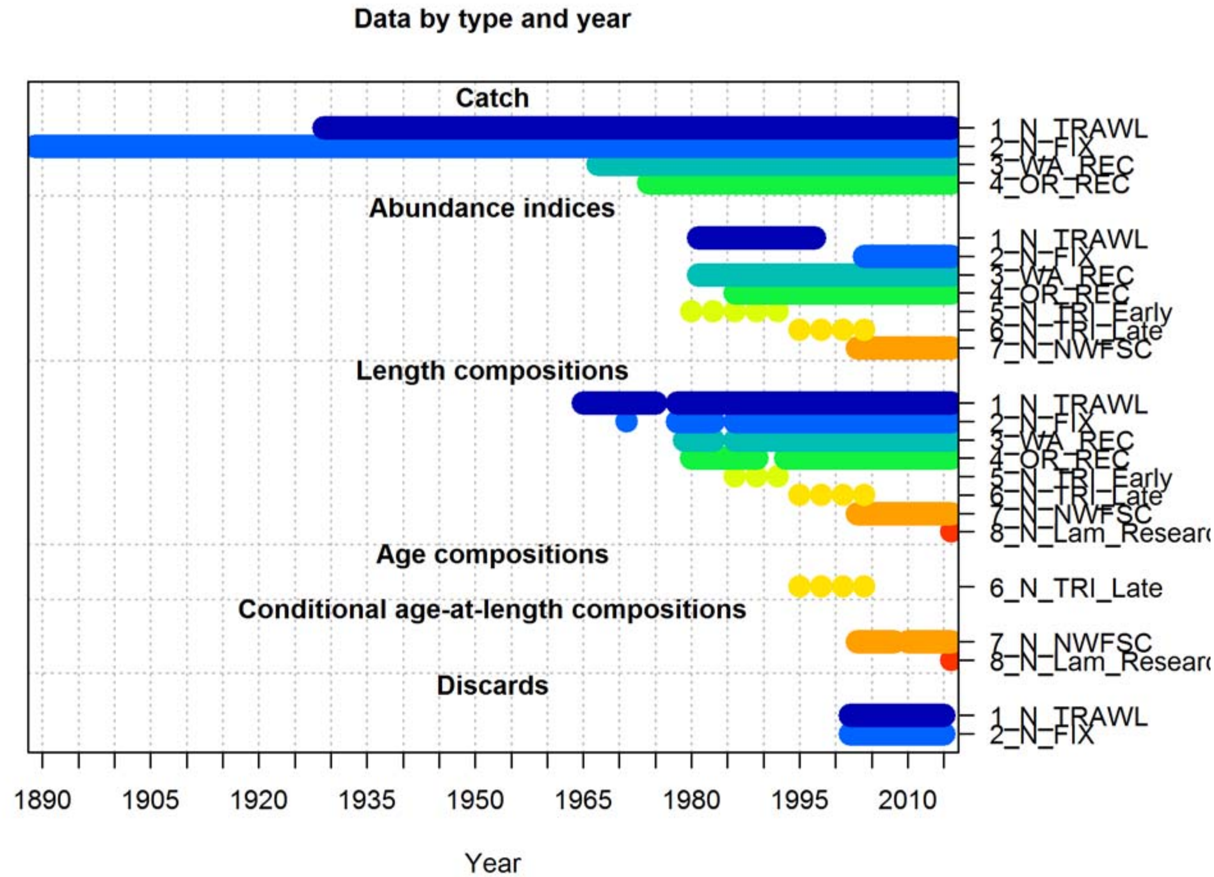


Figure 2. **Data used in the north stock assessment.**

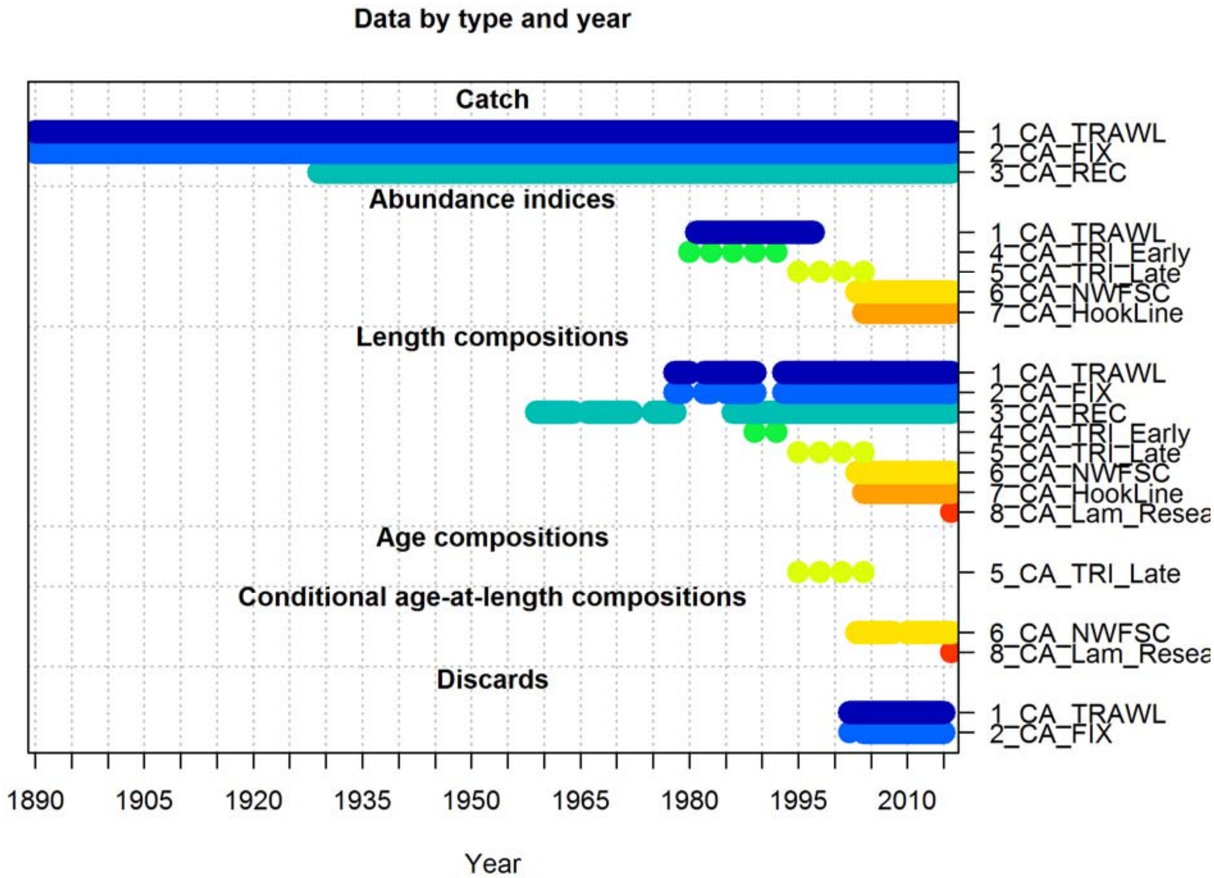


Figure 3. Data used in the south assessment.

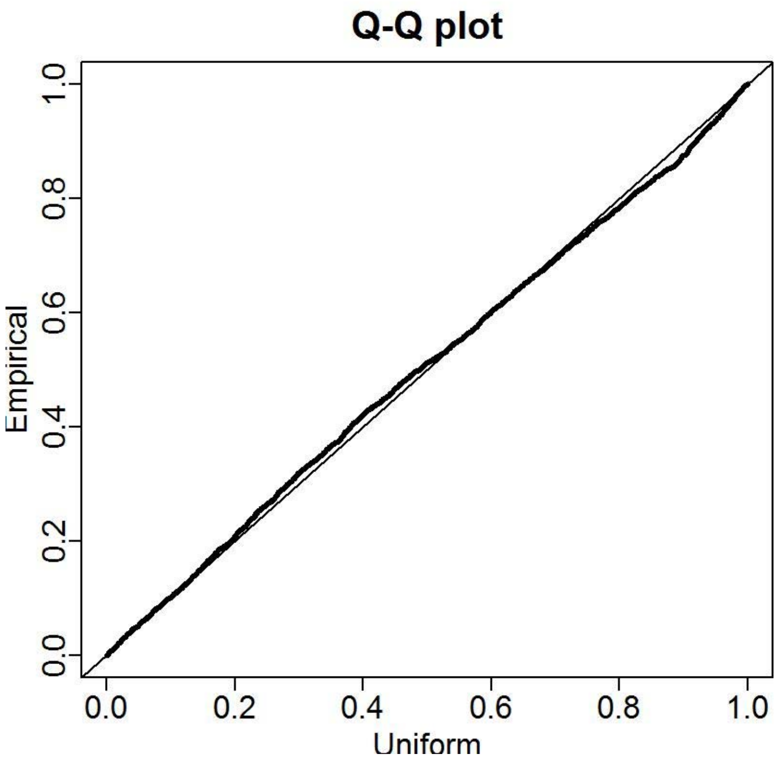


Figure 4. NWFSC survey index VAST Q-Q plot.

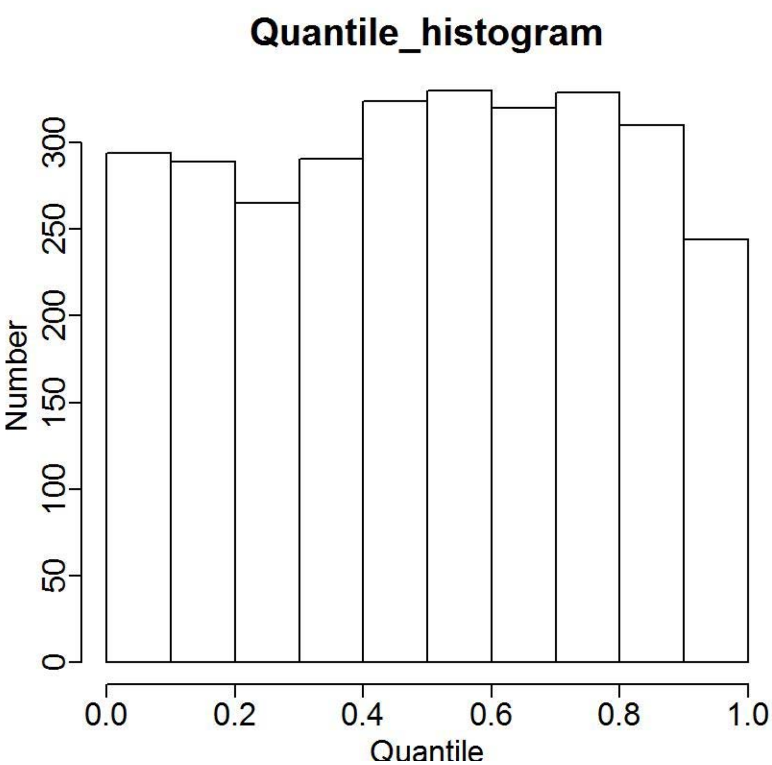


Figure 5. NWFSC survey index VAST binned by predicted encounter probability.

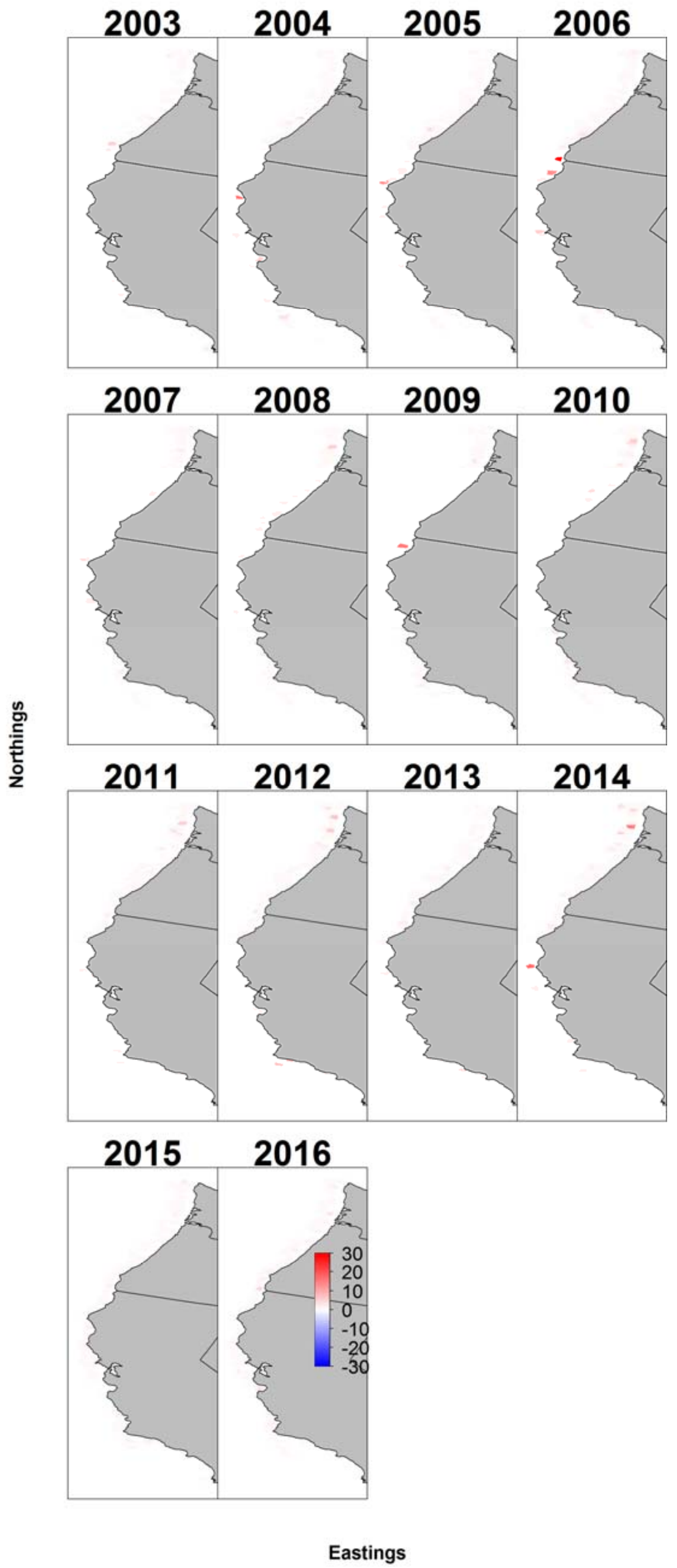


Figure 6. NWFSC survey index encounter probability Pearson residuals.

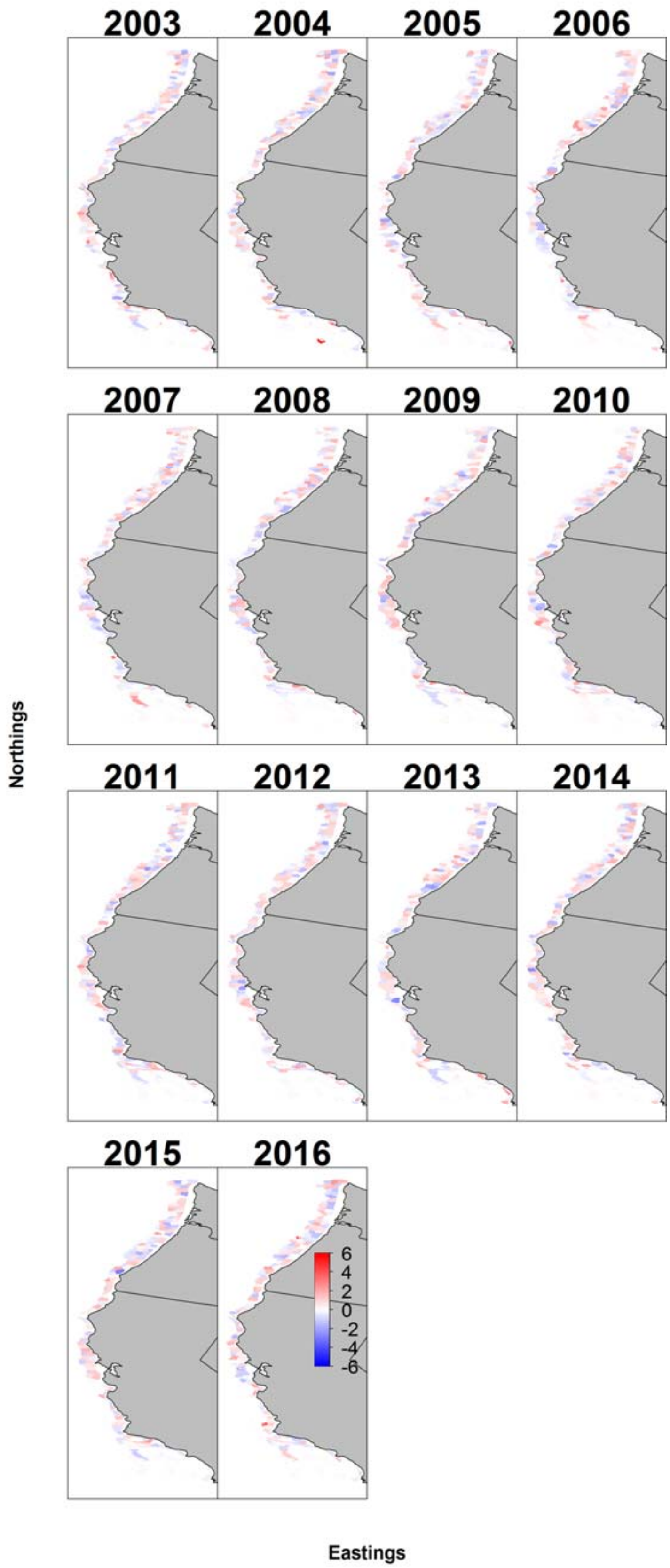


Figure 7. NWFSC survey index positive catch rate probability Pearson residuals.

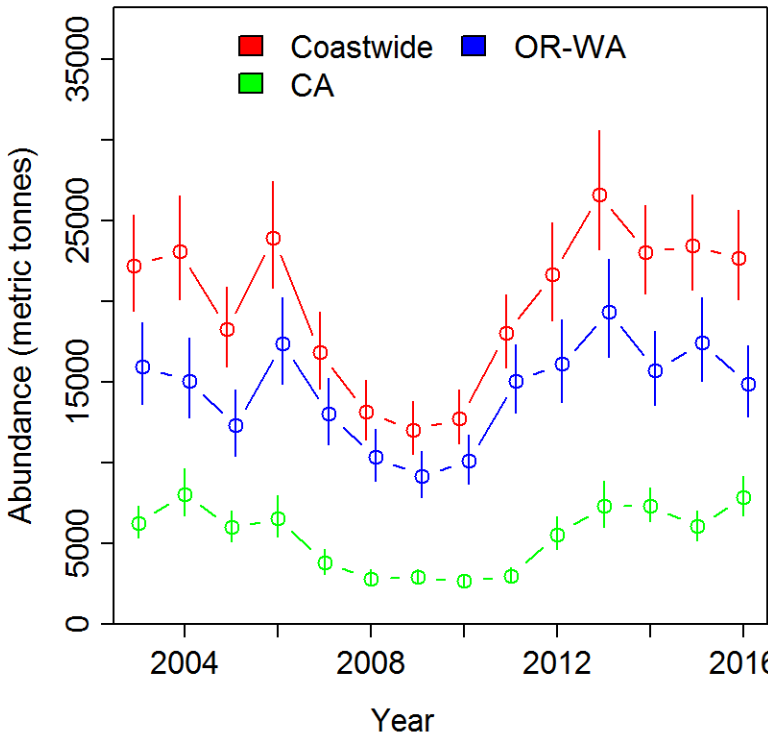


Figure 8. NWFSC coast-wide, north (WA and OR), and south (CA) survey indices.

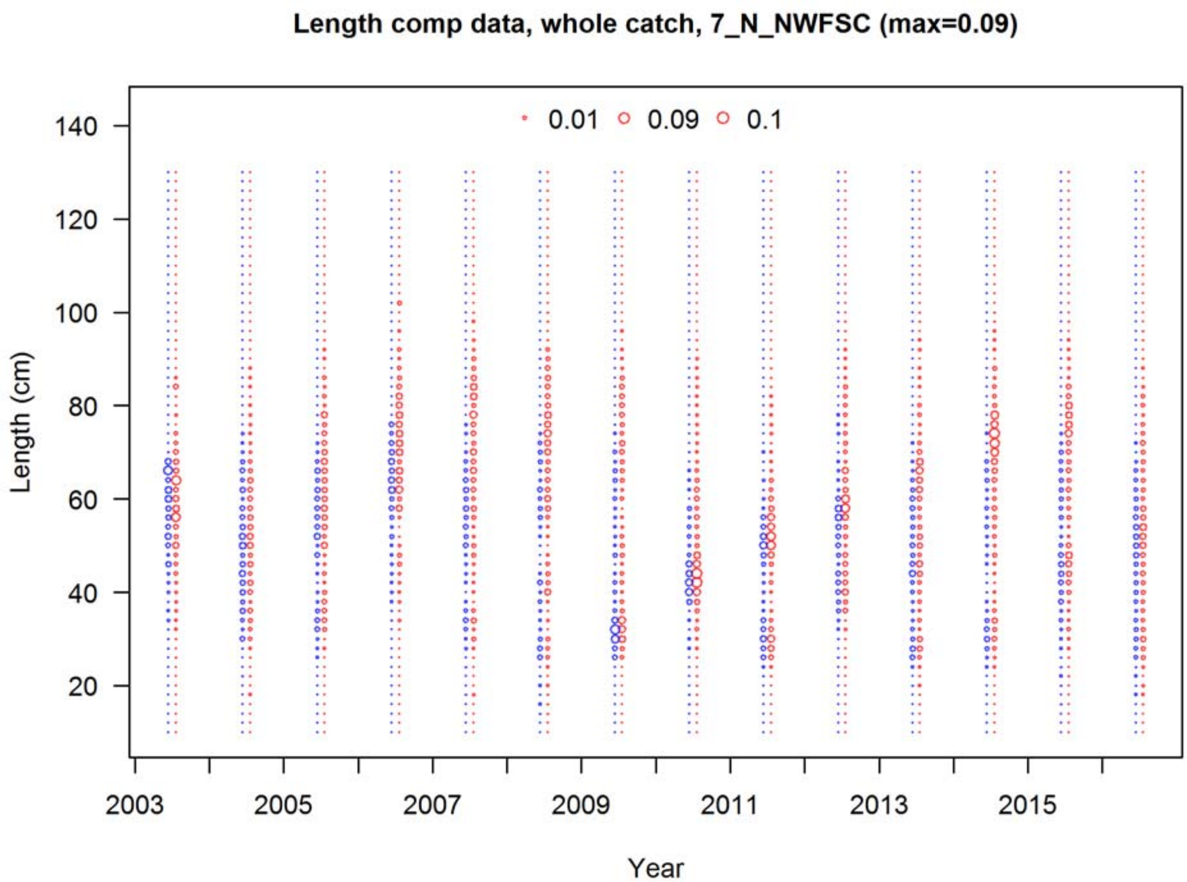


Figure 9. NWFSC survey length composition data, north.

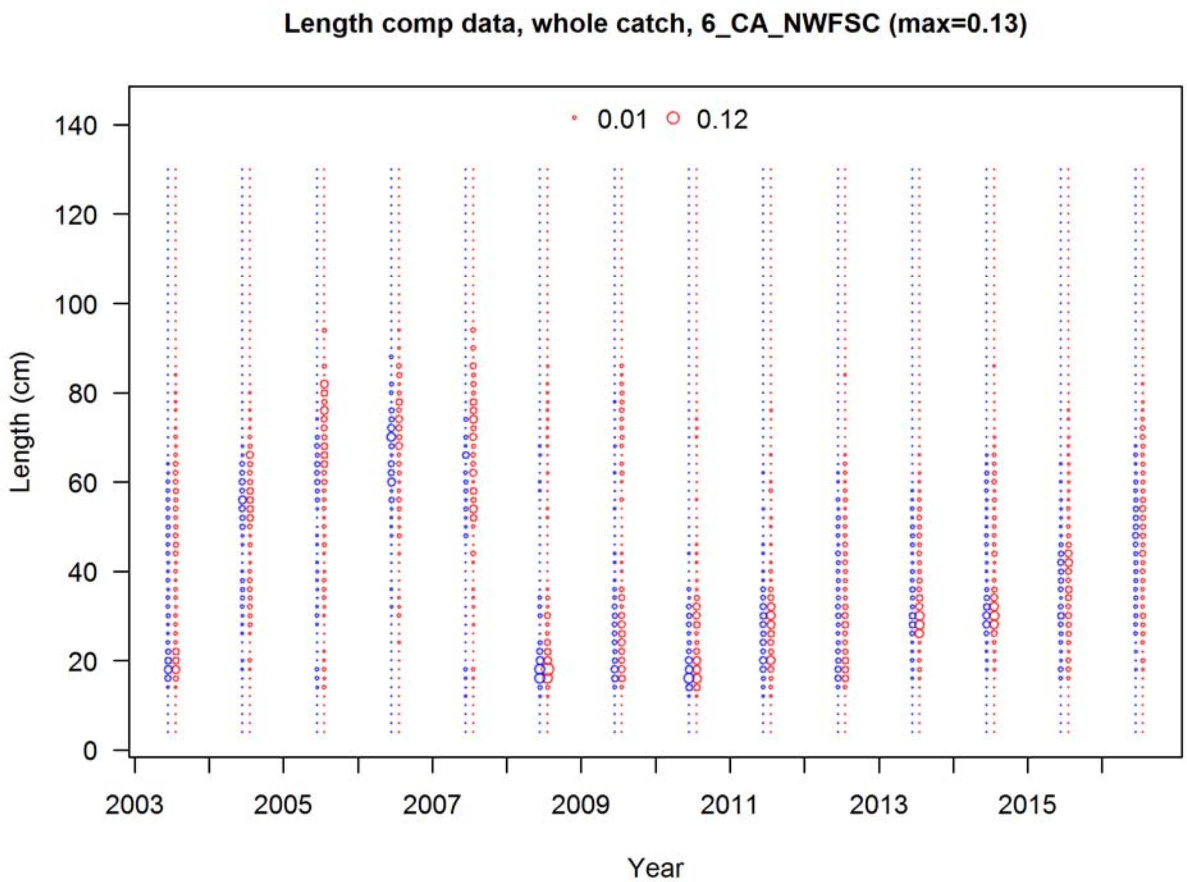


Figure 10. NWFSC survey length composition data, south.

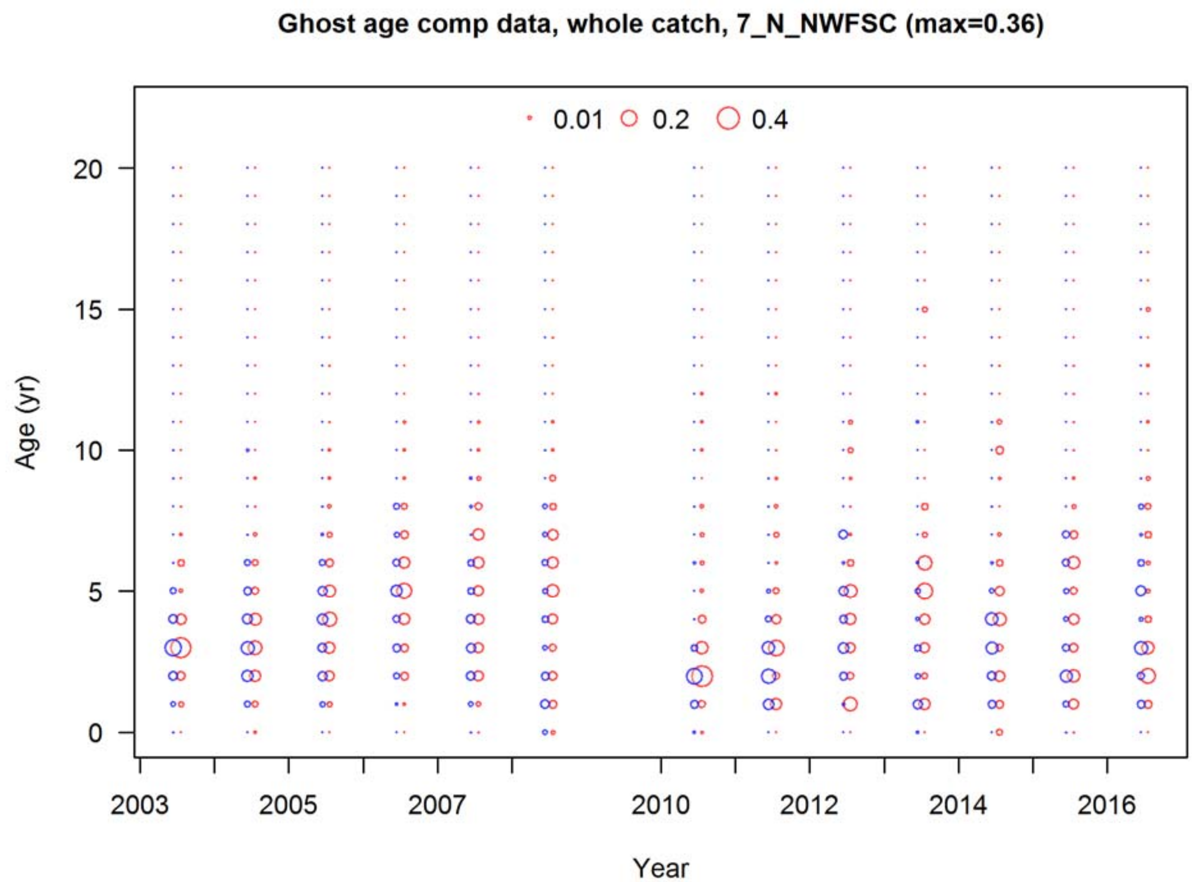


Figure 11. NWFSC survey marginal age composition data, north.

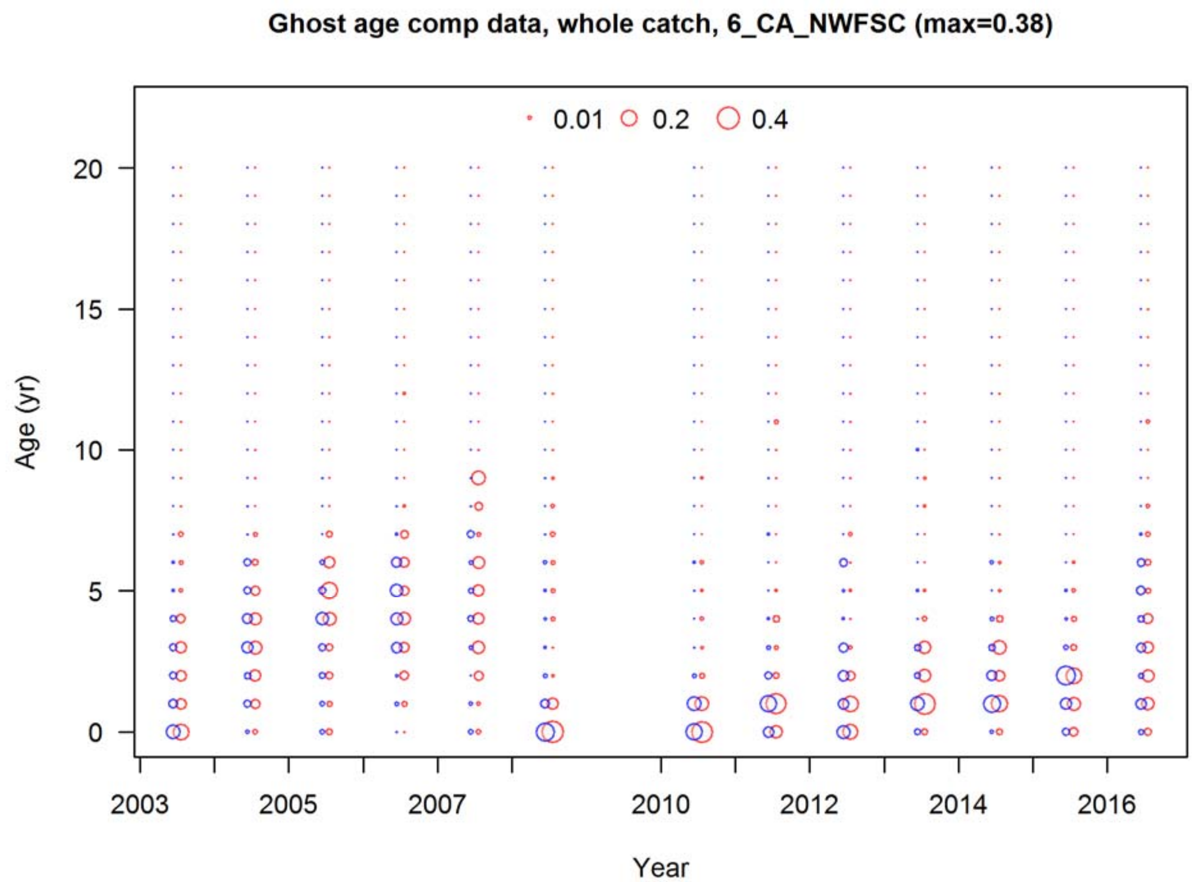


Figure 12. NWFSC survey marginal age composition data, south.

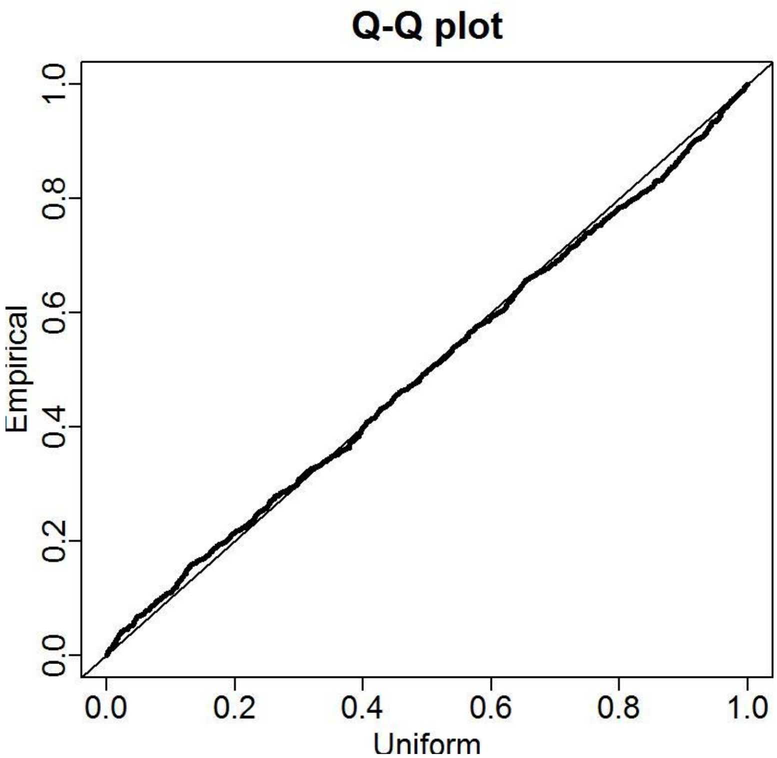


Figure 13. Triennial survey early index VAST Q-Q plot.

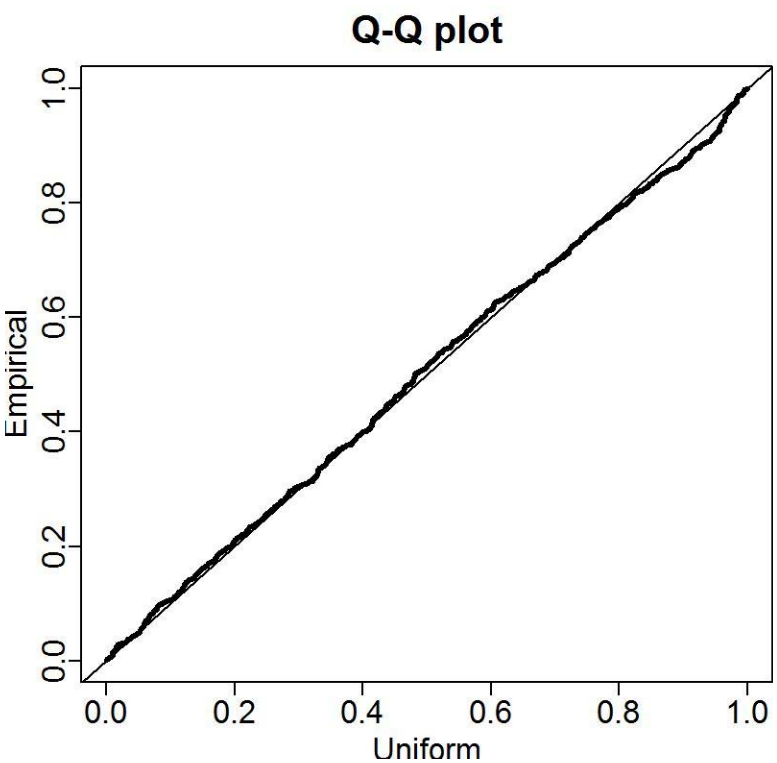


Figure 14. Triennial survey late index VAST Q-Q plot.

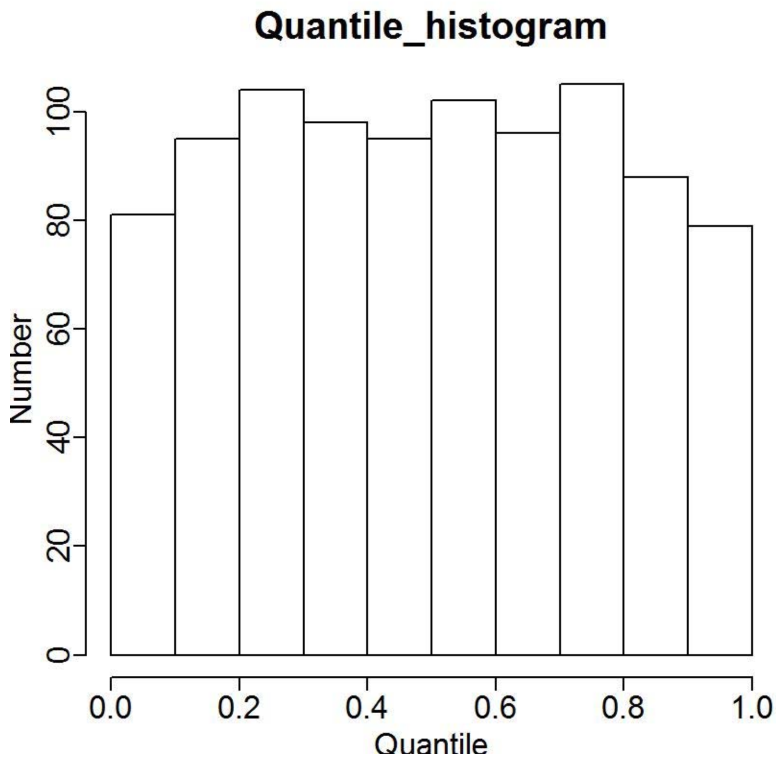


Figure 15. Triennial survey early binned index VAST binned by predicted encounter probability.

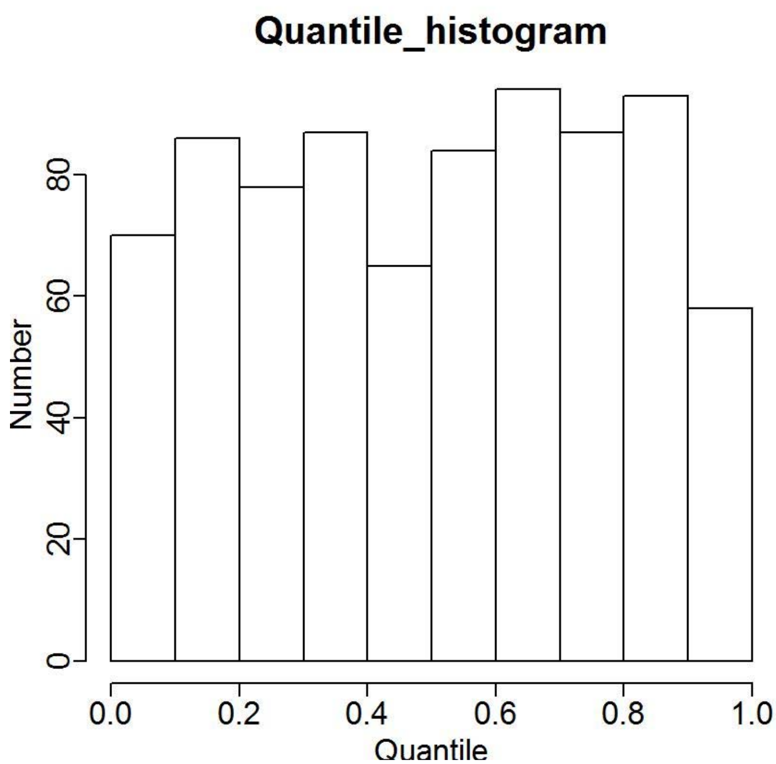


Figure 16. Figure 15. Triennial survey late binned index VAST binned by predicted encounter probability.

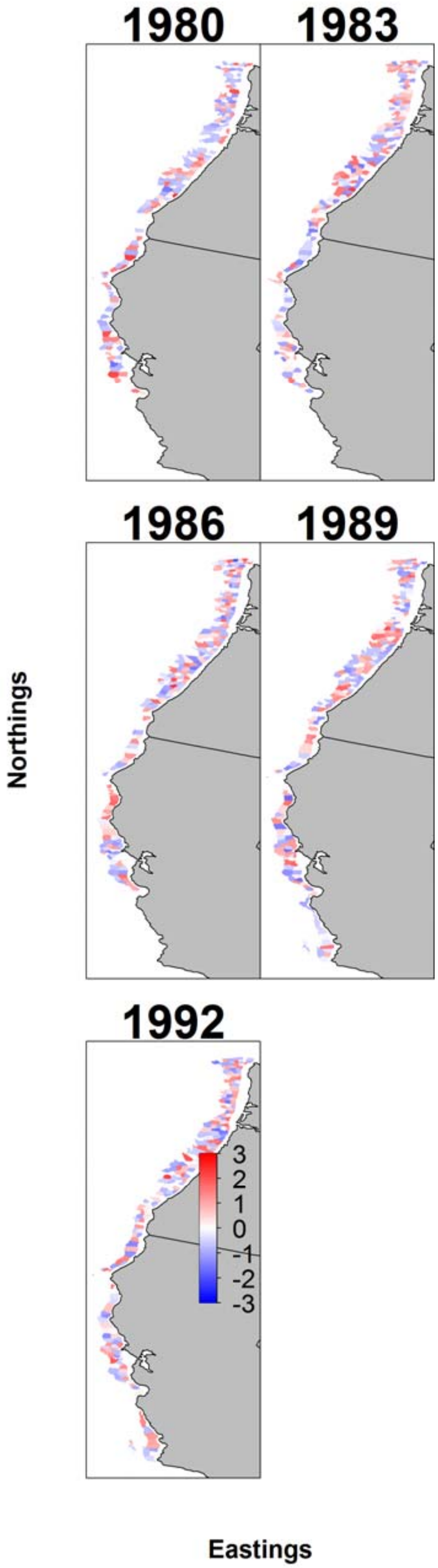


Figure 17. Triennial early survey index encounter probability Pearson residuals.

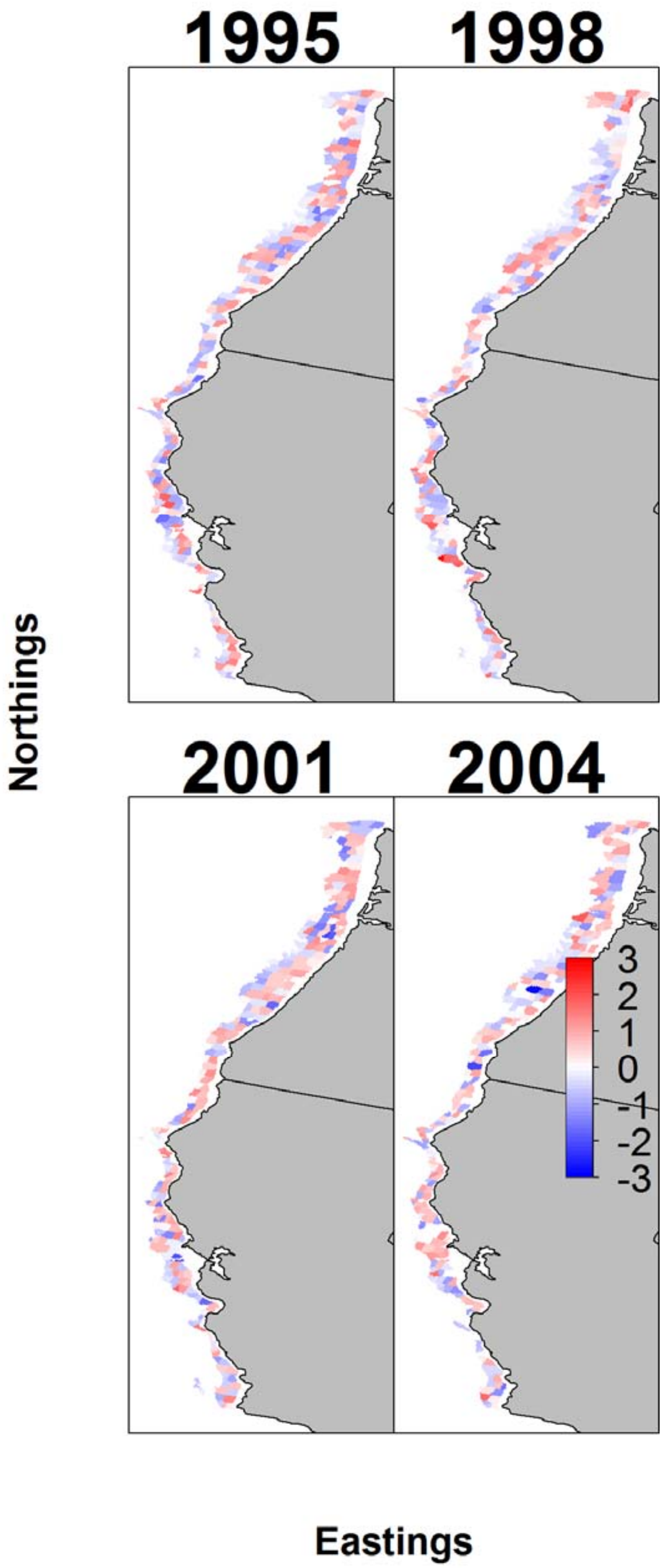


Figure 18. Triennial late survey index encounter probability Pearson residuals.

Figure 19. Triennial early survey index positive catch rate probability Pearson residuals.

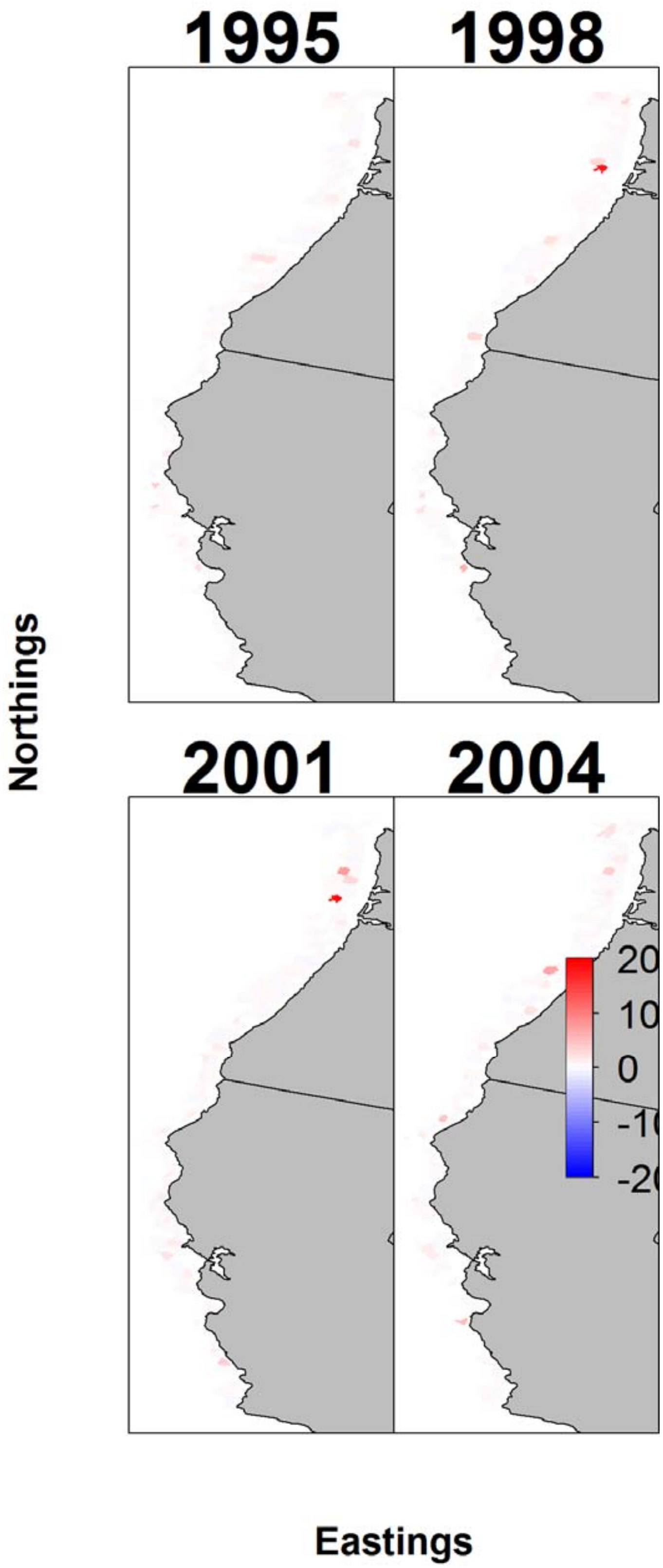


Figure 20. Triennial late survey index positive catch rate probability Pearson residuals.

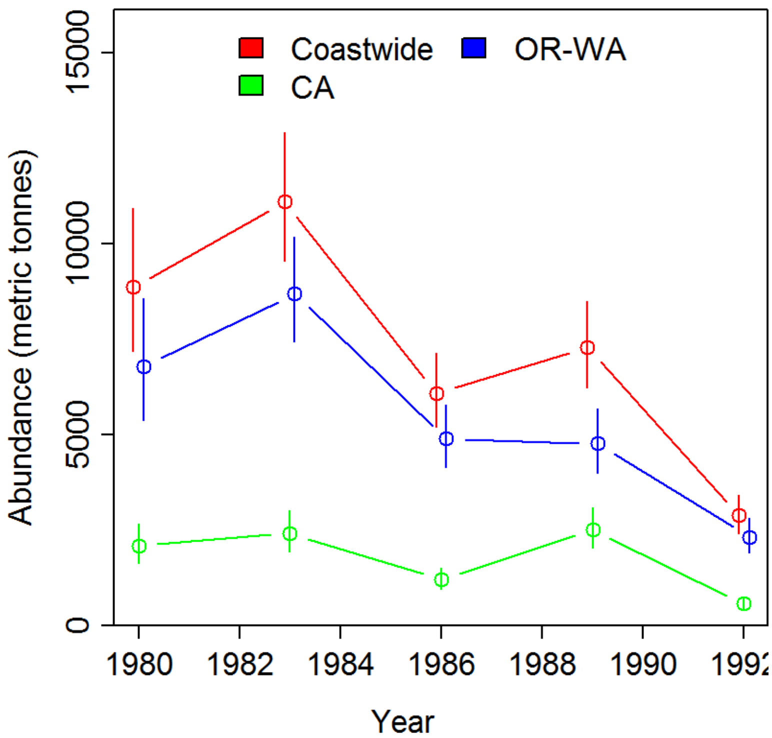


Figure 21. Triennial early coast-wide, north (WA and OR), and south (CA) survey indices.

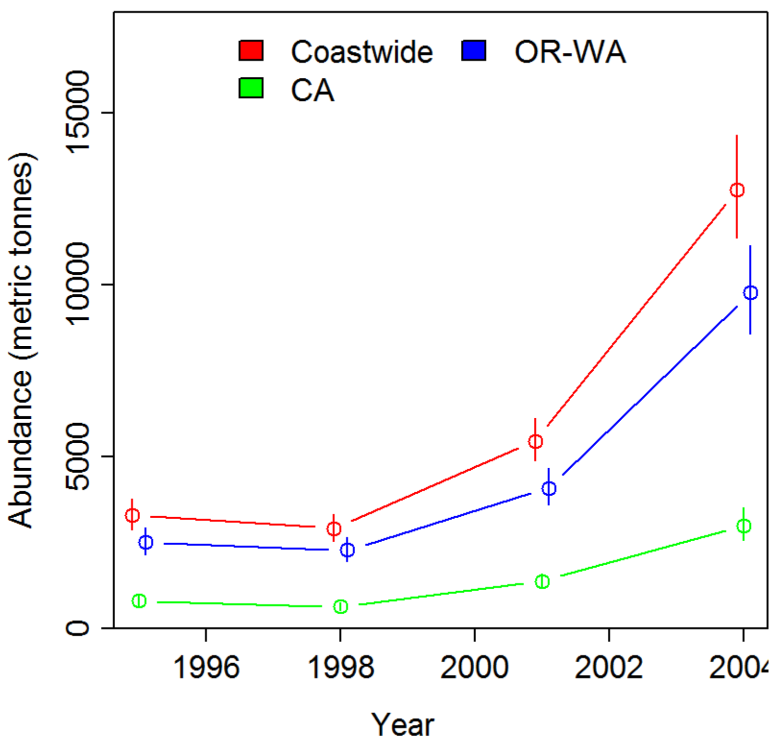


Figure 22. Triennial late coast-wide, north (WA and OR), and south (CA) survey indices.

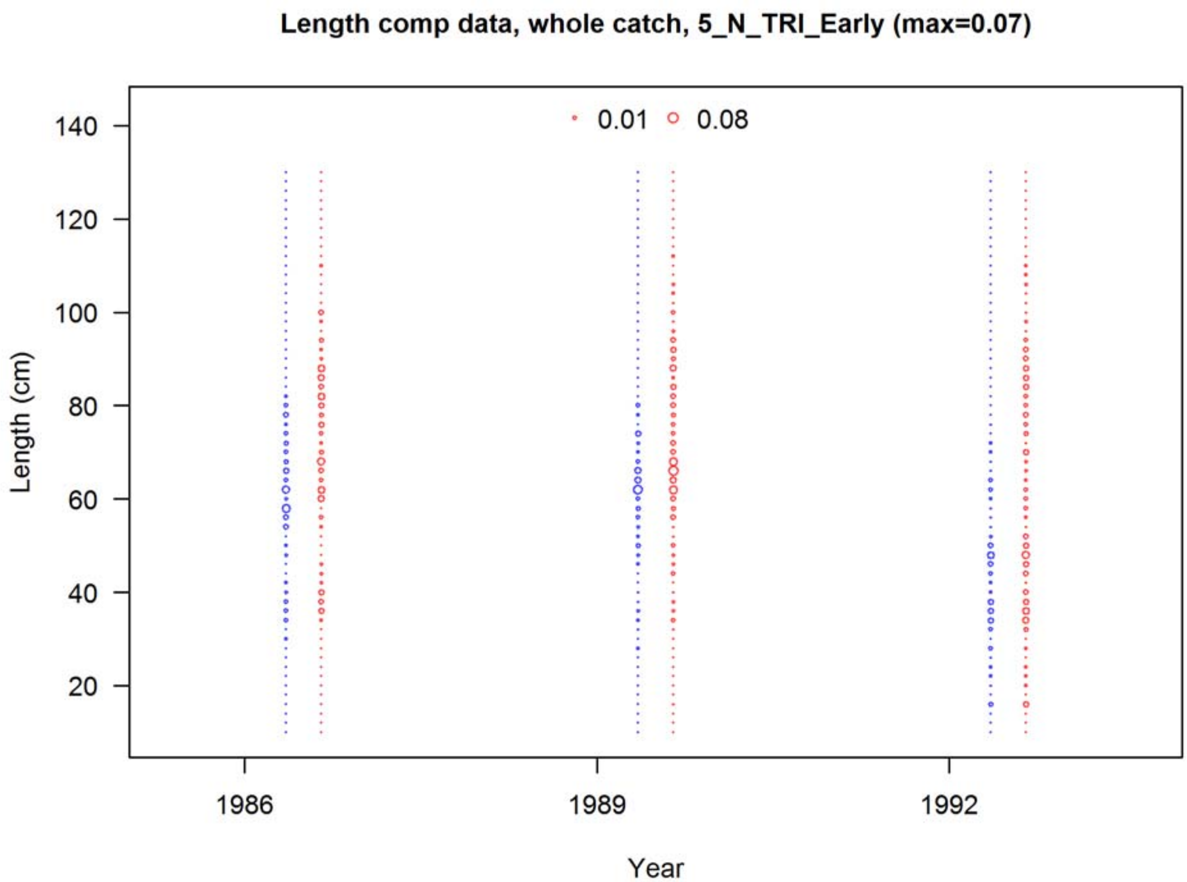


Figure 23. Triennial early survey composition data, north.

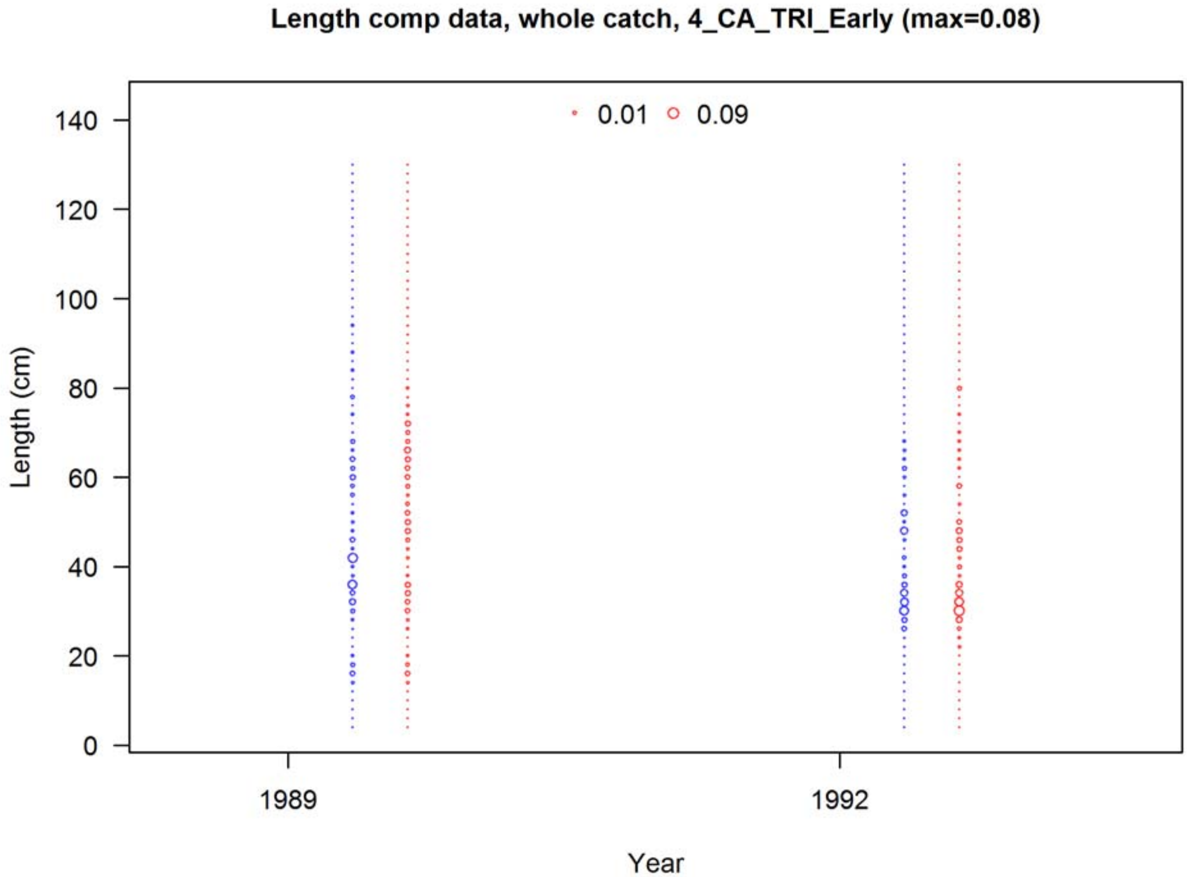


Figure 24. Triennial early survey composition data, south.

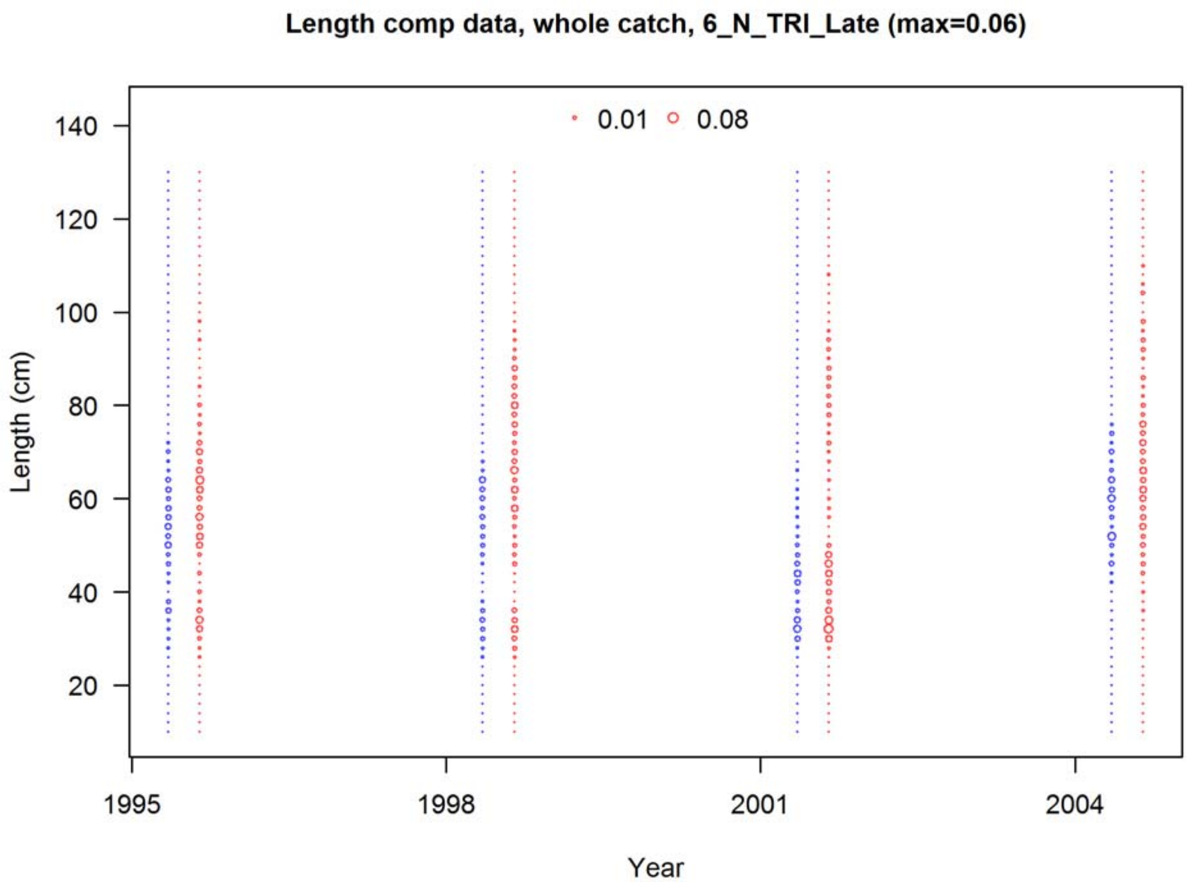


Figure 25. Triennial late survey composition data, north.

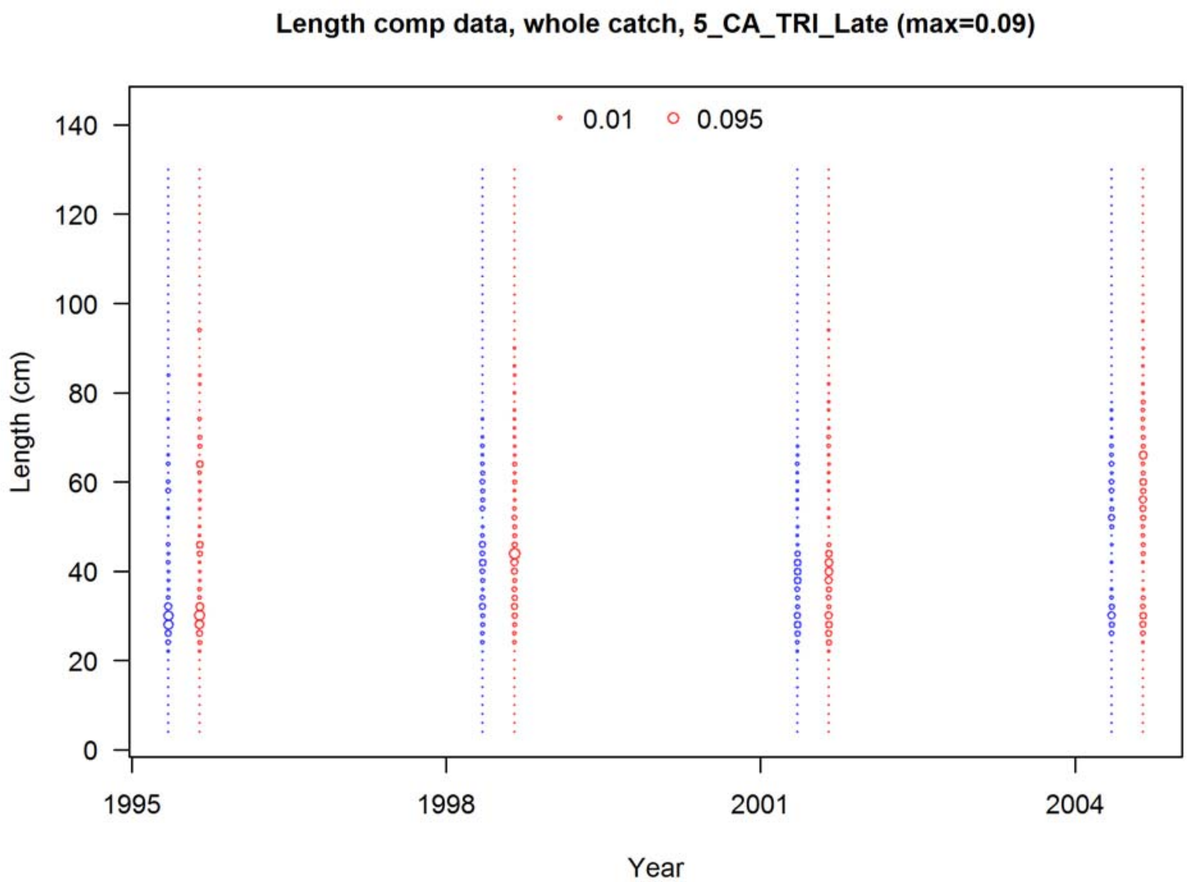


Figure 26. Triennial late survey composition data, south.

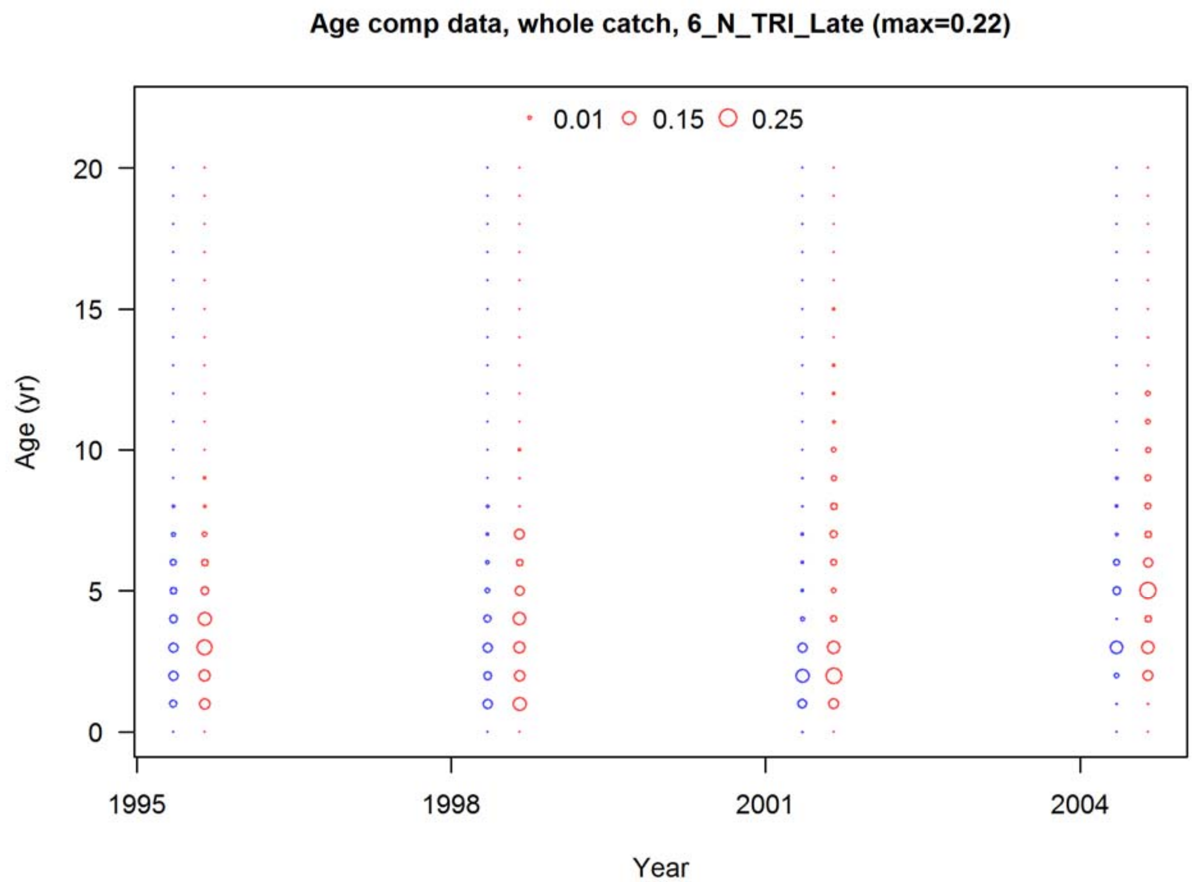


Figure 27. Triennial late age composition data, north.

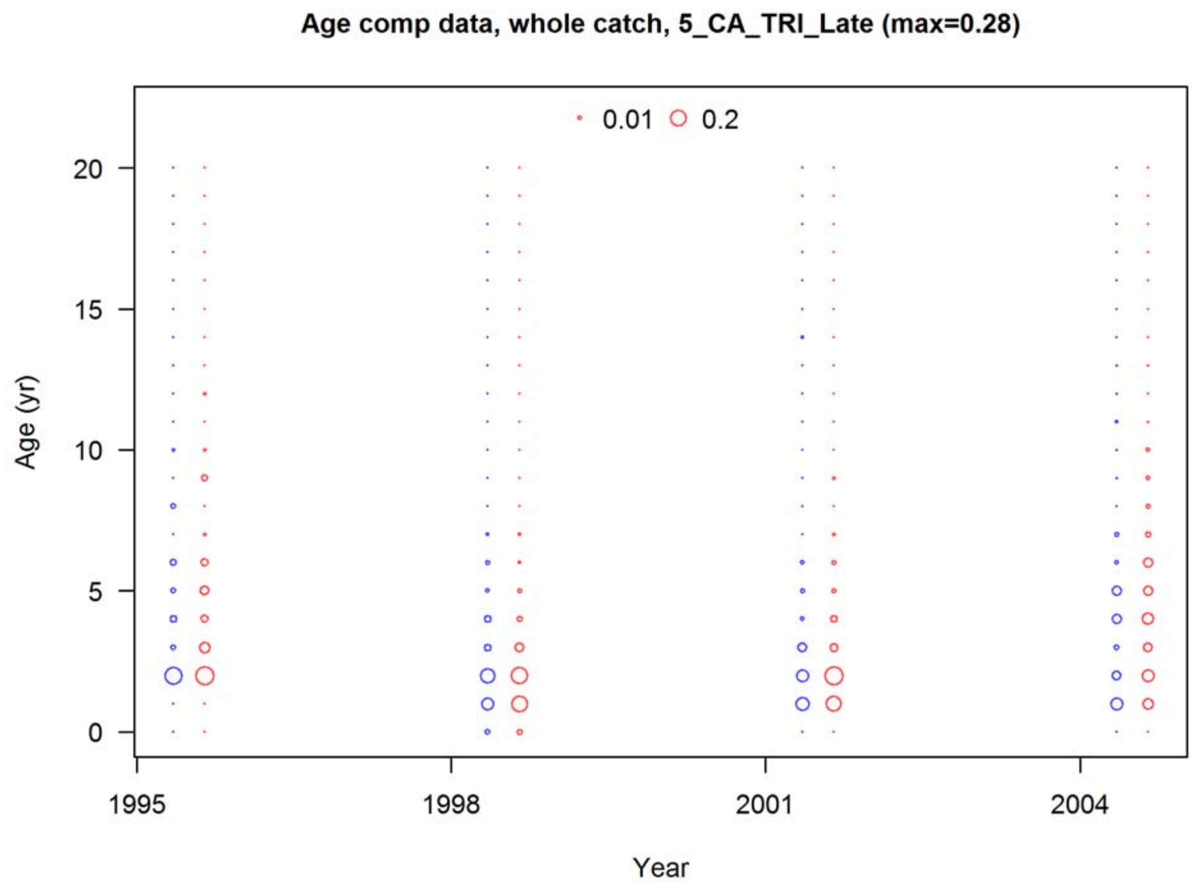


Figure 28. Triennial survey late age composition data, south.

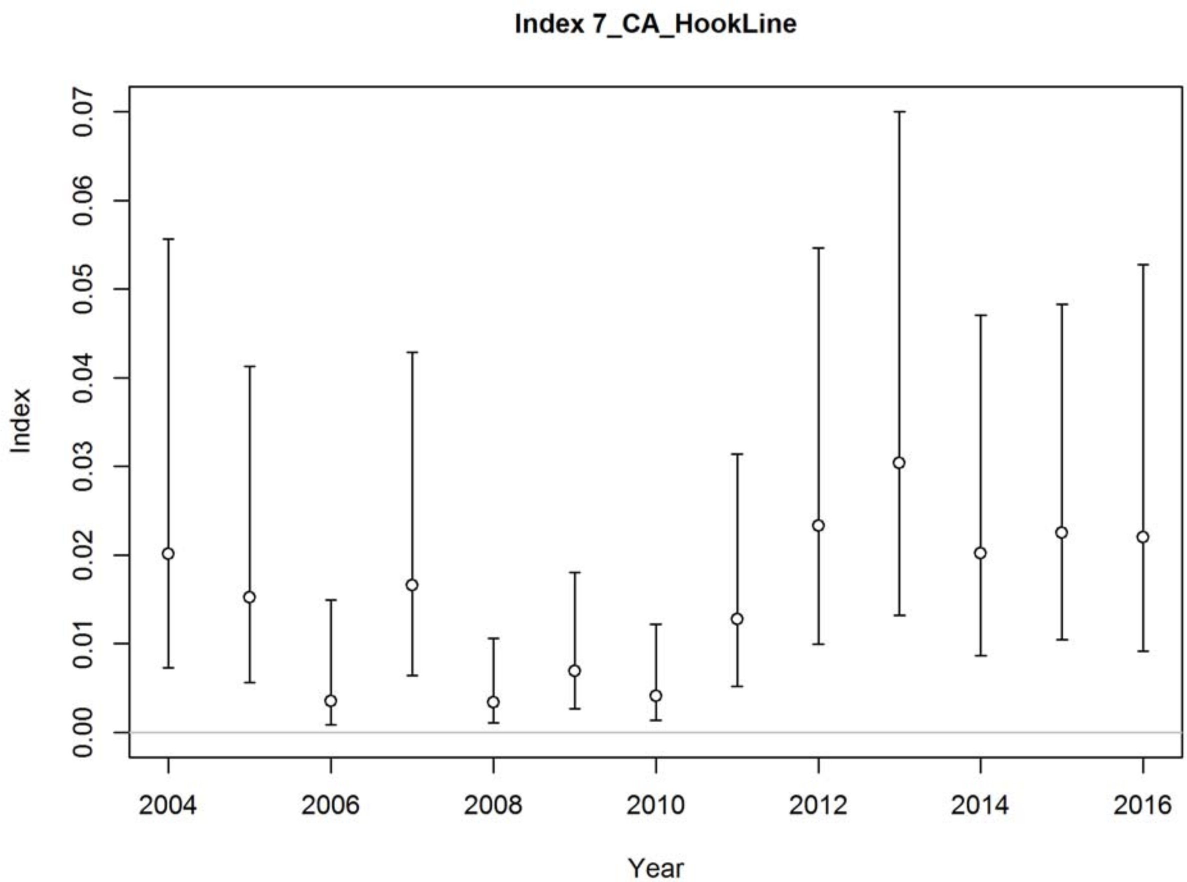


Figure 29. Southern CA Hook and Line survey posterior median index values (MCMC) with 95% prediction intervals.

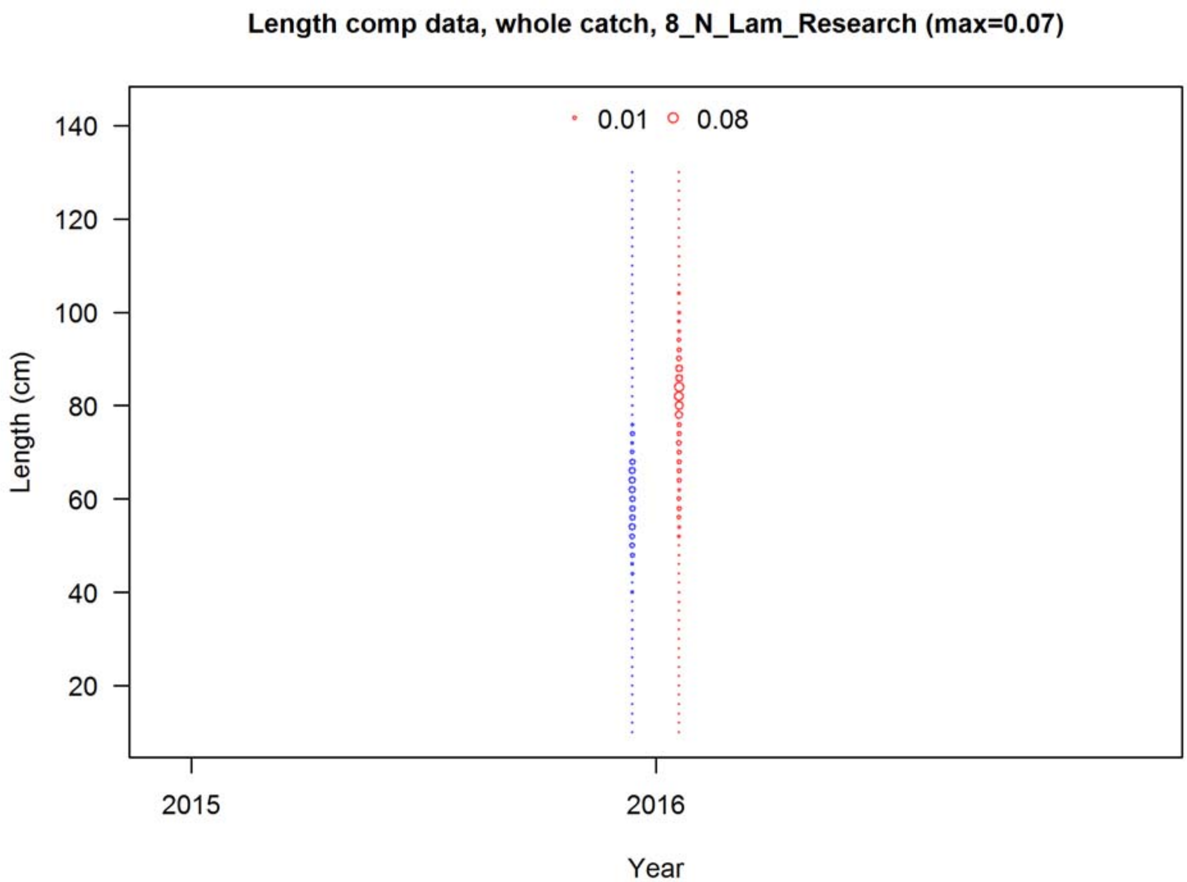


Figure 30. WA research length compositions, north.

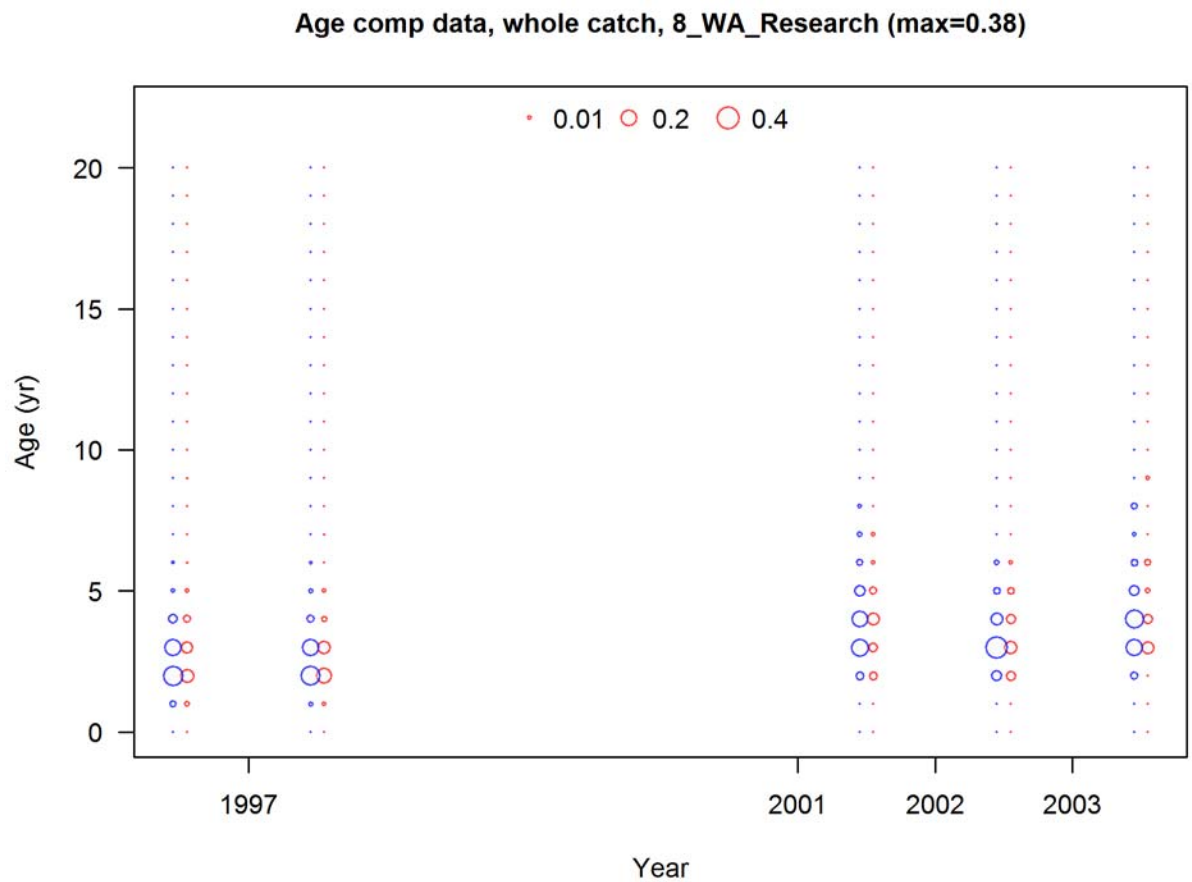


Figure 31. WA research age compositions, north.

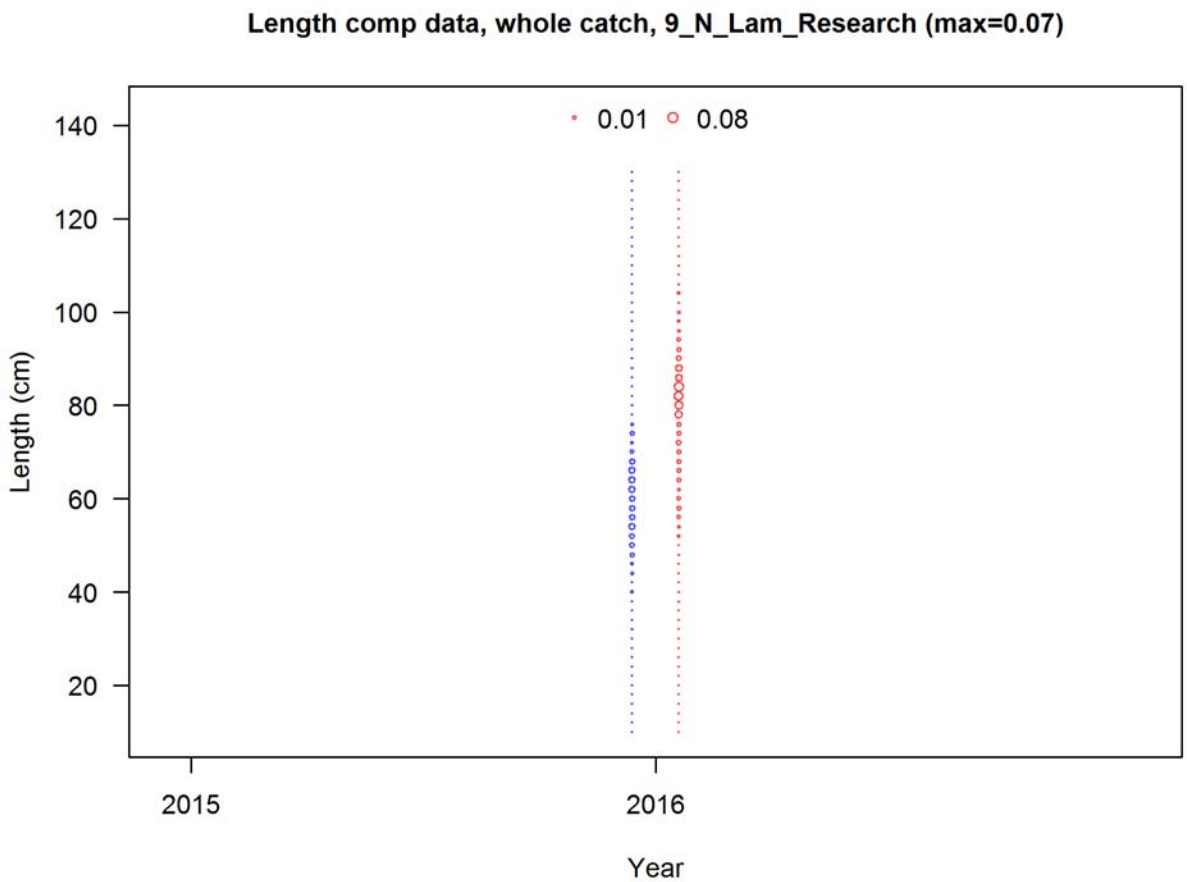


Figure 32. Lam research lengths, north.

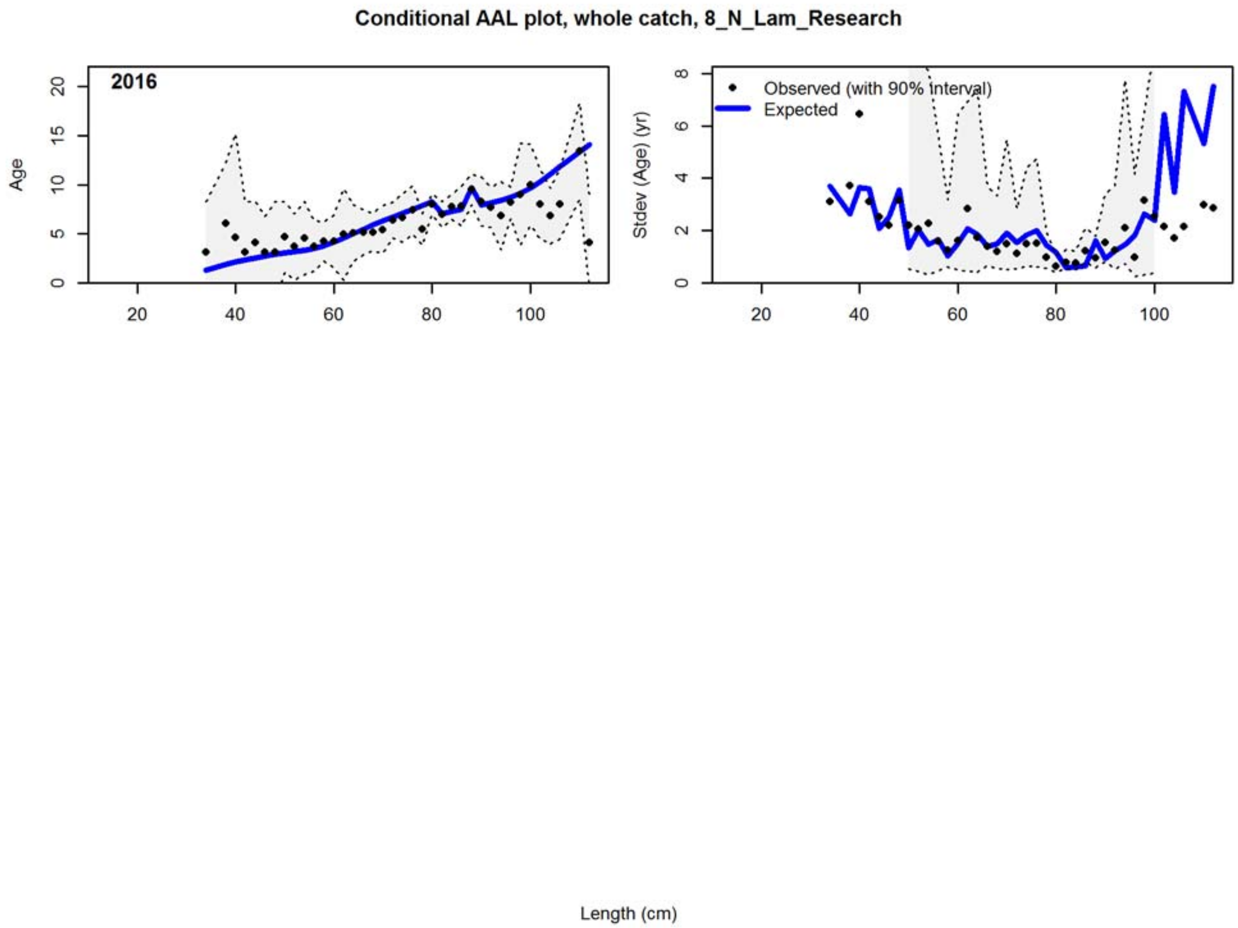


Figure 33. Lam research age compositions, north.

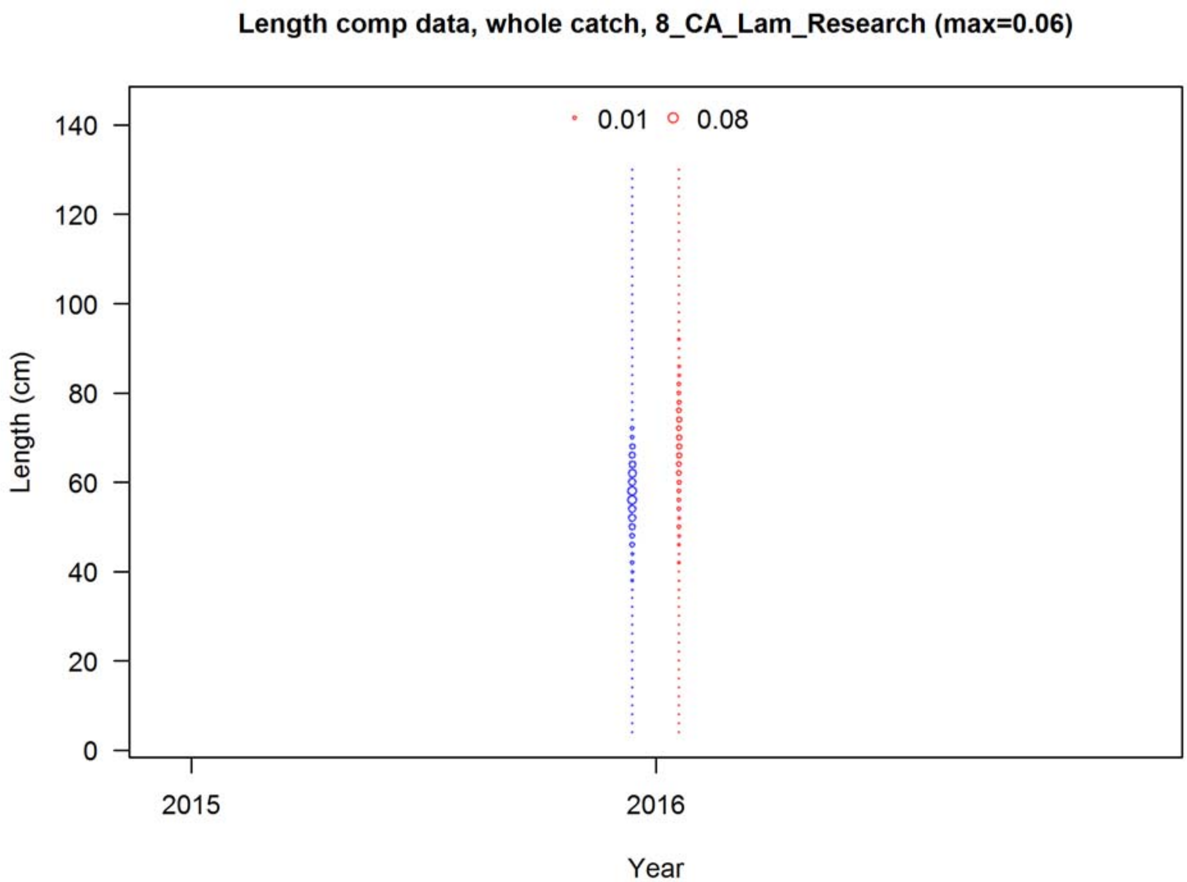


Figure 34. Lam research length compositions, south.

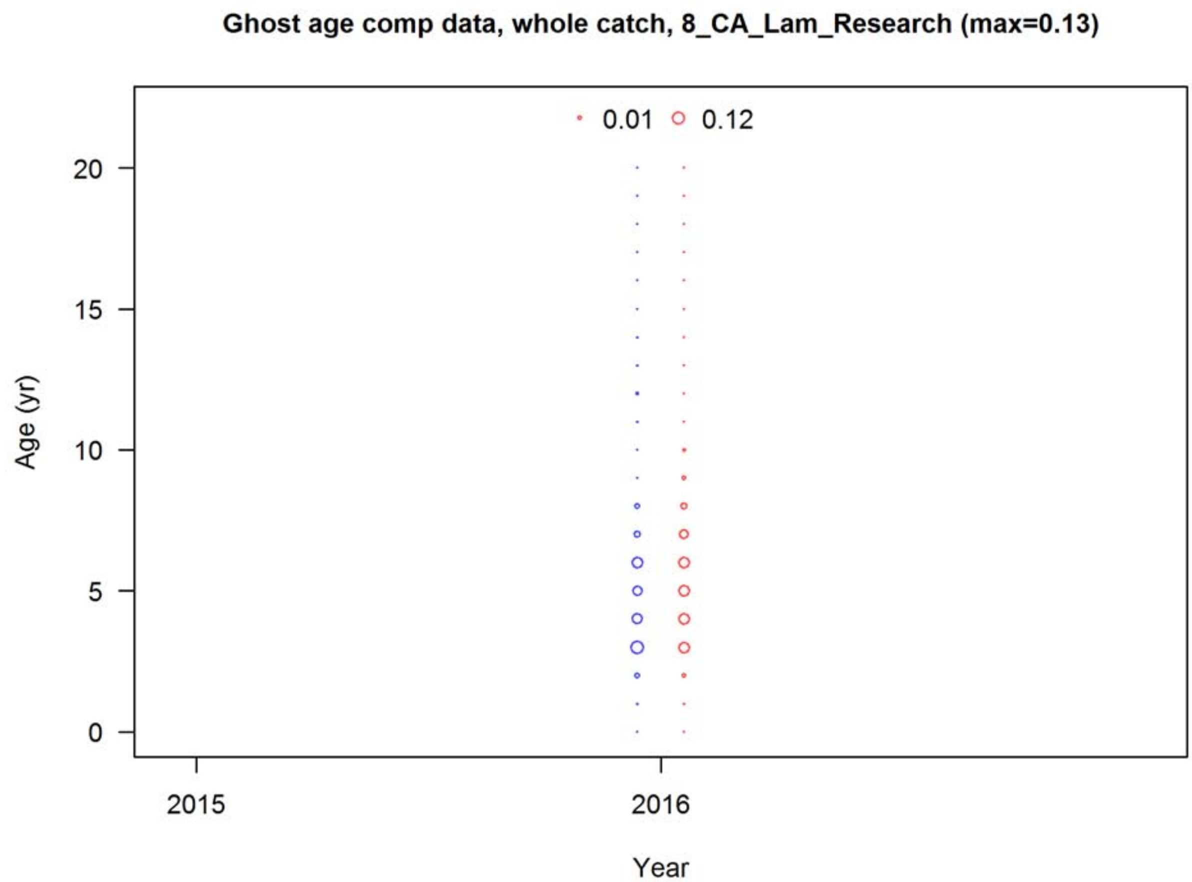


Figure 35. Lam research age compositions, south.

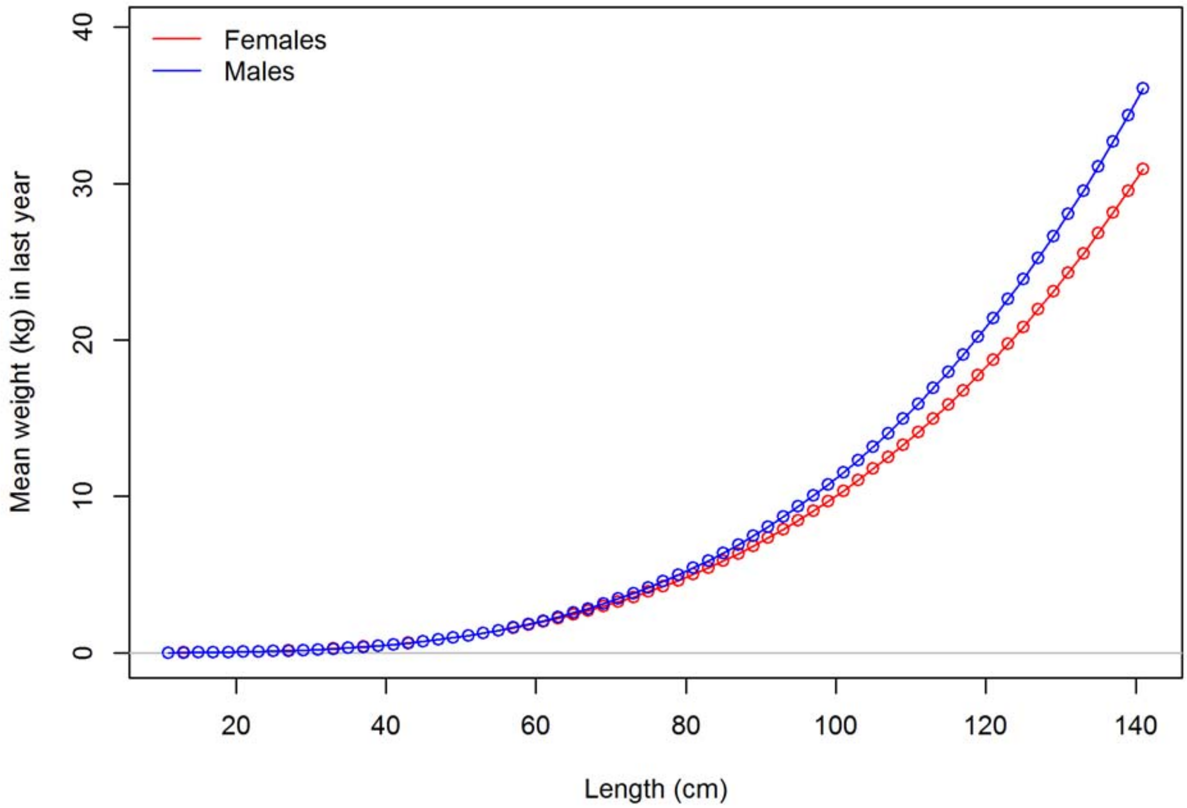


Figure 36. Length-weight relationship, north.

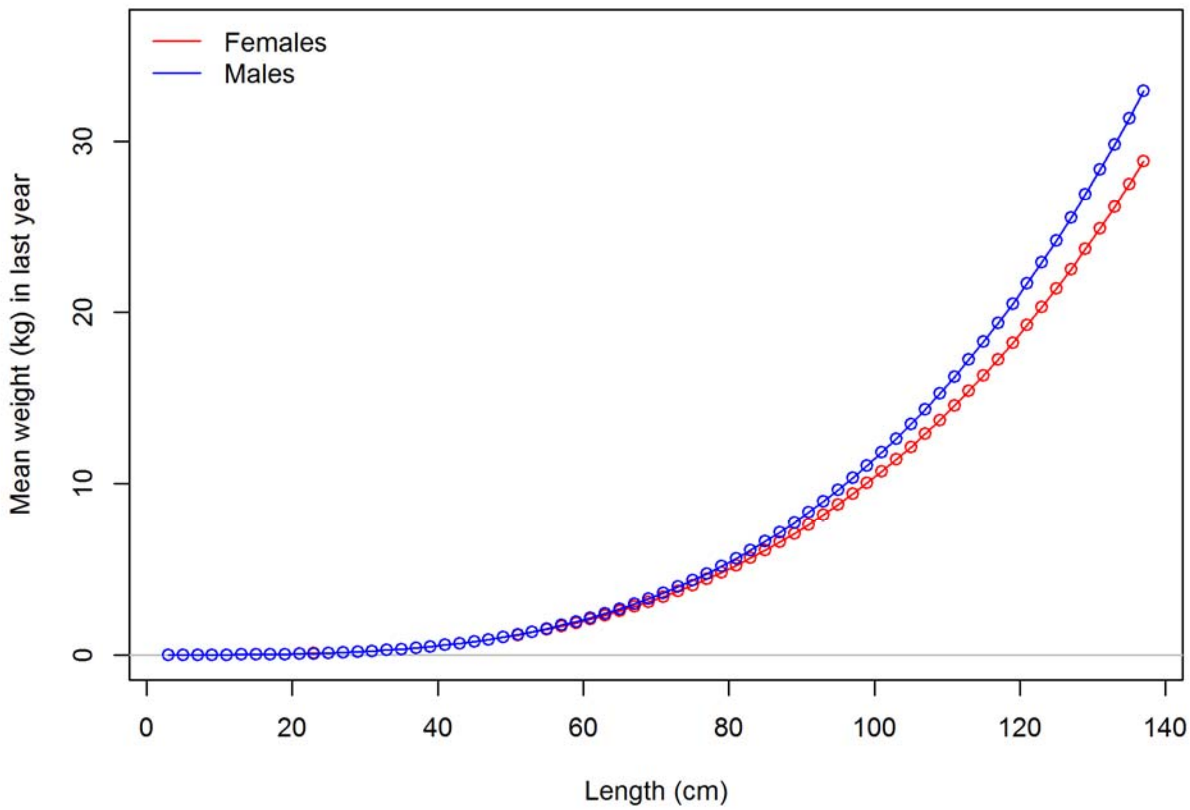
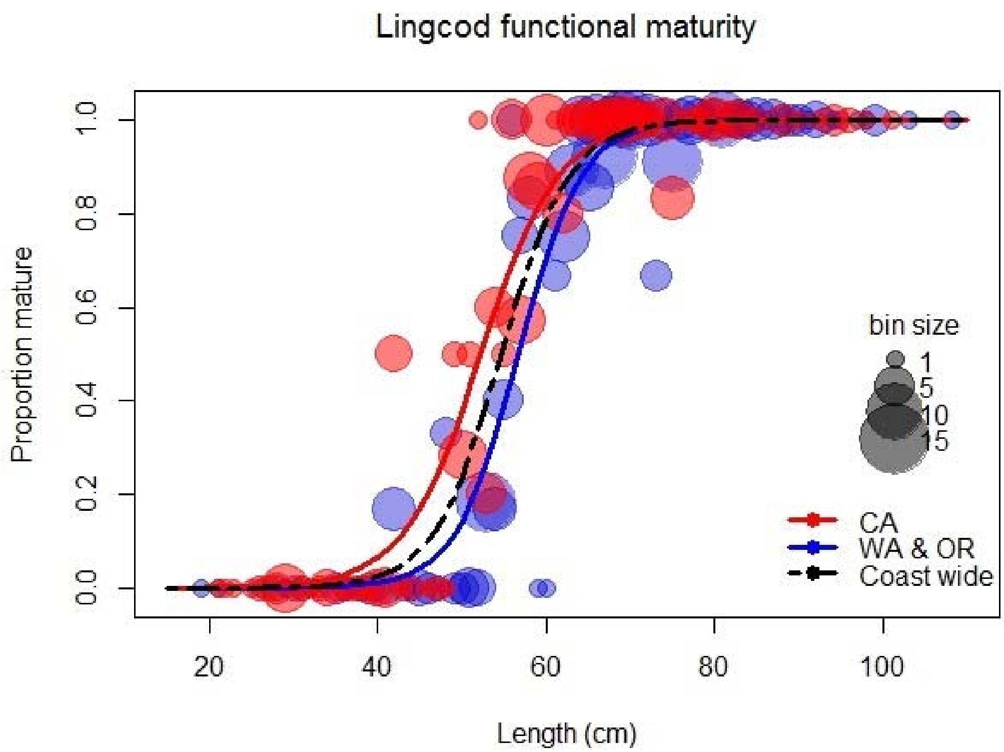


Figure 37. Length-weight relationship, south.



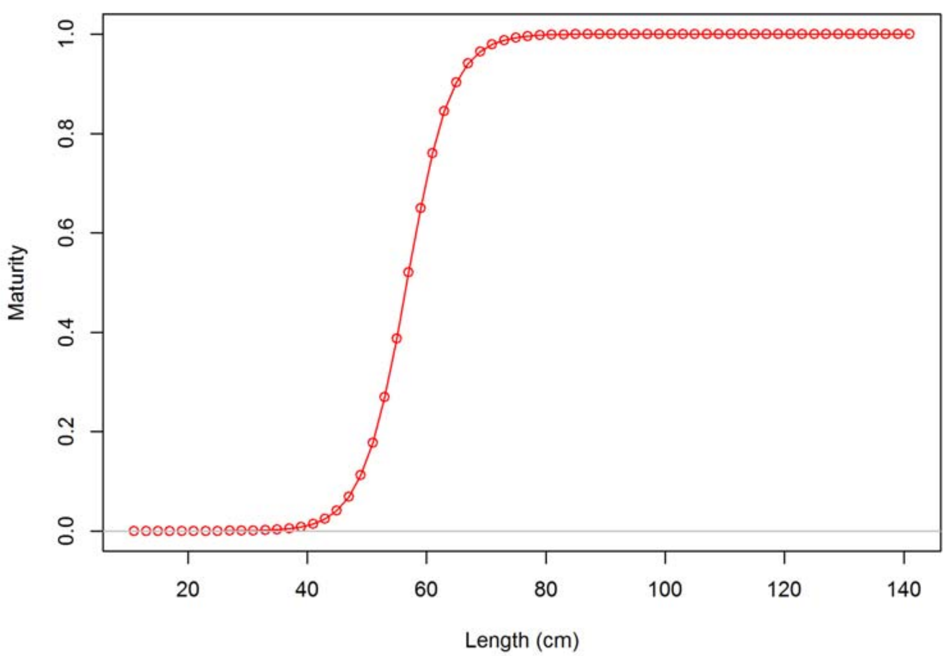


Figure 38. Maturity ogives, the top panel shows the data used to fit maturity ogives for both the north and south regions, the bottom panel shows the input to the north model.

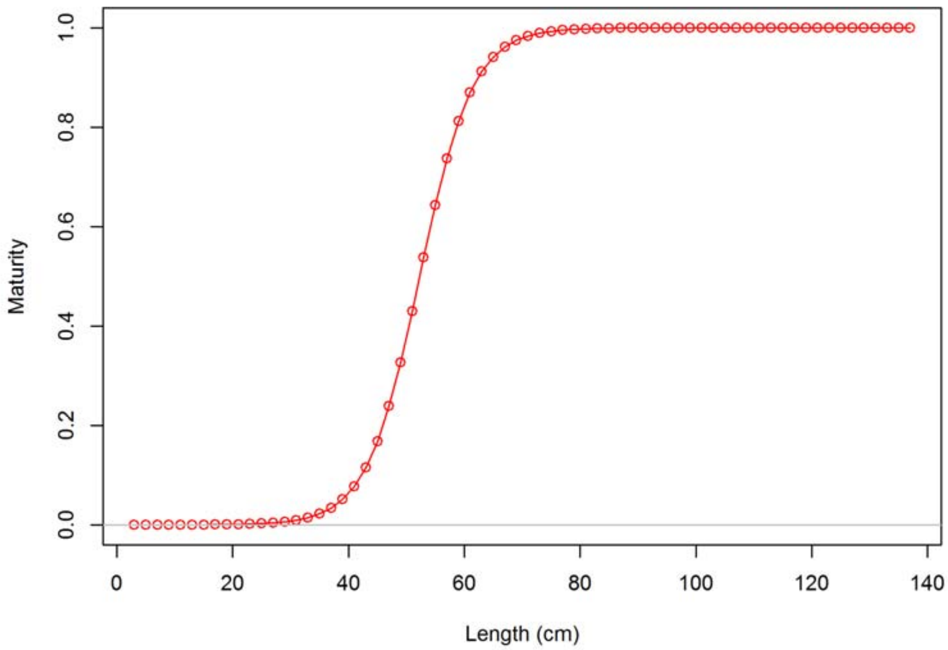


Figure 39. Maturity ogive input to the south.

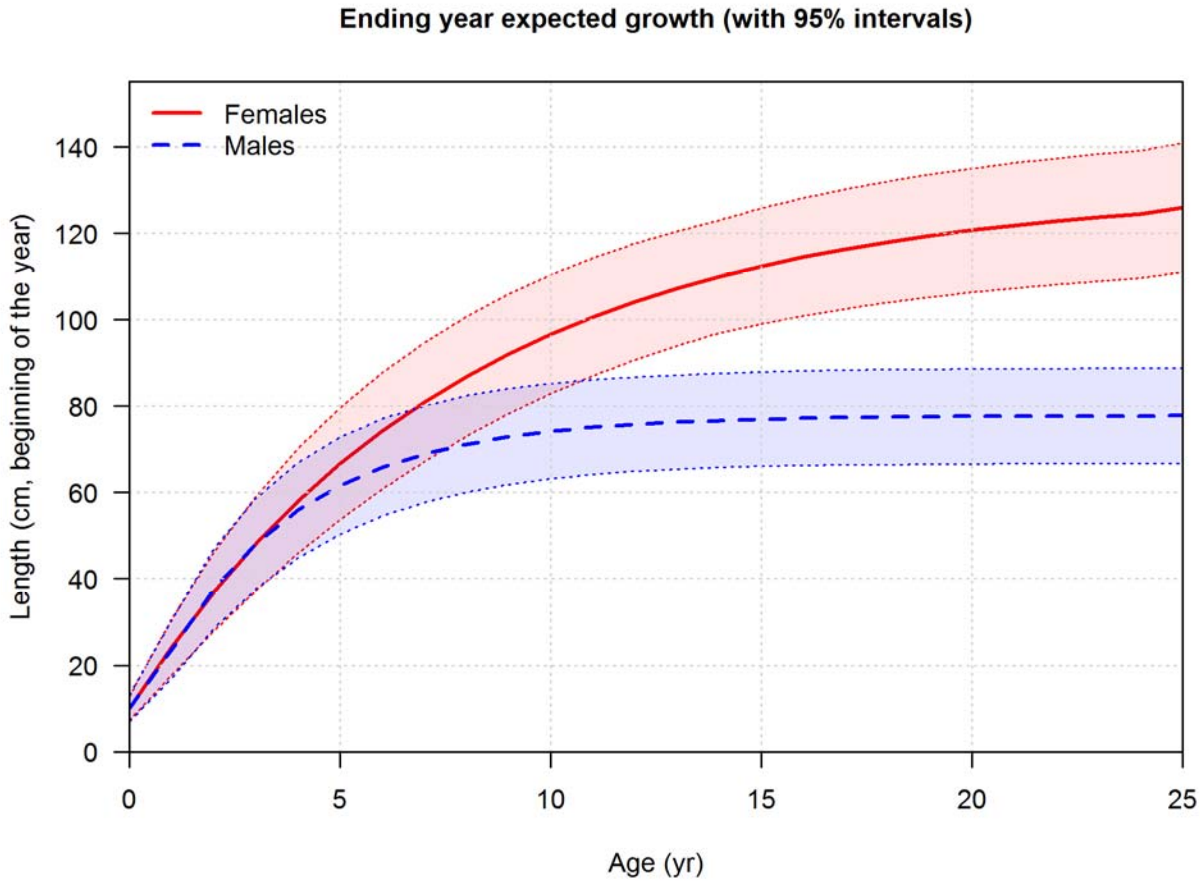


Figure 40. Model estimated growth, north.

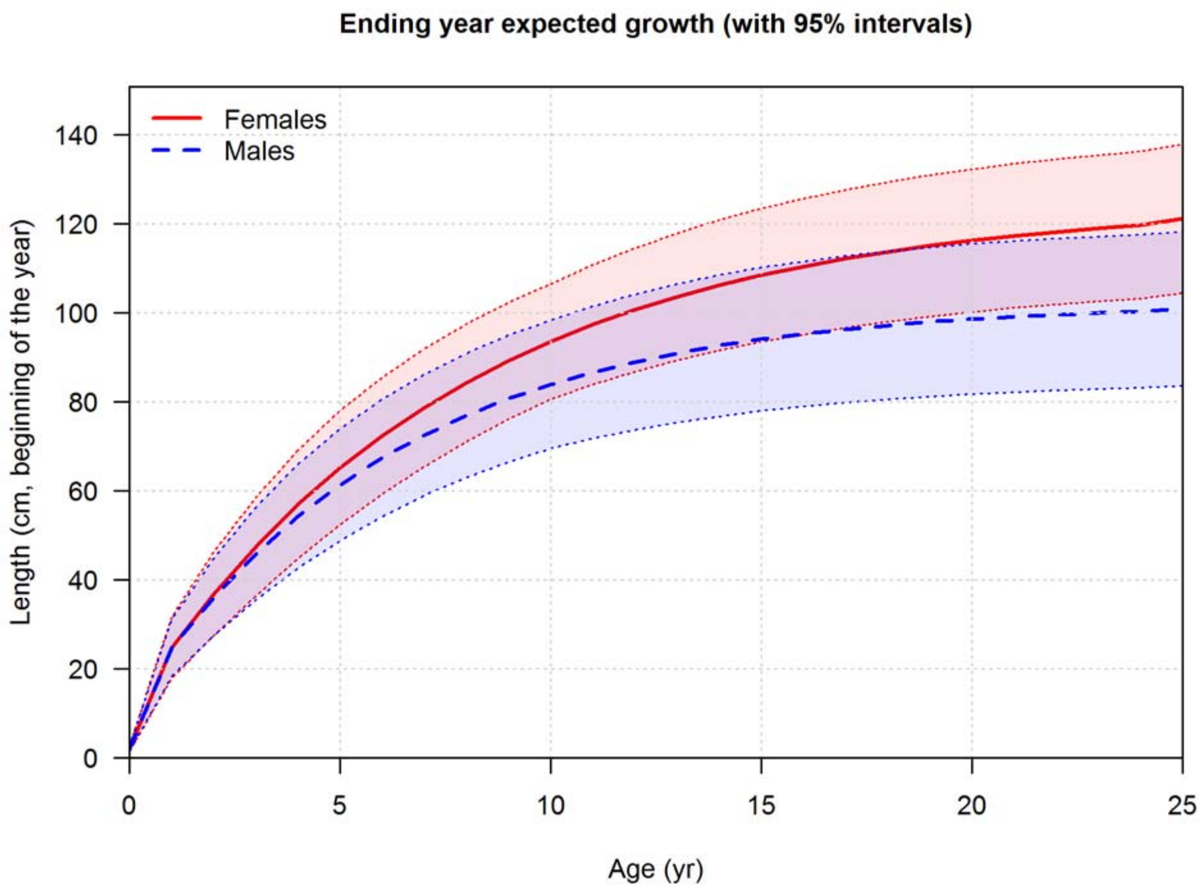


Figure 41. Model estimated growth, south

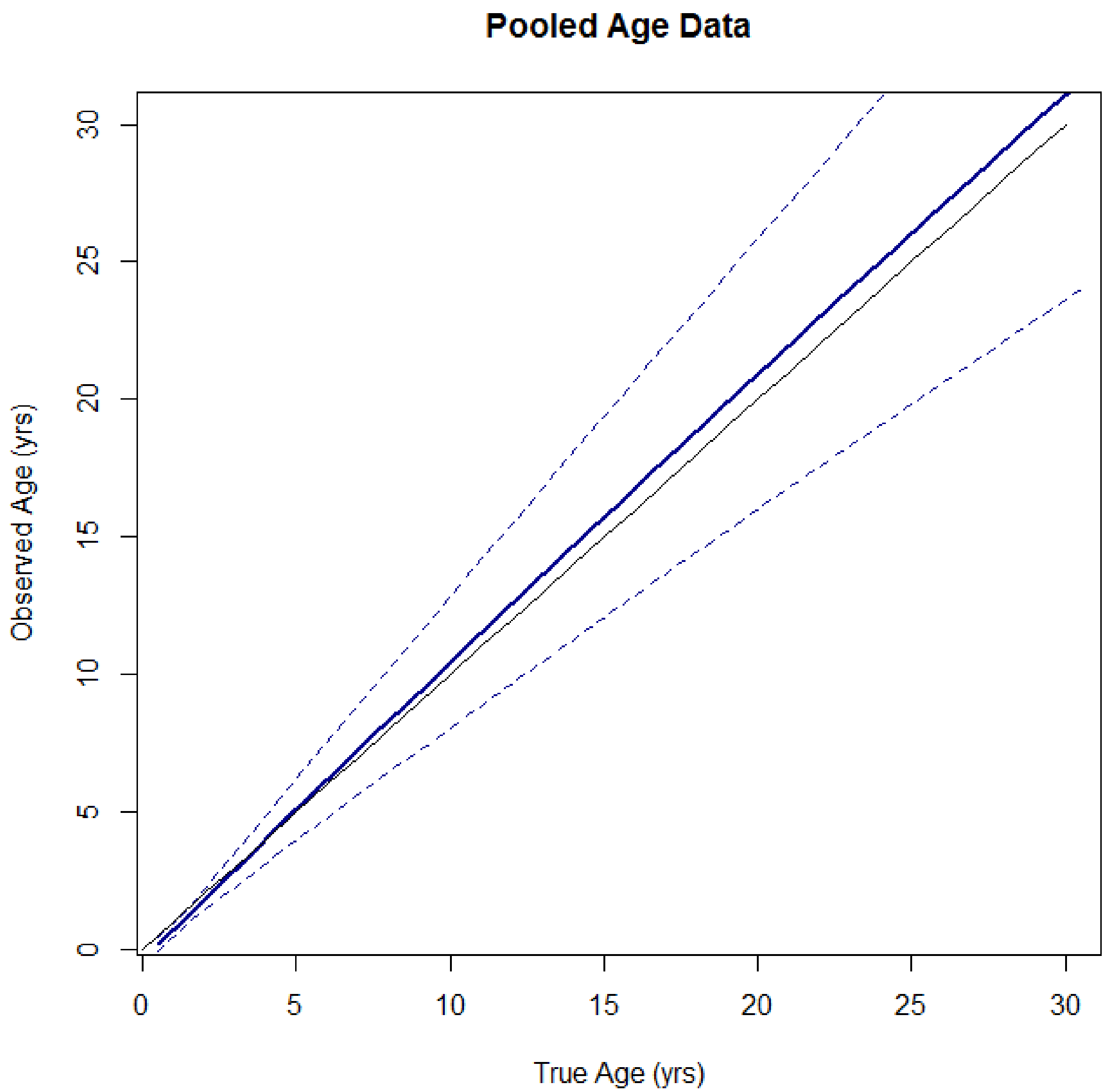


Figure 42. Aging error bias between labs and variability. The difference between the black 1:1 line (WDFW Lab) and the blue line (CAP) labs shows that the two labs age similarly, with the CAP lab aging fish as slightly older at older ages.

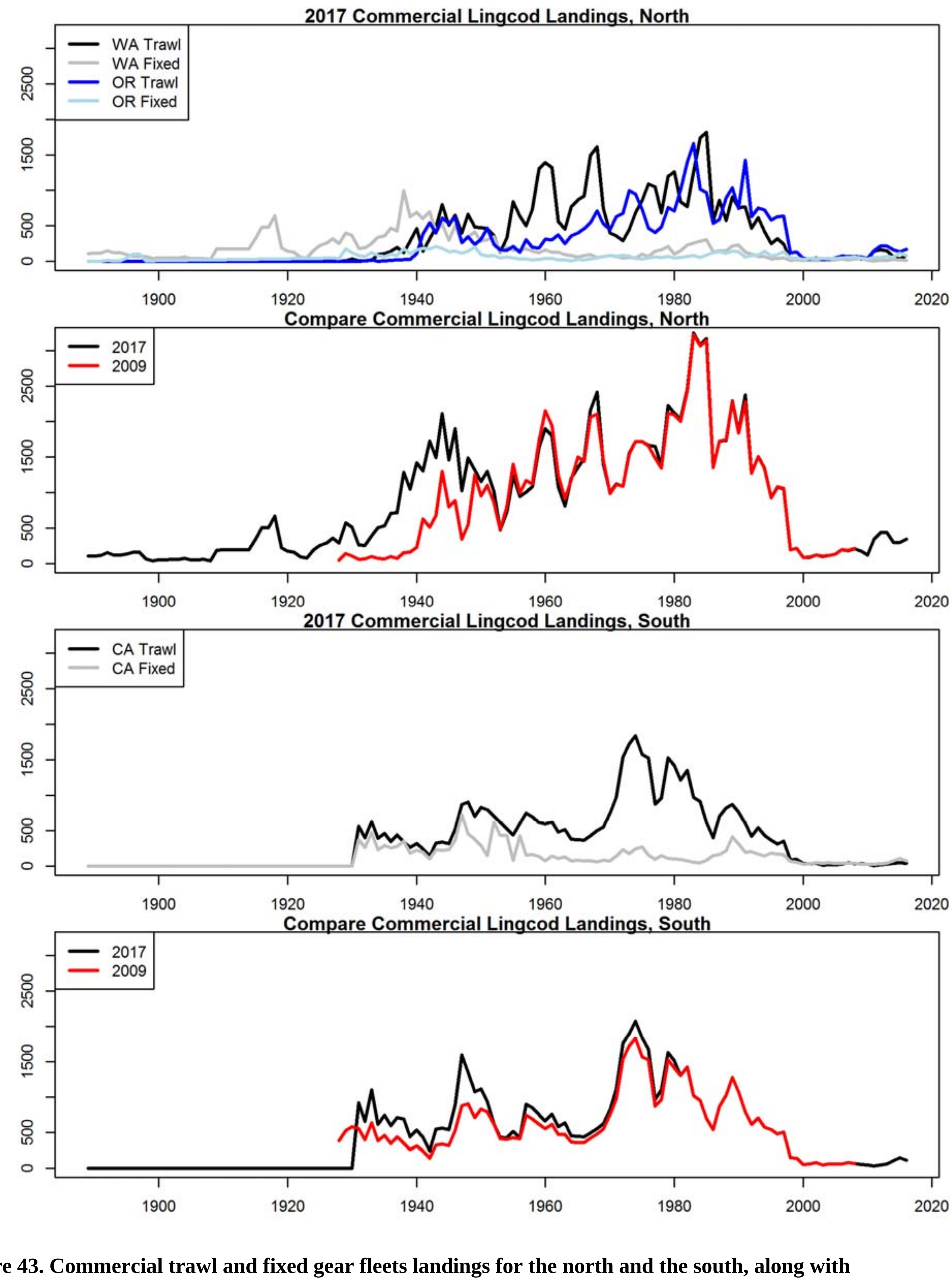


Figure 43. Commercial trawl and fixed gear fleets landings for the north and the south, along with comparison between landings used in the 2009 assessment and current assessment. Note that this figure only includes recorded data and not the assumed early catch ramp for CA used in the base model of this assessment.

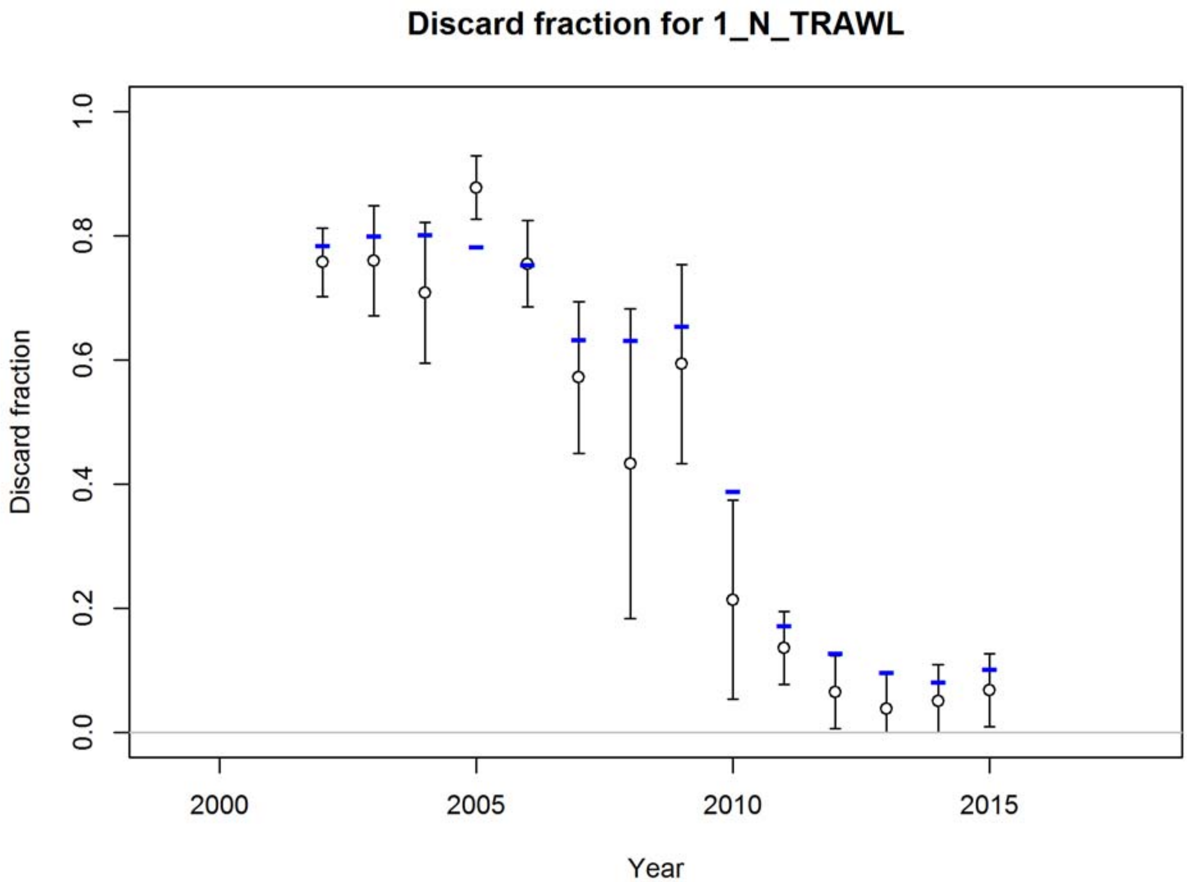


Figure 44. Discard fraction (circles) and the bootstrap uncertainty (vertical lines), trawl fleet, north. The blue horizontal lines are model fits to data.

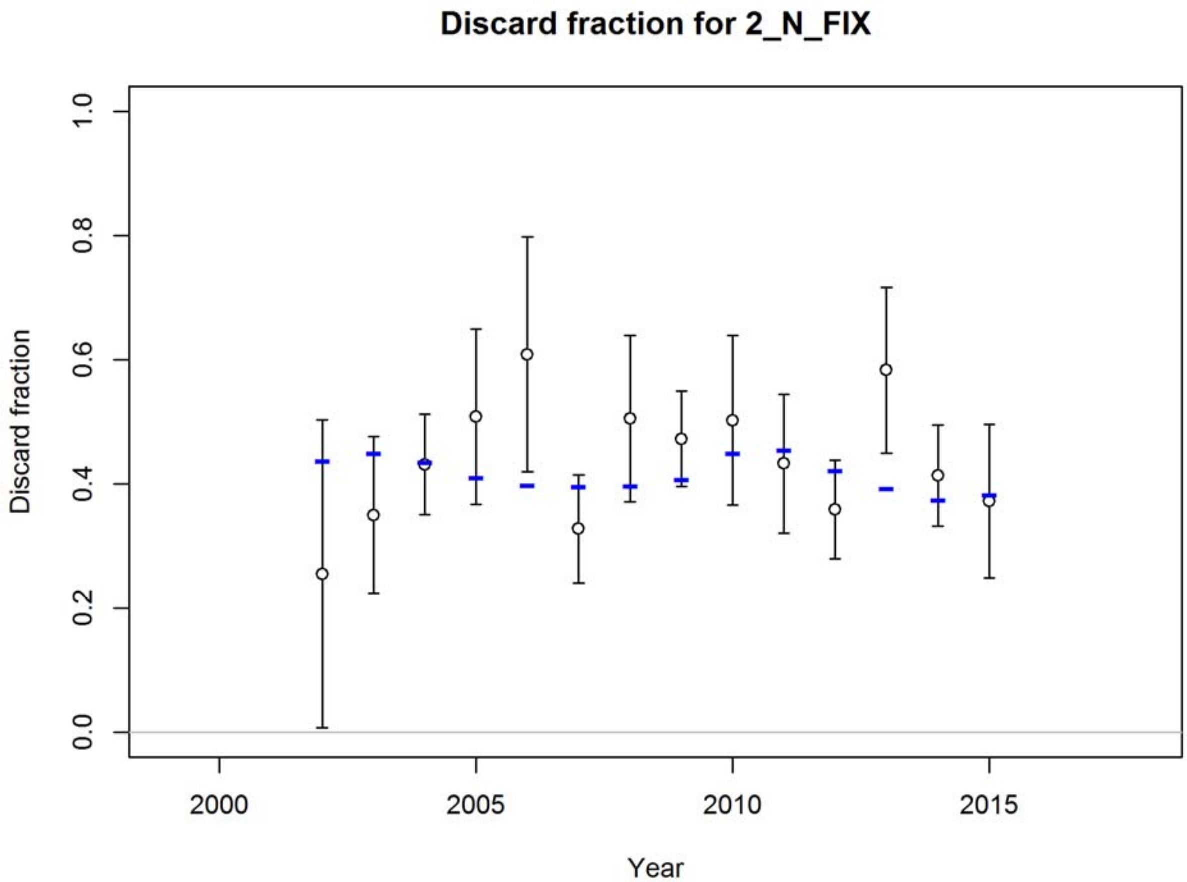


Figure 45. Discard fraction (circles) and the bootstrap uncertainty (vertical lines), fixed gear fleet, north. The blue horizontal lines are model fits to data.

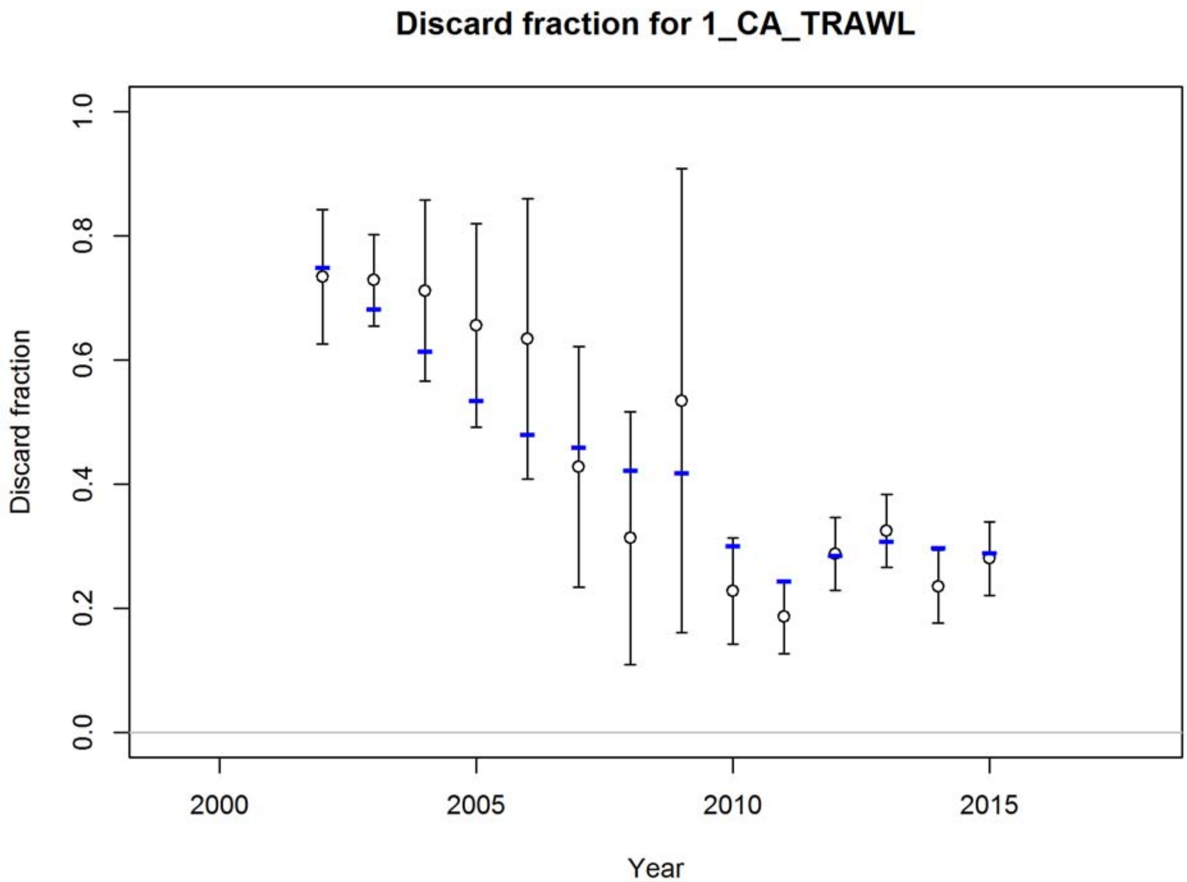


Figure 46. Discard fraction (circles) and the bootstrap uncertainty (vertical lines), trawl fleet, south. The blue horizontal lines are model fits to data.

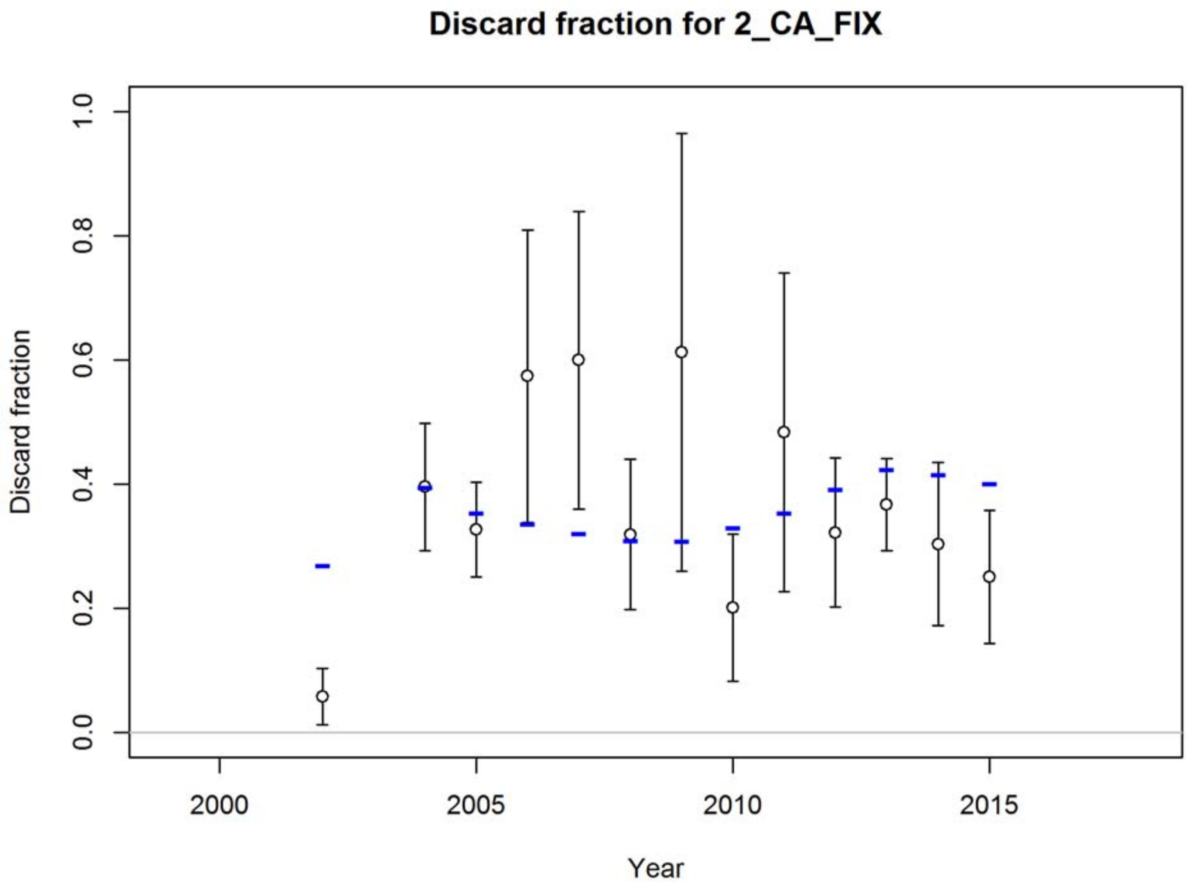


Figure 47. Discard fraction (circles) and the bootstrap uncertainty (vertical lines), fixed gear fleet, south. The blue horizontal lines are model fits to data.

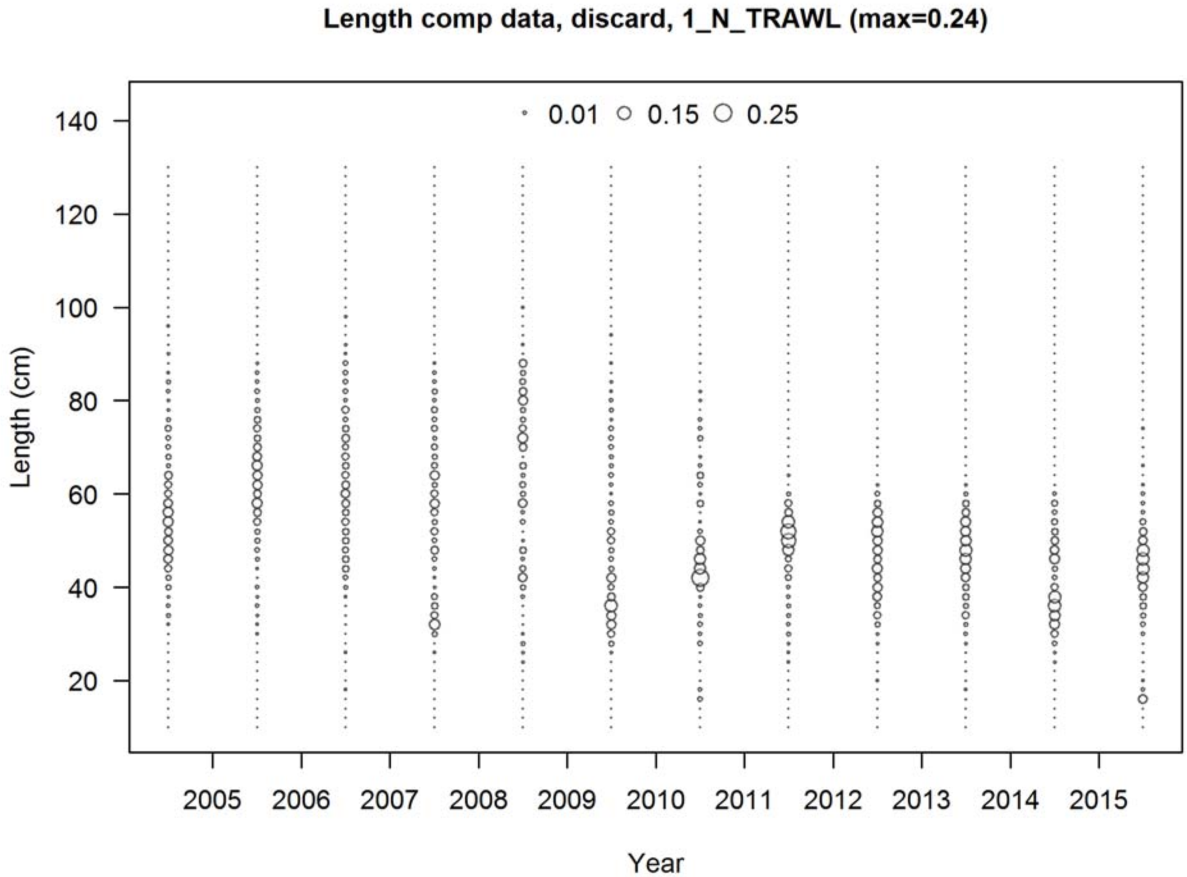


Figure 48. Discard length compositions, trawl fleet, north.

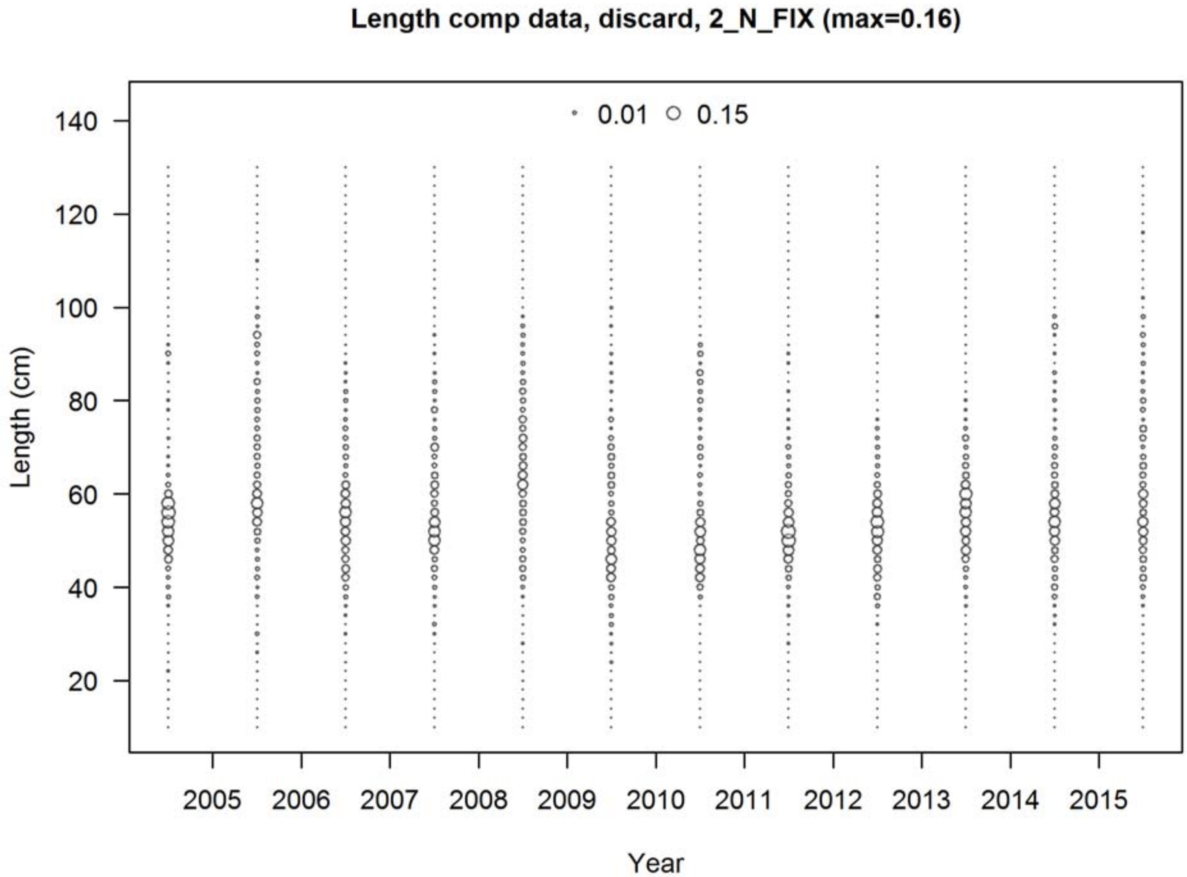


Figure 49. Discard length compositions, fixed gear fleet, north.

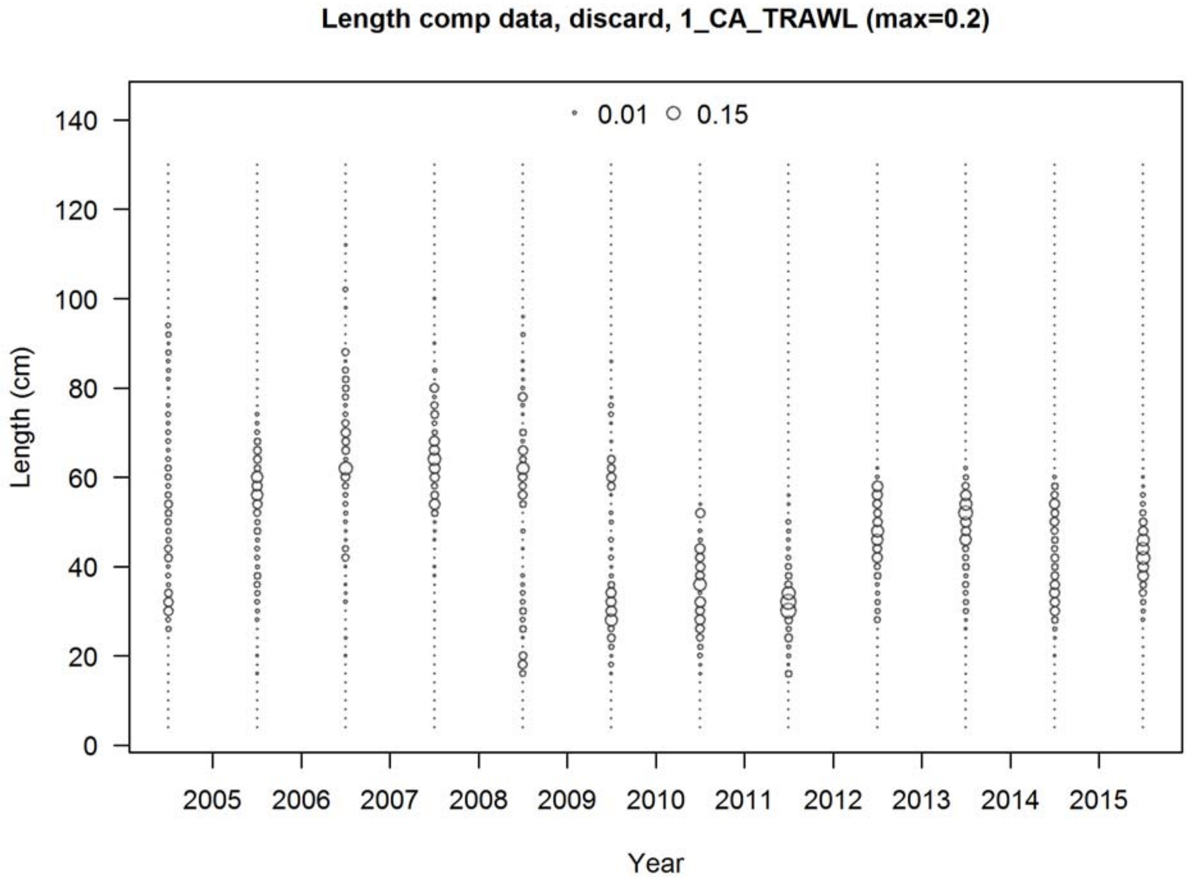


Figure 50. Discard length compositions, trawl, south.

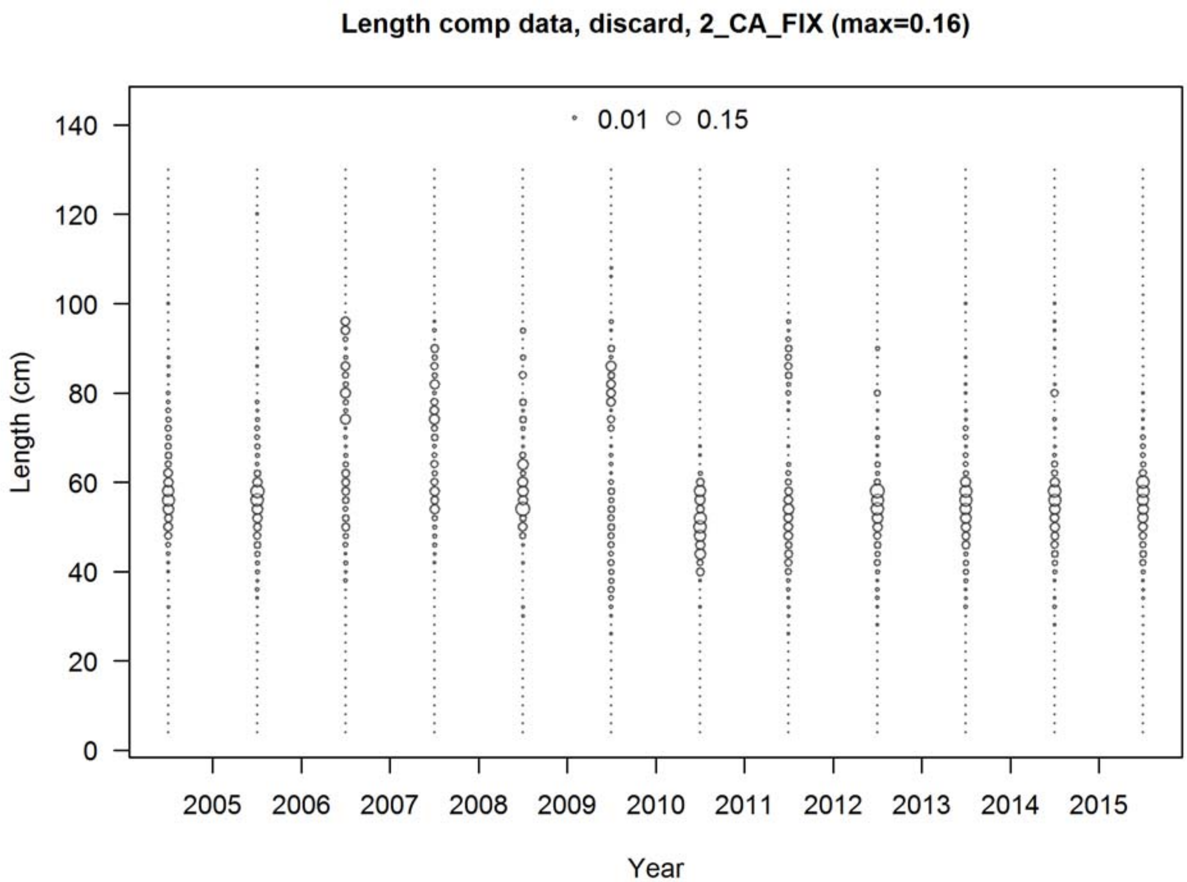


Figure 51. Discard length compositions, fixed gear fleet, south.

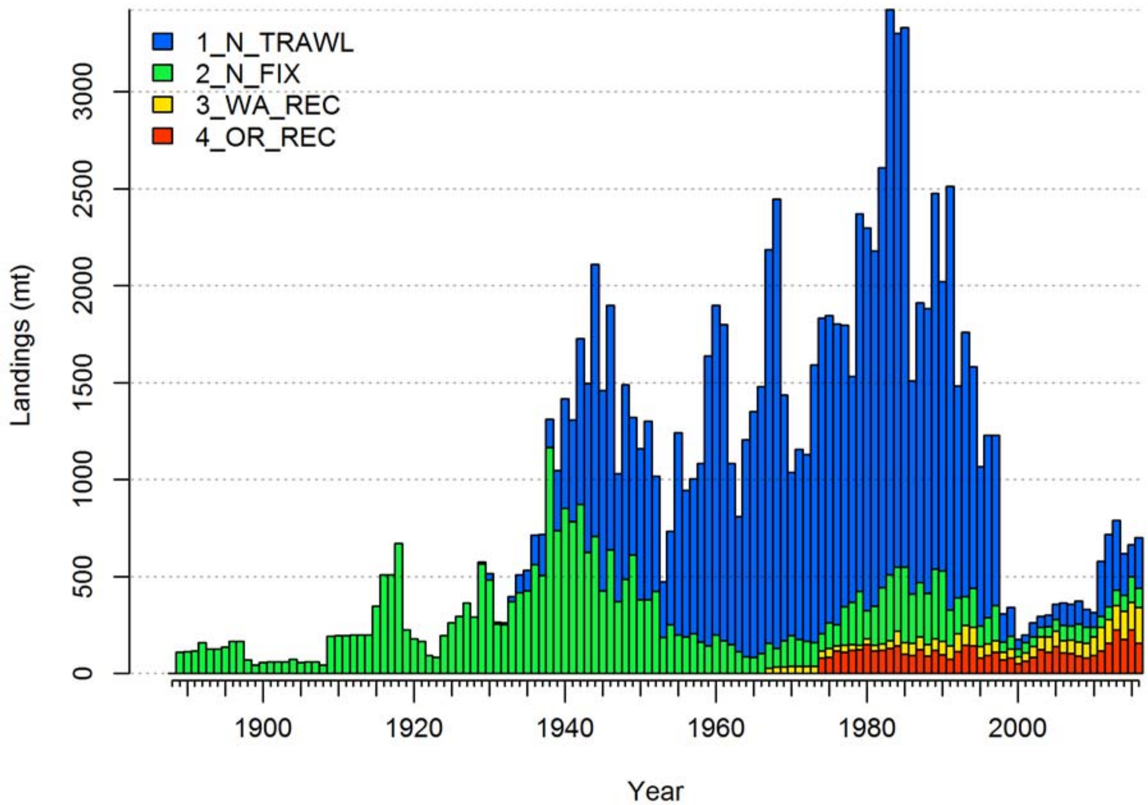


Figure 52. Commercial and recreational landings, north.

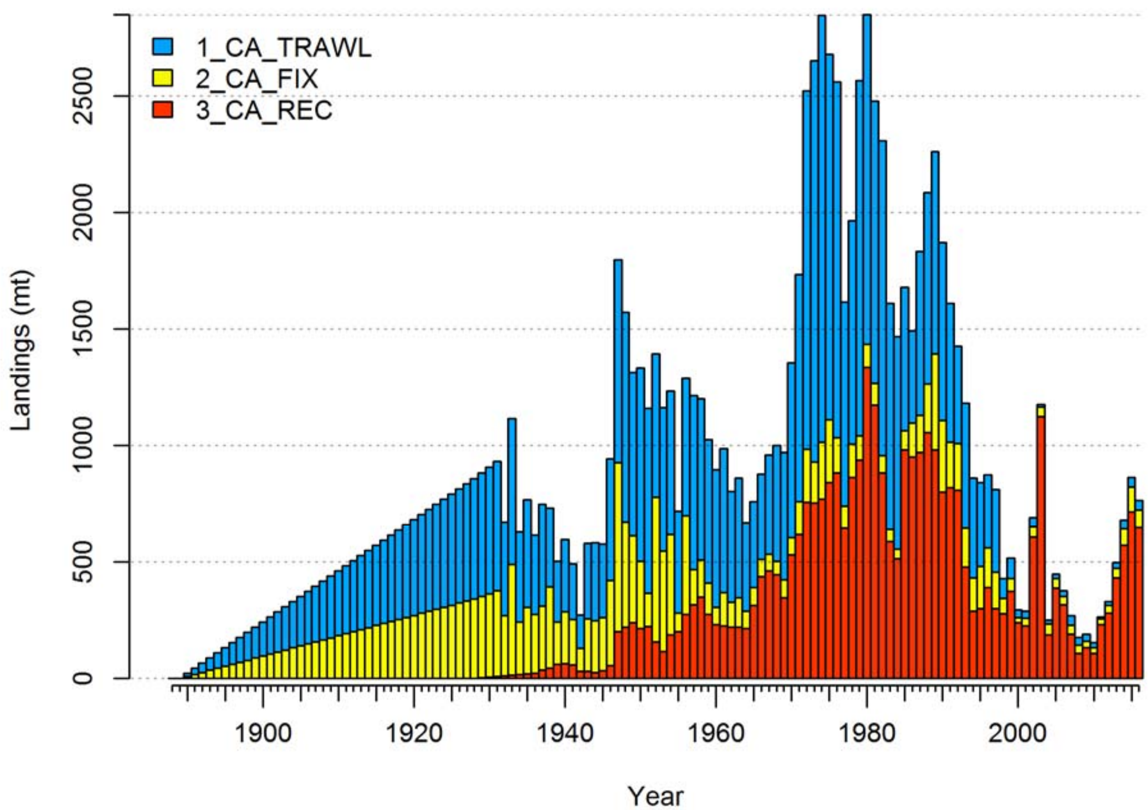


Figure 53. Commercial and recreational landings, south.

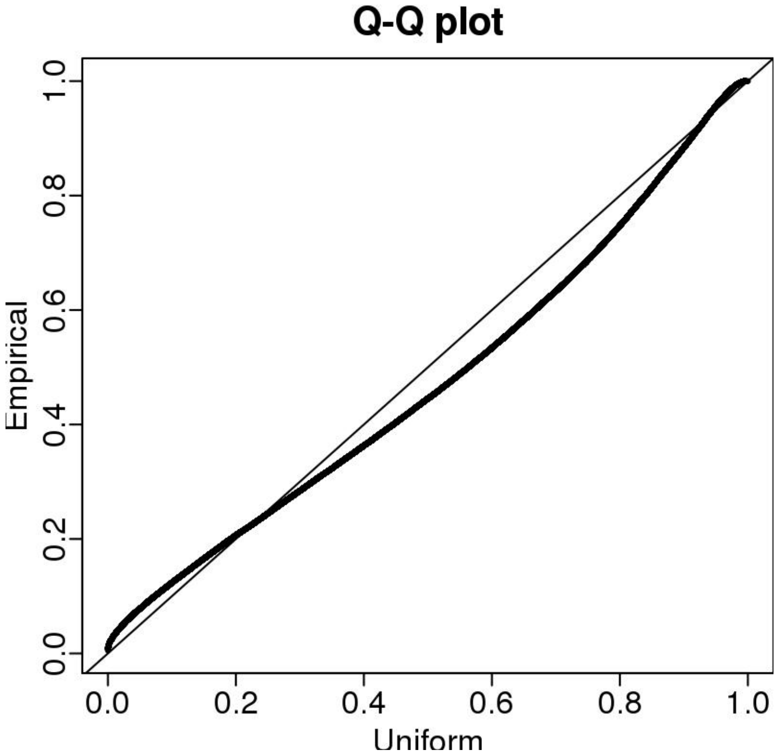


Figure 54. PacFIN logbook CPUE index VAST Q-Q plot.

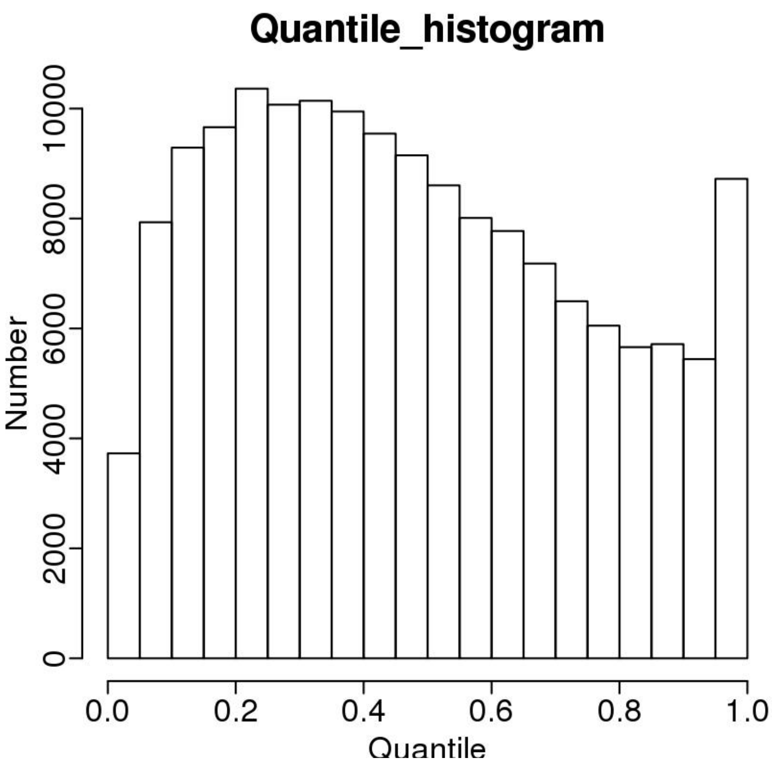


Figure 55. PacFIN logbook CPUE index VAST binned by predicted encounter probability.

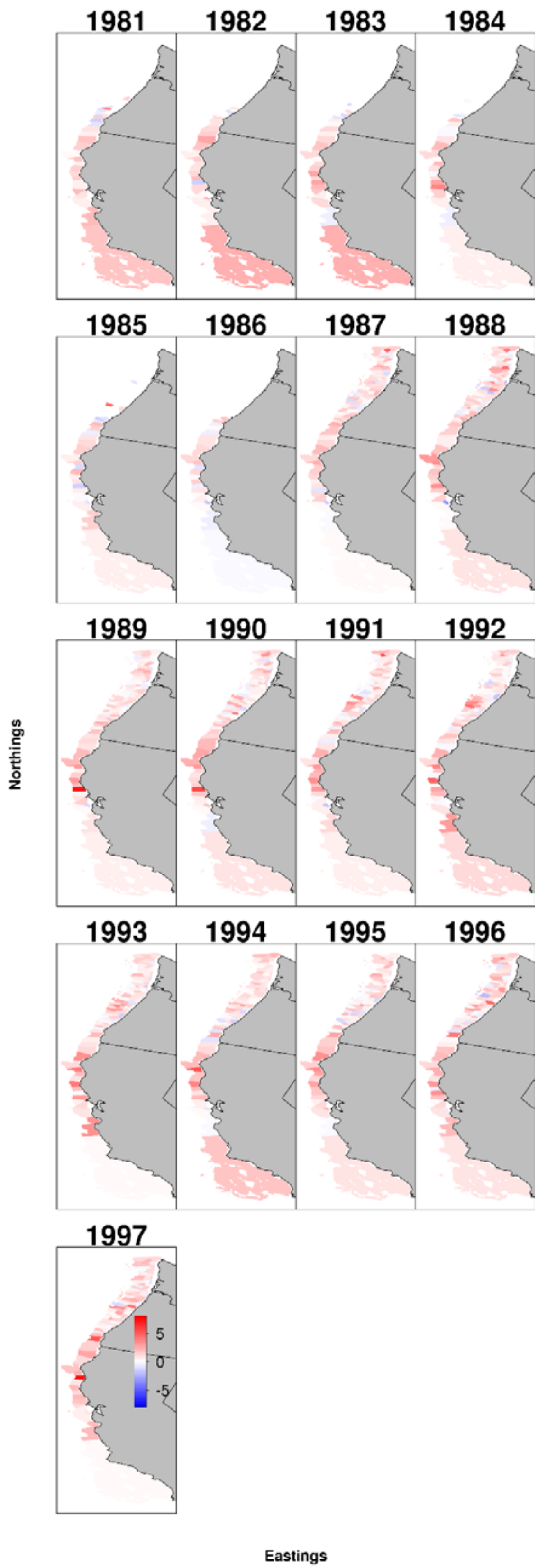


Figure 56. PacFIN logbook CPUE index encounter probability Pearson residuals.

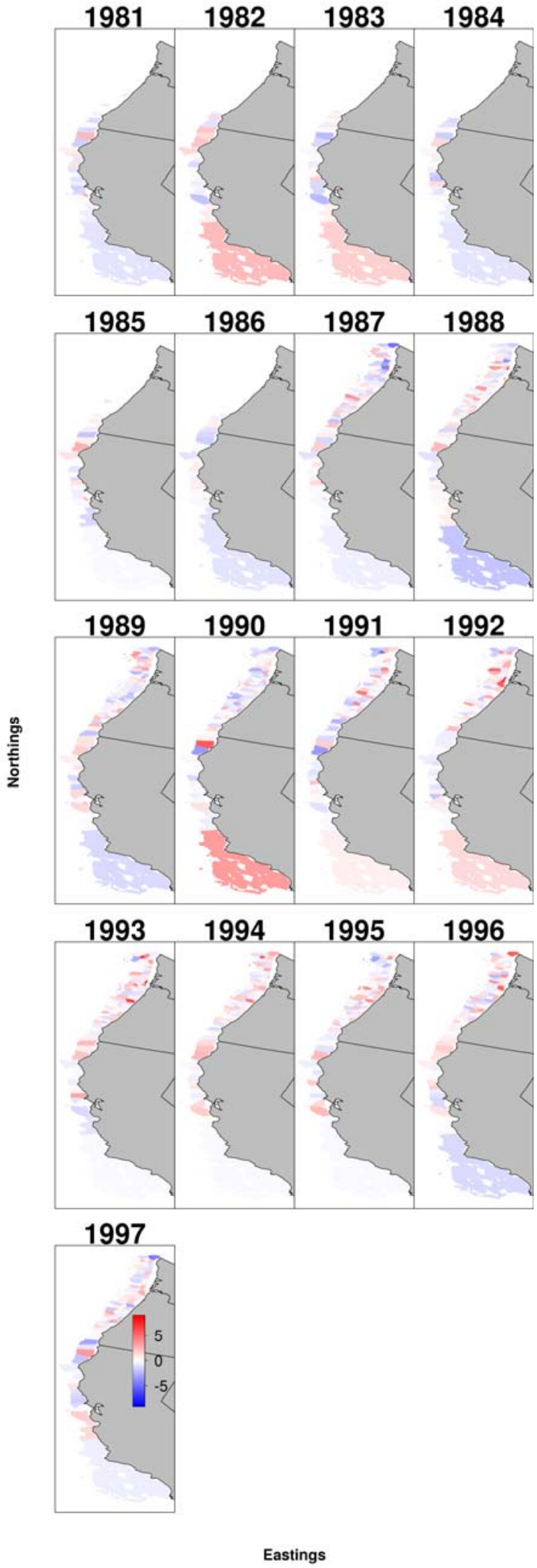


Figure 57. PacFIN logbook CPUE index VAST positive catch rate probability Pearson residuals.

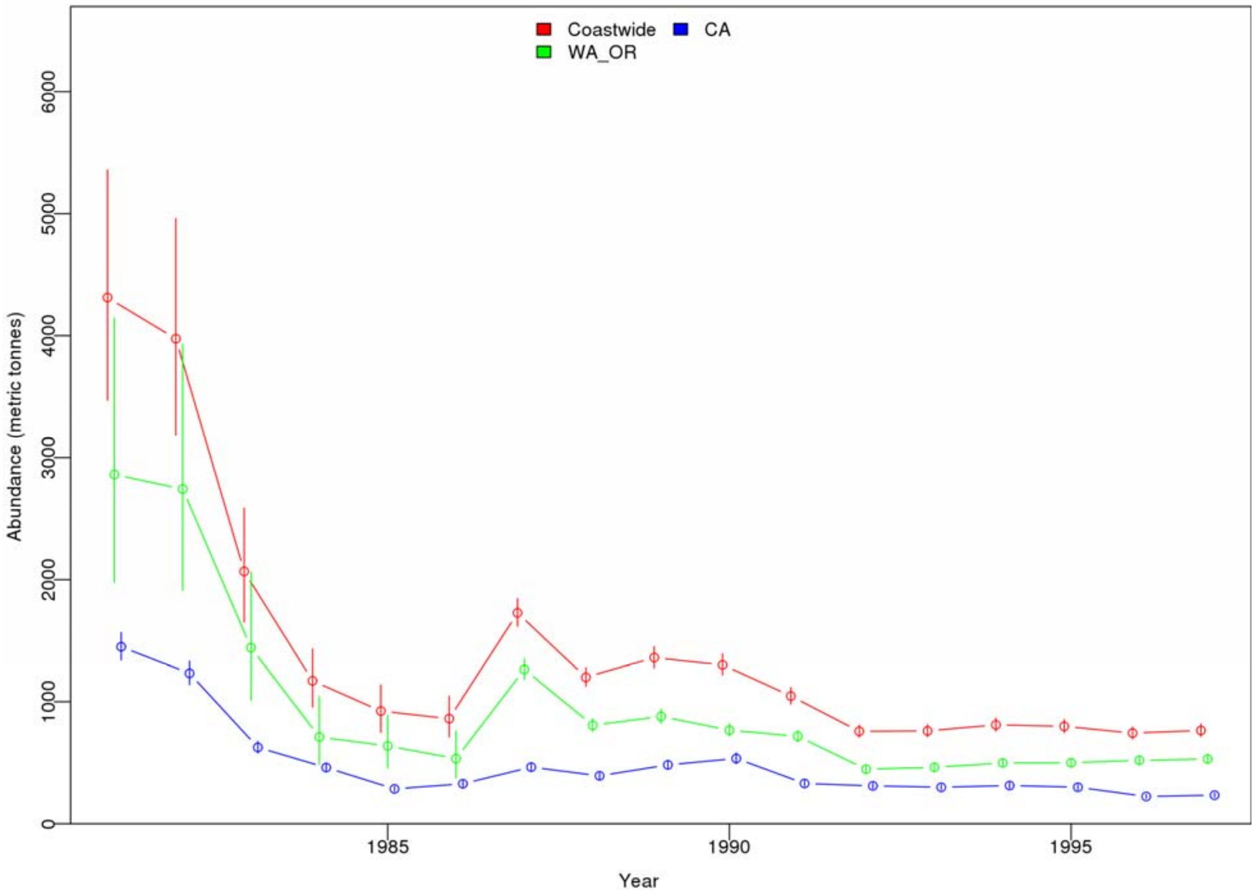


Figure 58. PacFIN logbook CPUE VAST indices.

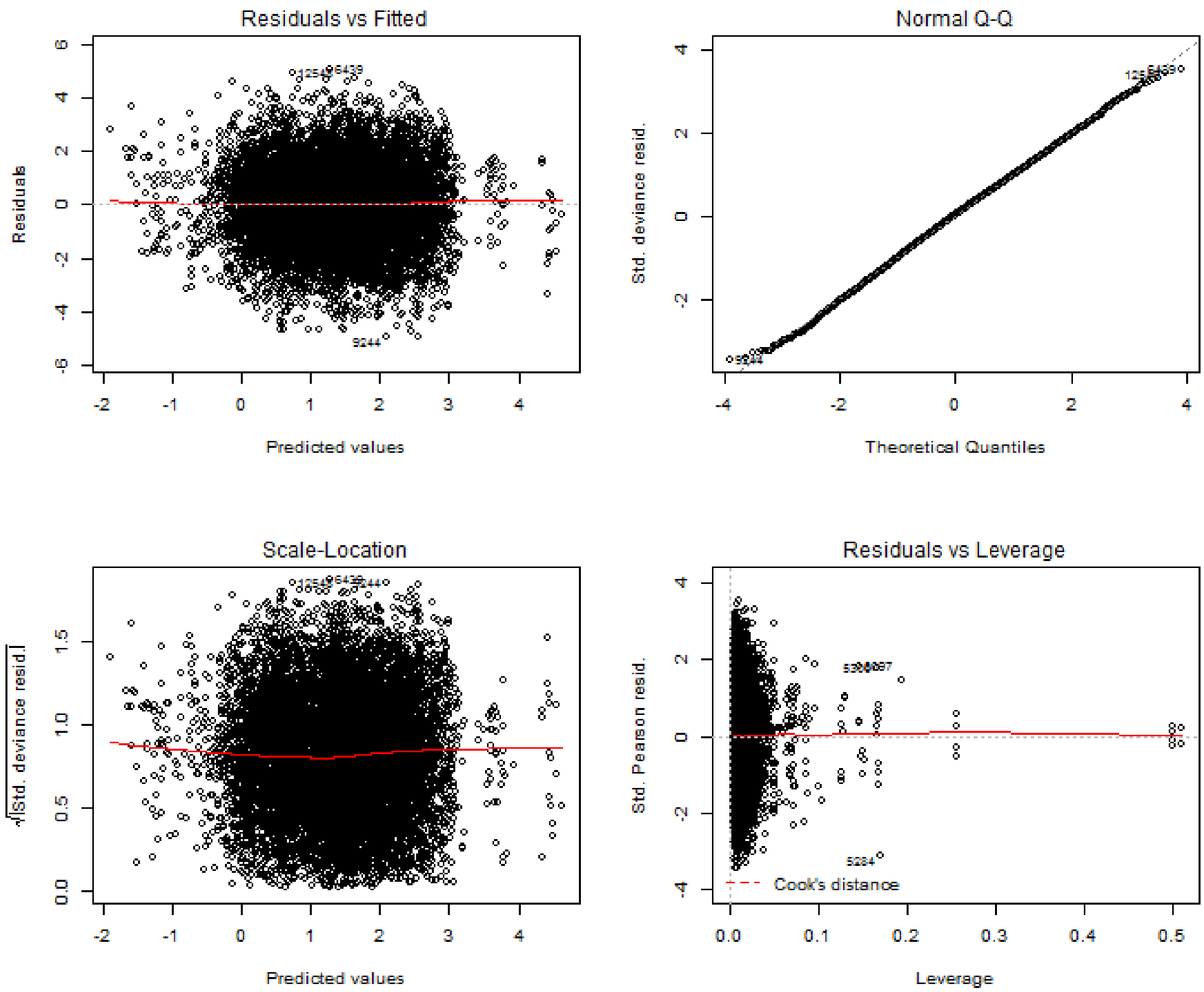


Figure 59. OR commercial nearshore logbook CPUE GLM diagnostics.

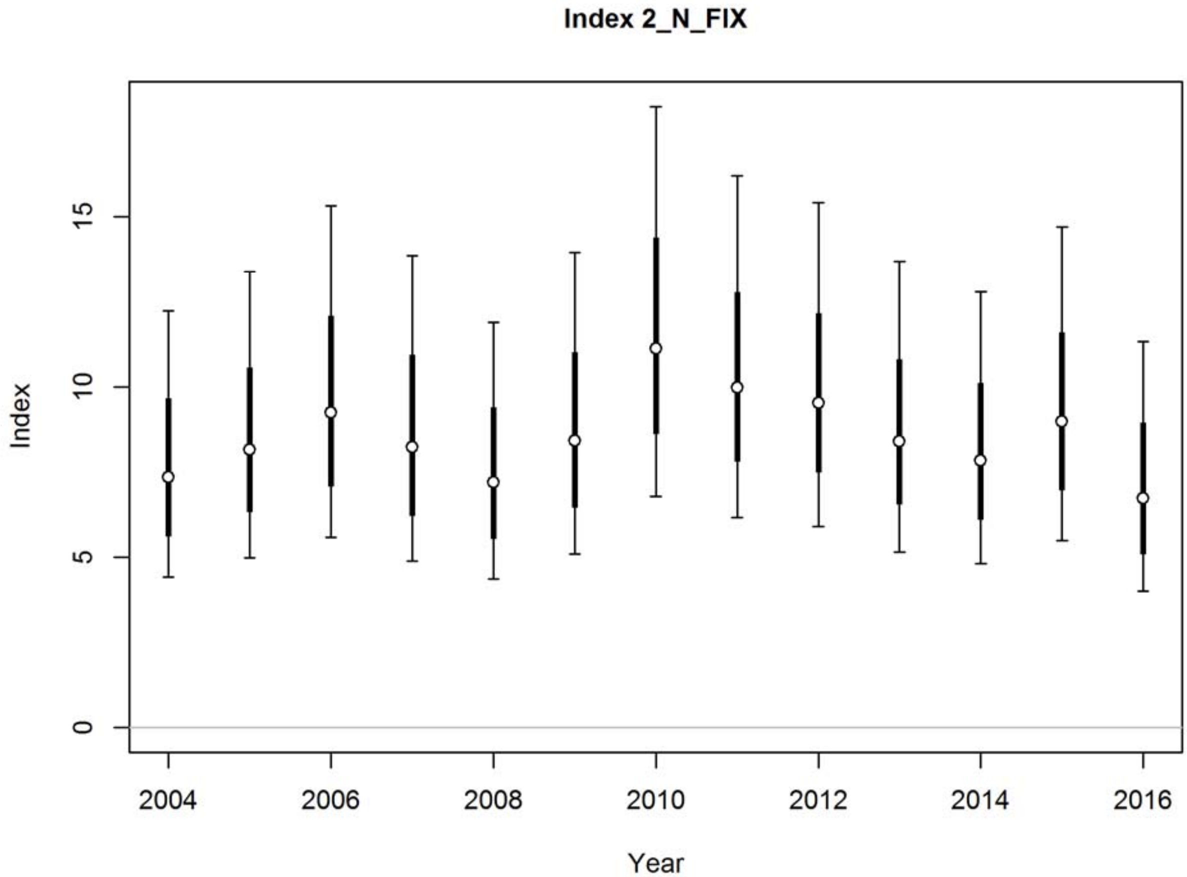


Figure 60. OR nearshore commercial logbook index.

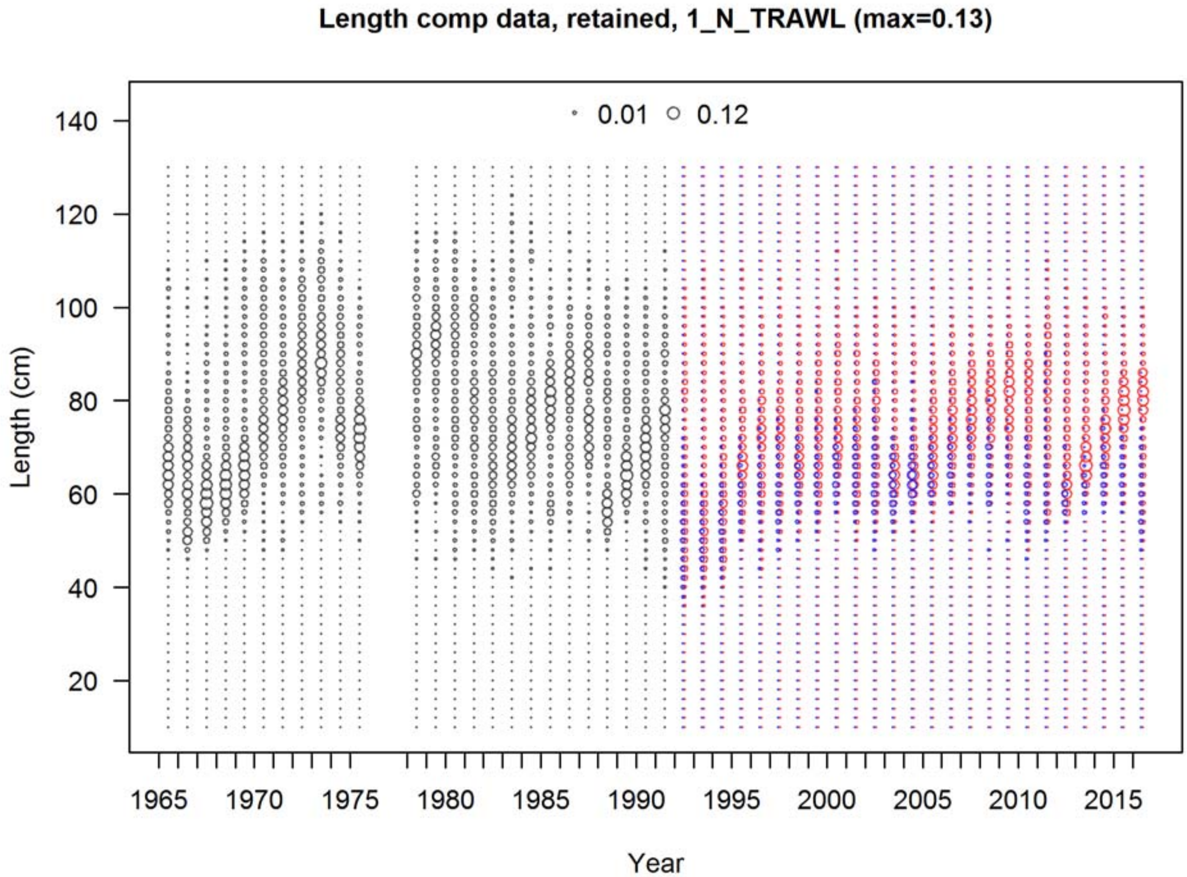


Figure 61. Commercial trawl length compositions, north. Grey circles represent unsexed composition, red and blue circles represent females and males, respectively.

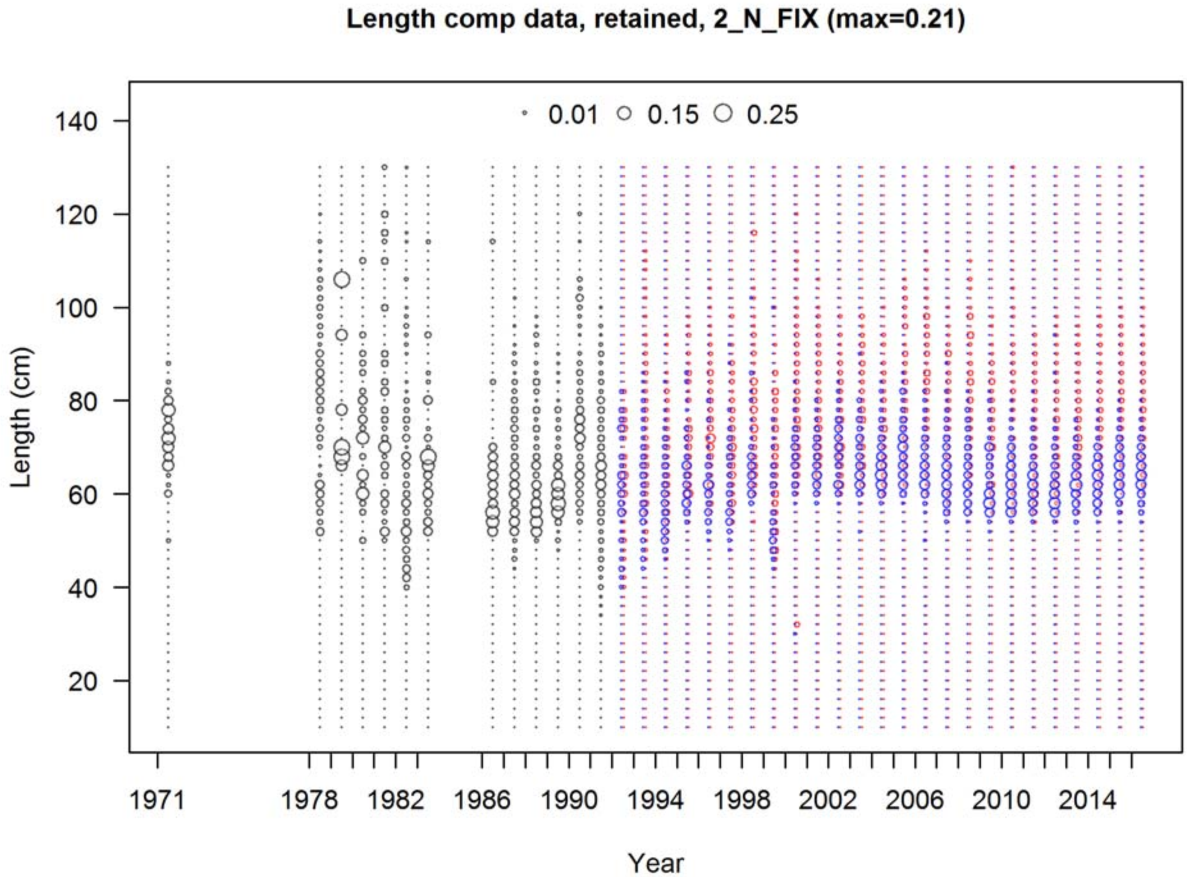


Figure 62. Commercial fixed gear length compositions, north. Grey circles represent unsexed composition, red and blue circles represent females and males, respectively.

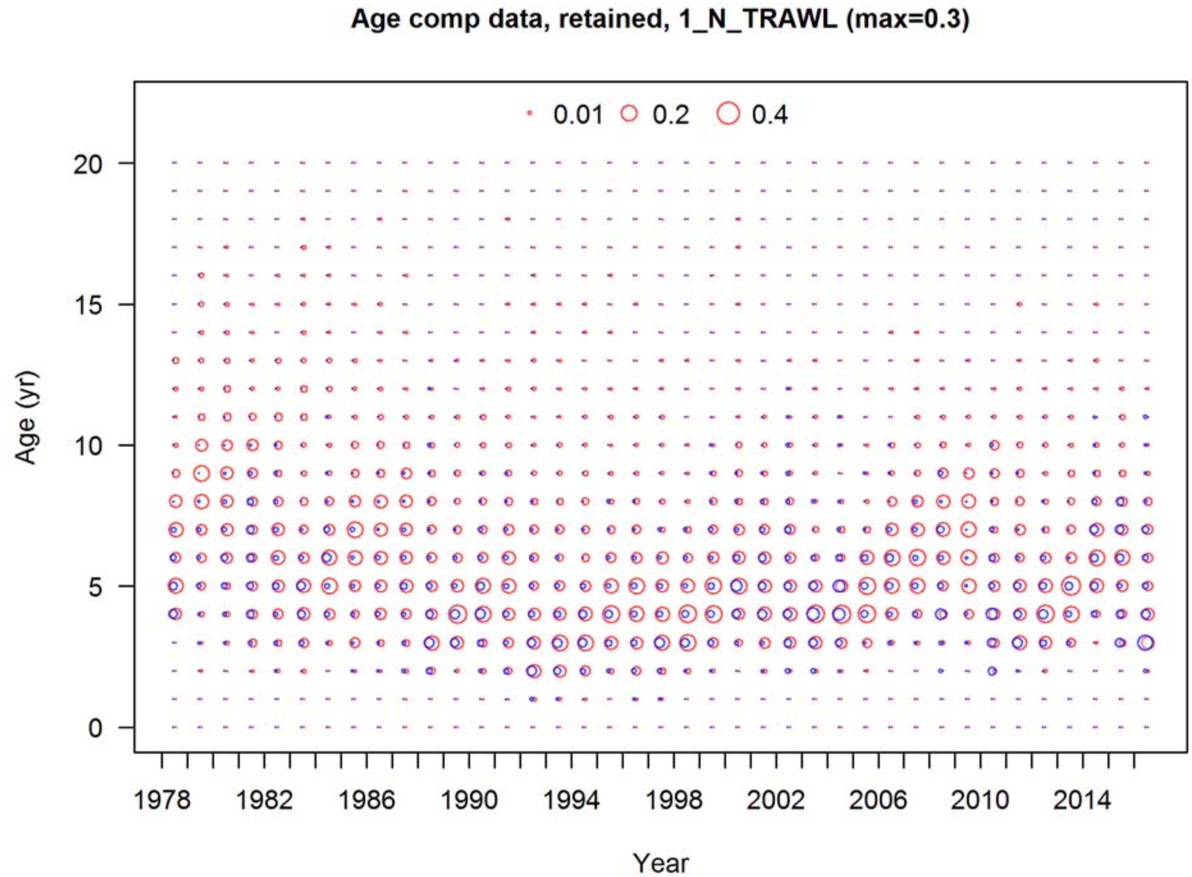


Figure 63. Commercial trawl age compositions, north.

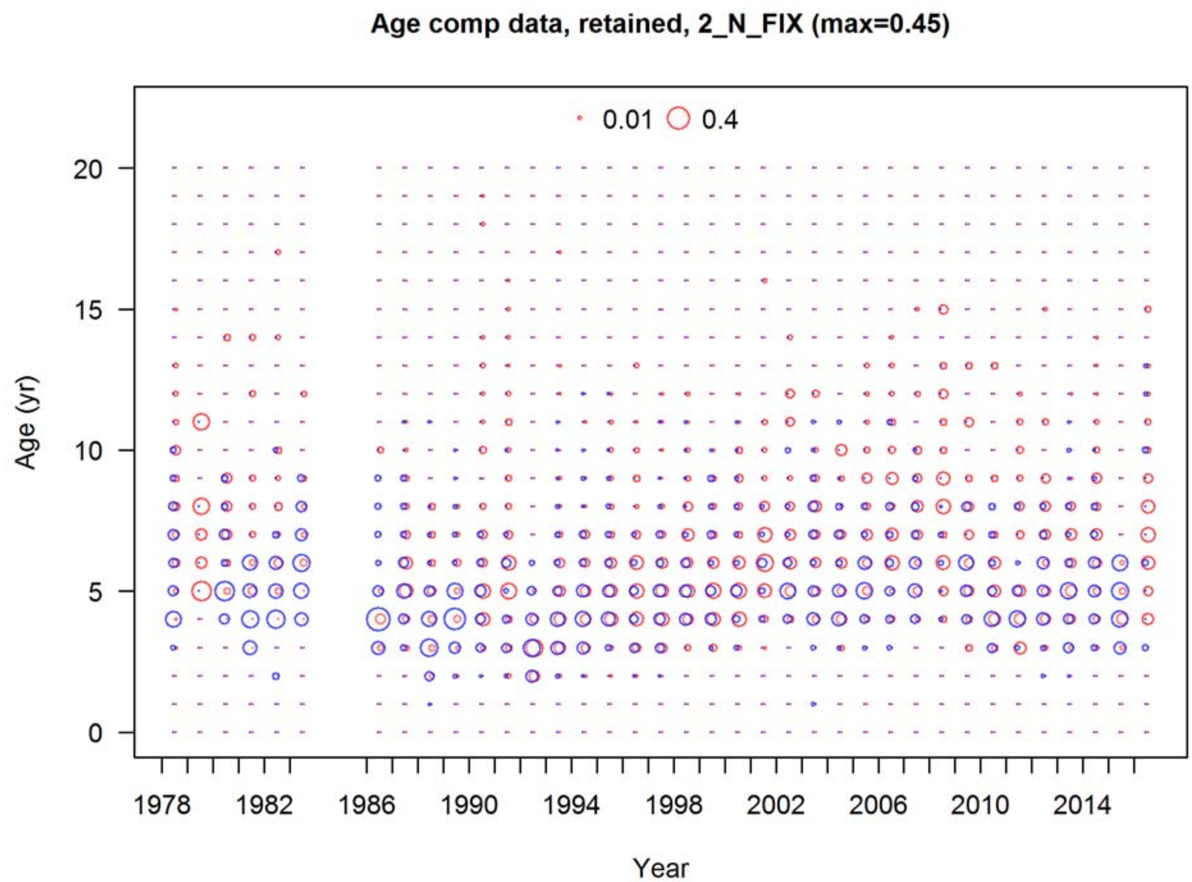


Figure 64. Commercial fixed gear age compositions, north.

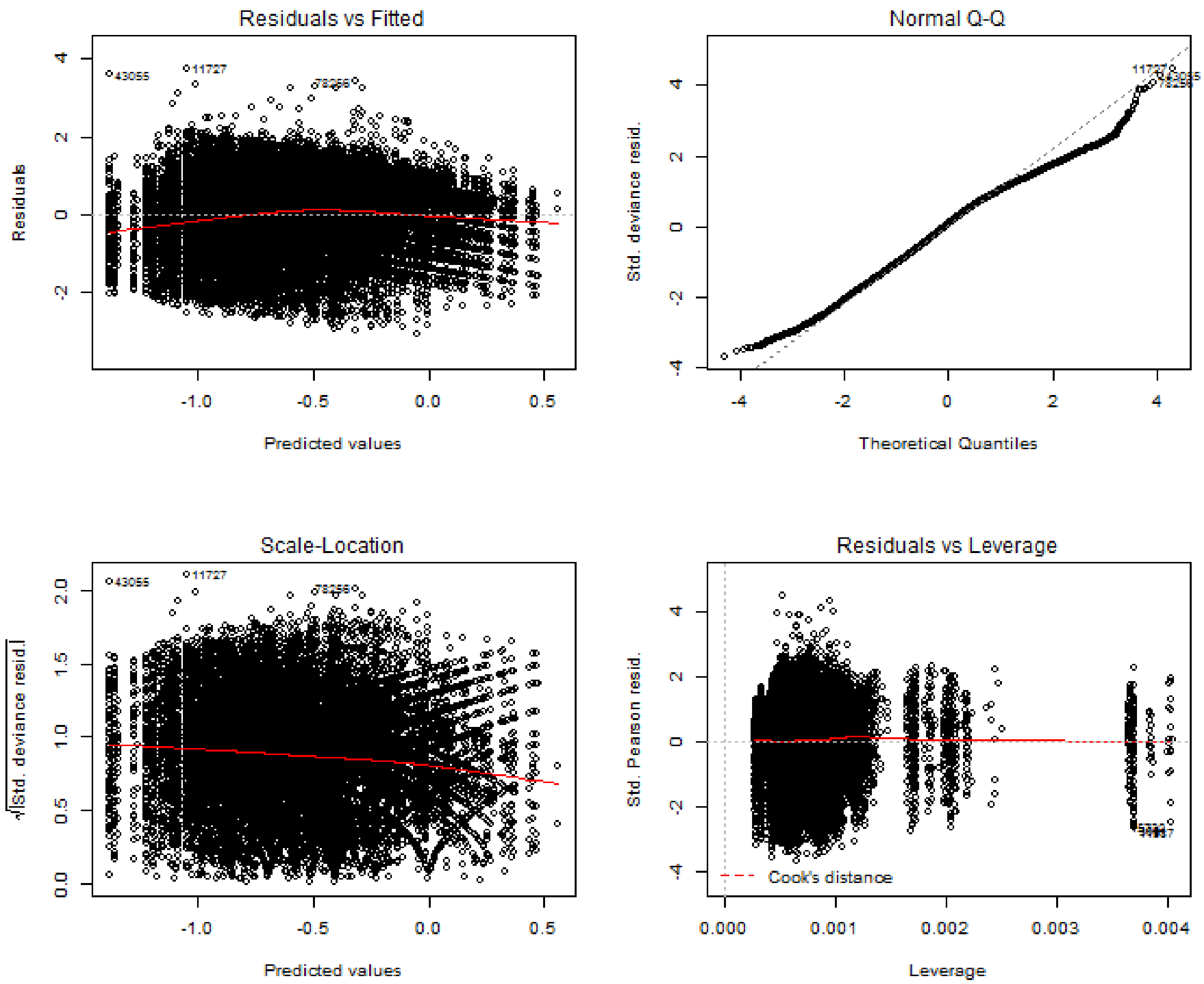


Figure 65. WA recreational dockside CPUE GLM diagnostics.

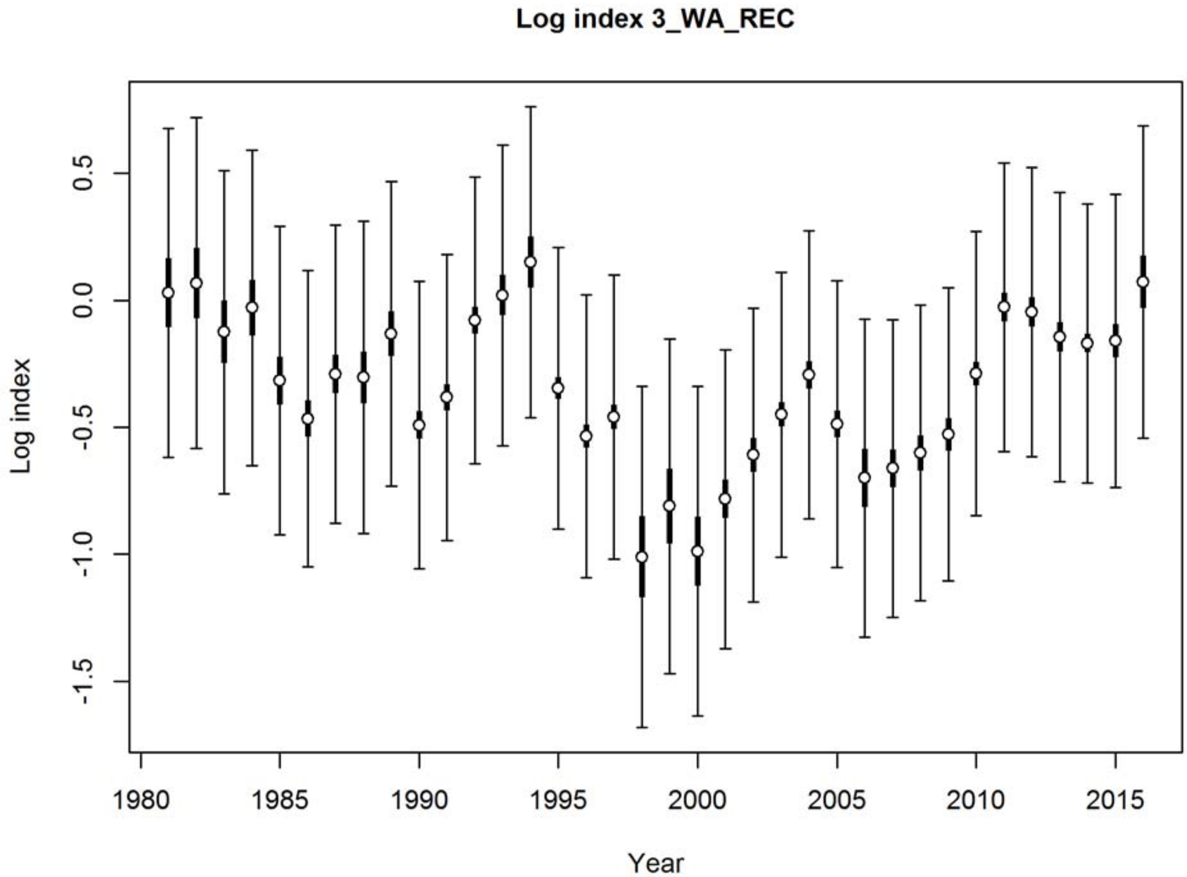


Figure 66. WA recreational dockside CPUE index.

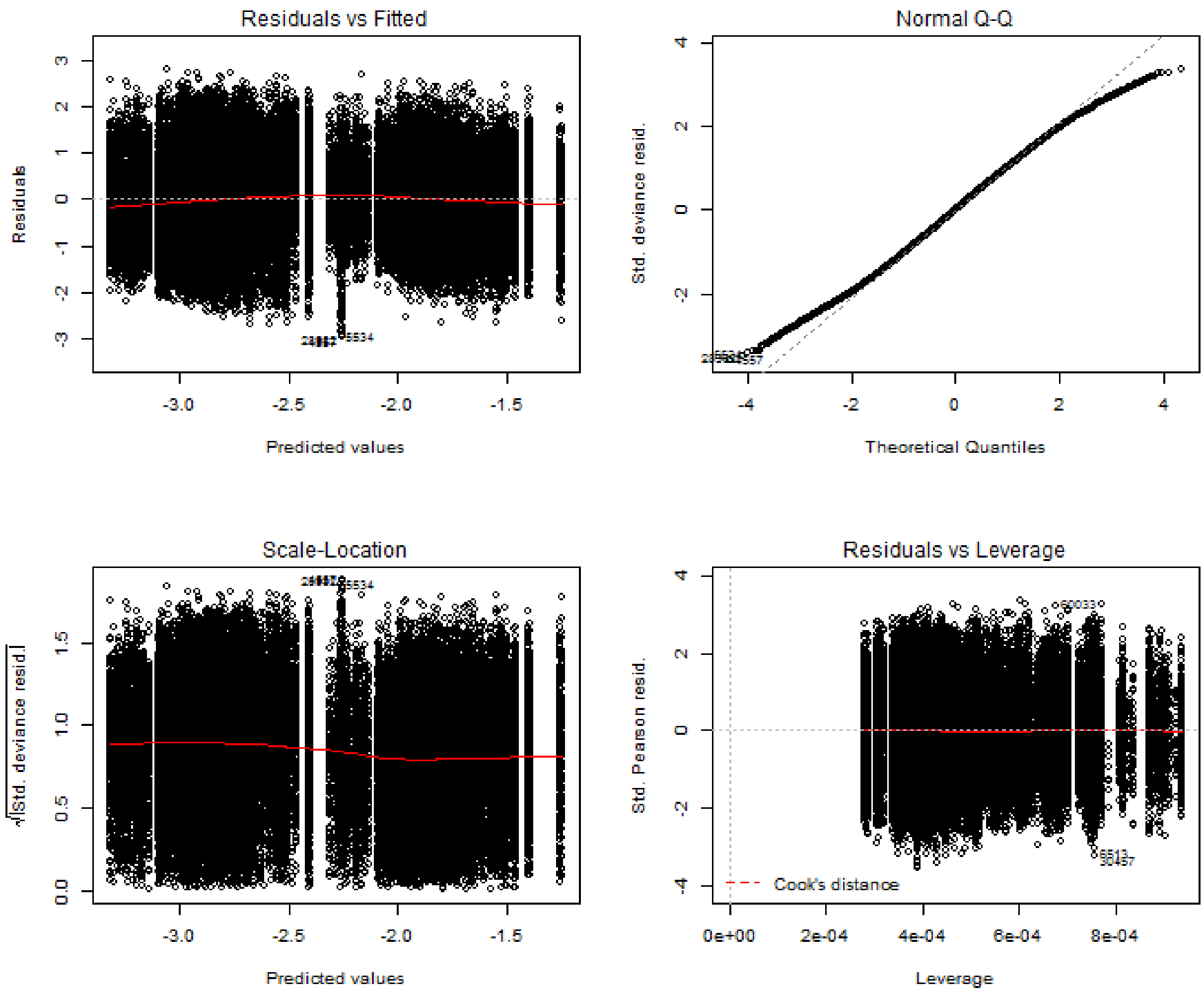


Figure 67. OR recreational dockside CPUE index GLM diagnostics.

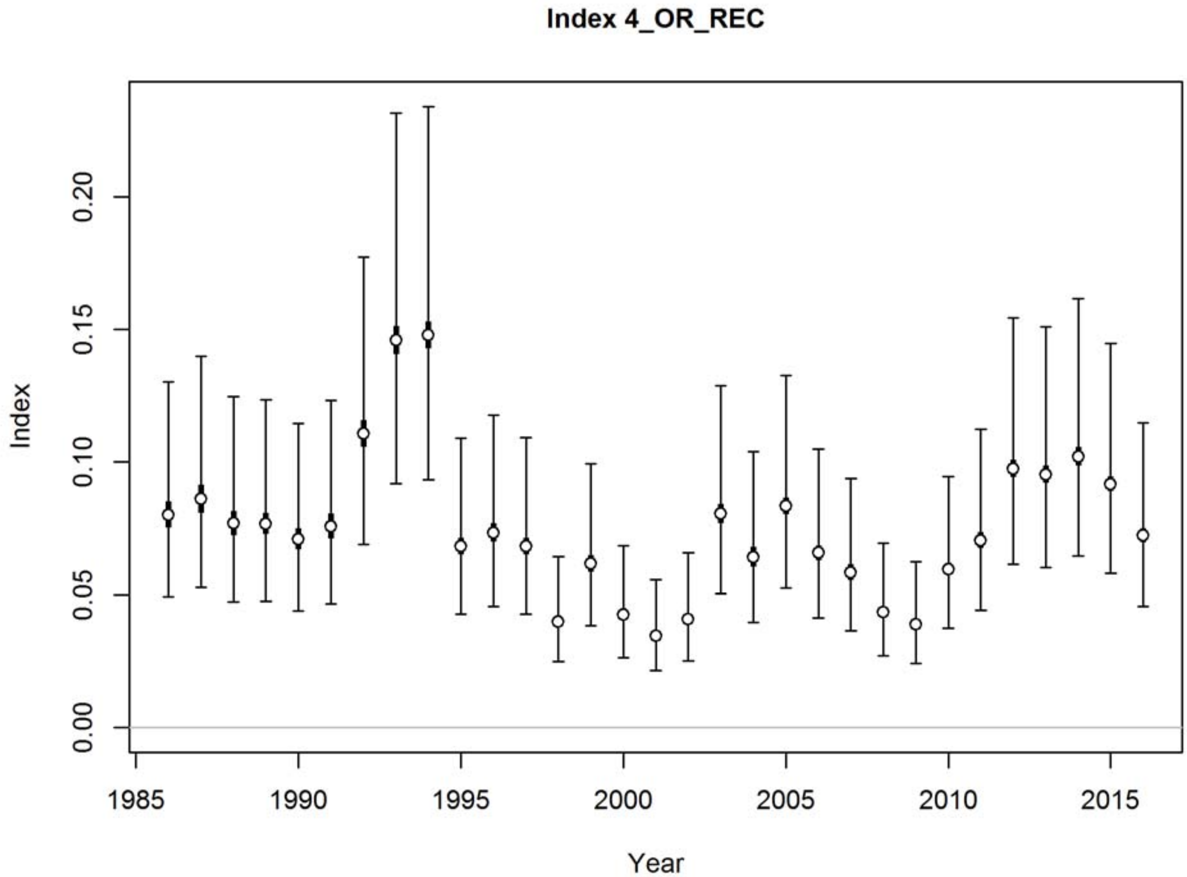


Figure 68. OR recreational dockside CPUE index.

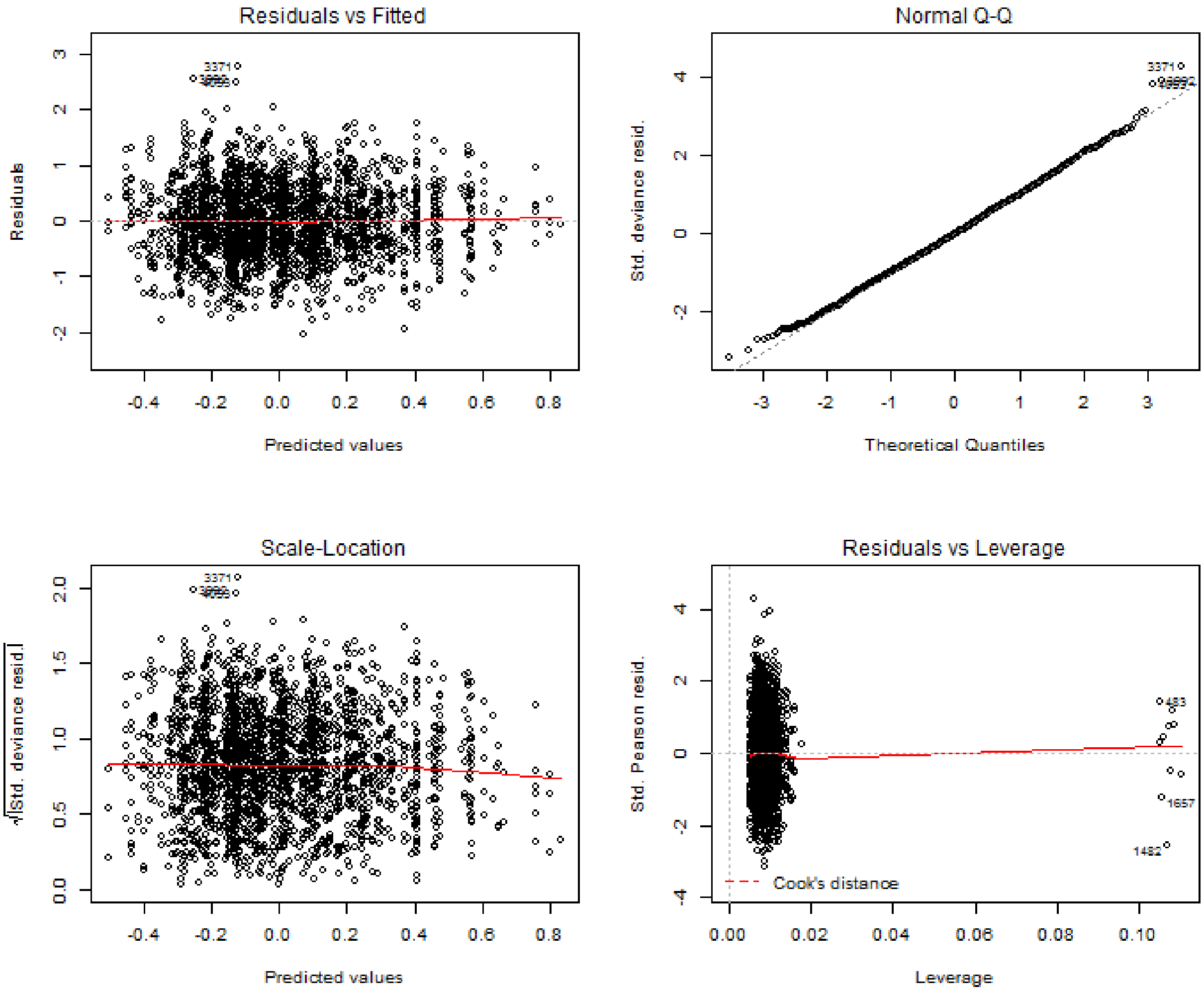


Figure 69. OR onboard observer CPUE index GLM diagnostics.

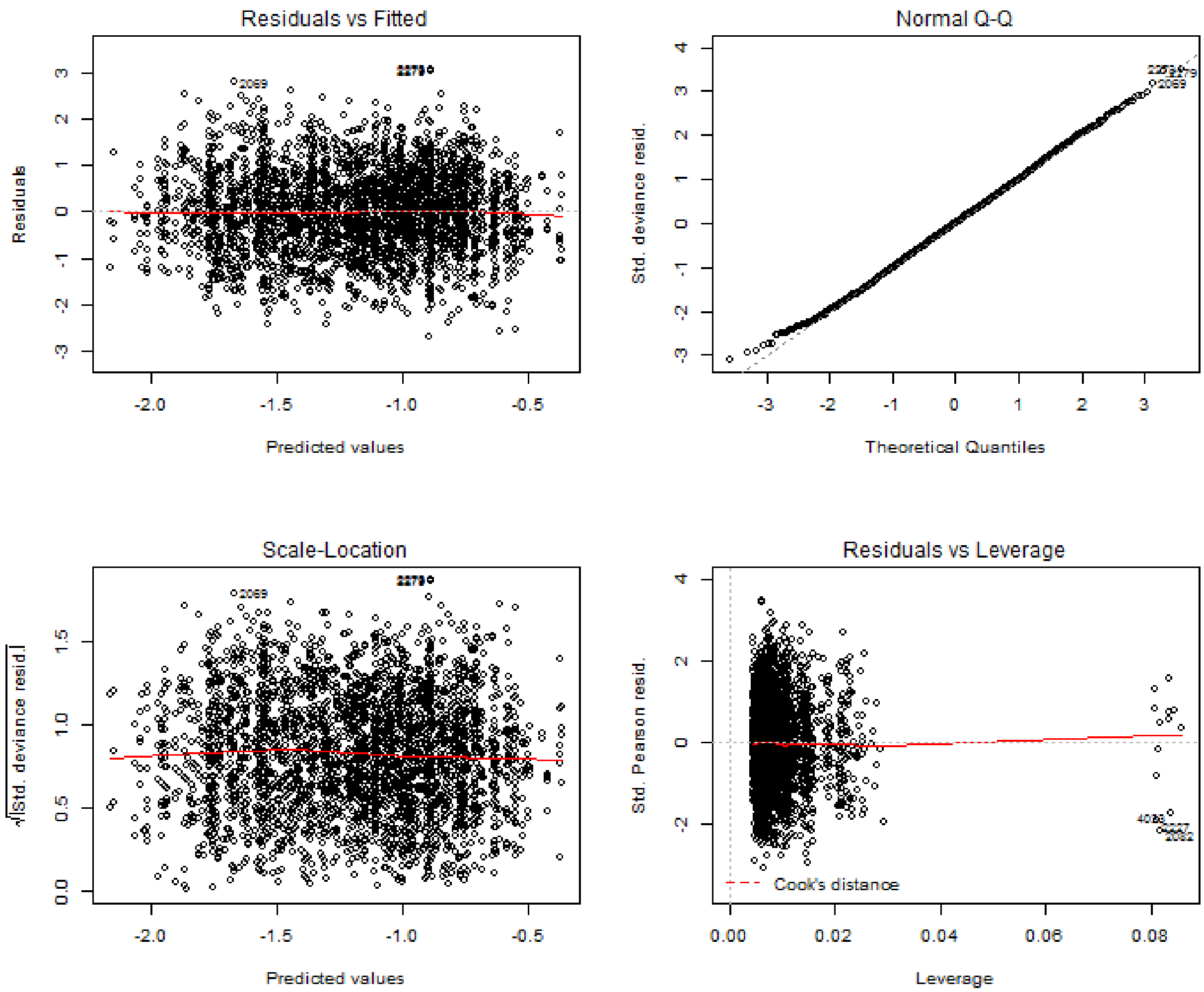


Figure 70. CA early recreational onboard observer CPUE index diagnostics.

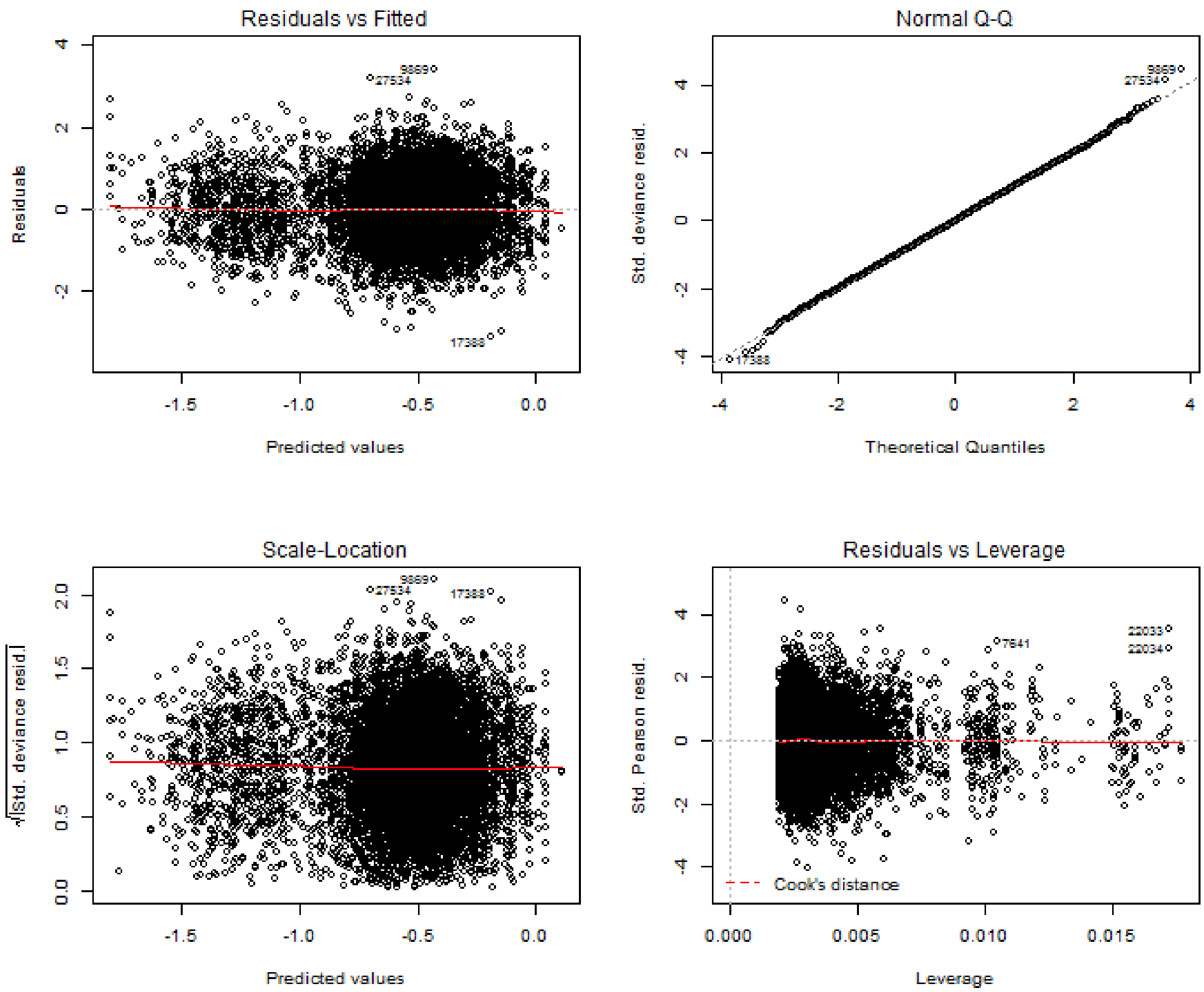


Figure 71. CA late onboard observer CPUE index diagnostics.

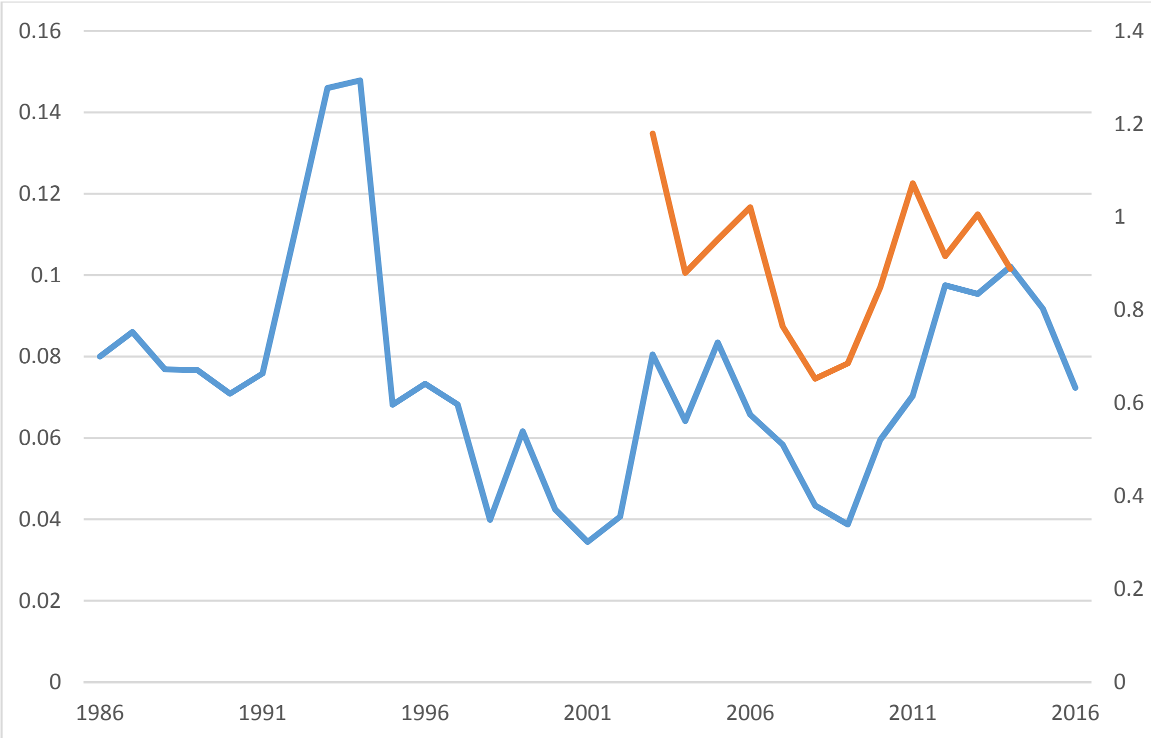


Figure 72. OR onboard observer recreational CPUE index (red, y-axis 2) compared to the OR dockside index (blue, y-axis 1).

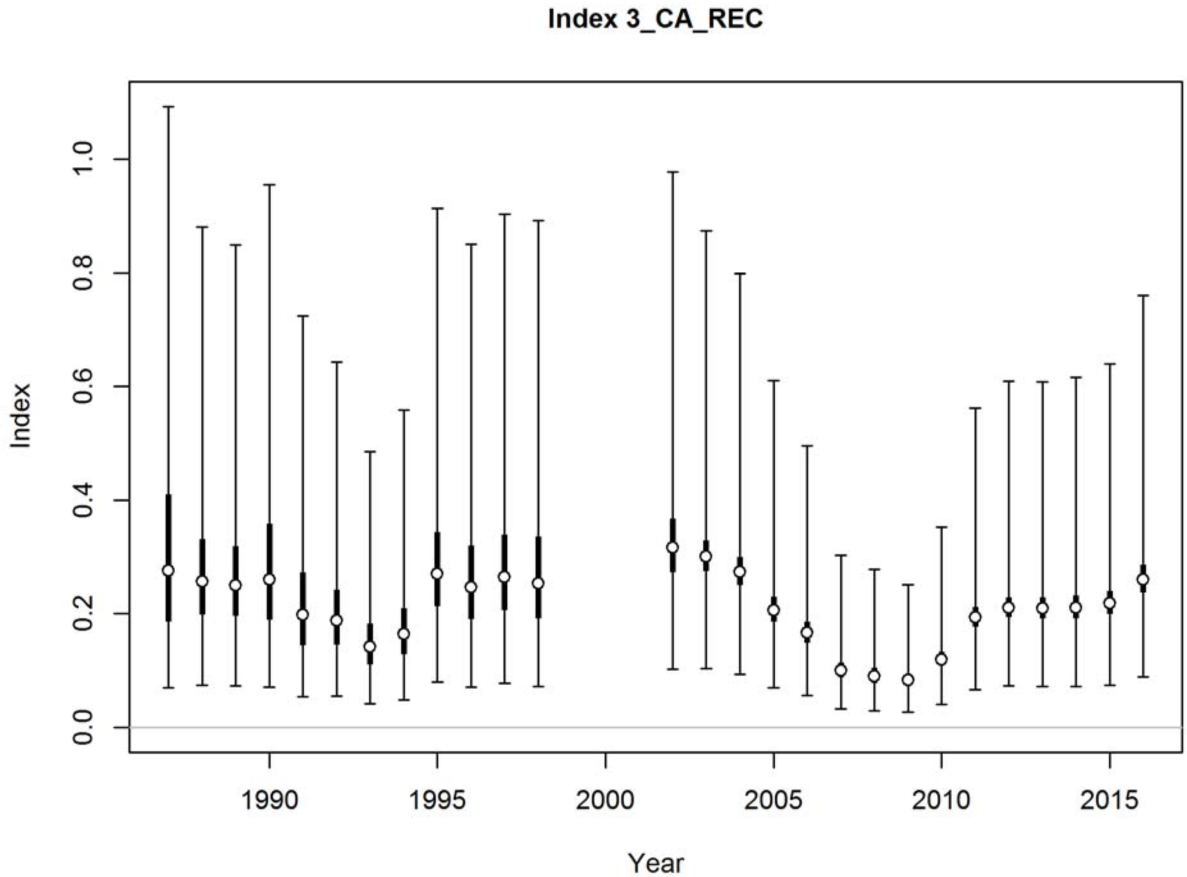


Figure 73. CA early and late onboard observer recreational CPUE indices.

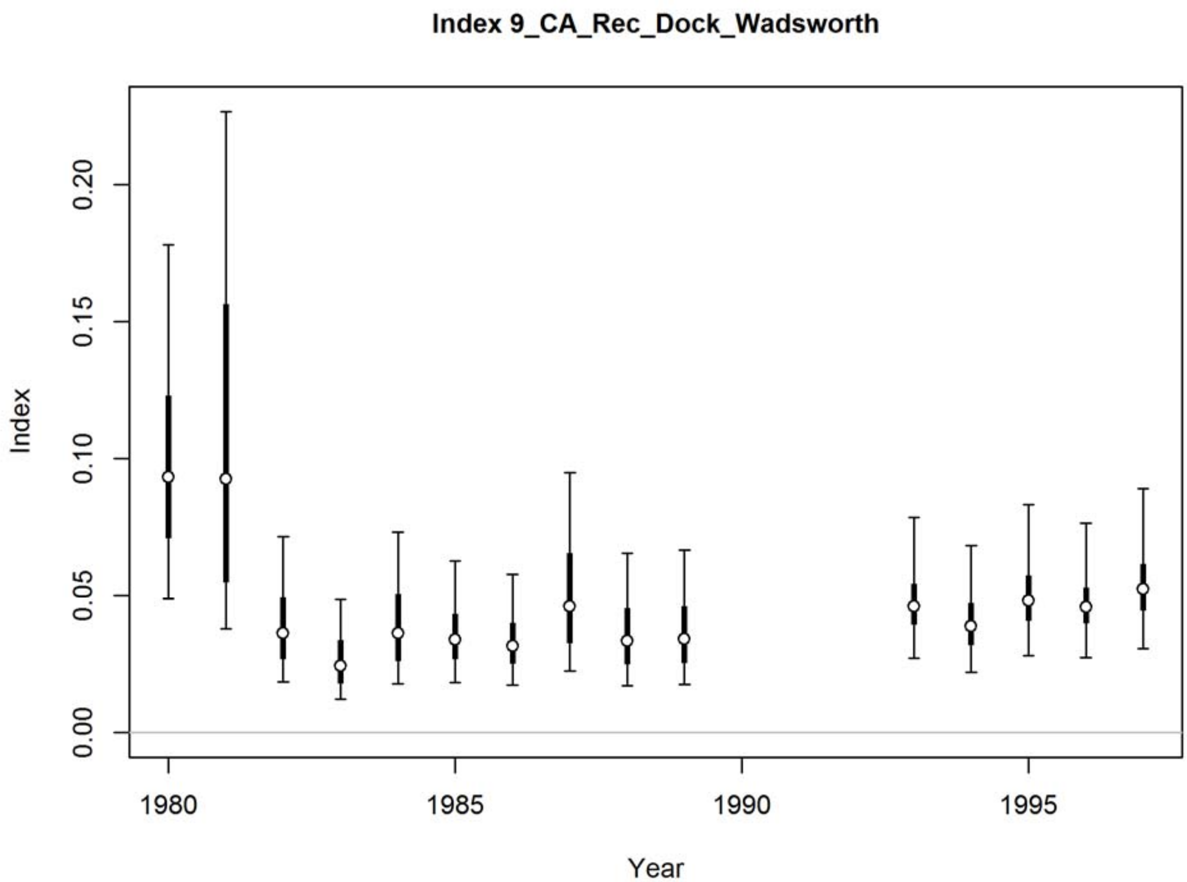


Figure 74. CA recreational dockside CPUE index.

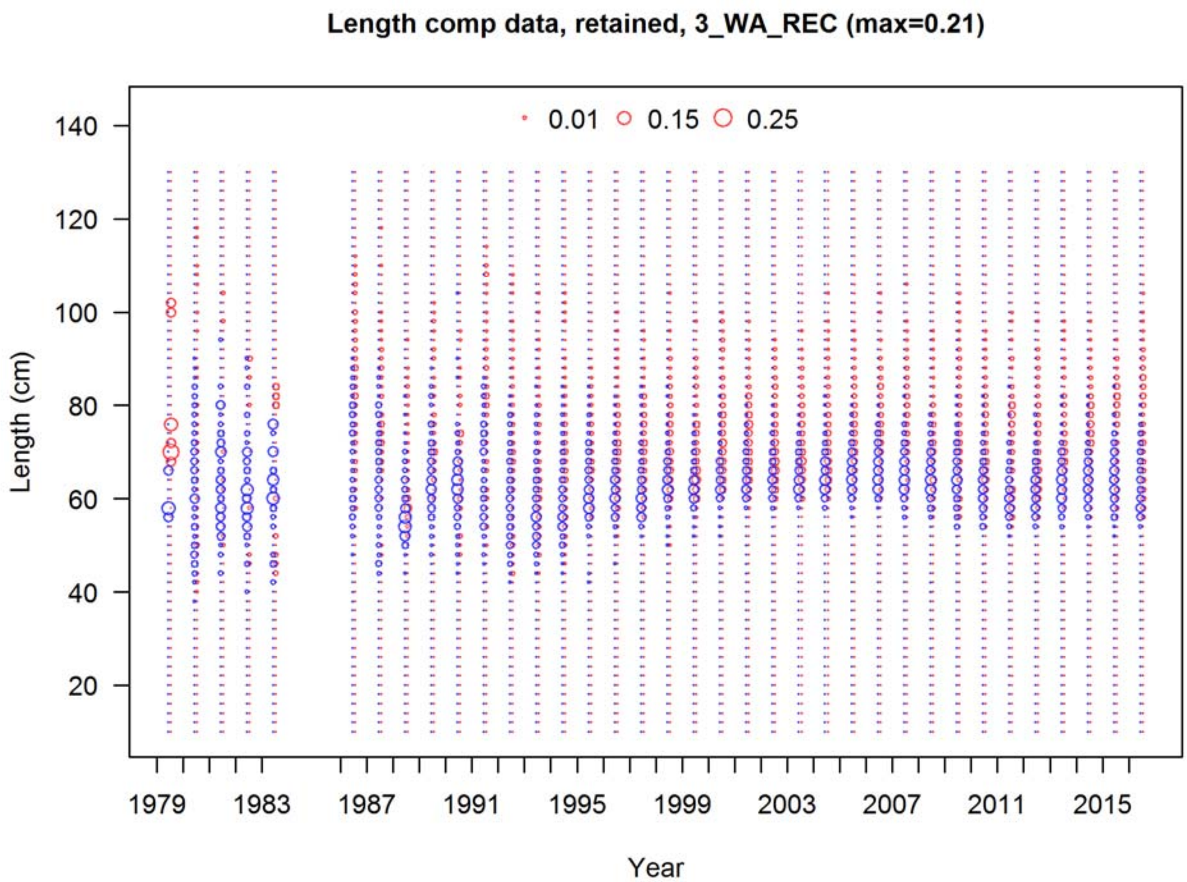


Figure 75. WA recreational length data.

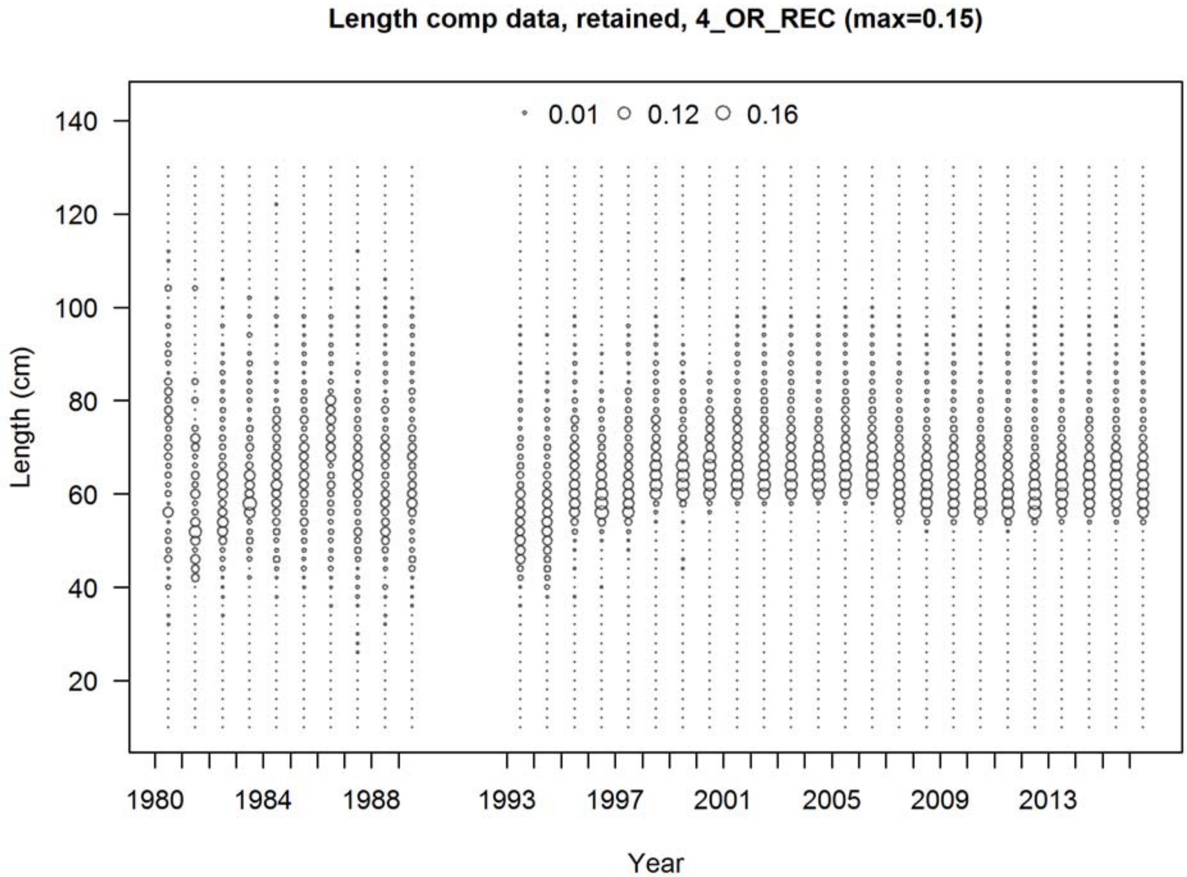


Figure 76. OR recreational length composition data.

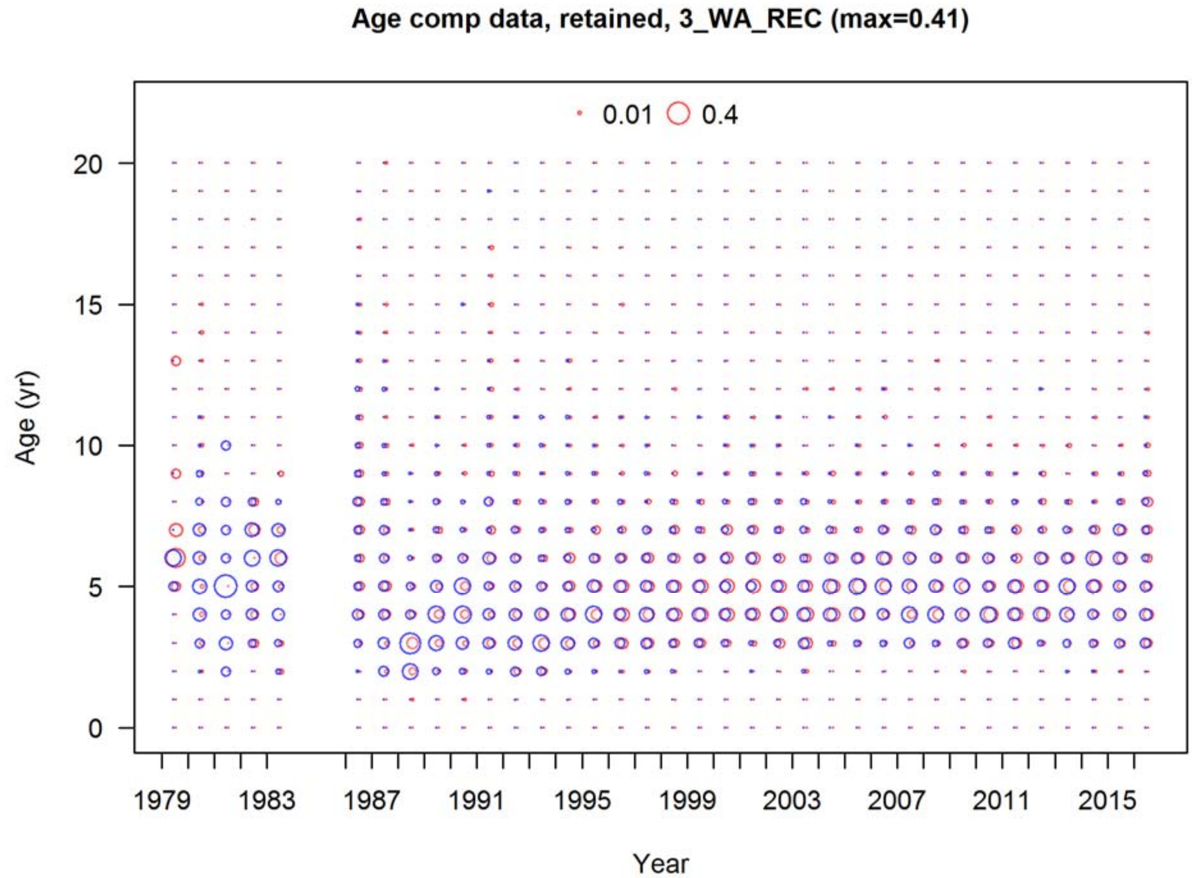


Figure 77. WA recreational age data.

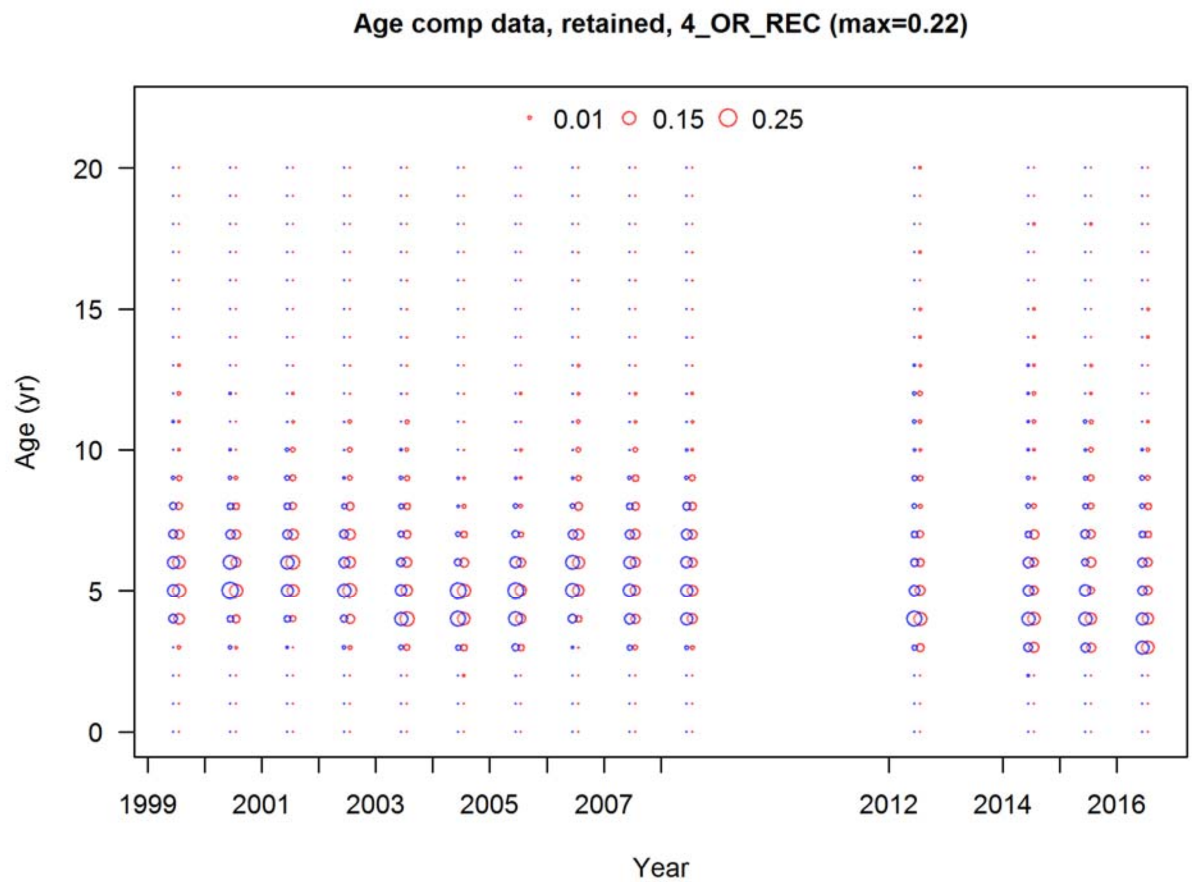


Figure 78. OR recreational age composition data.

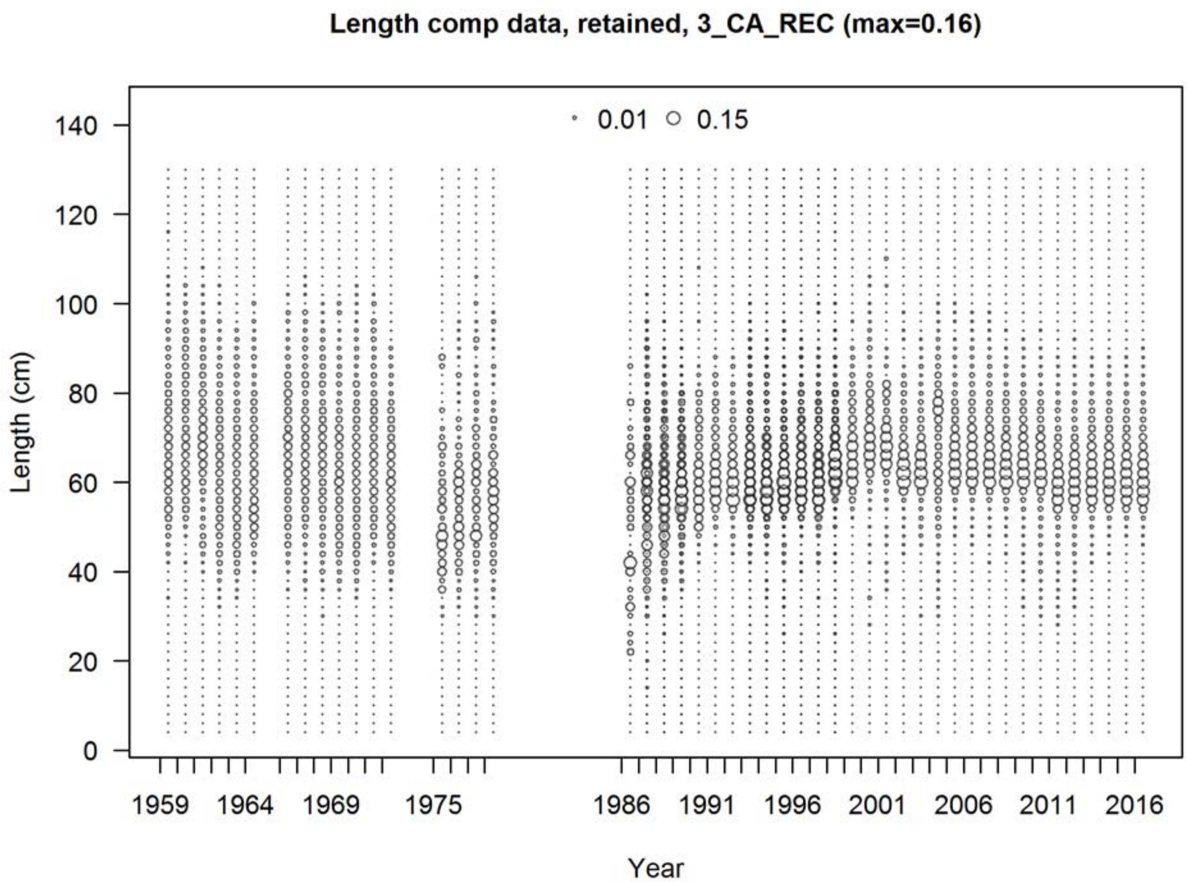


Figure 79. CA recreational length data.

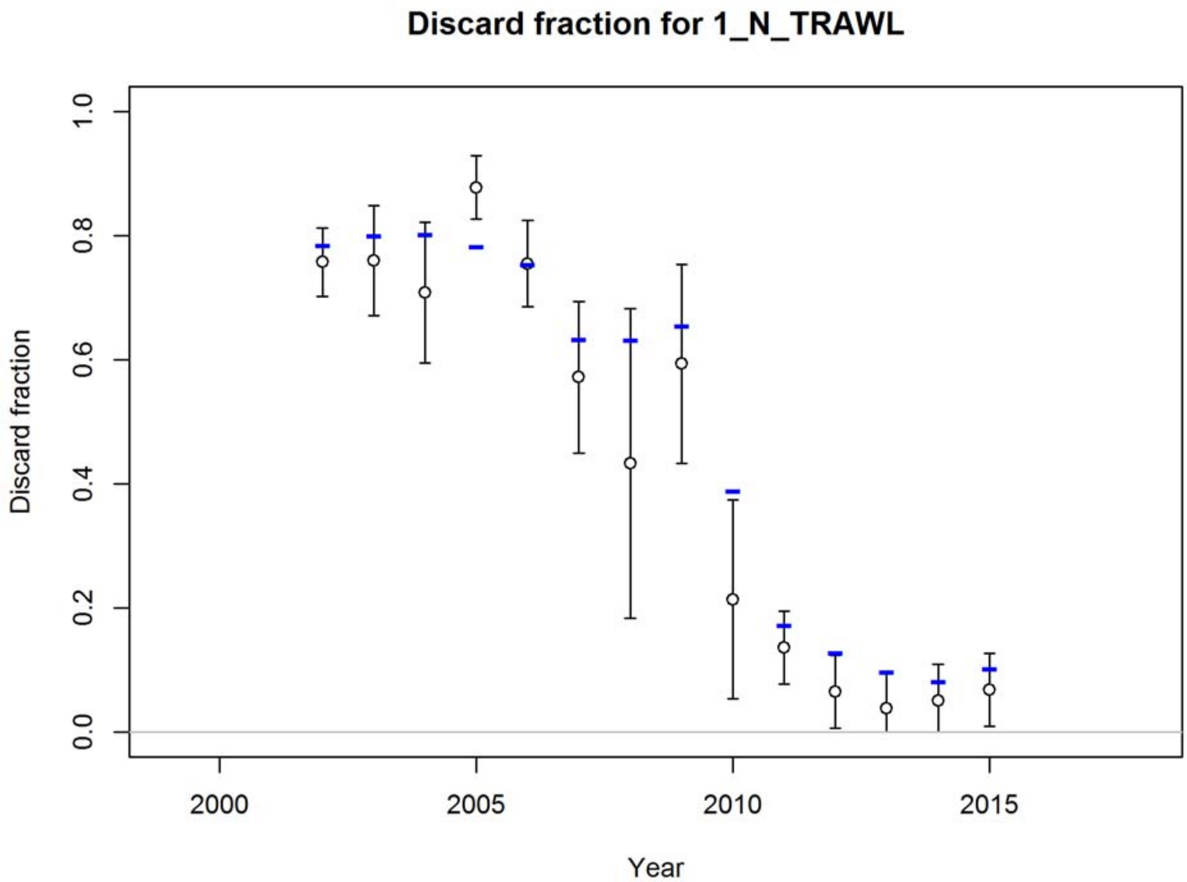


Figure 80. Discard fraction trawl fits, north. Blue horizontal dashes are model fits.

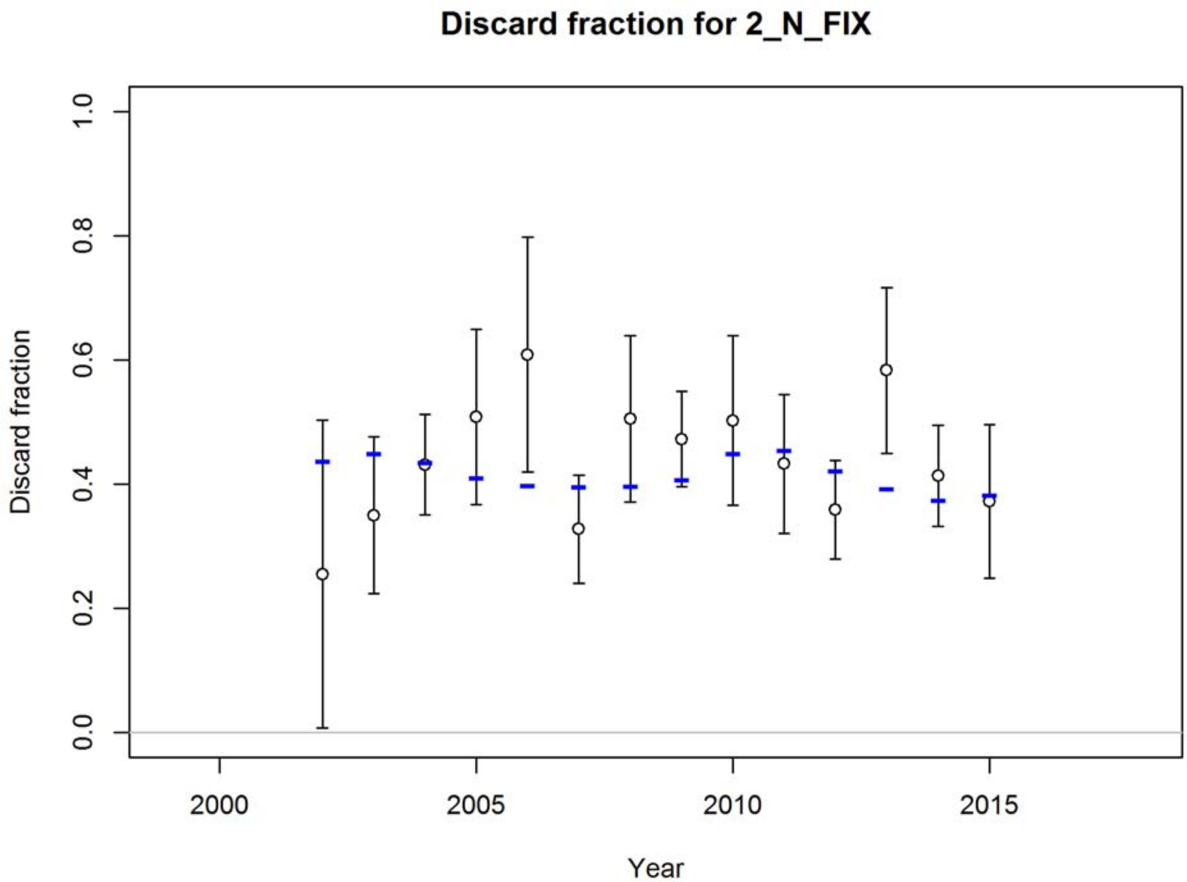


Figure 81. Discard fraction fixed gear fits, north. Blue horizontal dashes are model fits.

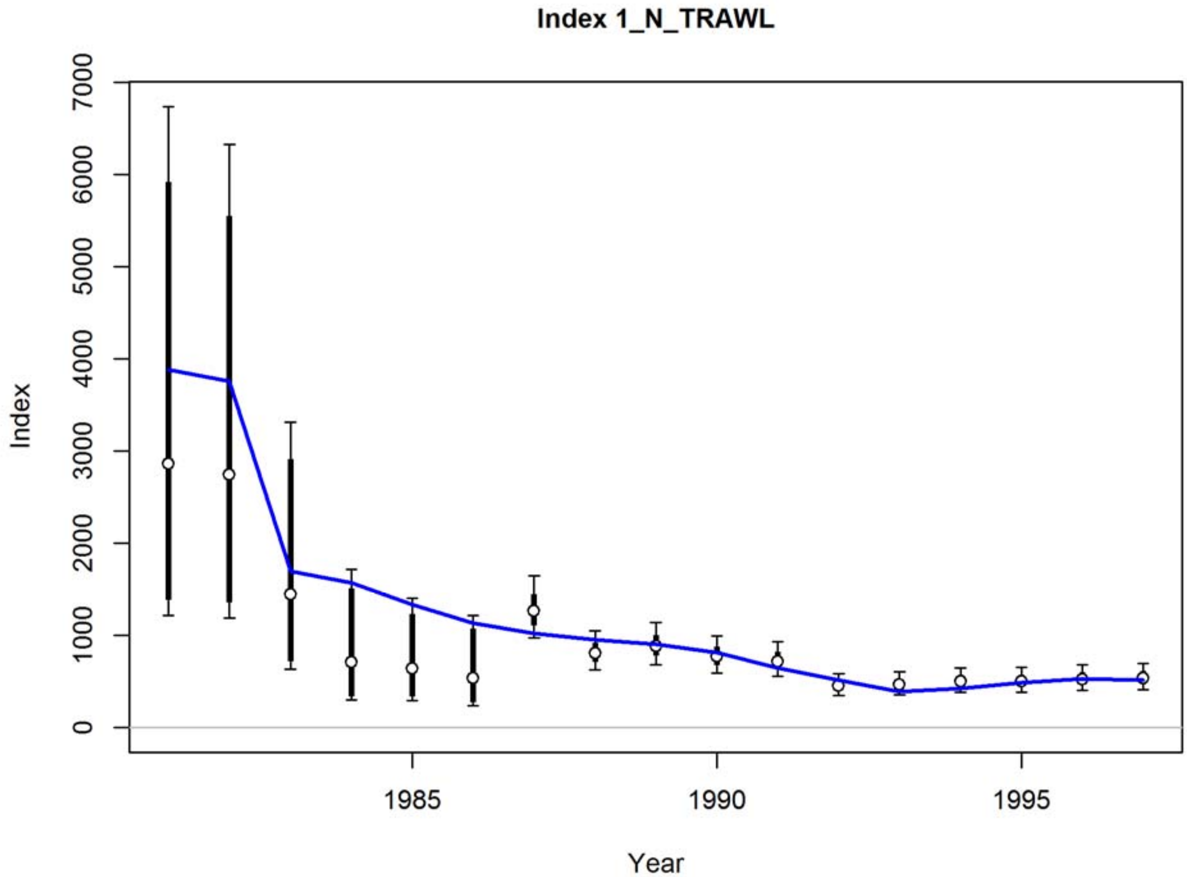


Figure 82. Trawl fleet index fit, north. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

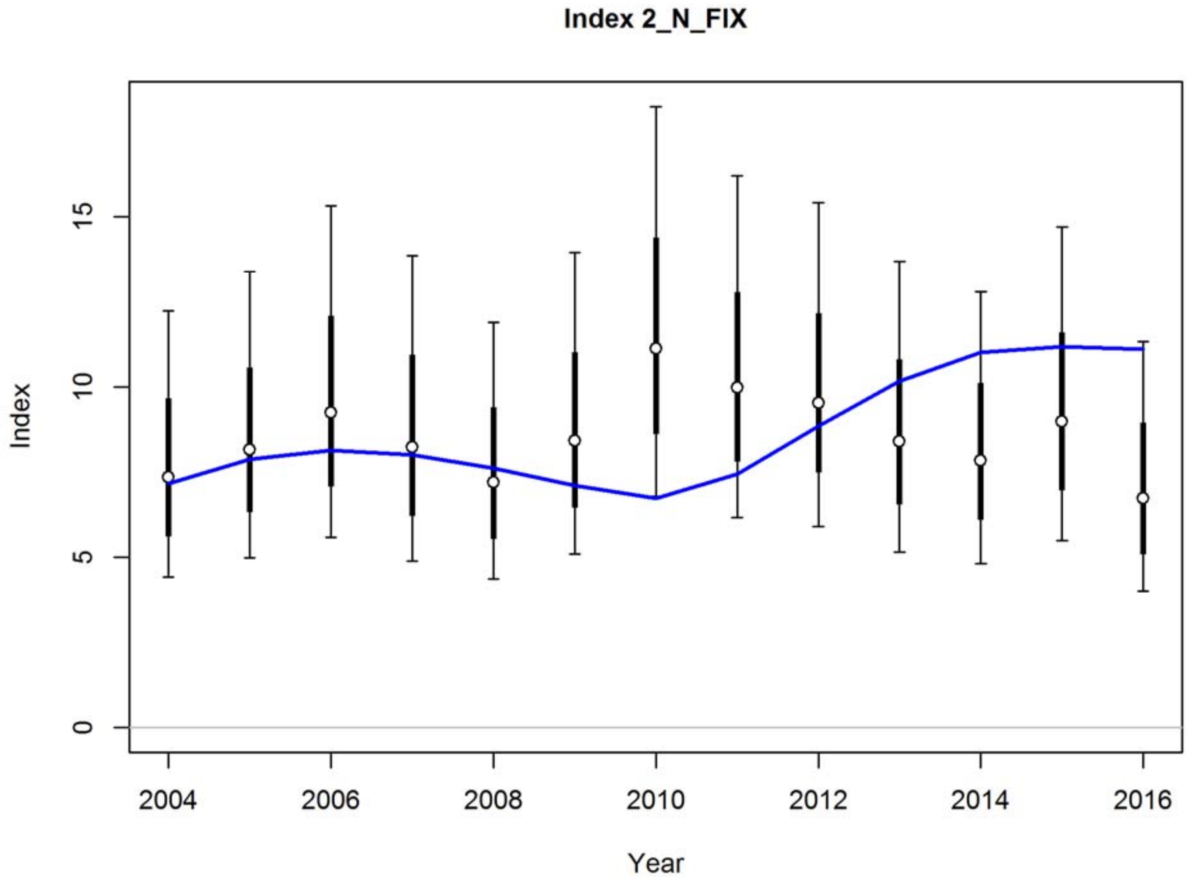


Figure 83. Fixed gear index fit, north. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

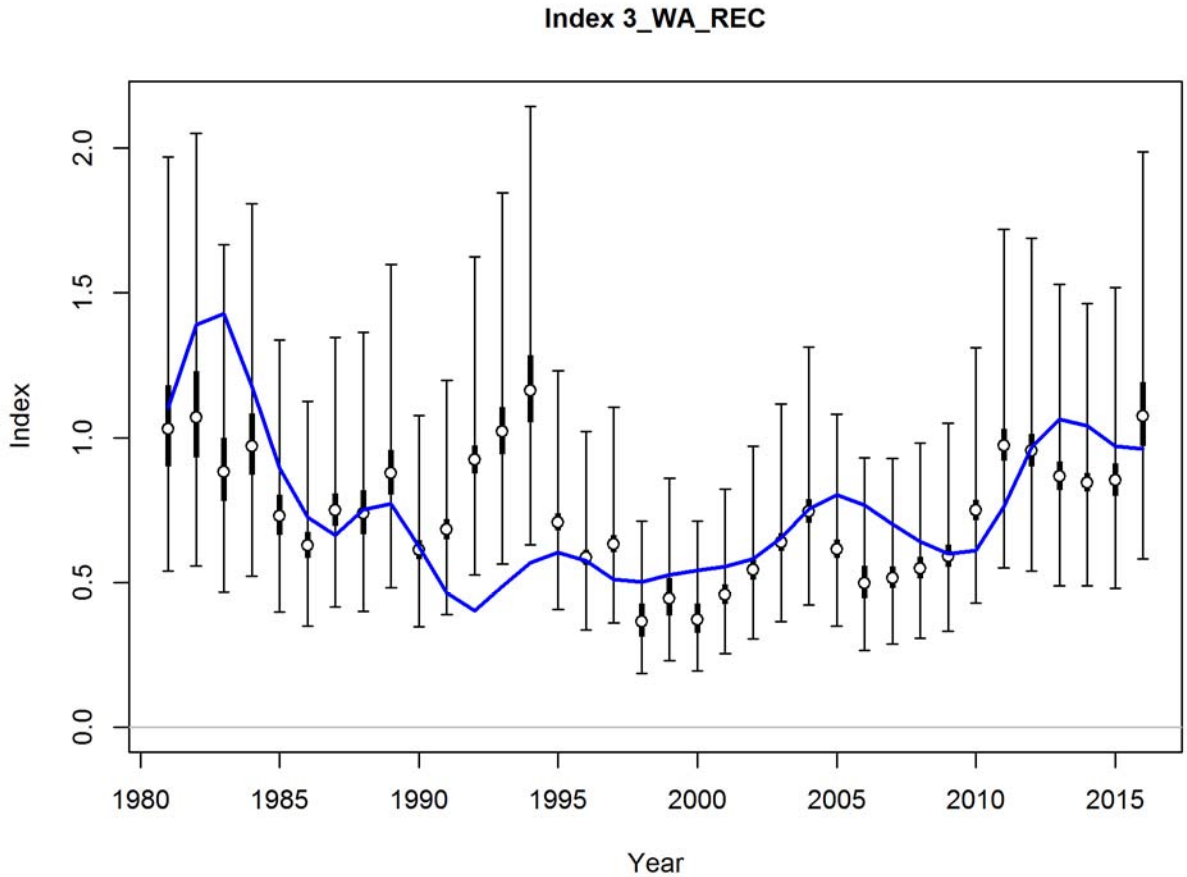


Figure 84. WA recreational CPUE index fit. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

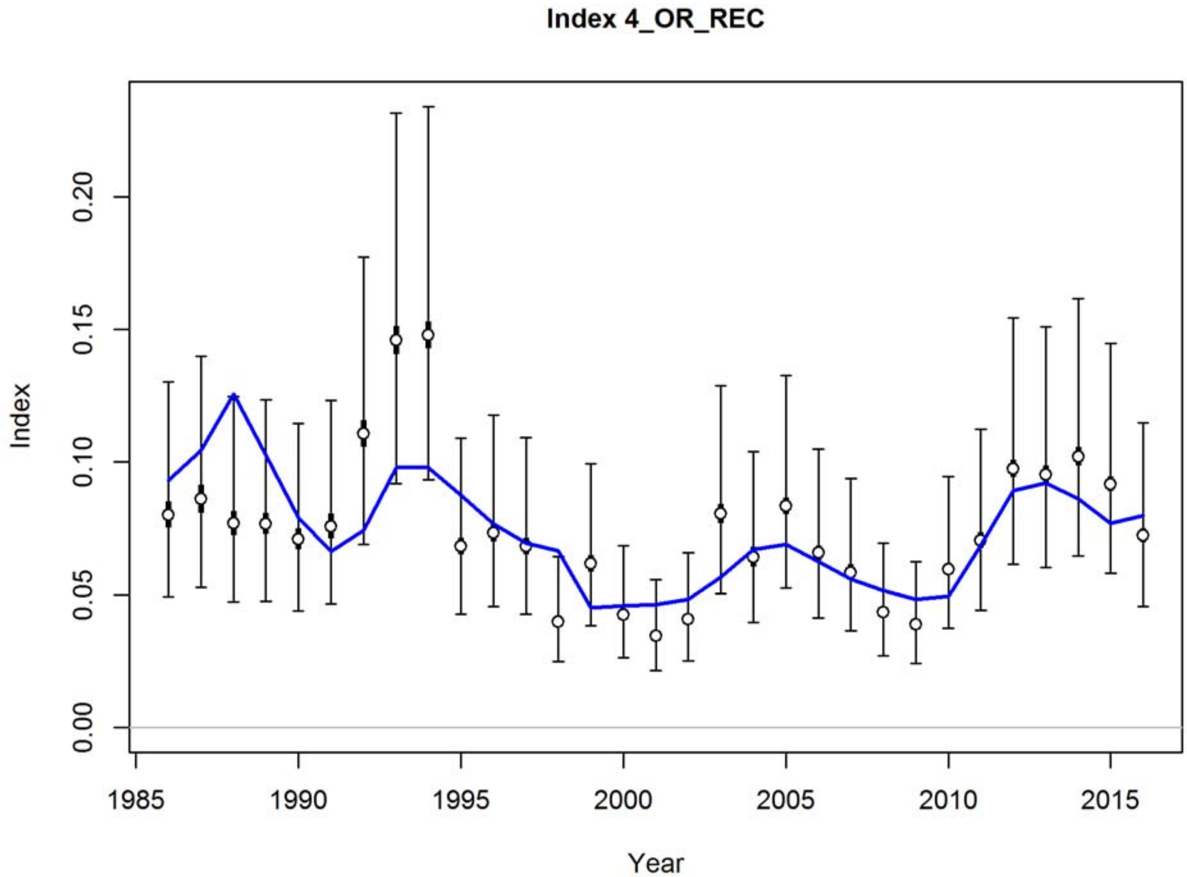


Figure 85. OR recreational CPUE index fit. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

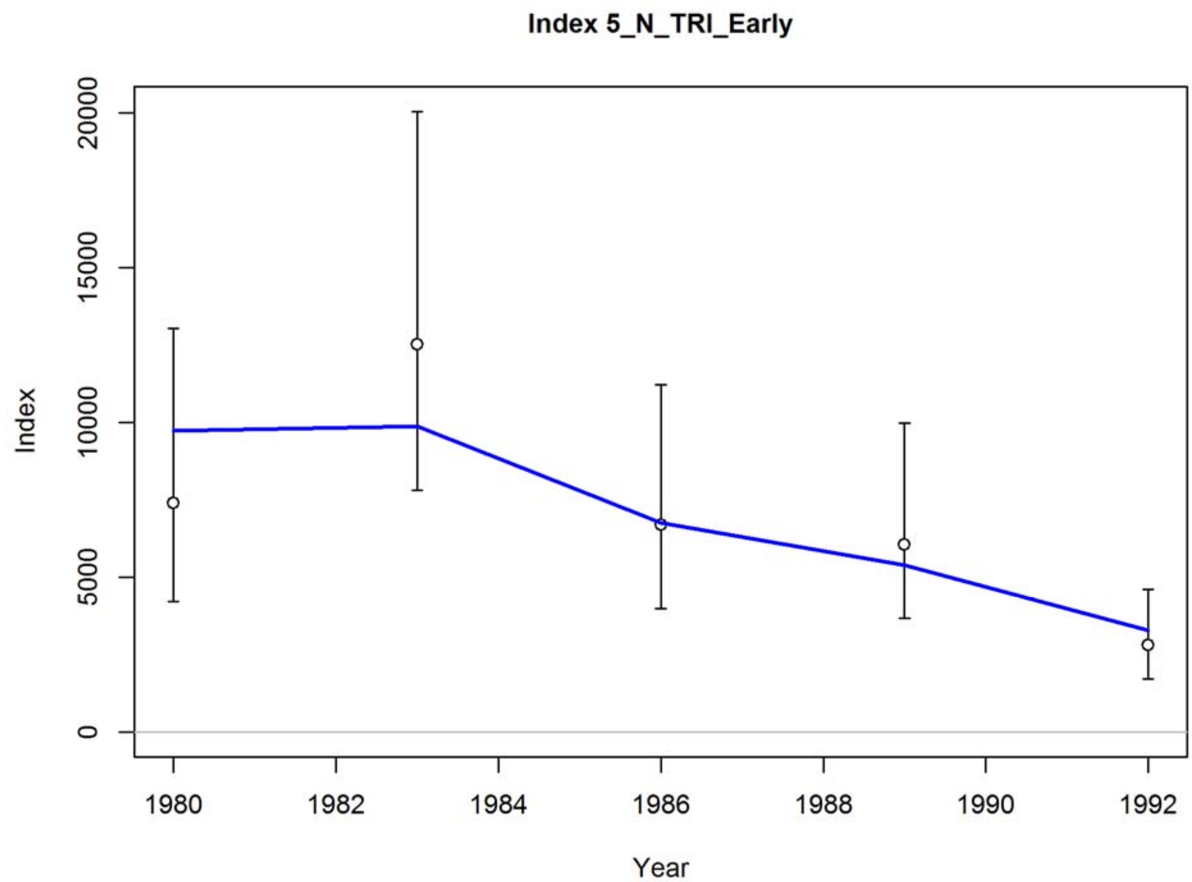


Figure 86. Triennial survey early fit.

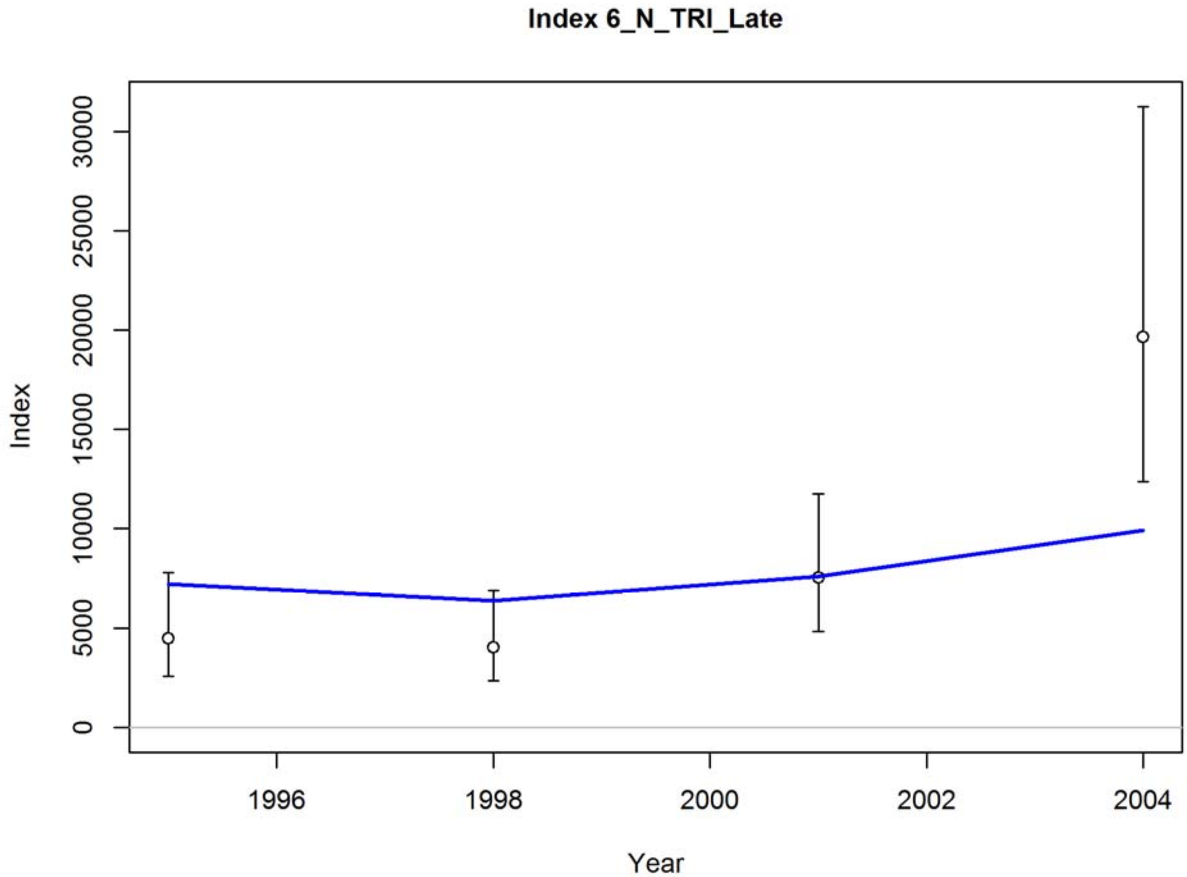


Figure 87. Triennial survey late fit.

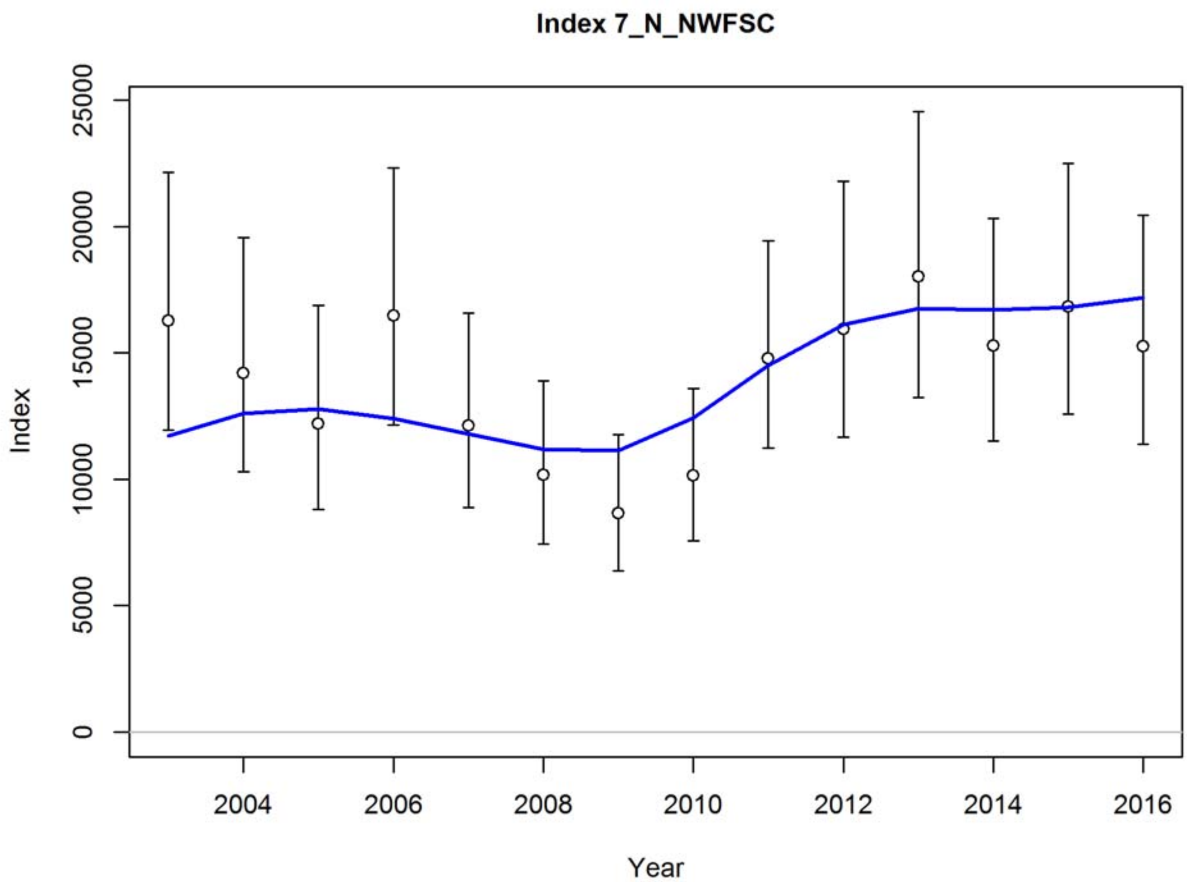


Figure 88. NWFSC survey fit.

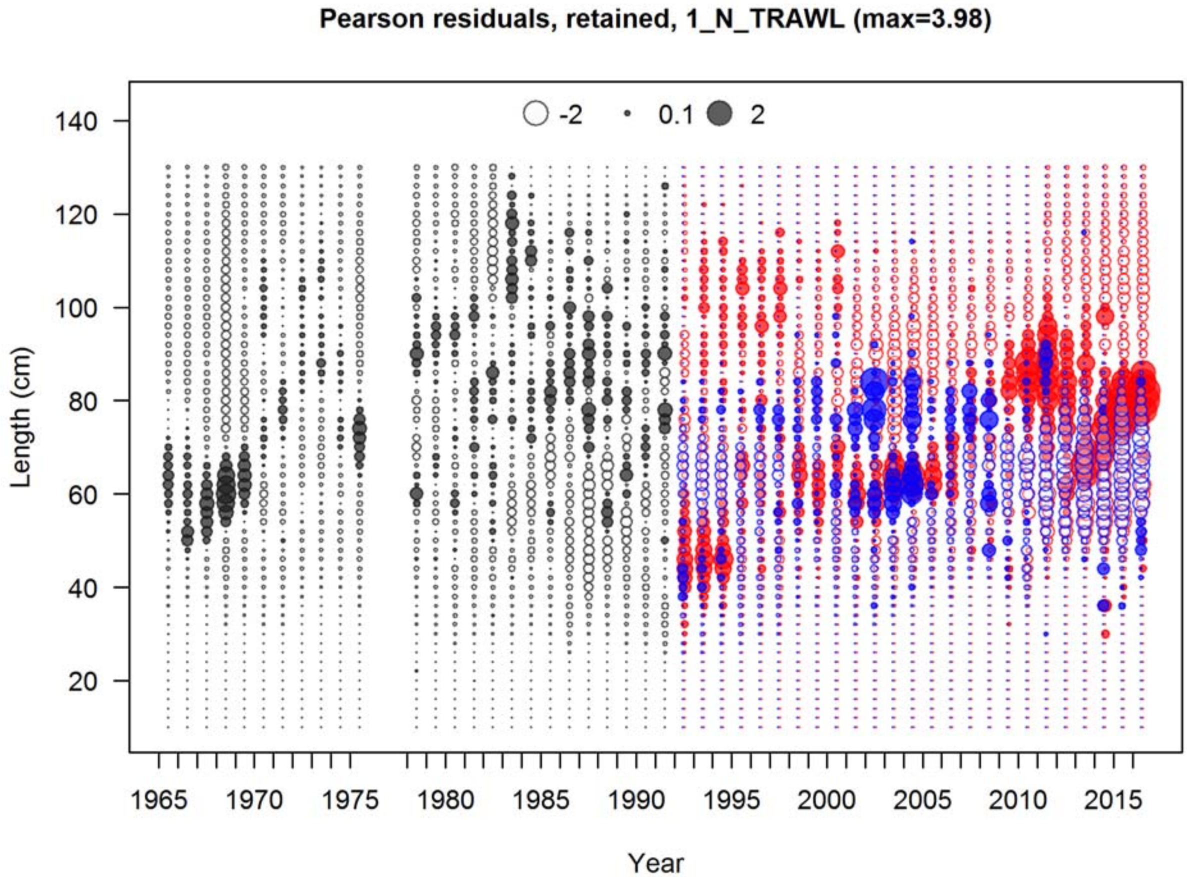


Figure 89. Commercial trawl length data Pearson residuals, north. Grey circles represent sex-combined compositions, while red and blue circles represent female and male compositions, respectively.

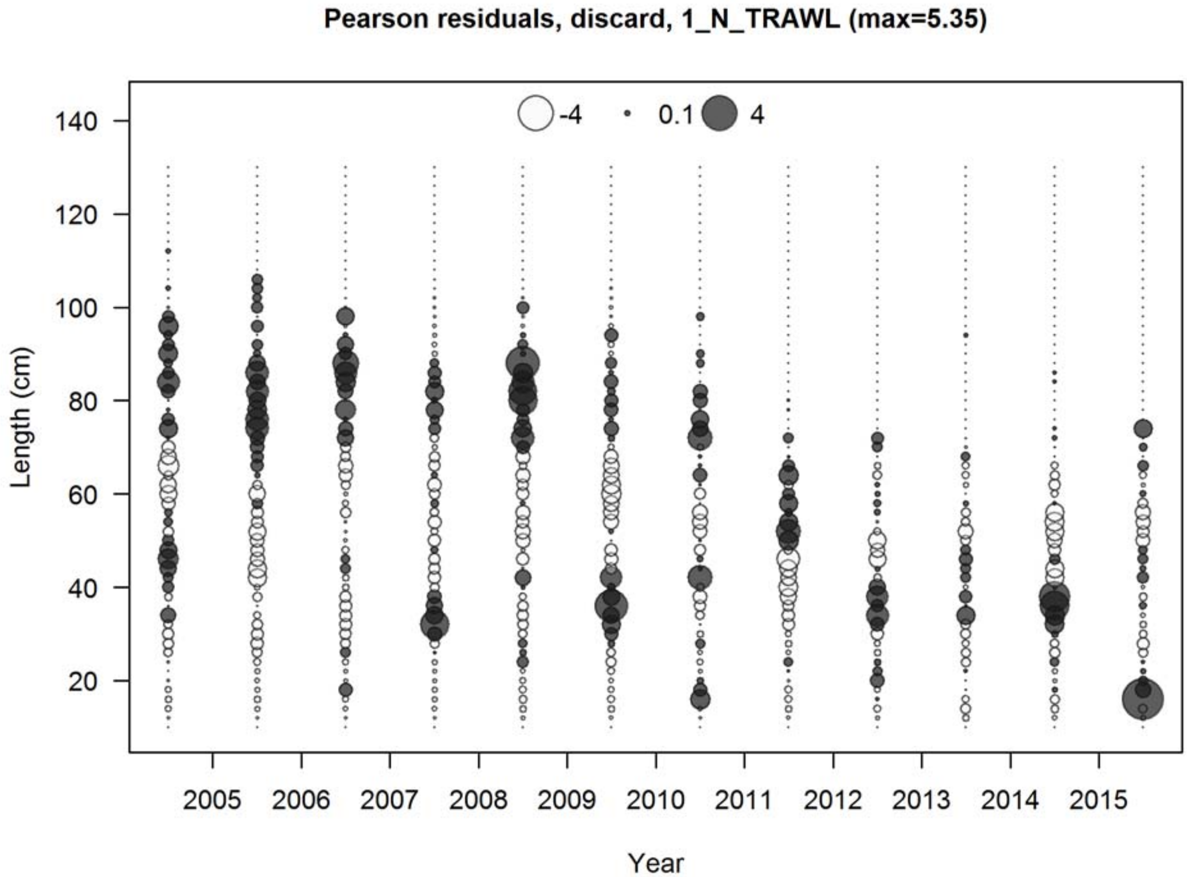


Figure 90. Commercial sex combined trawl discard length data Pearson residuals, north.

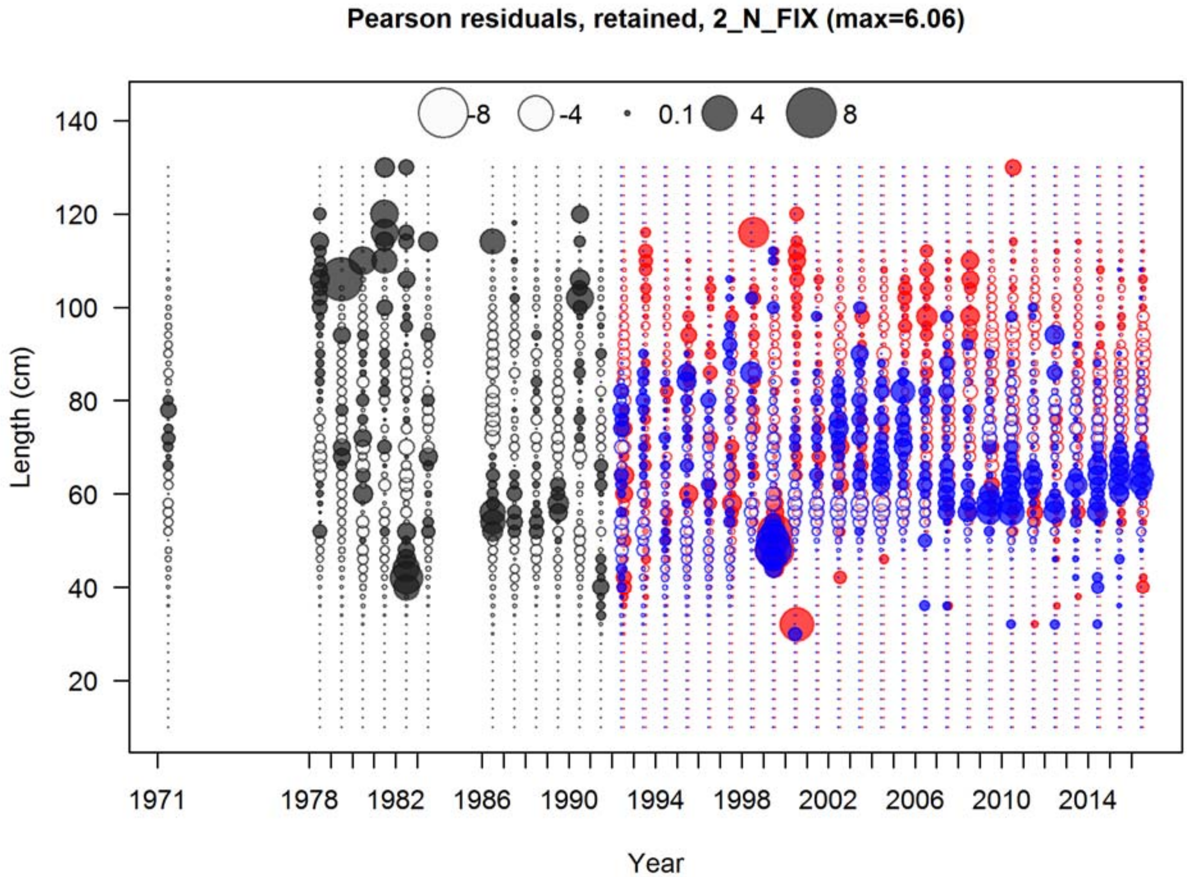


Figure 91. Commercial fixed gear fleet length data Pearson residuals, north. Grey circles represent sex-combined compositions, while red and blue circles represent female and male compositions, respectively.

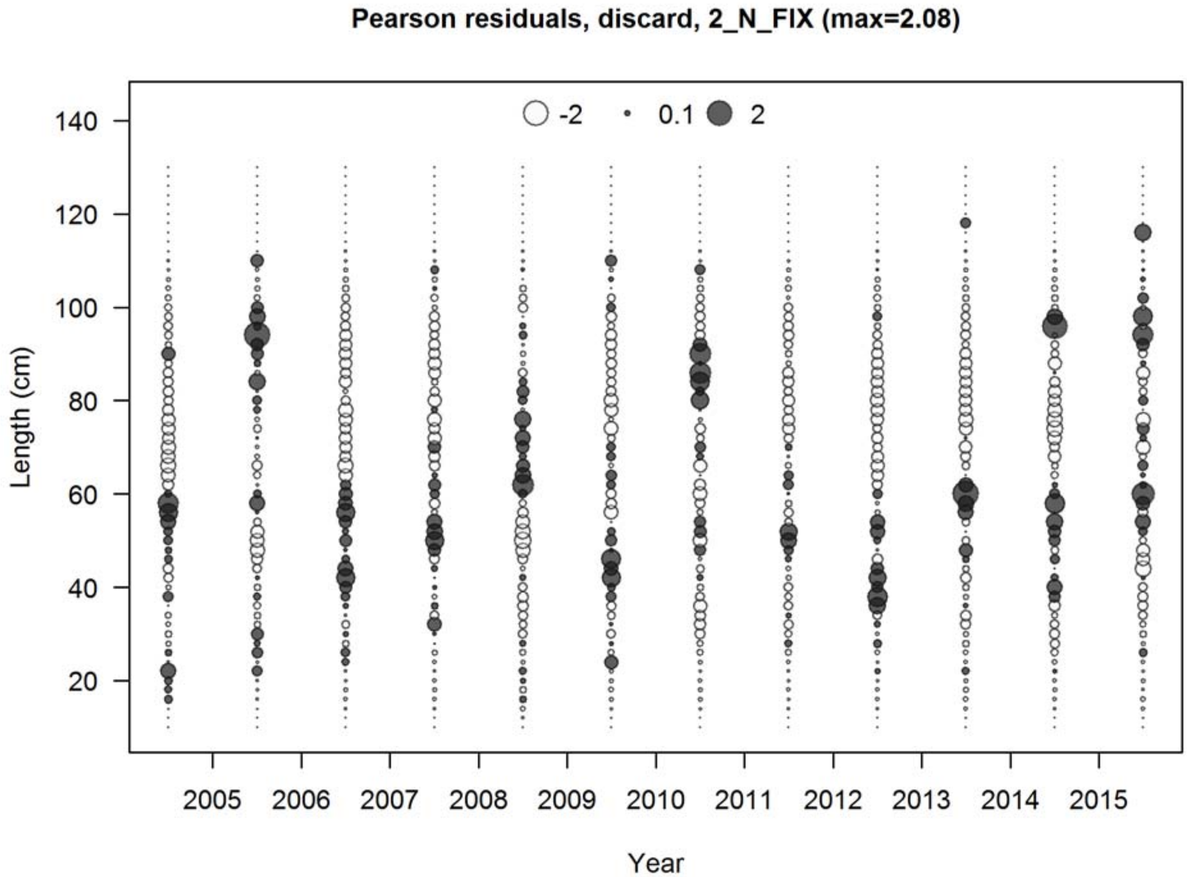


Figure 92. Commercial sex combined fixed gear discard length data Pearson residuals, north.

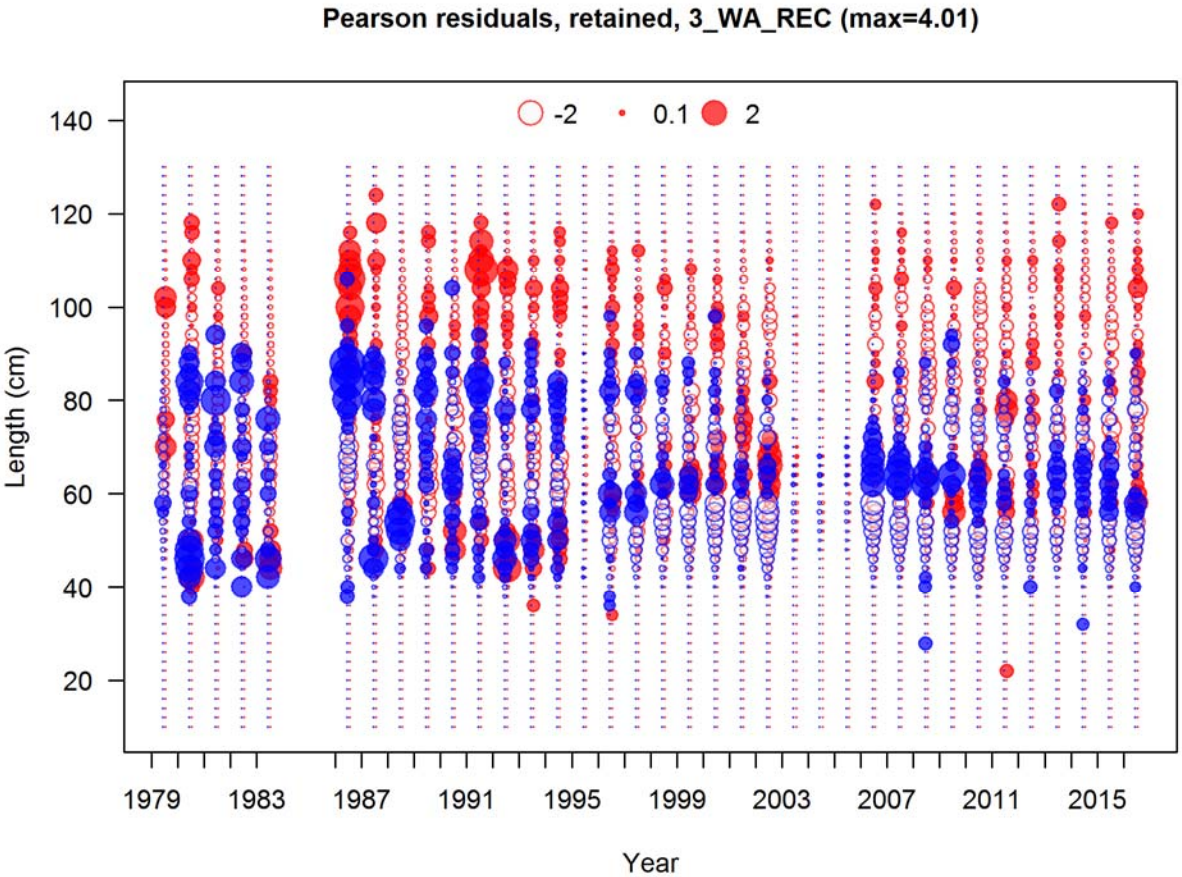


Figure 93. WA sex specific recreational length data Pearson residuals.

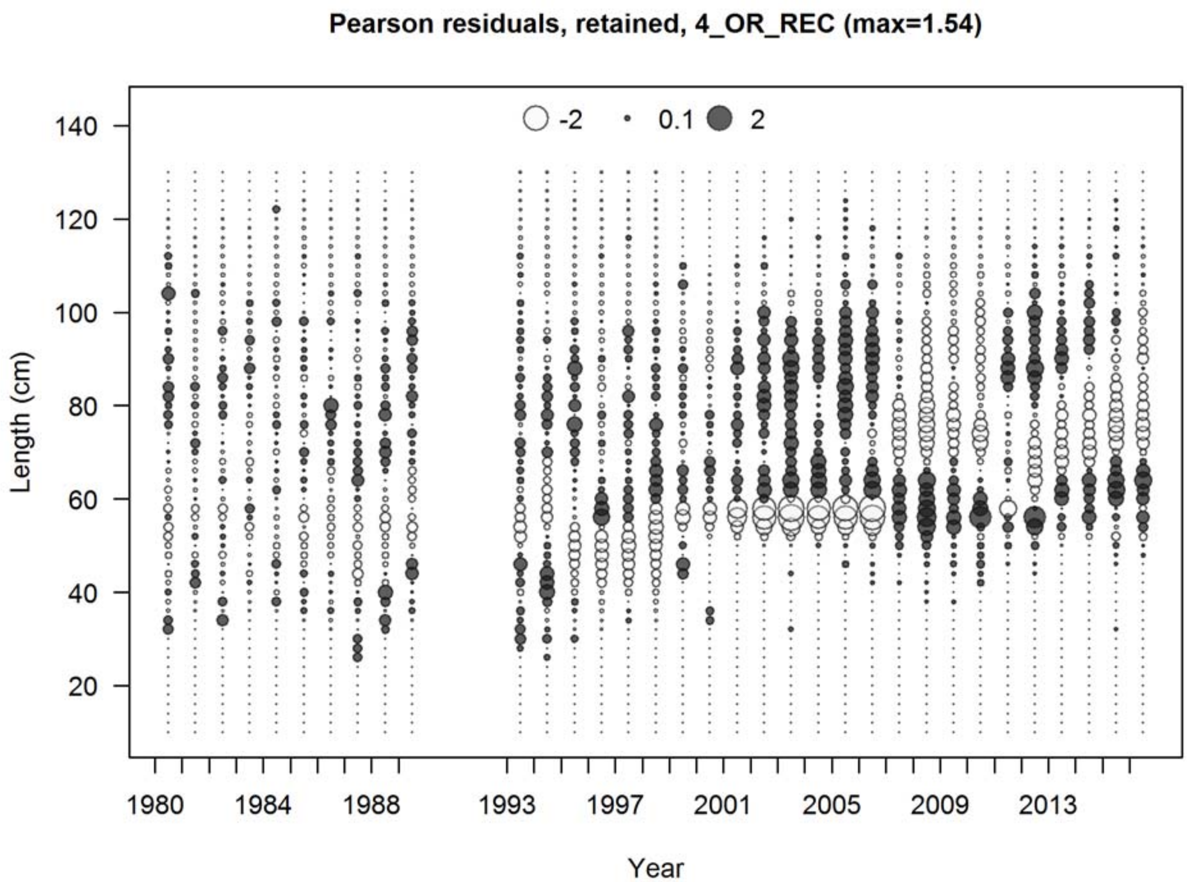


Figure 94. OR sex combined recreational length data Pearson residuals.

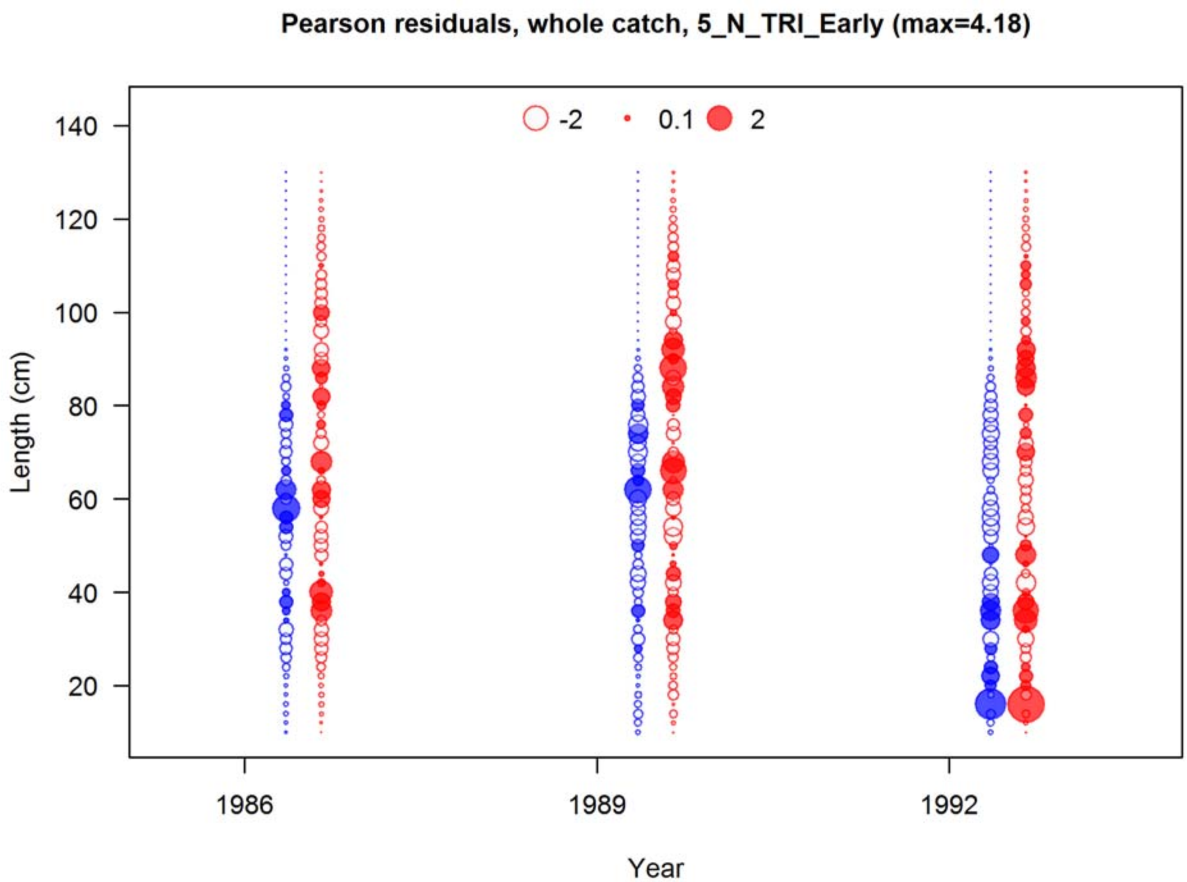


Figure 95. Triennial early sex specific length data Pearson residuals, north.

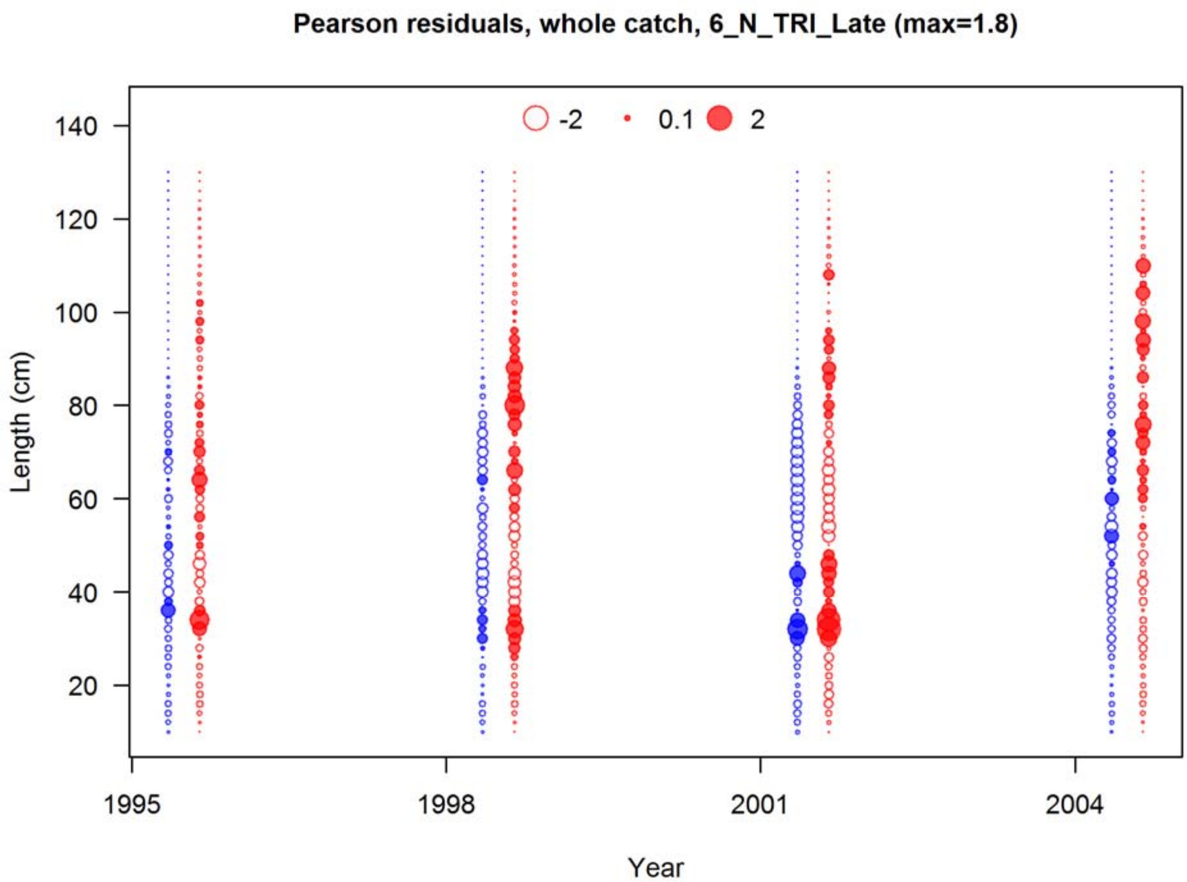


Figure 96. Triennial survey late sex specific length data Pearson residuals, north.

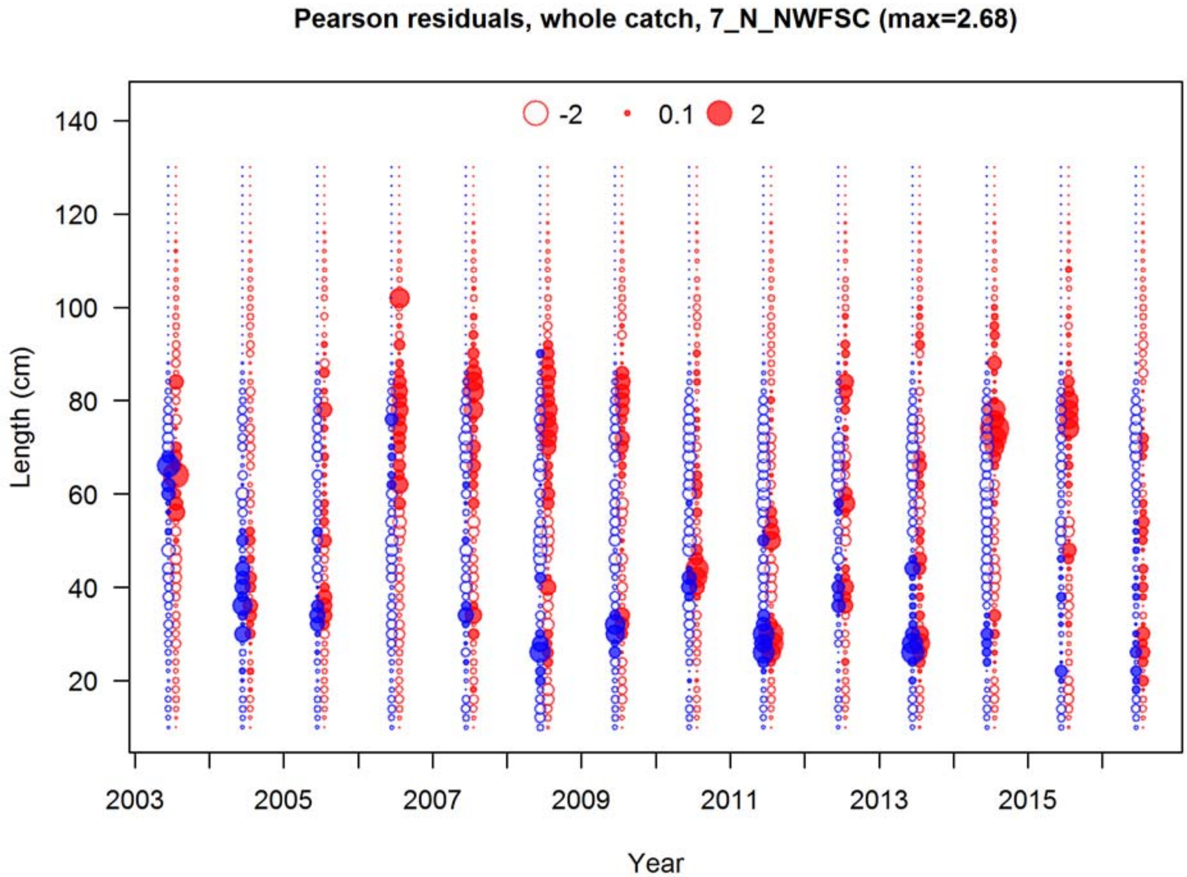


Figure 97. NWFSC survey sex specific length data Pearson residuals, north.

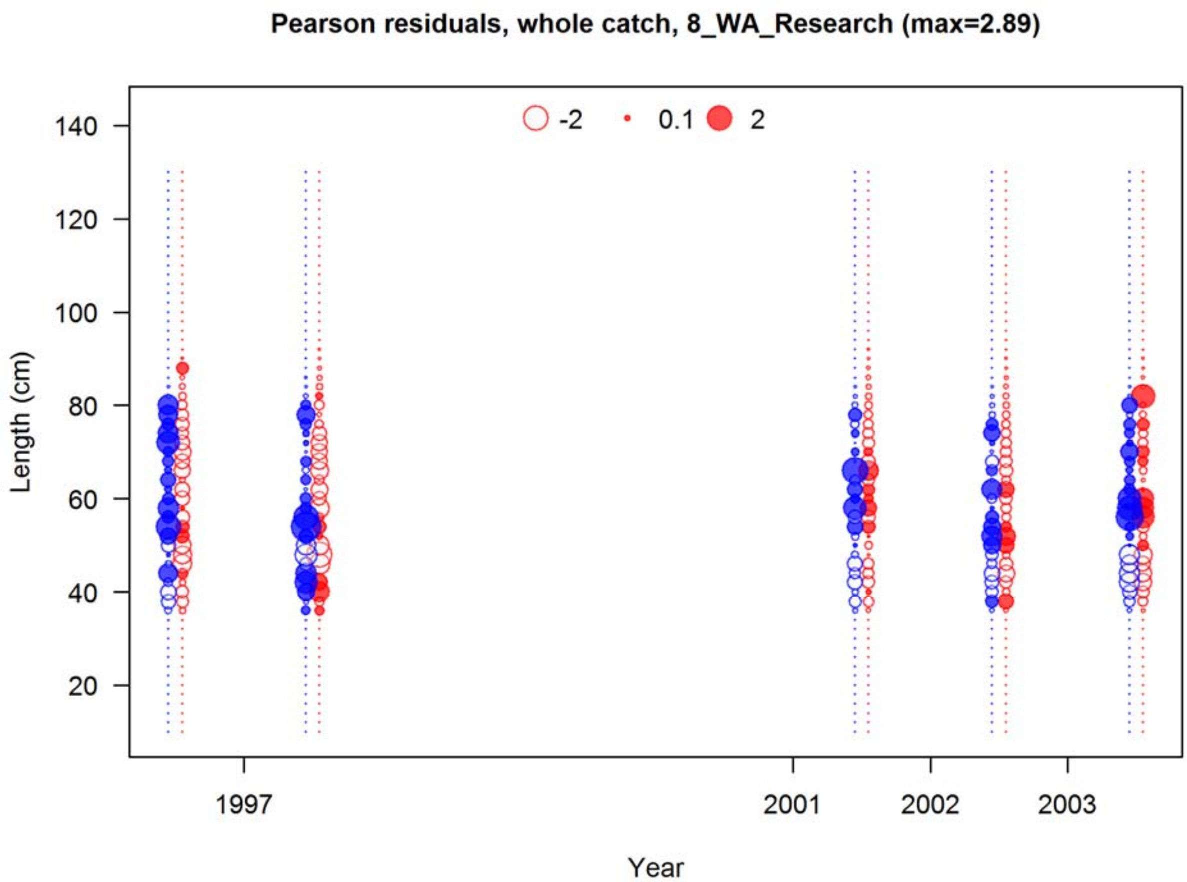


Figure 98. WA research sex specific length data Pearson residuals from the pre-STAR model. The final base model does not include these data.

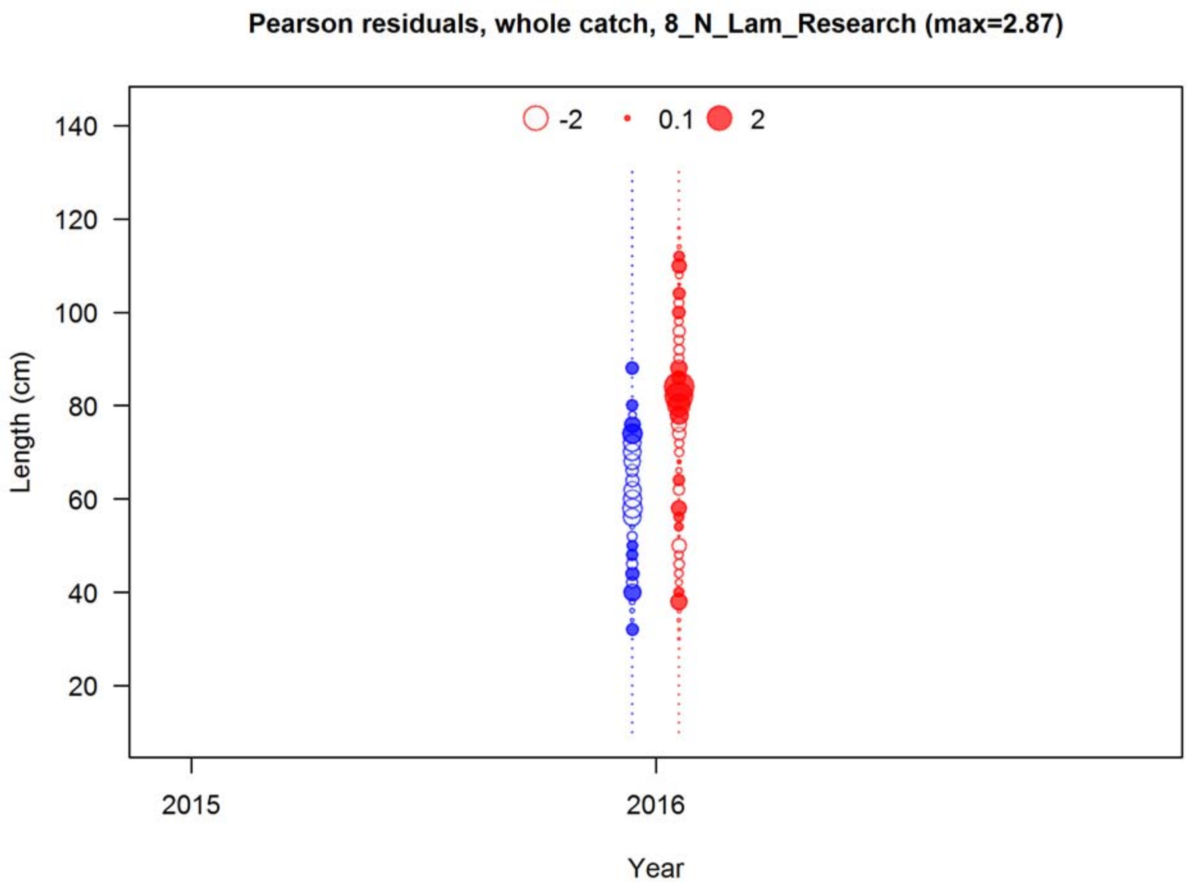


Figure 99. Lam sex specific research length data Pearson residuals, north.

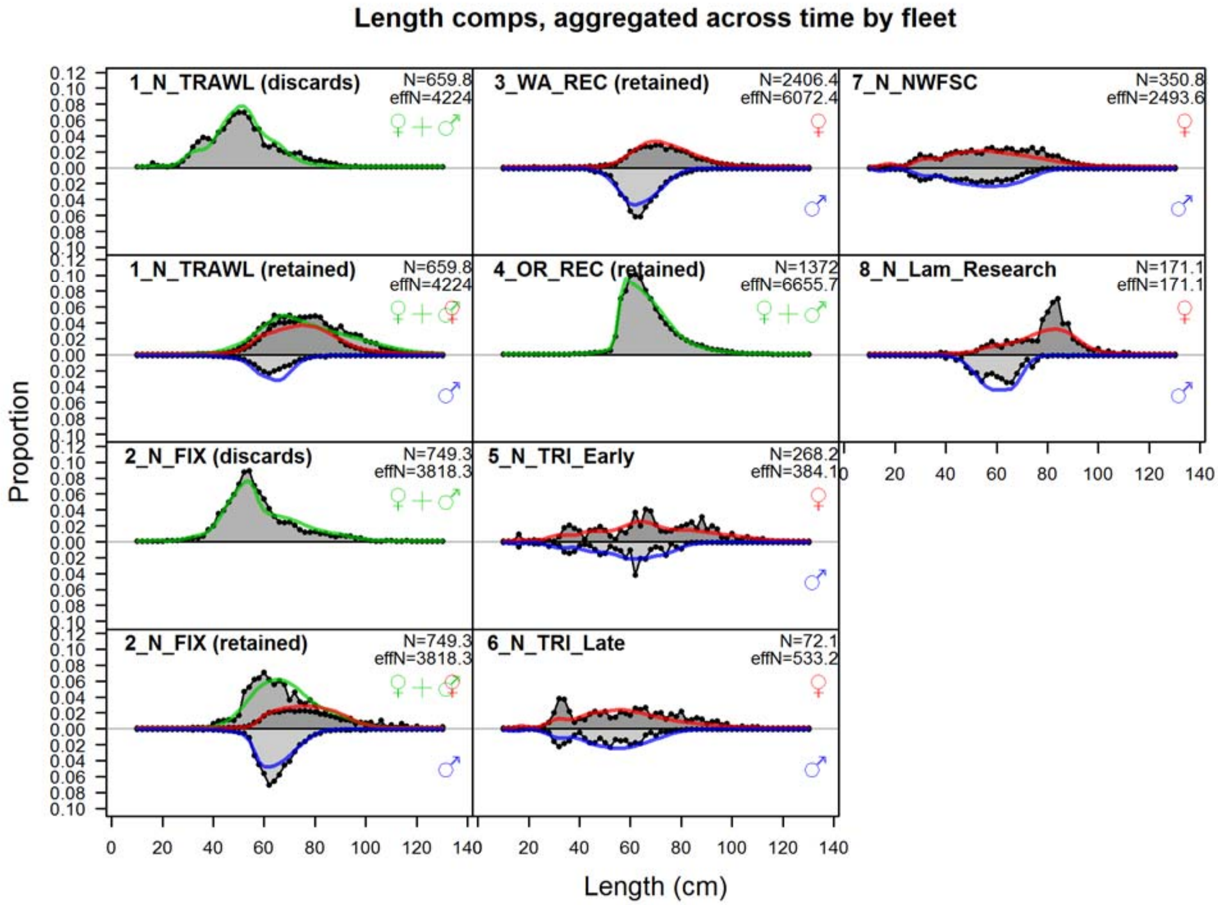


Figure 100. North model length composition data fits aggregated across time by fleet.

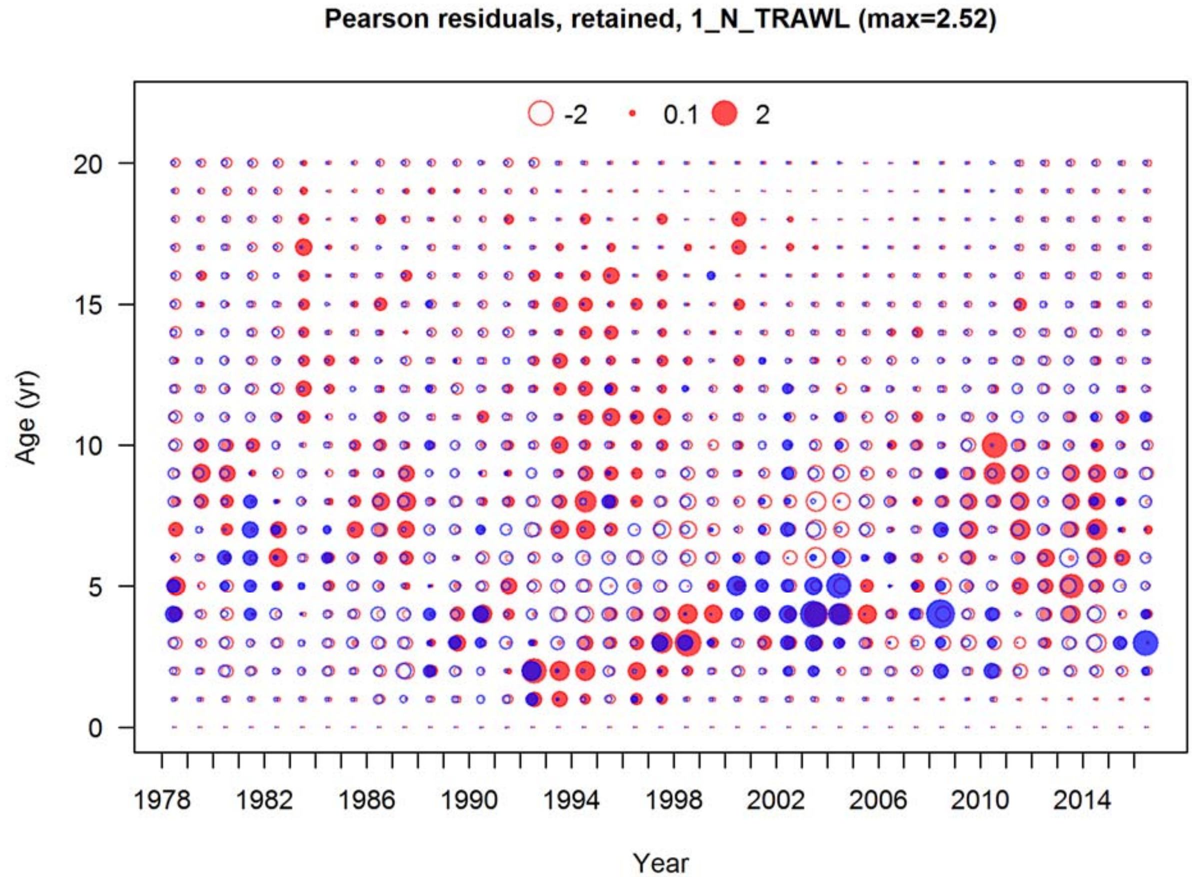


Figure 101. Commercial sex specific trawl age data Pearson residuals, north, from model sensitivity run that included these data.

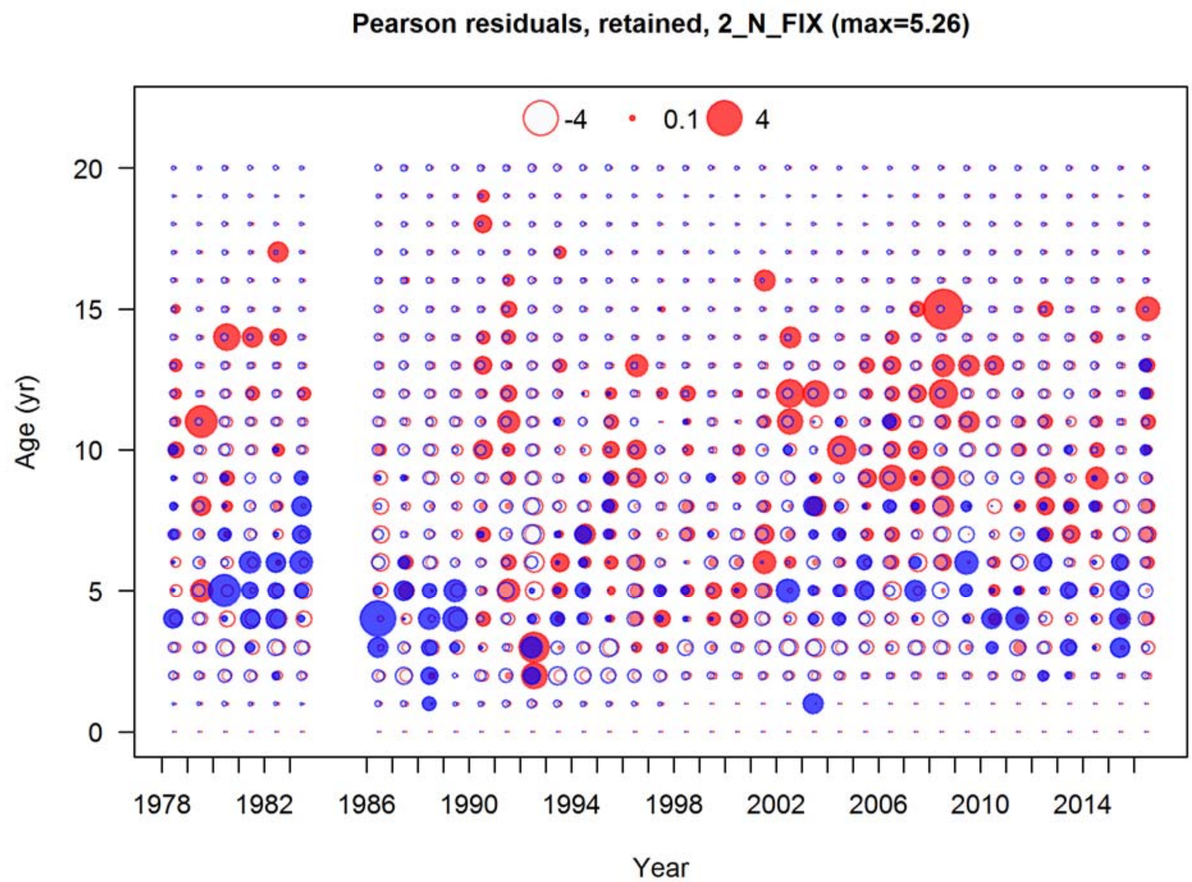


Figure 102. Commercial sex specific fixed gear age data Pearson residuals, north, from a model sensitivity run with these data.

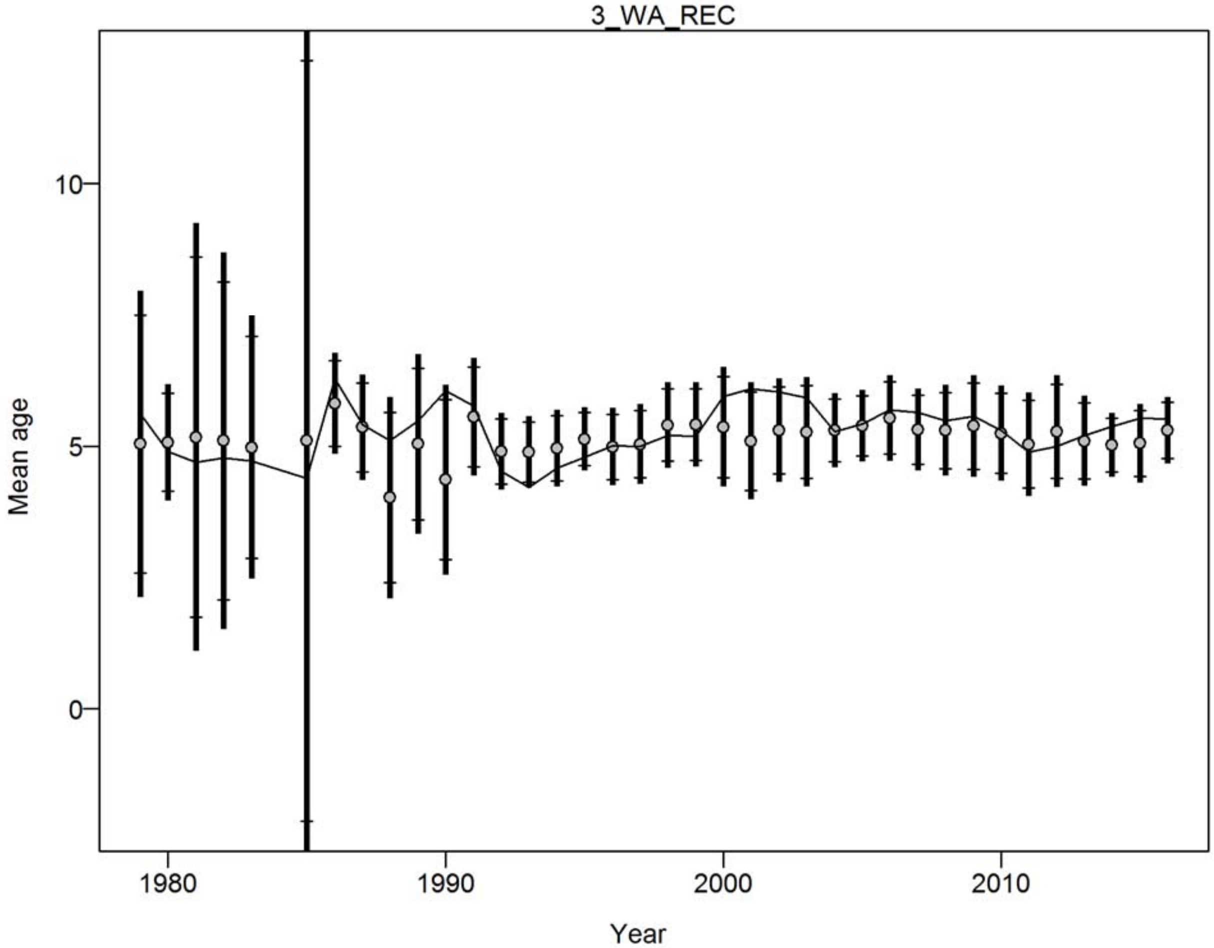


Figure 103. Fits to WA recreational age data from a model sensitivity to these data.

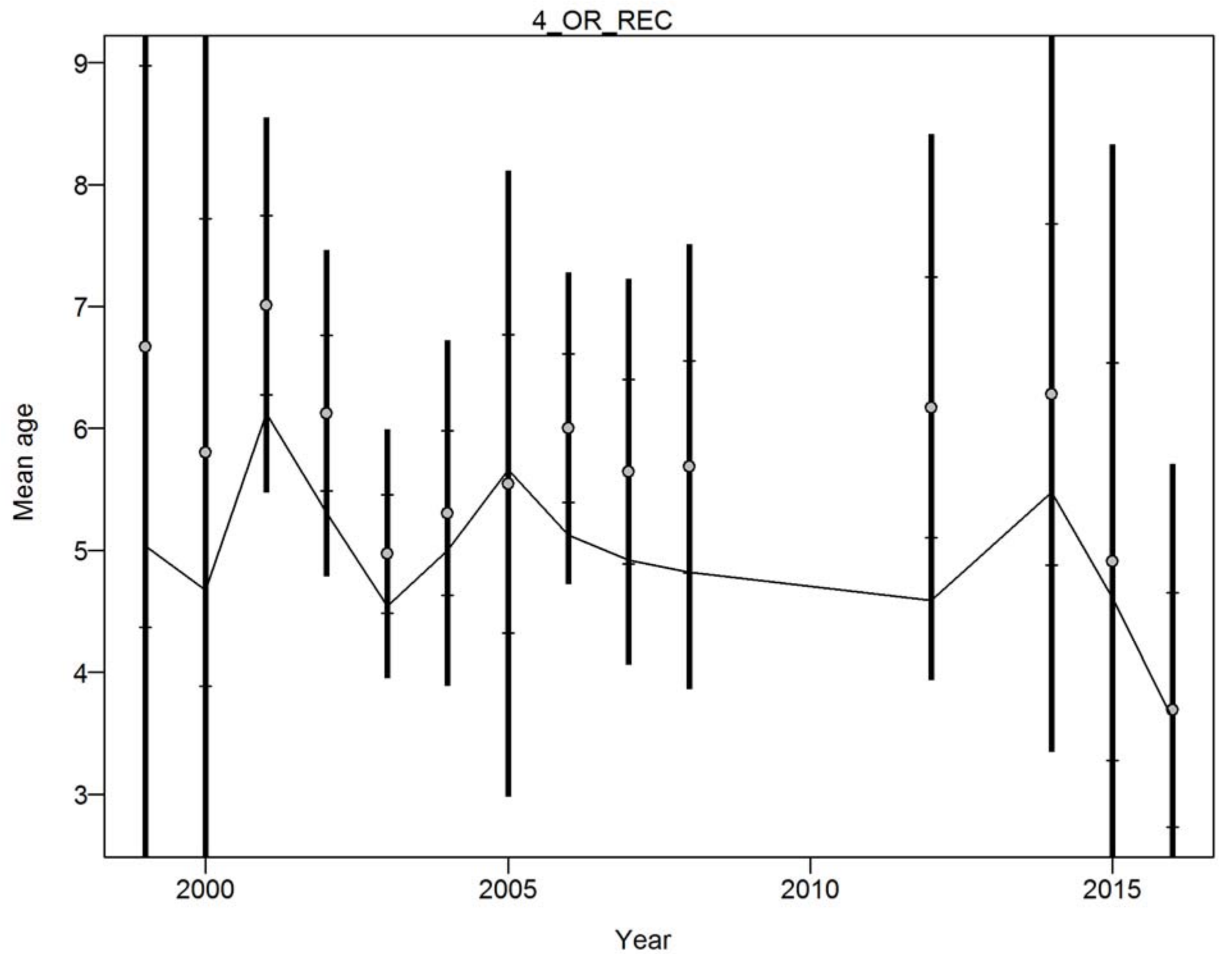


Figure 104. Fits to OR recreational age data from a model sensitivity run with these data.

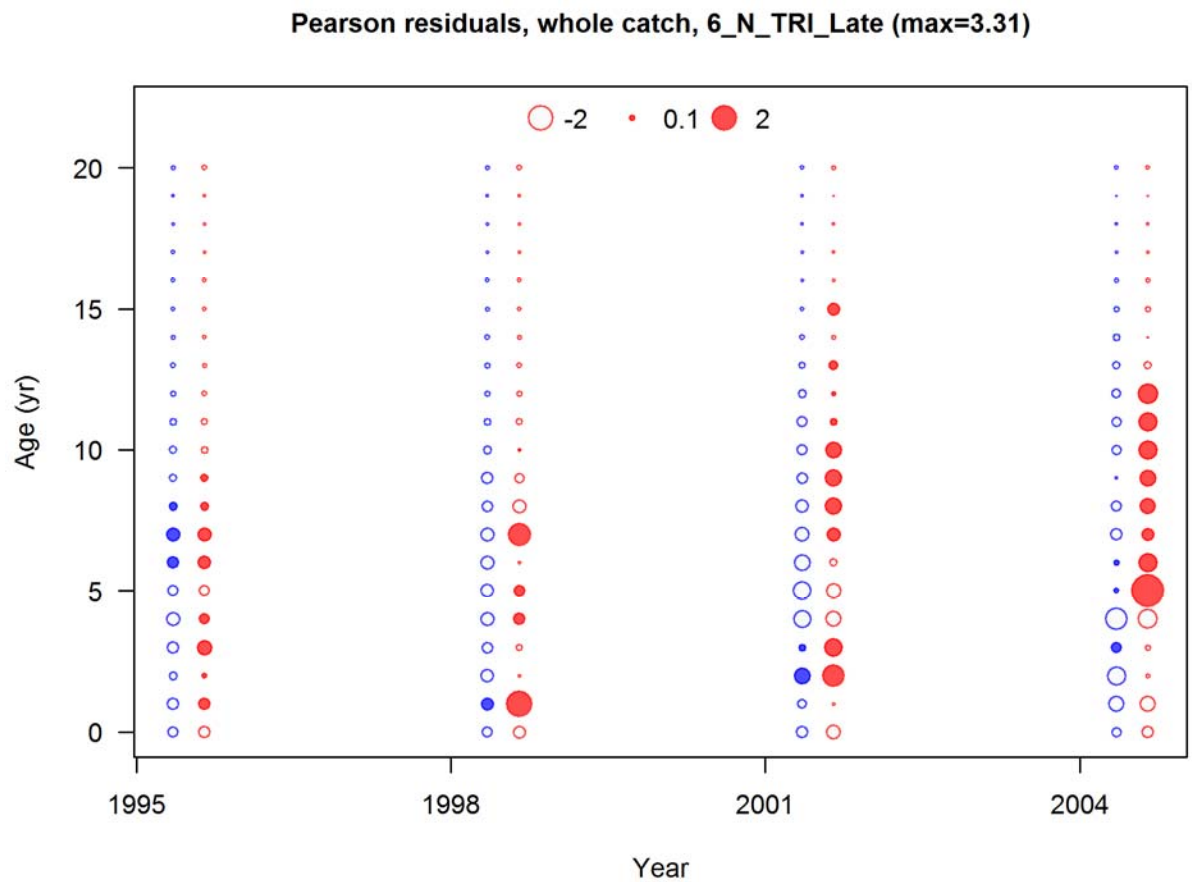


Figure 105. Triennial late survey sex specific age data Pearson residuals, north.

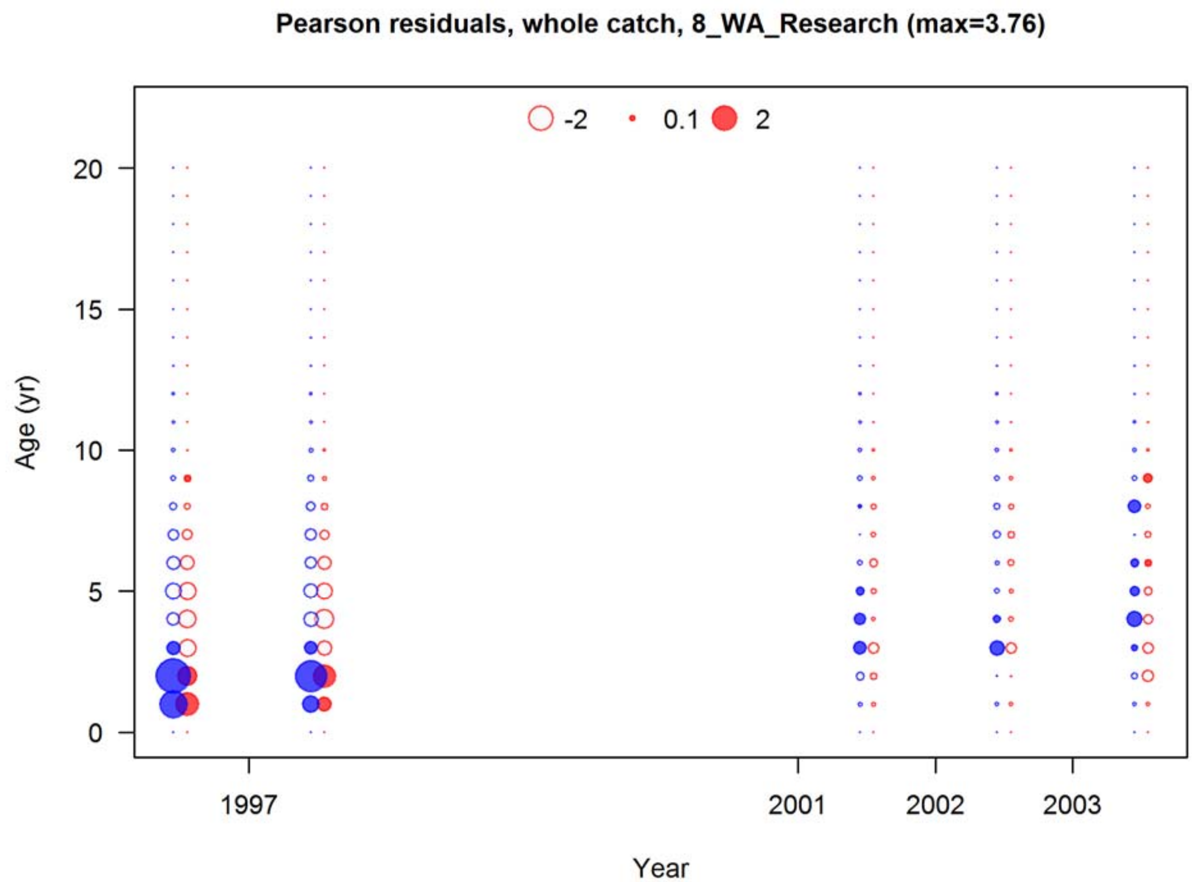


Figure 106. WA research sex specific age data Pearson residuals from a sensitivity run with these data.

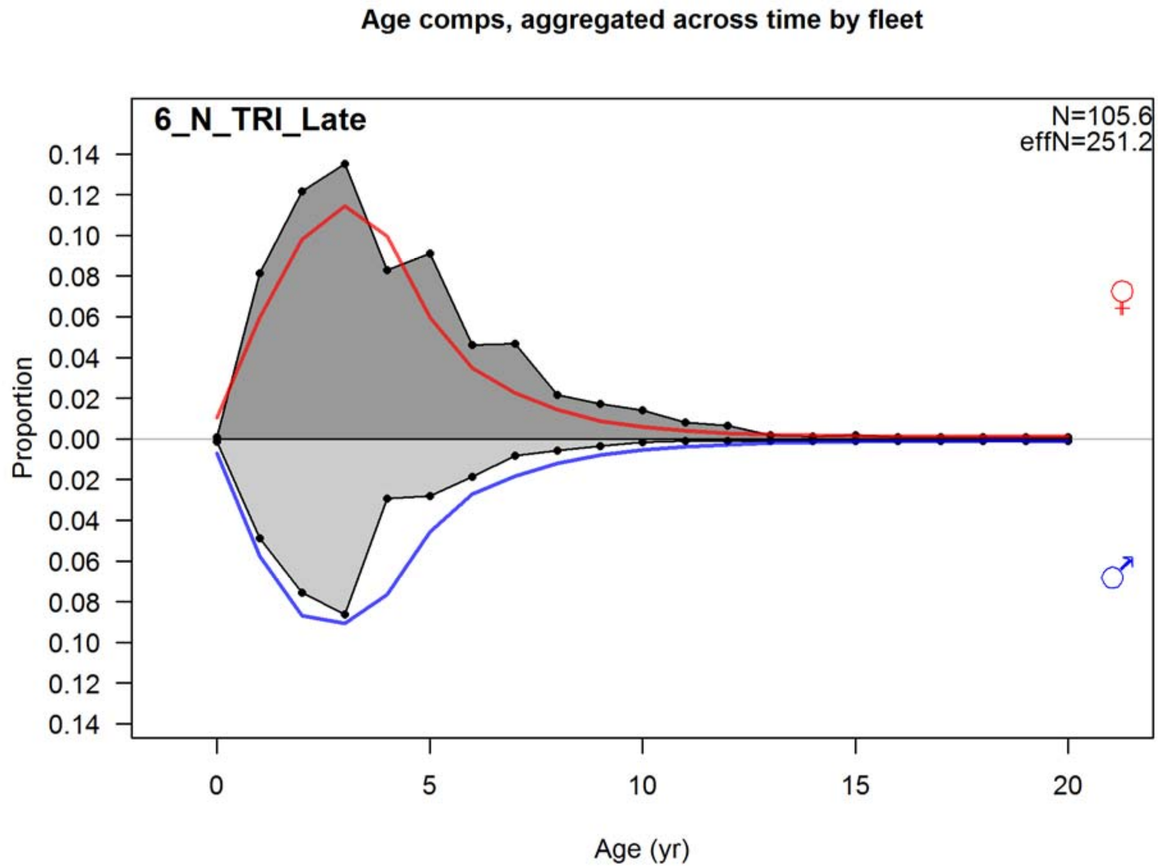


Figure 107. Age composition fits aggregated across time and by fleet for the north.

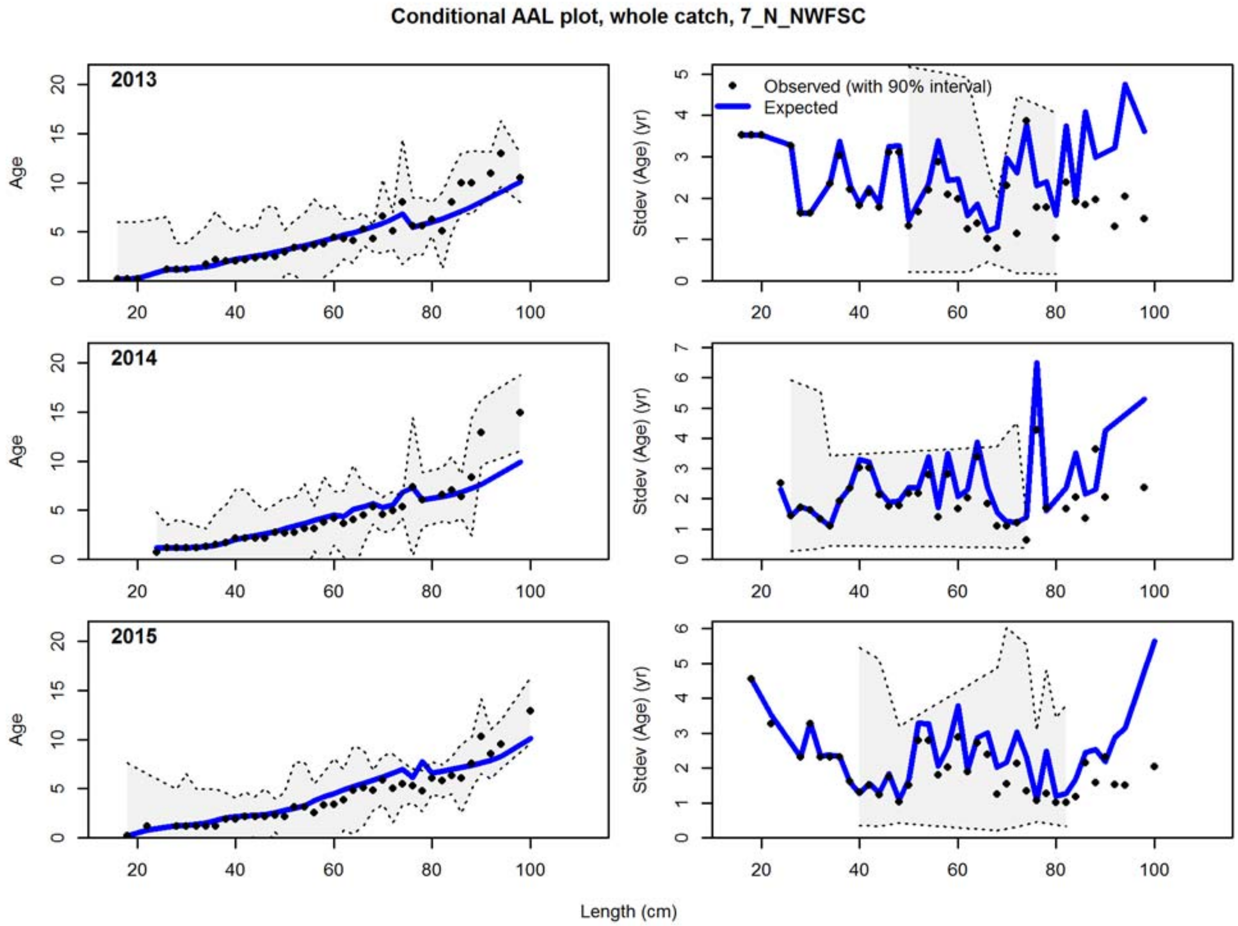


Figure 108. Conditional age-at-length (AAL) fits for the NWFSC survey data.

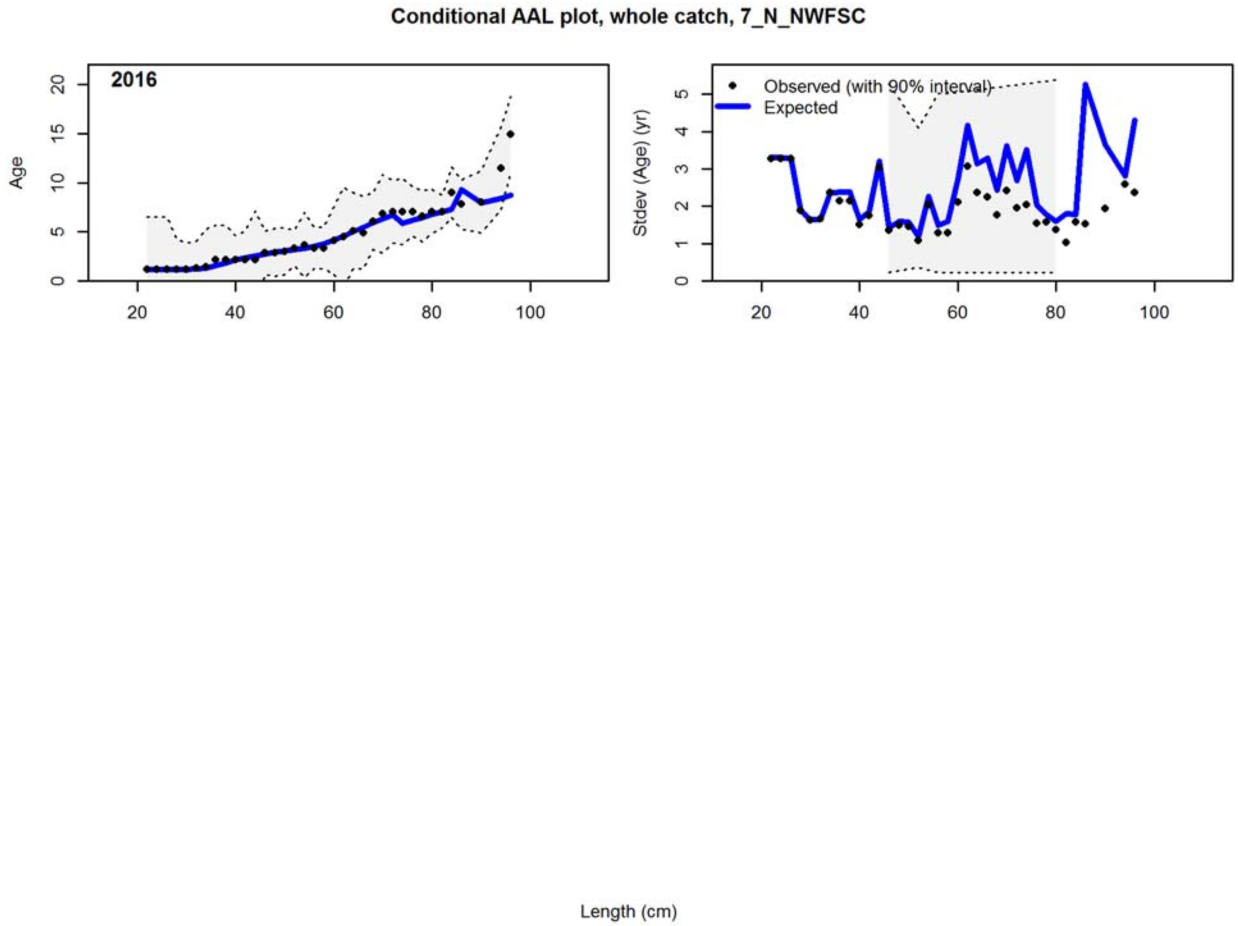


Figure 109. Conditional age-at-length (AAL) fits for Lam research data.

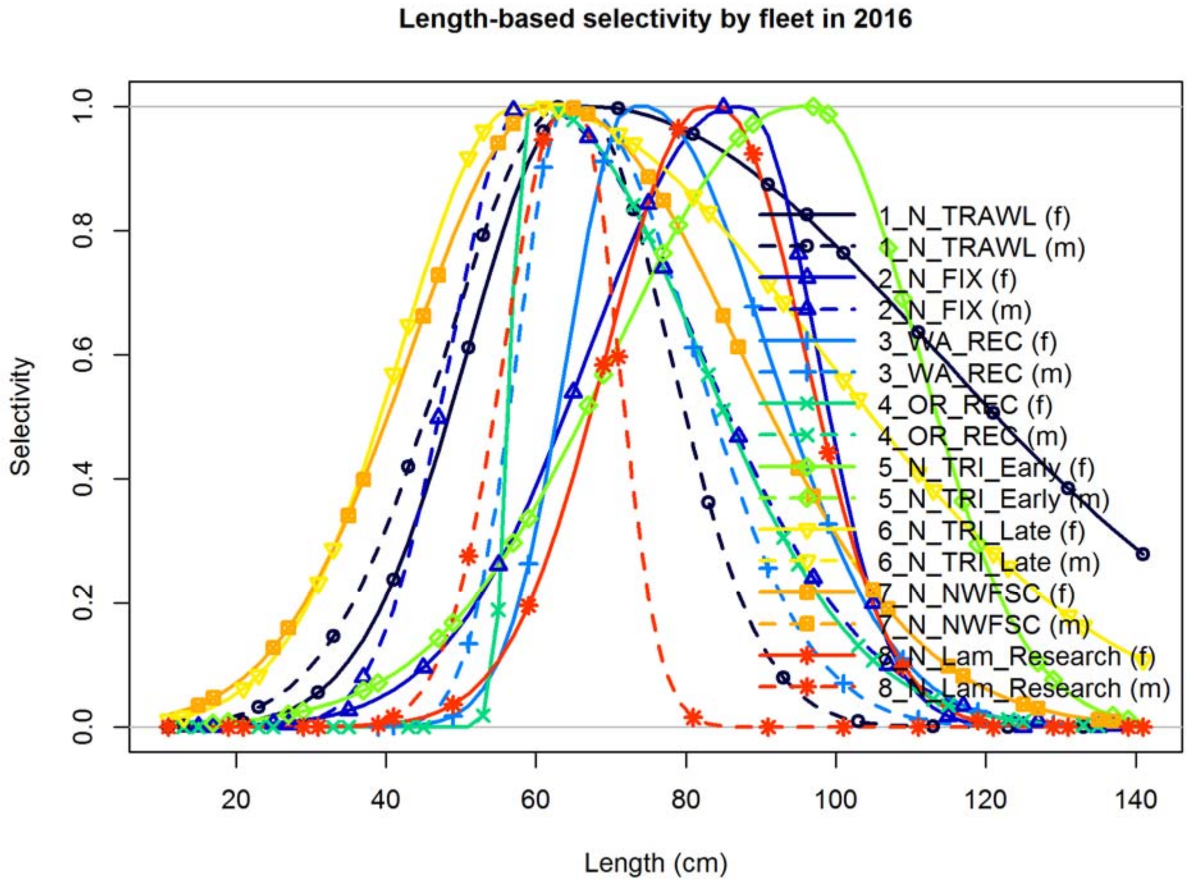


Figure 110. End year selectivity for each north model fleet. Go to the Auxiliary files r4ss plots folder for the north model run, open the SS Output html file, and go to the “sel” tab to see individual selectivity plots for each fleet as well as plots of retention curves for the commercial fleets.

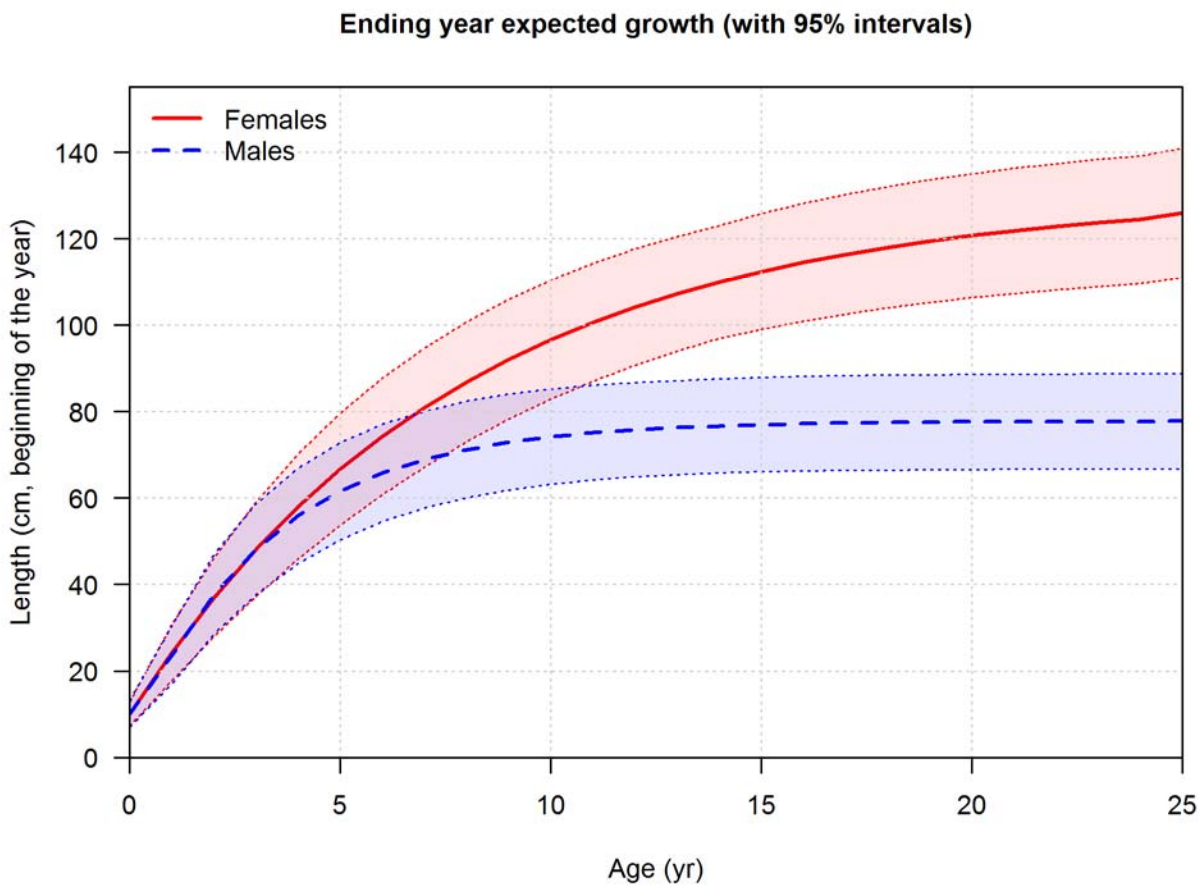


Figure 111. Estimated growth curves, north.

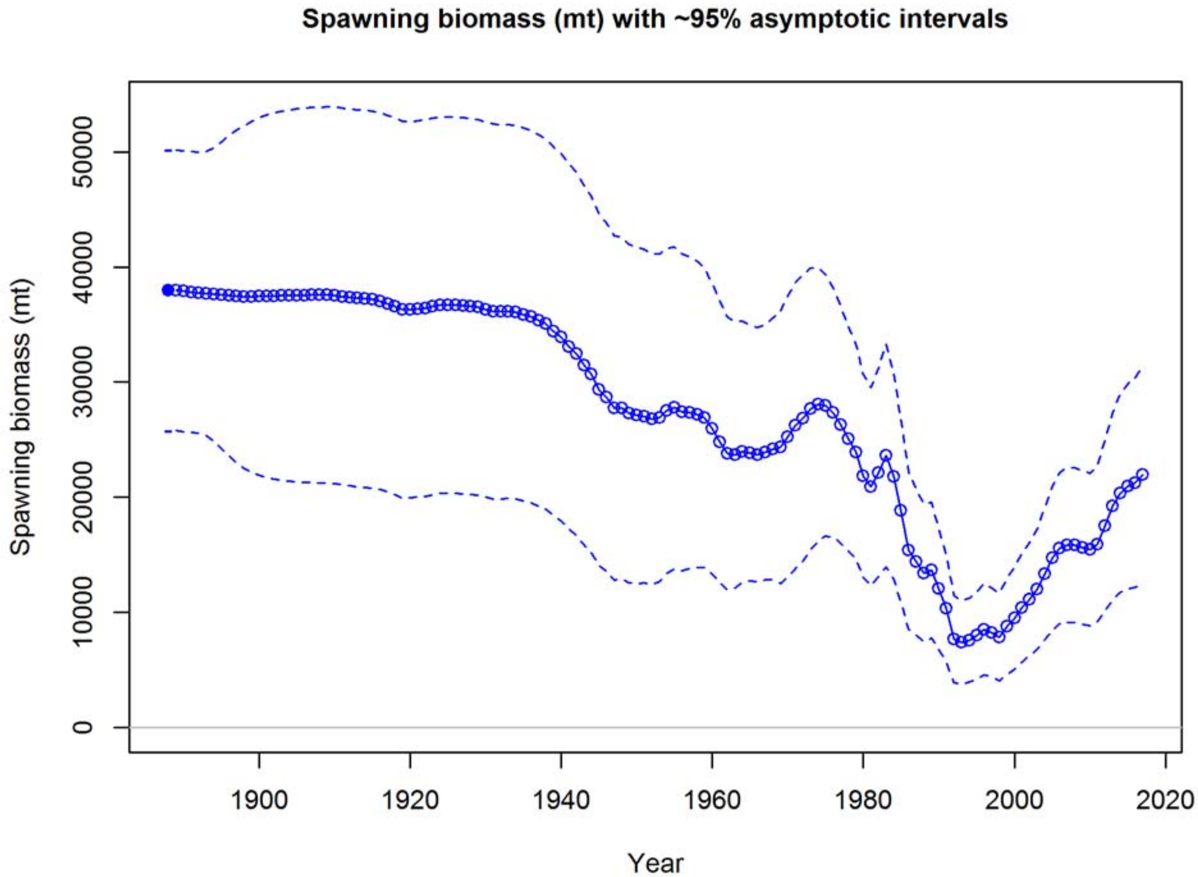


Figure 112. Time series of estimate spawning biomass, north.

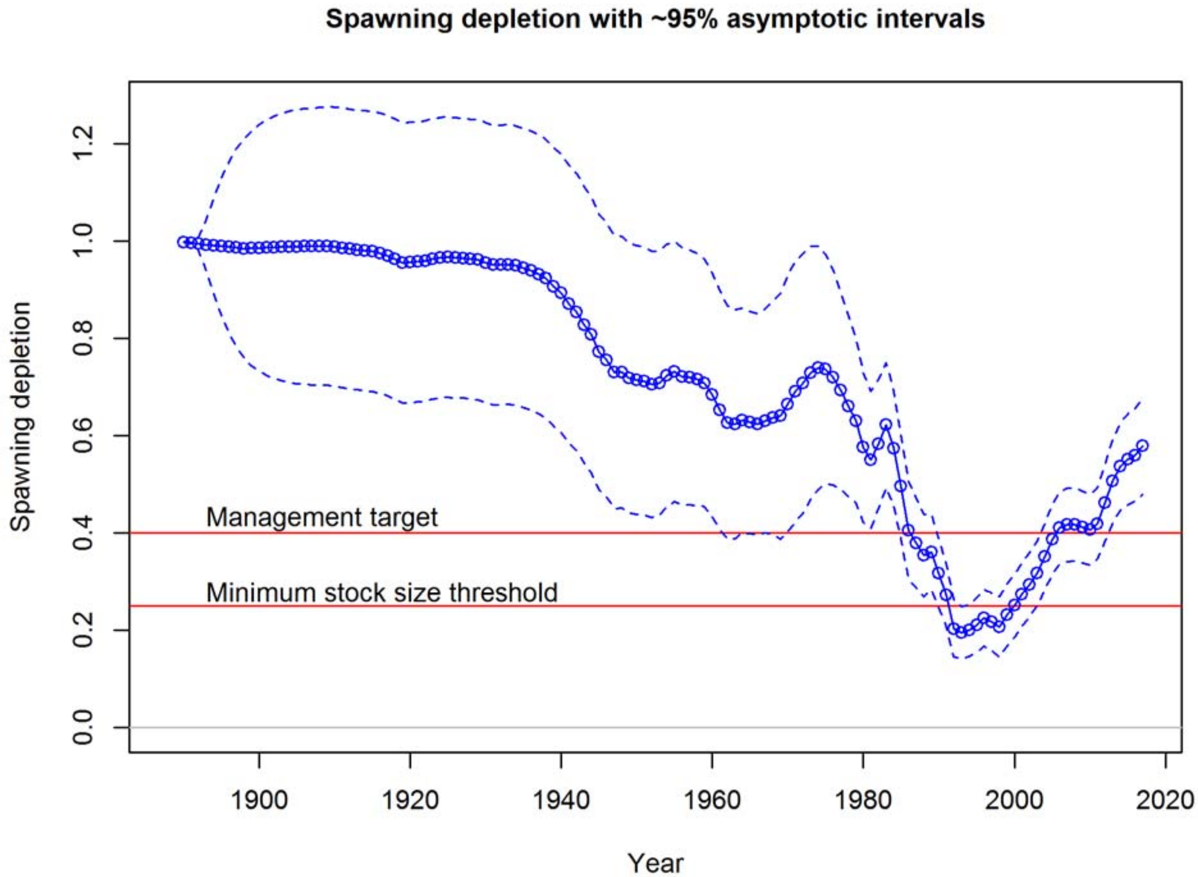


Figure 113. Time series of stock depletion, north.

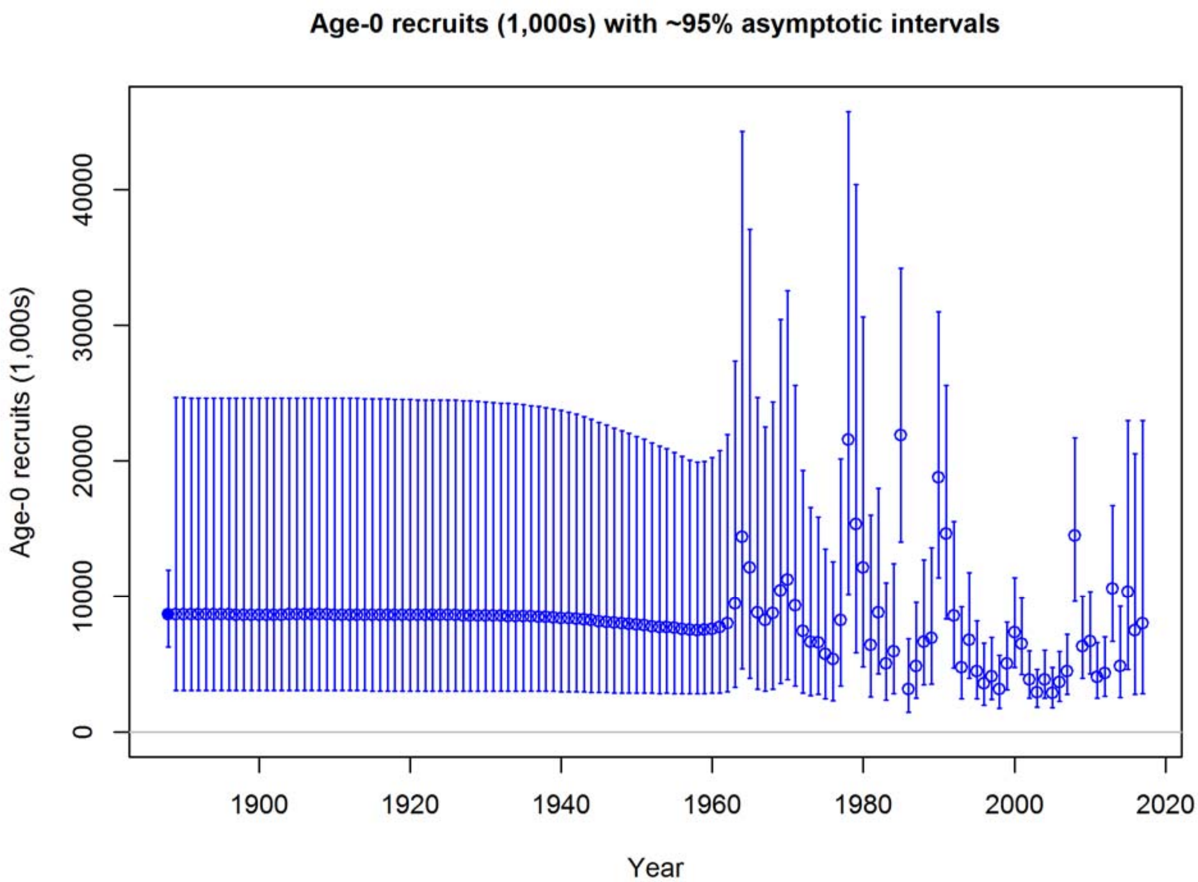


Figure 114. Time series of estimated recruits, north.

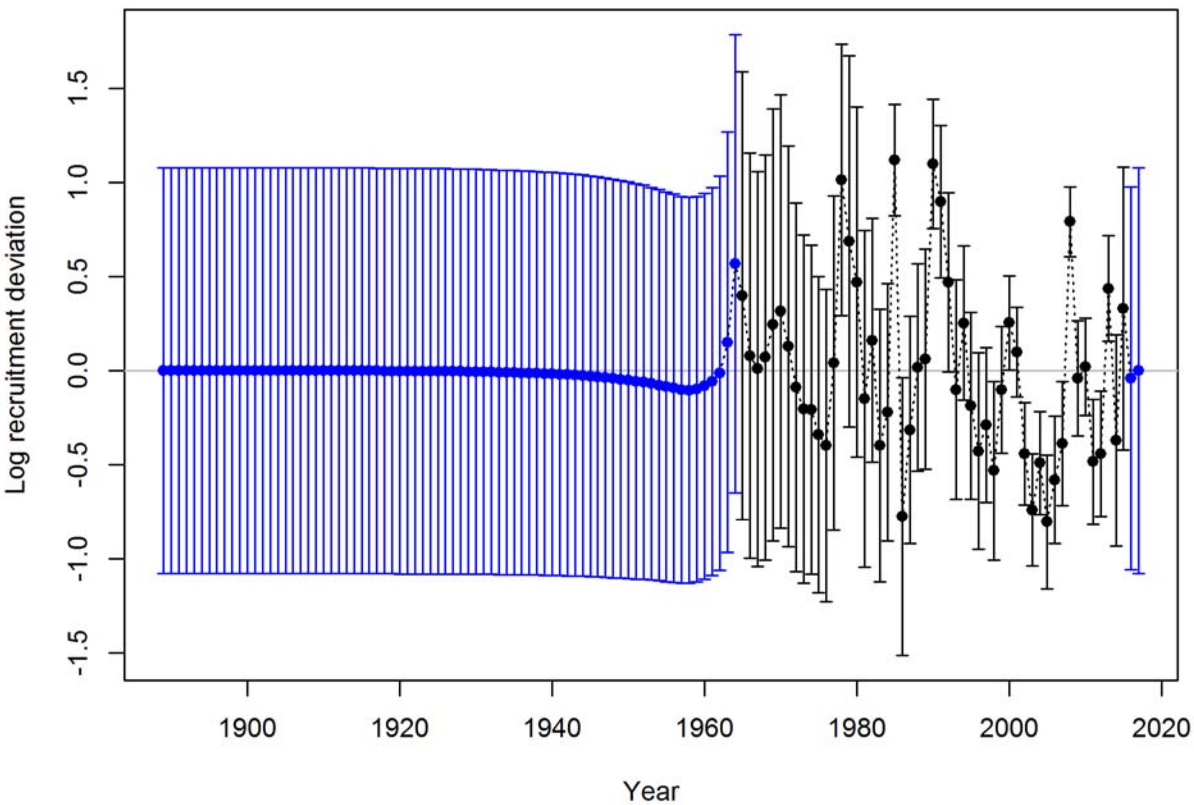


Figure 115. Estimated recruitment deviations, north.

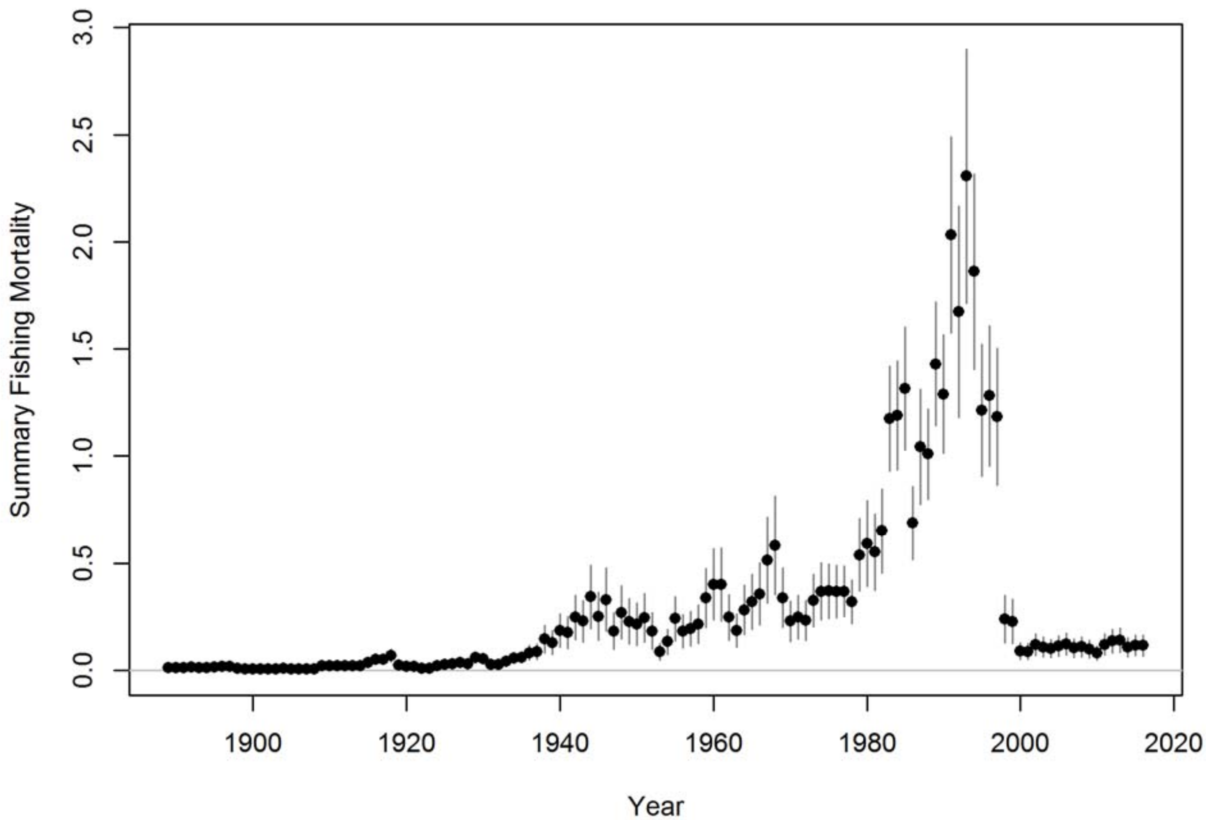


Figure 116. Time series of estimated Summary Fishing Mortality (F), north.

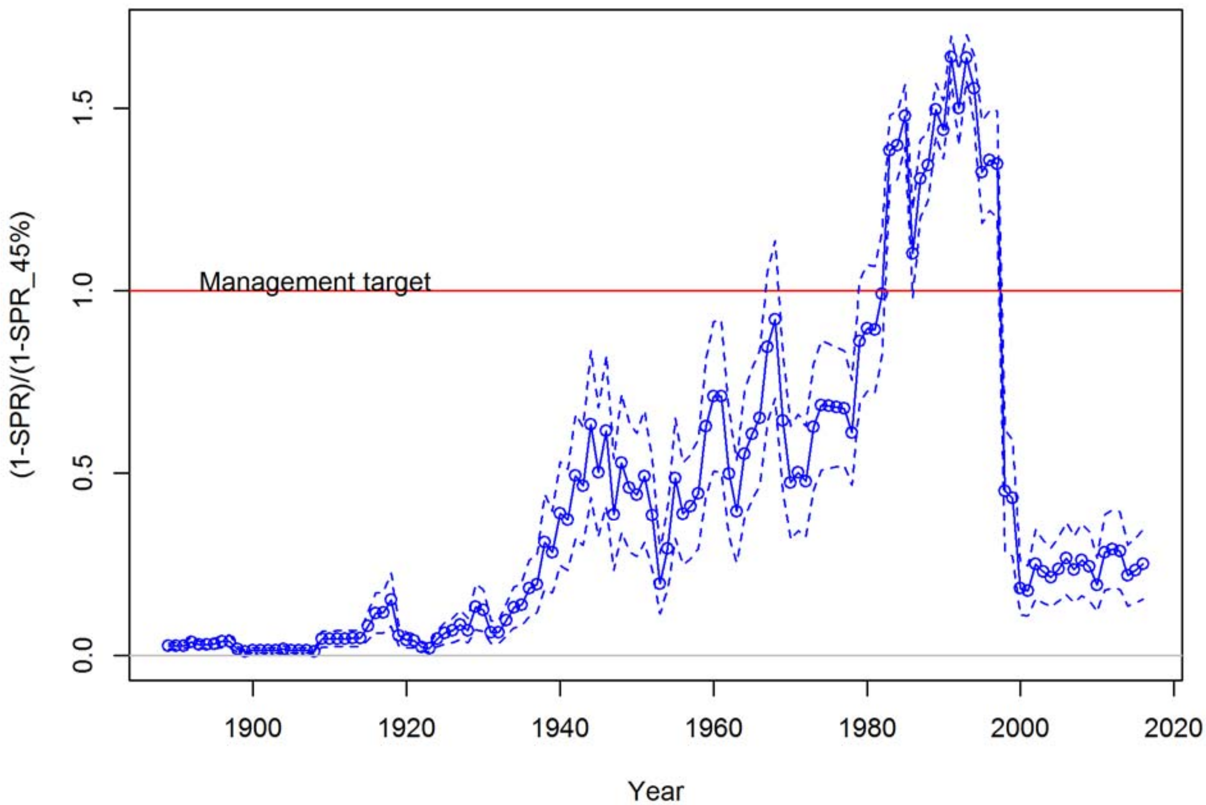


Figure 117. Time series of SPR ratio, north.

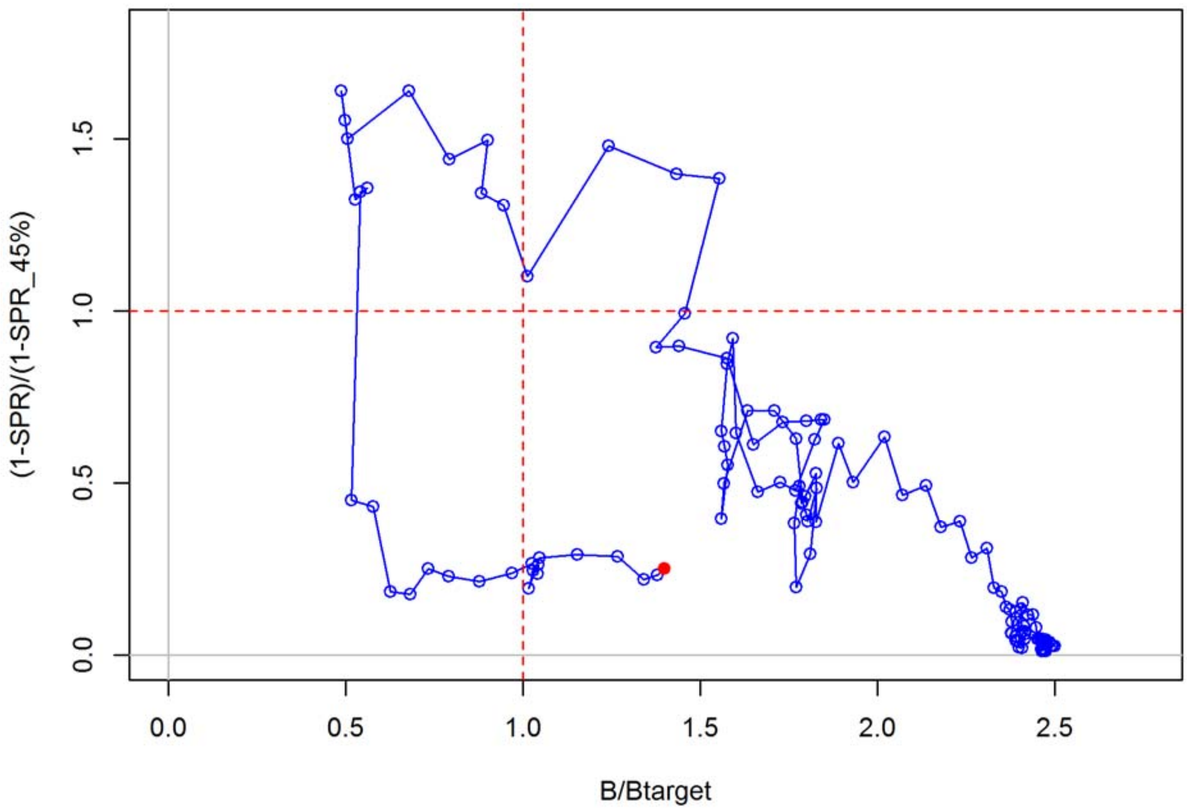


Figure 118. Phase plot of biomass ratio v. SPR ratio.

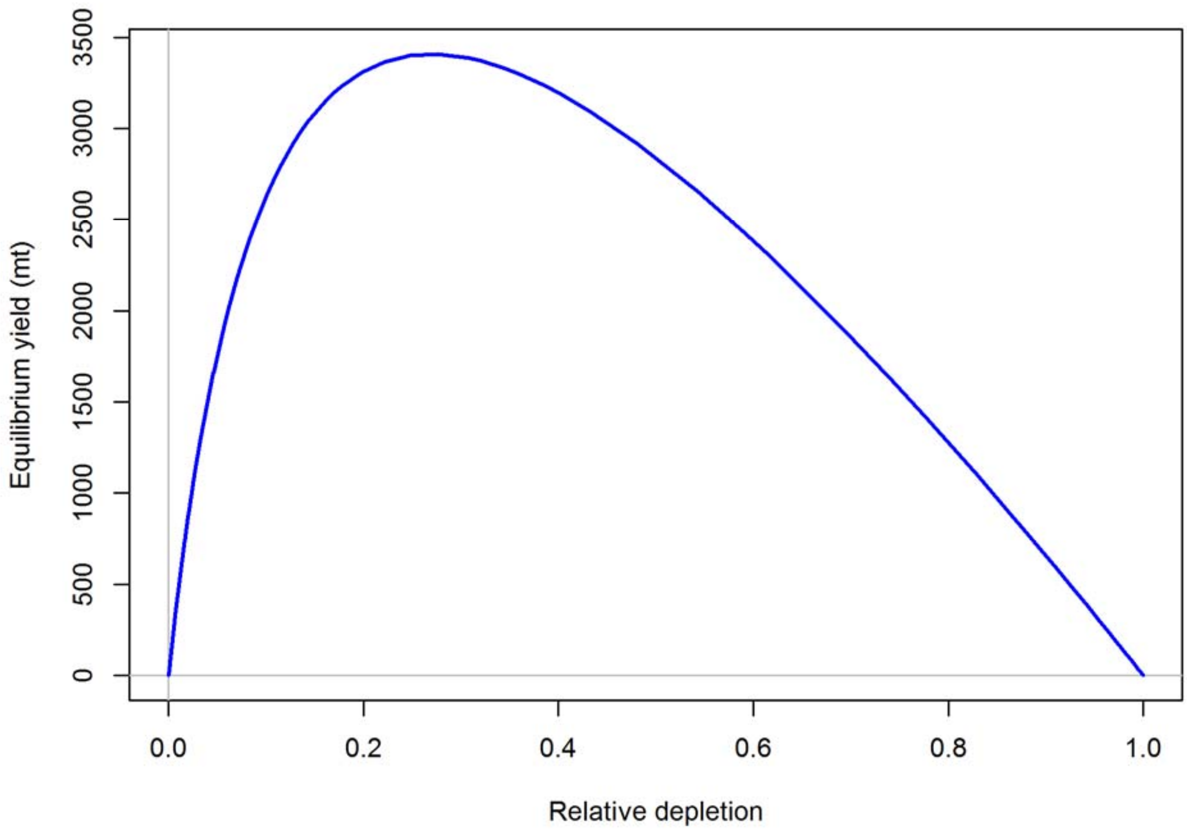


Figure 119. Equilibrium yield curve, north.

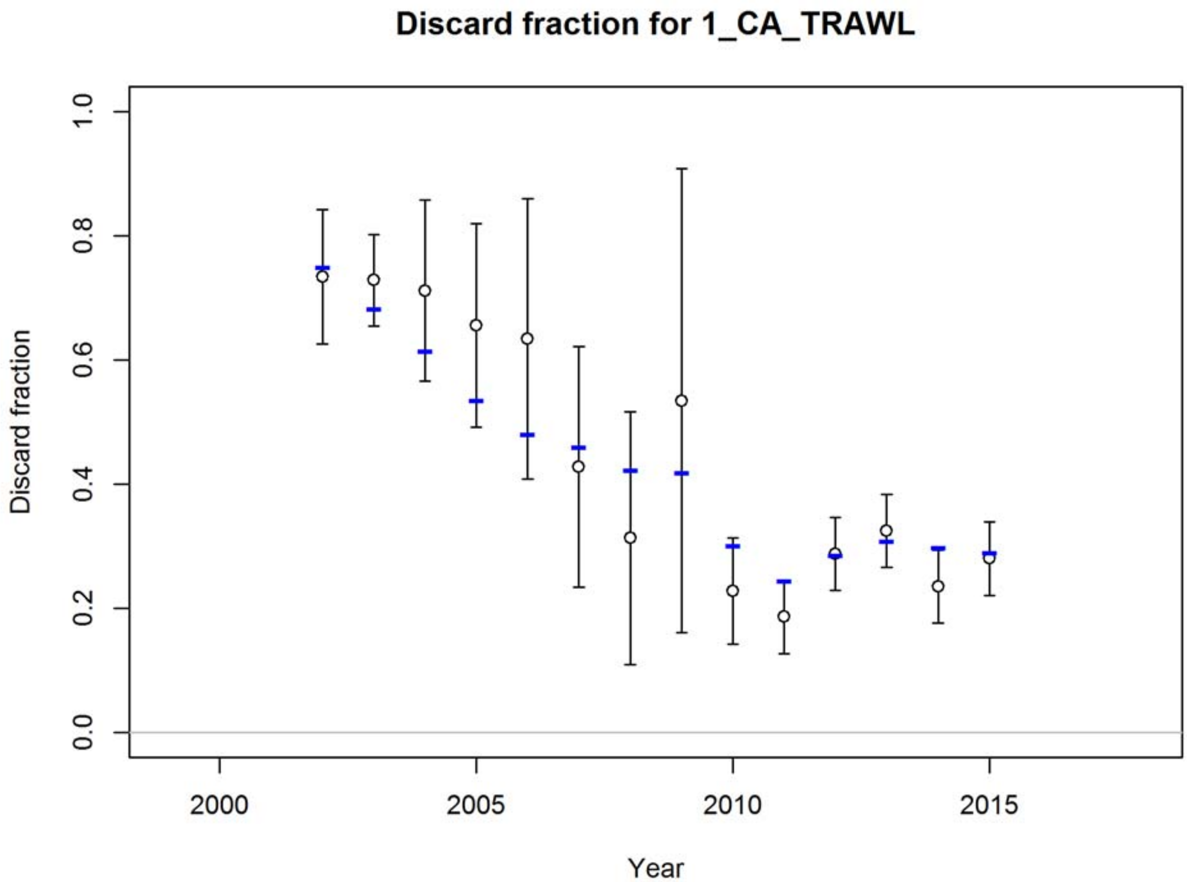


Figure 120. Commercial trawl discard fraction fits, south. Blue horizontal dashed lines are model fits.

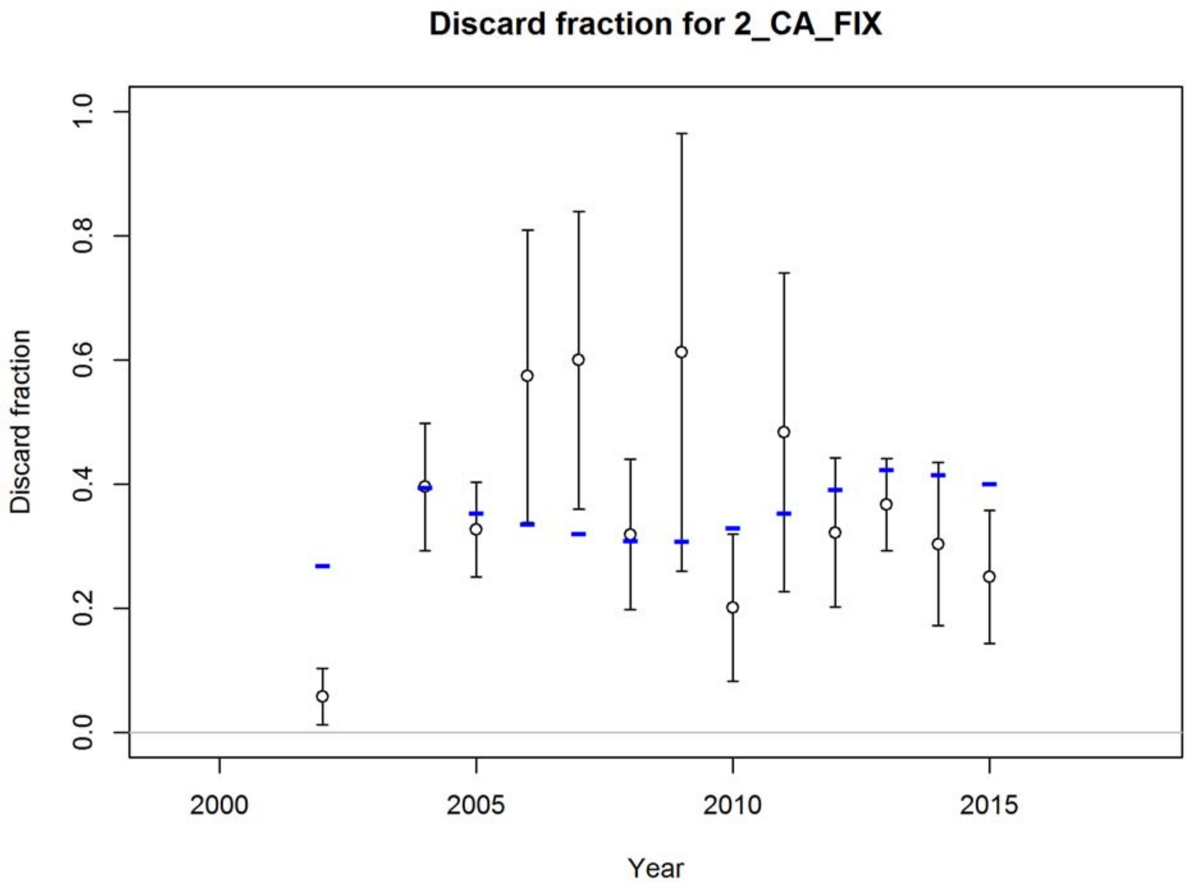


Figure 121. Commercial fixed gear discard fraction fits, south. Blue horizontal dashed lines are model fits.

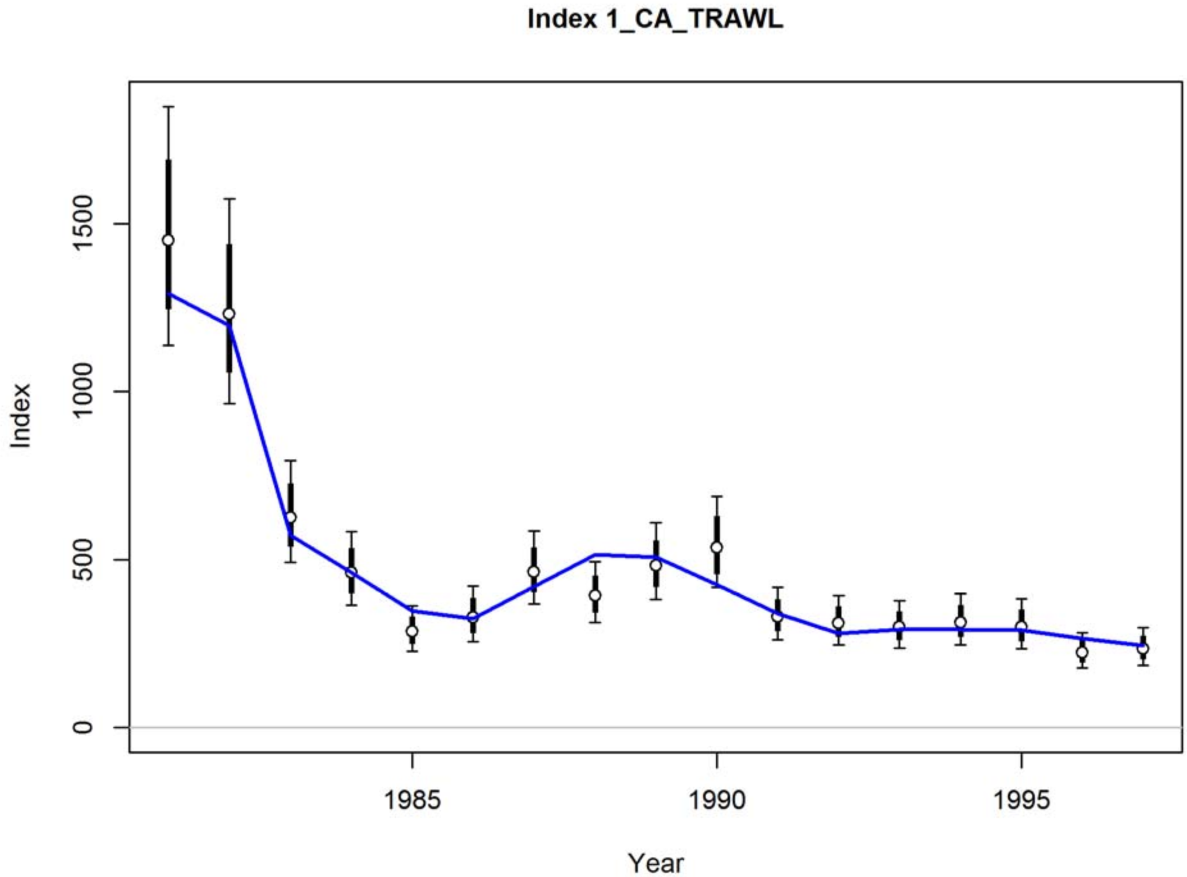


Figure 122. Commercial trawl CPUE fit, south. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

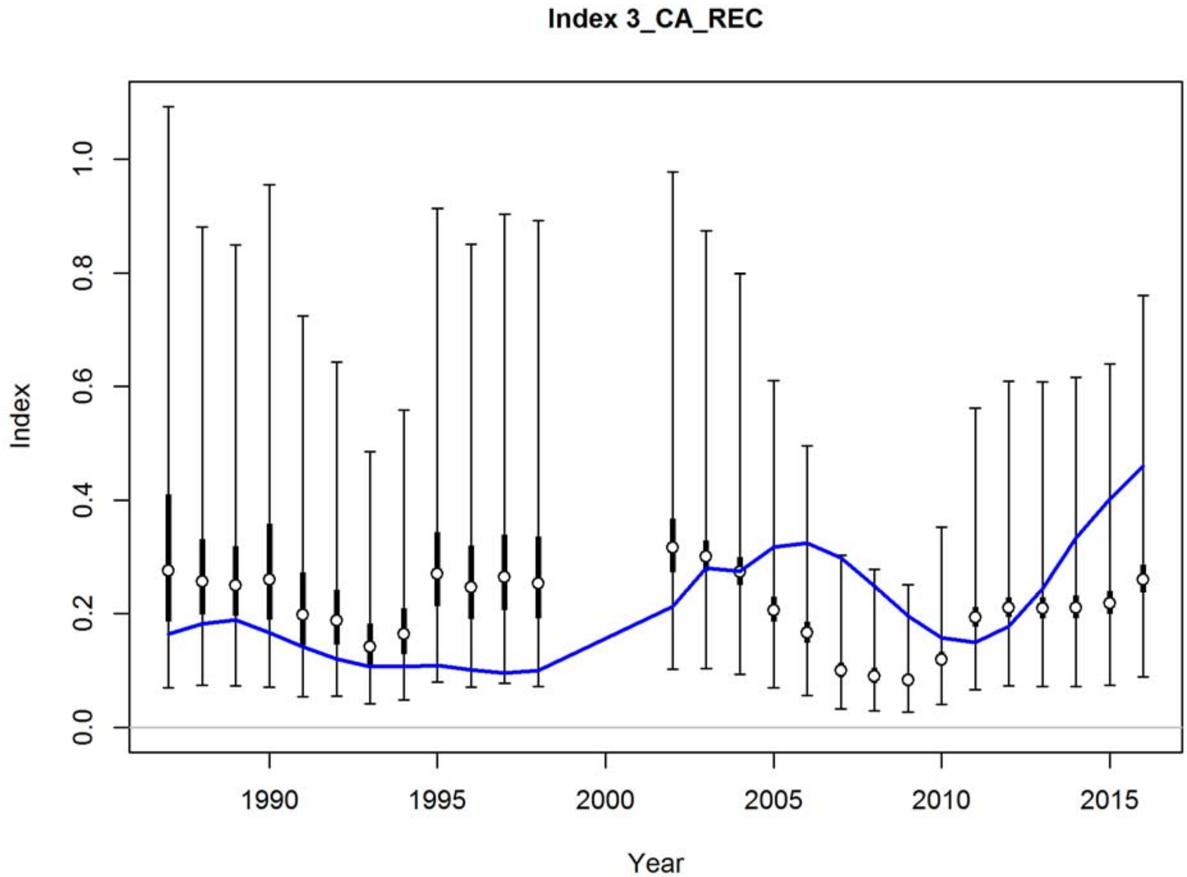


Figure 123. Recreation onboard observer CPUE fit, south, from a model sensitivity run with these data. Thick bars indicate the input standard deviations; light bars represent the estimated added standard deviations.

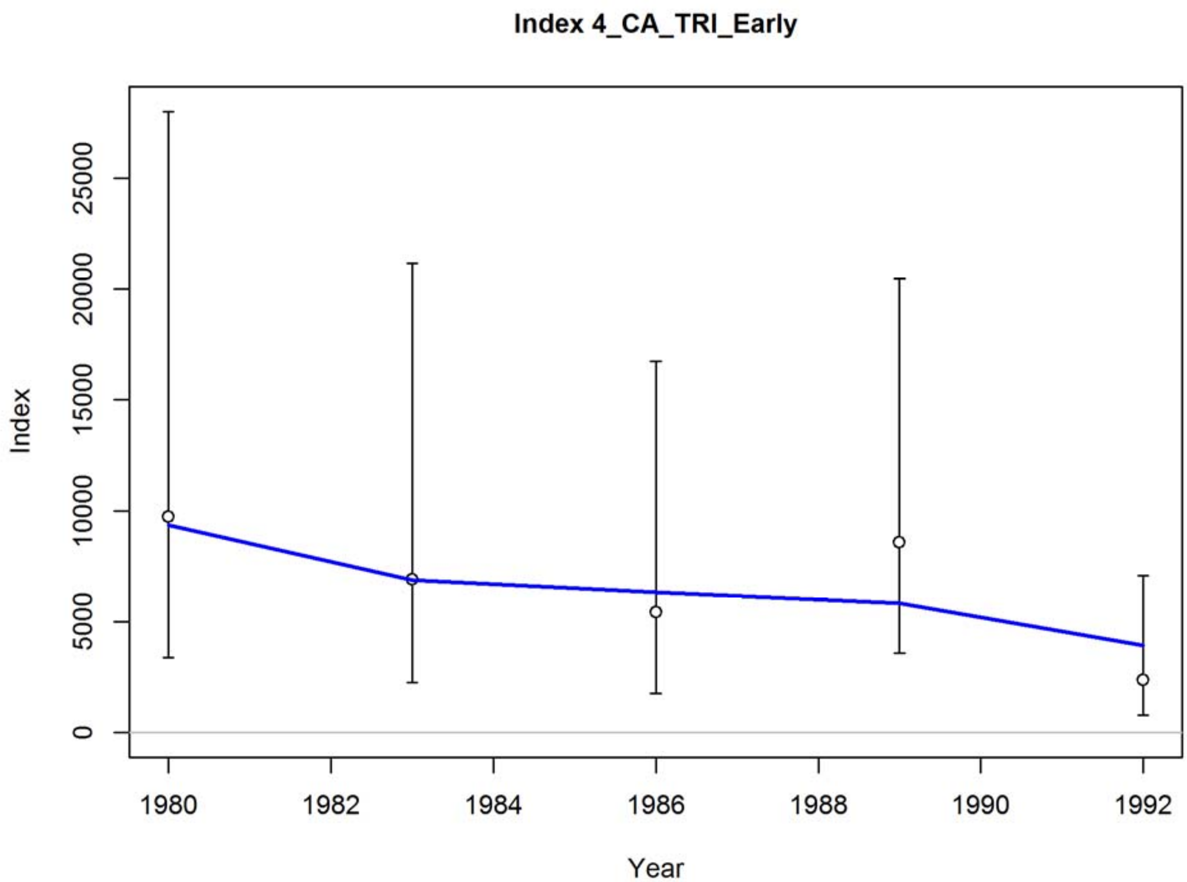


Figure 124. Triennial survey CPUE fit, south.

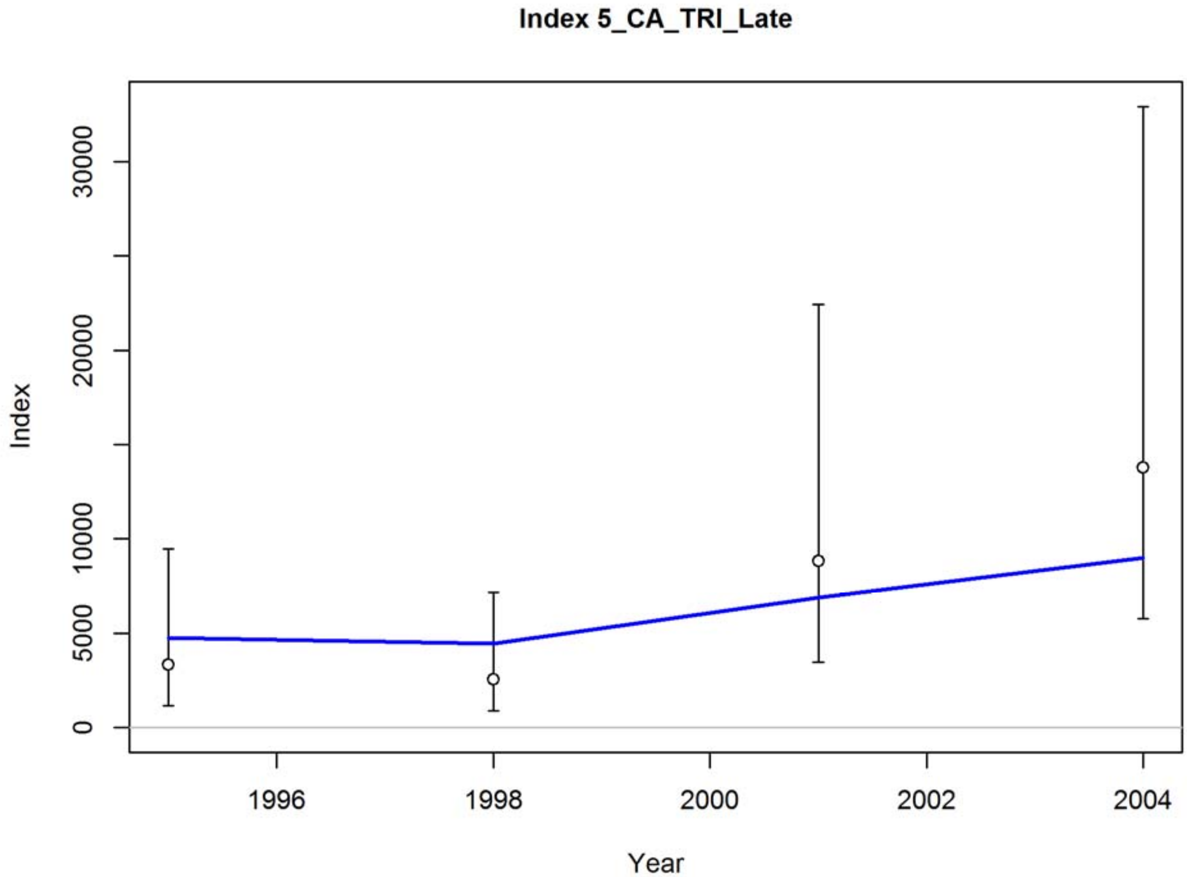


Figure 125. Triennial survey late CPUE fit, south.

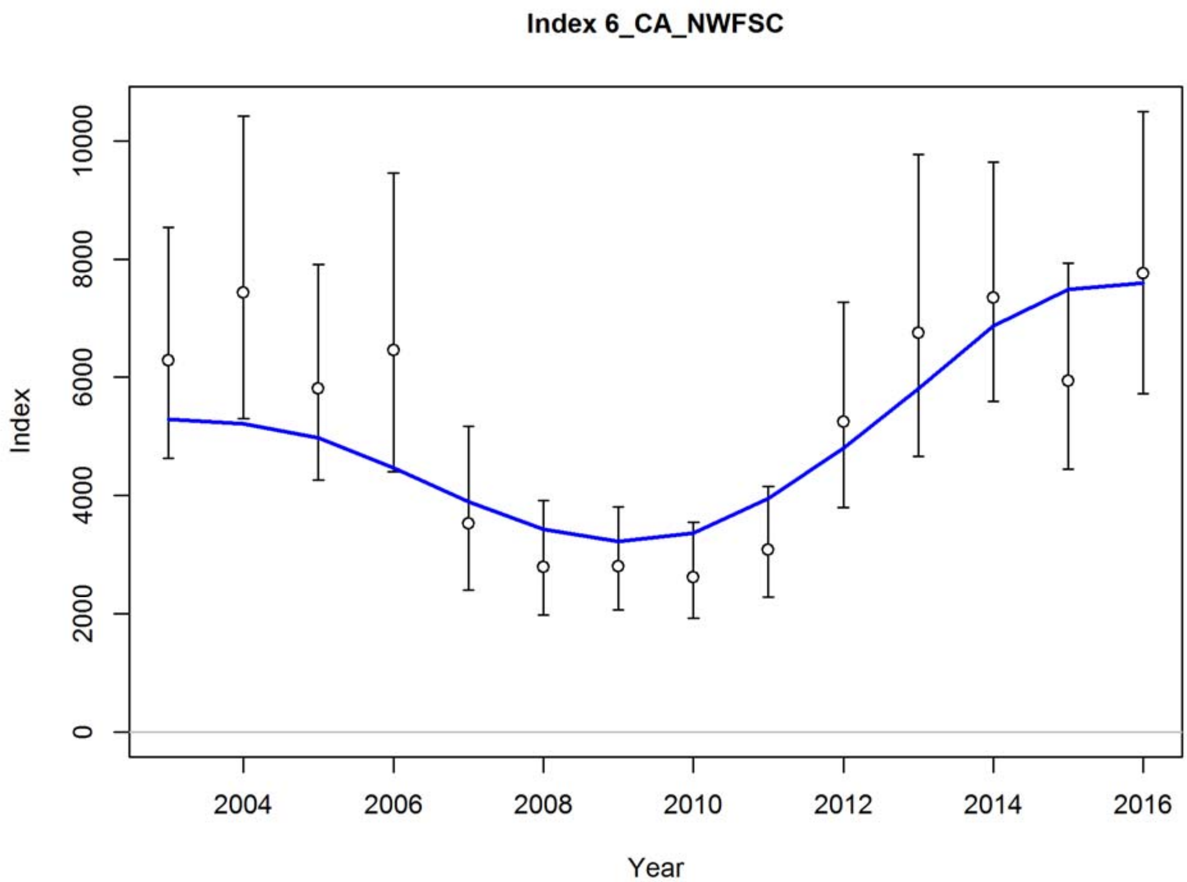


Figure 126. NWFSC survey index fit, south.

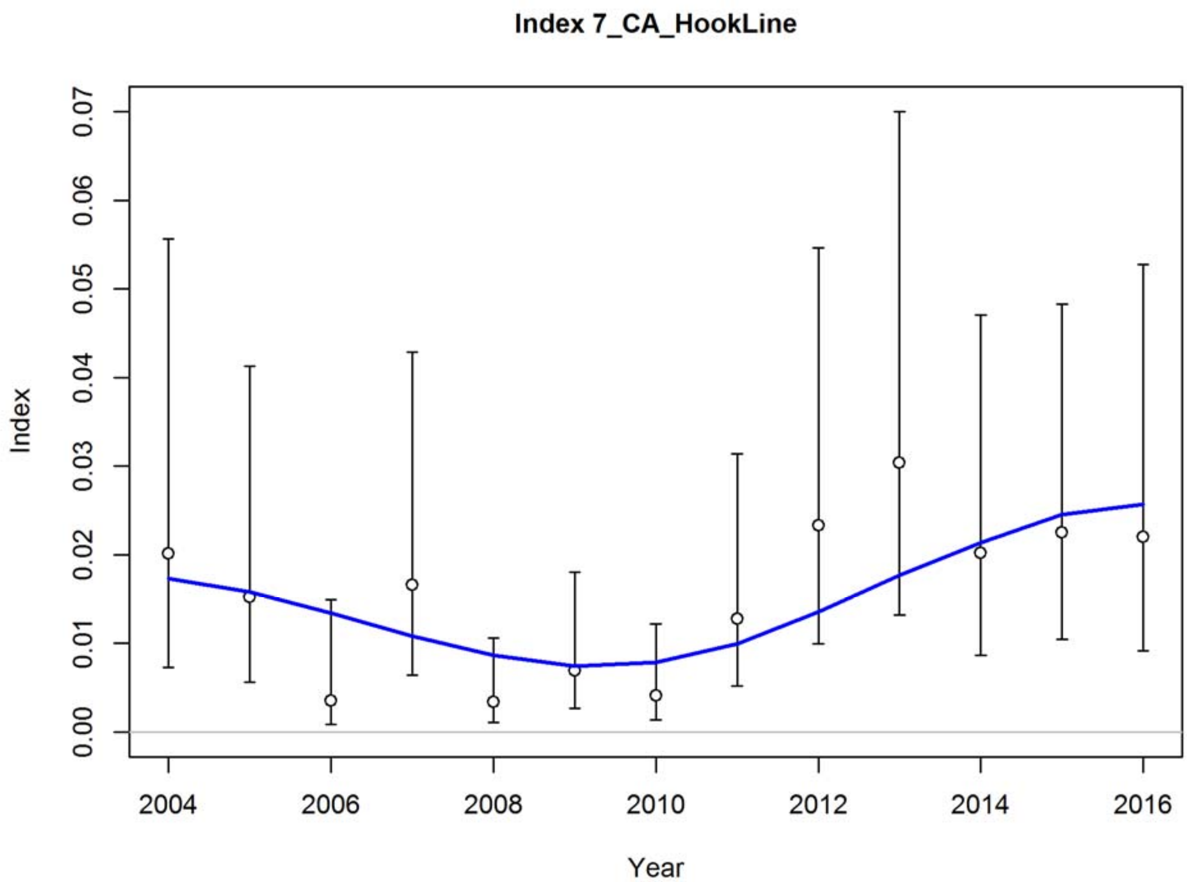


Figure 127. NWFSC Hook and Line survey fit.

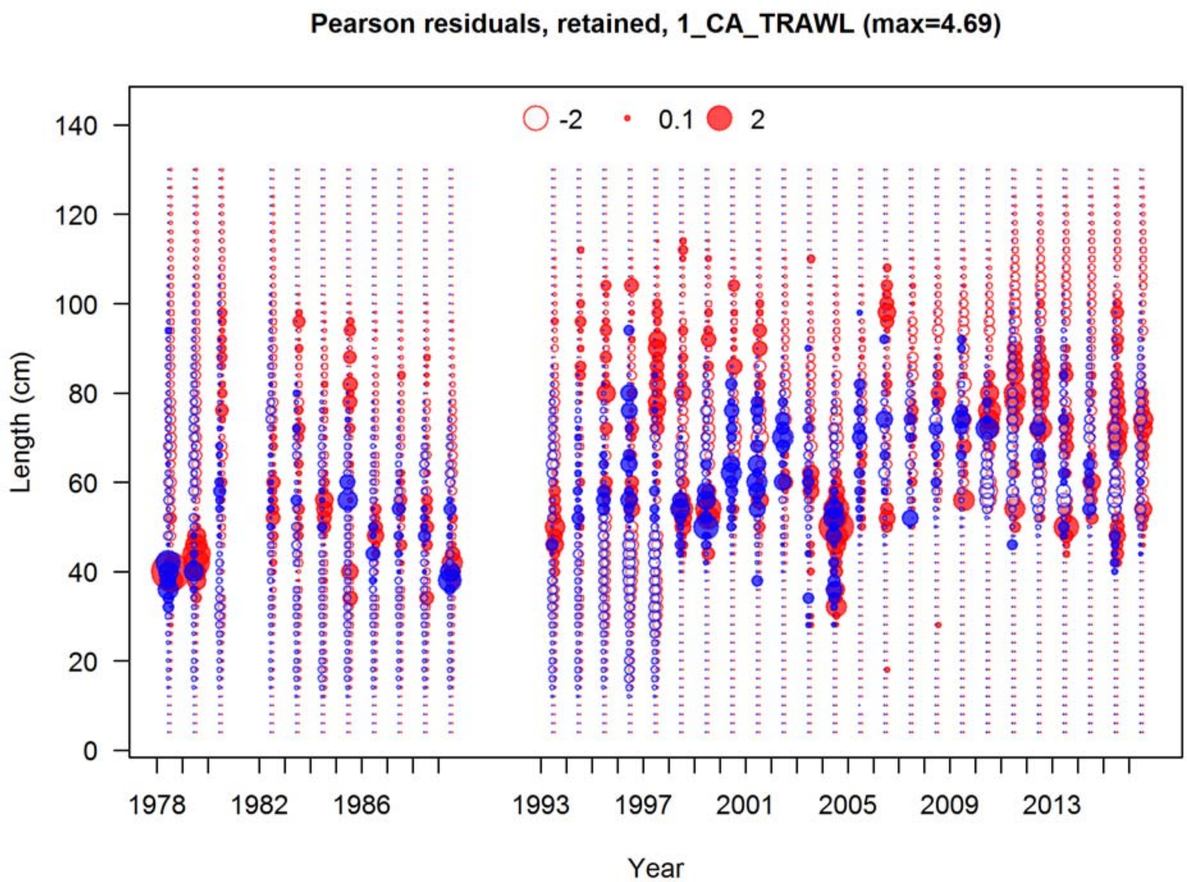


Figure 128. Commercial trawl sex specific length data Pearson residuals, south.

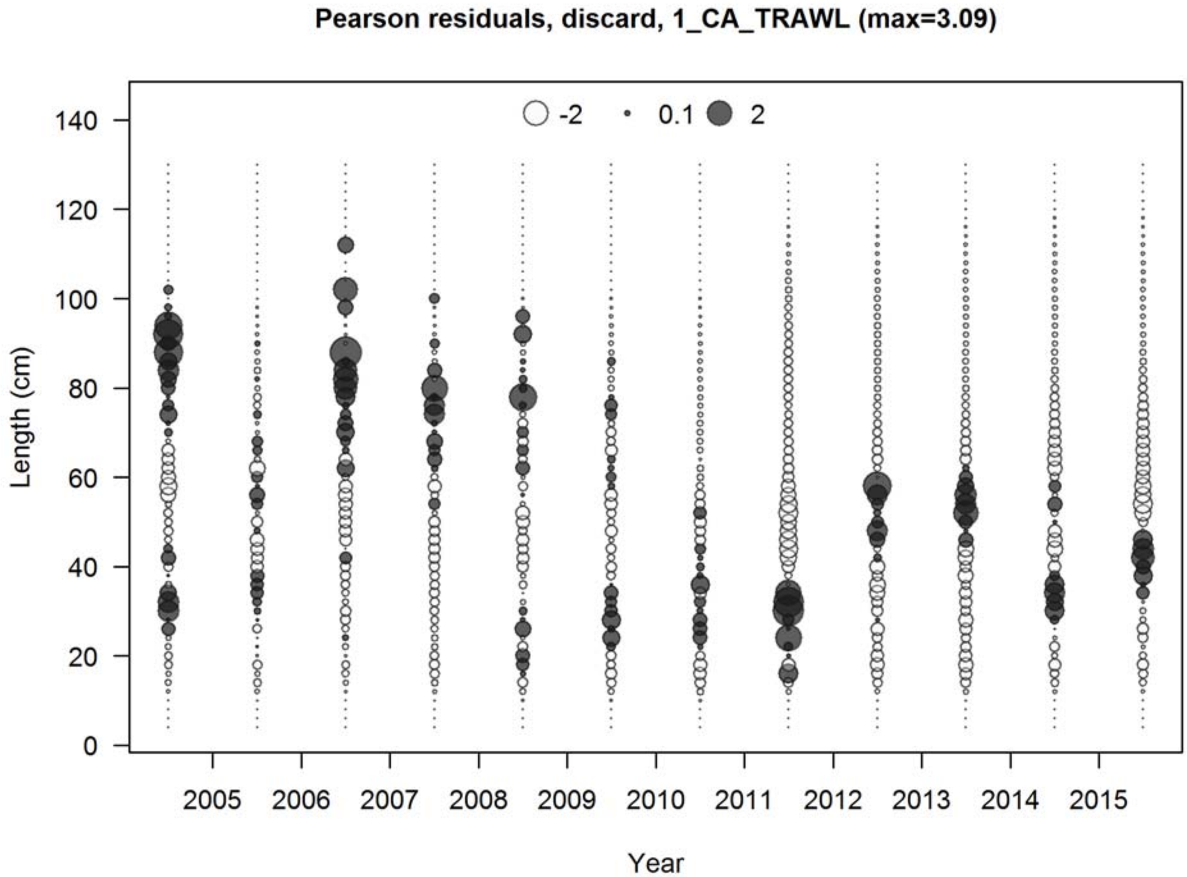


Figure 129. Commercial trawl sex combined discard length data Pearson residuals, south.

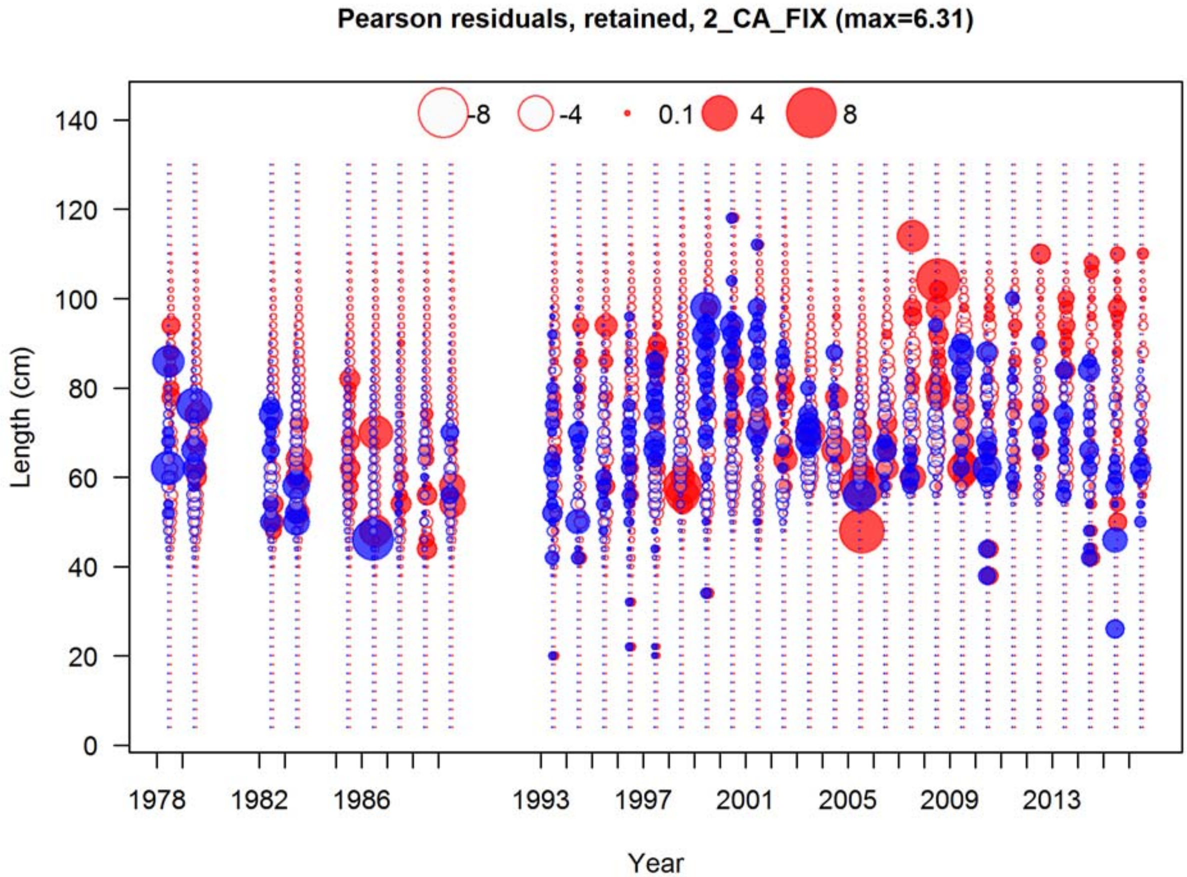


Figure 130. Commercial fixed gear sex specific length data Pearson residuals, south.

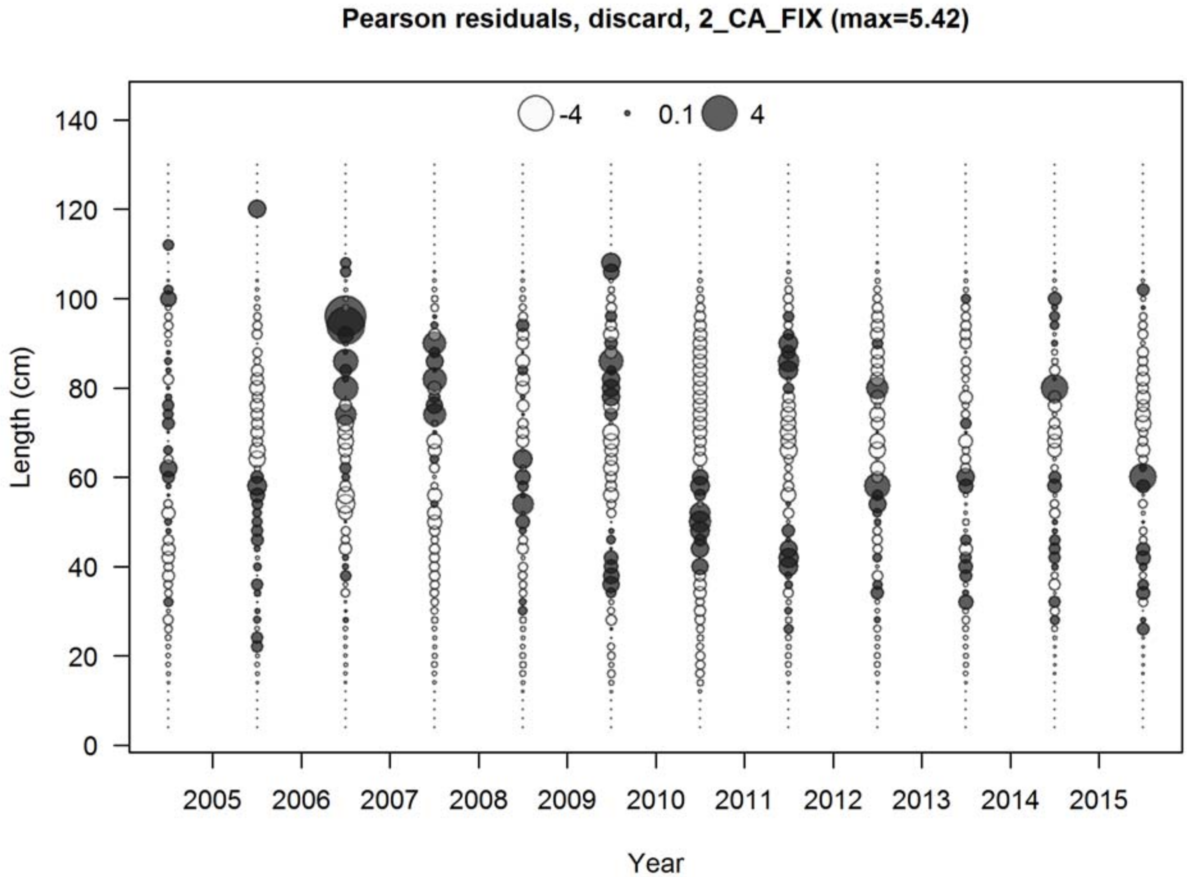


Figure 131. Commercial fixed gear sex combined discard length data Pearson residuals, south.

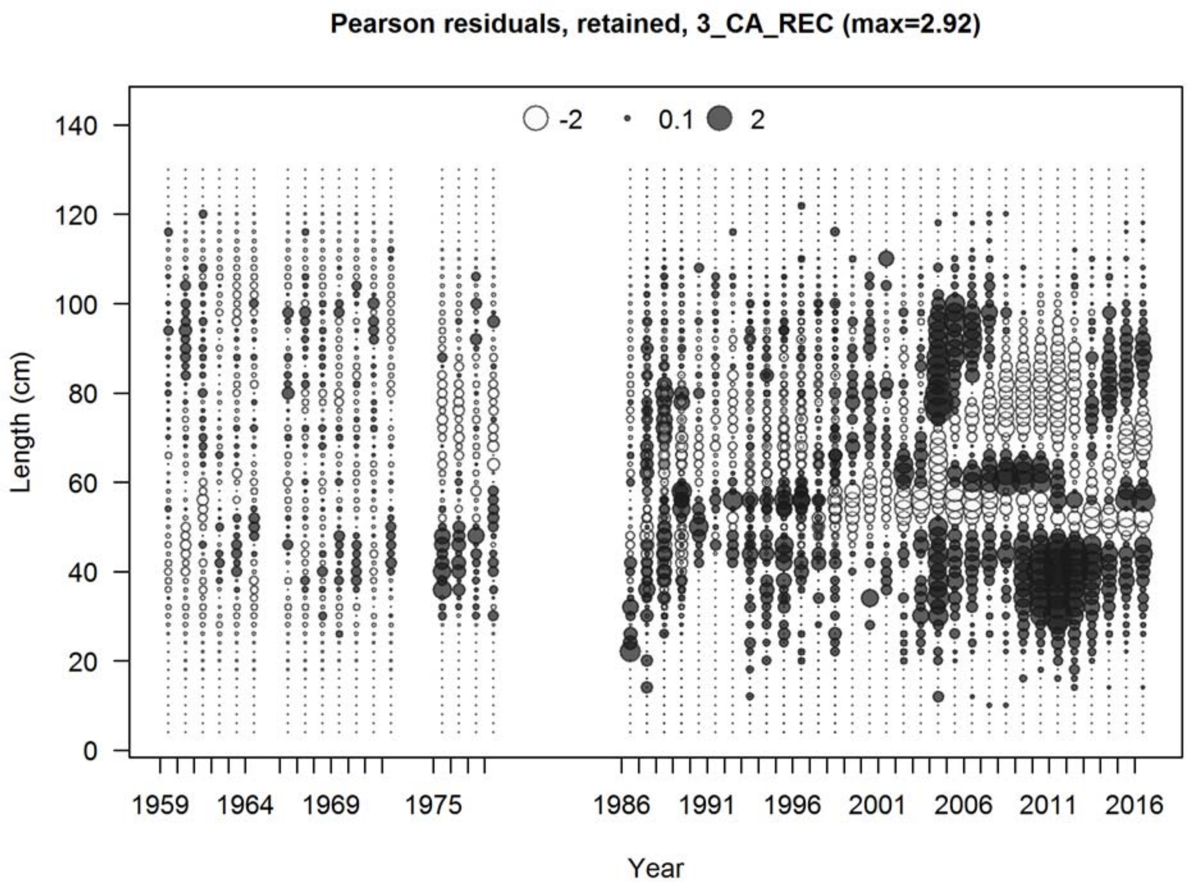


Figure 132. Recreational sex combined length data Pearson residuals, south.

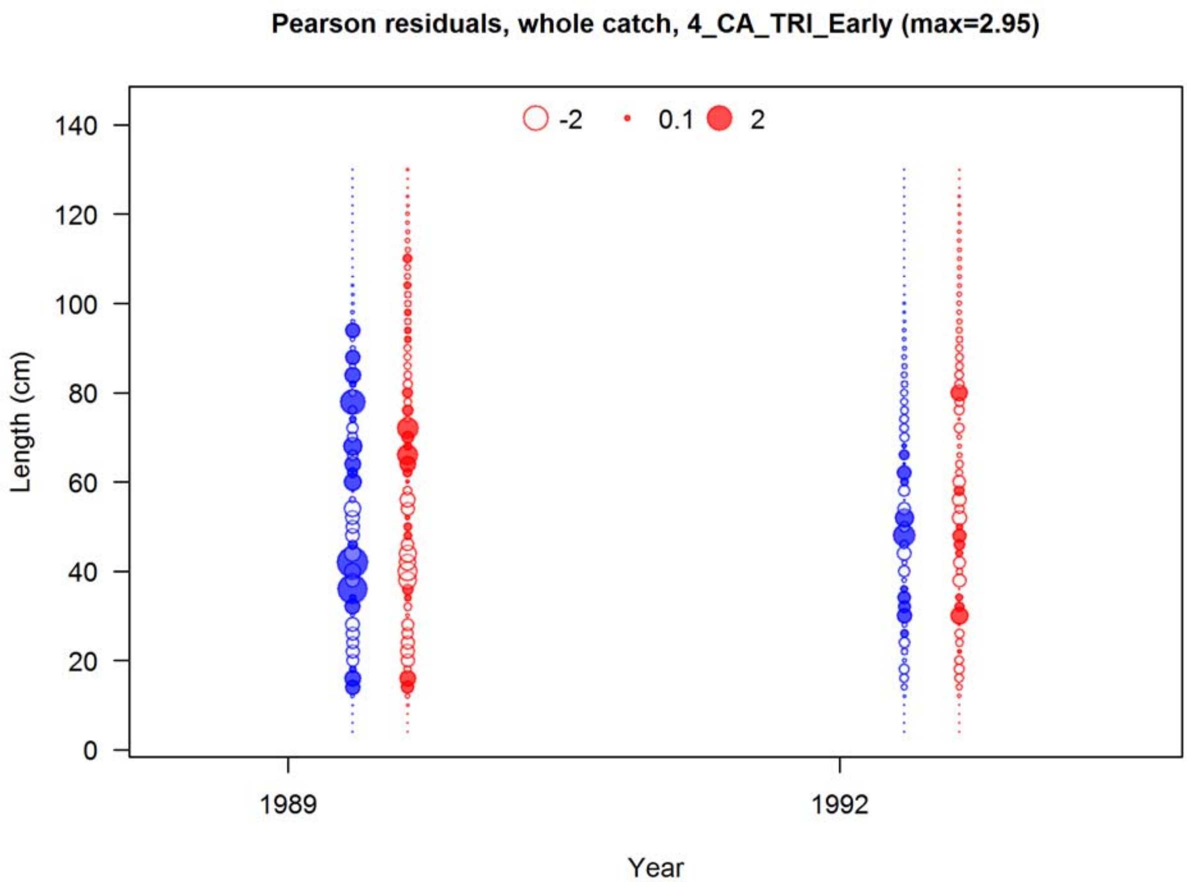


Figure 133. Triennial survey early sex specific length data Pearson residuals, south.

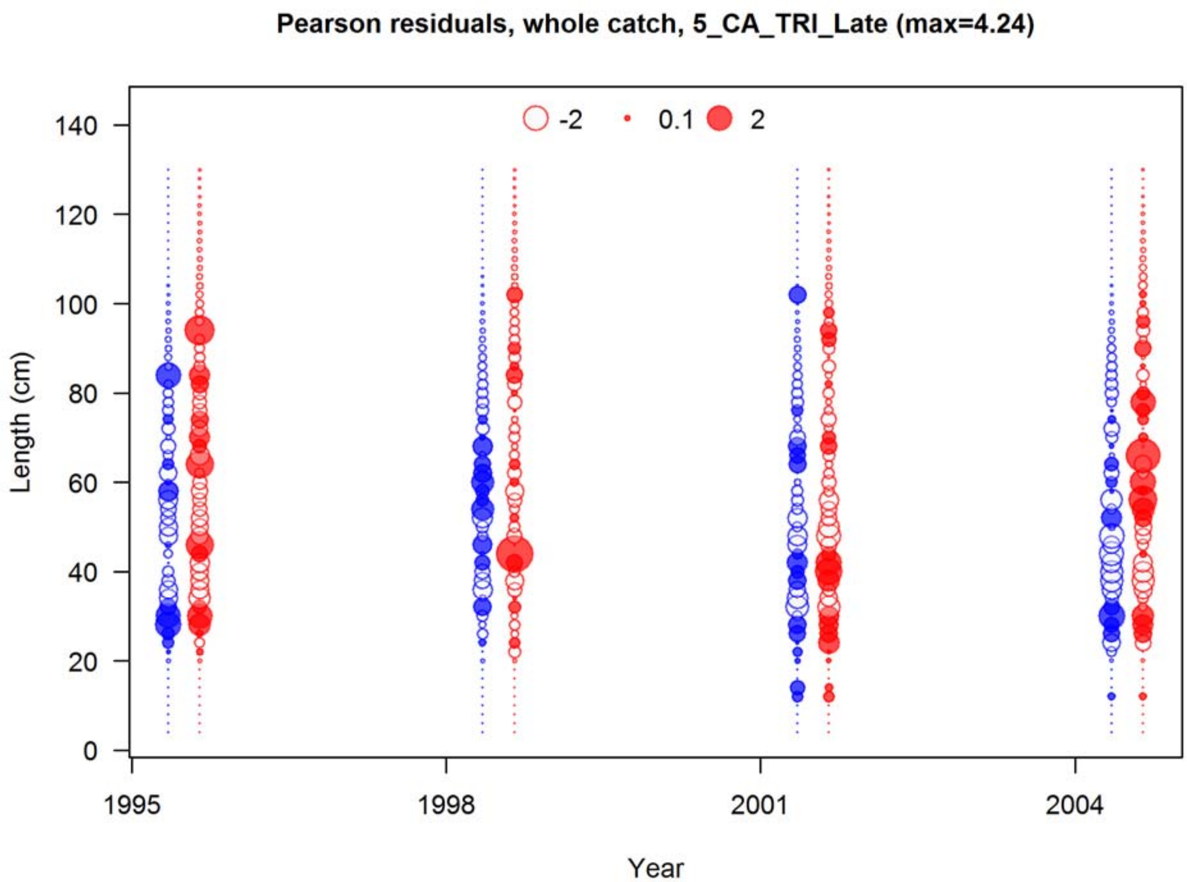


Figure 134. Triennial survey sex specific length data Pearson residuals, south.

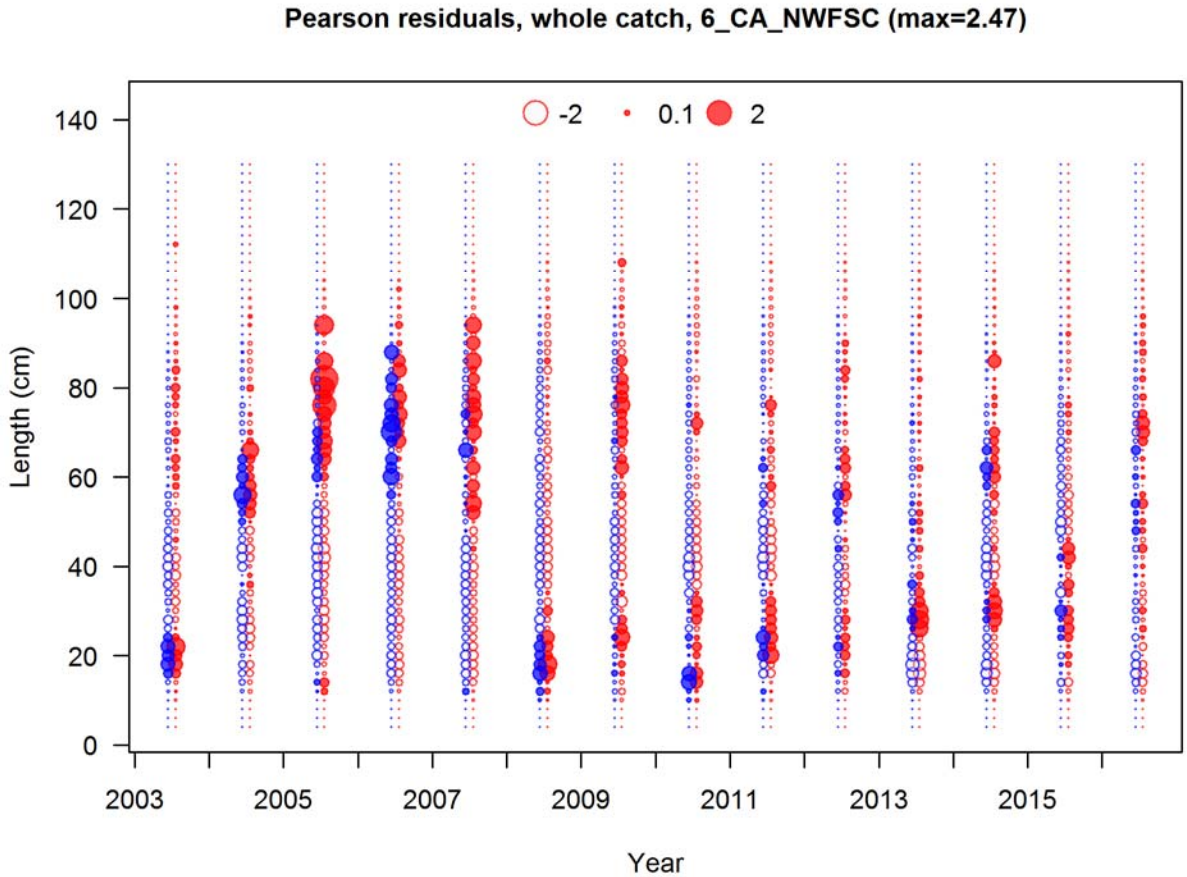


Figure 135. NWFSC survey sex specific length data Pearson residuals, south.

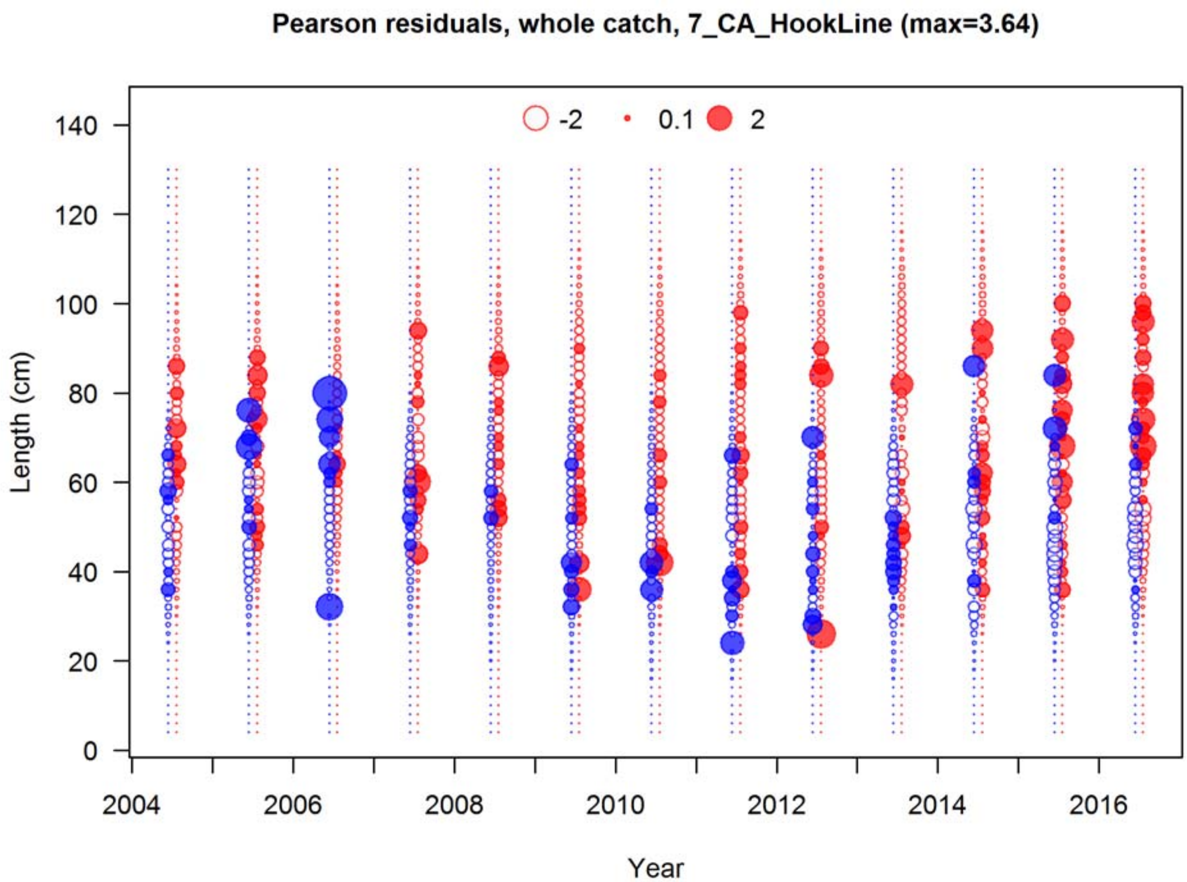


Figure 136. NWFSC hook and line survey sex specific length data Pearson residuals, south.

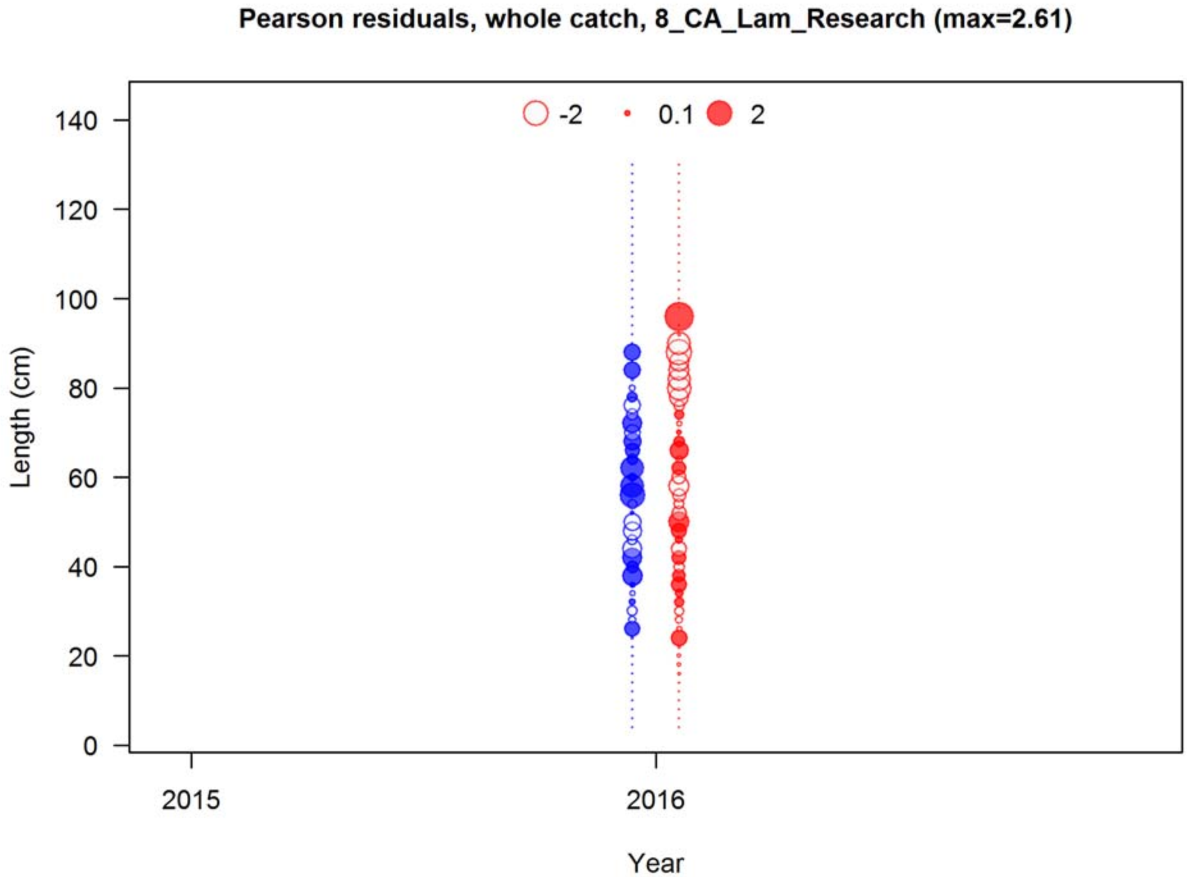


Figure 137. Lam sex specific research length data Pearson residuals, south.

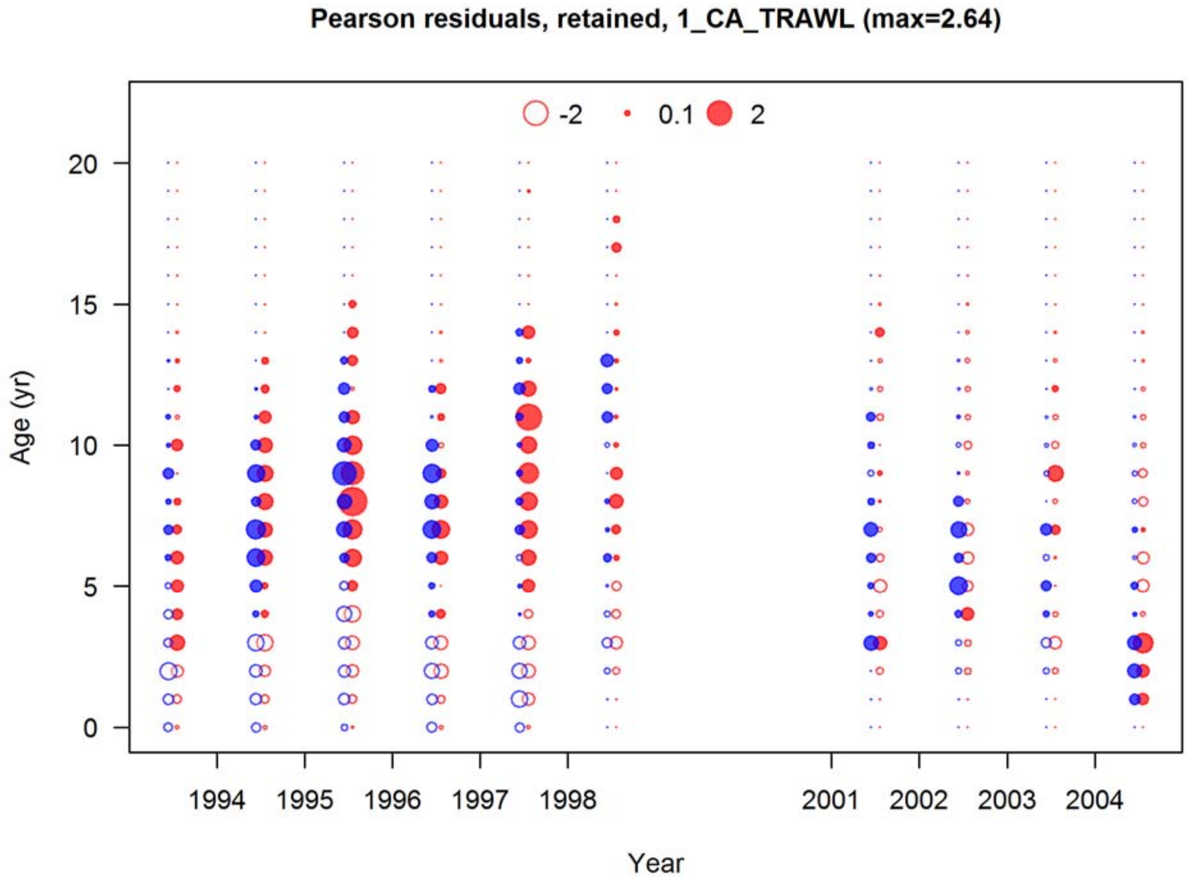


Figure 138. Commercial trawl sex specific age data Pearson residual, south, from a model sensitivity run with these data.

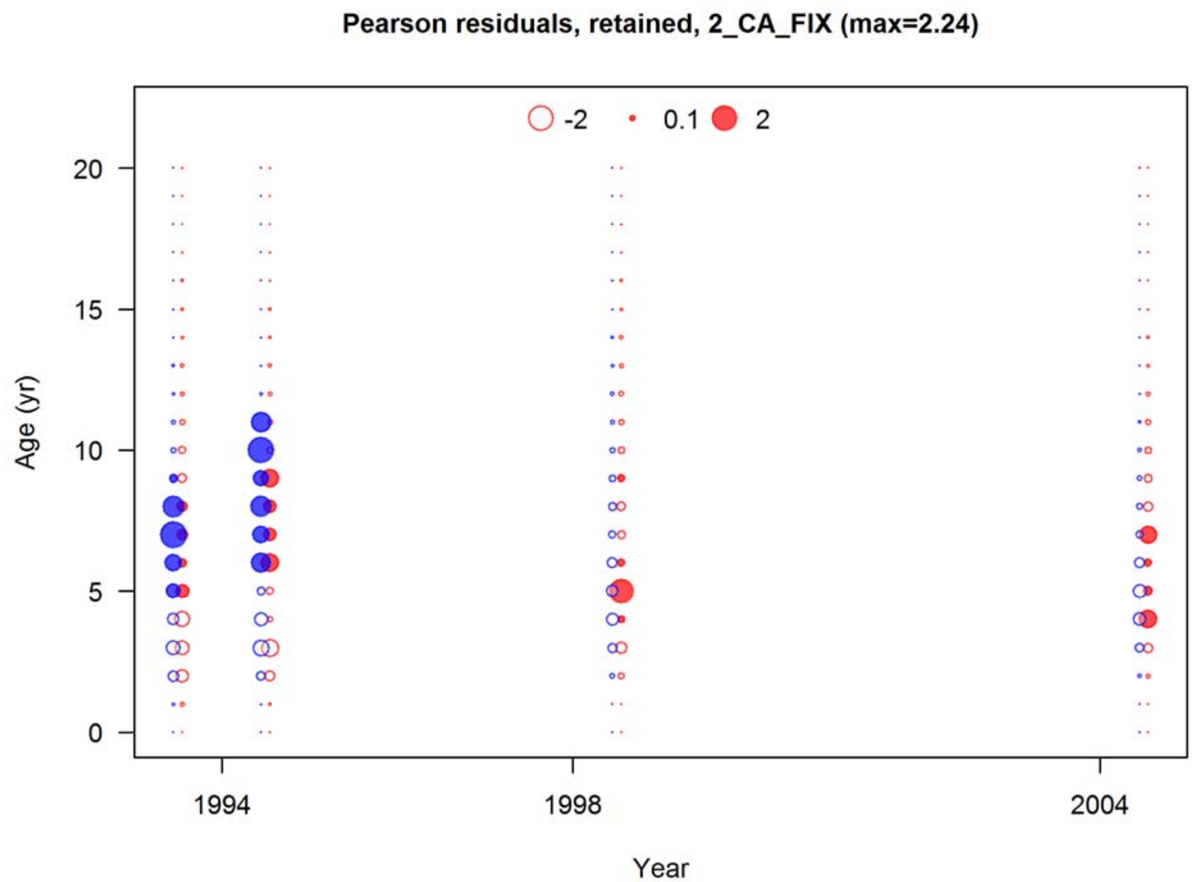


Figure 139. Commercial fixed gear sex specific age data Pearson residuals, south, from a model sensitivity run with these data.

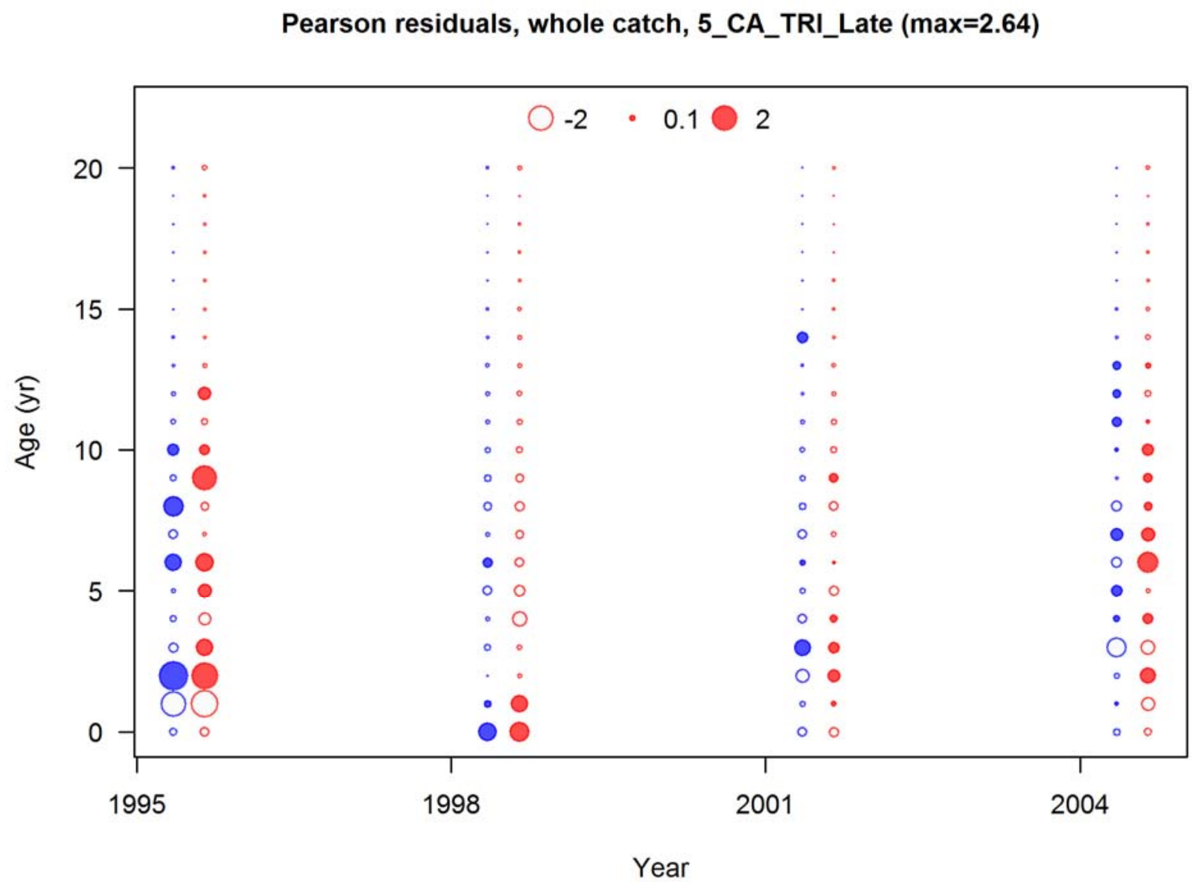


Figure 140. Triennial survey late sex specific age data Pearson residuals, south.

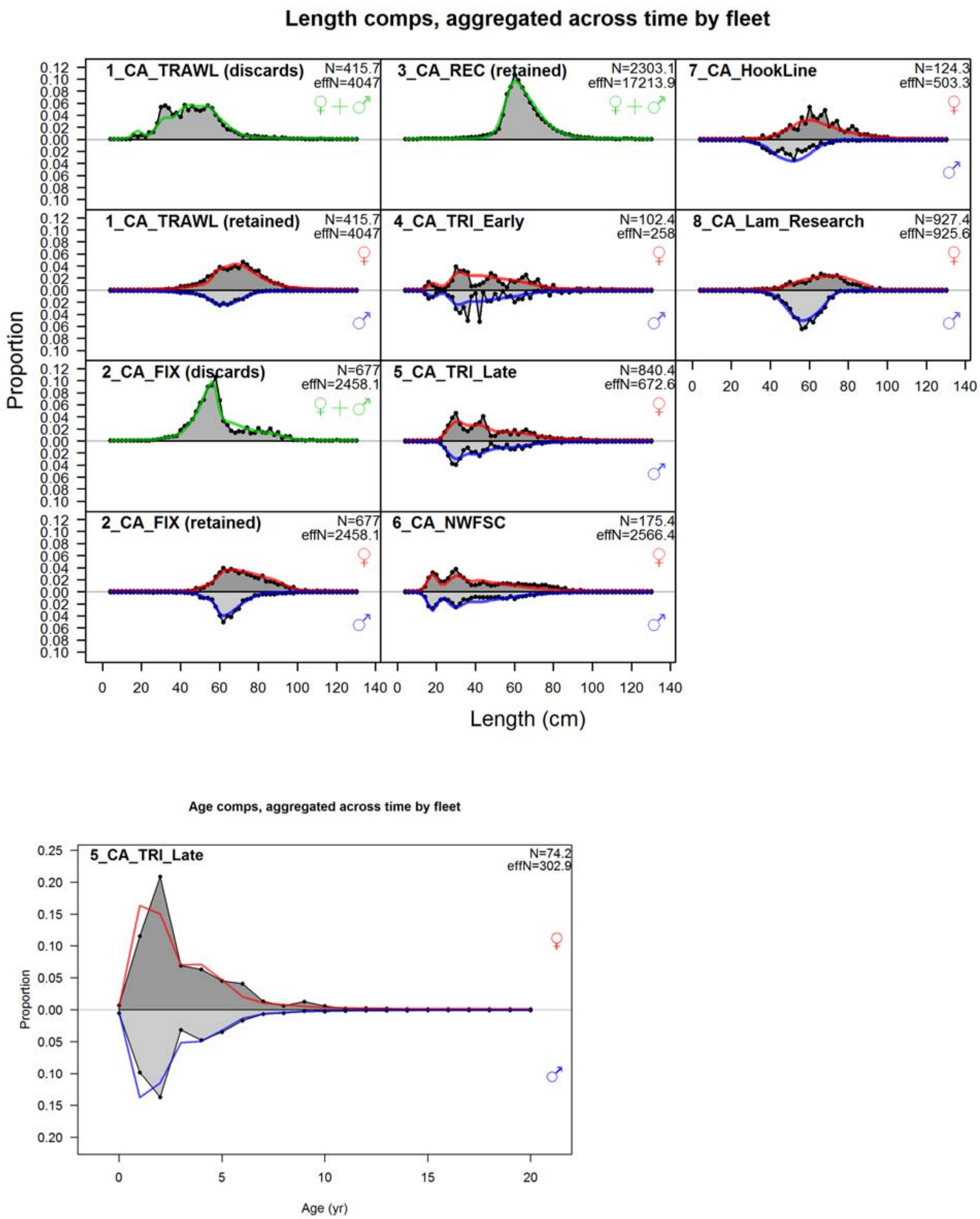


Figure 141. Length (top panel) and age (bottom panel) composition data fits aggregated across time for each fleet, south.

comp_condAALfit_Andre_plotsflt6mkt0_page4.png

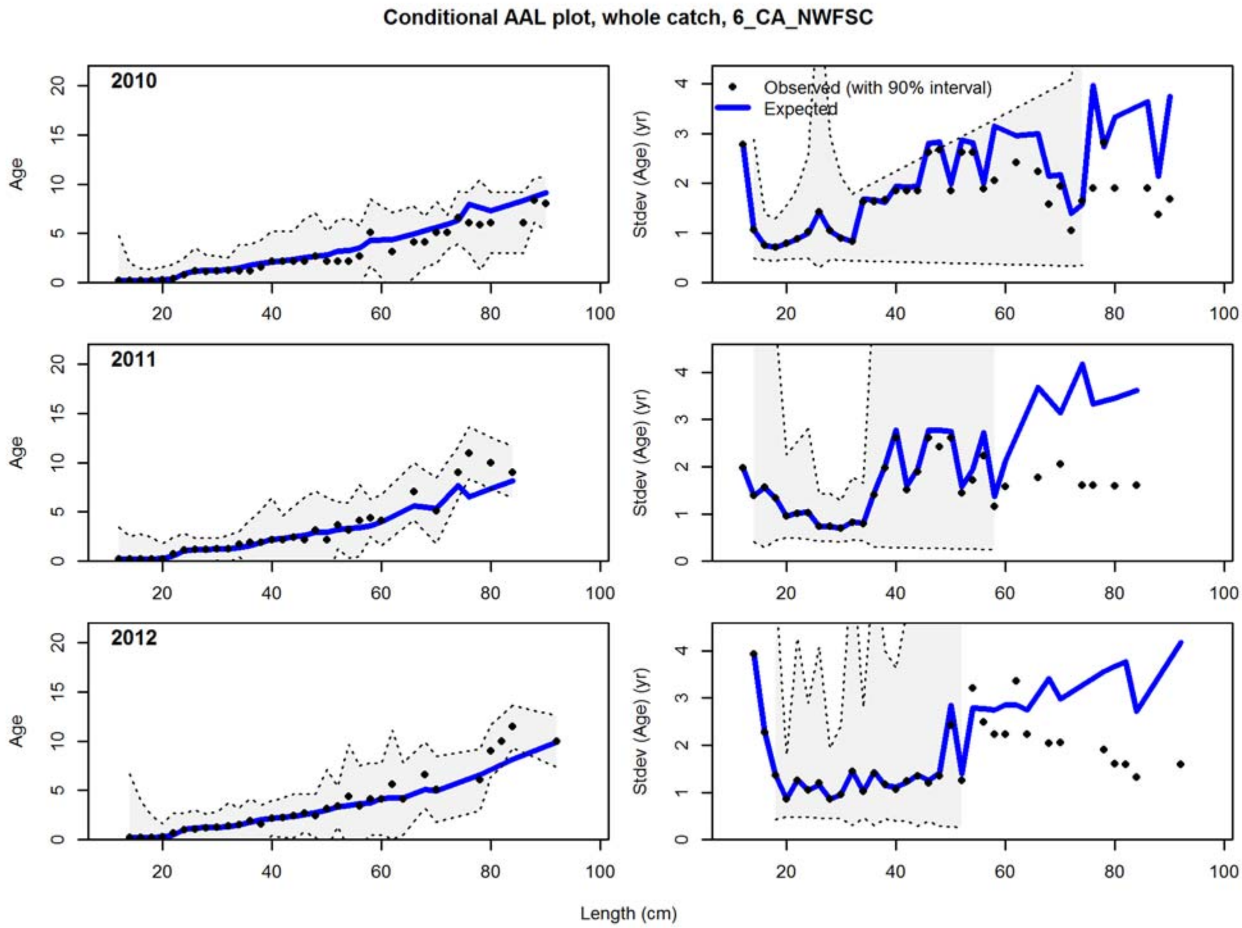


Figure 142. NWFSC conditional age-at-length (AAL) fits, south.

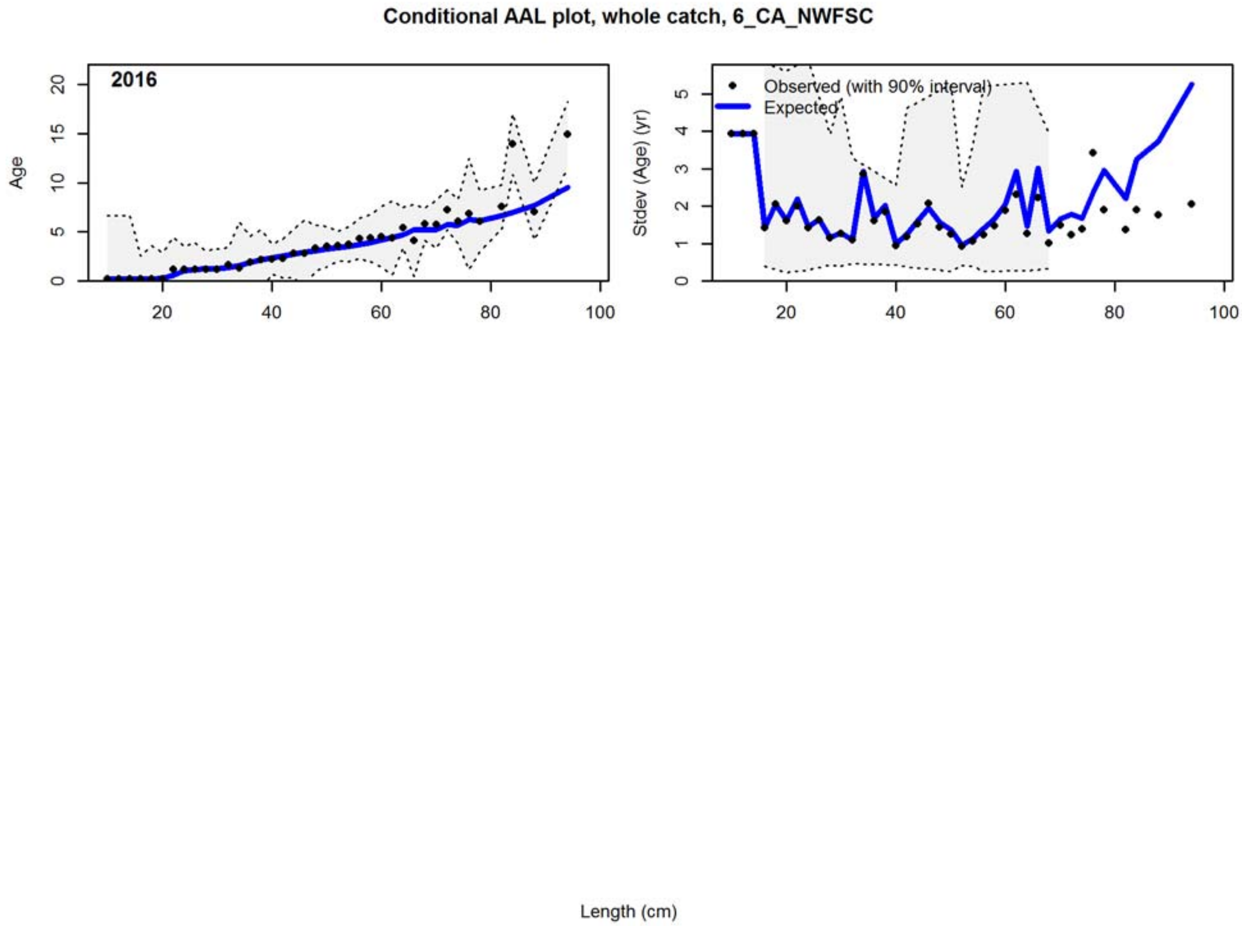


Figure 143. Lam research conditional age-at-length (AAL) fits, south.

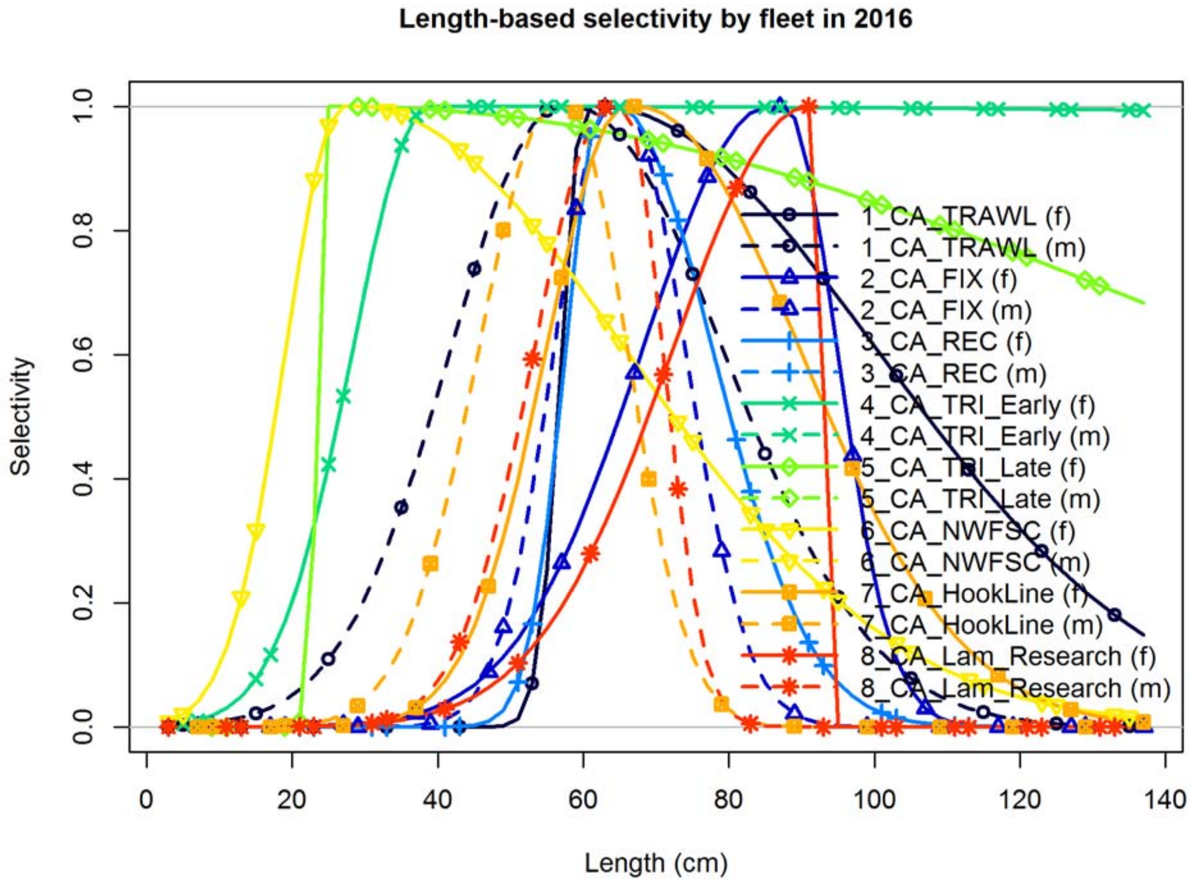


Figure 144. Estimated end year selectivity curves for each fleet, south. Go to the Auxiliary files r4ss plots folder for the south model run, open the SS Output html file, and go to the "sel" tab to see individual selectivity plots for each fleet as well as plots of retention curves for the commercial fleets.

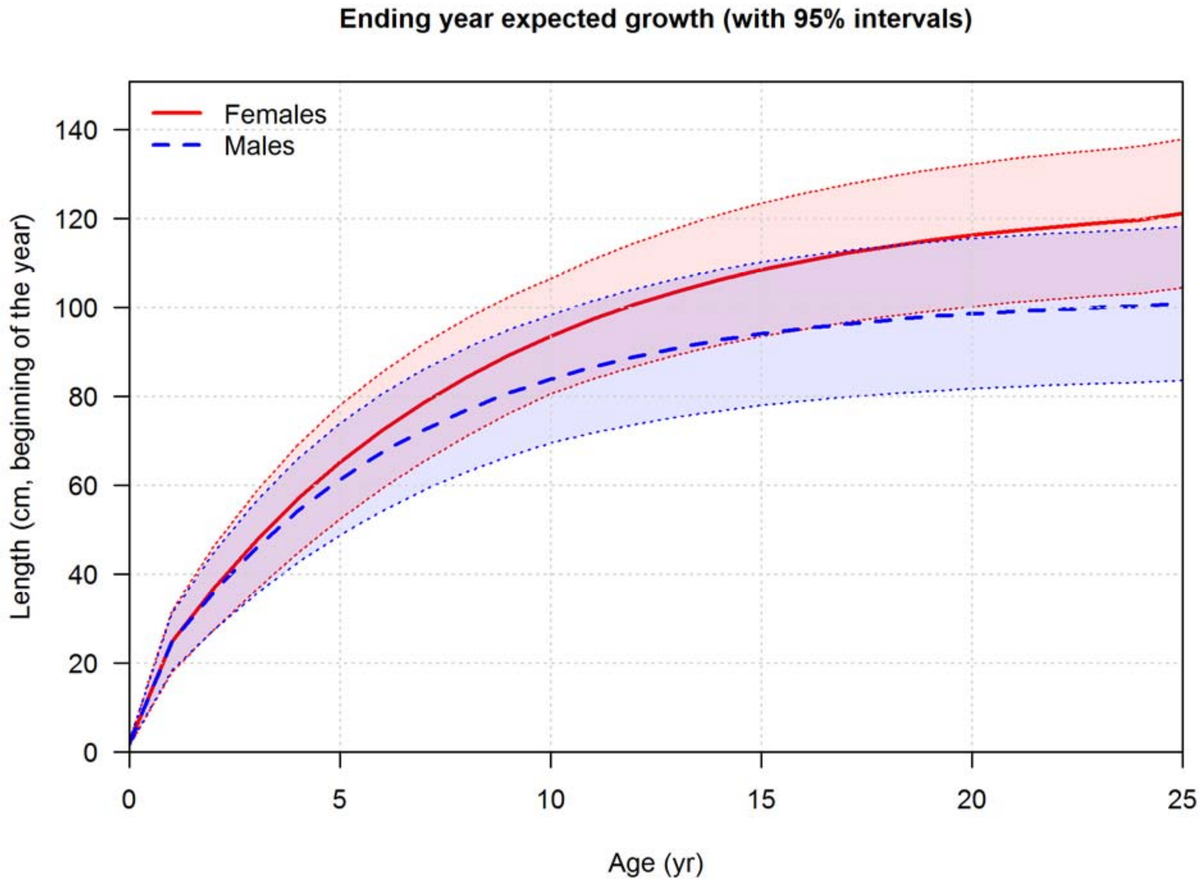


Figure 145. Estimated growth curves, south.

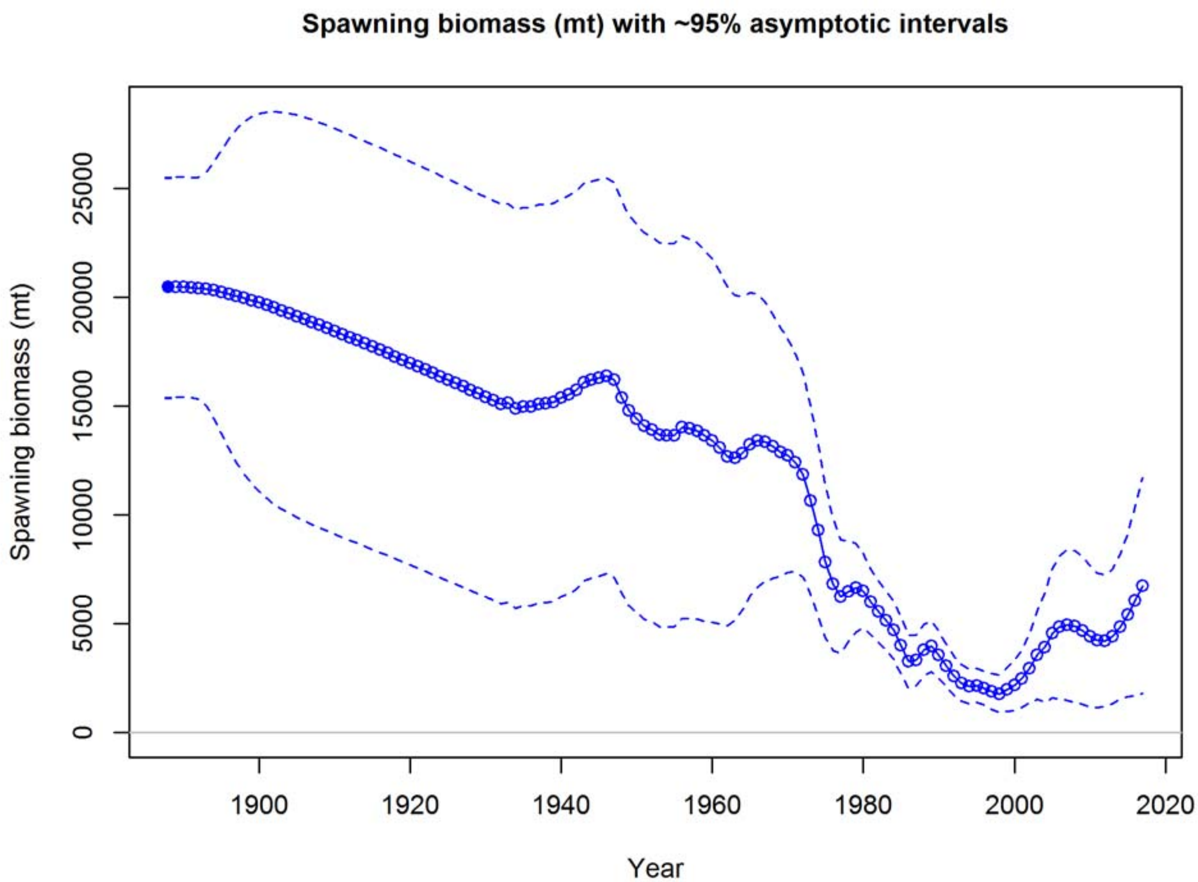


Figure 146. Time series of estimate spawning biomass, south.

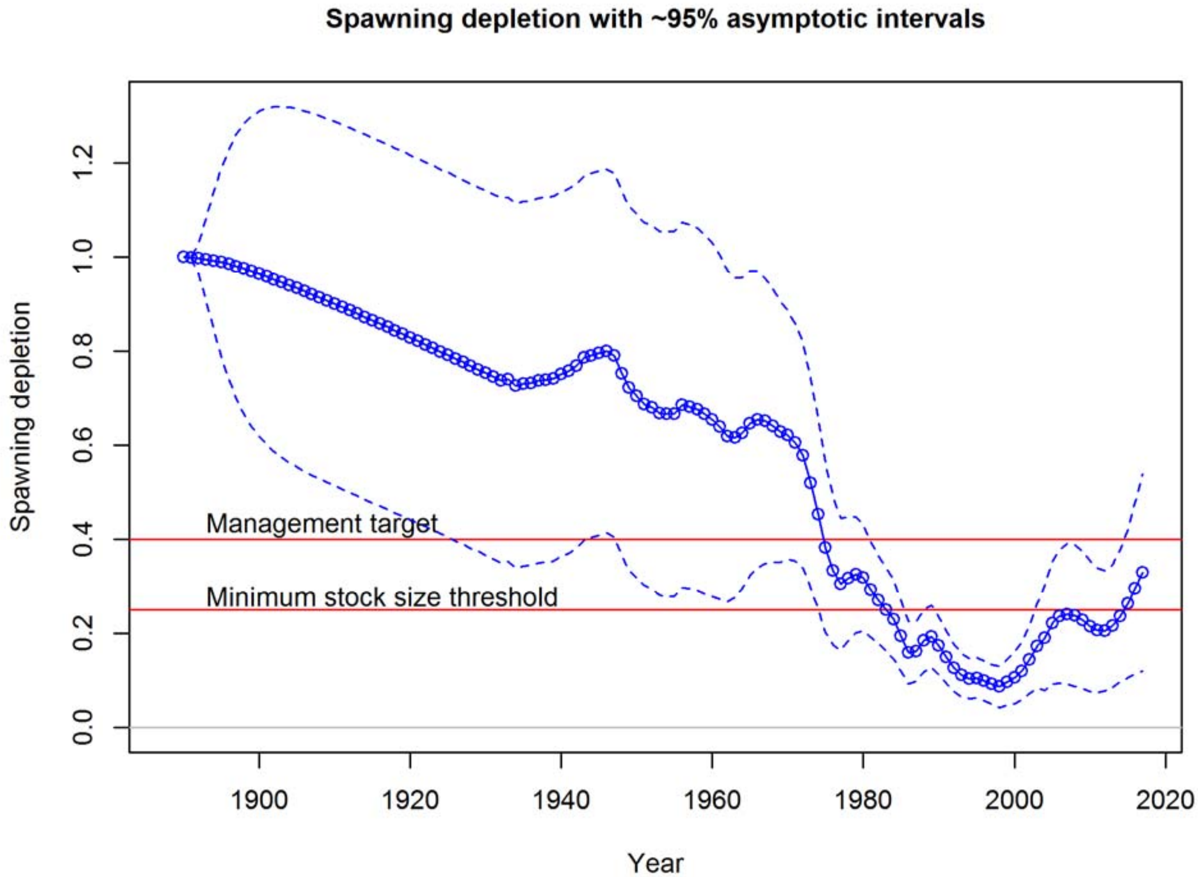


Figure 147. Time series of estimated stock depletion, south.

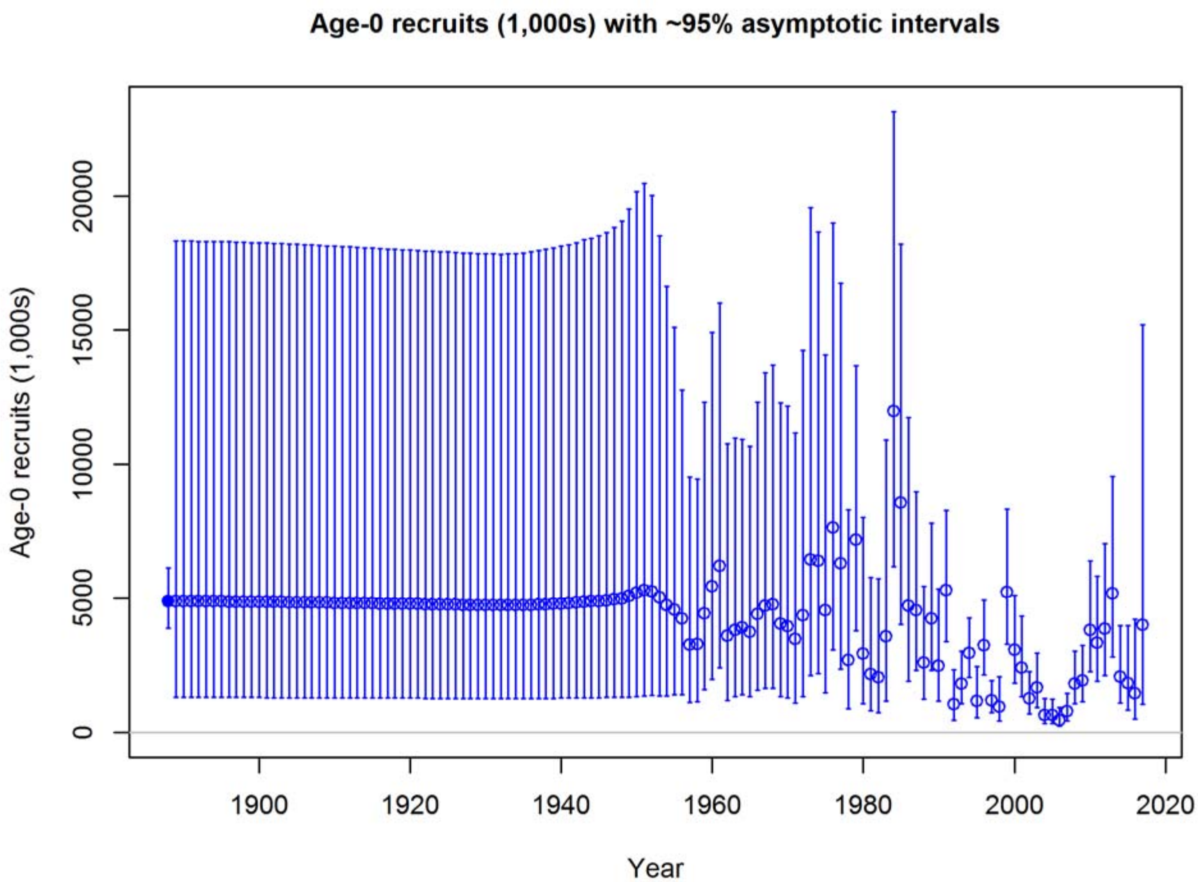


Figure 148. Time series of estimated age-0 recruits, south.

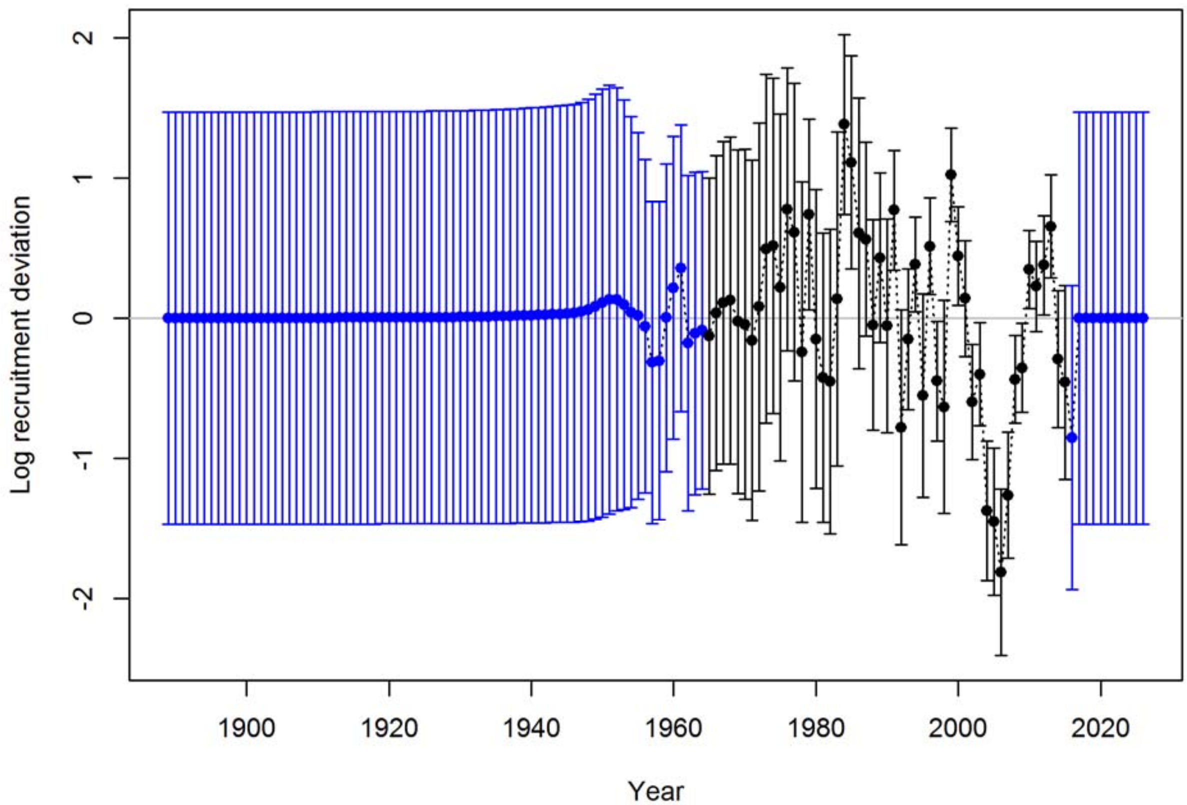


Figure 149. Time series of estimated recruitment deviations, south.

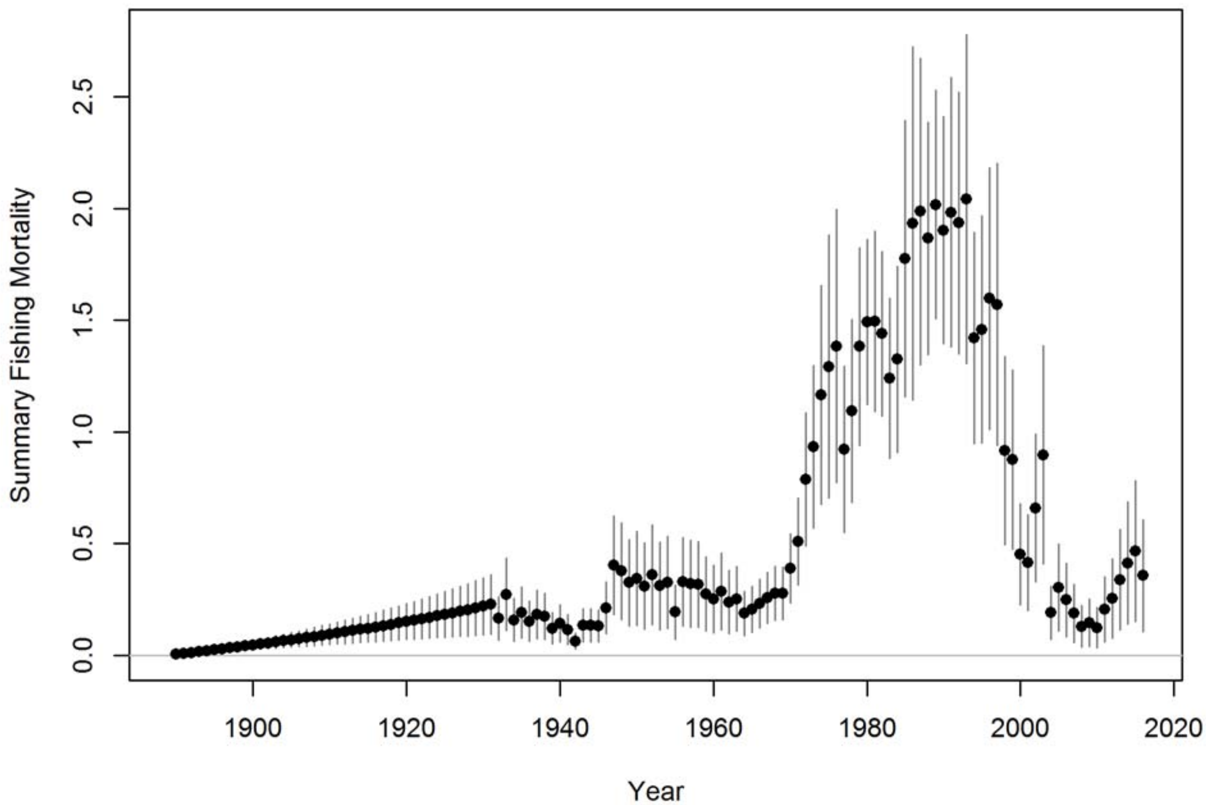


Figure 150. Time series estimated summary fishing mortality (F), south.

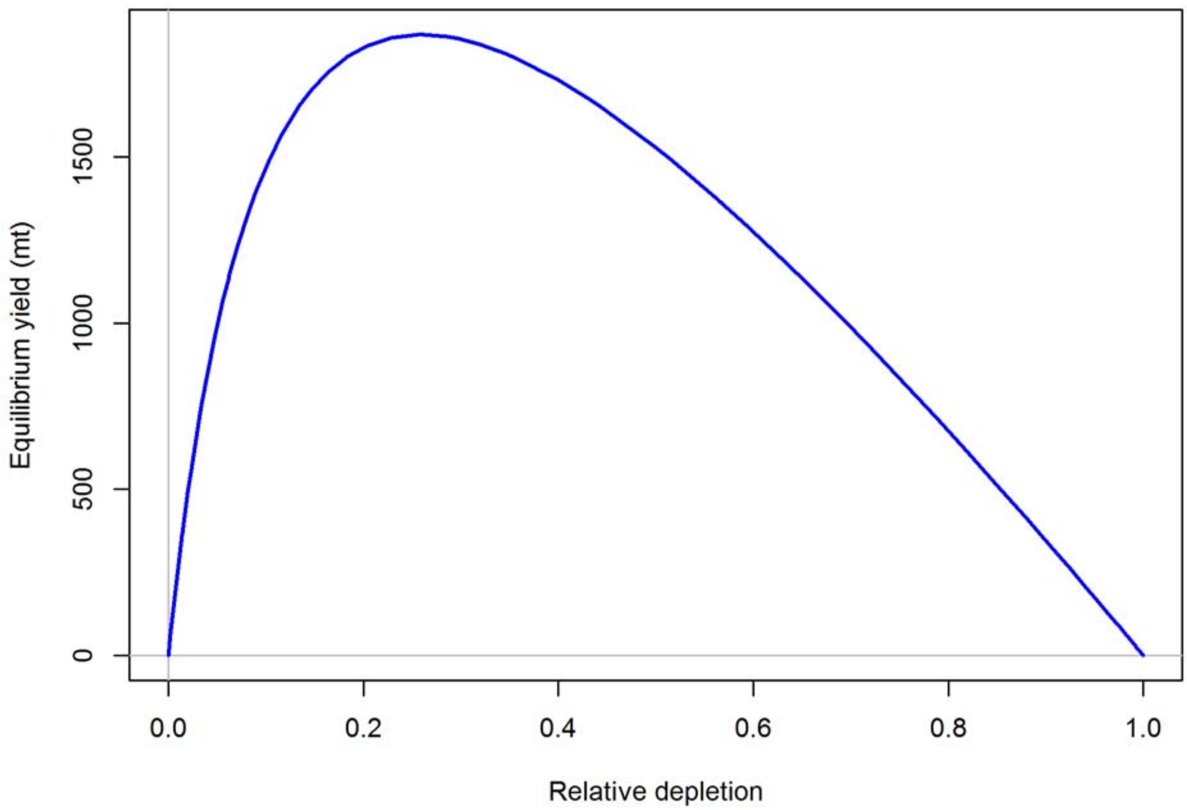


Figure 151. Equilibrium yield curve, south.

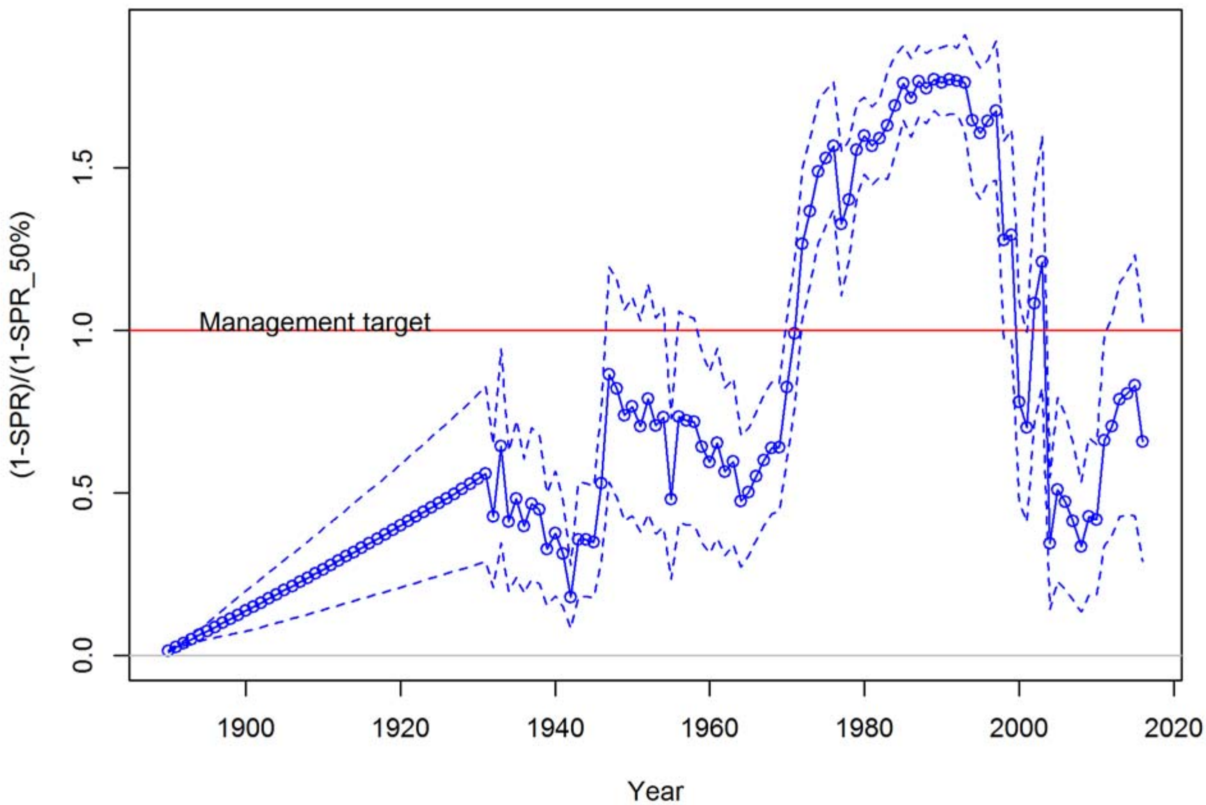


Figure 152. Time series of SPR ratio, south.

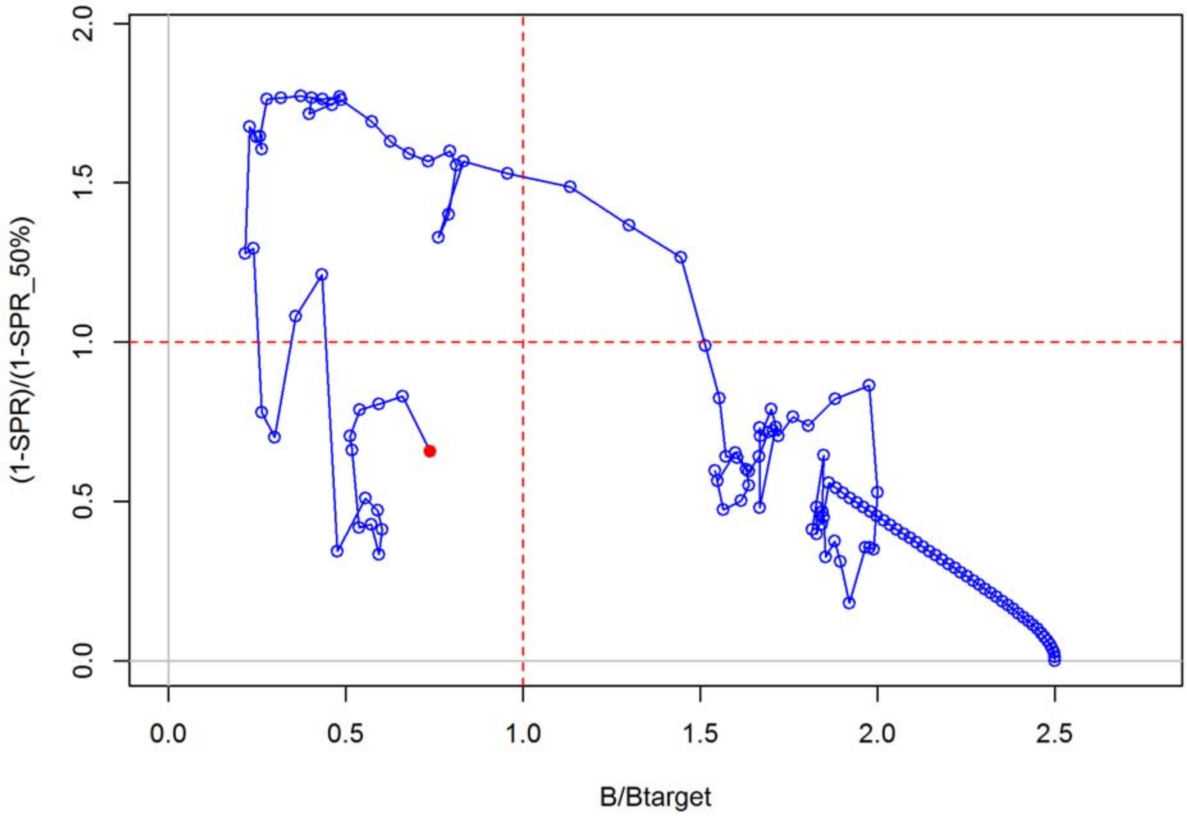


Figure 153. Phase plot of biomass ratio v SPR ratio, south.

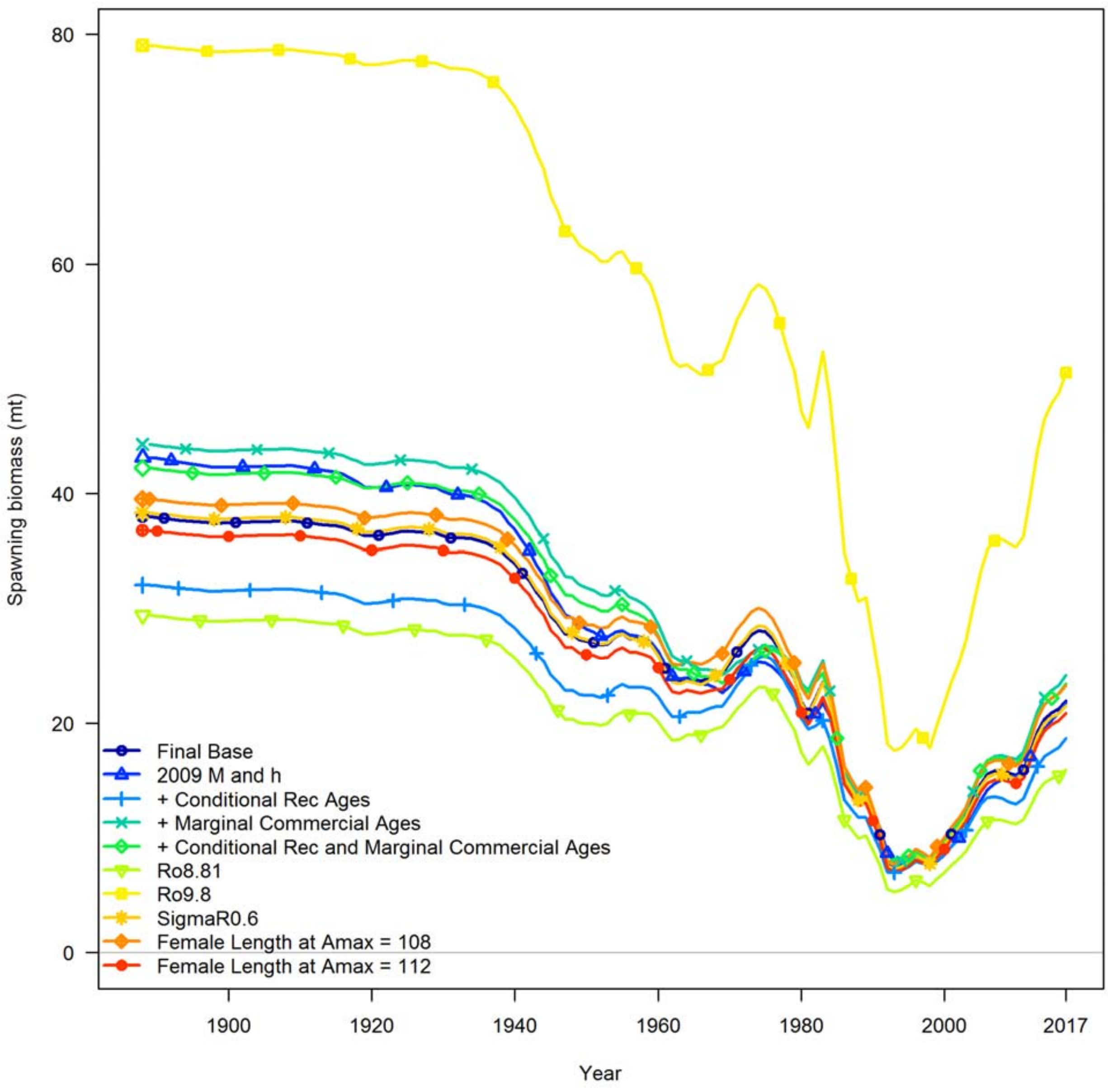


Figure 154. Sensitivity in spawning biomass to north model sensitivity runs. The run 2009 M and h sets these values to those used in the 2009 stock assessment. The run + Conditional Rec Ages includes both WA and OR recreational age data as CAAL compositions. The run + Marginal Commercial Ages includes all commercial age data as prepared for the STAR panel version of this assessment. The run + Conditional Rec and Marginal Commercial Ages adds all fishery age data into the model. The runs Ro8.81 and Ro9.8 fix the parameter for unfished recruitment at each value; these runs bracket the base model. The run SigmaR0.6 fixed the input parameter for recruitment variability to 0.6. The runs Female Length at Amax = 108 and Female Length at Amax = 112 fix the values for this parameter at 108 cm and 112 cm, respectively.

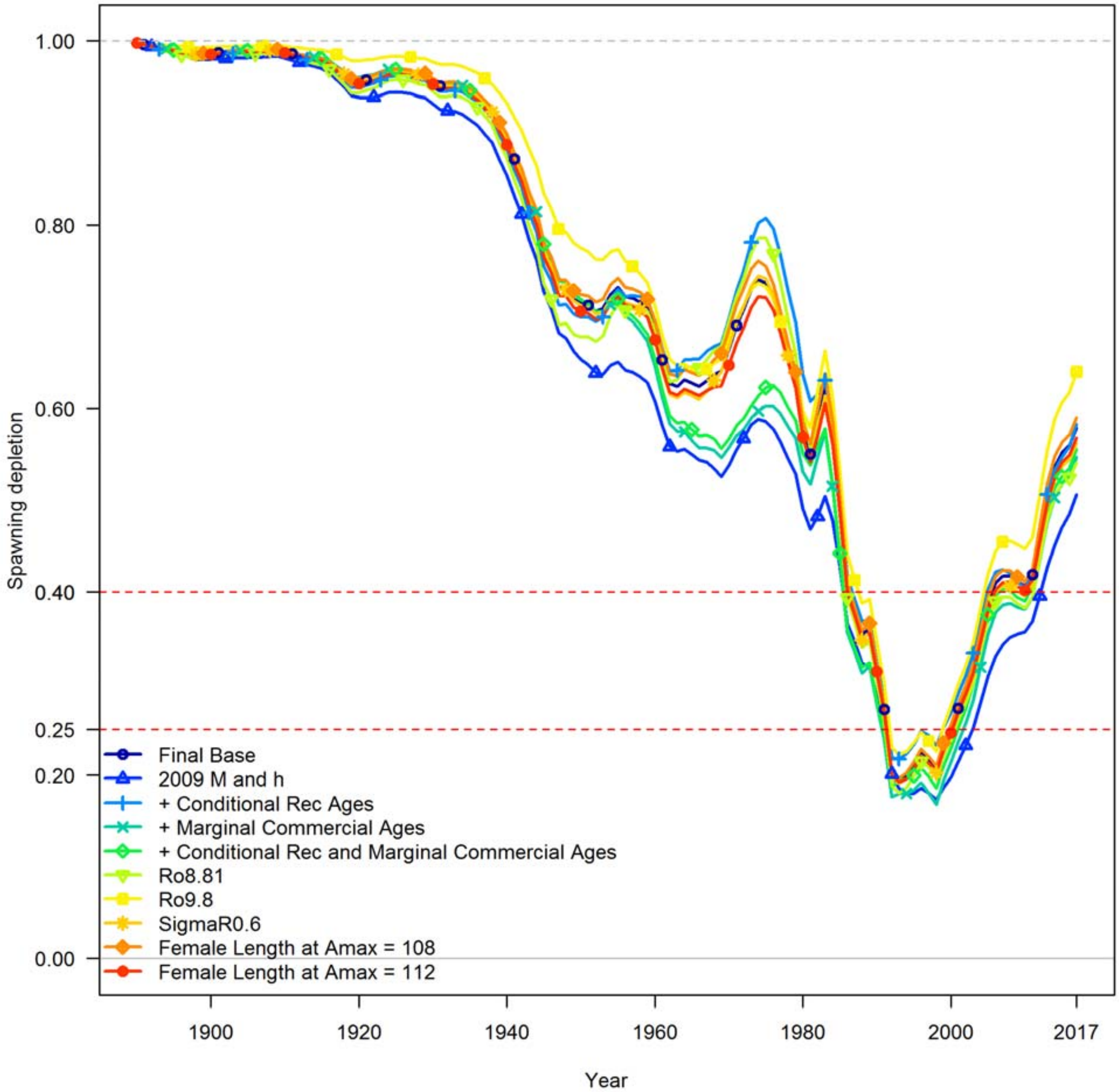


Figure 155. Sensitivity in stock depletion to north model sensitivity runs. The run 2009 M and h sets these values to those used in the 2009 stock assessment. The run + Conditional Rec Ages includes both WA and OR recreational age data as CAAL compositions. The run + Marginal Commercial Ages includes all commercial age data as prepared for the STAR panel version of this assessment. The run + Conditional Rec and Marginal Commercial Ages adds all fishery age data into the model. The runs Ro8.81 and Ro9.8 fix the parameter for unfished recruitment at each value; these runs bracket the base model. The run SigmaR0.6 fixed the input parameter for recruitment variability to 0.6. The runs Female Length at Amax = 108 and Female Length at Amax = 112 fix the values for this parameter at 108 cm and 112 cm, respectively.

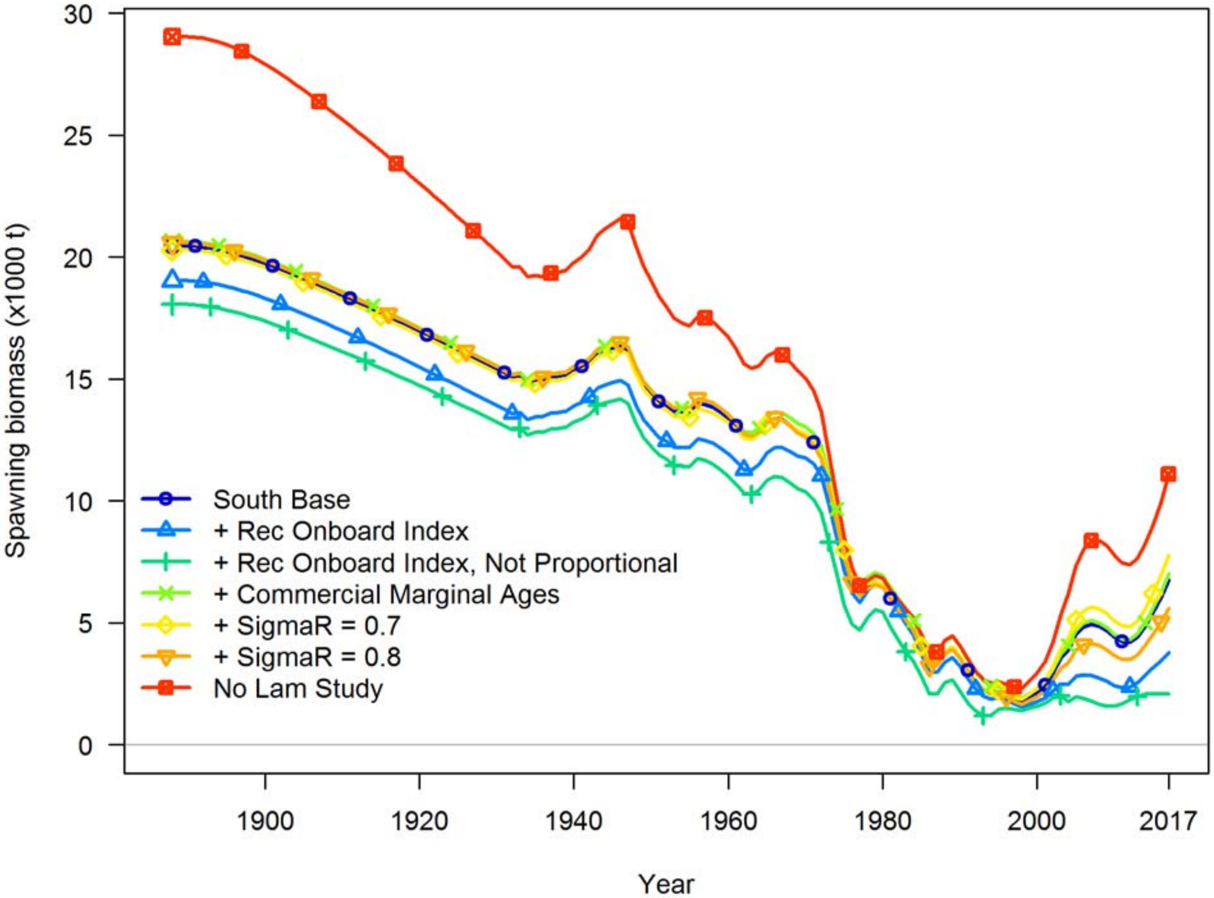


Figure 157. Sensitivity in spawning biomass to south model sensitivity runs. The run + Rec Onboard Index adds the CA recreational onboard observer index to the model as proportional to biomass. The run + Rec Onboard Index, Not Proportional adds the CA recreational onboard observer index to the model with a parameter that allows the index to be fit as not proportional to biomass. The run + Commercial Marginal Ages add the commercial age data as prepared for the pre-STAR draft assessment back into the model. The runs SigmaR = 0.7 and SigmaR = 0.8 change the fixed value for recruitment variability to 0.7 and 0.8, respectively. The run No Lam Study removes the Lam research CAAL and length composition data from the model.

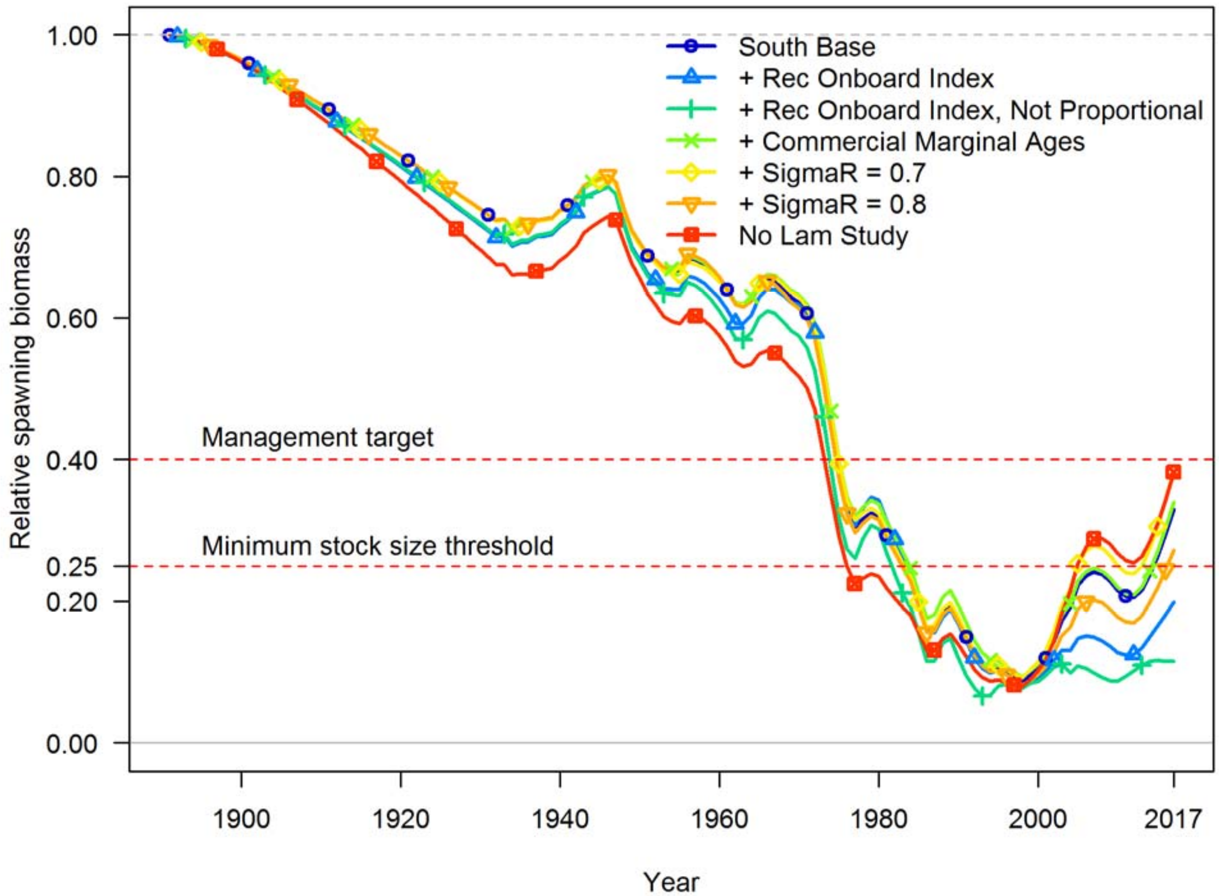


Figure 156. Sensitivity in stock depletion to south model sensitivity runs.

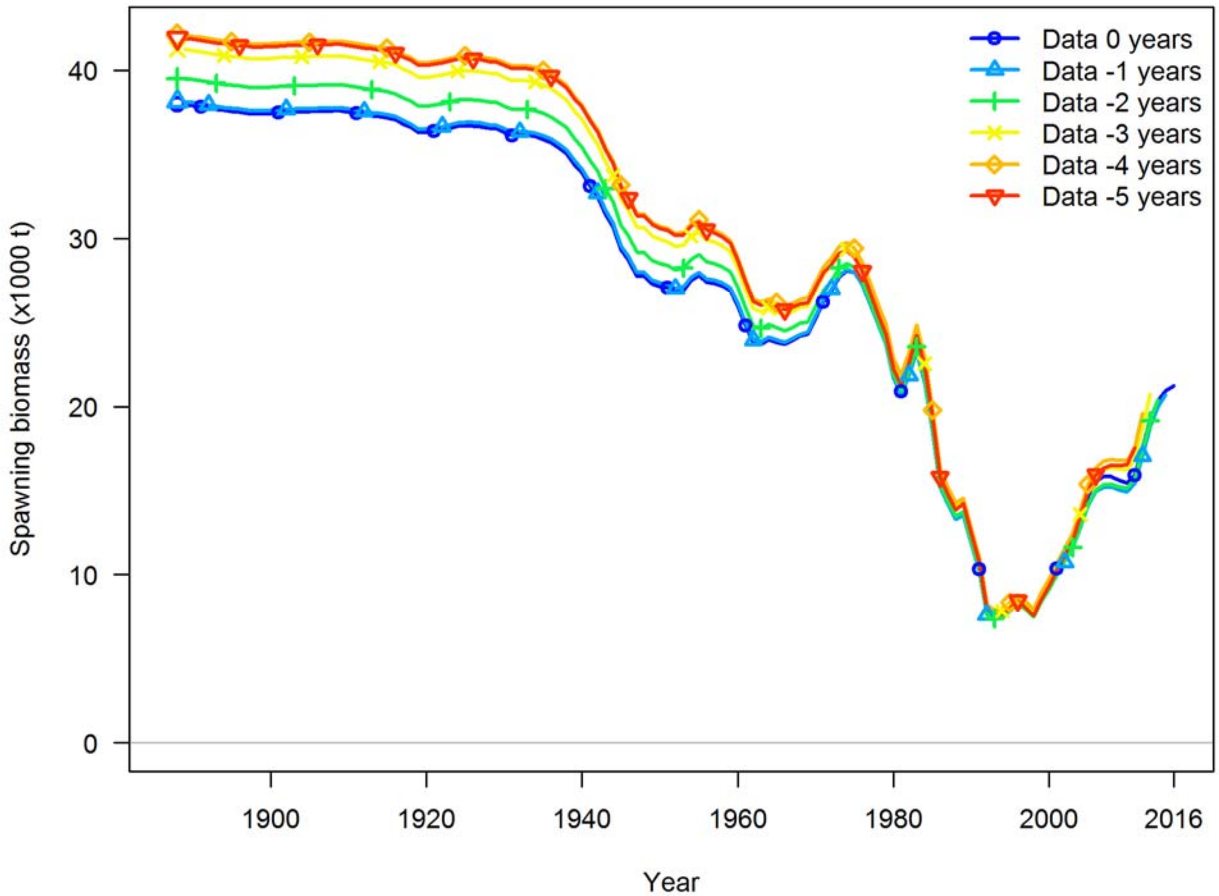


Figure 157. North base spawning biomass retrospective model runs.

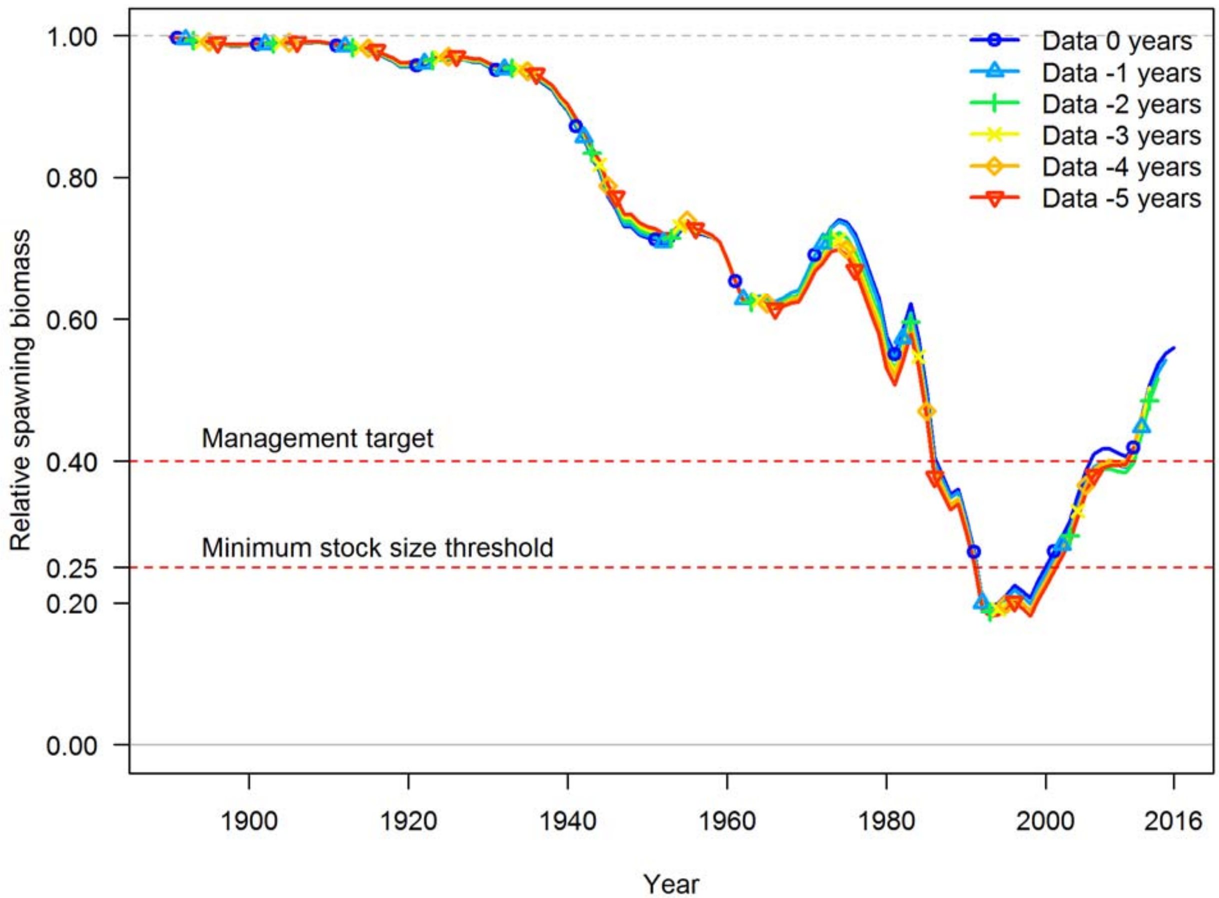
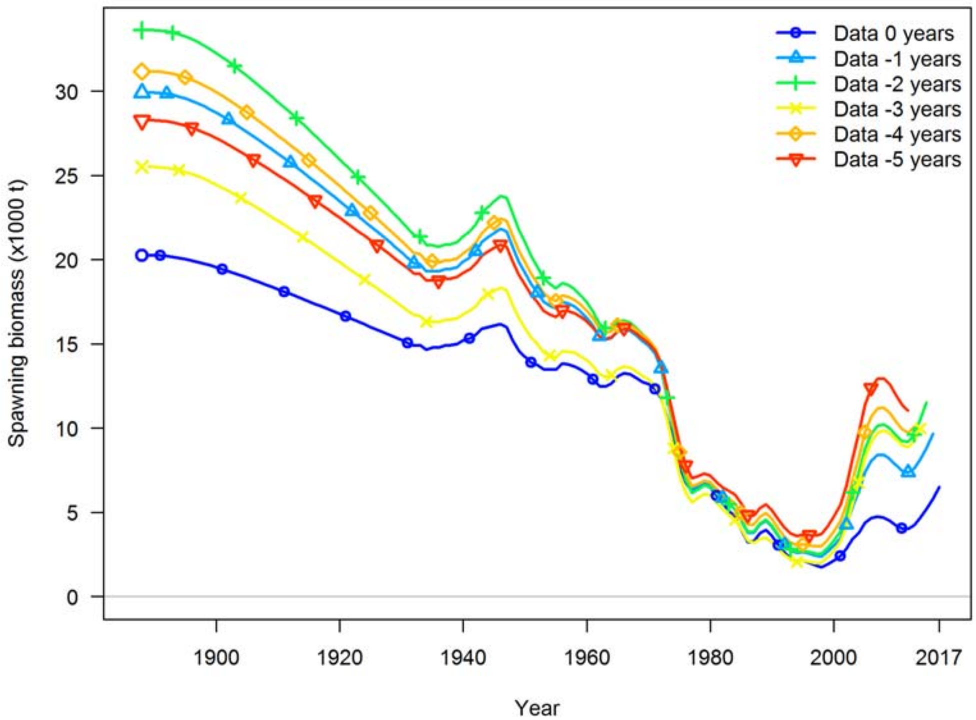


Figure 158. North base stock depletion retrospective model runs.



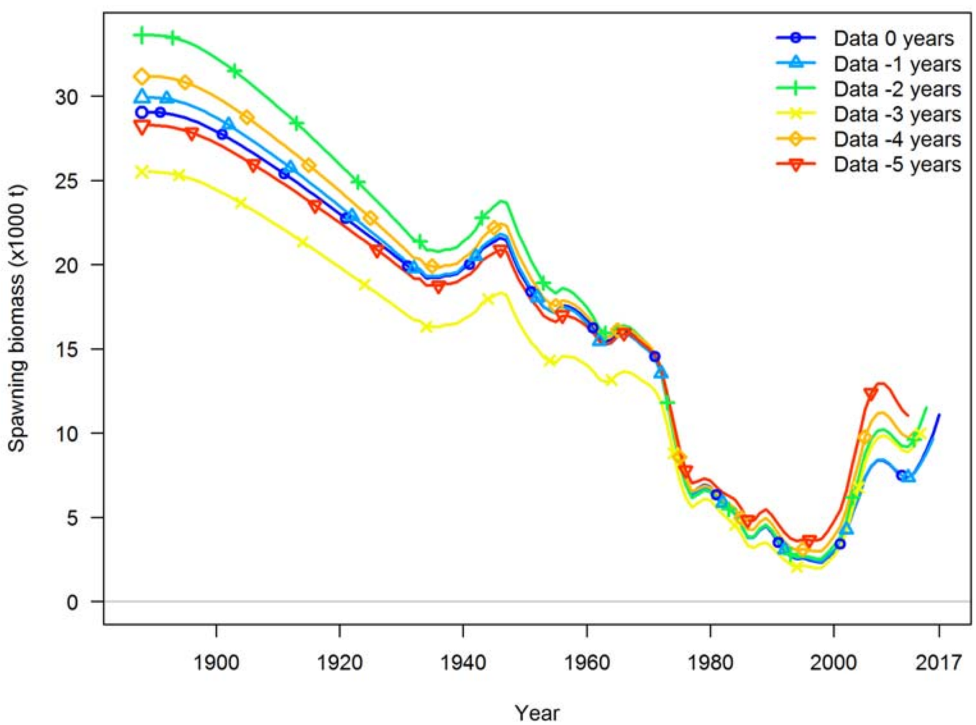
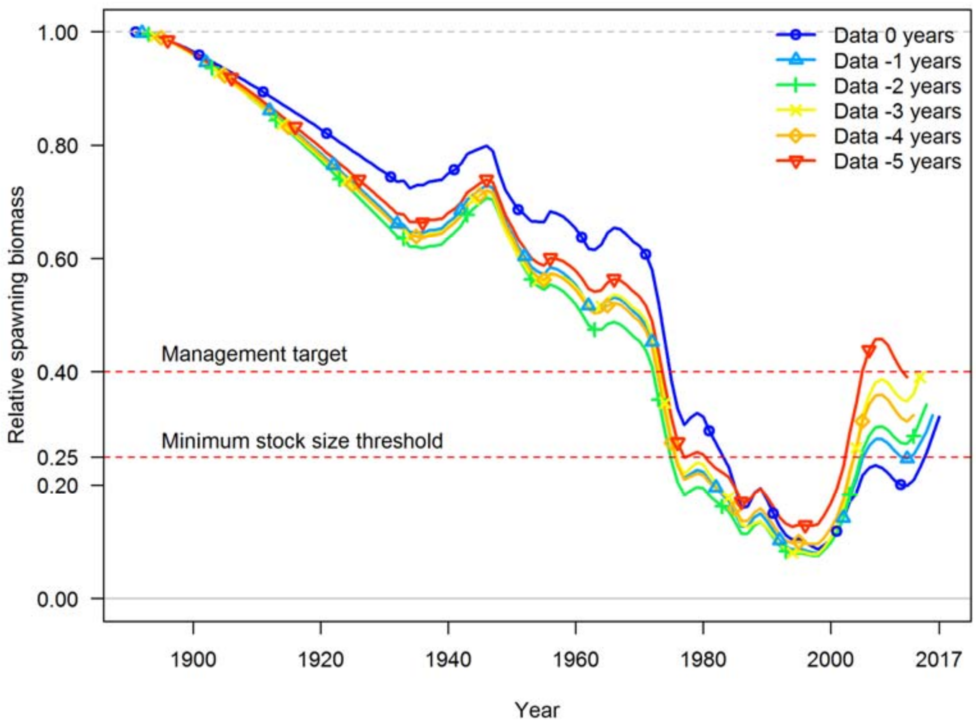


Figure 159. South base spawning biomass retrospective with (top panel) and without (bottom panel) the Lam data set.



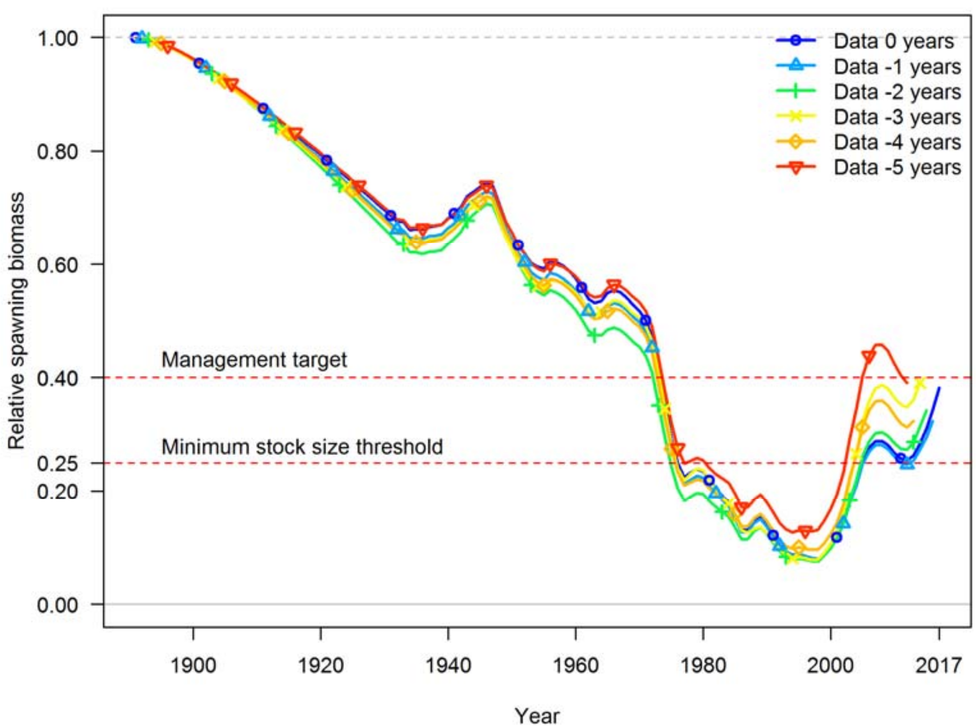


Figure 160. South base stock depletion retrospective with (top panel) and without (bottom panel) the Lam data set.

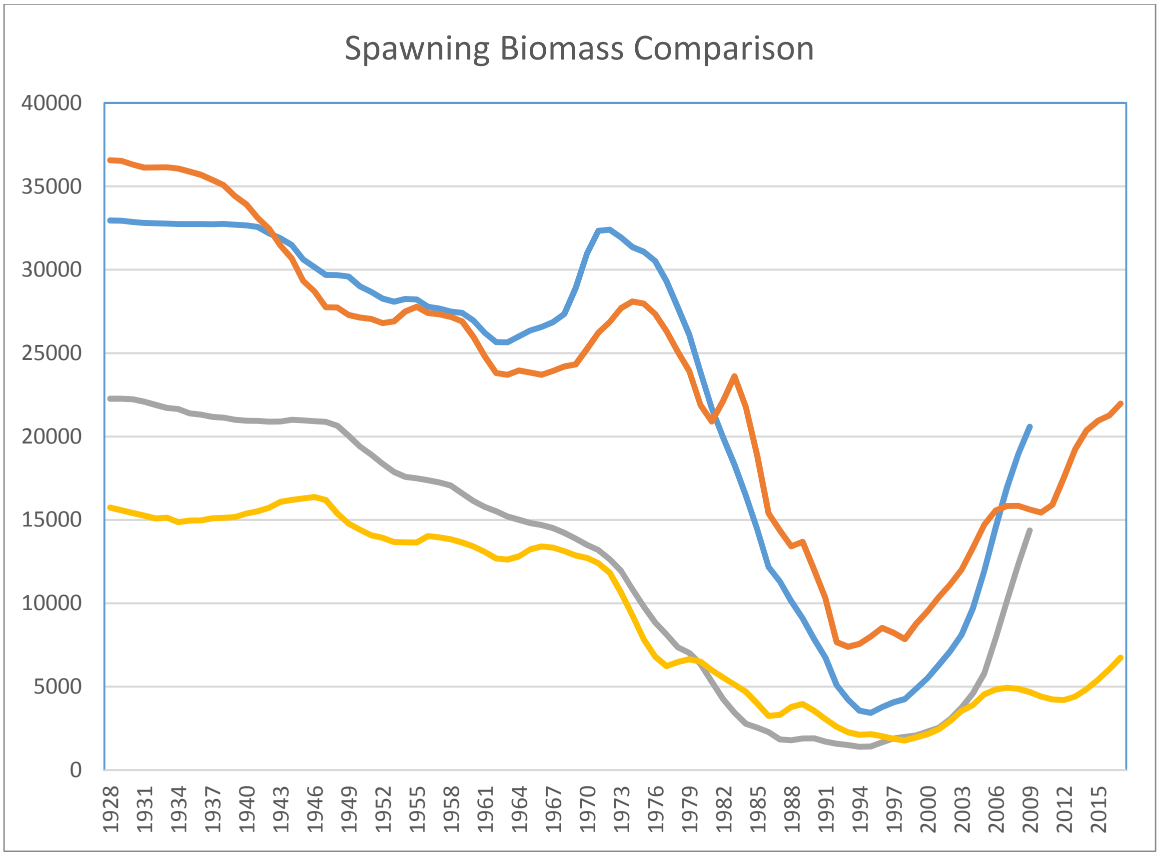


Figure 161. Comparison of spawning biomass trends between the 2009 and 2017 models. The 2009 north, 2017 north, 2009 south, and 2017 south models are show in blue, red, grey and yellow, respectively.

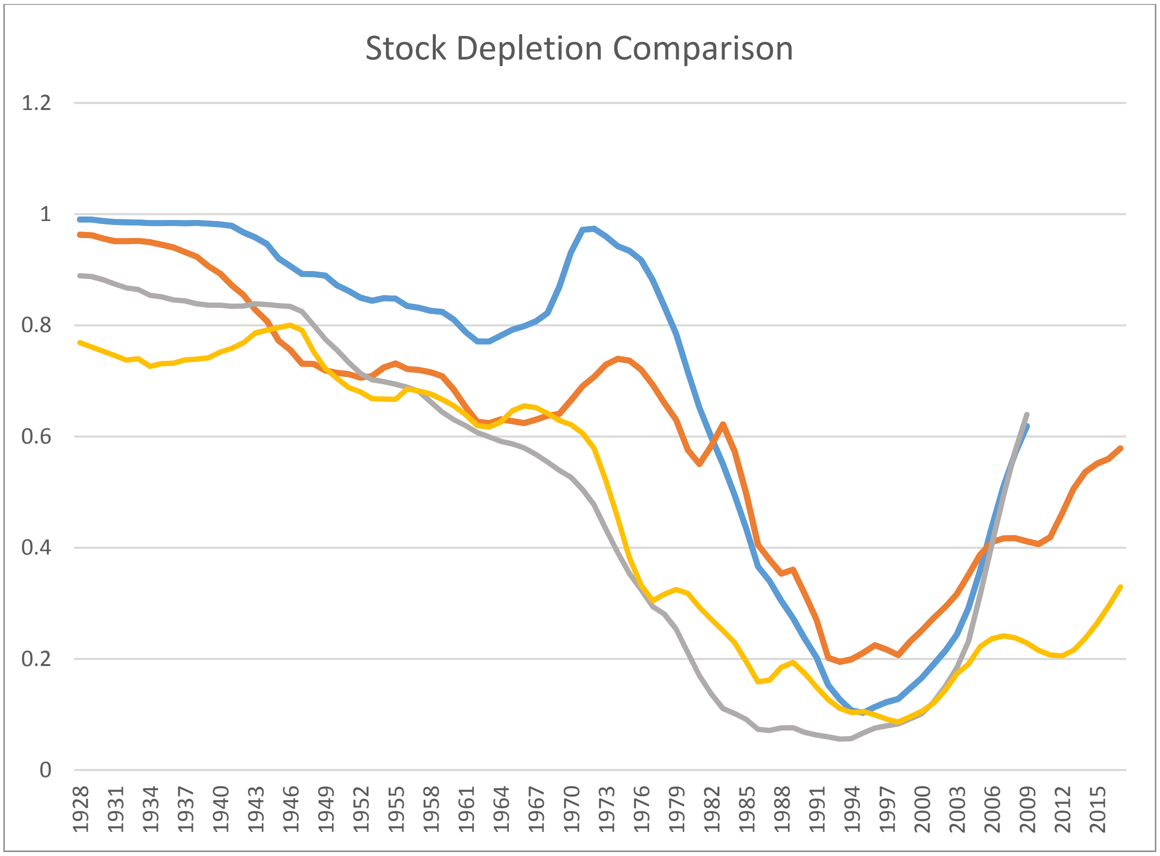


Figure 162. Comparison of stock depletion from the 2009 and 2017 models. The 2009 north, 2017 north, 2009 south, and 2017 south models are show in blue, red, grey and yellow, respectively.

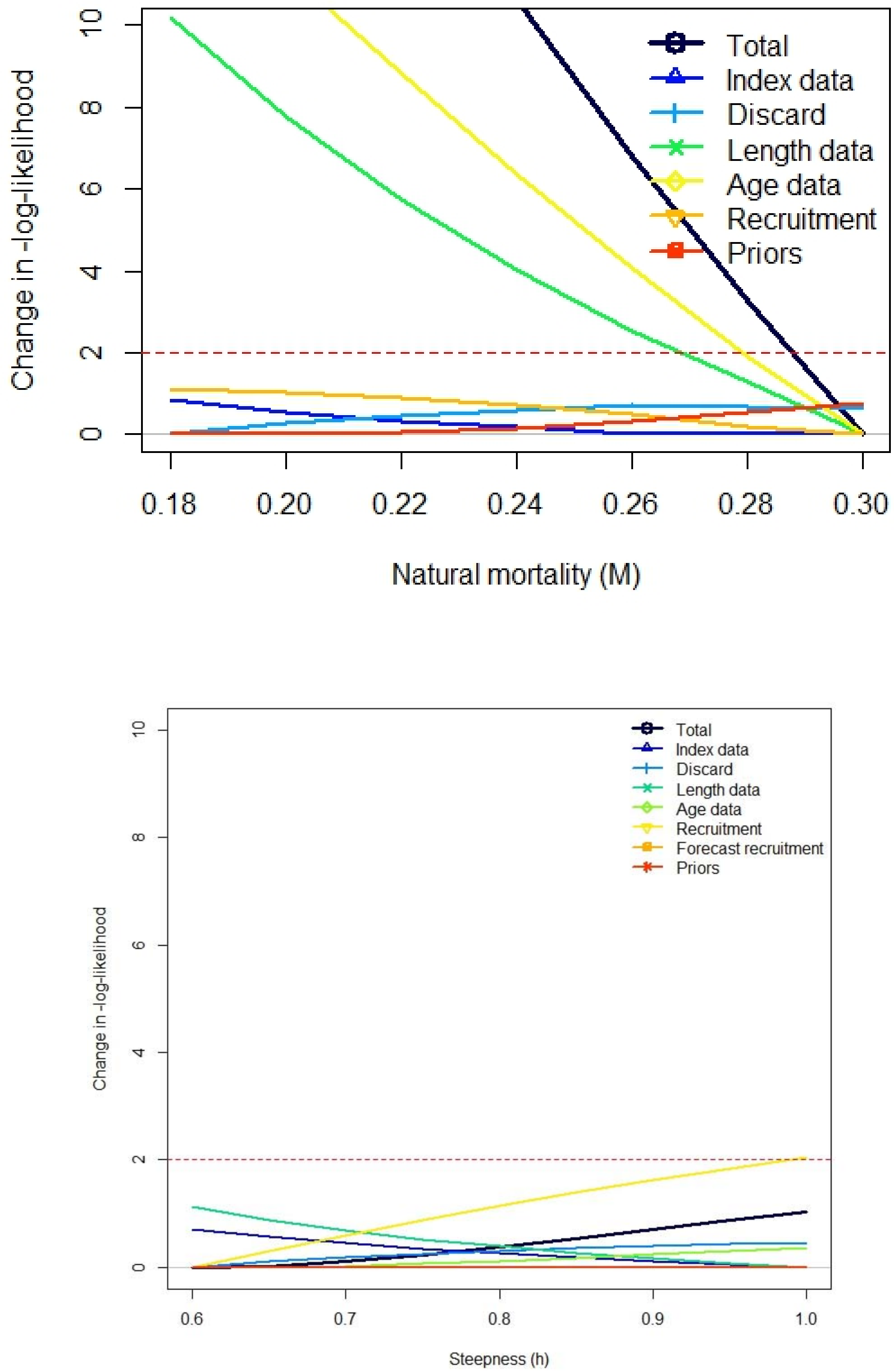


Figure 163. Female natural mortality (top panel) and stock-recruit steepness (bottom panel) likelihood profiles, north.

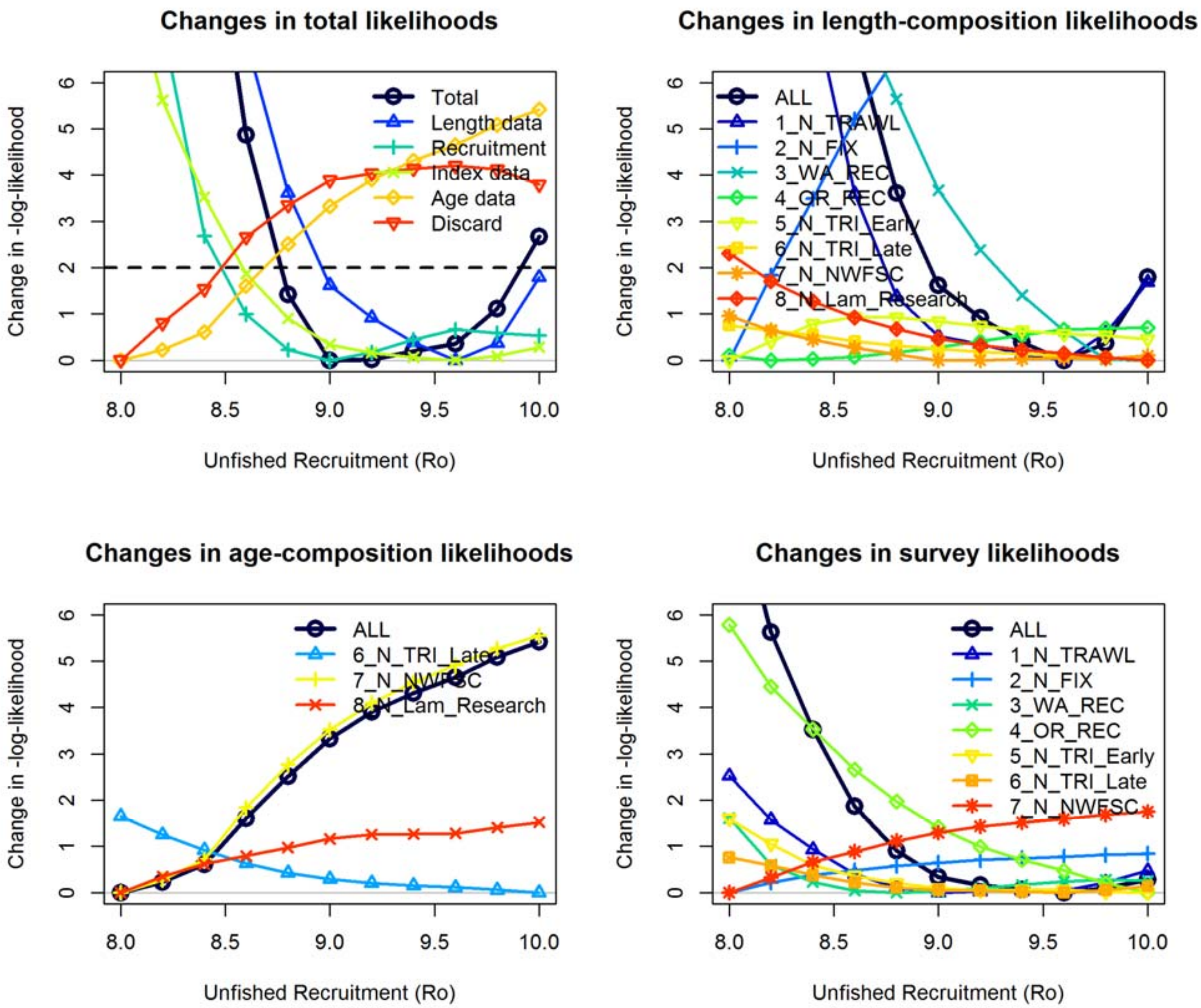


Figure 164. Estimated log unfished recruitment likelihood profile, north.

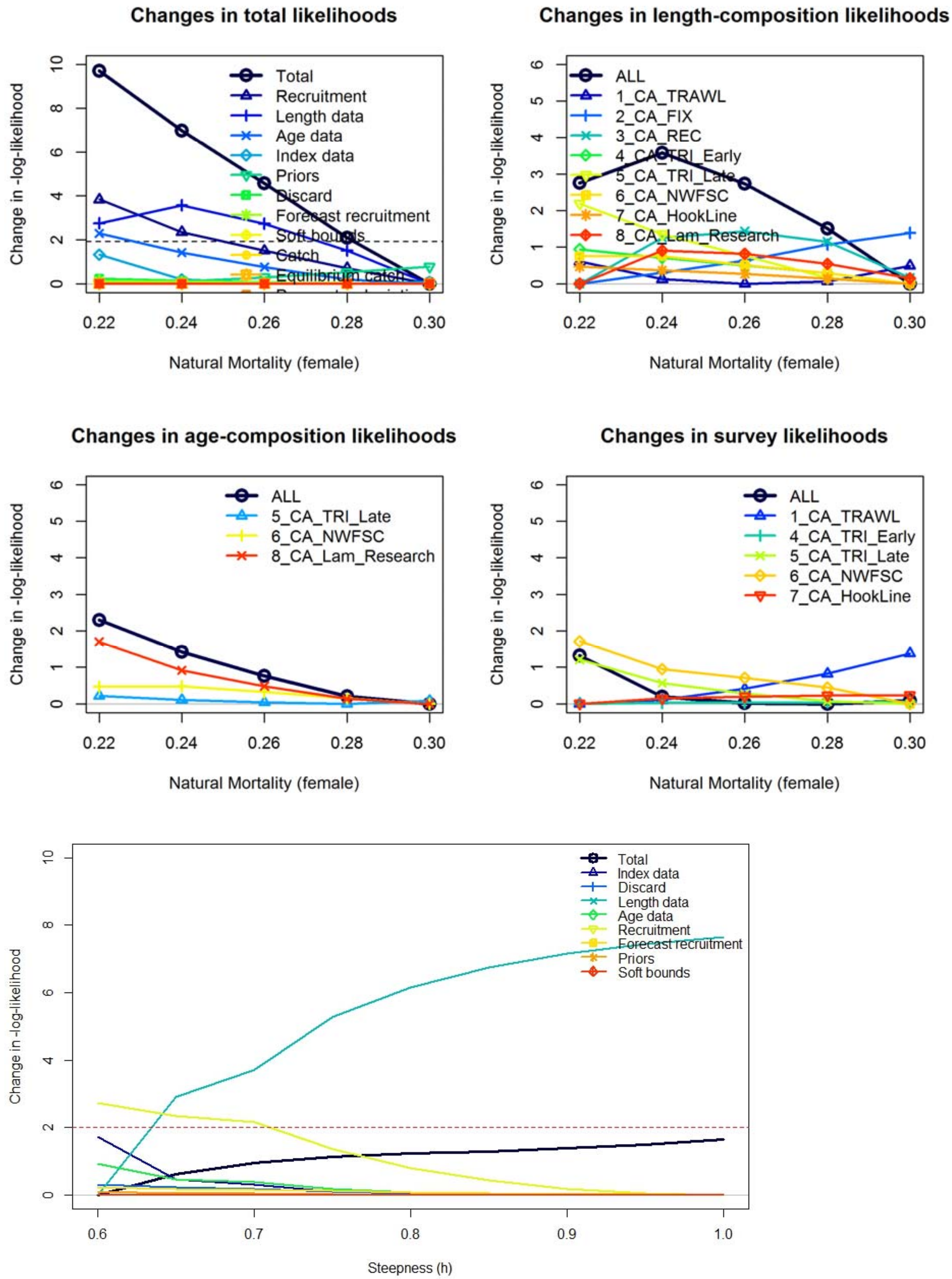


Figure 165. Female natural mortality (top panels) and stock-recruit steepness (bottom panel) likelihood profiles, south.

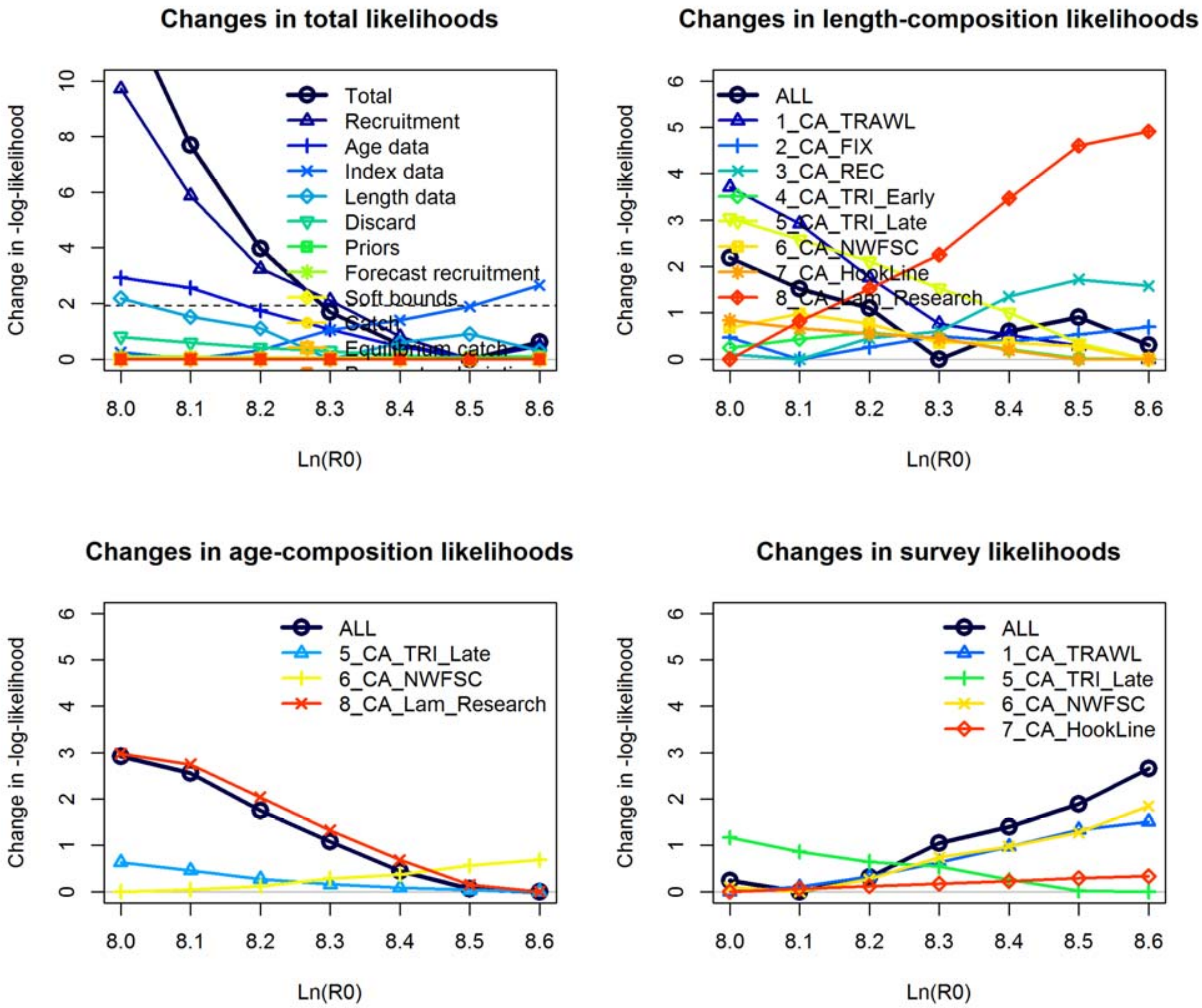


Figure 165. Estimated log unfished recruitment likelihood profile, south.

Appendix 1.

This appendix includes tables documenting VAST model specifications for the data sets analyzed using the VAST software as well as a comparison of the VAST and design based indices for the NWFSC survey data. For more detailed descriptions of the VAST modeling framework, see the User Manual available at: https://github.com/James-Thorson/VAST/blob/master/examples/VAST_user_manual.pdf

Table A1. Specifications and gradients for the VAST model runs.

Survey Data Set	NWFSC North	NWFSC South	Triennial North Early	Triennial North Late	Triennial South Early	Triennial South Late	PacFIN Logbooks
Number of knots	250	250	250	250	250	250	100
Maximum gradient	0.000589	0.000448	< 1e-06	< 1e-06	< 1e-06	< 1e-06	0.564
Is hessian positive definite?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was bias correction used?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distribution for measurement errors	Lognormal	Lognormal	Lognormal	Lognormal	Lognormal	Lognormal	Gamma
Spatial effect for encounter probability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spatio-temporal effect for encounter probability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spatial effect for positive catch rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spatio-temporal effect for positive catch rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A2. Summary of coefficients for the NWFSC survey and PacFIN trawl logbook VAST model runs.

	NWFSC North and South, Individually		PacFIN Trawl Logbooks	
Coefficient_name	Number_of_coefficients	Type	Number_of_coefficients	Type
beta1_ct	14	Fixed	11	Fixed
beta2_ct	14	Fixed	11	Fixed
L_epsilon1_z	1	Fixed	1	Fixed
L_epsilon2_z	1	Fixed	1	Fixed
L_omega1_z	1	Fixed	1	Fixed
L_omega2_z	1	Fixed	1	Fixed
L1_z	1	Fixed		
L2_z	1	Fixed	1	Fixed
lambda1_k	1	Fixed		
lambda2_k	1	Fixed		
ln_H_input	2	Fixed	2	Fixed
logkappa1	1	Fixed	1	Fixed
logkappa2	1	Fixed	1	Fixed
logSigmaM	1	Fixed	1	Fixed
Epsiloninput1_sft	3724	Random	1276	Random
Epsiloninput2_sft	3724	Random	1276	Random
eta1_vf	8	Random		
eta2_vf	8	Random	162	Random
Omegainput1_sf	266	Random	116	Random
Omegainput2_sf	266	Random	116	Random

Table A3. Summary of coefficients for the Triennial survey VAST model runs.

		Number_of_coefficients			
Coefficient_name	Type	Triennial North Early	Triennial North Late	Triennial South Early	Triennial South Late
beta1_ct	Fixed	5	4	5	4
beta2_ct	Fixed	5	4	5	4
L_epsilon1_z	Fixed	1	1	1	1
L_epsilon2_z	Fixed	1	1	1	1
L_omega1_z	Fixed	1	1	1	1
L_omega2_z	Fixed	1	1	1	1
L1_z	Fixed	1	1	1	1
L2_z	Fixed	1	1	1	1
ln_H_input	Fixed	2	2	2	2
logkappa1	Fixed	1	1	1	1
logkappa2	Fixed	1	1	1	1
logSigmaM	Fixed	1	1	1	1
Epsiloninput1_sft	Random	3458	2660	3458	2660
Epsiloninput2_sft	Random	3458	2660	3458	2660
eta1_vf	Random	7	6	7	6
eta2_vf	Random	7	6	7	6
Omegainput1_sf	Random	266	266	266	266
Omegainput2_sf	Random	266	266	266	266

Figure A4. Comparison of design based and VAST indices for the NWFSC survey data, north and south. The blue line is the design-based index; the red line is the VAST index.