2017 Lingcod Stock Assessment

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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 Catch
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

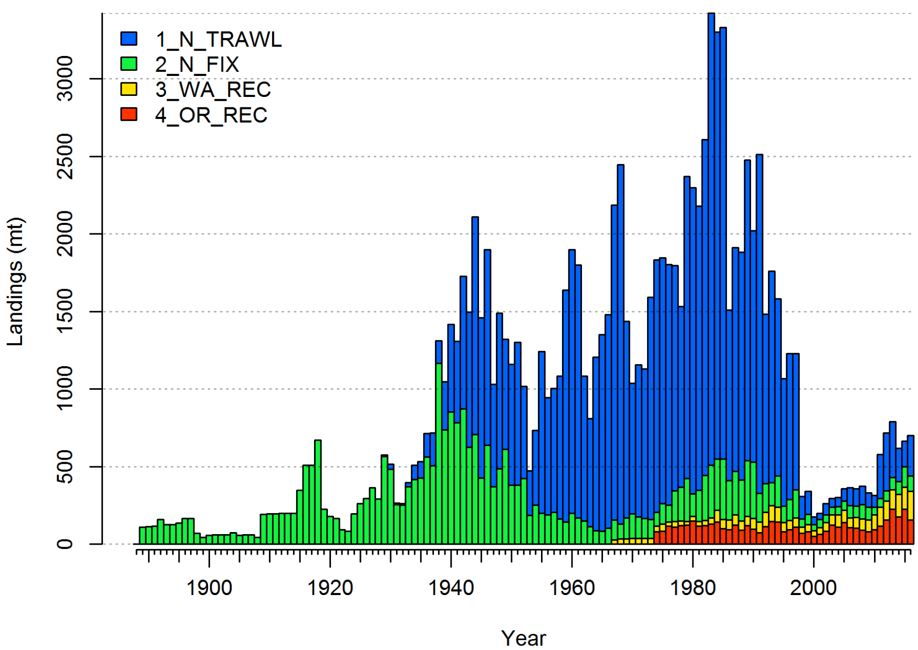

Figure a. North area landings.

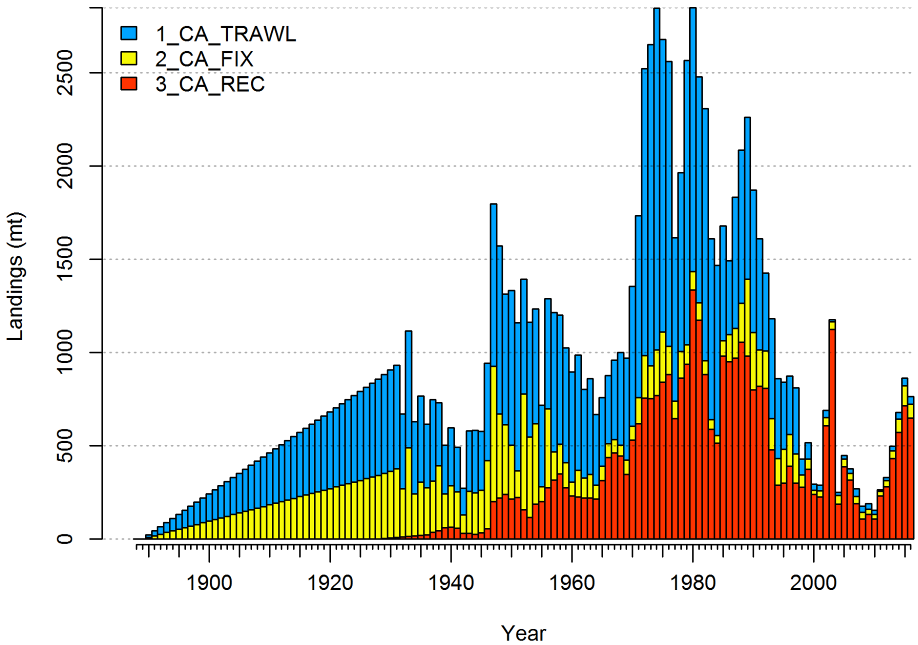

Figure b. South area landings

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 32.1% (11.1–53.1, 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 20,260 mt (15,304–25,215 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 6,509 mt (1,624–11,394 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	4,398	1,475–7,321	21.7	8.7–34.7
2006	4,667	1,443–7,892	23	8.8–37.3
2007	4,757	1,362–8,153	23.5	8.5–38.4
2008	4,681	1,260–8,102	23.1	8.1–38.1
2009	4,496	1,169–7,824	22.2	7.6–36.8
2010	4,232	1,062–7,401	20.9	7.0–34.7
2011	4,065	1,044–7,087	20.1	6.9–33.2
2012	4,032	1,081–6,983	19.9	7.1–32.7
2013	4,242	1,224–7,259	20.9	7.9–34.0
2014	4,674	1,407–7,942	23.1	9.0–37.1
2015	5,209	1,527–8,891	25.7	9.9–41.5
2016	5,827	1,561–10,093	28.8	10.4–47.1
2017	6,509	1,624–11,394	32.1	11.1–53.1

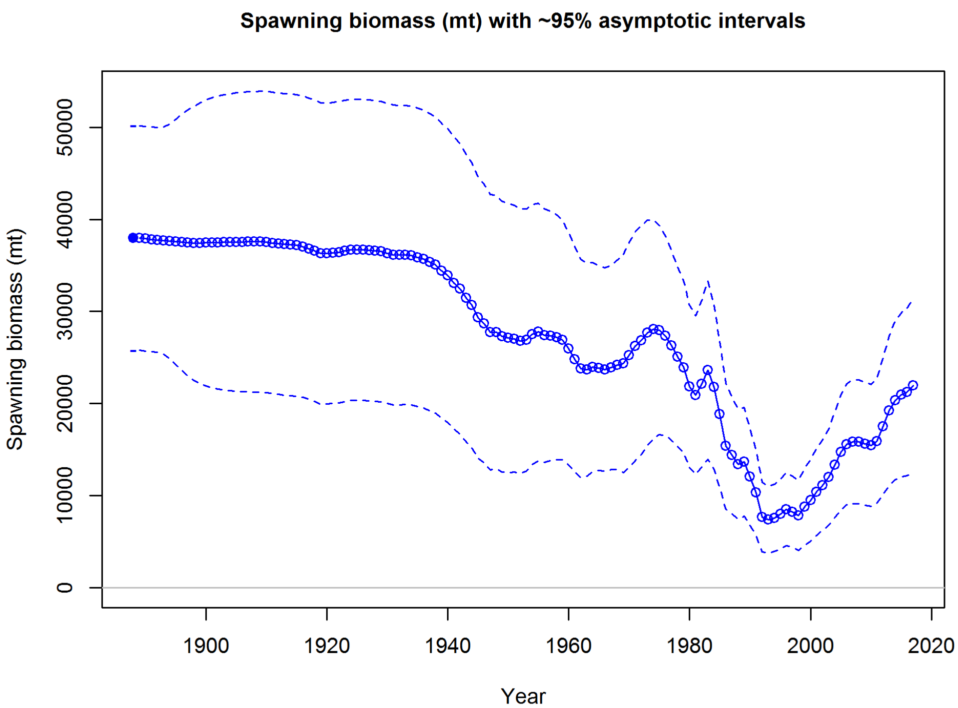

Figure c. Time series of spawning biomass, north.

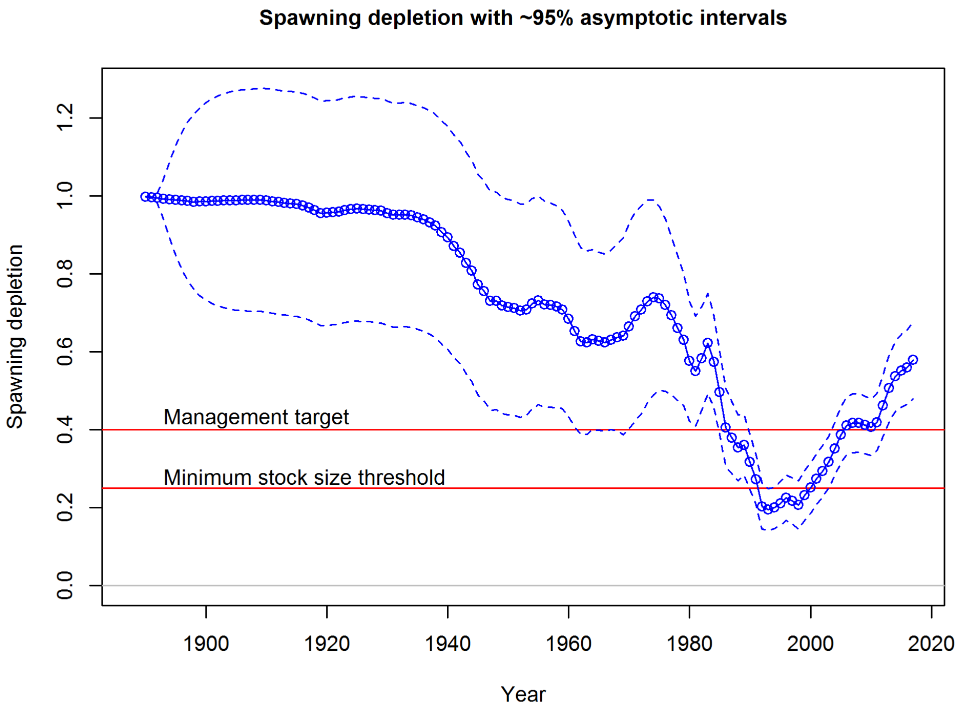

Figure d. Time series of stock depletion, north.

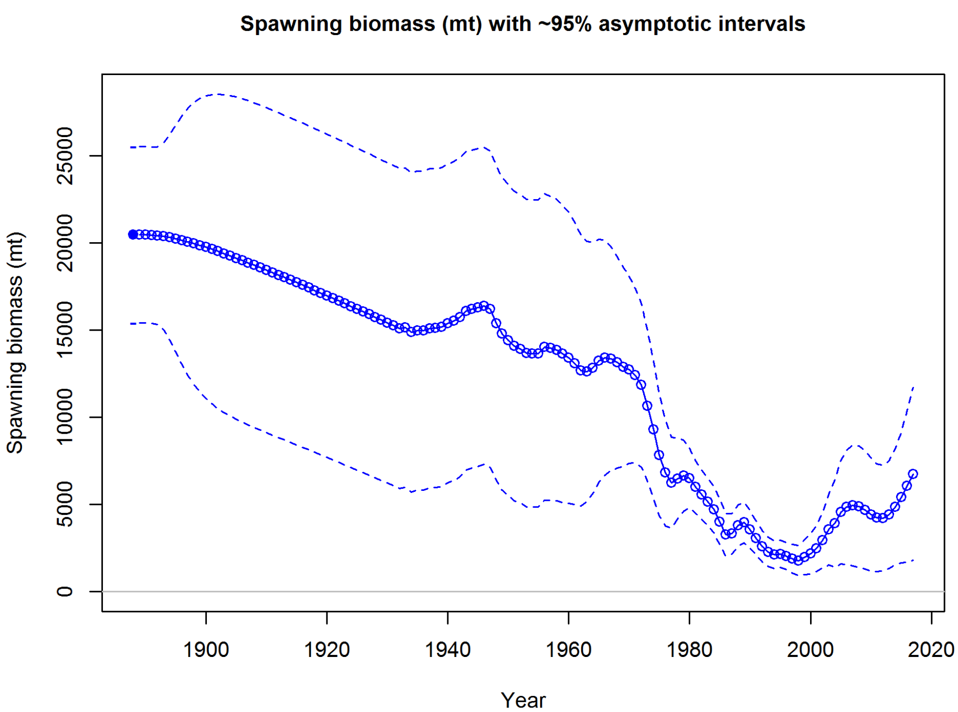

Figure e. Time series of spawning biomass, south.

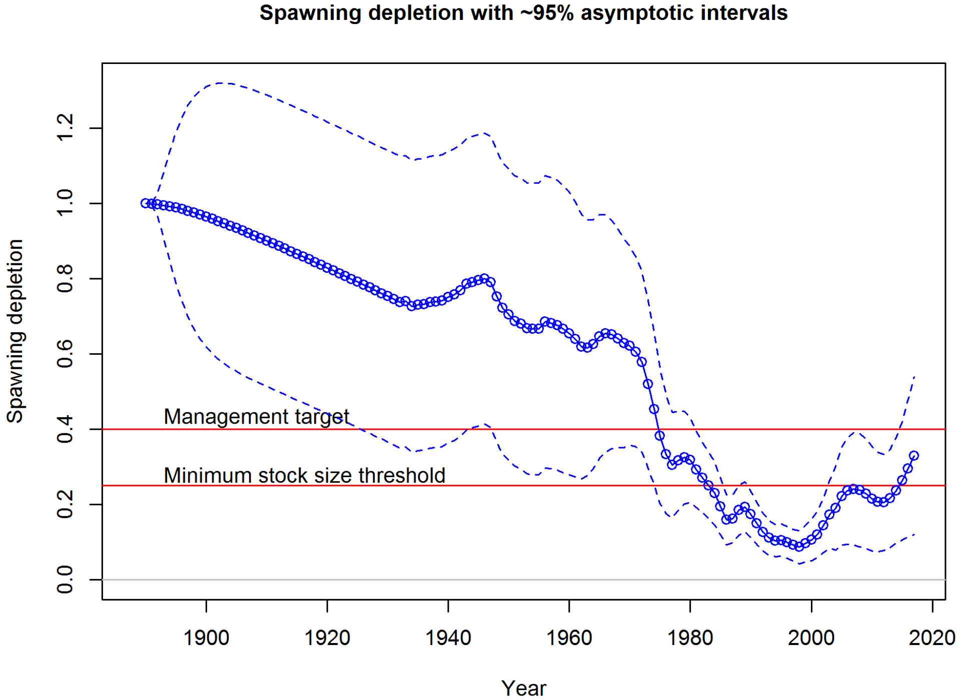

Figure f. Time series of stock depletion, south.

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	620	319–1,204	-1.466	-1.989–-0.942
2006	441	217–898	-1.826	-2.417–-1.235
2007	769	416–1,421	-1.277	-1.723–-0.832
2008	1,752	1,043–2,942	-0.449	-0.759–-0.138
2009	1,884	1,118–3,175	-0.362	-0.678–-0.045
2010	3,727	2,218–6,264	0.342	0.067–0.617
2011	3,255	1,855–5,711	0.221	-0.098–0.540
2012	3,773	2,058–6,917	0.372	0.018–0.726
2013	5,066	2,728–9,408	0.648	0.279–1.017
2014	2,030	1,056–3,901	-0.301	-0.788–0.187
2015	1,783	815–3,902	-0.466	-1.157–0.225
2016	1,425	490–4,143	-0.857	-1.940–0.226
2017	3,953	1,042–15,002	0	-1.470–1.470

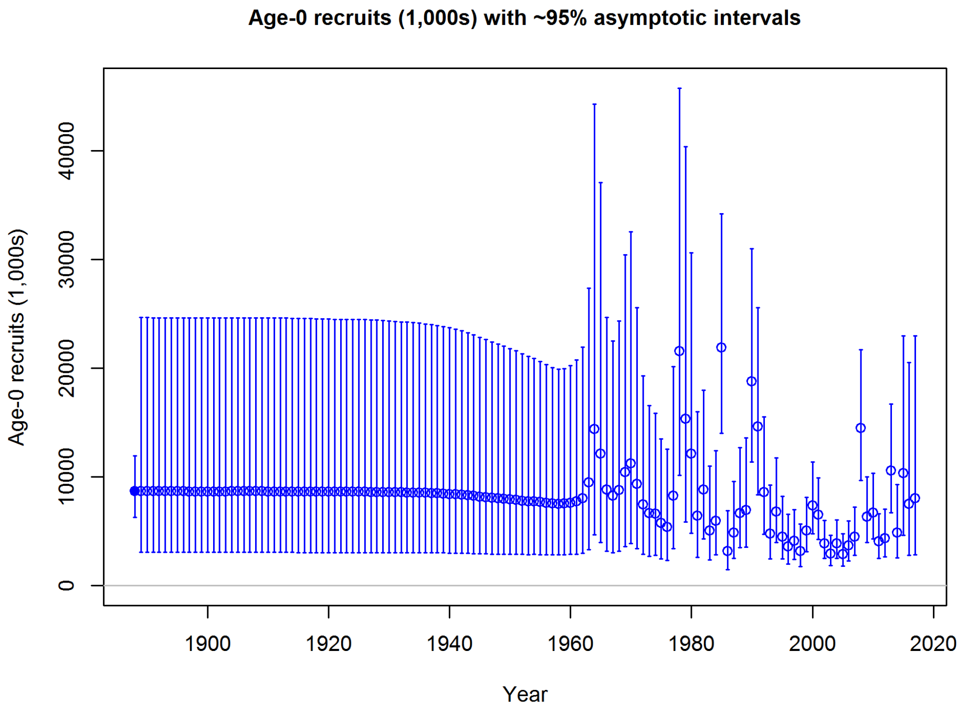

Figure g. Time series of estimated recruitment, north.

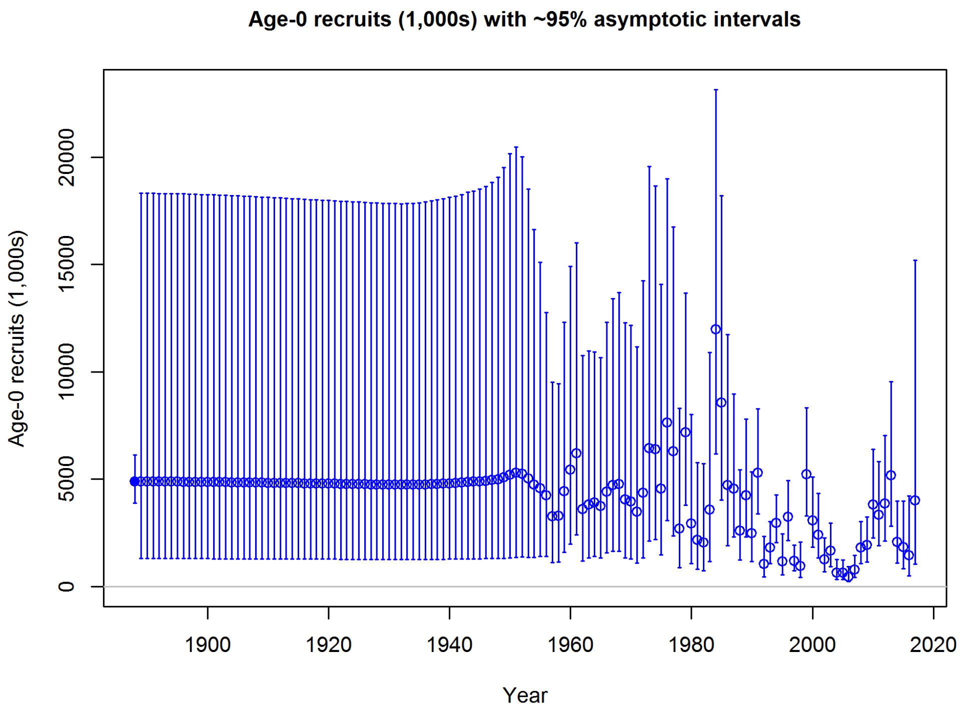

Figure h. Time series of estimated recruitments, south.

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
		57.57–103.02	0.481	0.278–0.685

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	0.4767	20.92–74.42	0.313	0.109–0.518
2006	0.4424	18.60–69.88	0.256	0.081–0.430
2007	0.3865	15.64–61.67	0.194	0.056–0.333
2008	0.3128	12.26–50.29	0.134	0.036–0.232
2009	0.3998	17.05–62.92	0.152	0.039–0.264
2010	0.3911	17.18–61.03	0.128	0.033–0.224
2011	0.6159	31.18–91.99	0.213	0.058–0.368
2012	0.6564	34.36–96.92	0.264	0.077–0.451
2013	0.7323	39.64–106.82	0.35	0.113–0.588
2014	0.7489	39.84–109.95	0.427	0.140–0.714
2015	0.7712	39.51–114.73	0.482	0.151–0.814
2016	0.6118	26.46–95.90	0.368	0.105–0.630

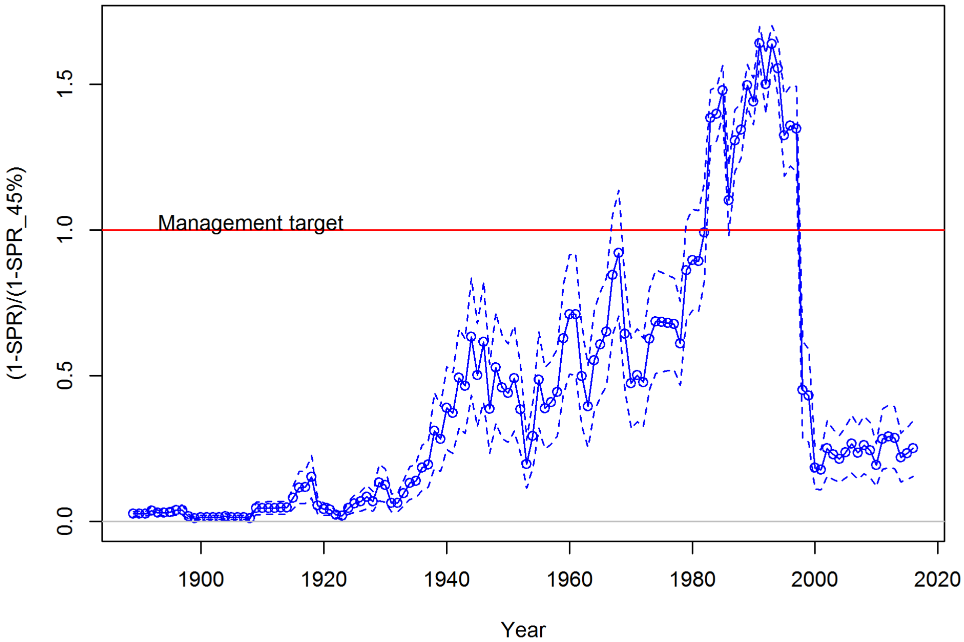

Figure i. Estimated spawning potential ratio (SPR), north. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

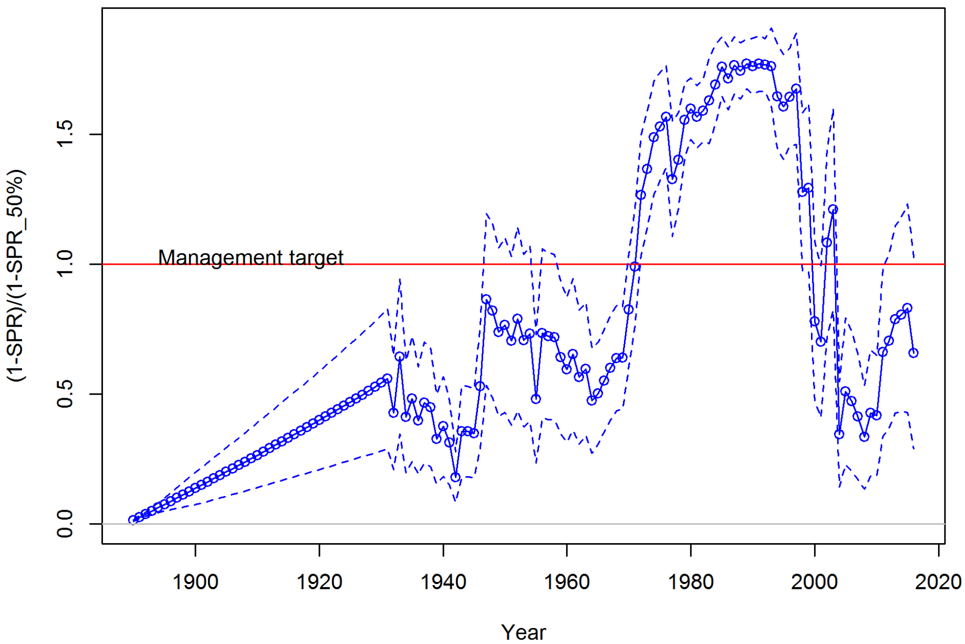

Figure j. Estimated spawning potential ratio (SPR), south. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

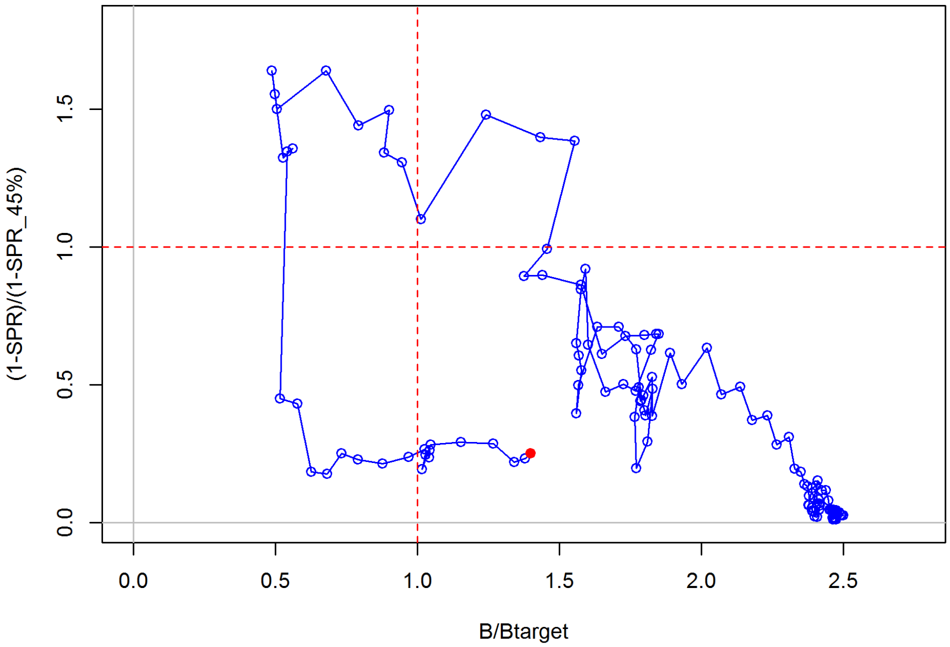

Figure k. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, north.

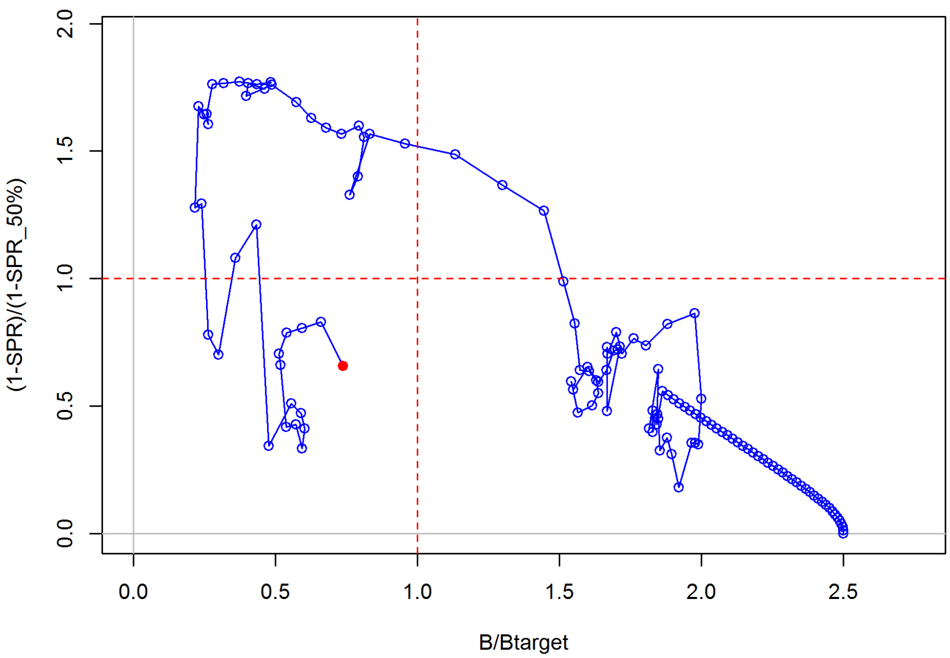

Figure l. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, south.

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 7,780 mt (5,877–9,683 mt 95% asymptotic interval) in the south, which gives catches of 3197 mt (2,184–4,210 mt, 95% asymptotic interval) for the north and 1746 mt (1,372–2,121, 95% asymptotic standard deviation) for the south (Tables i and j). Equilibrium yield at the proxy FMSY harvest rate is 3,409 mt (2,329–4,489 mt, 95% asymptotic interval) and 1,856 mt (1,458–2,253 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)	20,260	15,304–25,215
Unfished Age 3+ Biomass (mt)	31,235	23,914–38,556
Spawning Biomass (2017)	6,509	1,624–11,394
Unfished Recruitment (R0)	4,848	3,747–5,949
Depletion (2017)	32.13	11.14–53.12
Reference Points Based SB40%		
Proxy Spawning Biomass (SB40%)	8,104	6,122–10,086
SPR resulting in SB40%	0.464	0.464–0.464
Exploitation Rate Resulting in SB40%	0.126	0.116–0.135
Yield with SPR Based On SB40% (mt)	1,720	1,351–2,089
Reference Points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45)	7,780	5,877–9,683
SPR45	0.45	NA
Exploitation rate corresponding to SPR45	0.132	0.122–0.142
Yield with SPR45 at SBSPR (mt)	1,746	1,372–2,121
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	5,265	3,972–6,559
SPRMSY	0.339	0.334–0.344
Exploitation rate corresponding to SPRMSY	0.197	0.185–0.209
MSY (mt)	1,856	1,458–2,253

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 21.31% of the CA biomass being in the 40-10 to 42 region. This value 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. Tables k and l show recent management quantities as well as stock projection under alternative harvest policies.

Table k. Recent trends in landings and total catch (mt) relative to management guidelines as well as requested management options for 2019 and 2020. 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
2005	Coast-wide	2,922	NA	NA	2,414	NA	NA	356	502	449
2006	Coast-wide	2,716	NA	NA	2,414	NA	NA	364	544	378
2007	Coast-wide	6,706	NA	NA	6,706	NA	NA	358	459	270
2008	Coast-wide	5,853	NA	NA	5,853	NA	NA	374	480	177
2009	Coast-wide	5,278	NA	NA	5,278	NA	NA	331	424	190
2010	Coast-wide	4,829	NA	NA	4,829	NA	NA	315	343	154
2011	Split at 42º N	4,961	2438	2523	4,432	2,330	2,102	578	611	263
2012	Split at 42º N	4,848	2251	2597	4,315	2,151	2,164	717	748	329
2013	Lingcod Split at 40º10' N	4,668	3,334	1,334	4,147	3,036	1,111	790	813	498
2014	Lingcod Split at 40º10' N	4,438	3,162	1,276	3,941	2,878	1,063	619	632	679
2015	Lingcod Split at 40º10' N	4,215	3,010	1,205	3,834	2,830	1,004	662	677	864
2016	Lingcod Split at 40º10' N	4,027	2,891	1,136	3,665	2,719	946	702	723	763
2017	Lingcod Split at 40º10' N	5,051	3,549	1,502	4,584	3,333	1,251	NA	NA	NA
2018	Lingcod Split at 40º10' N	4,683	3,310	1,373	4,254	3,110	1,144	NA	NA	NA

Table l. PFMC requested management options for 2019 through 2026, all units are in metric tons. Note that the south area ACL has the 40-10 control rule applied to the values.

Option 1			OFL		ABC		ACL	
			Assessment	Management	Assessment	Management	Assessment	Management
Year	Area	Buffer	Areas	Areas	Areas	Areas	Areas	Areas
2019	North	0.956	4,690	4,957	4,484	4,728	4,484	4,704
2020	North	0.956	4,459	4,701	4,262	4,483	4,262	4,459
2021	North	0.956	4,272	4,539	4,084	4,328	4,084	4,303
2022	North	0.956	4,126	4,431	3,945	4,223	3,945	4,202
2023	North	0.956	4,013	4,344	3,836	4,139	3,836	4,121
2024	North	0.956	3,923	4,269	3,751	4,067	3,751	4,053
2025	North	0.956	3,850	4,204	3,681	4,004	3,681	3,993
2026	North	0.956	3,789	4,149	3,622	3,951	3,622	3,943
2019	South	0.913	1,253	986	1,144	900	1,032	812
2020	South	0.913	1,136	894	1,037	816	921	724
2021	South	0.913	1,253	986	1,144	900	1,030	811
2022	South	0.913	1,429	1,124	1,305	1,027	1,206	949
2023	South	0.913	1,555	1,224	1,420	1,117	1,338	1,053
2024	South	0.913	1,624	1,278	1,483	1,167	1,418	1,116
2025	South	0.913	1,663	1,309	1,518	1,195	1,467	1,154
2026	South	0.913	1,690	1,330	1,543	1,214	1,503	1,183
Option 2								
2019	North	0.956	4,690	4,957	4,484	4,739	4,484	4,713
2020	North	0.956	4,459	4,699	4,262	4,492	4,262	4,466
2021	North	0.956	4,272	4,537	4,084	4,337	4,084	4,310
2022	North	0.956	4,126	4,428	3,945	4,233	3,945	4,209
2023	North	0.956	4,013	4,341	3,836	4,150	3,836	4,129
2024	North	0.956	3,923	4,265	3,751	4,078	3,751	4,060
2025	North	0.956	3,850	4,200	3,681	4,015	3,681	4,001
2026	North	0.956	3,789	4,144	3,622	3,962	3,622	3,950
2019	South	0.956	1,253	986	1,198	943	1,077	847
2020	South	0.956	1,129	888	1,079	849	953	750
2021	South	0.956	1,244	979	1,189	936	1,063	836
2022	South	0.956	1,417	1,115	1,355	1,066	1,242	977
2023	South	0.956	1,539	1,211	1,471	1,158	1,375	1,082
2024	South	0.956	1,605	1,263	1,534	1,207	1,453	1,143
2025	South	0.956	1,641	1,291	1,569	1,234	1,501	1,181
2026	South	0.956	1,666	1,311	1,593	1,253	1,536	1,209

Unresolved Problems and Major Uncertainties

A few outstanding issue remain for lingcod stock assessment on the west coast of the U.S. First, in many cases the commercial age data are not randomly sampled with respect to lengths and 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, 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 m through m2. 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, the current medium term projection of expected catch under both harvest policies, shows increasing spawning biomass and depletion from the base model, with the stock remaining in the precautionary zone during the projection period. The lack of strong increases in 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 one case, in which the current control rule is applied to the low stock state of nature (bottom left corner of the table). Note that the catch specified in the above scenario is an order of magnitude above recent landings. 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 overfished (lower left corner) to well above target stock size (upper right corner). All states of nature from the constant catch scenario, that specifies catches similar to recent levels, suggest that the stock will increase towards, or exceed the target reference point.

Table l. 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

Table m1. Model projections, buffer 0.956, south.

Year	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	1,712	1,518	11,230	6,509	32.1%
2018	1,528	1,393	10,605	6,424	31.7%
2019	1,253	1,077	9,647	6,055	29.9%
2020	1,129	953	9,798	5,855	28.9%
2021	1,244	1,063	10,338	6,012	29.7%
2022	1,417	1,242	10,941	6,329	31.2%
2023	1,539	1,375	11,424	6,621	32.7%
2024	1,605	1,453	11,789	6,848	33.8%
2025	1,641	1,501	12,079	7,028	34.7%
2026	1,666	1,536	12,324	7,182	35.4%

Table m2. Model projections, buffer 0.913, south.

Year	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	1,712	1,518	11,230	6,509	32.1%
2018	1,528	1,393	10,605	6,424	31.7%
2019	1,253	1,032	9,647	6,055	29.9%
2020	1,136	921	9,843	5,883	29.0%
2021	1,253	1,030	10,413	6,059	29.9%
2022	1,429	1,206	11,043	6,394	31.6%
2023	1,555	1,338	11,557	6,705	33.1%
2024	1,624	1,418	11,952	6,952	34.3%
2025	1,663	1,503	12,239	7,151	35.3%
2026	1,690	1,558	12,540	7,322	36.1%

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 using a buffer of 0.956, 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		Base case		High	
			Ln(R0) = 8.122		Ln(R0) = 8.493		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	3,400	24%	6,055	30%	8,885	34%
	2020	700	3,239	23%	6,083	30%	9,017	34%
	2021	700	3,359	24%	6,386	32%	9,478	36%
	2022	700	3,647	26%	6,903	34%	10,210	39%
	2023	700	3,983	28%	7,499	37%	11,054	42%
	2024	700	4,329	31%	8,116	40%	11,927	45%
	2025	700	4,676	33%	8,727	43%	12,790	49%
	2026	700	5,026	35%	9,325	46%	13,628	52%
	2027	700	5,375	38%	9,904	49%	14,430	55%
	2028	700	5,722	40%	10,460	52%	15,191	58%
75% ACL catch	2019	808	3,400	24%	6,055	30%	8,885	34%
	2020	715	3,177	22%	6,017	30%	8,950	34%
	2021	798	3,290	23%	6,312	31%	9,403	36%
	2022	931	3,528	25%	6,775	33%	10,082	38%
	2023	1,031	3,737	26%	7,239	36%	10,792	41%
	2024	1,090	3,894	27%	7,659	38%	11,468	44%
	2025	1,126	4,019	28%	8,040	40%	12,100	46%
	2026	1,152	4,131	29%	8,395	41%	12,695	48%
	2027	1,173	4,236	30%	8,727	43%	13,251	50%
	2028	1,191	4,334	31%	9,038	45%	13,770	52%
ABC 40-10 Rule	2019	1,077	3,400	24%	6,055	30%	8,885	34%
	2020	953	3,023	21%	5,855	29%	8,785	33%
	2021	1,063	3,010	21%	6,012	30%	9,097	35%
	2022	1,242	3,108	22%	6,329	31%	9,627	37%
	2023	1,375	3,150	22%	6,621	33%	10,165	39%
	2024	1,453	3117	22%	6,848	34%	10,651	40%
	2025	1,501	3040	21%	7,028	35%	11,086	42%
	2026	1,536	2945	21%	7,182	35%	11,486	44%
	2027	1,564	2839	20%	7,318	36%	11,855	45%
	2028	1,588	2724	19%	7,439	37%	12,195	46%

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	0.48	0.44	0.39	0.31	0.4	0.39	0.62	0.66	0.73	0.75	0.77	0.61	NA
Exploitation Rate	0.31	0.26	0.19	0.13	0.15	0.13	0.21	0.26	0.35	0.43	0.48	0.37	NA
Age 3+ Biomass (mt)	7,485	7,760	7,563	7,229	6,773	6,330	6,321	6,419	7,323	8,207	9,240	10,690	11,230
Spawning Biomass (mt)	4,398	4,667	4,757	4,681	4,496	4,232	4,065	4,032	4,242	4,674	5,209	5,827	6,509
95% Confidence Interval	1,475–7,321	1,443–7,892	1,362–8,153	1,260–8,102	1,169–7,824	1,062–7,401	1,044–7,087	1,081–6,983	1,224–7,259	1,407–7,942	1,527–8,891	1,561–10,093	1,624–11,394
Recruitment	620	441	769	1,752	1,884	3,727	3,255	3,773	5,066	2,030	1,783	1,425	3,953
95% Confidence Interval	319–1,204	217–898	416–1,421	1,043–2,942	1,118–3,175	2,218–6,264	1,855–5,711	2,058–6,917	2,728–9,408	1,056–3,901	815–3,902	490–4,143	1,042–15,002
Depletion (%)	21.7	23	23.5	23.1	22.2	20.9	20.1	19.9	20.9	23.1	25.7	28.8	32.1
95% Confidence Interval	8.7–34.7	8.8–37.3	8.5–38.4	8.1–38.1	7.6–36.8	7.0–34.7	6.9–33.2	7.1–32.7	7.9–34.0	9.0–37.1	9.9–41.5	10.4–47.1	11.1–53.1