Agenda Item H.5
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A 2019 catch-only projection from the 2017 Lingcod Stock Assessment

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Executive Summary Stock

This a catch-only projection of an assessment of 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 (including all line 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 (including all line gears), and CA recreational fisheries. Both models start during 1889, at the onset of landings.

Landings/Catch History

Historical commercial landed 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 gear such as longline, troll, and hook and line, hereafter referred to as "fixed gear" vessels (Tables a and b, Figures a and b). Commercial discards in 2017 were modeled using discard rate and length composition data to estimate retention curves, while estimates of recreational discards were included in the total landings. For this catch only update, both commercial and recreational discards were included in their respective 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
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	224.00	790.01
2014	217.53	82.20	141.58	176.09	617.41
2015	163.40	132.54	271.95	226.17	794.07
2016	262.74	98.31	349.69	154.66	865.40
2017	507.36	114.64	164.34	175.64	961.98
2018	290.90	117.50	143.35	210.80	762.55

* Note that the WA recreational landings are entered into Stock Synthesis 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
2007	42.74	36.47	190.73	269.94
2008	34.00	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
2017	124.83	80.33	499.49	704.66
2018	203.39	73.86	382.11	659.35

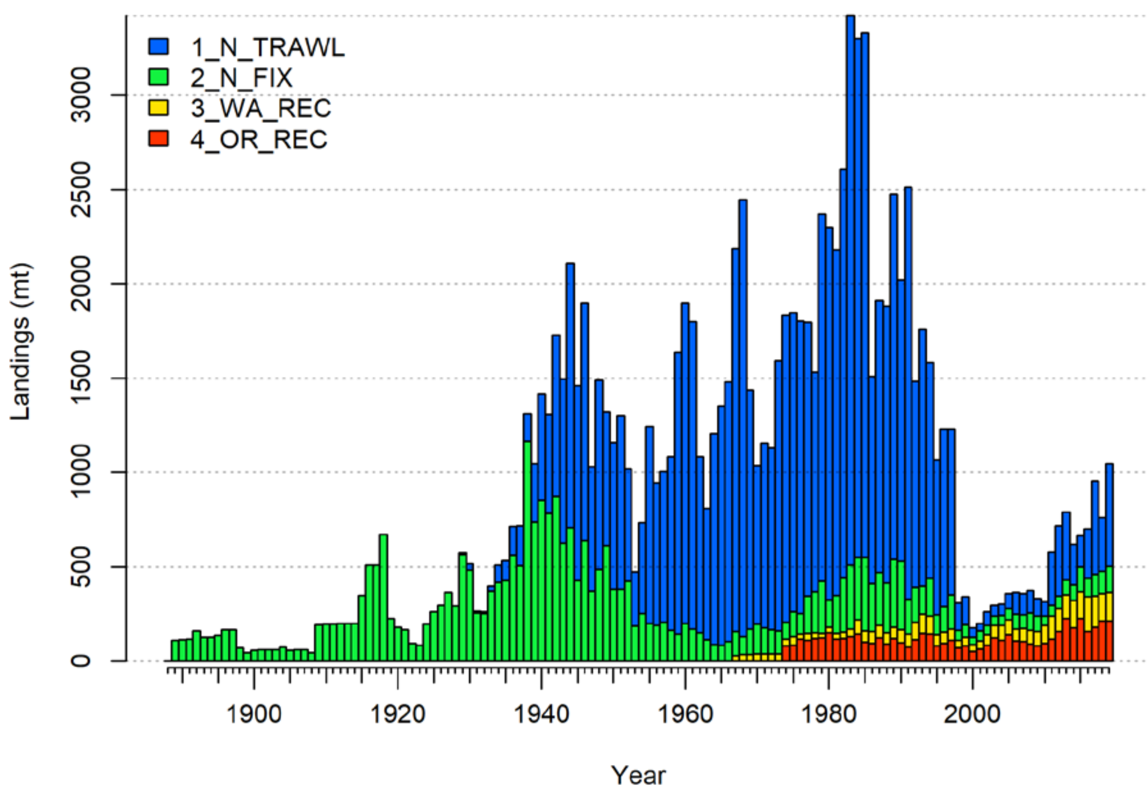

Figure a. North area landings.

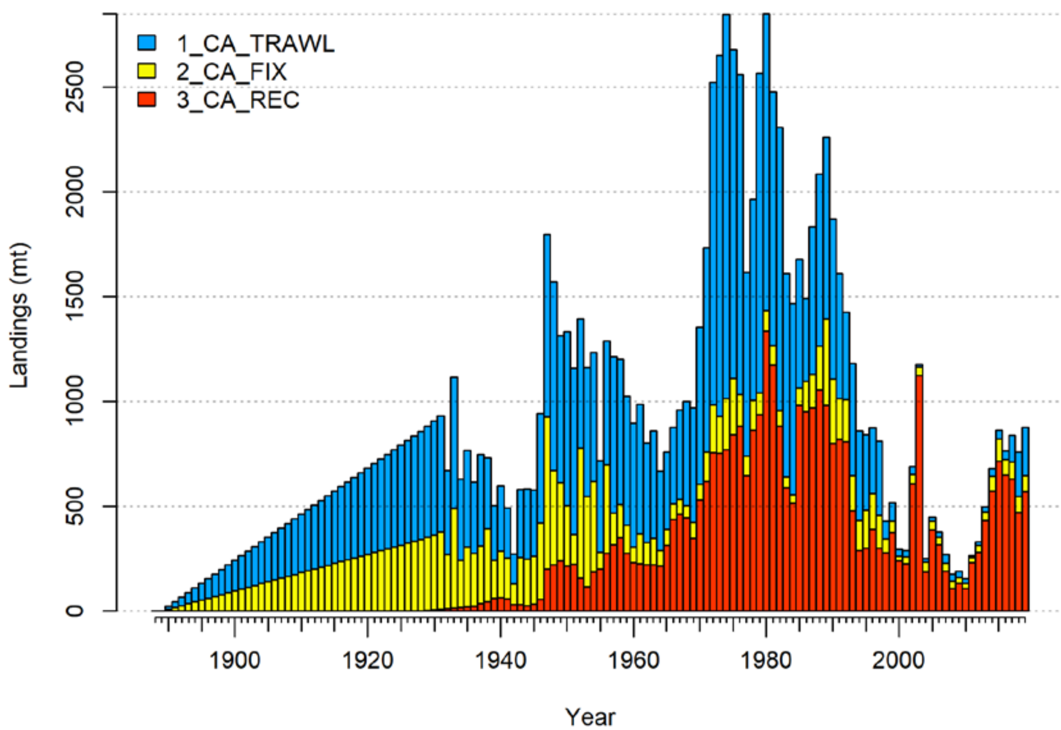

Figure b. South area landings

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 Conditional-age-at-length (CAAL) data from the NWFSC bottom trawl survey). Concerns regarding biased sub-sampling for age-determination from commercial and recreational samples lead to these age composition data being excluded from the base models. In this assessment the impact of the currently available age data are shown in model sensitivity runs. 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.

Of the key productivity parameters female natural mortality is fixed at the median of the prior, male natural mortality is estimated, and stock-recruit steepness is 0.7, in keeping with the treatment of h for similar nest guarding species (e.g. Kelp Greenling). 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 1889, just prior to reliable length and age composition entering the models. Selectivities are estimated using the double normal pattern for all fleets and surveys. Retention is estimated for the commercial fishing fleets and is fit with time blocks to account for management changes.
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. 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. If the index is included (see south model sensitivities) the estimate of unfished stock size is similar to the base model but stock status that is well below the overfished threshold.

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 (40% of the estimated unfished spawning biomass). 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 (10% of the estimated unfished spawning biomass) 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 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 (between 25% and 40% of the estimated unfished spawning biomass).

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

Years	Spawning Biomass (mt)	95% Asymptotic Interval	Estimated Depletion (%)	95% Asymptotic Interval
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	10,122–24,922	46.1	38.3–54.0
2013	19,235	11,116–27,354	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	56.0	46.4–65.5
2017	21,976	12,517–31,434	57.9	47.9–67.8
2018	22,587	12,749–32,424	59.5	49.0–69.9
2019	23,583	13,207–33,958	62.1	50.7–73.5

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

Years	Spawning Output	95% Asymptotic Interval	Estimated Depletion (%)	95% Asymptotic Interval
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
2018	6,812	1,511–12,114	33.6	10.8–56.4
2019	6,822	1,344–12,299	33.7	10.1–57.2

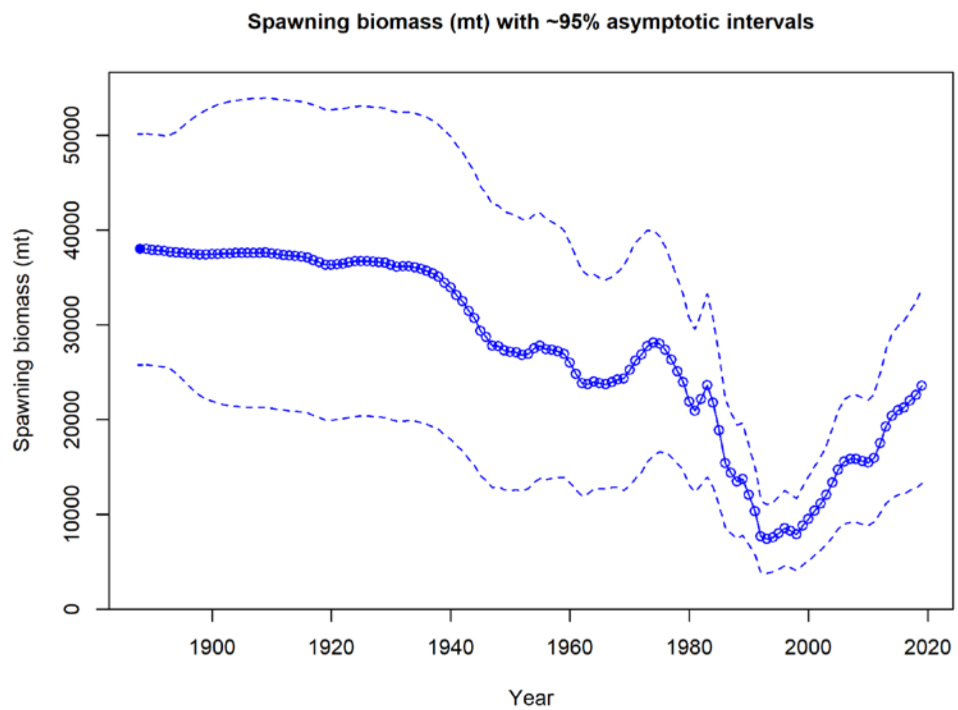

Figure c. Time series of spawning biomass, north.

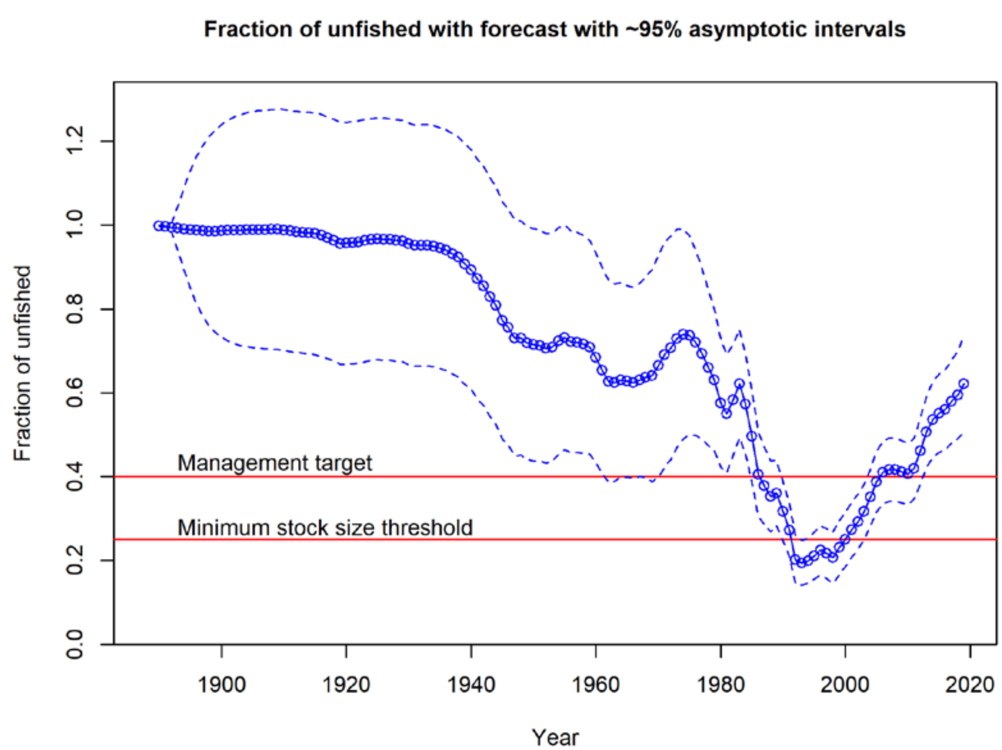

Figure d. Time series of stock depletion, north.

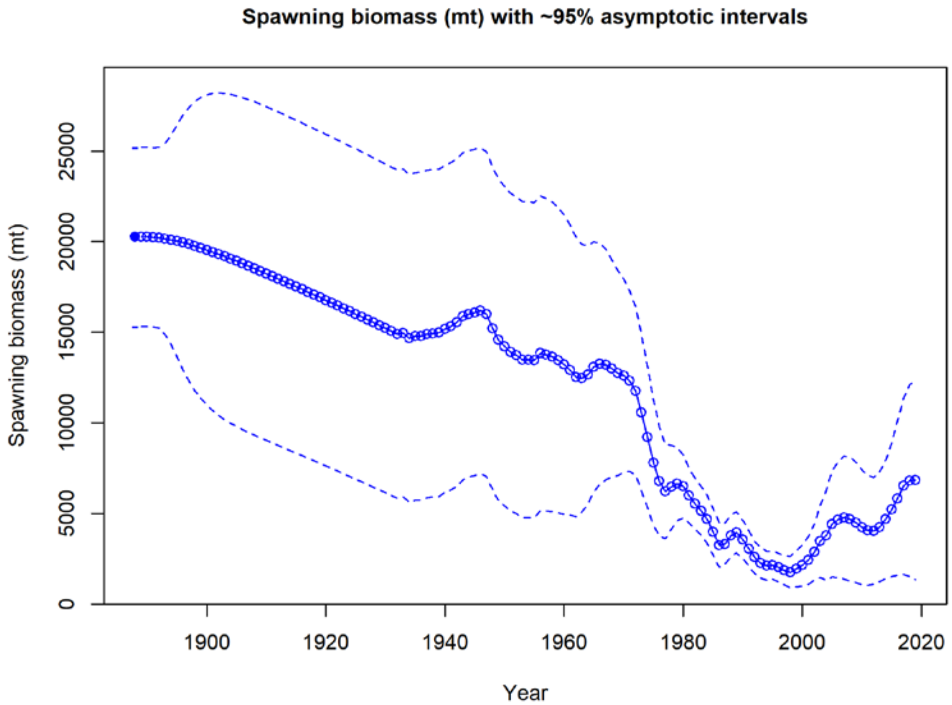

Figure e. Time series of spawning biomass, south.

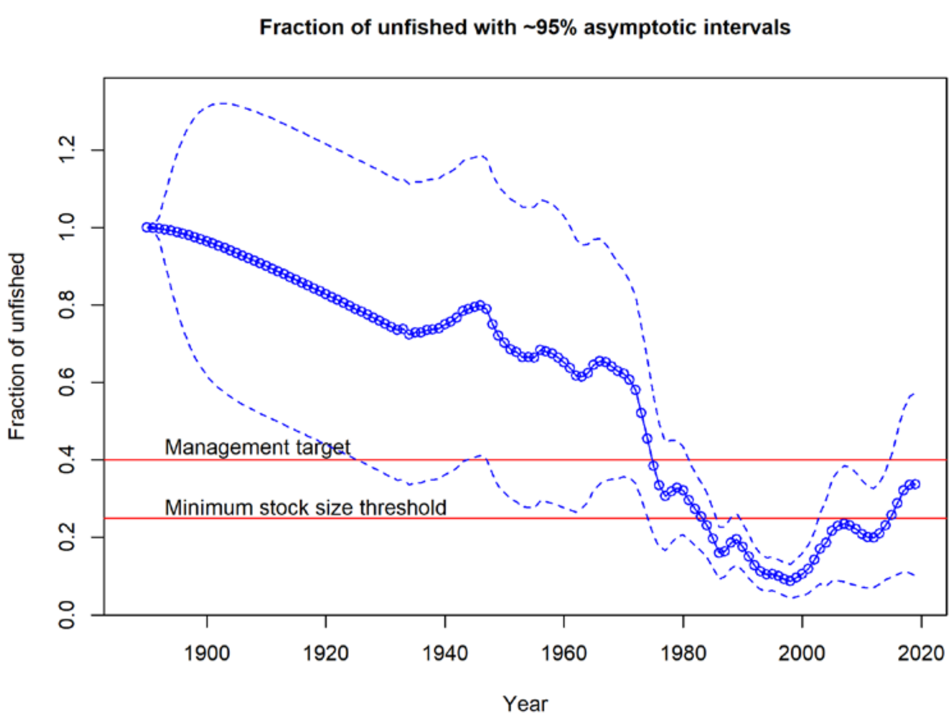

Figure f. Time series of stock depletion, south.

Recruitment

Recruitments in both the north and south were estimated from the model start (1889) 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
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	-0.440	-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	4,637–22,972	0.330	-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
2018	8,074	2,826–23,068	0	-1.078–1.078
2019	8,132	2,847–23,231	0	-1.078–1.078

Table f. Recent recruitment, south.

Years	Recruitment (1,000's)	95% Asymptotic Interval	Recruitment Deviations	95% Asymptotic Interval
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
2018	4,002	1,054–15,193	0	-1.470–1.470
2019	4,003	1,053–15,214	0	-1.470–1.470

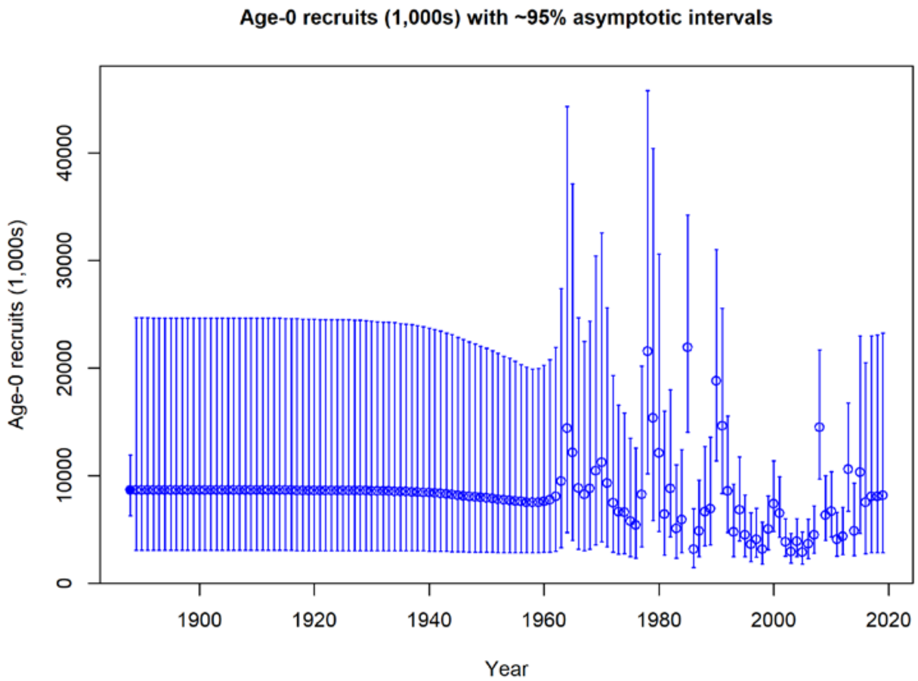

Figure g. Time series of estimated recruitment, north.

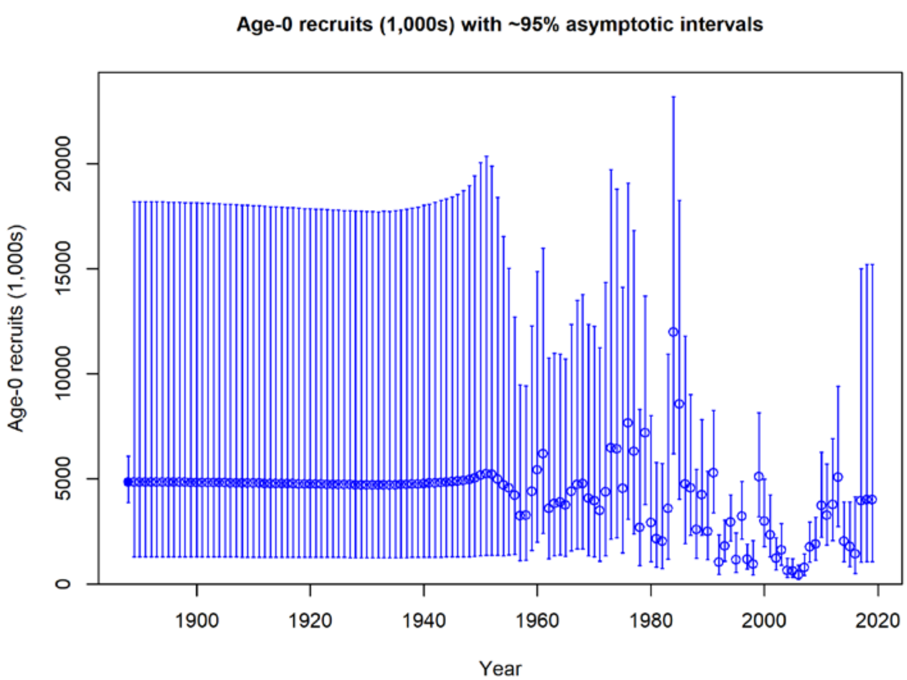

Figure h. Time series of estimated recruitments, south.

Exploitation Status

Historical harvest rates rose steadily through the 1990s, exceeding the target spawning potential ratio (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 2000s it appears that harvest rates exceeded the management target for two years. In recent years, the 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 histories in terms of both biomass and relative SPR, $(1\text{-SPR})/(1\text{-SPR}_{45\%})$, are portrayed graphically via phase plots (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
2007	23.55	14.53–32.56	0.103	0.059–0.146
2008	26.19	16.21–36.17	0.110	0.063–0.156
2009	24.44	15.05–33.83	0.099	0.057–0.140
2010	19.30	11.89–26.71	0.080	0.046–0.113
2011	28.18	17.82–38.55	0.120	0.071–0.169
2012	29.14	18.47–39.81	0.136	0.080–0.192
2013	28.65	18.08–39.22	0.139	0.082–0.196
2014	21.83	13.48–30.17	0.107	0.063–0.152
2015	23.24	14.35–32.14	0.115	0.067–0.163
2016	25.04	15.46–34.62	0.115	0.067–0.163
2018	32.95	20.67–45.22	0.156	0.090–0.222
2019	25.47	15.39–35.55	0.117	0.066–0.168

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
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
2018	0.5935	24.06–94.65	0.355	0.081–0.628
2019	0.7204	31.83–112.24	0.423	0.085–0.761

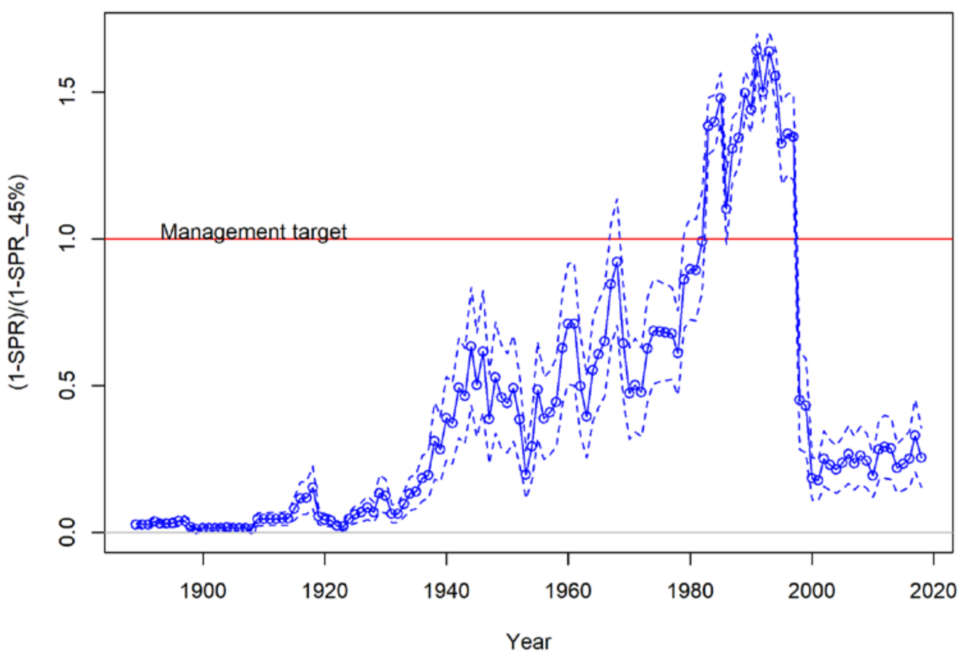

Figure i. Estimated spawning potential ratio (SPR), north. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

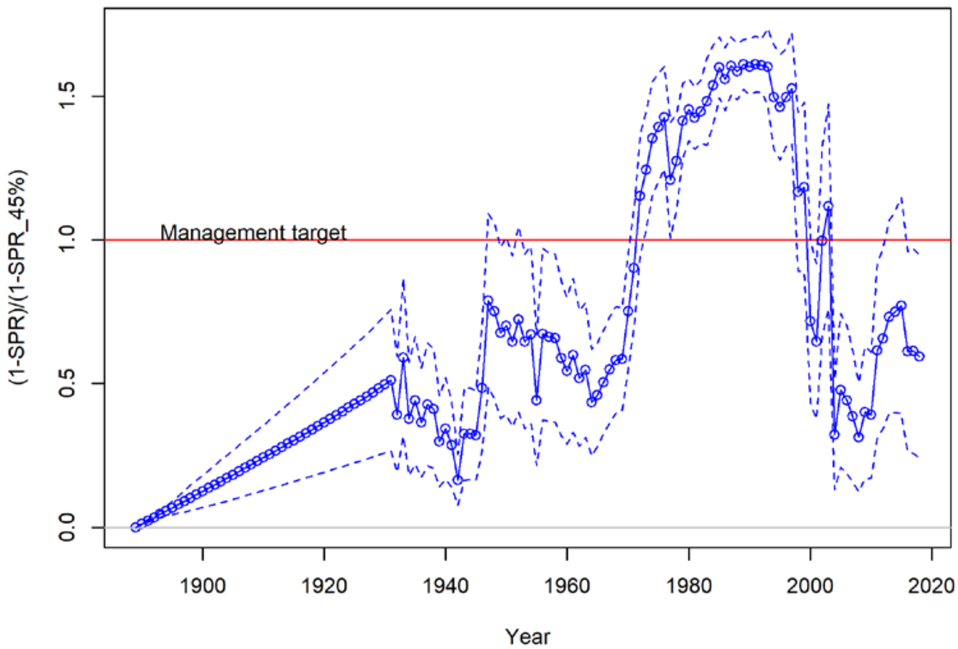

Figure j. Estimated spawning potential ratio (SPR), south. One minus SPR is plotted so that higher exploitation rates occur in the upper portion of the y-axis.

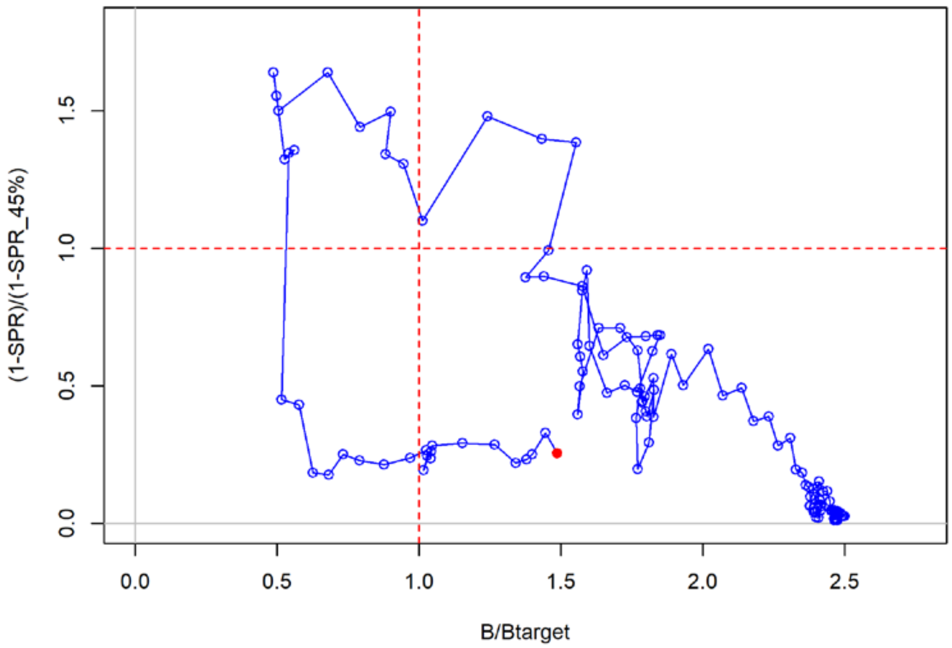

Figure k. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, north.

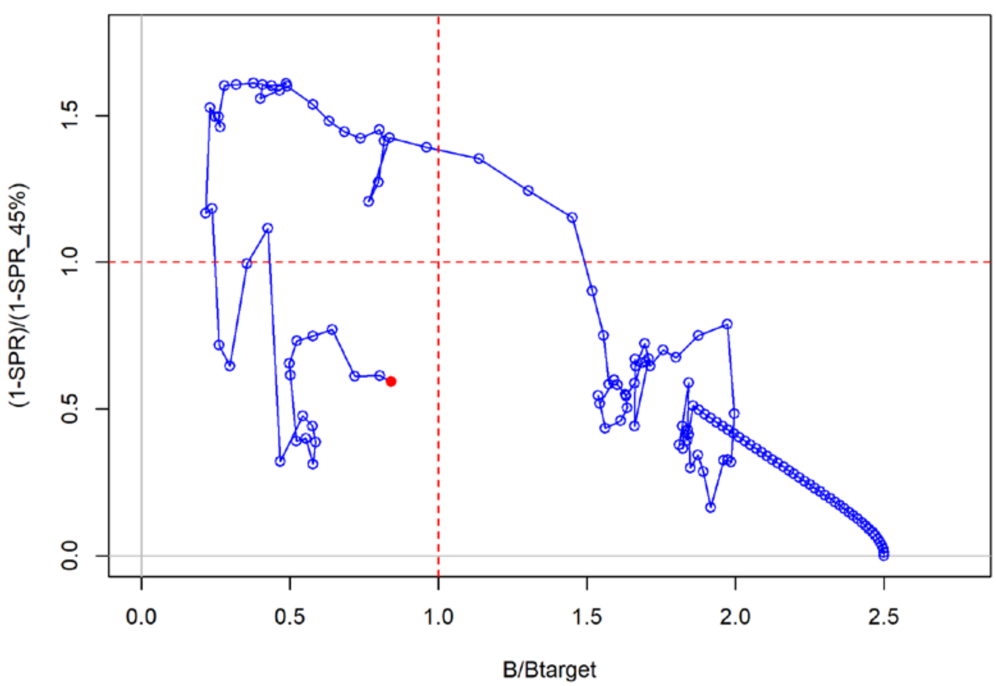

Figure l. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass, south.

Ecosystem Considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. Lingcod often feed on species of rockfish that are targeted by fisheries, potentially influencing the natural mortality of these rockfish species (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 (SB40%) from approximately the 1980s through the early 2000s. Fishing intensity since approximately 2005 has been below the target (SPR45%) 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 (2019)	23,583	13,207–33,958
Unfished Recruitment (R0)	8,664	5,870–11,458
Depletion (2019)	62.10	50.69-73.51
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 (2019)	6,822	1,344–12,299
Unfished Recruitment (R0)	4,848	3,747–5,949
Depletion (2019)	33.67	10.14–57.20
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 annual catch targets (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 48% 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 annual catch limit (ACL). Table k shows recent management quantities.

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 (Somers et al. 2017), which are the "official" records for determining whether the ACL has been exceeded. Note that the definition of ‘North’ and ‘South’ changes based on what is given in the Spatial Management Strata column.

Years	Spatial Management Strata	Coast-wide OFL	North OFL	South OFL	Coast-wide ABC	North ABC	South ABC	North Landings	South Landings	North Total Dead	South Total Dead
2007	Coast-wide	6,706	NA	NA	6,706	NA	NA	628		748	
2008	Coast-wide	5,853	NA	NA	5,853	NA	NA	551		671	
2009	Coast-wide	5,278	NA	NA	5,278	NA	NA	521		626	
2010	Coast-wide	4,829	NA	NA	4,829	NA	NA	469		503	
2011	Split at 42º N	4,961	2438	2523	4,432	2,330	2,102	578	263	611	265
2012	Split at 42º N	4,848	2251	2597	4,315	2,151	2,164	717	329	748	3349
2013	Lingcod Split at 40º10′ N	4,668	3,334	1,334	4,147	3,036	1,111	790	498	813	505
2014	Lingcod Split at 40º10′ N	4,438	3,162	1,276	3,941	2,878	1,063	619	679	632	690
2015	Lingcod Split at 40º10′ N	4,215	3,010	1,205	3,834	2,830	1,004	662	864	677	877
2016	Lingcod Split at 40º10′ N	4,027	2,891	1,136	3,665	2,719	946	702	763	723	774
2017	Lingcod Split at 40º10′ N	5,051	3,549	1,502	4,584	3,333	1,251	1,095	588	NA	NA
2018	Lingcod Split at 40º10′ N	4,683	3,310	1,373	4,254	3,110	1,144	NA	NA	NA	NA
2019	Lingcod Split at 40º10′ N	6,253	5,110	1,143	5,978	4,885	1,093	NA	NA	NA	NA
2020	Lingcod Split at 40º10′ N	5,745	4,768	977	5,492	4,558	934	NA	NA	NA	NA

Unresolved Problems and Major Uncertainties

A few outstanding issues 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, there is evidence of bias in some years with respect to age sampling. One option for dealing with this situation includes resampling the ages to ensure that they are representative of the sampled lengths. However, the SSC should agree an acceptable range of options for dealing with this issue prior to the 2019 stock assessment cycle. 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 considers the results of ongoing genetic analyses with respect to lingcod stock structure and that is able to explore linkages between the north and south regions. Current publications on lingcod stock structure suggest that 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 taken from Mexican waters. Landings of lingcod from Mexican waters need to be removed from the U.S. landings in future lingcod assessments. The south model also lacks fishery dependent age data due to a lack of sampling for age structures, which increases uncertainty in the south area model estimates. 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. Given that a majority of the jitter runs were unable to converge to the south base model, this issue should be investigated during future lingcod south assessments. Finally, the south model lacks fishery dependent age data. Obtaining recreational fishery data from California could provide improved information on recent stock trends.

Harvest Projections and Decision Table

The lingcod stock assessments are Category 1 stock assessments, thus projections and decision tables are based on using P*=0.45 and the yearly buffer reductions. The yearly buffer reductions are combined with the 40-10 harvest control rule to calculate OFLs, ABCs and ACLs. The total catches in 2019 and 2020 were set at the PFMC groundfish management team (GMT) requested values of 1,085 mt in the north and 908 and 921 mt for 2019-2020, respectively, in the south model area, the 2019-2020 exploitation rates were used to distribute catches among the fisheries. Note that the 1,085 mt, is an estimate, converted from #'s of fish for WA Rec.

Table l shows stock projections of management quantities, as requested by PFMC council staff, for both the stock assessment areas and converted to the management areas under alternative harvest policies requested by the PFMC. Note that the conversion between stock assessment areas and management areas assumes that 21.3% of the CA biomass is 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). (The equations to make this conversion, where 'S' is South, 'N' is North, 'M' is Management, and 'A' is Assessment are: $S_M = 0.787S_A$; $N_M =$

$N_A + 0.213S_A$.)

Standard harvest projections that include both management quantities and trends in stock size and status are provided in Tables m1 and m2. In the north, current medium-term projections of expected catch, spawning biomass and depletion from the base model project a declining trend through 2030 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 2030, 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. Note that without a new stock assessment the yearly buffer reductions will eventually protect stocks, while this doesn't achieve maximum sustainable yield (MSY), it does leave fish in the ocean to harvest at a later time.

Decision tables are provided in Tables n and o. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviation for the 2017 spawning biomass from the base model. Specifically, the 2017 spawning biomass for the high and low states of nature are given by the base model mean +/-1.15*standard deviation (the 12.5th and 87.5th percentiles). A search across fixed values of Ro was used to attain the 2017 spawning biomass values for the high and low states of nature. The high catch streams were based on the 40-10 harvest control rule. At the request of the PFMC GMT representative on the STAR panel the moderate catch streams were set to 40% ACL attainment for the north management area and 70% ACL attainment in the south management area. Finally, the low catch stream was set to ~700 mt, a level similar to recent average catches.

In the north, current medium-term forecasts based on the alternative states of nature project that the stock will not fall below the target stock size. Note that the catches specified in the ACL scenario (ranging from 5,009 to 3,469 mt) are much larger than recent landings (~900 mt). 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. However, catching the full ACL catches result in stock declines at the low state of nature and modest stock increases under the base case and high state of nature.

Table l. The PFMC current harvest control rule (HCR), all units are in metric tons. Note that the south area ACL has the 40-10 control rule catch reduction applied because the stock is estimated to be in the precautionary zone. The HCRs implements a GMT request to assume partial attainment of the 2019-2020 ACLs of 1,085 mt in the north model area and 908 and 921 mt for 2019-2020, respectively, in the south model area. Full ACL attainment from 2021 forward is then used. The current HCR implements the yearly buffer reductions for a P* = 45, category 1 stock in the north and south. (Note that the 1,085 mt, is an estimate, converted from #'s of fish for WA Rec.)

Year	Area	Buffer	Assessment Areas	Management Areas	Assessment Areas	Management Areas	Assessment Areas	Management Areas
			OFL		ABC		ACL	
2021	North	0.926	5,477	5,816	5,071	5,386	5,071	5,369
2022	North	0.922	5,034	5,395	4,641	4,974	4,641	4,958
2023	North	0.917	4,695	5,074	4,305	4,653	4,305	4,639
2024	North	0.913	4,453	4,844	4,066	4,422	4,066	4,410
2025	North	0.909	4,284	4,682	3,894	4,256	3,894	4,245
2026	North	0.904	4,160	4,563	3,761	4,125	3,761	4,115
2027	North	0.900	4,066	4,472	3,660	4,025	3,660	4,017
2028	North	0.896	3,991	4,400	3,576	3,942	3,576	3,935
2029	North	0.892	3,930	4,341	3,505	3,872	3,505	3,866
2030	North	0.887	3,879	4,292	3,441	3,807	3,441	3,802
2021	South	0.926	1,594	1,255	1,476	1,162	1,400	1,102
2022	South	0.922	1,695	1,334	1,563	1,230	1,490	1,172
2023	South	0.917	1,780	1,401	1,632	1,285	1,567	1,233
2024	South	0.913	1,834	1,444	1,675	1,318	1,617	1,273
2025	South	0.909	1,868	1,470	1,698	1,336	1,647	1,296
2026	South	0.904	1,890	1,487	1,709	1,345	1,664	1,310
2027	South	0.900	1,906	1,500	1,716	1,350	1,677	1,320
2028	South	0.896	1,919	1,510	1,719	1,353	1,687	1,327
2029	South	0.892	1,930	1,519	1,721	1,355	1,693	1,333
2030	South	0.887	1,939	1,526	1,720	1,353	1,697	1,335

Table m1. Model projections, north model area (WA and OR).

Year	Buffers (P* = 0.45; Cat. 1 stock)	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	NA	5,173.6	1,085.1	37,306.0	23,582.7	62.1%
2020	NA	5,342.4	1,086.3	38,407.4	24,437.7	64.4%
2021	0.926	5,476.5	5,098.6	39,412.3	25,187.0	66.3%
2022	0.922	5,033.9	4,667.4	36,458.1	23,285.8	61.3%
2023	0.917	4,694.8	4,330.8	34,073.3	21,626.6	57.0%
2024	0.913	4,453.2	4,091.1	32,234.5	20,267.0	53.4%
2025	0.909	4,283.8	3,919.4	30,800.4	19,187.5	50.5%
2026	0.904	4,160.4	3,787.0	29,667.4	18,329.8	48.3%
2027	0.900	4,066.3	3,686.2	28,762.8	17,642.0	46.5%
2028	0.896	3,991.2	3,603.1	28,030.1	17,084.1	45.0%
2029	0.892	3,929.7	3,532.9	27,432.5	16,629.1	43.8%
2030	0.887	3,878.9	3,469.0	26,943.3	16,257.1	42.8%

Table m2. Model projections with yearly buffer reductions, south model area (CA).

Year	Buffers (P* = 0.45; Cat. 1 stock)	Predicted OFL (mt)	ACL Catch (mt)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	NA	1,634.9	908.2	10,896.0	6,821.6	33.7%
2020	NA	1,512.6	920.8	11,161.0	6,712.2	33.1%
2021	0.926	1,594.5	1,400.2	11,649.4	6,848.1	33.8%
2022	0.922	1,695.1	1,489.5	11,852.8	6,920.4	34.2%
2023	0.917	1,780.1	1,566.8	12,056.3	7,035.5	34.7%
2024	0.913	1,834.4	1,617.1	12,227.7	7,140.3	35.2%
2025	0.909	1,867.9	1,647.3	12,364.8	7,227.7	35.7%
2026	0.904	1,889.9	1,664.4	12,481.1	7,303.1	36.1%
2027	0.900	1,906.2	1,677.3	12,585.6	7,371.7	36.4%
2028	0.896	1,919.0	1,686.6	12,680.5	7,435.0	36.7%
2029	0.892	1,929.6	1,693.5	12,766.7	7,493.3	37.0%
2030	0.887	1,938.8	1,696.8	12,845.3	7,547.1	37.3%

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 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.
7. Given that a majority of the jitter runs were unable to converge to the south base model, this issue should be investigated during future lingcod south assessments.
8. The south model lacks fishery dependent age data. Obtaining recreational fishery data from California could provide improved information on recent stock trends.

Rebuilding Projections

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

Table n. North model decision table of 12-year projections for alternate states of nature (columns) and management options (rows). Summary of model outputs for the preferred council HCR, north (WA + OR), using the yearly buffer reductions. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviation for the 2017 spawning biomass from the base model. Specifically, the 2017 spawning biomass for the high and low states of nature are given by the base model mean +/-1.15*standard deviation (the 12.5th and 87.5th percentiles). A search across fixed values of Ro was used to attain the 2017 spawning biomass values for the high and low states of nature. The total catches in 2019 and 2020 were set at the GMT requested values of ~1,085 mt.

			State of nature					
			Low 2017 Spawning Biomass *Ln(Ro)=8.81*		ase 2017 Spawning Biomass *Ln(R0) = 9.0669*		High 2017 Spawning Biomass *Ln(Ro)=9.8*	
Probability			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
~700mt Constant Catch	2021	700	18,007	61.20%	25,187	66.30%	58,665	74.20%
	2022	700	18,717	63.60%	26,106	68.70%	60,594	76.70%
	2023	700	19,400	65.90%	26,968	71.00%	62,350	78.90%
	2024	700	20,038	68.10%	27,760	73.10%	63,930	80.90%
	2025	700	20,623	70.10%	28,478	75.00%	65,339	82.70%
	2026	700	21,154	71.90%	29,122	76.70%	66,581	84.30%
	2027	700	21,631	73.50%	29,696	78.20%	67,672	85.60%
	2028	700	22,059	75.00%	30,206	79.50%	68,629	86.90%
	2029	700	22,442	76.30%	30,658	80.70%	69,466	87.90%
	2030	700	22,782	77.40%	31,056	81.80%	70,196	88.80%
~40% ACL	2021	2,039	18,006	61.20%	25,187	66.33%	58,665	74.25%
	2022	1,867	17,864	60.72%	25,247	66.49%	59,727	75.59%
	2023	1,732	17,806	60.52%	25,365	66.79%	60,734	76.86%
	2024	1,636	17,834	60.62%	25,545	67.27%	61,699	78.09%
	2025	1,568	17,931	60.95%	25,774	67.87%	62,618	79.25%
	2026	1,515	18,073	61.43%	26,032	68.55%	63,477	80.34%
	2027	1,474	18,242	62.01%	26,304	69.27%	64,273	81.34%
	2028	1,441	18,428	62.64%	26,580	70.00%	65,006	82.27%
	2029	1,413	18,623	63.30%	26,854	70.72%	65,679	83.12%
	2030	1,388	18,820	63.97%	27,122	71.42%	66,293	83.90%
ACL	2021	5,099	18,007	61.21%	25,187	66.33%	58,665	74.25%
	2022	4,667	15,912	54.09%	23,286	61.32%	57,737	73.07%
	2023	4,331	14,092	47.90%	21,627	56.95%	56,938	72.06%
	2024	4,091	12,602	42.83%	20,267	53.37%	56,340	71.30%
	2025	3,919	11,410	38.78%	19,188	50.53%	55,938	70.79%
	2026	3,787	10,446	35.51%	18,330	48.27%	55,691	70.48%
	2027	3,686	9,646	32.79%	17,642	46.46%	55,564	70.32%
	2028	3,603	8,961	30.46%	17,084	44.99%	55,529	70.28%

	2029	3,533	8,364	28.43%	16,629	43.79%	55,565	70.32%
	2030	3,469	7,832	26.62%	16,257	42.81%	55,655	70.44%

Table o. South model decision table of 12-year projections for alternate states of nature (columns) and management options (rows). Summary of model outputs for the preferred council HCR, south (CA), using the yearly buffer reductions. Uncertainty in management quantities for the north and south models was characterized using the asymptotic standard deviation for the 2017 spawning biomass from the base model. Specifically, the 2017 spawning biomass for the high and low states of nature are given by the base model mean +/- 1.15*standard deviation (the 12.5th and 87.5th percentiles). A search across fixed values of Ro was used to attain the 2017 spawning biomass values for the high and low states of nature. The total catches in 2019 and 2020 were set at the GMT requested values of 908 and 921 mt, respectively.

			State of nature					
			Low 2017 Spawning Biomass *Ln(Ro)=8.122*		e 2017 Spawning Biomass *Ln(R0) = 8.493*		High 2017 Spawning Biomass *Ln(Ro)=8.742*	
Probability			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
~700mt Constant Catch	2021	700	3,008	21.67%	6,848	33.80%	9,941	37.71%
	2022	700	3,285	23.66%	7,336	36.21%	10,641	40.37%
	2023	700	3,620	26.08%	7,923	39.11%	11,468	43.50%
	2024	700	3,964	28.56%	8,537	42.14%	12,332	46.78%
	2025	700	4,302	30.99%	9,144	45.14%	13,185	50.01%
	2026	700	4,637	33.40%	9,734	48.04%	14,009	53.14%
	2027	700	4,971	35.82%	10,300	50.84%	14,794	56.12%
	2028	700	5,305	38.22%	10,839	53.50%	15,536	58.93%
	2029	700	5,634	40.59%	11,348	56.01%	16,227	61.56%
	2030	700	5,955	42.90%	11,823	58.36%	16,867	63.98%
~75% ACL	2021	1,050	3,008	21.67%	6,848	33.80%	9,941	37.71%
	2022	1,117	3,088	22.24%	7,129	35.19%	10,432	39.57%
	2023	1,175	3,180	22.91%	7,465	36.84%	11,006	41.75%
	2024	1,213	3,249	23.40%	7,795	38.48%	11,583	43.94%
	2025	1,235	3,296	23.75%	8,107	40.01%	12,139	46.05%
	2026	1,248	3,335	24.02%	8,401	41.47%	12,668	48.05%
	2027	1,258	3,370	24.28%	8,681	42.85%	13,169	49.95%
	2028	1,265	3,406	24.54%	8,948	44.17%	13,642	51.75%
	2029	1,270	3,440	24.79%	9,200	45.41%	14,084	53.43%
	2030	1,273	3,474	25.03%	9,437	46.58%	14,495	54.98%
ACL	2021	1,400	3,008	21.67%	6,848	33.80%	9,941	37.71%
	2022	1,490	2,892	20.83%	6,920	34.16%	10,224	38.78%
	2023	1,567	2,772	19.97%	7,036	34.73%	10,571	40.10%
	2024	1,617	2,623	18.89%	7,140	35.24%	10,916	41.41%
	2025	1,647	2,453	17.67%	7,228	35.67%	11,241	42.64%
	2026	1,664	2,270	16.35%	7,303	36.05%	11,548	43.81%
	2027	1,677	2,078	14.97%	7,372	36.39%	11,839	44.91%
	2028	1,687	1,877	13.52%	7,435	36.70%	12,113	45.95%
	2029	1,693	1,664	11.99%	7,493	36.99%	12,371	46.93%
	2030	1,697	1,438	10.36%	7,547	37.25%	12,611	47.84%

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

Years	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	201
1-SPR/ 1-SPR_45%	0.24	0.26	0.24	0.19	0.28	0.29	0.29	0.22	0.23	0.25	0.33	0.25	
Exploitation Rate	0.1	0.11	0.1	0.08	0.12	0.14	0.14	0.11	0.11	0.11	0.16	0.12	
Age 3+ Biomass (mt)	23,974	23,493	23,078	23,041	27,371	29,480	31,302	31,650	31,634	33,759	34,064	36,070	3
Spawning Biomass (mt)	15,833	15,842	15,627	15,441	15,912	17,522	19,235	20,366	20,939	21,258	21,976	22,587	2
95% Confidence Interval	9,111–22,556	9,095–22,589	8,940–22,314	8,826–22,056	9,150–22,674	10,122–24,922	11,116–27,354	11,723–29,009	12,019–29,858	12,150–30,365	12,517–31,434	12,749–32,424	1 3
Recruitment	4,460	14,491	6,292	6,671	4,058	4,319	10,580	4,851	10,322	7,516	8,037	8,074	8
95% Confidence Interval	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	4,637–22,972	2,755–20,502	2,813–22,958	2,826–23,068	2 2
Depletion (%)	41.7	41.7	41.2	40.7	41.9	46.1	50.7	53.6	55.1	56	57.9	59.5	
95% Confidence Interval	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	49.0–69.9	5

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

Years	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1-SPR/ 1-SPR_45%	0.39	0.31	0.4	0.39	0.62	0.66	0.73	0.75	0.77	0.61	0.61	0.59	NA
Exploitation Rate	0.19	0.13	0.15	0.13	0.21	0.26	0.35	0.43	0.48	0.37	0.39	0.35	NA
Age 3+ Biomass (mt)	7,563	7,229	6,773	6,330	6,321	6,419	7,323	8,207	9,240	10,690	11,230	11,252	10,896
Spawning Biomass (mt)	4,757	4,681	4,496	4,232	4,065	4,032	4,242	4,674	5,209	5,827	6,509	6,812	6,822
95% Confidence Interval	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	1,511–12,114	1,344–12,299
Recruitment	769	1,752	1,884	3,727	3,255	3,773	5,066	2,030	1,783	1,425	3,953	4,002	4,003
95% Confidence Interval	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	1,054–15,193	1,053–15,214
Depletion (%)	23.5	23.1	22.2	20.9	20.1	19.9	20.9	23.1	25.7	28.8	32.1	33.6	33.7
95% Confidence Interval	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	10.8–56.4	10.1–57.2