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Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2025/054

OUTSIDE LINGCOD (*OPHIODON ELONGATUS*) STOCK ASSESSMENT FOR BRITISH COLUMBIA IN 2025

CONTEXT

This Science Advisory Report stems from the regional peer review on April 8–10, 2025, on the Assessment of Lingcod (*Ophiodon elongatus*) (Outside) in British Columbia. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Lingcod (*Ophiodon elongatus*) is a commercially important species of groundfish. Lingcod is a large, predatory fish in the Hexagrammidae family, unique to the west coast of North America. Key results from the stock assessment for British Columbia (BC) outside waters (PMFC[1] Areas 3CD + 5ABCDE) in 2025 are reported here. Harvest advice is required to determine if current harvest levels are sustainable and compliant with DFO's Decision-Making Framework Incorporating the Precautionary Approach.

SCIENCE ADVICE

The results below are reported as medians (with 90% credibility intervals in parentheses derived from the base case run).

Status

- The probability that the female spawning stock biomass (B) at the beginning of 2025 is greater than the limit reference point (LRP: 0.2 B_0) and candidate upper stock reference points (USRs: 0.35 and 0.4 B_0) is > 0.99, placing the outside stock in the Healthy zone of the Precautionary Approach (PA) framework.
- Current stock status (B_{2025} / B_0) is 1.120 (0.961, 1.290).
- There is a very high probability (> 0.99) that the fishing mortality rate (F) in 2024 was below all of the candidate removal reference (RR) rates.

Trends

- Annual stock status (B_t / B_0) for Outside Lingcod slowly trended downward from 1927 to 1978, then fluctuated on a roughly decadal basis between values of 0.5 and 1.25 until 2025. At no time did the 95% credibility envelope fall below either candidate USR.

Ecosystem and Climate Change Considerations

- Higher recruitment deviations were associated with higher sea floor oxygen, lower sea floor salinity, and lower lagged North Pacific Gyre Oscillation (NPGO). Recruitment deviations

[1] Pacific States Marine Fisheries Commission. PMFC areas are similar to but differ slightly from GMU areas.

were weakly correlated with biomass of surface phytoplankton, smaller copepod species, and Pacific Herring. No single environmental variable appeared to have much predictive power alone.

- Coastwide indices of average body condition tended to be highest for all sex and maturity classes at the start of the environmental time series (2002). Body condition appeared positively associated with warmer, fresher, and more oxygen-rich water chemistry and Pacific Herring spawning stock biomass (SSB). However, in contrast to recruitment, immature body condition was associated with a higher NPGO index on a two-year lag.

Stock Advice

- Decision tables based on B_0 reference points and using constant-catch policies up to 7,000 t/y show:
  - > 95% probability of remaining above the LRP in 10 years at catches <= 6,500 t/y;
  - > 90% probability of remaining above both candidate USRs in 10 years at catches <= 5,000 t/y.
- Candidate TRPs are 0.4, 0.45, and 0.5 B_0.
- The probability of remaining below the three RR rates associated with the candidate TRPs in 10 years at catches <= 4,500 t/y is >= 64%.
- The Outside Lingcod stock is expected to decline over the next 10 years, even under a no-catch scenario as the cohort from the strong 2016 recruitment event ages out of the population. However, the stock is expected to remain above the LRP and candidate USRs with a very high probability (> 99%) at catch levels up to 3,500 t/y (compared to average annual coastwide catches of 1,585 t/y for 2020–2025).

Other Management Questions

- No biological justification was found to support assessing the outside stock at a finer scale than the outside coastwide level (excluding PMFC Area 4B).

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

2024 Terms of Reference

Assessment Type

Full Assessment: Full peer-reviewed stock assessment

Most Recent Assessment Date

1. Last Full Assessment: Outside Lingcod in 2010, King et al. (2012)
2. Last Interim-Year Update: N/A

Assessment Approach

1. Single stock assessment model
2. Statistical catch-at-age (fitted to data using the Stock Synthesis 3 model platform)

3. A two-sex, age-structured, stochastic model was used to reconstruct the population trajectory of Outside Lingcod from 1927 to the beginning of 2025 using NOAA's Stock Synthesis 3 model platform (v.3.30.23.1, Methot et al. 2024). The population was assumed to be in equilibrium with average recruitment and with no fishing at the beginning of the reconstruction (in 1927). Outputs comprised estimates from Bayesian posteriors from Markov Chain Monte Carlo (MCMC) runs. Additional model assumptions were evaluated across 21 sensitivity runs (see Appendix Table 1 for descriptions). Ecosystem considerations were explored outside of the assessment model.

Stock Structure Assumption

Stock overview information:

- One stock coastwide (exclusive of PMFC 4B), corresponding to the PMFC boundaries 3CD + 5ABCDE, with a set of derived parameters, including reference points;
- Both PMFC and Groundfish Management Unit (GMU) reporting areas resemble each other, with small differences between the two area definitions, primarily for the inshore areas. It is not expected that these small differences will cause a mismatch in advice between the assessed and managed areas at the scale of this analysis.

Reference Points

The unfished (B_0) reference points used were based on an approximate equivalence to the provisional Precautionary Approach framework of 0.4 and 0.8 B_{MSY} reference points (DFO 2006, 2009). Estimates used for analysis and decisions for each stock are derived from a Bayesian analysis that yielded a posterior set of ~100,000 simulations. MSY-based reference points are not appropriate for characterizing stock status and exploitation rate because they are strongly determined by the steepness parameter, which is highly uncertain in this assessment.

- Limit Reference Point (LRP): 0.2 B_0;
- Candidate Upper Stock Reference (USR): 0.35 B_0 and 0.4 B_0;
- Candidate Removal Reference (RR): $F_{0.4\,\mathrm{B0}}$, $F_{0.45\,\mathrm{B0}}$, and $F_{0.5\,\mathrm{B0}}$;
- Candidate Target Reference Point (TRP): 0.4 B_0, 0.45 B_0, and 0.5 B_0.

Data

The main data inputs to the SS3 coastwide model included:

- Catch time series (1927–2024) for the outside waters of BC (3CD + 5ABCDE);
- Recreational catch data from 1985 to 2024, and imputed catch data from 1927 to 1985;
- Abundance index series from four surveys (no commercial CPUE index series were used);
- Age composition data from three fleets (bottom trawl, bottom trawl discard[2], and hook and line) and three surveys (synoptic bottom trawl [SYN], hard bottom longline [HBLL], and the International Pacific Halibut Commission Fishery Independent Setline Survey [IPHC]);
- Fixed biological parameters (growth, maturity) estimated externally using data from BC research/ survey and commercial fishery trips.

[2] Bottom trawl discard uses cohort slicing to assign ages without error based on the growth model. See Research Document for full description.

ASSESSMENT

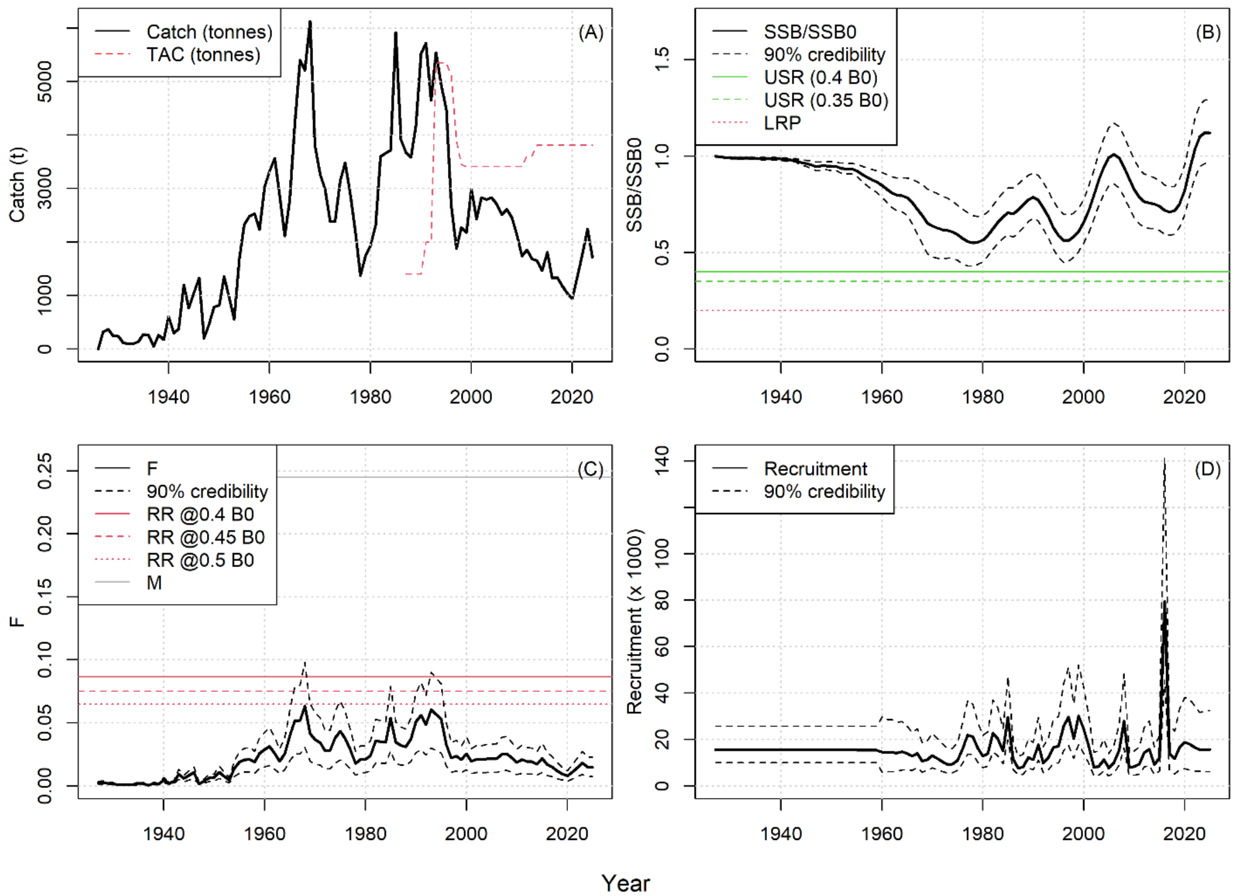

Figure 1. Coastwide (excluding Area 4B): (A) Reconstructed commercial catch in tonnes (solid black line) and total allowable catch in tonnes (dashed red line), (B) female spawning stock biomass (SSB) relative to the unfished biomass (B0) with the LRP (0.2 B0, red dotted line) and candidate USRs (0.35 B0 and 0.4 B0, dashed and solid green lines, respectively), (C) fishing mortality rate (F) in relation to the proposed RR rates (F0.4 B0, F0.45 B0, and F0.5 B0) and natural mortality (M), (D) recruitment (thousands of age-0 fish). Mean values in panels B - D appear as solid black lines, and the 90% credibility envelopes are delimited by dashed black lines.

Historical and Recent Stock Trajectory and Trends

Biomass

Female spawning biomass at the beginning of 2025 (B_{2025}) was above the LRP biomass and above the candidate USRs biomass, with the female mature biomass estimated to be 1.120 (0.961, 1.290) times greater than B_0 in 2025 (Figure 1B, Table 1). The female spawning stock biomass fluctuates, but remains above the candidate USRs since 1927.

The probability that the female spawning biomass at the beginning of 2025 (B_{2025}) is greater than the LRP and both the candidate USRs is > 0.99. There is also a very high probability (> 0.99) that the fishing mortality rate in 2024 (F_{2024}) is below all of the candidate RR rates (Figure 1C).

Recruitment

The largest recruitment event for Lingcod occurred in 2016 (Figure 1D), which coincides with large recruitment events for several other groundfish species in the region (e.g., Bocaccio and Petrale sole) (DFO 2024, DFO 2025). The stock is projected to decline as this cohort ages. A large 2021 recruitment event may be evident in the length data and length-based sensitivity analysis.

Table 1. Derived parameter quantiles from 10,000 samples of the MCMC posterior of the coastwide (excluding Area 4B) base case model. Definitions: B_{2025} – spawning biomass at the start of 2025, B_0 – unfished equilibrium spawning biomass, F_{2024} – fishing mortality rate in 2024, $F_{0.4\,B0}$ – equilibrium fishing mortality rate at 0.4 B_0. All biomass (B) values are in tonnes.

Quantity	5%	25%	50%	75%	95%
B_{2025}	42,328	54,562	67,759	86,573	138,272
B_{2025} / B_0	0.961	1.053	1.120	1.188	1.290
B_0	42,969	51,406	60,386	73,443	110,332
B_{2025} / 0.2 B_0	4.804	5.265	5.599	5.940	6.449
B_{2025} / 0.35 B_0	2.745	3.009	3.199	3.394	3.685
B_{2025} / 0.4 B_0	2.402	2.632	2.800	2.970	3.224
F_{2024}	0.007	0.012	0.015	0.018	0.023
$F_{0.4\,B0}$	0.086	0.136	0.172	0.211	0.267
$F_{0.45\,B0}$	0.100	0.156	0.198	0.243	0.307
$F_{0.5\,B0}$	0.115	0.181	0.228	0.280	0.355

History of Harvest and Total Allowable Catch

BC Outside Lingcod commercial catch was reconstructed back to 1927 (Figure 1A). The assessment model started from assumed equilibrium conditions in 1927. Table 2 shows catches since the implementation of validated releases by the at-sea observer (1996 trawl) or electronic monitoring (2006 line and trap) programs. Total Allowable Catch (TAC) in fishing year 2024 (Feb 21, 2024 to Feb 20, 2025, Trawl + Hook & Line) was 950 t in Area 3C, 800 t in Area 3D, 1,062 t in Areas 5AB, 1,000 t in Areas 5CDE, and 3,812 t coastwide (excluding Area 4B).

Recreational catch from the creel survey that began in 1984 was included, with data back to 1927 interpolated following Huynh et al. (2024). Missing coastwide data after 1984 were estimated using Generalized Linear Models (GLMs). First Nations Food, Social and Ceremonial (FSC) catch is not included except for dual fishing catch recorded as commercial catch. The full catch history is available in the Research Document (Haggarty et al., in prep.[3]).

[3] Haggarty, D.R., Carruthers, T.R., Walker, L.C., English, P.A., Huynh, Q.C. In prep. Outside Lingcod (*Ophiodon elongatus*) Stock Assessment for British Columbia in 2024. DFO Can. Sci. Advis. Sec. Res. Doc.

*Table 2. Recorded catches of Outside Lingcod (landings and releases, in tonnes). All landings were validated by the Dockside Monitoring Program. * The line and trap releases were recorded as counts and converted to weights using an average round weight of 1.9 kg for sub-legal Lingcod and 5.7 kg for legal Lingcod.*

Year	Trawl (landed)	Trawl (released)	Line (landed)	Line (released) *	Trap (landed)	Trap (released) *	Total
1996	1881.68	79.51	-	-	-	-	1961.19
1997	1117.65	117.17	-	-	-	-	1234.82
1998	1236.69	199.85	-	-	-	-	1436.54
1999	1074.17	105.85	-	-	-	-	1180.02
2000	1853.03	110.78	-	-	-	-	1963.81
2001	1377.57	99.1	-	-	-	-	1476.67
2002	1808.96	187.76	-	-	-	-	1996.72
2003	1750.69	154.19	-	-	-	-	1904.88
2004	1771.59	97.69	-	-	-	-	1869.28
2005	1697.98	70.03	-	-	-	-	1768.01
2006	1834.5	58.9	573.5	74.11	0.73	1.45	2543.19
2007	1700.04	76.99	777.6	88.67	0	1.51	2644.81
2008	1373.14	84.38	932.88	88.21	0.06	1.89	2480.56
2009	1255.42	79.14	760.66	72.72	0.01	0.52	2168.47
2010	914.58	89.89	685.41	72.31	0.05	0.43	1762.67
2011	973.29	113.36	706.48	63.02	0	0.13	1856.28
2012	643.54	135.01	841.41	72.52	0.11	0.23	1692.82
2013	754.49	60.6	782.01	54.59	0.04	0.29	1652.02
2014	723.06	20.11	675.13	45.23	0.39	0.13	1464.05
2015	790.17	38.77	920.49	42.07	0.45	0.81	1792.76
2016	471.5	20.29	784.73	42.86	0.1	0.04	1319.52
2017	422.14	13.9	835.01	42.32	0.51	0.41	1314.29
2018	321.09	35	761.99	52.12	0.02	0.11	1170.33
2019	175.76	23.75	777.04	109.03	0.02	0.12	1085.72
2020	301.77	42.13	550.67	74.72	1.04	0.2	970.53
2021	492.68	45.44	748.46	58.16	3.71	1.18	1349.63
2022	739.44	62.15	871.95	58.55	2.45	2.45	1736.99
2023	901.32	105.46	1132.58	58.7	0.94	2.37	2201.37
2024	831.52	101.43	683.72	50.2	1.12	0.16	1668.15

Projections

As the 2016 cohort ages out of the population, it can be expected that the stock will decline, and assuming a return to average recruitment levels (Figure 2). Base Case model projections of various constant catch policies suggest a high probability of remaining above the LRP or the candidate USRs over the next ten years (Table 3, 4, and 5). The probabilities of fishing mortality F staying below the candidate removal reference for the ten year projections are shown in Table 6, 7, and 8.

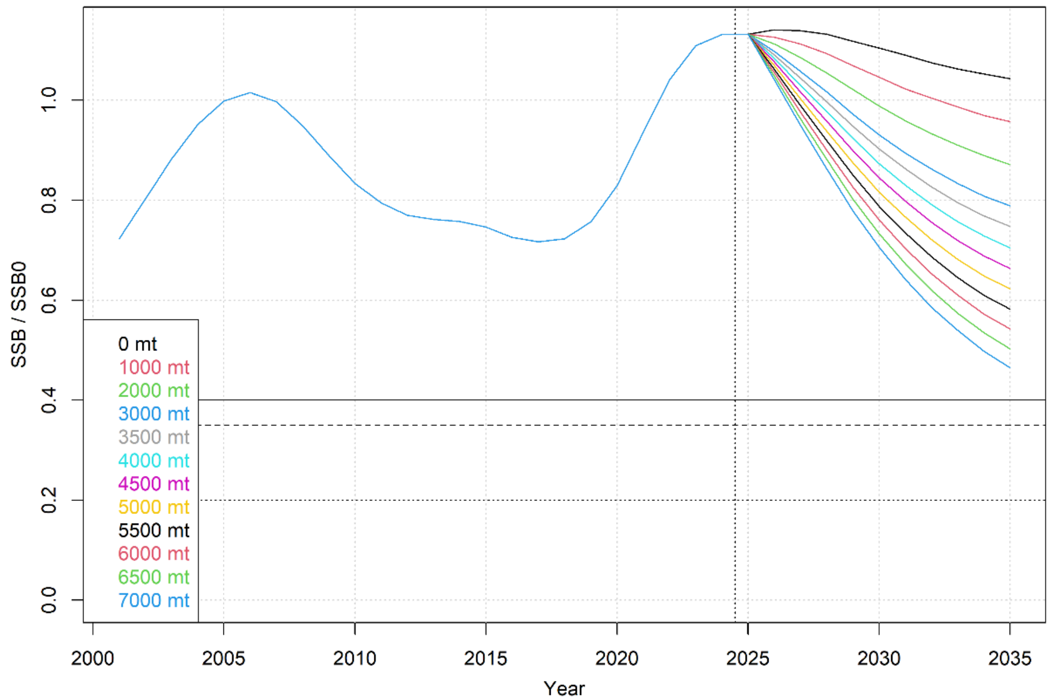

Figure 2. Median projected spawning stock biomass relative to equilibrium unfished levels for various constant catch levels. TACs are set for the principal fleets; additional non-retained catch is assumed for the bottom trawl discard fleet.

Table 3. Probability of remaining above the LRP of 0.2 B0 over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
4000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
4500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
5000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
5500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
6000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99
6500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99	0.98
7000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99	0.97	0.95

Table 4. Probability of remaining above the candidate USR of 0.35 B_0 over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
4000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
4500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99
5000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.98	0.97
5500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.98	0.96	0.94
6000	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.98	0.95	0.92	0.88
6500	>0.99	>0.99	>0.99	>0.99	>0.99	0.98	0.96	0.92	0.87	0.82
7000	>0.99	>0.99	>0.99	>0.99	0.99	0.97	0.92	0.87	0.80	0.75

Table 5. Probability of remaining above the candidate USR of 0.4 B_0 over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
4000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99
4500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.98	0.97
5000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.98	0.96	0.93
5500	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.97	0.95	0.92	0.87
6000	>0.99	>0.99	>0.99	>0.99	>0.99	0.98	0.95	0.91	0.86	0.81
6500	>0.99	>0.99	>0.99	>0.99	0.99	0.96	0.91	0.85	0.79	0.73
7000	>0.99	>0.99	>0.99	>0.99	0.98	0.94	0.87	0.79	0.72	0.64

Table 6. Probability that fishing mortality F remains below the candidate RR ($F_{0.4\,B0}$) over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3500	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99
4000	>0.99	>0.99	>0.99	>0.99	0.99	0.99	0.99	0.98	0.97	0.97
4500	>0.99	>0.99	0.99	0.98	0.97	0.96	0.95	0.93	0.91	0.90
5000	>0.99	0.99	0.97	0.95	0.93	0.90	0.88	0.85	0.83	0.80
5500	0.99	0.96	0.94	0.90	0.86	0.82	0.78	0.74	0.72	0.69
6000	0.96	0.93	0.89	0.82	0.78	0.73	0.68	0.63	0.59	0.56
6500	0.93	0.88	0.81	0.74	0.68	0.62	0.56	0.53	0.49	0.46
7000	0.88	0.80	0.73	0.65	0.58	0.52	0.47	0.43	0.40	0.37

Table 7. Probability that fishing mortality F remains below the candidate RR ($F_{0.45\ B0}$) over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3500	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99	0.98	0.98	0.98
4000	>0.99	>0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.92	0.91
4500	0.99	0.98	0.97	0.95	0.92	0.90	0.87	0.85	0.83	0.81
5000	0.98	0.95	0.92	0.89	0.84	0.81	0.77	0.73	0.70	0.68
5500	0.94	0.90	0.85	0.79	0.74	0.70	0.65	0.60	0.57	0.54
6000	0.89	0.83	0.76	0.70	0.64	0.58	0.53	0.49	0.46	0.43
6500	0.82	0.75	0.67	0.59	0.52	0.47	0.43	0.39	0.36	0.34
7000	0.75	0.66	0.57	0.50	0.44	0.38	0.35	0.32	0.29	0.28

Table 8. Probability that fishing mortality F remains below the candidate RR ($F_{0.5\ B0}$) over 10 projection years for various constant catch (CC) levels for the MCMC run of the base case model.

CC (t/y)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
0	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
1000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
2000	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
3000	>0.99	>0.99	>0.99	>0.99	>0.99	0.99	0.99	0.99	0.99	0.98
3500	>0.99	>0.99	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93
4000	0.99	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.83	0.82
4500	0.96	0.94	0.91	0.87	0.83	0.79	0.76	0.72	0.70	0.67
5000	0.92	0.87	0.82	0.76	0.71	0.67	0.62	0.58	0.55	0.53
5500	0.84	0.78	0.72	0.65	0.59	0.53	0.50	0.46	0.43	0.40
6000	0.76	0.68	0.60	0.54	0.48	0.43	0.39	0.36	0.34	0.32
6500	0.67	0.58	0.50	0.43	0.38	0.34	0.31	0.28	0.27	0.25
7000	0.57	0.49	0.41	0.35	0.31	0.28	0.25	0.23	0.21	0.20

Ecosystem and Climate Change Considerations

The largest Lingcod recruitment event detected since 1978 (the period for which age data informs the assessment model) occurred in 2016, which coincides with large recruitment events for several other groundfish species in the region. Higher sea floor oxygen, lower seafloor salinity, and lower North Pacific Gyre Oscillation (NPGO) index values (two-year lag) were all associated with higher recruitment deviations throughout the time series. Biomass of surface phytoplankton, smaller copepod species, and Pacific Herring all showed some positive correlation with recruitment deviations. No single relationship appeared to have much predictive power alone, suggesting that recruitment is likely best explained by a combination of these and other variables, and potential interactions among them.

Coastwide indices of average body condition tended to be highest for all sex and maturity classes in the early 2000s (when this time series begins) and most variable for mature females. Splitting these indices by survey area suggests that the southern region (off the west coast of Vancouver Island) experienced worse conditions in 2008 than the rest of the coast. Likewise, peaks in average body condition for mature females in 2016 were most pronounced in the north (Queen Charlotte Sound and Hecate Strait).

Body condition appeared positively associated with warmer, fresher, and more oxygen-rich water and with Pacific Herring SSB. However, in contrast to recruitment, immature body condition was associated with a higher NPGO index (lagged two years).

PROCEDURE FOR INTERIM-YEAR UPDATES

For the purposes of planning assessment updates, constant catch projections were carried out for the alternative Ricker stock-recruitment relationship that also fitted the input data estimates at much higher B_0 biomass levels. These projections suggest that dropping below the more pessimistic candidate USR level occurs in 44% of simulations at a constant catch similar to the current TAC (approx. 4000 mt). It is recommended that the stock be reassessed in 2030.

OTHER MANAGEMENT QUESTIONS

Advice on stock structure of the Outside Lingcod was also produced. No biological justification was found in the data analyzed or in the literature reviewed to support the need to assess the stock at a finer scale than coastwide in the outer waters. The inside/Strait of Georgia stock will continue to be assessed separately.

SOURCES OF UNCERTAINTY

There is uncertainty over the stock recruitment relationship. Specifically, how much additional recruitment is observed when spawning biomass is low. This leads to considerable quantitative uncertainty over B_{MSY} reference points, which is why it was recommended that advice be provided using B_0 reference points. Qualitatively, there is a consistent conclusion across the Base Case model and a wide range of sensitivity analyses (Appendix 1): there is a very low probability of dropping below either the LRP or the candidate USRs over the next 10 years given current exploitation rates (Table 3, 4, and 5). The Base Case model estimates of recruitment exhibit a moderately high degree of variability. Since estimated historical spawning stock biomass remains above approximately half of unfished levels, there is little contrast with which to estimate the stock recruitment relationship and there is a high degree of uncertainty regarding recruitment compensation. There is uncertainty in the strength of recent cohorts and therefore additional uncertainty in near-term projections due to a lack of age-composition data after 2019. Age composition data are also very sparse for some surveys and fishing fleets, leading to uncertainty over selectivities that can substantively affect perceptions of stock status.

Research Recommendations

The assessment provided the following research recommendations:

- Continue monitoring and sampling Lingcod on Synoptic Bottom Trawl and Hard Bottom Longline surveys.
- Collect biological data from commercial (trawl, longline, hook and line) and recreational fisheries.
- Continue to explore environmental contributors to recruitment strength and condition, including investigating the coherence of strong recruitment in groundfish species in 2016.
- We stress the need for increased capacity in the Sclerochronology Lab and strongly recommend that more fin rays be aged prior to the next assessment to inform the strength of incoming cohorts.

Through discussions during the regional peer-review (RPR) meeting, participants developed the following additional recommendations for research or considerations for future models:

- Conduct research to inform steepness/resilience of the population to use B_{MSY}-based reference points.
- Collect diet data on surveys to help understand density dependence and environmental covariates, including incidence of cannibalism.
- Collect Lingcod biological data on the Sablefish survey to better understand Lingcod life history and to explore hypotheses about the shape of survey selectivity and cryptic biomass.
- Adopt One Step Ahead (OSA) residuals instead of Pearson residuals in model diagnostic checks.
- Consider disaggregating the groundfish synoptic and hard bottom longline surveys into their component surveys to allow different selectivities be fit to the biological data for each survey area.
- Consider different selectivity curves that might be appropriate for each fleet.
- Consider length-based selectivity rather than using only age-based selectivity.

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APPENDIX

Table A1. Sensitivity tests run in the assessment.

Sensitivity test	Configuration
M1: Age-dependent M	M is inversely related to length with an expected unfished survival equal to Base Case M (age 5 fish have Base Case M).
M2: Alternative M value	M consistent with the value from likelihood profiling which is approximately 80 percent of the Base Case model input value.
S1: Logistic selectivity in IPHC survey	IPHC has a distribution of age frequencies (and estimated dome-shaped selectivity) most consistent with the logistic assumption. The descending width of the double normal selectivity is fixed to a high value.
S2: Younger selectivity of hook and line fleet (and hence recreational fleet)	Hook and line peak age is fixed to age 4 which is approximately 2/3 the value of the maximum likelihood estimate (approximately age 6). The ascending width of the normal selectivity is also fixed at the maximum likelihood estimate of the Base Case model.
S3: Priors on selectivity parameters are even more uniformative	The variance of the beta priors for steepness were doubled.
R1: Ricker stock-recruitment relationship	Ricker stock recruitment curve with same steepness prior.
R2: Lower prior mean for steepness	The beta prior has mean 0.7 and standard deviation of 0.1
R3: Less precise steepness prior	The beta prior has mean 0.75 and standard deviation of 0.141 (variance is doubled)
D1: No trawl discard fleet (100 percent discard survival)	Catches of the trawl discard fleet are set close to zero.
D2: Trawl discard mortality is 50 percent (rather than 100 percent)	Catches of the trawl discard fleet are halved.
D3: Alternative imputation of historical trawl discards	Discarding of trawl calculated from discarding rate from 1996 - 2000. This assumes a discard fraction (by weight) of 0.093 compared with 0.082 for the base assumption (1996-2005) an 0.085 for (1996-2024).
I1: Leave one out survey index: SYN	Synoptic trawl survey weight reduced to 1/100

Sensitivity test	Configuration
I2: Leave one out survey index: HBLL	Hard bottom longline survey weight reduced to 1/100.
I3: Leave one out survey index: IPHC	International Halibut Commission survey weight reduced to 1/100
I4: Leave one out survey index: Triennial	Triennial survey weight reduced to 1/100.
I5: Use of the SMMS survey	The small mesh multispecies survey (1975 - 2022) is included as an index with age-selectivity mirroring the synoptic trawl survey.
W1: Higher weight (precision) of age composition data	ESS = 75
W2: Even higher weight (precision) of age composition data	ESS = 100
L1: Include length composition data	Length composition data are included in the estimation. Effective sample size configuration (ESS = 50) and selectivity setup (priors and functional forms) is the same as age-selectivity.
C1: Equilibrium catches prior to 1927	Initial equilibrium (’spool-up’) fishing mortality rates for the trawl, trawl discard and hook and line fleets are estimated assuming that the stock was at equilibrium in 1927 subject to 1927 catches.
A1: Aging error included in model	Empirical aging error was added to the model.

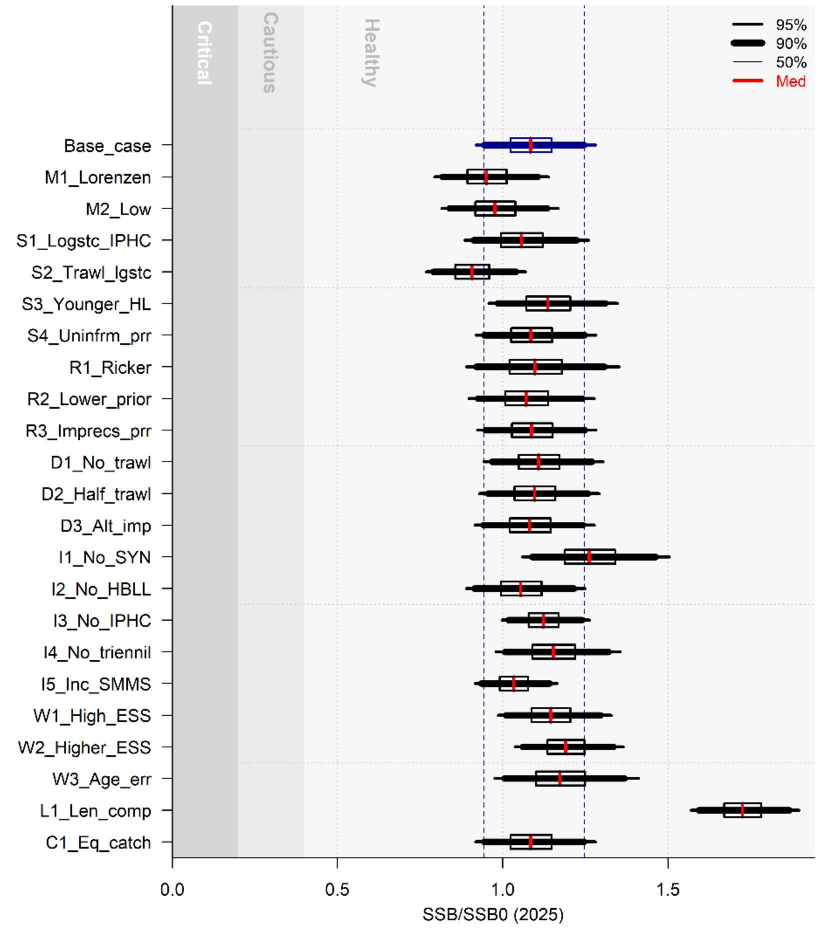

Figure A1. Estimated stock status (SSB relative to SSB0) for the base case and 21 sensitivity runs. The critical, cautious and healthy zones are demarked by the LRP (0.2 B0) and upper candidate USR (0.4 B0). The vertical blue dashed lines correspond with the 90 percent credibility interval of the base case model. See Appendix 1 for a description of these sensitivity runs.

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