Agenda Item E.8
Attachment 7
September 2017

Status of Yellowtail Rockfish (*Sebastes flavidus*) Along the U.S. Pacific Coast in 2017

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Post-STAR DRAFT, August 11th, 2017

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Stock

This assessment reports the status of the Yellowtail Rockfish (*Sebastes flavidus*) resource in U.S. waters off the coast of the California, Oregon, and Washington using data through 2016.

The Pacific Fishery Management Council (PFMC) manages the U.S. fishery as two stocks separated at Cape Mendocino, California (40° 10'N). The northern stock has long been assessed on its own; the southern stock is managed as part of the "Minor Shelf Rockfish" complex. This assessment analyzed each stock independently, with the southern stock extending southward to the U.S./Mexico border and the northern stock extending northward to the U.S./Canada border (Figure a).

The Southern model was not robust enough for management purposes, mainly due to lack of data. Therefore although the data and sensitivities investigated for the model are reported in this document, the results of any of those sensitivities should be interpreted with the recognition that the model is not considered suitable for management. We therefore report estimates and projections only for the Northern model.

The most recent fully integrated assessment (Wallace and Lai 2005), following the pattern of prior assessments, included only the Northern stock which it divided into three assessment areas with divisions at Cape Elizabeth (47° 20'N) and Cape Falcon (45° 46'N). The northern stock was assessed most recently using a data-moderate assessment method in 2013 (Cope et al. 2013). The southern stock was also analyzed using the data-moderate method but that model was never reviewed or put forward for management. The contribution of the southern stock to the overfishing limit (OFL) for the Southern Shelf Complex was determined using Depletion-Based Stock Reduction Analysis (Dick and MacCall 2011).

Since the 2005 assessment, reconstruction of historical catch by Washington and Oregon makes any border but the state line (roughly 46° N) incompatible with the data from those states. Additionally, an unknown amount of the groundfish catch landed in northern Oregon is believed to have been caught in Washington waters. This is not an issue that can be resolved at present, and we have elected to address the stock in two areas consistent with the management border at Cape Mendocino. This is consistent, as well, with a recent genetic analysis (Hess et al. 2011) that found distinct stocks north and south of Cape Mendocino but did not find stock differences within the northern area.

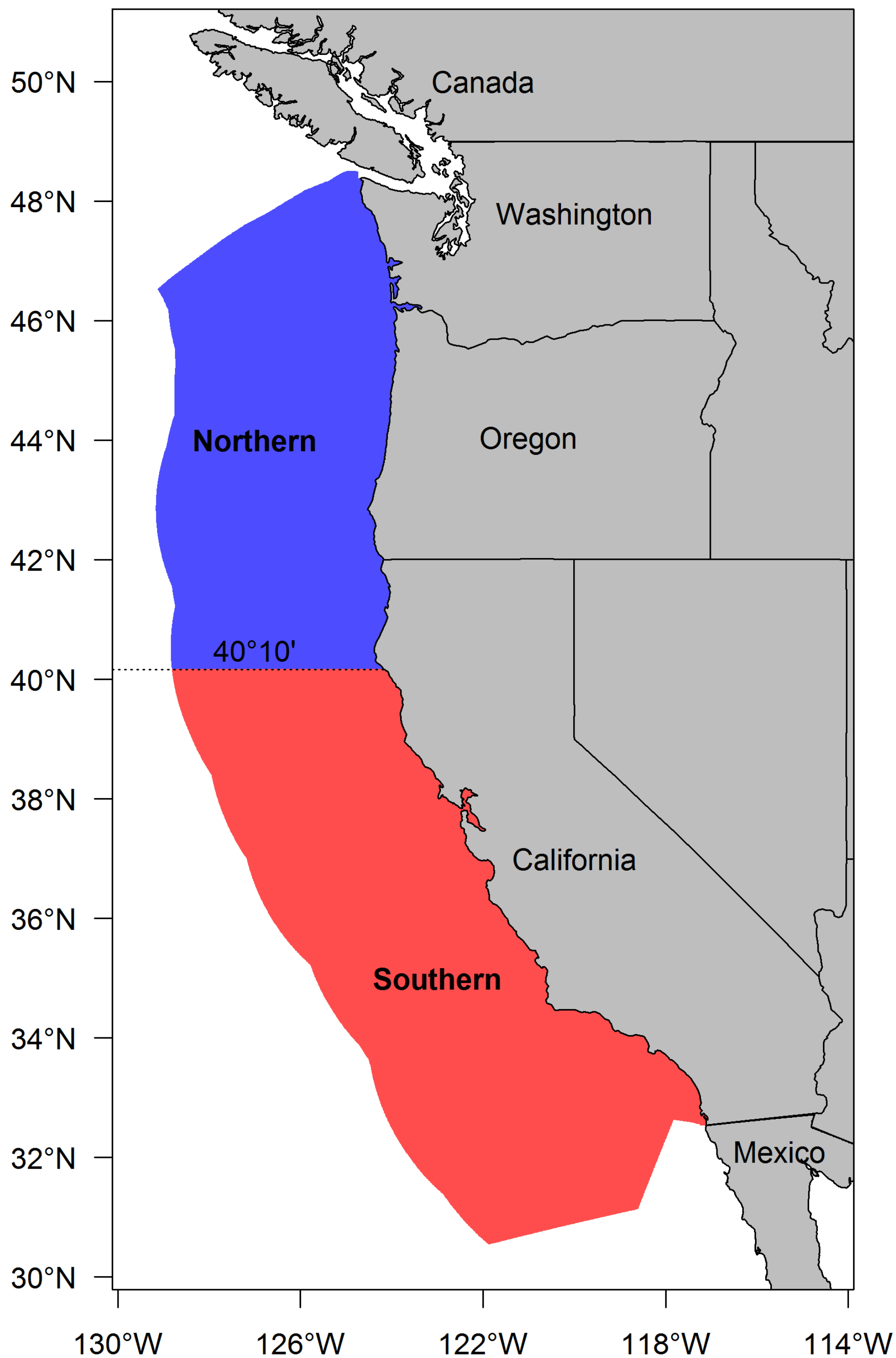

Figure a: Map depicting the boundaries for the base-case model.

Catches

Catches from the Northern stock (Figure b) were divided into four categories: commercial catch, bycatch in the at-sea hake fishery, recreational catch in Oregon and California (north of 40° 10'N), and recreational catch in Washington. The first three of these fleets were entered in metric tons, but the recreational catch from Washington was entered in the model as numbers of fish with the average weight calculated internally in the model from the weight-length relationship and the estimated selectivity for this fleet (which is informed by the length-compositions). Catches have been increasing over the past 10 years (Table a) but remain well below the peak catch due to management measures, included lower catch limits and closed areas.

Catches from the Southern stock (Figure c) were divided into two categories: commercial and recreational catch, both of which were entered as metric tons. Catches over the past 10 years have remained far below the peak levels, with the majority of recent catch coming from the Recreational fishery (Table b)

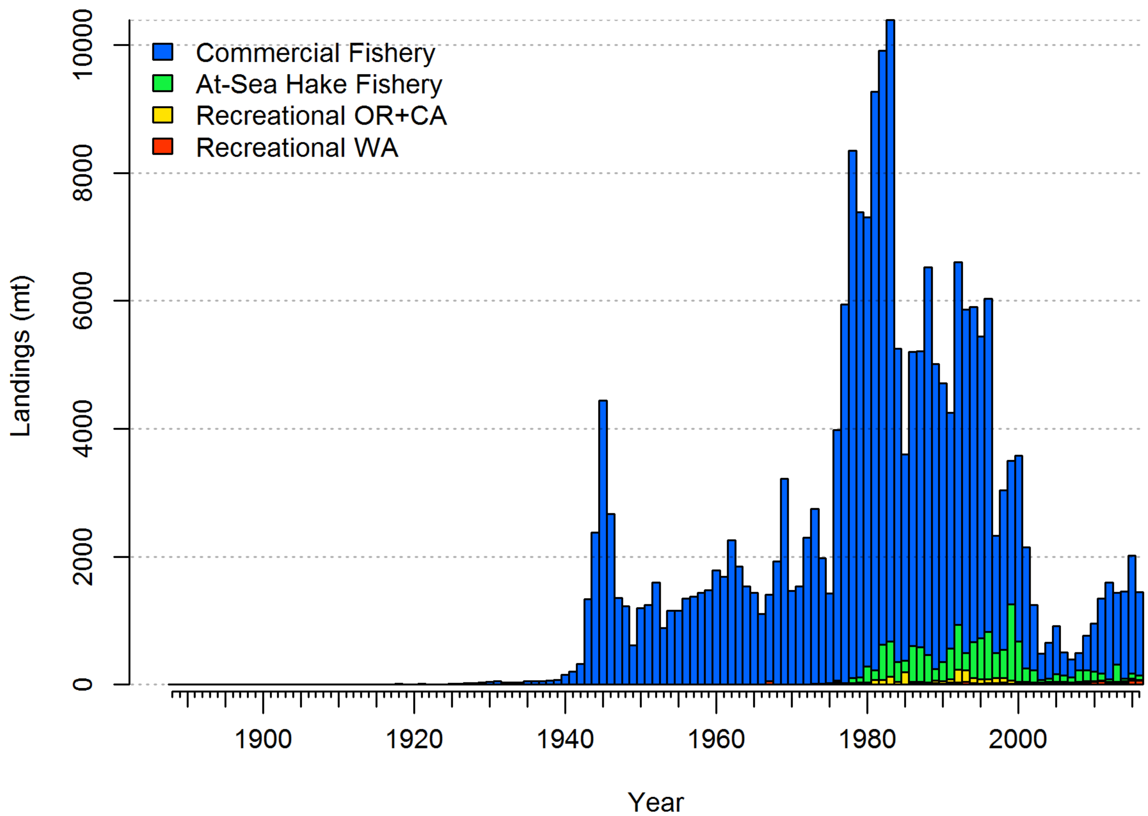

Figure b: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity.

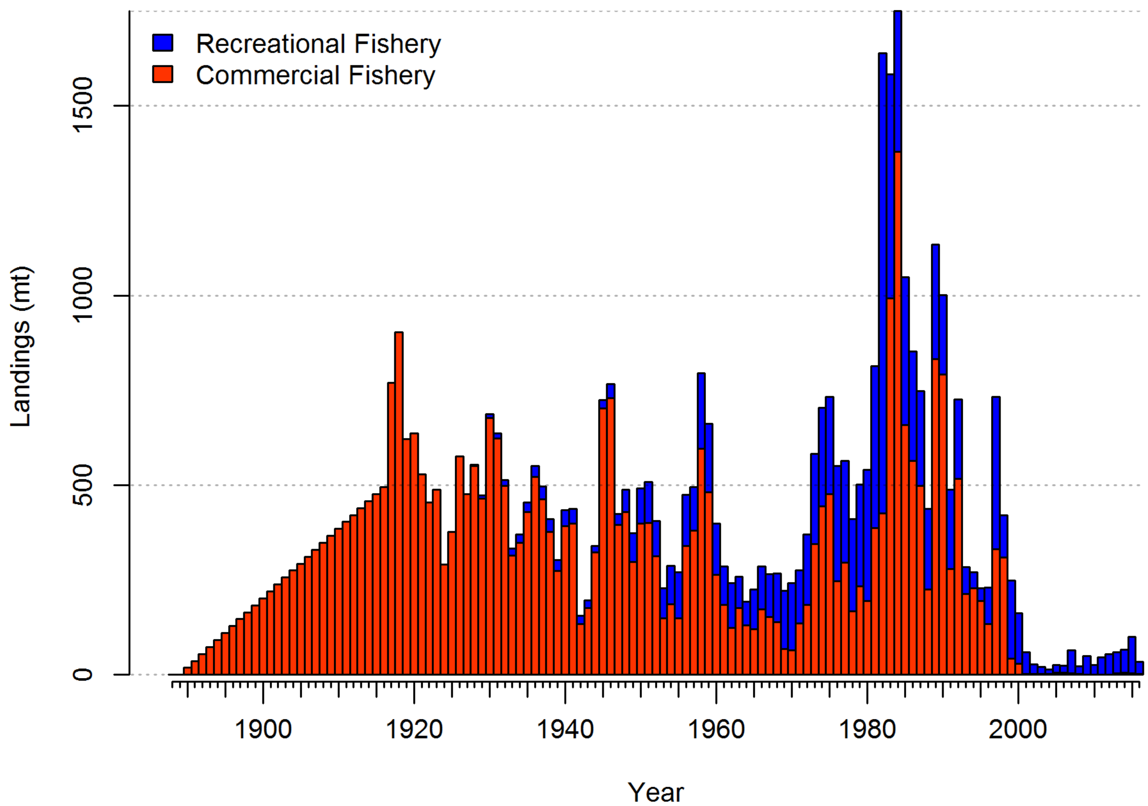

Figure c: Estimated catch history of Yellowtail Rockfish in the Southern model.

Table a: Recent Yellowtail Rockfish catch by fleet for the Northern model (north of 40° 10'N).

Year	Commercial (mt)	At-sea hake bycatch (mt)	Recreational OR+CA (mt)	Recreational WA (1000s)
2006	358	109	23	14
2007	276	79	18	15
2008	276	175	24	18
2009	539	176	17	28
2010	754	150	12	38
2011	1181	101	18	43
2012	1509	43	20	19
2013	1117	269	20	24
2014	1366	42	16	33
2015	1841	86	29	56
2016	1308	62	14	60

Table b: Recent Yellowtail Rockfish catch by fleet for the Southern model (south of 40° 10'N).

Year	Recreational (mt)	Commercial (mt)
2006	19	5
2007	60	4
2008	20	2
2009	48	1
2010	24	1
2011	45	1
2012	53	1
2013	56	4
2014	60	5
2015	96	4
2016	32	2

Data and Assessment

Yellowtail Rockfish north of Cape Mendocino (40° 10'N) was most recently assessed as part of a 2013 data-moderate stock assessment (Cope et al. 2013) that did not include any length or age data. The northern stock was previously assessed in 2000 (Tagart et al. 2000) with that assessment updated in 2003 and 2005 (Lai et al. 2003, Wallace and Lai (2005)). The stock south of 40° 10'N has never been fully assessed due to the lack of data for this area.

Northern model landings are from one recreational and two commercial fisheries: the commercial trawl fishery and the bycatch of Yellowtail Rockfish in the Hake fishery. The Triennial Trawl Survey and the NWFSC Shelf-Slope Survey provide fishery-independent information. A research study and the West Coast Groundfish Observing Program provide data on discards. Length and age samples are available from 1972 to the present (308,133 and 16,781 samples, respectively).

Southern model landings are treated as one recreational and one commercial fishery. Two recreational surveys have been conducted onboard private fishing vessels, and a Hook and Line Survey conducted by the NWFSC provides fishery-independent survey data, although this survey is conducted mainly outside the range of the stock, and has only been sampling since 2004. No discard data are available for the Southern model. Biological sampling since 1980 provides 179,308 length samples, however age sampling was sparse (6,352 samples) and mainly covers the period 1980-1999.

Lack of data for the Southern model contributed heavily to its failure to meet standards for use in management.

This assessment uses Stock Synthesis version 3.30. The Northern model begins in 1889, as does the Southern model. In both cases those starting years were chosen based on the first year of the available catch data and the start of the estimated recruitment deviations was at a later point, so both models were assumed to start at an unfished equilibrium. Steepness was fixed in both models at 0.718. Natural mortality was estmated in the Northern model for females with a male offset, and those estimated values from the Northern model were used as fixed values in the Southern model. Growth parameters, selectivities, equilibrium recruitment and recruitment deviations were estimated in both models.

Stock Biomass

The spawning output for the Northern model was estimated to have fallen below 40% of unfished equilibrium in the early 1980s, to a minimum of 29.3% in 1984 but has rebounded since to 75.2% in 2017 (˜95% asymptotic interval: ± 61.2%-89.2%) (Figures d and e, Table c).

The spawning output and depletion from the final Southern model are shown in the same set of figures for comparison, although this model is not being put forward for management, however most variations of the Southern model explored during development and review showed the stock to be healthy and well above management targets.

Table c: Recent trend in beginning of the year spawning output and depletion for the Northern model for Yellowtail Rockfish.

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	12.128	(7.86-16.39)	0.809	(0.604-1.013)
2009	12.569	(8.27-16.87)	0.838	(0.637-1.039)
2010	12.827	(8.53-17.12)	0.855	(0.66-1.051)
2011	12.846	(8.6-17.09)	0.857	(0.668-1.045)
2012	12.740	(8.6-16.88)	0.850	(0.67-1.029)
2013	12.472	(8.46-16.49)	0.832	(0.663-1.001)
2014	12.157	(8.28-16.04)	0.811	(0.651-0.97)
2015	11.841	(8.09-15.6)	0.790	(0.639-0.94)
2016	11.482	(7.83-15.14)	0.766	(0.621-0.91)
2017	11.278	(7.69-14.86)	0.752	(0.612-0.892)

Table d: Recent trend in beginning of the year spawning output and depletion for the Southern model for Yellowtail Rockfish.

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	2.801	(0-6.43)	0.636	(0.482-0.79)
2009	2.805	(0-6.41)	0.637	(0.492-0.783)
2010	2.841	(0-6.46)	0.645	(0.506-0.784)
2011	2.915	(0-6.6)	0.662	(0.527-0.797)
2012	3.019	(0-6.8)	0.686	(0.553-0.819)
2013	3.158	(0-7.09)	0.717	(0.583-0.852)
2014	3.316	(0-7.41)	0.753	(0.615-0.891)
2015	3.513	(0-7.83)	0.798	(0.653-0.943)
2016	3.767	(0-8.37)	0.856	(0.699-1.013)
2017	4.099	(0-9.08)	0.931	(0.756-1.106)

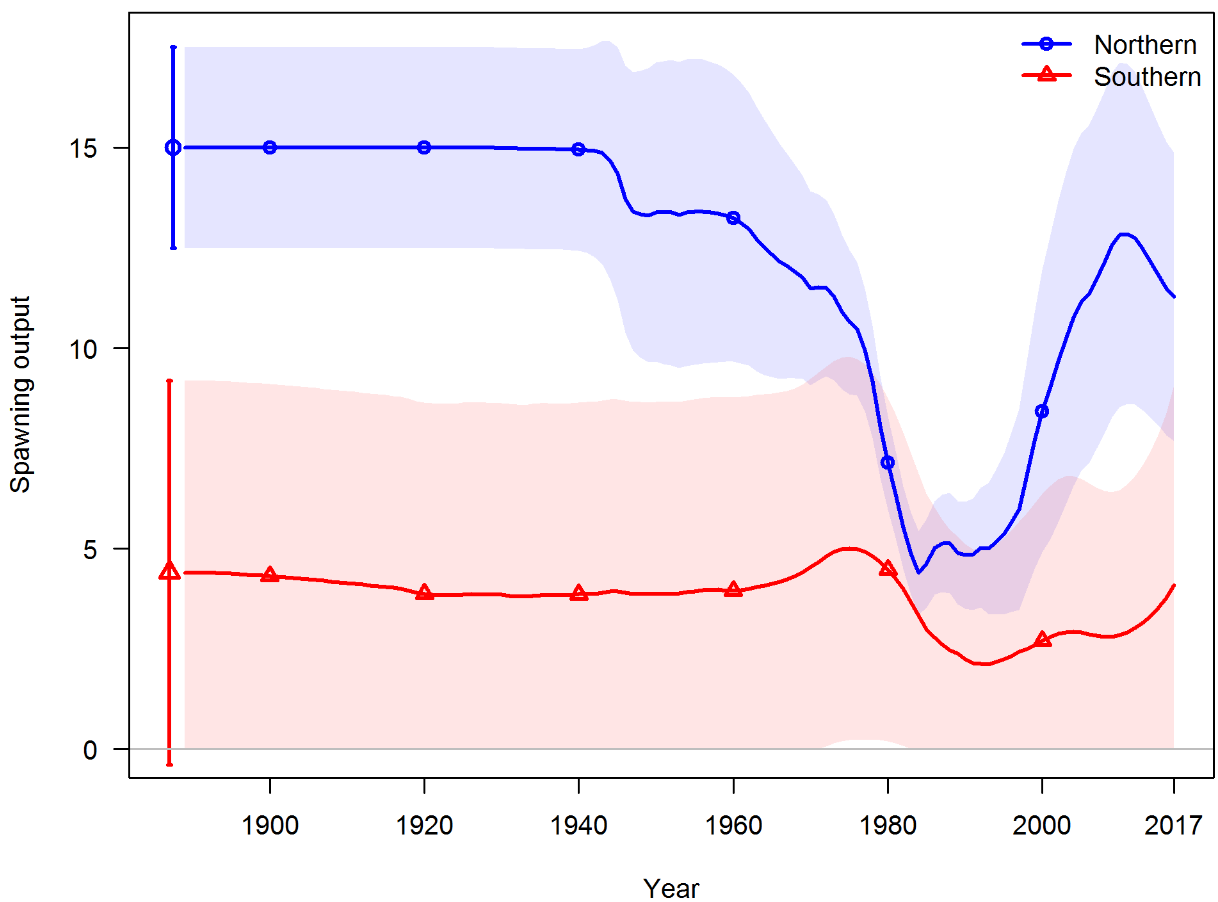

Figure d: Time series of spawning output trajectory (line: median; shaded areas: approximate 95% credibility intervals) for the base case Northern model and final Southern model.

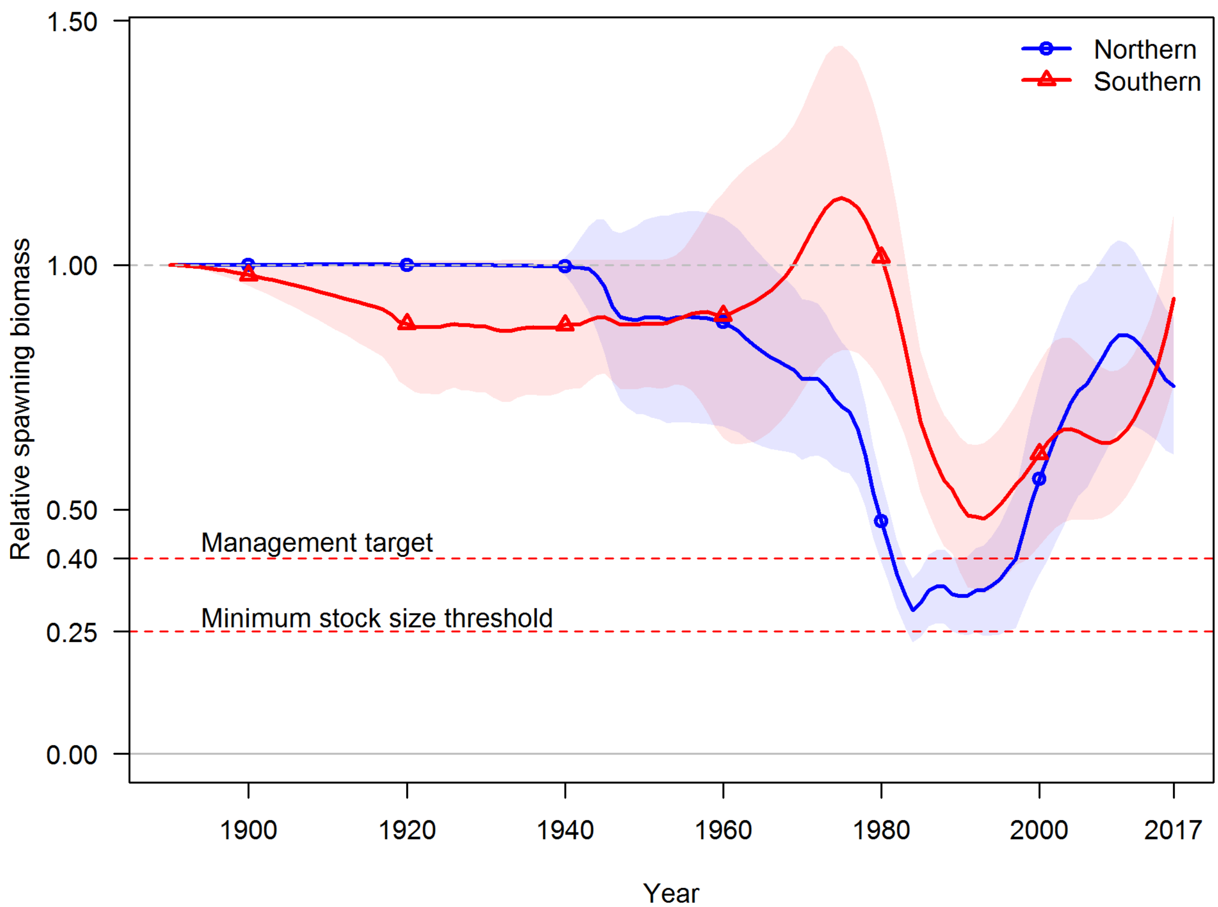

Figure e: Estimated relative depletion with approximate 95% asymptotic confidance intervals (dashed lines) for the base case Northern model and final Southern model.

Recruitment

The Northern model recruitments have ranged from roughly 21 million to 72 million since 2008, although with large uncertainty. Recruitments have shown remarkable consistency since 2013.

Southern model recruitments have ranged from 21 million to 103 million. In 2008 and 2010 it estimates especially large recruitments and extra large recruitment deviations.

Table e: Recent recruitment for the Northern model.

Year	Estimated Recruitment (millions)	~ 95% confidence interval
2008	66.69	(37.78 - 117.74)
2009	20.82	(9.86 - 43.95)
2010	72.38	(38.52 - 136)
2011	29.34	(12.68 - 67.92)
2012	38.43	(15.07 - 98.01)
2013	53.49	(19.02 - 150.45)
2014	50.06	(17.82 - 140.61)
2015	49.53	(18 - 136.34)
2016	49.20	(17.89 - 135.27)
2017	49.09	(17.86 - 134.94)

Table f: Recent recruitment for the Southern model.

Year	Estimated Recruitment (millions)	~ 95% confidence interval
2008	103.48	(31.51 - 339.77)
2009	58.70	(16.09 - 214.16)
2010	87.54	(25.05 - 305.87)
2011	51.00	(13.23 - 196.67)
2012	25.48	(6.62 - 97.99)
2013	42.54	(12.66 - 142.92)
2014	33.50	(9.71 - 115.53)
2015	30.74	(8.58 - 110.13)
2016	20.87	(4.91 - 88.65)
2017	25.39	(5.24 - 123.02)

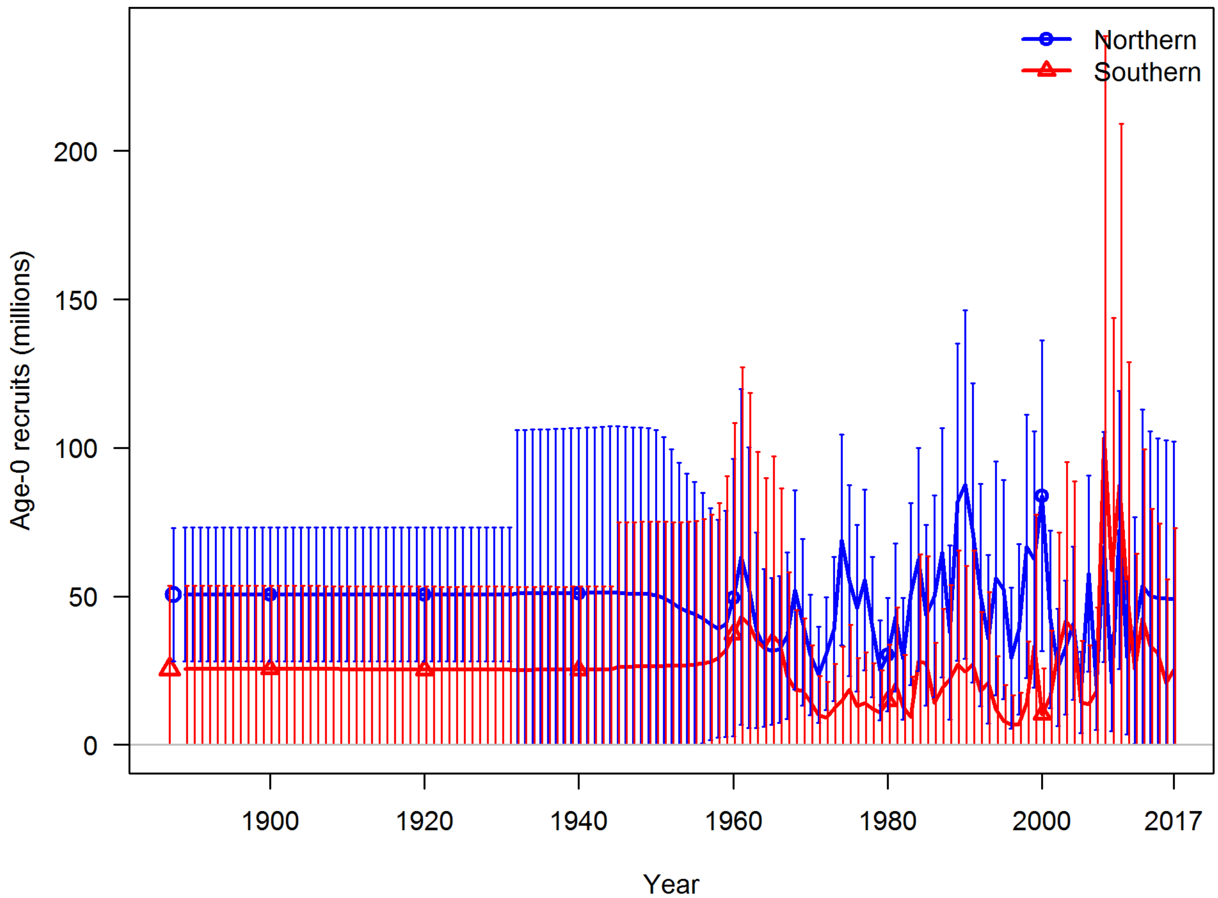

Figure f: Time series of estimated Yellowtail Rockfish recruitments for the base-case Northern model and final Southern Model with 95% confidence or credibility intervals.

Exploitation status

The Northern model is estimated to have experienced overfishing throughout the 1980s and 1990s relative to the current SPR-based harvest limits (Figure g). However, in recent years, the fishing intensity has been well within the management limits and exploitation rates (catch divided by age 4+ biomass) are estimated to have been less than 2% per year (Table g).

A summary of Yellowtail Rockfish exploitation histories for the Northern base model is provided as Figure h.

Table g: Recent trend in spawning potential ratio and exploitation for Yellowtail Rockfish in the Northern model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is catch divided by age 4+ biomass.

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.172	(0.04-0.3)	0.006	(0.001-0.011)
2008	0.108	(0.06-0.16)	0.004	(0.002-0.005)
2009	0.209	(0.11-0.31)	0.008	(0.004-0.012)
2010	0.292	(0.12-0.47)	0.012	(0.004-0.02)
2011	0.250	(0.16-0.35)	0.010	(0.007-0.014)
2012	0.293	(0.19-0.4)	0.012	(0.008-0.017)
2013	0.277	(0.18-0.38)	0.011	(0.007-0.015)
2014	0.284	(0.18-0.39)	0.011	(0.007-0.015)
2015	0.383	(0.25-0.51)	0.016	(0.01-0.022)
2016	0.294	(0.19-0.4)	0.012	(0.008-0.016)

Table h: Recent trend in spawning potential ratio and exploitation for Yellowtail Rockfish in the Southern model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is catch divided by age 4+ biomass.

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.038	(0-0.08)	0.001	(0-0.003)
2008	0.013	(0-0.03)	0.000	(0-0.001)
2009	0.027	(0-0.06)	0.001	(0-0.002)
2010	0.013	(0-0.03)	0.000	(0-0.001)
2011	0.021	(0-0.05)	0.001	(0-0.002)
2012	0.022	(0-0.05)	0.001	(0-0.002)
2013	0.022	(0-0.05)	0.001	(0-0.002)
2014	0.023	(0-0.05)	0.001	(0-0.002)
2015	0.032	(0-0.07)	0.001	(0-0.002)
2016	0.011	(0-0.02)	0.000	(0-0.001)

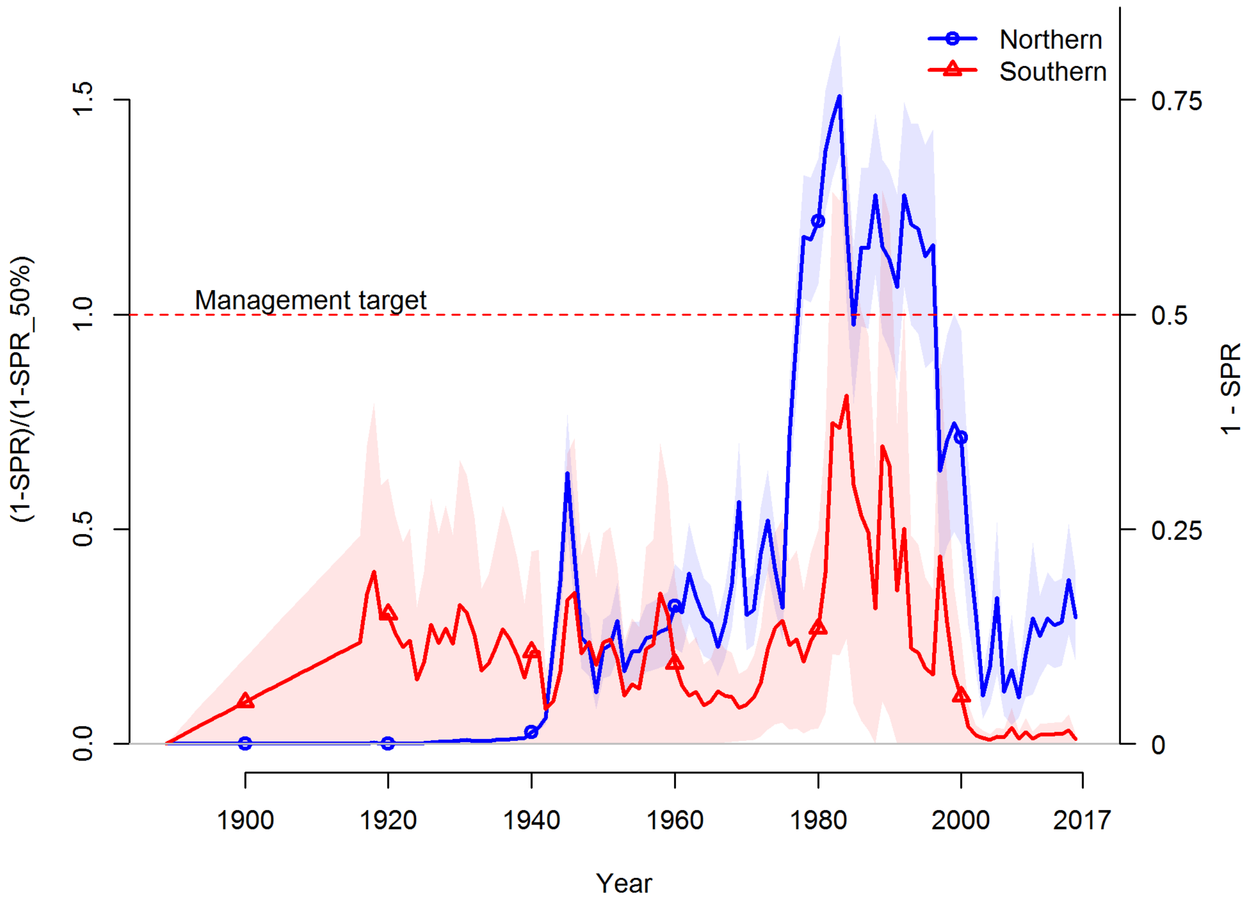

Figure g: Estimated spawning potential ratio (SPR) for the base-case Northern model and final Southern model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2016.

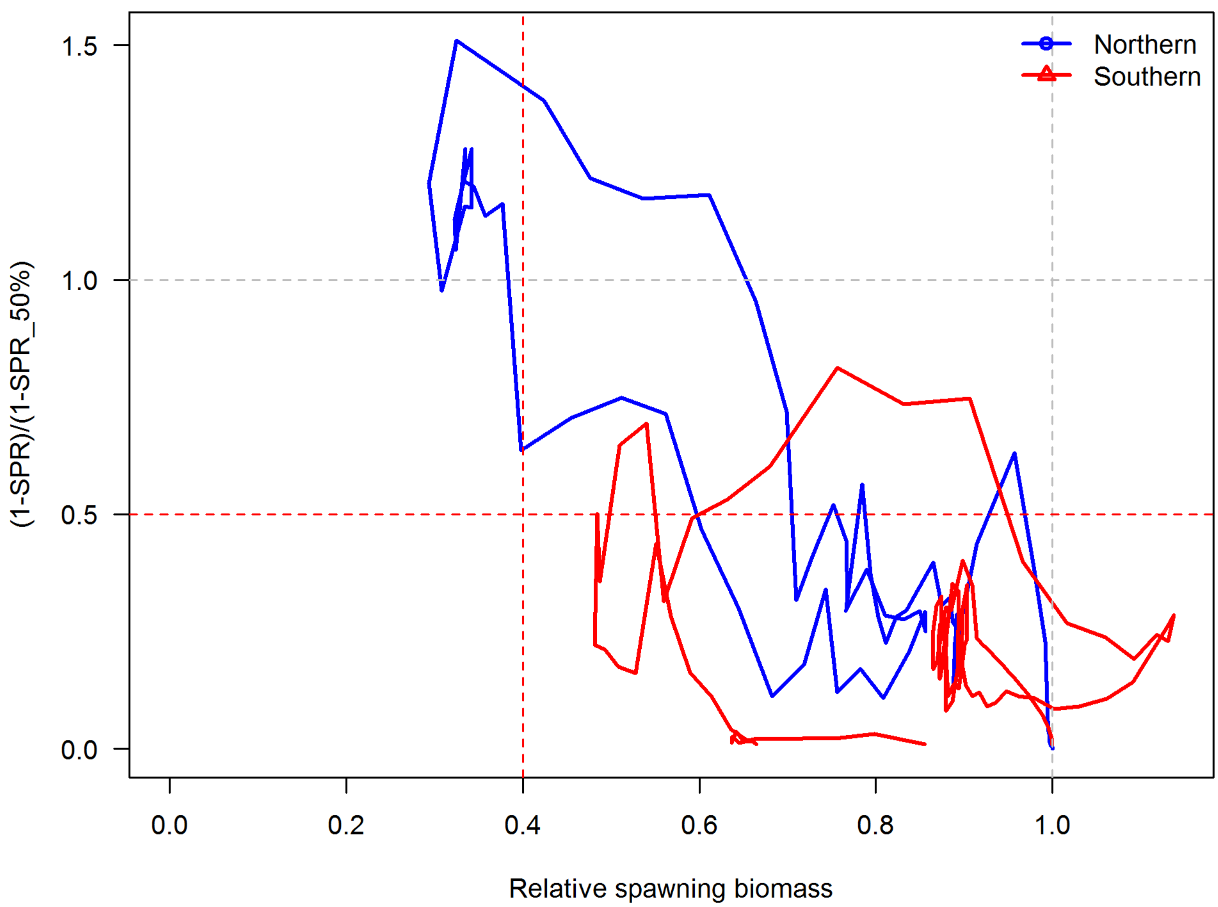

Figure h: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case Northern model and final Southern model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass.

Ecosystem Considerations

Rockfish in general are sensitive to the strength and timing of the upwelling cycle in the Eastern Pacific, which affects where pelagic juveniles settle, and impacts the availability of the zooplankton which the young require.

Yellowtail Rockfish feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well. Large juveniles and adults eat fish (small Pacific whiting, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms. They are prey for Chinook Salmon, Lingcod, Cormorants, Pigeon Guillemots and Rhinoceros Auklets. (Love 2011)

Reference Points

Yellowtail Rockfish are managed relative to biomass reference points at $B_{40\%}$ (the B_{MSY} proxy) and $B_{25\%}$ (the minimum stock-size threshold). Harvest rates are managed relative to an F_{MSY} proxy $SPR = 50\%$ which corresponds to a Relative Fishing Intensity, $(1-SPR)/(1-SPR_{50\%})$, of 100%. This assessment estimates the Northern stock to be above the $B_{40\%}$ threshold with Relative Fishing Intensity below 100% ($SPR > 50\%$ which means the Spawning Potential is greater than 50% of the unfished Spawning Potential).

The estimated relative depletion level for the Northern model in 2017 is 75.2% (˜95% asymptotic interval: ± 61.2%-89.2%, corresponding to an unfished spawning output of 11.3 trillion eggs (˜95% asymptotic interval: 7.69-14.86 trillion eggs) of spawning output in the base model (Table i). Unfished age 4+ biomass was estimated to be 161.6 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 6 trillion eggs, which gives a catch of 5434.5 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 5115 mt.

Estimated equilibrium yield curves for the base-case Northern model is shown in Figure i.

Table i: Summary of reference points and management quantities for the base case Northern model.

Quantity	**Estimate**	**~95% Confidence Interval**
Unfished spawning output (trillion eggs)	15	(12.5-17.5)
Unfished age 4+ biomass (1000 mt)	161.6	(126.4-196.9)
Unfished recruitment (R0, millions)	50.6	(28.1-73.1)
Spawning output(2016 trillion eggs)	11.5	(7.8-15.1)
Relative Spawning Output (depletion)2016)	0.7656	(0.6212-0.9101)
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$)	6	(5-7)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.0575	(0.0552-0.0598)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	5434.5	(4035.6-6833.3)
Reference points based on SPR proxy for MSY		
Spawning output	6.7	(5.6-7.8)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.051	(0.049-0.0531)
Yield with SPR_{proxy} at SB_{SPR} (mt)	5115	(3806.5-6423.5)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	3.4	(2.8-4)
SPR_{MSY}	0.3043	(0.2984-0.3103)
Exploitation rate at MSY	0.0888	(0.0846-0.093)
MSY (mt)	6123.8	(4501.9-7745.6)

Management Performance

Total catch (including landings and discards) from the Northern stock has remained well below the management limits in recent years (Table j) and harvest specifications for 2017 and 2018 are set at values similar to the previous years.

Table j: Northern model recent total catch relative to the management guidelines. Estimated total catch includes estimated discarded biomass. Note: the OFL was termed the ABC prior to implementation of FMP Amendment 23 in 2011. The ABC was redefined to reflect the uncertainty in estimating the OFL under Amendment 23. Likewise, the ACL was termed the OY prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2007	4585	-	4585	856
2008	4510	-	4510	520
2009	4562	-	4562	1100
2010	4562	-	4562	1624
2011	4566	4364	4364	1350
2012	4573	4371	4371	1594
2013	4579	4378	4378	1433
2014	4584	4382	4382	1461
2015	7218	6590	6590	2017
2016	6949	6344	6344	1449
2017	6786	6196	6196	-
2018	6574	6002	6002	-

Table k: Southern model recent total catch relative to harvest specifications. The southern stock of yellowtail rockfish has been managed in the Southern Shelf Rockfish complex during this period. The values in this table represent the yellowtail harvest specification contributions to the complex and, as such, are not the reference limits used in managing fisheries catches. There were no harvest specifications for this stock prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2011	1248.90	1042.20	1042.20	45.9
2012	1248.90	1042.20	1042.20	53.7
2013	1064.40	887.70	887.70	59.9
2014	1064.40	887.70	887.70	65.4
2015	1064.40	887.70	887.70	99.3
2016	1064.40	887.70	887.70	33.6
2017	1064.40	887.70	887.70	-
2018	1064.40	887.70	887.70	-

Unresolved Problems And Major Uncertainties

At the STAR meeting the Northern model underwent a major change in that the two fishery-dependent indices that had been included in the pre-STAR model were withdrawn. Representatives of the Groundfish Advisory Panel and Washington Department of Fish and Wildlife identified mistaken assumptions about the datasets used in developing these indices. In the case of the commercial logbook index, this had to do with underestimating the impact of changes in reporting the species and market categories which was occuring differently among the three reporting states. The Hake bycatch index was developed with inaccurate information about the Hake fleet of the time, which was much more heterogeneous than had been believed. These indices were removed because the biases introduced could not be addressed within the time-frame of the review; however they were influential in the model, and both merit further investigation.

In the past, the Northern stock has been modeled as three stocks assumed to have a latitudinal cline in growth. This was not addressed in the present model, in part because the Hess study (Hess et al. 2011) suggests there is no genetic basis for such a cline, and because of objections raised by Washington and Oregon over boundary assumptions made previously. Future research should examine the assumption that growth is invariant along the coast, and evaluate whether the Northern model is sensitive to alternate assumptions.

Another structural decision in the Northern model was in treating female natural mortality as age-independent. This conflicts with prior assessments of Yellowtail Rockfish and with recent assesments of other rockfish stocks. Sex ratios in the data change definitively with age, and old females are conspicuous in their absence. Assessments have addressed this by increasing female mortality after a certain age. One problem with this approach is in defining the age at which such a change occurs. Another is that this assumes that the disappearance of older females is not due to their retirement to habitat unavailable to the fishery. In any case, this was not investigated during the present assessment, and may have provided further insight had it been.

The Southern model unquestionably had insufficient data to support an age-structured model. The ages were sparse and the period since 1999 was barely represented at all. The only fishery-independent survey (the Hook and Line Survey) is conducted mostly outside of the range of the species, and there is no discard data available for the Southern model. Attempting this separate assessment of the Southern stock is useful in defining what constitutes sufficient data, but also in that discussions engendered by the lack of data has identified an otolith collection at the SWFSC that could be investigated, as well as otoliths collected in the Hook and Line Survey that have not been aged.

A final problem common to all stocks caught in the midwater is the lack of a targeting survey. The STAR panel report accompanying this document suggests several avenues to approach this problem. Because depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry that deserves further attention.

Decision Tables

Potential OFL projections for the Northern model are shown in Table l.

A decision table for the Northern model is provided in Table m. The initial catch streams chosen during the STAR panel with input from the GMT and GAP representatives are as follows.

- Base catch stream. Annual catches for each fleet are calculated within Stock Synthesis for from the Base Model by applying the default SPR-based control rule with a 0.956 adjustment from OFL to ACL associated with a P-star of 0.45 and the default 0.36 Sigma for Category-1 stocks
- Historic target opportunity catch stream example. This is based on a calculation by the GMT of the based on an average attainment during a period when there was a mid-water fishery targing Yellowtail. It results in an total annual catch of approximately 4000 mt.
- Recent 5-year average. It results in an total annual catch of approximately 2000 mt.

These are shown in the table in order of increasing average catch.

Allocation of catch among fleets for the years 2019 and beyond was based on an average ratio among fleets over the last 5 years as follows: Commercial, 89.6%; At-sea Hake Bycatch, 6.6%; Recreational Oregon and California, 1.2%; and Recreational Washington, 2.6%. For the years 2017 and 2018, the fleet-specific catches were based on the following calculations.

- Recreational catch of 620 mt in 2017 and 597 mt in 2018 based on the set-asides in the harvest specifications. These were divided among the two recreational fleets based based on the recent 5-year average split among them estimated as 35% to the Oregon and Northern California and 65% to Washington.
- At-sea Hake bycatch of 300 mt based on current set-aside.
- Commercial catch of 5276 and 5105 mt in 2017 and 2018 based on the difference between the ACLs for these two years (6196 and 6002 mt, respectively) and the values for the recreational and At-sea Hake fisheries noted above.

In all these calculations, the catch of the Washington Recreational fleet relative to the other fleets is based on the estimated catch in biomass, but the forecast catches for this fleet are input in numbers of fish to match the inputs of the historic catch in the model. The conversion of biomass to numbers in the forecast is based on an average weight of 1.056 kg calculated from the period since 2003 after the estimated change in selectivity of both recreational fleets. Minor discrepencies between this average and the average weight estimated within the model within the forecast period are the source of the small difference between the catch values shown in the decision table and the 2000 and 4000 mt values for two of the catch streams as well as the difference between the 5979 mt catch for 2018 in these forecasts and the 6002 ACL for that year.

No decision table for the Southern model was developed because this model is not recommended for use in management.

Table l: Projections of potential OFL (mt) for the Northern model, using the base model forecast.

Year	OFL
2017	7462.77
2018	6963.32
2019	6568.18
2020	6261.27
2021	6033.99
2022	5876.95
2023	5776.23
2024	5715.12
2025	5677.99
2026	5652.84
2027	5631.77
2028	5610.41

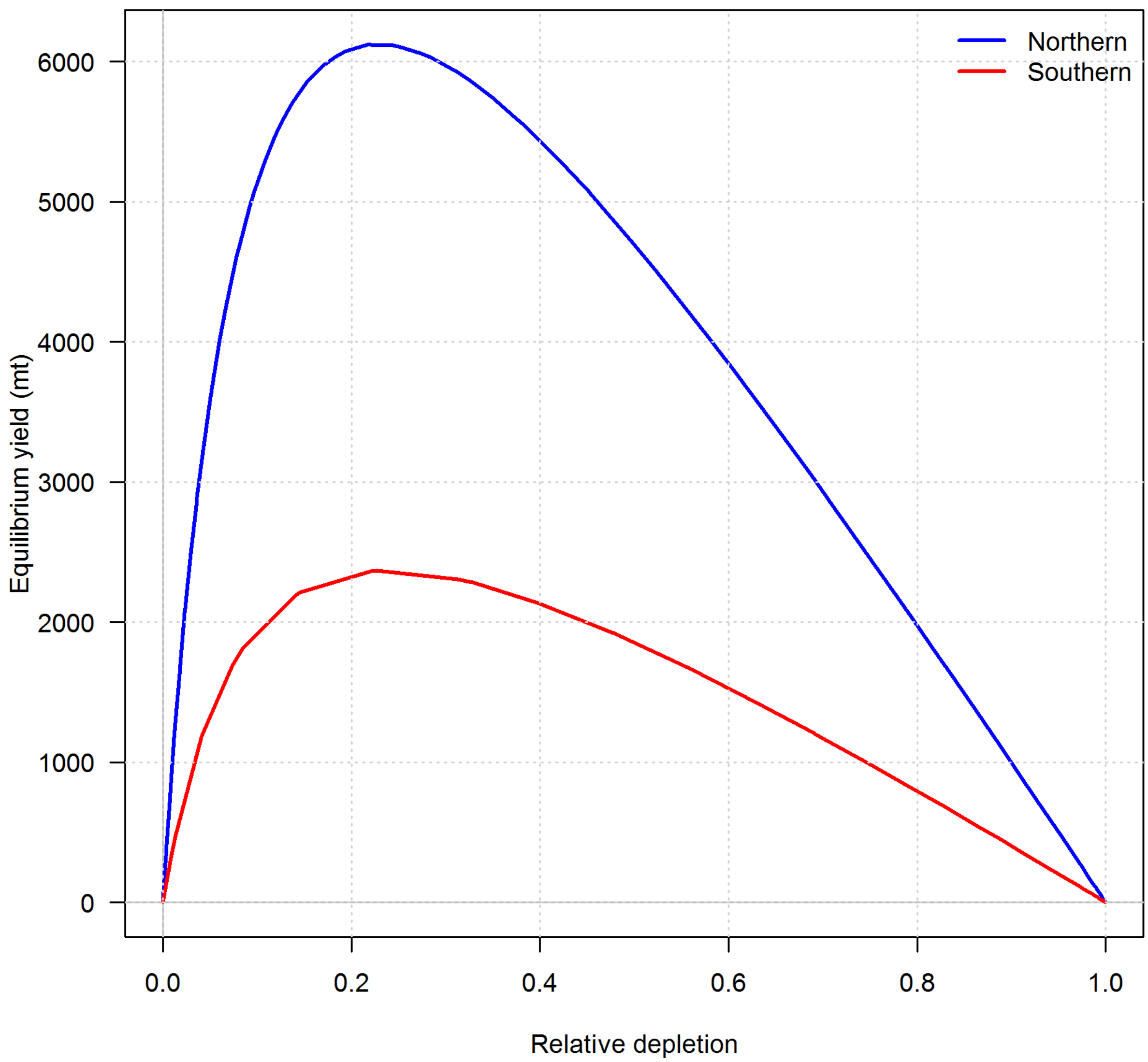

Figure i: Equilibrium yield curve for the base-case Northern model and final Southern model.

Table m: Summary of Spawning Output and Relative Spawning Output (Depletion) over 12-year projections for alternate states of nature based on an axis of uncertainty for the Northern model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. Projections for the years 2017/18 are shown in the first two rows and are used in all catch streams.

			States of nature					
			Low state (M = 0.122)		Base (M = 0.174)		High state (M = 0.249)	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
2017/18	2017	6196	8.30	0.50	11.30	0.75	17.90	0.82
	2018	5979	7.60	0.46	10.50	0.70	16.60	0.76
Recent 5-year average (approx. 2000 mt)	2019	1998	7.00	0.42	9.80	0.65	15.60	0.71
	2020	1997	7.00	0.42	9.80	0.65	15.40	0.70
	2021	1997	7.10	0.43	9.80	0.65	15.50	0.71
	2022	1997	7.20	0.43	9.80	0.65	15.80	0.72
	2023	1997	7.30	0.44	9.90	0.66	16.30	0.74
	2024	1998	7.40	0.44	10.10	0.67	16.80	0.77
	2025	1998	7.60	0.46	10.20	0.68	17.30	0.79
	2026	1998	7.70	0.46	10.40	0.69	17.80	0.81
	2027	1998	7.90	0.48	10.60	0.71	18.10	0.83
	2028	1998	8.20	0.49	10.70	0.71	18.40	0.84
Historic target opportunity catch stream example (approx. 4000 mt)	2019	3996	7.00	0.42	9.80	0.65	15.60	0.71
	2020	3994	6.70	0.40	9.50	0.63	15.20	0.69
	2021	3994	6.50	0.39	9.20	0.61	15.00	0.68
	2022	3993	6.30	0.38	9.00	0.60	15.10	0.69
	2023	3993	6.10	0.37	8.90	0.59	15.40	0.70
	2024	3993	6.00	0.36	8.90	0.59	15.80	0.72
	2025	3993	5.90	0.35	8.90	0.59	16.20	0.74
	2026	3993	5.90	0.35	8.90	0.59	16.60	0.76
	2027	3993	5.90	0.35	8.90	0.59	16.90	0.77
	2028	3994	5.90	0.35	8.90	0.59	17.10	0.78
Base catch stream	2019	6442	7.00	0.42	9.80	0.65	15.60	0.71
	2020	6122	6.40	0.38	9.20	0.61	14.90	0.68
	2021	5881	5.80	0.35	8.60	0.57	14.50	0.66
	2022	5709	5.30	0.32	8.20	0.55	14.50	0.66
	2023	5595	4.90	0.29	8.00	0.53	14.60	0.67
	2024	5522	4.60	0.28	7.80	0.52	15.00	0.68
	2025	5475	4.40	0.26	7.70	0.51	15.30	0.70
	2026	5442	4.30	0.26	7.60	0.51	15.60	0.71
	2027	5416	4.20	0.25	7.50	0.50	15.90	0.73
	2028	5392	4.10	0.25	7.50	0.50	16.10	0.73

Table n: Results summary for base-case Northern model and final Southern model.

Model Region	Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Northern Model	Landings (mt)	494.2	762.7	957.7	1348.8	1592.7	1432.5	1459.8	2015.4	1447.9	-
	Total Est. Catch (mt)	520.2	1100.2	1624.1	1349.7	1593.8	1433.3	1460.8	2016.8	1448.9	-
	OFL (mt)	4510	4562	4562	4566	4573	4579	4584	7218	6949	6786
	ACL (mt)	4510	4562	4562	4364	4371	4378	4382	6590	6344	6196
Northern Model	(1-SPR)(1-$SPR_{50\%}$)	0.108	0.209	0.292	0.250	0.293	0.277	0.284	0.383	0.294	
Base Case	Exploitation rate	0.004	0.008	0.012	0.010	0.012	0.011	0.011	0.016	0.012	
	Age 4+ biomass (mt)	139.69	138.78	134.91	134.22	129.32	129.70	125.70	127.51	125.63	123.87
	Spawning Output	12.13	12.57	12.83	12.85	12.74	12.47	12.16	11.84	11.48	11.28
	95% CI	(7.86-16.39)	(8.27-16.87)	(8.53-17.12)	(8.6-17.09)	(8.6-16.88)	(8.46-16.49)	(8.28-16.04)	(8.09-15.6)	(7.83-15.14)	(7.69-14.86)
	Depletion	0.81	0.84	0.86	0.86	0.85	0.83	0.81	0.79	0.77	0.75
	95% CI	(0.604-1.013)	(0.637-1.039)	(0.66-1.051)	(0.668-1.045)	(0.67-1.029)	(0.663-1.001)	(0.651-0.97)	(0.639-0.94)	(0.621-0.91)	(0.612-0.892)
	Recruits	66.69	20.82	72.38	29.34	38.43	53.49	50.06	49.53	49.20	49.09
	95% CI	(37.78 - 117.74)	(9.86 - 43.95)	(38.52 - 136)	(12.68 - 67.92)	(15.07 - 98.01)	(19.02 - 150.45)	(17.82 - 140.61)	(18 - 136.34)	(17.89 - 135.27)	(17.86 - 134.94)
Southern Model	(1-SPR)(1-$SPR_{50\%}$)	0.013	0.027	0.013	0.021	0.022	0.022	0.023	0.032	0.011	
Final Model	Exploitation rate	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	
	Age 4+ biomass (mt)	49.35	53.47	53.77	53.52	53.68	67.55	75.29	87.65	94.23	95.92
	Spawning Output	2.80	2.81	2.84	2.91	3.02	3.16	3.32	3.51	3.77	4.10
	95% CI	(0-6.43)	(0-6.41)	(0-6.46)	(0-6.6)	(0-6.8)	(0-7.09)	(0-7.41)	(0-7.83)	(0-8.37)	(0-9.08)
	Depletion	0.64	0.64	0.65	0.66	0.69	0.72	0.75	0.80	0.86	0.93
	95% CI	(0.482-0.79)	(0.492-0.783)	(0.506-0.784)	(0.527-0.797)	(0.553-0.819)	(0.583-0.852)	(0.615-0.891)	(0.653-0.943)	(0.699-1.013)	(0.756-1.106)
	Recruits	103.48	58.70	87.54	51.00	25.48	42.54	33.50	30.74	20.87	25.39
	95% CI	(31.51 - 339.77)	(16.09 - 214.16)	(25.05 - 305.87)	(13.23 - 196.67)	(6.62 - 97.99)	(12.66 - 142.92)	(9.71 - 115.53)	(8.58 - 110.13)	(4.91 - 88.65)	(5.24 - 123.02)

Research And Data Needs

The following research will be valuable for future Yellowtail Rockfish assessments:

1. A problem common to assessments of all stocks caught in the midwater is the lack of a targeting survey. Because limits on the take of depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry.

2. Research to determine whether old females of a variety of rockfish species actually have a mortality rate different than that of younger females. Assessments variously treat the discrepancies seen in sex ratios of older fish as either mortality-related or due unavailability to the fishery (e.g., ontogenetic movement offshore, or to rockier habitats). As these assumptions impact model outcomes very differently, resolving this issue would greatly improve confidence in the assessments.

3. A hindrance to analysis of the commercial fishery is the inability to distinguish between midwater and trawl gear, particularly in data from the 1980s-1990s. Reliable recording of gear type will ensure that this does not continue to be problematic for future assessments.

4. We recommend that the next assessment of the Northern stock be an update to this assessment, unless fishing patterns change dramatically, or new sources of data are discovered.

5. For the next full assessment, we suggest the following:

    - A commercial index in the North. This is by far the largest segment of the fishery, and the introduction of the trawl rationalization program should mean that an index can be developed for the current fishery when the next full assessment is performed.
    - Further investigation into an index for the commercial logbook dataset from earlier periods.
    - Further analysis of growth patterns along the Northern coast. The previous full assessment subdivided the Northern stock based on research showing differential growth along the coast, and although data for the assessment is no longer available along the INPFC areas used in that analysis, there may be some evidence of growth variability that would be useful to include in a future assessment.

6. The Southern stock cannot be evaluated with a full statistical catch-at-age model unless more data are made available. In particular, we feel that the following are minimally required:

    - A longer timeseries of the juvenile rockfish CPUE in the south, which will of course only be available after several years have elapsed.

- A timeseries of recent ages for the Southern model. The commercial age timeseries currently stops in 2002. Otoliths have been collected for all years in the Hook & Line survey, however only samples from 2004 have been aged. There may also be a collection otoliths associated with research at the SWFSC, and these should be investigated as well.