Agenda Item H.3
Attachment 8
September 2015

Status of Kelp Greenling (*Hexagrammos decagrammus*) along the Oregon Coast in 2015

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Executive Summary

Stock

This is the second stock assessment of the population status of Kelp Greenling (*Hexagrammos decagrammus* [Pallas, 1810]) along the Oregon coast (Figure 1). Kelp Greenling is endemic to nearshore rocky reef, kelp forest, and eelgrass habitats of the Northeast Pacific Ocean and ranges from southern California, north to the Alaskan Aleutian Islands, but is rarely found south of Point Conception, California. The first stock assessment of Kelp Greenling (Cope and MacCall, 2005) modeled a separate substock off the coast of California. However, there was insufficient population information (e.g., age, growth, natural mortality, abundance index) at the time for the California assessment results to be used for management advice. Subsequently, a data-poor assessment for waters off California was conducted and used for specifying an overfishing-level (OFL) contribution to the 'Other Fish' complex. In Washington nearshore waters, there is no commercial fishery for Kelp Greenling nor are there substantial recreational removals of Kelp Greenling. The spatial extent of this assessment includes the waters off the coast of Oregon.

Catches

Kelp Greenling is predominantly caught using hook-and-line gear by recreational fishermen and by hook-and-line or longline gear by commercial fishermen. Several other gear types harvest incidental amounts of Kelp Greenling (including fish pots, crab pots, troll gear, and trawl gear). Their preferred habitat is often easily accessible from shore or with a small vessel, making Kelp Greenling a frequent target for recreational fishermen. The onset of a readily available market for live fish, along with attractive ex-vessel prices, was a main driving force for the development of a Kelp Greenling commercial fishery in the late 1990s. Total landings have generally increased through time with a major peak occurring in 2002, resulting primarily from an exceptionally large commercial harvest in that year (Figure E1). Since the implementation of management limits (fleet size limit, annual landing caps, and daily and period landing limits) for the commercial fishery in 2004, landings have been generally stable. Landings were episodic from 1980 through the late 1990s, primarily driven by frequent fluctuations in shore and estuary-boat removals over the course of several years. Recent landings have been dominated by the commercial sector (Table E1).

The most significant change in the harvest trend for Kelp Greenling has resulted from the development of a live-fish market. This fishery started in northern California in the late 1980s and spread northward during the late 1990s to Oregon in order to supply the live-fish market in San Francisco, CA. Commercial landings of Kelp Greenling were available from the Pacific Fisheries Information Network (PacFIN; 1988 – 2014). Landings prior to 1988 are believed to be negligible, because only minor removals (0.3% on average compared to later years), were recorded on fish tickets from 1988 – 1995, prior to the advent of the live-fish market. More than 95% of commercial landings occur along the southern Oregon coastline at the ports of Gold Beach and Port Orford. Kelp Greenling is one of several nearshore species targeted for the live-fish market.

Historically, a significant portion of Oregon's Kelp Greenling landings came from the recreational fishery (particularly through shore and estuary-boat fishing modes). However, the magnitude of Oregon's recreational Kelp Greenling harvest prior to the early 1970s was not well documented, and there have been spans of years since that time with little information from the shore-based and estuary-boat fishing modes. The ocean-boat recreational fleet rarely targets Kelp Greenling, instead landings are often incidental when targeting other species such as Lingcod and Black Rockfish. Catch data begin in 1973 for the ocean-boat fishing mode and in 1981 for the estuary boat and shore fishing modes. For years prior to 1980 and for recent years (2005 – 2014), no direct information was available to estimate catch from estuary-boat and shore based fishing modes, so a catch reconstruction was completed for these periods. Nonetheless, there remains significant uncertainty around total landings for estuary-boat and shore-based fishing modes, particularly during periods where catch information was extrapolated from fishing license sales (pre-1980) or from recent years (2005-2014).

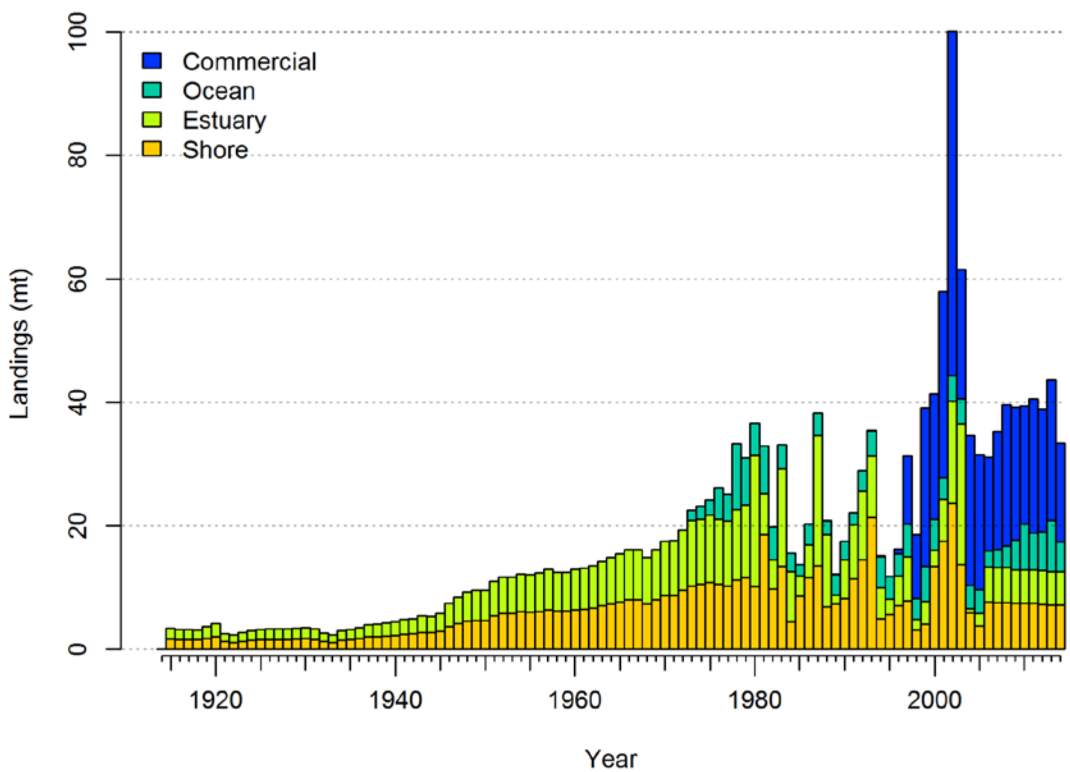

Figure E1. Stacked time series of Kelp Greenling landings (mt) by fleet for Oregon waters.

Table E1. Recent landings (mt) for Kelp Greenling by fleet.

Year	Commercial	Recreational Ocean Boat	Recreational Estuary Boat	Recreational Shore	Total Landings
2005	21.38	3.90	2.00	3.70	30.98
2006	14.83	2.67	5.60	7.50	30.60
2007	18.72	2.90	5.60	7.40	34.63
2008	22.43	3.48	5.60	7.40	38.91
2009	21.05	4.77	5.40	7.30	38.52
2010	18.73	7.37	5.40	7.30	38.80
2011	21.25	5.91	5.40	7.30	39.86
2012	19.44	6.22	5.40	7.20	38.27
2013	22.35	8.26	5.30	7.10	43.02
2014	15.72	4.75	5.30	7.10	32.87

Data and assessment

Kelp Greenling were assessed previously in 2005 (Cope and MacCall 2005). For Oregon, management advice regarding the status of the stock was determined to be acceptable (spawning biomass depletion of 49% of unfished levels). However, it was decided that an OFL could not be determined because of substantial uncertainties associated with overall catch levels, particularly from shore-based fishing modes. It is important to note that under current PFMC guidelines an OFL could have been determined for this assessment by applying the overfishing probability P* tier categories to establish a suitable buffer given the level of uncertainty in recent estimates of spawning biomass.

This assessment uses the most recent version of Stock Synthesis (version 3.24u) available. The assessment is structured as a single, sex-disaggregated, unit population, spanning Oregon coastal waters, and operates on an annual time step covering the period 1915 to 2014. The input files used for the stock assessment can be found in the appendices (pp. **Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**, and **Error! Bookmark not defined.**). Fleets were specified for recreational and commercial sectors. The recreational sector was split into three main fleets according to fishing mode, a proxy for the location of fishing. These include ocean-boat, estuary-boat, and fishing from shore fleets. The commercial sector was represented by one fleet, which included a combination of hook-and-line and longline gear types. Data used in the assessment includes time-series of commercial and recreational landings, three abundance indices (catch per unit effort or CPUE), length compositions for each fleet, and age compositions from the recreational ocean-boat fleet and the commercial fleet. Discard mortality rates were also used for each fleet to expand total landings to total catch.

Stock biomass

Kelp Greenling spawning biomass was estimated to be 316 mt in 2015 (~95% asymptotic intervals: 116-516 mt), which when compared to unfished spawning biomass equates to a depletion level of 80% (~95% asymptotic intervals: 0.59-1.00; Table E2) in 2015. Depletion is a ratio of the estimated spawning biomass in a particular year relative to estimated unfished, equilibrium spawning biomass. In general, spawning biomass has been trending slightly downwards until the early to mid-2000s and has since been trending slightly upwards (Figure E2). Considerable variation in stock sizes occurs during this time frame when the model allows for interannual deviations from the stock-recruitment relationship. Stock size is estimated to be at the lowest level throughout the historic time series in 1998, but has since increased as a result of strong recruitment in 2000 and 2009. Throughout the time series, the stock is estimated to be above the management target of $B_{40\%}$ (Figure E3).

Table E2. Recent trends in the beginning of the year biomass and depletion for Kelp Greenling in Oregon waters.

Year	Spawning Biomass (mt)	~ 95% confidence intervals	Estimated depletion	~ 95% confidence intervals
2006	346.17	(162-531)	0.87	(0.74-1.00)
2007	318.88	(146-492)	0.80	(0.68-0.93)
2008	277.73	(123-432)	0.70	(0.59-0.81)
2009	265.76	(113-419)	0.67	(0.55-0.79)
2010	282.47	(115-450)	0.71	(0.57-0.85)
2011	362.24	(144-581)	0.91	(0.72-1.10)
2012	415.18	(163-667)	1.05	(0.82-1.27)
2013	403.17	(157-650)	1.02	(0.79-1.25)
2014	354.51	(134-575)	0.89	(0.68-1.10)
2015	315.98	(116-516)	0.80	(0.59-1.00)

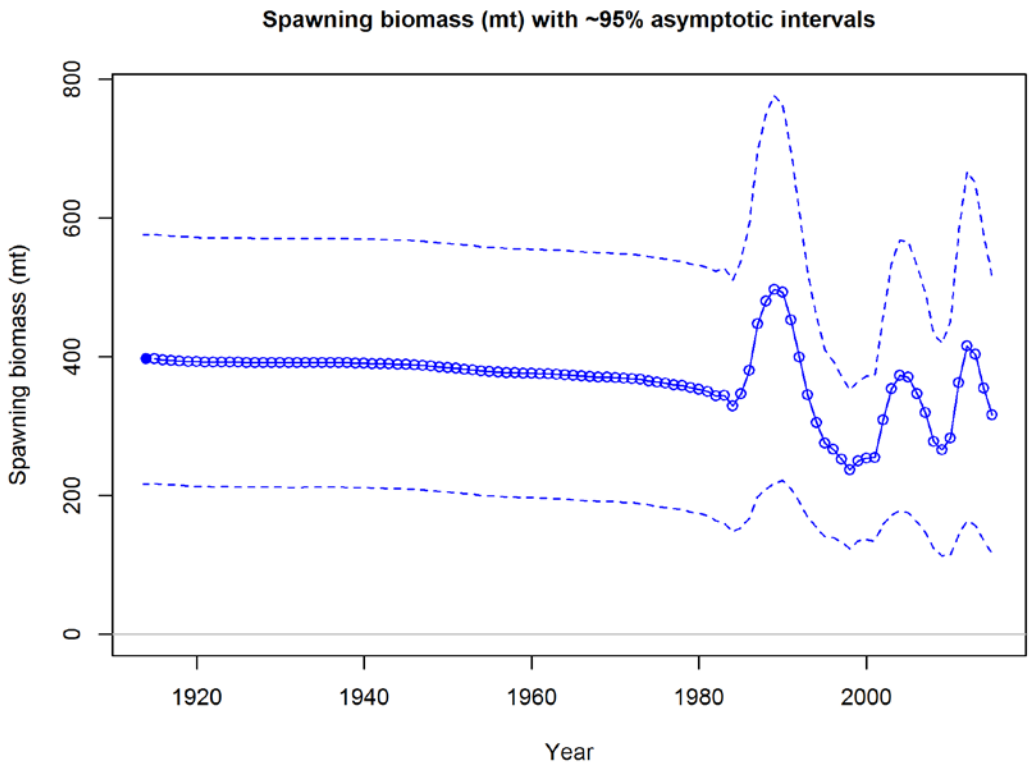

Figure E2. Time series of spawning biomass for Kelp Greenling in Oregon waters.

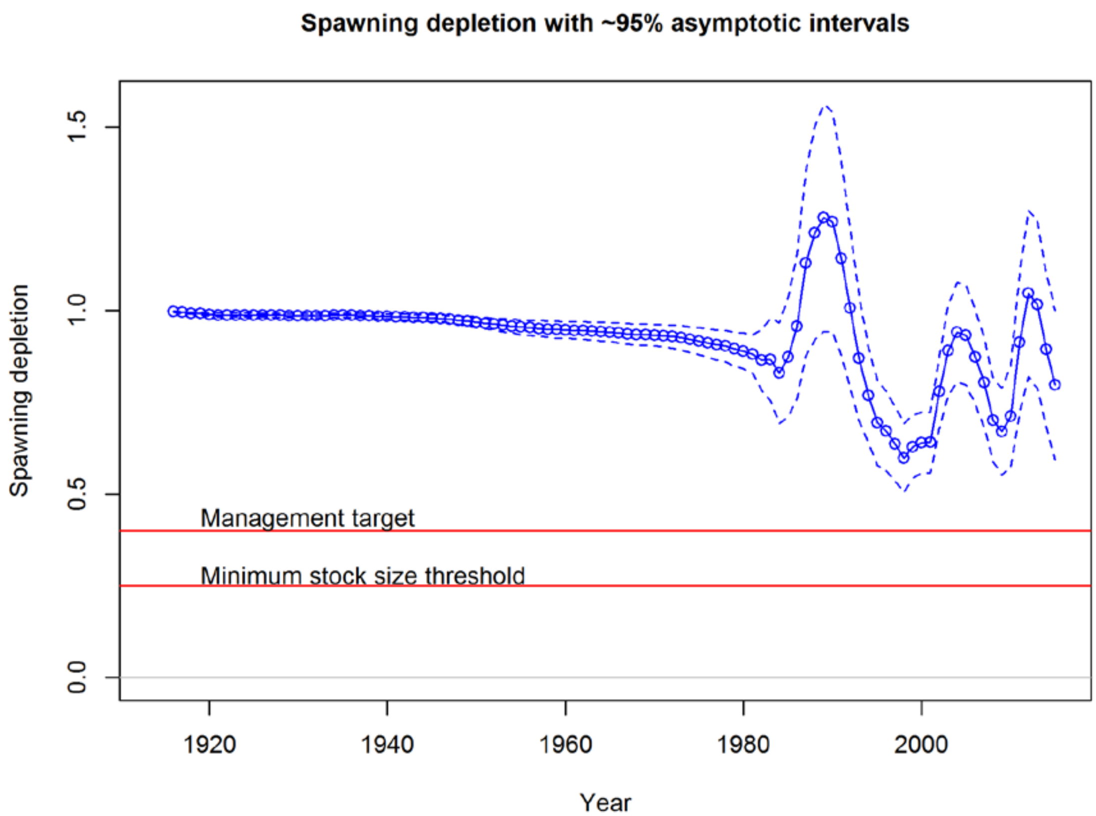

Figure E3. Estimated relative depletion relative to management reference points for Kelp Greenling in Oregon waters.

Recruitment

Recruitment variability was notably dynamic for Kelp Greenling (Table E3, Figure E4) and indicated above average recruitment in 2009. Other years with relatively high estimates of recruitment were 1985 and 2000. In recent years (2012-2014), the model had difficulty estimating recruitment levels because of a lack of cohort information contained in the most recent data.

Table E3. Recent trend in estimated recruitment for Kelp Greenling in Oregon waters.

Year	Estimated Recruitment (1,000s)	~ 95% confidence intervals
2006	432	(148-715)
2007	1,495	(674-2,315)
2008	1,827	(799-2,856)
2009	3,524	(1,559-5,489)
2010	1,855	(736-2,973)
2011	487	(86-889)
2012	447	(0-916)
2013	996	(0-2,141)
2014	1,433	(0-3,365)
2015	1,413	(0-3,318)

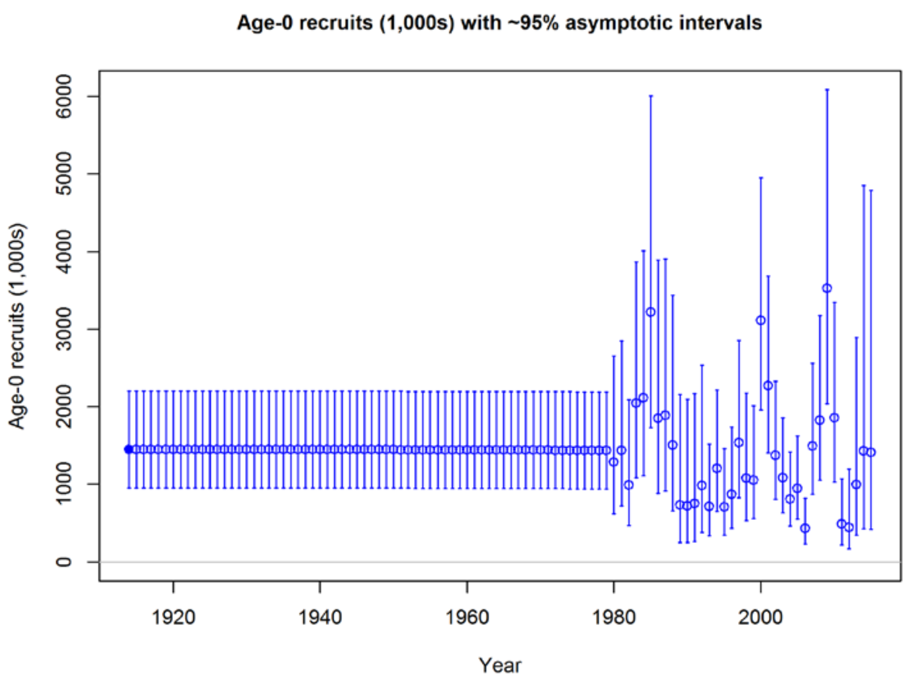

Figure E4. Time series of estimated recruitments with approximate 95% asymptotic intervals for Kelp Greenling in Oregon waters.

Exploitation status

Harvest rates have been generally increasing through time, reaching a maximum in 2002 (0.51, or 51% of the target level) before declining again to 0.21 in 2014 (Table E4, Figure E5). Fishing intensity is estimated to have been below the target throughout the time series. In 2014, Kelp Greenling biomass is estimated to have been at 2.24 times higher than the target biomass level, while experiencing fishing intensity 4.76 times lower than the SPR fishing intensity target (Figure E6).

Table E4. Recent trend in spawning potential ratio (entered as 1-SPR / 1-$SPR_{45\%}$) and exploitation for Kelp Greenling in Oregon waters.

Year	Estimated (1-SPR) / (1-$SPR_{45\%}$)	~ 95% confidence intervals	Harvest rate (ratio)	~ 95% confidence intervals
2005	0.18	(0.09-0.26)	0.14	(0.07-0.21)
2006	0.20	(0.11-0.30)	0.15	(0.07-0.22)
2007	0.25	(0.13-0.36)	0.19	(0.09-0.30)
2008	0.27	(0.14-0.39)	0.21	(0.10-0.33)
2009	0.26	(0.13-0.39)	0.19	(0.09-0.30)
2010	0.23	(0.11-0.35)	0.14	(0.06-0.23)
2011	0.22	(0.11-0.34)	0.14	(0.06-0.22)
2012	0.21	(0.10-0.33)	0.15	(0.06-0.24)
2013	0.24	(0.12-0.37)	0.19	(0.08-0.31)
2014	0.21	(0.09-0.33)	0.16	(0.06-0.26)

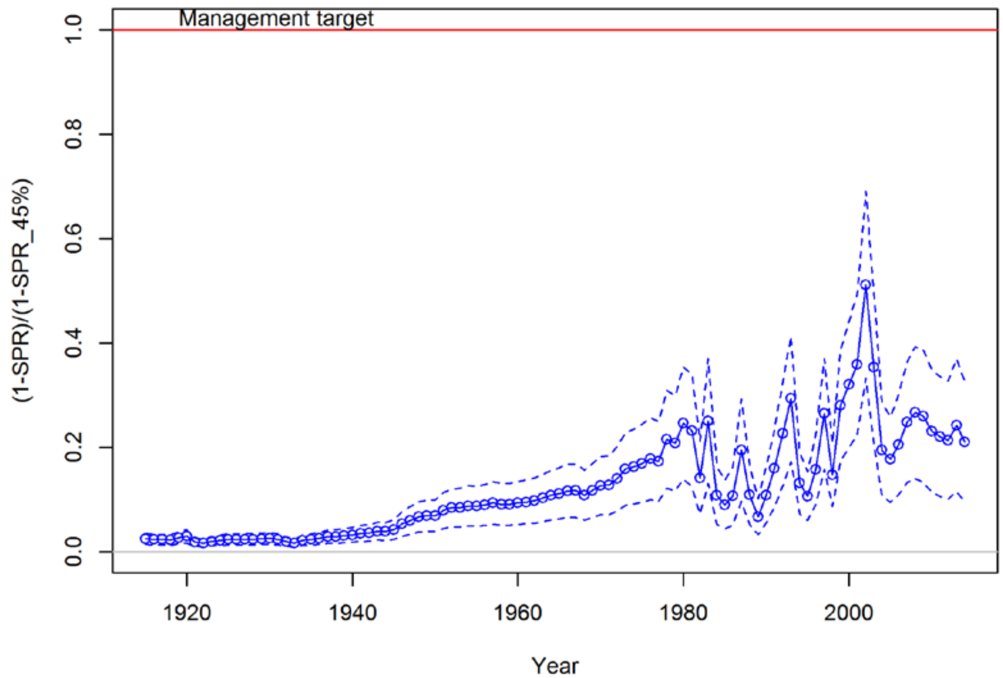

Figure E5. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as the red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{45\%}$. The last year of the time series is 2014.

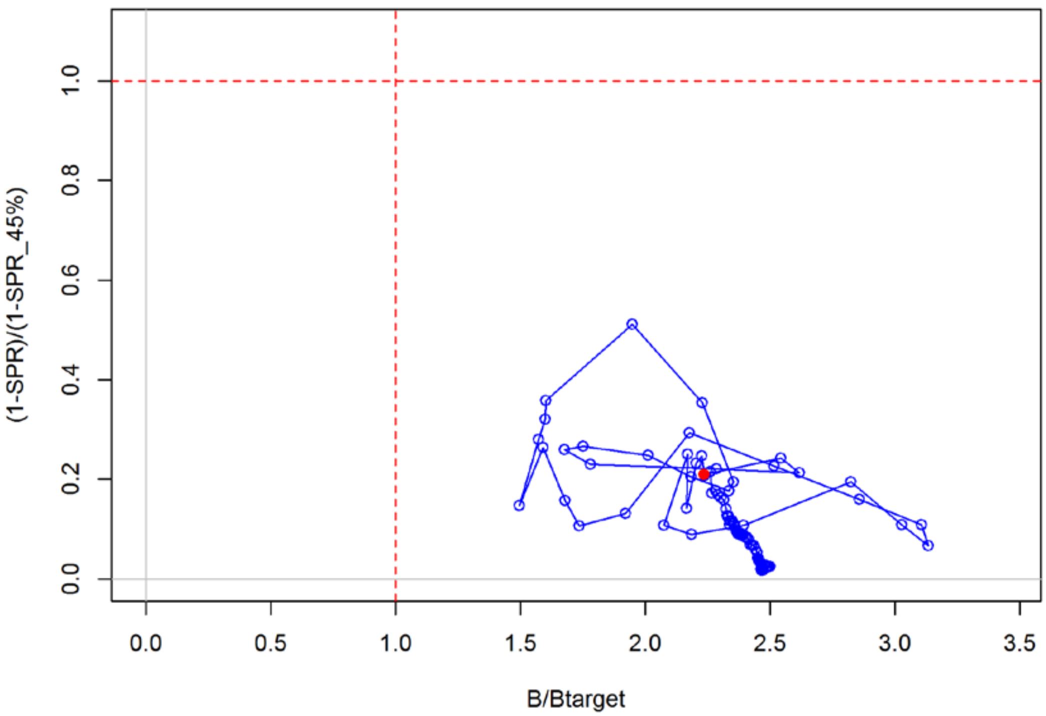

Figure E6. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 45% (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The red point indicates the year 2014.

Ecosystem considerations

Kelp Greenling is ubiquitous in suitable habitat including subtidal and intertidal nearshore and estuarine rocky habitats, both natural and man-made, and biogenic substrates. Important Kelp Greenling habitat associations include bedrock, large boulder, and small boulder habitats. Environmental factors altering nearshore habitat may have a direct or indirect impact on the Oregon Kelp Greenling stock. No research was uncovered that quantified ecosystem level effects on Kelp Greenling; therefore, considerations such as environmental correlations and food web interactions were not explicitly included in the assessment.

Reference points

Reference points and management quantities for the Oregon Kelp Greenling base-case model are listed in (Table E5). The Kelp Greenling stock is estimated to be above the biomass target. In general, there has been a declining (though variable) trend in spawning biomass from the beginning of the time series through the early 2000s. Spawning biomass has since increased (though variable) as a result of large recruitment events in 2000 and 2009. The estimated relative depletion level in 2015 is 80% (~95% asymptotic interval: 59% - 100%), corresponding to 316 mt (~95% asymptotic interval: 116 - 516 mt) of spawning biomass in the base model. Unfished spawning stock biomass was estimated to be 397 mt in the base case model. The target stock size based on the biomass target (*SB*40%) is 159 mt, with the corresponding SPR giving an MSY of 129 mt. Equilibrium yield at the proxy *FMSY* harvest rate corresponding to *SPR45*% is 130 mt.

Table E5. Summary of reference points and management quantities for the Kelp Greenling base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (mt)	397	(217-576)
Unfished recruitment (R0, thousands)	1,451	(838-2,064)
Spawning Biomass (2015)	316	(116-516)
Depletion (2015)	0.80	(0.59-1.00)
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	159	(87-230)
SPR resulting in $B_{40\%}$	0.46	(0.46-0.46)
Exploitation rate resulting in $B_{40\%}$	0.18	(0.17-0.18)
Yield at $B_{40\%}$ (mt)	129	(73-184)
Reference points based on SPR proxy for MSY		
Spawning biomass	152	(83-221)
SPR_{proxy}	0.45	
Exploitation rate corresponding to SPR_{proxy}	0.18	(0.18-0.19)
Yield with SPR_{proxy} at SB_{SPR} (mt)	130	(74-187)
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	111	(60-161)
SPR_{MSY}	0.36	(0.35-0.36)
Exploitation rate corresponding to SPR_{MSY}	0.24	(0.23-0.25)
MSY (mt)	136	(77-194)

Management performance

The status of Kelp Greenling was last determined in 2004 (Cope and MacCall 2005) to be above the default target management level (40% spawning biomass depletion) at 49%. An OFL or ACL was not determined from the results of that assessment, leaving little formal guidance for setting annual fishing limits and harvest guidelines. Without a federal OFL, Oregon has regulated Kelp Greenling harvest through the implementation of annual state-specified harvest limits for the greenling complex (Table E6). In 2003, these harvest levels were set at the 2000 landings level for both recreational (5.2 mt) and commercial (19.5 mt) fisheries through the state public process. In 2004, the commercial fishery state-specified harvest limit was increased 20% to 23.4 mt to allow for higher harvest levels of a perceived healthy stock. In the recreational fishery, these annual harvest limits were breached from 2009 - 2013, but in other years landings did not exceed limits. Commercial landings from the greenling complex are monitored and regulated by state-specified two-month cumulative trip limits. In the commercial fishery, state harvest limits have never been breached. Even though the recreational fishery has exceeded the state limit for that fleet in some years, it is important to note that total estimated fishing mortality has been well below what the current assessment estimates were the largest sustainable removals possible in those years.

Table E6. Recent trend in total commercial and recreational ocean-boat removals of Kelp Greenling relative to state instructed harvest limits for a greenling species complex. Removals were calculated as total landings plus the estimated number of dead discards.

Year	Management Guideline	Commercial Limit (mt)	Estimated Commercial Catch (mt)	Recreational Limit (mt)	Estimated Recreational Catch (mt)	Combined Limit (mt)
2005	State harvest limit	23.4	21.8	5.2	4.0	28.6
2006	State harvest limit	23.4	15.1	5.2	2.7	28.6
2007	State harvest limit	23.4	19.1	5.2	2.9	28.6
2008	State harvest limit	23.4	22.9	5.2	3.5	28.6
2009	State harvest limit	23.4	21.5	5.2	4.9	28.6
2010	State harvest limit	23.4	19.1	5.2	7.5	28.6
2011	State harvest limit	23.4	21.7	5.2	6.0	28.6
2012	State harvest limit	23.4	19.9	5.2	6.3	28.6
2013	State harvest limit	23.4	22.8	5.2	8.4	28.6
2014	State harvest limit	23.4	16.1	5.2	4.8	28.6
2015	OFL ('Other Fish')	14				
2016	OFL ('Other Fish')	16.6				

Unresolved problems and major uncertainties

The data for this assessment provided little contrast and significant noise throughout the time series, resulting in significant uncertainties about Kelp Greenling population dynamics. The major sources of uncertainty in this assessment were the values for natural mortality, growth, population scale (i.e., virgin recruitment level), and the catch history for recreational estuary-boat and shore fishing modes. Natural mortality could not be reliably estimated within the assessment model, and thus was fixed for males and females at the median of the prior distribution developed through meta-analytic approaches (Hamel 2015, Then et al. 2015) based on maximum age. The specification of maximum age itself is uncertain, and this uncertainty will propagate to the assumed values for natural mortality. With no ageing error available for Kelp Greenling (Cabezon was used as a proxy to provide ageing error information), it is difficult to translate such estimation error to maximum age. Further, natural mortality estimates were based on observed values for maximum age, which could be underestimated if the number of age samples is small or older fish are less vulnerable to being caught.

There was very little ageing information for age-0 and age-1 Kelp Greenling, yet by age-1 these fish can grow to 60-70% of their maximum length. This feature of the data, coupled with this species very rapid growth, resulted in significant uncertainty in the form of the von Bertalanffy growth function at young ages. The combination of growth and natural mortality uncertainty leads to significant uncertainty about population scale. The range of natural mortality values examined as a decision table major axis of uncertainty resulted in population scales that approached extrapolated density estimates from reef-level research survey transects in the territorial sea (see Appendix H for further details, pp. **Error! Bookmark not defined.**).

The catch history for estuary boat and shore recreational fishing modes in recent years (2006-2014) is unknown. The main catch, effort, and biological sampling that were in place for these modes ceased in 2005. In this assessment, these catches were extrapolated from information available in the time series, and do not capture the range of variability that is often seen with recreational fisheries from one year to the next.

During the course of the STAR panel, it was determined that there were unresolved problems associated with the MRFSS (Marine Recreational Fisheries Statistics Survey) database, and these data are important because they cover the longest time period (1980 – 2005). In particular, the MRFSS database includes multiple columns for length information, some values entered as integers and some entered with many decimal places; the assumption being that integers are real measurements and values with decimals (>> hundredths place) were estimated from weight. However, different length columns contain integers for different years, making it challenging to infer real length measurements, and column labels have changed over time. The MRFSS database needs to have clearly documented metadata associated with it.

Other unresolved problems identified at the STAR panel include a) lack of ageing error for Kelp Greenling and b) lack of clarity on a best method for weighting (tuning) compositional data. The best way to approach this weighting remains unresolved for all stocks. This assessment used the harmonic mean approach of McAllister and Ianelli (1997).

Forecast

A projection of the Kelp Greenling population up to year 2026 was examined that would result in reaching the biomass target (SB ratio = 0.40) by the final year (2026; Table E7). Fleet specific catches during the first two years (2015 – 2016) were set to their average over the most recent three years (2012 – 2014; i.e., status quo levels). In order to reach the biomass target, total catch would need to more than triple that of current status quo levels.

Table E7. Projection of Kelp Greenling spawning biomass and depletion using the base case model for the scenario of achieving the biomass target (SB40%) *in 10 years. Total catch in 2015 and 2016 were set to the average over the most recent three years (2012 – 2014).*

Year	Total Catch (mt)	Age 1+ Biomass (mt)	Spawning Biomass (mt)	Depletion
2015	38.7	1,131	316	0.80
2016	38.7	1,141	300	0.76
2017	239.1	1,156	299	0.75
2018	201.0	1,007	246	0.62
2019	177.5	912	214	0.54
2020	162.5	851	194	0.49
2021	152.7	810	181	0.46
2022	146.1	782	173	0.44
2023	141.7	763	167	0.42
2024	138.5	749	163	0.41
2025	136.3	739	160	0.40
2026	134.5	732	158	0.40

Decision table

The main axis of uncertainty that was identified for this assessment was alternative states of nature for male and female natural mortality (Table E8). The specification of natural mortality for the base model was done by fixing the parameter at the median of a prior distribution, which was proportional to maximum age (observed female maximum age = 15; male = 17). Alternative states were developed by using the same maximum age formulation as in the base model, but applying maximum age values of ±2 years from that observed for females and males. These high and low levels of natural mortality resulted in bounds on estimated spawning stock biomass that were similar to bounds when extrapolating density estimates from research survey transects (see Appendix H for further details, pp. **Error! Bookmark not defined.**).

Three alternative forecast catch scenarios were examined: high, low, and following the ABC/ACL according to the 40:10 rules. The low catch scenario applied 2014 levels of catch to each fleet from 2017 – 2026 (total catch = 33.5 mt). The high catch scenario applied 2002 levels of catch to each fleet from 2017 – 2026 (total catch = 100.2 mt). Catch in 2002 was significantly higher than any other year during the time series, and this level of catch occurred prior to the 2004 implementation of state imposed commercial and recreational harvest limits. The ABC/ACL scenario applied a level of catch consistent with 40:10 rules, where a buffer of 4.4% was used to calculate ABC (log sigma = 0.36, P* = 0.45) from the OFL based on SPR45%. For all scenarios, catch by fleet during 2015 and 2016 was set to the fleet-specific average over the most recent three years (2012-2014).

Table E8. Decision table summarizing 12-year projections (2015 – 2026) under three different scenarios for male and female natural mortality and three alternative static catch scenarios. The state of nature for natural mortality was based on maximum age calculations using ± 2 years from the base case for males and females.

		State of nature								
		Low			Base case			High		
		M_f = 0.318			M_f = 0.360			M_f = 0.415		
		M_m = 0.285			M_m = 0.318			M_m = 0.360		
Relative prob. of ln(SB_2015):		0.25			0.5			0.25		
Management decision	Year	Catch (mt)	Spawning Biomass (mt)	Depletion	Catch (mt)	Spawning Biomass (mt)	Depletion	Catch (mt)	Spawning Biomass (mt)	Depletion
High Observed Catch (Based on 2002 Landings)	2017	100.2	177	0.67	100.2	299	0.75	100.2	1,127	0.82
	2018	100.2	160	0.61	100.2	286	0.72	100.2	1,145	0.83
	2019	100.2	147	0.56	100.2	277	0.70	100.2	1,167	0.85
	2020	100.2	136	0.52	100.2	270	0.68	100.2	1,186	0.86
	2021	100.2	126	0.48	100.2	265	0.67	100.2	1,202	0.87
	2022	100.2	118	0.45	100.2	260	0.66	100.2	1,214	0.88
	2023	100.2	111	0.42	100.2	257	0.65	100.2	1,223	0.89
	2024	100.2	105	0.40	100.2	254	0.64	100.2	1,231	0.89
	2025	100.2	99	0.38	100.2	251	0.63	100.2	1,236	0.90
	2026	100.2	94	0.36	100.2	249	0.63	100.2	1,240	0.90
Low Observed Catch (Based on 2014 Landings)	2017	33.5	177	0.67	33.5	299	0.75	33.5	1,127	0.82
	2018	33.5	179	0.68	33.5	305	0.77	33.5	1,163	0.84
	2019	33.5	183	0.70	33.5	312	0.79	33.5	1,200	0.87
	2020	33.5	187	0.71	33.5	319	0.80	33.5	1,232	0.89
	2021	33.5	190	0.72	33.5	325	0.82	33.5	1,257	0.91
	2022	33.5	193	0.73	33.5	330	0.83	33.5	1,276	0.93
	2023	33.5	195	0.74	33.5	333	0.84	33.5	1,291	0.94
	2024	33.5	197	0.75	33.5	336	0.85	33.5	1,303	0.95
	2025	33.5	199	0.76	33.5	339	0.85	33.5	1,311	0.95
	2026	33.5	200	0.76	33.5	341	0.86	33.5	1,318	0.96
ABC/ACL	2017	121.8	177	0.67	229.8	299	0.75	996.9	1,127	0.82
	2018	107.0	154	0.58	194.9	249	0.63	817.5	901	0.65
	2019	97.4	139	0.53	173.2	218	0.55	712.2	770	0.56
	2020	91.0	129	0.49	159.2	199	0.50	647.9	692	0.50
	2021	86.5	122	0.46	150.0	186	0.47	607.5	645	0.47
	2022	83.5	117	0.45	143.8	178	0.45	581.6	614	0.45
	2023	81.3	114	0.43	139.6	172	0.43	564.5	594	0.43
	2024	79.7	112	0.42	136.6	168	0.42	552.8	581	0.42
	2025	78.5	110	0.42	134.5	165	0.42	544.8	571	0.41
	2026	77.7	108	0.41	133.0	163	0.41	539.2	565	0.41

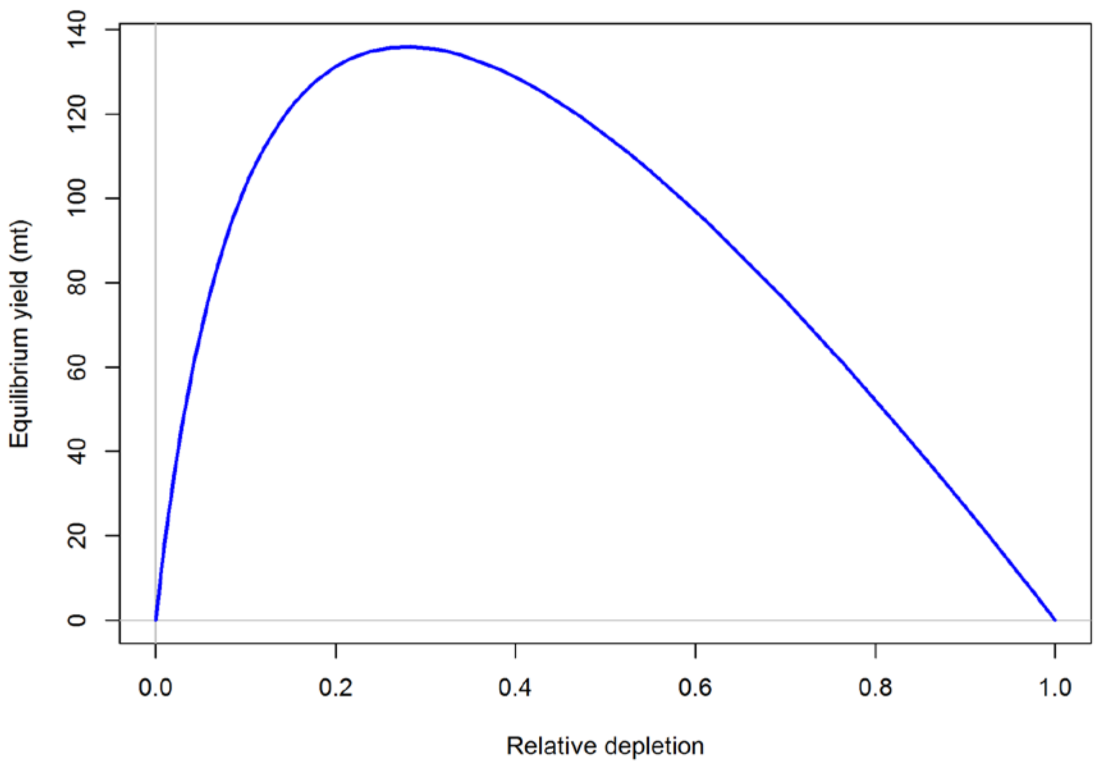

Figure E7. Equilibrium yield curve for the Kelp Greenling base case model. Values are based on 2014 fishery selectivity and with steepness fixed at 0.7.

Research and data needs

There are several areas of further research or data acquisition that would have a high probability of improving the estimation of population parameters for Kelp Greenling in Oregon waters. These include, but are not limited to, the following:

1. Fishery-independent surveys of abundance for nearshore species, including Kelp Greenling, would provide information about population trends that don't rely on data collected directly from the fishery and the inherent complexities that those data entail. Surveys that result in a time series of information covering a representative spatial extent of the population would be most advantageous.

2. Improved data collection relevant to basic fishery statistics (catch/effort) for recreational shore and estuary-boat fleets, including biological sampling where possible, to monitor changes in these highly dynamic fishing modes.

3. The collection of gender-specific information is generally straightforward given the visual ease (color and markings) of identifying Kelp Greenling by gender and the

collection of this information should be implemented for Ocean Recreational Boat Samplers (ORBS).

4. The double reading of Kelp Greenling otoliths would provide some indication into error and bias for this influential source of information.

5. Kelp Greenling stock structure needs to be studied and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible for Kelp Greenling, and data to support that hypothesis would be beneficial for future assessments.

6. Research into the implications and complexities of managing a stock where both genders contribute to spawning potential (e.g., through a Management Strategy Evaluation) would help guide future assessments and management for species such as Kelp Greenling (males exhibit nest-guarding behavior).

Table E9. Summary of base case model results for Kelp Greenling in Oregon waters.

Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total landings (mt)	30.98	30.60	34.63	38.91	38.52	38.80	39.86	38.27	43.02
Total removals (mt)	31.59	31.17	35.28	39.65	39.26	39.52	40.61	38.98	43.83
1-SPR	0.10	0.11	0.14	0.15	0.14	0.13	0.12	0.12	0.13
Exploitation rate	0.14	0.15	0.19	0.21	0.19	0.14	0.14	0.15	0.19
Age 1+ biomass (mt)	1,327	1,308	1,283	1,274	1,279	1,297	1,302	1,305	1,288
Spawning Output	370	346	319	278	266	282	362	415	403
~95% CI	(175-566)	(162-531)	(146-492)	(123-432)	(113-419)	(115-450)	(144-581)	(163-667)	(157-650
Recruitment (1,000s)	945	432	1,495	1,827	3,524	1,855	487	447	996
~95% CI	(422-1,468)	(148-715)	(674-2,315)	(799-2,856)	(1,559-5,489	(736-2,973)	(86-889)	(0-916)	(0-2,141
Depletion (%)	0.93	0.87	0.80	0.70	0.67	0.71	0.91	1.05	1.02
~95% CI	(0.80-1.07)	(0.74-1.00)	(0.68-0.93)	(0.59-0.81)	(0.55-0.79)	(0.57-0.85)	(0.72-1.10)	(0.82-1.27)	(0.79-1.2