Projection Uncertainty: Assessing the Change in Uncertainty During Projection Periods Based on Decision Table States of Nature

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Motivation

Estimates of stock size and status produced by stock assessments are uncertain. It is important to account for this uncertainty when setting harvest limits that would avoid overfishing. The Pacific Fishery Management Council has specified levels of uncertainty based upon stock categorization (higher categories assume a higher level of uncertainty) when setting Acceptable Biological Catches (ABCs). The reduction between the assessment-estimated Overfishing Limit (OFL) and the ABC is based on uncertainty surrounding stock size, termed "sigma". The sigma value adopted by management is based on the amount of uncertainty in the assessment year spawning biomass to reduce the forecasted OFLs. However, the more years removed from the time of the last assessment, the more uncertainty there is surrounding stock size and status based on recruitment (as well as other population of fishery dynamics) for unobserved years. To date, management has not adjusted the sigma applied to set ABCs based on the time since last assessment. This work provides a preliminary analysis examining change in uncertainty over the projection period for U.S. West Coast groundfish stocks.

Methods

Decision tables are included in U.S. West Coast assessment documents as a method to express uncertainty surrounding key parameters. Potential low and high states of nature relative to the base model under potential removal scenarios over a ten-year projection period are included as a way to explicitly state potential future population sizes. The base state of nature, which represents the estimates applied for management, is assumed representative of the likely state of the stock and is assigned a 50% probability (assuming a normal distribution for the uncertainty). The low and high states of nature should represent the upper and lower 25% percentiles from a normal distribution given the main source of uncertainty identified in the assessment.

To evaluate potential levels in changing uncertainty since the time of the last assessment, the low and base states of nature provided within category 1 assessment decision tables were evaluated. The change in projected spawning biomass between the low and the base states were used to calculate uncertainty over the projection period where the odds ratio is calculated as:

$$\sigma_t = ln(SB_{t,base}/SB_{t,low})/p$$

where $SB_{t,base}$ is the spawning biomass (or output) of the base state of nature in year t, $SB_{t,low}$ is the spawning biomass (or output) of the low state of nature in year t, and p is the confidence interval value set at the 12.5^{th} percentile value of 1.15.

The category 1 stock assessments included in this analysis are shown in Table 1. The majority of low and base states of nature based on ABC removals were pulled from decision tables from the most recent full stock assessment. In the case that ABC catches were not one of the decision table catch streams, the base and low states of nature were run with ABC removals for this analysis.

Several assessments have unique situations regarding the decision table that required rerunning in order to create the states of nature for this analysis. The kelp greenling assessment model estimated the uncertainty surrounding the final biomass as a value greater than the default sigma value for category 1 stocks (0.44 vs. 0.36). This sigma value was used to calculate the corresponding buffer and the resulting ABC projection. Assessments from 2009 did not include a reduction between the OFL and the ABC value using a buffer. These assessments were rerun using ABC values that included the current management buffer of 0.956 (sigma = 0.36 and P* =0.45). The only exception to this was the 2007 chilipepper assessment that projected ABC catches without a buffer. This model was not rerun due to technical difficulties of rerunning this older assessment, and the values were taken straight from the decision table. The low state of nature from the 2013 petrale sole assessment results in a higher stock status and biomass relative to the base model. This unexpected behavior was due to the model estimating both natural mortality and steepness. In the low state of nature, which fixed natural mortality at a lower value, the model increased the estimated steepness value relative to the base model. The low state was rerun with natural mortality fixed at the low value and steepness fixed at the base model estimate. Additionally, bocaccio and yelloweye rockfish were excluded on the basis that catches for overfished stocks are strictly managed and have limited variability due to low harvest rates.

The change in uncertainty over the projection period was scaled to the initial value for each stock to allow comparison across all assessments.

To provide contrast in the variability over the projection period between a stock where ABC or fixed catches were removed over the projection period, one stock from each life history grouping was rerun with fixed removals. Constant removals may result in lower variability between states of nature compared to situations when ABC catches are removed.

Additionally, the relationship between natural mortality and the change in uncertainty between the low and base states of nature based was examined. Stocks with faster dynamics, i.e., higher natural mortality, may have larger uncertainty between the states of nature by the end of the projection period that may need to be accounted for. Natural mortality values by stock are shown in Table 2. Only the female natural mortality values by stock were used. Canary rockfish has a ramp in female natural mortality for older fish. The base value for younger fish was used in this analysis.

Results

The scaled change in low and base states of nature by stock over the projection period are shown in Figure 1. The trends between the low and base states of nature varied by stock. Generally, the uncertainty increased over the projection period.

One notable exception to this trend was petrale sole. The low state of nature within the petrale sole 2013 assessment document actually converged towards the base state of the projection period. The low state of nature included within the assessment document for this stock had a low state of nature that ended up at a higher biomass relative to the base state due to a higher steepness value being estimated in the low state of nature. This analysis reran the low state by fixing the natural mortality at the low value and steepness at the base model value, but there still seemed to be compensation among parameters resulting in the low and base states of nature biomass converging over the projection period.

The trend between the low and the base state was summarized by PFMC management life history grouping shown in Table 3 and Figure 2. The flatfish life history type consisted of only petrale and Dover sole. The trend in uncertainty was driven by Dover sole, which had high variability between the states of nature, especially compared to petrale sole that decreased in variation over the projection period. The roundfish life history had a large amount of variation between the low and the base state of nature by the end of the projection period. Both kelp greenling and lingcod south stocks resulted in low states of nature that declined to zero biomass and were removed from these calculation due to this behavior. Examining the trend in variation for both of these stocks in Figure 1 show kelp greenling with a high variation relative to the other roundfish stocks, while the trend in lingcod south is similar to the northern stock and the trend

in the cabezon stocks. Finally, the rockfish assessments also showed an increasing trend of variation between the two states of nature over the projection period. The overall median variation across life history groups was a 43% increase relative to the start of projections.

The stocks which had removals based on a fixed catch stream had much lower variation, often with the low and base states of nature becoming closer rather than further apart, in contrast to when the same stocks had catches based on the ABC (Table 4). The driver of this pattern is the fixed catches are typically much lower than the ABC removals resulting in less variation in the low and base states of nature.

Finally, the relationship between the base female natural mortality values for each stock compared to the change in uncertainty in the projection period is shown in Figure 3. There was not a discernable pattern in the change of uncertainty between the start and the end of the projection period based on natural mortality. Despite this conclusion, it would still be expected that stocks with faster life history dynamics to have a large probability to diverge from projections compared to other stocks.

Summary

In summary, there was an increase in uncertainty over the projection period across the majority of category 1 stocks. The magnitude of change in that uncertainty was dependent on the life history type and catch removals. This analysis can be used a preliminary guide regarding the potential change in uncertainty that should be accounted for when setting catch limits for older U.S. west coast groundfish stock assessments. The results here represent potentially a best case scenario assuming that the model structure from the assessment is correctly specified to capture the dynamics of the modeled stock and that the values used in the decision table adequately captures the potential state of nature of the stock.

Tables

Table 1. List of groundfish assessments used in the analysis, the assessment year, if the values were obtained from assessment decision table, and the catch stream. Additional information is provided by stock where the catch stream was not pulled from the assessment decision table.

Stock	Assessment Year	Decision Table	Catch Stream	Alternative Fixed	Notes
aurora rockfish	2013	Y	ABC		
black rockfish (south)	2015	Y	ABC		
black rockfish (central)	2015	N	ABC		Reran to create ABC catches with buffer = 0.956
black rockfish (north)	2015	Y	ABC		
cabezon (south CA)	2009	N	ABC		Reran with buffer = 0.956
cabezon (north CA)	2009	N	ABC		Reran with buffer = 0.956
cabezon (OR)	2009	N	ABC	24 mt	ABC reran with buffer = 0.956. Fixed stream is half of the first year ABC value.
canary rockfish	2015	Y	ABC		
chilipepper rockfish	2007	Y	ABC		Catches in the assessment were based on 40:10 without a buffer applied
darkblotched rockfish	2015	N	ABC		Re-ran to create ABC catches with buffer = 0.956
Dover sole	2011	N	ABC	25,000 mt	ABC reran with buffer = 0.956. Fixed catches scenario based on 25,000 mt per year from decision table which are 30% of the first year ABC.
kelp greenling	2015	N	ABC		Re-ran to create ABC catches with buffer = 0.934
lingcod (north)	2017	Y	ABC		
lingcod (south)	2017	Y	ABC		
longnose skate	2007	Y	ABC	1,349 mt	ABC reran with buffer = 0.956. Fixed catches pulled from decision table scenario based on 1349 mt per year which are 50% of the first year ABC.
Pacific ocean perch	2017	Y	ABC	2,555 mt	Fixed catches pulled from decision table scenario based on SPR target yield which are 42% of the first year ABC.
petrale sole	2013	N	ABC		Reran with fixed parameters for M and steepness
sablefish	2011	Y	ABC		
splitnose rockfish	2009	N	ABC		Reran with buffer = 0.956
widow rockfish	2015	Y	ABC		
yellowtail rockfish (north)	2017	Y	ABC		

Table 4. Natural mortality values by stock. The values are representative of the base natural mortality value for females from each stock assessment.

Stock	Natural Mortality
aurora rockfish	0.035
black rockfish (south)	0.181
black rockfish (central)	0.170
black rockfish (north)	0.163
cabezon (south CA)	0.250
cabezon (north CA)	0.250
cabezon (OR)	0.250
canary rockfish	0.052
chilipepper rockfish	0.160
darkblotched rockfish	0.054
Dover sole	0.117
kelp greenling	0.360
lingcod (north)	0.180
lingcod (south)	0.180
longnose skate	0.200
Pacific ocean perch	0.054
petrale sole	0.152
sablefish	0.080
splitnose rockfish	0.048
widow rockfish	0.157
yellowtail rockfish (north)	0.145

Table 3. The scaled change in uncertainty between the first and final projection year when catches are based on ABC removals.

Projection Year	Flatfish		Roundfish		Rockfish		All Stocks Combined	
	Median	SD	Median	SD	Median	SD	Median	SD
1	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
2	1.16	0.02	1.10	0.07	1.04	0.07	1.08	0.07
3	1.28	0.04	1.21	0.13	1.14	0.13	1.17	0.13
4	1.38	0.19	1.30	0.18	1.22	0.19	1.25	0.18
5	1.46	0.40	1.39	0.23	1.30	0.24	1.30	0.24
6	1.52	0.65	1.48	0.27	1.32	0.29	1.32	0.30
7	1.59	0.92	1.58	0.31	1.32	0.34	1.32	0.38
8	1.66	1.21	1.69	0.35	1.32	0.45	1.33	0.48
9	1.73	1.51	1.79	0.39	1.32	0.59	1.38	0.60
10	1.82	1.81	1.88	0.43	1.31	0.70	1.43	0.71

Table 4. Comparison between the uncertainty by stock when the catch stream was at a fixed value versus the ABC.

Projection Year	Dover sole		longnose skate		Pacific ocean perch		cabezon (OR)	
	Fixed	ABC	Fixed	ABC	Fixed	ABC	Fixed	ABC
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.02	1.14	0.98	1.03	1.00	1.03	1.01	1.12
3	1.04	1.31	0.97	1.05	0.99	1.05	1.00	1.21
4	1.07	1.51	0.95	1.08	0.99	1.08	0.98	1.30
5	1.09	1.74	0.93	1.11	0.99	1.11	0.97	1.39
6	1.12	1.98	0.92	1.14	0.99	1.14	0.95	1.48
7	1.14	2.24	0.91	1.17	0.99	1.17	0.93	1.58
8	1.17	2.51	0.90	1.19	0.98	1.21	0.91	1.69
9	1.19	2.80	0.89	1.22	0.98	1.24	0.89	1.80
10	1.21	3.10	0.89	1.24	0.98	1.27	0.87	1.92

Figures

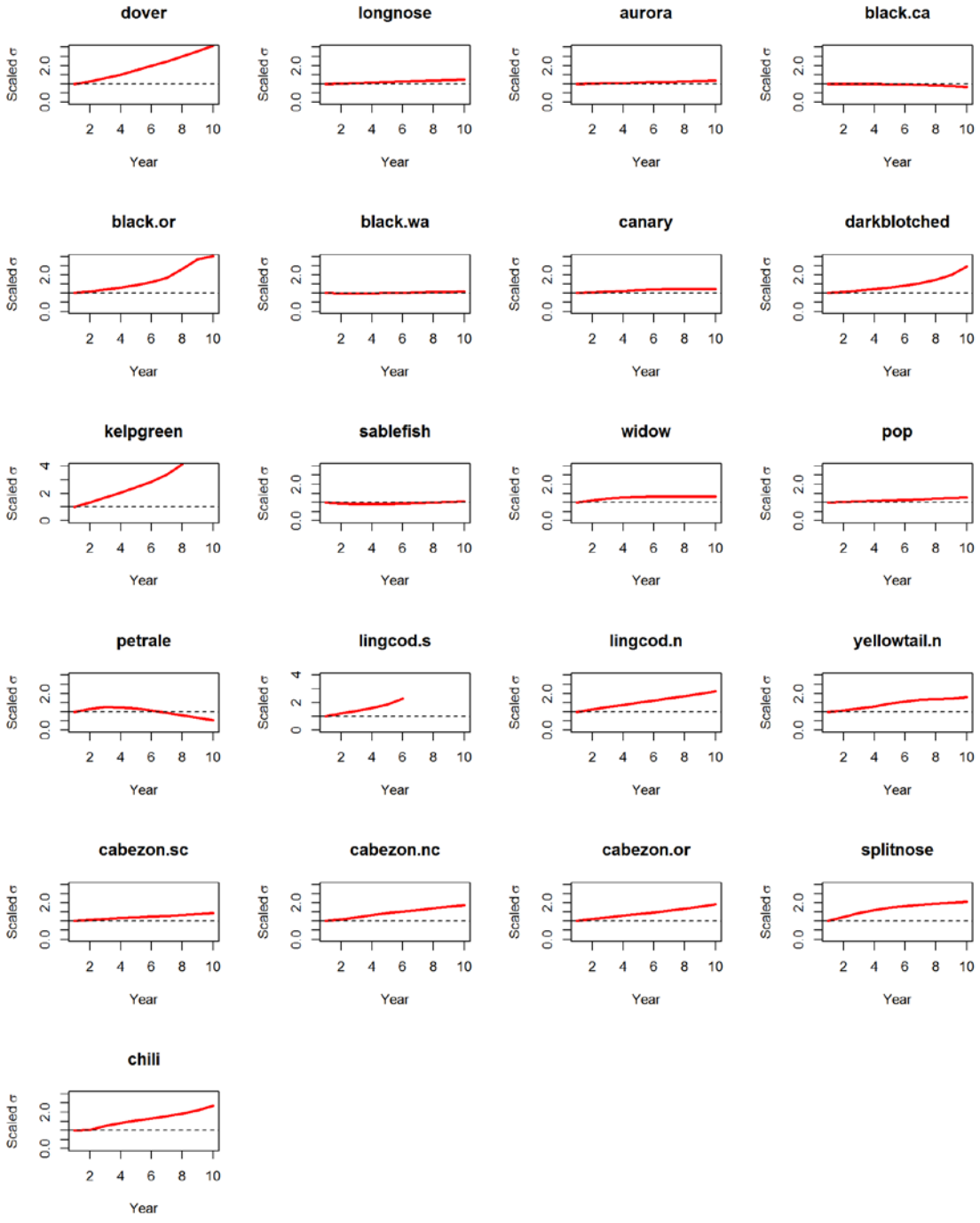

Figure 1. Change in the calculated uncertainty over the projection period by stock. The kelp greenling and the lingcod south assessments each had low states of nature that went to zero biomass by the end of the projection period.

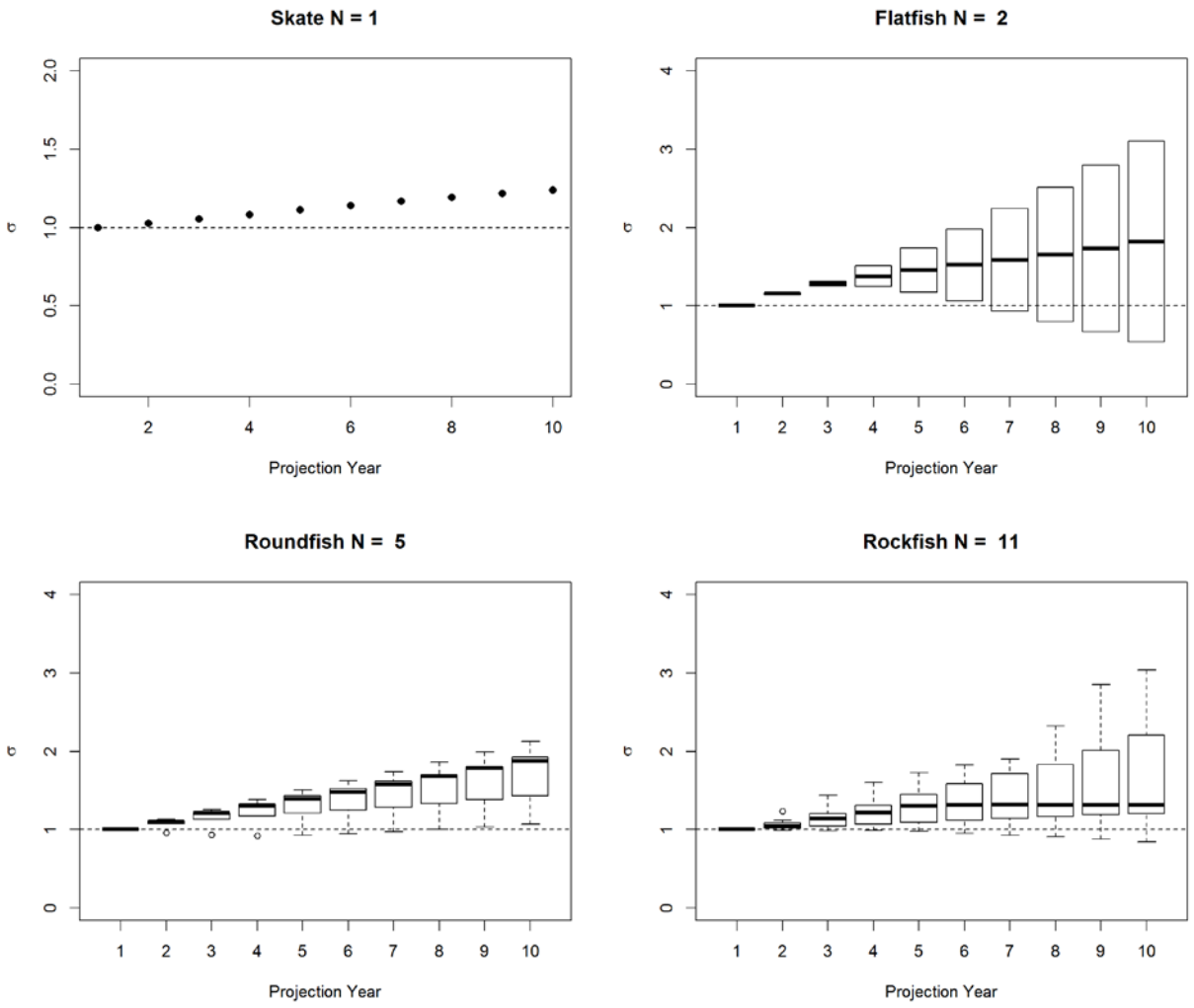

Figure 2. Change in the calculated uncertainty over the projection period by management grouped life history type. The kelp greenling and the lingcod south assessments were removed from the roundfish calculations because each had low states of nature that went to zero biomass by the end of the projection period.

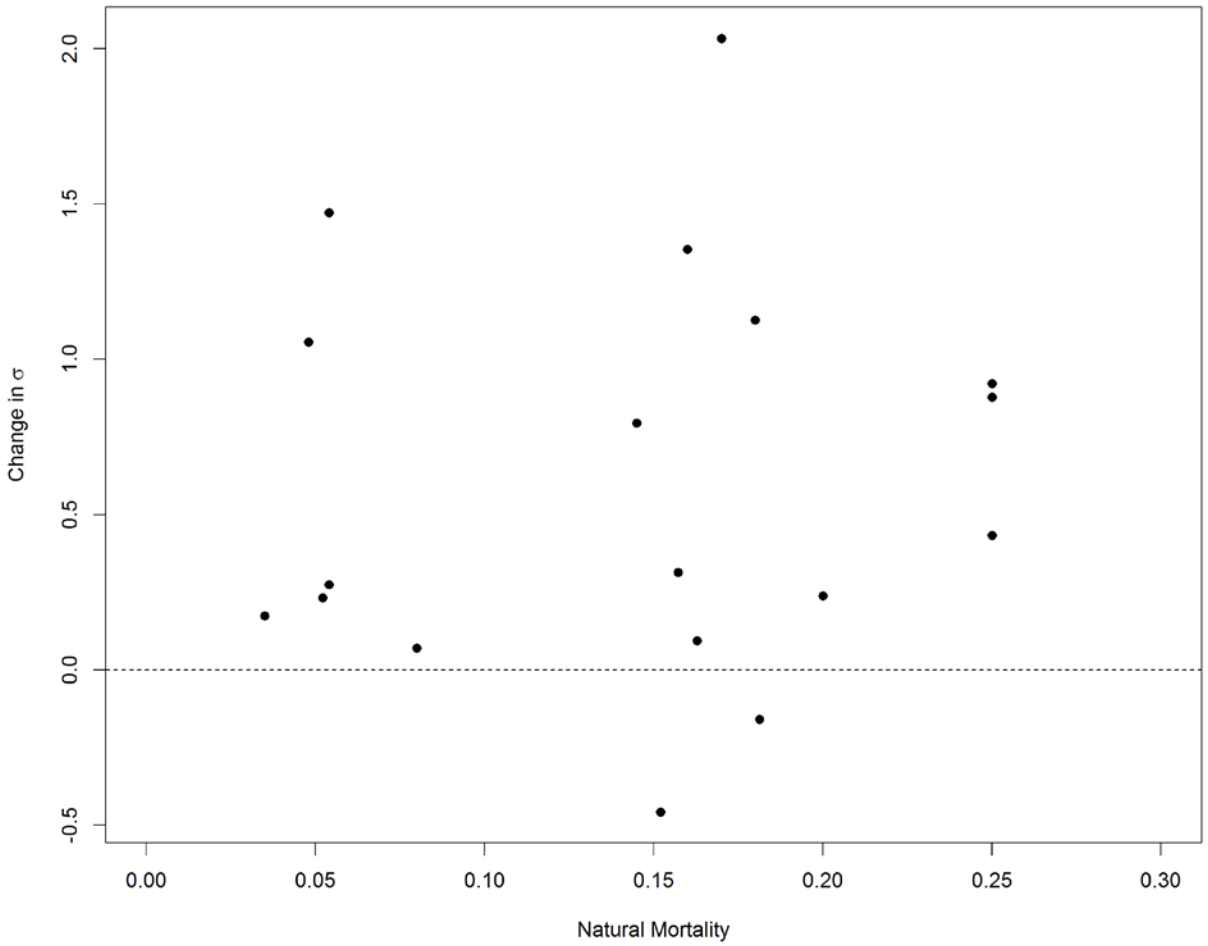

Figure 3. The change in the scaled uncertainty between the first and last projection years based on natural mortality. The kelp greenling and the lingcod south assessments are not reflected on the plot because each had low states of nature that went to zero biomass by the end of the projection period.