2017 Technical Revision to the Marine Survival Forecast of the OCN Coho Work Group Harvest Matrix

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Introduction

Amendment 13 (A13) to the Pacific Fishery Management Council's (PFMC) Pacific Coast Salmon Fishery Management Plan sets Oregon Coastal Natural (OCN) coho salmon allowable exploitation rates using a two dimensional matrix with observed parental returns and forecasted marine survival as the axes. In 2013, a methodology change revising the basis for forecasting marine survival was accepted by the PFMC.

The revision replaced the prior method, which was an index calculated as the number of Oregon Production Index (OPI) hatchery coho jacks returning in the prior year divided by the number of OPI hatchery coho smolts released in that same brood year. The new marine survival parameter is a forecasted OCN smolt-to-adult return rate. Using observed OCN smolt-to-adult return rates averaged across six life cycle monitoring (LCM) sites distributed across the Oregon Coast Coho ESU, ODFW staff created a predictive model using selected oceanographic indicators, jack observations on ODFW spawning ground surveys, and the jack/smolt ratio at the Mill Cr (Yaquina R.) LCM site as the predictor variables. ODFW created this model using an ensemble of generalized additive models (GAM). In the current PFMC process the model ensemble is refit each year with the addition of the latest set of predictor and response data.

ODFW LCM sites are funded in part by Oregon state general funds, and recent statewide general fund budget reductions have resulted in the elimination of the LCM site on the North Fork Nehalem River. Beginning with the 2018 forecast we will not be able to refit the models annually using all six of the LCM sites that comprised the 2013 method revision, due to the lack of the Nehalem site.

At least three alternative approaches are possible to adjust to this change:

- Discontinue the process of refitting the models annually and use the most recent refit models (2017) to forecast OCN marine survival into the future;
- Continue refitting the models annually, using the remaining five LCM locations to calculate OCN marine survival;
- Revert to the OPI hatchery jack/smolt indicator used prior to 2013.

Methods

Rupp et al. (2012b) and the 2013 Technical Revision to the OCN Coho Work Group Harvest Matrix (Suring and Lewis 2013) provide the source of the indicators and model process used to produce the marine survival forecast. The seven two-variable GAMs are refit annually to the OCN marine survival index estimated from six LCM sites. A LCM site consists of a paired adult and out-migrant trap. Data presented here were collected from 1998-2016 from six sites in the Oregon Coast Coho ESU (Figure 1). Spawner abundance at LCM sites was either a direct count from traps at complete barriers or estimated by mark-recapture methodology. Fish that entered traps were identified to species and sex and distinguished as wild or hatchery-produced based on presence or absence of an adipose fin clip. Coho salmon < 45 cm fork length were categorized as jacks and scales were taken from fish between 45 and 55 cm fork length for age assignment. Downstream juvenile salmonid out-migrants were captured with rotary screw traps or motorized incline plane traps. Fish were enumerated by species and age or size class, with coho salmon identified as fry (age 0) or smolts (age 1+). Trap capture efficiency was evaluated daily and weekly out-migrant estimates were summed for season totals. Additional details on adult and juvenile estimation methods and site specific details are found in Suring et al. (2014).

The LCM smolt to adult marine survival rate was derived by dividing the adjusted female spawner abundance in year *t* by half of the smolt production, assuming a 1:1 smolt sex ratio, in year *t-1*. Spawner abundance was adjusted for harvest impacts by dividing abundance by one minus the impact rate. The OCN marine survival index was calculated by averaging the marine survival rate from all sites. Beginning in the fall of 2017 the North Fork Nehalem LCM site will no longer be operated due to budget reductions. A modified marine survival index has been calculated from 1998-2016 by averaging the marine survival rate from the five remaining sites.

Forecast Alternatives

The current process to calculate an OCN marine survival index for A13 purposes used data from six LCM sites. For 2017 onward, data from only five LCM sites will be available, thus adjustments to current processes will be needed to provide information needed to support the A13 matrix approach. Alternatives include 1) using the current model fitting process but fit to the reduced marine survival index (referred to as the reduced index method), 2) using the current marine survival index but no longer refitting the GAMs annually (referred to as the fixed model method), or 3) using the pre-2013 method of using OPI hatchery jack/smolt ratios (referred to as OPIH jacks). To compare amongst these options we hindcast the marine survival using each method from 2014 to 2017 using the information that would have been available at the time of forecast in that year. The exception is we used final results for all indicators, such as the spawning ground survey peak jack count/mile, whereas during the normal process only preliminary results would have been available for use for some indicators.

The reduced index method was used to forecast marine survival in the same manner as the current method with the reduced marine survival index substituted for the OCN marine survival index in the model input dataframe. The fixed method parameterized the GAMs with the marine survival index and indicator data from 1998-2013. This fixed model was then used to create a forecast with indicator data from 2014-2017. The 1998-2013 data were chosen to use the models evaluated during the 2013 revision but hindcasts were also calculated using data from 1998-2009 to 1998-2014 to evaluate the effects training data on the fixed model results. After forecasts were created the Amendment 13 marine survival categories were delineated following the 2013 revision matrix. The OPIH jacks marine survival categories were delineated following the breakpoints in Sharr et al. (2000), consistent with methods prior to the 2013 revision.

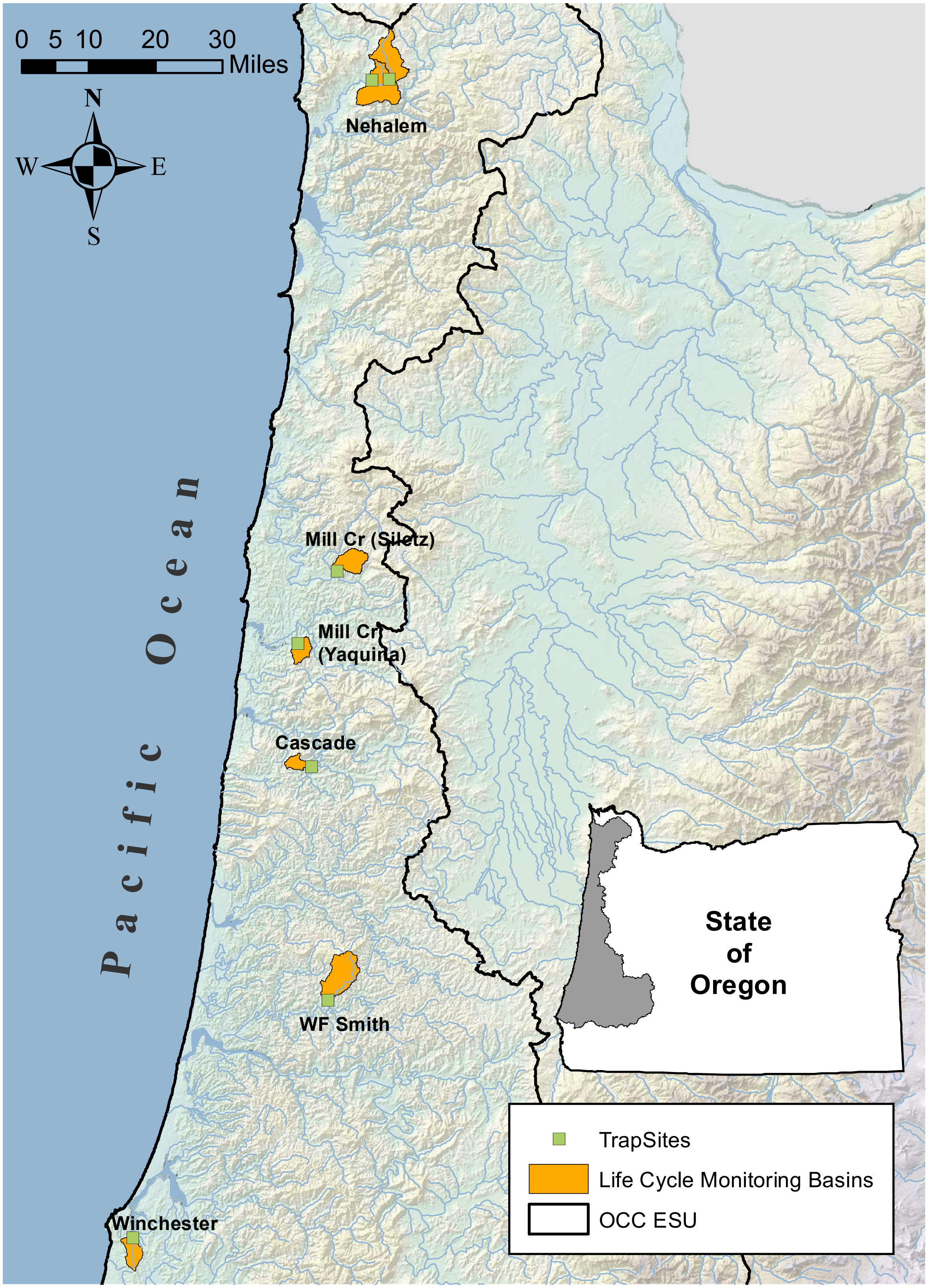

Figure 1. Oregon Department of Fish and Wildlife Life Cycle Monitoring Basins where both coho salmon adult returns and juvenile out-migrants are estimated.

Results

Reduced marine survival index

The reduced marine survival index was highly correlated to the full six-site OCN marine survival index (r=0.987). The means of the two indexes are very similar (Figure 2) and the regression coefficient cannot be differentiated from one (Coefficient: 1.043, SE: 0.043) suggesting that the reduced index is not biased compared to the full index. Though the relationship between the reduced index and observed spawner abundance is weaker than the relationship between the OCN index and abundance the reduced index should be suitable modification to the current method for meeting the information needs of the A13 matrix.

Method Comparison

The reduced index and fixed model methods forecast the same marine survival categories as the current predictor, both for the evaluation period of 2014-2017 and the entire model fit time series (Table 1). Over the evaluation period all the GAM methods forecast the observed marine survival category correctly twice, over predicted once, and under predicted once. The OPIH jacks method forecast the correct category twice and under predicted twice. The fixed model fit the observed data better than the reduced index or current method (R^2=0.703, 0.681, 0.680). The fixed model was the only alternative where the rank order of forecasts from 2014-2017 matched the observed survival (Figure 3), though this was not consistent over all training datasets. Forecast intervals were large relative to the differences in point estimates for the different methods (Table 2). OPIH jacks continue to have a poor relationship with OCN marine survival (R^2=0.125).

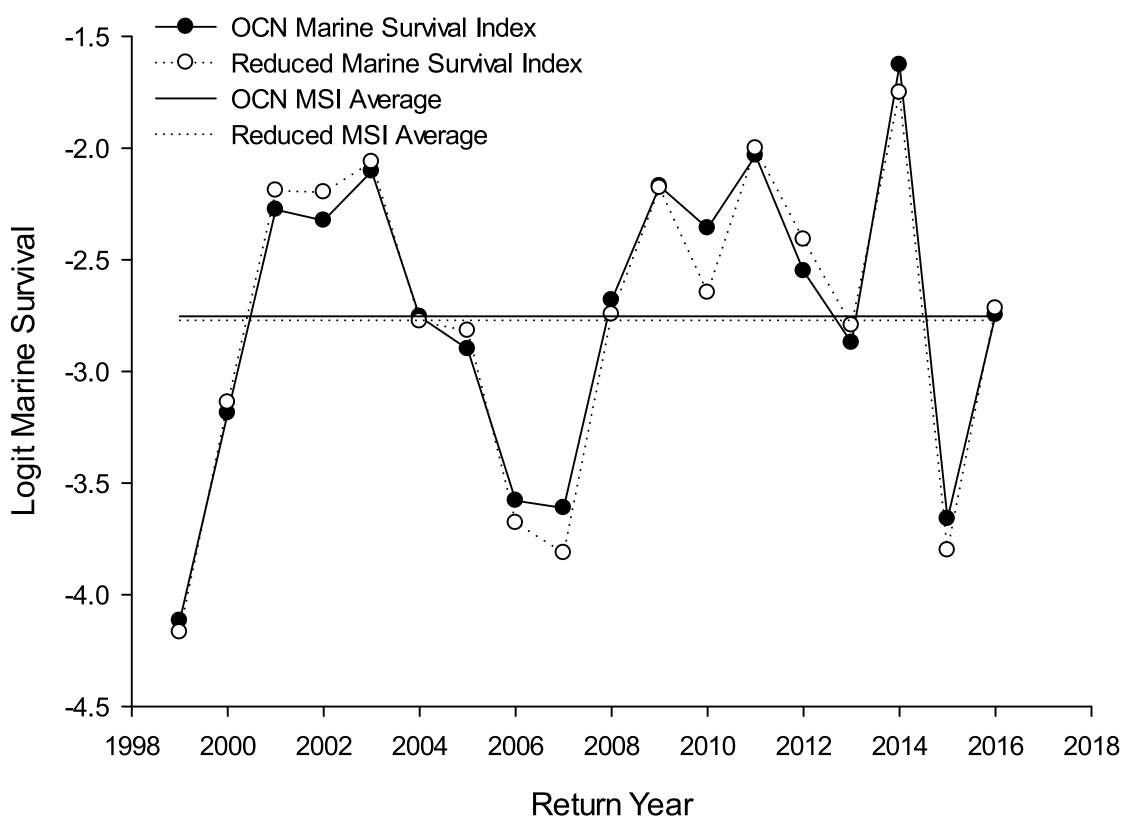

Figure 2. Time series comparison of the OCN and reduced marine survival indexes.

Table 1. Observed and predicted marine survival and marine survival categories. Incorrect predictions are highlighted: over predicted marine survival in red, under predicted in blue.

Return Year	LCM observed adult survival	LCM observed category	OPIH Jacks	Current Method & Fixed Model	Reduced Index
1999	1.6%	Ex. Low	Low	Low	Low
2000	4.0%	Low	Low	Medium	Medium
2001	9.3%	High	Medium	Medium	Medium
2002	8.9%	High	Low	High	High
2003	10.9%	High	Medium	High	High
2004	6.0%	Medium	Medium	Medium	Medium
2005	5.2%	Medium	Low	Medium	Medium
2006	2.7%	Low	Low	Low	Low
2007	2.6%	Low	Medium	Low	Low
2008	6.4%	Medium	Ex. Low	Medium	Medium
2009	10.2%	High	Medium	High	High
2010	8.6%	High	Low	Medium	Medium
2011	11.6%	High	Low	High	High
2012	7.2%	Medium	Low	Medium	Medium
2013	5.4%	Medium	Medium	Medium	Medium
2014	16.4%	High	Medium	Medium	Medium
2015	2.5%	Low	Low	Medium	Medium
2016	6.0%	Medium	Low	Medium	Medium
2017			*Low*	*Medium*	*Medium*

Table 2. Forecasts with 90% prediction intervals for the current and reduced index methods.

	Current Method			Reduced Index		
Forecast Year	Ensemble Mean	Lower 90% P.I.	Upper 90% P.I.	Ensemble Mean	Lower 90% P.I.	Upper 90% P.I.
2014	7.3%	2.3%	13.5%	7.4%	2.1%	15.0%
2015	7.2%	4.5%	15.1%	7.5%	4.4%	17.3%
2016	6.7%	3.9%	15.1%	6.6%	4.2%	15.4%
2017	5.6%	3.4%	15.7%	5.8%	3.1%	15.7%

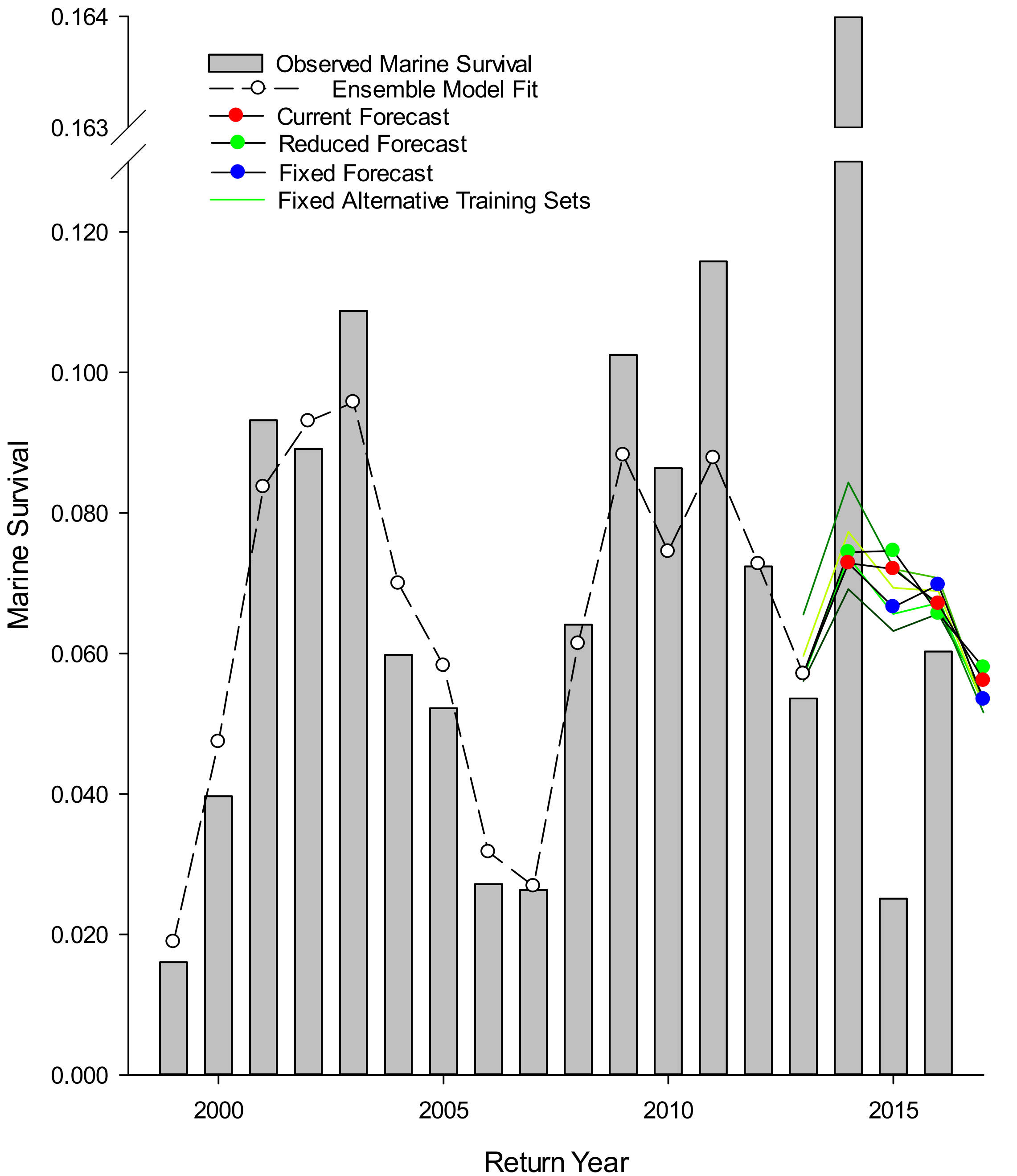

Figure 3. Observed marine survival with model fits and forecasts using the proposed methods from 2014-2017. The green lines without points show forecasts generated from fixed models with training datasets of varying length, from 1998-2010 to 1998-2014.

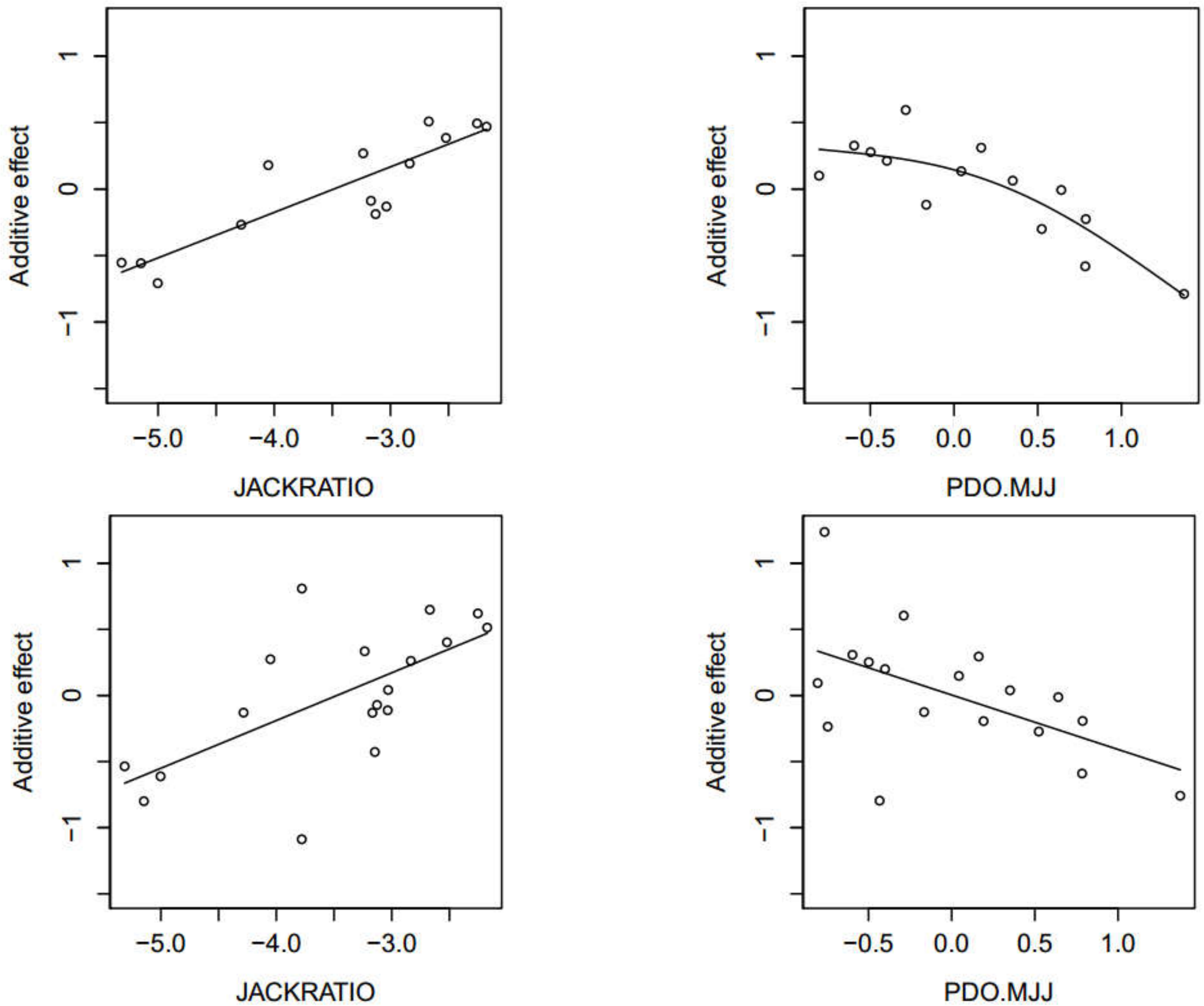

Figure 4. Partial regression plots for the 2013 revision model fit (top) and latest model fit (bottom) for the Mill Creek Yaquina LCM jack/smolt ratio and PDO May-June-July four year moving average indicators.

Refitting the ensemble models annually has changed the relationship between some indicators and the marine survival index. The PDO indicator had a curved fit to the marine survival index in all the models in the 2013 revision but, refit with data through 2016, now is fit with a straight line (Figure 4).

Discussion

The 2013 A13 Revision (Suring and Lewis, 2013) was created to improve harvest management of OCN coho salmon; to control harvest impacts such that they do not impede recovery of OCN coho salmon while also allowing for harvest of when appropriate. This analysis evaluates alternatives to revise the current process to manage the loss of one of the coho salmon marine survival monitoring sites.

While this analysis is not intended as a rigorous analysis of predictor performance post 2013 revision it is an opportunity to compare the forecasts with the original method, OPI hatchery jack/smolt ratios. Both methods predicted the observed marine survival category correctly in two of the four years since the revision was adopted; however, OPIH jacks continues to exhibit negative bias (Table 1). Since the 2013 revision there continues to be no relationship between OPIH jacks and OCN marine survival, and we have no evidence to suggest reverting to the original prediction method would provide a more useful forecast.

Modifying the OCN marine survival index to estimate marine survival from a reduced set of monitoring sites resulted in very small changes to the index with minor reductions to adult abundance fit and survival forecast model metrics. The reduced index does not exhibit bias and would not require any correction to be used as an analog of the current marine survival index. Generally, coho salmon metrics, such as adult returns, at all LCM sites are correlated to each other in a single year, indicating that large scale or common processes account for most of the variation in abundance across the ESU. However, regional patterns are apparent in some years. In 2010 coho salmon abundance in the North Coast monitoring area was stronger relative to the Mid Coast monitoring area whereas in 2012 the North Coast was weaker relative to the Mid Coast (Suring et al. 2014). Over the time period of the monitoring program intra-annual regional variation is much smaller than coast wide variation between years such that the loss of the north coast Nehalem LCM site does not have a large impact on the calculation of an OCN marine survival index.

Using static models with data collected through 2013 produced forecasts with minimally better fit to the observed marine survival pattern. Annually refitting the models may result in a poorer forecast if the indicators, which are intended to forecast early marine life history survival, are fit to years with abnormal survival situations, such as the 2015 return year which was effected by a strong El Niño. In the 2015 return year low observed marine survival may have been the result of later marine life history mortality which is unusual and which the models are not designed to predict. The static models, using data from 1998-2010 to 1998-2014, are intended as proxies for the fixed model method alternative, which would use marine survival data through the last year it is available, 2016. Refitting the models annually has resulted in changes in the relationship between some indicators and observed marine survival (Figure 4). These changes have been small but indicate that using a fixed model may overlook process changes that may improve the forecast or signal the need to revisit the forecast methods.

Conclusion

All of the evaluated alternatives except OPIH jacks would have resulted in the same fisheries management outcomes based on the A13 matrix. The original A13 forecast method, OPIH jacks, continues to be biased low. Using a fixed model provides a small improvement in forecast accuracy over the evaluation period but brings increased risks in overlooking changes in the relationships between indicators and marine survival. The A13 process is robust to changes in forecast skill (Rupp et al. 2012a) which suggests that annually refitting the reduced marine survival index may be the best method for predicting OCN marine survival.

References

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