MEMORANDUM

Department of Fish and Wildlife
Intra Departmental

Date: December 10, 2010
To: Files, HQ
From: Chris Kern
Subject: 2011 Willamette Spring Chinook Forecast

The final 2010 Willamette spring Chinook return is estimated at 110,500 total fish to the Columbia River mouth (Table 1). An estimated 16,500 of these were unmarked fish (15%). The 2010 total return was 177% of forecast. Clackamas River returns also performed better than forecasted; with 11,000 spring Chinook returning to the Clackamas River.

The total return of hatchery fish in 2010 is estimated at 94,000 fish at the Columbia River mouth, compared to 47,000 fish expected. Ladder counts indicate that about 53,000 marked hatchery fish passed through the fishway at Willamette Falls. The full reconstruction of the 2010 return is shown in Table 2.

Table 1. 2010 Willamette River projected and actual return (to Columbia River mouth).

	Columbia River Mouth Returns				
	Age 3	Age 4	Age 5	Age 6	Total
2010 Forecast	**1,414**	**45,948**	**14,645**	**655**	**62,662**
Lower	1,260	21,643	12,176	308	35,386
Upper	1,664	74,297	19,449	671	96,081
2010 Actual Return	**2,861**	**89,533**	**17,977**	**165**	**110,536**

The projection for 2010 assumed 25% of the return would be comprised of unmarked fish, based on the average percentage of unmarked fish seen in the 2007-2009 returns. Historic estimates of total wild returns were limited by absence of large-scale hatchery fin-marking programs prior to the 2000s. The return year 2003 was the first year in which all returning age classes of hatchery-reared fish were part of mass-marking programs. Prior to that time, fewer fish were adipose fin-clipped, making it difficult to estimate returns of wild fish. Current hatchery programs mark about 98% or more of the hatchery fish released in the Willamette Basin annually. Up to 2% of current hatchery releases are comprised of double-index coded-wire tag groups (DIT), which receive a CWT, but no fin clip. These fish are encountered and treated as "wild" in fisheries and run reconstructions that rely on adipose fin-clips to identify hatchery fish.

As has been noted in past years, there is a strong tendency for models used in projecting Willamette returns to underestimate the total return in years in which the run is increasing, and to overestimate the return in years in which the run is decreasing. This can be seen in the lag between projected and actual returns in Figure 1, as well as in the relationship shown in Figure 2. Projection errors are magnified by increasing or declining run size effects. Sources of error include variability in cohort survival and environmental conditions, as well as process error in estimating harvest and escapement. Several alternative models have been examined to attempt to improve the projection models, a process that is conducted annually.

Most forecast models utilize cohort regressions, and estimated abundance of cohorts is derived from run reconstructions. Abundance data from Willamette Falls is useful because it represents the most complete count, and little estimation is involved in estimating the total passage – the only estimation procedure is the assignment of ages to fish observed in the ladder. However, the Willamette Falls models are less able to account for the effects of Columbia and Lower Willamette River fisheries on variability in predicted returns. Models based on Columbia River abundance estimates of each age class require the addition of other estimation procedures to account for harvest and mortality to these points. Some models also use estimates of ocean abundance of each age class, requiring assumptions regarding ocean harvest and mortality to be applied to the point estimates. All of these procedures can introduce process error in the projection models in addition to natural variation in the population.

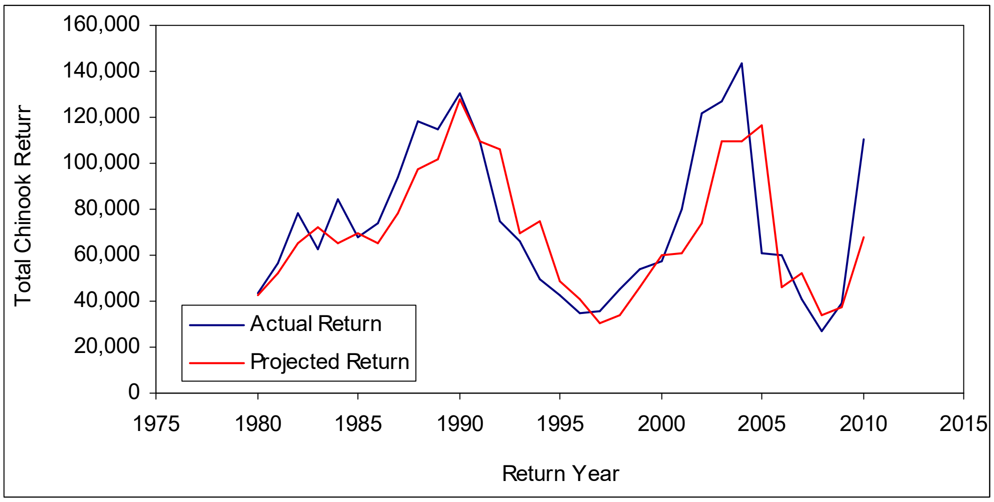


Figure 1. Actual and projected returns of Willamette River spring Chinook, 1975-2010.

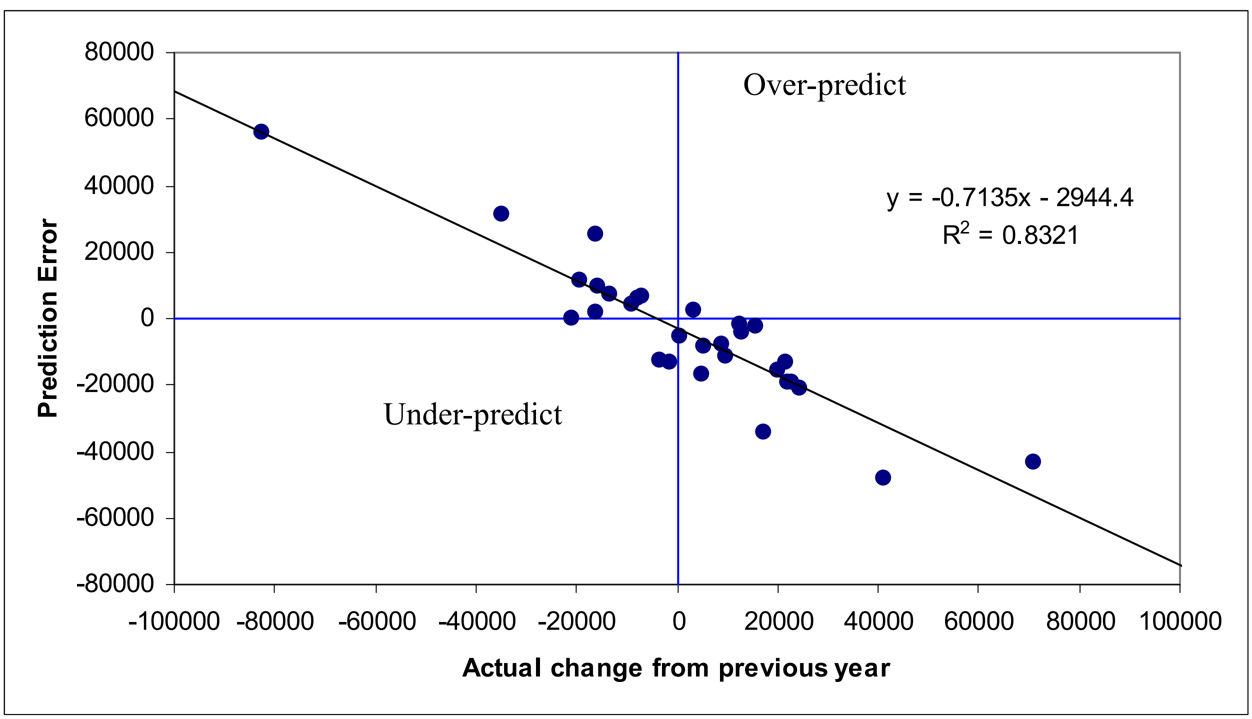


Figure 2. Errors in projections associated with declining or increasing run size effects.

Table 2. Preliminary summary of the 2010 Willamette River spring Chinook return.

Catch	Age 3	Age 4	Age 5	Age 6	Total
LCR Commercial (Gillnet)	8	1,173	345	14	1,540
LCR Commercial (Gillnet-rel. mortality)	0	42	12	1	55
Select Area Commercial	0	1,312	348	0	1,660
LCR Sport (kept catch)	83	3,562	1,693	0	5,338
LCR Sport (release mortality)	2	66	31	0	99
L. Will. Sport Fishery kept catch	718	18,087	3,491	33	22,329
L. Will. Sport Fishery release mortality [1]	12	309	60	1	382
Lower Clackamas Sport (kept catch)	38	622	77	0	737
Lower Clackamas Sport (rel. mortality) [1]	1	11	1	0	13
Totals	**862**	**25,184**	**6,058**	**49**	**32,153**
Escapement					
Willamette Falls Count [2]	1,766	54,646	10,547	100	67,059
Mortality Below Falls	7	168	33	0	208
Clackamas Hatchery swim-ins [2]	67	4,760	648	9	5,484
Clackamas Hatchery transfers from N.F. Dam [2]	34	2,391	326	4	2,755
Eagle Creek Hatchery Return [3]	3	217	30	0	250
North Fork Dam, Passed Upstream [2]	89	1,179	160	2	1,430
North Fork Dam, Recycled Downstream [2]	3	225	30	0	258
Natural Spawn Bel. N.F. Dam	1	40	5	0	46
Sea Lion Predation [4]	29	723	140	1	893
Totals	**1,999**	**64,349**	**11,919**	**116**	**78,383**
Run Entering Columbia	**2,861**	**89,533**	**17,977**	**165**	**110,536**
Run Entering Willamette	**2,768**	**83,378**	**15,548**	**150**	**101,844**
Run Entering Clackamas	**236**	**9,445**	**1,277**	**15**	**10,973**

Projections for Age 3 fish returning in 2011

In most years, either a simple cohort ratio of Age 2 (mini-jack) returns in year y versus Age 3 returns in year y+1 has been used to project Age 3 returns, or the recent 5-year average Age 3 return has been used. <u>For the 2011 projection, a regression of age 2/3 cohort ratio versus age 2 total return (r^2=0.79) produces an estimate of 1,300 Age 3 fish, and will be used for the point estimate of the forecast.</u>

Direct sibling regressions for projecting Age 3 returns from prior year Age 2 returns are problematic because the relationship between Age 2 and Age 3 returns is poor for Age 2 returns of less than 10,000 fish. For the 2011 return, the regression estimate of 800 Age 3 fish will be used for the lower bounds estimate. The 5-year average Age 3 return of 1,700 fish will be used for the upper bounds.

Projections for Age 4 fish returning in 2011

Age 4 returns are typically projected from the prior year's return of Age 3s. This relationship has worked well in most years, but did not accurately predict large Age 4 returns in the late 90s and early 2000s. In more recent years, the model has been relatively accurate compared with actual returns, although it substantially over-predicted the return of the Age 4s from the 2003 brood year (which was the poorest performing brood year on record), and underestimated the 2010 return. For 2011, this regression projects a return of 39,800 Age 4 fish, which will be used as the point estimate.

The average return of Age 4s following similar returns of Age 3s as the 2010 return has been about 35,000 fish, and this estimate will be used as the lower bound. The average cohort ratio for broods 1969-2006 is 18 Age 4s per Age 3 return, which generates a 2011 estimate of 51,600 fish, and will comprise the upper bound of the 2011 estimate.

Projections of Age 5 fish returning in 2011

Projections for Age 5 fish are estimated with methods similar to those for Age 4 fish. Similar issues exist regarding tendencies to over- or under-predict in decreasing or increasing run years. For recent return years, cohort ratios of Age 4 versus Age 5 returns have differed markedly from historical averages. The 2010 return of Age 4 fish was 89,500, which is 1,200 fish higher than the prior record return of Age 4 fish, which occurred in 2002. The 2002 return of Age 4 fish was followed in 2003 by a return of 78,000 Age 5 fish. However, another 80,000+ Age 4 return occurred in 2004 (81,000), and was followed by a return of only 39,000 Age 5 fish the following year. The 2011 point estimate for Age 5 returns is based on a log-normal regression of Age 4 to Age 5 fish for the last 10 years, and is similar to the average Age 5 return for the most recent broods that have had Age 4 returns >80,000 (~35,000). Using this model, the point estimate for the 2010 Age 5 return is 62,400 fish.

The lower bounds value is derived from Age 4 to Age 5 cohort ratios from the most recent 5 years, and produces an estimate of 48,000 fish. The upper bounds estimate of 78,000 is derived from a log-transformed linear regression of Age 4 vs. 5 for all brood years.

Projections for Age 6 fish returning in 2011

Age 6 comprise a very small portion of annual returns, and as a result are difficult to correlate with prior year returns of the same brood, but also contribute few fish to total returns and forecast errors. The 5-year cohort ratio of Age 5 to Age 6 was used to derive the point estimate of 600 fish for the 2011 return. The lower bounds estimate of 400 fish was derived from the 10-year cohort ratio, and the upper bounds estimate of 650 fish was derived from the 10-year average return.

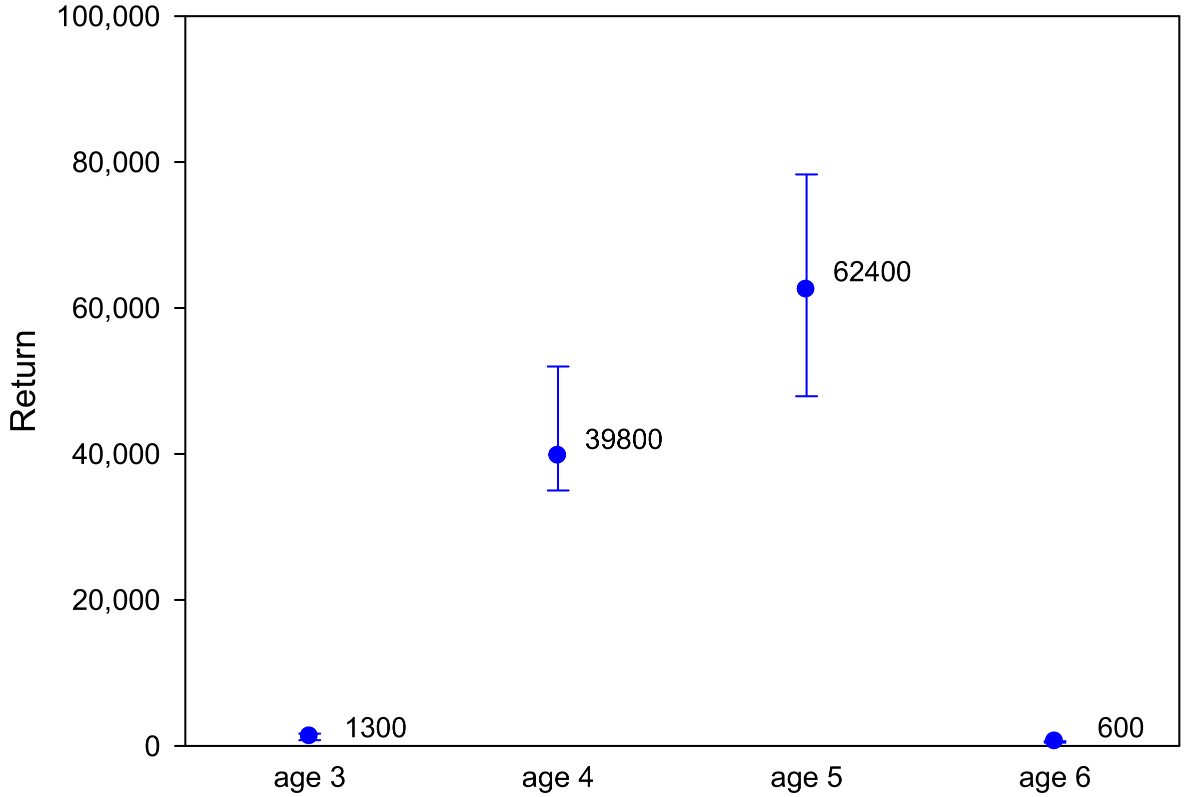
2011 Clackamas Return

Using a combination of regression models and cohort ratios similar to those used to estimate the total Willamette return, the 2011 Clackamas return is projected to be 12,200 Chinook. This number is included in the total estimated Willamette return numbers.

2011 Forecast Summary

Table 3. 2011 Projected Willamette spring Chinook return to Columbia River mouth.

	Columbia River Mouth Return				
	Age 3	Age 4	Age 5	Age 6	Total
2011 Forecast	**1,309**	**39,764**	**62,375**	**618**	**104,067**
Lower	779	35,000	47,917	437	84,134
Upper	1,685	51,582	78,302	637	132,207



The 2010 return contained an estimated 15% unmarked fish. For the period 2007-2009, the average percentage of unmarked fish was 25%. In recent years, low returns have been associated with a higher percentage of unmarked fish in the run. This percentage has decreased in years with large returns; however, due to the relatively recent advent of mass-marking in the Willamette, it is difficult to determine if this is a function of other factors as well as total run size. For the 2011 forecast, the average for 2009 (25%) and 2010 (15%) returns was used. Assuming an unmarked return of 20% for 2011, the number of hatchery fish returning to the Columbia River mouth would be 83,300 fish (Table 4).

Table 4. 2011 Projected Willamette Basin (Clackamas included) spring Chinook hatchery fish return to Columbia River mouth.

	Columbia River Mouth Returns (hatchery fish only)				
	Age 3	Age 4	Age 5	Age 6	Total
2011 Forecast	**1,048**	**31,811**	**49,900**	**495**	**83,253**
Lower	624	28,000	38,334	350	67,307
Upper	1,348	41,266	62,642	510	105,765

Hatchery Surplus Estimates

The harvestable surplus of the 2011 return of hatchery fish is calculated by subtracting the Willamette FMEP hatchery fish escapement goals from the total estimated hatchery return. Based on the FMEP, at a total hatchery-fish run size of 83,300 fish, the escapement goals for Willamette Falls and the Clackamas River are 32,000 and 4,900 fish, respectively. This results in a harvestable surplus of 46,400 fish. Of the total harvestable surplus, the FMEP specifies that 70% (32,500 fish) be allocated to recreational fisheries in the mainstem Columbia, lower Willamette, and lower Clackamas. The remaining 30% (13,900 fish) is to be allocated to commercial fisheries.

Appendix

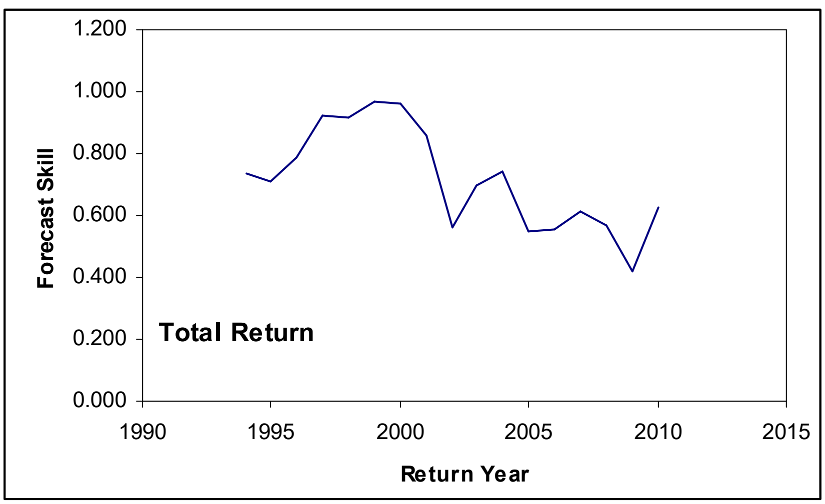
Forecast "Skill"

In an attempt to gauge the relative performance of forecasts, I am including a new statistic for this year's memo. This is based on an index developed by David Rupp for OCN coho forecast testing. The "forecast skill" index is a measure of how any forecast technique would perform versus a standardized method, in order to ease comparisons to other methods.

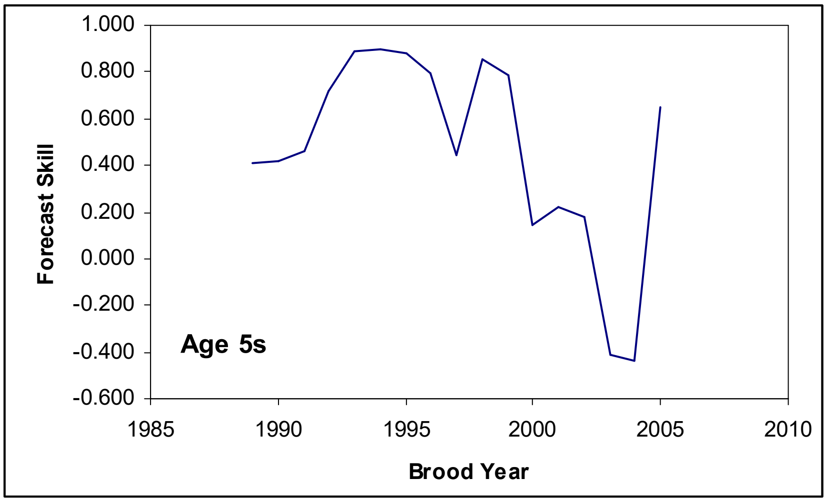
For the Willamette data sets, I am using the recent 10-year running mean actual returns as the reference data set, although any suitable reference could be used (i.e. standard linear sibling regression, etc.). For each year, the forecasted value is compared to the reference value using the formula $100\% - [\sum(Y'-Y)^2 / \sum(SSQR\ \tilde{Y}-Y)^2]$ where Y' is the predicted response for each model and year, $\tilde{Y}$ is the 10-year running mean of actual returns, and Y is the actual return.

The result is a ratio comparison of how well each predictor performs compared to the reference data, with a value near or <0 indicating that the reference data performs better and a value approaching 1 indicating that the model performs better. I calculated this statistic on a running 5-yr basis. So a forecast skill value for a predictor summarizes its relative performance over the most recent 5-yrs. This can also be calculated over the entire time series to evaluate the cumulative performance.

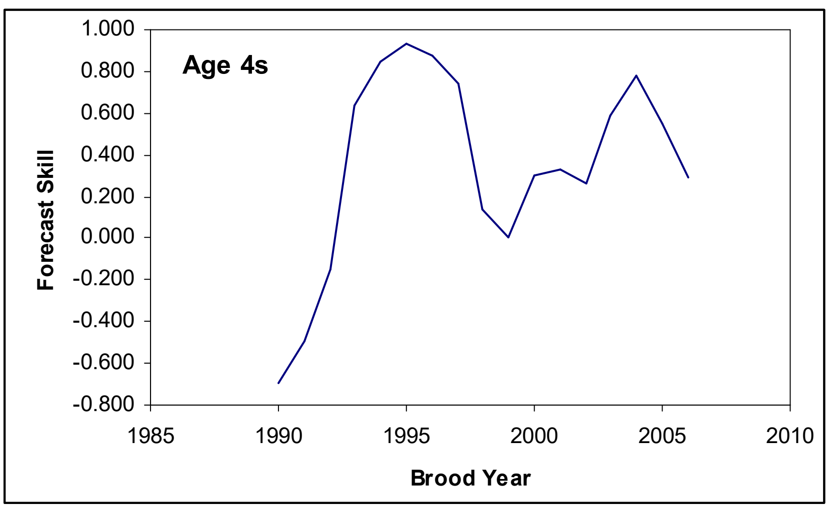
While this is one useful statistic, it is important to note that it is a summary of past performance, not a predictor of future performance. Also, because it encompasses a series of years, the series may include some years with very poor performance and some with very good performance. Evaluating year-to-year performance of individual models is difficult, but important and is not necessarily captured in this statistic.



This figure shows the gross performance of Willamette River total return forecasts over time. In this case, the forecasted total return number for each year, regardless of methods used to calculate it, is compared to the 10-year running mean. Forecasts during the late-90s performed substantially better than the reference dataset would have. More recent forecasts have done more poorly, but are still markedly better than the reference data. The skill statistic for return years 2006-2010 is 0.625, up from 0.422 for years 2005-2009.



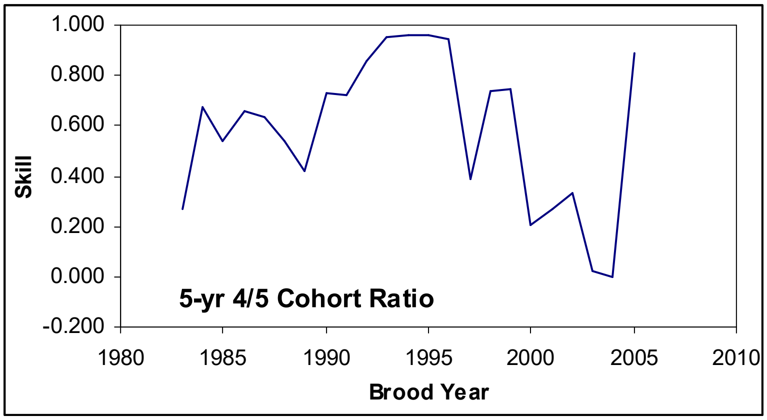
This figure is specific to Age 5 total predicted returns, regardless of forecast method used. During the 1990s broods, accuracy of Age 5 predictions was very good compared to the reference data. During this period, ratios of Age 4 to Age 5 fish were relatively consistent and relatively high. However, more recently, the 4-5 cohort ratio has been highly variable and generally lower than it had been historically (less 5s per Age 4). This is reflected in the drop in skill during this period, which was particularly affected by the returns of the 2002-2004 broods. The 2010 forecast (17,900) was much closer to the actual return (14,700), which improves the 5 yr skill for 2000-2005 brood returns (2005-2010 run years).



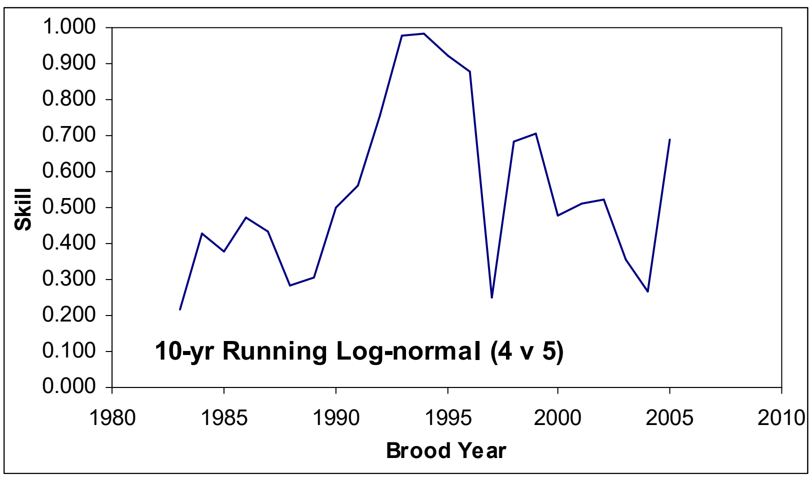
Forecasting Age 4 returns has been somewhat problematic. Age 3 to Age 4 cohort ratios are quite variable. Forecast skill reached a recent low in the 1999 brood year, and gradually improved over the period following. However, the last two brood years, 2005 and 2006 have not been forecasted as well. This is particularly affected by the unexpectedly large return of 89,000 Age 4 fish in 2010.

The following figures reflect the patterns of forecast skill for most of the models used to generate the 2011 forecasts.

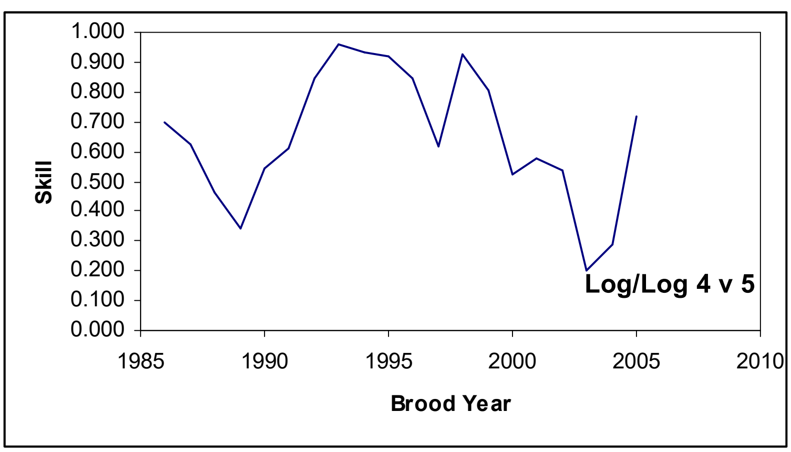
Age 5s



The 5 yr average age 4-5 cohort ratio was used to generate the lower bound of the 2011 estimate. This model performed very well for 2010 and during the 1990s, but would not have performed as well during much of the 2000s compared to the reference data.



The 2011 point estimate for Age 5 returns was derived from a log-normal regression of 10 yr Age 4v Age 5 returns by brood. This model would have performed fairly well if used in 2010 forecasts.

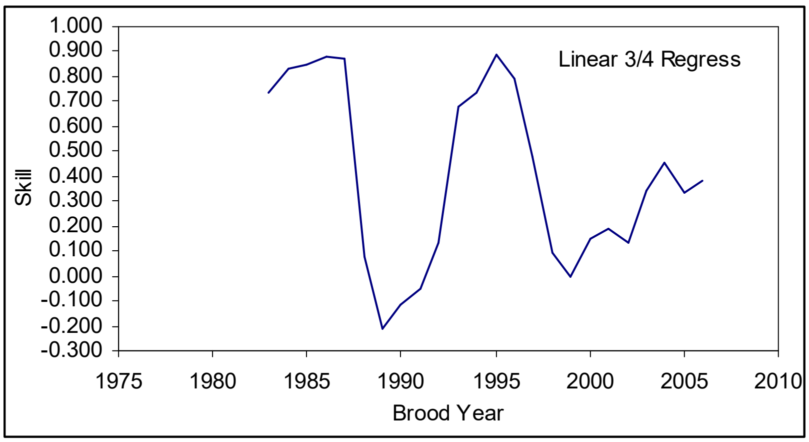


The upper bounds for the 2011 estimate was derived from a log-log regression of all years of Age 4 v Age 5 returns. This model would have performed quite well in 2010.

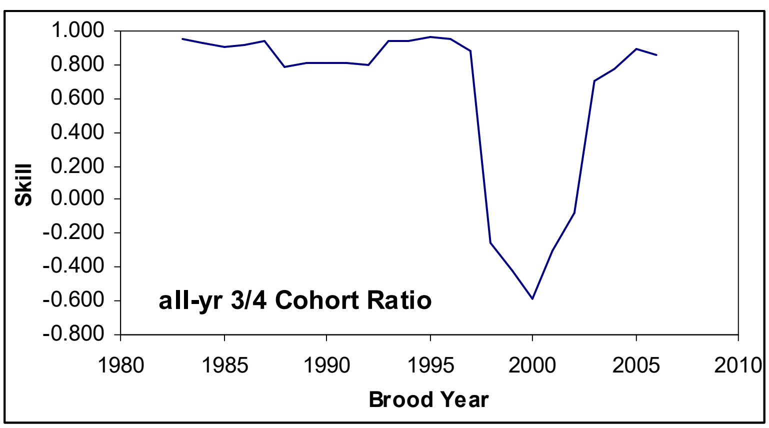
A continual theme in looking at skill or performance of the Age 4-Age 5 models is that nearly all models would have performed relatively poorly during much of the 2000s. This is another reflection on the recent apparent shift in Age 4 to 5 cohort ratios over this same time period and also demonstrates the difficulty in accurately projecting Age 5 returns in recent years. Improvements in the models shown above over the most recent sets of years may provide some hope that a return to fairly accurate forecasts may be possible.

Age 4

The lower bounds of the 2011 Age 4 estimate was derived from an average of Age 4 returns with prior year Age 3 returns +/- about 300 fish of the 2010 returns. Because of the methodology, I have not tried to estimate past year forecast skill for this estimate.



The 2011 Age 4 point estimate was derived from a linear Age 3 to Age 4 regression. This model would have had varying success over time in terms of forecast skill. It would have performed relatively well in recent years.



The all year 3-4 cohort ratio was used to derive the 2011 upper bounds for Age 4 returns. This model would perform quite well compared to the reference data in most years.

I intend to repeat this exercise in the future to see if it has value in helping track performance, and possibly selection, of various methods over time.