MEMORANDUM

Department of Fish and Wildlife
Intra Departmental

Date: December 11, 2009
To: Files, HQ
From: Chris Kern
Subject: 2010 Willamette Spring Chinook Forecast

The 2008 Willamette spring Chinook run again garnered significant public attention, due to a continued decline in fish returns, and in contrast to the 2008 Columbia River spring Chinook run, which was comparatively strong. The 2008 return is estimated at about 27,000 fish to the Columbia River mouth, compared to the 1980-2007 average of about 76,000. An estimated 7,300 of those were estimated to be naturally-produced fish, compared to the recent five-year average estimate of nearly 17,000 naturally-produced fish. The 2008 total return was 36% of the 1980-2007 average and the naturally-produced return was 42% of the recent five-year average return. Clackamas River returns performed better than Willamette River returns overall, with 7,200 spring Chinook returning in 2008.

The 2008 total return was 79% of the projected value, and was greater than the lower bounds of the 2008 forecasts (Table 1). However, the lower than projected return and the larger-than-expected percentage of naturally-produced fish in the return combined resulted in the number of returning hatchery fish (approximately 20,000 at the Columbia River mouth) being well below the 25,000 projected hatchery fish return. Although the escapement goal for Willamette Falls of 20,000 hatchery fish was not met in 2008, Willamette Basin hatchery facilities were able to meet broodstock needs for full production.

Table 1. 2008 Willamette River projected and actual return (to Columbia River mouth).

	Columbia River Mouth Return				
	Age 3	Age 4	Age 5	Age 6	Total
2008 Forecast	1,400	14,800	17,200	650	34,050
Lower	775	5,000	11,600	600	17,975
Upper	2,000	17,300	25,000	950	45,250
Actual 2008 Return	**710**	**21,862**	**4,227**	**217**	**27,016**

The projection for 2008 assumed 15% of the return would be comprised of wild fish, which was greater than past assumptions of 10%, due to the high percentage of wild fish seen in the 2007 return (nearly 25%). Estimates of total wild returns have been limited by historic absence of large-scale hatchery fin-marking programs. 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 impossible to directly 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. Prior to the 2008 return, adjustments for unclipped DIT fish were not made. Staff has recently completed a preliminary analysis to adjust for the impact of DIT fish and mark-selective fisheries on estimates of wild fish returns, which resulted in the estimate of 7,300 naturally-produced fish for 2008, and the estimated five-year average returned discussed above (Appendix Table). These estimates appear to be substantially larger than those discussed in annual FMEP reports, which have been considered minimum estimates of total wild returns.

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. Several alternative models have been examined to attempt to improve the projection models.

Most of the models utilize cohort regressions, and estimated abundance of cohorts is derived from run reconstruction. 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.

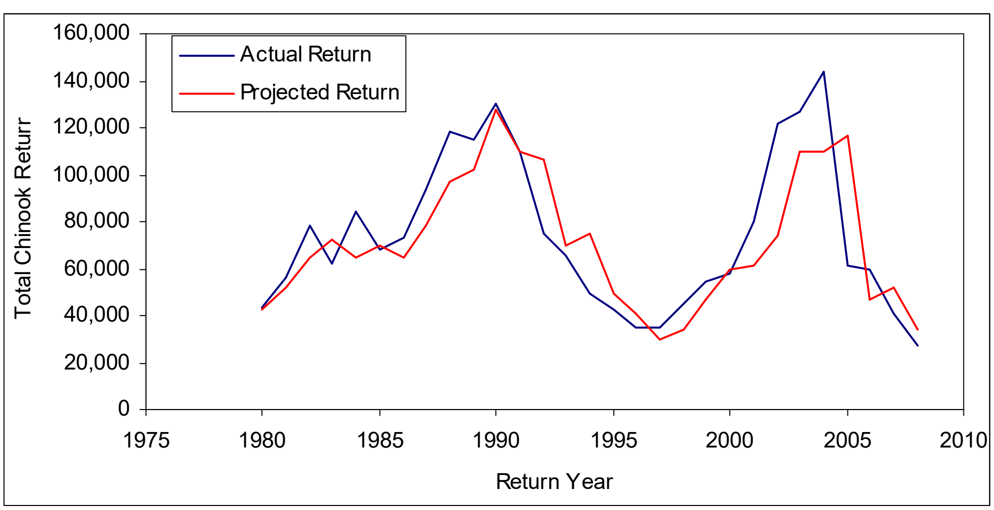

Figure 1. Actual and projected returns of Willamette River spring Chinook, 1975-2008.

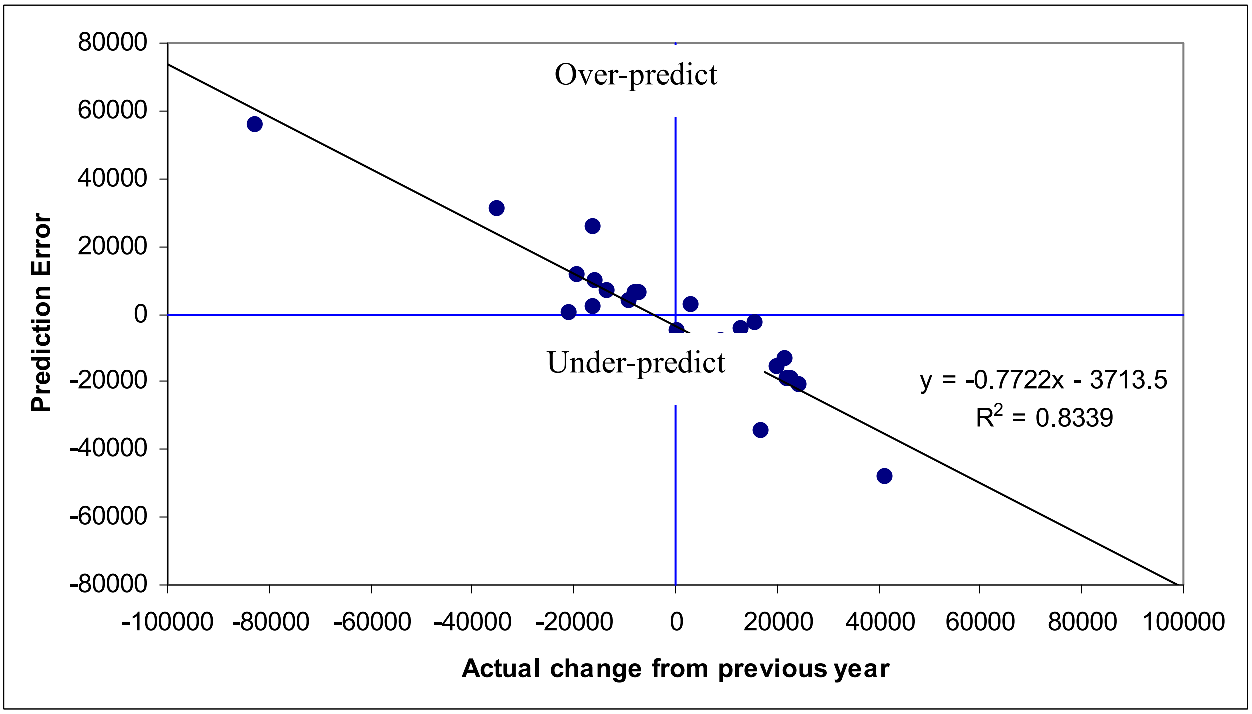

Figure 2. Errors in projections associated with declining or increasing run size effects.

Table 2. Preliminary summary of the 2008 Willamette River spring Chinook return.

Catch	Age 3	Age 4	Age 5	Age 6	Total
LCR Commercial (Gillnet)	0	0	1	0	1
LCR Commercial (Gillnet-rel. mortality)	0	0	0	0	0
SAF Commercial	5	77	18	0	100
LCR Sport (kept catch)	0	100	92	3	195
LCR Sport (release mortality)	0	4	4	0	7
L. Will. Sport Fishery (kept catch)	68	3,184	987	130	4,369
L. Will. Sport Fishery (rel. mortality)[1]	4	170	53	7	233
Lower Clackamas Sport (kept catch)	2	158	38	3	200
Lower Clackamas Sport (rel. mortality)[1]	0	9	2	0	11
Total Fishery Removals	**78**	**3,662**	**1,254**	**123**	**5,117**
Escapement					
Willamette Falls Count[2]	521	12,540	1,611	0	14,672
Mortality Below Falls	2	71	22	3	97
Clackamas Hatchery Return[2,3]	58	3,984	948	64	5,054
Eagle Creek Hatchery Return[4]	0	16	4	0	20
North Fork Dam, Passed Upstream[2]	48	1,413	336	23	1,820
NFD Recycles not seen in Clackamas Hatchery	0	30	7	0	38
Natural Spawn Bel. N.F. Dam	1	58	14	1	73
Sea Lion Predation[5]	2	91	28	4	125
Total Escapements	**632**	**18,203**	**2,970**	**95**	**21,899**
Run Entering Columbia	**710**	**21,862**	**4,227**	**217**	**27,016**
Percent	**2.6%**	**80.9%**	**15.6%**	**0.8%**	
Run Entering Willamette	**705**	**21,681**	**4,112**	**214**	**26,712**
Percent	**2.6%**	**81.2%**	**15.4%**	**0.8%**	
Run Entering Clackamas	**109**	**5,667**	**1,349**	**91**	**7,216**
Percent	**1.5%**	**78.5%**	**18.7%**	**1.3%**	

[1] Release mortality rate from Lindsey et. al. (12.2% of released fish).
[2] Uses actual counts for jacks.
[3] Includes 1,514 hatchery fish returned to Clackamas Hatchery from N. Fork Dam trap.
[4] USFWS estimate of fish returning to Eagle Creek Hatchery. Fish do not enter hatchery.
[5] Average of most recent five year period (2003-2007).
[6] Age composition based on scale analysis of Willamette River sport catch.
[7] Age composition based on scale analysis of Clackamas Hatchery returns.
[8] Age composition based on scale analysis of hatcheries above Willamette Falls.

Projections for Age 3 fish returning in 2009

In most years, either a simple cohort ratio of Age 2 (mini-jack) returns in year y-1 versus Age 3 returns in year y has been used to project Age 3 returns, or the recent 5-year average Age 3 return has been used. The cohort ratios used are typically the recent 5-yr or 10-yr averages (Figure 3.1). For the 2009 projection, the 5-yr average Age 3 return produces an estimate of 859 Age 3 fish. Cohort 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. However, there is a strong non-linear relationship between Age 2 return size and the cohort ratio of Age 2 to Age 3 fish which can be used to forecast the cohort ratio based on the Age 2 returns (Figure 3.2). This model produced an estimate of 2,672 Age 3 fish for 2009. When Age 2 returns are over 10,000 fish, there is a significant positive linear relationship between Age 2 and Age 3 fish ($r^2 = 0.800$; Figure 3.2) and this model projects a return of 1,413 Age 3 fish in 2008 based on the 2009 count of 10,277 Age 2 fish.

For the 2009 return, the regression estimate of 1,413 Age 3 fish will be used for the point estimate. The observed and predicted values for the 1969-2005 brood years using the regression model are shown in Figure 3.4, along with model residuals expressed as percent of actual return. The lower bounds estimate is 859 (recent average) and the upper bounds estimate is 2,672 (cohort ratio regression).

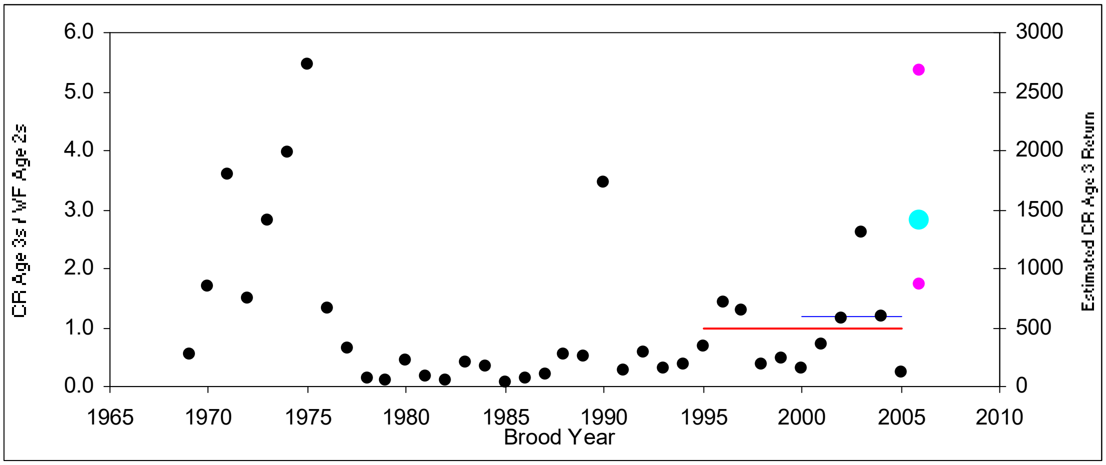

Fig. 3.1. Age 2 and Age 3 cohort ratios, 1969-2006 brood years. Red and blue lines indicate 10-yr and 5-yr cohort ratio averages (left hand y-axis). Light blue point = 2009 estimate (1,413), pink points = 2009 upper and lower estimates (2,672 and 859).

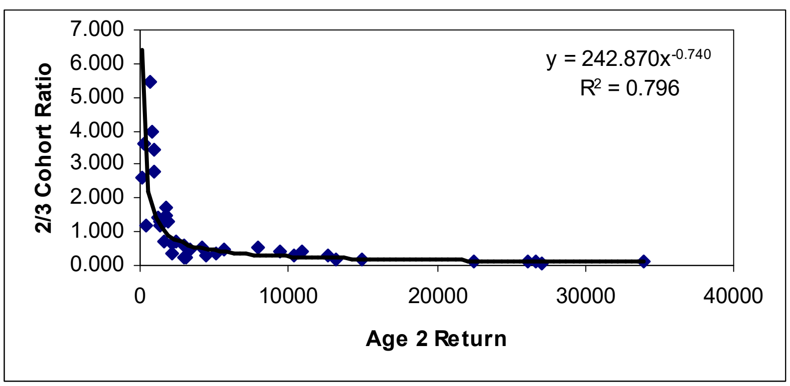

Figure 3.2. Age 2/Age 3 cohort ratios by size of Age 2 return, showing non-linear relationship between cohort ratio and Age run size.

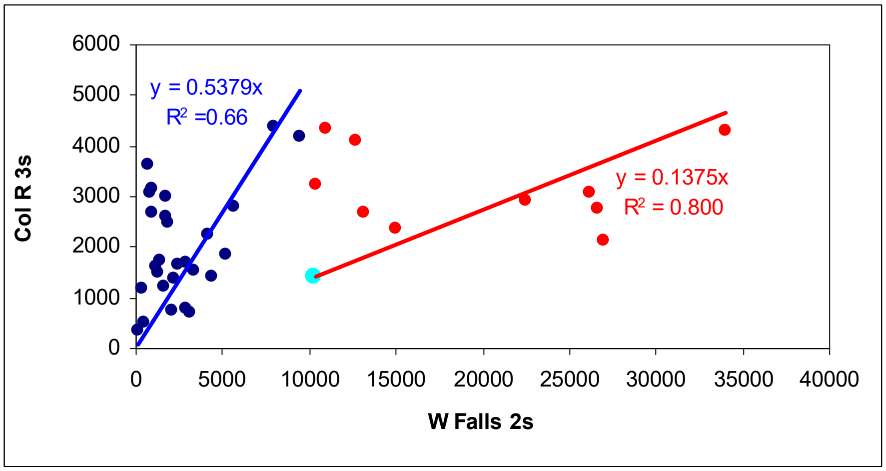

Fig. 3.3. Linear regression of Age 2 and Age 3 counts at Willamette Falls, brood years 1969-2006. Blue points are Age 2 counts below 10,000 fish and red points are counts above 10,000 fish. Light blue point is the 2009 projected estimate (1,413).

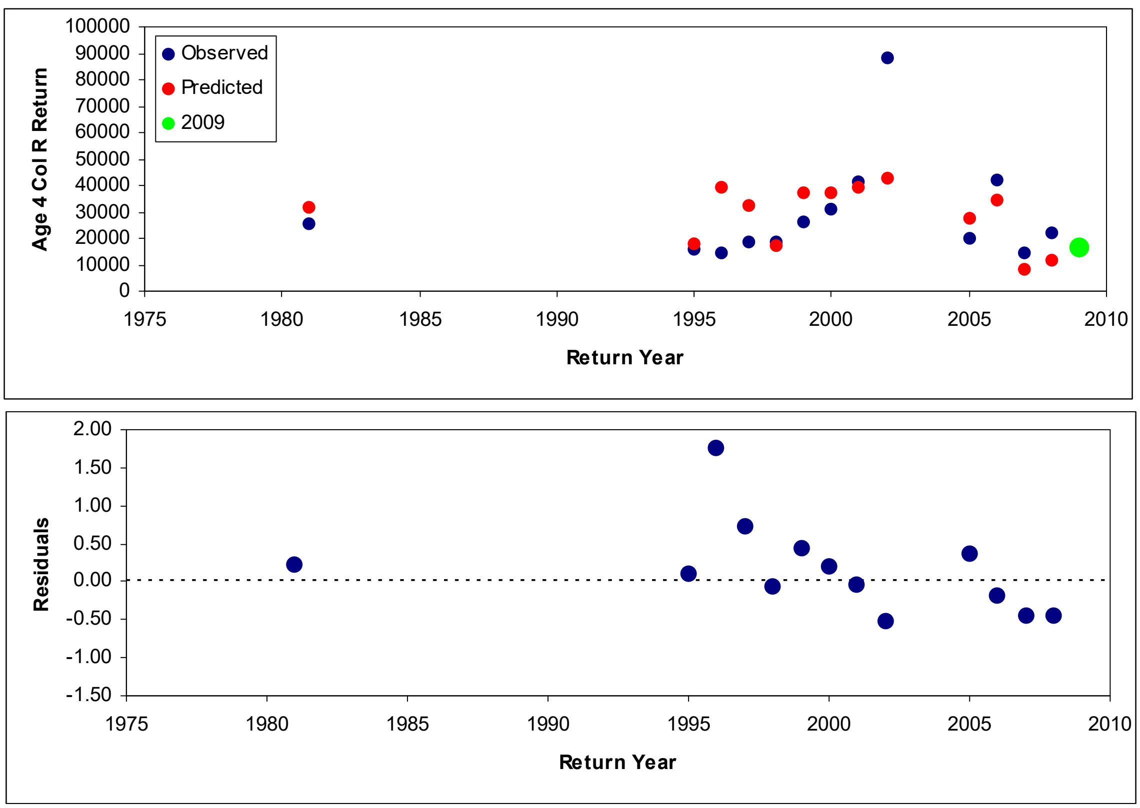

Figure 3.4. Observed versus projected Age 3 returns based on the Age 2 vs. Age 3 regression (top graph), and residuals of predicted minus observed estimates. (The model uses only Age 2 counts over 10,000 fish – 2008 return was 10,277).

Projections for Age 4 fish returning in 2009

No age samples are collected from adult fish passing Willamette Falls (Age 3 fish can usually be identified reliably by size). Staff has recently been utilizing age distributions from upriver hatchery returns to estimate the age distribution of adult fish at Willamette Falls.

For the third year in a row, Age 3 returns to the Willamette River were near record lows. However, despite the fact that the 2007 Age 3 return was the second lowest on recent record, the Age 4 return in 2008 was still 22,000 fish. It appears that the relationship between Age 3 and Age 4 fish changes at different size runs, indicating the need to either segregate Age 3 and Age 4 returns by Age 3 run size, or indicating the need to apply nonlinear regression models which can adjust for different slopes in the regression equation at different values for the dependent variable. For the 2009 forecast, the Age 3 and Age 4 cohort dataset was restricted to only those years in which Age 3 returns were 2,000 fish or lower. The resulting regression equation specifies a prediction slope that results in larger values of Age 4 from prior year Age 3 returns. This matches the recent information seen in recent returns in which low Age 3 returns, even from the extremely depressed 2003 brood year, have resulted in more Age 4 returns in the following year than the all-year regression model would have predicted. This regression projects a 2009 return of 16,220 Age 4 fish and will be used as the point estimate for the 2009 Age 4 projection (Figure 4.1).

A regression Age 3 versus Age 4 fish from all years produced an estimate of 9,564 fish, with an r^2 value of 0.810, and will be used as the lower bound. The 2008 return of Age 4 fish was 21,862 fish, and followed a 2007 Age 3 return of only 525 fish. This Age 4 return represents the highest "conversion" of Age 3 to Age 4 fish seen for Age 3 returns below 1,000 fish, and will be used to represent the upper bounds of the 2009 estimate.

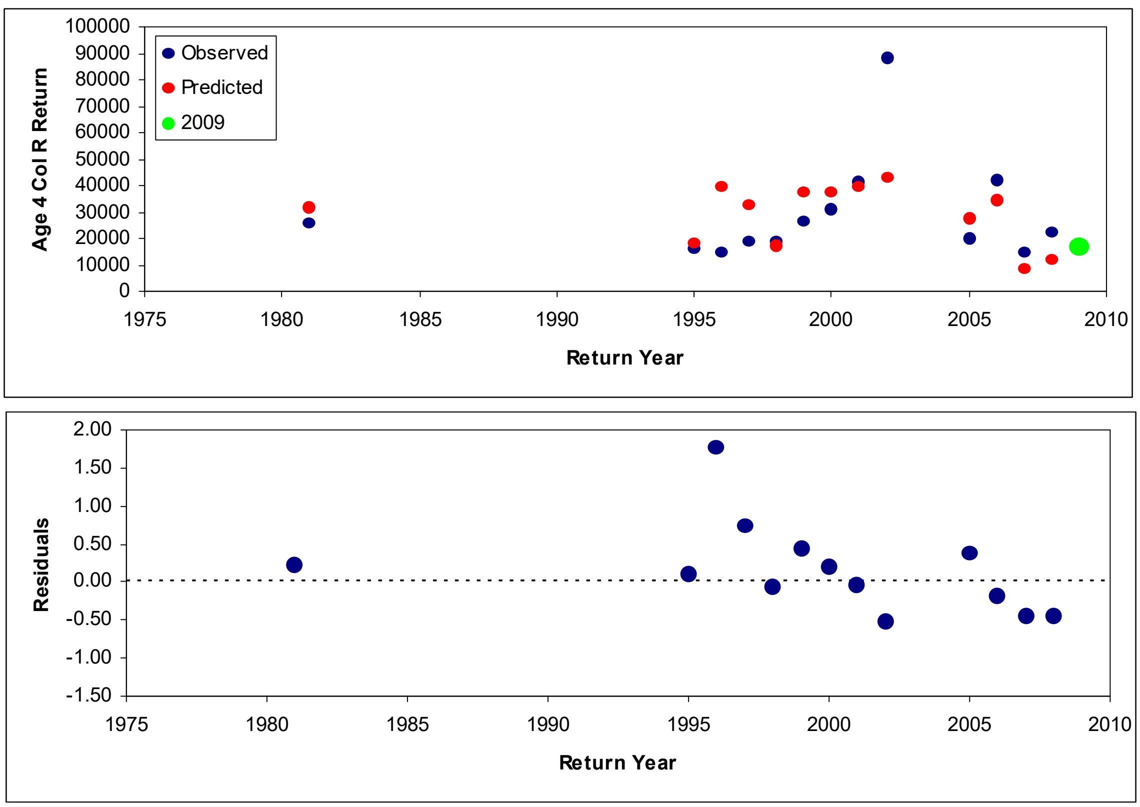

Fig. 4.1. Observed versus predicted Age 4 returns based on Age 3 returns of <2,000 fish in prior years (upper graph), and residuals of the model fits as a percent of the observed values (lower graph).

Projections of Age 5 fish returning in 2009

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, although in general, predictions of Age 5 fish from previous years' Age 4 fish tend to be more accurate than predictions of Age 4 fish from Age 3 fish.

For the 2009 estimate, a linear regression of Age 4 to Age 5 fish using brood years 1969-2003 was used to project 2009 Age 5 returns (r^2 = 0.910), resulting in a projected return of 19,880 fish. The 2008 return of Age 4 fish was nearly 22,000 fish, compared to a projected return of just 14,800. The cohort (brood year 2004) represented by 2009 Age 5 returns and 2008 Age 4 returns represented the second lowest Age 3 return on record in 2007. This low return contributed to a low Age 4 forecast for 2008. Since nearly 7,200 more Age 4 fish returned in 2008 than expected, it is possible that the Age 5 return for 2009 could show a similar unexpectedly large return. However, only 4,200 Age 5 fish returned in 2008, compared to the forecast of nearly 17,000, indicating that the relationship between Age 4 and Age 5 fish from the same cohort can be highly variable. Age 5 fish that returned in 2008 are from the same cohort (brood year 2003) as Age 3 fish that returned in 2006, which was a record low Age 3 return of 351 fish (see Discussion section).

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 15,317 fish. This is still much higher than the Age 5 return seen in 2008, which was the poorest on record, so caution is warranted, however the 2008 Age 5 return was part of the extremely poor 2003 brood year. Prior year returns of the 2004 brood year cohort (Age 5 in 2009) in 2007 and 2008 were mixed, with Age 3 fish returning in 2007 at the second lowest rate on record, but Age 4 fish returning in 2008 at 65% of the long-term average. The upper 90% confidence interval bound from the regression estimate (40,300 fish) will be used as the upper Age 5 estimate.

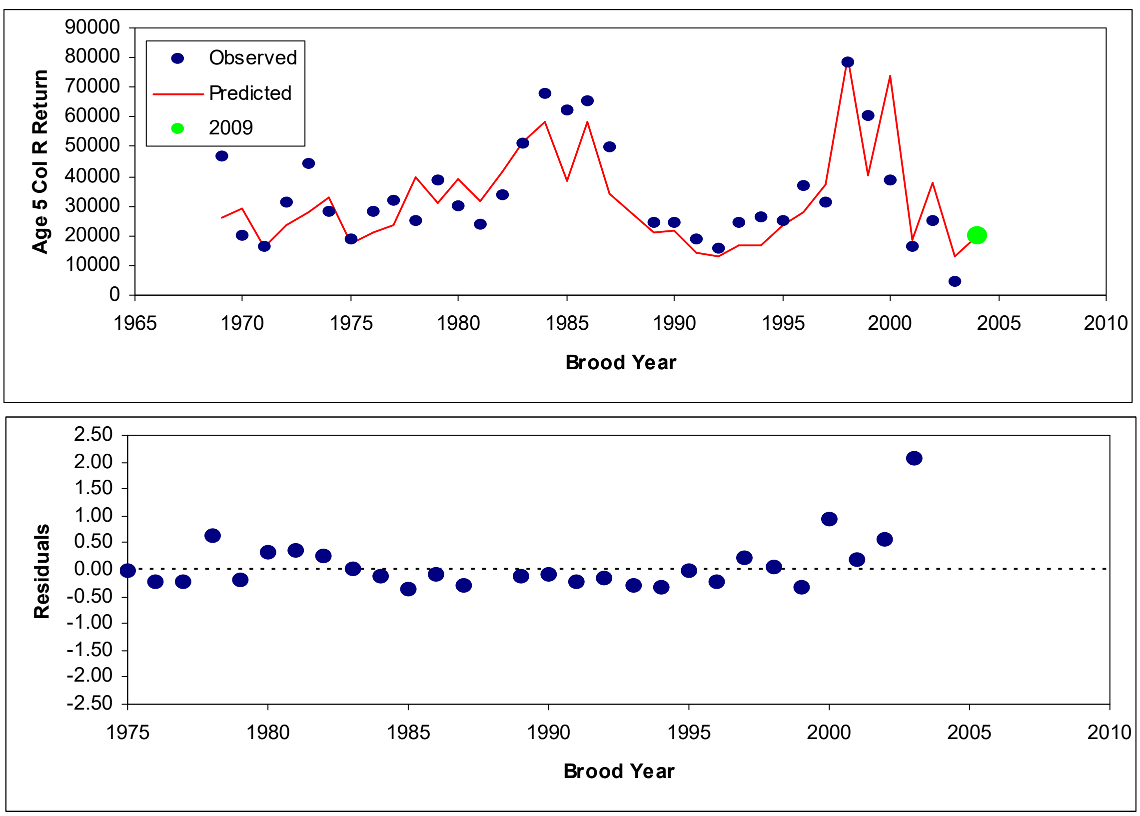

Fig. 5.1. Age 5 regression model based upon Age 4 returns (upper graph), and residuals expressed as percent of actual returns (lower graph). 2009 Age 5 estimate is shown by the light green point on the upper graph.

Projections for Age 6 fish returning in 2009

Age 6 fish returning in 2009 belong to the same cohort that produced the second lowest Age 3 return in 2006, a very poor Age 4 return in 2007, and a record low Age 5 return in 2008. Conversion of Age 5 fish in year y-1 to Age 6 fish in year y is typically poor, as most Willamette fish return at Age 4 or 5 and few at Age 6. Projections for Age 6 fish have typically been estimated using either simple cohort ratios of Age 5 and Age 6 fish, or average Age 6 returns over 5- or 10-year periods. A regression model (r^2 = 0.840) was also used to project Age 6 returns in 2009.

The Age 6 estimate from the linear regression model (101) will be used as the point estimate for the 2009 return.

The 5-year average cohort ratio estimate of 117 fish will be used as the upper bound, and the lower bound will be a projection of 0 Age 6 fish, which is possible given the very poor performance of the 2003 brood year returns in the last three years.

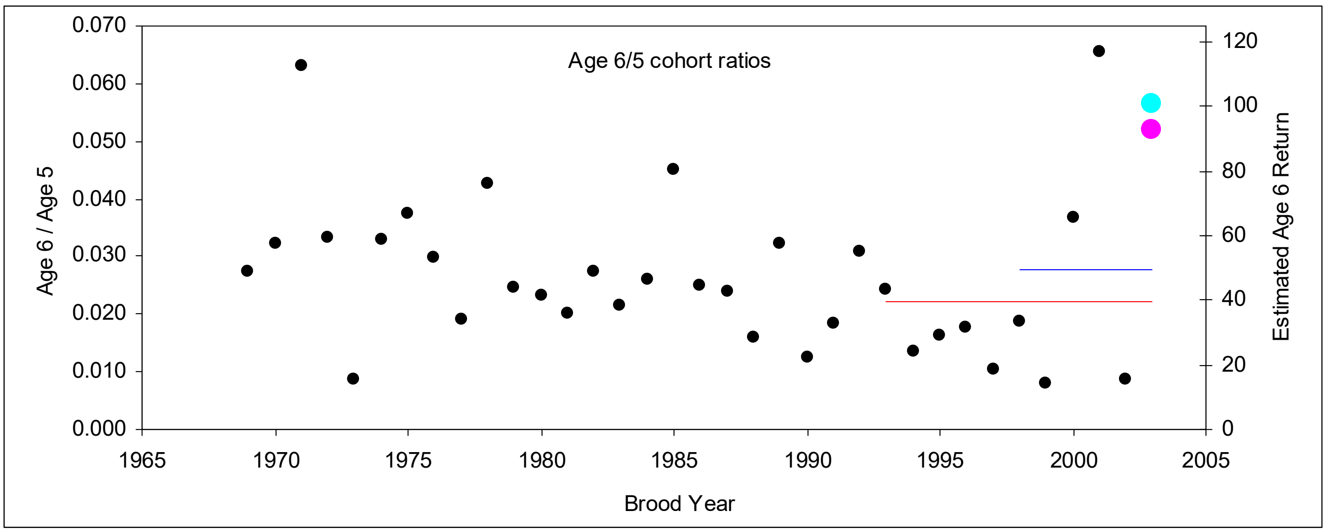

Fig. 6.1. Age 6 and Age 5 cohort ratios, 1969-2002 brood years. Red and blue lines indicate 10-yr and 5-yr average cohort ratios. Blue point = 5-yr cohort ratio of Age 6s 2009 estimate (117); pink point = regression 2009 estimate (101).

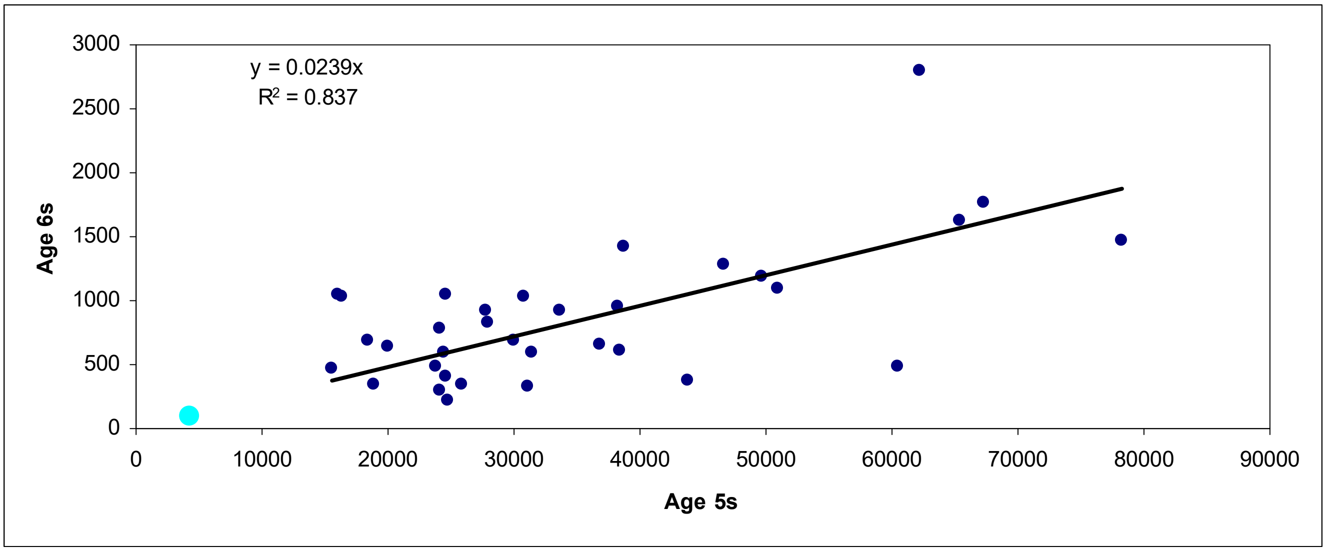

Fig. 6.2. Regression of Columbia River Age 5 and Age 6 returns. Red point = 2009 estimate (101).

2009 Forecast Summary

Table 3. 2009 Projected Willamette spring Chinook return to Columbia River mouth.

	Columbia River Mouth Returns				
	Age 3	Age 4	Age 5	Age 6	Total
2009 Forecast	**1,413**	**16,220**	**19,880**	**101**	**37,614**
Lower	859	9,564	15,317	0	25,704
Upper	2,672	21,862	40,300	117	64,951

Forecast Estimates: Age 3 = Age 2 (>10,000) v Age 3 regression, Age 4 = Age 3 (<2,000) v Age 4 regression, Age 5 = Age 4 v Age 5 regression, Age 6 = Age 5 v Age 6 regression.
Lower Bound's: Age 3 = 5-yr average return, Age 4 = Age 3 v Age 4 regression, Age 5 = Age 4/5 cohort ratio, Age 6 = 0 return (final year of bad BY 2003 return).
Upper Bound's: Age 3 = modified Age 2/3 cohort ratio, Age 4 = 2008 return (highest 4 return for 3s <1,000 in prior year), Age 5 = 90% upper CI for Age 4 v Age 5 regression model, Age 6 = 5-yr average cohort ratio.

The 2008 return contained an estimated 27% naturally-produced fish. The mark rate at the river mouth was 72% (the remainder of hatchery fish were unmarked DIT group fish). Assuming a wild return of 27% for 2009, the number of hatchery fish returning to the Columbia River mouth would be 27,500 fish. The 2007 return also had higher a wild percentage than previously expected, at 23%. The total estimated return of hatchery fish to the Columbia River mouth, assuming 73% of the run are hatchery fish, is shown in Table 4.

Table 4. 2009 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
2009 Forecast	**1,031**	**11,841**	**14,513**	**74**	**27,458**
Lower	627	6,982	11,182	0	18,791
Upper	1,951	15,969	29,419	85	47,423

The 2007 and 2008 Clackamas River returns also made up higher portions of the total run than expected, comprising 17% and 27% of these returns, respectively. For 2009, a separate forecast was calculated for the Clackamas River. Using regression models and cohort ratios, the 2009 Clackamas return is projected to be 6,400 Chinook. This estimate may underestimate the 2009 return, because the Clackamas return data used to project the return was not reconstructed to the Columbia River mouth. This means that fishery removals in the years the model is built on are inherently included in the model as part of "average conditions" experienced in the model years. This underestimate is likely small, on the order of hundreds of fish, not thousands. In contrast, the Columbia River mouth returns are estimated from reconstructions to the river mouth, and are therefore built upon pre-fishery run data.

If the total Willamette Basin return shown in Table 3 is reduced by 6,400 fish to account for the Clackamas return, then further reduced by the 27% wild fish estimate discussed above, the final hatchery-fish return destined for areas above Willamette Falls can be estimated (Table 5). In the absence of any fishery take, this estimate ranges from a low of 14,000 total hatchery fish to a high of 43,000 total hatchery fish, with a point estimate of 22,800. This value is only slightly larger than the minimum Willamette Falls hatchery fish escapement goal of 20,000 specified in the Willamette FMEP. If the 2009 Clackamas forecast (6,400 fish) is an underestimate, the return of fish to areas above Willamette Falls would be further reduced, due to higher turnoff into the Clackamas.

Table 5. 2009 Projected return of hatchery fish return destined for areas above Willamette Falls after Clackamas turnoff.

	Columbia River Mouth Returns (hatchery fish only)				
	Age 3	Age 4	Age 5	Age 6	Total
2009 Forecast	**909**	**10,454**	**11,375**	**60**	**22,798**
Lower	505	5,595	8,044	0	14,145
Upper	1,828	14,582	26,282	71	42,763

Hatchery Surplus Estimates

The estimated return of hatchery adult fish is calculated by subtracting the estimated hatchery jacks from the total estimated return. The harvestable surplus is calculated by subtracting the Willamette FMEP hatchery fish escapement goals from the total estimated return. For the Clackamas River, this exercise yields an estimate of 1,538 surplus hatchery adults (estimated adult hatchery fish return minus minimum hatchery fish escapement goal of 3,000 fish). For the Willamette River above Willamette Falls, this exercise yields an estimate of 1,889 surplus hatchery adults (estimated adult hatchery fish return minus minimum hatchery fish escapement goal of 20,000 fish).

The total number of estimated hatchery surplus for 2009 is therefore 3,427 fish available for fisheries in downstream of Willamette Falls.

Brood Year Performance

Table 6 shows returns, by age class, which have followed prior year returns from the same cohort. The results from brood year 2003, which had exceptionally poor returns, are noted by the superscript [a]. For instance, in return year 2006, the Age 3 (brood year 2003) return was 351 fish, which was the worst since at least 1972, and falls within the Age 3 count category of 0-1,000 fish in the table. The Age 4 return from the same brood year in 2007 was 14,192 fish, and the Age 5 return in 2008 was 4,158 fish. All three returns seen to date from this brood year (2003) have been record lows (Age 3 and Age 5), or near record lows (Age 4 – within 100-200 fish of the record low). Age 6 fish from this brood year may return in 2009. Results for brood year 2004, which comprised Age 3 returns in 2007, Age 4 returns in 2008, and Age 5 returns expected in 2009, are noted with superscript [b].

The 2008 Age 3 return was the third worst since at least 1972, and remained in the 0-1,000 category. It is worth noting that the 2008 Age 4 return, which also followed an Age 3 return of <1,000 fish, was the highest Age 4 return following so few Age 3 fish since at least 1972. If this "conversion" holds for the return of Age 5 fish from the same brood in 2009, the projected Age 5 return shown above is likely an underestimate. Based on typical Age 5 returns from prior year Age 4 returns, the minimum Age 5 return would be expected to be nearly 16,000 fish, with a maximum of 46,700 fish, and an average return of nearly 28,000 fish. The Age 5 return in 2008 (brood year 2003) was by far the lowest since at least brood year 1969. Given that Age 6 fish are relatively rare even in years following average Age 5 returns, it is very possible that 0 Age 6 fish from the 2003 brood year may return in 2009.

Table 6. Historic returns by cohort from year i-1 to year i. Brood years 1969 – 2005.

	Age 3 Count Size			
Age 4 Return	0-1,000 [a,b]	1,001-2,000	2,001-3,000	3,000+
Min	14,192 [a]	14,164	23,126	19,298
Max	21,875 [b]	88,338	43,647	81,321
Mean	17,665	33,626	32,374	45,547
	Age 4 Count Size			
Age 5 Return	0-20,000 [a]	20,100 – 30,000 [b]	30,100 – 40,000	40,100+
Min	4,158[a]	15,975	20,066	24,637
Max	25,816	46,724	49,734	78,333
Mean	17,625	27,726	35,330	47,307
Age 6 Return				
		Min	92 [a]	
		Max	2,795	
		Mean	862	

[a] 2003 Brood Year (Returns = age 3 in 2006, age 4 in 2007, age 5 in 2008, age 6 in 2009).
[b] 2004 Brood Year (Returns = age 3 in 2007, age 4 in 2008, age 5 in 2009).

Brood year returns from 1969 – 2003 are shown, ranked from highest (1) to lowest (35), in Figure 7. The total return to date for the 2003 brood year is 18,770 fish. The second lowest return was 31,800 fish for brood year 1992. However, the average brood year returns for 1991-1994 were lower than the average brood year returns from brood years 2001-2003, and if brood year 2004 continues to perform as it did in 2008, the recent average brood year returns will be substantially higher than those seen in the mid-1990s. Analysis is still underway to try to identify the causes of the 2003 brood year collapse, but preliminary work indicates that the hatchery fish from this brood year may have been released during a period of poor water conditions in the Willamette River. On top of this, it appears that both the hatchery and wild components of the 2003 brood year migrated to sea during the recent warm phase of the Pacific Decadal Oscillation in 2005. Warm phases of the PDO are associated with periods of poor salmon survival in the ocean. The combined effect of in-river and ocean conditions, and the short duration of the 2005 PDO shift may explain at least part of the very poor survival of the 2003 brood, in comparison with relatively healthy returns from Columbia River spring Chinook during the same period, and returns of other Willamette broods that, although poorer than average, have been within historical ranges of natural population fluctuations. The release timing of the hatchery fish from brood year 2003 may also explain why the 2003 brood hatchery fish seem to have performed more poorly than wild fish from the same brood year.

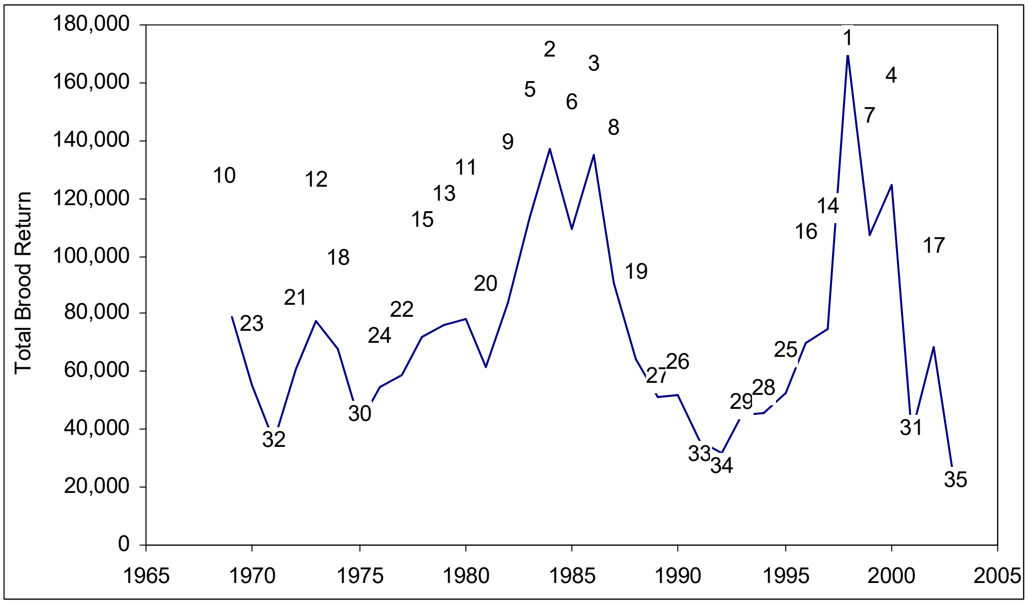

Figure 7. Total returns by brood year, brood years 1969-2003. Numbers indicate ranking from highest (1) to lowest (35) total return.

Appendix Table. Reconstructed estimates of wild Willamette River fish at the Columbia River mouth, 2000-2008. Return years 2000-2001 included hatchery brood years that preceded mass-marking, and % wild estimates for these years may be suspect due to lower proportions of marked hatchery fish in the returns.

	Columbia River mouth Naturally-produced fish						
Return Year	Age 3	Age 4	Age 5	Age 6	Sum	% Wild	3 yr avg % Wild
2000	*946*	*3,698*	*0*	*129*	*4,773*	*8.28%*	
2001	*485*	*12,407*	*0*	*21*	*12,913*	*16.07%*	
2002	*297*	*17,013*	*5,365*	*0*	*22,676*	*18.63%*	*14.33%*
2003	715	9,089	15,728	66	25,598	20.22%	18.31%
2004	170	14,097	10,405	232	24,903	17.24%	18.70%
2005	266	4,424	8,400	97	13,186	21.63%	19.70%
2006	72	8,154	2,845	282	11,353	19.03%	19.30%
2007	120	3,499	5,620	265	9,505	23.49%	21.38%
2008	198	6,206	894	32	7,330	27.16%	23.23%