Prediction of the 2003 Ocean Abundance of Rogue River Fall Chinook Salmon

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SUMMARY

The ocean population abundance of fall chinook salmon from the Rogue River for 2003 is predicted to be slightly less than occurring in 2002 but higher than abundance observed in any other prior year back through 1989. Relative to the base period used in scaling the Klamath Ocean Harvest Model (1986-2001), the prediction for 2003 is two times the average of the estimated actual abundance during this sixteen-year period; ranging from 26% of their estimated actual abundance in 1987 to 651% of their estimated actual abundance in 1999.

We continued the third year of a study to convert relative abundance indices to absolute estimates using mark-recapture. Returning fish were captured and tagged near the river mouth and recaptured as carcasses in survey areas. Based on this methodology, we estimated that 204,000 mature fall chinook passed river mile seven on their spawning migration in 2002. The 95% confidence limits of this population estimate ranged from 150,000 to 291,000 fish. We could find no obvious biases associated with this estimate. Modifications in methodology implemented in 2002 yielded improvements in precision and accuracy from ranges occurring during the first two years of the study. We recommend continuing this study in 2004 to provide additional data to use in converting indicies into actual population estimates.

INTRODUCTION

Fall chinook salmon produced in the Rogue River Basin are a major contributor to Oregon and California salmon fisheries. A prediction of ocean abundance of Rogue River chinook salmon is needed to account for their abundance in structuring ocean salmon fisheries that harvest Klamath fall chinook salmon (KRTAT 1988, Prager and Mohr 2001). The version of the Klamath Ocean Harvest Model that will be used to evaluate 2003 ocean season options is calibrated to estimated actual landings and fishery impacts that occurred during 1986-2001, and thus requires predictions of the 2003 ocean abundance of Rogue chinook to be scaled to their estimated actual ocean abundance during each of these 16 base years.

Validated rigorous abundance estimates for Rogue fall chinook are not available. However, key spawning areas have been surveyed in a consistent manner since 1977. Counts from these survey sites form the basis of an index of the run size of Rogue fall chinook. We use this index as a relative measure of Rogue fall chinook abundance and develop predictions of their ocean population abundance based on this relative index. This report describes predictions of the relative ocean population size of Rogue fall chinook for 2003 as indexed from spawning survey counts.

In 2000 we initiated a study to attempt to estimate the absolute run size of Rogue Basin fall chinook salmon by conducting a mark-recapture study. Our intent was to convert relative indices of abundance to absolute estimates by determining the fraction of the run that spawns in our index areas. This study was continued in 2002 and results to date are reported here.

METHODS

Mark-Recapture Study

Fall chinook were captured and tagged by a beach seine fished at Huntley Park (river mile 8). The seining operation consisted of 15 sets per day during three days each week from 15 July through 30 October. Captured chinook were measured (fork length), sexed and tagged with uniquely-colored anchor tags. Seven different tag colors were used over the course of the 3.5-month season. Tag colors were changed at approximately biweekly intervals to identify different portions of the run at recovery. Each fish received two tags (one tag at the base of each side of the dorsal fin).

The second capture event occurred as carcasses recovered on spawning surveys. In addition to recoveries on Standard Index areas (Figure 1), carcasses were also recovered in supplemental survey sites in the mainstem Rogue River and in the Illinois River Basin. A portion of the carcasses recovered on surveys was sampled for the presence of anchor tags. All sampled carcasses were examined for the presence of tags, measured for MEPS length, sexed and scale sampled. Tag loss was estimated by the fraction of recovered tagged fish that possessed only one of the two originally placed tags. Run size was estimated using the Petersen formula (Ricker 1975). Precision was estimating using Bootstrapping techniques (Buckland and Garthwaite 1991).

Abundance Prediction

Predictions of indexes of the ocean abundance of Rogue fall chinook salmon were derived by using linear regression analysis to relate indexes of ocean abundance of age i fish to indexes of inriver run size of age i-1 fish of the same cohort. Rogue fall chinook salmon contribute to ocean fisheries primarily at age 3-5, therefore individual regression models were developed to predict indexes of the ocean abundance of each of these three age classes.

Inriver run size was indexed by counts of spawned-out carcasses in the mainstem Rogue and Applegate Rivers. Two mainstem and four Applegate River survey areas were used (Figure 1, Appendix A). These six standard survey areas compose the spawning habitat intensively used by this stock. Counts were not conducted in the two mainstem survey areas in 1986 and 1987. These missing counts were estimated by a linear regression relationship between total counts in all six survey areas and total counts in the Applegate River survey areas for the 18 years available from 1981-98. This time span was chosen because it encompassed years in which Applegate Dam increased fall river flow and potentially influenced spawner distribution. Counts disrupted by high flows during the survey season were adjusted using the methods described in Whisler and Jacobs (2001). Additionally, some of the counts in Appendix A were revised to correct errors in data summaries and therefore may differ slightly from counts listed in pervious versions of this report.

Total carcass counts for the three years from 1978-80 were adjusted to compensate for pre-spawning mortality (Cramer et al. 1985). These adjustments were made by dividing each count by one minus the corresponding estimated annual mortality rate.

Age composition of the inriver run was estimated from scales collected from carcasses. Scale samples were read to determine proportions of age 2-5 fish (Borgerson and Bowden, 2001) and these proportions were applied to the total carcass count to obtain indexes of inriver run size for each age class. One-thousand-seventy-four scale samples were read to obtain the estimate of age composition in 2002.

Indexes of ocean population size were obtained using cohort reconstruction methods (**Appendix B**). These methods followed those used for Klamath fall chinook salmon (KRTAT 1990), except for the procedure used to estimate ocean impacts and May starting populations. We used indexes of May starting populations as scalars of ocean population size. Indexes of May starting populations were derived by applying estimates of ocean fishery harvest rates to the remaining portion of each respective cohort as follows:

$$\text{Maystrt}_i = (\text{inriver}_i + \text{fallstart}_{i+1})/(1\text{-harvest rate}_i)$$

where i equals a given age class.

Ocean impacts were estimated as:

$$\text{Ocean impact}_i = \text{Maystrt}_i - (\text{inriver}_i + \text{fallstart}_{i+1})$$

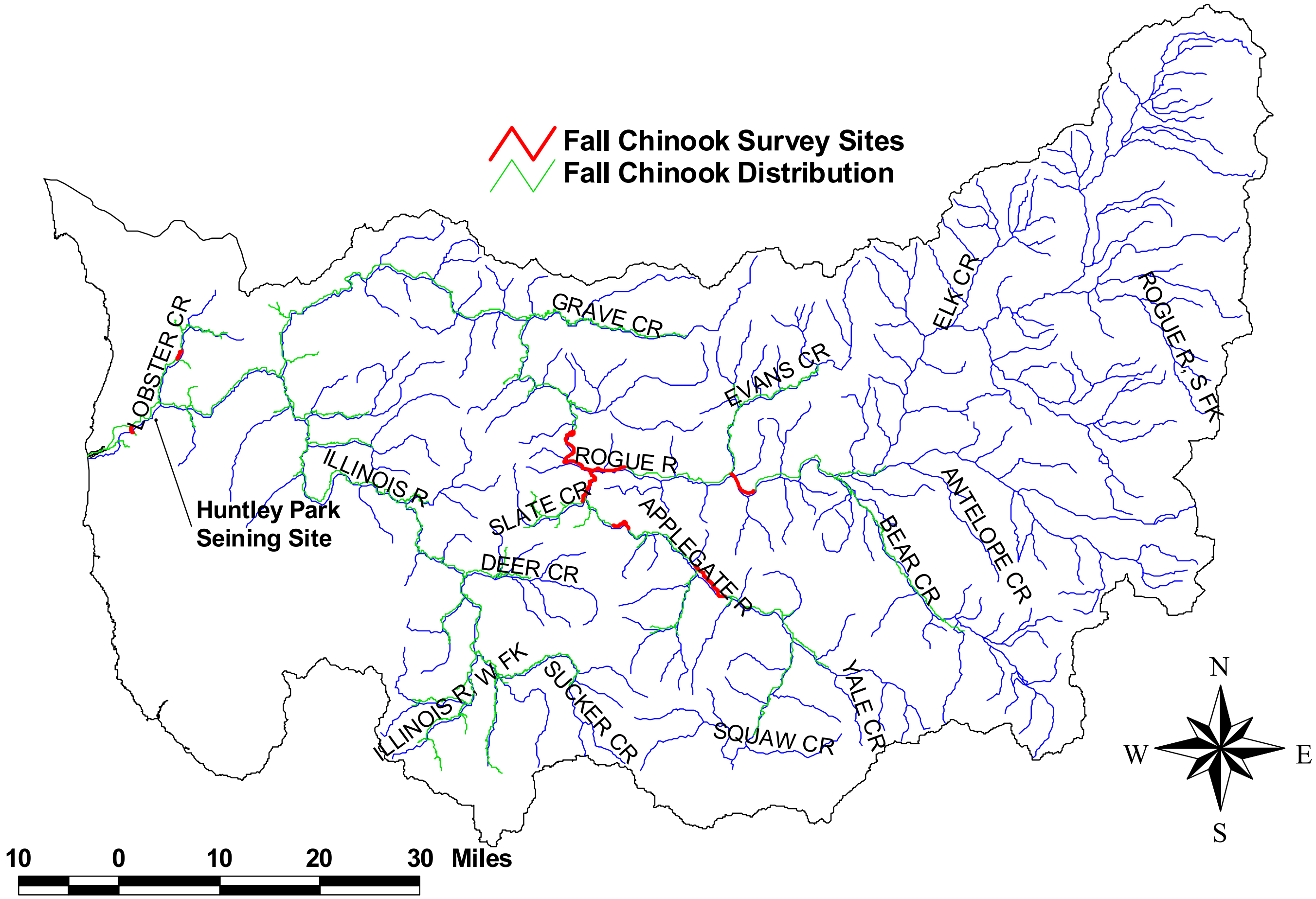

Figure1. Map of Rogue River Basin showing distribution of fall chinook salmon and locations of Huntley Park seining site and spawning surveys.

Indexes of reconstructed cohorts for the 1972-2000 broods appear in Appendix B. Complete reconstruction through inriver age-2 is available for the 1975-97 broods. Methods used to derive May starting populations for age-3 and 4 chinook for the 2002 return year differed from those described above, because only incomplete cohorts are available for these broods. The age-4 May starting population for 2002 was estimated by dividing the inriver run of age-4s by the mean maturity rate at age-4 for the 1975-97 broods (73.1%), and then dividing this value by one minus the 2002 age-4 harvest rate. The Age-3 May starting population for 2002 was estimated by dividing the inriver run of age-3s by the mean maturity rate at age-3 for the 1975-97 broods (15.1%), and then dividing his value by one minus the 2002 age-3 harvest rate.

Results And Discussion

Mark-Recapture Study

A total of 1,743 fall chinook were captured and tagged (Figure 2, Table 1). Only fish tagged with tag colors applied after 12 August were recovered on spawning surveys. It is likely that fish tagged prior to 12 August were late spring or summer Chinook destined for spawning areas upstream for spawning survey sites. To adjust for this, we removed fish tagged prior to 12 August from the population of tagged fish. This reduced the tagged population to 1,437 fish. Of the 32 tagged carcasses recovered, three were missing one of the two original tags. This equates to an estimated rate of 0.22% of the tagged fish loosing both tags. Applying this rate reduces the tagged population to 1,434 fish.

Table 1. Numbers of fish tagged and recaptured, and the duration between tagging and recovery for fall chinook in the Rogue Basin, 2002.

				Duration Between Tagging and Recovery (Days)	
Recovery Stratum	Tagged[a]	Carcasses Sampled	Tags Recovered	Mean	Range
Standard Surveys	1,433	2,582	21	76	63-99
Supplemental Surveys	1,434	2,093	11	80	85-71
Overall	1,434	4,675	32	77	65-99

a *Adjusted for tag loss.*

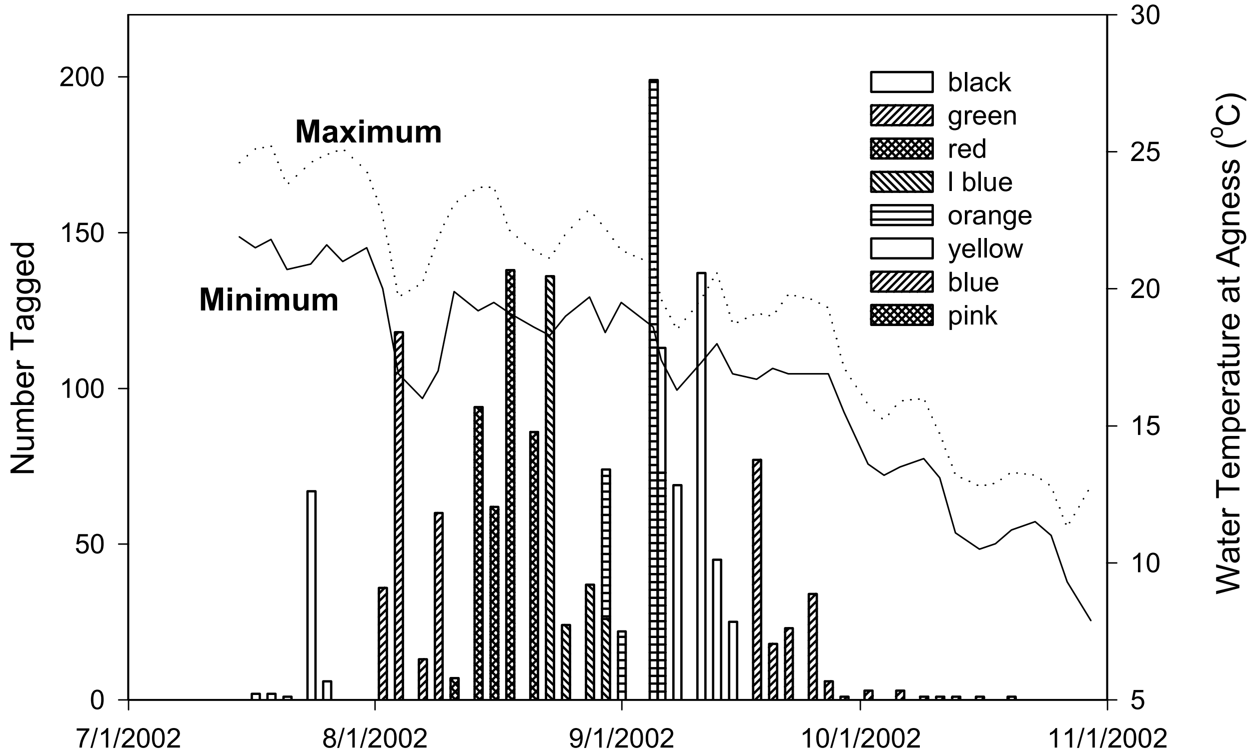

Figure 2. Timing of tagging of chinook at Huntley Park, 2002. Periods of tagging for individual tag color groups are shown. Also shown is the daily minimum and maximum water temperature of the Rogue River as recorded at the USGS gauge near Agness.

Twenty-one of the tagged fish were recovered on surveys in the mainstem Rogue River. Of the remaining 11 recoveries, seven were recovered in the Illinois Basin and four were recovered in the Applegate Basin. No tagged fish were recovered in lower river tributaries. The average duration between tagging and recovery was 77 days and ranged between 65 and 99 days. There was a difference in the timing of tagging between carcasses recovered in the mainstem Rogue and Applegate Rivers versus carcasses recovered in the Illinois River. Tagged carcasses recovered in the Rogue and Applegate Rivers were from tag groups having mean dates of tagging ranging from 17 August to 10 September. Alternatively, Tagged carcasses recovered in the Illinois River were from tag groups having mean dates of tagging ranging from 10 to 21 September. These results indicate that chinook spawning in the Illinois River have a later run timing than do chinook spawning in middle portions of the mainstem Rogue River or Applegate River.

Estimates of the run size with associated precision and bias of Rogue fall chinook migrating upstream of river mile seven are listed in Table 2. The highest precision and lowest bias were obtained from pooling recoveries obtained in standard and supplemental survey sites. The resulting population estimate has 95% confidence limits ranging from 150,00 to 291,00 fish.

Table 2. Population estimates, upper and lower 95% confidence limits, bias and precision of fall Chinook salmon migrating upstream of river mile seven in the Rogue River Basin, 2002.

		Bootstrap Analysis				
Recovery Stratum	Peterson Estimate	Average	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Bias[a]	Precision[b]
Standard Surveys	168,412	176,754	114,957	281,248	-4.7%	59%
Supplemental Surveys	250,362	274,113	156,011	596,653	-8.7%	118%
Overall	203,267	208,435	150,057	290,622	-2.5%	39%

a (*Difference of average bootstrap estimate and the Peterson estimate) / Peterson estimate.*
b *Upper 95% confidence interval / average bootstrap estimate.*

There was negligible bias associated with the population estimate calculated with the Petersen equation. Other sources of bias directly associated with the mark-recapture technique are more difficult to assess. Assumptions needed to be met for the mark-recapture estimator to be unbiased are:

1. all fish have an equal probability of being marked at the trap site; or,
2. all fish have an equal probability of being inspected for marks; or,
3. marked fish mix completely with unmarked fish in the population between events; and,
4. there is no recruitment to the population between capture events; and,
5. there is not trap induced behavior; and,
6. fish do not lose their marks and all marks are recognizable

An unbiased population estimate is obtained if any of the first three assumptions hold true and all of assumptions 4-6 hold true. In regards to the mark-recapture conduced for Rogue fall chinook, assumptions 1 and 2 are assumed not to hold true. The proportion of chinook marked at the seining site sites varies due to flow conditions and capture inefficiencies. The same holds true on the spawning grounds for carcass collection. Assumption 3 is generally thought to have held true. Although with only 32 tag recoveries it is difficult to rigorously test this assumption, there are no obvious indications that this assumption was violated. Tagged fish were recovered throughout the period of carcass collection and were spatially distributed throughout the locations of carcass recovery. Regarding assumption 4, recruitment to the population between tagging and recovery was not possible because of distinct and temporally distant periods of the two capture events.

Violation of assumption 5 would occur if tagging causes significant mortality prior to spawning. Although water temperatures during the first capture and tagging operation can be high (Figure 2), tagging crews reported that the capture and tagging procedure did not appear to be overly stressful. Fish were processed quickly and behaved normally after tagging. Seining was conducted during the morning hours to take advantage of the coolest available water temperatures. No mortalities of tagged fish were observed or reported near the seining location or during a couple of boat surveys conducted during the peak of the tagging season and extending 20 miles upstream of the seining site.

Violation of assumption 5 would also occur if the vulnerability of recovery varied between tagged and untagged carcasses sampled during the second capture event. This condition could occur if tags enhanced the delectability of carcasses. This was unlikely however, given the small size of the tags used.

Tag loss (assumption 6) was negligible. Based on double tagging and the recovery of single tagged carcasses, we estimated that 0.22% of the tagged fish lost both tags. Further, only intact carcasses that could readily be inspected for the presence of tags were included in the sample of the second capture event. Given these factors, we felt confident in assuming that tag loss did not affect the accuracy of the population estimate.

The estimated run size of 150,000-290,000 in the Rogue Basin for 2002 is impressively large. Using a method that expands Huntley Park seine catches for flow-related capture efficiencies (ODFW 1992) produces an estimate run size of 81,000 fish. This estimate falls outside the confidence intervals of the Petersen estimate, however estimates of precision for the seine expansion method are not available. Further, there are potential biases associated with assumptions inherent in the seine expansion method that are difficult to assess.

A third alternative approach for estimating the abundance of Rogue fall chinook is to extrapolate spawner density in survey sites to the extent of spawning habitat available in the basin. In 2002, we recovered an average of 504 carcasses per mile in the standard surveys. Given the channel size and morphology and the water clarity that occurs during the survey season, this density only represents a portion of the actual density of carcasses in these surveys. Estimates of the rate of available fall chinook carcasses recovered on spawning surveys are not available for the Rogue Basin, however estimates are available from the mainstem Nehalem and Coos Rivers (ODFW unpublished data). Based on recoveries of carcasses that were tagged, reintroduced into the river channel and recovered on subsequent visits, surveyors recovered and average of 36% of the carcasses that were present in these two basins. Applying this recovery rate to the observed density for the Rogue standard surveys yields an estimated 1,400 carcasses per mile in these sites.

Based on the distribution shown in Figure 1, there is 492 miles of the Rogue Basin where fall chinook spawning can occur. It is unlikely that spawning throughout this extend occurs at as high of a density as that occurring in the standard surveys. A conservative estimate of an appropriate value would be a density of 25% of that occurring in the standard surveys. Appling this assumption to the extrapolation yields an estimate of 172,000 spawners for 2002. This estimate is well within the 95% confidence intervals for the Petersen estimate, despite that the Petersen estimate includes harvest as well as spawner escapement and that the extrapolation only includes spawners.

Over the last three seasons, we have made progress towards the goal of providing absolute abundance estimates of Rogue fall chinook. After initial evaluation, the estimate for 2002 appears plausibly accurate and reasonably precise. For the most part, the work needed to derive abundance estimates has come directly through minor modifications in the methodologies of ongoing monitoring efforts. Given this situation, the approach developed over the last three seasons is a highly cost-effective means of improving our knowledge of this important fisheries resource. We therefore recommend continuing the mark-recapture study in 2003 using the same approach used in 2002. If possible, supplemental surveys should again be conducted to increase the sample size of the second capture event and thus improve the precision of the estimate. An additional alternative for improving precision would be to sample the recreational fishery in the middle portion of the Rogue River.

Abundance Prediction

The predicted index of ocean abundance of Rogue fall chinook salmon for 2003, along with actual (post-season) indexes of ocean abundance in 1977-2001 appear in Table 3. Predictive relationships based on the data set for age 3-5 fish are presented in Figures 3-5. These relationships were revised beginning in 1999 based on a data set that was adjusted for the effects of river flow on carcass recovery discussed earlier and by forcing the intercept through zero (Whisler and Jacobs 2001). For the evaluation of the accuracy of these adjustments, please refer to the 1999 version of this report.

The predicted abundance of age-4 chinook for 2003 is the highest occurring since 1988 and the prediction for age-3 fish, although lower than the actual abundance in 2002 is higher than any other prior year back through 1989.

A means of assessing the aptness of predictive regression models is to compare predictions to actual estimates of abundance. Table 4 compares the predictive accuracy of the regression models. Comparisons are made for each available year back to 1992. We assessed accuracy of predictive models by hind-casting abundance predictions for each year and comparing these values to post season abundance estimates for the data set. Predictive models for age-3, age-4 and age-5 fish have not exhibited any net bias over the last 11 years. Pared t-tests showed differences between predicted and post-season values to be not significantly different from zero.

Despite the lack of bias being detected in the long-term performance of the predictors, there appears to be a negative bias in the age-3 predictor in recent years. Since 1997, this predictor has consistently under predicted age-3 abundance. This pattern may be the result of a change in the maturity rate of Rogue fall chinook. Since harvest restrictions have been implemented in 1991, reduced ocean harvest rates have resulted in a higher portion of the spawning escapement being comprised of older aged fish (t-tests comparing proportions of age-4 and age-5 fish among spawners in 1975-87 versus 1988-97 brood years, $p<0.05$). Age of maturity has been shown to be heritable in chinook salmon. With recent returns being produced by older aged parents, the maturity rate for younger aged fish may be declining from levels that exited when fewer older aged fish were in the spawning population. The accuracy of the sibling-sibling predictive approach we use is assumes that maturity rates are relatively constant.

Table 3. Abundance of Rogue fall chinook salmon as indexed from carcass recoveries, 1977-2003.

RETURN YEAR	TOTAL CARC-ASSES[c]	AGE COMPOSITION (%)				OCEAN HARVEST RATE (%) [a]		INRIVER RUN INDEX				OCEAN POPULATION INDEX [b]			
		2	3	4	5	AGE 3	AGE 4-5	AGE 2	AGE 3	AGE 4	AGE 5	AGE 3	AGE 4	AGE 5	TOTAL
1977	3,745	63.8	25.6	9.0	1.0	23	55	2,389	959	337	37	9,753	1,378	83	11,215
1978	10,193	10.0	60.1	22.1	1.0	23	55	1,019	6,126	2,253	102	38,657	5,215	227	44,099
1979	8,467	2.3	11.8	79.5	0.4	23	55	195	999	6,731	34	7,805	18,809	75	26,689
1980	2,632	15.6	9.3	35.2	23.7	23	55	411	245	927	624	5,225	3,988	1,386	10,599
1981	6,399	18.3	57.0	16.8	5.1	21	53	1,171	3,647	1,075	326	9,154	3,009	694	12,858
1982	3,520	20.1	37.9	35.9	3.7	30	52	708	1,334	1,264	130	9,811	2,868	271	12,950
1983	3,008	9.0	35.8	51.5	1.2	19	60	271	1,077	1,549	36	8,575	4,427	90	13,092
1984	3,663	10.8	34.1	50.4	3.0	8	38	396	1,249	1,846	110	9,875	4,695	177	14,747
1985	7,986	31.3	15.7	43.5	8.0	11	25	2,500	1,254	3,474	639	9,723	6,269	852	16,844
1986	20,400	15.8	63.8	12.0	2.6	18	46	3,223	13,015	2,448	530	71,279	5,920	982	78,181
1987	28,450	8.9	26.6	61.9	1.2	16	43	2,532	7,568	17,611	341	80,340	36,347	599	117,286
1988	32,965	4.1	14.7	76.5	4.6	20	39	1,352	4,846	25,218	1,516	17,334	47,934	2,486	67,754
1989	7,889	6.1	16.4	51.0	26.1	15	36	481	1,294	4,023	2,059	8,447	7,217	3,217	18,882
1990	1,914	2.4	14.5	71.4	11.2	30	55	46	278	1,367	214	6,043	4,709	476	11,229
1991	2,956	5.3	12.1	64.3	16.7	3	18	157	358	1,901	494	3,506	3,162	602	7,270
1992	2,830	16.4	12.1	53.0	18.2	2	7	464	342	1,500	515	4,371	2,434	554	7,359
1993	5,704	4.5	60.7	25.9	9.0	5	16	257	3,462	1,477	513	16,043	3,153	611	19,807
1994	7,895	6.7	9.6	72.9	10.8	3	9	529	758	5,755	853	2,982	9,423	937	13,342
1995	4,131	4.2	15.6	33.0	47.5	4	13	173	644	1,363	1,962	4,301	1,708	2,255	8,264
1996	2,569	4.7	16.8	75.3	3.2	5	16	121	432	1,934	82	2,436	2,788	98	5,321
1997	1,711	4.0	16.8	61.1	17.9	1	6	68	287	1,045	306	5,245	1,506	326	7,077
1998	3,641	1.1	13.8	77.5	7.4	0	9	40	502	2,822	269	3,833	3,924	296	8,054
1999	2,650	5.9	12.4	61.0	20.6	1	9	157	329	1,617	545	1,477	2,665	599	4,742
2000	3,592	6.3	55.0	21.9	16.2	6	10	226	1,976	787	582	9,933	907	647	11,487
2001	7,152	10.8	32.6	58.3	0.3	3	9	772	2,332	4,170	21	13,468	5,889	24	19,381
2002	12,741	7.1	31.2	55.4	6.2	5 [e]	17	905	3,975	7,059	790	23,524 [d]	9,267 [d]	952	33,744
2003												16,596	13,207	1,071	30,874

a HARVEST RATES FROM KLAMATH CHF COHORT ANALYSIS. VAUES FOR 1977-80 BASED ON 1981-83 AVERAGE.
b BASED ON COHORT RECONSTRUCTION METHODS. VALUES FOR 2003 PREDICTED FROM REGRESSION EQUATIONS.
c CARCASS COUNTS IN 1978, 1979 AND 1980 ADJUSTED FOR PRE-SPAWNING MORTALITY.
d PRELIMINARY, COMPLETE COHORT NOT AVAILABLE. USED MEAN MATURITY RATE TO DERIVE ESTIMATE.
e HARVEST RATE NOT AVAILABLE USED AVERAGE 3:4 HARVEST RATE RATIOS 1996-2001.

Figure 3. Prediction of age-3 Rogue fall chinook.

Age 2 on 3
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.844
R Square	0.712
Adjusted R Square	0.667
Standard Error	11149.147
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6774137512	6.77E+09	54.49677	2.91392E-07
Residual	22	2734676401	1.24E+08		
Total	23	9508813913			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	18.34628034	1.889266359	9.710796	2.05E-09	14.42817752	22.26438317

2003 estimate		
age 3 =	16,596	
based on	905	age 2

Age 3 Rogue River Fall Chinook Salmon
1975-97 Brood Years

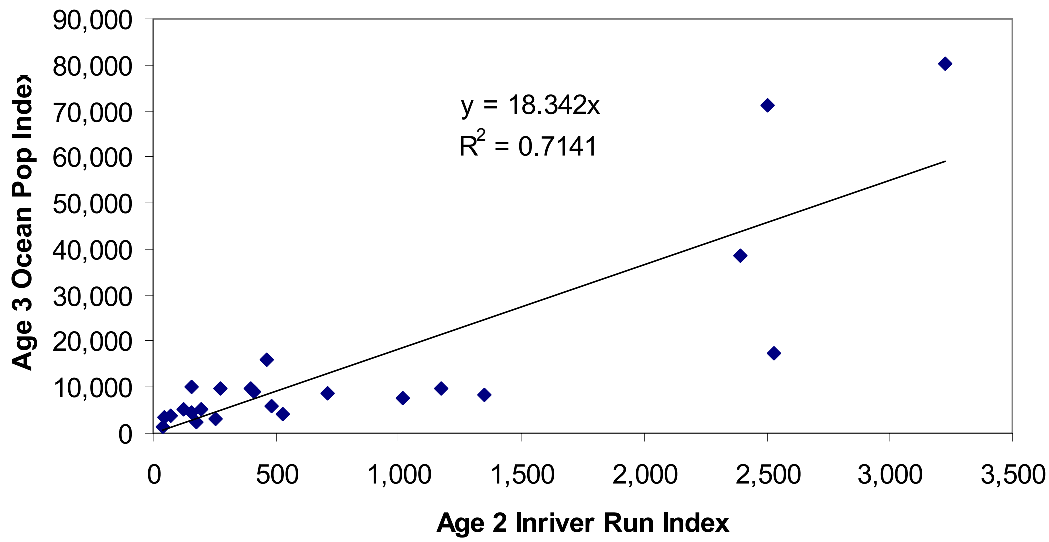

Figure 4. Prediction of age-4 Rogue fall chinook.

Age 3 on 4

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.857
R Square	0.734
Adjusted R Square	0.689
Standard Error	5931.278
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2137153841	2.14E+09	60.74901	1.24753E-07
Residual	22	773961292.7	35180059		
Total	23	2911115133			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	3.322478931	0.327694333	10.13896	9.39E-10	2.642881749	4.002076112

2003 estimate		
age 4 =	13,207	
based on	3,975	age 3

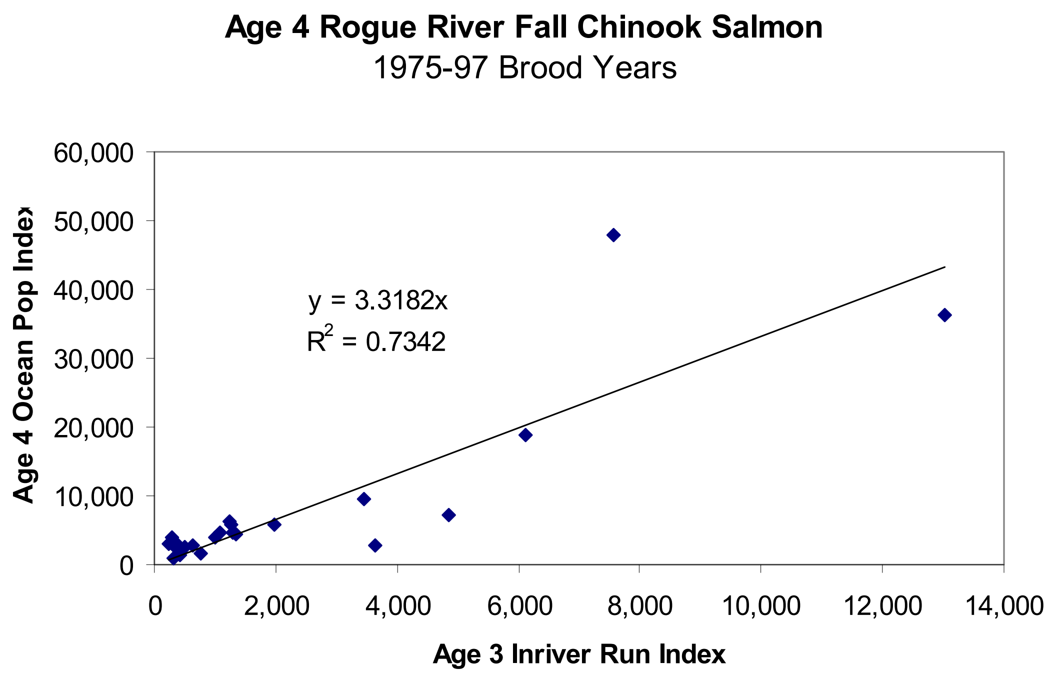

Figure 5. Prediction of age-5 Rogue fall chinook.

Age 4 on 5
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.824
R Square	0.678
Adjusted R Square	0.633
Standard Error	457.247
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9703334.368	9703334	46.41085	9.77609E-07
Residual	22	4599643.362	209074.7		
Total	23	14302977.73			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.15168963	0.013703454	11.06944	1.84E-10	0.123270375	0.180108885

2003 estimate		
age 5 =	1,071	
based on	7,059	age 4

Age 5 Rogue River Fall Chinook Salmon
1975-97 Brood Years

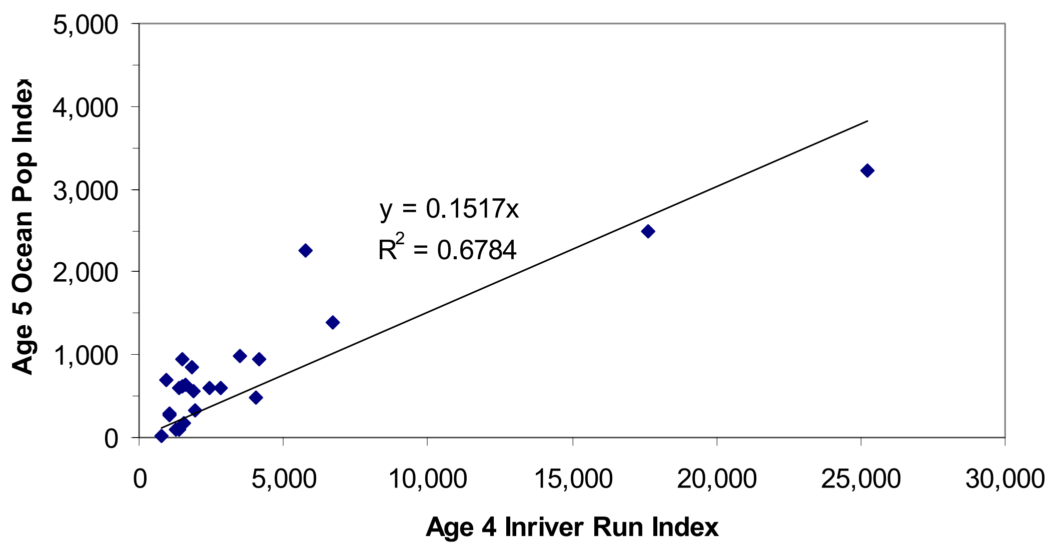

Table 4. Assessment of the accuracy of pre-season predictions of ocean abundance for Rogue fall chinook salmon, 1992-2001. Index values in thousands of fish.

Year	Age	Pre-season Prediction	Post-season Estimate	Pre-season/ Post-season
1992	3	4.4	4.1	1.06
1993		12.9	17.3	0.75
1994		7.2	3.3	2.21
1995		14.8	4.5	3.33
1996		4.8	2.6	1.83
1997		3.2	5.9	0.54
1998		1.6	3.7	0.43
1999		1.1	2.0	0.55
2000		4.3	9.9	0.43
2001		6.3	13.5	0.47
2002		14.0	23.5	0.60
Mean				**1.11**
1992	4	1.5	2.3	0.65
1993		1.5	2.9	0.51
1994		14.9	9.5	1.56
1995		3.2	1.9	1.71
1996		2.7	2.7	1.01
1997		1.7	1.6	1.11
1998		1.2	4.0	0.28
1999		2.1	2.7	0.78
2000		1.4	0.9	1.54
2001		8.4	5.9	1.43
2002		7.7	9.3	0.83
Mean				**1.04**
1992	5	0.3	0.5	0.57
1993		0.2	0.6	0.42
1994		0.2	0.9	0.26
1995		0.9	2.5	0.37
1996		0.2	0.1	2.36
1997		0.3	0.3	0.89
1998		0.2	0.3	0.57
1999		0.5	0.6	0.83
2000		0.3	0.6	0.46
2001		0.1	0.0	4.24
2002		0.7	1.0	0.74
Mean				**1.06**

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REFERENCES

Borgerson. L.A. and R.K. Bowden. 2001. Scale Analysis. Annual Progress Report. Oregon Department of Fish and Wildlife, Portland.

Buckland, S.T. and P.H. Garthwaite. 1991. Quantifying precision of mark-recapture estimates using bootstrap and related methods. Biometrics. 47:255-268.

Cramer, S.P., T.D. Satterthwaite, R.R. Boyce and B.P. McPherson. 1985. Lost Creek Dam fisheries program phase 1 completion report. Oregon Department of Fish and Wildlife, Portland.

Klamath Technical Advisory Team (KRTAT). 1988. Description of Klamath River fall chinook ocean fishery model for use in 1988 management. Rancho Cordova, California.

Klamath Technical Advisory Team (KRTAT). 1990. Cohort analysis of Klamath River Basin fall chinook salmon of the 1979 through 1984 brood years. Rancho Cordova, California.

Oregon Department of Fish and Wildlife (ODFW). 1992. Rogue Basin fisheries evaluation phase II completion report: effects of Lost Creek Dam on fall chinook salmon in the Rogue River. Oregon Department of Fish and Wildlife, Portland.

Prager, Michael H., Michael S. Mohr, 2001: The Harvest Rate Model for Klamath River Fall Chinook Salmon, with Management Applications and Comments on Model Development and Documentation. North American Journal of Fisheries Management: Vol. 21, No. 3, pp. 533–547

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Environment Canada Bulletin 191, Ottawa.

Whisler J. and S. Jacobs. 1999. Prediction of 1999 ocean abundance of Rogue River fall chinook salmon. Available from the Oregon Department of Fish and Wildlife, Corvallis.

Appendix A. Data set of Rogue basin carcasses counts of fall chinook, 1977-2001. ***Bold Italicized*** values have been adjusted for effects of high flow during carcass recovery season.

RETURN YEAR	ADJUSTED CARCASS COUNTS IN SURVEY AREAS								
	ROGUE		APPLEGATE				TOTAL	TOTAL	GRAND
	MAIN79	MAIN39	APP110	APP117	APP132	SLATE	ROGUE	APPLEGATE	TOTAL
1977	***480***	***719***	***1,041***	***1,202***	141	162	***1,199***	***2,546***	***3,745***
1978	756	1,174	4,807	1,007	180	1,148	1,930	7,142	9,072
1979	***233***	***252***	586	309	102	550	***485***	***1,547***	***2,032***
1980	170	242	826	280	36	236	412	1,378	1,790
1981	370	***1,414***	***2,605***	***744***	824	442	***1,784***	***4,615***	***6,399***
1982	634	1,130	877	300	329	250	1,764	1,756	3,520
1983	***217***	***916***	***859***	***424***	***339***	253	***1,133***	***1,875***	***3,008***
1984	***423***	***838***	***931***	***818***	***300***	352	***1,262***	***2,401***	***3,663***
1985	557	1,254	2,073	2,099	1,197	806	1,811	6,175	7,986
1986	--	--	3,558	***3,202***	***3,848***	1,065	--	***11,673***	--
1987	--	--	6,794	5,116	4,062	141	--	16,113	--
1988	***2,170***	***13,274***	***7,489***	***5,389***	***4,521***	122	***15,444***	***17,521***	***32,965***
1989	761	2,833	1,897	1,202	1,117	79	3,594	4,295	7,889
1990	273	381	329	477	442	12	654	1,260	1,914
1991	289	731	707	694	515	20	1,020	1,936	2,956
1992	332	772	434	775	472	45	1,104	1,726	2,830
1993	423	1,733	1,011	1,571	933	33	2,156	3,548	5,704
1994	839	1,952	949	1,480	2,629	46	2,791	5,104	7,895
1995	522	1,359	582	810	844	14	1,881	2,250	4,131
1996	276	499	***737***	***665***	***379***	13	***775***	***1,794***	***2,569***
1997	246	543	217	418	245	42	789	922	1,711
1998	366	***995***	***528***	***845***	***871***	36	***1,361***	***2,280***	***3,641***
1999	207	506	396	795	654	92	713	1,937	2,650
2000	295	897	612	1029	671	88	1,192	2,400	3,592
2001	691	2,111	793	1,230	2,229	48	2,802	4,300	7,102
2002	1,087	4,460	1,859	3,236	2,033	66	5,547	7,194	12,741

Appendix B. Reconstructed cohorts of 1975-96 broods of Rogue fall chinook as indexed by adjusted carcass counts.

	AGE 2	AGE 3				AGE 4				AGE 5			
BROOD YEAR	INRIVER	FALL START	MAY START	OCEAN IMPACT	INRIVER	FALL START	MAY START	OCEAN IMPACT	INRIVER	FALL START	MAY START	OCEAN IMPACT	INRIVER
1972										104	83	46	37
1973						1,723	1,378	758	337	283	227	125	102
1974		19,507	9,753	2,276	959	6,519	5,215	2,868	2,253	94	75	41	34
1975	2,389	77,314	38,657	9,020	6,126	23,511	18,809	10,345	6,731	1,733	1,386	763	624
1976	1,019	15,610	7,805	1,821	999	4,985	3,988	2,193	927	868	694	368	326
1977	195	10,450	5,225	1,219	245	3,761	3,009	1,595	1,075	339	271	141	130
1978	411	18,309	9,154	1,922	3,647	3,585	2,868	1,491	1,264	113	90	54	36
1979	1,171	19,621	9,811	2,943	1,334	5,533	4,427	2,656	1,549	222	177	67	110
1980	708	17,150	8,575	1,629	1,077	5,869	4,695	1,784	1,846	1,065	852	213	639
1981	271	19,750	9,875	790	1,249	7,836	6,269	1,567	3,474	1,228	982	452	530
1982	396	19,446	9,723	1,070	1,254	7,400	5,920	2,723	2,448	749	599	258	341
1983	2,500	142,558	71,279	12,830	13,015	45,434	36,347	15,629	17,611	3,107	2,486	969	1,516
1984	3,223	160,679	80,340	12,854	7,568	59,918	47,934	18,694	25,218	4,022	3,217	1,158	2,059
1985	2,532	34,668	17,334	3,467	4,846	9,021	7,217	2,598	4,023	595	476	262	214
1986	1,352	16,895	8,447	1,267	1,294	5,886	4,709	2,590	1,367	753	602	108	494
1987	481	12,086	6,043	1,813	278	3,953	3,162	569	1,901	692	554	39	515
1988	46	7,011	3,506	105	358	3,043	2,434	170	1,500	764	611	98	513
1989	157	8,742	4,371	87	342	3,941	3,153	504	1,477	1,171	937	84	853
1990	464	32,086	16,043	802	3,462	11,778	9,423	848	5,755	2,819	2,255	293	1,962
1991	257	5,964	2,982	89	758	2,134	1,708	222	1,363	122	98	16	82
1992	529	8,602	4,301	172	644	3,485	2,788	446	1,934	407	326	20	306
1993	173	4,871	2,436	122	432	1,882	1,506	90	1,045	370	296	27	269
1994	121	10,490	5,245	52	287	4,905	3,924	353	2,822	749	599	54	545
1995	68	7,667	3,833	0	502	3,331	2,665	240	1,617	808	647	65	582
1996	40	2,955	1,477	15	329	1,134	907	91	787	29	24	2	21
1997	157	19,867	9,933	596	1,976	7,362	5,889	530	4,170	1,190	952	162	790
1998	226	26,937	13,468	361	2,332	11,584	9,267	1,575	7,059				
1999	772	47,049	23,524	1,176	3,975								
2000	905												