Prediction of the 2004 Ocean Abundance of Rogue River Fall Chinook Salmon

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ABSTRACT

The 2004 ocean population abundance of fall chinook salmon from the Rogue River is predicted to be 80% of that in 2003 and 85% of that in 2002. However, the 2004 abundance is predicted to be higher than the abundance observed in any other prior year back through 1989. Relative to the base period used in scaling the Klamath Ocean Harvest Model (1986-2003), the prediction for 2004 is 2.4-times the average of the estimated actual abundance during this 18-year period; ranging from 24% of their estimated actual abundance in 1987 to 582% of their estimated actual abundance in 1999.

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 2004 ocean season options is calibrated to estimated actual landings and fishery impacts that occurred during 1986-2002, and thus requires predictions of the 2004 ocean abundance of Rogue chinook to be scaled to their estimated actual ocean abundance during each of these 17 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 2004 as indexed from spawning survey counts.

METHODS

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 previous 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. Six hundred ninety-nine scale samples were read to obtain the estimate of age composition in 2003.

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:

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

Indexes of reconstructed cohorts for the 1972-2001 broods appear in **Appendix B**. Complete reconstruction through inriver age-2 is available for the 1975-98 broods. Methods used to derive May starting populations for age-3 and 4 chinook for the 2003 return year differed from those described above, because only incomplete cohorts are available for these broods. The age-4 May starting population for 2003 was estimated by dividing the inriver run of age-4s by the mean maturity rate at age-4 for the 1975-98 broods (76.8%), and then dividing this value by one minus the 2003 age-4 harvest rate. The Age-3 May starting population for 2003 was estimated by dividing the inriver run of age-3s by the mean maturity rate at age-3 for the 1975-98 broods (17.8%), and then dividing this value by one minus the 2003 age-3 harvest rate.

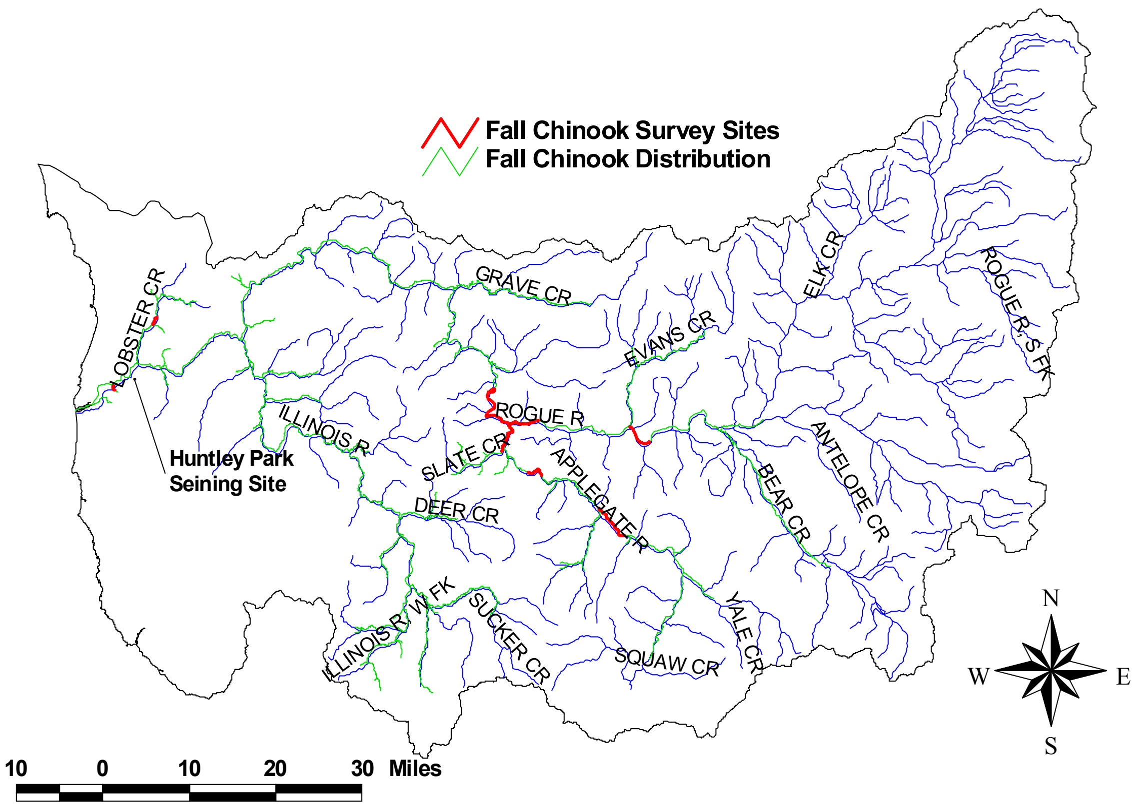

Figure1. Map of Rogue River Basin showing distribution of fall chinook and salmon survey sites.

Results And Discussion

The predicted index of ocean abundance of Rogue fall chinook salmon for 2004 along with actual (post-season) indexes of ocean abundance in 1977-2002 appear in Table 1. Predictive relationships based on the data set for age 3-5 fish are presented in Figures 2-4. 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.

With the exception of 2002, which had almost 23,000 age-3 chinook, the predicted abundance for 2004 age-3 chinook is the highest occurring since 1987. The prediction for age-4 chinook is 7,700 fish, down from almost 20,000 in 2003, but comparable to the highest counts seen up through 1989. The prediction for age-5 chinook is higher than all years back to 1977 with the exception of 1988, 1989 and 1994.

A means of assessing the aptness of predictive regression models is to compare predictions to actual estimates of abundance. Table 2 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 12 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, and with the exception of 2003, 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 existed when fewer older aged fish were in the spawning population. The accuracy of the sibling-sibling predictive approach we use assumes that maturity rates are relatively constant.

Table 1. Abundance of Rogue fall chinook salmon as indexed from carcass recoveries, 1977-2004.

RETURN YEAR	TOTAL CARCASSES [c]	AGE COMPOSITION (%) 2	3	4	5	OCEAN HARVEST RATE (%) [a] AGE 3	AGE 4-5	INRIVER RUN INDEX AGE 2	AGE 3	AGE 4	AGE 5	OCEAN POPULATION INDEX [b] 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	9,892	907	647	11,446
2001	7,152	10.8	32.6	58.3	0.3	3	9	772	2,332	4,170	21	13,920	5,859	24	19,802
2002	12,741	7.1	31.2	55.4	6.2	2	15	905	3,975	7,059	790	22,829 [d]	8,972	929	32,731
2003	15,603	6.3	14.9	76.6	2.3	8	21	983	2,325	11,952	359	14,222 [d]	19,697 [d]	454	34,373
2004												18,092	7,734	1,767	27,594

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 2004 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.

Figure 2. Prediction of age-3 Rogue fall chinook.

Age 2 on 3
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.839170514
R Square	0.704207151
Adjusted R Square	0.66072889
Standard Error	11063.556
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6702395843	6.7E+09	54.75712	2.1012E-07
Residual	23	2815252240	1.22E+08		
Total	24	9517648083			

	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	18.40524894	1.873385801	9.824591	1.07E-09	14.52986042	22.28063746

2004 estimate		
age 3 =	18,092	
based on	983	age 2

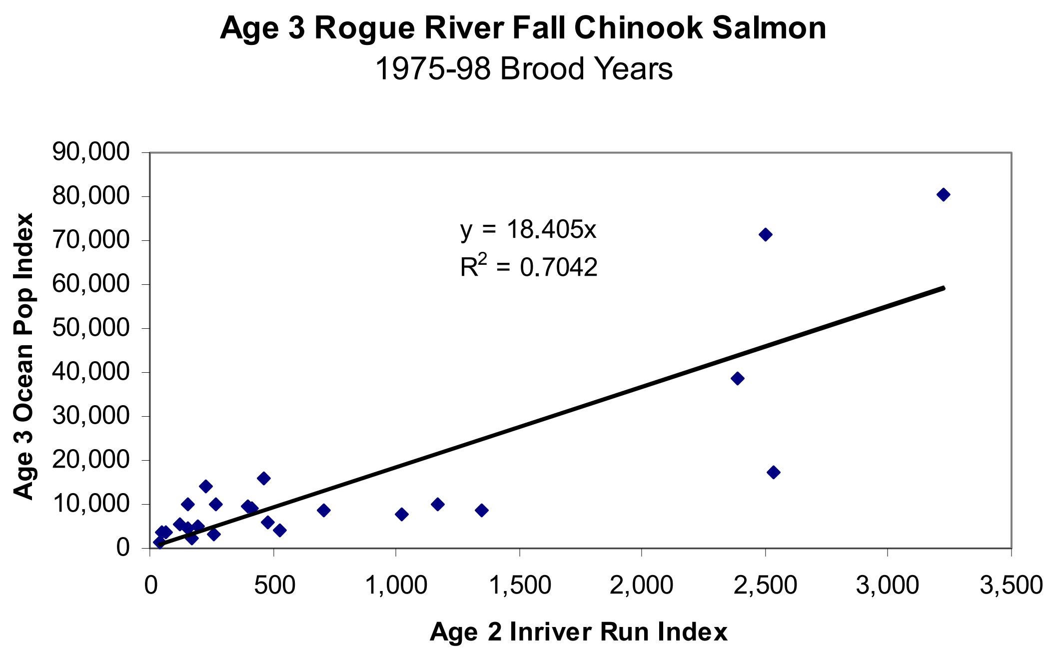

Figure 3. Prediction of age-4 Rogue fall chinook.

Age 3 on 4
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.856607118
R Square	0.733775755
Adjusted R Square	0.690297495
Standard Error	5808.367459
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2138709301	2.14E+09	63.39333	6.38831E-08
Residual	23	775954048.5	33737133		
Total	24	2914663349			

	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	3.326686044	0.318273971	10.45227	3.3E-10	2.668287068	3.985085021

2004 estimate		
age 4 =	7,734	
based on	2,325	age 3

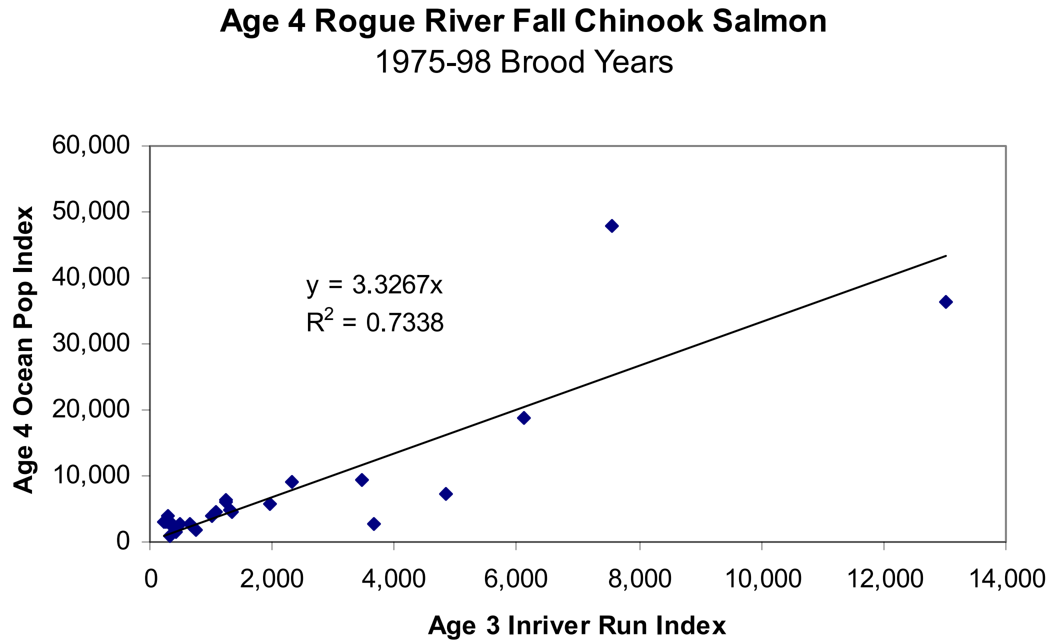

Figure 4. Prediction of age-5 Rogue fall chinook.

Age 4 on 5
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.81064101
R Square	0.657138847
Adjusted R Square	0.613660586
Standard Error	463.8619059
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9485148.008	9485148	44.08255	1.12399E-06
Residual	23	4948860.958	215167.9		
Total	24	14434008.97			

	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	0.147868683	0.013600723	10.87212	1.54E-10	0.119733482	0.176003884

2004 estimate		
age 5 =	1,767	
based on	11,952	age 4

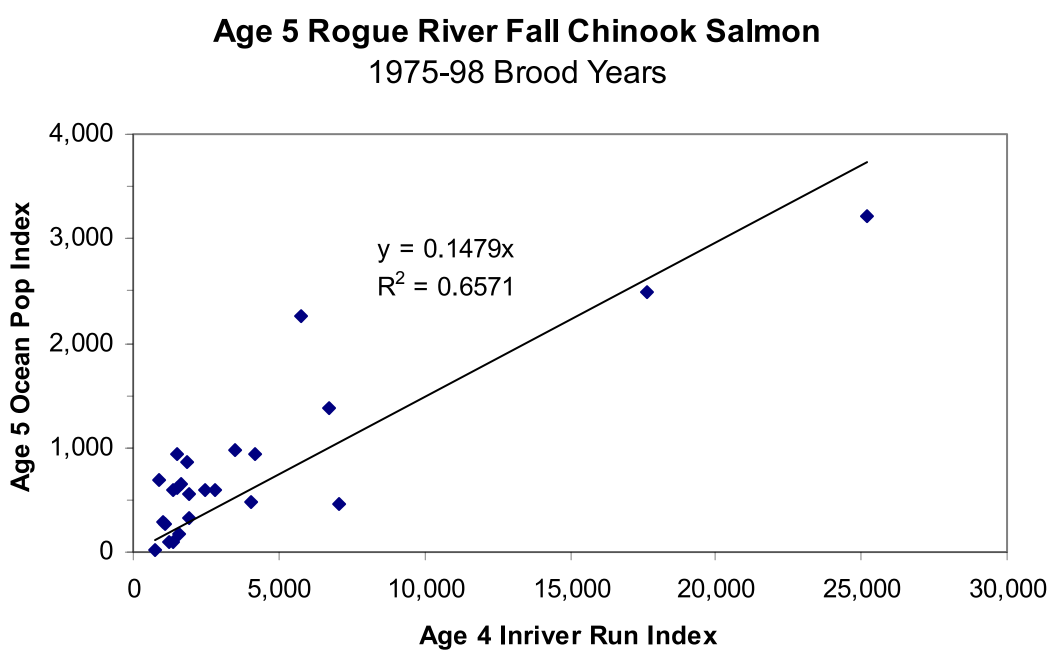

Table 2. Assessment of the accuracy of pre-season predictions of ocean abundance for Rogue fall chinook salmon, 1992-2003. Index values in thousands of fish.

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	13.9	0.45
2002		14.0	22.8	0.61
2003		16.6	14.2	1.17
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	9.0	0.86
2003		13.2	19.7	0.67
Mean				**1.01**
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	0.9	0.75
2003		1.1	0.5	2.42
Mean				**1.18**

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Appendix A. Data set of Rogue basin carcasses counts of fall chinook, 1977-2003. ***Bold Italicized*** values have been adjusted for effects of high flow during carcass recovery season.

RETURN	ADJUSTED CARCASS COUNTS IN SURVEY AREAS								
	ROGUE		APPLEGATE				TOTAL	TOTAL	GRAND
YEAR	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	2,279	48	2,802	4,350	7,152
2002	1,087	4,460	1,859	3,236	2,033	66	5,547	7,194	12,741
2003	1,458	5,390	1,796	1,671	5,163	125	6,848	8,755	15,603

Appendix B. Reconstructed cohorts of 1975-98 broods of Rogue fall chinook as indexed by adjusted carcass counts.

BROOD	AGE 2	AGE 3				AGE 4				AGE 5			
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	19,785	9,892	594	1,976	7,323	5,859	527	4,170	1,162	929	139	790
1998	226	27,839	13,920	373	2,332	11,215	8,972	1,346	7,059	568	454	95	359
1999	772	45,658	22,829	457	3,975	24,621	19,697	4,136	11,952				
2000	905	28,444	14,222	1,138	2,325								
2001	983												