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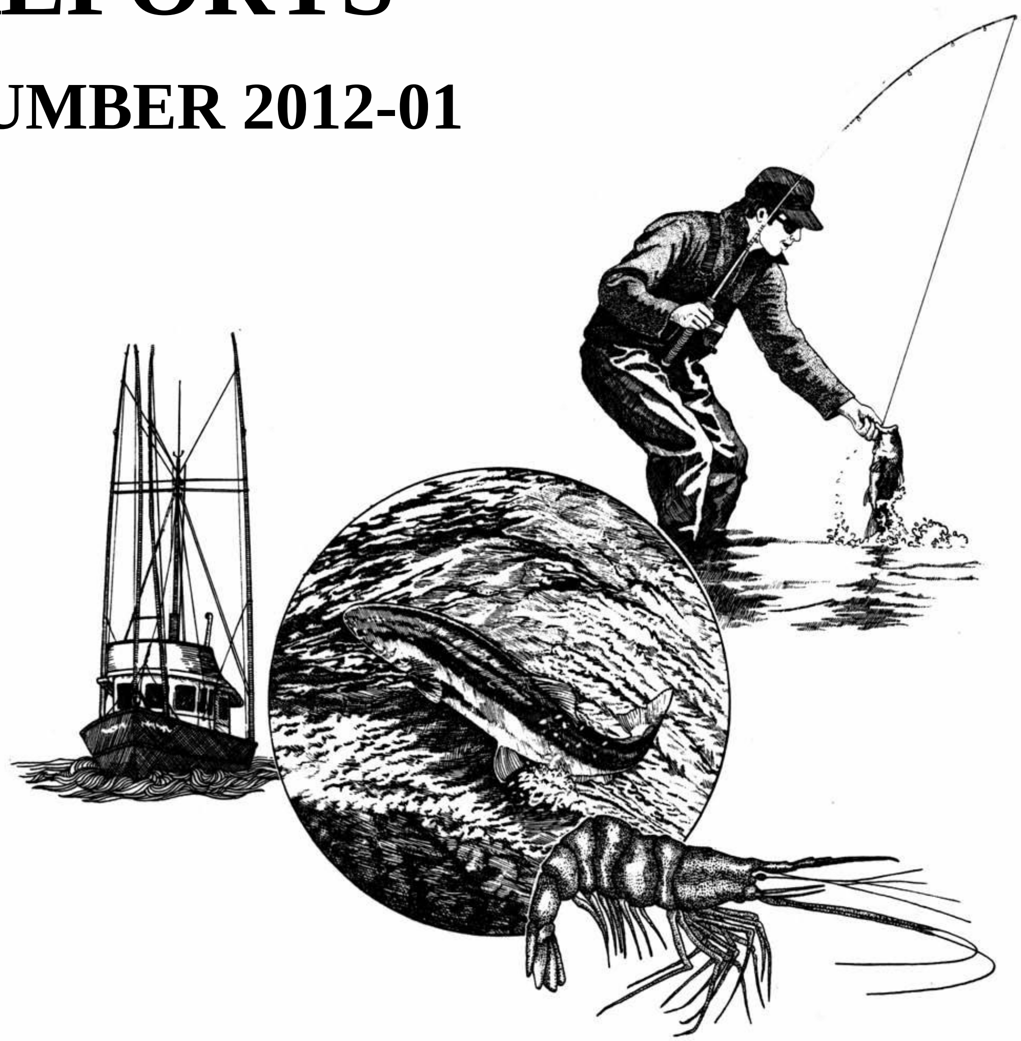

FISH DIVISION
Oregon Department of Fish and Wildlife

Using Calibrated Index Surveys to Estimate Chinook Spawner Escapement into the Salmon River, Oregon

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Abstract

The Pacific Salmon Commission has designated the Salmon River hatchery stock of fall Chinook as an Exploitation Rate Indicator Stock (ERIS) for all 16 naturally produced stocks of fall Chinook on Oregon's north coast. The Pacific Salmon Treaty (PST) specifies the necessity of these stocks to model the effects of mixed stock fisheries on wild Chinook salmon. The ocean migration patterns and catch rates of this stock are thought to closely resemble Oregon's north migrating Chinook from coastal basins ranging from the Necanicum River in the north to the Siuslaw River in the south. A relatively long and continuous history of mark and recapture experiments with corresponding extensive spawning ground surveys and harvest estimates from a fresh water creel, serves as the foundation for a predictive model of spawner abundance. Peak counts from two spawning ground surveys were identified as an index that strongly correlates with relatively precise abundance estimates derived from a Peterson two event mark-recapture model. Index surveys are less labor intensive than previous mark-recapture activities, and evidence suggests they are an efficient and cost effective method to estimate spawner abundance.

Introduction

Pacific Salmon Treaty

The Pacific Salmon Treaty (PST) is a written agreement between the United States and Canada signed in 1985 with the intent to protect and manage salmon stocks that originate in one country and are subject to harvest by the other. The Pacific Salmon Commission (PSC) is the authority responsible for implementing the PST and serves as a forum for cooperation between the Parties in the establishment of PST principles. Implementation of these principles are expected to provide conservation measures for all species of Pacific salmon in order to achieve optimum production and to divide the harvests so each country reaps the benefits of its management investment. The Commission also serves as a forum for consultation between the Parties on their salmonid enhancement operations and research programs.

The Chinook Agreement signed in 1999 amended the PST from a fixed-ceiling based harvest management strategy to a coast wide, aggregate abundance based management (AABM) approach. This new agreement was intended to enable the Parties to cooperatively manage their respective fisheries to sustain healthy stocks and rebuild stocks that have yet to achieve biological based escapement objectives. This fundamental PST management approach provided the opportunity to equitably distribute the conservation responsibility between the two countries, to attain escapement objectives for shared salmon stocks and to ultimately sustain dependent fisheries. The agreement establishes abundance based fishing regimes, based on run strength for the major salmon intercepting fisheries in the United States and Canada. Larger catches will be allowed when abundance is higher and catches will be constrained in years when abundance is down. These regimes are designed to implement the conservation and harvest sharing principles of the PST.

Within the Pacific Salmon Treaty (PST), Chinook salmon fisheries are managed under two different regimes, aggregate abundance-based management (AABM) and individual stock-based management (ISBM). The AABM fisheries include the sport, net and troll fisheries in and off of Southeast Alaska (SEAK), Northern British Columbia (NBC) troll, Queen Charlotte Islands (QCI) sport, and West Coast Vancouver Island (WCVI) troll and certain WCVI sport fisheries. All other fisheries which intercept stocks encountered in AABM fisheries are managed under the ISBM and Pacific Fisheries Management Council (PFMC) obligations. The AABM are mixed stock fisheries. The impacts of these fisheries vary. The North Oregon Coast (NOC) stocks are primarily caught in or affected by AABM fisheries and in our terminal fisheries. The Mid-Oregon Coast (MOC) stocks are also impacted by AABM fisheries but not as strongly. The AABM fisheries are driven by five stocks: 1) North Oregon Coast, 2) Columbia upriver brights, 3) Fraser early and late run, 4) West Coast Vancouver Island, and 5) Washington coastal. On May 22, 2008, the PSC reached an agreement of proposed changes to the Treaty chapters that were up for renewal, and recommended the ratification of the agreement to the governments of Canada and the U.S. Both governments have ratified that agreement. The changes to all five renewed chapters took effect January 1, 2009. They will be in effect for the 2009 fishing season and remain in place through 2018.

Exploitation Indicator Stock

Fall Chinook salmon originating from Salmon River Hatchery are released annually to provide recreational fishing opportunities and to represent many of Oregon's coastal Chinook stocks for PST management. The Salmon River hatchery is located at river kilometer 8, at the head of tidewater. Construction of the hatchery was completed in 1976, and fish releases began in 1977. Fall Chinook releases have ranged from approximately 100,000 to 330,000 fish annually (Pacific States Marine Commission; RMIS Database). Two additional releases in the system occurred in 1933 (10,000) and 1940 (50,000). The current production target is 200,000 Chinook smolts. Since 1987, all fish released have been adipose fin clipped (Ad) and coded wire tagged (CWT).

Ocean harvest of Salmon River Chinook occurs primarily off the coasts of Alaska and British Columbia (Nicholas and Hankin 1988). Salmon River Chinook are recognized as a member of the North Oregon Coast (NOC) aggregate. These fish are far north migrating Chinook stocks. In addition to the Salmon, the NOC aggregate includes the Nehalem, Miami, Kilchis, Wilson, Trask, Tillamook, Nestucca, Siletz, Yaquina, Alsea, and Siuslaw River basins. In 1986, the Pacific Salmon Commission funded a program to assess marine survival of Salmon River Chinook relative to changes in ocean harvest, and subsequently approved this stock as an Exploitation Rate Indicator Stock (ERIS) for the NOC aggregate. As an ERIS, this marked group of Salmon River hatchery fish is assumed to represent naturally produced stocks within coastal streams of the NOC and is designated under the PST to estimate the exploitation rate, incidental fishing mortality, catch distribution, and survival rate of the aggregate. A primary objective of an ERIS is to estimate the total returns of each tag code to the basin. There are three components of these returns that must be monitored to achieve this objective: total recreational harvest, total broodstock collection, and total spawner escapement.

Harvest, Broodstock and Spawner Escapement

Oregon Department of Fish and Wildlife (ODFW) personnel estimate the total return of Chinook salmon to Salmon River each fall. Chinook returning to the Salmon River are destined for one of the following fates: harvest in the tidewater recreational fishery, harvest in the riverine recreational fishery, capture at the hatchery, spawn naturally in the river basin, or die naturally prior to spawning (Williams et al 1990). The distribution of fish in each of these destinations was estimated as follows. A creel survey was used to estimate angler harvest of Chinook salmon for both the bay and riverine portions of the basin. The count of Chinook collected at the hatchery for broodstock was recorded. Between 1986 and 2002, a mark-recapture experiment was historically used to estimate the spawning escapement. Pre-spawning mortality was recorded when observed but never appeared to affect a large component of the run. With these components adequately estimated, the total numbers of cwt Chinook returning by brood year were determined with measured certainty. Boechler and Jacobs (1987) originally described the methods used to estimate the terminal escapement of fall Chinook from Salmon River. Subsequent modifications were made by Jacobs and Boechler (1988), Schindler et al. (1989), Williams et al. (1993), and Nuzum and Williams (1991).

From the inception of the Salmon River project in 1986, a statistical creel was conducted to gather harvest information to estimate the total number of Chinook harvested from the river basin and to sample adipose clipped fish for snouts containing CWTs. An appropriate expansion was applied to each tag code and the proportion of Chinook removed from the system by age class was estimated (Nuzum and Williams 1991). The number of Chinook collected at the hatchery for broodstock was documented and snouts from adipose clipped Chinook collected. Chinook collection at the hatchery was considered a census, thus no expansion was necessary.

Prior to 1986, standardized spawning surveys were used to assess trends in spawner abundance by generating a peak fish per mile index. From 1986 to 2002, a mark-recapture study was conducted to annually estimate the abundance of Chinook escaping to the spawning grounds. An intensive spawning ground survey protocol was implemented as the second capture event of the mark–recapture experiment and to sample the spawning grounds for CWT's from adipose clipped Chinook. An appropriate expansion was applied to each tag code and the proportion of Chinook escaping to the spawning grounds by age class was determined. From these studies, angler harvest has been estimated to be between 650 and 2,000 adult Chinook annually, and spawning escapement estimates have ranged from approximately 950 to 5,300 adult Chinook.

Funding cuts and increased operating costs instigated a review of these methods to identify changes that would create a more efficient and cost effective program without jeopardizing PST data standards. The extensive years of mark-recapture data and corresponding spawning ground survey dataset provided the opportunity to conduct a regression analysis between a visual survey index and a relatively precise spawner escapement estimate based on a Peterson mark-recapture model.

The objective of this study was to identify and document methodology that would allow ODFW personnel to transition from mark-recapture techniques to conducting index surveys that adequately estimate spawner abundance while reducing costs and maintaining a robust dataset. Specifically we set out to determine whether a visual index of live and/or dead fish from the spawning grounds can be used to accurately and precisely estimate spawner abundance. Precise spawner estimates are needed to meet criteria of an ERIS under PST management of a mixed stock fishery. This report describes that analysis and documents the present method to estimate Chinook spawner escapement in the Salmon River basin.

Study Area

The Salmon River is a small stream that drains from the Coast Range Mountains on the north-central coast of Oregon. The basin is situated just north of the town of Lincoln City, and meets the ocean on the south side of Cascade Head. The river drains an area of approximately 195 km^2. Normal stream flows in Salmon River range from less than 1 cubic meter per second (cms) to a high of 170 cms. Average annual flow is approximately 11 cms (CCSP 1991). Low flows occur in late summer, with peak discharges generally in December or January.

The headwaters and upper mainstem of the Salmon River primarily flow through corporate timberlands with minor federal holdings (U.S. Forest Service and Bureau of Land Management). Land use is dominated by commercial forestry. Extensive residential development exists along the lower reaches of the mainstem and the three major tributaries; Slick Rock Creek, Bear Creek, and Panther Creek. The tidewater and bay are dominated by pasture and lowland marshes.

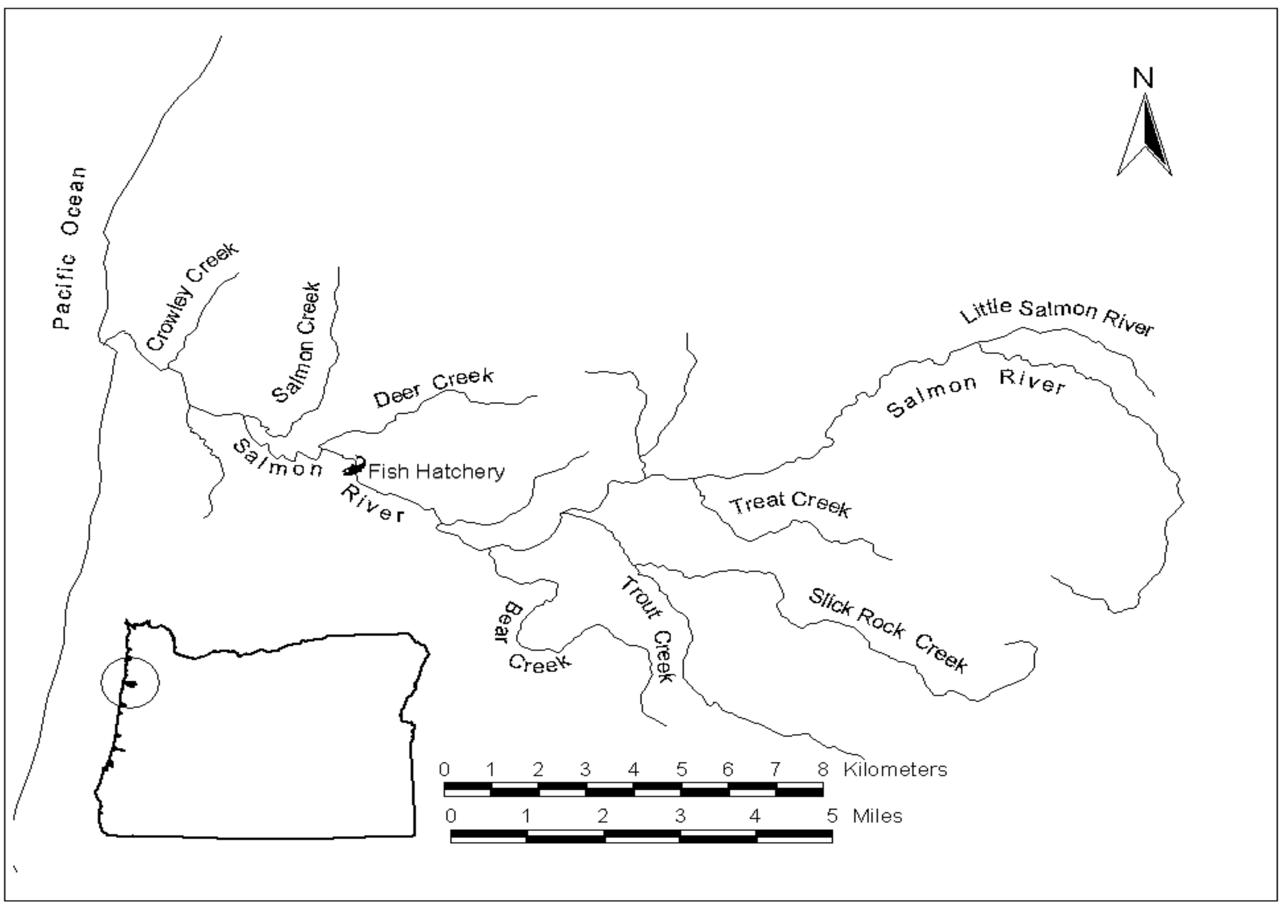

Figure 1: Map of Salmon River basin with the location of the fish hatchery noted.

Salmon River is home to several species of salmonids, including Chinook salmon (*Onchorynchus tshawystcha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), and cutthroat trout (*O. clarkii*). Fall Chinook salmon from

Salmon River are characterized as far north migrating, rearing in the ocean primarily off Alaska and British Columbia. Salmon River fall Chinook return to the estuary from August through November. They range in age from 2 to 6 years of age. The primary freshwater spawning migration takes place from October through December, with peak spawning generally in early November. Juvenile Chinook move over the summer from the area of spawning to rear in the lower mainstem and estuary (Coastal Chinook Salmon Plan 1991). Chinook smolts migrate to the ocean as sub-yearlings (Volk et al 2010).

Methods

Data Collection

The analysis for this report uses a dataset collected during the initial ERIS assessments in the Salmon River from 1986 through 2003. The data were compiled and imported into a standard database format for analysis. Upon review, survey data from 1986 and 1987 were excluded from this analysis due to inconsistent or incomplete datasets from the spawning ground surveys. An insufficient recovery of marked salmon from the final year (2003) of mark and recapture, resulted in an estimate of abundance with unacceptably large confidence intervals (C.V. > 25%), therefore, those data were also excluded from further analysis.

Spawner escapement was estimated using Petersen mark-recapture techniques. Stream reaches with distinct boundaries were established, and a spawning ground survey protocol was followed throughout this period. These survey reaches were described and stratified by size (mainstem and tributary) and frequency of survey (Table 1). The collection methods for the mark-recapture experiment and survey protocol are described in Boechler and Jacobs (1987).

Table 1: Description of spawning ground surveys and survey frequency conducted in the Salmon River basin from 1986 through 2002. Table adapted from Boechler and Jacobs (1987). W=Weekly, S=Spot Check, WI=Weekly Selected as Index.

Strata	Survey Reach	Reach Length (Miles)	Survey Length (Miles)	Frequency
Mainstem				
	Tidewater	0.4	0.4	S
	Hatchery Area	1.4	0.5	W
	Hatchery to Panther Cr	1.5	1.5	W
	Panther Cr to Slick Rock Cr	2.6	2.4	S
	Slick Rock Cr to Widow Cr	1.5	1.5	S
	Widow Cr to Deer Cr 2	2.2	2.2	W
	Deer Cr 2 to Prairie Cr	2.6	1.1	W
	Prairie Cr to Little Salmon R	2.6	2.6	WI
	Little Salmon R to Trib. G	2.0	0.6	S
	Trib G. to Trib H.	2.0	1.4	S
Total Mainstem			22.1	
Tributaries	Salmon Creek (Upper)	2.7	.85	W
	Salmon Creek (Lower)	2.7	0.6	S
	Deer Creek 1	3.8	2.3	W
	Bear Creek (Lower)	2.0	2.0	WI
	Bear Creek (Middle)	1.4	1.4	W
	Bear Creek (Upper)	1.1	1.9	W
	Slick Rock Creek	8.8	2.1	S
	Trout Creek	8.9	1.9	S
Total Tributaries			16.7	

Index of Abundance

The peak count of a survey reach was defined as the maximum sum of live and dead adult Chinook (>600 mm) recorded on any given day throughout the survey period. The peak counts were divided by the survey length to normalize the values (# of fish/mile). The index of abundance (I) was defined as the average sum of the peak count/mile values for the index surveys, and can be determined from the following equation.

$$I = \overline{\sum}\left(\sum_{n=1}^{n} p_i / m_i\right)$$

Where

n = the number of survey reaches used in the index calculation;
p= maximum sum of live and dead Chinook in survey reach *i*
m= miles surveyed in survey reach *i*

Two spawning ground surveys; Lower Bear Creek and Prairie Creek to Little Salmon River were identified as the index surveys that best represent Chinook spawner abundance within the Salmon River basin (Table 2). These two survey reaches were selected because they have established start and end boundaries, they were conducted on a consistent basis, and they supported some degree of spawner density (non-zero) throughout the mark-recapture study period. They are thought to represent both tributary and mainstem spawning habitat that likely represent the spawning habitat of the Salmon River under various flow and run strength regimes. We also assumed that established protocols were followed throughout the period (Williams et al 1990).

Table 2: Physical description of the standard index spawning ground surveys in Salmon River, Oregon.

Reach ID	Segment	Length (miles)	Description
25296.00	1.0	2.0	Survey from the mouth of Bear Creek upstream 2.0 miles to a point 0.5 mile above Bear Creek Road bridge. From Rose Lodge drive west on Hwy 18 approx. 1 mile to Bear Creek. Park and enter at mouth. Survey from mouth (no start sign by request of landowner) upstream to end point (sign on alder at right.) Exit right to road at large pullout.
25315.00	1.1	2.6	Survey Salmon River from the confluence of Prairie Creek upstream 2.6 miles to the confluence with Little Salmon River.

Spawner Escapement

The Chapman version of the Lincoln-Peterson mark-recapture formula was used to estimate fall Chinook escapement onto the spawning grounds. Estimates were derived using the following equation (Williams et al. 2002):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1$$

Where

$\hat{N}$ = the estimated spawner escapement of fall Chinook on to the spawning grounds;
M = the number of fall Chinook tagged at the trap site;
C = the number of fall Chinook recovered on the spawning grounds; and
R = the number of recovered tagged fall Chinook.

Schwarz and Taylor (1998) describe the assumptions for use of the Peterson estimator as:

1. Either or both capture events are simple random samples, (i.e. all fish have an equal probability of being marked at the trap site; or, all fish have an equal probability of being inspected for marks; or, marked fish mix completely with non-marked fish in the population between events; and,
2. There is no recruitment to the population between capture events; and,
3. There is not trap induced behavior; and,
4. Fish do not lose their marks and all marks are recognizable

The variance for $\hat{N}$ was estimated from the following equation (Williams et al. 2002):

$$Var(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}$$

Regression Analysis

A series of regressions were performed to evaluate the relationships between the Petersen estimate of spawner escapement and the visual peak count from the index surveys using the statistical program S-Plus. Initially, we applied an ordinary least squares regression (OLS) to the dataset. However, in the case of the Salmon River, the variances of the response variable (i.e., mark-recapture estimates) were unequal across years. Therefore, we decided to try a method more appropriate in circumstances where it is known *a priori* that not all observations contribute equally to the fit. This is the method of weighted least squares (WLS) regression as described by Ramsey and Schafer (1997). The estimated WLS regression coefficients minimize the weighted sum of squared residuals depicted by the following equation:

$$\sum_{i=1}^{n} w_i (\hat{N}_i - \hat{\hat{N}}_i)^2$$

where $\hat{N}_i$ =Petersen abundance estimate for year *i*, $\hat{\hat{N}}_i$ =predicted abundance based on regression model (see Results), and w_i = 1/Var($\hat{N}_i$).

Finally, a polynomial term was added to the WLS regression in an attempt to further improve the fit of the regression model to the dataset and consequently the predictive ability of the regression model.

The 95% confidence intervals for the WLS (with polynomial) escapement estimates were adjusted for compound uncertainty and determined using Scheffe's F-multiplier (Ramsey and Schafer 1997):

$$CI = N \pm \sqrt{(3 \times F_{3,12})} \times SE$$

Where:

CI= the 95 % confidence intervals of the index derived prediction of spawner escapement
N= spawner escapement point estimate
F=Scheffe's F-multiplier with degrees of freedom
SE=standard error of the predicted spawner escapement point estimate

Using the resulting regression models developed above, we selected the best fit model based on R-squared and developed a table of estimated population sizes with confidence intervals.

Results

Mark-recapture estimates and peak count spawning indices

Although mark-recapture studies in the Salmon River were conducted from 1986-2003; data quality issues with the index surveys in 1986 and 1987 and with the abundance estimates in 2003 disqualified these years from the calibration analysis. Spawner escapement as derived by Lincoln-Peterson methods ranged from 956 to 5,202 adults during the study period (Table 3). Although there is a wide range in year to year variance estimates, the abundance estimates are relatively precise for the assessment period (i.e. CV's are all under 24%). Survey peak count indices ranged from a minimum of 14 to a maximum of 117 adults.

Table 3: Average peak count per mile of two index surveys, results from mark-recapture study, and derived estimates of Chinook escapement for Salmon River, 1988-2002. M = number of adult salmon marked, C = total number of adults captured in second capture event, and R = number of marked adults captured in second (recapture) event.

Year	Peak Count Survey Index	Lincoln-Peterson (L-P) inputs			L-P Population Estimates		
		M	C	R	*N*	*var(N)*	% CV
1988	117	1093	1906	400	5201.6	33683.1	3.5
1989	35	613	782	241	1985.6	6798.8	4.1
1990	20	72	257	12	1447.8	117016.0	23.6
1991	29	643	263	102	1649.6	13421.6	7.0
1992	14	177	334	26	2207.5	135864.8	16.6
1993	17	381	277	110	955.7	3482.8	6.1
1994	55	686	641	151	2900.7	32708.7	6.2
1995	55	237	578	41	3280.0	191213.6	13.3
1996	96	629	947	111	5331.5	182461.2	8.0
1997	55	130	709	24	3719.4	415597.3	17.3
1998	22	259	352	28	3163.8	272262.5	16.4
1999	31	397	227	48	1850.9	47220.9	11.7
2000	40	367	629	86	2663.8	53109.6	8.6
2001	55	530	636	107	3130.9	59532.8	7.7
2002	37	399	685	89	3047.9	68780.6	8.6

Regression analyses

The ordinary least square (OLS) regression analysis indicated a positive linear relationship between the peak count indices and the mark-recapture abundance estimates, (R^2 =0.783, p<0.0001, Appendix A). Although this relationship may be strong, it is not considered appropriate for predictive modeling due to the violation of the assumption for constant variance between independent variables. The mark-recapture escapement estimates have variances that differ between years, thus a weighted least square regression was also performed using the statistical program S-Plus.

The weighted least square regression analysis also produced a strong positive relationship with better fit than the OLS regression (R^2=0.9085, p<0.0001, Appendix B).

In a weighted least square regression model, points with greater precision (lower variance) receive greater weight. For example, in our mark-recapture dataset, years such as 1997 and 1998 would have substantially less influence over the fitting of the regression line than years such as 1989 and 1993. To illustrate the impact of not taking the weights into account, two graphs are depicted below comparing the non-weighted (OLS) and weighted (WLS) regressions (Figure 2). The intent when using weighted least squares regression is to ensure that each data point has an appropriate level of influence on the final parameter estimates given the level of certainty around each point.

Comparing the fit of the line on the lower left of each graph you can see that the OLS regression (2A) tries to fit the line between all of the points equally whereas the WLS regression (2B) tries to fit the line between the more precisely estimated points. More importantly, the confidence and prediction bands show the gains in precision (lower variance) achieved by the WLS regression.

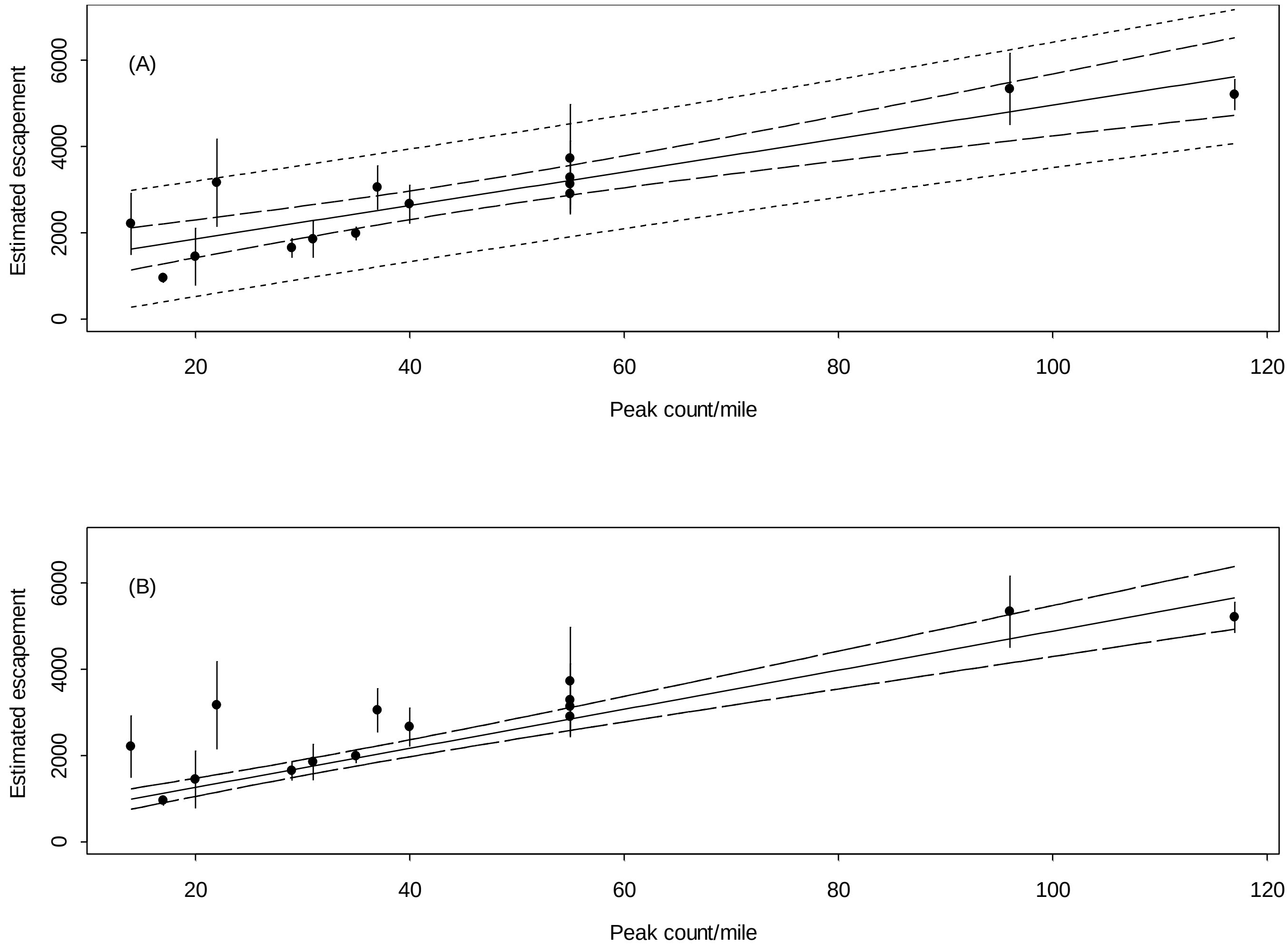

Figure 2: Results from an ordinary least squares (OLS) regression (A) and a weighted least squares (WLS) regression (B) of estimated escapement on peak counts per mile performed in S-Plus. Vertical lines on scatter plot depict 95% confidence intervals (estimate +/- 1.96 SE). The long-dashed lines indicate the 95% confidence band for the estimated means; the short-dashed lines indicate the 95% confidence band for individual predicted values (the two lines appear to overlap in the WLS regression (B) because the residual mean squared error is so small).

Lastly, the addition of the polynomial terms resulted in a slight increase in R-squared (WLS R^2=0.915 and polynomial R^2=0.938). Therefore, we considered the polynomial WLS model to be the most robust model from which to make predictions (Figure 3 Appendix C).

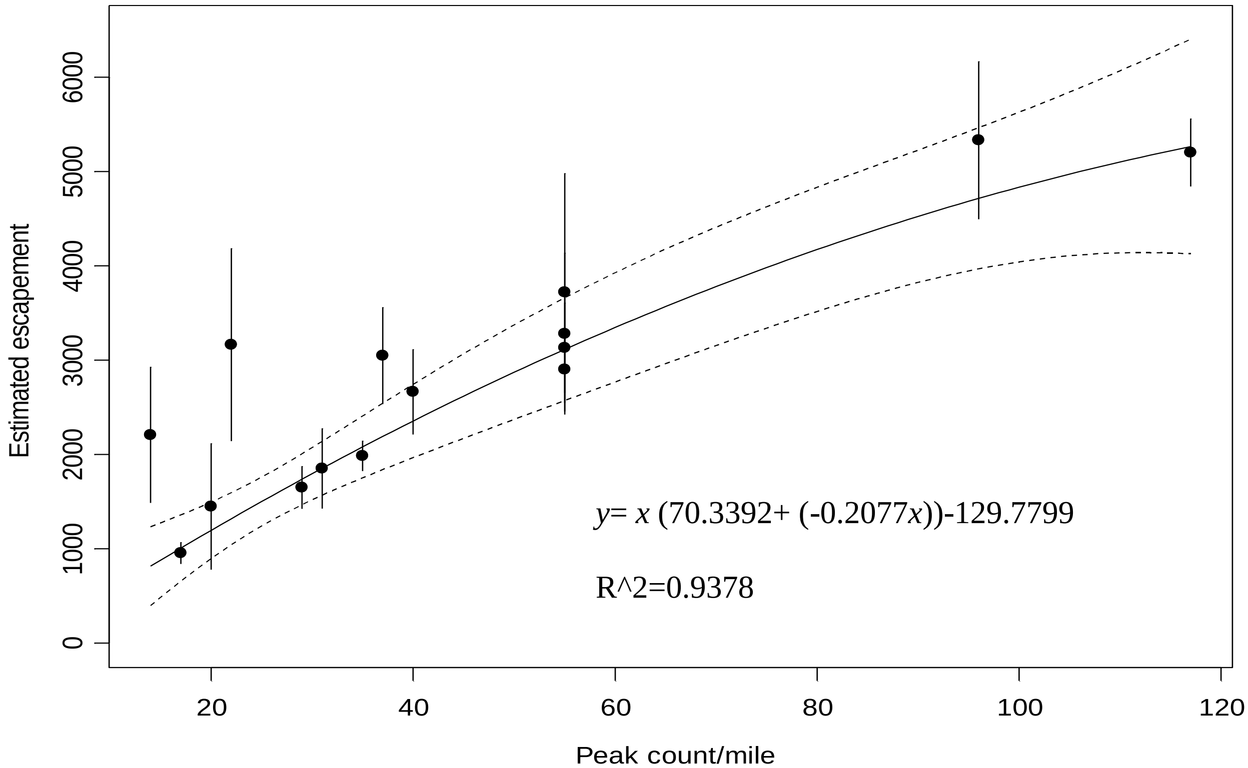

Figure 3: Graphical results from a polynomial weighted least squares regression performed in S-Plus of estimated escapement on peak counts per mile. Vertical lines on scatter plot depict 95% confidence intervals (estimate +/- 1.96 SE). The dashed lines indicate the 95% confidence band for individual predicted values (adjusted for compound uncertainty).

Modeled predictive estimates

The final step in our analysis was to derive escapement estimates and associated measures of uncertainty from all peak count index values within the range of the observed data. Predictions for escapement were calculated for all potential index values between the observed counts of 14 to 117. The estimated standard errors, CVs, and lower and upper 95% confidence intervals adjusted for compound uncertainty (Scheffe's F-multiplier: estimate $\pm$ sqrt(3*$F_{3,12}$)*SE) were also derived for each of these index intervals (Table 5).

A comparison of Salmon River mark-recapture abundance estimates and WLS regression estimates suggests a relatively robust predictive model, as the confidence intervals of each estimate overlap in 13 of the 15 years studied (Figure 5). Only in the years 1992 and 1998 do the 95% confidence intervals of the predictive values fall outside those of the mark-recapture estimates. The reasons for these discrepancies are unclear but may be explained by bias associated with low recovery rates of marked fish and/or by inclement weather and flow conditions that may have prevented survey personnel from attaining a true peak count.

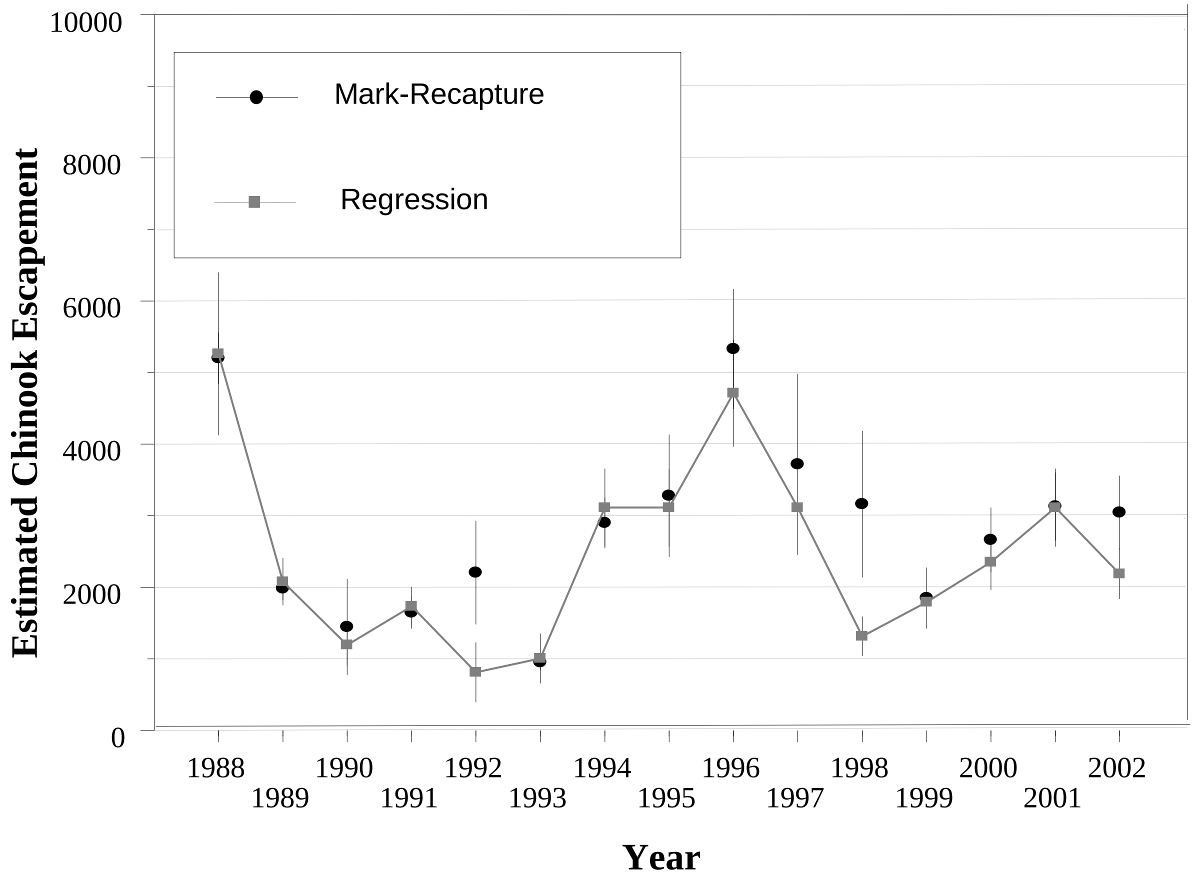

Figure 4: Comparison of Lincoln-Peterson escapement estimates (95% confidence intervals based on asymptotic normality) with predictions from polynomial weighted least squares regression model (95% confidence intervals adjusted for compound uncertainty using the Scheffe's F multiplier).

Peak	Escapement	SE	CV	LB95	UB95	Peak	Escapement	SE	CV	LB95	UB95
14	815.1	129.1	15.8	397.2	1233.0	66	3611.8	188.9	5.2	3000.4	4223.2
15	879.5	121.7	13.8	485.6	1273.3	67	3654.6	190.3	5.2	3038.9	4270.3
16	943.4	114.7	12.2	572.1	1314.7	68	3696.9	191.5	5.2	3077.2	4316.7
17	1007.0	108.3	10.8	656.6	1357.4	69	3738.9	192.7	5.2	3115.3	4362.4
18	1070.1	102.4	9.6	738.8	1401.4	70	3780.4	193.8	5.1	3153.2	4407.6
19	1132.8	97.1	8.6	818.7	1446.9	71	3821.5	194.9	5.1	3190.8	4452.2
20	1195.1	92.4	7.7	896.1	1494.1	72	3862.2	195.9	5.1	3228.2	4496.2
21	1257.0	88.4	7.0	970.8	1543.2	73	3902.5	196.9	5.0	3265.3	4539.6
22	1318.5	85.2	6.5	1042.7	1594.2	74	3942.3	197.8	5.0	3302.1	4582.6
23	1379.5	82.7	6.0	1111.8	1647.3	75	3981.8	198.8	5.0	3338.6	4625.0
24	1440.2	81.0	5.6	1177.8	1702.5	76	4020.8	199.7	5.0	3374.7	4667.0
25	1500.4	80.1	5.3	1241.0	1759.8	77	4059.5	200.6	4.9	3410.3	4708.6
26	1560.2	80.0	5.1	1301.3	1819.1	78	4097.7	201.5	4.9	3445.6	4749.7
27	1619.6	80.5	5.0	1359.0	1880.2	79	4135.4	202.4	4.9	3480.4	4790.5
28	1678.6	81.7	4.9	1414.1	1943.0	80	4172.8	203.4	4.9	3514.7	4830.9
29	1737.1	83.4	4.8	1467.0	2007.2	81	4209.8	204.3	4.9	3548.5	4871.1
30	1795.3	85.7	4.8	1517.9	2072.6	82	4246.3	205.4	4.8	3581.7	4910.9
31	1853.0	88.3	4.8	1567.1	2138.8	83	4282.4	206.5	4.8	3614.3	4950.5
32	1910.3	91.3	4.8	1614.8	2205.8	84	4318.2	207.6	4.8	3646.3	4990.0
33	1967.2	94.5	4.8	1661.3	2273.1	85	4353.5	208.8	4.8	3677.6	5029.3
34	2023.7	98.0	4.8	1706.6	2340.8	86	4388.3	210.2	4.8	3708.3	5068.4
35	2079.7	101.6	4.9	1751.0	2408.5	87	4422.8	211.6	4.8	3738.1	5107.5
36	2135.4	105.3	4.9	1794.7	2476.1	88	4456.8	213.1	4.8	3767.2	5146.5
37	2190.6	109.0	5.0	1837.7	2543.5	89	4490.5	214.8	4.8	3795.4	5185.6
38	2245.5	112.9	5.0	1880.2	2610.7	90	4523.7	216.6	4.8	3822.7	5224.7
39	2299.9	116.7	5.1	1922.3	2677.5	91	4556.5	218.6	4.8	3849.2	5263.8
40	2353.9	120.5	5.1	1963.9	2743.8	92	4588.9	220.7	4.8	3874.7	5303.1
41	2407.4	124.3	5.2	2005.3	2809.6	93	4620.9	223.0	4.8	3899.2	5342.6
42	2460.6	128.0	5.2	2046.4	2874.8	94	4652.4	225.5	4.8	3922.7	5382.2
43	2513.3	131.7	5.2	2087.3	2939.4	95	4683.6	228.2	4.9	3945.1	5422.1
44	2565.7	135.3	5.3	2128.0	3003.4	96	4714.3	231.1	4.9	3966.4	5462.2
45	2617.6	138.8	5.3	2168.5	3066.7	97	4744.6	234.2	4.9	3986.6	5502.6
46	2669.1	142.2	5.3	2208.9	3129.3	98	4774.5	237.6	5.0	4005.7	5543.4
47	2720.2	145.5	5.4	2249.2	3191.1	99	4804.0	241.2	5.0	4023.5	5584.4
48	2770.8	148.8	5.4	2289.4	3252.3	100	4833.0	245.0	5.1	4040.2	5625.9
49	2821.1	151.9	5.4	2329.5	3312.7	101	4861.7	249.1	5.1	4055.6	5667.8
50	2870.9	154.9	5.4	2369.5	3372.3	102	4889.9	253.5	5.2	4069.8	5710.1
51	2920.3	157.9	5.4	2409.5	3431.2	103	4917.7	258.1	5.2	4082.7	5752.8
52	2969.3	160.7	5.4	2449.4	3489.3	104	4945.2	262.9	5.3	4094.3	5796.0
53	3017.9	163.4	5.4	2489.2	3546.6	105	4972.1	268.1	5.4	4104.6	5839.7
54	3066.1	166.0	5.4	2529.0	3603.2	106	4998.7	273.5	5.5	4113.6	5883.8
55	3113.9	168.5	5.4	2568.7	3659.0	107	5024.9	279.2	5.6	4121.3	5928.4
56	3161.2	170.8	5.4	2608.4	3714.0	108	5050.6	285.2	5.6	4127.6	5973.6
57	3208.1	173.1	5.4	2648.0	3768.3	109	5075.9	291.5	5.7	4132.7	6019.2
58	3254.6	175.2	5.4	2687.5	3821.8	110	5100.8	298.1	5.8	4136.3	6065.3
59	3300.7	177.3	5.4	2727.0	3874.5	111	5125.3	304.9	5.9	4138.7	6112.0
60	3346.4	179.2	5.4	2766.4	3926.5	112	5149.4	312.0	6.1	4139.7	6159.2
61	3391.7	181.1	5.3	2805.6	3977.7	113	5173.1	319.5	6.2	4139.4	6206.8
62	3436.5	182.8	5.3	2844.8	4028.2	114	5196.3	327.2	6.3	4137.7	6255.0
63	3481.0	184.5	5.3	2883.9	4078.0	115	5219.2	335.1	6.4	4134.7	6303.7
64	3525.0	186.1	5.3	2922.9	4127.1	116	5241.6	343.4	6.6	4130.4	6352.8
65	3568.6	187.5	5.3	2961.7	4175.5	117	5263.6	352.0	6.7	4124.7	6402.5

Table 4: Predicted Chinook escapement for a given peak count/mile index value using a polynomial WLS regression performed in S-Plus (SE = standard error of prediction, CV=SE/Escape, LB95 = lower bound of 95% confidence interval of predicted value, UB95 = upper bound of 95% confidence interval of predicted value)

Discussion

Sampling Salmon River harvest and spawner escapement is essential to maintain a representative harvest rate indicator stock for the NOC aggregate stocks. These data are an important factor in Oregon's ability to manage coastal stocks under PST abundance based management requirements for mixed stock fisheries. Identification of cost-effective, accurate, and precise means to develop harvest and escapement estimates is critical. Our assessment of the relationship between spawner surveys and mark-recapture abundance estimates demonstrated that a spawning ground index based on live and carcasses counts can be used to estimate spawner abundance with some degree of precision. Peak counts from two survey reaches were identified as an index that best tracts spawner escapement abundance. Implementing this procedure significantly reduces personnel costs by eliminating the need to conduct mark-recapture activities.

We recommend that periodic mark-recapture studies be conducted to monitor the performance of the model and make adjustments if necessary. Escapement abundance cannot be estimated with any degree of certainty when peak counts fall outside the measured ranges, thus no extrapolations are included on the predictive table. In the event of extreme returns (high or low); the regression equation derived from the data in this report (Figure 3) can be used to calculate a point estimate, however confidence in the estimate would be low.

Currently; ODFW is using the polynomial WLS regression model described here to generate the Salmon River Chinook escapement estimates necessary for inclusion into the PSMFC's Regional Mark Processing Center (RMPC). The RMPC provides essential services to international, state, federal, and tribal fisheries organizations involved in marking and tagging anadromous salmonids throughout the Pacific region. The RMPC also serves as the site for the U.S. on-line Regional Mark Information System (RMIS) database. RMIS facilitates the exchange of U.S. CWT data with Canada that is necessary for PST management of Chinook salmon.

This technique has provided significant cost savings through the transition from a labor intensive mark-recapture approach of estimating spawner abundance to a simple visual index from spawning ground surveys while continuing to maintain data quality expectations of the USCTC necessary to manage under the PST regime. The project requires a crew of three working four months to complete the necessary field sampling. Without this minimum commitment, the Salmon River hatchery fish cannot fully function as an exploitation rate indicator stock

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Literature Cited

Boechler, J. L., and S. E. Jacobs. 1987. Catch and Escapement of Fall Chinook Salmon from Salmon River, Oregon. 1986. Oregon Department of Fish and Wildlife Progress Report, Fish Division, Portland.

Coastal Chinook Salmon Plan (CCSP). 1991. Comprehensive Plan for production and Management of Oregon's Anadromous Salmon and Trout. Oregon Department of Fish and Wildlife, 18 December 1991. 65 p.

Jacobs, S.E., and J.L. Boechler, 1988. Catch and Escapement of Fall Chinook Salmon from Salmon River, Oregon. 1987. Oregon Department of Fish and Wildlife Progress Report, Marine Recourses Program. #NA-87-ABH-00017. Portland.

Nicholas, J.W., and D.G. Hankin 1988. Chinook Salmon Populations in Oregon Coastal River Basins: Description of Life Histories and Assessment of Recent Trends in Run Strengths. Oregon Department of Fish and Wildlife Information Report #88-1. Portland.

Nuzum, D. and R. Williams. 1991. Exploitation Rate Indicator Stock Monitoring; Catch and Escapement of the North Oregon Coastal Fall Chinook from Salmon River, Oregon, 1990. Oregon Department of Fish and Wildlife, Ocean Salmon Management NA90AA-H-FM191, Annual Progress Report, Newport.

Pacific States Marine Fisheries Commission (PSMFC). RMIS database at: www.rmpc.org/index.html

Ramsey F.L and D.W. Schafer, 2002. The Statistical Sleuth; a Course in Methods of Data Analysis (2nd edition) 1999-2002. Duxbury Publishing, Pacific Grove, CA. 816 p.

Schindler, E.D., S.E. Jacobs, and M.A. Lewis. 1989. Catch and Escapement of Fall Chinook salmon from Salmon River , Oregon. 1988. Oregon Department of Fish and Wildlife, Marine resources Program Project. NA-88-ABH-00044, Annual Progress Report, Portland.

Schwarz, C.J. and C.G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Can. J. Fish. Aquat. Sci. 55:281-296.

Volk, E.C., D.L. Bottom, K.K. Jones and C.A. Simenstad. 2010. Reconstructing Juvenile Chinook Salmon Life History in the Salmon River Estuary, Oregon, Using Otolith Microchemistry and Microstructure. Transactions of the American Fisheries Society 139:535-549

Williams, B.K., J.D. Nichols, and M.J. Conroy. 2002. Analysis and Management of Animal Populations. Academic Press. 14:291-292, 817p.

Williams, R, M.A. Lewis, S.E. Jacobs and E.D. Schindler. 1990. Exploitation Rate Indicator Stock Monitoring-Freshwater Catch and Escapement of the Far North Oregon Coastal Indicator-Fall Chinook Salmon from Salmon River, Oregon, 1989.

Appendix A

Results from OLS regression from statistical package S-Plus

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1084.732	286.756	3.783	0.00228 **
Peak counts	38.740	5.395	7.180	7.15e-06 ***

Residual standard error: 584.2 on 13 degrees of freedom

Multiple R-squared: 0.7986,   Adjusted R-squared: 0.7831
F-statistic: 51.55 on 1 and 13 DF, p-value: 7.153e-06

Appendix B

Results from WLS regression from statistical package S-Plus.

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	358.093	149.246	2.399	0.0321
Peak counts	45.234	3.822	11.835	2.47e-08

Residual standard error: 2.223 on 13 degrees of freedom

Multiple R-squared: 0.9151, Adjusted R-squared: 0.9085
F-statistic: 140.1 on 1 and 13 DF, p-value: 2.468e-08

Appendix C

Results from fitting polynomial weighted least squares regression model in S-plus.

Coefficients:

	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-129.7799	268.4582	-0.4834	0.6375
Peak counts	70.3992	12.5022	5.6309	0.0001
I(peak.counts^2)	-0.2077	0.0993	-2.0920	0.0584

Residual standard error: 1.98 on 12 degrees of freedom
Multiple R-Squared: 0.9378
F-statistic: 90.41 on 2 and 12 degrees of freedom, the p-value is 5.812e-008

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