OPTIMAL INDEXING

OF LEWIS RIVER COHO JACKS

FOR OPI FORECASTING 1970-89

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Washington Department of Fisheries
Planning, Research and Harvest Management Program
Columbia River Laboratory
16118 N.E. 219th St., P.O. Box 999
Battle Ground, Washington 98604

Larrie LaVoy
Cindy LeFleur
Guy Norman
Don McIsaac

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Introduction

The Oregon Production Index Technical Team (OPITT) met on November 2, 1989 to discuss an alternative method for predicting the public hatchery component of the OPI. The proposal was to change the existing model in three ways; 1) eliminate the 1986 data point, 2) eliminate the delayed smolt term, 3) use jacks/day at Merwin Dam as a third term in the regression equation. This proposal is discussed by Lawson (1989).

OPITT agreed with the above changes, but also agreed to examine subsequent analysis by WDF of alternative methods of indexing coho production in the Lewis River and adopt a data set different then jacks/day at Merwin Dam if a better one could be found. Because coho from the Lewis River hatcheries (Lewis River and Speelyai) are significant contributors to the OPI area, proper representation of this production is needed for reliability of the OPI forecast.

A variety of consistency problems have been associated with the jack index for the Lewis River. In addition to the problems discussed by Lawson (1989), LeFleur and LaVoy (1989) and Norman (1983), both the data set used in the 1989 OPI forecast and the Merwin jacks/day data set contain an inconsistency in the proportion of total Lewis system jacks trapped at Merwin Dam before and since the first year that Lewis ladder began operation in 1982. Jacks that otherwise would have migrated to Merwin Dam have been intercepted (the term siponed will be used) by the Lewis Hatchery ladder. Consequently, Merwin Dam jacks/day since 1982 may underestimate production in the system relative to historical years.

Other factors also raise concerns about the use of Merwin Dam jacks as a Lewis River production index. Since 1985, Lewis River Hatchery has released all the coho in the system; Speelyai rears coho to fingerling size which are then transferred to Lewis Hatchery for final rearing and release. Homing to the Merwin Dam trap may be reduced over historical levels because of different release strategy and the presence of Lewis ladder. Another factor includes the operation of Merwin Dam trap and complications associated with steelhead. In 1985 and again in 1989, the hatchery manager closed the trap after operating the trap for a limited number of days because of the problem of handling large numbers of steelhead. In these years, the trap was not operated during virtually all of the arrival period of the late stock which comprises most of the production. Reduced or curtailed operation of Merwin Dam trap is expected in the future after a new steelhead hatchery is built adjacent to Merwin Dam.

A thorough analysis was conducted involving both statistical and qualitative scrutiny of Lewis system coho accounting. The result was a data set of Lewis River Hatchery ladder "counts" 1970-88, including 1970-81 when no ladder existed. Two time series variations resulted from this data set. The first was a Lewis

ladder index for all years 1970-88. The second variation contained Lewis ladder values only for the years after expansion of the Lewis River Hatchery (1980-on).

Three types of regression models each using three different sets of data were compared. The first regression in each model used traditional or proposed Lewis system indexing. The second and third regression in each model substituted the two time series variations of ladder jacks for the original Lewis system jack factor. The three different types of OPI models included: 1) adopted OPI model in 1989 which used the traditional Merwin and Lewis data set, 2) Lawson model which used Merwin jacks/day, and 3) two variable partitioned model that used the traditional Merwin and Lewis data set.

This report was prepared for the OPITT meeting on February 6-7, 1990. As part of the meeting accomplishments, OPITT will select the optimum Lewis system jack index to be used in the 1990 forecast.

Methods

For the years prior to the operation of Lewis ladder (pre-1982), a projected ladder jack escapement was calculated using: 1) historical Merwin Dam counts corrected for siphoning, 2) the numbers of coho released from Speelyai and Lewis hatcheries, and 3) the actual jacks collected at both Merwin Dam and Lewis ladder during 1982-84.

The years 1982-1984 were the only ones when coho were released from both Speelyai and Lewis hatcheries and when coho were trapped at Merwin Dam trap and Lewis ladder. Since 1985 all the coho in the system have been released from Lewis River Hatchery which is assumed to substantially influence the relative collection rates at Merwin Dam and Lewis ladder. Therefore, 1982-84 were the only years possible to represent the siphoning effect on Merwin Dam escapement from Lewis ladder. This siphoning factor (0.23) was derived from the relationship between the ratio of average Merwin jack returns to Lewis ladder jack returns (82-84) and the average Speelyai releases to Lewis Hatchery releases (82-84) (Equation a).

This method assumes Lewis releases are destined for Lewis ladder and Speelyai releases are destined for Merwin trap. The results show that the 1982-84 average return of Merwin jacks was 23 percent less than the number of jacks that would have resulted in a Merwin:Lewis ladder jack ratio that equaled the Speelyai:Lewis hatchery smolt release ratio. This siphoning factor (0.23) was applied to the historical Merwin Dam jack escapement to yield an estimate for the jack escapement at Merwin Dam if Lewis ladder was operating. The slightly downgraded historical Merwin jack counts were adjusted by the ratio of total releases in each year to the average during 1982-84, to account for the proportional variability in releases from each facility (Equation b).

Equation a)

$$s = 1 - \frac{(y_1 / b_1)}{(y_2 / b_2)} \times 100$$

where: s = Percent of Merwin jacks siphoned to Lewis ladder
y_1 = Merwin jack returns (1982-84 average)
y_2 = Speelyai smolt releases (1982-84 average)
b_1 = Lewis ladder jack returns (1982-84 average)
b_2 = Lewis hatchery smolt release (1982-84 average)

Equation b)

Lewis ladder jacks (year x) $= a/b \ (c \times d)(1-s)$

where: a = Total releases from Lewis system (year x)
b = Total releases from Lewis system (1982-84 avg)
c = Lewis ladder jacks (1982-84 avg)
d = Trap standard Merwin jacks (year x)
e = Trap standard Merwin jacks (1982-84 avg)

After estimates were derived for Lewis ladder (Tables 1 and 2), nine multiple linear regressions were performed and statistics compared using hindcasting and single year predictions. The models were:

Model 1a. Adopted model used for the 1989 OPI forecast
where: Y = Oregon public hatchery adults (w/o 1983)
and X1 = Columbia River jack index including traditional Merwin and Lewis ladder accounting
X2 = Oregon and California coastal jacks
X3 = Columbia River delayed smolts/total

Model 1b. Same as model 1a except Columbia River jack index includes Lewis ladder counts 1970-88.

Model 1c. Same as model 1a except Columbia River jack index includes Lewis ladder counts 1980-on.

Model 2a. Lawson proposal
where: Y = Oregon public hatchery adults (w/o 1983, 1986)
and X1 = Columbia River jacks without Lewis River
X2 = Oregon and California coastal jacks
X3 = Jacks/day in the Merwin trap

Model 2b. Same as model 2a except includes Lewis ladder counts 1970-88.

Model 2c. Same as model 2a except Columbia River jack index includes Lewis ladder counts 1980-on.

Model 3a. Partitioned jacks
where: Y = Oregon public hatchery adults (w/o 1983, 1986)
X1 = Columbia River jack index including traditional Merwin and Lewis ladder accounting
X2 = Oregon and California coastal jacks

Model 3b. Same as model 3a except Columbia River jack index includes Lewis ladder counts 1970-88.

Model 3c. Same as model 3a except Columbia River jack index includes Lewis ladder counts 1980-on.

Results

Model 1a,b,c:

Statistics for the three regressions were similar (Table 3). Fitness of the data was almost identical with a r2 range 0.92-0.93 with 13 degrees of freedom. Standard error of Y was 212.3 (Model 1b), 219.7 (Model 1a), and 224.3 (Model 1c). Correspondingly, the three models were similar when hindcasting and single year predictions were compared for 1980-89 adult forecasts (Table 4). All models had a "random" mixture of over and under prediction.

Model 2a,b,c:

Statistics for the Lawson model and the Lewis ladder variations are presented in Table 5. R2's were almost identical, ranging from 0.965 to 0.982. Standard error was the lowest for the Lawson model (2a) at 109.2 compared to 136.0 for Lewis ladder 1970-88 (2b) and 151.2 for Lewis ladder 1980-88 (2c). All models had a tendency to underpredict in the hindcasting and single year prediction analysis (Table 6).

Model 3a,b,c:

Regression statistics (Table 7) and prediction profiles (Table 8) were virtually the same for the two variable partitioned jack models. R2's were about 0.97 in all three cases. All models tended to overpredict the OPI.

Discussion

The models were judged on several criteria:

1. Statistical quality e.g. r2, standard error.
2. Prediction history or pattern.
3. Potential for future accounting problems/adjustments. (Least annual manipulations)
4. Consistency in time series accounting.
5. Common sense.

All models performed well and were almost similar to each other for criteria 1 and 2. Generally, models 2a,b,c and models 3a,b,c had superior statistical fit to models 1a,b,c but had a tendency to underpredict more often than in models 1a,b,c. The inclusion of the unexpectedly abundant year of 1986 in models 1a,b,c may partially explain these factors.

Incorporating either of the Lewis ladder jack indices into the three different model types did not significantly change the regression line from the original "a" series regressions. Models incorporating the Lewis ladder index from 1970-88 slightly outperformed the Lewis ladder index that contained jack values for the past expansion years (1980-on).

Selecting a model which contains a jack index that best represents Lewis River production is complicated. The traditional representation for Lewis River has been the combination of Merwin Dam trap and Lewis ladder adjusted to a number of standard trapping days. Previous adopted OPI models have used Merwin Dam trap jacks as part of the Lewis system index and have performed satisfactorily in the past.

The use of Merwin Dam for all or part of a Lewis system jack index will present complications resulting from irregular or curtailed operation due to the WDW steelhead hatchery. In 1989, steelhead once again forced the early shutdown of the Merwin Dam trap which will require yet another year of "Lewis River adjustments" if the adopted model is retained for 1990.

Conclusions/Recommendations

1. If the 1989 adopted model is retained (Col. R. jks; OR-CA coastal jks; and delayed smolts; w/o 1983), incorporate one of the 2 different time series of Lewis ladder jacks as representing Lewis system production.

2. If the Lawson proposal is used in 1990, incorporate the Lewis ladder data set instead of Merwin jacks per day.

3. If other models are adopted for 1990, the emphasis should be to use Lewis ladder jacks only as representing Lewis system production. The majority of the fish that enter the Lewis River are destined for Lewis River Hatchery; only a minority of the fish that enter the Lewis River are destined for Merwin Dam trap.

4. Anticipate that if Merwin Dam jacks continue to be a part of any "adopted" model, future jack values from the Lewis system will be mostly derived, because of the expected erratic operation when the WDW steelhead hatchery begins full scale production.

References

Lawson, P. 1989. Proposed revisions to the public hatchery component of the Oregon Production Index (OPI) predictor. Oregon Department of Fish and Wildlife, Newport, OR. 25 pp.

LeFleur, C. and LaVoy, L. 1989. Simplification of procedures for OPI accounting of Lewis River coho. Washington Department of Fisheries. Memorandum. 8 pp.

Norman, G. 1983. Estimate of coho jacks that would have entered the Lewis River Hatchery trap in 1980 and 1981, had the trap been in place. Washington Department of Fisheries. Memorandum. 6 pp.

Table 1. Lewis River jack coho abundance indices.

Adult Year	OPI Adults	Lewis System Index (1000's)					
		A	B	C	D	E	F
1971	2539.0		2.689	3.015	3.4	81.5	3.0
1972	1495.0		2.958	2.958	4.2	58.0	3.0
1973	1423.4		2.269	2.708	4.9	73.2	2.7
1974	2560.6		3.204	3.387	6.8	91.5	3.4
1975	1266.2		1.571	2.153	3.7	58.2	2.2
1976	2869.9		0.834	1.543	2.9	41.7	1.5
1977	704.3		0.078	0.100	0.2	2.2	0.1
1978	1529.3		1.105	1.105	1.8	21.7	1.1
1979	1095.1		0.698	0.849	1.4	18.9	0.8
1980	1005.4		0.188	0.368	0.7	8.2	0.4
1981	878.0		0.385	0.385	0.6	5.1	1.0
1982	1122.4		3.532	4.183	23.3	93.0	24.9
1983	470.1	6.217	1.830	1.830	8.2	31.0	10.0
1984	622.1	11.032	2.683	2.683	11.0	31.6	13.7
1985	619.1	1.537	0.552	0.552	1.5	9.7	2.0
1986	2281.7	13.969	2.416	2.245	14.0	42.4	16.4
1987	791.3	1.401	0.019	0.058	1.4	1.4	1.5
1988	1387.4	21.069	2.931	2.931	21.1	40.2	24.0
1989		12.633	1.471	1.471	12.6	17.7	14.1

A = Lewis ladder actual raw counts ('85 adj. for small adults).
B = Merwin Dam actual raw counts ('85 adj. for small adults).
C = Merwin Dam adjusted to standard trapping days.
D = Lewis ladder after 0.23 reduction to historical Merwin Dam.
E = Merwin Dam jacks/day.
F = Lewis system jacks used for 1989 OPI forecast (Merwin Dam 1970-79; Merwin Dam plus estimated Lewis ladder 1980-81; Merwin Dam plus Lewis ladder 1982-on).

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Table 2. Data base for OPI public hatchery adults.

		JACKS (Y-1)					SMOLTS (millions by adult contribution yr)							
		Columbia R. Index					Col. R.		Lewis River					
									Speelyai		Lewis R.		Total	
Adult Year	Adults	A	B	C	D	OR-CA Coastal	Total	Del./tot.	Early	Late	Early	Late	Early	Late
1971	2539.0	172.4	172.8	169.4	169.4	6.6	25.0	0.00	0.68	0.00	0.85	0.00	1.53	0.00
1972	1495.0	99.6	100.8	96.6	96.6	2.9	30.7	0.00	1.05	0.00	0.89	0.00	1.94	0.00
1973	1423.4	83.5	85.8	80.9	80.9	5.6	31.1	0.00	1.54	0.00	0.93	0.00	2.47	0.00
1974	2560.6	128.7	132.1	125.3	125.3	12.1	29.4	0.00	1.98	0.00	0.77	0.00	2.75	0.00
1975	1266.2	73.3	74.9	71.2	71.2	1.1	28.6	0.00	1.29	0.00	1.09	0.00	2.38	0.00
1976	2969.9	144.9	146.2	143.3	143.3	25.3	30.1	0.00	0.65	0.75	0.64	0.52	1.29	1.27
1977	704.3	46.1	46.3	46.0	46.0	7.5	28.9	0.00	0.00	1.47	1.18	0.00	1.18	1.47
1978	1529.3	98.5	99.1	97.3	97.3	4.0	33.0	0.00	0.00	1.33	1.14	0.00	1.14	1.33
1979	1095.1	64.5	65.1	63.7	63.7	8.4	32.6	0.10	0.00	1.23	1.02	0.00	1.02	1.23
1980	1005.4	51.3	51.6	50.9	50.9	6.1	28.9	0.25	0.62	0.88	1.00	0.00	1.62	0.88
1981	878.0	42.0	41.6	41.6	41.0	8.1	29.4	0.06	0.00	0.00	0.92	1.15	0.92	1.15
1982	1122.4	57.5	55.9	55.9	32.6	6.3	31.8	0.15	0.84	0.84	3.65	2.81	3.99	3.65
1983	470.1	62.8	61.0	61.0	52.8	7.2	27.7	0.17	0.88	0.00	0.50	3.47	1.38	3.47
1984	622.1	31.8	29.1	29.1	18.1	3.4	27.9	0.15	1.11	0.00	0.00	2.77	1.11	2.77
1985	819.1	18.8	18.3	18.3	16.8	7.8	30.4	0.25	1.13	0.00	0.00	3.17	1.13	3.17
1986	2281.7	67.3	64.9	64.9	50.9	12.9	28.9	0.39	0.00	0.00	0.68	4.66	0.68	4.66
1987	791.3	24.3	24.2	24.2	22.8	8.6	33.4	0.22	0.00	0.00	1.23	4.40	1.23	4.40
1988	1387.4	75.1	72.2	72.2	51.1	12.7	28.8	0.25	0.00	0.00	0.97	4.38	0.97	4.38
1989	(1374.4)	55.3	53.9	53.9	41.2	10.4	29.5	0.26	0.00	0.00	0.99	3.88	0.99	3.88
									0.00	0.00	1.06	4.33	1.06	4.33

A = Col. R. jks for 1989 forecast.
B = Col. R. with Lewis ladder 1970-1988 (after 0.23 downgrade to historical Merwin Dam jacks).
C = Col. R. with Lewis ladder 1980-88 (1980,81 estimated; others actual counts).
D = w/o Lewis system jacks all years.

Table 3. Summary of regression statistics for the 1989 adopted OPI model and two variations using Lewis River ladder jacks.

Model 1a. Adopted model for 1989 forecast with traditional Lewis accouting; Col. R. jks (X1), OR-CA jks (X2), Del/total smolts (X3); w/o 1983.

Regression Output:

Constant		-196.253	
Std Err of Y Est		219.7	
R Squared		0.927	
No. of Observations		17	
Degrees of Freedom		13	
X Coefficient(s)	15.96	34.14	1340.82
Std Err of Coef.	1.77	11.57	571.06

Model 1b. Adopted model except Lewis ladder all years and no Merwin Dam; Col. R. w/Lewis (X1), OR-CA jks (X2), Delayed/Total smolts (X3); w/o 1983.

Regression Output:

Constant		-211.213	
Std Err of Y Est		212.3	
R Squared		0.932	
No. of Observations		17	
Degrees of Freedom		13	
X Coefficient(s)	15.97	33.65	1501.89
Std Err of Coef.	1.71	11.19	561.77

Model 1c. Adopted model except Lewis ladder 1980-on; Col. R. w/Lewis (X1), OR-CA jks (X2), Delayed/Total smolts (X3); w/o 1983.

Regression Output:

Constant		-180.719	
Std Err of Y Est		224.3	
R Squared		0.924	
No. of Observations		17	
Degrees of Freedom		13	
X Coefficient(s)	16.31	33.12	1382.84
Std Err of Coef.	1.86	11.86	586.92

Table 4. Comparison of the 1989 adopted OPI model with two variations of Lewis River jack accounting.

HINDCASTING:

Adult Year	Adults	Model 1a Pred.	Model 1a Resid.	Model 1a Error	Model 1b Pred.	Model 1b Resid.	Model 1b Error	Model 1c Pred.	Model 1c Resid.	Model 1c Error
1980	1005.4	832.9	372.5	37.0%	651.4	354.0	35.2%	623.1	382.3	38.0%
1981	878.0	864.0	14.0	1.6%	838.3	39.7	4.5%	870.3	7.7	0.9%
1982	1122.4	1044.9	77.5	6.9%	998.0	124.4	11.1%	1032.0	90.4	8.1%
1984	622.1	737.0	-114.9	18.5%	545.3	76.8	12.3%	552.2	69.9	11.2%
1985	619.1	579.0	40.1	6.5%	597.8	21.3	3.4%	581.9	37.2	6.0%
1986	2281.7	1529.4	752.3	33.0%	1520.5	761.2	33.4%	1503.7	778.0	34.1%
1987	791.3	831.2	-39.9	5.0%	847.2	-55.9	7.1%	845.5	-54.2	6.8%
1988	1387.4	1856.8	-469.4	33.8%	1822.5	-435.1	31.4%	1833.0	-445.6	32.1%
1989	1374.4	1390.2	-15.8	1.1%	1388.5	-14.1	1.0%	1390.7	-16.3	1.2%
SS Resids			947901.8			920780.4			967701.3	
Mean Error			324.5			319.9			327.9	
Mean % Error			15.9%			15.5%			15.4%	

SINGLE YEAR PREDICTIONS:

Adult Year	Adults	Model 1a Pred.	Model 1a Resid.	Model 1a Error	Model 1b Pred.	Model 1b Resid.	Model 1b Error	Model 1c Pred.	Model 1c Resid.	Model 1c Error
1980	1005.4	1166.1	-160.7	16.0%	1193.7	-188.3	18.7%	1187.1	-181.7	18.1%
1981	878.0	831.2	46.8	5.3%	815.9	62.1	7.1%	839.0	39.0	4.4%
1982	1122.4	1137.9	-15.5	1.4%	1118.9	3.5	0.3%	1137.0	-14.6	1.3%
1984	622.1	628.6	-6.5	1.0%	593.3	28.8	4.6%	603.9	18.2	2.9%
1985	619.1	705.3	-86.2	13.9%	719.0	-99.9	16.1%	711.8	-92.7	15.0%
1986	2281.7	1841.4	440.3	19.3%	1845.1	436.6	19.1%	1834.3	447.4	19.6%
1987	791.3	780.2	11.1	1.4%	795.1	-3.8	0.5%	793.0	-1.7	0.2%
1988	1387.4	1771.4	-384.0	27.7%	1744.8	-357.4	25.8%	1753.1	-365.7	26.4%
1989	1374.4	1390.2	-15.8	1.1%	1388.5	-14.1	1.0%	1390.7	-16.3	1.2%
SS Resids			377419.8			368614.8			377879.7	
Mean Error			204.8			202.4			204.9	
Mean % Error			9.7%			10.4%			9.9%	
R sqrd (adj)			0.927			0.932			0.924	

Three Variable Regressions:

Model 1a. Adopted method for 1989 forecast; Col. R. jks w/Merwin and Lewis ladder, OR-CA jks, Delayed/Total Col. R. smolts; w/o 1983.

Model 1b. Same as 1a except Lewis R. production based on ladder counts for all years.

Model 1c. Same as 1a except Lewis R. production based on ladder counts 1980-on

Table 5. Summary of regression statistics for the Lawson model (November, 1989) and two variations using Lewis River ladder jacks.

Model 2a. Lawson model November, 1989: Col. R. w/o Lewis (X1), OR-CA jk (X2), Merwin Dam jacks/day; w/o 1983,86.

Regression Output:

Constant		50.950	
Std Err of Y Est		109.2	
R Squared		0.982	
No. of Observations		16	
Degrees of Freedom		12	
X Coefficient(s)	10.97	44.50	5.04
Std Err of Coef.	0.81	5.59	1.07

Model 2b. Lewis ladder all years for Merwin jks/day: Col. R. w/o Lewis (X1), OR-CA coastal jk (X2), Lewis ladder all years (X3); w/o 1983,86.

Regression Output:

Constant		36.086	
Std Err of Y Est		136.0	
R Squared		0.972	
No. of Observations		16	
Degrees of Freedom		12	
X Coefficient(s)	13.78	35.20	16.28
Std Err of Coef.	0.84	6.76	5.11

Model 2c. Lewis ladder 1980-88 for Merwin jks/day: Col. R. w/o Lewis (X1), OR-CA coastal jk (X2), Lewis ladder 1980-88 (X3); w/o 1983,86.

Regression Output:

Constant		52.595	
Std Err of Y Est		151.2	
R Squared		0.965	
No. of Observations		16	
Degrees of Freedom		12	
X Coefficient(s)	14.21	34.39	13.55
Std Err of Coef.	1.00	7.61	5.56

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Table 6. Comparison of the Lawson model (November, 1989) with two variations of Lewis River jack accounting.

HINDCASTING:

Adult Year	Adults	Model 2a Pred.	Model 2a Resid.	Model 2a Error	Model 2b Pred.	Model 2b Resid.	Model 2b Error	Model 2c Pred.	Model 2c Resid.	Model 2c Error
1980	1005.4	833.5	171.9	17.1%	807.1	198.3	19.7%	NA	NA	NA
1981	878.0	835.6	42.4	4.8%	808.1	69.9	8.0%	NA	NA	NA
1982	1122.4	1128.4	-6.0	0.5%	2320.0	-1197.6	106.7%	1219.8	-97.4	8.7%
1984	622.1	516.0	106.1	17.1%	583.7	38.4	6.2%	571.0	51.1	8.2%
1985	619.1	603.1	16.0	2.6%	508.6	110.5	17.8%	530.2	88.9	14.4%
1987	791.3	665.4	125.9	15.9%	649.5	141.8	17.9%	668.1	123.2	15.6%
1988	1387.4	1377.4	10.0	0.7%	1639.9	-252.5	18.2%	1593.9	-206.5	14.9%
1989	1374.4	1054.7	319.7	23.3%	1175.1	199.3	14.5%	1166.4	208.0	15.1%
SS Resids			161055.5			1615723.4			121085.7	
Mean Error			133.8			423.7			116.0	
Mean % Error			10.2%			26.1%			9.6%	

SINGLE YEAR PREDICTIONS:

Adult Year	Adults	Pred.	Resid.	Error	Pred.	Resid.	Error	Pred.	Resid.	Error
1980	1005.4	921.7	83.7	8.3%	963.6	41.8	4.2%	985.0	20.4	2.0%
1981	878.0	886.8	-8.8	1.0%	896.0	-18.0	2.1%	922.0	-44.0	5.0%
1982	1122.4	1157.5	-35.1	3.1%	1086.5	35.9	3.2%	1048.3	74.1	6.6%
1984	622.1	559.9	62.2	10.0%	584.3	37.8	6.1%	575.8	46.3	7.4%
1985	619.1	631.0	-11.9	1.9%	566.6	52.5	8.5%	579.9	39.2	6.3%
1987	791.3	690.4	100.9	12.7%	675.8	115.5	14.6%	691.4	99.9	12.6%
1988	1387.4	1379.1	8.3	0.6%	1530.9	-143.5	10.3%	1501.5	-114.1	8.2%
1989	1374.4	1054.7	319.7	23.3%	1175.1	199.3	14.5%	1166.4	208.0	15.1%
SS Resids			124778.6			81198.1			77786.1	
Mean Error			117.7			95.0			93.0	
Mean % Error			7.6%			7.9%			7.9%	
R sqrd (adj)			0.982			0.972			0.965	

Three Variable Regressions:

Model 2a. Lawson model proposed November, 1989; Col. R. jks w/o Lewis, OR-CA jks, Merwin Dam jacks/day; w/o 1983,86.
Model 2b. Same as 2a except Lewis R. production based on ladder counts for all years.
Model 2c. Same as 2a except Lewis R. production based on ladder counts 1980-on

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Table 8. Comparison of two variable partitioned models using traditional jack accounting and two Lewis ladder jack count variations.

HINDCASTING:

Adult		Model 3a			Model 3b			Model 3c		
Year	Adults	Pred.	Resid.	Error	Pred.	Resid.	Error	Pred.	Resid.	Error
1980	1005.4	912.6	92.8	9.2%	896.2	109.2	10.9%	924.4	81.0	8.1%
1981	878.0	869.0	9.0	1.0%	845.7	32.3	3.7%	873.1	4.9	0.6%
1982	1122.4	1034.3	88.1	7.8%	998.8	123.6	11.0%	1025.9	96.5	8.6%
1984	622.1	571.2	50.9	8.2%	529.7	92.4	14.9%	543.2	78.9	12.7%
1985	619.1	550.4	68.7	11.1%	552.1	67.0	10.8%	553.5	65.6	10.6%
1987	791.3	674.1	117.2	14.8%	679.4	111.9	14.1%	682.5	108.8	13.7%
1988	1387.4	1554.2	-166.8	12.0%	1508.1	-120.7	8.7%	1529.7	-142.3	10.3%
1989	1374.4	1176.5	197.9	14.4%	1159.8	214.6	15.6%	1173.2	201.2	14.6%
SS Resids			104487.4			114414.9			98994.0	
Mean Error			107.7			112.8			104.9	
Mean % Error			9.8%			11.2%			9.9%	

SINGLE YEAR PREDICTIONS:

Adult										
Year	Adults	Pred.	Resid.	Error	Pred.	Resid.	Error	Pred.	Resid.	Error
1980	1005.4	969.7	35.7	3.6%	975.9	29.5	2.9%	982.9	22.5	2.2%
1981	878.0	909.6	-31.6	3.6%	909.4	-31.4	3.6%	919.2	-41.2	4.7%
1982	1122.4	1063.5	58.9	5.2%	1041.6	80.8	7.2%	1060.3	62.1	5.5%
1984	622.1	602.0	20.1	3.2%	570.8	51.3	8.2%	579.8	42.3	6.8%
1985	619.1	574.4	44.7	7.2%	578.0	41.1	6.6%	576.7	42.4	6.8%
1987	791.3	679.4	111.9	14.1%	687.5	103.8	13.1%	688.2	103.1	13.0%
1988	1387.4	1534.3	-146.9	10.6%	1493.0	-105.6	7.6%	1512.5	-125.1	9.0%
1989	1374.4	1176.5	197.9	14.4%	1159.8	214.6	15.6%	1173.2	201.2	14.6%
SS Resids			81410.0			80684.7			76408.2	
Mean Error			95.1			94.7			92.1	
Mean % Error			7.7%			8.1%			7.8%	
R sqrd (adj)			0.967			0.971			0.965	

Two Variable Regressions:

Model 3a. Partitioned jacks with traditional OPI jacks: Col. R. jks w/ traditional Lewis, OR-CA coastal jacks w/o 1983,86.

Model 3b. Same as 3a except Lewis R. production based on ladder counts for all years.

Model 3c. Same as 3a except Lewis R. production based on ladder counts 1980-on