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Update on Ocean Distribution of Coded Wire Tagged Spring/Summer Chinook

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Introduction

This essay is an update on our earlier memo of May 23, 1996. In that memo, we analyzed coded wire tag (CWT) recoveries of spring chinook released from three hatcheries located between Bonneville and McNary dams (Carson, Klickitat, and Warm Springs), and compared their ocean recovery patterns with those of two lower Snake hatcheries (Looking Glass and Sawtooth). We concluded there was a distinct, statistically significant pattern in the sparse ocean recoveries from the two groups: Snake River fish were more likely to be captured south of the Columbia River, while Bonneville-McNary (BONN-MCN) fish were more likely to be found north of the Columbia. This is important in the context of the PATH analysis for several reasons. In the analyses in Chapters 3, 5, and elsewhere, an important assumption underlies the strength of the conclusion that the decline of Snake River stocks is caused by their passage through the Snake River hydrosystem. This assumption is that "variations among stocks in ocean survival are not systematic differences between up-river [Snake] and mid-lower stocks, as regional stock groups," (p. 5-5).

This assumption must, we believe, be regarded as just that: an assumption that is not directly supported by data. It is very common in fisheries modeling to assume that natural mortality rates are constant (at least past the age when recruitment to the fishery begins). However, as Hilborn and Walters (1992, p. 366) note in the context of virtual population analysis [VPA]:

> An additional assumption [for VPA] is that M [natural mortality rate] is constant. It is generally hard enough to get one estimate of M; the idea of trying to measure changes in M is quite frightening. Unfortunately, there are a number of reasons to believe that M might change over time, among them changes in food availability, predators, or other environmental factors. Major efforts are being made to include these effects in VPA… The data requirements are so great that such approaches are likely to only be used in a few of the most intensively studied fisheries.

Chapter 5 cites Bradford (1995) and Ricker (1976) in (indirect) support of the ocean survival assumption. The review by Bradford (1995) could find no direct estimates of smolt-to-adult survival for natural stocks of chinook. Bradford derives an estimate of 1-2% ocean survival based on egg-to-smolt survival, estimated fecundity and estimated exploitation rates, but that estimate is neither specific to particular age classes (i.e., mortality could happen at any time between the onset of smolt migration and return to the spawning ground) nor to particular stocks. The oft-cited Ricker (1976) article has an estimate of instantaneous mortality of 0.013 per month for chinook in the last year of ocean life. However, this estimate is actually based on work done on coho. Ricker thought that he found one reasonable estimate for (hatchery) chinook of 0.035 per month, but he believed it was biased by non-catch losses and hence was "too large" (p. 1512, Table 10).

For some purposes, especially harvest management, treating unknown and variable natural ocean mortality rates as known and constant may not make much difference (e.g., Kope 1987). However, for PATH upstream-downstream comparisons, the assumption has considerable importance, since many PATH conclusions hinge on the assumption that ocean mortality rates do not vary *systematically* between the Snake and lower Columbia stocks. Suppose, for the sake of argument, that one treats ocean mortality rates as largely unknown and variable rather than as known and fixed constants. The question then becomes whether there is reason to suppose that they may differ between Snake and lower Columbia river stream-type chinook. We think there are four inter-related lines of evidence that suggest that they may be different:

1. The two stock groups are genetically distinct from one another (Williams, 1996). As he notes, ocean distributions of salmon are thought to be genetically influenced, which suggests that the fish could be distributed quite differently.
2. The genetic differences in turn are associated with at least one relevant, readily measurable difference: the Snake River stocks are more likely to return at age 5 rather than age 4, compared to lower river fish (age distributions in Beamesderfer et al. 1996). For example, 87% of John Day spawners are age 4, while 70% of Middle Fork Salmon spawners are age 5. This obviously gives ocean mortality (whatever its actual values over time and across stocks and age classes) additional time to affect Snake River fish.
3. The ocean distributions of hatchery stream-type chinook collected and reared in the two areas (Snake and Columbia) are quite possibly different, as shown in the remainder of this memo.

4. Recent ocean conditions (since the mid-70's) have been more favorable for fish migrating into the Alaskan current than for those heading into the California current (e.g., Chapter 12 of the PATH report). Combined with (1)–(3), this suggests that ocean mortality rates could differ among the two groups, if one is willing to assume that natural fish migrate in roughly the same patterns as tagged hatchery groups from similar geographic areas.

Our 1996 memo was criticized on several counts, summarized in a June 19 1996 memo by Dave Marmorek. These included the following:

> 1. Rick noted … that the bottom line is that it is not necessary to assume the same ocean mortality for each stock. What is necessary is that differences in ocean mortality among stocks are random, and not systematic differences between upstream and downstream stocks post-1970, which might confound the estimates of the dam effect (μ)….
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> 2. Table 4 of [the May 1996] memo shows that all hatcheries are significantly different from one another (models 5, 6, 7, and 8 in Table 4). The upstream/downstream grouping, therefore, also shows significant differences, as would any other random grouping. This in itself does not negate the assumptions made in Chapter 5, as each individual stock has its own error term, reflecting individual differences that are unexplained by μ or ?.
>
> 3. Rick … noted that there appeared to be significant year effects in the data, which are ignored when the data are aggregated over years. These year effects occur within individual hatcheries as well as among hatcheries. He felt that by not looking at interaction terms (e.g. year * area, year * area * hatchery), one can end up attributing to individual hatcheries effects that are actually due to interaction terms.
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> 4. The coded wire tag data looks at the distributions of adults in their final year [**note: actually at ages 3-6**] at sea. Mortality effects are much more likely to occur in the previous year (i.e. the third year of the salmon's life). Ricker (1976) estimated the ocean mortality for chinook at 0.2 in their final year at sea.
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> 5. The analysis in Chapter 5 examines changes in wild salmon; Charlie's memo looks at hatcheries. The two are not necessarily comparable.
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> 6. Finding a difference between upstream and downstream stocks does not in itself negate the MLE model. What would be a confounding influence is a systematic difference in the up/down river stock survival rates (either pre- or post- migration corridor) that coincided in time with the construction of dams. The MLE finds a systematic difference in survival, even after factoring out common year-effects (which was an original explanation for the decline in stock productivity), and the systematic difference occurs in time coincident with putting in the dams. Following Occam's razor, the dams are the simplest explanation for the estimated systematic difference in survival.
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> 7. Cormack and Skalski (1992) had examined one brood year only. The analysis completed by Charlie Paulsen and Tim Fisher lumps over many brood years, some of which are entirely non-overlapping in terms of hatchery releases.

8. Cormack and Skalski warn that where there are many zeros in the data, the data should be reanalyzed with such sets of zeros omitted and any differences of the outcomes of the two analyses regarded as a need for cautious interpretation (CJFAS 49: pp. 1818, paragraph before “Aggregation” heading). This wasn’t done in the analysis of Paulsen and Fisher.

In this memo, we provide additional analysis which addresses many of these issues. First, we confine our analyses to release years that are the same for the groups being compared. Second, we include a comparison of hatchery and wild fish CWT recoveries in ocean fisheries, for fish releases from Bonneville to McNary. Third, we include several additional hatcheries in our sample. Fourth, we perform an explicit comparison of hatchery recoveries whereby fish are grouped into Snake and BONN-MCN classes, and one where each hatchery is its own “group”. In order to address concerns on Point (8), we perform most analyses on recoveries that are grouped over all recovery ages. Finally, given the extremely sparse ocean recoveries, we bootstrap two of the models and examine the empirical distributions of the parameters.

We remind the reader that we are not proposing differential ocean mortality as the sole or primary explanation for the decline of Snake stocks. Instead, we suggest that it may be a contributing factor to the recent phase (post-1970’s) of their decline, and a confounding factor for analyses which posit that passage through the Snake hydrosystem is the only cause of differential mortality.

Data

Data for the statistical analyses consist of release numbers, observed ocean recoveries, and expanded ocean recoveries for CWT tagged fish in three broad groups: hatchery fish from Bonneville-McNary, wild releases from Bonneville-McNary, and hatchery releases from the lower Snake hatcheries. For the hatchery-wild comparison, which had few test releases or “first generation” fish transferred from other hatcheries, we screened the data to eliminate the few fish that originated at hatcheries other than the point of release, transport/control groups, and fish involved in other test releases (for diet, release timing, or other experiments). For the Snake vs. Bonneville-McNary analysis, we excluded transport/control groups and wild fish, but included other test and first-generation release groups in some models, in order to increase the sample size. When these fish were included, we estimated parameters for their effects (see next section).

Variable definitions are shown in **Table 1a**. Recovery areas are the high seas, Alaska, British Columbia, California, Oregon and Washington. REL_EXP is an offset in the GLIM for which the value is constrained to 1 (see Methods section below). The structure for each model estimated is shown in **Table 1b**. Non-zero ocean recoveries for data used in the hatchery-wild comparison are shown **Table 2** and **Figure 1**; similar data for the Snake vs. BONN-MCN comparisons are shown in **Tables 5A and 5B,** and **Figures 2** and **3**. The release groups in each comparison were constrained so that they "overlap," in the sense that there are ocean recoveries from both groups in all release years being compared in any given model. This constraint, along with the addition of several more hatcheries, results in a rather different dataset than that used in the May 1996 analysis.

Methods

There are several potential problems associated with assessments of similarities among recovery patterns of Columbia River spring chinook. First, and perhaps most important, the very small number of recoveries means that the statistical power of tests of homogeneity is likely to be low. Second, since recoveries are rare events, there will be many zeroes in the data, since many hatcheries have no recoveries in some fisheries (e.g., Wind River fish in the CA fishery). It is tempting to assume a log-normal distribution for the recoveries, but the zeroes pose substantial problems in this regard.

Cormack and Skalski (1992), following Green and Macdonald (1987), described a method for dealing with these problems, which we have applied to the CWT data described above. Essentially, they recommend using a Poisson distribution that is scaled to allow for the sampling effort in each fishery where fish are recovered. The model is estimated using a general log-linear model (GLIM). They actually investigated several methods; the one used here and in most of their results is shown in Equation 1.

$$E(n_{ij}) = \mu_{ij} = R_i \theta_{ij} f_j \qquad \text{Eq. 1}$$

Where :

i indexes release groups (i.e., tag codes);

j indexes fisheries or recovery areas (state or province in our models);

n_{ij} is the observed number of fish in tag code i recovered in fishery j;

$E(n_{ij})$ is the number of tag codes from release group i expected to be recovered in fishery j;

μ_{ij} is the number of tag codes from release group i in expected to be found in the sample inspected from fishery j;

θ_{ij} is the probability that a fish with tag code i is caught in fishery j;

R_i is the number of fish released bearing tag code i;

f_j is the proportion of fishery j inspected for tag codes (expansion factor).

Equation (1) can be expressed as a log-linear model:

$$\ln(\mu_{ij}) = \ln(R_i f_j) + \ln(\theta_{ij}) \qquad \text{Eq. 2}$$

with scaled variance

$$Var(n_{ij}) = \phi\mu_{ij} \qquad \text{Eq. 3}$$

where ϕ is an unknown constant of proportionality to be estimated, and the other terms are as defined for (1).

The $\ln(R_i f_j)$ term in Eq. 2 is used as an offset, and the value of the parameter is constrained to equal one in the estimation procedure[1]. The ln (θ_{ij}) term in Eq. 2 can be partitioned into effects due to the hatchery of origin, recovery area, etc. These effects are what of interest in the present analysis.

In the results shown here, we used Cormack and Skalski's model 3A. To verify that the software (SAS© Version 6.12 PROC GENMOD) and our interpretation of their model are accurate, we duplicated their reported results using the data in the article.

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[1] Note that because of the offset, the dependent variable is, in effect, the proportion of fish recovered in each fishery. In addition, the offset gives a lower weight to recoveries with higher expansion factors.

Results

In principle, one could classify the recoveries by hatchery, recovery area, release year, and age at recovery. However, the sparseness of the matrix of recoveries makes this impossible - too many of the interactions were "aliased," to use the GLIM jargon (i.e., their effects are confounded with one another), to be estimable. Therefore, we found it necessary to limit the comparisons to those variables we believed were germane to the PATH analyses. Depending on the analysis, these consist of the following classifications of the CWT recoveries:

- Releases of hatchery or wild origin
- Releases from the Snake or the BONN-MCN portion of the river
- Year released
- Age at recapture
- Whether or not it was a test release
- Whether or not it was a release of first-generation transfers (i.e., parent stock originated at another hatchery)
- The state or province of marine recapture (for all models)

In no case were we able to estimate a fully interacted model.

We used a hatchery/wild designation and recovery area for the comparison of marine recovery patterns of hatchery and wild releases. We estimated two types of model, one using all observations, and a second using 500 random draws of 345 observations each. Goodness of fit statistics for the model using all observations are shown in **Table 3**, and analysis of deviance (ANODEV) information is shown in **Table 4**. The proportion of deviance explained (analogous to an R-square statistic) is not very high, at about 0.11 (Tables 3 and 4). A finding of interest to PATH is the fact that we found no significant difference in ocean recoveries between the hatchery and wild groups (**Table 4**, last section).

The distribution of residuals from the model is markedly skewed and non-normal[2] (**Figure 4**, Anscombe residuals), in large part because the recoveries are so sparse. Therefore, based on suggestions from the April 1997 PATH workshop, we bootstrapped the model (500 random draws from the sample space, 345 randomly selected observations per sample) to examine the

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[2] Distributions of raw residuals, likelihood residuals, and Cook's "D" show similar patterns for both this mode and for Model 2C, discussed later

"empirical" distribution of the parameters[3]. This result was repeated in the bootstrap results. **Figure 6** shows the distribution of parameter estimates for one term, the (hatchery * California) interaction term; results were similar for the other recovery areas. Although the distribution has a mode of about -2, the parameter is not significantly different from 0 at $\alpha = 0.05$, which supports the results of the model which contained- all observations.

We also re-analyzed the ocean distribution of Snake and BONN-MCN hatchery fish, using a dataset that differed from the May 1996 data in several respects. First, we included several additional hatcheries (Round Butte, Dworshak, and Rapid River). Second, we only analyzed release groups that were "paired" by release year, as noted in **Data** section. Third, we looked at the question of whether or not the release patterns differed only because they involved different hatcheries, or because there were systematic differences between Snake and BONN-MCN fish. Finally, as with the hatchery/wild model, we estimated (and bootstrapped) a model which did not include age at recovery.

Goodness of fit results are shown in Table 6,, and analysis of deviance is shown in Table 7. Results for one model (2B) should be viewed with caution, since it failed to converge. However, the Aikaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) should be reliable, and the lower scores suggest that the model which groups hatcheries into Snake and BONN-MCN provides a better fit to the data than the model in which each hatchery has its own classification. The ANODEV results for model 2B show a significant difference between recoveries by river reach (BONN-MCN vs. Snake).

Model 2C is similar to 2A and 2B, but was estimated including first-generation transfers and test releases (with terms for them in the model), and collapsed the recoveries over age at recovery. We did not include year of release in this model due to the extreme sparseness of the recoveries. The model shows a significant difference between Snake and Bonneville-McNary recoveries by recovery area when estimated with all observations (Tables 6 and 7). However, as with the hatchery/wild model, the residuals from this model are markedly skewed (**Figure 5**). The (river reach * recovery area) parameters were not significantly different from zero when we bootstrapped the model, judging from the empirical distributions of the bootstrapped parameters. This is shown for the California recovery area in **Figure 7**; results for the other recovery areas were similar.

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[3] Note that since the observations from the full dataset were selected at random, any given observation may appear several times or not at all in any given bootstrap sample

Discussion

We believe that we have addressed most criticisms of the earlier report, insofar as possible with the data in hand. The results of our re-analysis of the data are as follows:

1. The differences among hatcheries appear to be systematic, depending on the region (Snake or BONN-MCN) where the hatcheries are located. Obviously, a model with each hatchery as a classification variable will fit the data better (in terms of the proportion of total deviance explained) than one which groups hatcheries together, but it does so at the cost of adding additional parameters. Both the AIC and BIC suggest using a model with stocks grouped by river reach.
2. Recovery percentages clearly differ across years. One cannot analyze a fully interacted model (year * river reach * recovery age *….). However, we have looked at the data in a pair-wise fashion to reduce the problems that may result from the "year effect" due to changes in harvest or migratory patterns.
3. We could find no significant differences in ocean recovery patterns between hatchery and natural fish produced in the BONN-MCN river reach, using either the entire dataset or bootstrapped subsets. This suggests that using hatchery fish as a surrogate for naturally produced fish is not unreasonable when looking at broad patterns of ocean recoveries. Whether or not hatchery fish can be used as surrogates for wild fish in other comparisons (e.g., smolt-to-adult survival, in-river survival, etc.) is not addressed by this analysis.
4. The results for the Snake vs. Bonneville-McNary comparison are more ambiguous. Significant differences are detected by the models when using the entire dataset, but these differences are at most less apparent when using bootstrapped subsets of the data. This is partly due to the very sparse recoveries.
5. Although it is probably true that significant ocean mortality occurs before the fish are first recovered (after spending one winter in the ocean), the CWT database contains no recoveries of "ocean age 0" spring chinook from the stocks we investigated. We do not know where the fish go between release as smolts and the time recoveries begin to appear at ocean age 1, and we cannot address this question with the available CWT data.

The difference between the all-observation and bootstrapped results for the upriver-downriver comparison could be addressed in other ways. For example, we have not done extensive residual analysis or influence diagnostics on the models, beyond those noted in the previous section. It is possible that the most influential observations are not those with positive ocean recoveries, but are due to some other factor, such as release group size or the expansion factor. In addition, the difference in results between the two techniques introduces a somewhat philosophical question: whether one should use all of the available data (the non-bootstrapped model) or only portions of it (the bootstrapped model) when investigating a question where the data are very sparse.

Finally, we note that this analysis is not the first to suggest systematic differences between BONN-MCN and Snake recoveries. Wahle et al (1981) analyzed marine and freshwater recoveries of stream-type chinook from hatcheries throughout the Columbia Basin. We display a subset of their results for the BONN-MCN and Snake areas in **Tables 8 and 9**. Their results demonstrated that Snake hatchery stocks were far more likely to be recovered in Oregon and California than were the BONN-MCN stocks, especially for BY70 releases. It is also apparent that there were substantial differences between the two brood years. In addition, their data suggest that harvest or migration patterns changed dramatically between BY70-71 and the earliest CWT data that we employed (BY76+). Marine recoveries averaged about 65 percent of total recoveries basin-wide for the BY70-71 recoveries. This number would likely by one to three orders of magnitude smaller for the Snake and BONN-MCN stocks in recent years.

We welcome comments on this analysis. While it would be useful to include mid-Columbia stocks, releases and recoveries of these fish have been too scarce to be useful in a GLIM analysis. It may be possible to do a hatchery-wild GLIM comparison for the Snake fish as more transport study data become available that separate hatchery and wild releases. In addition, it would be interesting to examine stocks from the lower Columbia (below Bonneville Dam) to see if their recovery patterns differ substantially from those further upstream.

Finally, we have two specific questions for reviewers:

- Would it be appropriate to investigate alternative methods to account for zeros in the data other than the Poisson distribution we assumed (i.e. arc-sine, etc.)?
- We believe that, given the pattern of the residuals, outlier deletion may be a good idea for future analyses. Does this make statistical/biological sense?

References

Anderson, James J. 1995. "Influence of climate on fish, review," in *Plan for Analyzing and Testing Hypotheses (PATH): Preliminary Report on Retrospective Analyses*, Marmorek, D. R., I. P. Parnell, and D. Bouillon, editors. March 15, 1996.

Beamesderfer, R., H. Schaller, M. Zimmerman, C. Petrosky, O. Langness, and L. LaVoy, 1996, "Spawner-recruit data for spring and summer chinook salmon populations in Idaho, Oregon, and Washington," draft manuscript, October 4, 1996.

Bradford, M. 1995. "Comparative review of Pacific salmon survival rates," Can. J. Fish. Aquat. Sci. 52: 1327-1338.

Cormack, R. M. and J. R. Skalski. 1992. "Analysis of coded wire tag returns from commercial catches. Can. J. Fish. Aquat. Sci. 49: 1816-1825.

Deriso, R. , D. Marmorek, and I. Parnell. 1996. "Retrospective analysis of passage mortality of spring chinook in the Columbia River," in *Plan for Analyzing and Testing Hypotheses (PATH): Preliminary Report on Retrospective Analyses*, Marmorek, D. R., I. P. Parnell, and D. Bouillon, editors. March 15, 1996.

Deriso, R. 1995. "An initial prototype of an MLE and Bayesian framework for Columbia River spring chinook stock and recruitment analysis," in *Plan for Analyzing and Testing Hypotheses (PATH): Information Package for Workshop 1*, Marmorek, D. R., I. P. Parnell, editors. September 28, 1995.

Green, P. E. J., and P. D. M. Macdonald. 1987. "Analysis of mark-recapture data from hatchery-raised salmon using log-linear models. Can. J. Fish. Aquat. Sci. 44: 316-326.

Hilborn, R. and C. J. Walters. 1992. *Quantitative Fisheries Stock Assessment*, Chapman and Hall, New York.

Kope, R. G., 1987. "Separable virtual population analysis of Pacific salmon with application to marked chinook salmon, *Oncorhynchus tshawytscha*, from California's Central Valley, Can. J. Fish. Aquat. Sci. 44: 1213-1220.

Ricker, W. E. 1976. "Review of the rate of growth and mortality of Pacific salmon in salt water, and non-catch mortality caused by fishing," Can. J. Fish. Aquat. Sci. 33: 1483-1524.

Wahle, R. J., E. Chaney, and R. E. Pearson. 1981. "Areal distribution of marked Columbia River basin Spring Chinook salmon recovered in fisheries and at parent hatcheries," Marine Fisheries Review 43(12): 1-9.

Williams, J. 1996. "Comments on the PATH final report of retrospective analyses," memorandum, November 15, 1996

Table 1a. Definitions of Variables in Analysis.

Variable	Label
EST_REC	Expanded recoveries
EXPFACT	Observed/estimated recoveries
HATCHERY	Hatchery name/release location
FRSTGEN	"Y" if 1st generation release, "N" otherwise
NUM_REL	Number in tag group
OBS_REC	Observed recoveries, no expansion
REC_AGE	Years from release to recovery
REC_AREA	Area recovered (CA, OR, WA, BC, AK, HS-High Seas
REL_EXP	ln(number released * expansion factor)
REL_YR	Calendar Year Released
RIVREACH	Bonneville-McNary, Snake, etc.
SUBBASIN	Subbasin closest to hatch/release location
TEST_REL	"Y" if test release group, "N" otherwise
WILD	"NO" for hatchery, else "YES"

Table 1b. Models Estimated

Model	Description	Test and 1st Generation Releases?	Bootstrapped?
1	BONN-MCN Hatchery vs. Wild	No	Yes
2A	BONN-MCN vs. Snake Hatchery Releases	No	No
2B	Like 2B, but Individual Hatcheries	No	No
2C	BONN-MCN vs. Snake Hatchery Releases	Yes	Yes

Table 2. Ocean Recoveries of Bonneville-McNary Hatchery and Wild Yearling Chinook, Released 1978-1982, All Recovery Ages Grouped Together, No Test or First-Generation Releases

SUBBASIN	WILD	TEST_REL	NUM_REL	REC_AREA	OBS_REC	EST_REC
Deschutes	NO	N	46,230	WA	1	2
Deschutes	NO	N	39,278	OR	1	1
Deschutes	NO	N	8,919	WA	1	2
Deschutes	YES	N	1,084	BC	2	3
Deschutes	YES	N	1,084	OR	2	4
Deschutes	YES	N	1,084	WA	1	3
Deschutes	YES	N	2,649	OR	1	6
Deschutes	NO	N	28,891	WA	2	11
Deschutes	NO	N	24,302	BC	3	11
Deschutes	NO	N	24,302	CA	1	6
Deschutes	NO	N	24,302	WA	2	8
Deschutes	NO	N	44,212	WA	1	3
Deschutes	NO	N	24,410	OR	4	4
Deschutes	NO	N	26,766	CA	1	5
John Day	YES	N	8,029	AK	1	2
John Day	YES	N	4,056	BC	1	14
Klickitat	NO	N	144,851	BC	7	32
Klickitat	NO	N	144,851	WA	1	3
Klickitat	NO	N	146,349	AK	7	24
Klickitat	NO	N	146,349	BC	2	6
Klickitat	NO	N	146,349	OR	1	13
Klickitat	NO	N	146,349	WA	2	6
Klickitat	NO	N	90,754	AK	7	32
Klickitat	NO	N	90,754	BC	18	67
Klickitat	NO	N	90,754	OR	6	7
Klickitat	NO	N	90,754	WA	12	32
Warm Springs	YES	N	1,493	CA	1	5
Warm Springs	YES	N	1,577	WA	1	5
Warm Springs	NO	N	168,000	BC	2	8
Warm Springs	NO	N	168,000	WA	2	5
Warm Springs	NO	N	27,816	BC	1	3
Warm Springs	YES	N	115	BC	2	11
Warm Springs	YES	N	115	WA	2	3
Warm Springs	NO	N	66,033	WA	1	2
Warm Springs	NO	N	165,402	BC	1	4
Warm Springs	NO	N	80,554	WA	1	2
Wind	NO	N	37,499	BC	1	2
Wind	NO	N	82,098	BC	1	15
Totals			2,346,414		104	372

Table 3. Goodness of Fit for Model 1: Ocean Recoveries of Bonneville-McNary Hatchery and Wild Yearling Chinook, Released 1978-1982.

Model Description	**1: Hatchery vs. Wild Releases**
Main Effects	**Wild, Recovery Area**
Interactions	**Wild * Recovery Area**
Observations	345
Null Model Deviance	661.5535
Number of Parameters	10
D.O.F.	335
Scale Parameter, SQRT(PHI)	1.3236
Deviance	586.8877
Proportion of Deviance Explained By Model	0.113
Pearson Chi-Square	9437.9814
Scaled Pearson Chi-Square	5387.23
Log-likelihood from SAS	-137.724
Correction (Sum(log(Y!)))	100.439
Corrected Log-Likelihood	-195.055
AIC	410.110
BIC	448.546

Table 4. ANODEV for Model 1: Ocean Recoveries of Bonneville-McNary Hatchery and Wild Yearling Chinook, Released 1978-1982.

Source	**NDF**	**DDF**	**F**	**Pr>F**	**chi-square**	**Pr>Chi**
WILD	1	335	1.5079	0.2203	1.5079	0.2195
REC_AREA	4	335	3.8409	0.0046	15.3637	0.004
WILD*REC_AREA	4	335	0.4045	0.8054	1.618	0.8056

Table 5A. Ocean Recoveries of Bonneville-McNary and Snake River Hatchery Yearling Chinook, Released 1983-1990, by Release Age, No test or 1st Generation Releases.

RIVREACH	HATCHERY	REL_YR	NUM_REL	REC_AREA	REC_AGE	OBS_REC	EST_REC
BON_MCN	ROUND BUTTE	1983	42,865	CA	5	1	4
BON_MCN	ROUND BUTTE	1983	27,907	OR	1	1	1
BON_MCN	ROUND BUTTE	1983	27,907	WA	3	1	3
BON_MCN	ROUND BUTTE	1983	52,425	BC	3	1	1
SNAKE	SAWTOOTH HATCHERY	1983	51,450	HS	2	1	4
BON_MCN	CARSON NFH	1984	18,172	BC	4	1	4
BON_MCN	CARSON NFH	1984	19,401	OR	2	1	1
BON_MCN	CARSON NFH	1984	19,001	OR	2	1	1
BON_MCN	CARSON NFH	1984	28,462	OR	2	1	1
BON_MCN	CARSON NFH	1984	29,160	OR	2	1	1
BON_MCN	ROUND BUTTE	1984	27,640	OR	2	1	1
BON_MCN	ROUND BUTTE	1984	50,133	BC	3	2	5
BON_MCN	ROUND BUTTE	1984	50,133	BC	4	1	3
BON_MCN	ROUND BUTTE	1984	50,133	OR	3	3	0
BON_MCN	ROUND BUTTE	1984	52,488	BC	3	1	3
BON_MCN	ROUND BUTTE	1984	29,938	AK	3	1	0
BON_MCN	ROUND BUTTE	1984	29,938	CA	3	1	4
SNAKE	LOOKINGGLASS	1984	28,334	CA	3	2	8
SNAKE	LOOKINGGLASS	1984	27,537	OR	3	5	0
BON_MCN	CARSON NFH	1985	17,384	BC	4	1	3
BON_MCN	CARSON NFH	1985	14,175	OR	2	1	1
BON_MCN	CARSON NFH	1985	12,411	OR	2	2	2
BON_MCN	CARSON NFH	1985	25,701	OR	2	1	1
BON_MCN	CARSON NFH	1985	19,737	OR	2	1	1
BON_MCN	CARSON NFH	1985	15,011	OR	2	1	1
BON_MCN	ROUND BUTTE	1985	56,017	OR	2	1	1
BON_MCN	ROUND BUTTE	1985	59,389	BC	3	1	7
BON_MCN	ROUND BUTTE	1985	59,389	BC	4	1	3
SNAKE	RAPID RIVER	1985	19,725	BC	4	1	3
BON_MCN	ROUND BUTTE	1986	63,815	BC	4	2	10
BON_MCN	ROUND BUTTE	1986	63,815	HS	2	1	0
BON_MCN	ROUND BUTTE	1986	63,815	OR	4	1	4
SNAKE	LOOKINGGLASS	1986	52,915	OR	3	1	0
SNAKE	RAPID RIVER	1986	103,125	BC	4	1	4
BON_MCN	ROUND BUTTE	1988	51,430	HS	3	1	1
BON_MCN	ROUND BUTTE	1988	51,430	WA	3	1	1
BON_MCN	ROUND BUTTE	1988	58,379	BC	2	1	1
BON_MCN	ROUND BUTTE	1988	58,379	BC	3	1	0
BON_MCN	ROUND BUTTE	1988	58,379	WA	4	1	2
SNAKE	DWORSHAK NFH	1988	62,350	AK	4	1	4
SNAKE	LOOKINGGLASS	1988	46,760	WA	4	1	1
BON_MCN	ROUND BUTTE	1989	27,322	BC	4	1	3
BON_MCN	ROUND BUTTE	1989	19,608	BC	4	1	4
BON_MCN	ROUND BUTTE	1989	19,971	WA	4	1	15
SNAKE	DWORSHAK NFH	1989	21,148	OR	3	3	0
SNAKE	LOOKINGGLASS	1990	48,878	WA	4	1	3
SNAKE	LOOKINGGLASS	1990	65,002	WA	3	1	1
SNAKE	LOOKINGGLASS	1990	65,002	WA	4	1	2
SNAKE	LOOKINGGLASS	1990	61,609	WA	5	1	3
SNAKE	RAPID RIVER	1990	55,100	WA	5	1	1
			2,080,195			62	128

Table 5B. Ocean Recoveries of Bonneville-McNary and Snake River Hatchery Yearling Chinook, Released 1983-1990, by Release Age, Including test and 1st Generation Releases.

SUBBASIN	HATCHERY	TEST_REL	FRSTGEN	REL_YR	NUM_REL	REC_AREA	OBS_REC	EST_REC
Clearwater	HAGERMAN NFH	Y	Y	1984	33,650	OR	1	1
Clearwater	DWORSHAK NFH	Y	Y	1988	62,350	AK	1	4
Clearwater	DWORSHAK NFH	N	Y	1989	21,148	OR	3	0
Deschutes	ROUND BUTTE	N	N	1983	42,865	CA	1	4
Deschutes	ROUND BUTTE	N	N	1983	27,907	BC	1	4
Deschutes	ROUND BUTTE	N	N	1983	27,907	OR	1	1
Deschutes	ROUND BUTTE	N	N	1983	27,907	WA	1	3
Deschutes	ROUND BUTTE	N	N	1983	52,425	BC	1	1
Deschutes	ROUND BUTTE	N	N	1984	27,640	OR	1	1
Deschutes	ROUND BUTTE	N	N	1984	50,133	BC	3	8
Deschutes	ROUND BUTTE	N	N	1984	50,133	OR	3	0
Deschutes	ROUND BUTTE	N	N	1984	52,488	BC	1	3
Deschutes	ROUND BUTTE	N	N	1984	29,938	AK	1	0
Deschutes	ROUND BUTTE	N	N	1984	29,938	CA	1	4
Deschutes	ROUND BUTTE	N	N	1985	56,017	OR	1	1
Deschutes	ROUND BUTTE	Y	N	1985	59,389	BC	2	10
Deschutes	ROUND BUTTE	Y	N	1985	61,502	BC	1	4
Deschutes	ROUND BUTTE	Y	N	1985	61,502	OR	1	5
Deschutes	ROUND BUTTE	Y	N	1986	63,815	BC	2	10
Deschutes	ROUND BUTTE	Y	N	1986	63,815	HS	1	0
Deschutes	ROUND BUTTE	Y	N	1986	63,815	OR	1	4
Deschutes	ROUND BUTTE	Y	N	1987	51,003	HS	1	0
Deschutes	ROUND BUTTE	Y	N	1987	61,895	OR	6	0
Deschutes	ROUND BUTTE	Y	N	1988	51,430	HS	1	1
Deschutes	ROUND BUTTE	Y	N	1988	51,430	WA	1	1
Deschutes	ROUND BUTTE	Y	N	1988	58,379	BC	2	1
Deschutes	ROUND BUTTE	Y	N	1988	58,379	WA	1	2
Deschutes	ROUND BUTTE	N	N	1989	27,322	BC	1	3
Deschutes	ROUND BUTTE	N	N	1989	19,608	BC	1	4
Deschutes	ROUND BUTTE	N	N	1989	19,971	WA	1	15
Grand Ronde	LOOKINGGLASS	N	Y	1983	50,491	OR	2	0
Grand Ronde	LOOKINGGLASS	N	Y	1984	28,334	CA	2	8
Grand Ronde	LOOKINGGLASS	N	Y	1984	27,537	OR	5	0
Grand Ronde	OXBOW	N	Y	1984	35,376	CA	1	6
Grand Ronde	OXBOW	N	Y	1984	35,376	HS	1	2
Grand Ronde	LOOKINGGLASS	N	Y	1985	37,533	OR	2	2
Grand Ronde	LOOKINGGLASS	Y	Y	1985	50,825	BC	2	7
Grand Ronde	LOOKINGGLASS	Y	Y	1986	48,761	AK	1	1
Grand Ronde	LOOKINGGLASS	Y	Y	1986	48,761	BC	2	8
Grand Ronde	LOOKINGGLASS	Y	Y	1986	50,687	AK	1	2
Grand Ronde	LOOKINGGLASS	Y	Y	1986	50,687	BC	2	10
Grand Ronde	LOOKINGGLASS	Y	N	1986	52,915	OR	1	0
Grand Ronde	LOOKINGGLASS	N	Y	1988	42,744	CA	1	2
Grand Ronde	LOOKINGGLASS	Y	Y	1988	46,760	WA	1	1
Grand Ronde	LOOKINGGLASS	N	Y	1988	43,220	OR	1	4
Grand Ronde	LOOKINGGLASS	Y	Y	1990	48,878	WA	1	3
Grand Ronde	LOOKINGGLASS	Y	Y	1990	65,002	WA	2	3
Grand Ronde	LOOKINGGLASS	Y	Y	1990	61,609	WA	1	3

Table 5B. (Concluded)

SUBBASIN	HATCHERY	TEST_REL	FRSTGEN	REL_YR	NUM_REL	REC_AREA	OBS_REC	EST_REC
Rapid	RAPID RIVER	Y	N	1985	19,725	BC	1	3
Rapid	RAPID RIVER	Y	N	1986	103,125	BC	1	4
Rapid	RAPID RIVER	Y	N	1990	55,100	WA	1	1
Salmon	RAPID RIVER	Y	Y	1983	35,075	BC	1	2
Salmon	RAPID RIVER	Y	Y	1983	51,450	HS	1	4
Snake	RAPID RIVER	Y	N	1983	40,300	OR	1	1
Wind	CARSON NFH	N	N	1984	18,172	BC	1	4
Wind	CARSON NFH	N	N	1984	19,401	OR	1	1
Wind	CARSON NFH	N	N	1984	19,001	OR	1	1
Wind	CARSON NFH	N	N	1984	28,462	OR	1	1
Wind	CARSON NFH	N	N	1984	29,160	OR	1	1
Wind	CARSON NFH	N	N	1985	17,384	BC	1	3
Wind	CARSON NFH	N	N	1985	14,175	OR	1	1
Wind	CARSON NFH	N	N	1985	12,411	OR	2	2
Wind	CARSON NFH	N	N	1985	25,701	OR	1	1
Wind	CARSON NFH	N	N	1985	19,737	OR	1	1
Wind	CARSON NFH	N	N	1985	15,011	OR	1	1
Wind	CARSON NFH	N	N	1987	26,971	BC	1	3
Wind	CARSON NFH	N	N	1987	29,035	HS	1	1
Wind	CARSON NFH	N	N	1987	18,690	AK	1	3
Wind	CARSON NFH	N	N	1987	18,690	WA	1	2
Total					2,807,973		95	198

Table 6. Goodness of Fit for Models of Bonneville-McNary and Snake River Hatchery Yearling Chinook, Released 1983-1990.

Model Description	2A: Snake vs. BON-MCN Ocean Recoveries	2B: Hatcheries vs. Ocean Recoveries	2C: Snake vs. BON-MCN Ocean Recoveries
Main Effects	River Reach, Recovery Area, Release Year, Recovery Age	Hatchery, Recovery Area, Release Year, Recovery Age	River Reach, Recovery Area, Test Release, 1st Generation
Interactions	River Reach * Recovery Area	Hatchery * Recovery Area	River Reach * Recovery Area, River Reach * 1st Generation, River Reach * Test Release
Observations	5490	5490	1842
Null Model Deviance	673.6806	673.6806	770.1405
Number of Parameters	22	70	17
D.O.F.	5468	5420	1825
Scale Parameter, SQRT(PHI)	0.314	0.2893	0.5862
Deviance	538.9844	453.6951	627.0761
Proportion of Deviance Explained By Model	0.200	0.327	0.186
Pearson Chi-Square	15157.9053	7136.9149	7768.5003
Scaled Pearson Chi-Square	153737.5279	85273.41406	22607.14
Log-likelihood from SAS	-3158.2223	-3209.5481	-1061.118
Correction (Sum(log(Y!)))	11.1435994	11.1435994	24.367
Corrected Log-Likelihood	-3271.245135	-3342.694253	-1132.027
AIC	6586.490	6825.389	2298.054
BIC	6731.925	7288.136	2391.870

Table 7. ANODEV for Models of Bonneville-McNary and Snake River Hatchery Yearling Chinook, Released 1983-1990.

Model 2A:							
	Source	NDF	DDF	F	Pr>F	chi-square	Pr>Chi
	RIVREACH	1	5468	7.7677	0.0053	7.7677	0.0053
	REC_AREA	5	5468	69.5904	0.0001	347.9519	0.0001
	REL_YR	6	5468	46.0601	0.0001	276.3604	0.0001
	REC_AGE	4	5468	106.8119	0.0001	427.2475	0.0001
	RIVREACH*REC_AREA	5	5468	16.7441	0.0001	83.7206	0.0001
Model 2B:	Not Applicable; Model Cannot Converge						
Model 2C							
	RIVREACH	1	1825	0.1072	0.7434	0.1072	0.7434
	REC_AREA	5	1825	34.4947	0.0001	172.4735	0.0001
	TEST_REL	1	1825	22.5095	0.0001	22.5095	0.0001
	FRSTGEN	1	1825	0.5554	0.4562	0.5554	0.4561
	REL_YR	1	1825	113.7519	0.0001	113.7519	0.0001
	RIVREACH*REC_AREA	5	1825	2.6348	0.0221	13.1742	0.0218
	RIVREACH*FRSTGEN	1	1825	3.2079	0.0734	3.2079	0.0733
	RIVREACH*TEST_REL	1	1825	19.0197	0.0001	19.0197	0.0001

Table 8. Recoveries of Marked Yearling Chinook, Brood Years 1970-71, From Wahle et al. 1981.

Brood Year	Region	Hatchery	AK	BC	WA	OR	CA	Columbia	Hatchery	Total	Marine as % of Total
70	Bonneville-McNary	3 Hatcheries	4	6	27	0	5	98	72	212	19.8
	Bonneville-McNary (Deschutes)	Oak Springs	0	0	109	27	11	236	112	495	29.7
		Wizard Falls	2	0	6	0	0	124	86	218	3.7
	Snake	Lochsa	0	0	0	0	0	0	0	0	
		Kooskia	0	0	13	6	27	2	0	48	95.8
		Rapid River	4	0	78	84	18	37	82	303	60.7
		Hayden Creek	0	0	0	0	0	4	4	8	0.0
		Pahsimeroi Pond	0	0	0	0	0	0	2	2	0.0
		Decker Pond	0	0	34	0	0	0	10	44	77.3
	Brood Year Total		10	6	267	117	61	501	368	1330	34.7
71	Bonneville-McNary	Carson	4	3	200	67	38	19	299	630	49.5
		Little White Salmon	2	0	168	44	20	2	502	738	31.7
		Klickitat	2	127	241	36	0	12	22	440	92.3
	Bonneville-McNary (Deschutes)	Fall River	16	77	117	98	69	37	15	429	87.9
	Snake	Kooskia	0	0	0	0	0	0	53	53	0.0
		Rapid River	2	9	42	7	0	26	292	378	15.9
		Hayden Creek	0	4	24	33	9	0	9	79	88.6
		Pahsimeroi Pond	0	28	50	6	0	0	36	120	70.0
		Decker Pond	6	21	9	10	0	0	0	46	100.0
	Brood Year Total		32	269	851	301	136	96	1228	2913	54.5

Table 9. Marine Recovery, Brood Years 1970-71, Based on Wahle et al. 1981.

Brood Year	AK	BC	WA	OR	CA	Total Marine Recoveries
Bonneville-McNary BY 70, Percent of Marine Recoveries	3.0%	3.0%	72.1%	13.7%	8.1%	100.0%
Snake BY 70, Percent of Marine Recoveries	1.5%	0.0%	47.3%	34.1%	17.0%	100.0%
Bonneville-McNary BY 71, Percent of Marine Recoveries	1.8%	15.6%	54.6%	18.4%	9.6%	100.0%
Snake BY 71, Percent of Marine Recoveries	3.1%	23.8%	48.1%	21.5%	3.5%	100.0%

Figure 1. Model 1 (Hatchery-Wild) Expanded Ocean Recovery proportions

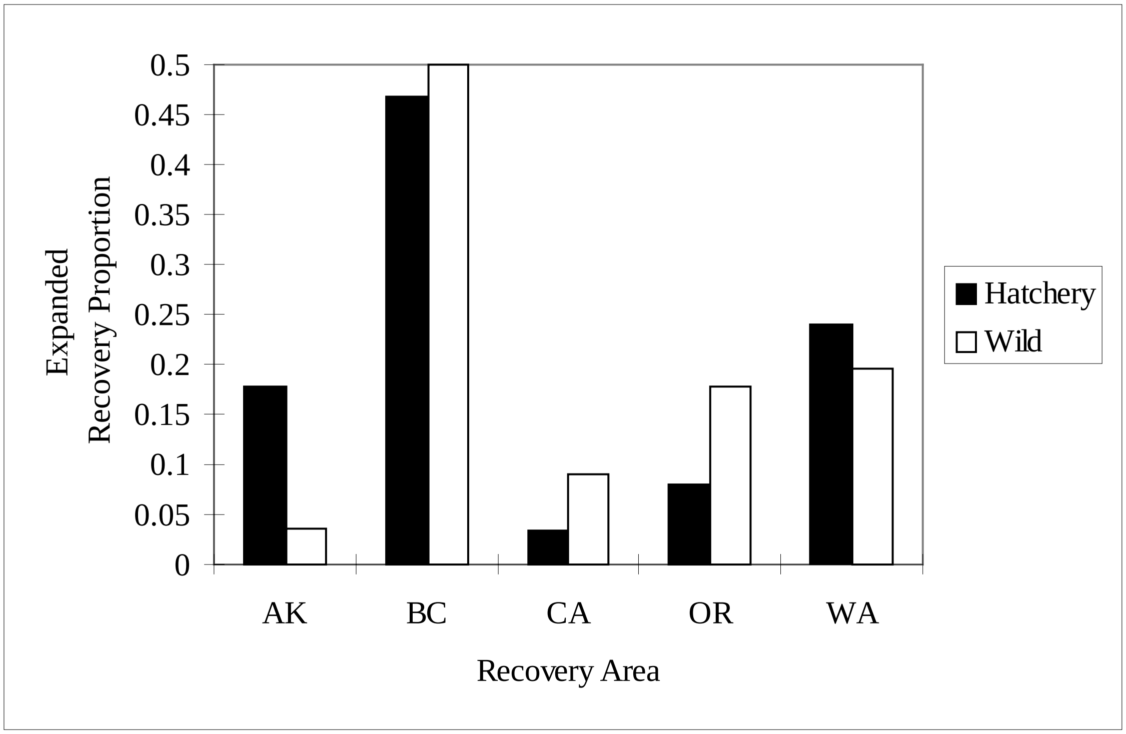

Figure 2. Model 2A (BONN-MCN vs. Snake, No test or 1st Generation tag groups) Expanded Ocean Recovery proportions

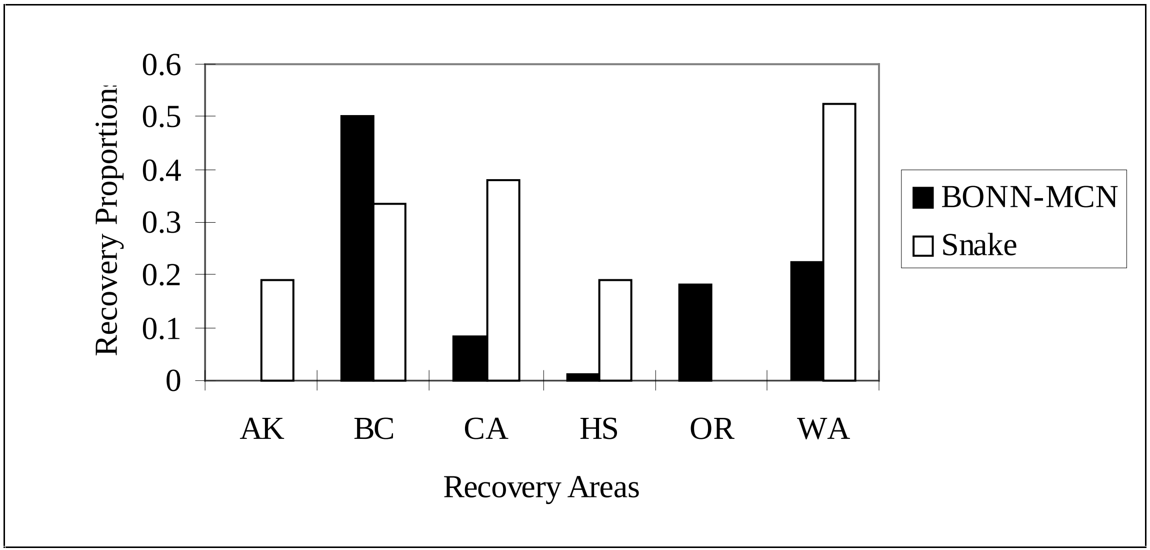

Figure 3. Model 2C (BONN-MCN vs. Snake, With test and 1st Generation tag groups)

Expanded Ocean Recovery proportions

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Figure 4. Model 1 (Hatchery-Wild)Normal Probability Plots of Anscombe Residuals

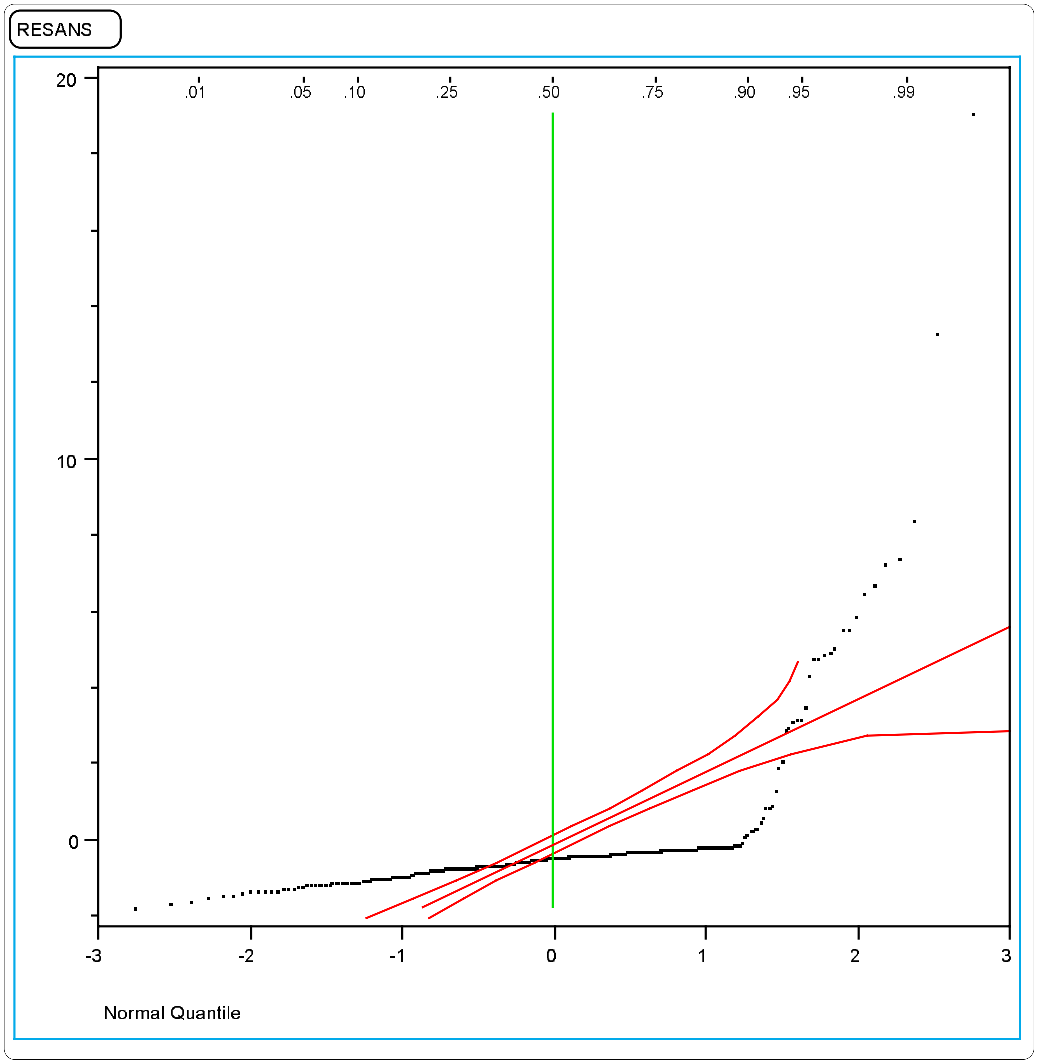


Figure 5. Model 2C (Snake vs. Bonneville-McNary) Normal Probability Plots of Anscombe Residuals

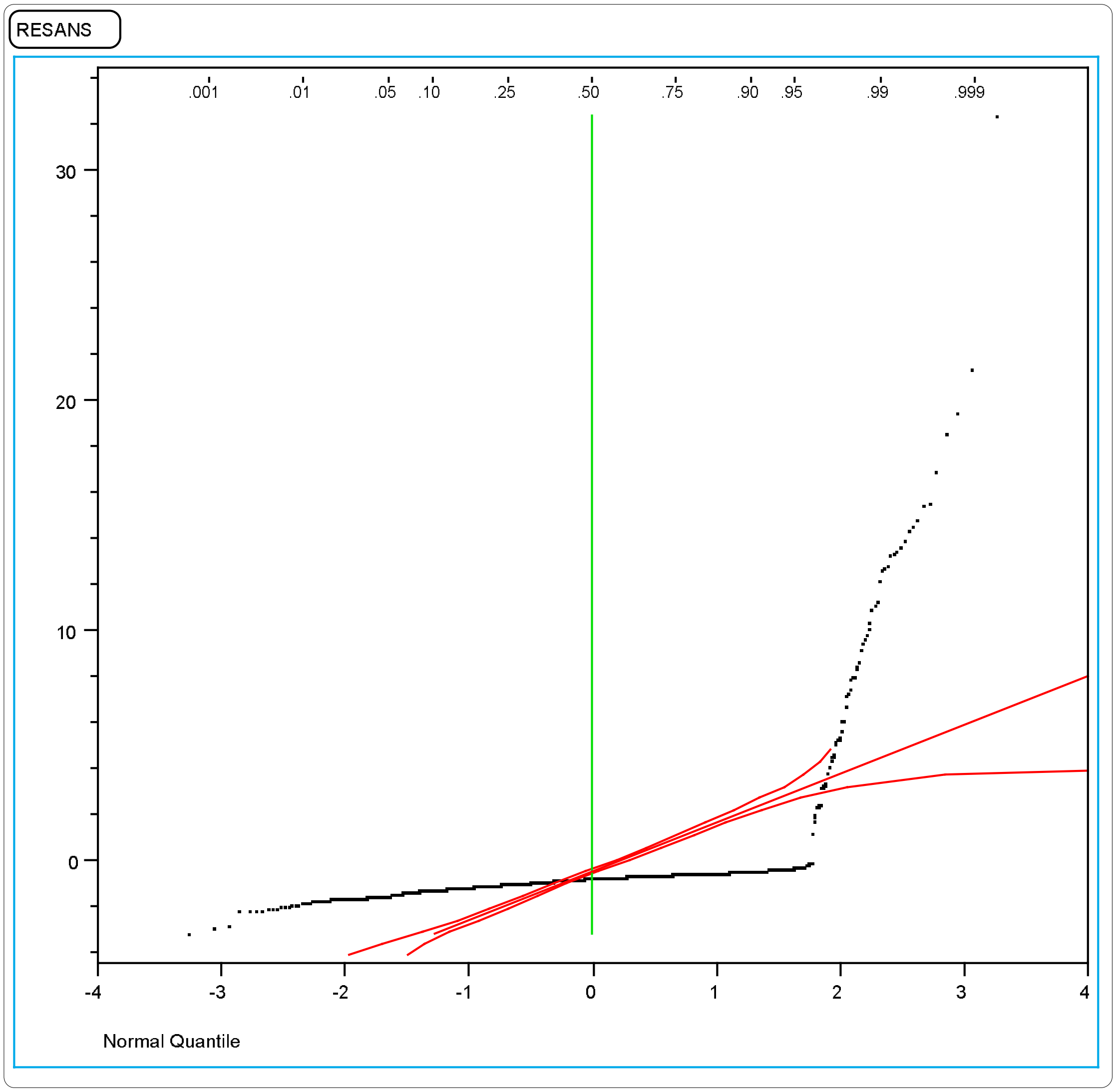


Figure 6. Model 1 Bootstrap, Distribution of Estimated Betas for Hatchery* California Recoveries

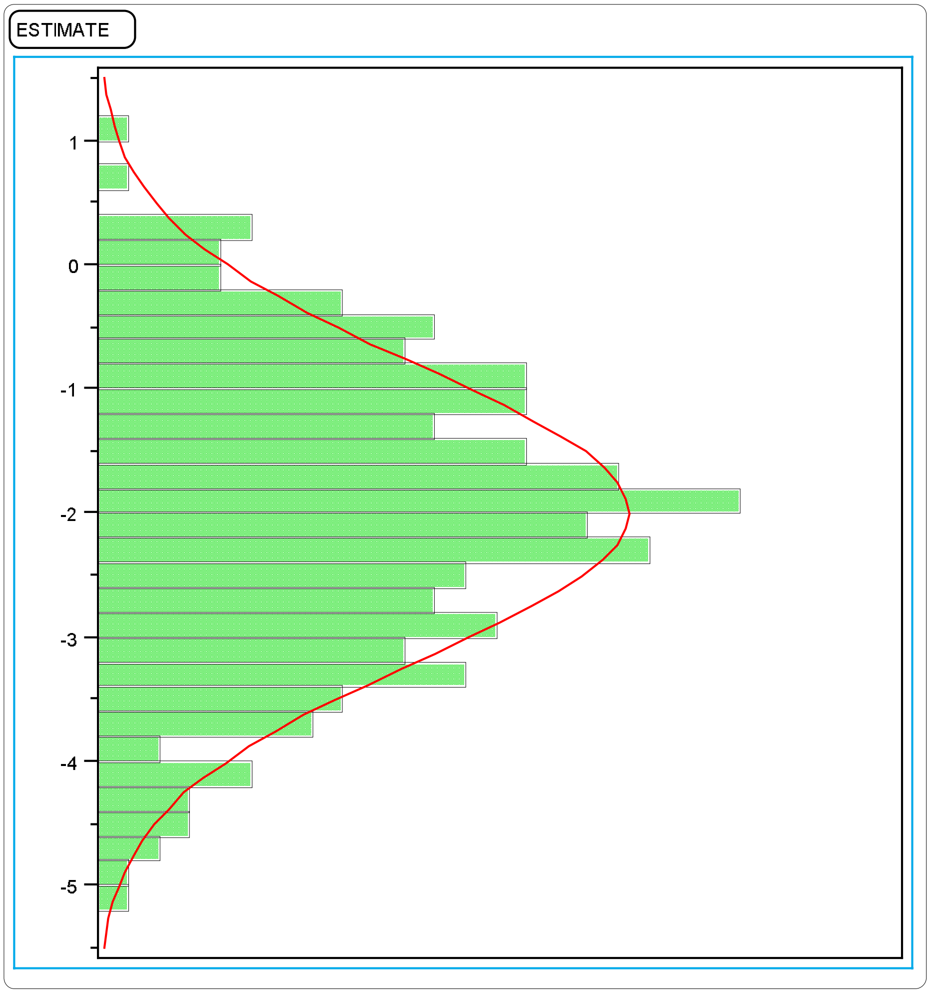
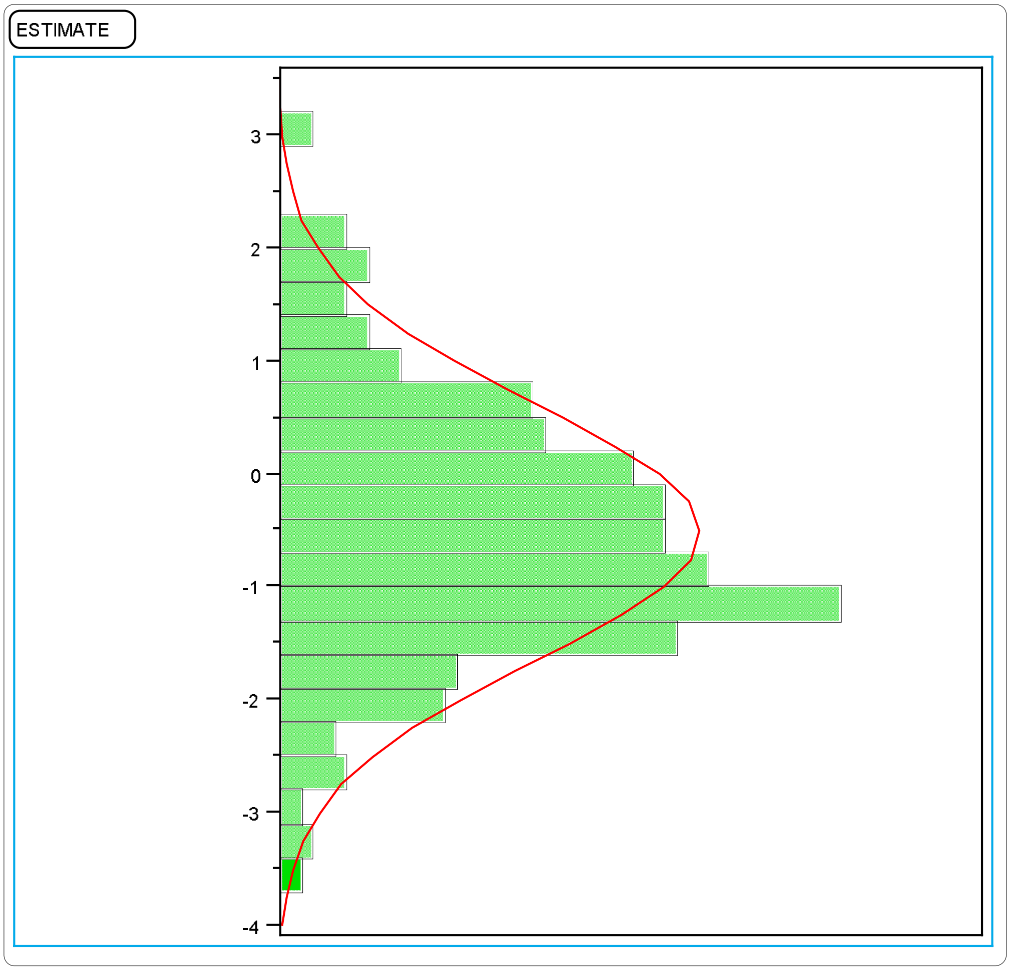


Figure 7. Model 2C Bootstrap, Distribution of Estimated Betas for BONN-MCN * California Recoveries



APPENDIX A: DETAILED RESULTS

Model 1

Hat v Wild, Bonneville-McNary

PARM	LEVEL1	LEVEL2	DF	ESTIMATE	STDERR	CHISQ	PVAL
INTERCEPT			1	-10.3808	0.6618	246.0438	0.0001
WILD	NO		1	-0.3621	0.7109	0.2595	0.6105
WILD	YES		0	0	0	.	.
REC_AREA	AK		1	-1.3707	1.4798	0.858	0.3543
REC_AREA	BC		1	0.2403	0.8879	0.0733	0.7866
REC_AREA	CA		1	-1.3927	1.4798	0.8857	0.3466
REC_AREA	OR		1	-0.282	1.0109	0.0778	0.7803
REC_AREA	WA		0	0	0	.	.
WILD*REC_AREA	NO	AK	1	0.4969	1.5435	0.1036	0.7475
WILD*REC_AREA	NO	BC	1	0.2039	0.951	0.046	0.8302
WILD*REC_AREA	NO	CA	1	-1.5091	1.7701	0.7269	0.3939
WILD*REC_AREA	NO	OR	1	-0.7628	1.1114	0.4711	0.4925
WILD*REC_AREA	NO	WA	0	0	0	.	.
WILD*REC_AREA	YES	AK	0	0	0	.	.
WILD*REC_AREA	YES	BC	0	0	0	.	.
WILD*REC_AREA	YES	CA	0	0	0	.	.
WILD*REC_AREA	YES	OR	0	0	0	.	.
WILD*REC_AREA	YES	WA	0	0	0	.	.

Model 2A

Parameter			DF	Estimate	Std Err	chi-square	Pr>Chi
	Value						
INTERCEPT			1	-17.3004	0.257	4533.22	0.0001
RIVREACH	BON_MCN		1	-0.526	0.2089	6.3425	0.0118
RIVREACH	SNAKE		0	0	0	.	.
REC_AREA	AK		1	-1.7906	0.3391	27.8794	0.0001
REC_AREA	BC		1	-1.095	0.2563	18.2454	0.0001
REC_AREA	CA		1	-1.0934	0.2563	18.1939	0.0001
REC_AREA	HS		1	-1.7893	0.3391	27.8404	0.0001
REC_AREA	OR		1	0.4033	0.1655	5.9412	0.0148
REC_AREA	WA		0	0	0	.	.
REL_YR	1983		1	1.5358	0.2001	58.9367	0.0001
REL_YR	1984		1	2.03	0.1582	164.6598	0.0001
REL_YR	1985		1	1.6039	0.1704	88.614	0.0001
REL_YR	1986		1	0.5137	0.1901	7.3001	0.0069
REL_YR	1988		1	0.8782	0.1885	21.7045	0.0001
REL_YR	1989		1	0.7942	0.1912	17.2571	0.0001
REL_YR	1990		0	0	0	.	.
REC_AGE	1		1	-1.0995	0.3625	9.1979	0.0024
REC_AGE	2		1	1.6089	0.1986	65.65	0.0001
REC_AGE	3		1	2.1781	0.1914	129.4444	0.0001
REC_AGE	4		1	1.7565	0.1966	79.8085	0.0001
REC_AGE	5		0	0	0	.	.
RIVREACH*REC_AREA	BON_MCN	AK	1	0.3979	0.4881	0.6647	0.4149
RIVREACH*REC_AREA	BON_MCN	BC	1	2.4615	0.3113	62.5077	0.0001
RIVREACH*REC_AREA	BON_MCN	CA	1	0.4014	0.3737	1.1539	0.2827
RIVREACH*REC_AREA	BON_MCN	HS	1	1.0898	0.4347	6.2864	0.0122
RIVREACH*REC_AREA	BON_MCN	OR	1	1.0393	0.2405	18.6809	0.0001
RIVREACH*REC_AREA	BON_MCN	WA	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	AK	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	BC	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	CA	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	HS	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	OR	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	WA	0	0	0	.	.

Model 2B

Parameter		Recovery Area	DF	Estimate	Std Err	chi-square	Pr>Chi
INTERCEPT			1	-34.5902	1913.749	0.0003	0.9856
HATCHERY	CARSON NFH		1	-1.6953	3084.2485	0	0.9996
HATCHERY	DWORSHAK NFH		1	-1.1341	4366.2914	0	0.9998
HATCHERY	HAGERMAN NFH		1	-0.852	13296.5299	0	0.9999
HATCHERY	KOOSKIA NFH		1	-0.4817	7847.7339	0	1
HATCHERY	LOOKINGGLASS		1	18.7256	1913.749	0.0001	0.9922
HATCHERY	POWELL REARING P		1	-0.4817	17673.4576	0	1
HATCHERY	RAPID RIVER HATC		1	17.0608	1913.749	0.0001	0.9929
HATCHERY	ROUND BUTTE		1	18.2958	1913.749	0.0001	0.9924
HATCHERY	SAWTOOTH HATCHER		1	-0.6022	2889.2065	0	0.9998
HATCHERY	WARM SPRINGS NFH		0	0	0	.	.
REC_AREA	AK		1	-1.6537	5623.6362	0	0.9998
REC_AREA	BC		1	-0.7747	0.1656	21.8908	0.0001
REC_AREA	CA		1	-0.3122	3312.5342	0	0.9999
REC_AREA	HS		1	-0.8542	4029.0478	0	0.9998
REC_AREA	OR		1	-1.1247	4487.3729	0	0.9998
REC_AREA	WA		0	0	0	.	.
REL_YR	1983		1	0.4692	0.1935	5.8812	0.0153
REL_YR	1984		1	1.5463	0.1528	102.438	0.0001
REL_YR	1985		1	1.3029	0.1646	62.6288	0.0001
REL_YR	1986		1	0.05	0.1798	0.0774	0.7808
REL_YR	1988		1	0.4511	0.1703	7.0163	0.0081
REL_YR	1989		1	0.3864	0.1756	4.8416	0.0278
REL_YR	1990		0	0	0	.	.
REC_AGE	1		1	-1.1011	0.3341	10.8629	0.001
REC_AGE	2		1	1.6076	0.183	77.1802	0.0001
REC_AGE	3		1	2.214	0.1765	157.3975	0.0001
REC_AGE	4		1	1.7875	0.1812	97.2964	0.0001
REC_AGE	5		0	0	0	.	.
HATCHERY*REC_AREA	CARSON NFH	AK	1	0	8249.3287	0	1
HATCHERY*REC_AREA	CARSON NFH	BC	1	19.5381	2418.7093	0.0001	0.9936
HATCHERY*REC_AREA	CARSON NFH	CA	1	0	4981.6322	0	1
HATCHERY*REC_AREA	CARSON NFH	HS	1	0	5985.7275	0	1
HATCHERY*REC_AREA	CARSON NFH	OR	1	21.4896	5097.712	0	0.9966
HATCHERY*REC_AREA	CARSON NFH	WA	0	0	0	.	.
HATCHERY*REC_AREA	DWORSHAK NFH	AK	1	20.7092	6857.6488	0	0.9976
HATCHERY*REC_AREA	DWORSHAK NFH	BC	1	0	6987.5184	0	1
HATCHERY*REC_AREA	DWORSHAK NFH	CA	1	0	6886.236	0	1
HATCHERY*REC_AREA	DWORSHAK NFH	HS	1	0	8235.5357	0	1
HATCHERY*REC_AREA	DWORSHAK NFH	OR	1	21.2537	5961.4246	0	0.9972
HATCHERY*REC_AREA	DWORSHAK NFH	WA	0	0	0	.	.
HATCHERY*REC_AREA	HAGERMAN NFH	AK	1	0	33311.4997	0	1
HATCHERY*REC_AREA	HAGERMAN NFH	BC	1	0	23427.5157	0	1
HATCHERY*REC_AREA	HAGERMAN NFH	CA	1	0	20510.4657	0	1
HATCHERY*REC_AREA	HAGERMAN NFH	HS	1	0	24416.5471	0	1
HATCHERY*REC_AREA	HAGERMAN NFH	OR	1	0	26951.5088	0	1
HATCHERY*REC_AREA	HAGERMAN NFH	WA	0	0	0	.	.
HATCHERY*REC_AREA	KOOSKIA NFH	AK	1	0	19806.3994	0	1
HATCHERY*REC_AREA	KOOSKIA NFH	BC	1	0	13550.7888	0	1
HATCHERY*REC_AREA	KOOSKIA NFH	CA	1	0	12167.3773	0	1
HATCHERY*REC_AREA	KOOSKIA NFH	HS	1	0	14500.2523	0	1

Model 2B (Concluded)

Parameter		Recovery Area	DF	Estimate	Std Err	chi-square	Pr>Chi
HATCHERY*REC_AREA	KOOSKIA NFH	OR	1	0	16013.1217	0	1
HATCHERY*REC_AREA	KOOSKIA NFH	WA	0	0	0	.	.
HATCHERY*REC_AREA	LOOKINGGLASS	AK	1	-21.701	16176.8904	0	0.9989
HATCHERY*REC_AREA	LOOKINGGLASS	BC	1	-21.701	9773.6262	0	0.9982
HATCHERY*REC_AREA	LOOKINGGLASS	CA	1	-0.5916	3312.5342	0	0.9999
HATCHERY*REC_AREA	LOOKINGGLASS	HS	1	-21.701	10938.9449	0	0.9984
HATCHERY*REC_AREA	LOOKINGGLASS	OR	1	1.296	4487.3729	0	0.9998
HATCHERY*REC_AREA	LOOKINGGLASS	WA	0	0	0	.	.
HATCHERY*REC_AREA	POWELL REARING P	AK	1	0	44200.4788	0	1
HATCHERY*REC_AREA	POWELL REARING P	BC	1	0	31281.949	0	1
HATCHERY*REC_AREA	POWELL REARING P	CA	1	0	27229.616	0	1
HATCHERY*REC_AREA	POWELL REARING P	HS	1	0	32407.0659	0	1
HATCHERY*REC_AREA	POWELL REARING P	OR	1	0	35767.7014	0	1
HATCHERY*REC_AREA	POWELL REARING P	WA	0	0	0	.	.
HATCHERY*REC_AREA	RAPID RIVER HATC	AK	1	-20.7057	21483.0969	0	0.9992
HATCHERY*REC_AREA	RAPID RIVER HATC	BC	1	1.487	0.3911	14.4538	0.0001
HATCHERY*REC_AREA	RAPID RIVER HATC	CA	1	-20.7057	11106.8974	0	0.9985
HATCHERY*REC_AREA	RAPID RIVER HATC	HS	1	-20.7057	14473.9635	0	0.9989
HATCHERY*REC_AREA	RAPID RIVER HATC	OR	1	-20.7057	16535.0427	0	0.999
HATCHERY*REC_AREA	RAPID RIVER HATC	WA	0	0	0	.	.
HATCHERY*REC_AREA	ROUND BUTTE	AK	1	0.2527	5623.6362	0	1
HATCHERY*REC_AREA	ROUND BUTTE	BC	0	2.093	0	.	.
HATCHERY*REC_AREA	ROUND BUTTE	CA	1	-0.3745	3312.5342	0	0.9999
HATCHERY*REC_AREA	ROUND BUTTE	HS	1	0.1463	4029.0478	0	1
HATCHERY*REC_AREA	ROUND BUTTE	OR	1	1.6757	4487.3729	0	0.9997
HATCHERY*REC_AREA	ROUND BUTTE	WA	0	0	0	.	.
HATCHERY*REC_AREA	SAWTOOTH HATCHER	AK	1	0	7797.2455	0	1
HATCHERY*REC_AREA	SAWTOOTH HATCHER	BC	1	0	3853.8245	0	1
HATCHERY*REC_AREA	SAWTOOTH HATCHER	CA	1	0	4696.7678	0	1
HATCHERY*REC_AREA	SAWTOOTH HATCHER	HS	1	18.7036	4573.6534	0	0.9967
HATCHERY*REC_AREA	SAWTOOTH HATCHER	OR	1	0	6264.8006	0	1
HATCHERY*REC_AREA	SAWTOOTH HATCHER	WA	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	AK	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	BC	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	CA	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	HS	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	OR	0	0	0	.	.
HATCHERY*REC_AREA	WARM SPRINGS NFH	WA	0	0	0	.	.

Model 2C

PARM	LEVEL1	LEVEL2	DF	ESTIMATE	STDERR	CHISQ	PVAL
INTERCEPT			1	602.1057	60.3542	99.5247	0.0001
RIVREACH	BON_MCN		1	-19.3756	0.4432	1911.3259	0.0001
RIVREACH	SNAKE		0	0	0	.	.
REC_AREA	AK		1	-0.6893	0.4145	2.7659	0.0963
REC_AREA	BC		1	0.4361	0.309	1.9925	0.1581
REC_AREA	CA		1	-0.3934	0.3784	1.0807	0.2985
REC_AREA	HS		1	-1.0816	0.4786	5.1073	0.0238
REC_AREA	OR		1	0.979	0.2806	12.1715	0.0005
REC_AREA	WA		0	0	0	.	.
TEST_REL	N		1	-0.056	0.1952	0.0823	0.7742
TEST_REL	Y		0	0	0	.	.
FRSTGEN	N		1	-0.9099	0.2936	9.6042	0.0019
FRSTGEN	Y		0	0	0	.	.
REL_YR			1	-0.3101	0.0304	104.1178	0.0001
RIVREACH*REC_AREA	BON_MCN	AK	1	-0.246	0.6421	0.1467	0.7017
RIVREACH*REC_AREA	BON_MCN	BC	1	0.9658	0.4282	5.0878	0.0241
RIVREACH*REC_AREA	BON_MCN	CA	1	-0.5212	0.6194	0.7079	0.4001
RIVREACH*REC_AREA	BON_MCN	HS	1	0.8379	0.6194	1.8296	0.1762
RIVREACH*REC_AREA	BON_MCN	OR	1	0.6403	0.4023	2.5336	0.1114
RIVREACH*REC_AREA	BON_MCN	WA	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	AK	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	BC	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	CA	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	HS	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	OR	0	0	0	.	.
RIVREACH*REC_AREA	SNAKE	WA	0	0	0	.	.
RIVREACH*FRSTGEN	BON_MCN	N	0	21.4077	0	.	.
RIVREACH*FRSTGEN	BON_MCN	Y	0	0	0	.	.
RIVREACH*FRSTGEN	SNAKE	N	0	0	0	.	.
RIVREACH*FRSTGEN	SNAKE	Y	0	0	0	.	.
RIVREACH*TEST_REL	BON_MCN	N	1	-1.1485	0.2594	19.6027	0.0001
RIVREACH*TEST_REL	BON_MCN	Y	0	0	0	.	.
RIVREACH*TEST_REL	SNAKE	N	0	0	0	.	.
RIVREACH*TEST_REL	SNAKE	Y	0	0	0	.	.