Analyses of 'D'

Appendix 23

P. Wilson, H. Schaller, N. Bouwes, C. Petrosky, and P. Budy

The sensitivity analysis identifies D as the most influential parameter affecting system survival differences between the two passage models. CRiSP uses a very different D value than the FLUSH model. Both the CRiSP and FLUSH derivations of D have been formally critiqued (Anderson 1998a, 1998b, Wilson et al. 1998a, 1998b, Deriso 1998, Collie 1998, Saila 1998). We reiterate several important points from these critiques (currently not mentioned in this report), indicating that the method of calculating CRiSP retrospective and prospective D values was not consistent with the evidence and analysis presented by Anderson (1998a).

Model outcomes are highly sensitive to assumptions about the efficacy of the transportation program. This efficacy may be expressed in several ways. The research used to evaluate the transportation program was based on paired releases of fish into transport barges (or trucks) and back into the river as controls. Thus relative survival rate estimates called transport/control (T/C) ratios were produced. The data from these studies, along with other information, can be used to estimate a statistic (D) which estimates the post release survival rate of transported fish relative to in-river migrants that have survived to below Bonneville Dam. Finally, the survival rate of transported fish to returning adults (Smolt to Adult Return or SAR rates) can be used to evaluate the transportation program.

CRiSP derivation of D values have undergone several transformations during the PATH process (see Wilson et al. 1998b), and each of the transformations have had a dramatic influence on model results. We therefore believe that current assumptions in the formulation of D values need to be stated in this report to avoid ambiguity with earlier CRiSP estimates of D. We first highlight problems with D values used in the CRiSP retrospective analysis. We will summarize the major reasons why CRiSP D values are misleading, even if the hypotheses used to develop them are assumed to be true. A more complete discussion can be found in Wilson et al. (1998a, b), Collie (1998), Saila (1998). We also demonstrate how these problems have a large effect on the ratio of prospective to retrospective system survivals from CRiSP, and hence on survival and recovery probabilities under the different management scenarios.

D values are calculated as the product of the T/C ratio and the ratio of direct hydrosystem survival rates of non-transported control fish and transported fish (V_c/V_T). T/C studies were conducted over several years. These studies measured the adult return from smolts that had been tagged and either transported or left in the river during their migration. The ratio of the number of transported fish to in-river fish returning is the T/C ratio. Most of the T/C ratios used in the calculation of D are similar between CRiSP and FLUSH, with the exception of 1995, where CRiSP used T/C ratios estimated from studies where results were incomplete. Adult return data for the T/C study conducted in 1995 were incomplete at the time model runs were conducted and submitted for analyses in this report. Therefore, predictions of the T/C ratio were used for 1995. CRiSP used the NMFS prediction from the 1995 study that T/C would be 2.0. This predicted T/C value was used to produce a median D value for post-1979. First, a geometric mean is the appropriate statistic for describing the central tendency of a set of ratios (*see below*), not the median. Second, the actual 1995 T/C ratio (including smolt subjected to bypass mortality) for wild spring/summer chinook was 1.76. However, a T/C of 0.86 was observed for wild smolts that were not detected at collector projects (smolts past dams via spill and turbine) (R. Kiefer, IDFG, personal communication). Kiefer's T:C value of 0.86 is important in that it shows the lower mortality of smolts that are not bypassed and suggests that the true in-river survival rate is greater than that of control fish. The lower T/C value of Kiefer also indicates that the "controls" used in T/C studies are not true controls, as indicated in Mundy et al.'s (1994) review.

Measures of central tendency of a set of ratios

Anderson uses the median as a measure of central tendencies in different time periods in the current hypothesis (Anderson 1998b), but he used the arithmetic mean in the first version of the D ~ f(descaling) hypothesis (Anderson 1997). Use of the median of a series of Ds can either overestimate or underestimate the true central tendency. The average of the time series is also incorrect; it is always an overestimate (unless each value is identical). The correct metric to use is the geometric mean. This is because D is the ratio of two survival rates, with the choice of numerator and denominator (i.e. whether it's the ratio of transported to non-transported survival, or vice-versa) being arbitrary; and the range of possible values of D is not symmetrically distributed about 1 (i.e. D cannot be < 0, but can be much greater than one).

D is estimated from T/C study data in both CRiSP and FLUSH by applying an annual scalar, namely V_c/V_t, for each year corresponding to an annual study. V_c is the survival rate to Bonneville Dam tailrace of "control" (non-transported) fish from the control release point and V_t is the survival rate of transported fish from collection to Bonneville Dam tailrace (assumed to be .98). Since D is simply a T/C ratio estimate multiplied by a scalar, and statistics appropriate to ratios are used in estimating T/C confidence intervals (e.g. log transforming of T/C estimates and variances in Harmon et al. 1993), one should use the geometric mean as the measure of central tendency of D. As Zar (1984) writes (p. 24): "The geometric mean may also be computed as the antilogarithm of the arithmetic mean of the logarithms of the data. It is appropriate only when all the data are positive values (and if the data are not all equal, the geometric mean is less than the arithmetic mean). *This measure finds use in averaging ratios where it is desired to give each ratio equal weight*, and in averaging percent changes…" (emphasis added).

Our point about geometric mean being the proper statistic to use can be illustrated with the data used in CRiSP. Here, we instead use a very simple example. Suppose there are two estimates of D which one has reason to believe are equally valid. For clarity of illustration, we choose very different values: 0.2 and 5.0. What is the best guess at what D really is? The first estimate implies that *non-transported* fish survive 5 times better, while the second indicates that *transported* fish survive 5 times better. Phrased this way, it is obvious that there is no reason to conclude that either survives better, and although the variance is large, the most likely value of D is 1.0. But the average of the two ratios of transported to non-transported survivals is 2.6, as is the median. The geometric mean, however, correctly gives a value of 1.0. If we expressed D as the ratio as non-transported fish survival to transported survival, the average of the two ratios would be 2.6 in favor of non-transported fish, as would the median. This is exactly contrary to our result with the original choice of numerator and denominator. The geometric mean, however, again gives the correct value: 1.0.

Reanalysis of retrospective and prospective D values under CRiSP hypothesis

The CRiSP TURB4 retrospective application of D uses a constant value for pre-1980 (pre-1980 median D) and a constant value for post 1980 (post-1980 median D). CRiSP is used to calculate annual Ds for T/C study years, and the median of the 1968-79 values is used to represent the pre-1980 water year retrospective D. In the prospective analysis BSM and the alpha model randomly select from a distribution of CRiSP Ds with a mean equal to the post-1980 median. The difference in the median value between prospective D and pre-1980 retrospective D expresses the improvements in transport survival that are thought to have occurred after initial transport problems were resolved. This difference in the prospective and pre-1980 retrospective D thus has a large influence on system survival and consequently the spawning escapement results (Figures 3-9, 3-27, and 3-28 of July 3, 1998 WOE). However, the division of periods seems to be inconsistent with a correct analysis of the reported CRiSP D values. The 1978 and 1979 D values (geometric mean of 0.708) are more consistent with the post-1980 values (geometric mean of .664) than the pre-1977 values (Table 1), since the passage years used in the retrospective analysis start in 1977.

Table 1. D and ln(D) for each Snake R. transport study, estimated from CRiSP and descaling hypothesis. First two columns reproduced from Table 1 in Anderson (1998a).

Year	D	ln(D)	**Period**	Median	Average	**Geomean**
68	0.519	-0.65585	**68-76**	0.139	0.187	**0.100**
69	0.655	-0.42312	**78-79**	0.378	1.305	**0.708**
70	0.356	-1.03282	**86-95**	0.633	0.676	**0.664**
71	0.129	-2.04794	**68-79**	0.174	0.466	**0.163**
71	0.139	-1.97328	**78-95**	0.571	1.025	**0.688**
72	0.072	-2.63109				
72	0.075	-2.59027				
73	0.184	-1.69282				
73	0.247	-1.39837				
75	0.084	-2.47694				
75	0.14	-1.96611				
76	0.022	-3.81671				
76	0.164	-1.80789				
76	0.004	-5.52146				
76	0.011	-4.50986				
78	0.298	-1.21066				
78	3.43	1.23256				
78	2.208	0.792087				
78	0.378	-0.97286				
79	0.209	-1.56542				
86	0.571	-0.56037				
89	0.695	-0.36384				
94	0.554	-0.59059				
95	0.885	-0.12217				

A total of five T/C studies were conducted for 1978 and 1979; no controls returned to enable a T/C estimate from the 1977 study. An F test of the variance of the ln(Ds) in the period 1968-1976 and 1978-1979 shows no difference in the variance, while a t-test on the two periods showed the geometric means are different (Table 2). The geometric means for the 1978 and 1979 Ds are not significantly different from the geometric mean of the post 1980 Ds (p=.92, two tailed test). Thus it seems the use of retrospective D values calculated from a pre-1980 and post-1980 period is arbitrary. The real difference in periods, under the Anderson hypothesis and using CRiSP estimates of in-river survival, appears to be between pre-1977 and post-1977 D values (Table 2). In fact, full-scale transportation did not begin until 1977. Splitting the D values into a pre-1980 and post-1979 period, and using the median of D estimates corresponding to each T/C study, greatly overestimates the difference between prospective and retrospective D values in water years 1977-1979.

Table 2. Test for between-period differences in geometric mean of D estimates (from Anderson 1998). Average and variance of ln(D) were used in tests.

Periods tested:	68-76 vs. 78-79	78-79 vs. 86-95	68-76 vs. 78-95
N(1)	15	5	15
N(2)	5	4	9
Variance (1)	1.95	1.60	1.95
Variance (2)	1.60	0.0467	0.821
F value	1.22	34.3	2.38
P for F test	0.467	0.0077	0.110
Equal variance assumed in t-test ?	Yes	No	Yes
T-value	-2.77	0.112	-3.69
P for t-test (two tailed)	0.0126	0.916	0.00129

We provide an example of how implementing the correct D value for CRiSP TURB4 in 1977 through 1979 would influence the ratios of system survivals input into the BSM, through system survival expressed as the term $\ln(\omega_{prospective}/\omega_{retrospective})$ (system survival is the number of inriver smolts below BON divided by the population at the head of the first project). We replaced the current retrospective median D value of .174 for 1977 through 1979 with the geometric mean value .708 for 1978 and 1979, and the prospective (86-95) median D value of .633 with the geometric mean .664. The mean of the $\ln(\omega_{prospective}/\omega_{retrospective})$ for A1 is 0.67 using the original median D1 (0.174) for the pre-1980 retrospective D value (Figure 2). The mean of the $\ln(\omega_{prospective}/\omega_{retrospective})$ for A1 dropped to .428 using the pre-1980 retrospective geomean D value of .708 (D2). The difference for A2 is similar (Figure 3, this report). The pattern of $\ln(\omega_{prospective}/\omega_{retrospective})$ for A1 between D1 and D2 (Figure 1) is similar to the patterns in figure 3-28 of the July 3 WOE which compares the Old CRiSP D with New CRiSP D values. Therefore, one would expect a drop in the average jeopardy probabilities in the range between model runs with Old D and New D. The correct implementation of D will undoubtedly result in a drop in the CRiSP survival and recovery probabilities, especially for A1 and A2.

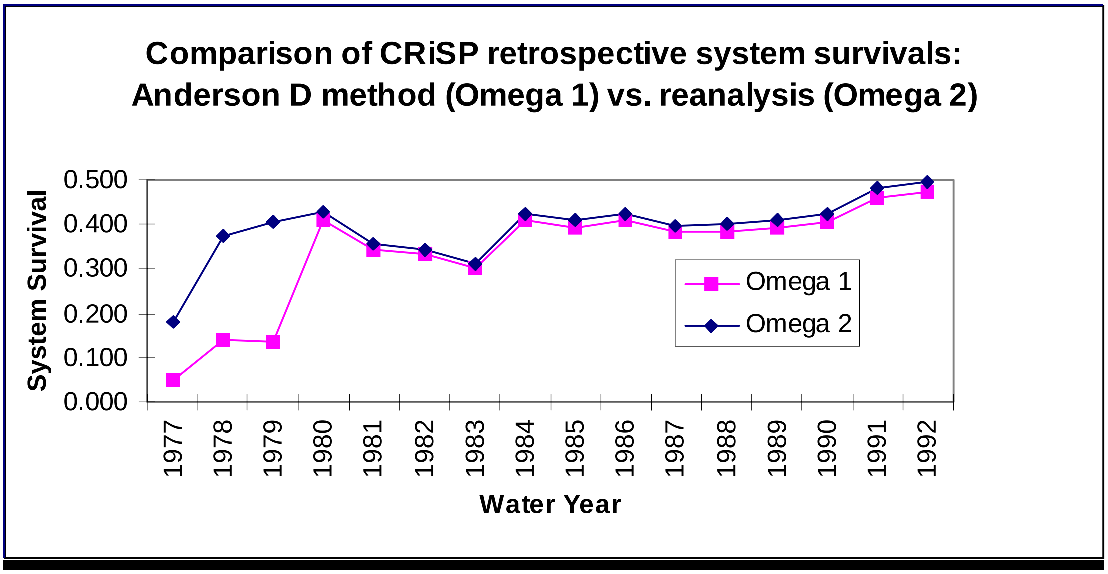

Figure 1. Comparison of CRiSP system retrospective survivals under two methods: 68-79 median D (pre-1980) and 86-95 median D (post-1979) (Omega 1); and 68-76 geometric mean D (pre-1980) and 78-95 geometric mean (post-1979) (Omega 2).

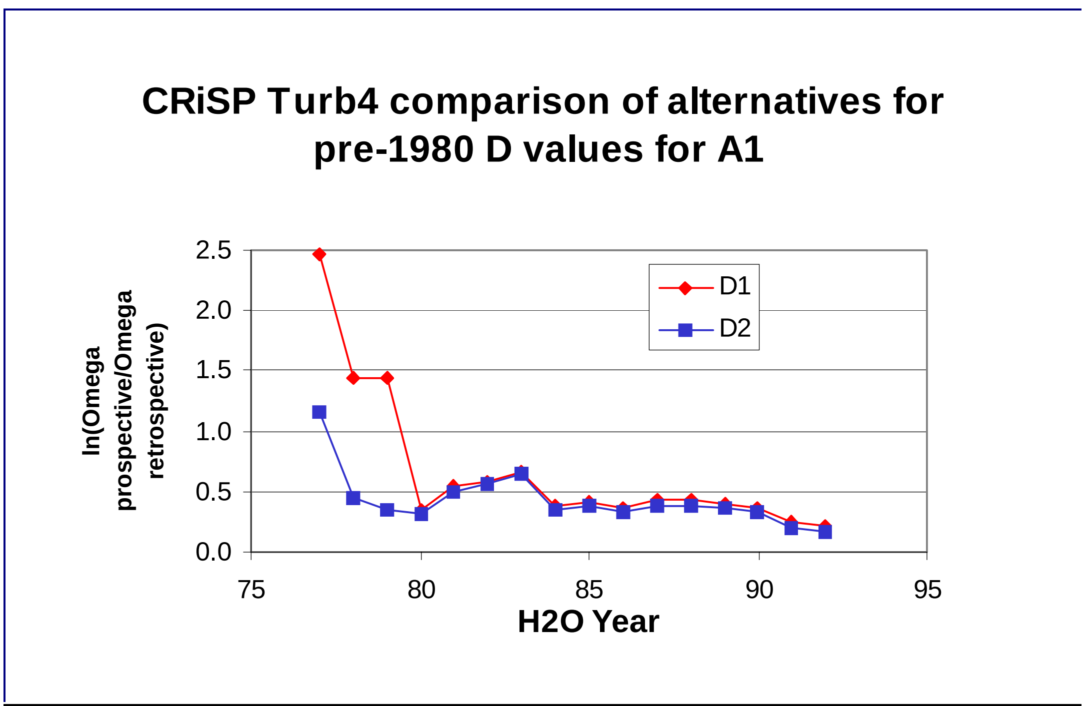

Figure 2. Comparison of ratio of A1 CRiSP system survivals to retrospective CRiSP system survivals, using Omega 1 (D1) and Omega 2 (D2) values (see Fig. 1 and text for explanation).

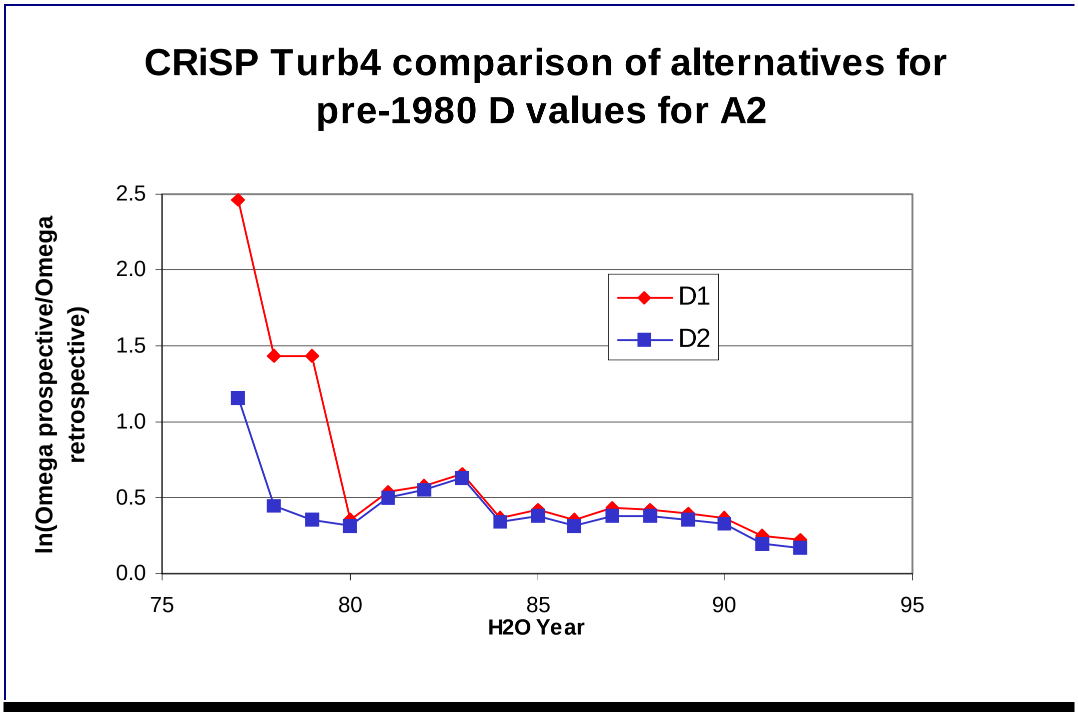

Figure 3. Comparison of ratio of A2 CRiSP system survivals to retrospective CRiSP system survivals, using Omega 1 (D1) and Omega 2 (D2) values (see Fig. 1 and text for explanation).

It should also be noted that the retrospective, pre-1980 median D value used in the prospective life-cycle modeling included the effect of the 1976 D estimates in Anderson's (1998a) Table 1. They were excluded only from the regression of D estimates vs. descaling; *they were not excluded from calculation of the pre-1980 D value used in the life-cycle modeling*, even though, as Anderson (1998a) notes: "The 1976 D values were also identified as outliers because this was a year of high spill and the CRiSP passage model underestimated the observed survivals by a significant amount." This statement is confirmed by inspection of Figure A.2.1-16b in PATH Preliminary Decision Analysis Report on Spring/Summer chinook (February 5, 1998). Because D is positively related to V_c and there are four T/C estimates for 1976, this is another factor contributing, under his model of transportation survival, to an underestimate of retrospective D, and hence a spuriously high ratio of prospective to retrospective system survival. The average, median, and geometric mean D's for the same periods as shown in Table 1 are reproduced below, this time without the 1976 values (Table 3).

Table 3. Recalculation of pre-1977 and pre-1980 D central tendency measures, excluding 1976.

Period	Median	Average	**Geomean**
68-75	0.140	0.236	**0.180**
68-79	0.228	0.570	**0.276**

A comparison of Table 3 to Table 1 demonstrates that the pre-80 median D, used in the life cycle modeling, increases from 0.174 to 0.228, an increase of 31%. The pre-1980 geomean D increases by 69% (.163 to .276). Still, the true distinction between periods appears to be pre-1977 and post-1977. The pre-1977 geometric mean D increases by 80% (.100 to .180).

Influence of control survival rate estimates on Ds under the two hypotheses

The influence of inclusion of D estimates from a year when CRiSP significantly underestimated in-river survival was described above. The impact of the TURB4 assumption on pre-1980 V_c's, and hence on pre-1980 D's, is more dramatic, and incompatible with Anderson's (1998b) critique of FLUSH.

Anderson (1998b) has criticized the FLUSH model for hypothesizing that the rate of mortality of smolts is affected by their experience in passing through the hydrosystem. In the FLUSH model, impacts such as descaling and energy depletion from dam and reservoir passage are hypothesized not only to instantaneously kill some smolts; the cumulative effects are posited to weaken some of the survivors and decrease their probability of surviving a given day as they migrate lower in the hydrosystem. He writes, "It requires that the longer fish are in the river the greater their mortality. A biological mechanism that imposes such a strong effect on mortality, is to the best of my knowledge, unknown and unobserved" and "In comparison, the CRiSP model does not have the problem of indeterminancy conditioned on the past history, since the mortality rate is independent of past history." A more detailed response to this criticism is provided in Appendix 22.

Below, CRiSP values for total (5-project—1968, 7-8 project—1971 on) in-river survival rates are reproduced for several years prior to 1980, when the TURB4 hypothesis claims that descaling at dams led to high levels of mortality. For these years, CRiSP adjusted control survival rate estimates for transport studies are also reproduced. The adjustments are made for those years when control fish were transported upstream of the collection project and forced to migrate through that project a second time.

Table 4. CRiSP V_n's and V_c's, selected years. V_n's are from C. Toole spreadsheet A0diag4.xls, and Figure A.2.1-16b in PATH Preliminary Decision Analysis Report on Spring/Summer Chinook, February 4, 1998. V_c's are from Anderson (1998a).

Year	Total In-river surv (Vn)	LGR Vc	LGO Vc	IHR Vc
1968	37.6%	N/A	N/A	24.6%
1971	9.6%	N/A	8.2%	N/A
1972	14.6%	N/A	6.6%	N/A
1975	13.0%	8.8%	N/A	N/A
1976	4.8%	4.2%	4.7%	N/A
1979	15.7%	13.7%	N/A	N/A

As can be seen in Table 4, in these years control survival rate is always less than total in-river survival rate; in some years the control survival rate is substantially less than the full hydrosystem rate. This is also seen in Figure 3-24 in the draft Weight of Evidence Report. The control reach is always at least one reservoir less than the total hydrosystem reach; sometimes it is two reservoirs and one dam shorter. The only way CRiSP control survival rates can be less than the total survival rate is for the cumulative impacts of passage experience, through multiple dam passage and represented by V_{stress}, to lower the survival rate of "control" fish that were forced to pass the collection dam one more time than run-of-the-river (non-control) fish. In Anderson's V_{stress}

equation, descaling mortality of non-transported fish is "resolved" in 6 days (Anderson 1998a). Since no change in migration rate of these fish is posited or modeled, control fish thus stressed should complete the migration from point of release to the end of the hydrosystem in the same amount of time as run-of-the-river fish. Therefore, under this hypothesis, the mortality rate per day of smolts increases with cumulative hydrosystem passage effects. Of course, descaling also occurs at non-collector projects, and if the hypothesis about the collector dams is true, descaling should be causing mortality in these lower reaches as well. This effect is similar in theory to that which Anderson has criticized FLUSH for and which is implicitly assumed in fitting the reservoir survival function to empirical estimates of survival over reaches of different length. In actuality, in years with high descaling rate estimates, the TURB4 effect is much more dramatic than that which is assumed in FLUSH.

Unlike CRiSP, the FLUSH T/C vs. V_c relationship does not depend on passage model survival estimates before 1986. The FLUSH relationship relies on control survival rates derived from simple expansion of empirical survival rate estimates from 1971-1979 (PATH Preliminary Decision Analysis Report, Appendix A p. 79). FLUSH control survivals are always greater than total in-river survival (Figure 3-24, WOE report), as the control reach each year, including those years where control fish passed through the collection project twice, is always shorter (includes fewer dams + reservoirs) than the total hydrosystem. Williams et al. (1998) express concern that overestimation of survival rate in 1971 by FLUSH leads to a mis-estimation of D, potentially introducing significant error in the prospective modeling results. The 1971 survival estimate was not used in calibrating FLUSH. Predictions from that year are not used in the prospective life cycle modeling. No survival estimate of any kind from FLUSH that year has any other significant influence on the T/C vs. V_c relationship or D values used in prospective modeling. It has no impact on the reservoir survival function, or any effect on prospective modeling results, since only water years 1977-92 are used. The overestimation in 1971 (because it was a very high flow and spill year, combined with ghost turbine bays and no spill deflectors to mitigate the gas bubble trauma [GBT] impacts of these enormous spills) is not worrisome. Since the dams have been finished and improved since that time, the same kind of mortality due to GBT under those water conditions as in the past are not expected. In fact, in 1997 huge flows and spills, on the order of those in 1971, were recorded, yet estimated survival was high and there was little evidence of GBT in the Smolt Monitoring Program.

Williams et al. (1998) also raise doubts about FLUSH control survival rates used in other retrospective years. They state that FLUSH estimates appear "quite high relative to Raymond (1979) estimates." They use FLUSH results calibrated to TURB4 assumptions about pre-1981 turbine and bypass survivals. The STFA analytical team has repeatedly criticized and questioned the credibility of TURB4; more detailed critiques are provided in Appendix 22. TURB4 was modeled with FLUSH not because the STFA analytical team believes it is likely to be correct, but because it is one of the several dam survival hypotheses that were supposed to be run with both passage models in this process. The assumption of TURB4 mortality during the 1970s has a large effect on the FLUSH reservoir survival relationship (PATH Decision Analysis Report, Figures A.2.1-8 and A.2.1-9). It also results in a poorer retrospective fit to the empirical reach survival data than TURB1 and TURB5 (WOE report Table 4-4), and a poorer fit to the S-R data with the Alpha model (WOE report, Table 4-2). Comparing FLUSH TURB4 survival estimates to the Raymond estimates is not a proper test of the STFA hypotheses.

The effect of mismatched TURB assumptions and descaling on 'D':

An additional problem with the implementation of D values in the CRiSP model is the use of the wrong D values for TURB1 and TURB5 assumptions. The TURB4 retrospective D values were used for all three TURB assumptions. That is, if V_n's are estimated using TURB1, the Vc should be estimated with TURB1. The problem applies to the retrospective D values used in 1977 through 1979 migration years, since under Anderson's descaling of in-river fish hypothesis, extra bypass mortality occurred to fish passing dams prior to 1981 (PATH Decision Analysis Report 1998). D values in these years (as in all years) are affected by estimates of V_c [since $D = (T/C)*(V_c/V_t)$], and the V_c values calculated by CRiSP should be estimated using consistent TURB assumptions. The pre-1980 median D value of 0.174 for TURB4 increases to 0.308 for D values calculated using CRiSP TURB1 Vc's (Anderson 1997). The geometric mean value for 1978 and 1979 was 0.708 for TURB4 and the value increased to 0.747 for TURB1. The implementation of consistent TURB4 assumptions with D values has the potential to significantly affect the results, leading to reduced probabilities of exceeding jeopardy standards. This is because 75% of the 106 CRiSP runs that favored A1 or A2 over A3 were with TURB1 or TURB5 assumptions about in-river survival, mismatched with TURB4 V_c estimates.

As discussed above, D values are also sensitive to the ratio of in-river survival of the control fish (V_c) to survival of transported fish (V_T). As V_T is unaffected by assumptions about dam survival at projects below the collection point, only changes in V_c affect this ratio. Anderson (1998a) suggested that in-river survival is affected by descaling where V_c is now a product of hydrosystem survival (V_n) and descaling survival (V_{stress}). Therefore, an estimate of D is now equal to $T/C*(V_n*V_{stress})/V_t$. However, the tagged fish in the T/C studies included only fish that were **not** descaled: "fish that are diseased, descaled, previously marked, or in poor condition are systematically removed from the experimental lots (Smith et al. 1988, Matthews et al. 1988)" (Mundy et al. 1994). The importance of this observation is that D is calculated from an observed value on fish that are not descaled mixed with survivorship of fish that are descaled. T/C ratios would be very different if descaled fish had been used in these experiments, if Anderson's hypothesis is to be believed. In fact, D is extremely sensitive to descaling; a change from 0% to 1% descaling causes D to decrease by 15% (Figure 4).

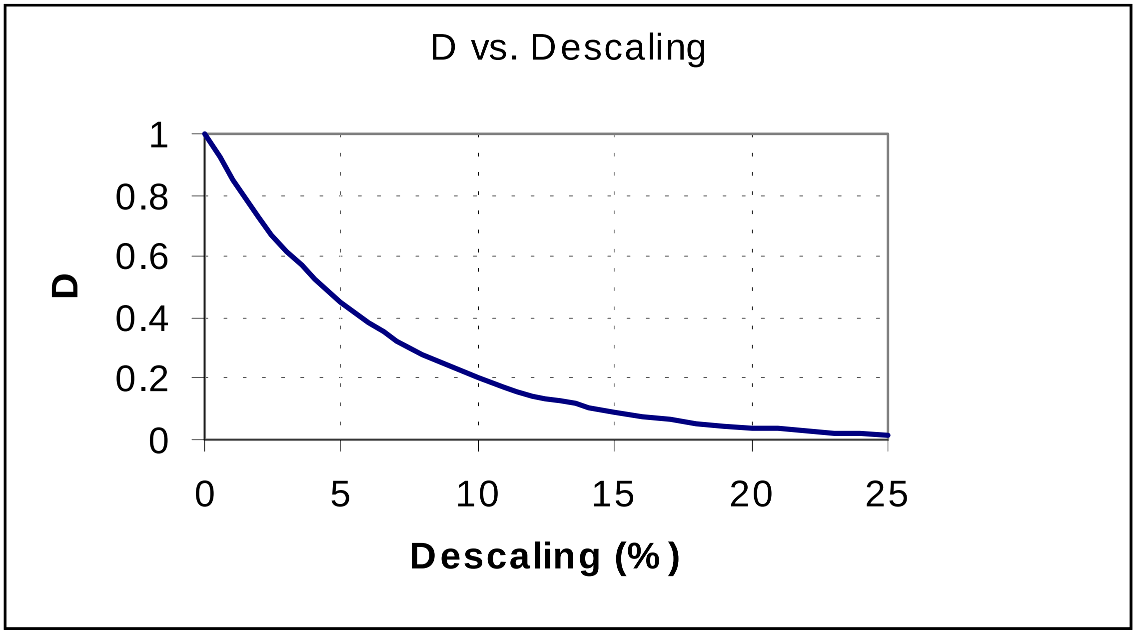

Figure 4. Predicted D under J. Anderson's January 12, 1998 hypothesis.

We agree with Collie's (1998) conclusion that "the most serious problem with these data is that descaled salmon were removed from transport experiments negating any relationship between the reported descaling rates and the estimates of D."

D is the ratio of post-hydrosystem mortality of transported to non-transported fish. If bypass facilities cause a high rate of descaling, then D will likely be low as descaling mortality would occur in the hydrosystem for non-transported fish (since Anderson's hypothesis assumes mortality due to descaling occurs within 6 days for non-transported fish) and in the post-hydrosystem for transported fish. Under his TURB4 hypothesis about bypass and turbine survival of in-river fish, Anderson decreases D for earlier years by applying the descaling function to estimate V_n (and hence V_c), and then stops applying this function after 1980, presumably to represent the improvements in collection facilities (PATH Decision Analysis Report on Spring/Summer Chinook, 2nd Draft, Appendix A, Section A.2.3). However, descaling continues to occur post-1980 (Figure 5). Applying the TURB4 descaling relationship to recent estimates of descaling (coinciding with the latest turbine survival studies) of yearling chinook is instructive. For instance, these vary from 0.9 % in 1995 @ LGR to 9.2% in 1993 @ LMN (Table A.2.3-3 in Decision Analysis, 2nd draft). These descaling values correspond to 3.1% and 27.4% mortality (96.9% and 72.6% survival), respectively, using Anderson's relationship. Going back earlier in the post-1982 period, descaling gets as high as 18.4% (1983 @ LGR), resulting in 47.3% mortality. This could substantially decrease expected future D's. We suggest that actual descaling estimates be used rather than assuming that after 1980 descaling is no longer a problem.

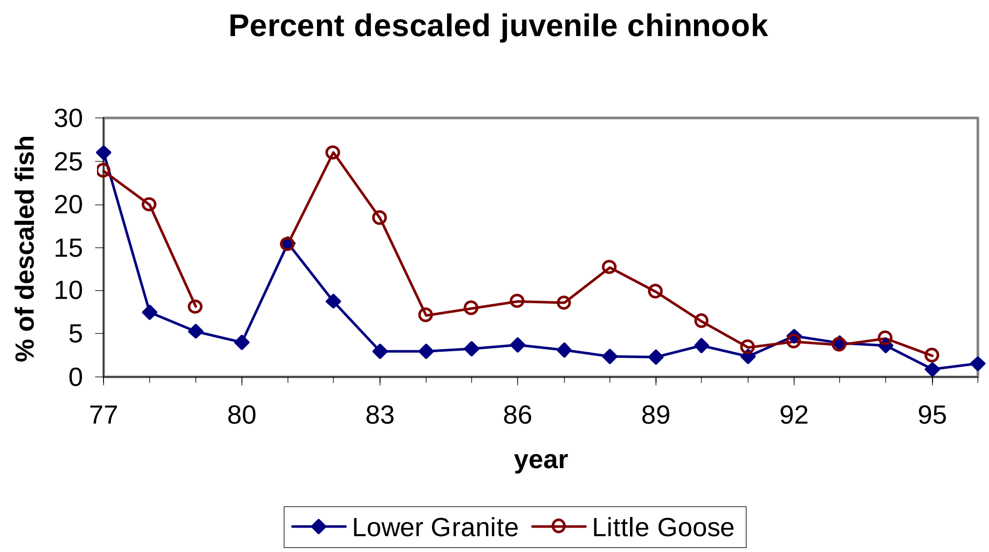

Figure 5. Descaling rates at upper two projects. From Preliminary Decision Analysis Report, Table A.2.3-3.

The 1986 and 1989 D estimates in CRiSP assumed no effect of descaling, as TURB4 includes the assumption that negative impacts from descaling at dams vanished after 1980. Since no plausible reason has been given why descaling was so deadly prior to 1981 but innocuous afterward, the V_c estimates used to calculate 86-95 D should include mortality represented by the V_{stress} equation of Anderson (1998a). This would lower D's estimated for prospective and post-1980 retrospective periods, and hence act to lower the geometric mean ratio of prospective to retrospective system survival.

Evidence regarding whether 'D' is increasing

New CRiSP D values (i.e., those based on Anderson [1998a] and included in WOE report) indicate that a 3.8 fold improvement in post-hydrosystem survival of transported fish relative to that of non-transported fish occurred after 1979 (Figure 3-27 in WOE report). Since 1980, SARs of transported fish have been consistently less than the 2% to 6% interim goal defined in PATH (Marmorek and Peters 1998). Not only have SARs remained extremely low, there is no indication that the gap has narrowed between performance of Snake River stocks and down river stocks, as might be expected if transportation and hydrosystem improvements were merely masked by generally poor ocean conditions for all stocks. The differential mortality between Snake River and downriver stocks ("mu") did not decrease over time: the mean of mu by period was 1.5, 1.5, 0.8, 1.5 and 2.1 for 1972-1974, 1975-1979, 1980-1984, 1985-1989, and 1990-1992 brood years, respectively (Deriso et al. 1996; Fig. 5-5). The differential mortality increased significantly (ibid.) as water velocities decreased during the smolt migration. Examination of these data does not support a hypothesis that migration conditions, including transportation survival, were continually improving for Snake River stocks compared to downriver stocks.

References

Anderson, J.J. 1997. Critiques on transport and extra mortality hypotheses. Draft PATH document, December 22, 1997.

Anderson, J.J. 1998a. Critique on transport and extra mortality hypothesis. PATH document. PATH document. January 12, 1998 (Included in February 5, 1998 submission to SRP).

Anderson, J.J. 1998b. Weight of evidence for passage, transport, extra mortality, and aggregate hypothesis. July 27, 1998.

Deriso, R., D. Marmorek and I. Parnell. 1996. Retrospective analysis of passage mortality of spring chinook of the Columbia River. Chapter 5 *In*: Marmorek, D. R. and 21 co-authors. 1996. Plan for analyzing and testing hypotheses (PATH): final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies, Ltd., Vancouver, B.C.

Deriso. R. 1998. Some comments on the paper "Critiques on transport and extra mortality hypotheses" (J. Anderson, Dec 22, 1997). Draft dated January 9, 1998.

Harmon, J.R. and 5 co-authors. 1993. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1992. Annual Report of Research, Corps of Engineers and NMFS.

Mundy, P.R. and 9 co-authors. 1994. Transportation of juvenile salmonids from hydroelectric projects in the Columbia River Basin: an independent peer review. Final Report, U.S. Fish and Wildlife Service, 911 N.E. 11th Ave, Portland OR 97232.

Williams, J., S. Smith, T. Cooney, and C. Toole. 1998. Compilation of comments on Draft PATH weight of evidence report. Memo to D. Marmorek and C. Peters. July 27, 1998.

Zar, J.H. 1984. Biostatistical analysis. Second edition. Prentice-Hall Inc, Englewood Cliffs, N.J. 718 p.