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December 10, 2002

Tom Karier
Northwest Power Planning Council
Spokane Office
851 SW 6th, Suite 1100
Portland, OR 97204-1348
November 12, 2002

Dear Mr. Karier:

Following is our response to your November 7, 2002 data request, which is a set of nine specific questions regarding the October 14, 2002 Fish Passage Center memorandum entitled, " Preliminary Update on Juvenile Migration Characteristics". The October 14, memorandum is an update provided to the state, tribal and federal fishery managers on progress made to that date on our assignment to summarize data and analysis that addresses the question of the relationship between flow and survival of spring migrating fish. Work has been continuing on that assignment and substantial analysis has been added since the preliminary update. Many of your questions address components of our complete analysis. We have organized our response according to your specific questions, which are presented in bold print. In accordance with our normal procedures we have provided copies of this response to Columbia Basin Fish and Wildlife Authority members and as a courtesy to other Northwest Power Planning Council members and staff.

1. Your sample seems to be limited to yearling chinook and steelhead. What time of year are these steelhead migrating? Do you have similar results for subyearling chinook or other summer migrants?

Our specific assignment was directed at spring migrating fish. The PIT tagged data used in the travel time and survival analyses span the time period from April 1 to May 26 for yearling chinook and April 17 to May 28 for steelhead in the Snake River reach. April 21 to June 1 for both yearling chinook and steelhead in the Mid-Columbia River reach and April 25 to June 5 for yearling chinook and May 11 to June 8 for steelhead in the Lower Columbia River. Because the start and end of the major part of the migration season varies from year to year, there are years in which too few PIT tagged fish are available to meet the minimum criteria of at least 300 PIT tagged smolts for estimation purposes. Therefore, the actual range of dates of PIT tagged fish used in the analyses may vary across the years, but it will always be a subset of the overall date range shown above. Steelhead and yearling chinook migration passage data is available for spring and summer migrating salmon and steelhead. Passage timing for all species is summarized in Fish Passage Center Annual Reports. Passage timing data is available for the run at large and also by specific mark groups.

When considering specific fish passage operations, specific stock passage timing is considered, since individual stocks have differing passage patterns. As an example we have included the individual passage distribution patterns of PIT tagged yearling hatchery and wild chinook at John Day Dam. Although spring chinook stocks are present at John Day Dam from early April to mid-June, the following graph show that operations that might decrease flows and or spill in April at the John Day project, would impact John Day River wild chinook, Umatilla River hatchery and wild chinook and Yakima River wild chinook more than other chinook stocks passing the John Day project.

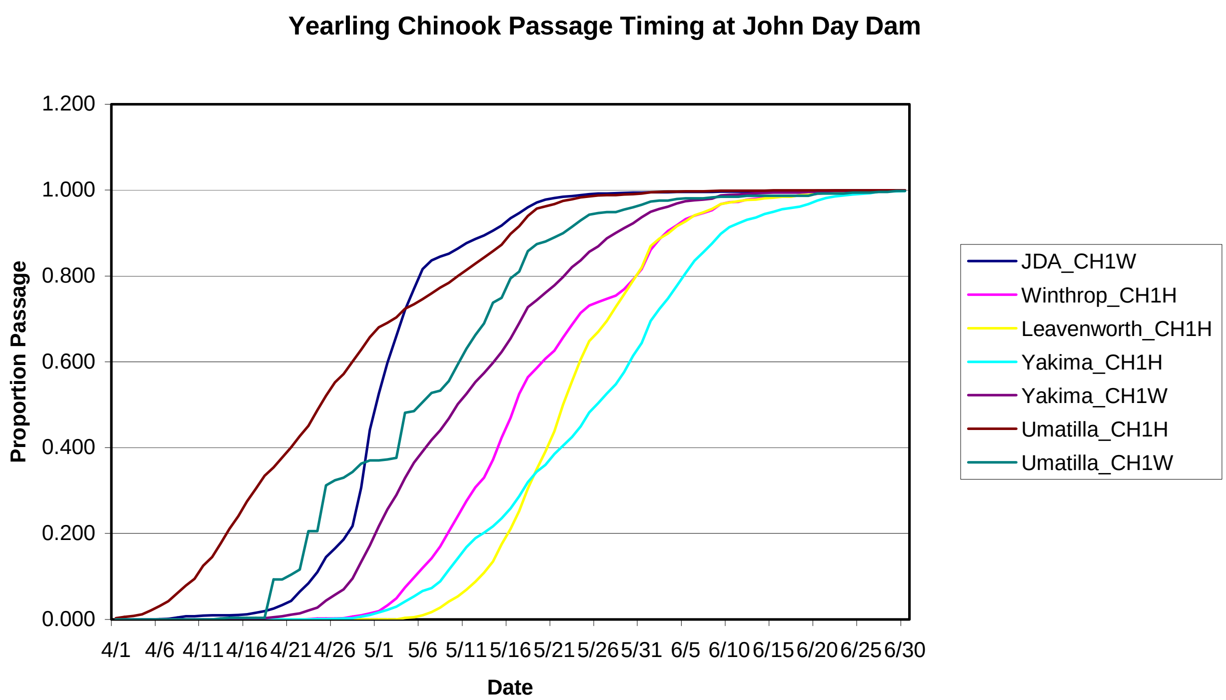

Figure 1. Yearling chinook passage timing at John Day Dam.

Flow conditions can affect passage timing, travel time and passage index magnitude. In particular the historic data shows that in low flow years passage timing can be truncated causing passage-timing distribution to be shifted earlier. Passage distribution and timing is based upon the arrival of survivors to downstream sites. In low flow years the passage distribution can be truncated because survival can decrease as the flows decline throughout the passage season. In low flow years the 90% point of passage can occur on earlier dates than in higher flow years, having the effect of compressing the passage distribution.

An extensive study of the Snake River fall chinook conducted by the US Fish and Wildlife Service has been underway since 1992. This study and others have explored the migration characteristics of subyearling fall chinook in relation to environmental variables such as flow and water temperature. Theses studies have documented the migration timing of fall chinook in the Snake River. July and August are the primary months of the year when wild subyearling Snake River fall chinook salmon pass downstream in Lower Granite Reservoir (Connor et al. 2000, 2001, 2002). Passage in Lower Granite Reservoir takes a considerable amount of time. For example, Connor et al. (In press a) estimated the wild subyearling fall chinook salmon from the Snake River spent from 20 to 57 days in Lower Granite Reservoir.

In addition, these studies address how summer flow augmentation influences flow and temperature in Lower Granite Reservoir. These studies have documented that releases of stored water from Dworshak Reservoir and reservoirs upstream of Hells Canyon Dam undoubtedly increase flow in Lower Granite Reservoir during July and August when wild subyearling chinook salmon are in the reservoir (Connor et al. 1998, In press b). For example, flow in Lower Granite Reservoir increased from approximately 600 to 1,250 m^3/s when summer flow was implemented in 1994. Increases in Lower Granite Reservoir flow associated with augmentation in July and August were also documented for the years 1992,1993, 1995, 1998, and 2000 (Connor et al. and In press b). Releases of stored water from Dworshak Reservoir undoubtedly decrease the temperature in Lower Granite Reservoir. For example, in 1992 temperature declined from 20 to 17^{o}C because of releases of cool water made from Dworshak Reservoir (Connor et al. 1998). Numerous other examples of temperature decreases in Lower Granite Reservoir caused by releasing cool water from Dworshak Reservoir are given in Connor et al. (1998, and In press b). The only peer-reviewed studies on survival of wild subyearling Snake River fall chinook salmon survival (Connor et al. 1998, In press b) provide strong evidence for a relation between flow and survival, and between temperature and survival. Both studies showed that survival increases as flow increases and temperature decreases, and that these two environmental variables act simultaneously to influence survival. In both studies, the authors concluded (after rigorous independent peer-review of their analyses and results) that summer flow augmentation during July and August increased survival of summer migrants.

In addition to peer-review during publication, the U.S. Fish and Wildlife Service study results were also reviewed during 2001 by an Independent Scientific Advisory Board (ISAB) appointed by the Northwest Power Planning Council to objectively evaluate the efficacy of summer flow augmentation. The ISAB (2001; page 3) made the following recommendation to the Northwest Power Planning Council.

> "Flow augmentation should continue, largely because Connor's studies show benefits for wild fish.........."

Several publications have been completed as a result of this study, and others, which address the passage characteristics of sub yearling migrants. These in addition to Berggren and Filardo (1993) are listed on the attached page.

2. Is it possible to identify BIOP flow targets in the Figures? This would essentially be the particular water transit time that corresponds to a given flow target in the BIOP.

Yes, we have identified the water transit times that result from the BIOP flow. The following three figures demonstrate the relation between flow and water transit time through the Lower Snake River, the McNary Pool, and the Middle Columbia River. Figure 2 displays the relation between water transit time from Lower Granite Dam to Ice Harbor Dam and the average Discharge at Little Goose, Lower Monumental and Ice Harbor dams; the Spring Biological Opinion flow range at Lower Granite is highlighted. From Figure 2, water transit time would be approximately 7.7 days between Lower Granite and Ice Harbor at an average flow of 85 kcfs (lower range of BiOp). At an average flow of 100 kcfs (upper range of BiOp), water transit time would be approximately 6.6 days between the same points.

Figure 3 displays the relation between water transit time from Ice Harbor Dam to McNary Dam and average Discharge at McNary Dam; the Biological Opinion flow range at McNary is highlighted. From Figure 3, water transit time would be approximately 3.0 days between Ice Harbor and McNary at an average flow of 220 kcfs (lower range of BiOp) and 2.5 days at a discharge of 260 kcfs (upper BiOp range).

Figure 4 displays the relation between water transit time from Rock Island Dam through the Hanford Reach and average discharge at Priest Rapids Dam; the Biological Opinion flow range at Priest Rapids is highlighted. From Figure 4, water transit time would be approximately 3.7 days from Rock Island Dam through the Hanford Reach at a Priest Rapids discharge of 135 kcfs (Spring BiOp Objective).

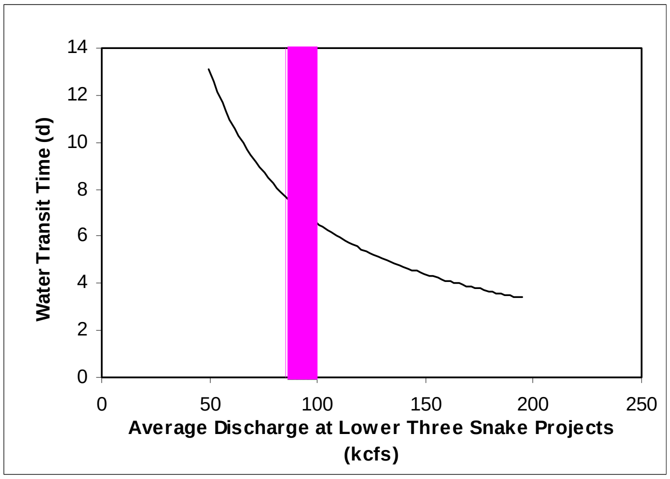

Figure 2 Water transit time between Lower Granite Dam and Ice Harbor Dam as a function of the average Discharge at Little Goose, Lower Monumental and Ice Harbor dams**.** The Biological Opinion flow objective range at Lower Granite (85-100 kcfs) is highlighted.

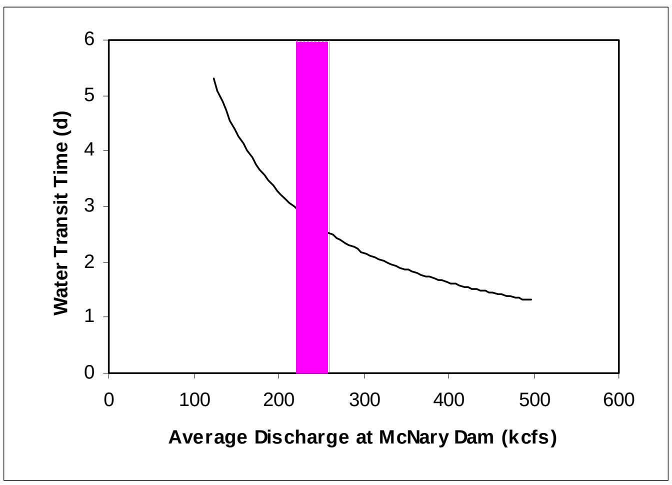

Figure 3 Water transit time between Ice Harbor Dam and McNary Dam as a function of the average Discharge at McNary Dam**.** The Biological Opinion flow objective range at McNary Dam (220-260 kcfs) is highlighted.

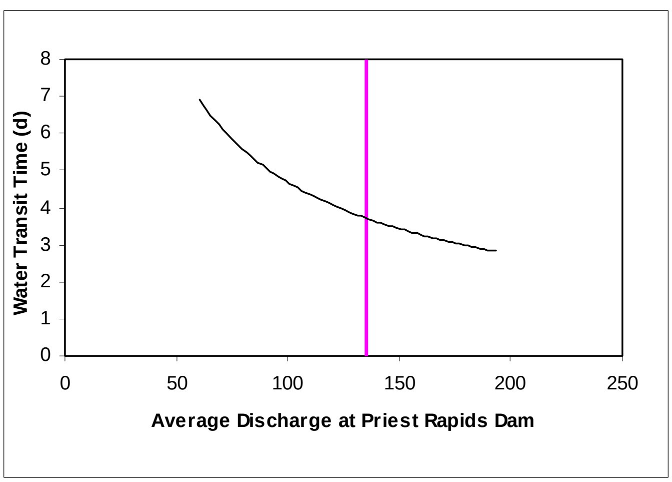

Figure 4 Water transit time between Rock Island Dam through the Hanford Reach as a function of the average Discharge at Priest Rapids Dam**.** The Biological Opinion flow objective at Priest Rapids Dam (135 kcfs) is highlighted

3. What would be necessary to use your estimates to calculate the quantitative impact of flow augmentation actions on water transit time, travel time and survival? Can you do this?

The difficulty in determining the effect of "flow augmentation" is that flow augmentation implicitly means that flow is being added to a level of flow provided for other uses. The present hydrosystem operations as anticipated by the Biological Opinion are the result of consideration and melding of power, flood control, recreation, resident fish and fish passage needs. It is difficult therefore to quantify actual "flow " for fish passage. Flows provided for fish migration also generates power and other benefits. The separation of flows provided for fish benefits versus power or other benefits is an accounting issue that has never been clearly resolved. For example, the accounting of flow for fish or power was raised during the winter months of 2001, when power demand required higher flows during the winter months, which also benefited the natural spawning area below Bonneville Dam. Similar accounting issues have been raised regarding spill. The Biological Opinion identifies specific levels of spill for fish passage; often spill levels are higher because of flood control or flow in excess of power generation needs. The accounting for this excess spill separately from the BIOP spill levels is a prevailing question. We do not know how to accurately and separately account for the amount of flow that results from each of the purposes of system operations. Our analysis addresses the benefit of flow for fish passage regardless of whether the flow is the result of flood control releases or hydropower generation.

The effect of flow increases and decreases on fish travel time can be estimated using the flow/water transit time and travel time relationships developed for specific River reaches. These relationships have been developed over several decades over a wide variation of conditions. The recent data and the historical data have remained consistent over the years. This is because the mechanisms of travel time are less complicated and involve fewer variables. Flow is the direct and determining factor over fish travel time. On the other hand, juvenile survival estimates are an index describing the juvenile migration. Determination of incremental flow and survival is difficult because of the actual complex mechanisms that determine survival. A within year flow survival relationship does not emerge in the present data, not because flow is not important but, because of several factors including the limitations of data collection and analysis. First, juvenile survival is the result of many direct and indirect environmental and biotic variables. By necessity these variables such as flow are described as averages over a period of time. This dampens the effect of that variable. Second, within year flow survival relationships are not apparent from available data because the individual survival release groups overlap and the environmental variables such as flow is averaged over many days and many overlapping release groups. Third, annual estimates of survival address the problem of overlap to some degree, however the annual flow average (even over large groups) had not changed substantially until 2001, when the Biological Opinion measures were not implemented. Our present data shows a significant flow survival relationship as a result of the large change that occurred in the flow variable when the Biological Opinion measures were not implemented.

The FPC identified these issues in memorandums to the Fishery Managers in 1992 and again in 1995 that the problem of excessive overlapping of PIT tagged release groups as they migrate through the study reach will not allow discrete partitioning of the incremental effects of environmental or biotic variables that affect survival. NMFS recognized this phenomenon after implementing the methodology for several years. Smith and Muir (1996) state, "Identifying and quantifying relationships between environmental variables and survival and travel time of release groups of PIT tagged migrant juvenile salmonids have presented difficult challenges. Chief among these is that fish from a single release group do not migrate as a group but spread out over time. If conditions change over a short period of time relative to the time it takes for the bulk of the release group to migrate through a particular river section then different fish from the group experience different levels of various environmental factors. In this situation estimated survival probabilities (defined for the entire release group) are usually valid estimates of average survival for the group. However, it is difficult to accurately quantify the environmental conditions to which the entire release group was exposed and to relate that to the survival estimates. More over, if a series of releases is made and migrations are protracted the various release groups may have considerable overlap in passage distributions, further clouding the relationship between survival probabilities and environmental variables by decreasing the contrast in the levels of exposures among the various groups."

The above problems created by overlapping environmental and biotic conditions within a single year are reduced when comparisons are made across years. Nevertheless, the environmental and biotic conditions observed across years must span a fairly wide range of values to offset the natural variability inherent in them. Therefore the regression analyses demonstrate statistical significant differences in survival due to these environmental and biotic conditions. The year 2001 is so an important in these regression analyses because it defines the true range of conditions that are possible in the present hydrosystem. When 2001 survival data is considered, the FPC analyses demonstrate that statistically significant relations between reach survival of yearling chinook and steelhead smolts and the flow-related variable of water transit time are obtainable. But even these relations do not allow the determination of incremental effects of flow augmentation alone. In our answer to your Question 9, we discuss how spill also influences the smolt survival in the reach by providing the route of highest survival at each dam to the proportion of smolts that utilize that route. Therefore, in every reach survival estimate there are contributions of both spill passage at the dams and flow-related variables in the reservoirs to the overall smolt survival estimates. We have been successful in demonstrating that analyses of survival data must include a series of years in order to get a wide enough range of environmental and biotic conditions to show statistically significant relations between smolt survival and a joint set of predictor variables which include a flow-related variable.

4. Why did you fit a linear curve to figures 2,3, and 4 when the pattern is clearly non-linear?

The equation is actually a linear function. The curve in figures 2, 3, and 4 pertain to smolt travel time as a function of water transit time. As shown in Berggren and Filardo (1993), there is a similar relation between smolt travel time and the reciprocal of flow and between water transit time and the reciprocal of flow. That relation was curvilinear. For salmonid smolts, the relation was TT = intercept + slope*(1/flow) where flow was indexed at Ice Harbor Dam for the paper. Also in that paper, water transit time from Lower Granite Dam to McNary Dam was computed as "three-pool volume"/"IHR flow" plus "one-pool volume"/"(IHR flow +140)" where the 140 kcfs was the average water budget flows of the late 1980's.

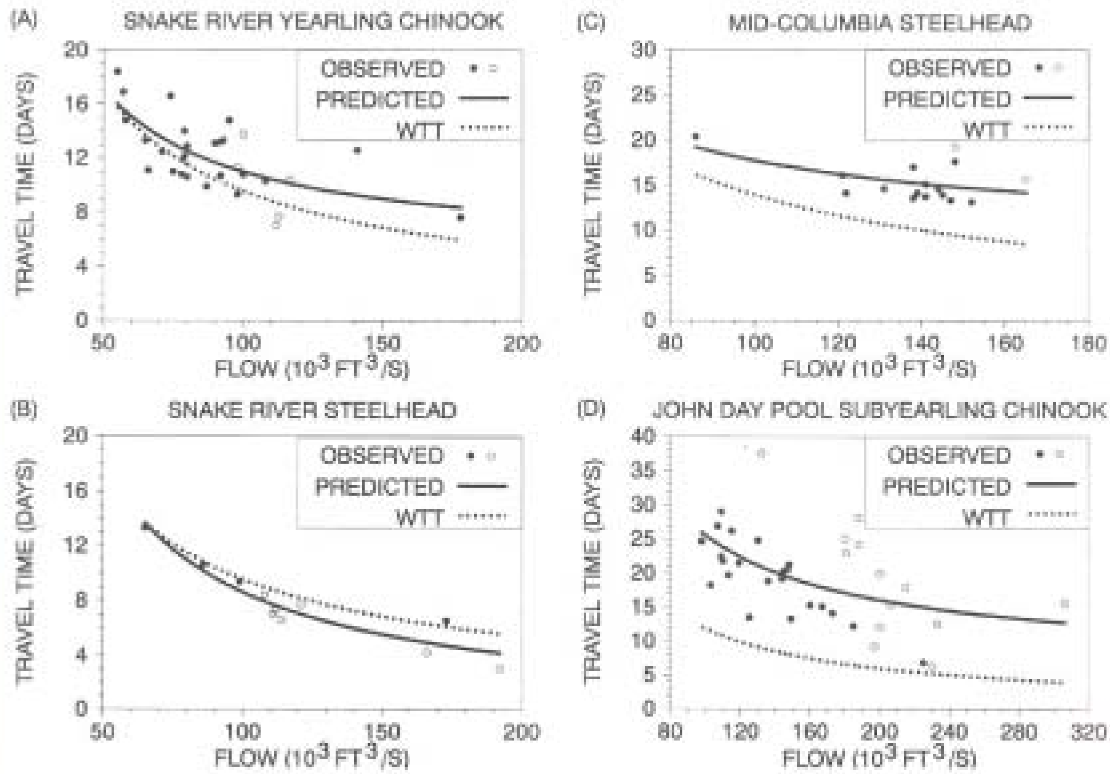

FIGURE 3.—Observed and predicted fish travel time estimates, and estimated water transit time (WTT), versus flow for (A) Snake River yearling chinook salmon, (B) Snake River steelhead, (C) middle Columbia River steelhead, and (D) lower Columbia River (John Day pool) subyearling chinook salmon. Open circles (○) denote pre-water budget years 1981–1983; solid circles (●) denote post-water budget years 1984 and beyond.

In the current calculation of WTT, each of the four pool's volume is divided by its respective flow to produce an individual WTT between each successive dam. The sum of these WTT may be viewed as the overall reach volume (VOL) divided by the average reach flow (FLOW), and written as WTT = VOL/FLOW. This may be rewritten as WTT/VOL = 1/FLOW. The smolt travel time relation is TT = intercept + slope*(1/FLOW), and may be rewritten as (TT-intercept)/slope = (1/FLOW). Since we are relating both WTT and TT to the same average FLOW, the relation between TT and WTT becomes (TT-intercept)/slope = WTT/VOL. This may be rewritten as TT = intercept + (slope/VOL)*WTT. This equation is of the form $Y=b_0+b_1X$ which is the equation of a linear relation. Therefore, when regressing smolt TT by WTT, the underlying relation in theory remains a linear relation. In addition, when we look at the data plotted in figures 2, 3,and 4, we do not see a departure from a linear trend as your comment would imply.

5. What difference was made in the analysis by dropping out observations for years 1993, 1994, 1995 and 1997? (page 2). Would the inclusion of these observations, individually or collectively, alter the conclusions? (page 2).

No, the inclusion of these observations would not alter the conclusions. The years 1998 to 2002 provides the best set of PIT tagged data for evaluating the effects of flow, spill, and river temperature on smolt survival. The reasons are two-fold. First, in estimating survival from Lower Granite Dam tailrace to McNary Dam tailrace, a high detection capability at dams downstream of McNary Dam is paramount to obtaining estimates with good precision. Prior to 1998, the only PIT tagged fish detected at John Day Dam were those collected in the airlift sample from a single one of the 48 gatewell slots at the project, which effectively limited downstream detection to one dam (i.e., Bonneville Dam). Starting in 1998, all fish in the bypass channel at John Day Dam passed through PIT tag detectors. This resulted in a much higher detection rate of PIT-tag fish passing the dam. Second, the high flows of 1996 and 1997 resulted in most PIT tagged smolts passing the Snake River dams during nighttime periods, when dissolved gas exceeded 125% as indexed at Ice Harbor Dam. Those conditions represent time periods when spill was well beyond hydraulic capacity of the Snake River projects and outside the range of conditions called for in the Biological Opinion. Because we are interested in determining the impacts of the NW Power Planning Council's draft amendments that would reduce flows and spills below the NMFS' Biological Opinion, it is imperative that we obtain the best equations for predicting smolt survival with these reductions. Therefore, data in years of high dissolved gas or early years of low detection probabilities do not help in obtaining a useful predictive equation for evaluating the NWPPC proposed operational changes.

Initially, we have conducted analyses with 1995, 1996, and 1997 data included for yearling chinook and with 1996 and 1997 data included for steelhead. After the exclusion of temporal blocks where individual reach survival estimates had a Coefficient of Variation in excess of 25% (analogous to a 95% confidence interval of approximately +/- 50% of the point estimate) and where dissolved gas levels were 126% or higher, these additional years contributed four more temporal blocks (3 from 1995) for hatchery chinook, five more temporal blocks (4 from 1995) for wild chinook, and one more temporal block (in 1996) for steelhead to the data set containing the 1998 to 2002 data. These additional data points had no impact on the survival parameters generated with the data of the last five years. In fact, when we applied the multiple regression equation generated with the 1998 to 2002 data to the WTT, proportion spill, and water temperature data from the nine temporal/rearing type blocks of usable data from 1995 and 1996, we obtained predicted survival estimates that were within 0.1 units from all observed survival estimates with the exception of wild chinook in 1996.

Later we investigated the use of weighted regression using the reciprocal of the coefficient of variation squared as the weight. This is the weighting method used by NMFS in two recent publications. The weighted regression was applied to all temporal blocks including those blocks that previously had been excluded from the standard linear regression based on the maximum 25% coefficient of variation criterion. The weighted regression was successful in effectively downplaying the contribution of estimates of low precision, however, the method had the opposite ill effect of overemphasizing the contribution of a very few temporal blocks whose survival estimates had extremely high precision. In effect, the weighted regression overemphasized the data from years 1999 and 2001 for hatchery chinook and 1998 and 2001 for wild chinook relative to all other years. The "true" variance of any survival estimate may be viewed as consisting of a population variance component and true sampling variation component. When the sampling effort is low so that the estimate of the true sampling variation (within lots variation) is larger than the population variance (between lots variation), Burnham et al (1987) recommends using the reciprocal of the coefficient of variation squared, as we did here. However, when the sampling effort is high (i.e., large numbers of fish released and high probability of detection), the "within lot" variation becomes small relative to the "between lot" variation. In these cases the theoretical variances obtained from the model output ("within lot" variation) becomes too low and doesn't adequately reflect the full variance component (i.e., the "between lot" and "within lot" sources of variation) of the survival estimate. Because weighted regression is very sensitive to the magnitude of the weights, it is very important to have variance components that fully account for both sources of variation. Only through replication does one obtain the means of estimating the "between lot" component of variation. Therefore, it is more prudent to not use weighted regression when only one observation per temporal block is available. As a rule of thumb, Myers (1990) recommends that the estimated weights should be based on nine or more replicated runs. Otherwise, he cautions that the analyst that "ignoring the weights often may be the most effective course of action." That is the course of action taken in our final analysis.

As for the years 1993 and 1994, the inability to estimate directly survival to the tailrace of McNary Dam makes data from these years unavailable. NMFS has taken survival estimates from the tailraces of Lower Granite Dam to Little Goose Dam in 1993 and Lower Granite Dam to Lower Monumental Dam and expanded to the remaining portion of the reach to McNary Dam tailrace under the assumption that the rate of survival remained unchanged in the lower portion of the reach. When we compared estimated survivals in the Lower Monumental Dam tailrace to McNary Dam tailrace to what would have been obtained by using the survival rate estimated from Lower Granite Dam tailrace to Lower Monumental Dam tailrace in recent years, we saw that such an extrapolation of survival rate was inappropriate. Part of the problem stems from the fact that when survival is overestimated (or underestimated) in an upper reach, the next reach downstream will tend to be underestimated (or overestimated). Extrapolation of data from the upstream reach to the downstream reach leads to inaccurate estimates in this situation. Therefore, we recommend against the use of 1993 and 1994 data for estimating survival to the tailrace of McNary Dam.

6. What years are covered in the observations in Figure 1?

Figure 1 includes years 1995 through 2002. The purpose of the graph was to illustrate the conversion of daily average discharge to water travel time. The daily release travel time points from the survival studies did not contribute to the purpose of the graph. In our subsequent analysis we modified the graph so that it illustrates the date average discharge conversion to water travel time (wtt) without fish travel time references. Figures 2, 3, and 4 in this memo clarify the point.

7. Why are there many observations for the flow/water transit time in Figure 1 for the Snake and only three observations for flow and travel time in Figure 6 for the Columbia?

Figure 1 and Figure 6 are illustrating two different things. Figure 1 is illustrating the daily average discharge versus water travel time, and in the October 14 memo the flow experienced by daily survival releases were included. While figure 6 is illustrating an annual average fish travel time in the Mid- Columbia. That is one travel time point per year from 1998 to 2000. This plot is included in the Oct 14 memo from our 2001 Fish Passage Center annual report.

8. Figure 12 identifies estimated annual survival of in-river PIT tagged yearling chinook and steelhead from McNary Dam tailrace to Bonneville Dam tailrace, why are only 2000 and 2001 data displayed? Is it possible to display all years for which PIT tag data is available?

Yes, it is now possible to display survival estimates in the lower Columbia River reach from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling chinook and steelhead from migration years 1999 to 2002. For PIT tagged smolts detected at McNary Dam prior to 1999, there were too few detections at the downstream dams and trawl to obtain adequate estimates of survival to the tailrace of Bonneville Dam. PIT tag detection capabilities with the trawl were greatly enhanced starting in 2000 with the shift to the new ISO tags. In each year, the PIT tagged yearling chinook passage distribution at McNary Dam was split into three two-week periods (April 25 – May 8, May 9 – May 22, and May 23 – June 5). The PIT tagged steelhead passage distribution was pooled into a single month-long passage period (May 11 – June 8) to get a large enough release group for survival estimation. Estimates of reach survival and associated 95% confidence intervals are presented in Table 1 for yearling chinook and Table 2 for steelhead.

Table 1. Yearling Chinook estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 1999 to 2002.

Year	Release Date Range	Survival	95% CI	
			Lower	Upper
1999	4/25-5/8	0.67	0.41	0.94
	5/9-5/22	0.76	0.66	0.86
	5/23-6/5	0.66	0.47	0.85
2000	4/25-5/8	0.66	0.49	0.84
	5/9-5/22	0.67	0.53	0.81
	5/23-6/5	n/a		
2001	4/25-5/8	0.45	0.25	0.66
	5/9-5/22	0.52	0.41	0.63
	5/23-6/5	0.59	0.53	0.66
2002	4/25-5/8	0.69	0.56	0.83
	5/9-5/22	0.81	0.70	0.92
	5/23-6/5	0.68	0.42	0.94

Table 2. Steelhead estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 1999 to 2002.

Year	Survival	95% CI	
		Lower	Upper
1999	0.72	0.52	0.92
2000	0.51	0.35	0.66
2001	0.22	0.13	0.31
2002	0.53	0.22	0.85

9. Perhaps the most important finding is in Figures 7, 8, and 9 between survival and water transit time are the observations on the right end of the x-axis primarily from 2001 because of the high water transit time? Could survival for these cases be lower because spill was significantly reduced that year? If that is the case would that alter your third conclusion on page 11 about the relationship between flow and survival?

No, based on our analysis, the conclusions about flow would not change. Yes, analysis shows that increased spill is a significant factor in increased survival. With regard to figures 7, 8, and 9, it is true that the observations with the longest WTT (water transit times) are from 2001 as expected because the flows in 2001 were the lowest of the years analyzed. Likewise, the survival in 2001 was the lowest of the years analyzed due to both the lack of spill and lower flows of 2001. The influence of spill on the survival estimates may be seen as follows. For each reservoir and dam segment of the reach, survival may be viewed as the product of two components, a reservoir survival component and a dam passage component. In the dam passage component, survival may be view as the weight average survival across each passage route, such as spillway route, turbine route, and bypass channel route (if present), where the weight is equal to the population of smolts using each route. Because the spill passage route has been shown to be the safest route of passage (the benefit of this improvement in survival can be offset during periods of excessively high flows when gas may be a problem), increases in the amount of spill and numbers of fish passing through that route will have a direct effect on the reach survival estimate. Therefore, the level of spill has a direct effect on every reach survival estimate. And in the reach from Lower Granite Dam tailrace to McNary Dam tailrace, the lack of spill at Little Goose, Lower Monumental, and Ice Harbor dams, and limited late-season spill at McNary Dam in 2001 definitely had an effect on the magnitude of survival estimated for yearling chinook and steelhead in that year. Survival was further compromised in 2001 by the extremely low flows that year. Under these low flows, water clarity was higher and exposure time to predation was longer thus increasing smolt mortality rates due to predation by other fish and birds.

The fact that the lower reach survival in 2001 was not simply due to the lack of spill rather than the joint effect of no spill and low flows is seen in the Mid-Columbia River reach. In the reach from Rock Island Dam tailrace to McNary Dam tailrace, though spill did not occur at McNary Dam until late in the spring migration period, the level of spill at both Wanapam and Priest Rapids Dam remained high throughout the 2001 springtime migration. Of the years analyzed, the flows in the Mid-Columbia River were lowest in 2001, as was seen in the Snake River. Again, under these low flows, water clarity was higher and exposure time to predation was longer thus increasing smolt mortality rates due to predation by other fish and birds. In the Mid-Columbia River reach, estimated survival of yearling chinook and steelhead was lower in 2001 than the other years just as it had been in the Snake River reach. These lower survivals occurred, despite the relatively “normal” proportions of spill that occurred, highlighting the effect low flows can have on survival despite the presence spill. This is not to say that spill is not important to survival however.

Because spill has a direct effect on the magnitude of a reach survival estimate, it is important to include a spill related variable in all multiple regression models, otherwise the effect of spill will be confounded within the parameter estimates of the other variables in the model (*i.e.*, a case of model misspecification). A look at the bivariate and multiple regression models for steelhead in the Snake River reach provides an example of the effect of not including the most complete set of explanatory variables in the regression model. The slope of the WTT variable in the bivariate model is -0.0627, and when spill proportion is added to the model the slope of WTT drops to -0.0418. The steeper slope in the bivariate model results from the confounding of the spill-related effect in the WTT variable. From the standpoint of predicting survival, the bivariate model is quite adequate due to its high R^2 of 0.83, and the small increase in R^2 (to 0.87) that occurs with the inclusion of the spill proportion variable in a multiple regression. However, from a mechanistic viewpoint, the inclusion of the spill variable provides a more through explanatory model for showing the inter-relationship between flow-related and spill-related effects on the survival of migrating salmonid smolts.

The historic data includes other low flow years, in addition to 2001, 1973 and 1977. The analysis and data that are the foundation of the Biological Opinion measures established range of flow objectives. As long as the Biological Opinion flow objectives are mostly met, survival will vary only within that range. The inclusion of the 2001 data documents the range of survivals that are possible when Biological Opinion measures are not implemented.

We hope these answers clarify the questions that you asked. If you need any further information please feel free to contact us.

Sincerely,

Michele DeHart
Fish Passage Center Manager

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