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MEMORANDUM

TO: Fish Passage Advisory Committee
Ron Boyce, ODFW
Tom Lorz, CRITFC

Michele DeHart

FROM: Michele DeHart

DATE: February 9, 2010

RE: Review of the NOAA Transportation analyses and potential effects of reducing spill for fish passage in May and beginning the transportation program earlier in the spring and supporting analyses.

In response to your requests the FPC staff reviewed the recent NOAA transportation analyses, *Analyses of juvenile Chinook salmon and steelhead transport from Lower Granite and Little Goose dams, 1998-2008* (NOAA 2009a). We reviewed the subject analyses relative to the FPAC discussions of the 2008 Biological Opinion (BiOp) measures to modify the present main stem hydro system juvenile fish passage operations to increase the proportion of juvenile out migrating salmon and steelhead that are transported.. The BiOp includes initiating the transportation program earlier than has recently occurred and eliminating spill throughout the season when flows are low, or during two weeks in May under any flow conditions. The Biological Opinion also discusses adaptive management which would allow consideration of other management alternatives based upon recent data and analysis. We reviewed the NOAA analysis and the Biological Opinion operations within a management decision framework, which include other species such as sockeye and lamprey. This framework is consistent with the recommendations of the ISAB emphasizing the importance of a multi-species perspective that considers all species of interest (ISAB, 2008). Even if the NOAA analysis were convincing, a full evaluation of a management decision to increase the proportion of steelhead transported should include consideration of the impacts of this management decision on (i) other species that may not benefit from transportation, (ii) degradation of in-river passage conditions for fish remaining in river (iii) an increase in mortality on other species from decreasing spill, and (iv) the impacts of increased straying of transported steelhead to other areas. None of these issues were addressed in the NOAA analysis.

This memorandum is presented in four sections:

1. FPC staff review of NOAA (2009a).
2. Effects of BiOp implementation on other species.
3. Making Comparisons of years with similar in-river conditions and years with similar ocean conditions (includes preliminary 2007 steelhead estimates)
4. The relationship between transport benefits and in-river survival.

In these sections we have included previous FPC analyses that address the impacts of reducing spill and increasing fish transportation as outlined in the BiOp. Our conclusions are listed below followed by detailed discussion of each point.

- The subject NOAA analysis does not provide convincing support for the BiOp to change juvenile fish passage operations from the "spread-the risk" balanced operation presently implemented. We provide specific comments on the analysis in following discussion.
- Implementation of the BiOp will potentially degrade in-river migration conditions for fish remaining in river. These species include, Chinook, sockeye, coho, steelhead and lamprey. Recent analysis shows that spill increases reach survival, decreases travel time and increases SAR. In addition NOAA analysis (Muir et al.,2008) indicates that increasing the proportion of steelhead not transported increases steelhead survival in-river.
- The BiOp operations will increase the proportion of yearling spring/summer Chinook, fall Chinook, coho and sockeye transported. The available data indicates that transportation may be detrimental to sockeye and does not show a benefit for spring/summer Chinook yearlings or fall Chinook juveniles. Decreasing or eliminating spill will force more juvenile lamprey through screened powerhouse passage routes.
- Modeling exercises revealed that the 2008 BiOp transportation operations (earlier start date and maximizing transportation by eliminating spill in May) increased the transportation proportion of yearling Chinook to a greater extent than steelhead in low and moderate flow years. The increase in transportation proportions in high flow years was comparable between yearling Chinook and steelhead. The proportion of sockeye being transported from Snake River projects increased in only low and moderate flow years (absolute increase of 0.18-0.22).
- Comparative Survival Study analyses show that TIR (Transportation: In-river Ratio) is related to in-river survival. As in-river survival improves, as has occurred over the past few years of the court ordered spill program, the TIR decreases. Smolts that were not bypassed returned as adults at a greater rate than smolts that were bypassed. The benefits of transportation were lower in 2007 (with court ordered spill) than in 2005 (without court ordered spill).
- The CSS (2009) found that straying rates during the adult migration were higher for adults that were transported as juveniles versus those that out migrated in-river. This was statistically significant for Snake River hatchery Chinook and Snake River wild and hatchery steelhead but not for wild Chinook. The majority of the transported hatchery

and wild steelhead in the CSS that strayed were detected in the Deschutes and John Day rivers. Increasing the proportion of steelhead transported may increase straying rates.

- The Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River (Carmichael et al, 2009) has identified steelhead straying from other areas as a limiting factor for recovery of distinct steelhead populations in the Deschutes and John Day rivers.
- The proportion of steelhead transported under recent operations has been near 50%, which has been the goal of the spread-the risk operation. The spread the risk operation is intended to be a management approach that balances the risk of transportation and degradation of in-river conditions for some species against the potential benefit of transporting steelhead (ISAB,2008).
- Comparison of 2007 and 2005 illustrates the benefit of the spread the risk management approach to transportation in low flow years. These years were similar in terms of flow and water temperature but differed in the provision of spill. In-river SARs increased more from 2005 to 2007 than transportation SARs. This resulted in lower TIRs for 2007 than 2005 reflecting the benefits of spill and the reduced proportion transported in 2007 compared to 2005. In-river survival was higher and travel time was faster in 2007 than 2005.
- Adaptive management as anticipated in the Biological Opinion would allow consideration of additional management options based upon recent data and analysis. In the two most recent low flow years, 2005, and 2007, the provision of spill in 2007 increased in-river survival. Based upon recent data and limited data for the low flow year of 2001, increased spill to the gas cap could be considered as a means to mitigate for low flows.

FPC staff review of NOAA (2009a)

The basic approach of NOAA (2009) is to apply Poisson log-linear regressions to data on PIT-tagged smolts collected at Lower Granite and Little Goose dams. Smolts collected at Lower Monumental Dam, the third transportation dam within the Lower Snake River, were not analyzed. The data analyzed using regressions are conditioned upon *only those smolts that undergo the collection process*. The regressions do not include data from smolts that were able to avoid the collection and bypass systems and the associated stresses and mortality that the collection systems appear to impart (Budy et al. 2002). In addition to the data being conditioned on collected smolts only, some of the data are also conditioned on smolts that were collected and tagged at Lower Granite Dam. Because of the potential for immediate or delayed tagging mortality, results based on smolts collected and tagged at Lower Granite Dam will likely differ from results based on smolts that were collected but were tagged upriver, often in the previous fall.

Because of the high degree of conditioning inherent in the data analyzed, a high degree of caution is warranted when interpreting the results, especially when extending the results to categories of smolts that were not analyzed (e.g., smolts that were not collected, or other species such as sockeye, coho, lamprey or fall Chinook). Due to this conditioning, analyses based on smolts released upriver of Lower Granite Dam may provide a rough indication of whether transporting or bypassing a collected smolt at Lower Granite Dam or Little Goose Dam historically resulted in higher probability of adult return, given a particular year, release date, tagging location, species, and rear-type combination. However, the results vary considerably by release location, year, passage history, species, rear-type and date, with complex two-way and even three-way interactions. Because the fitted probability of adult return depended upon each particular combination of these factors, the analyses provide little guidance for management decisions on whether to bypass or transport all of the mixed-species, mixed-rear-type smolts collected on a particular day in future years. That is, the results indicate that the probability of adult return is inconsistent, varying by year, release location, passage history, species, rear-type and release date. Due to this inconsistency, future management decisions on whether to bypass or transport collected smolts could be harmful or beneficial to particular portions of the mixed-species, mixed-rear-type complex of smolts and non-smolts (i.e., lamprey) that would be subject to the ramifications of the bypass-or-transport management decision. We agree that these "analyses do not address management strategies related to provision of spill" (NOAA 2009a, p. 4).

In addition to these issues associated with the conditioning inherent in the data analyzed, we have concerns regarding data that were apparently excluded, along with the low sample sizes that resulted from the decision of using weekly release groups. NOAA (2009a, p. 15) states that there were no wild steelhead transported in 1998 and no hatchery steelhead transported in 2002. However, when using CSS fish, which are only a portion of the whole run, to summarize transport numbers at LGR across years there were 193 transported wild steelhead in 1998 and 124 transported hatchery steelhead in 2002 (Table 1). The number of transported wild steelhead was similar across migration years 1998-2002 and the number of transported hatchery steelhead in 2002 was similar to the number of wild steelhead transported that year. Presumably, when applying all possible marks in PTAGIS there would be even more available for this analysis. Therefore it is unclear why these data were excluded from the analysis. It should be noted that these two cases (i.e. wild steelhead in 1998 and hatchery steelhead in 2002) had the lowest SAR ratios of transported relative to bypassed steelhead smolts (SAR[T0}:SAR[c1}) over years analyzed in the CSS (Tuomikoski et al. 2009) Obviously, excluding data from years that indicate poorer performance of transportation relative to bypass will bias the results in favor of transportation. A related issue is the decision to use weekly release groups in the analyses. As shown in Table 1, several of the groups analyzed had only a few hundred detections over the entire migration season. With SARs typically less than 1%, dividing these detections over seven to eight weekly release groups results in only a handful of smolts in each weekly release group and zero or single digit adult returns. As a result of these low sample sizes, there is considerable uncertainty in the weekly SARs, which may be one reason behind the inconsistent responses discussed above. Using two-week or monthly release groups would have reduced this problem by some degree.

Table 1. Summary of the number of wild and hatchery steelhead and spring-summer Chinook smolts released upriver of Lower Granite Dam as part of the CSS study that were subsequently collected and either bypassed or transported from Lower Granite Dam by migration year.

	wild steelhead		hatchery steelhead		wild Chinook		hatchery Chinook	
Year	Transported	Bypassed	Transported	Bypassed	Transported	Bypassed	Transported	Bypassed
1998	193	2,709	808	11,879	820	6,877	20,158	6,713
1999	221	2,733	766	8,171	1,109	7,138	9,694	2,649
2000	206	6,713	399	13,750	327	7,636	18,361	5,375
2001	158	10,744	331	17,810	452	17,239	54,278	45,957
2002	126	3,927	124	4,830	1,640	3,808	16,854	8,694
2003	1,242	3,746	2,068	4,367	5,098	7,237	28,414	15,422
2004	3,381	6,169	353	12,323	8,963	12,729	49,524	34,421
2005	3,562	6,748	632	11,968	12,962	12,151	53,965	36,070
2006	1,608	1,259	304	4,306	3,761	3,208	21,454	11,727
2007	1,746	1,157	1,006	3,443	2,023	4,112	14,213	13,102

In an effort to extend and apply the regression analyses to groups that were not analyzed (i.e., smolts that were not collected), NOAA (2009a) presents an "adjusted baseline" standard. They present estimates of the ratio of the SARs of smolts that were not collected relative to the SARs of smolts that were collected. However, results from the CSS (Tuomikoski et al. 2009, Table 2 below) indicate that these ratios may be much higher than the ratios reported in NOAA (2009a). The mean ratio of non-detected:bypassed SARs in the CSS was 2.07 for wild steelhead and 1.84 for wild Chinook, while the geometric mean ratios were 1.67 and 1.71, respectively. These ratios have ranged up to 4.0 for wild Chinook and 5.1 for wild steelhead. Because of the large inter-annual variability of this ratio, predictions for any future year are highly sensitive uncertain, and critically depend on the ratio value. For example, SARs of non-collected wild steelhead and Chinook were nearly double the SARs of bypassed wild steelhead and Chinook in 2006 whereas the ratios were near unity in 2000. It is unclear exactly why these ratios vary across years, but this example indicates that the nominal value of these ratios in any future year could be quite variable. As a result, the relative SARs of non-collected versus bypassed smolts are highly uncertain, and this uncertainty is not accounted for through the use of geometric mean values in the "adjusted baseline" standards. Again, we agree that these "analyses do not address management strategies related to provision of spill" (NOAA 2009a, p. 4).

Table 2. Data on the ratio of SAR(C0) : SAR(C1) across juvenile migration years for wild (W) and hatchery (H) Chinook (CHN) and steelhead (STH) from Tuomikoski et al. (2009). In some years there were too few smolts to calculate an SAR for the C0 (undetected at LGR, LGS and LMN) category (e.g. 2001 and 2005 for Chinook and 2001, 2004 and 2005 for steelhead). Migration year 2007 results for steelhead were incomplete at the time of writing the CSS report.

Year	CHN-H	CHN-W	STH-H	STH-W
1994		4.00		
1995		1.48		
1996		2.00		
1997	1.10	2.53	1.41	2.87
1998	1.73	1.27	4.05	5.10
1999	1.27	1.13	1.76	1.78
2000	1.23	1.03	0.90	1.06
2002	1.08	1.23	0.96	0.71
2003	1.25	1.94	1.84	0.87
2004	1.60	2.23		
2006	1.89	1.90	1.15	2.14
2007	1.24	1.37		
Mean:	1.38	1.84	1.73	2.07
Geometric Mean:	1.35	1.71	1.52	1.67
NOAA (2009) Table 2:	1.26	1.09	1.81	1.27

Transport proportion

FPC estimated a lower proportion of yearling Chinook and steelhead transported in 2007 and 2008 than NOAA while showing similar numbers in 2006. The biggest difference in estimates for yearling Chinook was for wild smolts in 2007, for which NOAA estimated 24.8% and FPC estimated 16.8%. Both estimates are low—in fact the lowest estimated transport proportion of any year for which the data were measured. However, the higher estimates of transport proportion in the NOAA analysis affect the calculation of their “adjusted standard” for comparison with modeled T:M ratios since it is weighted by proportion of fish undetected (which is inversely related to transport probability).

Using the AICc and QAICc best fitting model to predict SARs and T:M

The authors do not present how the best model, which is used for each predicted T:M curve, is weighted compared to the competing models. For example, the model that generated the curves in Figure A10 had seventeen other competing models in the model selection process. It would be beneficial to note the AIC or QAICc scores and weights for all 18 models or at least the top competing models by weight. Since no tables of models were provided for each year, species and rearing type, it was difficult to know how much better the selected model (i.e. with lowest QAICc) fit as compared to other models (its relative weight). If the goal is prediction, as it seems to be here when generating the T:M curve, a model averaging approach is recommended over a best model approach (Burnham and Anderson 2002 and 2004). By using only the most parsimonious model and predicting using only this model, the authors ignored model selection uncertainty in the model selection process. A model averaging approach can address this. The strength of model averaging is that if multiple models are similar in their QAICc, model averaging can capture the relative contribution of each model without being restricted to a single model. When possible to calculate, a model averaged estimator "often has a more honest measure of precision and a reduced bias compared to the estimator from just the best selected model" (Burnham and Anderson 2004).

Goodness of Fit

The authors fitted models for 11 years of data for wild and hatchery Chinook, and 10 years of data for wild and hatchery steelhead at two separate transportation sites (LGR and LGS) for a total of 84 models. Each model was then used to generate daily predicted transportation to in-river smolt-to-adult return differentials. On many occasions the predicted SAR vs. date line appears to fit poorly to the empirical SAR data. No sort of model validation was presented for these models or a pseudo R^2 (Dobson 2002) which would give an indication of the fit of each particular model.

Based on a visual inspection of the predicted SAR curves plotted with the empirical SAR estimates in NOAA (2009a), in general, the models tended to fit the in-river groups better than the transport groups -- especially for those groups released above LGR "L_0" (e.g. Figures A34, A35). Furthermore, the models also tended to fit the LGR released Transport SAR data better than the SAR's for transport fish released above LGR (e.g. A31). This is likely a function of sample size, with transport SAR's from fish released above LGR having the fewest data points. When the T:M predictive models were simplified from the ratios of these other models it seems to have lead to predictive relationships that did not always fit the actual relationship well (Figure A34). Again, without some measure of goodness of fit to understand how well the model fit the data, managers do not know how to apply the results of this analysis to management decisions.

The use of an alternate standard (i.e. not 1) for T:M ratio.

NOAA uses a formula to calculate the alternate T:M ratio to incorporate differences in SAR of detected versus "never detected" groups of in-river migrants. The adjustment they use is based upon increasing the T:M standard upward based on the proportion of fish that migrated without detection at Snake River collector dams.

The use of a hybrid standard that combines detected and non-detected groups to determine the T:M ratio to compare transported groups to is not helpful for determining when to "maximize transport" as the authors state if by "maximize transport" they mean to shut off spill and transport all fish. The interpretation of the alternate standard comparison is important for managers. In the 2008 BiOp, NOAA calls for the termination of spill from May 7th to May 20th in order to "maximize transport" of steelhead. The question of whether steelhead would benefit (as measured with SAR's) by "no spill" transport operations would be better answered by comparing non-detect in-river SAR's to transport SAR's adjusted by dates. Since NOAA uses seasonal average adjustments to in-river SAR's it would make more sense to compare seasonal average transport SAR's to SAR's of non-detects. Additionally, data from the CSS indicate that SARs for non-detected fish are much higher than SARs for bypassed fish, summarized in Table 2 above and these ratios are considerably higher than those presented in NOAA (2009a), . Any upcoming year subject to a management decision could display similar disparities between non-detected and bypassed fish, and using a mean value to represent this disparity underestimates the true uncertainty in the data and the sensitivity of the predictions to this uncertainty

An analysis comparing seasonal SARs of transported vs. non detected fish also needs to take into account reach survival and its' impacts on T:M ratios, which are addressed in another section of this review. The CSS study has presented data showing that as in-river survival decreases, the benefit of transportation increases and that as in-river survival increases the benefit of transportation decreases (see discussion of 2005 vs. 2007 conditions).

Duplicating and describing fit for three cases of the NOAA (2009a) models

As stated above, the fit for the top models and model validation for each case in the NOAA (2009a) analysis are not presented. The FPC staff conducted a simplified parallel analysis of a few cases from the NOAA (2009a) analysis to ascertain how well the models may be fitting the data. The CSS PIT-tagged hatchery Chinook groups (Catherine Creek, Dworshak, Imnaha, McCall, and Rapid River hatcheries) compose most of the hatchery spring/summer Chinook released above LGR in many years. Therefore, FPC staff used CSS hatchery Chinook (e.g. marked above LGR) data and fit Poisson Generalized Linear Models with program R (R Development Core Team 2009) for selected years. We chose to mimic the 2002-2004 NOAA (2009a) hatchery Chinook analysis because these three years utilized only fish marked above LGR, which should consist mostly of CSS hatchery Chinook, and these years each have one, two and three variable models as the top selected model. In following the NOAA (2009a) approach, the Location (L) variable would be zero in all cases for groups marked above LGR. When only above LGR marks are utilized, there are no models that include the L variable so that the full model is then D + T + D:T. We then evaluated the goodness-of-fit for the top model in the FPC analysis using a pseudo-R^2 (or explained deviance) which is calculated as (Zuur 2009):

$$100 \times \frac{\textbf{null deviance - residual deviance}}{\textbf{null deviance}} \qquad (1)$$

The results of the FPC model selection exercises are shown in Table 3 along with information from NOAA (2009a) top models used to predict T:M. The criterion used for model selection by the FPC was the AICc which assumes no overdispersion. When there is a lack of overdispersion, QAICc (used in NOAA (2009a)) and AICc have the same value. The use of QAICc when accounting for overdispersion can result in a different "best model" than AICc. Given that the top model selected is the same in all three cases, it appears that the FPC analysis is mimicking NOAA (2009a) and overdispersion may be small if present. The model weight for FPC selected best models ranged from 44 – 99% and lends support to our suggestion that model averaging may be a better approach (see above comments). Further, the pseudo-r-squared ranged from 0.5-1.61%. Therefore, the best model in each case explained only 0.56-1.69 % of the variation in adult return rates and supports our statement that this analysis has little applicability to management decisions on hydrosystem operations or transportation implementation decisions.

Table 3. NOAA (2009) model results for hatchery Chinook 2002-2004 and FPC analysis of CSS Hatchery Chinook 2002-2004. The Pseudo-R-squared for the FPC models are in bold text.

Analysis/ year/ group	No. released above LGR	Top model selected	Model selection criterion	Model weight	Null Deviance	Residual deviance	Pseudo-R-squared
NOAA/ 2002/ hatchery Chinook	250,240	D + T + D*T	QAICc	-	-	-	-
FPC/ 2002/ CSS hatchery Chinook	206,083	D + T + D*T	AICc	99.2%	2789.70	2745.40	**1.61%**
NOAA/ 2003/ hatchery Chinook	362,82?*	T	QAICc	-	-	-	-
FPC/ 2003/ CSS hatchery Chinook	225,320	T	AICc	44.0%	2608.30	2593.90	**0.56%**
NOAA/ 2004/ hatchery Chinook	53,25?*	D + T	QAICc	-	-	-	-
FPC/ 2004/ CSS hatchery Chinook	216,852	D + T	AICc	70.6%	2821.20	2774.40	**1.69%**

* It is possible that this is a typographical error in NOAA (2009a) as the numbers released above LGR appear to be low and have a misplaced comma; question mark inserted by FPC staff.

Finally, there is no explanation in the methods of NOAA (2009a) outlining exactly how the 95% "confidence envelope" is calculated for the predicted T:M curve. Since the magnitude of these confidence lines are vital to the interpretation of the T:M curve in relation to 1 or the adjusted comparison line, an explanation of the calculation of these values is needed.

Effects of BiOp implementation on other species.

The spread the risk operation recognizes that operations within the migration corridor must be balanced among all species. Spread-the-risk operations are intended to be a management approach that balances the risk transportation poses to some species and the degradation of conditions to fish remaining in river from maximizing transportation, against the potential benefit for transported steelhead. The objective of spread the risk is to manage at near 50% for each species. The policy of maximizing transportation that was implemented in past years did not result in rebuilding endangered runs. Newer data indicates that the spread the risk management approach, utilizing spill for fish passage and reducing the proportion of fish transported benefits sockeye and in-river migrating steelhead and salmon. Adult returns from the

2006 and 2007 outmigration years indicates that implementing spread the risk may benefit all stocks including sockeye. This is consistent with NOAA's conclusion that transportation does not appear to benefit sockeye. In addition, a previous NOAA analysis has shown a negative correlation between proportion of Snake River sockeye transported and sockeye SARs (NOAA,2009b, also FPC memo 2/18/09) Previous analysis conducted by the FPC indicate that higher spill, higher flow and reduced transportation proportion result in increase in sockeye adult returns (FPC memorandums). Table 4 below illustrates the changes in proportion transported under present management as compared to past years' high transport proportions.

Table 4. Comparison of the 2009 estimate of the proportion of Snake River Basin smolt population in Lower Granite Dam forebay that are "destined for transportation" and the corresponding estimates from 2000 to 2008. For yearling Chinook and steelhead, the results exclude transport at McNary Dam.

Species- age group	Transport Proportion									
	2009	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Yearling Chinook	0.36 (H) 0.40 (W)	0.493 (H) 0.488(W)	0.242 (H) 0.168 (W)	0.611 (H) 0.579 (W)	0.92	0.870	0.629	0.683	0.980	0.71
Steelhead	0.46 (H) 0.48 (W)	0.41 (H) 0.447(W)	0.47 (H) 0.437 (W)	0.76 (H) 0.793 (W)	0.94	0.964	0.670	0.677	0.986	0.81
Subyearling Chinook	0.51 (H) 0.45(W)	0.581 (H) 0.463(W)	0.357 (H) 0.358 (W)	0.521 (H) 0.562 (W)	0.809	0.972	0.895	0.929	0.962	0.93
Sockeye	0.654	0.620	0.532	0.592	0.859	0.952	0.758	0.663	0.950	0.518

Lamprey

Reducing spill to transport additional steelhead will be detrimental to lamprey, since elimination of spill will result in additional juvenile lamprey passage through screened power house bypass systems (Starke and Dalen 1995,1998; Moursand et al., 2000, 2001, 2002, 2003; Bleich and Moursand, 2006). Impingement of juvenile lamprey on turbine intake screens is a serious regional problem. Lamprey timing data indicate that a large portion of the lamprey passage distribution will be negatively impacted by the reduction in spill outlined in the 2008 BiOp.

Adverse Impacts of Eliminating Spill in May on other Snake River Species

The BiOp will increase the proportion of yearling Chinook, fall Chinook, coho and sockeye transported. Available data indicates that transportation may be detrimental to sockeye (Williams et. al., 2005). Available data does not show a benefit of transportation of fall Chinook juveniles. Decreasing or eliminating spill will force more juvenile lamprey through screened powerhouse passage routes.

In years where seasonal average flows exceed 65 Kcfs, the 2008 BiOp calls for the termination of spring spill and implementation of maximum transportation at Snake River collector projects (LGR, LGS, and LMN) from May 7 through May 20th.

The primary rational for eliminating voluntary spill and implementing maximum transport is to increase the proportion of the steelhead run that is transported. This is based in large part on studies conducted previous to the court ordered spill program that indicate higher SAR's for transported steelhead versus those that migrated in-river or were bypassed. Although transported wild steelhead have generally had higher SAR's than those migrating in-river through non-detected or bypassed routes (notable exceptions include 1998 and 2006), transportation has often been detrimental or equivocal compared to in-river migration for wild Snake River spring/summer Chinook.. Furthermore, what data there are suggest that there is no benefit of transportation for Snake River subyearling Chinook. It is unknown what kind of impact transportation has on Snake River coho but transportation may be detrimental to Snake River sockeye (Williams et. al., 2005). In addition to transportation potentially being detrimental to sockeye, the 2008 BiOp (Section 8.4.3.1) states that "despite changes in configuration and operations in the hydrosystem, rates of descaling and mortality are higher for sockeye than for other species, although the reason for this discrepancy is unknown". This implies that, compared to other salmonids, bypass systems at the projects may have more of an impact on sockeye juveniles compared to other species.. Therefore, eliminating or reducing spill at Snake River projects would effectively increase the proportion of juveniles encountering the juvenile bypass system and/or the turbines, and thus increase the potential for descaling and/or mortality.

Switching to maximum transportation with no spill from May 7th to May 20th will inevitably increase the proportion of yearling Chinook, subyearling Chinook, sockeye, and coho that are transported, which could lead to a negative impact on these species, given the lack of data showing a benefit from transportation. Furthermore, switching to a no-spill operation during this time could also have an impact on migrating juvenile lamprey, as a no-spill operation would mean that all juvenile lamprey will be bypassed or pass through turbines instead of passing through spill.

To investigate the potential impact of operating at maximum transportation with no spill from May 7th to May 20th, FPC staff estimated the proportion of the population of yearling Chinook, steelhead, sockeye, coho, and subyearling Chinook passing Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams during this time, over the past twelve years (1998-2009). These estimates are based on the daily passage index for each species at LGR, LGS, and LMN.

FPC staff also estimated a passage index for juvenile lamprey at LGR, LGS, and LMN over the same twelve years. To do this, we expanded the daily sample counts of juvenile lamprey to a collection count, using the same expansion used for yearling Chinook or subyearling Chinook, depending on the time of year. These daily collection counts were then expanded to a daily passage index, which accounts for daily fluctuations in operations. Equation 2 provides the general equation used for the daily passage index for lamprey juveniles.

$$PI = \text{total collection count} * ((\text{powerhouse flow} + \text{spill flow}) / \text{powerhouse flow})) \qquad (2)$$

Results from this analysis can be found in Table 5 below. On average, approximately 35-42% of steelhead juveniles pass LGR, LGS, or LMN during the period of the maximum transport/no spill operation. However, approximately 34-46% of Snake River yearling Chinook, 21-39% of sockeye, and 23-39% of coho juveniles also pass LGR, LGS, or LMN during this time (Table 5). Furthermore, approximately 13-18% of lamprey juveniles pass LGR, LGS, or LMN during this time. Given that such a high proportion of yearling Chinook, sockeye, coho, and lamprey juveniles pass these collector projects during this time, it is highly likely that eliminating spring spill from May 7th to May 20th would significantly increase the proportion of these populations that would be transported. This is a particularly risky strategy, given that there is no evidence of transportation providing a benefit to these species and that this maximum transport/no spill operation would increase the number of lamprey, coho, sockeye, steelhead and chinook juveniles that are subjected to the bypass screens or pass through the turbines at these transport projects.

Table 5. Annual percent of yearling Chinook, steelhead, sockeye, coho, subyearling Chinook, and lamprey juveniles passing Lower Granite, Little Goose, and Lower Monumental dams during the period of no spill/maximized transportation operation (May 7-20).

		Percent Passing During Max. Transport Operation (May 7 to May 20)					
Project	**Migration Year**	**Yearling Chinook**	**Steelhead**	**Sockeye**	**Coho**	**Subyearling Chinook**	**Lamprey Juvenile**
LGR	1998	19.3	30.5	77.1	53.4	1.8	26.7
	1999	33.6	18.2	11.1	8.2	0.0	2.7
	2000	26.8	34.9	17.9	12.2	0.1	24.4
	2001	38.7	37.0	21.6	14.9	0.0	17.8
	2002	32.0	19.6	45.9	15.8	0.0	0.87
	2003	35.9	28.8	1.2	18.8	0.1	2.4
	2004	18.3	44.5	31.5	43.5	0.1	8.1
	2005	35.5	54.0	46.9	74.5	6.4	10.8
	2006	39.8	32.1	48.7	54.2	4.5	12.7
	2007	26.8	41.0	82.5	61.1	0.7	58.6
	2008	60.2	45.7	47.6	71.9	1.0	49.4
	2009	43.8	29.9	29.6	37.1	0.8	0.0
	Average	**34.2**	**34.7**	**38.5**	**38.8**	**1.3**	**17.9**
LGS	1998	38.1	44.1	50.2	32.3	0.0	39.5
	1999	38.0	23.6	10.0	10.8	0.0	6.0
	2000	30.0	21.8	3.4	5.3	0.1	6.7
	2001	51.1	43.8	14.2	10.9	0.0	23.1
	2002	42.7	43.8	26.5	2.5	0.0	0.0
	2003	31.2	14.6	0.1	4.7	0.0	0.4
	2004	37.8	35.5	18.6	9.7	0.3	13.9
	2005	69.8	73.1	13.1	73.6	13.4	25.3
	2006	37.6	30.0	23.5	27.2	4.0	6.0
	2007	86.4	74.7	56.8	59.1	1.3	29.4
	2008	56.6	56.2	12.5	26.8	0.1	51.7
	2009	30.8	17.1	22.7	12.8	0.3	2.3
	Average	**45.8**	**39.8**	**21.0**	**23.0**	**1.6**	**17.0**
LMN	1998	41.6	53.3	35.0	32.7	0.0	0
	1999	48.7	37.8	13.2	7.8	0.0	1.1
	2000	30.7	25.9	2.3	6.2	0.1	0.8
	2001	38.5	42.9	31.1	0.4	0.4	1.7
	2002	53.2	24.3	30.5	2.8	0.0	0.5
	2003	32.7	24.2	0.8	13.0	0.1	0.2
	2004	16.7	21.7	22.0	14.8	15.9	18.5
	2005	47.5	70.3	14.1	81.3	0.7	19.2
	2006	60.3	43.4	31.7	35.5	0.3	23.0
	2007	87.0	85.2	60.5	70.2	0.6	77.6
	2008	27.1	23.8	7.0	8.6	0.1	5.9
	2009	55.4	51.9	16.0	22.8	0.1	5.5
	Average	**44.9**	**42.1**	**22.0**	**24.7**	**1.5**	**12.8**

Estimated Proportion Transported Under BiOp Operations:

To further illustrate the potential impacts of the 2008 BiOp operations on transportation proportions, FPC staff estimated the proportion of yearling Chinook, steelhead, and sockeye that would have been transported in 2007, 2008, and 2009, had these years been operated under the 2008 BiOp. These estimates incorporate impacts of an earlier start date for transportation of April 21st and of switching to the max-transport/no-spill operation in May (May 7-20) as outlined in the 2008 BiOp.

To do this, the spring period was broken into four separate time periods. These time periods were: 1) March 26-April 20 (some spill + no transportation), 2) April 21-May 6 (spill + transportation), 3) May 7-20 (no spill + transportation), and 4) May 21-June 30 (spill + transportation). For each of the years analyzed, FPC staff relied on timing data during these four time periods (i.e., proportion passing) and adjusted timing at LGS and LMN based on median travel times from LGR for each year. Estimates of transport proportions for periods 1, 2, and 4 relied on actual project specific detection probabilities for each year and on whether transportation was to take place under the 2008 BiOp or not. For migration years 2007 and 2009, estimates of transport proportions for period 3 (no spill + transport) relied on project specific detection probabilities from 2001, which was a year where no spill was provided at Snake River transportation projects. However, flows through most of May and June of 2008 were in excess of hydraulic capacity and would have resulted in uncontrolled spill, even under the 2008 BiOp operations. Therefore, for 2008, the estimated transport proportion for period 3 (no spill + transport) relied on actual project specific detection probabilities for 2008, instead of 2001 detection probabilities. These actual detection probabilities for 2008 incorporate the high flows in this year.

Early pre-season forecasts for 2010 are showing that there is a high likelihood that average spring flows (April–June) on the Snake River will be less than 65 Kcfs. According to the 2008 BiOp, when spring flows (April-June) are projected to be less than 65 Kcfs, a no spill/max transportation operation will be implemented, where transportation would begin on April 3rd. To estimate the impact of this operation, FPC staff estimated transportation proportions for yearling Chinook, steelhead, and sockeye. As with the previous analysis, the spring period was broken into four periods. However, all four periods relied on project specific detection probabilities from 2001, which was a year when no spill was provided at the Snake River transportation projects.

Operating under the 2008 BiOp resulted in increases in transportation proportions for yearling Chinook and steelhead for all the years we analyzed and for sockeye in 2007 and 2009 (Table 6). In a low flow year (e.g., 2007), the BiOp operation had a large impact on the proportion of yearling Chinook, steelhead, and sockeye that were transported (Table 6). The absolute increase in proportions transported were 0.33 for yearling Chinook, 0.23-0.26 for steelhead, and 0.18 for sockeye. These data indicate that, in a low flow year like 2007, the BiOp operation has a larger impact on yearling Chinook than it does on steelhead, in terms of the proportion transported.. In a high flow year (e.g., 2008), the BiOp operation has less of an impact on the proportion of yearling Chinook, steelhead, and sockeye that were transported (Table 6). The absolute increase in proportions transported were 0.19-0.20 for yearling Chinook, 0.20-0.22 for steelhead, and 0.0

for sockeye (Table 6). These data indicate that, in a high flow year like 2008, where May and June flows were in excess of hydraulic capacity, the BiOp operation increases the proportion of yearling Chinook and steelhead that are transported in a similar manner. In a moderate flow year (e.g., 2009), the absolute increase in proportion transported was 0.35-0.38 for yearling Chinook, 0.30-0.35 for steelhead, and 0.22 for sockeye (Table 6). As with the low flow year, these data indicate that, in a moderate flow year like 2009, the BiOp operation has a larger impact on yearling Chinook than it does on steelhead, in terms of the proportion transported perspective.

Finally, under the low flow scenario (i.e., spring flows less than 65 Kcfs), approximately 98% of yearling Chinook, 99% of steelhead, 92% of subyearling Chinook, and 94% of sockeye will be transported at Snake River transportation facilities between April 3 and June 30 (Table 5).

Table 6. Estimated transportation proportions for yearling Chinook, steelhead, and sockeye under actual operations in 2007 – 2009 versus those that would have occurred if these years had been operated under the 2008 BiOp. Also provided are estimates of transportation proportion when spring flows are projected to be less than 65 Kcfs and thus no spill is provided.

Species	Actual Transport Proportions			Estimated Transport Proportions (BiOp Operations)			
	2009	**2008**	**2007**	**2009**	**2008**	**2007**	**Flow <65 Kcfs**
Yearling Chinook	0.36 (H) 0.40 (W)	0.49 (H) 0.49 (W)	0.24 (H) 0.17 (W)	0.74 (H) 0.75 (W)	0.68 (H) 0.69 (W)	0.57 (H) 0.50 (W)	0.98 (H) 0.98 (W)
Steelhead	0.46 (H) 0.48 (W)	0.41 (H) 0.45(W)	0.47 (H) 0. 44 (W)	0.80 (H) 0.78 (W)	0.63 (H) 0.65 (W)	0.73 (H) 0.67 (W)	0.99 (H) 0.99 (W)
Sockeye	0.65	0.62	0.53	0.87	0.62	0.71	0.94

Straying

The Conservation and Recovery Plan (Recovery Plan) for Oregon Steelhead Populations in the Middle Columbia River (Carmichael et al, 2009) has identified steelhead straying from other areas as a limiting factor for recovery of distinct steelhead populations in the Deschutes and John Day rivers.

In the viability assessment discussion (page 6.3 paragraph 3) of spawner composition criteria, the Recovery Plan states that, "a significant proportion of natural spawners are out-of-DPS strays that resulted in a high risk rating for the spawner composition metric". In discussion of limiting factors, (page 8.2) the Recovery Plan states:

> "Out-of-DPS hatchery strays pose significant risk to several of Oregon's Mid-C steelhead populations, particularly to the Eastside and Westside Deschutes and John Day populations. Viability assessments, summarized in Section 6 of this document and presented in Appendix B ,identified that a significant proportion of spawners in the Deschutes River and John Day River populations were out-of-DPS strays. In addition, these populations were rated at high risk for spawner composition due to the abundance of strays. Biologists remain especially concerned regarding the continuing detrimental

impact of stray out-of-DPS hatchery fish in natural spawning areas on the genetic traits and productivity of these natural populations."

In the Recovery Plan discussion of Management Strategies to recover these stocks, the Recovery Plan identifies management action number "4. Reduce the proportion of Snake River hatchery smolts that are transported from Lower Granite and Little Goose dams. [Recent evidence from Perry et al. (2006 unpublished data) indicates that transported smolts may stray at significantly higher rates than in-river migrants. There are limited data available to examine the relationship. This is a non consensus action that the Sounding Board indicated should be examined in more detail when additional data are available.]" The following CSS analysis (2009) confirms the Perry et al, (2006)conclusions in the discussion of management strategies..

The CSS (2009) found that straying rates during the adult migration were higher for individuals that were transported as juveniles versus those that out migrated in-river. This was statistically significant for Snake River hatchery Chinook and Snake River wild and hatchery steelhead but not for wild Chinook. Further the majority of the steelhead strays were found in lower Columbia River subbasins (Deschutes and John Day rivers) Increasing the proportion of steelhead transported may increase straying rates.

In the CSS 2009 annual report, the authors calculated straying rates for Snake River Chinook and steelhead. A stray was defined as any adult fish last detected outside the FCRPS (Federal Columbia River Power System) without a subsequent detection within the FCRPS; for Chinook, jacks were excluded. Adult detection sites used within the FCRPS were BON, MCN, ICH, and LGR during the BON to LGR adult migration. Most of the Chinook strays were found in the Mid Columbia River; and the data were pooled for hatchery Chinook from migration years 2001-2007 to overlap with potential adult detection in this area. Only a single wild Chinook was detected as a stray so this group was not included. The majority of the steelhead strays were found in lower Columbia River subbasins (Deschutes and John Day rivers);and the steelhead data were pooled from migration years 2005-2007 to overlap with the detection of adults in this area. The stray rate was the sum the number of strays divided by the numbers of adults detected at BON for a particular group of interest. This was calculated for both adults that were transported as juveniles and those that emigrated in-river. To test for a significant difference between these estimates, the authors used a non-parametric bootstrap approach (e.g. resampling with replacement) and calculated a new test statistic θ where, $\theta = \text{Straying\_rate}_{\text{transport}} - \text{Straying\_rate}_{\text{bypassed}}$. The 90% confidence interval around this statistic in relation to the value zero was used to indicate whether $\text{Straying\_rate}_{\text{transport}}$ was different than $\text{Straying\_rate}_{\text{bypassed}}$. At best, any straying rates would be minimal conservative estimates, because detections are not distributed across the Columbia Basin for all years, detection efficiencies at some of the newer detectors have not been established, and there are likely potential straying sites without PIT-tag detection.

Straying rates for adults at BON that were transported as juveniles were significantly higher than for adults at BON that had emigrated in-river. This relationship was true for hatchery Chinook and wild + hatchery steelhead. The point estimate of straying rates for hatchery Chinook that were transported as juveniles was 0.49%; for adults at BON that emigrated via in-river routes this was 0.08% (Figure 1). For steelhead, this was more disparate. The straying rates for transport and in-river categories of steelhead were 3.0% and 0.2% respectively (Figure 1). The lower limit of the confidence interval around the test statistic comparing the transported and in-river groups was more than zero indicating a statistically significant relationship.

It should be noted that several of these PIT tag detector sites were operating only over a portion of the years aggregated. The John Day river detector (JD1) and the Sherar's falls detector (SHERFT) composed 11 "last detects" of these fish and these two sites have operated only since 2007; the Sherar's falls detected operated only over a portion of 2007. This suggests that many fish that were never seen after BON during years prior to 2007 may have been entering these Lower Columbia River tributary rivers. This is in agreement with the 2003 & 2004 CSS annual report (Berggren et al. 2005) where most of the dropout-rate (the rate of unsuccessful adult migration) for wild and hatchery Chinook took place between BON and MCN.

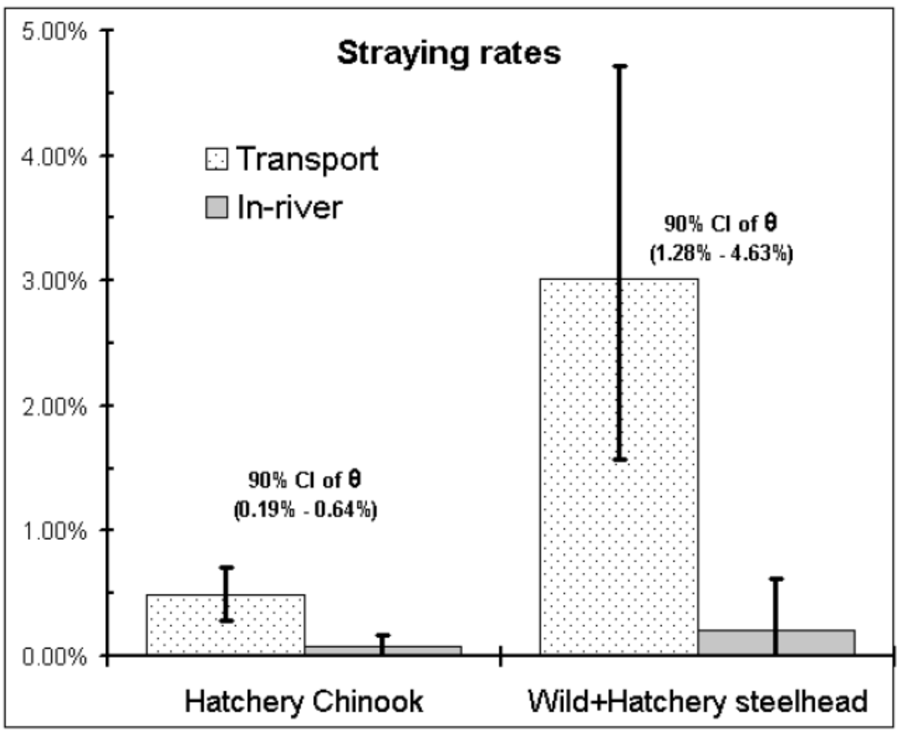


Figure 1. Straying rates for hatchery Chinook (pooled across migration years 2001-2007) and wild + hatchery steelhead (pooled across migration years 2005-2007). Each is shown for adults that were both transported as smolts and those that emigrated in-river. The bootstrapped 95% confidence interval for each rate is plotted. The confidence interval for the difference between bootstrapped straying rates (i.e. θ) is printed above each pair of estimates. Strays were defined as adults detected outside the FCRPS without a subsequent detection within the FCRPS, including LGR. Reprint of Figure 6.3 from CSS 2009 annual report.

Making Comparisons: years with similar in-river conditions and years with similar ocean conditions (includes preliminary 2007 steelhead estimates)

The Comparative Survival Study (CSS) is a management-oriented, large scale monitoring study. The long-term monitoring data provided by the CSS provides information on variability in smolt survival among life stages, study groups and migration years. Several key parameters are estimated within this goal. These include smolt travel times, in-river survival rates, smolt-to-adult survival rates and associations to environmental conditions, hydrosystem operations, and transportation protocols across a series of years.

In the CSS, estimation and comparison of annual SARs for hatchery and wild groups of smolts with different hydrosystem experiences between common start and end points are made for three categories of fish passage: tagged fish that are detected at Snake River collector dams (i.e., Lower Granite [LGR], Little Goose [LGS], or Lower Monumental [LMN]) and transported (T_0); tagged fish collected at Snake River dams and returned to the river (C_1), or tagged fish never collected or transported (C_0) at the Snake River dams. These SARs and the ratios derived from them in the CSS are estimated for the entire migration year.

The "Transportation: In-river Ratio" (hereafter referred to as TIR) is a measure of relative life-cycle survival for smolts experiencing two disparate outmigration conditions: transportation (T_0 group) and in-river (C_0 group) migration. The smolt to adult ratio includes survival during the smolt stage at Lower Granite Dam through the returning adult at Lower Granite Dam. The TIR is the ratio of the transported smolt SARs divided by in-river smolt SARs. When the TIR is greater than one, transported smolts survived to adulthood at a greater rate and when the TIR is less than one, in-river migrants had greater survival. Given that the TIR includes survival during the smolt life stage, the authors of the CSS (CSS 2009 Annual Report; Chapter 4) examined the hypothesis that TIRs may decrease as smolt survival increases.

The spring spill program in the Snake River has been in place since 1996. In the years through 2005, there was limited to non-existent spill when flows were low. Under previous management strategies hydrosystem operators have chosen to terminate spill in order to maximize transportation at the transportation dams when Snake River flows were low, as occurred in 2001, 2004 and 2005. Beginning in 2006, the constraints to spilling at Lower Granite, Little Goose, and Lower Monumental dams under lower flow conditions were lifted (Operations plan, Agreement between Bonneville Power Administration and the Tribes for 2007)As a result of that change, the low flow conditions of 2007 had spring spill percentages that remained high (Figure 2). With the provision of spill at the transportation dams in 2007, the PIT-tagged juvenile Chinook and steelhead provided data on a set of migration conditions that has not previously been observed: spill under low-flow conditions.

Additionally, the transportation program underwent a change in operations during 2006. Transportation was delayed at the three Snake River collector dams, with collection of smolts at Lower Granite Dam for transportation commencing April 20 and May 1 in 2006 and 2007, respectively, and delayed even later at the next two collector dams to account for smolt inter-dam migration rates. This was combined with an increased spill percentage, and resulted in a lower proportion of smolts being transported. The transportation percentage in 2001, 2004, and 2005 were three years with the highest transportation percentages of CSS PIT-tagged wild fish (Table 4, Figure 2). Conversely, 2007 had one of the lowest transportation percentages in recent years and much lower than other years with comparable flows. The higher spill percentage and delay of transportation undoubtedly contributed to a lower percentage of wild smolts transported in 2007 than other low flow years (Figure 2).

Smolt Migratory Conditions and Survival

The 2009 CSS Annual Report (Tuomikoski et al. 2009), illustrated how spill and flow affected juvenile yearling Chinook and steelhead under the unique conditions present during the spring of 2007. The approach for examining the effects of spill in 2007 was to compare and contrast the fish travel times and survival rates observed in 2007 with the fish travel times and survival rates that were observed in a year with similar flow conditions, but without voluntary spill at the transportation projects. As mentioned above, spring migration conditions in both 2004 and 2005 were characterized by low flows in the Snake River, and flow levels in both years were comparable to spring flows during 2007 (Figure 2). However, spill was provided at the transportation projects through most of April during 2004 and was rescinded in May 2004, whereas voluntary spill was not provided at the transportation projects during the entire spring of 2005. As a result, the migration conditions during the springs of 2007 and 2005 provide reasonable analogues for comparing and contrasting fish travel times and survival rates with and without spill at the transportation dams under low-flow conditions.

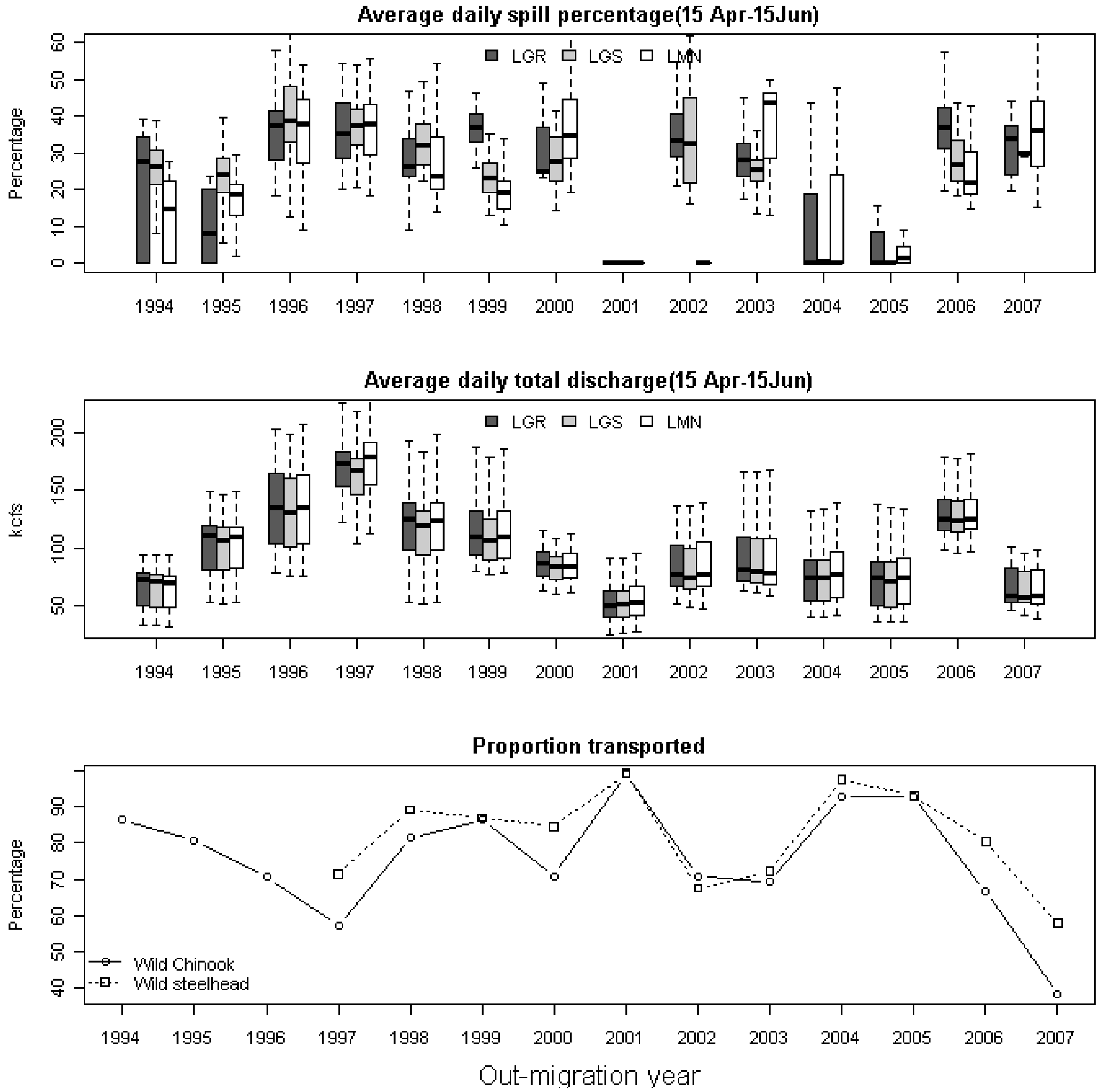


Figure 2. The top, middle, and bottom panels are summaries of spill percentage, flow, and the proportion transported over the historical context of the CSS. Reprint of Figure 1.4 from the 2009 CSS Annual Report.

Analyses in the 2009 CSS Annual Report compared the 2005 and 2007 data on environmental conditions, median fish travel time and survival rates in the LGR-MCN reach for the combined wild and hatchery steelhead (Table 7, Figure 3). Also present are environmental and biological data for 2001 (the lowest recent flow year), and 2006 (a high flow year under recent operations) for comparative purposes. For the combined wild and hatchery steelhead (hereafter designated simply as steelhead), water transit times were similar between 2005 and 2007, typically within three days of each other across the migration season (Table 7, Figure 3A). Water transit times in 2006 were faster than 2005 or 2007, while water transit times in 2001 were slower than 2005 or 2007 (Table 7, Figure 3A). These results demonstrate that in terms of water transit times, 2005 was analogous to 2007 in the Snake River through the Lower Granite Dam – McNary Dam reach. Likewise, average water temperatures were also similar during the spring migrations of 2005 and 2007, averaging only a difference of 0.2 degrees Celsius higher in 2007 (results from Table 3.6 in 2009 CSS Annual Report). However, the spill percentages were considerably higher in 2007. During the steelhead migration period, average spill percentages were 5 to 18 percentage points higher in 2007 than in 2005 (Table 7, Figure 3B). The average percent spill estimates in the Lower Granite Dam – McNary Dam reach during 2005 are greater than zero due to the provision of spill at Ice Harbor and McNary dams, which occurred despite the elimination of voluntary spill at the transportation dams in that year.

Table 7. Estimates of water transit time, average percent spill, median fish travel time and survival rate for wild and hatchery steelhead in the LGR-MCN reach during 2005 and 2007. The difference estimates are calculated by subtracting the 2005 values from the 2007 values. Reprint of Table 3.5 from 2009 CSS Annual Report.

Release	Water transit time (days)			Average spill (percent)			Median fish travel time (days)			LGR-MCN Survival		
Group	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference
1	15.4	12.9	-2.5	26.0	38.0	12	17.1	10.7	-6.5	0.47	0.69	0.22
2	12.8	10.5	-2.3	23.4	37.6	14	12.6	10.3	-2.4	0.60	0.73	0.13
3	10.3	10.3	0.0	26.8	35.6	9	8.9	7.6	-1.3	0.62	0.76	0.15
4	8.8	9.5	0.7	30.0	35.6	6	8.6	7.7	-0.9	0.66	0.60	-0.06
5	8.0	10.8	2.8	31.9	37.0	5	6.6	7.2	0.6	0.54	0.59	0.05
6	10.5	14.0	3.5	25.6	43.7	18	7.7	10.0	2.3	0.27	0.53	0.26
		Average:	0.4		Average:	10.6		Average:	-1.3		Average:	0.12

In terms of biological responses, steelhead showed marked improvements in fish travel time and survival in 2007 compared to 2005. Steelhead travel times were up to 6.5 days faster (first temporal group) and averaged a reduction of 1.3 days across the six temporal groups in 2007 compared to 2005 (Table 7, Figure 3C). Estimated survival rates were up to 26 percentage points higher (last temporal group) and averaged an increase of 12 percentage points across groups in 2007 compared to 2005 (Table 7, Figure 3D). These observations demonstrate that the provision of spill, even under low-flow conditions, can result in improved juvenile migration rates and survival rates in the Lower Granite Dam – McNary Dam reach.

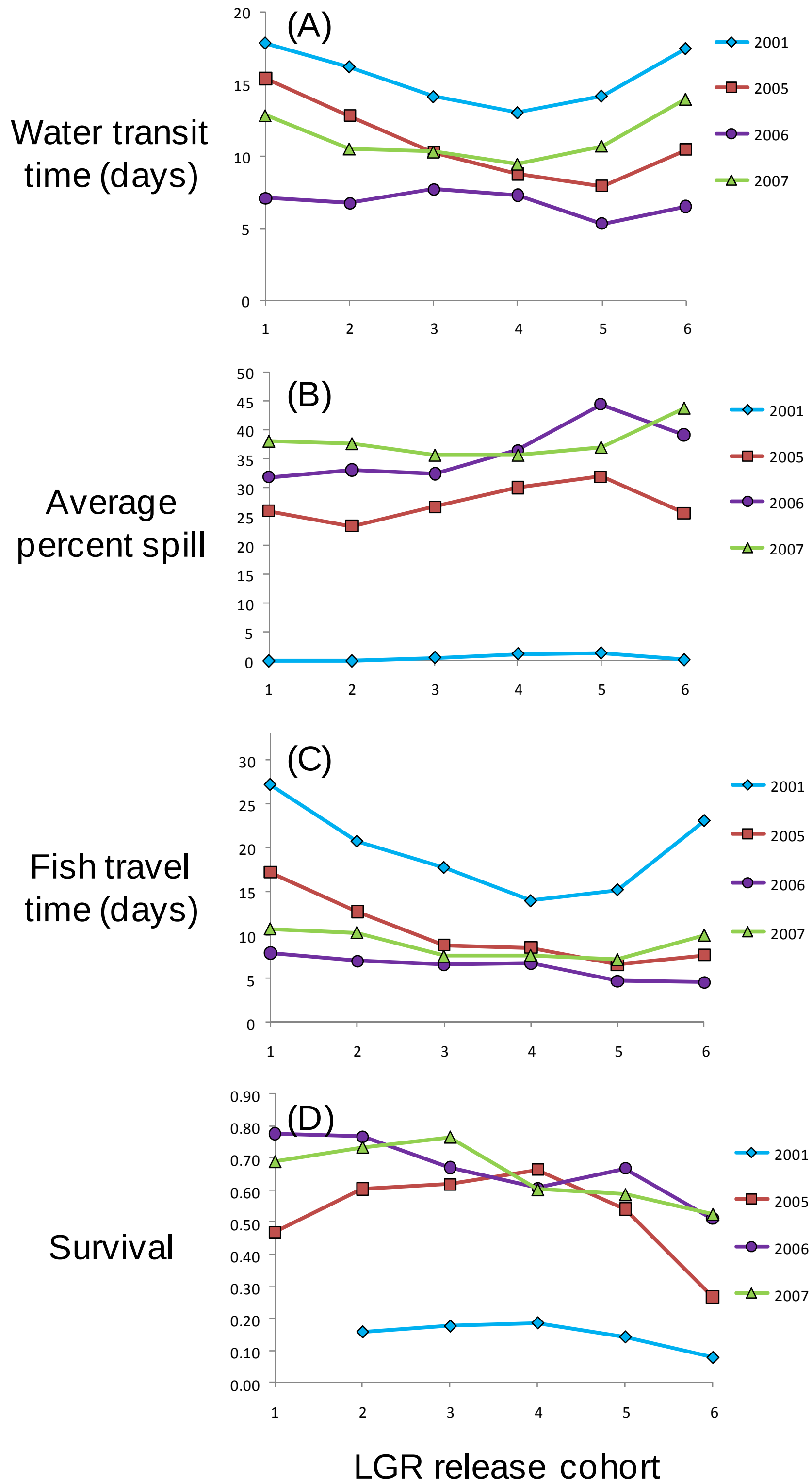


Figure 3. Water transit times (A), average percent spill levels (B), median fish travel times (C) and survival rates (D) for wild and hatchery steelhead in the LGR-MCN reach during 2001, 2005, 2006 and 2007. Reprint of Figure 3.23 from 2009 CSS Annual Report

There appear to be several environmental-biological mechanisms underlying these results. In terms of fish travel time, the multiple regression analysis results in Table 3.2 of the 2009 CSS Annual Report showed that for a given water transit time and Julian day, spill reduces migratory delay. With reduced travel time and a fixed instantaneous mortality rate, survival is expected to increase. The multiple regression analysis results in Table 3.3 of the 2009 CSS Annual Report showed that steelhead instantaneous mortality rates decrease with increasing spill levels, which would further enhance survival. In addition to altering migration rates, spill also functions to modify the proportion of fish passing the spillway, bypass and turbine routes. High spill percentages increase the proportion of fish that pass spillway routes, while low spill percentages increase the proportion of fish that pass turbine routes. Spillways have been found to be the migration route with the highest survival at Snake River dams, while turbine passage has been found to be the migration route with the lowest survival (Muir et al. 2001). Thus, the provision of spill increases the proportion of fish passing the highest survival route while also reducing the proportion of fish passing the lowest survival route.

The provision of spill also decreases the proportion of the population that is transported, increasing the number of in-river migrants (Figure 2). If predation mortality is density-dependent, then the provision of spill, with the commensurate increase in the number of in-river migrants should result in higher survival than would be achieved with fewer in-river migrants. It appears that each of these environmental-biological mechanisms contributed to the results that were observed in 2007. With high spill levels and better water transit times than occurred in 2007, we would expect that future steelhead survival rates would be even higher than was observed in 2007.

Effect of In-River Conditions and Ocean Conditions on In-River SARs and Transport to In-River Ratios (TIRs)

The return of adult salmon depends on both in-river and ocean conditions. The Northwest Fisheries Science Center (2010) has characterized annual ocean conditions based on a variety of atmospheric, physical oceanic and biological factors in regards to both Chinook and Coho salmon returns. Here we assume these general annual ocean conditions are applicable to steelhead smolts as well. Based on these characterizations of ocean conditions (Northwest Fisheries Science Center 2010) we present data for two “poor” ocean years (1998 & 2005) and two “moderate” ocean years (2001 & 2007). In Figure 4 we display in-river survival, in-river SARs, transport SARs and ln(TIR)s from the CSS. Juxtaposed across the poor ocean years, Snake River conditions could be characterized as: extremely high flow and high spill in 1998 and moderate flows and low spill in 2005 (see Figure 2). For the moderate ocean years, Snake River conditions were: extremely low flow and ~ zero spill in 2001 and low flows and high spill in 2007 (see Figure 2). It should be noted that, to our knowledge, the 2007 conditions of low flow and high spill in the Snake River are unique in the historical dataset.

In general, the relationship between transport SAR vs. ocean conditions and in-river survival vs. in-river conditions can be seen in these data. The transport SARs for wild steelhead track well with changing ocean conditions. These were higher transport SARs under moderate ocean years and lower transport SARs in poor ocean years (Figure 4C). This pattern was not as clear for hatchery steelhead (Figure 4C). SARs for in-river steelhead (both hatchery and wild) do not necessarily track with ocean conditions, as the highest SARs for in-river steelhead were from a poor (1998) and a moderate (2007) ocean year (Figure 4B). The in-river steelhead smolt survival is highest in the two years with the highest spill in the Snake River (1998 & 2007), and lowest in 2001, the only year with low flow and no spill conditions (Figures 2B and 4A). This further illustrates that improving in-river conditions (i.e., providing voluntary spill) will likely result in higher SARs for in-river steelhead.

When comparing the poor ocean years, good in-river conditions in 1998 appear to increase the in-river SAR beyond what might be expected and produce the lowest TIR for steelhead (Figures 4B and 4D). During 2005, less optimal in-river conditions with a lower in-river survival and lower in-river SAR produced a much higher TIR (Figures 4A, 4B, and 4D). Transport SARs are slightly higher in 2005 than 1998 but in-river SARs decrease by a much greater percentage and affect most of the change in TIRs across the two poor ocean condition years.

Comparisons of the moderate ocean years (2001 and 2007) reveal a similar pattern. The poor in-river conditions, low in-river survival, and low in-river SARs for 2001 resulted in the highest TIR shown here (Figures 4A, 4B, and 4D). Further, the in-river SAR for 2001 is even lower than both years with even worse ocean conditions (1998 & 2005) (Figure 4B), implying that poor in-river conditions may preclude the effects of a better ocean for in-river migrants. The unique in-river conditions during 2007 produced the second highest in-river survival and highest SAR shown here (Figure 4A and 4B). The TIR was much lower than the matching moderate ocean year 2001 (Figure 4D). The TIR was designed to measure the efficacy of transportation. If the TIR is related to in-river survival which is affected by in-river conditions then the efficacy of transportation is partially dependent on in-river conditions.

Comparing 2007 and 2005 illustrates the benefit of the spread the risk management approach to transportation in low flow years. These years were similar in terms of flow (Figure 2) but different in their in-river survivals (Figure 4A) and in-river SARs (Figure 4B). However, TIRs were lower in 2007 reflecting the benefits of spill and reduced proportion of transportation in 2007 as compared to 2005. However, while migration years 2005 and 2007 were similar in their in-river environmental conditions (i.e., flow, water transit time), they differed in their ocean conditions. As stated above, 2005 is considered a “poor” ocean year and 2007 is considered a “moderate” ocean year. It is possible that the increased SARs for 2007 out-migrants may be solely due to the “better” ocean conditions. If this were the case, one would expect the relative increase in SARs to be similar for transported and in-river groups. However between 2005 and 2007, the transport SAR increased by 360% for wild steelhead, remained the same for hatchery steelhead and increased 724% and 400% for their in-river migrating counterparts (Figure 4B and 4C). This reinforces the assertion that improved in-river conditions during 2007 enhanced the positive ocean influences on adult returns.

This exercise compared years with similar ocean conditions in order to remove the factor of ocean conditions on the TIR. The fact that wild steelhead the transport SARs are higher in years with better ocean conditions supports this assumption. It appears that in-river conditions may preclude or enhance oceanic effects on in-river SARs and the resulting TIRs. This is supported by the Comparative Survival study analyses summarized later in this discussion, showing that TIR is related to in-river survival. As in river survival improves, as has occurred over the past few years of the court ordered spill program, the TIR decreases.

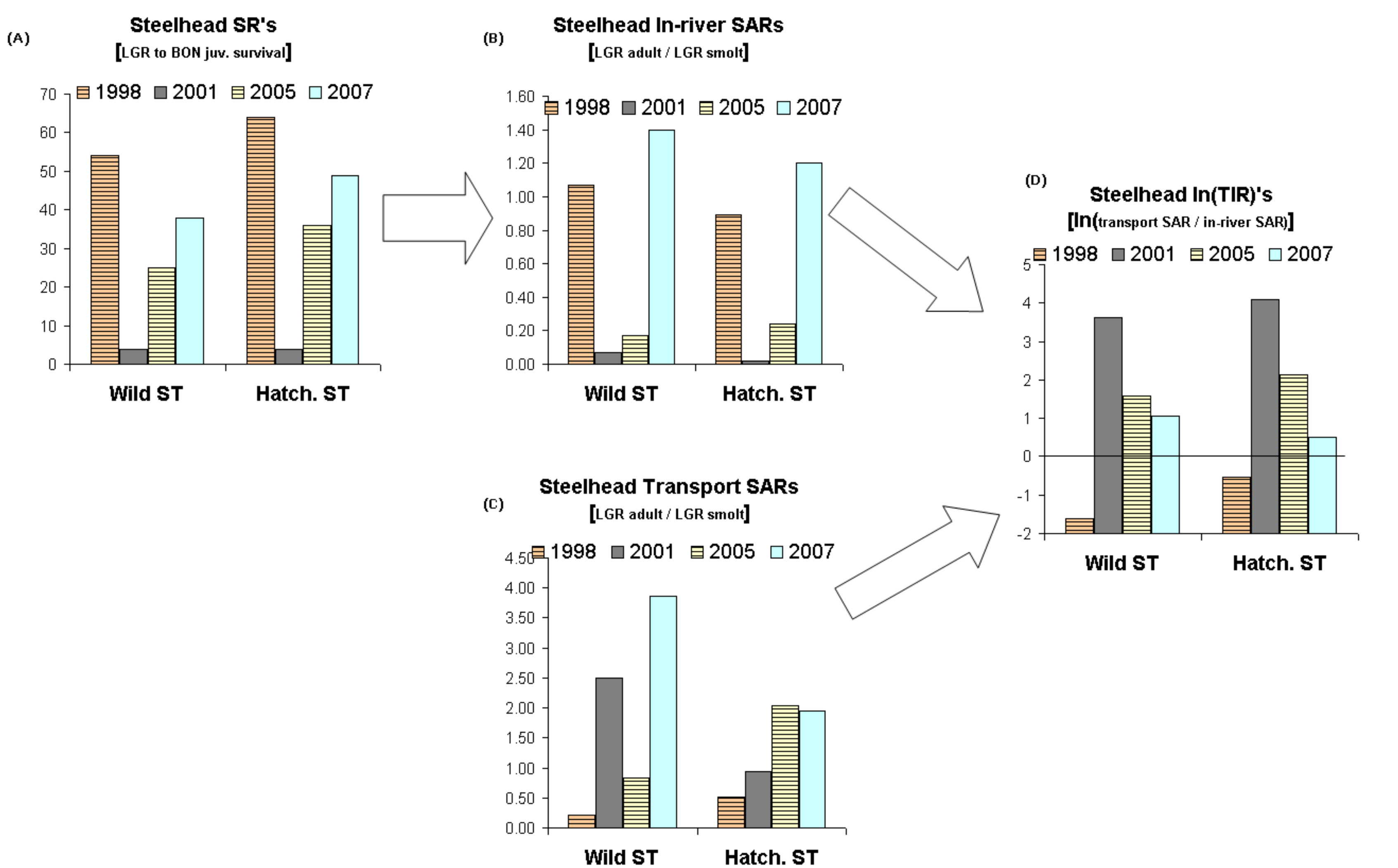


Figure 4. In-river survival (SR panel A), in-river SAR (panel B), transport SAR (panel C), and ln(TIR)s (panel D) for hatchery and wild steelhead from the CSS 2009 report for 1998, 2001, 2005, and preliminary 2007 estimates. Shaded bars are poor ocean years and unshaded bars are moderate ocean years. Note the different scales for the y-axes in panels B and C.

The relationship between transport benefits and juvenile survival, and in-river conditions

In addition to the previously presented comparisons of selected years, the CSS study has documented a relationship between TIRs, in-river survival and migration conditions (CSS 2009 Annual Report; Chapter 3. CSS 10-year Report; Chapter 2.) across all available years. This relationship extends to in-river conditions as well. In Figures 6 and 7 plots are displayed of TIRs versus WTT and spill proportion. Wild steelhead and wild Chinook TIRs were both less than 1.0 in 2006, a high-flow, high-spill year (Table 8, Figure2). In contrast, TIRs were high during the 2001 low-flow, no-spill migration year (Table 8, Figure2).. Environmental conditions in 2007 were unique in that flows were similar to 2005, , but relatively high levels of spill were provided (Figure 2). Despite 2007 flows being similar to the 2005 low-flow conditions (Figure 4), TIRs of wild Chinook and wild steelhead were much lower in 2007 than 2005 (Table 8) and not significantly different from one for wild Chinook. The results from 2007 suggest that the provision of spill may lower TIRs (i.e., increase the C_0SAR relative to the T_0 SAR), even under low-flow conditions. One mechanism for this result is that spill increases the survival of in-river migrants and reduces migration delay (see above), thus increasing the C_0SAR relative to the T_0 SAR, with the result being a TIR less than or equal to one.

The exact flow level at which transportation would clearly benefit all species, regardless of the provided spill levels is unknown. While the TIRs in 2001 were high, this occurred under a no-spill condition. The comparison of 2007 versus 2005 showed that SARs could be increased for in-river fish through the use of spill and, therefore, TIRs decreased. Given these results, it is quite possible that SARs could have increased in 2001 as well if spill had been provided, leading to lower overall TIRs than were observed.

The effects of changes in in-river survival on TIRs were consistent between wild steelhead and Chinook. When using Akaike's Information Criterion for small sample sizes, the model with a combined slope and intercept for wild steelhead and wild Chinook best characterized the available data (Figure 5, Table 8). These results indicated that the average TIRs are expected to be less than one when in-river survival from LGR to BON (S_R) values are greater than 0.55 and lend support to the hypothesis that TIRs decrease as in-river survival increases. Some of the relative transport benefit seen for wild steelhead may be due to their poorer in-river survival compared to Chinook (Figure 5; filled points = steelhead). This relationship suggests a relative detriment of transportation when S_R increases above 55%. Whereas in-river survival of wild Chinook has been above 55% in several recent years, wild steelhead in-river survival has only rarely exceeded 55%.

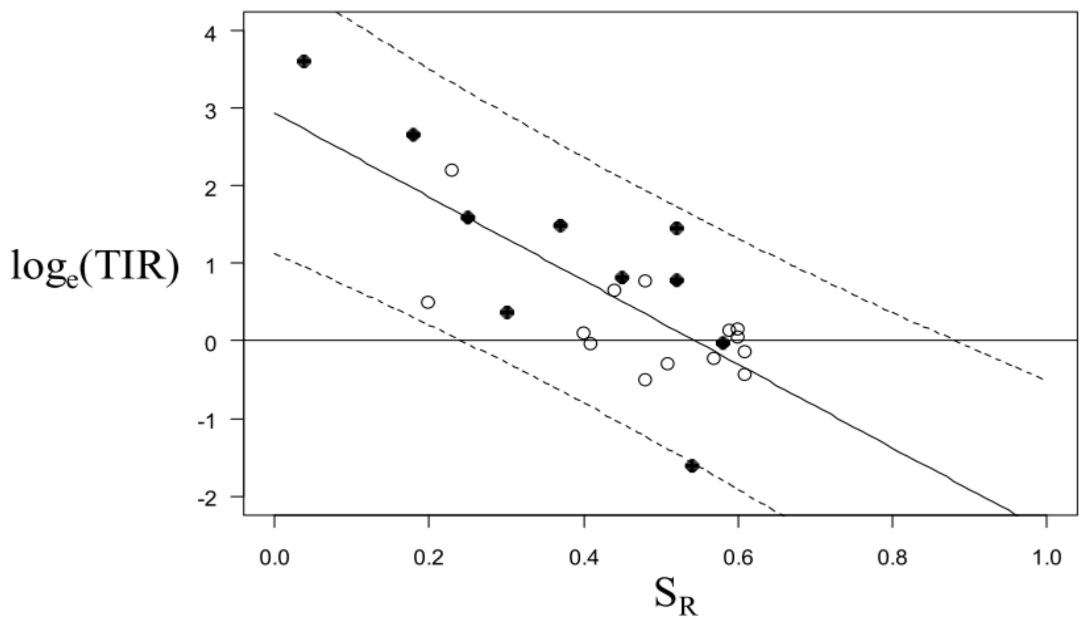


Figure 5. Natural logarithm of Transportation : In-river Ratio (TIR) versus in-river survival rate (S_R) for wild Chinook (open points) for juvenile migration years 1994-2007 and wild steelhead(filled points) for juvenile migration years 1997-2006. Broken lines represent the 95% prediction intervals for loge(TIR). Note the log scale for TIR so that when TIR=1, the plotted log$_e$(TIR) = zero. Reprint of Figure 4.9 from the 2009 CSS Annual Report.

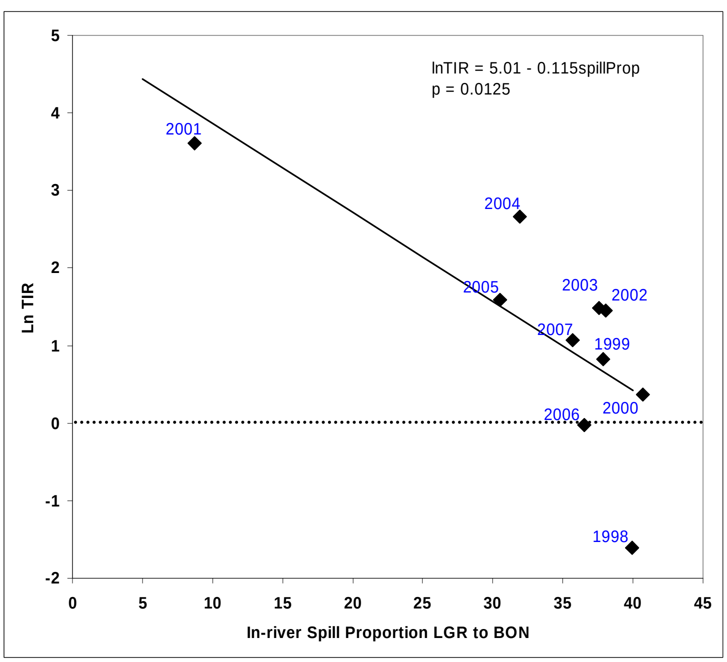


Figure 6. Weighted spill proportion LGR to BON versus TIR for wild steelhead 1998 to 2007.

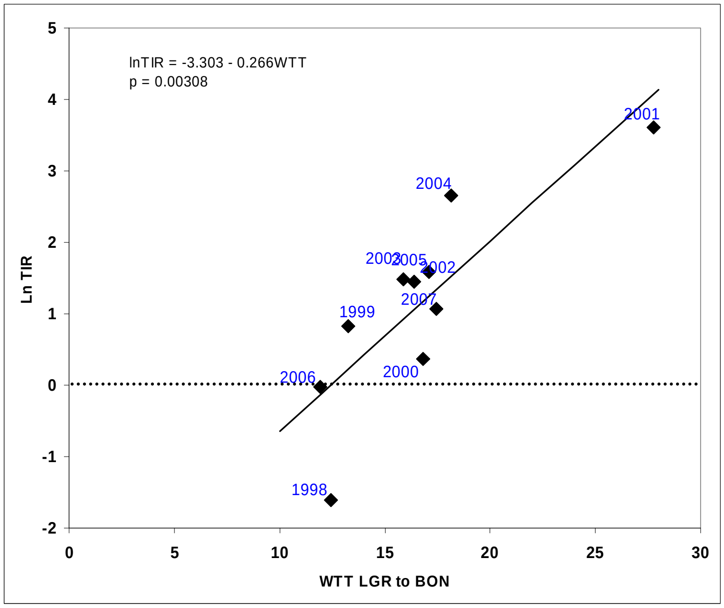


Figure 7. Weighted WTT LGR to BON versus TIR for wild steelhead 1998 to 2007.

Table 8. Estimated in-river survival LGR to BON (S_R), the Transportation: In-river Ratio (TIR), and the natural log of the TIR point estimate. S_R and TIR are shown with 90% confidence intervals. All estimates except those for 2007 steelhead are from tables 4.7, 4.8, 4.19, 4.20, 4.21, and 4.22 from the 2009 CSS annual report.

Species	Mig. Year	S_R		TIR		$\log_E$(TIR)
Wild Chinook	2001[A]	0.23	(0.20 – 0.27)	8.96	(3.61 – 16.8)	2.2
	2002	0.61	(0.52 – 0.76)	0.65	(0.45 – 0.94)	-0.4
	2003	0.60	(0.52 – 0.69)	1.05	(0.68 – 1.68)	0.0
	2004	0.40	(0.33 – 0.51)	1.09	(0.68 – 2.19)	0.1
	2005 [D]	0.48	(0.39 – 0.61)	2.14	(1.40 – 3.45)	0.8
	2006 [E]	0.57	(0.43 – 0.79)	0.79	(0.58 – 1.13)	-0.2
	2007 [E F]	0.60	(0.57 – 0.63)	1.15	(0.80 – 1.61)	0.1
Wild Steelhead	2001[A]	0.038	(0.027 – 0.059)	37.0	(10.6 – 94.6)	3.6
	2002	0.52	(0.41 – 0.69)	4.25	(2.12 – 7.67)	1.4
	2003	0.37	(0.31 – 0.44)	4.41	(2.74 – 7.73)	1.5
	2004 [D]	0.18 [B]	(0.13 – 0.26)	14.3	(7.20 – 42.1)	2.7
	2005 [D]	0.25 [C]	(0.20 – 0.34)	4.88	(3.01 – 7.98)	1.6
	2006 [E F]	0.58 [C]	(0.50 – 0.67)	0.98	(0.57 – 2.26)	0.0
	2007	0.38	(0.31 – 0.48)	2.86 [G]	(2.22 – 3.85)	1.1
Hatchery Steelhead	2001[A]	0.038	(0.023 – 0.082)	59.7	(0.0 – 215.6)	4.1
	2002	0.37	(0.29 – 0.49)	1.51	(0.38 – 3.33)	0.4
	2003	0.51	(0.42 – 0.61)	2.65	(1.93 – 3.71)	1.0
	2004 [D]	0.17 [B]	(0.13 – 0.23)	10.30	(5.40 – 17.9)	2.3
	2005 [D]	0.36 [C]	(0.30 – 0.46)	8.44	(5.04 – 13.41)	2.1
	2006 [E F]	0.62 [C]	(0.56 – 0.69)	1.49	(0.86 – 2.61)	0.4
	2007	0.49	(0.41 – 0.60)	1.68 [G]	(1.24 – 2.20)	0.5

A For migration year 2001, the SAR(C1) value is used in the derivation of TIR and D.

B to C Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 51% expansion MCN to BON; B = 25% expansion JDA to BON).

D In-river SAR is combination of groups C0 and C1 in derivation of TIR and D.

E Mig. year 2006 and 2007 data is combined groups TWS & BWS (see 2009 annual report)

F Incomplete with 2-salt adult returns through August 3, 2009

G Preliminary estimate; the adult migration to LGR for 2-salt adults is incomplete.

Adaptive management

Adaptive management is anticipated in the Biological Opinion. Adaptive management, is described as a tool that allows managers to use their management choices as experiments, to learn and to improve future choices (Parnell, 2009). Monitoring data collected in low flow years of 2001 and 2007 indicates that a substantial improvement in juvenile salmonid reach survival and travel time occurs when spill for fish passage is provided in a low flow year. The data from 2001 and 2007 infers that spill may be an effective measure to mitigate for low runoff volume and low flows. The provision of spill under low flow conditions is consistent with the ISAB recommendation that spill should be considered the default recommendation rather than simply one of the alternatives (ISAB, 2008). Further, terminating spill would eliminate the possibility of learning about the effects of spill reducing opportunities for improved decision making in the future (ISAB, 2008). In the extreme low flow year of 2001 the Biological Opinion spill for fish passage measures were not fully implemented. Transportation was maximized in the Snake River. A brief period of spill was provided at John Day, The Dalles, and Bonneville dams late in the spring migration season. Significant increases in survival were observed for both yearling Chinook (Figure 8) and steelhead (Figure 9) migrating past McNary Dam after May 21, coincident with the initiation of spill on May 25 at John Day Dam. Collection efficiency of bypass system for steelhead at John Day Dam dropped from 40% to 10% between the pre-spill and spill periods at John Day Dam as the spillway provided an additional route of passage. Estimated steelhead reach survival rates between McNary Dam tailrace and John Day tailrace increased from 31.4 to 38.1% for a relative increase of 21% after the initiation of spill at John Day Dam. It appears that both yearling Chinook and steelhead benefitted from passing through the spill route under the extremely low flow conditions (averaging 138 Kcfs) in the lower Columbia River at that time (FPC 2001 Annual Report).

Figure 8. Estimated survival from McNary Dam tailrace to Bonneville Dam tailrace for yearling Chinook passing McNary Dam during various time periods in 2001.

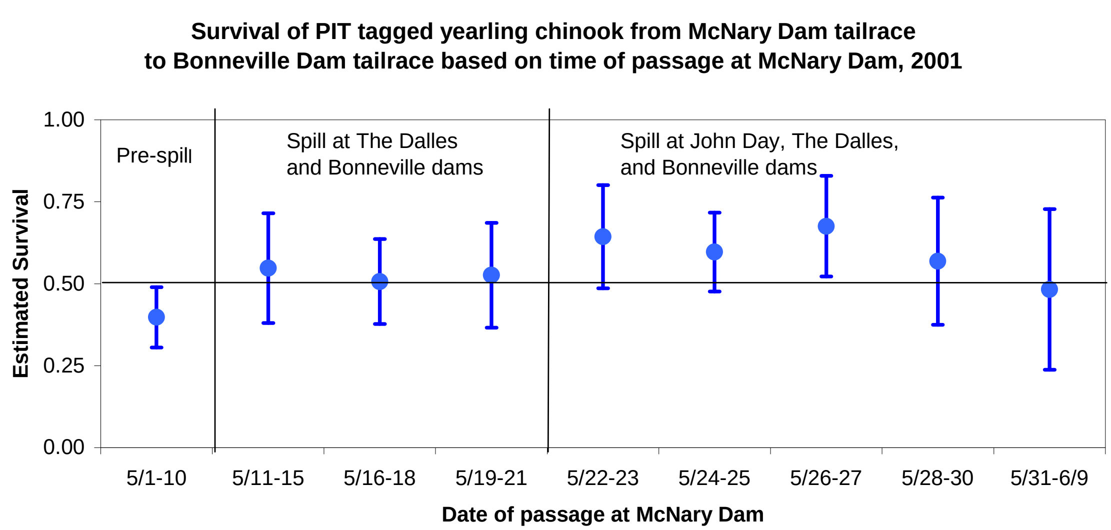
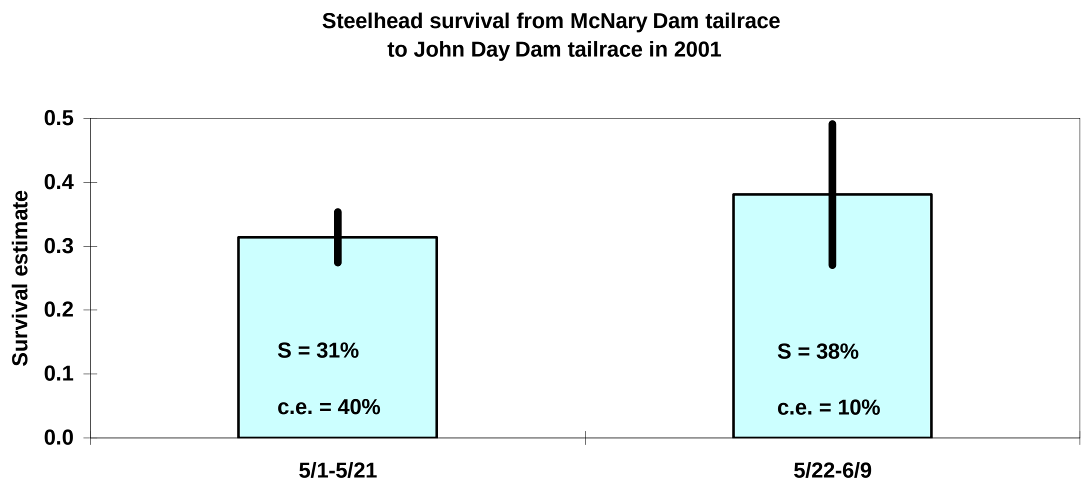


Figure 9. Estimated survival from McNary Dam tailrace to John Day Dam tailrace for steelhead passing McNary Dam May 1– May 21 before spill began on May 25 at John Day Dam and those passing McNary Dam May 22 – June 9 after spill began at John Day Dam.



Survival for steelhead from LGR to McNary in 2007 averaged 0.65 (ranging from 0.53 to 0.76). Based on WTT/flow survival relations for years 1998 to 2006 we would have predicted survival averaging about 0.42 (ranging from 0.30 to 0.52). This difference in survival, observed less predicted, averaged about 0.21. Conceptually, based on the WTT/flow survival relation, in order to achieve that level of survival improvement (i.e. + 0.21) by increasing flows alone, the flows would have had to have increased about 40 kcfs in the Snake River (increase from an average of 80 kcfs to 125 kcfs), and about 50 kcfs in the Columbia River at McNary Dam (from an average of 260 kcfs to 310 kcfs).

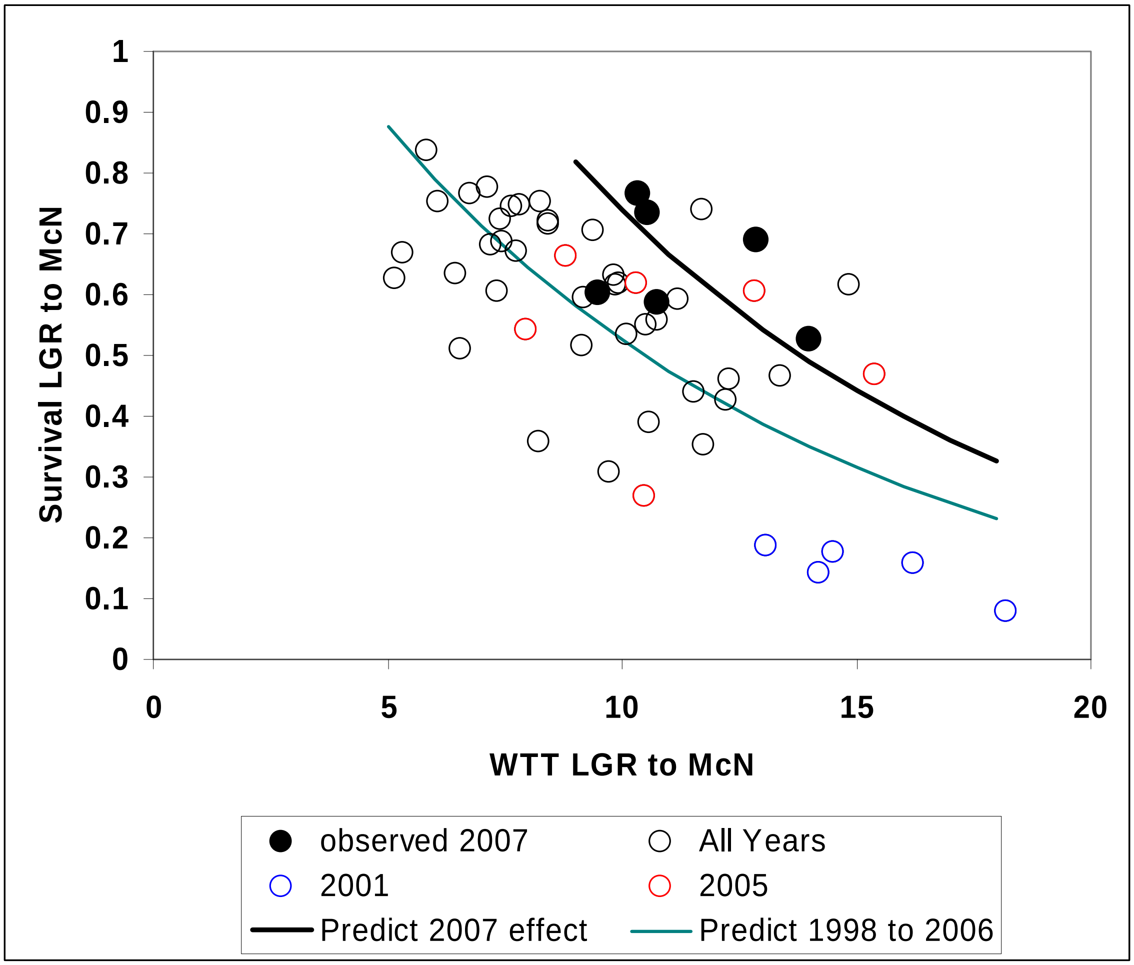


Figure 10. Flows in the Snake River (at Ice Harbor) averaged about 77 kcfs during passage of the survival groups in 2007 while flows at McNary average about 260. Survival was well above that prediction. If that survival improvement were attributed to spill then the increase in flows necessary to achieve that spill benefit could be directly determined based on where the observed survival would have fallen on the prediction curve.

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DATA REQUEST FORM

Request Taken By: Margaret Filardo **Date:** 1/18/10

Data Requested By:
Name: Tom Lorz - CRITFC **Phone:**
Address: **Fax:**
Email:

Data Requested:
Technical Review of NOAA Transportation Analysis

Data Format: Hardcopy [ ] Text [X] Excel [ ]

Delivery: Mail [ ] Email [X] Fax [ ] Phone [ ]

Comments:

Data Compiled By: FPC Staff **Date:** 2/09/10

Request # 5

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DATA REQUEST FORM

Request Taken By: Michele **Date:** 2-2-2010

Data Requested By:
Name: Ron Boyce **Phone:**
Address: ODFW **Fax:**
Email:

Data Requested:
see attached email
review impacts of implementing
NOAA transportation proposal

Data Format: Hardcopy ☐ Text ☐ Excel ☐

Delivery: Mail ☐ Email ☒ Fax ☐ Phone ☐

Comments:

Data Compiled By: FPC staff **Date:**

Request # #6

Michele Dehart

From:	Ron Boyce [ron.boyce@state.or.us]
Sent:	Monday, February 01, 2010 5:43 PM
To:	Michele Dehart
Cc:	Ed Bowles; Rick Kruger; Ron Boyce; Anthony Nigro
Subject:	Review of NOAA Transport Analyses
Attachments:	Transport analysis no appendices (16.dec.09).pdf; 1998-2008 transport analysis Memo to Suzumoto12-21-09.pdf; Transport analysis appendices only (16.dec.09).pdf

Michele- As you know, the attached NOAA Transport report was provided by Paul Wagner on January 14 to FPAC for review. I would like to request assistance from the Fish Passage Center to review the analyses and findings in the report regarding the survival benefits transportation vs inriver migration of Snake River Chinook and steelhead. In order to address this issue comprehensively, I would also like to request a review on other effects of transportation operations not included in the NOAA report such as effects on other species (ex: sockeye), effects on homing and straying of adults (particularly steelhead), migration timing, and other biological issues that should be considered. If possible, I would appreciate FPC's review within a month prior to the fish migration season to help inform us on 2010 hydro-operations. Thank you very much for your assistance and let me know of any questions.