FISH PASSAGE CENTER

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MEMORANDUM

TO: Ron Boyce, ODFW
Tony Nigro, ODFW

FROM: Michele DeHart

DATE: December 3, 2007

RE: Proposed maximum transportation, no voluntary spill for fish passage operation, May 15 to May 31, Snake River when flows are above 65 kcfs.

In response to your request, the Fish Passage Center staff reviewed the proposed no spill, maximum transportation operation and considered potential alternative operations to benefit steelhead. We reviewed and analyzed passage data, juvenile survival and smolt-to-adult return data for Snake River steelhead. Our review of the proposed operations, historical operations, historical fish passage data and analysis resulted in the following points for your consideration. A detailed discussion of each of these points is attached. **Our review and conclusions do not support the implementation of the proposed elimination of spill from May 15 through May 31**. Our review indicates that an alternative to improve steelhead survival and adult return could include decreases in water travel time in the Columbia River reach from McNary to Bonneville dams, and 24 hour spill for fish passage at John Day Dam within gas cap and adult passage constraints.

- The concept of maximizing transportation is not new and has been extensively tested through implementation for many years. Maximizing transportation of steelhead juveniles at Lower Granite, Little Goose and McNary dams occurred in 1978 through 1993. With the completion of transportation and collection facilities in 1993 at Lower Monumental Dam, maximization of transportation of steelhead was increased and a larger proportion of Snake River steelhead were transported. Maximizing transportation over all of these years did not preclude ESA listing of A-run and B-run steelhead in 1997.

- The Court ordered passage and spill operations implemented in 2006, including spill for fish passage throughout May and June, in a relatively high flow year, resulted in the transportation of an estimated 76% of the hatchery and 79 % of the wild steelhead originating above Lower Granite Dam. Survival of juvenile steelhead in 2006 between Lower Granite and McNary dams was 70%. In 2006, as in previous years the majority of steelhead were transported.
- The proposal to eliminate spill from May 15 – May 31 is based primarily on COMPASS model results and limited empirical data. The state, tribal and federal fishery agencies have documented their concerns regarding the use of COMPASS to determine passage operations. Those documents are available at www.fpc.org/documents . Other data analyses were not considered.
- The model is only as good as its data and assumptions. Limitations in data can certainly affect model outcome. The COMPASS basis, time of arrival at Bonneville versus SAR, is based on just a few years when most steelhead have been bypassed multiple times. The fact that there is a significant relation between the number of times bypassed and survival to adulthood limits the application of the COMPASS data set to describe the relation for steelhead in river migrants. The potential bias in the survival of in-river steelhead migrants to adult return raises significant concern regarding the application of the COMPASS model runs to fish passage management decisions.
- Data collected during the court ordered agreed upon spill operations in 2006 and 2007 indicates that spill is the most beneficial mitigation action implemented in recent years. We compared in-river juvenile steelhead survival rates calculated by NOAA Fisheries which occurred in 2006 a high flow high spill year with 2007 a low flow year when the 2007 operation agreement included spill. Steelhead survival from Lower Granite to McNary was 70% in 2006 the high flow year (seasonal average flow of 125 kcfs) and 69.5% in 2007 (seasonal average flow of 63 kcfs) indicating that spill was very important to survival in the Snake River. This indicates that eliminating spill would likely reduce the survival of steelhead remaining in-river.
- In 2006, a high flow year (spring season average of 326.5 kcfs), outages at John Day Dam resulted in spill of approximately 40% of instantaneous flow 24 hours per day. Juvenile steelhead survival from John Day to Bonneville Dam was 81% in that year. In 2007, a low flow year (spring season average of 245 kcfs) spill for fish passage at John Day was limited to 52% of instantaneous flow for nighttime hours. Juvenile steelhead survival from John Day to Bonneville was 61%.
- SAR data for steelhead indicate that spill increases smolt-to-adult survival. In an analysis examining the relationship between spill and smolt-to-adult survival, average spill for Lower Snake and Lower Columbia River dams, explained the greatest portion of variation in steelhead SARs from LGR to LGR for migration years 1998 to 2005. Using information criteria to examine the degree of fit for the best models to steelhead SAR data, average spill was the best single variable model and average spill was in all models with lowest AICc and BIC scores.
- The CSS ten year retrospective report (Report) summarized ten years of juvenile passage data. The Report showed that the two most influential variables on juvenile survival for steelhead in the Snake River were water travel time (flow) and spill.
- The CSS Report, which summarized juvenile data from 1996 through 2006, did not include adult return data from the implementation of the 2006-2007 operations

agreement. The CSS Report results indicate that overall transported steelhead SARs were higher than in-river migrating, bypassed SAR. However the SARS of transported steelhead were not sufficiently high to recover ESA listed stocks and were lower than historic SARs for steelhead.

- The CSS Report found that transportation to in river ratios (TIR) were generally less than 1.0 for wild Chinook and greater than 1.0 for wild steelhead. The CSS report found that in river survival rates for wild Chinook were higher than in-river survival rates for wild steelhead. The higher TIR for steelhead appears to be the result of low in-river survival for steelhead in the years summarized prior to 2006. The CSS report also indicates that in-river survival for steelhead can be improved by reducing water travel time and increasing spill.
- In-river survival estimates for steelhead in recent years have increased with higher spill passage in recent years, which may affect future analyses given the relationship between TIR and in-river survival.
- The CSS Report indicates that steelhead experience significant mortality in the middle Columbia River reach between McNary and Bonneville dams.
- The CSS Report findings do not support the proposed elimination of spill from May 15 to May 31 to maximize transportation of steelhead operation in the Snake River.
- Eliminating spill from May 15 to May 31 will only increase the proportion of steelhead transported by approximately 20%. The majority of steelhead are presently being transported with the present court ordered operation as occurred in 2006.
- A significant portion of the coho, sockeye, fall Chinook, spring Chinook, and steelhead juvenile migrants remaining in-river could be adversely impacted by the proposal to eliminate spill in the last two weeks of May. On average, the majority of Snake River sockeye and coho (63% to 76% for sockeye, 65%-79% for coho) juveniles pass Snake River collector projects during the times of the proposed maximum transport/no spill operation. On average, 20% of the sub-yearling Chinook migration and 15% of the spring Chinook migration (Table 6) would be adversely impacted by increased transportation, increased turbine passage, and increased passage delay by the elimination of spill.

Alternative operations to benefit steelhead could be considered

- **Data and analyses indicate that increasing spill and reducing water travel time (increasing flow) will increase steelhead juvenile survival and SARs.**
- **Data indicates that juvenile steelhead experience high mortality rates in the mid Columbia River reach from McNary Dam to Bonneville Dam.**
- **Survival estimates calculated by NOAA fisheries from 2006 and 2007 were similar although flow conditions were not, indicating that providing spill provided benefits to juvenile survival of in-river migrating steelhead even under low flow conditions.**
- **The survival of juvenile steelhead from John Day to Bonneville dams was significantly higher when 24 hour spill and high flows were provided in 2006 compared to night time spill only and low flows in 2007.**
- **An alternative operation, which could provide more benefit to juvenile steelhead survival and steelhead SARs, would be to spill 24 hours per day, within the gas cap and adult passage constraints at John Day Dam, to decrease passage delay and increase survival. In addition data indicates that decreasing water travel time will decrease steelhead travel time and arrival time to below Bonneville Dam.**

The concept of maximizing transportation of steelhead is not new and has been extensively tested through implementation for many years. The maximization and expansion of transportation of juvenile steelhead did not preclude the listing of Snake River A-run and B-run steelhead stocks as threatened.

Transportation of juvenile steelhead has been maximized at Lower Granite Dam and Little Goose Dam since 1978. The long term strategy for steelhead has been to maximize transportation at these two projects. There was no planned spill for fish passage provided until 1994. Planned spill began at Lower Monumental in 1988 and maximization of transportation began in 1993. Maximization of transportation began at McNary Dam in 1978 and planned spill for fish passage began in 1994.

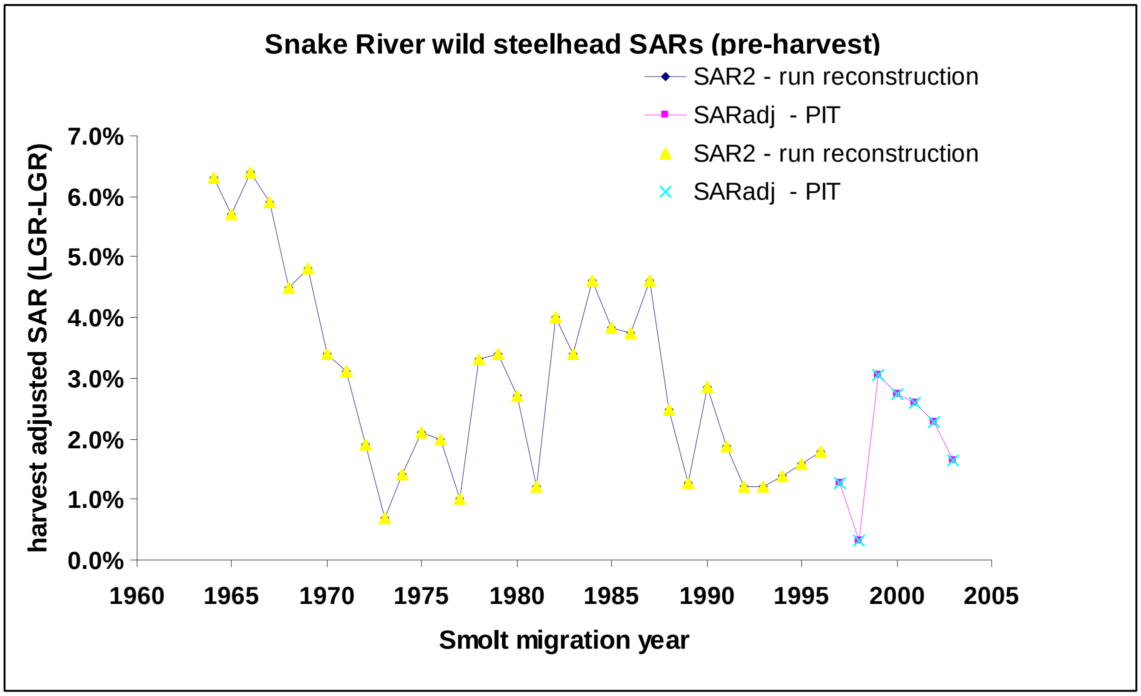
The following table shows that the majority of the juvenile steelhead have been transported even with the planned spill program implementation in recent years (1999-2006).

Comparison of the 2006 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 1999 to 2005. For yearling chinook and steelhead, the results exclude transport at McNary Dam.

Species-age group	**Transport Proportion[1]**							
	2006	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**
Yearling Chinook	0.611 (H) 0.579 (W)	0.92	0.870	0.629	0.683	0.980	0.71	0.777 (H) 0.862 (W)
Steelhead	0.76 (H) 0. 793(W)	0.94	0.964	0.670	0.677	0.986	0.81	0.825
Subyearling Chinook	0.521 (H) 0. 562(W)	0.809	0.972	0.895	0.929	0.962	0.93	0.870

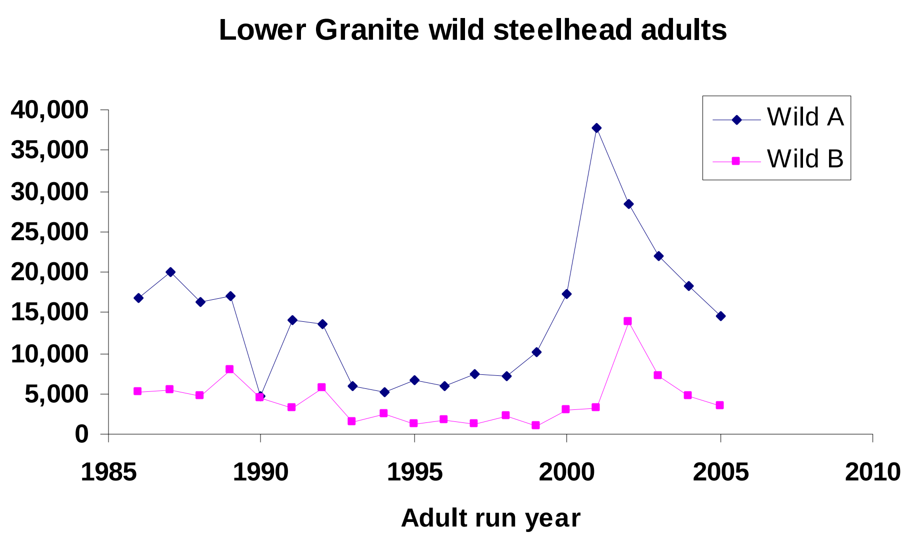
[1] In years 2000-2006, estimates of collection efficiency based on PIT tag data was used to generate a single annual estimate of proportion transported, while in 1999 assumed levels of high and low FGE and high and low spill effectiveness were used to generate a range for that year's estimate of proportion transported.

Although the majority of steelhead have been transported, as juveniles even with a planned spill program, their adult returns from the following run reconstruction and PIT tag SARs are not improving and steelhead SARs are not reaching the level needed for recovery. B-run steelhead in particular are at low levels as illustrated by the following run reconstruction plot.



Snake River wild steelhead SARs (pre-harvest)
SAR2 - run reconstruction
SARadj - PIT
SAR2 - run reconstruction
SARadj - PIT
harvest adjusted SAR (LGR-LGR)
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Smolt migration year

.



Lower Granite wild steelhead adults
Wild A
Wild B
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1985
1990
1995
2000
2005
2010
Adult run year

Average spill for Lower Snake and Lower Columbia River dams explained the greatest portion of variation in steelhead smolt -to-adult return from Lower Granite to Lower Granite for migration years 1998 to 2005.

Recent analyses have shown a strong correlation between ocean indices and adult returns of Snake River spring/summer Chinook (Scheuerell and Williams 2005, Schaller and Petrosky 2007). Other analyses by NOAA have examined the relationship between in-river survival (Lower Granite Dam to Bonneville Dam) and SARs and reported no statistically significant relationship. Based on this conclusion, it has been suggested that it would be difficult to develop a hydrosystem reach survival standard.

To further examine these issues, we used ocean indices of upwelling and sea surface temperatures identified by Scheuerell and Williams 2005, and Schaller and Petrosky (2007) to characterize the ocean environment that juvenile fish would experience in their first year in the ocean. We also used in-river conditions during juvenile out-migration to characterize the freshwater water environment each cohort would have experienced, including average spill proportion and water transit time through the hydro-system.

<u>Methods</u>

Reach survival estimates were produced for steelhead that migrated during the years 1998 to 2005 between Lower Granite Dam and Bonneville Dam. Passage date at Lower Granite Dam and travel time to Little Goose Dam was used to group juvenile migrants into five discrete, two-week cohorts for each year. For each two-week interval of passage at Lower Granite Dam, survival was estimated using Cormack-Jolly-Seber methods. The overall population of juvenile migrants destined to migrate in-river was expressed in Lower Granite Dam equivalents by tracking fish removed for transportation, and expressing those removals in equivalents at LGR based on survival to the downstream dam. In effect, fish removed for transportation or other purposes, reduced the starting population at Lower Granite Dam that would be used to calculate the in-river SAR back to that site.

Once the population at Lower Granite Dam destined to migrate in river was determined, PIT-tag adult returns to Lower Granite Dam were summarized, based on ocean age (e.g. minijacks, jacks, 2-ocean, 3-ocean). SAR's were calculated based on the number of adult returns divided by the in-river population. For yearling chinook, minijacks and jacks (0-ocean and 1-ocean) were not included in the adult return numbers, while for steelhead 1-ocean and older returns were considered adults.

Ocean indices were used to characterize the ocean productivity that juvenile fish would experience the year of ocean entry. For example, out-migrants in migration year 1995 would be assigned ocean indices from that calendar year. Several ocean indices were used in the analysis based on their correlations to SAR's, S/R, residuals, and first year ocean survival (S3) as shown by Hare and Mantua (2000) Scheuerell and Williams 2005, Schaller and Petrosky (2007): April and October Upwelling at transect Latitude 122 W, Longitude 45 N; May and September Pacific Decadal Oscillation (PDO) for the north Pacific Ocean. River conditions during juvenile out-migration were assigned based upon median travel time for the two-week cohorts. Spill proportion and water transit time was calculated for each cohort passing through the entire reach. Spill proportion was averaged for all 8 dams in the juvenile migration corridor, while water transit time through 7 dams (from Little Goose pool to Bonneville Pool) was summed.

Results and Discussion

Models were fitted to the natural log (SAR) using ocean indices as well as in-river conditions as covariates. The results are summarized in Table 1. The best fitting model was a two-variable model that included Average spill proportion (AV_SPIL_PROP) and date group (DATE_GRP). The other top models all included AV_SPIL_PROP, as well as DATE_GRP and then ocean indices such as May PDO (MAY_PDO). Water Transit time (WTT) was also present in several of the top models. While the top 3 models were not distinguishable based on AICc, the rule of parsimony would suggest that the two variable model including AV_SPIL_PROP and DATE_GRP was the best model for predicting SAR's. Models that did not include AV_SPIL_PROP resulted in substantially poorer fits with AICc scores 11.6-48.4 points above the best two variable model. Similarly, models that only included the ocean indices performed poorly compared to models that included indices characterizing the in-river environment.

Table 1. Models fitted to Ln SAR with resulting AICc and BIC scores. Models are sorted by AICc scores.

Variables in Models	P value	AICc	BIC	Variables
AV_SPIL_PROP+DATE_GRP	0	59.9	62.2	2
AV_SPIL_PROP+DATE_GRP+MAY_PDO	0	60.4	62.5	3
AV_SPIL_PROP+WTT+DATE_GRP+MAY_PDO	0	61.3	62.9	4
AV_SPIL_PROP+WTT+DATE_GRP+SEP_PDO+MAY_PDO	0	62.8	63.3	5
AV_SPIL_PROP+WTT+APR_UPWELL+DATE_GRP	0	63.1	64.7	4
AV_SPIL_PROP+DATE_GRP+SEP_PDO	0	63.2	65.3	3
AV_SPIL_PROP+APR_UPWELL+WTT+DATE_GRP+MAY_PDO	0	65.1	65.6	5
AV_SPIL_PROP+WTT+DATE_GRP+SEP_PDO+OCT_UPWLL+ MAY_PDO	0	65.9	64.7	6
AV_SPIL_PROP	0	67.4	69.6	1
AV_SPIL_PROP+WTT+DATE_GRP+APR_UPWELL+SEP_PDO +OCT_UPWLL	0	69.4	68.2	6
AV_SPIL_PROP+WTT	0	70.1	72.5	2
DATE_GRP+APR_UPWELL+MAY_PDO+SEP_PDO+OCT_UPW LL+WTT+AV_SPIL_PROP	0	71.5	67.8	7
DATE_GRP+WTT	0	81.9	84.3	2
WTT+DATE_GRP+MAY_PDO	0	84.0	86.1	3
APR_UPWELL+WTT+DATE_GRP+MAY_PDO	0	85.0	86.6	4
WTT	0.001	93.1	95.3	1
MAY_PDO+APR_UPWELL+SEP_PDO+OCT_UPWLL	0.044	103.0	104.6	4
DATE_GRP	0.212	103.2	105.3	1
APR_UPWELL	0.292	103.7	105.8	1
MAY_PDO	0.594	104.6	106.7	1
SEP_PDO	0.664	104.7	106.8	1
DATE_GRP+MAY_PDO	0.393	105.7	108.0	2
APR_UPWELL+SEP_PDO	0.428	105.9	108.2	2
DATE_GRP+SEP_PDO+MAY_PDO	0.484	108.3	110.4	3

Analyses by Budy et al, (2002) and Zabel (unpublished) have suggested that detection at multiple bypasses is correlated with decreased survival post-Bonneville Dam. Our results for steelhead are consistent with those findings. Analyses have shown a high correlation between steelhead reach survival and spill proportion (Schaller et al 2007). This analysis of SAR's and in-river conditions at out-migration suggests that some of the benefits of spill are realized beyond the in-river environment. This may be why linear regression analyses between in-river survival and SAR have not previously identified strong statistical relationships. Indices of in-river conditions, such as average spill proportion and water transit time, are likely to provide benefits that are not fully explained by reach survival estimates alone. While a good relation was shown to exist between juvenile survival and adult return rate, within at various categories of ocean indices, this analysis shows that the impacts of hydro-system passage conditions are likely to have impacts on ocean survival as well as juvenile hydro-system survival. In particular, water transit time, date of entry into hydrosystem, and average spill proportion were all important variables in describing SARs for Snake River steelhead.

The CSS study results do not support the proposed elimination of spill in order to maximize the transportation of steelhead.

NOAA has stated in public forums that the CSS data on wild steelhead supports their proposal to eliminate spill from May 15 to May 31 and into June each year. This claim is not supported by the CSS data, because CSS analyses have not addressed the benefits of spill versus no spill in comparison with transportation in weekly or bi-weekly time periods such as the NOAA proposed May 15 to May 31 time block. The CSS has shown that wild steelhead had transport-to-inriver ratios(TIRs) significantly greater than 1.0 in four out of the seven migration years (1997 to 2003) analyzed in the 10-year retrospective summary report (Table 3.14 in Schaller et al 2007). These results are based on ***annual*** estimates of transport SAR to inriver SAR ratios being statistically significantly greater than 1.0. Additional analyses of project-specific transport SARs show that most of the benefit of transportation occurs from transporting wild steelhead from Lower Granite Dam, the first dam encountered in the hydrosystem, while benefits from Little Goose and Lower Monumental dams are much more variable and intermediate in level between transport from Lower Granite Dam and simply passing inriver undetected (non-bypass route) past the three Snake River dams with transport facilities (Figure 4.2 in Schaller et al 2007). But these results only address the full migration season, and are not directly applicable to the question of whether spill should be terminated from May 15 to May 31 in order to maximize transportation.

The CSS has conducted analyses in which the full season has been partitioned into three temporal blocks – early (before April 26), middle (April 26-May 10), and late (after May 10). These analyses showed mean SARs for wild steelhead transported at Lower Granite Dam of 2.72% for early period, 3.21% for middle period, and 3.50% for late period. However, when looking at the shape of the SAR distributions (PDFs – probability density functions) for wild steelhead transported from Lower Granite Dam during each of these time periods (Figure 4.20 in Schaller et al 2007), the extreme variability exhibited in the late period PDF makes it unreliable for assessing any transport benefit during that late period (note that the distribution mode for the late period was only around 1% compared to 3% exhibited in the early and middle periods). Wild steelhead bypassed at Lower Granite Dam and continuing to migrate through the hydrosystem inriver had higher SARs during the early period than in the late period. However, these results do not address the expected SAR of wild steelhead passing the three Snake River collector dams undetected, which is primarily through spill when it is provided**.** Weekly or bi-weekly SARS can only be estimated on bypassed fish, not fish passing in spill. **In summary, these CSS results do not support the termination of spill from May 15 to May 31 in order to maximize transportation and should not be construed as supporting this proposed operation.**

In Chapter 2 of the CSS 10-year retrospective summary report (Schaller et al 2007), there are a series of analyses comparing fish travel time and survival rates to environmental and project-operational conditions that ultimately lead to predictive models. These models generally found that, for steelhead (wild and hatchery combined) the duration of time required to migrate through the hydrosystem (i.e. fish travel time) decreased with increasing flows, decreased with increasing spill proportion at a given flow and that these patterns occur for steelhead regardless of the time period of the migration. For a given flow level, steelhead survival is predicted to be higher early in the migration season than later in the season. These model prediction trends match observed data for steelhead shown in Table 2.9 for the flow effects and Table 2.10 for the spill effects in Schaller et al (2007). These findings are consistent with the comment made earlier that bypass wild steelhead SARs are higher earlier in the migration season. The results of the Chapter 2 analyses in Schaller et al (2007) clearly indicate that the provision of flow and spill are two management actions that will improve wild steelhead survival for those fish that remain inriver through the hydrosystem.

Review of data from 2001, a year with very low flows, no spill at Snake River collector dams, and maximum transportation through the season provides additional insight into this issue. The CSS 10-year retrospective summary report (Schaller et al 2007) estimated that 99.2% of the wild steelhead population arriving Lower Granite Dam forebay in 2001 were transported (Appendix E Table E-16). Review of the adult returns of PIT-tagged **wild steelhead smolts from 2001 that were transported and of those that remained in-river provides an indication of whether the full transportation occurring between May 15 and 31 was even beneficial in 2001** a year of extremely low flow. As stated earlier, steelhead travel time (duration) through the hydrosystem deceases and survival increases as flows and spill proportion levels increase. In a year like 2001 with extremely low flows, steelhead smolts encountered extremely poor migration conditions.

There were a total of 21 returning adults of wild steelhead PIT-tagged in Clearwater, Grande Ronde, Salmon, and Imnaha River drainages as well as mainstem Snake River trap at Lewsiton, Idaho for the 2001 migration year (Table 1). **Ten of these returning wild steelhead adults were from smolts that were transported, while the other eleven returning adults were of smolts that had migrated in-river.** Of those that had migrated in-river, three were never detected at any site, and the remaining eight were all detected first at Lower Granite Dam in 2001. As stated in Appendix A of Schaller et al (2007) and the 2005 and 2006 CSS annual reports (Berggren et al 2005, 2006), it was more likely the non-detected wild steelhead either completed their smolt migration in 2002 or passed undetected into the raceways during a computer outage in mid-May at Lower Granite Dam rather than traversed the entire hydrosystem undetected in 2001. Of the eight PIT-tagged wild steelhead adults whose juvenile migration was in-river following their detection at Lower Granite Dam in 2001, a total of six were confirmed to have residualized since they were subsequently detected at a downstream site in 2002. However, it is highly probable that even the other two smolts which were only detected in 2001, likewise held over and completed their migration in 2002. One of these smolts was only seen at Lower Granite Dam on May 4, 2001, while the other was detected again at Little Goose Dam on August 12, 2001, a total of 79 days after first being detected at Lower Granite Dam. Based on these adult returns, it appears likely that most wild steelhead that started migrating in-river in 2001, stopped and overwintered within the hydrosystem, and those surviving then completed their migration in 2002 under more favorable in-river conditions.

Table 1. Date of detections at PIT-tag monitoring sites of wild steelhead smolts from the 2001 migration year that subsequently have returning adult detections at Lower Granite Dam.

Tag Location[1]	**Capture History**	**LGR**	**LGS**	**LMN**	**MCN**	**JDA**	**BON**	**TWX**	**GRA**
			In-River Migrants						
CLW	10000000								9/25/03
SAL	10000000								9/20/03
SAL	10000000								9/5/04
SNK	11000001	9/23/01						**5/11/02**	10/11/03
SAL	11000000	5/4/01							7/1/04
IMN	11000010	5/19/01					**5/11/02**		10/1/03
SNK	11001000	5/20/01			**4/24/02**				9/27/03
IMN	11100000	5/18/01	**4/22/02**						10/12/03
IMN	11100000	5/27/01	8/14/01						11/14/03
GRN	11100100	5/28/01	6/5/01			**4/27/02**			9/12/03
IMN	11101010	5/14/01	5/17/01		**5/4/02**		**5/11/02**		9/22/03
			Transported Migrants						
GRN	11120000	4/29/01	5/2/01	5/5/01					9/2/02
SAL	11200000	4/24/01	4/28/01						9/14/02
IMN	11200000	5/3/01	5/8/01						4/22/03
IMN	11200000	5/16/01	**4/5/02**						10/7/03
CLW	11200000	5/1/01	5/5/01						10/29/03
SAL	12000000	5/7/01							9/11/02
SAL	12000000	5/2/01							10/1/02
IMN	12000000	4/25/01							9/25/03
IMN	12000000	4/25/01							10/27/03
CLW	12000000	4/29/01							3/28/04

[1] SNK=Snake River trap; SAL=Salmon R. basin; IMN=Imnaha R. basin; GRN=Grande Ronde R. basin; CLW=Clearwater R. basin.

Of the ten PIT-tagged wild steelhead adults that were transported as juveniles, all were first detected at Lower Granite Dam in 2001. Five of the returning adults were transported from Lower Granite Dam as smolts, four were transported from Little Goose Dam, and one was transported from Lower Monumental Dam. **Regardless of which dam these juvenile wild steelhead had been transported, all were transported before May 9, except for one fish**. This PIT-tagged smolt had been detected and bypassed at Lower Granite Dam on May 16, 2001, and was transported from Little Goose Dam on April 5, 2002, after having overwintered in the pool below Lower Granite Dam.

Under the extremely low flow conditions experienced in 2001, the PIT-tagged wild steelhead adult return data illustrate that smolts collected and transported before mid-May had documented survivors, as well as those smolts that overwintered and migrated inriver or with transportation in 2002. Likewise, wild steelhead smolts passing Lower Granite Dam throughout May and then overwintering at some downstream location before continuing their migration in 2002 had documented survivors. Even a smolt detected at Lower Granite Dam and bypassed there on September 23, 2001, survived to adulthood by overwintering and completing their in-river migration in 2002.

Based on the PIT-tagged wild steelhead adult returns of juveniles that began their smolt migrations in 2001, the NOAA proposal, in which spill is stopped to maximize transportation between May 15 and 31, would effectively not have benefited wild steelhead in that year. It appears wild steelhead were beginning the process of residualizing prior to May 15, and so transportation after that date may have had limited benefit.

In summary, results from the CSS do not support the NOAA proposal to eliminate spilling May 15 to 31 in order to maximize transportation of listed wild steelhead smolts. On the contrary, data on PIT-tagged wild steelhead in the CSS supports the provisions of adequate flows and spill proportion levels to keep the wild steelhead migration moving quickly through the hydrosystem in addition to transportation of collected wild steelhead. The annual spring freshet occurs around the May 15 to 31 period, with flows generally exceeding the Snake River dam's hydraulic capacity with uncontrolled spill occurring for some interval of time. This freshet helps push the remaining steelhead through the hydrosystem, and hydrosystem operational actions aimed at reducing the spill at the collector dams in order to maximize transportation of wild steelhead could be detrimental to the same wild steelhead population that the NOAA proposal is trying to benefit.

Relationships between in-river survival and transport to in-river ratio (*TIR*) indicate that steelhead transportation benefits are directly related to poor in-river conditions. In river conditions can be improved by decreasing water travel time and increasing spill for fish passage. Improved in-river survival will change the TIR.

The CSS (Schaller et al. 2007) found that transportation-to-in-river ratios (*TIRs*) were generally less than 1.0 for wild Chinook and greater than 1.0 for wild steelhead, which suggested that transported steelhead had higher smolt-to-adult survival rates (*SARs*) than steelhead that migrated in-river. However, the CSS also found that juvenile in-river survival rates were lower for wild steelhead than wild Chinook. One potential explanation for the higher *TIRs* for steelhead is that poor juvenile in-river migration conditions have resulted in poor in-river survival rates for steelhead. Under this hypothesis, improvements in in-river survival could result in *TIRs* less than 1.0 for steelhead along with providing higher *SARs* for steelhead that migrate in-river. To investigate this hypothesis, we examined the relationships between in-river survival rates and *TIRs* for each species. We also examined whether the relationship between in-river survival (S_R) and *TIR* was similar across species.

Methods and Results

Schaller et al. (2007) provides estimates of S_R and *TIR* for wild Chinook and wild steelhead. We used linear regression to assess the relationships between S_R and *TIR* for both species (Figure 1). The dependent variable (*TIR*) was log-transformed to better approximate normality in the error terms and to reduce heteroscedasticity. Table 3 below, contains the resulting parameter estimates and summary statistics from the fitted relationships. Both regressions demonstrated statistically significant slopes ($P = 0.03$ for Chinook and $P = 0.05$ for steelhead). For wild Chinook, the mean *TIR* is predicted to decline below 1.0 when in-river survival rates are greater than 0.52. For wild steelhead, the mean *TIR* is predicted to decline below 1.0 when in-river survival rates are greater than 0.55. Historically for wild Chinook, S_R has been greater than 0.52 in four years and in two of those years, *TIRs* were less than 1.0 (Appendix 1). Historically for wild steelhead, S_R has not been greater than 0.55, but the highest S_R (0.54) was associated with a *TIR* of 0.20 (Appendix 1).

Table 3. Equation parameter estimates, R^2-values, and *P*-values for regressions between S_R and Log(*TIR*)for wild Chinook and wild steelhead.

Species	Equation parameter estimates	R^2-values	*P*-value
wild Chinook	$\text{Log}(TIR) = 1.78 - 3.45S_R$	0.44	0.03
wild steelhead	$\text{Log}(TIR) = 3.51 - 6.46S_R$	0.55	0.05

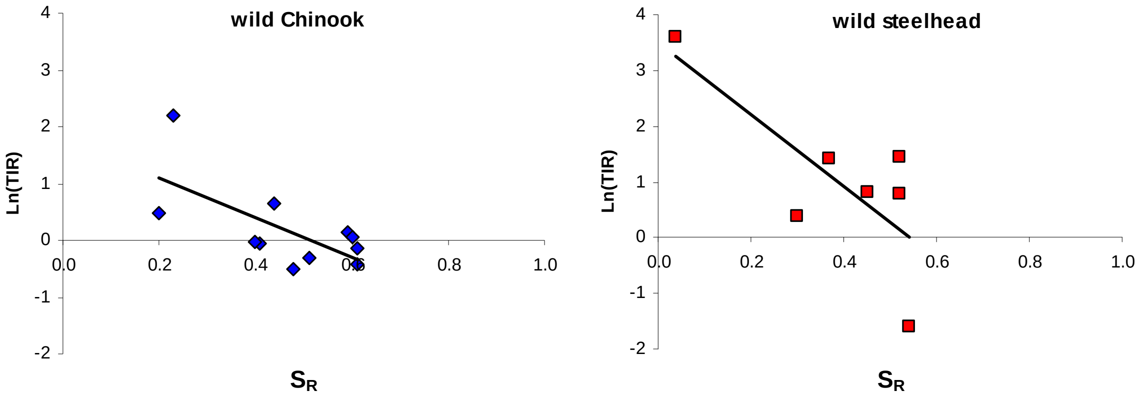


Figure 1. Regression relationships between in-river survival (S_R) and Log(*TIR)* for wild Chinook (left panel) and wild steelhead (right panel).

Next, we examined whether there were differences in the relationships between S_R and *TIR* by species. We fit four models (Table 4) to examine whether a common model could apply to both species or whether each species had different intercept and/or slope parameters describing the relationships between S_R and *TIR*. We used Akaike's Information Criterion (AIC) to determine the best-fitting model, with lower values of AIC indicating a better fit to the data.

The resulting AIC values indicate that a common (across-species) model can be used to characterize the relationship between S_R and *TIR* for both species (Table 4). Species-specific intercepts and/or slopes resulted in higher AIC-values than the model that used one intercept parameter and one slope parameter to characterize the relationship. The best-fit regression was: $\text{Log}(TIR) = 2.75 - 5.20S_R$, which had an R^2 of 0.50 and a highly significant slope ($P < 0.001$, Figure 2). The common model parameter estimates indicate that mean *TIR* will be less than 1.0 when S_R is greater than 0.53. Historically, five of the S_R estimates have been greater than 0.53, and three of the five estimates of *TIR* were less than 1.0 (Appendix 1).

Table 4. AIC values for the four models examined for describing the relationship between S_R and *TIR*.

Model	AIC
one intercept, one slope	48.74
species-specific intercept, one slope	49.40
one intercept, species-specific slope	50.31
species-specific intercept and slope	49.76

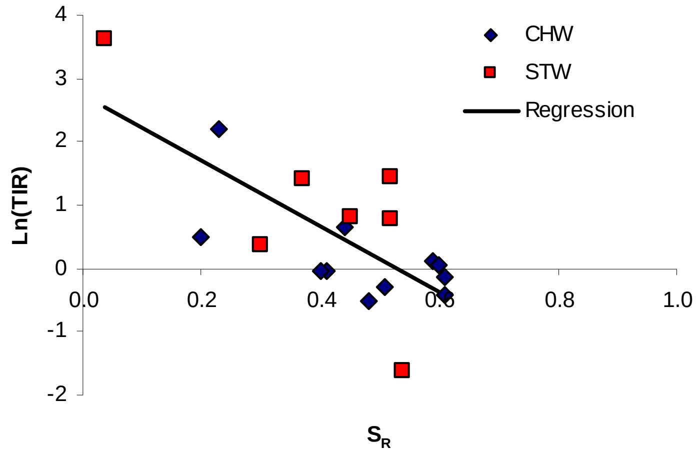


Figure 2. Lowest-AIC regression of the relationship between S_R and Log(*TIR*) for wild Chinook and wild steelhead combined.

Discussion

These results support the hypothesis that the higher *TIRs* observed for wild steelhead is a result of low in-river survival rates for wild steelhead. Over the time series examined, in-river survival rates have been considerably lower for steelhead compared to Chinook (average S_R = 0.46 for wild Chinook and 0.39 for wild steelhead). Using the common (across-species) model, mean *TIR* is predicted to be 2.06 when the in-river survival rate is 0.39. However, if in-river survival rates increased to values greater than 0.53, the mean *TIR* for both species is predicted to decline below 1.0. The S_R for steelhead was greater than 0.53 in only one year (1998, S_R = 0.54, Appendix 1), but steelhead demonstrated a *TIR* much less than 1.0 (*TIR* = 0.20, Appendix 1). Because in-river survival rates are so much lower for steelhead compared to Chinook, it is not surprising that the *TIRs* for steelhead are higher compared to Chinook. If the S_R for steelhead were similar to Chinook, these results suggest that *TIRs* would also be similar.

The results in Schaller et al. (2007) demonstrate that improvements in in-river survival for steelhead can be achieved through reductions in water travel time and increases in the percentage of spill. The highest weekly survival rate observed in the LGR-MCN reach (0.84) occurred during the last week in May 1999 when water travel time was 5.8 days (flow = 211 kcfs) and the average percent spill was 42%. The models developed in Schaller et al. (2007) also suggest that reduction or elimination of spill would dramatically reduce in-river survival rates for steelhead. For example, under conditions of 120 kcfs flow and 50% spill in the LGR-MCN reach during late May, steelhead survival is predicted to be 0.49 versus 0.27 under conditions of the same flow and 0% spill.

The expected result of management decisions to terminate or reduce spill based on *TIRs* becomes a self-fulfilling prophesy: the termination of spill would reduce the in-river survival rates of juvenile migrants (both steelhead and Chinook) resulting in *TIRs* greater than one. However, if juvenile migration conditions are improved through reductions in water travel time and increases in the percent spill, in-river survival rates would increase and *TIRs* would be less than one. An additional consideration is the overlap between other species (e.g., juvenile sockeye and fall Chinook) that would be experiencing the same migration conditions.

The information presented here on S_R and *TIRs* indicates that *TIRs* are largely a function of the conditions that are provided to in-river migrants. An important point to remember is that *TIR* is the *ratio* of the *SAR* of transported fish versus the *SAR* of fish that migrate in-river. Management decisions have limited ability to affect the *SAR* of fish that are transported as transport *SARs* are primarily a function of the environmental conditions experienced during the estuarine/early-ocean period. In contrast, management decisions have much greater ability to affect the *SARs* of fish that migrate in-river. Decisions to reduce water travel time or increase the percentage of spill functionally decrease the *TIR* by increasing the *SAR* of in-river migrants. These same decisions can increase the proportion of fish migrating in-river under improved migration conditions. As a consequence, increasing the proportion of fish migrating in-river under improved migration conditions is the *only* way to increase the population-level *SARs* of anadromous salmonids by increasing the *SARs* of fish that migrate in-river and reducing the number of fish that are transported.

Appendix 1. Data from Schaller et al. (2007) used in the analysis.

Year	S_R	Species	*TIR*	ln(*TIR*)
1994	0.20	CHW	1.62	0.48
1995	0.41	CHW	0.95	-0.05
1996	0.44	CHW	1.92	0.65
1997	0.51	CHW	0.74	-0.30
1998	0.61	CHW	0.87	-0.14
1999	0.59	CHW	1.14	0.13
2000	0.48	CHW	0.60	-0.51
2001	0.23	CHW	8.96	2.19
2002	0.61	CHW	0.65	-0.43
2003	0.60	CHW	1.05	0.05
2004	0.40	CHW	0.97	-0.03
1997	0.52	STW	2.20	0.79
1998	0.54	STW	0.20	-1.61
1999	0.45	STW	2.28	0.82
2000	0.30	STW	1.45	0.37
2001	0.04	STW	37.00	3.61
2002	0.52	STW	4.25	1.45
2003	0.37	STW	4.13	1.42

Survival estimates calculated by NOAA fisheries from 2006 and 2007 were similar although flow conditions were not, indicating that spill provided benefits to juvenile survival of in-river migrating steelhead, even under low-flow conditions. Additionally, in river survival for steelhead has increased in recent years, which have not been included in transport benefit analyses because adult returns are not complete.

The following table (Table 5) was developed from an August 31, 2007 NOAA National Marine Fisheries Service memo from John Ferguson on "Preliminary survival estimates for passage during the spring migration of juvenile salmonids through Snake and Columbia River reservoirs and dams, 2007". Juvenile steelhead survival (hatchery and wild combined) in 2007 was 0.695. This contrasts to the 2006 estimate, which was 0.702 and the 2001 estimate of 0.168. However, 2006 was a high flow year in the Snake River (125 Kcfs spring flow average), while 2007 was an extremely low flow year (63 Kcfs spring flow average). Given the relation between flow and survival for steelhead it was anticipated that juvenile survival would have been more like that observed in 2001 a drought year when average spring flow was about 48 Kcfs. The operational difference between the two years in the Snake River was that no spill occurred at Snake River collector projects in 2001, while spill occurred all through the spring migration period in 2007. At John Day Dam the difference in operations was high flow and spill of approximately 40% instantaneous flow 24 hour per day in 2006, compared to lower flow and spill of 52% instantaneous only during nighttime hours in 2007. As NOAA notes in their memo "The 2007 water year differed, and from the other low-flow year of 2001, in the amount (and percentage) of the flow volume that passed Snake River dams via spillways. The mean volume spilled at Lower Granite, Little Goose, and Lower Monumental dams was near constant throughout April and May of 2007. With the low flow of April, this represented the highest percentage of spill of the last 7 years." NOAA does make reference to the possibility that tern predation was lower this year, but no data have been analyzed to suggest this change.

Table 5. Mean estimated survival and standard error (s.e.) through various reaches of the Snake and Columbia River power system for steelhead originating in the Snake River 2001, 2007. (Hatchery and wild fish combined) Data from John Ferguson, August 31, 2007 memo.

Year	LGR –MCN	MCN -JDA	JDA-BVL
2001	0.168 (0.006)	0.337 (0.025)	0.753 (0.063)
2002	0.536 (0.025)	0.844 (0.063)	0.612 (0.098)
2003	0.597 (0.013)	0.879 (0.032)	0.630 (0.066)
2004	0.379 (0.023)	0.465 (0.078)	No estimate
2005	0.593 (0.018)	0.595 (0.040)	No estimate
2006	0.702 (0.016)	0.795 (0.045)	0.813 (0.083)
2007	0.695 (0.020)	0.947 (0.087)	0.614 (0.076)

The COMPASS model does not provide an adequate basis for eliminating spill the last two weeks of May to improve Snake River steelhead survival.

The Draft Biological Opinion states that terminating spill during the last two weeks of May and maximizing transportation provides a benefit for migrating steelhead. This conclusion is reached based on COMPASS model simulations. The foundation for the improvements predicted by the COMPASS model is based on a hypothesis that links salmonid survival to adulthood (SAR) based on the arrival time of juvenile migrants below Bonneville Dam (Scheuerell and Zabel, 2007 *draft manuscript).* With the exception of very early in the season, the earlier a migrant arrives below Bonneville Dam the higher the subsequent survival to adulthood.

While there is likely a biological basis for the relation between arrival below Bonneville and SARs, there are several shortcomings with the present COMPASS relation between arrival timing and SARs for steelhead. These shortcomings affect the ability to predict actual changes in adult survival from this information. Included in those shortcomings are:

- The relation between arrival timing and SARs for steelhead is based on limited data. The analysis used only four years of data available for steelhead (1999, 2000, 2002 and 2003).
- The SARs for steelhead used in the model are based on data collected mostly from years when overall in-river survival was low. The in-river survival in those years was likely affected by the river and project operations and the absolute number of migrating in-river steelhead juveniles. This bias inherently favors transported fish over in-river migrants.
- There is a clear relation between the number of times a juvenile migrant is bypassed and the subsequent survival to adulthood post juvenile hydrosystem passage. The relation can be developed for chinook because of sufficient data, and bypass can be used as a factor for explaining variability in SARs. However, the relation is not developed for steelhead because of the limited data. In response to the data limitations, all in-river migrants have been combined in the NOAA analyses (i.e. 0-bypass, 1-bypass, 2-bypass etc.) in characterizing the relation to SARs potentially biasing in-river migrant SARs too low.
- The COMPASS model uses two relations for describing arrival date below Bonneville and SARs. One is for in-river juveniles and the other is for transported juveniles. The SARs for in-river steelhead are generally lower than for transported steelhead. Consequently, in the model it is more likely that higher transported SARs were derived when the proportion of in-river migrants was low and the proportion of transported fish was high. This would favor a higher transportation SAR by increasing the proportion transported.
- It should be no surprise that the maximization of transport would yield a higher modeled survival given the model mechanics and assumptions that arrival timing at Bonneville determines survival. The model uses a two day transport for barged fish and therefore, transported fish will always arrive at Bonneville sooner than it would have as an in-river migrant. The maximization of transport modeled scenario gets more migrants to below Bonneville Dam on an earlier date than in- river migrants yielding a higher SAR.

The COMPASS model should be one tool for evaluating the efficacy of a measure under consideration in the Biological Opinion not the only tool. The model is only as good as its data and assumptions. Limitations in data can certainly affect model outcome. In this case, we see a relation that is based on just a few years when most steelhead were bypassed multiple times. The knowledge that there is a significant relation between the number of times bypassed and survival to adulthood should give pause regarding the use of a composite data set to describe the relation for steelhead in river migrants. Given this knowledge of the potential bias in the survival of in-river migrants to adulthood, it would be prudent to use extreme caution when making management changes to the way steelhead are handled in the system.

In conclusion, the COMPASS analysis does not provide an adequate basis for eliminating spill the last two weeks of May. There is too little data describing juvenile steelhead survival to adulthood, based on whether they migrated in-river or on the barge, to make actual management recommendations based on the COMPASS model.

The proposed operation eliminating spill from May 15 to May 31 will adversely affect other species passing during this time period by increasing turbine passage, increasing transportation and increasing passage delay at the projects.

In years where seasonal average flows exceed 65 Kcfs, the Draft 2007 Biological Opinion (2007 BiOP) calls for the termination of spring spill and implementation of maximum transportation at Snake River collector projects (LGR, LGS, and LMN), beginning May 15^{th}. This operation would continue until the initiation of summer spill, which would begin when subyearling Chinook exceed 50% of the collection at each Snake River project for a 3 day period after June 1. If subyearling Chinook do not exceed 50% of the collection for a 3 day period in June, summer spill at these projects would begin on July 1.

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 that indicate higher SARs for transported steelhead versus those that migrated in-river or were bypassed. Although transported steelhead have had higher SARs than those migrating in-river or bypassed, this is not the case for wild Snake River spring/summer Chinook. Furthermore, it is unclear whether there is a benefit to transporting Snake River subyearling Chinook. Finally, it is unknown what kind of impact transportation has on Snake River sockeye and coho juveniles. Switching to maximum transportation with no spill, beginning May 15, 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.

To investigate the potential impact of operating at maximum transportation with no spill (from May 15 through the initiation of summer spill), FPC staff estimated the proportion of the population of yearling Chinook, steelhead, sockeye, coho, and subyearling Chinook passing Lower Granite, Little Goose, and Lower Monumental dams during this time, over the past ten years (1998-2007). These estimates are based on the daily passage index for each species at LGR, LGS, and LMN. For each year, we determined the start date for summer spill at each project, based on the 50% subyearling Chinook criteria indicated in the 2007 BiOP. Results from this analysis can be found in Table 6.

On average, the vast majority of Snake River sockeye and coho (63.4 to 75.9% for sockeye, 64.9-78.6% for coho) juveniles pass Snake River collector projects during the times of the proposed maximum transport/no spill operation (Table 6). Given that such a high proportion of sockeye and coho populations are passing Snake River collection projects during this time, it is highly likely that eliminating spring spill from May 15 until the initiation of summer spill would significantly increase the proportion transported. This is a particularly risky strategy, given that there is no evidence of transportation providing a benefit to these species.

Table 6. Annual percentage of yearling Chinook, steelhead, sockeye, coho, and subyearling Chinook passing Lower Granite Dam during proposed period of no spill/maximized transportation operation (May 15 to Initiation of summer spill).

			Percent Passing During Max. Transport Operation (May 15 to Last Day of Max. Transport Operation)				
Project	**Year**	**Last Day of Max. Transport**	**Yearling Chinook**	**Steelhead**	**Sockeye**	**Coho**	**Subyearling Chinook**
LGR	1998	30-Jun	5.7	19.7	41.0	55.4	16.3
	1999	11-Jun	26.6	38.3	67.0	89.5	21.2
	2000	12-Jun	9.9	22.1	57.2	85.1	8.1
	2001	12-Jun	27.8	39.7	73.4	59.4	12.5
	2002	25-Jun	26.7	47.1	65.3	94.1	17.4
	2003	6-Jun	22.7	50.0	86.9	82.4	18.4
	2004	8-Jun	7.2	33.1	57.1	60.1	12.8
	2005	3-Jun	4.2	15.2	71.4	14.3	47.9
	2006	3-Jun	12.3	24.6	43.7	59.8	36.1
	2007	4-Jun	6.7	24.7	71.4	49.0	16.9
	Average	**11-Jun**	**15.0**	**31.4**	**63.4**	**64.9**	**20.8**
LGS	1998	30-Jun	15.1	29.8	78.3	84.7	8.9
	1999	23-Jun	37.9	46.8	67.4	86.6	28.4
	2000	17-Jun	18.2	12.1	62.6	76.1	16.7
	2001	26-Jun	55.3	54.9	15.4	26.8	7.9
	2002	18-Jun	37.1	54.9	35.7	95.7	15.5
	2003	16-Jun	42.6	61.2	89.8	94.8	38.5
	2004	11-Jun	14.5	35.9	65.9	78.0	27.0
	2005	3-Jun	19.9	28.8	74.4	47.7	20.9
	2006	3-Jun	23.8	29.2	62.4	91.2	28.1
	2007	8-Jun	43.9	53.6	83.6	72.7	16.7
	Average	**15-Jun**	**30.8**	**40.7**	**63.6**	**75.4**	**20.9**
LMN	1998	30-Jun	16.5	37.2	93.1	85.1	29.1
	1999	25-Jun	40.1	55.8	75.3	95.2	20.2
	2000	12-Jun	18.2	32.5	83.4	78.1	27.0
	2001	30-Jun	40.4	54.2	61.3	26.4	17.1
	2002	28-Jun	41.2	73.8	69.6	95.4	16.4
	2003	6-Jun	35.0	69.8	68.3	84.0	18.4
	2004	10-Jun	15.1	42.8	86.4	86.4	20.6
	2005	5-Jun	21.7	36.0	67.6	66.7	20.0
	2006	3-Jun	35.1	43.8	75.7	84.2	32.4
	2007	9-Jun	51.2	63.6	88.8	84.2	27.0
	Average	**15-Jun**	**31.5**	**50.9**	**76.9**	**78.6**	**22.8**

Implementing the proposed operation will only slightly increase the proportion of steelhead transported.

To assess the affect of the proposed elimination of spill on May 15, we estimated the proportion of steelhead which would have been transported in 2007 and 2006 if the proposed May 15 to May 31 elimination of spill was implemented in 2007 and 2006.

- The probability of steelhead originating above Lower Granite Dam being transported in 2007 under the operations agreement was estimated by FPC to be 47% for hatchery steelhead and 43% for wild steelhead. Ending spill in mid-May, as proposed by NOAA would have increased the proportion transported to approximately 65%. Implementing the NOAA proposal to eliminate spill the last two week of May in 2006 would have increase the proportion of steelhead transported by approximately 13%, from 78% to 90%.

- The estimated transport probabilities in 2007 were the lowest since FPC began calculating those numbers in 1999

- The lower portion transported in 2007 was due to higher than average spill proportions at Snake River collector dams and the delayed transport schedule. However, in-river survival of steelhead calculated by NOAA fisheries indicated a 69.5% survival of in-river migrating steelhead in 2007 which was similar to the 70% in-river survival which occurred in the high flow high spill year of 2006.

<u>Methods</u>

Daily passage indices were used to estimate steelhead passage timing over the season at Lower Granite Dam. This approach was compared to population indices based on estimated daily detection efficiencies of PIT-tagged steelhead and found to be very similar for the years 2003 to 2007. Detection efficiency estimates were generated from CJS reach survival estimates for Lower Granite, Little Goose and Lower Monumental dams, for both hatchery and wild PIT-tagged steelhead released above Lower Granite Dam. From the Lower Granite timing data (which was combined for hatchery and wild steelhead), and the detection efficiency estimates, the probability of steelhead being transported at Snake River collector dams was calculated.

The projected proportion of steelhead that would have been transported at Lower Granite Dam in 2007, had the new BiOp transport program been implemented, was also calculated. The new BiOP calls for maximum transport (by stopping spill) beginning May 15 at Snake collector dams. Spill would be begun anew in June, when 50% or more of the collection was subyearling chinook. Estimates of detection efficiency from 2001 were used to simulate what proportion of steelhead would have been collected at those sites in 2007 under the no spill scenario. Steelhead travel time, in 2007, was just under 3 days between LGR and LGS, and just under 6 days LGR and LMN. Therefore, fish arriving at Lower Granite Dam between May 9 and May 11 were assumed to pass LMN dam after spill had ended on May 15. Similarly, fish that passed LGR between May 12 and 14 were assumed to pass LGS and LMN after spill ended at those sites on May 15. Because it is difficult to determine what impact no spill would have had on collection at Little Goose and Lower Monumental dams, it was assumed in our estimate that those dams would have completed no spill operation in such a way that steelhead passing Lower Granite Dam after June 4 (the last date the no spill operation would have occurred in 2007 based on collection at LGR) would not be subject to transport at downstream sites.

Results

Detection probabilities used in the 2007 calculations are shown in Table 7. The CE values were derived from survival estimates, while the transport proportion of collection was derived from SMP data. The detection probabilities in 2007 were much lower at Lower Granite Dam and especially at Little Goose Dam, such that overall detection probability for 2007 was markedly lower than other years. Table 8, summarizes the transport probabilities for steelhead originating above Lower Granite Dam in 2007. As can be seen the 2007 values of 47% for hatchery and 43% for wild fish were much lower than any other recent year. The next closest year, 2003 at 67%, was a relatively high flow year.

Table 7. Estimated detection probabilities, transport proportions and resulting overall proportion of steelhead transported at transport dam.

Species/Rear Type	Dam	CE estimated detection probability	P(t) Proportion of collection transported[1]	P(j) overall proportion transported
Hatchery Steelhead	LGR	0.24	0.995	0.244
	LGS	0.35	0.993	0.346
	LMN	0.18	0.990	0.181
Wild Steelhead	LGR	0.22	0.995	0.219
	LGS	0.39	0.993	0.388
	LMN	0.25	0.990	0.249

[1] Proportion of collection transported was calculated as (total fish transported/total collection) during the time period when transport was occurring at each dam.

If the NOAA proposal had been implemented in 2007, based on actual collection at Lower Granite Dam, there would have been no spill between May 15 and June 4 at that project. Our estimate of the resulting transport proportion under the new BiOp scenario was 65%. This represents a 20 percentage point increase in the proportion of steelhead that would have been transported in 2007.

Table 8. Estimated proportion of steelhead arriving Lower Granite Dam "destined" to the transportation strategy.

	Migration Year								
Species	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Steelhead	0.83	0.81	0.99	0.68	0.67	0.96	0.94	0.76(H) 0.79(W)	0.47(H) 0.43(W)

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