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MONITORING AND EVALUATION OF SMOLT MIGRATION IN THE COLUMBIA BASIN

Volume III: Evaluation of the 1997 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook and Sockeye in the Snake River Basin using Program RealTime

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VOLUME III

Evaluation of the 1997 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook and Sockeye in the Snake River Basin using Program RealTime

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<u>Monitoring and Evaluation of Smolt Migration in the Columbia Basin</u>

Other Publications in this Series

Volume I: Townsend, R. L., J. R. Skalski, and D. Yasuda. 1998. Evaluation of the 1995 predictions of run-timing of wild migrant subyearling chinook in the Snake River Basin using program RealTime. Technical Report (accepted) to BPA, Project 91-051-00, Contract 91-BI-91572.

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<u>1997</u>

Townsend, R. L., D. Yasuda, and J. R. Skalski. 1997. Evaluation of the 1996 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-91572-1) to BPA, Project 91-051-00, Contract 91-BI-91572.

<u>1996</u>

Townsend, R. L., P. Westhagen, D. Yasuda, J. R. Skalski, and K. Ryding. 1996. Evaluation of the 1995 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-35885-9) to BPA, Project 91-051-00, Contract 87-BI-35885.

<u>1995</u>

Townsend, R. L., P. Westhagen, D. Yasuda, and J. R. Skalski. 1995. Evaluation of the 1994 predictions of the run-timing of wild migrant yearling chinook in the Snake River Basin. Technical Report (DOE/BP-35885-8) to BPA, Project 91-051-00, Contract 87-BI-35885.

<u>1994</u>

Skalski, J. R., G. Tartakovsky, S. G. Smith, P. Westhagen, and A. E. Giorgi. 1994. Pre-1994 season projection of run-timing capabilities using PIT-tag databases. Technical Report (DOE/BP-35885-7) to BPA, Project 91-051-00, Contract 87-BI-35885.

<u>1993</u>

Skalski, J. R., and A. E. Giorgi. 1993. A plan for estimating smolt travel time and survival in the Snake and Columbia Rivers. Technical Report (DOE/BP-35885-3) to BPA, Project 91-051-00, Contract 87-BI-35885.

Smith, S. G., J. R. Skalski, and A. E. Giorgi. 1993. Statistical evaluation of travel time estimation based on data from freeze-branded chinook salmon on the Snake River, 1982-1990. Technical Report (DOE/BP-35885-4) to BPA, Project 91-051-00, Contract 87-BI-35885.

Preface

Project 91-051 was initiated in response to the Endangered Species Act (ESA) and the subsequent 1994 Council Fish and Wildlife Program (FWP) call for regional analytical methods for monitoring and evaluation. This project supports the need to have the "best available" scientific information accessible to the Bonneville Power Administration (BPA), fisheries community, decision-makers, and public by analyzing historical tagging data to investigate smolt outmigration dynamics, salmonid life histories and productivity, and providing real-time analysis to monitor outmigration timing for use in water management and fish operations of the hydrosystem. Primary objectives and management implications of this project include: (1) to address the need for further synthesis of historical tagging and other biological information to improve understanding and identify future research and analysis needs; (2) to assist in the development of improved monitoring capabilities, statistical methodologies and software tools to aid management in optimizing operational and fish passage strategies to maximize the protection and survival of listed threatened and endangered Snake River salmon populations and other listed and nonlisted stocks in the Columbia River Basin; (3) to design better analysis tools for evaluation programs; and (4) to provide statistical support to the BPA and the Northwest fisheries community.

This report addresses measure 4.3C of the 1994 Northwest Power Planning Council's Fish and Wildlife Program with emphasis on improved monitoring and evaluation of smolt migration in the Columbia River Basin, and is the seventh in a series of technical reports presenting results of the application of the statistical program RealTime to create inseason predictions of the status of smolt migrations in the Columbia River Basin. Specifically, this methodology was applied to the 1997 in-season migration status and trend of the spring/summer-outmigration of wild yearling chinook and hatchery age 1+ sockeye from Redfish Lake, and the summer-outmigration of wild subyearling chinook, at Lower Granite Dam. It is hoped that making these real-time predictions and supporting data available on the Internet for use by the Technical Management Team (TMT) and members of the fisheries community will contribute to effective in-season population monitoring and assist in-season management of river and fisheries resources. Having the capability to more accurately predict smolt outmigration status improves the ability to match flow augmentation to the migration timing of ESA listed and other salmonid stocks and also contributes to the regional goal of increasing juvenile passage survival through the Columbia River system.

Abstract

Since the 1994 outmigration, program RealTime has been applied to provide in-season predictions of smolt outmigration timing for individual and aggregates of listed threatened and endangered Snake River salmon stocks. Results from the 1997 smolt outmigrations of wild Snake River yearling and subyearling chinook show prediction of run-timing can be accurately forecasted. The number of release sites meeting previous years' criteria for RealTime forecasts dropped to five for the wild spring/summer chinook parr PIT-tagged in 1996: Catherine Creek, Imnaha, Lostine, Minam and South Fork Salmon Rivers. An experiment in lessening previous RealTime requirements for forecasting a outmigration in progress added three release sites of chinook: Lake Creek, Secesh and South Fork Wenaha Rivers; and one release of age 1+ sockeye at Redfish Lake. Passage indices provided by the Fish Passage Center for Lower Granite Dam were monitored for the wild subyearling chinook outmigration. Investigation continued into basing predictions on historical years with similar flows as a way to improve forecasting performance for the wild subyearling outmigration.

Program RealTime's output is a series of estimated percentages of the status of the smolt outmigration throughout the season. To compare the performance the program from year to year, or to compare various assumptions used set up the forecasting, the mean absolute deviance (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion is calculated post-season. Furthermore, these MAD's are considered for three periods of the season: the first 50% of the season, the second 50%, and the entire season.

Wild yearling chinook

Individual release forecasting for 1997 was slightly worse on average than 1996, though the 1997 composite was improved over 1996. The performance of RealTime, averaged over all of the individual tag-sites monitored in 1997, resulted in a mean MAD of 7.7% for the overall season, 6.1% for the first half, and 8.2% for last half . The composite run (all the PIT-tagged fish from the RealTime-monitored releases pooled into one group) for 1997 resulted in MADs of 1.8% overall, 2.3% first half, 1.7% last half. The composite run did not include the releases from Lake Creek, Secesh River nor the South Fork of Wenaha River, as these did not meet the criteria used in the past for selecting releases to be monitored. The performance of RealTime for these three releases indicate that while it may not be necessary to have at least 30 outmigrational detections per year

for at least 3 years, if there are less annual detections than 30, more historical years will be needed to obtain reasonable forecasting accuracy.

Wild subyearling chinook

Two groupings of historical years were investigated as a basis for the 1997 predictions. One group used all historical years (AHY) of the data considered relevant to the present runs (1991-1996) and the other consisted of 1993, 1995 and 1996--years with flow levels similar to 1997 (HIGHY). Both groupings decreased in performance from 1996. The MAD's across the season in 1997 were almost consistently over double those of the 1996 season for both of the grouping of historical years. This trend continued into the breakdown into first and last half of the season for the AHY MAD, and the last half of the HIGHY MAD. The 1997 AHY, though, was improved over 1996's first-half high-flow year prediction performance. Both forecasts failed to predict a spurt of wild subyearling chinook arriving at Lower Granite Dam in September, but the HIGHY grouping was clearly a better forecasting basis than the AHY grouping. The MAD's across the season were 7.55 (AHY) and 4.33 (HIGHY). The HIGHY MAD (0.63) for the first half of the outmigration was much better than the AHY MAD (5.00). This was true as well for the last half of the outmigration, with the AHY MAD (8.57) being worse than that of the HIGHY MAD (5.81).

Hatchery Age 1+ Sockeye

The age 1+ sockeye were not included in composite forecasts, but did use the same prediction algorithm as the yearling chinook, as this was the first attempt at predicting that run. Program RealTime performance for the Redfish sockeye forecast was similar to the mean perfomance of the wild yearling chinook (MAD: 7.3 overall, 6.1 first half, 7.5 last half).

Executive Summary

1997 Objectives

1. Refine application of program RealTime to improve precision and accuracy of in-season predictions of the run-timing of the spring/summer-outmigration of wild Snake River yearling chinook and the summer-outmigration of wild Snake River subyearling chinook at Lower Granite Dam.
2. Predict and report in real-time the “percent run-to-date” and “date to specified percentiles” of the two specified outmigrations at Lower Granite Dam, based on the Fish Passage Center’s (FPC) passage index (wild subyearling chinook)[1] or PIT-tag detections (wild yearling chinook) from specific release sites.
3. Post on-line Internet-based predictions on outmigration status and trends to improve in-season population monitoring information available for use by the Technical Management Team and the fisheries community to assist river management.

Accomplishments

The number of release sites meeting previous years’ criteria for RealTime forecasts dropped to five for the wild spring/summer chinook parr PIT-tagged in 1996: Catherine Creek, Imnaha, Lostine, Minam and South Fork Salmon Rivers. An experiment in lessening previous RealTime requirements for forecasting a outmigration in progress added three release sites of chinook: Lake Creek, Secesh and South Fork Wenaha Rivers; and one release of age 1+ sockeye at Redfish Lake. Passage indices provided by the Fish Passage Center for Lower Granite Dam were monitored for the wild subyearling chinook outmigration. Investigation continued into basing predictions on historical years with similar flows as a way to improve forecasting performance for the wild subyearling outmigration. Objectives for subyearling and yearling chinook and the age 1+ sockeye were accomplished at Lower Granite Dam. On-line run-timing predictions were provided via the Internet (**http://www.cqs.washington.edu**) to the fisheries community throughout each smolt outmigration.

1. The FPC wild subyearling chinook fish passage indices at Lower Granite Dam are a mixture of wild fall chinook and small spring/summer chinook salmon, but are presumed to represent primarily fall chinook passage. Prior to 1993, some unknown faction of hatchery produced spring/summer chinook were likely also included in the index. From 1993 on, all hatchery-produced chinook released in the Snake River Basin have been fin-clipped to confirm their origin and distinguish them from ESA listed stocks.

Findings

Program RealTime's output is a series of estimated percentages of the status of the smolt outmigration throughout the season. To compare the performance the program from year to year, or to compare various assumptions used set up the forecasting, the mean absolute deviance[1] (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion is calculated post-season. In other words, the difference between what the program predicted was the status of the run (i.e. 27% of the total fish passing through Lower Granite Dam had been seen on a particular date) and what the actual status was (32% of the run had actually occurred that day), averaged over the total number of days comprising the outmigration. Furthermore, these MAD's are considered for three periods of the season: the first 50% of the season, the second 50%, and the entire season.

A. Wild yearling chinook

1. 1997 program performance

The performance of RealTime, averaged over all of the individual tag-sites monitored in 1997, resulted in a mean MAD of 7.7% for the overall season, 6.1% for the first half, and 8.2% for last half . On average, the program was off by 7.7 percentage points from the actual outmigration status. The mean 1997 MADs of the individual release sites are large due to poor performance the second half of the season for runs originating from Lake Creek, Minam River and the South Fork of Wenaha River, whereas the composite run (all the PIT-tagged fish from the RealTime-monitored releases pooled into one group) for 1997 resulted in MADs of 1.8% overall, 2.3% first half, 1.7% last half. The composite run did not include the releases from Lake Creek, Secesh River nor the South Fork of Wenaha River, as these did not meet the criteria used in the past for selecting releases to be monitored. The performance of RealTime for these three releases indicate that while it may not be necessary to have at least 30 outmigrational detections per year for at least 3 years, if there are less annual detections than 30, more historical years will be needed to obtain reasonable forecasting accuracy.

2. 1997 program performance compared 1996

1. Mean absolute deviance is the average absolute difference between the predicted proportion and the observed proportion of the outmigration distribution, calculated over the days in the outmigration.

Individual release forecasting for 1997 was slightly worse on average than 1996. Individual tag-site MAD's for 1996 were 5.7% overall, 7.8% first half, 4.6% last half, though the 1997 composite was improved over 1996 (1996 composite run MAD's: 2.4% overall, 1.9% first half, 2.5% last half).

B. Wild subyearling chinook

1. 1997 program performance

Two groupings of historical years were investigated as a basis for the 1997 predictions. One group used all historical years (AHY) of the data considered relevant to the present runs (1991-1996) and the other consisted of 1993, 1995 and 1996--years with flow levels similar to 1997 (HIGHY). Both forecasts failed to predict a spurt of wild subyearling chinook arriving at Lower Granite Dam in September, but the HIGHY grouping was clearly a better forecasting basis than the AHY grouping. The MAD's across the season were 7.55 (AHY) and 4.33 (HIGHY). The HIGHY MAD (0.63) for the first half of the outmigration was much better than the AHY MAD (5.00). This was true as well for the last half of the outmigration, with the AHY MAD (8.57) being worse than that of the HIGHY MAD (5.81).

2. 1997 program performance compared 1996

Both groupings decreased in performance from 1996. The MAD's across the season in 1997 were almost consistently over double those of the 1996 season for both of the grouping of historical years (1996 MAD's: 3.06 (AHY), 2.45 (HIGHY). This trend continued into the breakdown into first and last half of the season for the AHY MAD (1996 first half: 1.98, last half: 3.55), and the last half of the HIGHY MAD (1996 last half: 2.12). The 1997 AHY, though, was improved over 1996's first-half high-flow year prediction performance (MAD = 3.17).

C. Hatchery Age 1+ Sockeye

The age 1+ sockeye were not included in composite forecasts, but did use the same prediction algorithm as the yearling chinook, as this was the first attempt at predicting that run. Program RealTime performance for the Redfish sockeye forecast was similar to the mean perfomance of the wild yearling chinook (MAD: 7.3 overall, 6.1 first half, 7.5 last half).

Management Implications

The ability to accurately predict the outmigration status of composite or individual salmon and steelhead stocks at different locations in the Federal Columbia River Power System (FCRPS) can provide valuable information to assist water managers in optimizing operational and fish passage strategies to maximize benefits to smolt survival. As ambient river conditions effecting smolt survival change in-season, it is important for water managers to be able to access the risks to the individual stocks that comprise the different run timing segments of the overall population, so that adequate actions to protect weak, listed and endangered stocks can be taken. Since the 1994 outmigration, program RealTime has been applied to provide in-season predictions of smolt outmigration timing for individual and aggregates of listed threatened and endangered Snake River salmon stocks. These predictions have been made available to the fisheries community to assist in-season river management.

Recommendations

Results from the 1997 smolt outmigrations of wild Snake River yearling and subyearling chinook continue to show prediction of run-timing can be accurately forecasted and suggest improvements that can be made to the RealTime program. We recommend continuing the previous RealTime criteria in deciding which release sites are included in the RealTime composite run for the yearling chinook and to continue to investigate the less stringent criteria to improve the consistency and accuracy of predictions. The grouping of similar-flow years to form a historical basis for subyearling chinook should also continue, given its more successful results for this year, but do not eliminate the all-years' grouping, as the similar-flow-years grouping has only been investigated during "high" flow years.

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Acknowledgments

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Special appreciation is extended to Judy Cress and Peter Westhagen of the School of Fisheries at the University of Washington for providing critical data management and computer programming support, and to Dr. Al Giorgi for his guidance on biological characteristics of the wild subyearling chinook and thoughtful reviews of early drafts of this manuscript.

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Introduction

Regulating the timing and volume of water released from storage reservoirs (often referred to as flow augmentation) has become a central mitigation strategy for improving downstream migration conditions for juvenile salmonids in the Columbia River Basin. Threatened and endangered salmon stocks have received increased priority with regard to the timing of this flow augmentation, particularly in the Snake River. The optimum is to release water from the storage reservoirs at times when the listed stocks are in geographic locations where they encounter the augmented flow. The success of the flow augmentation, in turn, depends on releasing reservoir waters when and where wild smolt will benefit the most. This requires the ability to predict in real-time the status and trend in the outmigration timing.

Beginning in 1993, a task was initiated under this project to develop and provide real-time analyses of smolt outmigration dynamics for ESA listed stocks and other runs-at-large for the Snake and Columbia Rivers. Program RealTime, a statistical software program for predictions of run-timing (Skalski et al. 1994), was developed to take advantage of historical data to predict the proportion of a particular population that had arrived at an index site in real-time and to forecast elapsed time to some future percentile in a migration. The initial application of program RealTime used PIT-tag detections at Lower Granite Dam to predict the outmigrations of Snake River wild yearling spring/summer chinook at Lower Granite Dam in real-time. Since 1994, program RealTime has been used to make daily predictions of the “percent run-to-date” and “date to specified percentiles” for a number of individual streams included in the National Marine Fisheries Service (NMFS) ecological significant unit (ESU) for Snake River wild yearling spring/summer chinook (Townsend et al. 1995, 1996, 1997). The University of Washington CRiSP model incorporated the predictions of the run status to move the timing forecasts further down the Snake River to Little Goose, Lower Monumental and McNary Dams.

In addition, in 1995, the feasibility of using program RealTime to predict the general status and trend of the summer outmigrations of Snake River wild subyearling chinook at Lower Granite Dam was investigated (Townsend et al. 1998a,b). While information on the migrational characteristics of wild subyearling chinook are more limited than that of the wild spring/summer chinook in the Snake River system, some data on migrational timing have recently been collected and reported (Connor et al. 1993, 1994a, 1994b, 1996; Giorgi and Schlechte 1997; OWICU 1996; Smith et al. 1997). Because only minimal PIT-tagging of naturally-produced wild fall subyearling chinook occurs in the Snake River system due to low stock abundance, program RealTime was altered to use the daily passage index of wild subyearling chinook at Lower Granite Dam provided by the Fish Passage Center(FPC), rather than Lower Granite Dam PIT-tag detections, to characterize run-timing of summer migrants. The program's algorithms were adjusted, as the migrating behavior of subyearling chinook differs from spring/summer yearling chinook (Nelson et al. accepted; Rondorf et al. 1993, 1994a, 1994b, 1996; Connor et al. 1992, 1997, in-preparation-a, b; Garcia et al. in preparation; Tiffan et al. in preparation-a, b).

This report presents a post-season analysis of the results from the third year of using program RealTime for in-season prediction of the run-timing of the summer outmigration of wild subyearling chinook salmon and the fourth year for the spring/summer outmigration of wild yearling chinook salmon from the Snake River system. Observed 1997 data were compared to the predictions made by RealTime for the outmigration of yearling and subyearling chinook observed at Lower Granite Dam throughout the season. Appendix A displays the graphical reports of the RealTime program that were interactively accessible via the World Wide Web during the 1997 migration season. Appendix B contains graphical representations of historical passage distributions at Lower Granite Dam for each yearling chinook release site and the FPC passage index for subyearling chinook. Additional graphical reports and data for the 1997 season are available on the World Wide Web at address *http://www.cqs.washington.edu/crisprt/archive.html*.

Methods

Description of Data

Forecasts and tracking of outmigrational timing at Lower Granite Dam were provided for PIT-tagged wild yearling chinook from the end of March through July, and for the wild subyearling chinook passage index from June 1 through November. An outmigration of age 1+ sockeye from Redfish Lake in Idaho was added to the tracked runs this year. The PIT-tagged subyearling chinook and sockeye originated from nine release sites (Figure 1 and Table 1). For previous years' forecasting purposes, release sites were chosen for their consistent recovery numbers, having at least three years of data with a minimum of 30 tag detections per year. This was a conservative estimate of the minimum amount of historical data considered necessary to give usable forecasts of outmigration. This year, those requirements were loosened somewhat, to provide a greater number of release sites tracked and to determine if a lower historical standard would still provide a good basis for forecasting outmigrational patterns.

Additionally, the results from the 1996 wild yearling chinook outmigration suggested improvements that were made to the RealTime program. Until recently, almost all of the PIT-tagging of wild Snake River spring/summer chinook parr in the tributary streams used in the RealTime predictions has occurred during the summer season. Beginning in 1993, PIT-tagging expanded to fall and winter in addition to the summer season in some Idaho and Oregon streams as more traps were added and more intensive life-history research initiated (Ashe, B.L. et al. 1995, Blenden, M.L. et al. 1996, Keefe et al. 1995, 1996). Investigation into the season effect show differences in the migrational timing past Lower Granite Dam for the groups marked during different seasons (Keefe et al. 1995, 1996). These differences in the migration timing can confound the predictions of the RealTime program which are based almost entirely on historical trends in PIT-tag arrivals at Lower Granite Dam from parr marked during the summer season only. In order to maintain consistency to past predictions, a change was added to the 1997 RealTime criteria to include only PIT-tag detections for parr marked during the previous summer season.

The outmigration of wild subyearling chinook from the passage indices at Lower Granite Dam were obtained from the Fish Passage Center. Based on the results from 1996 RealTime forecasts (Townsend et al. 1998b) using subyearling passage indices, only the years 1991-1996 were used as reference years. One caveat to this information is that at the beginning of the fall run in May, it is impossible to differentiate wild subyearling chinook from small wild spring/summer yearling chinook without sacrificing the fish. This becomes less of an issue as the season progresses, but can make a large difference in the shape of the timing distribution at the beginning of the fall run (Conner et al. 1993). Because of this, the timing distribution of the smolt observed prior to 1 June was deemed too inconsistent for estimation purposes.

Figure 1: Map of Columbia Basin showing release sites used in the 1997 out-migration season forecast timing.

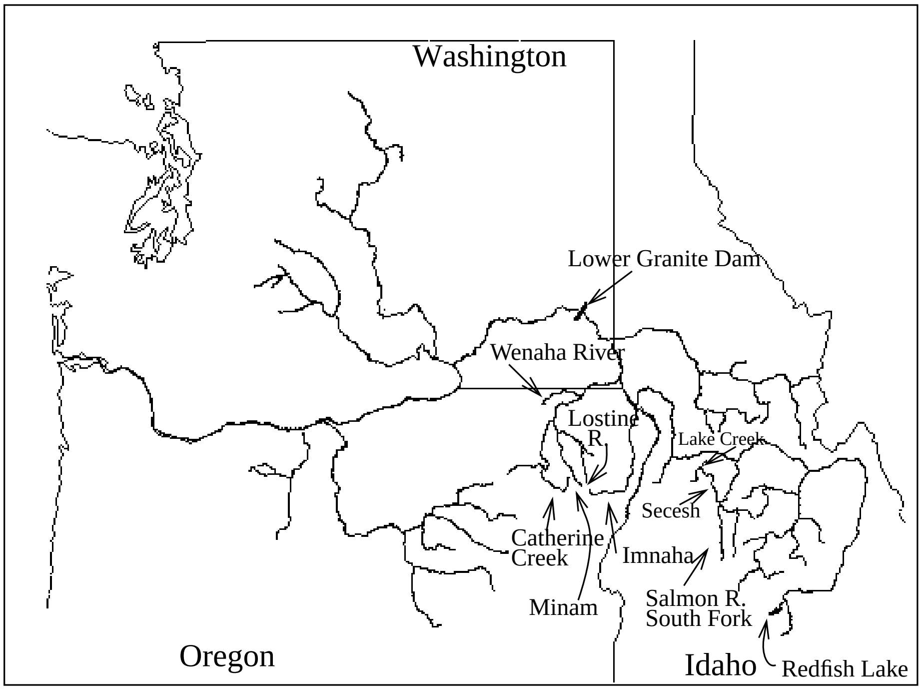


Table 1: The release sites used in predicting wild yearling chinook and Redfish Lake sockeye smolt run-timing by program RealTime in 1997.

Stream Name	GIS Hydrounits[a]
Catherine Creek	17060104
Imnaha River	17060102
Lake Creek	17060208
Lostine River	17060105
Minam River	17060106
Redfish Lake	17060201
Salmon River, South Fork	17060208
Secesh River	17060208
Wenaha River, South Fork	17060106

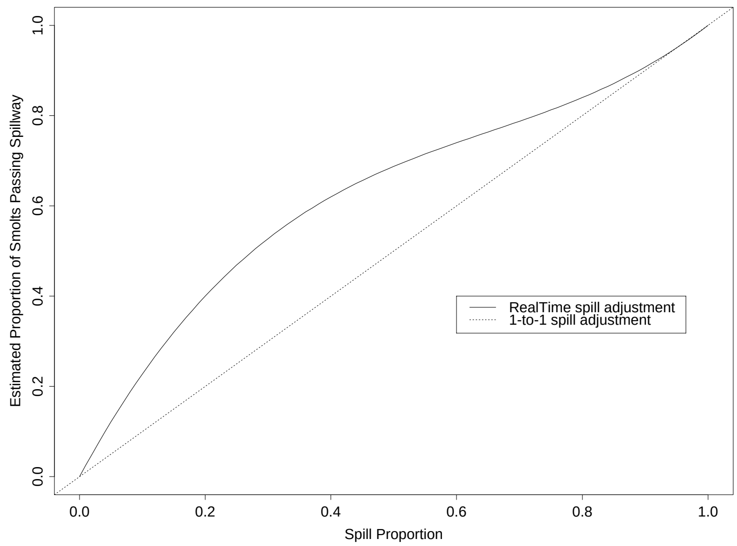
a. Geographical Information System (GIS) designations established by the U.S. Geological Survey.

As some smolt will pass dams undetected through the spill gates, the daily number of fish observed are adjusted for spill using a variant on a method suggested by Giorgi et al. (1985), Stuehrenberg et al. (1986) and Wilson et al. (1991). For 20 and 40% of the total water volume going through the spillway at Lower Granite Dam, the suggested spill effectiveness was 41 and 61%, respectively. A quadratic equation (1) approximates these two points of adjustment, as well as the points (0,0) and (1,1) (Figure 2).

$$y = 1.667x^3 - 3.25x^2 + 2.583x \qquad (1)$$

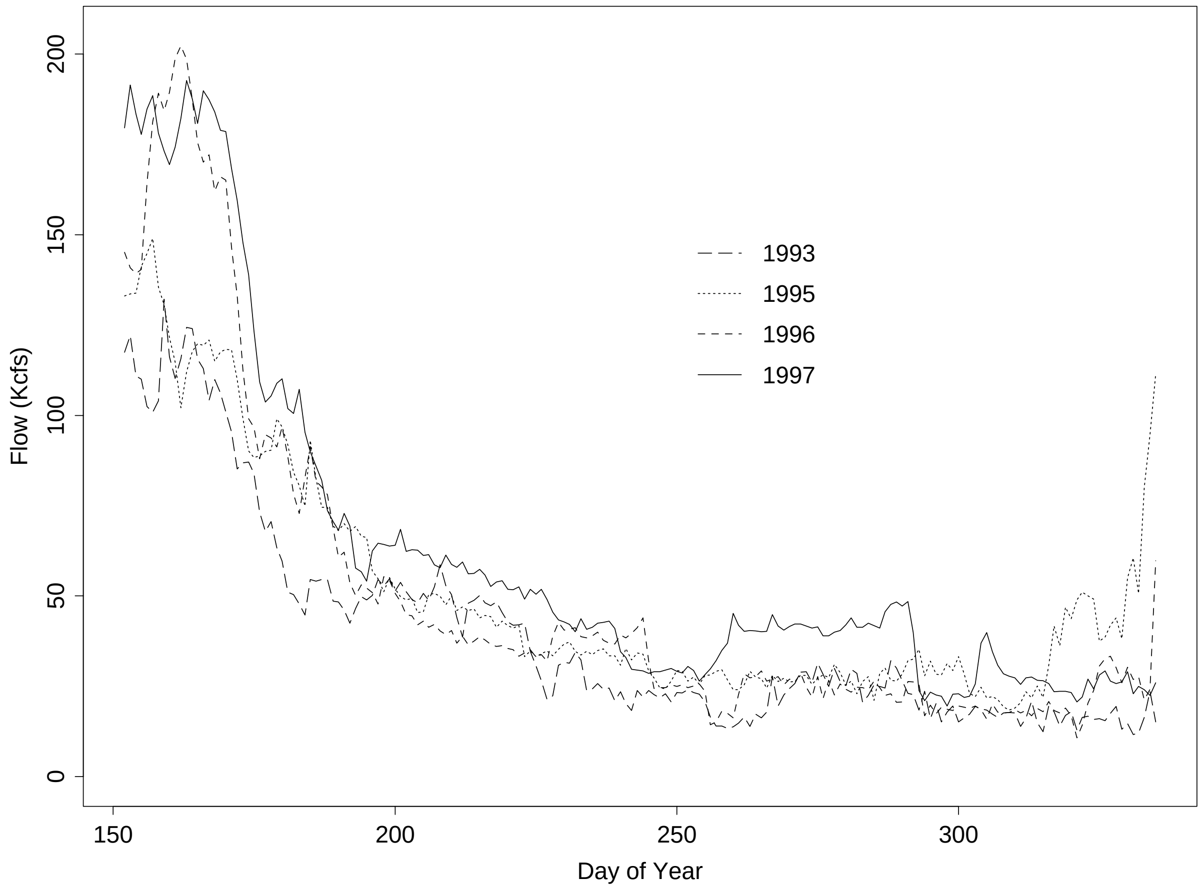
where: y = estimated proportion of smolts that passed unobserved through the spillway, and
x = proportion of total water volume through the spillway.

Figure 2: Program RealTime spill adjustment for observed smolt detected at Lower Granite Dam, compared to a one-to-one proportion-smolt to proportion-spill adjustment.



While flow has not been shown conclusively to have an impact on subyearling chinook travel time above Lower Granite Dam (Connor 1994b and 1996; Giorgi and Schlechte 1997; Smith et al. 1997), it may represent an indicator of similar environmental conditions experienced by the smolt (for example, temperature, flow and turbidity are all highly correlated). To test the theory that flow, or something correlated with flow, has an impact on wild subyearling outmigration timing, a separate "similar flow-years" group was created in addition to basing predictions on all historical years (AHY) available. The 1997 season was predicted to be a "high flow" year, similar to 1993, 1995 and 1996. Consequently, those years were treated as an alternative grouping (HIGHY) of historical years used in forecasting run timing. All four years were fairly close in flow and spill (Figure 3). Spill generally did not occur during the fall outmigration (after 1 June), reducing the variance contributed by the inflation of the observed outmigration numbers to account for the probability of smolt passing Lower Granite Dam through the spillways.

Figure 3: Flows during the period 30 May - 1 December at Lower Granite Dam for 1993, 1995-97.



Prediction Models

Since 1994, the RealTime Forecaster has been using least squares-based algorithms to make daily, realtime predictions. The Least Squares (LS) prediction method incorporates release-recapture information (or other external pre-run estimates) and a measure of the age of the run (number of days from the start of the outmigration to the present, weighted by the number of fish observed per day) in its prediction analysis. This effectively binds these indicators together into a single, more accurate and robust predictor. The 1997 version of the LS method[1] is nearly identical to prior years. The only change in the algorithm is an adjustment to the weighting function to incorporate release-recapture information from the prior year.

Least-Squares (LS) Algorithm

For a given day during the run, the LS algorithm computes the predicted proportion ($\hat{p}$) of the outmigration by finding the value of $\hat{p}$ that minimizes the estimated error according to historical run data. The $\hat{p}$ error is a weighted combination of the least-squares (LS) error, the release-recapture (RR) error, and the age-of-run (AR) error. Weighting depends on the age of the run and the quality of the historic data for the given stream. In the 1994 post-season analysis, the release-recapture method was shown to be a better predictor at the beginning of a run, deteriorating as time progressed. On the other hand, the least-squares method started poorly, but became a better predictor as the run progressed. To combine these two methods, the release-recapture algorithm prediction is heavily weighted initially, with weight shifted to the LS method over time. The initial weighting of the RR error also depends how consistent the release-recapture percentages are from year to year for the selected stream.

Least-Squares (LS) Error

The least-squares error (LSE) for each $\hat{p}$ is summed over the historical years for which data are available. The current run is smoothed using 3, 5-day smoothing passes to filter out statistical randomness. The same smoothing is done to the initial $\hat{p}$ percent of each historical year. Each outmigration pattern is divided into 100 equal portions and the slopes over each corresponding interval are computed. The sum of squares for a prediction compares the slopes for the current year (s_{oj}) versus the respective slopes for the initial $\hat{p}$ percent of the historical years ($s_{ij\hat{p}}$). The total squared error for each predicted percentage of outmigration $\hat{p}$ is calculated according to the formula:

$$LSE(\hat{p}) = \sum_{i=1}^{n} \sum_{j=1}^{100} (s_{oj} - s_{ij\hat{p}})^2 w_{ij} \qquad (2)$$

where s_{oj} = observed slope at the *j*th percentile ($j = 0, ..., 100$) for the current year of prediction,
$s_{ij\hat{p}}$ = slope at the *j*th percentile ($j = 0, ..., 100$) for the first *p* percent of the *i*th historical year ($i = 1, ..., n$), and

1. The LS algorithm was referred to as the New Least Squares (NLS) algorithm in the 1995 report for comparison purposes to the original form of the LS algorithm used for the 1994 outmigration season.

w_{ij} = weight for the *j*th percentile for the *i*th historical year.

For example, letting $\hat{p}$ = 30%, the present run will be compared to the first 30% of the outmigration for each historical year. Similar calculations are performed for each percentage from 0 to 100 percent. The percentage that minimizes the sum of squares (Eq. 2) is the best prediction for the current outmigration timing according to the LS algorithm. The weighting factor is included to more evenly distribute the squared error contribution throughout the outmigration distribution. The weights are:

$$w_{ij} = \frac{D_{oj} + D_{ij}}{R_o + R_i}$$

where D_{oj} = estimated number of days between the (*j*-1) and *j*th percentile for the present year,
D_{ij} = number of days between the (*j*-1) and *j*th percentile for the *i*th historical year (*i* = 1, ..., *n*),
R_o = range in days of the current observed outmigration, and
R_i = range in days of the ith historical year outmigration (*i* = 1, ..., *n*).

The effect of w_{ij} is to give more weight to the errors generated in the tails of the distribution, where the slopes tend to be flat and the number of days between each percentile point are high. Less weight is given to the mid-season, when large numbers of fish detected on a daily basis will create a steep slope in the cumulative distribution. The total sum of the weights adds to one.

Release-Recapture (RR) Error

For spring/summer PIT-tagged smolt, the Release-Recapture method made predictions of run timing by using the total recapture proportion observed in a previous season and then assuming that proportion to be similar for the present year. Further analysis of the release-recapture proportions show that this assumption is not true through the years for all streams, so the average proportion ($\bar{p}$) for an individual stream was used, as this method does work well for forecasting the first half of the season. The predicted percent of the run is calculated according to the formula:

$$RR = \frac{x_d}{\bar{p} \times N} \qquad (3)$$

where
RR = estimated proportion of the outmigration passed on day d,

x_d	= total observed smolt to day *d*,
$\bar{p}$	= mean total proportion of outmigration recovered, and
N	= total number of smolt tagged for the present year.

The number of fish tagged for the present year for a given stream or stream aggregate is multiplied by the mean recapture ratio ($\bar{p}$) of previous years (Table 2) to determine the total number of fish expected. The proportion passed is then estimated. For example, Catherine Creek observed a mean recapture percentage of 11.5% at Lower Granite Dam. For the 1996 run, 1682 smolt were released in Catherine Creek. The expected total number of smolt to be observed at Lower Granite Dam for 1996, based on historical data, would be estimated to be 193.43 smolt (1682 * 0.115).

Wild subyearling chinook present the problem that the total "released" is not known. Instead, the total number observed passage index the previous year is used as an estimate of the total passage index predicted for the present year (Table 3) (i.e. N = total number of smolt observed the previous year in Eq. 3).

RealTime then evaluates each possible percentage $\hat{p}$ (0 to 100) of the outmigration proportion at Lower Granite Dam by calculating an associated Release-Recapture error (RRE). The RRE($\hat{p}$) is the ratio of the predicted RR and each percentage $\hat{p}$ of the outmigration distribution:

$$RRE(\hat{p}) = \begin{cases} \dfrac{\hat{p}}{RR} & if \quad \hat{p} > RR \\ \dfrac{RR}{\hat{p}} & if \quad \hat{p} < RR \\ 1 & if \quad \hat{p} = RR \end{cases} \tag{4}$$

The prediction $\hat{p}$ is assigned the least amount of error ($RRE(\hat{p})$ = 1) when it is equal to RR and more error ($RRE(\hat{p})$ > 1) the further $\hat{p}$ is from RR.

Table 2: Summary for the sites used in predicting 1997 wild yearling chinook run-timing by program RealTime showing (1) number of tagged wild chinook salmon parr released in 1996, (2) detected number of smolts at Lower Granite Dam in 1997, (3) detected number of smolts, adjusted for spill, (4) number of years of historical data, (5) average historical spill-adjusted recapture percentage ($\bar{p}$) and (6) the spill-adjusted recapture percentage for 1997.

Tagging Location	(1) 1996 Parr Tagged	(2) 1997 PIT Detections	(3) Adjusted PIT Detections	(4) Years of Hist. Data	(5) Mean Historical Recapture $\bar{p}$ (%)	(6) 1997 Recapture *p (%)*[a]
Catherine Creek	585	51	120.2	6	11.5	20.6
Imnaha River	1017	98	191.1	8	9.8	18.8
Lake Creek	400	21	40.8	4	9.0	10.2
Lostine River	527	43	93.0	6	13.0	17.6
Minam River	589	49	92.4	4	12.8	15.7
Redfish Lake sockeye	1931	53	131.2	2	5.0	6.8
Salmon River, South Fork	700	36	78.9	7	8.6	11.3
Secesh River	260	34	62.7	8	8.3	24.1
Wenaha River, South Fork	62	10	19.6	4	11.2	31.6

a. Data Sources: PTAGIS Database and RealTime program output as of 9 September 1997.

Table 3: The total passage index numbers of wild subyearling chinook salmon detected at Lower Granite Dam, 1991-1997, June 1 and after.

Year	Number observed
1991	13,672
1992	5,744
1993	16,620
1994	6,765
1995	26,046
1996	17,548
1997	17,561

Age-of-Run (AR) Error

For the age-of-the-run portion of the algorithm, the prediction $\hat{p}$ was the historical proportion observed on a given day of outmigration for a specified historical year.

$$\hat{p} = p_{yd} \tag{4}$$

where p_{yd} = proportion of outmigration passed on day *d* for historical year *y*.

For a given day of run, the proportion predicted is given by the proportion observed in the index year on that day of the run (e.g. for a run estimated to be in its 15th day, the percentage passed by day 15 in a historical run is the estimated present percentage observed). This method was very unstable as historical patterns did not support a day-for-day matching in smolt migration through the years. On the other hand, the mean age of the run, weighted by the cumulative number of fish observed per day, appeared to offer further information and be more robust year to year. The mean fish-run-age (MFRA) is calculated for each *p* of the last historical outmigration and the present run by

$$MFRA(p) = \frac{\sum_{d=1}^{n} [fish_d \times (n + 1 - d)]}{\sum_{d=1}^{n} fish_d} \tag{5}$$

where:

$fish_d$ = number of fish observed on day *d*,
n = total number of days until the cumulative proportion *p* of the total smolt outmigration has been observed.

The present year's MFRA is matched to each historical year's MFRA. The historical observed *p* corresponding to the matching MFRA is the predicted $\hat{p}_{AR}$ from that year.

The Age-of-Run error associated with this prediction (ARE) is the ratio of the present run mean fish-run-age ($MFRA_{AR}$) and the predicted percentage $\hat{p}$ mean fish-run-age ($MFRA_{\hat{p}}$):

$$ARE(\hat{p}) = \begin{cases} \dfrac{MFRA_{\hat{p}}}{MFRA_{AR}} & if \quad MFRA_{\hat{p}} > MFRA_{AR} \\ \dfrac{MFRA_{AR}}{MFRA_{\hat{p}}} & if \quad MFRA_{\hat{p}} < MFRA_{AR} \\ 1 & if \quad MFRA_{\hat{p}} = MFRA_{AR} \end{cases} \tag{6}$$

This gives the prediction from the AR algorithm the least amount of error, with more error the further $\hat{p}$ is from p_{AR}.

Calculation of the Total Error

An error is computed for each $\hat{p}$ (0-100) by combining the three algorithms, and here is where the difference between the yearling and subyearling outmigration dynamics is handled. For the yearling chinook smolt outmigration in the spring/summer, the error is computed by Eq. 7a:

$$Err(\hat{p}) = \left(1 + \frac{LSE(\hat{p})}{LSE(\hat{p}) \times MFRA + 200.0}\right) \times \left(1 + \left[\frac{150}{MFRA^2 + RR^2} \times RRE(\hat{p})\right]^2\right) \times \left(1 + \frac{ARE(\hat{p})}{50.0}\right) \tag{7a}$$

while the three algorithms are weighted differently for the fall outmigration of the subyearling chinook:

$$Err(\hat{p}) = \left(1 + \frac{LSE(\hat{p})}{LSE(\hat{p}) \times MFRA + 200.0}\right) \times \left(1 + \left[\frac{50}{\left(MFRA + \frac{RR}{2}\right)^2} \times RRE(\hat{p})\right]^2\right) \times \left(1 + \frac{ARE(\hat{p})}{50.0}\right) \tag{7b}$$

where:

$ARE(\hat{p})$ = age-of-run error for $\hat{p}$ from Eq. 6,
$LSE(\hat{p})$ = least squares error for $\hat{p}$ from Eq. 2,
MFRA = mean fish-run-age for the present run from Eq. 5,
$\hat{p}$ = predicted proportion of observed present smolt outmigration,
RR = release-recapture predicted percentage from Eq. 3, and
$RRE(\hat{p})$ = release-recapture error for $\hat{p}$ from Eq. 4.

The MFRA in Eq.7a and 7b also serves the purpose of shifting weighting of the errors from the release-recapture algorithm to the least-squares algorithm as the age of the run increases. The constants were found by adjusting the equation to improve program prediction performance to the historical outmigration data. The program selects the $\hat{p}$ with the minimal calculated error.

Calculation of Performance of Program RealTime Across the Season

The results presented in Table 4 are the mean absolute deviance (MAD) of the daily predictions for the 1996 and 1997 spring chinook outmigrations. The MAD is calculated by the formula

$$MAD = \frac{\sum_{i=1}^{n} \left| \hat{p}_i - p_i \right|}{n} \qquad (8)$$

where $\hat{p}_i$ = predicted cumulative percentage of outmigration distribution completed for day i,
p_i = observed cumulative percentage of outmigration distribution completed for day i, and
n = total number of days in the outmigration run for the season.

The results are summarized in three columns: the MAD over the entire run, the MAD over the first half of the run (i.e. cumulative run to the 50% mark), and the MAD over the last half of the run.

Results

Wild yearling chinook

1997 program performance

The 1997 Program RealTime increased the number of release sites for which forecasts were provided from the six individual tag-sites investigated in 1996 to nine. The performance of RealTime, averaged over all of the individual tag-sites monitored in 1997, resulted in a mean MAD of 7.7% for the overall season, 6.1% for the first half, and 8.2% for the last half of the season. On average, the program was off by 7.7 percentage points from the actual outmigration status. The mean 1997 MAD of the individual release sites is large due to poor performance the second half of the season for runs originating from Lake Creek, Minam River and the South Fork of Wenaha River. In contrast, the composite run (selected runs of the PIT-tagged fish from the RealTime-monitored releases pooled into one group) for 1997 resulted in mean MADs of 1.8% overall, 2.3% first half, 1.7% last half of the season. The composite run did not include the releases from Lake Creek, Secesh River nor the South Fork of Wenaha River, as these did not meet the criteria used in the past for selecting releases to be monitored. A graph for the daily predictions of the 1997 RealTime composite run (Figure 4) gives a clearer picture of the season's performance. Though daily standard errors for the daily prediction are large, the point estimates are quite close to the actual outmigration distribution observed for 1997.

Figure 4: Composite run[1] daily forecast and the daily confidence intervals compared to the observed run for the yearling chinook 1997 out-migration season.

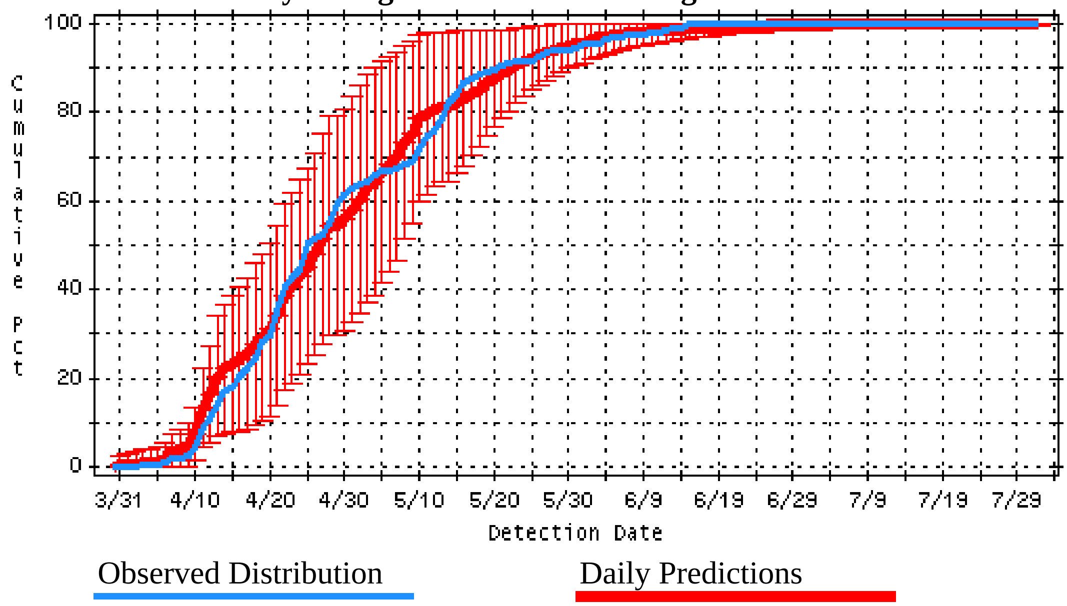


Figure 5 and Table 5 compare the percentage-passage dates of the individual stocks, the program RealTime composite run and a composite made up of ESU stock PIT-tagged during the previous summer. Using the distance of the release site to Lower Granite Dam, calculated from the release tables in the DART database via "DART PIT-tags observed by release site"[2], a lagging of migration timing for longer migration distance is apparent. The composite run did not include the releases from Lake Creek, Secesh River nor the South Fork of Wenaha River, as these were the releases which did not meet the criteria used in the past for selecting releases to be monitored. Appendix A contains additional graphs of the daily predictions of each individual stock. Further selected days throughout the outmigration season can be viewed on the World Wide Web at *http://www.cqs.washington.edu/crisprt/archive.html*. Results for predictions of spring/summer yearling

1. The composite for 1997 consists of the release sites from Catherine Creek; Imnaha, Lostine, Minam and South Fork Salmon Rivers. These were the releases that met all RealTime selection criteria.
2. World Wide Web address: http://www.cqs.washington.edu/dart/pit_rel_de.html. Data courtesy of Pacific States Marine Fisheries Commission.

chinook passage at other Snake and Columbia River dams from Little Goose to McNary Dams at downstream sites are available separately from the University of Washington School of Fisheries CRiSP project.

Table 4: Comparison of mean absolute deviances (MAD) for selected 1996 and 1997 streams and composite runs of wild yearling chinook smolt. Columns show percent MAD's for the entire run, the first 50% of the run, and the last 50% of the run (to two weeks after last detection).

	1996			1997		
Tagging Site	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Catherine Creek	5.4	3.3	6.1	7.4	7.9	7.1
Imnaha River	6.8	6.6	6.8	3.2	6.3	2.2
Lake Creek	---	---	---	10.2	1.0	11.8
Lostine River	9.5	18.7	4.3	4.4	5.4	3.9
Minam River	2.8	2.7	2.9	8.3	2.0	10.9
Redfish Lake (sockeye)	---	---	---	7.3	6.1	7.5
Salmon River, South Fork	6.2	9.6	4.9	6.5	6.0	6.6
Secesh River	---	---	---	7.3	9.1	7.1
Wenaha River, South Fork	3.4	6.2	2.8	13.9	11.0	15.7
mean MAD	5.7	7.8	4.6	7.7	6.1	8.2
median MAD	5.8	6.4	4.6	7.3	6.1	7.1
range	2.8 - 9.5	2.7 - 18.7	2.8 - 6.8	3.2 - 13.9	1.0 - 11.0	2.2 - 15.7
RealTime Composite Run[a]	2.4	1.9	2.5	1.8	2.3	1.7

a. The composite for 1997 consists of the release sites from Catherine Creek; Imnaha, Lostine, Minam and South Fork Salmon Rivers. These were the releases that met all RealTime selection criteria. The 1996 composite consists of the six release sites listed.

In addition to the RealTime composite, the migration timing for an ESU composite that included all Snake River wild spring/summer chinook stocks having parr PIT-tagged during 1997 was calculated. This new composite consisted of 1125 smolt detected at Lower Granite Dam, released from 17 different sites. The timing distribution and duration of the first 80% of the ESU composite and the RealTime composite are remarkably similar, however, the end dates of the ESU composite are more protracted than the RealTime composite (Table 5 and Figure 5) due to the trickling in of the fish during towards the end of the outmigration distribution.

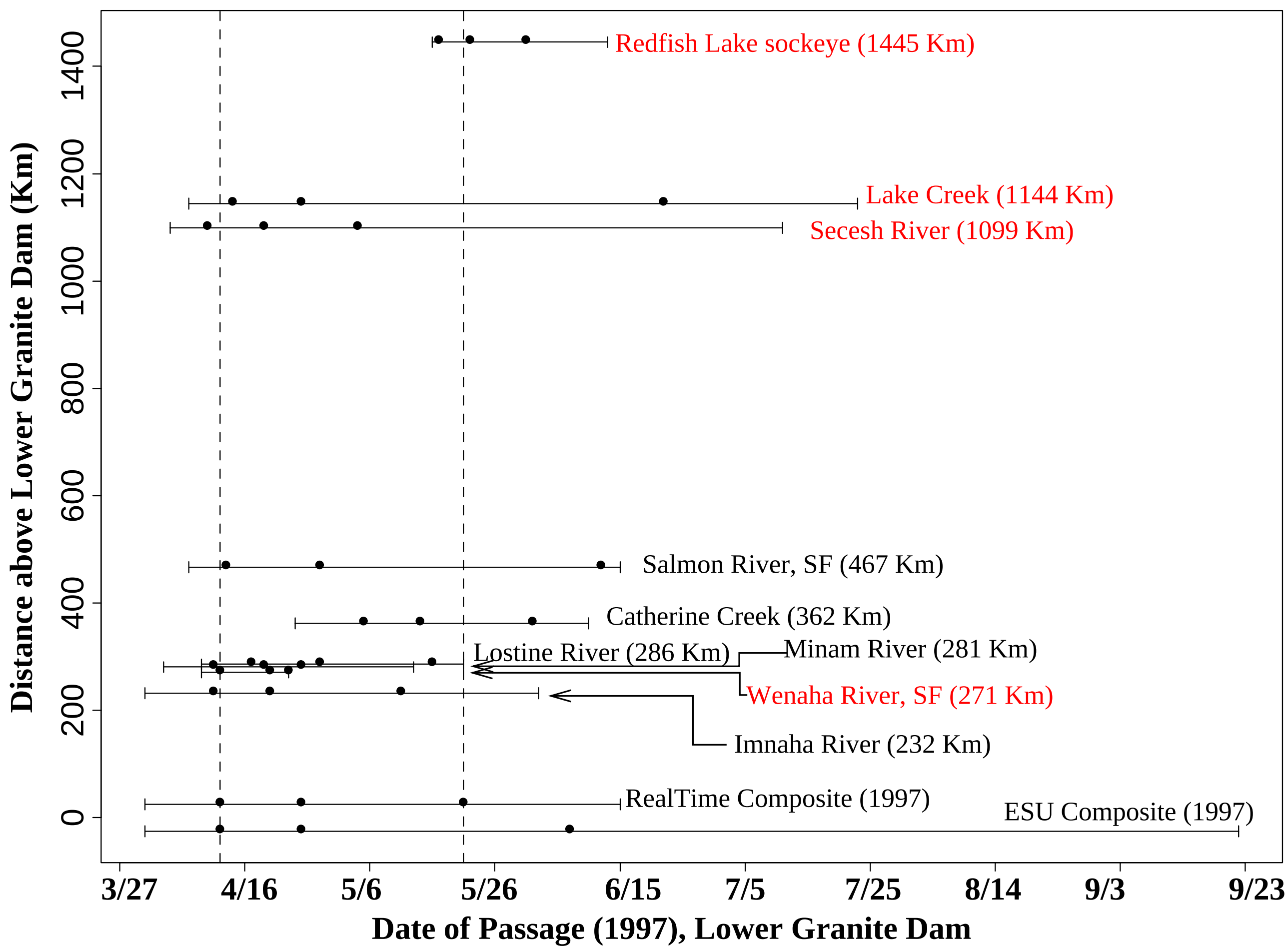
Table 5: Observed passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam in 1997 for PIT-tagged wild Snake River spring/summer chinook salmon smolts for the nine release sites, the RealTime and ESU composite runs, based on the parr PIT-tagged in 1996. The ESU composite is calculated from all spring/summer chinook PIT-tagged at designated ESU sites in 1996 and observed at Lower Granite Dam in 1997.

	Passage Dates at Lower Granite Dam			
Population or Stock	10%	50%	90%	Range
Catherine Creek	5/05	5/14	6/01	4/24 - 6/10
Imnaha River	4/11	4/20	5/11	3/31 - 6/02
Lake Creek	4/14	4/25	6/22	4/07 - 7/23
Lostine River	4/17	4/28	5/16	4/09 - 5/21
Minam River	4/11	4/19	4/25	4/03 - 5/13
Redfish Lake (sockeye)	5/17	5/22	5/31	5/16 - 6/13
Salmon River, South Fork	4/13	4/28	6/12	4/07 - 6/15
Secesh River	4/10	4/19	5/04	4/04 - 7/11
Wenaha River, South Fork	4/12	4/20	4/23	4/09 - 4/23
Program RealTime Composite[a]	4/12	4/25	5/21	3/31 - 6/15
ESU composite[b]	4/12	4/25	6/07	3/31 - 9/22

a. The composite consists of the release sites from Catherine Creek; Imnaha, Lostine, Minam and South Fork Salmon Rivers.

b. There were 17 release sites that qualified as an ESU site, but did not meet the RealTime criteria for individual stream forecasting for various reasons.

Figure 5: Timing plots of 1997 passage dates (10%, 50%, 90% (dots) and range(endpoints)) at Lower Granite Dam for PIT-tagged wild Snake River spring/summer chinook salmon smolts, the Redfish Lake sockeye release, the RealTime and ESU composite run, based on the parr PIT-tagged in 1996. The dashed lines show the dates that 10% and 90% of the out-migration passed Lower Granite Dam as estimated by the RealTime composite. Sites in red were not included in the RealTime composite.



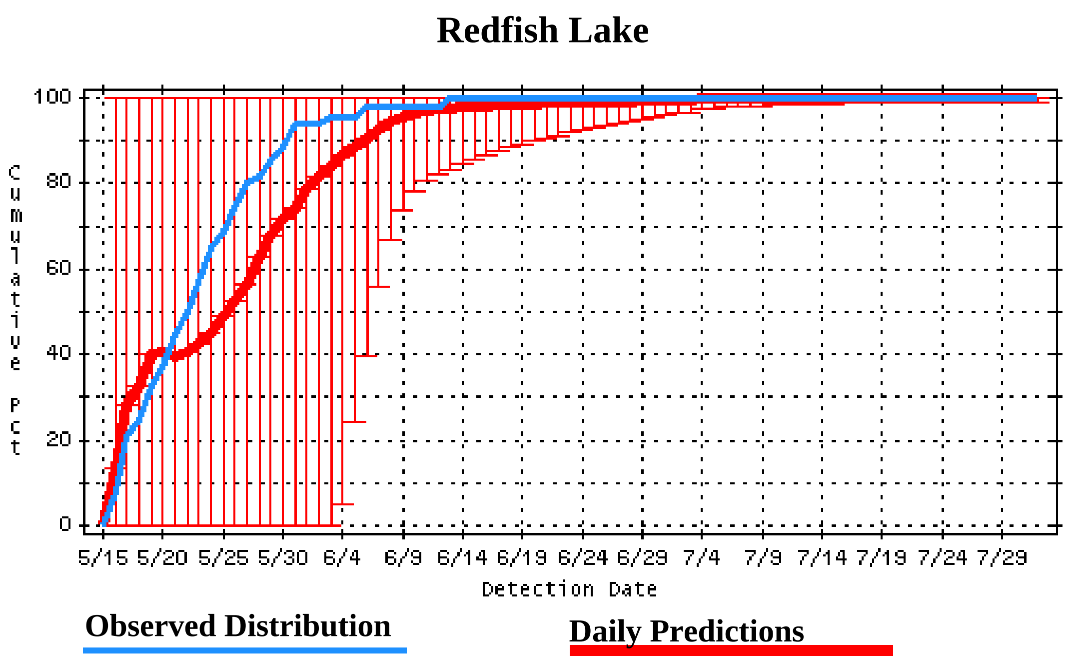
1997 program performance compared 1996

Program RealTime performance for the wild chinook yearling mean 1997 individual tag-site was slightly worse than the previous year. Mean MAD's for the 1996 individual releases were 5.7 for the overall season, 7.8 for the first half, and 4.6 for the last half of the season. The composite run for 1997 was improved over 1996 (1996 composite run MAD's:2.4 overall, 1.9 first half, 2.5 last half) in the overall season MAD and for the last half of the season.

Hatchery age 1+ sockeye

This is the first year of RealTime including a release of Age 1+ sockeye from Redfish Lake (Table 4). The sockeye were not included in composite forecasts, but did use the same prediction algorithm as the yearling chinook, as this was the first attempt at predicting that run. Program RealTime performance for the Redfish sockeye forecast was similar to the mean performance of the wild yearling chinook (MAD: 7.3 overall, 6.1 first half, 7.5 last half). Figure 6 shows the daily prediction performance for the season. The large confidence intervals reflect the lack of historical years (only two: 1995 and '96) used as a basis for predicting 1997 outmigration.

Figure 6: Hatchery Age 1+ sockeye run daily forecast and the daily confidence intervals compared to the observed run for the 1997 out-migration season.



Wild subyearling chinook

1997 program performance

Two groupings of historical years were investigated as a basis for the 1997 predictions. One group used all historical years (AHY) of the data considered relevant to the present runs (1991-1996) and the other consisted of 1993, 1995 and 1996--years with flow levels similar to 1997 (HIGHY). Both forecasts failed to predict a spurt of wild subyearling chinook arriving at Lower

Granite Dam in September, but the HIGHY grouping was clearly a better forecasting basis than the AHY grouping. The MAD's across the season were 7.55 (AHY) and 4.33 (HIGHY). The HIGHY MAD (0.63) for the first half of the outmigration was much better than the AHY MAD (5.00). This was true as well for the last half of the outmigration, with the AHY MAD (8.57) being inferior to the HIGHY grouping MAD (5.81). Figure 7 and Figure 8 both show the divergence of the predicted outmigration distribution from the observed distribution in September, but the HIGHY prediction more closely tracked the observed distribution prior to August 1st. Both forecasting methods regained accuracy during the third weekend of September, as the additional fish decreased to predicted levels. Daily prediction confidence intervals for the HIGHY grouping are much smaller than those of the AHY grouping, a result of the outmigration demonstrating more similar characteristics than to those years with other flow levels.

Figure 7: Daily forecast and the daily confidence intervals using outmigration historical years 1991-96 (AHY) compared to the observed passage index for the wild subyearling chinook 1997 out-migration season at Lower Granite Dam.

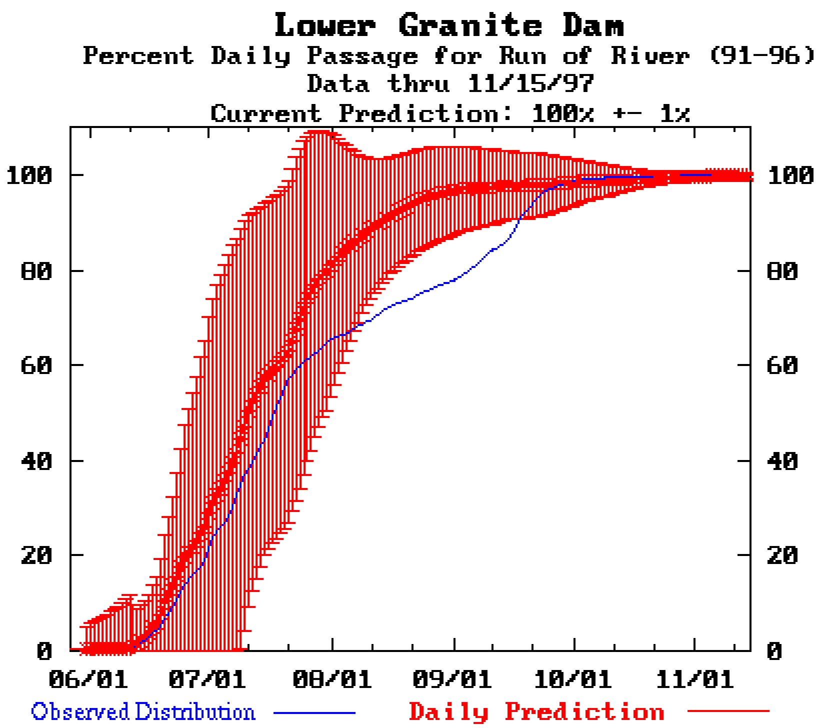
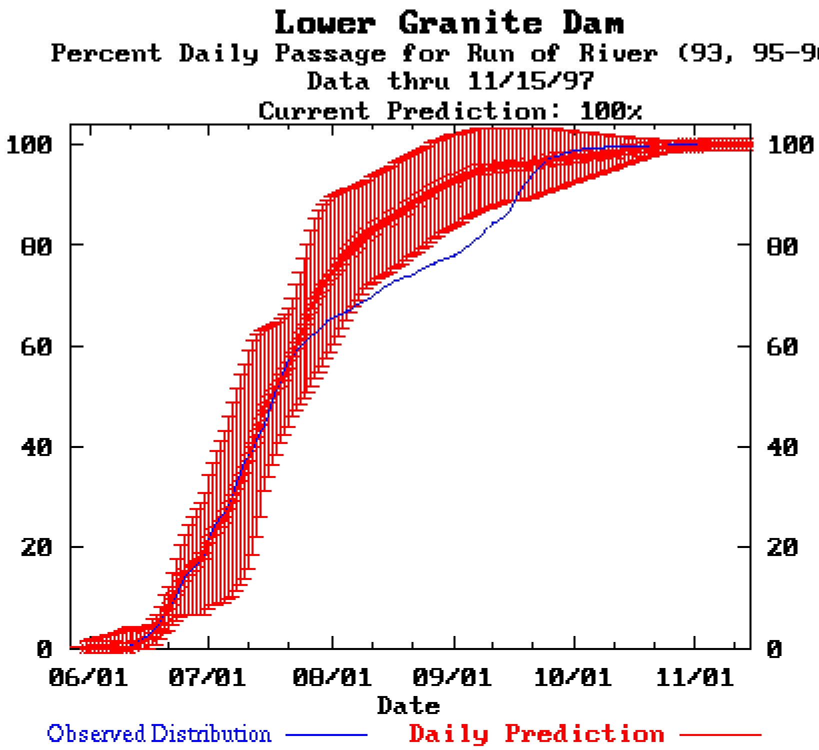


Figure 8: Daily forecast and the daily confidence intervals using outmigration historical years with similar high flows (1993, 95 & 96 (HIGHY)) compared to the observed passage index for the wild subyearling chinook 1997 out-migration season at Lower Granite Dam.



1997 program performance compared 1996

Both groupings decreased in performance from 1996 (Table 6). The MAD's across the season in 1997 were almost consistently over double those of the 1996 season for both groupings of historical years (1996 MAD's: 3.06 (AHY), 2.45 (HIGHY). This trend continued into the breakdown into first and last half of the season for the AHY MAD (1996 first half: 1.98, last half: 3.55), and the last half of the season HIGHY MAD (1996 last half: 2.12). The 1997 AHY, though, was improved over 1996's first-half high-flow year prediction performance (MAD = 3.17).

Table 6: Comparison of mean absolute deviances (MAD) for the 1996 and 1997 passage indices at Lower Granite Dam of wild subyearling chinook smolt. Columns show percent MAD's for the entire run, the first 50% of the run, and the last 50% of the run (to two weeks after last detection).

	1996			1997		
Historical year Base	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
All years	3.06	1.98	3.55	7.55	5.00	8.57
High Flow years (93, 95, 96)[a]	2.45	3.17	2.12	4.33	0.63	5.81

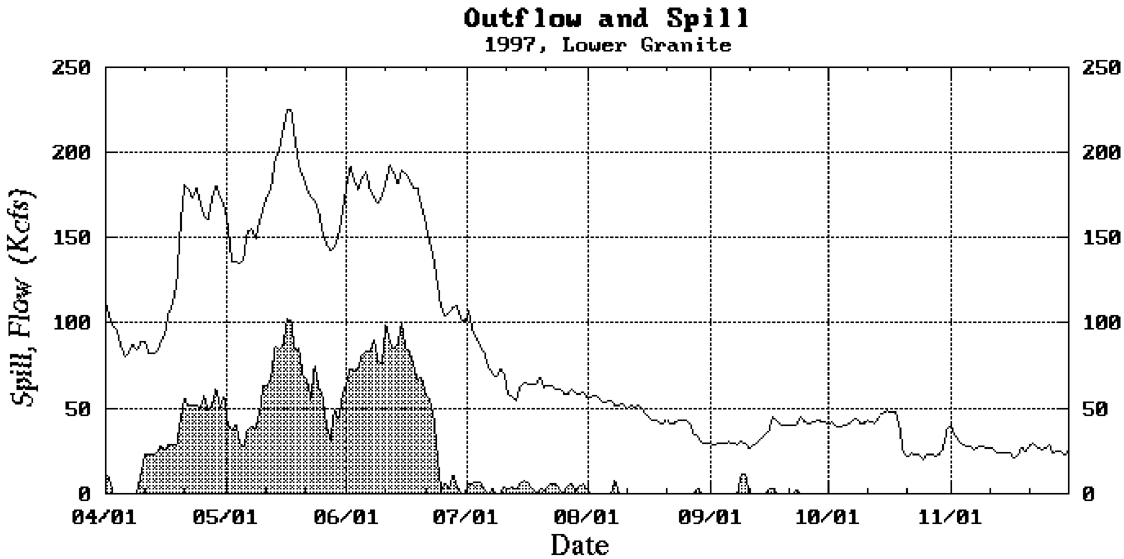
a. 1996 used only 1993 and 1995 for high flow year prediction.

Discussion

Wild yearling chinook

The 1997 outmigration experienced very high flows, with a large portion of this water being spilled from April through June (Figure 9). All of the releases recorded a higher than expected number of spill-adjusted fish at Lower Granite Dam (Table 2), and the RealTime algorithm was able to adjust for this increased number of fish for the qualified releases. The remaining releases for which the RealTime selection criteria where not met (Lake Creek, Secesh River and Wenaha River, South Fork) had less accuracy during the second half of the season, when the pattern-matching part of the algorithm became more dominant in determining the forecasted status of the outmigration. A large number of fish released is more crucial to determine the pattern of the out-migration distribution, and the Wenaha River was hampered by a very small release size. Though Secesh River had smaller number of fish released than Lake Creek, RealTime was able to forecast with more accuracy due to a higher number of historical years to compare to the present outmigration (8 versus 4 years for Lake Creek).

Figure 9: Total flow and spill at Lower Granite Dam for April-November, 1997.



The RealTime composite prediction, the average of the five individual stock predictions, gave very satisfactory predictions that were within 3%for most of the wild yearling chinook outmigration. The success of the composite predictions is due to the smoothing effects of simple averaging, which tends to cancel or decrease the overall effect of randomly occurring errors such as the higher-than-observed predictions for Catherine Creek. The 1997 timing plots of the dates of cumulative percentiles of passage at Lower Granite Dam show two runs, releases from Lake Creek and Secesh River, having later migration timing than the RealTime composite (Figure 5). These differences highlight the importance of having information on the migration status of the individual stocks that comprise the different run timing segments of the overall wild populations so that water managers can adequately access the risks to individual stocks when making their decisions on operations and fish passage strategies.

Hatchery age 1+ sockeye

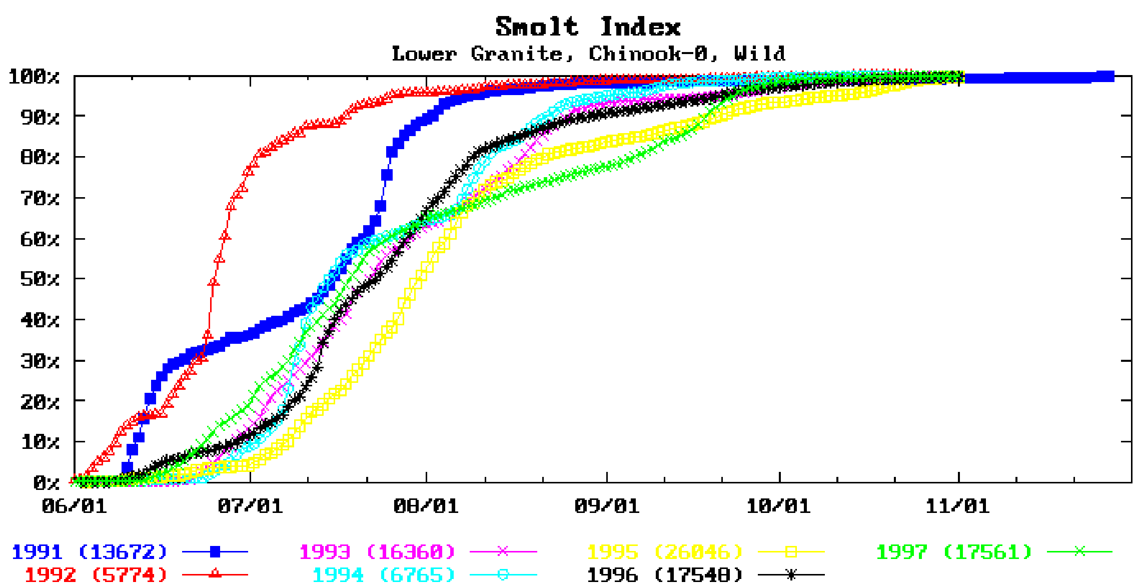
This trial investigation of the ability of RealTime to forecast hatchery age 1+ sockeye runs from Redfish Lake is encouraging. Point estimates were very close to the observed outmigration distribution for the first forty percent and last nine-five percent of the run. The mid-section deviance is to be expected, as there were only two historical years of data to base predictions on. It is recommended that RealTime continue to be used to forecast sockeye outmigrational status at

Lower Granite, with the expectation of improved results as more historical years are added to the data base.

Wild subyearling chinook

A graphical comparison of the daily predictions using the AHY grouping (Figure 7) and the HIGHY grouping (Figure 8) and their 95% confidence intervals against the observed run for the year show that both forecasts failed to predict a spurt of wild subyearling chinook at Lower Granite Dam in September. This late surge of smolt had not occurred in previous years (1991-1996), and thus would not be predicted by the pattern-matching algorithm of RealTime (Figure 10). Using similar high-flow years removed the two outmigrational patterns least like the distribution which occurred in 1997, thus bringing the predicted HIGHY outmigration closer to the final outcome than the AHY grouping predictions. This is the second year that predictions based on like-flow years has yielded better predictions than using all historical years for the subyearling chinook, and significantly so this year. Both of these groupings have been for high flow years, and it remains to be seen if the trend will continue in years with average or below-average flows.

Figure 10: Wild Snake River subyearling chinook salmon historical cumulative percentage passage dates for 1991-97.



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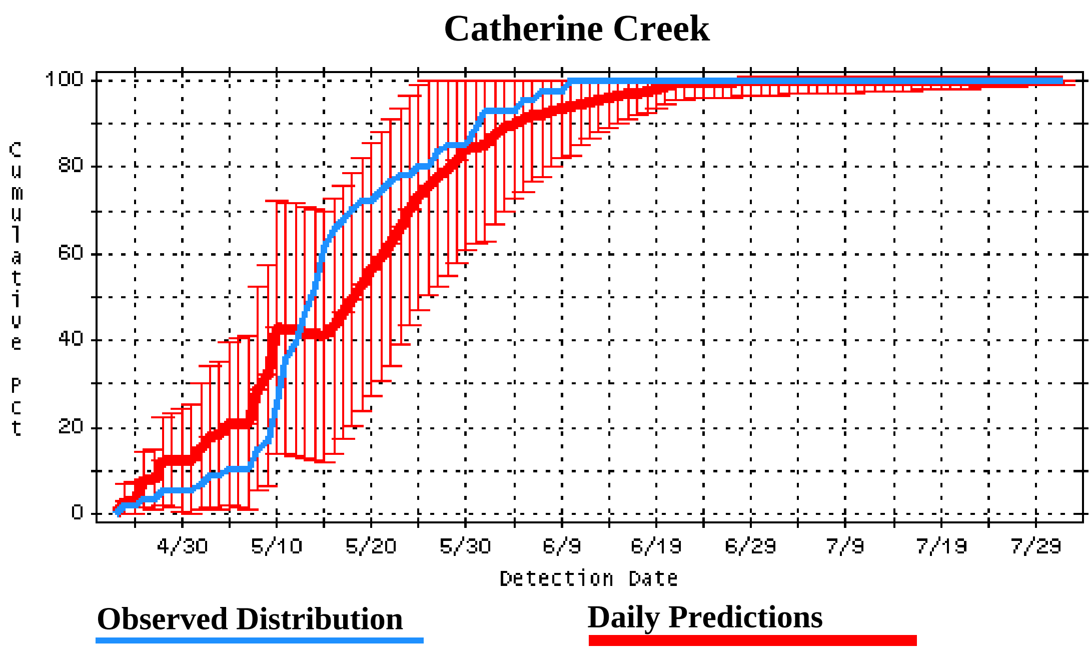
Appendix A

Individual Performance Plots for the 1997 Outmigration of Wild Yearling Chinook

Figure A1: Catherine Creek and Imnaha River Daily Predictions.



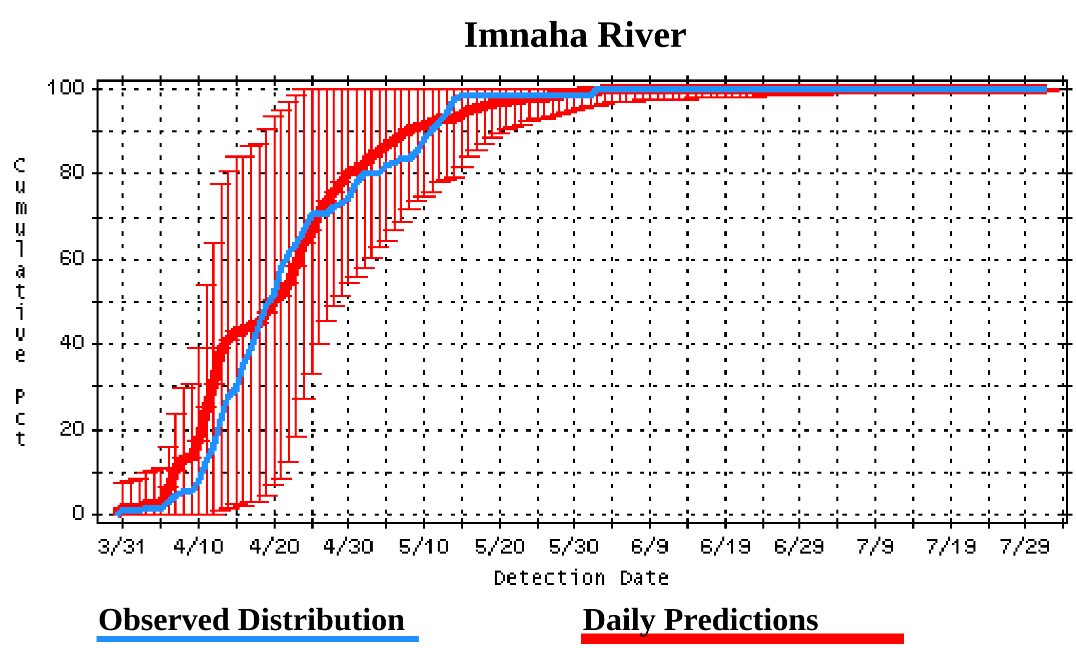
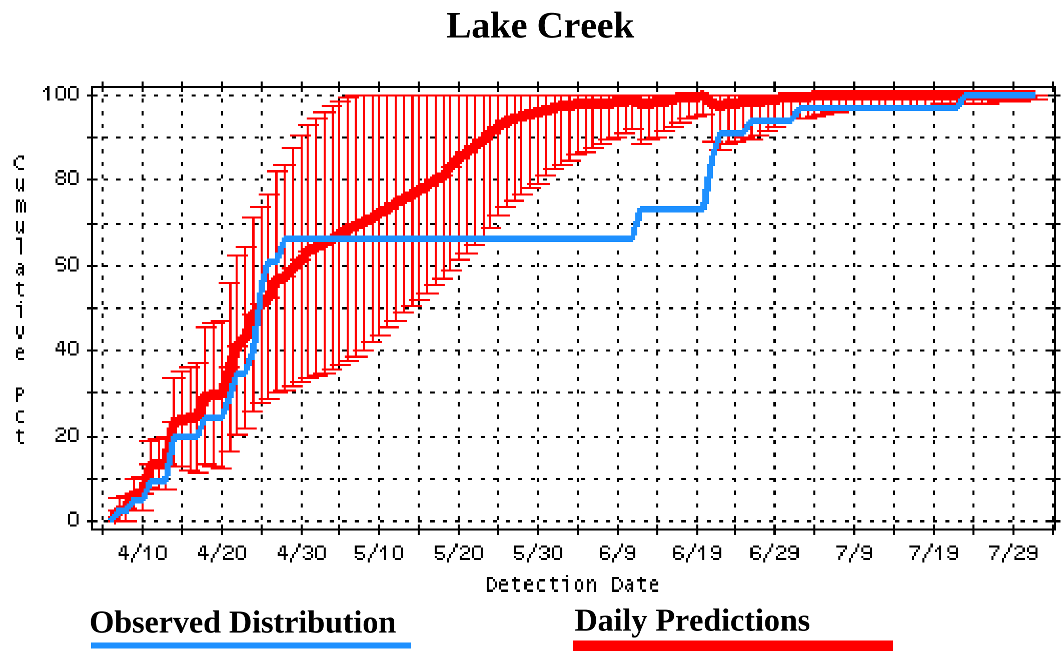


Figure A2: Lake Creek and Lostine River Daily Predictions.



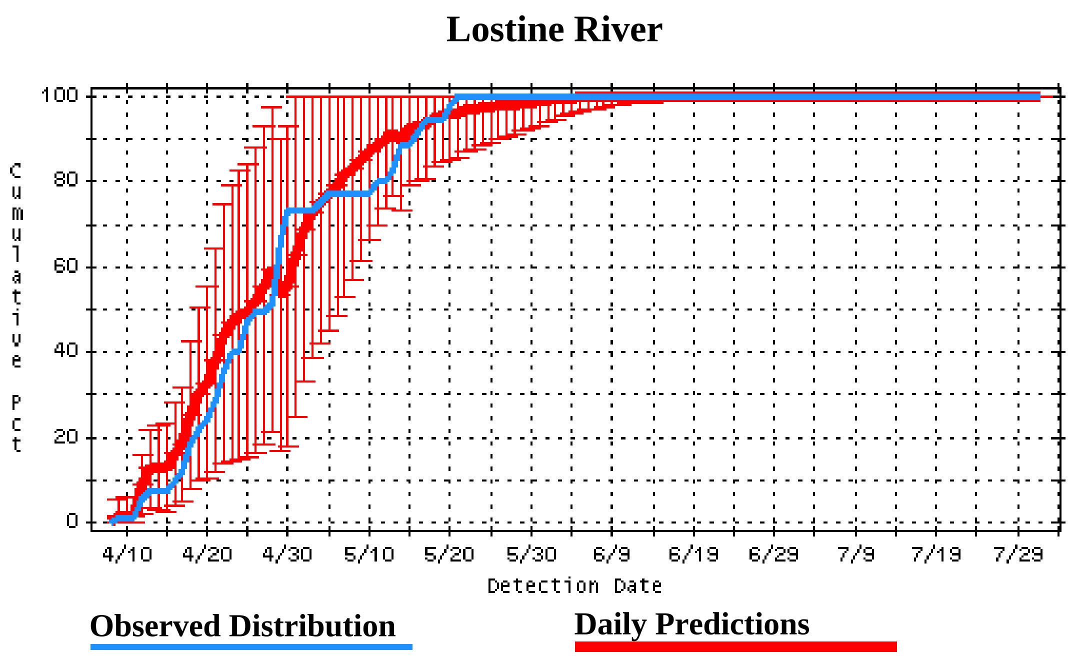
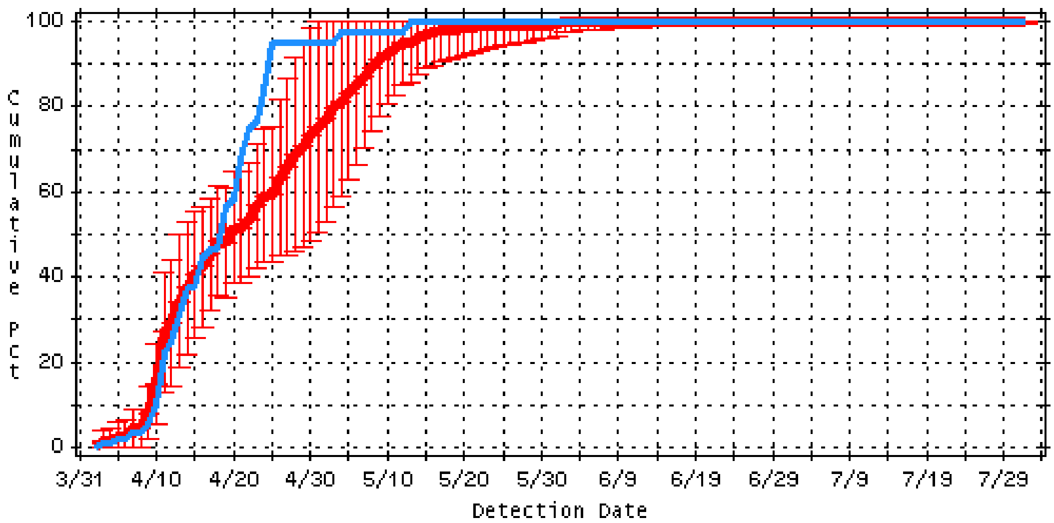


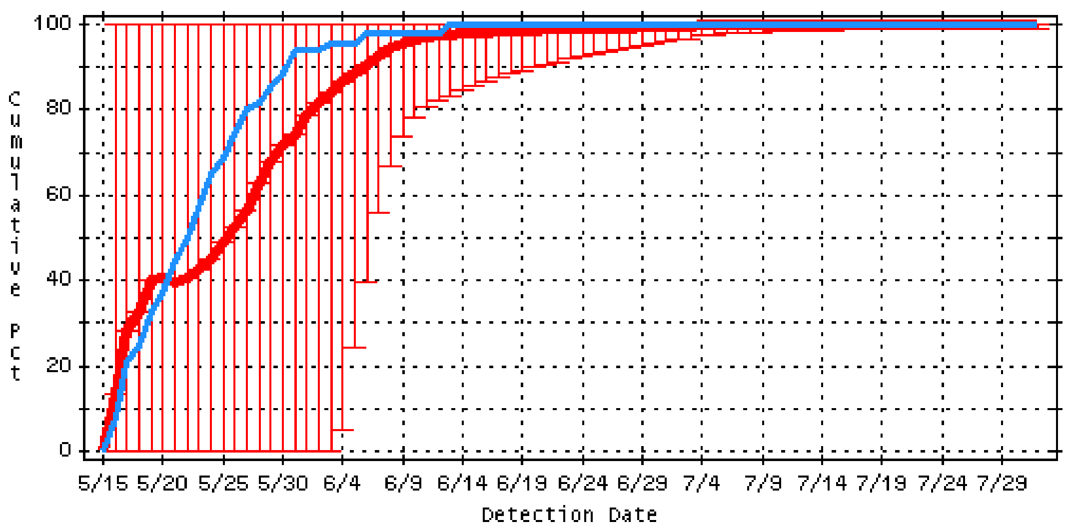
Figure A3: Minam River and Redfish Lake Daily Predictions

Minam River



Observed Distribution **Daily Predictions**

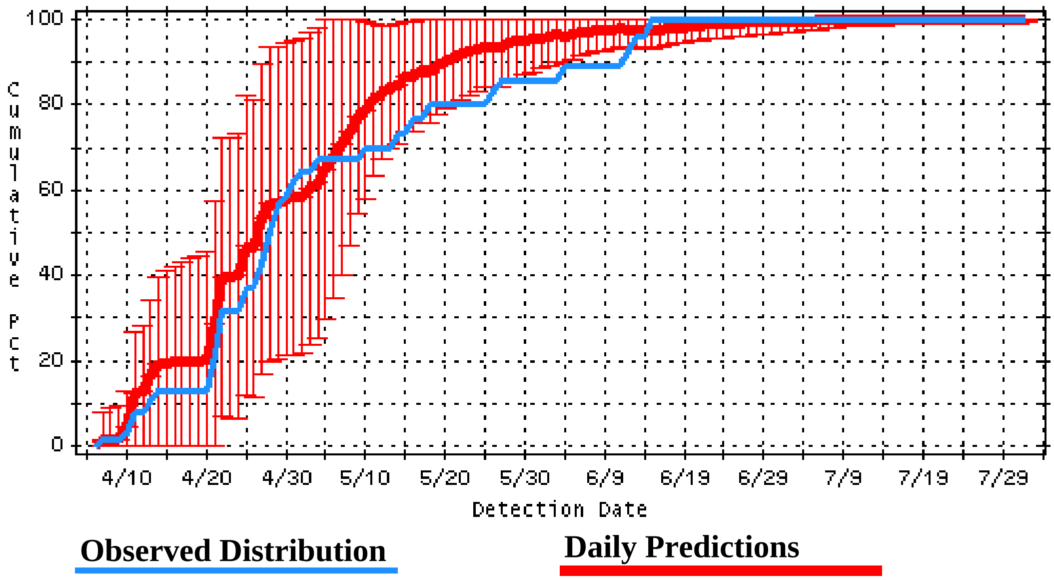
Redfish Lake



Observed Distribution **Daily Predictions**

Figure A4: Salmon River, South Fork and Secesh River Daily Predictions.

Salmon River, South Fork



Secesh River

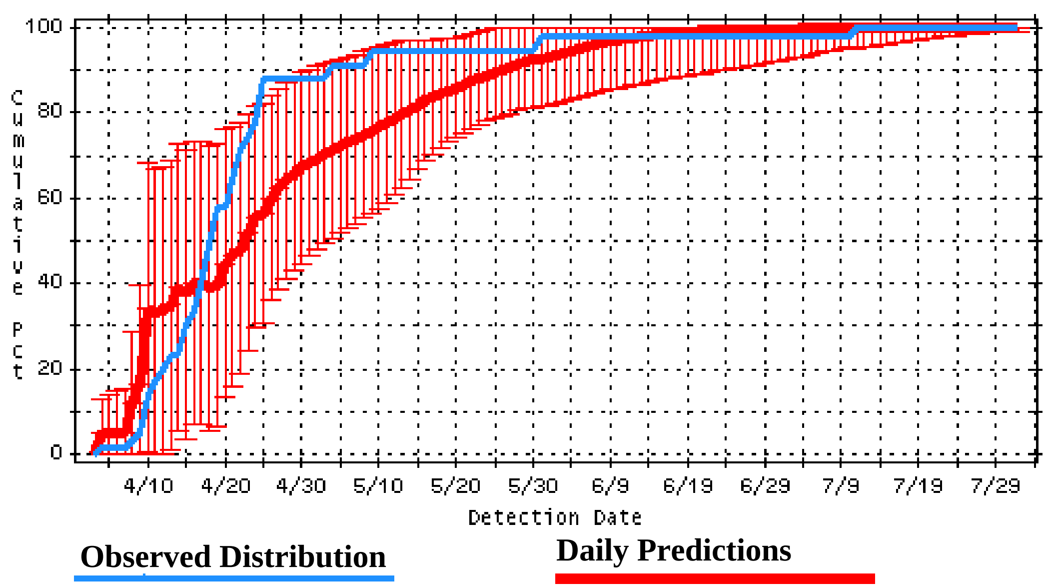
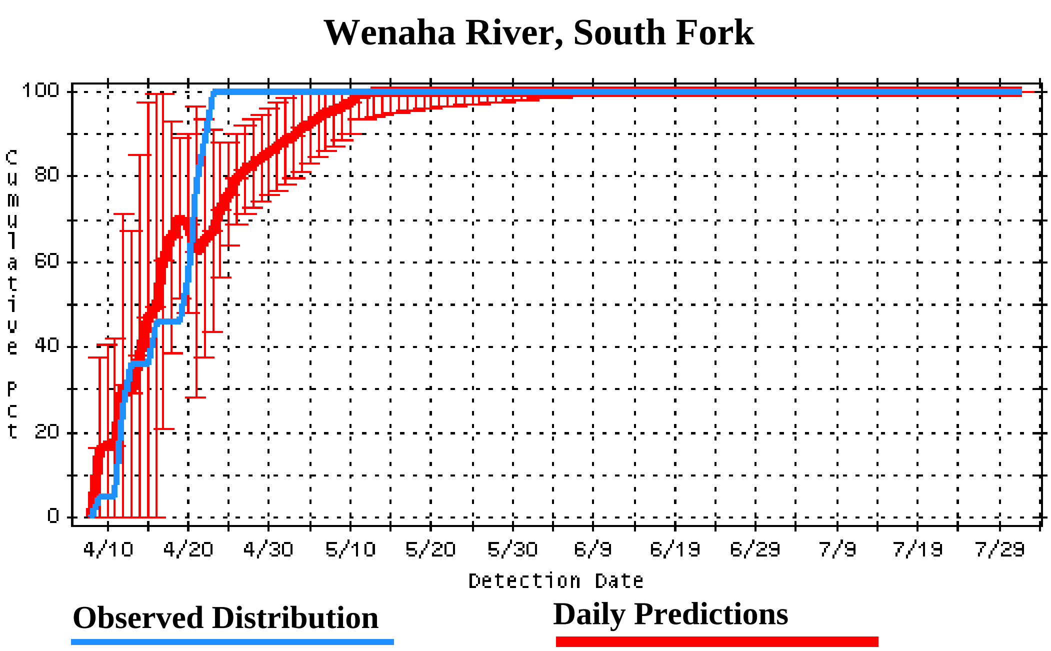


Figure A5: Wenaha River, South Fork Daily Prediction



Appendix B

Historical timing plots and dates of passage at Lower Granite Dam (from PIT-tag data) for the individual wild yearling chinook release sites and the Lower Granite Dam passage index for wild subyearling chinook tracked by program RealTime during the 1997 outmigration season.

Figure B1: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Catherine Creek.

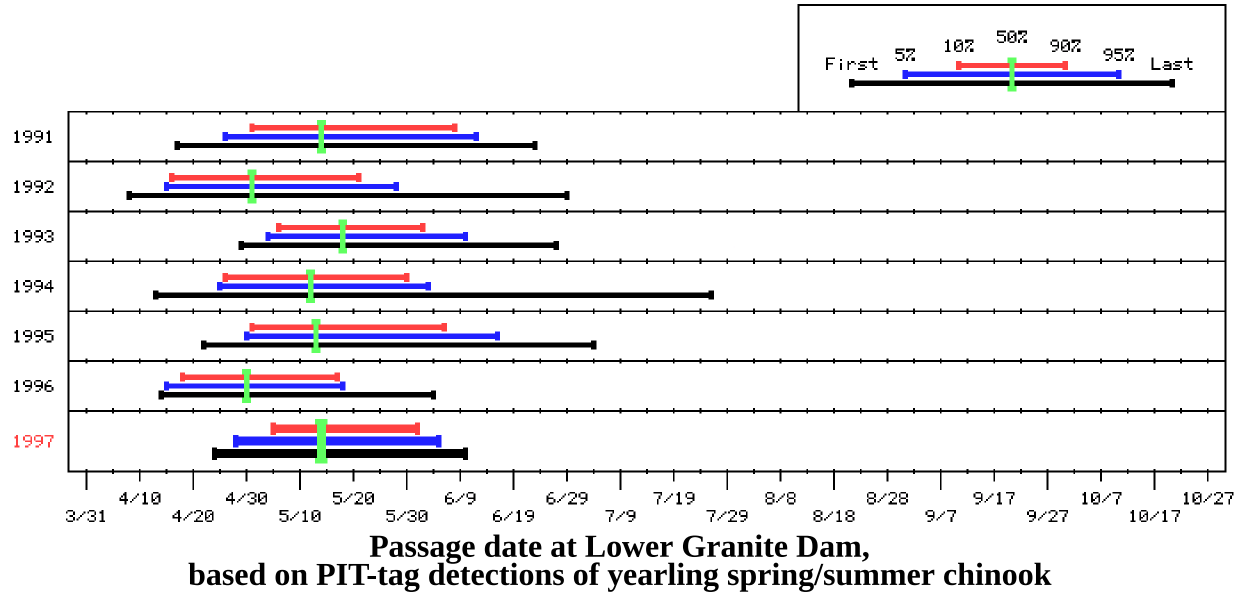


Table B1: Historical Catherine Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/17	4/26	5/1	5/14	6/8	6/12	6/23	39	1014	77	77.8	7.7
1992	4/8	4/15	4/16	5/1	5/21	5/28	6/29	36	940	67	67.0	7.1
1993	4/29	5/4	5/6	5/18	6/2	6/10	6/27	28	1108	102	158.2	14.3
1994	4/13	4/25	4/26	5/12	5/30	6/3	7/26	35	1000	76	110.5	11.0
1995	4/22	4/30	5/1	5/13	6/6	6/16	7/4	37	2061	202	268.1	13.0
1996	4/14	4/15	4/18	4/30	5/17	5/18	6/4	30	1682	116	261.7	15.6
1997	4/24	4/28	5/05	5/14	6/01	6/05	6/10	28	585	51	120.2	20.6

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B2: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Imnaha River.

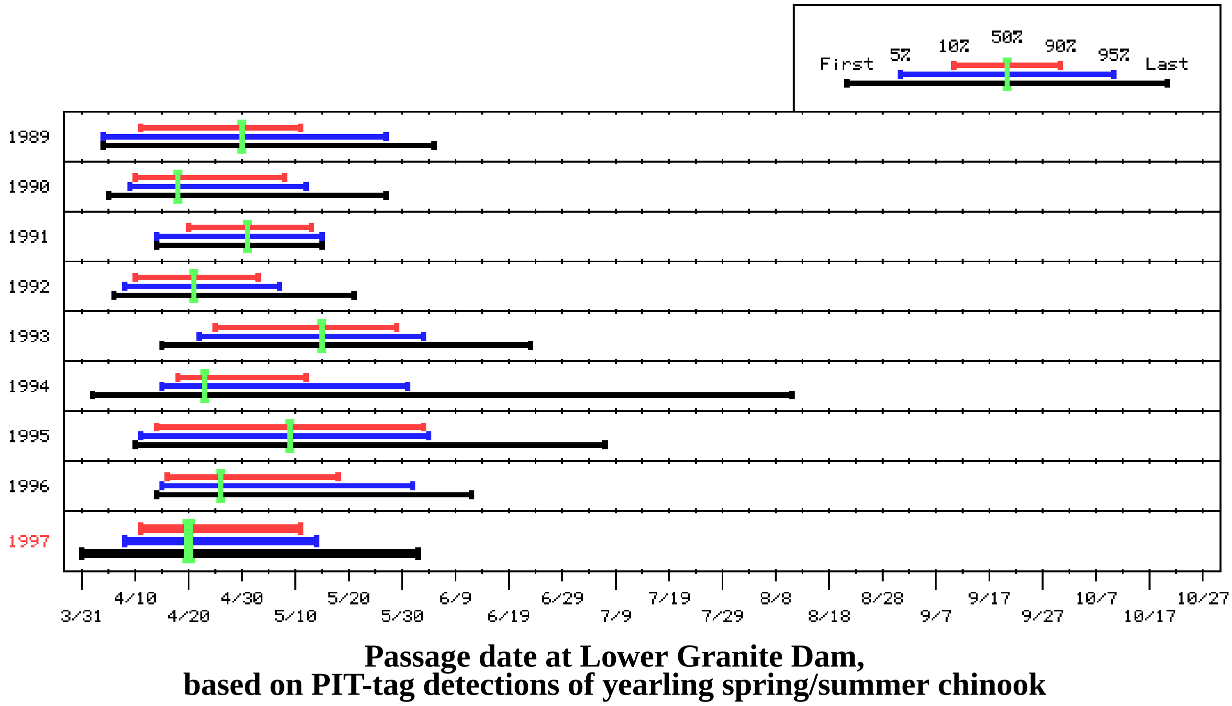


Table B2: Historical Imnaha River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/4	4/4	4/11	4/30	5/11	5/27	6/5	31	1213	73	73.0	6.0
1990	4/5	4/9	4/10	4/18	5/8	5/12	5/27	29	2005	161	161.0	8.0
1991	4/14	4/14	4/20	5/1	5/13	5/15	5/15	24	334	18	18.0	5.4
1992	4/6	4/8	4/10	4/21	5/3	5/7	5/21	24	759	73	73.0	9.6
1993	4/15	4/22	4/25	5/15	5/29	6/3	6/23	35	1003	63	88.3	8.8
1994	4/2	4/15	4/18	4/23	5/12	5/31	8/11	25	1753	205	218.2	12.4
1995	4/10	4/11	4/14	5/9	6/3	6/4	7/7	51	999	40	50.9	5.1
1996	4/14	4/15	4/16	4/26	5/18	6/1	6/12	33	997	97	233.5	23.4
1997	3/31	4/08	4/11	4/20	5/11	5/14	6/02	31	1017	98	191.1	18.8

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B3: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Lake Creek.

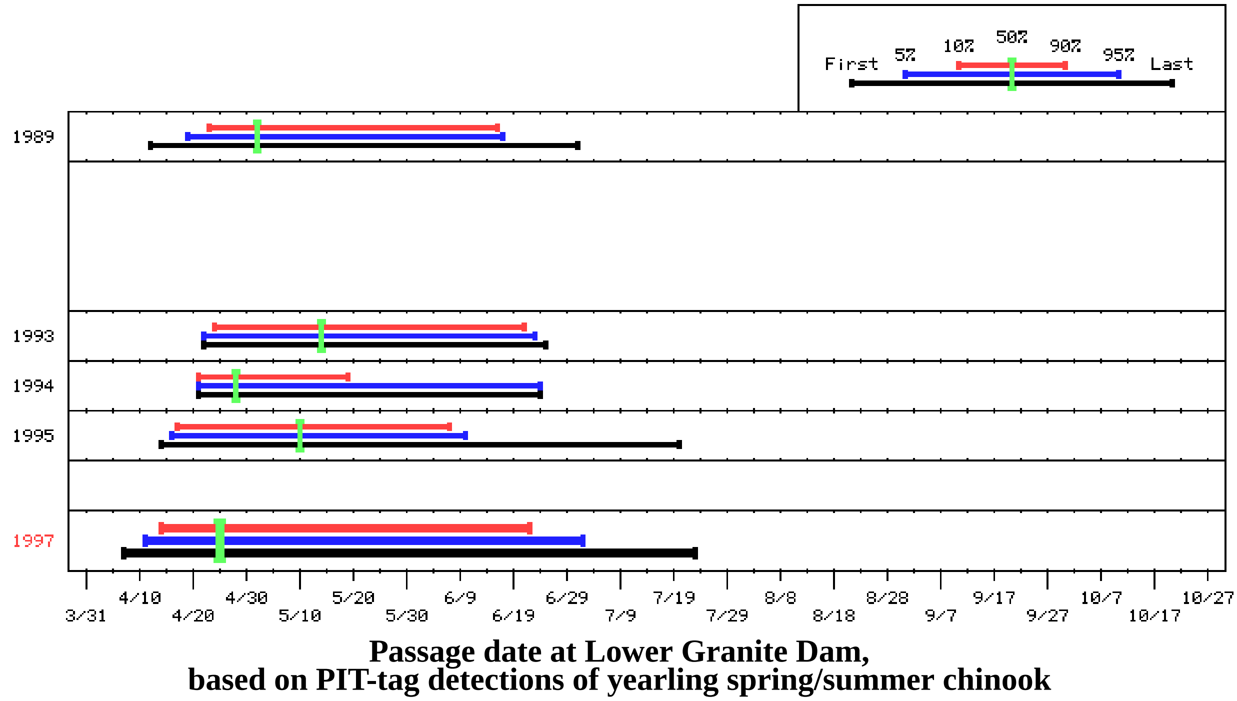
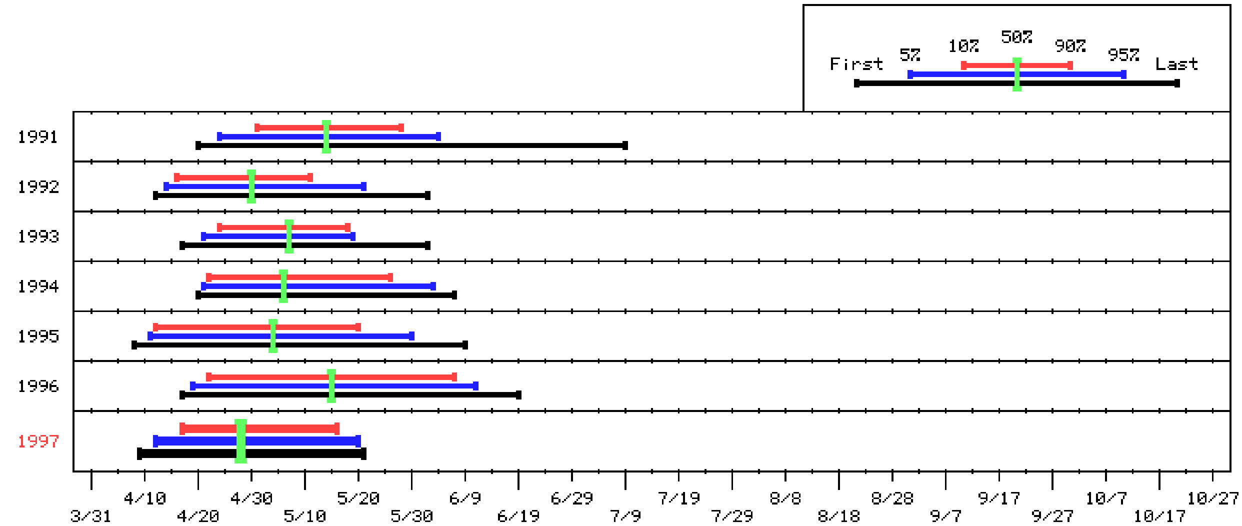


Table B3: Historical Lake Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/12	4/19	4/23	5/02	6/16	6/17	7/01	55	660	51	51.0	7.7
1993	4/22	4/22	4/24	5/14	6/21	6/23	6/25	59	255	27	31.1	12.2
1994	4/21	4/21	4/21	4/28	5/19	6/24	6/24	29	252	17	19.8	7.9
1995	4/14	4/16	4/17	5/10	6/07	6/10	7/20	52	406	25	33.2	8.2
1997	4/07	4/11	4/14	4/25	6/22	7/02	7/23	70	400	21	40.8	10.2

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B4: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Lostine River.



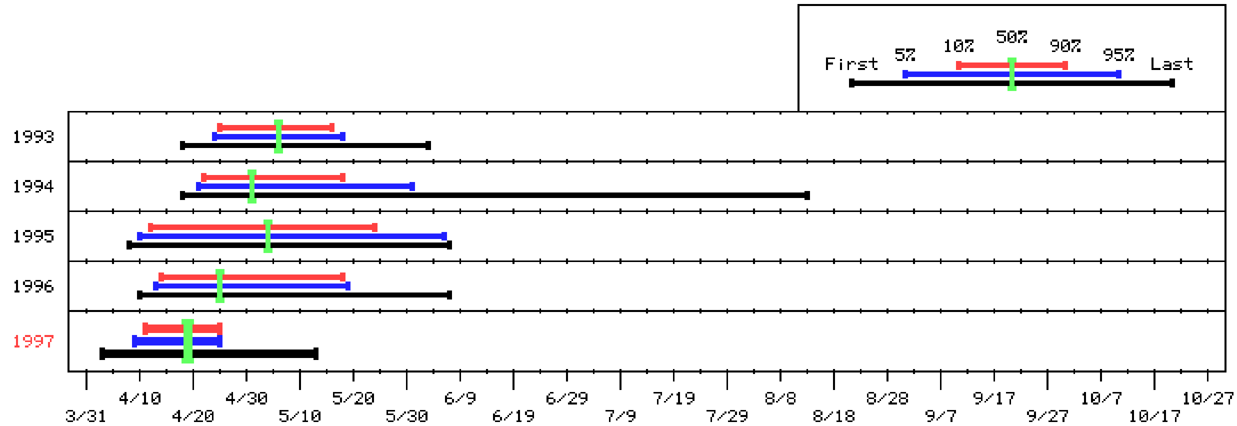
Passage date at Lower Granite Dam,
based on PIT-tag detections of yearling spring/summer chinook

Table B4: Historical Lostine River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/20	4/24	5/1	5/14	5/28	6/4	7/9	28	1017	90	90.8	8.9
1992	4/12	4/14	4/16	4/30	5/11	5/21	6/2	26	1107	92	92.0	8.3
1993	4/17	4/21	4/24	5/7	5/18	5/19	6/2	25	1016	123	156.1	15.4
1994	4/20	4/21	4/22	5/6	5/26	6/3	6/7	35	733	71	87.4	11.9
1995	4/8	4/11	4/12	5/4	5/20	5/30	6/9	39	1008	112	142.0	14.1
1996	4/17	4/19	4/22	5/15	6/7	6/11	6/19	47	978	81	188.2	19.2
1997	4/09	4/12	4/17	4/28	5/16	5/20	5/21	30	527	43	93.0	17.6

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B5: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Minam River.



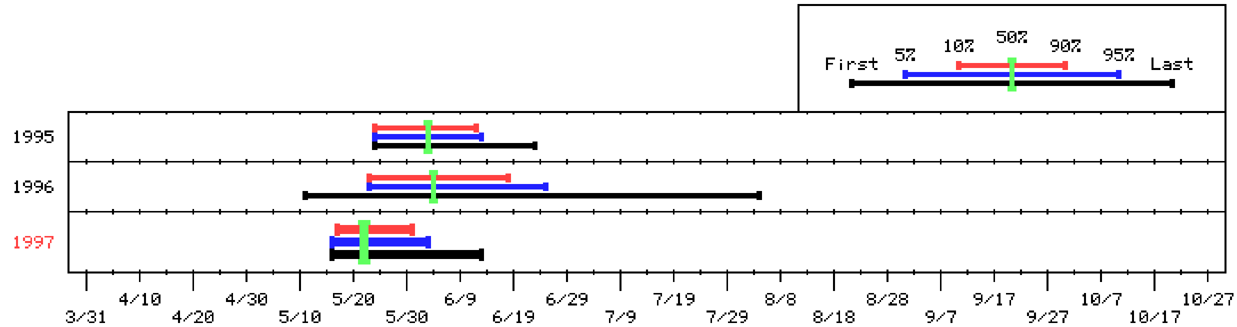
Passage date at Lower Granite Dam, based on PIT-tag detections of yearling spring/summer chinook

Table B5: Historical Minam River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	4/18	4/24	4/25	5/6	5/16	5/18	6/3	22	1003	105	125.5	12.5
1994	4/18	4/21	4/22	5/1	5/18	5/31	8/13	27	1005	112	133.3	13.3
1995	4/8	4/10	4/12	5/4	5/24	6/6	6/7	43	998	70	89.3	9.0
1996	4/10	4/13	4/14	4/25	5/18	5/19	6/7	35	998	68	164.9	16.5
1997	4/03	4/09	4/11	4/19	4/25	4/25	5/13	15	589	49	92.4	15.7

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B6: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for age 1+ sockeye salmon released from the Redfish Lake



Passage date at Lower Granite Dam, based on PIT-tag detections of sockeye

Table B6: Historical Redfish Lake outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1995	5/24	5/24	5/24	6/03	6/12	6/13	6/23	20	2728	20	26.6	1.0
1996	5/11	5/23	5/23	6/04	6/18	6/25	8/04	27	4246	160	377.8	8.9
1997	5/16	5/16	5/17	5/22	5/31	6/03	6/13	15	1931	53	131.2	6.8

(1) Age 0+ juvenile sockeye PIT-tagged and released during the summer/fall of the year prior to detection year.
(2) PIT detections of yearling Age 1+ sockeye salmon at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of Age 1+ sockeye smolts at Lower Granite Dam.

Figure B7: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Salmon River (South Fork)

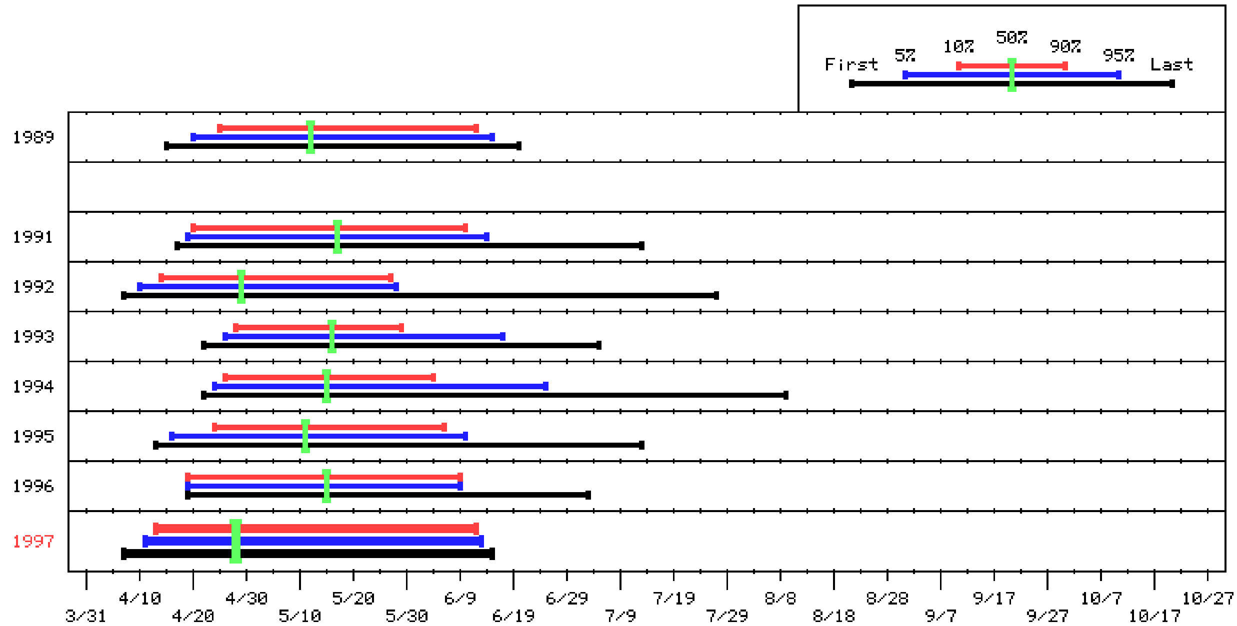
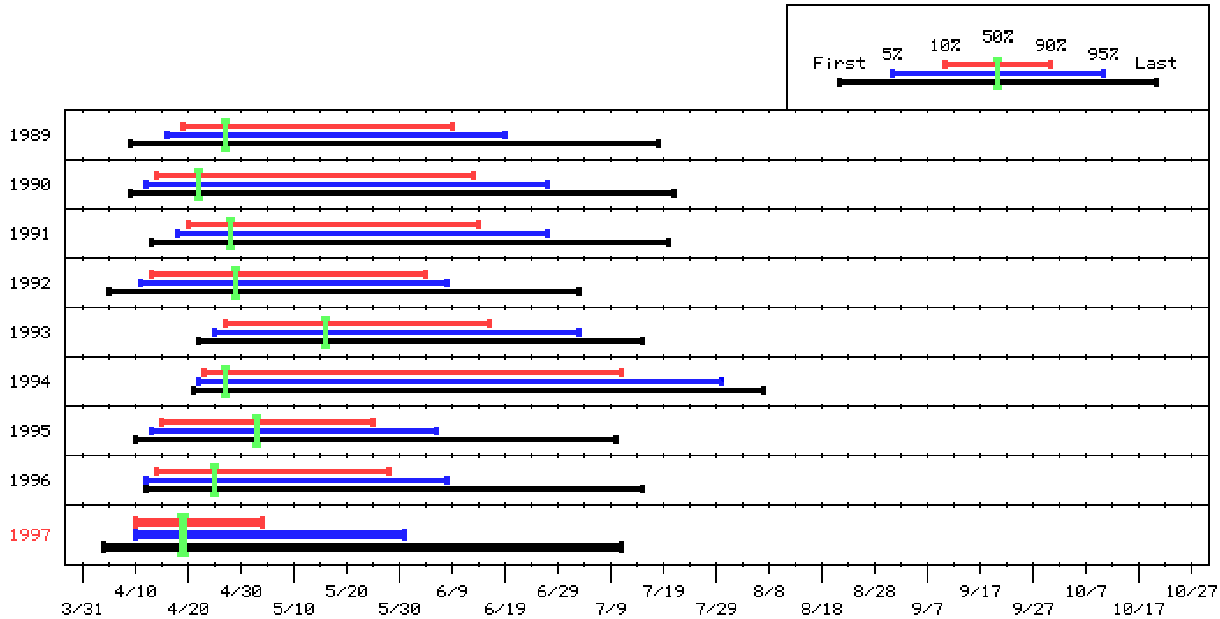


Table B7: Historical Salmon River (South Fork) outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/15	4/20	4/25	5/12	6/12	6/15	6/20	49	2226	84	84.0	3.8
1991	4/17	4/19	4/20	5/17	6/10	6/14	7/13	52	992	98	98.8	10.0
1992	4/7	4/10	4/14	4/29	5/27	5/28	7/27	44	1031	81	81.0	7.9
1993	4/22	4/26	4/28	5/16	5/29	6/17	7/5	32	1718	173	262.0	15.2
1994	4/22	4/24	4/26	5/15	6/4	6/25	8/9	40	5951	450	645.1	10.8
1995	4/13	4/16	4/24	5/11	6/10	6/10	7/13	48	1574	78	105.2	7.0
1996	4/19	4/19	4/19	5/15	6/9	6/9	7/3	52	700	16	37.2	5.3
1997	4/07	4/11	4/13	4/28	6/12	6/13	6/15	61	700	36	78.9	11.3

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B8: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild yearling chinook salmon smolt released from the Secesh River.



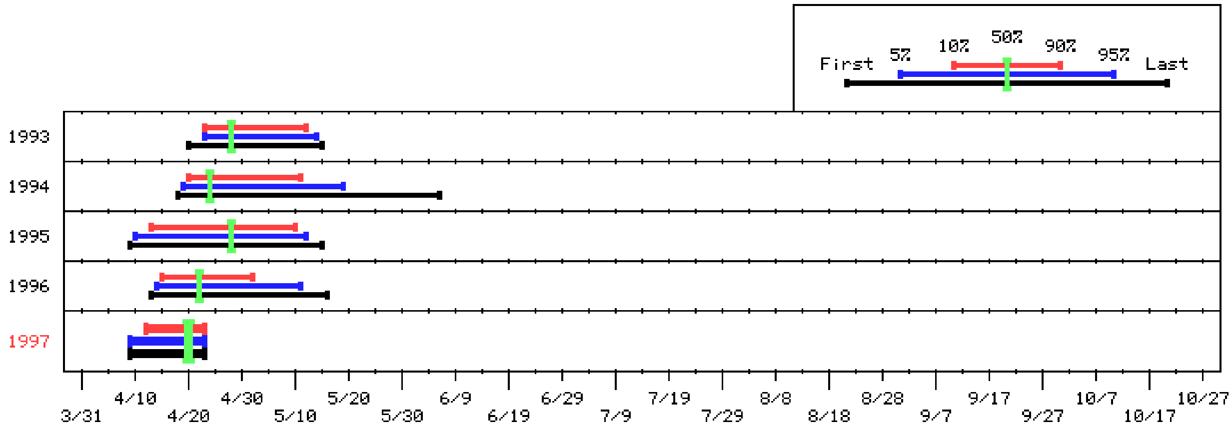
Passage date at Lower Granite Dam,
based on PIT-tag detections of yearling spring/summer chinook

Table B8: Historical Secesh River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/09	4/16	4/19	4/27	6/09	6/19	7/18	52	1940	190	190.0	9.8
1990	4/09	4/12	4/14	4/22	6/13	6/27	7/21	61	2176	157	157.0	7.2
1991	4/13	4/18	4/20	4/28	6/14	6/27	7/20	56	1018	71	72.3	7.1
1992	4/05	4/11	4/13	4/29	6/04	6/08	7/03	53	1013	40	40.0	3.9
1993	4/22	4/25	4/27	5/16	6/16	7/03	7/15	51	327	30	37.0	11.3
1994	4/21	4/22	4/23	4/27	7/11	7/30	8/07	80	422	32	33.0	7.8
1995	4/10	4/13	4/15	5/03	5/25	6/06	7/10	41	1551	90	112.4	7.2
1996	4/12	4/12	4/14	4/25	5/28	6/08	7/15	45	571	26	70.0	12.3
1997	4/04	4/10	4/10	4/19	5/04	5/31	7/11	25	260	34	62.7	24.1

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B9: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild Snake River yearling chinook salmon smolt released from the Wenaha River (South Fork).



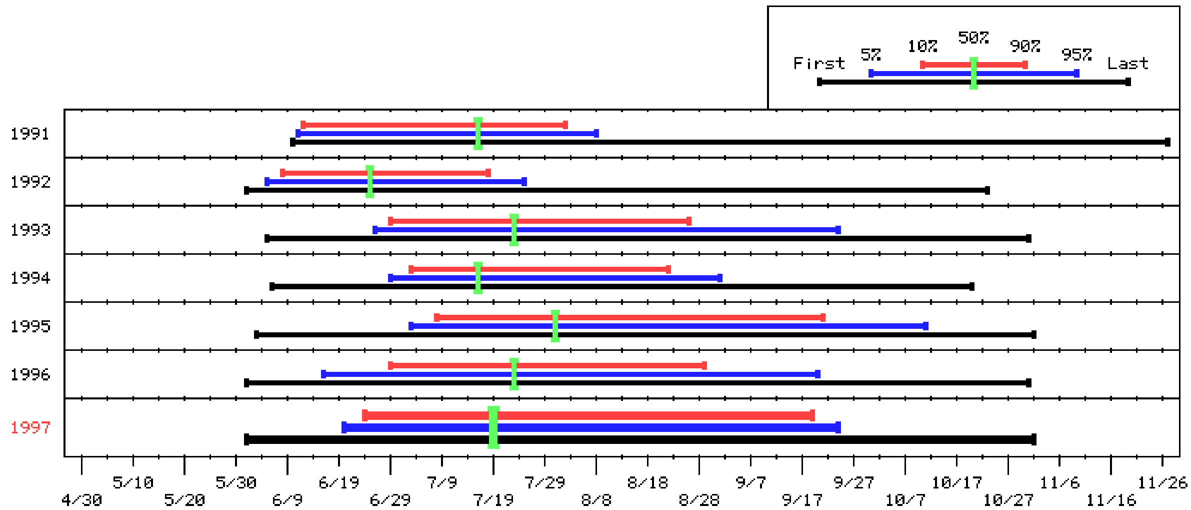
**Passage date at Lower Granite Dam,
based on PIT-tag detections of yearling spring/summer chinook**

Table B9: Historical Wenaha River (South Fork) outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	4/20	4/23	4/23	4/28	5/12	5/14	5/15	20	569	60	62.5	11.0
1994	4/18	4/19	4/20	4/24	5/11	5/19	6/6	22	788	68	73.4	9.3
1995	4/9	4/10	4/13	4/28	5/10	5/12	5/15	28	746	53	62.1	8.3
1996	4/13	4/14	4/15	4/22	5/2	5/11	5/16	18	827	53	132.4	16.0
1997	4/09	4/09	4/12	4/20	4/23	4/23	4/23	12	62	10	19.6	31.6

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B10: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild Snake River subyearling chinook salmon smolt passage indices for 1991-1997.



Passage date at Lower Granite Dam, based on passage indices of wild subyearling chinook

Table B10: Historical wild subyearling chinook outmigration timing characteristics at Lower Granite Dam using histoical passage indices for 1991-97.

Detection Year	Passage Dates (1)							Duration Middle 80% (days)	6/1 - last LGR Pass. Index (2)	Total LGR Pass. Index (3)	BOS Date (4)	First Detection Date (5)	EOS Date (6)
	First	5%	10%	50%	90%	95%	Last						
1991	6/10	6/11	6/12	7/16	8/02	8/08	11/27	52	13672	13874	3/28	4/14	11/27
1992	6/01	6/05	6/08	6/25	7/18	7/25	10/23	41	5744	5966	4/02	4/29	10/31
1993	6/05	6/26	6/29	7/23	8/26	9/24	10/31	59	16620	16908	4/15	5/11	10/31
1994	6/06	6/29	7/03	7/16	8/22	9/01	10/20	51	6765	6812	4/02	5/23	11/01
1995	6/03	7/03	7/08	7/31	9/21	10/11	11/01	76	26046	26645	3/29	4/10	11/01
1996	6/1	6/16	6/29	7/23	8/29	9/20	10/31	62	17548	18498	3/26	4/04	11/01
1997	6/1	6/20	6/24	7/19	9/19	9/24	11/01	88	17561	19128	3/27	4/06	10/31

(1) Percentage passage dates based on wild subyearling passage indices for period 6/1 to last data. First is the first subyearling starting at 6/1.
(2) LGR FPC Wild Subyearling Chinook Passage Indices, All Flow Years yearly totals for period 6/01 to last data.
(3) LGR FPC Wild Subyearling Chinook Passage Indices, All Flow Years yearly totals for the entire SMP sampling period.
(4) Beginning of SMP sampling at LGR.
(5) First subyearling chinook of the SMP sampling period at LGR.
(6) End of SMP sampling at LGR.

Figure B11: Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for wild Snake River subyearling chinook salmon smolt passage indices for high flow years only (1993, 95-97).

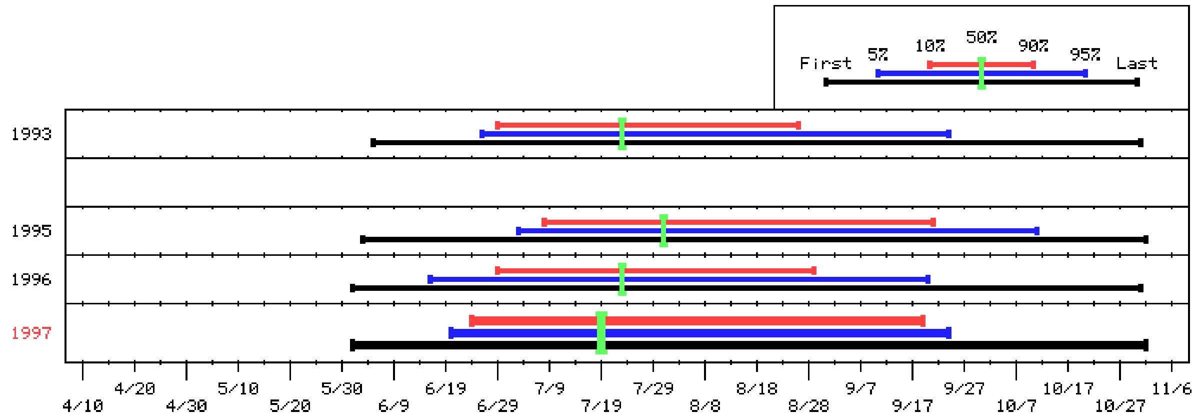


Table B11: Historical wild subyearling chinook outmigration timing characteristics at Lower Granite Dam using histoical passage indices for high flow years only (1993, 95-97).

Detection Year	Passage Dates (1)							Duration Middle 80% (days)	6/1 - last LGR Pass. Index (2)	Total LGR Pass. Index (3)	BOS Date (4)	First Detection Date (5)	EOS Date (6)
	First	5%	10%	50%	90%	95%	Last						
1993	6/05	6/26	6/29	7/23	8/26	9/24	10/31	59	16620	16908	4/15	5/11	10/31
1995	6/03	7/03	7/08	7/31	9/21	10/11	11/01	76	26046	26645	3/29	4/10	11/01
1996	6/1	6/16	6/29	7/23	8/29	9/20	10/31	62	17548	18498	3/26	4/04	11/01
1997	6/1	6/20	6/24	7/19	9/19	9/24	11/01	88	17561	19128	3/27	4/06	10/31

(1) Percentage passage dates based on wild subyearling passage indices for period 6/1 to last data. First is the first subyearling starting at 6/1.
(2) LGR FPC Wild Subyearling Chinook Passage Indices, All Flow Years yearly totals for period 6/01 to last data.
(3) LGR FPC Wild Subyearling Chinook Passage Indices, All Flow Years yearly totals for the entire SMP sampling period.
(4) Beginning of SMP sampling at LGR.
(5) First subyearling chinook of the SMP sampling period at LGR.
(6) End of SMP sampling at LGR.

Appendix C

Daily expansion factors for the spillway flow at Lower Granite Dam, 1997.

Table C1: Daily expansion factors for spillway at Lower Granite Dam, 1997. Daily observed PIT detections at Lower Granite Dam were adjusted for spill using the equation:

$$y = 1.667x^3 - 3.25x^2 + 2.583x.$$

Date (1997)	Expansion	Date (1997)	Expansion	Date (1997)	Expansion	Date (1997)	Expansion
03/31	1.44	04/29	2.31	05/28	1.74	06/26	1.17
04/01	1.31	04/30	2.07	05/29	2.32	06/27	1.06
04/02	1.23	05/01	2.30	05/30	2.05	06/28	1.28
04/03	1.00	05/02	1.95	05/31	2.37	06/29	1.12
04/04	1.00	05/03	1.96	06/01	2.41	06/30	1.00
04/05	1.00	05/04	2.11	06/02	2.53	07/01	1.00
04/06	1.00	05/05	1.77	06/03	2.58	07/02	1.15
04/07	1.00	05/06	1.66	06/04	2.70	07/03	1.17
04/08	1.00	05/07	1.85	06/05	2.85	07/04	1.19
04/09	1.00	05/08	1.89	06/06	2.87	07/05	1.20
04/10	1.38	05/09	1.89	06/07	3.00	07/06	1.06
04/11	1.90	05/10	2.09	06/08	3.31	07/07	1.00
04/12	2.01	05/11	2.52	06/09	2.94	07/08	1.11
04/13	1.99	05/12	2.42	06/10	2.83	07/09	1.00
04/14	2.04	05/13	2.52	06/11	3.46	07/10	1.00
04/15	2.20	05/14	2.87	06/12	2.98	07/11	1.17
04/16	1.98	05/15	2.72	06/13	2.92	07/12	1.08
04/17	1.96	05/16	2.68	06/14	3.10	07/13	1.21
04/18	1.90	05/17	2.93	06/15	3.39	07/14	1.09
04/19	1.79	05/18	2.90	06/16	2.90	07/15	1.26
04/20	1.98	05/19	2.64	06/17	2.93	07/16	1.36
04/21	2.16	05/20	2.88	06/18	2.75	07/17	1.27
04/22	2.06	05/21	2.48	06/19	2.47	07/18	1.12
04/23	2.11	05/22	2.49	06/20	2.66	07/19	1.00
04/24	2.06	05/23	2.20	06/21	2.45	07/20	1.10
04/25	2.08	05/24	2.85	06/22	2.49	07/21	1.09
04/26	2.39	05/25	2.51	06/23	2.28	07/22	1.18
04/27	2.12	05/26	2.46	06/24	1.61	07/23	1.27
04/28	2.10	05/27	1.97	06/25	1.04		