# EVALUATION OF THE 1996 PREDICTIONS OF THE RUN-TIMING OF WILD MIGRANT SPRING/SUMMER YEARLING CHINOOK IN THE SNAKE RIVER BASIN USING PROGRAM REALTIME

## TECHNICAL REPORT


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Project Number 9 l-05 1
Contract Number 96BI9 1572

MARCH 1997

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# Preface

Project 9 1-05 1 was initiated in 199 1 in response to the Endangered Species Act (ESA) listings in the Snake River Basin of the Columbia River system. Primary objectives were to 1) address the need for further synthesis of historical tagging and other biological information to improve understanding and identify future research and analysis needs and 2) to assist in the development of improved monitoring capabilities, statistical methodologies and software tools to assist in optimizing operational and fish passage strategies to maximize the protection and survival of listed threatened and endangered Snake River salmon populations.

Beginning in 1993, a major focus of this project became the in-season prediction of the general timing of smolt outmigrations of the listed Snake River wild salmon populations. Data provided from smolt monitoring and research projects, the Fish Passage Center (FPC), the Pacific States Marine Fisheries Commission PIT-Tag Information System (PTAGIS) primary database centers and the University of Washington second-tier database DART (Data Access in Real Time) information system were used in the systematic analysis of historical data and the development of statistical methods and interactive software tools.

The initial version of program RealTime, a statistical software program for predictions of run-timing (Skalski et al. 1994) was developed and tested during the 1994 Snake River spring smolt outmigration. Program RealTime used PIT-tag data from PTAGIS, based on fish releases from the Columbia Basin Fish and Wildlife Agencies tagging studies. In making predictions, the method uses state-of-the-art approaches to pattern recognition, nonlinear least-squares, feedback loops, numerical logic and bootstrap variance estimation. Specifically, the PIT-tag detections at Lower Granite Dam were 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 spring/summer yearling chinook. In this first year, two experimental approaches, a synchronized historical run pattern matching algorithm and a least-squares algorithm, were compared to two algorithms suggested by FPC (Townsend, et al. 1995).

In 1995, following evaluation of the performance of the 1994 algorithms of program RealTime (PIT Forecaster) and further discussions with technical members of the FPC and other parties of the Columbia River fisheries community, the best attributes of all the algorithms in use were combined into an improved version of program RealTime, denoted as the New Least-Squares (NLS) prediction method. Like 1994, real-time PIT-tag detections at Lower Granite Dam were used to make predictions of the general timing of the 1995 spring outmigrating wild spring/summer chinook (Townsend, et al. 1996).

For the1996 migration season, program RealTime was integrated with the University of Washington Columbia River Salmon Passage project (CRISP), to allow the prediction of spring/summer yearling chinook passage at other Snake and Columbia River dams from Little Goose to McNary Dams (results are reported by the CRiSP project (Hayes et al. 1997)). This report contains the 1996 season results of the forecasts for wild spring/summer yearling chinook outmigration timing at Lower Granite Dam.

# Acknowledgments

We wish to express thanks to the many fisheries agencies, Tribes and other institutions that have expended considerable resources in the generation, assembly, analysis and sharing of Columbia River biological, hydrologic, operational and other related information. Deserving particular thanks are the staff of the agencies and Tribes responsible for conducting the annual Columbia River Smolt Monitoring Program, the Fish Passage Center and the Pacific States Marine Fisheries Commission PIT-Tag Information System (PTAGIS) primary database centers for providing timely in-season access to fish passage and PIT-tag information and the University of Washington second-tier database DART (Data Access in Real Time) information system which receives, processes and provides access to biological, hydrologic and operational information via the internet.

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.

Funding support for this work came from the Pacific Northwest region's electrical ratepayers through the Columbia River Fish and Wildlife Program administered by the Bonneville Power Administration.

# Executive Summary

## Objective

The objective of Program RealTime is to predict and report in real-time the "percent run-to-date" and "date to specified percentiles" wild migrant spring/summer yearling chinook outmigration which arrive at Lower Granite Dam for both individual and a composite of Snake River streams.

## Accomplishment

Some adjustments had to be made to program RealTime algorithms in 1996, as less wild spring/summer chinook parr were PIT-tagged in 1995 due to low spawner abundance in most Snake River streams in 1994. In-season predictions of migration status were made for only six stocks during the 1996 smolt outmigration: Catherine Creek, the Grande Ronde, Imnaha, Lostine, South Fork Salmon and South Fork Wenaha rivers. Objectives were accomplished for the six selected stocks. On-line run-timing predictions were provided via the Internet to the fisheries community throughout the spring smolt outmigration.

## Findings

The 1996 prediction performance was very comparable to the program's performance the prior year. Using the mean absolute deviance[1] (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion as a measure of accuracy, the MAD's across all six sites in 1996 (5.7 over the entire season, 7.8 first half of the season, 4.6 last half) continued to improve over the previous years' performance: the mean 1995 MAD's across release sites were 6.4 overall, 7.1 first half, 6.1 last half. The 1996 composite (of the six stocks) forecast MAD's (2.4 overall, 1.9 first half, 2.5 last half) were similar to the MAD's for the 1995 composite forecast (2.2 overall, 2.7 first half, 2.0 last half). The increase in prediction error in the last half of the 1996 outmigration season is attributed to the sudden out-flux of fish between 10 and 20 May for four of the six stocks, and may be associated with increased flow and spill at Lower Granite Dam which occurred over the same period in the Columbia Basin.

## 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

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

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 1996 smolt outmigration of Snake River spring/summer chinook show prediction of run-timing can be accurately forecasted and suggest improvements that can be made to the RealTime PIT Forecaster program. We recommend changing the PIT Forecaster criteria to include only PIT-tag detections for parr marked during the previous summer season to improve the consistency and accuracy of predictions.

# Introduction

Three Ecologically Significant Units (ESU) of Pacific salmon (spring/summer chinook, fall chinook and sockeye salmon) have been designated as either threatened or endangered (T&E) under the Endangered Species Act (ESA) in the Snake River Basin. The tributary populations of spring/summer chinook ESU reside primarily in the Snake River Basin, in the drainages of the Salmon, Lemhi, Pahsimeroi, Grande Ronde, and Imnaha River, all of which are situated upstream of Lower Granite Dam. Additionally, a small population resides in the Tucannon River, which enters the Snake River between Lower Monumental and Little Goose dams. The fall chinook ESU is comprised of the progeny produced from the spawning populations of fall chinook in the Snake, Tucannon, Clearwater and Grande Ronde Rivers. The sockeye ESU currently consists of Redfish Lake stock sockeye in the captive broodstock program at Eagle and Beef Creek hatcheries, and the hatchery fish released from this program into the Redfish Lake, Pettit Lake, Pettit Creek, and Redfish Lake Creek; wild residual sockeye in the Redfish Lake and their out-migrating progeny; any naturally-spawned progeny of broodstock adults released into Redfish Lake in 1993-94; and any adults returning to Redfish or Pettit Lake.

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 Snake River. 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.

Since 1988, juvenile wild Snake River spring/summer chinook salmon have been PIT-tagged through monitoring and research programs conducted by the Columbia River fisheries agencies and Tribes. Information from these studies is presented in reports by the Fish Passage Center (1994, 1995. 1996), National Marine Fisheries Service (Accord et al. 1992, 1994, 1995a, 1995b, 1996, Matthews et al. 1990, 1992), Idaho Department of Fish and Game (Kiefer et al. 1990, 1993, 1994), Oregon Department of Fish and Game (Walters et al. 1996. Keefe et al. 1995. 1996) and the Nez Perce Tribe (Ashe et al. 1995, Blenden et al. 1996). The detection of tagged individuals at Lower Granite Dam provides a measure of the temporal and spatial distribution of the wild populations. Program RealTime was developed to take advantage of this historical data to predict the proportion of a particular population that had arrived at the index site in real-time and to forecast elapsed time to some future percentile in a migration. The capability of accurately predict smolt outmigration status improves the ability to match water management and operations to migration timing of ESA listed and other salmonid and steelhead stocks and contributes to the regional goal of increasing juvenile passage survival through the Columbia River system.

This report is a post-season analysis of the accuracy of the 1996 predictions from the program RealTime. Observed 1996 migration data collected at Lower Granite Dam were compared to the predictions made by RealTime for the spring outmigration of wild spring/summer chinook.

Appendix A displays the graphical reports of the RealTime program that were interactively accessible via the World Wide Web during the 1996 migration season. Final reports are available at address http://www.cqs.washington.edu/crisprt/.The 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. An analysis of the dams below Lower Granite Dam is available separately (Hayes et al. 1997-in press).

# Methods

### Description of Data

The 1996 spring outmigration of wild spring/summer chinook from six individual streams were used in evaluating the performance of program RealTime. These streams were chosen for their consistent recovery numbers, each having at least three years of data with a minimum of 30 tag detections per year. This was the minimum amount of historical data considered necessary in the formulation of the program. Five of the six tag sites examined were in Oregon, with the Salmon River South Fork being the only qualifying tag site in Idaho (Fig. 1, Table 1). The reduction of tagging efforts in Idaho led to the abandonment of predictions for nine sites included in 1995 (Table 3). As a result, the 1996 composite run is strongly represented by the Oregon stocks.

**Figure l: Map of Columbia Basin showing release sites used in the 1996 out-migration season forecast timing.**

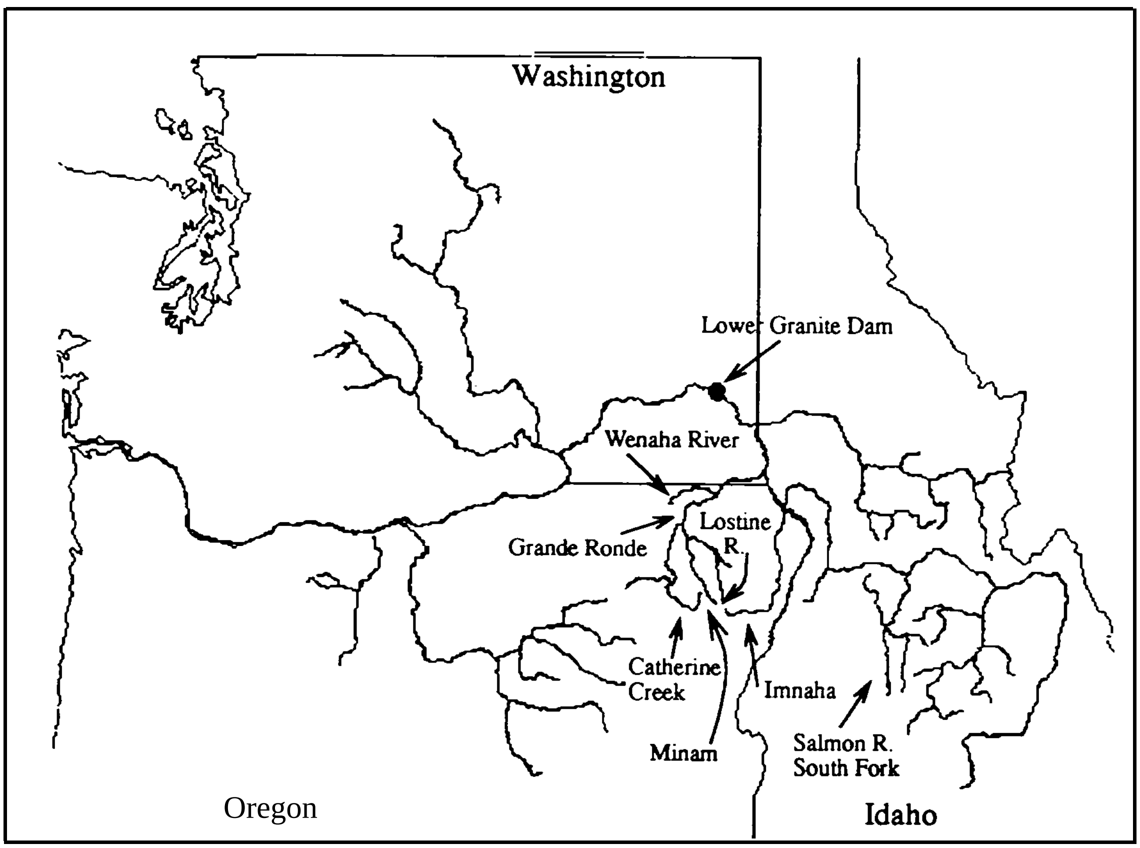


**Table 1: The six individual tag-sites used in predicting smolt run-timing by program RealTime in 1996.**

| Stream Name | GIS Hydrounits[a] |
|---|---|
| Catherine Creek | 17060104 |
| Imnaha River | 17060102 |
| Lostine River | 17060105 |
| Minam River | 17060106 |
| salmon River. south Fork | 17060208 |
| Wenaha River. South Fork | 17060106 |

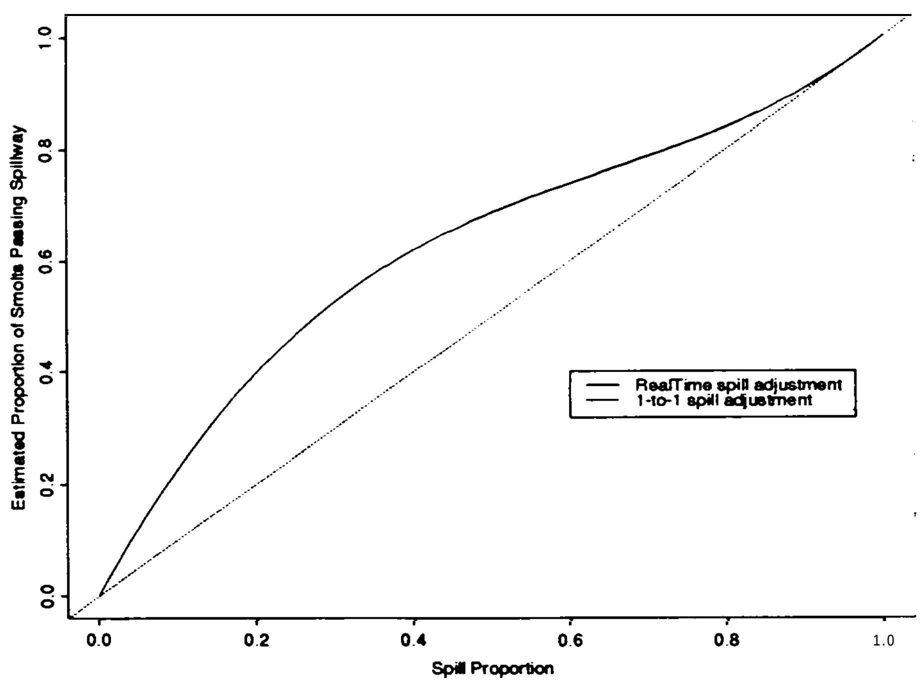
a. Geographical Information System (GIS) designations established by the U.S. Geological Survey.

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.**



# 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 1995 and 1996 versions of the LS method[1] are nearly identical. The only change in the algorithm is an adjustment to the weighting function to incorporate release-recapture information for 1996.

## 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

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

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 ith 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 L-S algorithm used for the 1994 outmigration season.

$w_{ij}$ = weight for the $j$th percentile for the ith 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) andjth percentile for the present year,
$D_{ij}$ = number of days between the (i-1) and $j$th percentile for the ith 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 fat 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**

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).

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:

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

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 six sites used in predicting 1996 run-timing by program RealTime showing (1) number of tagged wild chinook salmon parr released in 1995, (2) detected number of smolts at Lower Granite Dam in 1996, (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 1996.**

| Tagging Location | (1) 1995 Parr Tagged | (2) 1996PIT Detections | (3) Adjusted PIT Detections | (4) Years of Hist. Data | (5) Mean Historical Recapture $\bar{p}$ (%) | (6) 1996 Recapture $p$ (%)[a] |
|---|---|---|---|---|---|---|
| Catherine Creek | 1682 | 116 | 261.7 | 5 | 11.5 | 15.6 |
| Imnaha River | 999 | 97 | 233.5 | 7 | 9.9 | 22.4 |
| Lostine River | 978 | 81 | 188.2 | 5 | 13.0 | 19.2 |
| Minam River | 998 | 68 | 165.0 | 3 | 12.8 | 16.5 |
| Salmon River. South Fork | 700 | 16 | 37.2 | 6 | 8.6 | 5.3 |
| Wenaha River. South Fork | 827 | 53 | 132.4 | 3 | 11.2 | 16.0 |

a. Data Sources: PTAGIS Database and RealTime program output as of 20 November 1996.

## Age-of-Run (AR) Error

The mean-fish-run-age (MFRA) is the average number of days since the outmigration started, weighted by the number of fish observed per day. The MFRA is calculated for each outmigration portion $\hat{p}$ of the last historical outmigration and the present run at Lower Granite Dam 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 ($MFRA_{\hat{p}}$):

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

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 by

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

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,
$p$ = 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.5 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 3 are the mean absolute deviance (MAD) of the daily predictions for the 1995 and 1996 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

The 1996 Program RealTime performance was very comparable to the performance of program RealTime in 1995, despite being composed of only six individual tag-sites. Five of the release sites were in the Grande Ronde and Imnaha River systems, with the remaining site in the Salmon River drainage. In the 1995 report, nine of the thirteen tag sites were in the Salmon River drainage; the remaining four sites were in the Grande Ronde and Imnaha river systems.The mean 1996 individual tag-site MAD's (5.7 overall, 7.8 first half, 4.6 last half) were improved over the mean 1995 individual tag-site MAD's (6.4 overall, 7.1 first half, 6.1 last half). The 1996 composite run MAD's (2.4 overall, 1.9 first half, 2.5 last half) were similar to the MAD's for the 1995 composite run (2.2 overall, 2.7 first half, 2.0 last half). A graph for the daily predictions of the 1996 RealTime composite run (Figure 3) gives a clearer picture of the season's performance.

Figure 4 and Table 4 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"[1], a lagging of

1. World Wide Web address: http://www.cqs.washington.edu/dart/pit_rel_de.html. Data courtesy of Pacific States Marine Fisheries Commission.

migration timing for longer migration distance is not as apparent as last year. However, in 1996, PIT-tag detections were dominated by early streams less than 500 kilometers above Lower Granite Dam. Low adult escapement of Snake River wild spring/summer chinook in 1994 to many of the streams greater than 500 kilometers above Lower Granite Dam prevented the marking of parr during the 1995 summer season in many of the these streams which generally exhibit later patterns of spring smolt outmigration timing at Lower Granite Dam. Additionally, the small numbers seen from the South Fork of the Salmon River had minimal impact on the RealTime composite prediction. Appendix A contains graphs for 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/*. Results for predictions of spring/summer yearling chinook passage at other Snake and Columbia River dams from Little Goose to McNary Dams at downstream sites are available separately (Hayes et al. 1997-in press).

**Figure 3: Composite run daily forecast and the daily confidence intervals compared to the observed run for the 1996 out-migration season.**

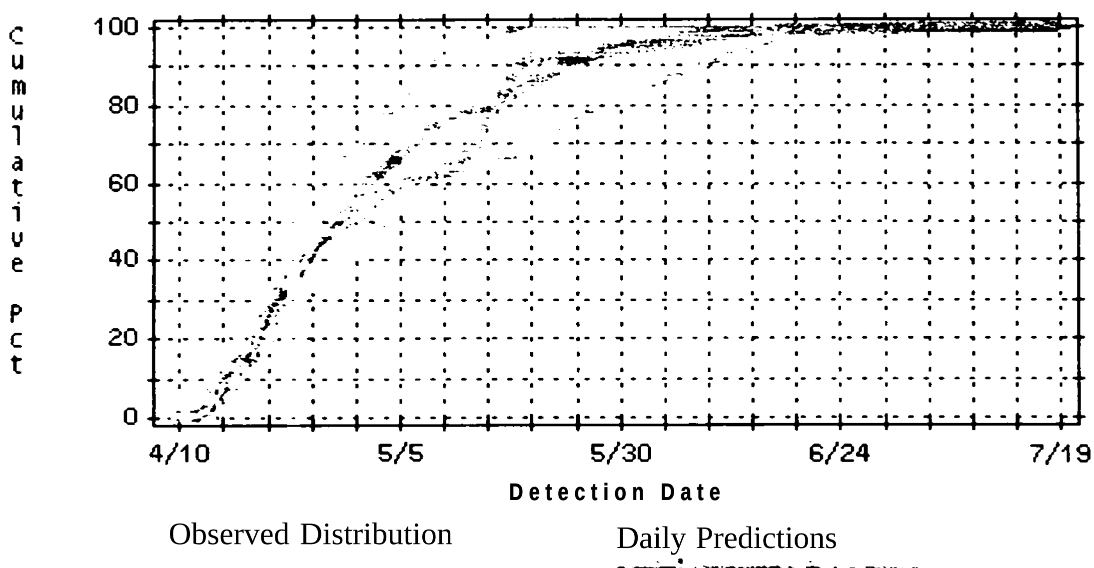


**Table 3: Comparison of mean absolute deviances (MAD) for selected 1995 and 1996 streams and composite runs. Columns show percent MAD's for the entire run, the first 50% of the run. and the last 50% of the run (to two weeks after last detection).**

| | 1995 | | | 1996 | | |
|---|---|---|---|---|---|---|
| Tagging Site | Total Run | First 50% | Last 50% | Total Run | First 50% | Last 50% |
| Bear Valley Creek | 4.5 | 5.6 | 3.9 | --- | --- | --- |
| Big Creek | 2.9 | 6.1 | 1.5 | --- | --- | --- |
| Catherine Creek | 5.6 | 2.7 | 6.6 | 5.4 | 3.3 | 6.1 |
| Elk Creek | 6.6 | 8.2 | 5.8 | --- | --- | - - |
| Grande Ronde River | 6.4 | 5.0 | 7.6 | --- | --- | --- |
| Imnaha River | 10.0 | 15.5 | 7.7 | 6.8 | 6.6 | 6.8 |
| Lostine River | 3 5 | 3.4 | 3.6 | 9.5 | 18.7 | 4.3 |
| Marsh Creek | 4.9 | 7.8 | 3.6 | --- | --- | - - |
| Minam River | --- | - - | --- | 2.8 | 2.7 | 2.9 |
| Salmon River | 15.5 | 13.1 | 16.1 | --- | --- | - - |
| Salmon River. East Fork | 4.6 | 7.0 | 3.5 | --- | --- | - - |
| Salmon River. South Fork | 8.7 | 8.6 | 8.7 | 6.2 | 9.6 | 4.9 |
| Secesh River | 2.8 | 3.8 | 2.5 | mm- | --- | - - |
| Valley Creek | 7.3 | 5.1 | 8.9 | --- | --- | --- |
| Wenaha River. South Fork | --- | - - | --- | 3.4 | 6.2 | 2.8 |
| **mean MAD** | 6.4 | 7.1 | 6.1 | 5.7 | 7.8 | 4.6 |
| **median MAD** | 4.9 | 6.1 | 5.8 | 5.8 | 6.4 | 4.6 |
| **range** | 2.8 - 15.5 | 2.7 - 15.5 | 2.5 - 16.1 | 2.8 - 9.5 | 2.7 - 18.7 | 2.8 - 6.8 |
| Composite Runs | 2 2 | 2.7 | 2.0 | 2.4 | 1.9 | 2.5 |

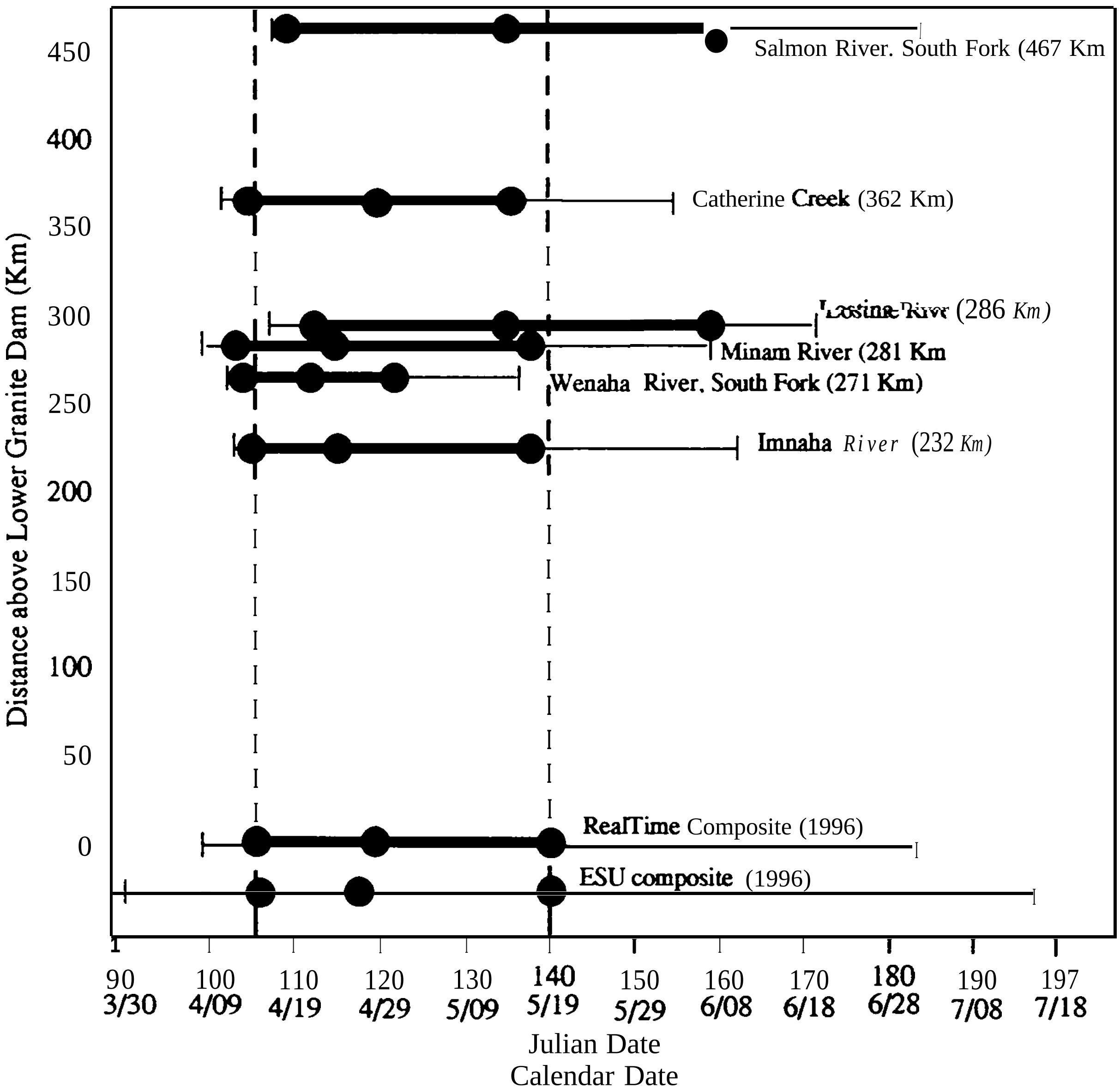
In addition to the RealTime composite, composed of only the six streams that met the 1996 criteria of the RealTime program algorithms, the migration timing for an ESU composite that included all Snake River wild spring/summer chinook stocks having parr PIT-tagged during 1995 was calculated. This new composite consisted of 693 smolt detected at Lower Granite Dam. released from 15 different sites. The timing distribution and duration of the middle 80% of the ESU composite and the RealTime composite are remarkably similar, however, the start and end dates of the ESU composite are more protracted than the RealTime composite (Table 4 and Figure 4). The limited marking in 1996 restricted the accurate application of program RealTime to only a few individual ESU streams.

**Table 4: Observed passage dates (0%, 10%. 50%, 90% and 100%) at Lower Granite Dam in 1996 for PIT-tagged wild Snake River spring/summer chinook salmon smolts for the six individual stocks. the RealTime and ESU composite runs. based on the parr PIT-tagged in 1995. The ESU composite is calculated from all spring/summer chinook PIT-tagged at designated ESU sites in 1995 and observed at Lower Granite Dam in 1996.**

| | Passage Dates at Lower Granite Dam | | | |
|---|---|---|---|---|
| Population or Stock | 10% | 50% | 90% | Range |
| Catherine Creek | 18 April | 30 April | 17 May | 14 April - 4 June |
| Imnaha River | 16 April | 26 April | 18 May | 14 April - 12 June |
| Lostine River | 22 April | 15 May | 7 June | 17 April - 19 June |
| Minam River | 14 April | 25 April | 18 May | 10 April - 7 June |
| Salmon River. South Fork | 19 April | 15 May | 9 June | 19 April - 3 July |
| Wenaha River. South Fork | 15 April | 22 April | 2 May | 13 April - 16 May |
| Program RealTime Composite[a] | 16 April | 30 April | 19 May | 10 April - 3 July |
| ESU composite[b] | 15 April | 27 April | 19 May | 29 March - 15 July |

a. The composite consists of the 6 individual release sites mentioned above.
b. There were 15 release sites that qualified as an ESU site. but did not meet the RealTime criteria for individual stream forecasting for various reasons..

**Figure 4: Timing plots of 1996 passage dates (10%. SO%, 90% (dots) and range(endpoints)) at Lower Granite Dam for PIT-tagged wild Snake River spring/summer chinook salmon smolts for the six individual stocks. the RealTime and ESU composite run, based on the parr PIT-tagged in 1995. The dashed lines show the dates that 10% and 90% of the outmigration passed Lower Granite Dam as estimated by the RealTime composite of the six sites.**



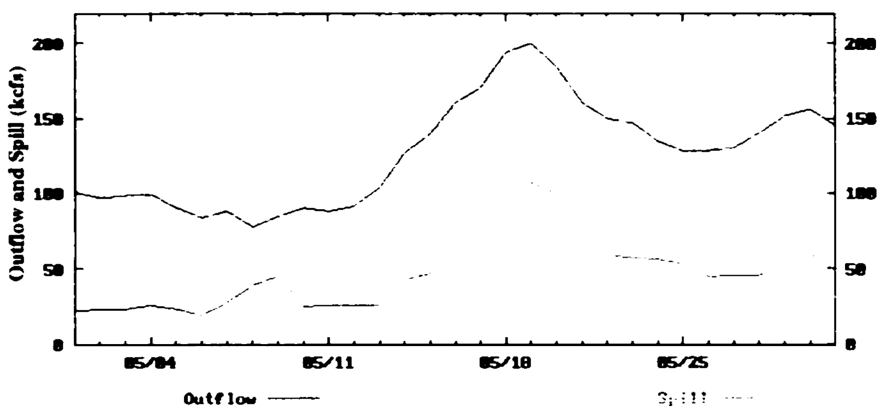

# Discussion

The 1996 outmigration experienced very high, early flows, with a large portion of this water being spilled. Five of the six individual stocks that made up the composite run (all except the Salmon River, South Fork) recorded a higher than expected number of spill-adjusted fish

(Table 2). Though the river conditions in 1996 varied from previous years, characterized by higher flows than previously experienced, we were pleased with the performance of the 1996 program **RealTime**.

The 1996 program **RealTime** predictions for the individual stocks were fairly accurate, with the exception of the Lostine River run, where predictions of run status were above the observed proportion-passed for most of the observed run (Appendix A). This is largely due to the close match that the first half of the season had to previous years. From the first arrivals until mid-May, the Lostine River run resembled historical runs in both shape and numbers, and had this been the case, the run would have been smaller and shorter. An unexpected number of Lostine outmigrants began to arrive mid-May and continued into the middle of June. This flush of outmigrants also occurred in three other release sites (Catherine Creek, Imnaha and Salmon (South Fork) Rivers), approximately May 10-20, coinciding with a large increase in both flow and spill at Lower Granite Dam (Fig. 5).

**Figure 5: Total flow and spill at Lower Granite Dam for May, 1996.**




The **RealTime** composite prediction, the average of the six individual stock predictions, gave very satisfactory predictions that were within 3% for most of the run. 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 prediction for the 1996 run from Lostine River.

The 1996 timing plots of the dates of cumulative percentiles of passage at Lower Granite Dam show two streams, the Salmon River South Fork and Lostine River, having later migration timing than the **RealTime** composite (Figure 4). 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.

The results from the 1996 outmigration further suggest improvements that can be made to the **RealTime** program. Presently, the program criteria consider PIT detections from parr marked during the calendar year immediately preceding the year of spring outmigration. 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 been during the summer season. Beginning in 1993, PIT-tagging occurred in 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 was 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 pax-r marked during the summer season only. In order to maintain consistency to past predictions, a change the 1997 RealTime criteria to include only PIT-tag detections for parr marked during the previous summer season is proposed. Additionally, prediction algorithms for migrant groups marked and released during seasons other than the summer season will be investigated.

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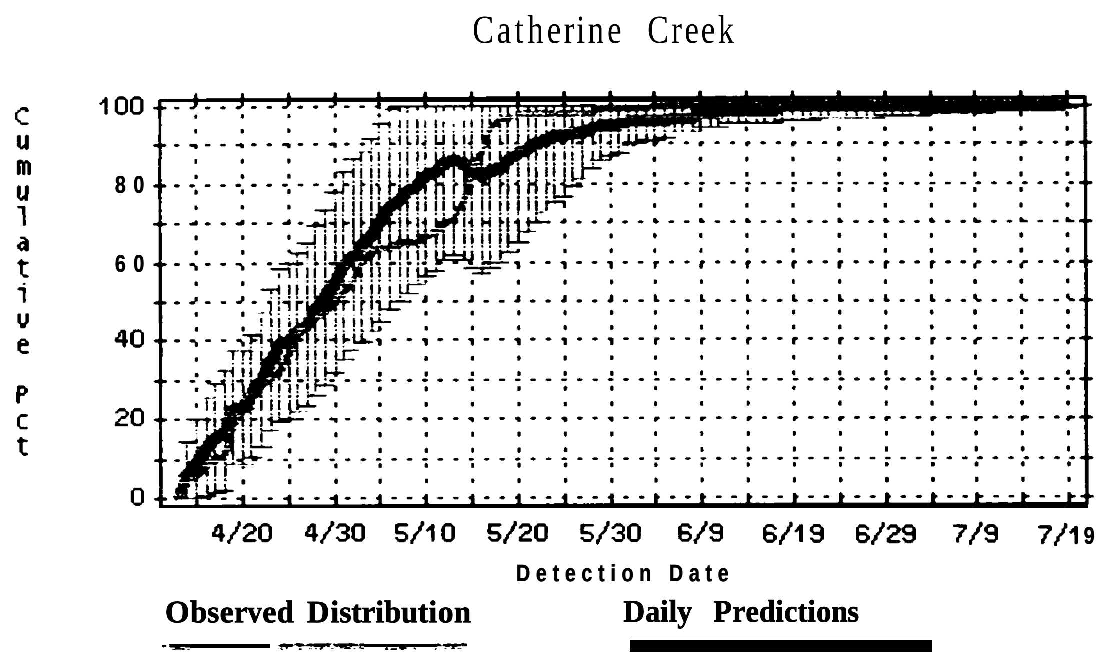
# Appendix A

Performance Plots for the 1996 **Out-migration** Season

**Figure Al: Catherine Creek and Imnaha River Daily Predictions.**



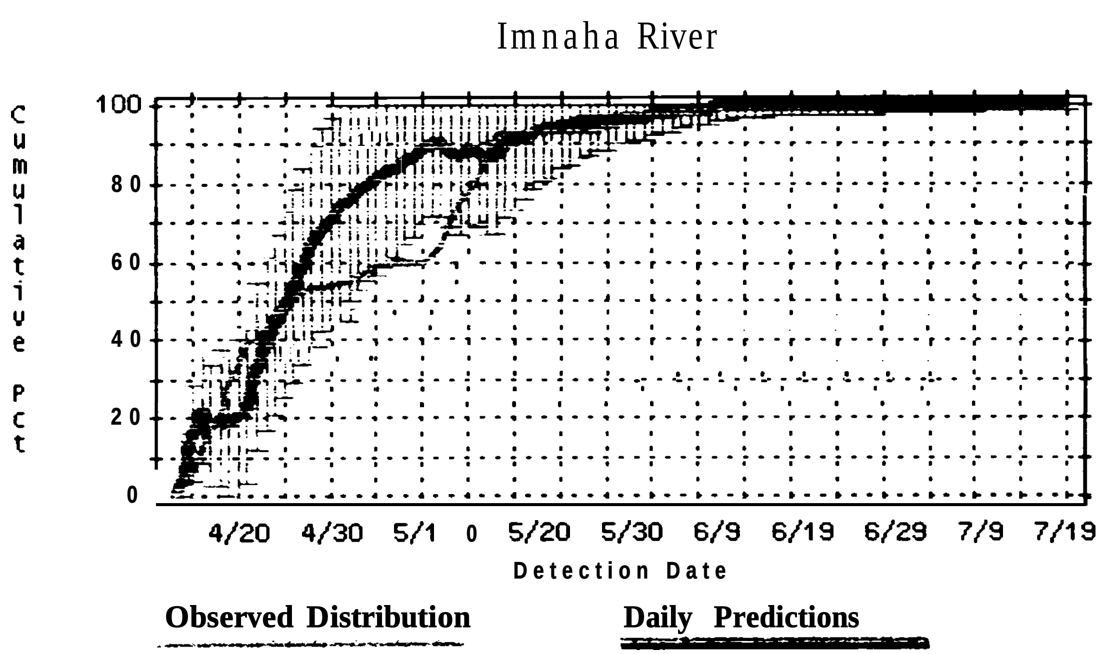
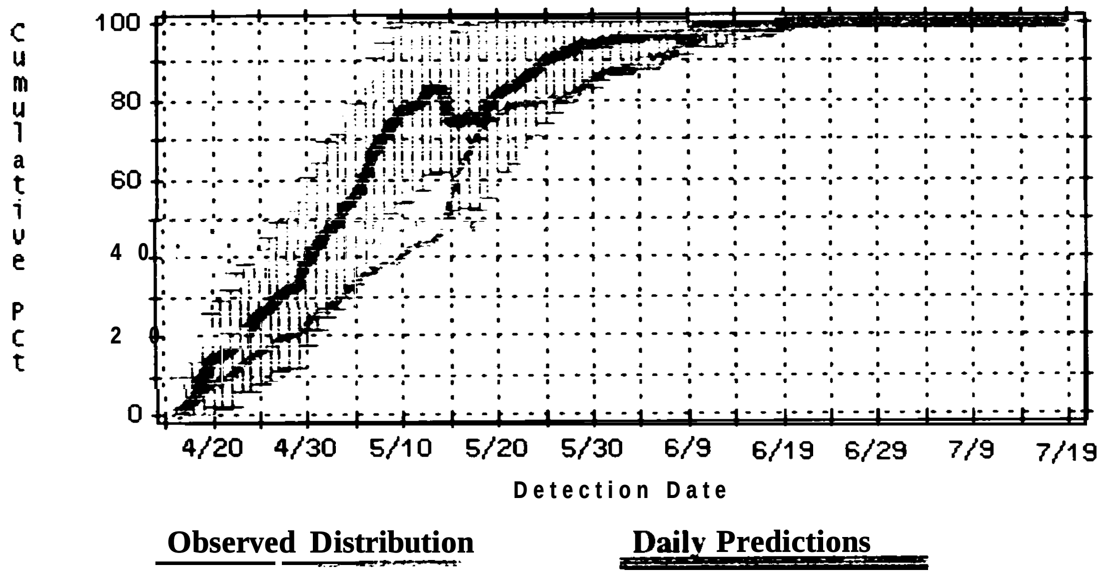



**Figure A2: Lostine River and Minam River Daily Predictions.**

Lostine River




Minam River

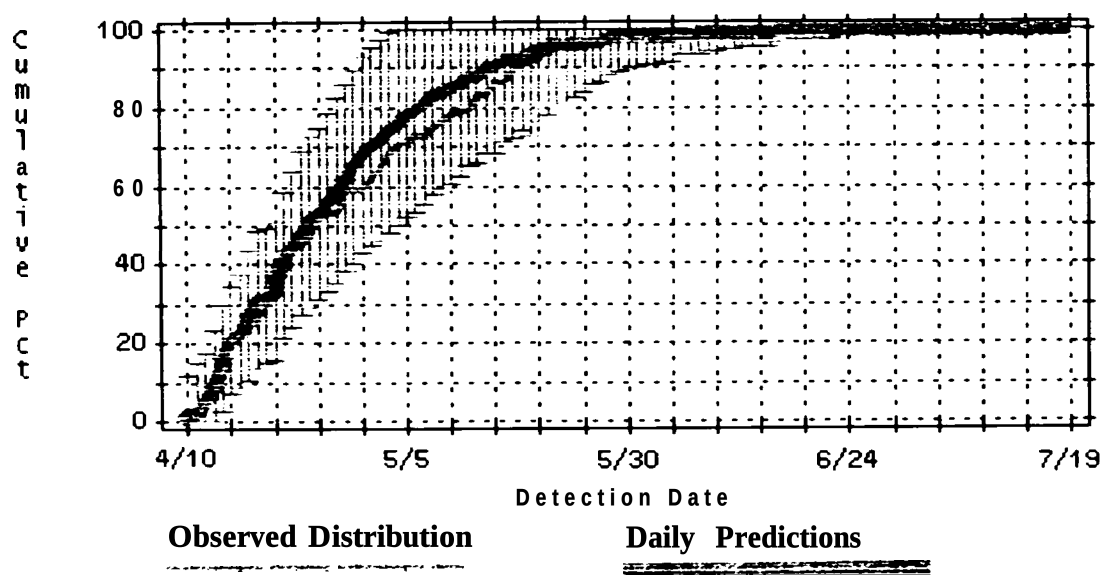
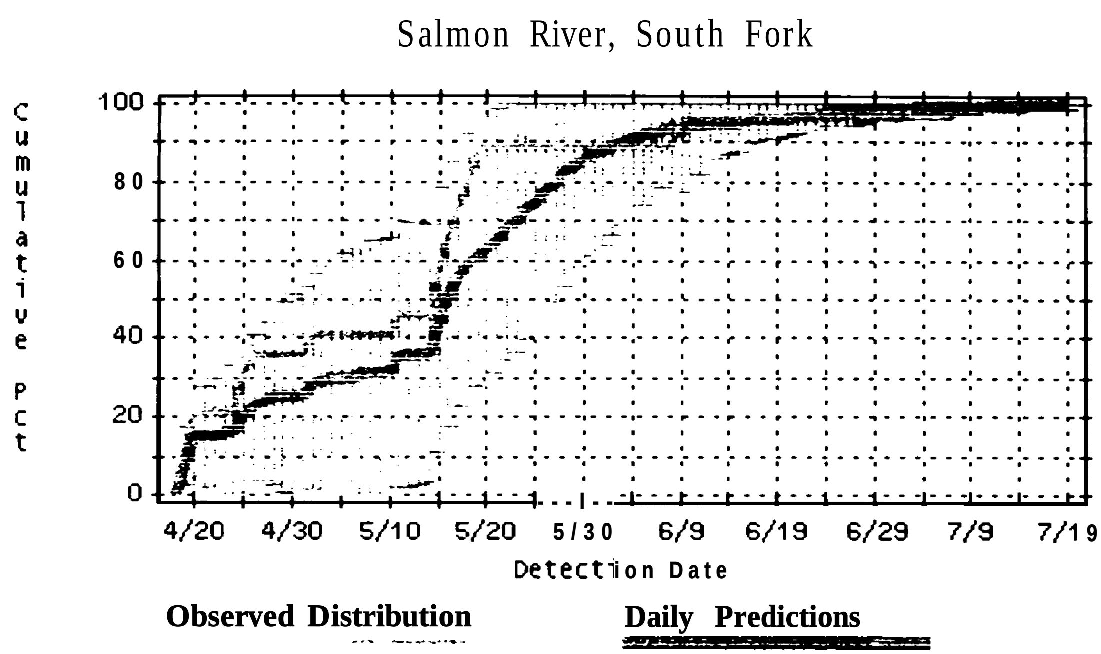
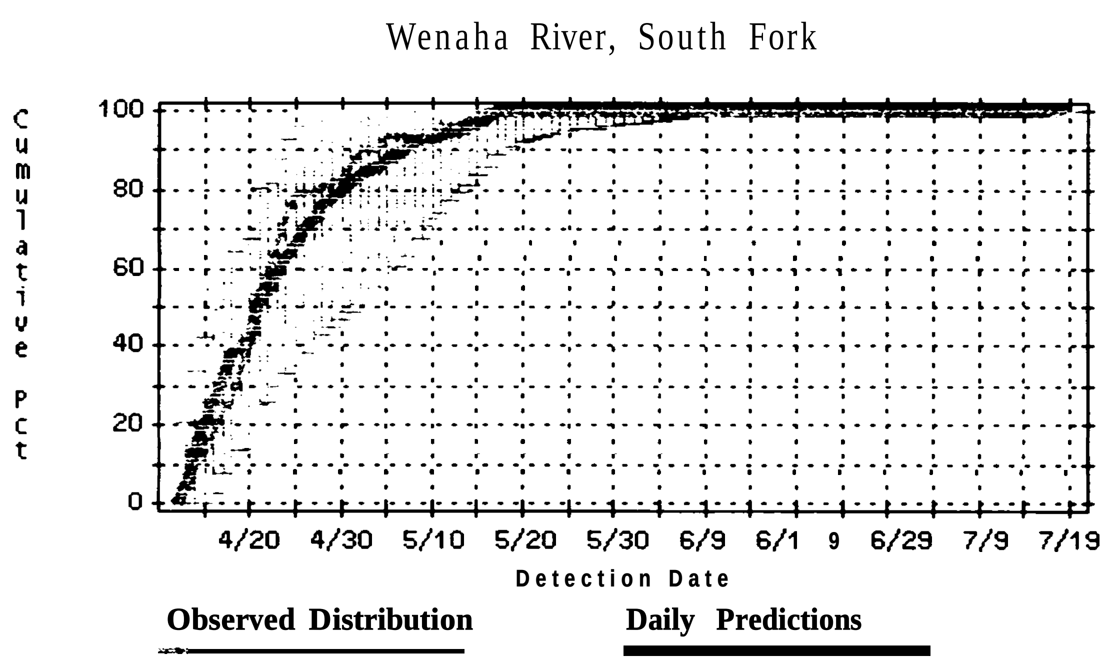


**Figure A3: Salmon River, South Fork and Wenaha River, South Fork Daily Predictions.**

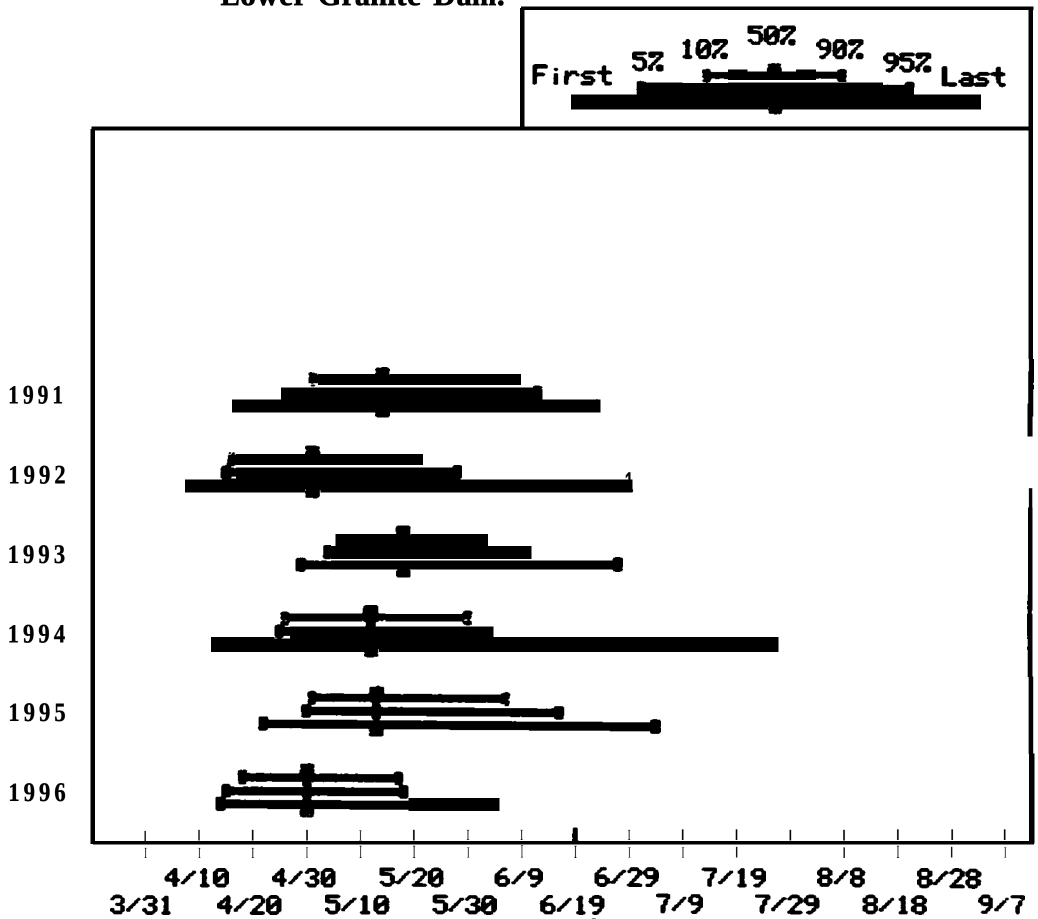


# Appendix B

Historical timing plots and dates of passage at Lower Granite Dam (from **PIT-**tag data) for the six individual streams tracked by program **RealTime** during the 1996 outmigration season.

**Figure B1: Historical Catherine Creek outmigration distribution at Lower Granite Dam.**



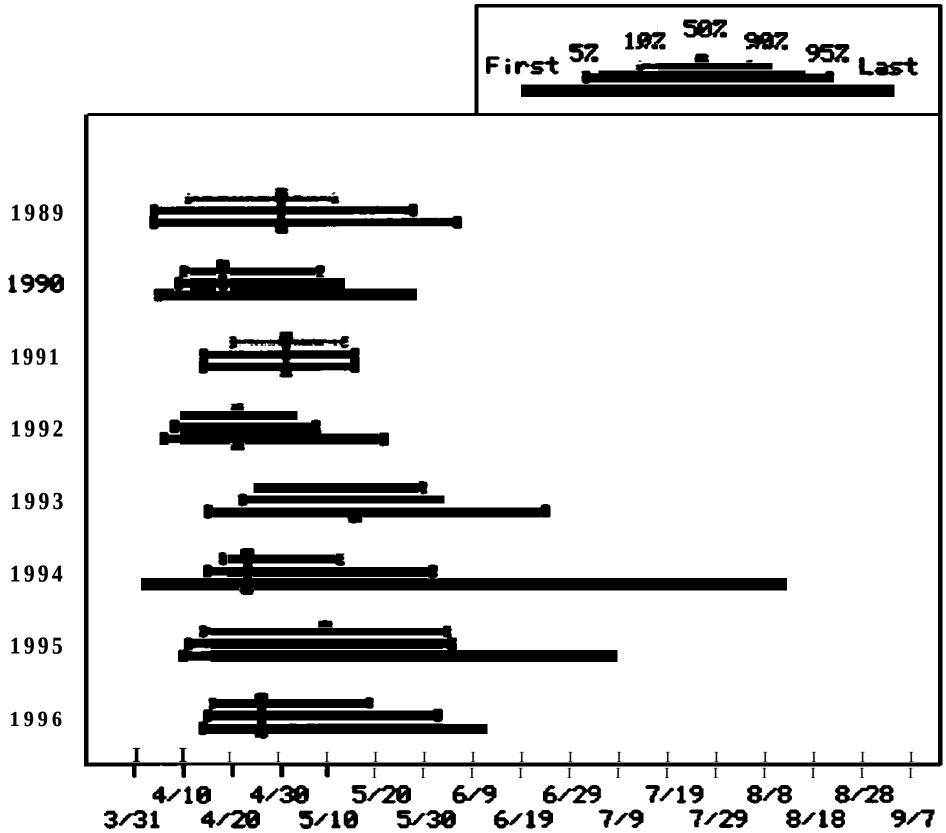

Passage Date at Lower Granite Dam,
based on PIT detections of yearling spring/summer chinook

**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 | 77.8396 | 7.7 |
| 1992 | 4/8 | 4/15 | 4/16 | 5/1 | 5/21 | 5/28 | 6/29 | 36 | 940 | 67 | 67 | 7.1 |
| 1993 | 4/29 | 5/4 | 5/6 | 5/18 | 6/2 | 6/10 | 6/27 | 28 | 1108 | 102 | 158.2549 | 14.3 |
| 1994 | 4/13 | 4/25 | 4/26 | 5/12 | 5/30 | 6/3 | 7/26 | 35 | 1000 | 76 | 110.4933 | 11.0 |
| 1995 | 4/22 | 4/30 | 5/1 | 5/13 | 6/6 | 6/16 | 7/4 | 37 | 2061 | 202 | 268.5996 | 13.0 |
| 1996 | 4/14 | 4/15 | 4/18 | 4/30 | 5/17 | 5/18 | 6/4 | 30 | 1682 | 116 | 261.7382 | 15.6 |

(1) Parr PIT- tagged and released during the summer/fall 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: Historical Imnaha River outmigration distribution at Lower Granite Dam.



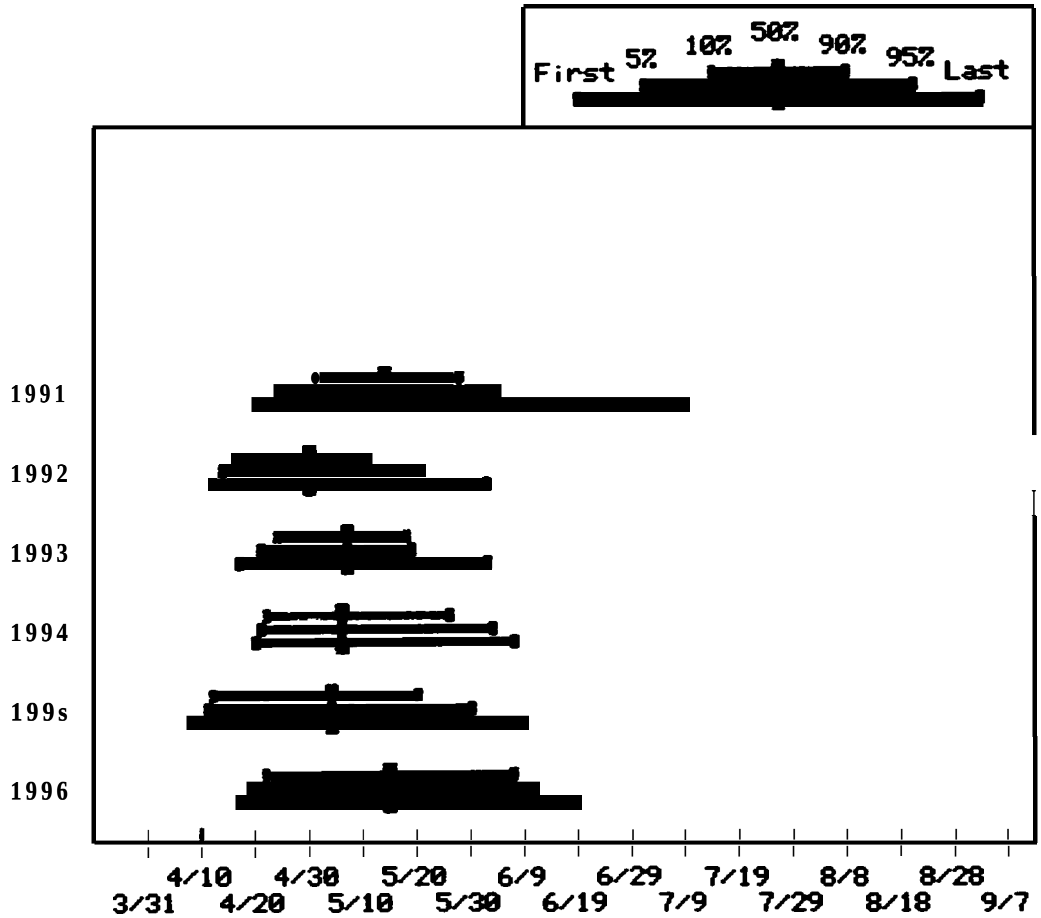

Passage Date at Lower Granite Dam, based on PIT detections of yearling spring/summer chinook

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 | 6.0 |
| 1990 | 4/5 | 4/9 | 4/10 | 4/18 | 5/8 | 5/12 | 5/27 | 29 | 2005 | 161 | 161 | 8.0 |
| 1991 | 4/14 | 4/14 | 4/20 | 5/1 | 5/13 | 5/15 | 5/15 | 24 | 334 | 18 | 18 | 5.4 |
| 1992 | 4/6 | 4/8 | 4/10 | 4/21 | 5/3 | 5/7 | 5/21 | 24 | 759 | 73 | 73 | 9.6 |
| 1993 | 4/15 | 4/22 | 4/25 | 5/15 | 5/29 | 6/3 | 6/23 | 35 | 1003 | 63 | 88.3505 | 8.8 |
| 1994 | 4/2 | 4/15 | 4/18 | 4/23 | 5/12 | 5/31 | 8/11 | 25 | 1753 | 205 | 218.2332 | 12.4 |
| 1995 | 4/10 | 4/11 | 4/14 | 5/9 | 6/3 | 6/4 | 7/7 | 51 | 999 | 40 | 50.8661 | 5.1 |
| 1996 | 4/14 | 4/15 | 4/16 | 4/26 | 5/18 | 6/1 | 6/12 | 33 | 997 | 97 | 233.4590 | 23.4 |

(1) Parr PIT-tagged and released during the summer/fall 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: Historical Lostine River outmigration distribution at Lower Granite Dam.**



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

**Table B3: Historical Lostine River outmigration timing characteristics.**

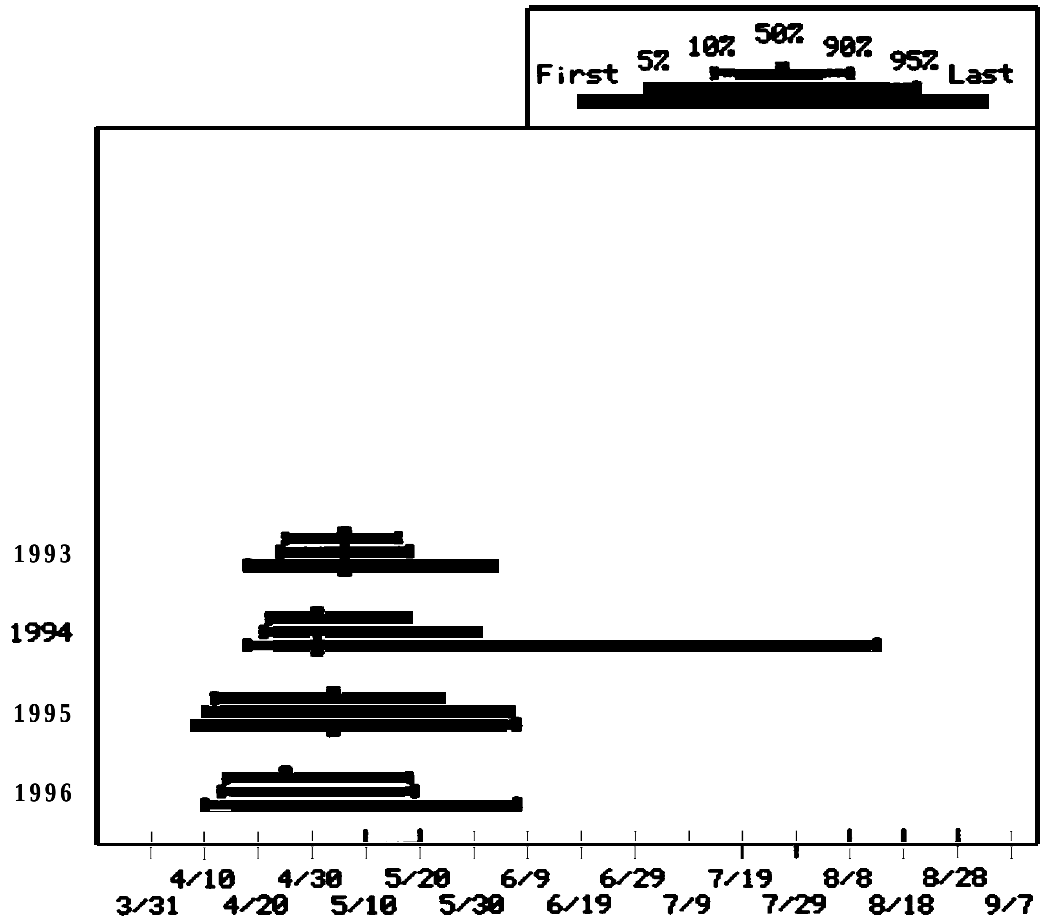
| Detection Year | Detection Dates | | | | | | | Duration Middle 80% (days) | Parr Released (1) | LGR PIT Detections (2) | Adjusted LGR PIT Detections (3) | % (3)/(1) x 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | 5% | 10% | 50% | 90% | 95% | Last | | | | | |
| 1991 | 4/20 | 4/24 | 5/1 | 5/14 | 5/28 | 6/4 | 7/9 | 28 | 1017 | 90 | 90.8396 | 8.9 |
| 1992 | 4/12 | 4/14 | 4/16 | 4/30 | 5/11 | 5/21 | 6/2 | 26 | 1107 | 92 | 92 | 8.3 |
| 1993 | 4/17 | 4/21 | 4/24 | 5/7 | 5/18 | 5/19 | 6/2 | 25 | 1016 | 123 | 156.0881 | 15.4 |
| 1994 | 4/20 | 4/21 | 4/22 | 5/6 | 5/26 | 6/3 | 6/7 | 35 | 733 | 71 | 87.3734 | 11.9 |
| 1995 | 4/8 | 4/11 | 4/12 | 5/4 | 5/20 | 5/30 | 6/9 | 39 | 1008 | 112 | 142.0105 | 14.1 |
| 1996 | 4/17 | 4/19 | 4/22 | 5/15 | 6/7 | 6/11 | 6/19 | 47 | 978 | 81 | 188.1730 | 19.2 |

(1) Parr PIT-tagged and released during the summer/fall 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: **Historical Minam** River **outmigration** distribution at Lower Granite Dam.



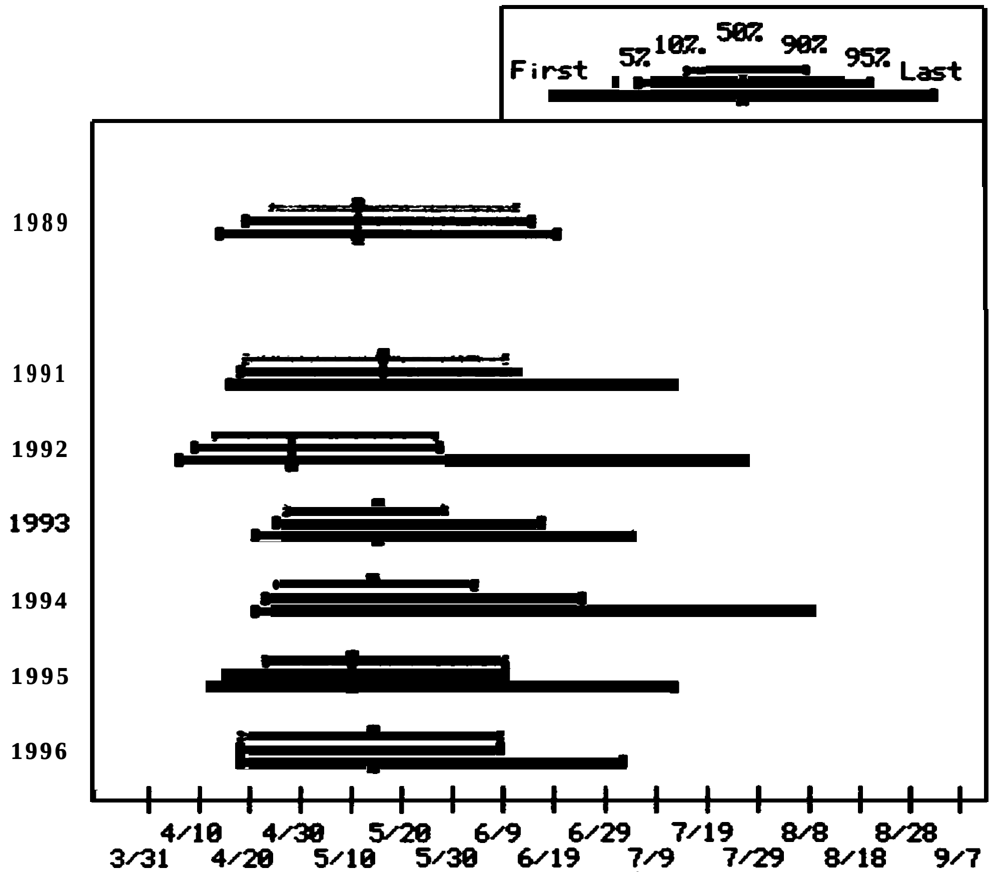

Passage Date at Lower Granite Dam,
based on PIT detections of **yearling** spring/summer chinook

## Table **B4: 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 | 125.4875 | 12.5 |
| 1994 | 4/18 | 4/21 | 4/22 | 5/1 | 5/18 | 5/31 | 8/13 | 27 | 1005 | 112 | 133.2790 | 13.3 |
| 1995 | 4/8 | 4/10 | 4/12 | 5/4 | 5/24 | 6/6 | 6/7 | 43 | 998 | 70 | 89.4617 | 9.0 |
| 1996 | 4/10 | 4/13 | 4/14 | 4/25 | 5/18 | 5/19 | 6/7 | 35 | 998 | 68 | 164.9517 | 16.5 |

(1) Parr PIT-tagged and released during the summer/fall 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:** Historical Salmon River (South Fork) **outmigration** distribution at Lower Granite Dam.



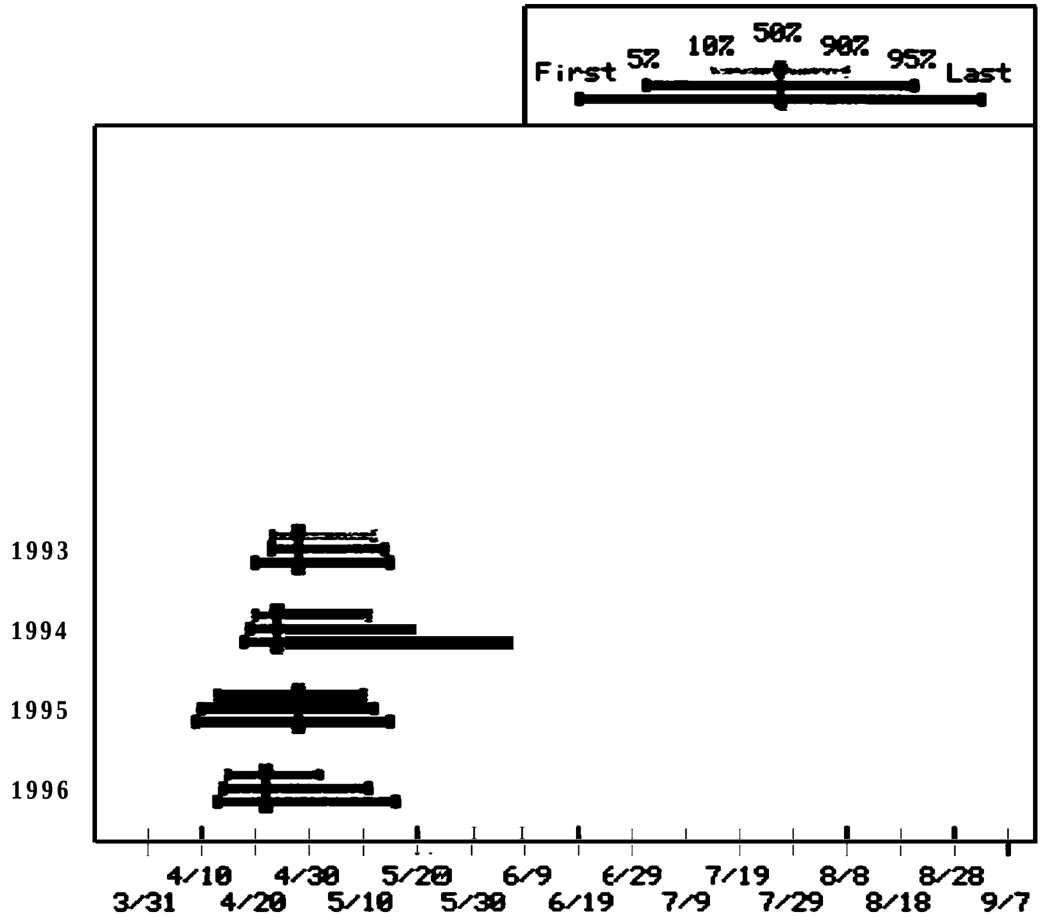

Passage Date at Lower Granite Dam,
based on PIT detections of yearling spring/summer chinook

Table **B5:** 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 | 3.8 |
| 1991 | 4/17 | 4/19 | 4/20 | 5/17 | 6/10 | 6/14 | 7/13 | 52 | 992 | 98 | 98.83% | 10.0 |
| 1992 | 4/7 | 4/10 | 4/14 | 4/29 | 5/27 | 5/28 | 7/27 | 44 | 1031 | 81 | 81 | 7.9 |
| 1993 | 4/22 | 4/26 | 4/28 | 5/16 | 5/29 | 6/17 | 7/5 | 32 | 1718 | 173 | 261.9623 | 15.2 |
| 1994 | 4/22 | 4/24 | 4/26 | 5/15 | 6/4 | 6/25 | 8/9 | 40 | 5951 | 450 | 645.1197 | 10.8 |
| 1995 | 4/13 | 4/16 | 4/24 | 5/11 | 6/10 | 6/10 | 7/13 | 48 | 1574 | 78 | 109.6849 | 7.0 |
| 1996 | 4/19 | 4/19 | 4/19 | 5/15 | 6/9 | 6/9 | 7/3 | 52 | 700 | 16 | 37.1644 | 5.3 |

(1) Parr PIT-tagged and released during the summer/fall 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: Historical Wenaha River (South Fork) outmigration distribution at Lower Granite Dam.**




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

**Table B6: 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 | 62.4796 | 11.0 |
| 1994 | 4/18 | 4/19 | 4/20 | 4/24 | 5/11 | 5/19 | 6/6 | 22 | 788 | 68 | 73.4074 | 9.3 |
| 1995 | 4/9 | 4/10 | 4/13 | 4/28 | 5/10 | 5/12 | 5/15 | 28 | 746 | 53 | 62.0842 | 8.3 |
| 1996 | 4/13 | 4/14 | 4/15 | 4/22 | 5/2 | 5/11 | 5/16 | 18 | 827 | 53 | 132.4230 | 16.0 |

(1) Parr PIT-tagged and released during the summer/fall 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.

# Appendix C

Daily expansion factors for the spillway flow at Lower Granite Dam. 1996.

**Table Cl: Daily expansion factors for spillway at Lower Granite Dam, 1996. Daily observed PIT detections at Lower Granite Dam were adjusted for spill using the equation:**

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

| Date (1996) | Expansion | Date (1996) | Expansion | Date (1996) | Expansion | Date (1996) | Expansion |
|---|---|---|---|---|---|---|---|
| 04/10 | 3.19 | 05/04 | 1.93 | 05/28 | 2.24 | 06/21 | 2.17 |
| 04/11 | 4.44 | 05/05 | 1.93 | 05/29 | 2.32 | 06/22 | 2.05 |
| 04/12 | 4.89 | 05/06 | 1.78 | 05/30 | 2.54 | 06/23 | 1.66 |
| 04/13 | 4.86 | 05/07 | 2.19 | 05/31 | 2.30 | 06/24 | 1.76 |
| 04/14 | 4.61 | 05/08 | 3.19 | 06/01 | 2.19 | 06/25 | 2.42 |
| 04/15 | 3.70 | 05/09 | 3.40 | 06/02 | 2.21 | 06/26 | 2.34 |
| 04/16 | 2.64 | 05/10 | 2.02 | 06/03 | 2.06 | 06/27 | 2.25 |
| 04/17 | 2.90 | 05/11 | 2.07 | 06/04 | 2.30 | 06/28 | 1.89 |
| 04/18 | 2.89 | 05/12 | 2.01 | 06/05 | 2.44 | 06/29 | 1.00 |
| 04/19 | 2.78 | 05/13 | 1.88 | 06/06 | 258 | 06/30 | 1.05 |
| 04/20 | 2.72 | 05/14 | 2.30 | 06/07 | 2.43 | 07/01 | 1.00 |
| 04/21 | 3.33 | 05/15 | 2.30 | 06/08 | 2.64 | 07/02 | 1.21 |
| 04/22 | 3.40 | 05/16 | 255 | 06/09 | 2.71 | 07/03 | 1.46 |
| 04/23 | 2.78 | 05/17 | 2.76 | 06/10 | 2.78 | | |
| 04/24 | 1.93 | 05/18 | 3.14 | 06/11 | 2.63 | | |
| 04/25 | 1.82 | 05/19 | 3.42 | 06/12 | 2.56 | | |
| 04/26 | 1.59 | 05/20 | 3.45 | 06/13 | 2.58 | | |
| 04/27 | 1.83 | 05/21 | 3.14 | 06/14 | 2.58 | | |
| 04/28 | 1.63 | 05/22 | 2.63 | 06/15 | 2.60 | | |
| 04/29 | 1.74 | 05/23 | 2.57 | 06/16 | 2.85 | | |
| 04/30 | 1.77 | 05/24 | 2.72 | 06/17 | 2.77 | | |
| 05/01 | 1.75 | 05/25 | 2.71 | 06/18 | 2.89 | | |
| 05/02 | 1.84 | 05/26 | 2.36 | 06/19 | 2.37 | | |
| 05/03 | 1.83 | 05/27 | 2.35 | 06/20 | 3.03 | | |