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Monitoring and Evaluation of Smolt Migration in the Columbia River Basin, Volume I

Evaluation of the 1995 Predictions of the Run-timing of Wild Migrant Subyearling Chinook in the Snake River Basin using Program RealTime

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MONITORING AND EVALUATION OF SMOLT MIGRATION IN THE COLUMBIA RIVER BASIN

VOLUME I

Evaluation of the 1995 Predictions of the Run-Timing of Wild Migrant Subyearling Chinook in the Snake River Basin Using Program RealTime

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Monitoring and Evaluation of Smolt Migration in the Columbia Basin

Other related publications, reports and papers available through the professional literature or from the Bonneville Power Administration (BPA) Public Information Center - CKPS-1, P.O. Box 3621, Portland, OR 97208.

1997

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.

1996

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1994

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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) listings in the Snake River Basin of the Columbia River Basin. 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 to help identify future research and analysis needs; (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 and other listed and nonlisted stocks in the Columbia River Basin; and (3) to design better analysis tools for evaluation programs; and (4) to provide statistical support to the Bonneville Power Administration and the Northwest fisheries community.

The following 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. In this report, the performance and feasibility of using statistical program RealTime to predict the general migration status and trend of the summer outmigration of wild subyearling chinook at Lower Granite Dam is presented. 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 monitoring and improve the information available to the fisheries community to assist in-season management of fish and river resources.

Abstract

In 1995, the University of Washington investigated the application of program "RealTime" to predict outmigration timing of Snake River wild subyearling chinook at Lower Granite Dam. The objective of the project was to predict and report in real-time the "percent run-to-date" and "date to specified percentiles" of wild subyearling chinook outmigration at Lower Granite Dam. Because only minimal PIT tagging of naturally-produced wild fall subyearling chinook occurs in the Snake River, 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. Due to the nature of the FPC Lower Granite Dam wild subyearling chinook passage index, the ability to accurately delineate only the wild subyearling fall chinook component is problematic, and the outmigration population described is generalized to wild subyearling chinook. Program RealTime was successfully altered and daily predictions on the outmigration status trends for wild subyearling chinook at Lower Granite Dam were made and provided via the Internet to the fisheries community throughout the smolt outmigration.

Due to the nature of data and the lack of historical depth, this algorithm does not predict the wild subyearling chinook as well as it has the wild spring/summer chinook, but statistical precision should increase as responses to environmental conditions are characterized better and the number of historical years usable by the program increases. Using the mean absolute deviance (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion as a measure of accuracy, the program had an estimation error of 7.6% MAD during the first half of the season. The second half of the season had an average estimation error of 3.1% MAD, and the overall seasonal performance was 5.4% MAD.

Executive Summary

1995 Objectives

1. Investigate applying RealTime to predict outmigration timing of Snake River wild subyearling chinook at Lower Granite Dam.

2. Predict and report in real-time the "percent run-to-date" and "date to specified percentiles" of wild subyearling chinook outmigration at Lower Granite Dam.

3. Make predictions on outmigration status and trends available via the Internet, for use by the fisheries community to improve in-season monitoring and evaluation information and to assist river management.

Accomplishments

Because only minimal PIT tagging of naturally-produced wild fall subyearling chinook occurs in the Snake River, 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. Due to the nature of the FPC Lower Granite Dam wild subyearling chinook passage index[1], the ability to accurately delineate only the wild subyearling fall chinook component is problematic, and the outmigration population described is generalized to wild subyearling chinook. Program RealTime was successfully altered and daily predictions on the outmigration status trends for wild subyearling chinook at Lower Granite Dam were made and provided via the Internet to the fisheries community throughout the smolt outmigration.

Findings

In 1995, Program RealTime (PIT Forecaster) used an improvement in the 1994 Least Squares (LS) algorithm (Skalski et al. 1994, Townsend et al. 1995), denoted as the New Least Squares (NLS) prediction method, which was then applied to the fish passage indices provided by the FPC. Due to the nature of data and the lack of historical depth, this algorithm does not predict the wild subyearling chinook as well as it did the wild spring/summer chinook (Townsend et al. 1996), but statistical precision should increase as responses to environmental conditions are char-

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 the ESA listed stocks.

acterized better and the number of historical years usable by the program increases. Using the mean absolute deviance[1] (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion as a measure of accuracy, the program had an estimation error of 7.6% MAD during the first half of the season. The second half of the season had an average estimation error of 3.1% MAD, and the overall seasonal performance was 5.4% MAD.

Management Implications

The ability to accurately predict the outmigration status of the wild subyearling chinook salmon stock 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 assess the risks to the overall population, so that adequate actions to protect weak, listed and endangered stocks can be taken. Providing run-timing predictions real-time in-season contributes to effective monitoring and evaluation and adaptive management and improves the information available to the fisheries community to assist in-season river management.

Recommendations

The 1995 algorithm of program RealTime (Passage Index Forecaster) used two-dimensional pattern matching of passage index and date. This approach did not perform as well as for predicting the migration timing of wild subyearling chinook as it has for the wild yearling chinook (Townsend et al. 1995, 1996). Migrational timing, duration and magnitude for Snake River subyearling chinook have been shown to be influenced by environmental conditions such as temperature and flow (Connor 1994b and 1996; OWICU 1996) but no consistent characterization describing subyearling chinook migratory responses to environmental conditions has yet been adopted. In an attempt to better characterize the influences environmental conditions have on the year-to-year variability in the outmigration timing of wild subyearling chinook, program RealTime will explore incorporating additional annual information of flow and temperature patterns into its algorithms in the future.

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.

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, 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 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. Data provided from Columbia Basin 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 tools.

Initially, the focus was on using PIT-tag detections to predict the outmigration timing of spring runs of Snake River wild yearling spring/summer chinook at Lower Granite Dam in real-time. 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. The historical information from these studies is presented in reports by the FPC (1994, 1995, 1996-in press), National Marine Fisheries Service (Accord et al. 1992, 1994, 1995a, 1995b, 1996), Idaho Department of Fish and Game (Kiefer et al. 1993, 1994), Oregon Department of Fish and Game (Walters et al. 1993, 1994a; Keefe et al. 1994b) and the Nez Perce Tribe (Ashe et al. 1995).

Program RealTime (PIT-Forecaster) was developed to take advantage of this historical data to estimate the proportion of specific wild yearling spring/summer chinook populations that had arrived at the index site and to forecast the number of days to some future percentile in a migration. 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 River 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 "percentage 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. In the 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 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 (this report). 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; OWICU 1996). 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 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, in-preparation-a,b,c; Garcia et al. in preparation; Tiffan et al. in preparation-a,b).

This report presents a post-season analysis of the accuracy of the 1995 predictions from program RealTime for the Snake River wild subyearling chinook. Observed 1995 data were compared to the predictions made by RealTime for the outmigration of wild subyearling chinook observed at Lower Granite Dam throughout the season. Graphical reports for selected days throughout the 1995 season are available on the World Wide Web at address http://www.cqs.washington.edu/rt/chin0_out.html.

Methods

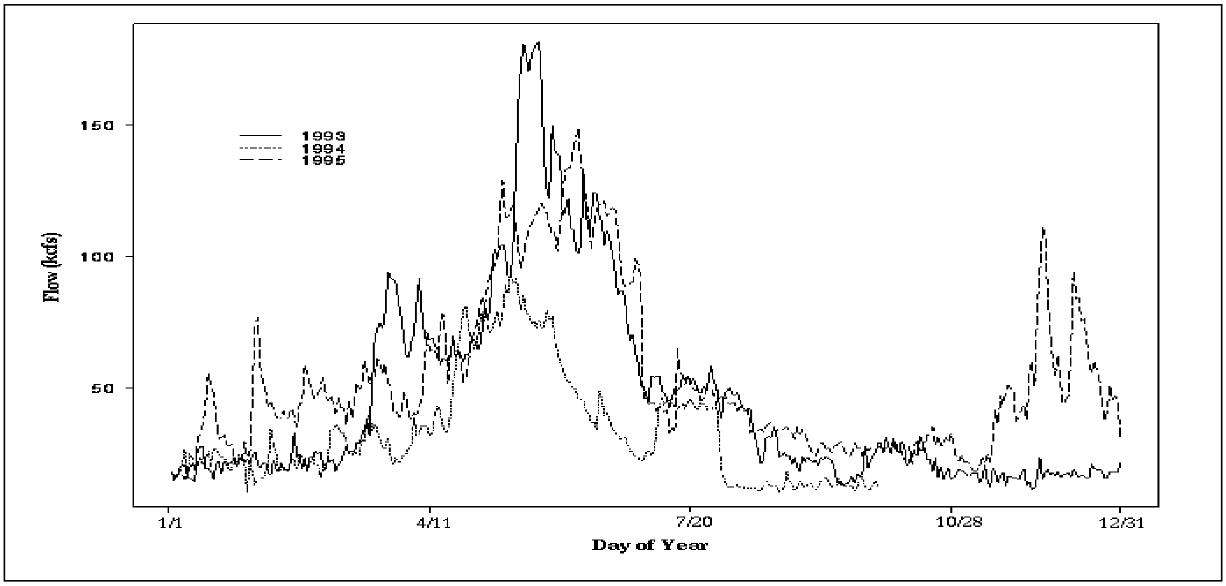
Description of Data

The outmigration of wild subyearling chinook from the passage indices at Lower Granite Dam were obtained from the Fish Passage Center to evaluate the 1995 performance of the New Least Squares (NLS) algorithm. 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. The FPC began to systematically differentiate between yearling and subyearling chinook in 1991. One caveat to this information is that at the beginning of the wild subyearling fall chinook migration in May, it is problematic to differentiate subyearling fall chinook from small wild spring/summer yearling chinook without sacrificing the fish. This becomes less of an issue towards the end of the year, but can make a large difference in the shape of the timing distribution at the beginning of the subyearling fall chinook outmigration (Connor et al. 1993).

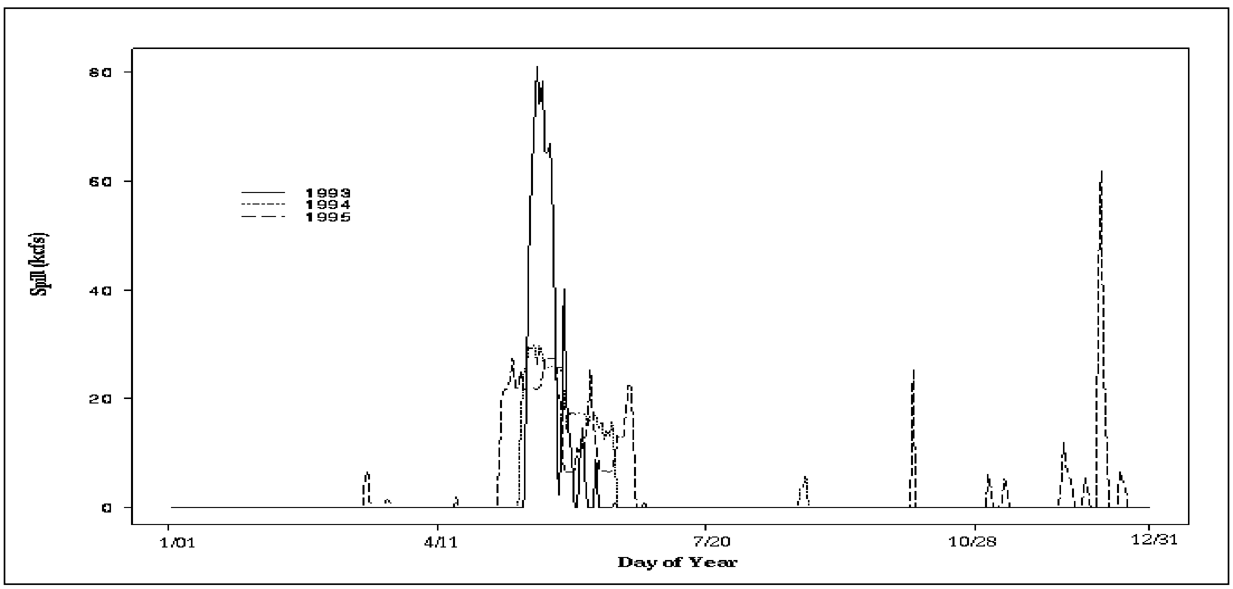
Two other sources of variance in the year-to-year outmigration are the amounts of spill and flow experienced by the fish. Flow appears to have an impact on subyearling outmigration timing, and thus may have to be taken into account in the outmigration prediction process in the future. The flows in 1993 and 1994 greatly differ from each other (Figure 1). Spill, though generally not occurring during the subyearling outmigration, did generate some additional variability in the 1995 outmigration through the spill correction of the passage index numbers.

Figure 1: The amount of (a) outflow and (b) spill at Lower Granite Dam for 1993, 1994 and 1995.

a.



b.



Prediction Models

The New Least Squares (NLS) method (Townsend, et al. 1996) is a variation of the Least Squares (LS) prediction method used for the 1994 season for the spring wild yearling chinook, incorporating release-recapture information and an improved measure of the age of the run (using the mean fish-run-age vice the raw age of the run) into its prediction algorithm.

New Least-Squares (NLS) Algorithm

For a given day in the run, the NLS algorithm computes the predicted percentage ($\hat{p}$) 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 of the RealTime program using PIT tagged smolt, 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 on the consistency of release-recapture history for the selected stream or river composite.

Least-Squares (LS) Error

The squared error for each $\hat{p}$ is summed over the historical years for which data are available. Each outmigration pattern is divided into 100 equal portions and the slopes at each corresponding point are computed. The sum of squares for a prediction compares the slopes for the current year (s_{oj}) versus the respective slopes for the historical years (s_{ij}). The total squared error for each predicted percentage of outmigration $\hat{p}$ is calculated according to the formula

$$LSE(\hat{p}) = \sum_{i=1}^{n} \sum_{j=0}^{\hat{p}} (s_{oj} - s_{ij})^2 w_{ij} \qquad (1)$$

where s_{oj} = observed slope at the jth percentile ($j = 0, ..., p$) for the current year of prediction,
s_{ij} = slope at the jth percentile ($j = 0, ..., p$) for the ith historical year ($i = 1, ..., n$), and
w_{ij} = weight for the jth 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. 1) 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 jth percentile for the present year,

D_{ij} = number of days between the (j-1) and jth 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 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 year and then assuming that proportion to be observed again in the present year. 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 1). The predicted percent of the run is calculated according to the formula

$$RR = \frac{x_d}{N} \qquad (2)$$

where

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

x_d = total observed smolt to day d, and

N = total number of smolt observed the previous year.

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 RRE($\hat{p}$) and each percentage $\hat{p}$ of the outmigration distribution:

$$RRE(\hat{p}) = \begin{cases} \dfrac{\hat{p}}{RR} & if \quad \hat{p} > RR \\ \dfrac{RR}{\hat{p}} & if \quad \hat{p} < RR \\ 1 & if \quad \hat{p} = RR \end{cases} \tag{3}$$

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

Table 1: The total passage index numbers of wild subyearling chinook salmon historically detected at Lower Granite Dam, 1993-1995.

Year	Number observed
1993	16474
1994	6812
1995[a]	26645

a. as of 12 December 1995

Age-of-Run (AR) Error

For the age-of-the-run method, 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 p_{AR} from that year.

The Age-of-Run error (ARE) associated with this prediction 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 by

$$Err(\hat{p}) = \left(1 + \frac{LSE(\hat{p})}{LSE(\hat{p}) \times MFRA + 200.0}\right) \times \left(1 + \left[\frac{100}{MFRA^2 + RR \times 16} \times RRE(\hat{p})\right]^2\right) \times \left(1 + \frac{ARE(\hat{p})}{50.0}\right) \quad (7)$$

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. 1,

MFRA = mean fish-run-age for the present run from Eq. 5,

RR = predicted proportion of observed present smolt outmigration from Eq. 2, and

$RRE(\hat{p})$ = release-recapture error for $\hat{p}$ from Eq. 3.

The MFRA in Eq. 6 also serves the purpose of shifting the 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 heuristically adjusting the equation and observing program prediction performance for 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 2 contain the mean absolute deviance (MAD) of the NLS prediction for the observed 1995 data. The MAD is calculated by the formula

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

where $\hat{p}_i$ = predicted cumulative percentage of run completed for day i,

p_i = observed cumulative percentage of run completed for day i, and

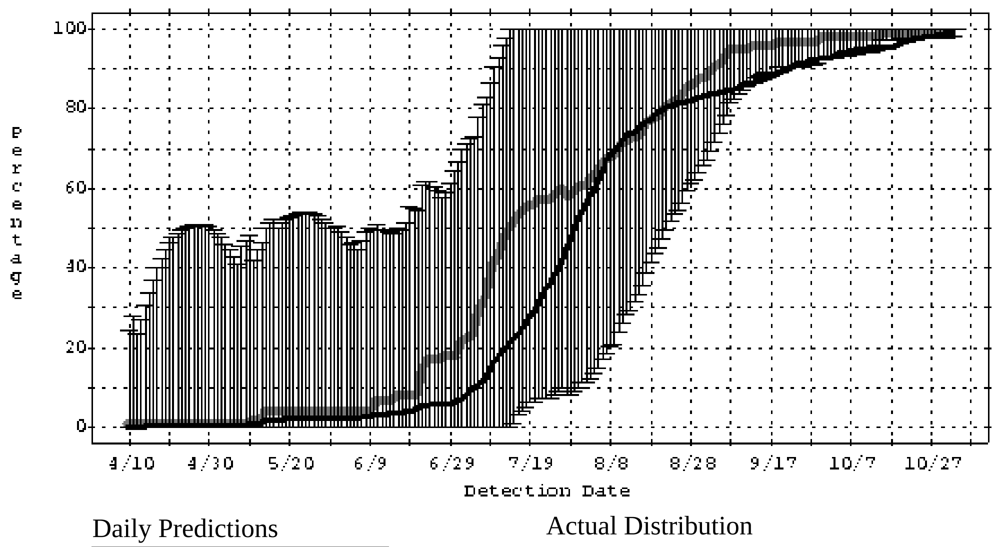
n = total number of days in run for 1994 season.

The methods are compared three ways: the MAD over the entire run, the MAD over the first half of the run (i.e. cumulative run to the 50%), and the MAD over the last half of the run.

Results

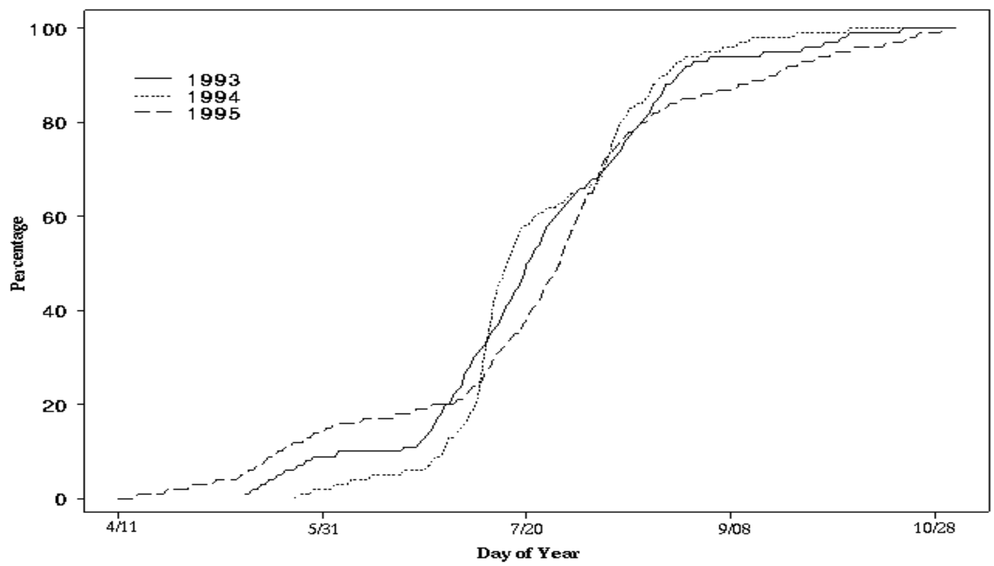
Figure 2[1] compares the day-to-day predictions and 95% confidence intervals with the observed run for the year. The day-to-day point estimates track the observed run fairly closely at the beginning of the run, and for a period of approximately 30 days three-quarters through the season, but tended to over-estimate the status of the run otherwise. This over-estimation occurs in the first half of the season and is reflected by the 7.63 MAD (Table 2). The second half of the season improves to a MAD of 3.13, and an overall season MAD of 5.42. Confidence intervals were extremely large, maintaining an almost 50-percentage point spread though most of the season. With only two historical years of data, RealTime has very little information upon which to base predictions and calculate variances for confidence intervals (Fig. 3).

Figure 2: Day-to-day predictions and the daily confidence intervals compared to the observed wild subyearling chinook salmon outmigration for 1995.



1. Graphical reports for selected days throughout the 1995 season are available on the World Wide Web at address http://www.cqs.washington.edu/rt/chin0_out.html.

Figure 3: Wild Snake River subyearling chinook salmon historical cumulative percentage passage dates for 1993, 1994 and 1995.



Timing plots of the three years of subyearling chinook outmigration show large variation from year to year in the mid-outmigration distribution (Fig. 4). Ending dates are within a couple days of each other due to FPC ceasing further monitoring for the year.

Figure 4: Timing plots of passage dates (10%, 50%, 90% and range) at Lower Granite Dam for wild Snake River subyearling chinook salmon smolt passage indices for the three years that data were available: 1993, 1994 and 1995.

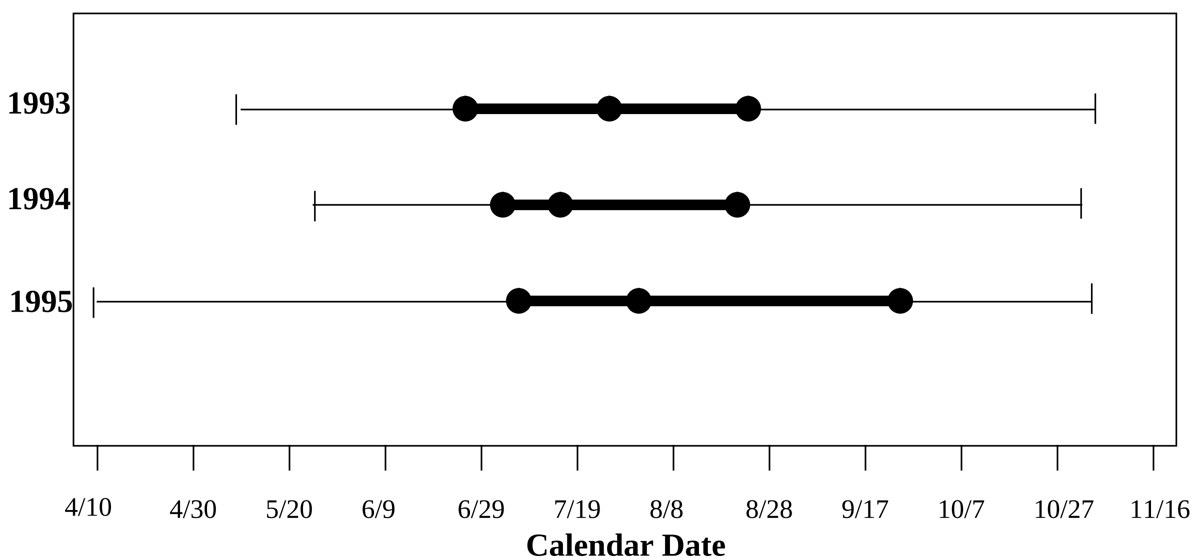


Table 2: Comparison of mean absolute deviances (MAD) for Lower Granite Dam passage indices for the 1995 wild subyearling chinook daily outmigration predictions.

period	MAD
entire 1995 season	5.42
first 50% of 1995 season	7.63
last 50% of 1995 season	3.13

Discussion

This is the first attempt of using program RealTime for estimating the migrational timing of wild Snake River wild subyearling chinook. The lack of adequate historical years and the variation observed between the annual out-migrations of the subyearling chinook combined to create large confidence interval estimates. As more years are added to the historical base and the program RealTime algorithm is further refined, these confidence intervals will decrease. The 1995 algorithm of program RealTime (Passage Index Forecaster) used two-dimensional pattern matching of passage index and date. This approach did not perform as well as for predicting the migration timing of wild subyearling chinook as it has for the wild yearling spring/summer chinook (Townsend et al. 1995, 1996). Migrational timing, duration and magnitude for Snake River wild subyearling chinook have been shown to be influenced by temperature and flow (Connor 1994b and 1996; OWICU 1996), but no consistent characterization describing subyearling chinook migratory responses to environmental conditions has yet been adopted. In an attempt to better describe the influences environmental conditions have on the year-to-year variability in the outmigrational timing of wild subyearling chinook, program RealTime will explore incorporating additional annual information of flow and temperature patterns into its algorithms in the future.

The higher than observed prediction of the 1995 daily outmigration proportion passed prior to 1 June appears to be influenced by the trickle of outmigration of subyearling chinook, when the sampling rate of the smolt monitoring program at Lower Granite Dam is low. At the low sampling rate in the early part of the season, these few passage index values tend to be heavily scaled to represent a relatively large number of fish passing through Lower Granite at the time. In addition, some of these early arrivals may be small spring/summer chinook, which cannot be visually differentiated from subyearling chinook (Connor et al. in-preparation-a, OWICU 1996). The proportion of small spring/summer chinook yearling to subyearling chinook in this mixture varies from year to year. This combination tends to give the beginning tail of the outmigration a good deal of annual variation. Another potential modification to program RealTime will be to weight passage index data prior to 1 June less.

Weighting factors in the Mean-Fish-Age were initially estimated from the spring chinook salmon historical data. New weights will be incorporated into the algorithms in 1996 and 1997 to better predict run timing as greater historical information on the outmigration subyearling chinook accumulates.

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Appendix A

Table A1: Spill-adjusted fish passage indices at Lower Granite Dam for wild subyearling chinook salmon for 1993, 1994 and 1995 (as of December 12, 1995). Data provided by the Fish Passage Center.

Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts	Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts
04/10	--	--	33	05/05	--	--	0
04/11	--	--	0	05/06	--	--	0
04/12	--	--	0	05/07	--	--	0
04/13	--	--	11	05/08	--	--	0
04/14	--	--	0	05/09	--	--	0
04/15	--	--	50	05/10	--	--	0
04/16	--	--	0	05/11	100	--	186
04/17	--	--	0	05/12	0	--	0
04/18	--	--	0	05/13	0	--	0
04/19	--	--	0	05/14	0	--	187
04/20	--	--	0	05/15	0	--	0
04/21	--	--	0	05/16	0	--	0
04/22	--	--	0	05/17	0	--	0
04/23	--	--	0	05/18	0	--	0
04/24	--	--	0	05/19	90	--	0
04/25	--	--	0	05/20	77	--	132
04/26	--	--	0	05/21	0	--	0
04/27	--	--	0	05/22	0	--	0
04/28	--	--	0	05/23	0	31	0
04/29	--	--	0	05/24	0	16	0
04/30	--	--	0	05/25	0	0	0
05/01	--	--	0	05/26	0	0	0
05/02	--	--	0	05/27	0	0	0
05/03	--	--	0	05/28	0	0	0
05/04	--	--	0	05/29	0	0	0

Table A1 (continued)

Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts	Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts
05/30	21	0	0	06/26	167	62	0
05/31	0	0	0	06/27	306	60	22
06/01	0	0	0	06/28	176	48	11
06/02	0	0	0	06/29	316	125	44
06/03	0	0	31	06/30	164	110	0
06/04	0	0	36	07/01	252	20	70
06/05	10	0	0	07/02	204	50	150
06/06	0	15	0	07/03	268	80	240
06/07	10	0	0	07/04	416	104	320
06/08	0	0	37	07/05	332	84	100
06/09	0	0	0	07/06	304	112	240
06/10	10	15	61	07/07	196	192	240
06/11	0	0	71	07/08	204	340	290
06/12	0	0	60	07/09	224	470	480
06/13	0	0	23	07/10	244	250	450
06/14	10	7	0	07/11	248	375	480
06/15	0	6	12	07/12	276	250	390
06/16	10	4	37	07/13	208	125	200
06/17	10	8	25	07/14	376	220	300
06/18	0	0	25	07/15	294	130	360
06/19	20	4	49	07/16	316	140	310
06/20	10	5	27	07/17	266	150	260
06/21	20	3	97	07/18	59	130	370
06/22	110	3	196	07/19	599	20	510
06/23	230	0	44	07/20	240	50	400
06/24	160	47	44	07/21	270	90	420
06/25	173	50	78	07/22	268	40	480

Table A1 (continued)

Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts	Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts
07/23	302	30	560	08/21	198	58	90
07/24	427	20	470	08/22	209	52	230
07/25	257	50	490	08/23	137	69	96
07/26	168	20	320	08/24	157	79	65
07/27	115	20	550	08/25	157	45	90
07/28	138	48	960	08/26	249	36	74
07/29	323	48	610	08/27	129	17	78
07/30	156	48	660	08/28	68	22	57
07/31	181	48	580	08/29	48	21	56
08/01	120	40	510	08/30	53	12	61
08/02	91	4	630	08/31	49	18	128
08/03	78	24	620	09/01	45	18	77
08/04	174	36	260	09/02	29	12	74
08/05	137	20	610	09/03	19	12	76
08/06	106	83	700	09/04	17	13	72
08/07	173	181	670	09/05	19	4	48
08/08	193	159	360	09/06	19	5	55
08/09	157	182	270	09/07	19	6	41
08/10	163	164	370	09/08	26	32	56
08/11	197	120	390	09/09	21	33	97
08/12	186	128	390	09/10	11	25	92
08/13	206	88	130	09/11	1	23	129
08/14	267	44	130	09/12	7	21	99
08/15	110	32	160	09/13	5	14	86
08/16	145	48	290	09/14	2	7	58
08/17	199	40	210	09/15	5	4	63
08/18	281	88	190	09/16	3	13	77
08/19	267	96	240	09/17	8	9	120
08/20	293	80	250	09/18	16	5	97

Table A1 (continued)

Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts	Calendar Date	1993 Observed Counts	1994 Observed Counts	1995 Observed Counts
09/19	23	3	125	10/11	12	1	37
09/20	22	6	148	10/12	17	2	39
09/21	5	2	147	10/13	21	0	18
09/22	9	0	98	10/14	5	6	94
09/23	43	1	161	10/15	6	0	62
09/24	42	9	93	10/16	3	3	71
09/25	30	2	82	10/17	17	3	53
09/26	56	14	83	10/18	7	2	52
09/27	22	11	85	10/19	8	0	86
09/28	36	6	87	10/20	14	1	111
09/29	47	5	65	10/21	3	2	84
09/30	45	6	65	10/22	13	1	110
10/01	12	5	--	10/23	2	1	79
10/02	65	0	--	10/24	9	2	72
10/03	43	2	53	10/25	12	3	42
10/04	44	0	59	10/26	6	2	45
10/05	74	3	64	10/27	7	1	47
10/06	50	0	66	10/28	4	6	34
10/07	27	1	43	10/29	6	15	52
10/08	27	0	18	10/30	5	4	35
10/09	15	2	29	10/31	4	13	16
10/10	27	1	46	11/01	8	--	78