JUVENILE SALMONID PIT-TAG STUDIES AT PROSSER DAM AND THE CHANDLER CANAL FISH COLLECTION FACILITY, YAKIMA RIVER, 1991 AND 1992

by

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and

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EXECUTIVE SUMMARY

In 1991 and 1992, the National Marine Fisheries Service completed the second and third years of a 3-year study to estimate juvenile salmonid (*Oncorhynchus spp.*) timing and survival characteristics related to passage through the Prosser Dam complex, including the Chandler Canal and the Chandler fish collection facility, on the Yakima River. Yearling chinook (*O. tshawytscha*) and coho salmon (*O. kisutch*) were collected at the Chandler facility, PIT tagged, and released at various locations in the Yakima River, Chandler Canal, and the Chandler facility. Individual fish were subsequently detected at PIT-tag detection monitors at the Chandler facility and/or McNary Dam on the Columbia River. Survival through various reaches, PIT-tag detection efficiency, and Chandler Canal fish entrainment proportion parameters were estimated using maximum likelihood techniques.

The research objectives in 1991 and 1992 were to: 1) assess the effects of passage through the Chandler Canal and the Chandler facility on the survival of juvenile salmonids, 2) determine the entrainment rate of juvenile salmonids into the Chandler Canal as a function of river flow, and 3) determine the efficiency and reliability of the PIT-tag monitoring system at the Chandler facility. The initial 1990 research plan was expanded in 1991 and 1992 to include several more release locations and many more release days.

A total of 26,267 yearling chinook and 8,359 coho salmon in groups of approximately 200 fish in 1991 and 125 fish in 1992 were PIT tagged and released at each release location. Releases were made over 35 days in 1991 and 11 days in 1992. Mortality related to the tagging and holding process for both years was approximately 1%. Data from three of the release dates were

not used in the analyses due to apparent malfunctions of the main PIT-tag detector in the Chandler facility.

In general, the assumptions of the statistical methodology were not violated. However, data from one of the release days was not used in the maximum likelihood analysis due to violation of one of the assumptions.

The measured mortality in the Chandler Canal and facility was 7-16% for yearling chinook and 11% for coho salmon. This mortality increased to 63% after mid-May 1992, when canal water temperatures exceeded 15°C (59°F) and water flow was less than 30.0 cms (1060 cfs).

Prediction curves relating the proportions of water (Fl) and fish (Fi) entrained into the Chandler Canal were calculated as $Fi = 1.368 - 0.234/Fl$ and $Fi = 0.828 + 0.213 \times Fl$ for yearling chinook and coho salmon, respectively. Entrainment estimates into the Chandler Canal under various flows based on these curves will have fairly low precision, will be valid only for flows observed in these studies, and will require adjustment for expected Chandler Canal survival.

Fish entrainment proportion and survival estimates for Chandler Canal were also generated using information from Chandler facility detections of fish released in the Prosser Dam forebay and at the headworks of the Chandler Canal. These estimates were quite similar to the statistically optimum maximum likelihood estimates and the methods used to calculate them can be used for future studies. However, 100% survival in the Prosser Dam forebay must be assumed and the Chandler facility PIT-tag detection efficiency must be estimated.

The detection efficiency of the Chandler facility main PIT-tag detector was estimated as consistently exceeding 95%, although at least three down-time occasions lasting several hours were observed.

Most of the PIT-tagged fish released above the Chandler facility were detected within a few hours. Median travel time to McNary Dam decreased over time, from as long as 17 days to as short as 6 days for yearling chinook salmon and from 5 days to 3 days for coho salmon.

If precise survival estimates in the Yakima River system are required, additional studies are needed to improve precision and accuracy of the estimated fish/flow entrainment relationship and determine more accurately mortalities related to passage through the Chandler Canal and facility. Also, high efficiency of the Chandler facility PIT-tag detection system should be maintained and detector malfunctions or down-time should be fully documented.

INTRODUCTION

Juvenile salmonid survival studies planned for the Yakima Basin will require the release and recapture of large numbers of marked fish. Before these studies can be implemented, information is needed about potential recovery and survival rates of marked fish at proposed sampling sites. The type of mark employed and the efficiency of equipment used to detect or capture and examine fish must be evaluated, since accurate and precise survival estimates depend on their reliability. Recovery and survival rates are expected to vary with species and life stage as well as environmental factors such as river flow and water temperature.

The Chandler Canal originates downstream from Prosser Dam at river kilometer 76 on the Yakima River (Figs. 1 and 2). This canal delivers water for power production (approximately 28.3 m^3/second (1000 cfs)) and irrigation (approximately 11.3 m^3/second (400 cfs)). A trash removal and fish diversion screen facility is located 1.6 km downstream from the canal headworks. A bypass pipe diverts fish through the Chandler Canal juvenile fish collection facility (Chandler facility) and back into the Yakima River (Fig. 2).

In 1990, the National Marine Fisheries Service (NMFS) began a 3-year study to assess the mark-recovery capabilities of the Chandler facility and to estimate juvenile salmonid timing and survival characteristics related to passage through the Chandler Canal and facility. Results of the 1990 study were reported by Ruehle and McCutcheon (1994). The primary objectives of the 1991 and 1992 studies were:

1) To assess the effects of the Chandler Canal and the Chandler facility passage on the survival of juvenile salmonids;

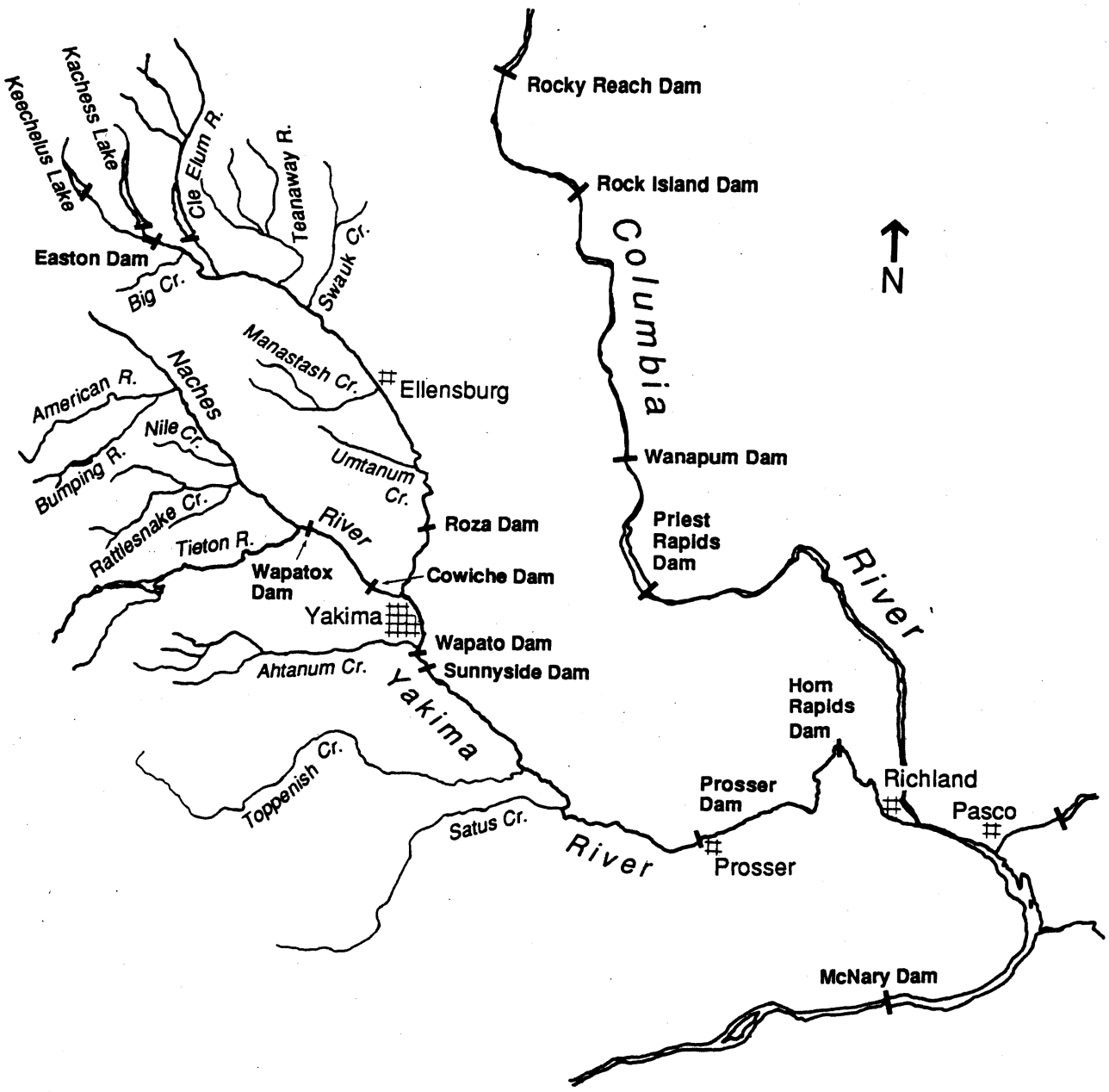

Figure 1. Map of the Yakima River and the adjacent Columbia River showing locations of major water diversion and hydroelectric dams.

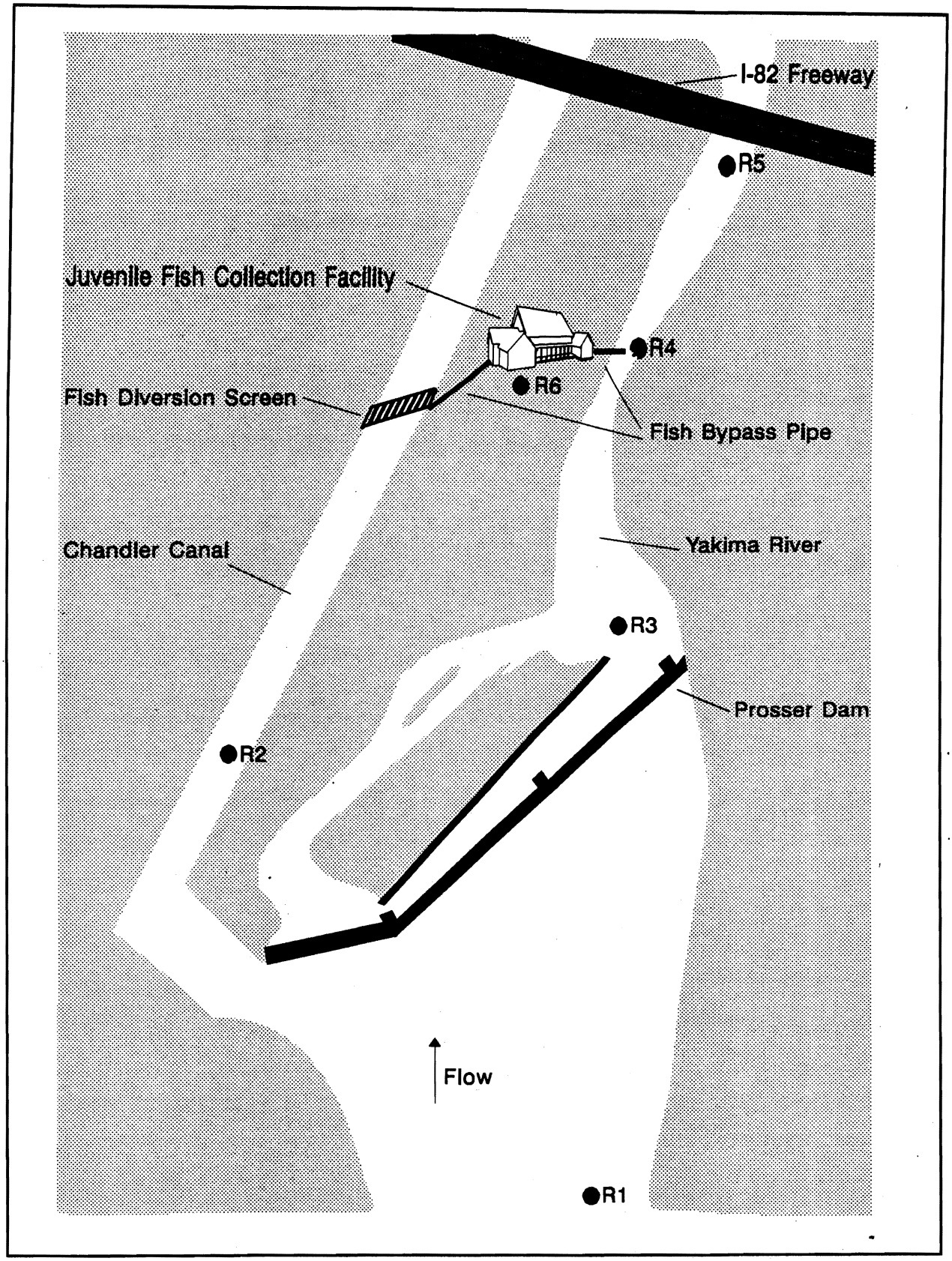

Figure 2. Yakima River near Prosser, WA showing Chandler Canal, juvenile fish collection facility, and release locations (●R) of PIT-tagged juvenile salmon.

2) To determine the entrainment rate of juvenile salmonids into the Chandler Canal as a function of river flow; and

3) To determine the efficiency and reliability of the PIT-tag monitoring system at the Chandler facility;

METHODS

Experimental Design

Yearling chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) were acquired from the sampling system in the Chandler facility. The fish were PIT tagged using procedures and equipment similar to those described by Prentice et al. (1990). Fish were rejected prior to tagging if they were diseased, injured, descaled, or previously marked. After tagging, fish were allowed to recover in portable containers supplied with aerated water from the Chandler Canal. Individual release groups were held in separate containers. PIT-tagged fish were held for a minimum of 24 hours for recovery and to evaluate delayed mortality. Equal numbers of fish were tagged for all releases on the same day, with generally 200 and 125 fish per release location in 1991 and 1992, respectively.

PIT-tagged fish were released in the evening as simultaneously as possible at all release locations. The release locations were as follows (see Fig. 2):

R1 = Approximately one km upstream from Prosser Dam.

R2 = The headworks of the Chandler Canal.

R3 = Immediately below Prosser Dam.

R4 = At the Chandler facility outfall.

R5 = At the I-82 bridge.

R6 = Immediately after the main PIT-tag detector in the Chandler facility.

PIT-tagged fish were subsequently detected at the main and sample PIT-tag detectors at the Chandler facility (R1 and R2) and/or the main and sample detectors at McNary Dam (all releases). Tagged fish included in the sample at the Chandler facility were held until the following morning, examined, and released into the outfall pipe.

Data Analysis

Database Procedures

Completed tag and release files were electronically transferred (uploaded) to the PIT-tag Information System (PTAGIS) database maintained by the Pacific States Marine Fisheries Commission (PSMFC). Uploaded files contained tagging session and release details (dates, locations, etc.) and information for each tagged fish (PIT-tag code, species, length, miscellaneous comments, etc.). PIT-tag detections were collected automatically by the PIT-tag detectors at the Chandler facility and McNary Dam, and information such as PIT-tag code and observation date and site for each detected fish was uploaded to an observation file.

The initial data analysis step was to retrieve data from the PTAGIS tagging and observation files. For each year, tagging and observation reports were generated in the comma-separated variable (CSV) format and contained the combined information from all releases. The tagging report contained one record of tagging and release information per PIT-tagged fish, while the observation report contained multiple records per PIT-tagged fish: one for every detection time and location.

Quality Control

The reports described above were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated or information corrected where appropriate. A record of all eliminations or changes was kept. Records were eliminated for the following reasons:

1) PIT-tagged fish was detected before release.

2) Detected PIT-tagged fish was previously classified as a mortality.

3) PIT-tagged fish was detected at McNary Dam before detection at the Chandler facility.

4) PIT-tagged fish was detected at the Chandler facility from release groups R3-R6.

Mortalities that occurred between tagging and release were recorded, and a mortality file was uploaded to PTAGIS. A CSV mortality report was generated, and subsequently mortalities were eliminated from the tagging report.

Due to the quality control process, all data used in statistical analyses were from PIT-tagged fish known to be released alive at the intended release location and date and whose detection records were consistent and logical as to downstream passage.

Multinomial Likelihood Estimation

The following parameters were estimated using maximum likelihood estimation procedures (Burnham et al. 1987, Mood et al. 1974):

S1 = Survival probability from one km above Prosser Dam to its tailrace or the beginning of Chandler Canal.

S2 = Survival probability from the beginning of Chandler Canal to the main PIT-tag detector in the Chandler facility.

S3 = Survival probability from the Prosser Dam tailrace to the Chandler facility outfall.

SA = Survival probability from just below the sample diversion gate in the Chandler facility to the outfall.

S4 = Survival probability from the Chandler facility outfall to the I-82 bridge (estimated only in 1992).

SM1 = Combined probability of survival from the Chandler facility outfall to, and recapture at, McNary Dam (estimated in 1991).

SM2 = Combined probability of survival from the I-82 bridge to, and recapture at, McNary Dam (estimated in 1992).

D = Diversion probability into Chandler Canal.

P = Detection probability in the Chandler facility (i.e., detection by the main or sample PIT-tag detectors).

The data were summarized in detection histories[1] as defined in Table 1. The detection histories were assumed multinomially distributed for each release group. The likelihood function was the probability of the observed data viewed as a function of the parameters (Burnham et al. 1987). Therefore, a multinomial likelihood function was used for each release group and the likelihood model for the study was written as a product of I independent likelihoods, where I was the number of release groups (I = 4 for 1991 and 5 or 6 for 1992).

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[1]Detection histories were denoted as capture histories in the historical mark-recapture literature. However, PIT-tagged fish were not "captured" as much as their passage through a location was "detected".

Table 1. Potential detection histories for PIT-tagged yearling chinook and coho salmon released in 1991 or 1992. Abbreviations: CHF-Chandler facility; MCN-McNary Dam; R1-approximately one km upstream from Prosser Dam; R2-the headworks of the Chandler Canal; R3-immediately below Prosser Dam, R4-the CHF outfall; R5-the I-82 bridge; R6-immediately below the main PIT-tag detector in the CHF.

Detection History	Explanation
1 1 1	Released at R1, detected at the CHF, detected at MCN.
1 1 0	Released at R1, detected at the CHF, not detected at MCN.
1 0 1	Released at R1, not detected at the CHF, detected at MCN.
1 0 0	Released at R1, not detected at the CHF, not detected at MCN.
2 1 1	Released at R2, detected at the CHF, detected at MCN.
2 1 0	Released at R2, detected at the CHF, not detected at MCN.
2 0 1	Released at R2, not detected at the CHF, detected at MCN.
2 0 0	Released at R2, not detected at the CHF, not detected at MCN.
3 1	Released at R3, detected at MCN.
3 0	Released at R3, not detected at MCN.
4 1	Released at R4, detected at MCN.
4 0	Released at R4, not detected at MCN.
5 1	Released at R5, detected at MCN.
5 0	Released at R5, not detected at MCN.
6 1	Released at R6, detected at MCN.
6 0	Released at R6, not detected at MCN.

The goal of the estimation procedure was to find the parameter values that maximized the likelihood function; that is, the values which gave the greatest likelihood of giving rise to the observed data (Kendall and Stuart 1977, Hogg and Craig 1978). This was done for the likelihood function in this study using an iterative Newton-Raphson procedure (Seber 1982). The procedure required reasonable initial estimates, which were obtained using method-of-moment (MOM) estimators derived as shown in Appendix 1 (Mood et al 1974). Maximum likelihood estimates (MLEs) were the parameter solutions of the iterative procedure. The last step in the iterative procedure also provided estimates of the asymptotic standard errors of the MLEs based on the assumed multinomial sampling variability (Seber 1982).

Several different likelihood models were used to obtain MLEs for the various situations in this study. Separate models were used for 1991 and 1992 study years, and one or two additional releases (R5 or R5 and R6) were made in 1992: this allowed estimation of the parameters S4 and SM2 rather than just SM1 as in 1991. Also, in cases where the best initial MOM estimate for P and/or D was 100% (i.e., 1.0), P and/or D were fixed at 100% in the likelihood models (due to mathematical constraints), and the remaining parameters were estimated.

Maximum likelihood estimation was preferred over method-of-moment estimation. MLEs are theoretically statistically superior to MOMs because they have asymptotic properties including normality, unbiasedness, and minimum variance (Kendall and Stuart 1977).

Tests of assumptions--For the multinomial likelihood analyses, there were two critical assumptions:

A1) All PIT-tagged fish in a release group had homogeneous and independent survival probabilities through downstream reaches and detection probabilities at the Chandler facility and/or McNary Dam.

A2) All PIT-tagged fish in all groups released on the same day had homogeneous and independent survival probabilities below the Chandler facility outfall in 1991 and below the I-82 bridge in 1992. These groups also had homogeneous and independent detection probabilities at McNary Dam.

Assumptions of independence could not be tested with the experimental design and data in this study. Also, in general, homogeneity of survival and detection probabilities within a release group could not be tested but to assume homogeneity seemed reasonable since the fish were released at exactly the same time and location.

Fish released in the Prosser Dam forebay and subsequently diverted into the Chandler Canal could experience differential survival downstream from the Chandler facility outfall and differential detection at McNary Dam than those not diverted, if the two groups did not remix below the outfall. This would violate Assumption A1. The validity of Assumption A1, based on downstream remixing of diverted and undiverted R1 fish, was tested using the Pearson chi-square test of homogeneity for McNary Dam passage distributions (Sokal and Rohlf 1981). This test was based on the following K×2 contingency table:

		Diverted into Chandler Canal and detected at the Chandler facility	
		Yes	No
Day of McNary Dam passage	1		
	2		
	⋮	⋮	⋮
	K		

Table entries were the totals of PIT-tagged fish from each subgroup passing McNary Dam on each of K days (K varied considerably between release days over time and years). P-values were determined using a Monte Carlo estimate of a nonparametric exact approach (Mehta and Patel 1992).

Fish that passed through the Chandler facility and were included in the daily facility sample could experience differential survival downstream and differential detection at McNary Dam than those not sampled. This would occur if their survival or behavior was affected by the sampling process or if they did not remix below the outfall. This would also violate Assumption A1. The validity of Assumption A1, based on mixing of sampled and unsampled R1 and R2 fish, was tested using the Pearson chi-square test of homogeneity for McNary Dam passage distributions. The test was based on this K×2 contingency table:

		Included in the Chandler facility sample	
		Yes	No
Day of McNary Dam passage	1		
	2		
	⋮	⋮	⋮
	K		

The effect of the sampling process on downstream survival and detection was only tested if the chi-square test was not significant, since a lack of mixing would imply potential differences due to other factors. The test was to compare the proportion of sampled and unsampled fish (all originally detected by the Chandler facility main PIT-tag detector) detected at McNary Dam. The validity of Assumption A1, based on the effect of the Chandler facility sampling process, was tested using a t-test on the ratio of sampled to unsampled McNary Dam detection proportions.

The validity of Assumption A2, based on downstream mixing of all groups released on the same day, was tested using the Pearson chi-square test of homogeneity for McNary Dam passage distributions. This test was based on the following K×I contingency table where I = 4 or 1991 and 5 or 6 for 1992:

		Release Group		
		R1	...	RI
Day of McNary Dam passage	1		...	
	2		...	
	⋮	⋮	...	⋮
	K		...	

Comparison-wise Error Rate--Each set of chi-square contingency table tests was considered a separate and independent experiment, with each test within the set considered a separate and independent comparison. Significance levels for individual tests were selected to control the comparison-wise Type I error rate, α, rather than the experiment-wise Type I error rate. However, when enough multiple tests were done within an experiment with the same null hypothesis, one or more tests were expected to be significant for the comparison-wise α by chance alone. Therefore, if the number of significant tests per experiment was similar to the number expected by chance, the tested assumption was deemed valid for those comparisons and for the experiment. The comparison-wise significance level was set at $\alpha = 0.05$ for this study.

Expanded Detection Proportion Estimation

As previously stated, the maximum likelihood approach to parameter estimation was considered optimum in this study, given the various release locations and PIT-tag detections at both the Chandler facility and McNary Dam. However, limited parameter estimation was possible when survival to or detection at McNary Dam was extremely low. When the PIT-tag detection efficiency of the Chandler facility (P), or of just the main PIT-tag detector, was known or could be estimated, S2 could also be estimated. The expanded detection proportion (EDP) S2 estimate was the proportion of R2 fish detected by the main and sample detectors (or just the main detector) divided by P (or the main detector efficiency). The EDP and MLE estimates of S2 were compared by examining the ratio, MLE/EDP.

Relative Recapture Estimation

When the PIT-tag detection efficiency of the Chandler facility (P) or of just the main PIT-tag detector was unknown or unestimated, but was assumed to be equal between release groups,

D could be estimated by the relative recapture (RR) method. The RR estimate of D was the proportion of detected R1 fish divided by the proportion of detected R2 fish. However, this estimate was only valid under the assumption that Prosser Dam forebay survival was 100%. The RR and MLE estimates of D were compared by examining the ratio, MLE/RR.

Chandler Facility Main PIT-tag Detector Efficiency

The maximum likelihood procedure described above was used to estimate overall PIT-tag detection efficiency of the Chandler facility. However, the efficiency of the main PIT-tag detector was estimated independent of the likelihood analyses. This estimate was the proportion of PIT tags detected on the sample PIT-tag detector that had been previously detected on the main detector. This estimate was a lower bound on the Chandler facility PIT-tag detection efficiency and was probably fairly close to the actual facility efficiency since the sample detector only had the potential of detecting the sampled fraction of all PIT-tagged fish.

Survival Relationship with Water Temperature and Flow

The relationship between fish survival and prevailing biological and environmental conditions was examined by comparing estimated survival in various reaches to the release date and average daily water temperature and flow. Water flow and temperature were taken from the Bureau of Reclamation HYDROMET system at locations PRO (Prosser Dam Reservoir), YRPW (Yakima River below Prosser Dam), and CHCW (Chandler Power Canal) and were averaged over the day of release. Visual inspection of the appropriate scatterplots and/or regression analyses were used for the comparisons.

Chandler Canal Flow Diversion versus Fish Entrainment

The functional relationship between the proportion of river flow diverted into the Chandler Canal on the day of release and the MLE of the proportion of fish entrained into the canal (D) was examined by visual inspection of the scatterplot and by regression analyses. The exact regression equations were chosen using three criteria:

1) The equations explained a significant amount of the variability in fish entrainment estimates (i.e., strong correlations which were significantly larger than zero).

2) The equations fit well statistically (i.e., they met assumptions that the regression residuals were randomly scattered around zero and reasonably normally distributed).

3) The equations were fairly mathematically straightforward and biologically logical and understandable.

Additionally, 95% prediction intervals were calculated for the regression equations to quantify the uncertainty in individual entrainment predictions (Weisberg 1985).

Travel Time

Minimum and median travel time in hours from release to detection at the Chandler facility main PIT-tag detector was calculated for each R1 and R2 release group. Travel time differences were compared between R1 and R2 on each release day. The travel time statistics were examined to characterize the short-term migrational characteristics of the PIT-tagged fish released over time and between fish released in the Prosser Dam forebay and Chandler Canal at the same time.

Median travel time in days from release to detection at McNary Dam was calculated for all release groups. Maximum differences between median travel times were calculated for groups released on the same day and McNary Dam passage distributions were plotted for the release

groups on each release day. The passage distributions and median travel times were examined to characterize differences in migrational distributions of PIT-tagged fish between release groups and over time.

RESULTS AND DISCUSSION

Test Conditions

Fish for treatment groups were PIT tagged and released 13 April to 23 May 1991 and 3 April to 4 June 1992 (Tables 2 and 3). A total of 26,267 yearling chinook and 8,359 coho salmon were tagged on 35 and 11 dates, respectively[2]. Tagged group sizes varied between days but were generally around 200 in 1991 and 125 in 1992. Release groups R1-R4 were included on all release days in both years, while R5 was on all 1992 release days and R6 was only on 6 days each in 1992 for yearling chinook and coho salmon.

Quality Control

Records of 24-hour delayed mortality were not generally kept in 1991. Only three mortalities were noted on the PTAGIS database: one was in release group R1 on 2 May, and the other two were in release group R3 on 17 and 23 April. Overall delayed mortality in 1992 was low at 1.1% (204/18,328) with nearly half of the mortalities occurring in the last three June releases (Table 4). These three release days were not included in maximum likelihood survival and entrainment estimates. Mortality of the remaining test groups was only 0.7% (111/16,078).

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[2]PIT-tag tagging files were named TERxxyyy.ijk, where, xx was the study year; yyy was the Julian tagging date; i was the release location (e.g., for R1, i = 1; note that in 1991 i = 3 for R2 and i = 2 for R3); j was a letter indexing the release days (e.g., for release 1, j = A); and k was A or C for yearling chinook and coho salmon, respectively.

Table 2. Numbers of yearling chinook and coho salmon PIT tagged at the Chandler facility and released at various locations in 1991. Abbreviations: R1-approximately one km upstream from Prosser Dam; R2-the headworks of the Chandler Canal; R3-immediately below Prosser Dam; R4-the Chandler facility outfall.

Release	Release Location			
Date	R1	R2	R3	R4
Yearling chinook salmon				
14 April	150	150	149	150
15 April	200	200	200	200
16 April	200	200	200	200
17 April	200	200	200	200
22 April	200	200	200	200
23 April	200	200	199	200
24 April	200	200	200	201
25 April	225	225	225	225
26 April	225	225	225	225
1 May	225	224	225	225
2 May	225	225	225	225
3 May	200	200	200	200
4 May	250	250	250	250
5 May	200	200	200	200
7 May	200	200	200	200
Total	3100	3099	3098	3101
Coho salmon				
16 May	175	176	175	175
17 May	200	200	200	200
18 May	200	200	200	200
21 May	200	200	200	200
23 May	200	200	199	200
Total	975	976	974	975
Grand Total	4075	4075	4072	4076

Table 3. Numbers of yearling chinook and coho salmon PIT tagged at the Chandler facility and released at various locations in 1992. Abbreviations: R1-approximately one km upstream from Prosser Dam; R2-the headworks of the Chandler Canal; R3-immediately below Prosser Dam; R4-the Chandler facility outfall; R5-the I-82 bridge; R6-immediately below the main PIT-tag detector in the Chandler facility.

Release	Release Location					
Date	R1	R2	R3	R4	R5	R6
Yearling chinook salmon						
3 April	125	125	125	125	125	
4 April	175	175	175	175	175	
5 April	150	154	149	150	150	
6 April	150	150	150	150	150	
7 April	150	150	150	150	150	
14 April	125	125	125	125	125	
16 April	125	125	125	125	125	
18 April	125	125	125	125	125	
20 April	125	125	125	125	125	125
21 April	125	125	125	125	125	125
22 April	125	125	125	125	125	125
12 May	125	125	124	124	125	
13 May	123	125	124	125	124	
21 May	125	125	125	125	125	
22 May	125	125	125	125	125	
23 May	125	124	125	124	124	
27 May	125	125	125	125	125	
2 June	125	125	125	125	125	125
3 June	125	125	125	125	125	125
4 June	125	125	125	125	125	125
Total	2623	2628	2622	2623	2623	750
Coho salmon						
28 April	125	125	125	125	125	125
29 April	125	125	125	125	125	125
30 April	125	125	125	125	125	84
5 May	125	125	125	125	125	125
6 May	125	125	125	125	125	125
7 May	125	125	125	125	125	125
Total	750	750	750	750	750	709
Grand Total	3373	3378	3372	3373	3373	1459

Table 4. Numbers of 24-hour delayed mortalities for the various release groups of yearling chinook and coho salmon PIT tagged at the Chandler facility in 1992. Abbreviations: R1-approximately one km upstream from Prosser Dam; R2-the headworks of the Chandler Canal; R3-immediately below Prosser Dam; R4-the Chandler facility outfall; R5-the I-82 bridge; R6-immediately below the main PIT-tag detector in the Chandler facility.

Release	Release Location					
Date	R1	R2	R3	R4	R5	R6
3 April	1					
4 April		2				
5 April			1			
6 April						
7 April						
14 April	1				1	
16 April	2	1	3	3	1	
18 April			1			
20 April		1	6			
21 April		1				
22 April	7		3			
28 April	1				1	
29 April		6	2		1	1
30 April						
5 May						
6 May						
7 May						
12 May	3	4	14	4	6	
13 May	1	1			4	
21 May			3		7	
22 May	1	3	1		6	
23 May	1	3	1	1		
27 May						
Total	18	22	35	8	27	1
2 June	2	2	1	3	10	3
3 June	4	1	5	3	2	6
4 June	13	6	13	10	7	2
Total	19	9	19	16	19	11
Grand Total	37	31	54	24	46	12

We assumed that the unreported 24-hour delayed mortality in 1991 was similar to that observed in 1992, and that it was random with respect to release group. The resultant unknown bias of 1991 parameter estimates was considered trivial and would have only affected recapture probabilities and precision estimates.

There were very few PIT-tag observation anomalies for both years. Only 12 fish in release groups R3-R6 were erroneously detected at the Chandler facility, and no fish were detected at McNary Dam before having been detected at the Chandler facility. Two fish classified as mortalities were detected at the Chandler facility, and three fish were observed before release; PIT-tag records for theses fish were deleted from the observation files.

Careful examination of the data and the statistics generated in survival and travel-time analyses indicated that the main PIT-tag detector at the Chandler facility malfunctioned or was inoperative during important passage periods on 7 May 1991, 7 April 1992, and 12 May 1992. This led to a potentially serious bias in statistical estimates (see Appendix 2). Therefore, data and statistics from these days are not presented further in this report, except for travel-time analyses to McNary Dam. Similar detector or Chandler facility problems may have existed on other dates as well but could not be adequately documented.

Very few PIT-tagged fish from the three June 1992 releases were detected at McNary Dam (Appendix Table 3j). Parameter estimates for these releases from the maximum likelihood procedure were unattainable. Sufficient fish were detected at the Chandler facility for PIT-tag detector efficiency estimation using sample detections as well as Chandler Canal survival estimates based on expanded R2 detections at the facility. Relative recapture estimates of the proportion of fish entrained into the Chandler Canal were also possible. However, the RR

method required 100% survival in the Prosser Dam forebay. While this occurred on average for all other releases in which MLE Prosser Dam forebay survival estimates were calculated, mean daily water temperature and flow in the forebay for these June 1992 releases were outside the ranges observed for all other releases. Therefore, inference of 100% Prosser Dam forebay survival for these late releases was not statistically prudent, and entrainment estimates were not made. Data from these releases were also not used in McNary Dam travel-time analyses.

The release date for the 1 May 1991 R1-R3 releases was incorrectly reported to PTAGIS as 30 April 1991. Release times for the 20 April R1 and R2 releases and the 21 May R1 release in 1992 appeared to be reported as 3 and 1 hours too early, respectively, based on examination of travel-time data to the Chandler facility main PIT-tag detector. Release dates and times were not reported for the 13 May 1992 R3 release and the 30 April 1992 R5 and R6 releases. The release times used in travel time analyses were estimated from the other release groups on the appropriate day.

Tests of Assumptions

Assumption A1

None of the chi-square tests to assess mixing downstream from the Chandler facility outfall for detected and undetected fish from R1 releases were significant at the 0.05 comparison-wise error rate (Table 5 and Appendix Tables 1a-1e). Due to very small or zero sample sizes for R1 fish not detected at the Chandler facility, no chi-square tests were done for groups released in May 1991 or during all of 1992. The tests that were done, therefore, were quite limited as an overall assessment of the validity of Assumption A1, particularly for coho salmon, which had no valid tests. However, for most of the groups not tested, a very high proportion of tagged fish

Table 5. Tests of homogeneity of McNary Dam passage distributions for yearling chinook salmon released one km above Prosser Dam and detected or not detected at the Chandler facility. P-values calculated using Monte Carlo approximation of the exact method. No tests conducted in May 1991 or all of 1992 due to small sample sizes of undetected fish.

Release Date (1991)	χ^2	Degrees of Freedom	P-value
14 April	15.11	16	0.5925
15 April	16.78	21	0.8317
16 April	20.36	20	0.4555
17 April	20.82	19	0.3505
22 April	13.89	16	0.6532
23 April	16.43	17	0.5325
24 April	12.55	16	0.7783
25 April	20.29	17	0.2325
26 April	22.09	15	0.0897

were estimated to be entrained into the Chandler Canal. Thus, discussion of the validity of this assumption based on these R1 mixing tests is moot.

For yearling chinook salmon in 1991 and 1992, only 1 of 28 chi-square tests of mixing downstream from the Chandler facility outfall for R1 and R2 fish, sampled and unsampled at the facility, was significant at the $\alpha = 0.05$ comparison-wise error rate (Tables 6 and 7 and Appendix Tables 2a-2c and 2e). (Note that tests were not done for releases after 21 May 1992 due to very small sample sizes.) Since about 1 ($28 \times 0.05 = 1.4$) of the 28 tests would be expected to be significant by chance, the 3 April 1992 result was not considered indicative of a failure of Assumption A1.

All of the 1991 and two of the six 1992 coho salmon chi-square tests were highly significant (Tables 6 and 7 and Appendix Tables 2b and 2d). The significant results appeared to be due to a 1-day shift in the McNary Dam passage distributions, which were quite compact. Survival and detection probabilities probably did not vary significantly over such short time periods. Therefore, Assumption A1 was most likely not substantially violated.

The relative proportion of Chandler facility sampled to unsampled R1 and R2 fish detected at McNary Dam was significantly lower than 1.00 for yearling chinook salmon in 1991 at 0.92 (SE = 0.02) ($t = 3.38$, $df = 12$, $P = 0.0055$; Table 8). This implied an 8% higher mortality for sampled fish in 1991. This proportion in early April 1992 was not significantly different from 1.00 at 1.08 (SE = 0.09) ($t = 0.84$, $df = 3$, $P = 0.4608$), but was significantly lower after mid-April at 0.77 (SE = 0.04) ($t = 5.83$, $df = 5$, $P = 0.0021$). (Note that tests were not done for releases in May 1992 due to very small sample sizes.) This implied a 24% higher mortality for sampled fish

Table 6. Tests of homogeneity of McNary Dam passage distributions for yearling chinook and coho salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in 1991 and sampled or not sampled at the Chandler facility. P-values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P-value
Yearling chinook salmon			
14 April	18.07	22	0.7634
15 April	19.00	24	0.7471
16 April	21.05	22	0.5372
17 April	25.46	21	0.2057
22 April	15.26	19	0.7618
23 April	17.29	18	0.5353
24 April	15.98	17	0.5515
25 April	14.42	18	0.7571
26 April	13.63	16	0.6547
1 May	16.83	15	0.3249
2 May	22.35	15	0.0597
3 May	16.05	13	0.2284
4 May	15.65	13	0.2581
5 May	11.76	11	0.3717
7 May	14.56	12	0.2672
Coho salmon			
16 May	43.46	7	<0.0001
17 May	28.68	9	0.0002
18 May	48.23	8	<0.0001
21 May	24.09	5	0.0001
23 May	53.95	6	<0.0001

Table 7. Tests of homogeneity of McNary Dam passage distributions for yearling chinook and coho salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in 1992 and sampled or not sampled at the Chandler facility. P-values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P-value
Yearling chinook salmon			
3 April	35.31	24	0.0273
4 April	9.02	22	0.9978
5 April	22.62	22	0.4297
6 April	22.47	20	0.3084
7 April	13.87	17	0.7534
14 April	16.38	23	0.9128
16 April	22.63	21	0.3624
18 April	18.12	19	0.5549
20 April	23.16	19	0.2340
21 April	9.54	16	0.9323
22 April	14.99	17	0.6370
12 May	9.41	12	0.9046
13 May	12.16	15	0.8469
21 May	14.40	11	0.3186
22 May	--[a]		
23 May	--		
27 May	--		
2 June	--		
3 June	--		
4 June	--		
Coho salmon			
28 April	14.33	11	0.1967
29 April	15.75	13	0.2480
30 April	9.84	12	0.6183
5 May	14.33	10	0.1221
6 May	26.91	14	0.0043
7 May	31.13	17	0.0142

[a] Dashes indicate test not done due to very small sample sizes.

Table 8. The relative proportion detected at McNary Dam (MCN) of fish sampled at the Chandler facility (CHF) to unsampled which were released one km above Prosser Dam or at the headworks of the Chandler Canal in 1991 and 1992.

Release Date	Sampled at CHF	Detected at MCN	Proportion Detected at MCN	Not Sampled at CHF	Detected at MCN	Proportion Detected at MCN	Ratio of Proportions
Yearling chinook salmon							
14 April 1991	58	20	0.345	183	70	0.383	0.901
15 April 1991	50	16	0.320	233	102	0.438	0.731
16 April 1991	78	29	0.372	258	97	0.376	0.989
17 April 1991	130	42	0.323	199	76	0.382	0.846
22 April 1991	103	41	0.398	199	91	0.457	0.870
23 April 1991[a]							
24 April 1991	111	48	0.432	184	91	0.495	0.874
25 April 1991	207	100	0.483	118	58	0.492	0.983
26 April 1991	251	129	0.514	123	62	0.504	1.020
1 May 1991	215	104	0.484	207	102	0.493	0.982
2 May 1991	178	68	0.382	250	108	0.432	0.884
3 May 1991	142	52	0.366	222	92	0.414	0.884
4 May 1991	142	55	0.387	337	137	0.407	0.953
5 May 1991	45	18	0.400	334	128	0.383	1.044
7 May 1991[b]							
Total or Mean	1710	722	0.400	2847	1214	0.435	0.920
SE[c]			0.017			0.013	0.024
3 April 1992	63	35	0.556	161	74	0.460	1.209
4 April 1992	84	32	0.381	224	104	0.464	0.821
5 April 1992	76	41	0.539	197	88	0.447	1.208
6 April 1992	72	37	0.514	196	94	0.480	1.072
7 April 1992[b]							
Total or Mean	295	145	0.497	778	360	0.463	1.077
SE			0.040			0.007	0.091
14 April 1992	69	31	0.449	147	75	0.510	0.881
16 April 1992	66	28	0.424	156	91	0.583	0.727
18 April 1992	56	27	0.482	157	85	0.541	0.891
20 April 1992	49	17	0.347	152	82	0.539	0.643
21 April 1992	77	31	0.403	138	77	0.558	0.722
22 April 1992	65	25	0.385	137	72	0.526	0.732
12 May 1992[b]							
13 May 1992	46	10	0.217	76	22	0.289	--[d]
21 May 1992	59	3	0.051	114	15	0.132	--
22 May 1992	31	1	0.032	94	5	0.053	--
23 May 1992	41	2	0.049	82	3	0.037	--
27 May 1992	34	0	0.000	149	4	0.027	--
2 June 1992	19	0	0.000	111	7	0.063	--
3 June 1992	17	1	0.059	95	12	0.126	--
4 June 1992	8	0	0.000	68	4	0.059	--
Total or Mean	255	17	0.051	789	72	0.098	0.766
SE			0.025			0.031	0.040
Coho salmon							
16 May 1991	110	38	0.345	207	67	0.324	1.067
17 May 1991	117	38	0.325	255	72	0.282	1.150
18 May 1991	136	32	0.235	250	86	0.344	0.684
21 May 1991	74	21	0.284	282	97	0.344	0.825
23 May 1991	63	16	0.254	295	47	0.159	1.594
28 April 1992	61	27	0.443	164	77	0.470	0.943
29 April 1992	64	34	0.531	161	89	0.553	0.961
30 April 1992	48	23	0.479	194	101	0.521	0.920
5 May 1992	71	24	0.338	172	41	0.238	1.418
6 May 1992	62	18	0.290	171	50	0.292	0.993
7 May 1992	60	17	0.283	179	67	0.374	0.757
Total or Mean	866	288	0.346	2330	794	0.355	1.028
SE			0.029			0.036	0.082

[a] No estimate calculated due to poor mixing at McNary Dam.
[b] No estimate calculated due to Chandler facility PIT-tag detector malfunction.
[c] SE = Standard Error of the Total or Mean.
[d] Dashes indicate ratio not calculated due to small sample sizes.

in 1992 in mid-to-late April. Chandler facility survival estimates were adjusted (see later sections) for this violation of Assumption A1.

For coho salmon in both years, the relative proportion of fish sampled at the Chandler facility to those unsampled for R1 and R2 groups detected at McNary Dam was not significantly different from 1.00 at 1.03 (SE = 0.08) ($t = 0.35$, $df = 10$, $P = 0.7372$; Table 8). Therefore, the sampling procedure apparently did not cause a violation of Assumption A1 for coho salmon.

Assumption A2

Only 3 of 32 chi-square tests for yearling chinook salmon mixing at McNary Dam were significant at the $\alpha = 0.05$ comparison-wise error rate (Tables 9 and 10 and Appendix Tables 3a-3c, 3e, 3f, 3i, and 3j). However, about 2 ($32 \times 0.05 = 1.6$) of the 32 tests would be expected to be significant by chance. Therefore, the 14 April 1991 and 5 April 1992 results were not considered indicative of a failure of Assumption A2.

The highly significant result for 23 April 1991 ($P = 0.0040$), however, implied a lack of mixing for that group of releases. Comparison of the median travel times and visual inspection of the McNary Dam passage distributions for that release indicated R1 and R2 fish passed McNary Dam 1 day later than R4 fish and 2-3 days later than R3 fish. River conditions at McNary Dam fluctuated somewhat over the time period when fish from these groups were arriving at the dam but did not exhibit a strong trend through time (USACE 1991). Due to the potential violation of Assumption A2, data were omitted from the maximum likelihood analysis for this release day. For 23 April 1991, the RR estimate was used for the entrainment estimate and the EDP estimate was used for the Chandler Canal survival estimate.

Table 9. Tests of homogeneity of McNary Dam passage distributions for yearling chinook and coho salmon released one km above Prosser Dam, at the headworks of the Chandler Canal, immediately below Prosser Dam, or at the Chandler facility outfall in 1991. P-values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P-value
Yearling chinook salmon			
14 April	100.4	81	0.0461
15 April	86.2	84	0.4100
16 April	84.0	75	0.1915
17 April	91.0	78	0.1192
22 April	61.2	66	0.6851
23 April	86.4	57	0.0040
24 April	66.9	63	0.3176
25 April	63.8	63	0.4519
26 April	63.7	57	0.2375
1 May	57.8	51	0.2127
2 May	52.2	48	0.2979
3 May	54.4	42	0.0643
4 May	54.1	42	0.0787
5 May	51.3	42	0.1362
7 May	62.4	51	0.0941
Coho salmon			
16 May	62.2	36	0.0006
17 May	52.1	39	0.0208
18 May	56.2	21	<0.0001
21 May	28.7	12	0.0023
23 May	36.9	15	0.0003

Table 10. Tests of homogeneity of McNary Dam passage distributions for yearling chinook and coho salmon released one km above Prosser Dam, at the headworks of the Chandler Canal, immediately below Prosser Dam, at the Chandler facility outfall, at the I-82 bridge, or immediately below the main PIT-tag detector in the Chandler facility in 1992. P-values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P-value
Yearling chinook salmon			
3 April	103.1	112	0.7537
4 April	130.5	112	0.0809
5 April	130.7	104	0.0247
6 April	89.9	92	0.5553
7 April	106.5	108	0.5337
14 April	106.4	116	0.7756
16 April	100.8	96	0.3327
18 April	111.6	100	0.1673
20 April	121.9	110	0.1798
21 April	112.1	125	0.8371
22 April	99.7	100	0.4890
12 May	118.6	108	0.2179
13 May	125.1	128	0.5821
21 May	75.6	84	0.8362
22 May	63.8	56	0.2481
23 May	44.7	44	0.4510
27 May	53.8	52	0.5092
2 June	--[a]		
3 June	--		
4 June	--		
Coho salmon			
28 April	75.0	85	0.8478
29 April	98.0	95	0.3725
30 April	96.3	85	0.1379
5 May	75.2	85	0.8407
6 May	126.1	115	0.1432
7 May	101.2	95	0.2712

[a] Dashes indicate test not done due to very small sample sizes

All of the 1991 coho salmon chi-square mixing tests were highly significant, while all of the 1992 tests were not (Tables 9 and 10 and Appendix Tables 3d, 3g, and 3h). Nearly all fish from all groups released on the same day in 1991 were detected over a 3- to 4-day time period, whereas the distributions in 1992 were much more protracted. The significant chi-square values reflected fluctuations in McNary Dam passage over short time periods, with R1 or R2 releases generally passing less than 1 day later than R3 and R4. Survival and detection probabilities probably did not vary significantly over such short time periods. Therefore, Assumption A2 was most likely not violated by the lack of mixing found in 1991.

Survival

Estimates

Maximum likelihood estimates of survival (S1-S4, SA, SM1, and SM2) for the various reaches were obtained using the observed detection history totals (Appendix Tables 4 and 5). Initial MOM estimates for the iterative likelihood solutions are shown in Appendix Tables 6 and 7. Estimated sampling error precision of the daily estimates (i.e., standard errors) are listed in Appendix Tables 8 and 9.

Estimated mean survival in the 1-km reach above Prosser Dam was approximately 100% across years and species (Tables 11 and 12). Mean estimates ranged between 97.3 and 106.2% with standard errors between 0.8 and 2.1%. While true survival must be less than or equal to 100%, estimated survivals from the likelihood analyses used for this study were assumed to be randomly distributed about the true survival and were not similarly constrained. Therefore, if true survivals were at or near 100%, it was reasonable to have several estimates greater than 100% for

Table 11. Parameter estimates for maximum likelihood analyses in 1991. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; SM1-Chandler facility outfall to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility; SE-standard error.

Release Date	S1	S2	S3	SM1	D	SA	P
Yearling chinook salmon							
14 April	0.949	0.987	0.957	0.467	0.670	0.800	1.[a]
15 April	1.030	0.984	0.957	0.470	0.460	0.887	0.976
16 April	1.031	0.990	1.012	0.405	0.681	0.931	1.
17 April	0.962	0.969	1.282	0.425	0.779	0.841	0.985
22 April	1.010	0.945	1.247	0.365	0.597	1.203	1.
23 April[b]							
24 April	1.018	0.986	1.095	0.443	0.509	1.061	0.989
25 April	0.979	0.964	0.915	0.524	0.518	0.933	1.
26 April	0.973	0.977	0.991	0.520	0.748	0.985	0.991
1 May	1.030	0.947	1.096	0.462	0.966	1.054	1.
2 May	0.972	0.973	1.000	0.520	0.991	0.787	1.
3 May	1.022	0.958	0.989	0.475	0.916	0.828	0.987
4 May	0.963	0.992	1.026	0.460	1.008	0.871	0.980
5 May	0.989	0.997	0.959	0.485	1.022	0.798	0.948
7 May[c]							
Mean	0.994	0.974	1.041	0.463	0.759	0.921	0.979[d]
SE	0.008	0.005	0.031	0.013	0.057	0.035	0.006
Coho salmon							
16 May	0.991	0.978	0.953	0.411	0.925	0.793	0.982
17 May	1.013	0.985	1.018	0.275	0.877	1.075	1.
18 May	0.975	0.980	1.090	0.335	1.	0.913	1.
21 May	0.931	1.005	0.813	0.375	0.873	0.877	0.985
23 May	0.958	0.988	1.382	0.170	0.908	1.032	0.971
Mean	0.973	0.987	1.051	0.313	0.896[d]	0.938	0.979[d]
SE	0.014	0.005	0.094	0.042	0.013	0.052	0.004

[a] Parameter estimate was assumed to be 1.000.
[b] No estimates calculated due to poor mixing at McNary Dam.
[c] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[d] Mean does not include assumed P=1.000 estimates.

Table 12. Parameter estimates for maximum likelihood analyses in 1992. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; S4-Chandler facility outfall to the I-82 bridge survival; SM2-I-82 bridge to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility; SE-standard error.

Release Date	S1	S2	S3	S4	SM2	D	SA	P
Yearling chinook salmon								
3 April	0.952	0.952	1.029	0.944	0.576	0.968	0.895	0.983
4 April	1.028	0.896	1.051	0.931	0.537	0.968	0.875	1.[a]
5 April	0.956	0.974	1.180	0.868	0.607	0.888	0.894	1.
6 April	1.018	0.928	1.086	1.066	0.507	1.012	0.905	0.956
7 April[b]								
14 April	1.004	0.912	0.897	1.268	0.492	0.942	0.790	0.982
16 April	0.939	0.935	1.088	0.794	0.589	1.	1.137	1.
18 April	0.965	0.958	1.022	0.910	0.624	0.867	0.926	0.968
20 April	1.003	0.871	1.116	0.901	0.568	0.860	1.075	1.
21 April	1.035	0.919	0.813	0.938	0.640	0.857	0.821	1.
22 April	0.918	0.904	0.980	1.015	0.544	0.946	0.897	0.982
12 May[b]								
13 May	1.013	0.508	1.472	0.697	0.413	0.925	0.911	1.
21 May	1.106	0.696	0.984	1.322	0.127	0.912	0.616	1.
22 May	1.101	0.484	0.756	0.960	0.101	1.	0.496	1.
23 May	1.082	0.492	1.000	1.296	0.056	1.	0.656	1.
27 May	1.009	0.738	1.190	0.720	0.056	1.	0.542	1.
2 June[c]								
3 June[c]								
4 June[c]								
April Mean	0.982	0.925	1.026	0.964	0.568	0.923[d]	0.922	0.974[d]
SE	0.013	0.010	0.034	0.041	0.015	0.019	0.034	0.005
May Mean	1.062	0.583	1.080	0.999	0.151	0.919[d]	0.644	1.
SE	0.021	0.055	0.120	0.135	0.067	0.006	0.072	
Coho salmon								
28 April	1.039	0.952	1.000	1.081	0.452	0.873	0.975	1.
29 April	1.020	0.941	0.880	1.127	0.476	1.001	0.949	0.982
30 April	1.022	0.984	0.978	0.935	0.582	0.970	0.908	1.
5 May	1.000	0.976	1.156	0.849	0.424	1.	0.828	1.
6 May	0.967	0.978	1.224	0.980	0.400	0.999	0.775	0.973
7 May	0.975	0.976	0.944	1.059	0.408	1.	0.930	1.
Mean	1.004	0.968	1.030	1.005	0.457	0.961[d]	0.894	0.978[d]
SE	0.012	0.007	0.054	0.042	0.028	0.030	0.031	0.004

[a] Parameter estimate was assumed to be 1.000.
[b] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[c] No estimates calculated due to very small sample sizes.
[d] Mean does not include assumed P=1.000 estimates.

individual releases, and often for the overall average. However, the average estimate was expected to be within two standard errors of 100%. This was not the case for the mean S1 survival for yearling chinook salmon in May 1992 and indicated a possible lack of fit or failure of the assumptions of the likelihood model for those releases. However, this low survival estimate was most likely related to low recapture rates at McNary Dam.

The estimated mean survivals in 1991 of 97.1 (SE = 0.5%) and 98.7% (SE = 0.05%) for yearling chinook and coho salmon, respectively from the entrance of the Chandler Canal to the main facility PIT-tag detector were high (Table 11). Fairly high survival of 92.5 (SE = 1.0%) and 96.8% (SE = 0.7%) for yearling chinook and coho salmon, respectively was estimated in 1992 before 12 May (Table 12) .. However, yearling chinook mean survival fell to 58.3% (SE = 5.5%) after 12 May and to 47.7% (SE = 5.0%) in June (EDP estimates in Table 14 used in June).

For the reach in the Yakima River from the tailrace of Prosser Dam to the Chandler facility outfall, estimated mean survival exceeded 100% for both years and species and ranged from 102.6 to 108.0% (Tables 11 and 12). However, standard errors ranged between 3.1 and 12.0%, implying actual survival was around 100%. The high variation in estimates appeared random over time and was a result of small sample sizes and/or recapture rates at McNary Dam. This was particularly true after 12 May 1992.

Separate survival estimates for the reach from the Chandler facility outfall to the I-82 bridge were only available for 1992. Mean survival was high for both species, averaging 96.4 (SE = 4.1%) and 99.9% (SE = 13.5) for yearling chinook salmon in April and May, respectively, and 100.5% (SE = 4.2%) for coho salmon (Table 12). The large standard errors reflected small sample sizes or low recapture rates at McNary Dam, particularly after 12 May.

Mean survival in the short reach between the main PIT-tag detector in the Chandler juvenile facility and the outfall back into the Yakima River was estimated at 92.1% (SE = 3.5%) in 1991 for yearling chinook salmon and 93.8 (SE = 5.2%) and 89.4% (SE = 3.1%) for coho salmon in 1991 and 1992, respectively (Tables 11 and 12). The yearling chinook salmon estimate included an estimated 8% mortality due to the sampling process at the facility. The adjusted overall 1991 survival estimate for yearling chinook salmon that passed through the facility and outfall but were not sampled was 94.6% (SE = 3.6%; Table 13). Mean survival results for yearling chinook salmon in 1992 were fairly complicated (Table 12). In early April, survival averaged 89.2% (SE = 0.6%) with no detectable mortality due to the sampling process. Later in April, it averaged 94.1% (SE = 5.6%) with nearly all the mortality attributed to the sampling process. The adjusted mean was 101.4% (SE = 6.6%). In May, mean survival dropped to 64.4% (SE = 7.2%), but the effect of the sampling process on this low survival could not be estimated. The large standard errors reflected small sample sizes and/or recapture rates at McNary Dam.

Virtually no salmonid mortality was observed in the Yakima River from 1 km above Prosser Dam to the I-82 bridge over the time and river conditions tested for both yearling chinook and coho salmon. Passage through the Chandler Canal and facility and back into the Yakima River resulted in roughly 11% mortality for coho salmon and 7-16% mortality for yearling chinook salmon, except in late May 1992 when it averaged 63%. For coho salmon, most of the mortality occurred in the segment between the Chandler facility entrance and its outfall and was not a result of the sampling process. For yearling chinook salmon, it was difficult to determine a consistent pattern of the location of mortality, except that in late May 1992 high mortality occurred both in the Chandler Canal and through the Chandler facility. While Chandler Canal

Table 13. Adjusted Chandler facility to outfall survival estimates for yearling chinook salmon releases where significant mortality was detected due to the facility sampling process in 1991 and 1992 (see Table 8).

Release Date	Sampled fish relative survival	Chandler facility sample proportion	Maximum likelihood estimated Chandler facility survival	Adjusted unsampled Chandler facility survival
14 April 1991	0.901	0.241	0.800	0.819
15 April 1991	0.731	0.177	0.887	0.931
16 April 1991	0.989	0.232	0.931	0.933
17 April 1991	0.846	0.395	0.841	0.896
22 April 1991	0.870	0.341	1.203	1.259
23 April 1991[a]				
24 April 1991	0.874	0.376	1.061	1.114
25 April 1991	0.983	0.637	0.933	0.943
26 April 1991	1.020	0.671	0.985	0.972
1 May 1991	0.982	0.509	1.054	1.064
2 May 1991	0.884	0.416	0.787	0.827
3 May 1991	0.884	0.390	0.828	0.867
4 May 1991	0.953	0.296	0.871	0.883
5 May 1991	1.044	0.119	0.798	0.794
7 May 1991[b]				
Mean	0.920	0.369	0.921	0.946
SE[c]	0.024	0.046	0.035	0.036
14 April 1992	0.881	0.319	0.790	0.821
16 April 1992	0.727	0.297	1.137	1.237
18 April 1992	0.891	0.263	0.926	0.953
20 April 1992	0.643	0.244	1.075	1.177
21 April 1992	0.722	0.358	0.821	0.912
22 April 1992	0.732	0.322	0.897	0.982
Mean	0.766	0.301	0.941	1.014
SE	0.040	0.017	0.056	0.066

[a] No estimates calculated due to poor mixing at McNary Dam.
[b] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[c] SE = Standard Error of the Mean.

survival was assumed to be related to river conditions, low survival through the Chandler facility may have resulted from a combination of the sampling process, river conditions, and avian predation at the facility outfall.

Comparison with River Conditions

Since nearly all survival estimates (S1-S4) were high and averaged close to 100% (except for yearling chinook salmon S2 estimates), no attempt was made to correlate survival in the corresponding reaches with river conditions such as water temperature or flow volume (Appendix Table 10). It was apparent over the range of conditions tested that survival was not affected by any environmental factors.

However, the precipitous decline in S2 yearling chinook salmon survival estimates after 12 May 1992 suggested that survival between the Chandler Canal and the facility for that species was linked to some water condition in the canal. Therefore, the relationships between S2 survival estimates and water temperature and volume were examined. Estimates from 1991 and 1992 were combined based on the assumption that any cause-and-effect relationship would be the same in both years.

Lower survival through the Chandler Canal for yearling chinook salmon was clearly associated with later release dates at higher water temperatures and lower flow volumes (Figs. 3-5). However, the paucity of data falling in the middle of distributions for release date, water temperature, and canal water-flow distributions made it difficult to determine the functional relationship between these variables and canal survival. Threshold- and continuous-type models could not be differentiated using the observed data. Therefore, statistical models were not developed for these relationships. Significant yearling chinook salmon mortality in the Chandler

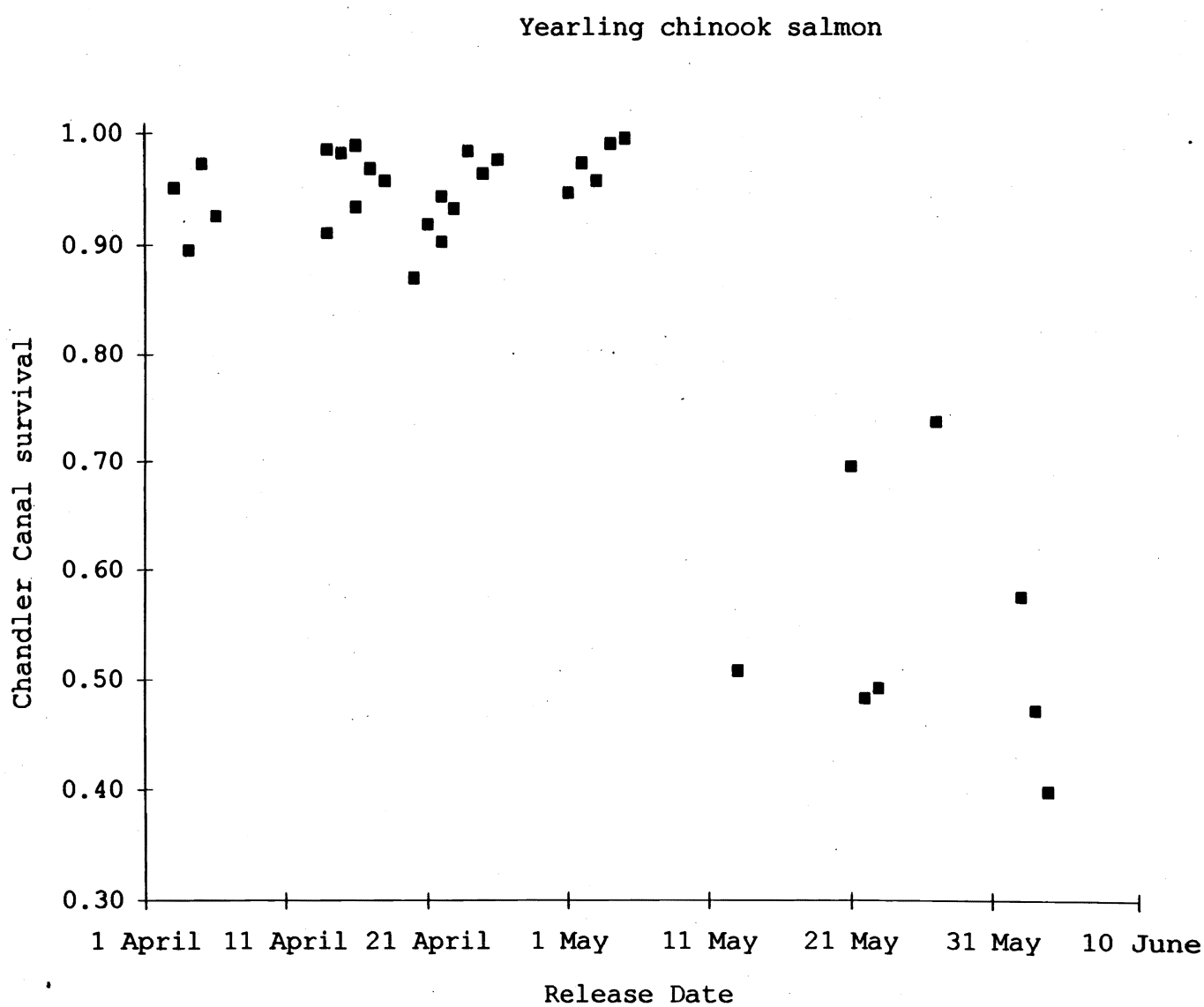

Figure 3. Release date versus estimated Chandler Canal survival in 1991 and 1992.

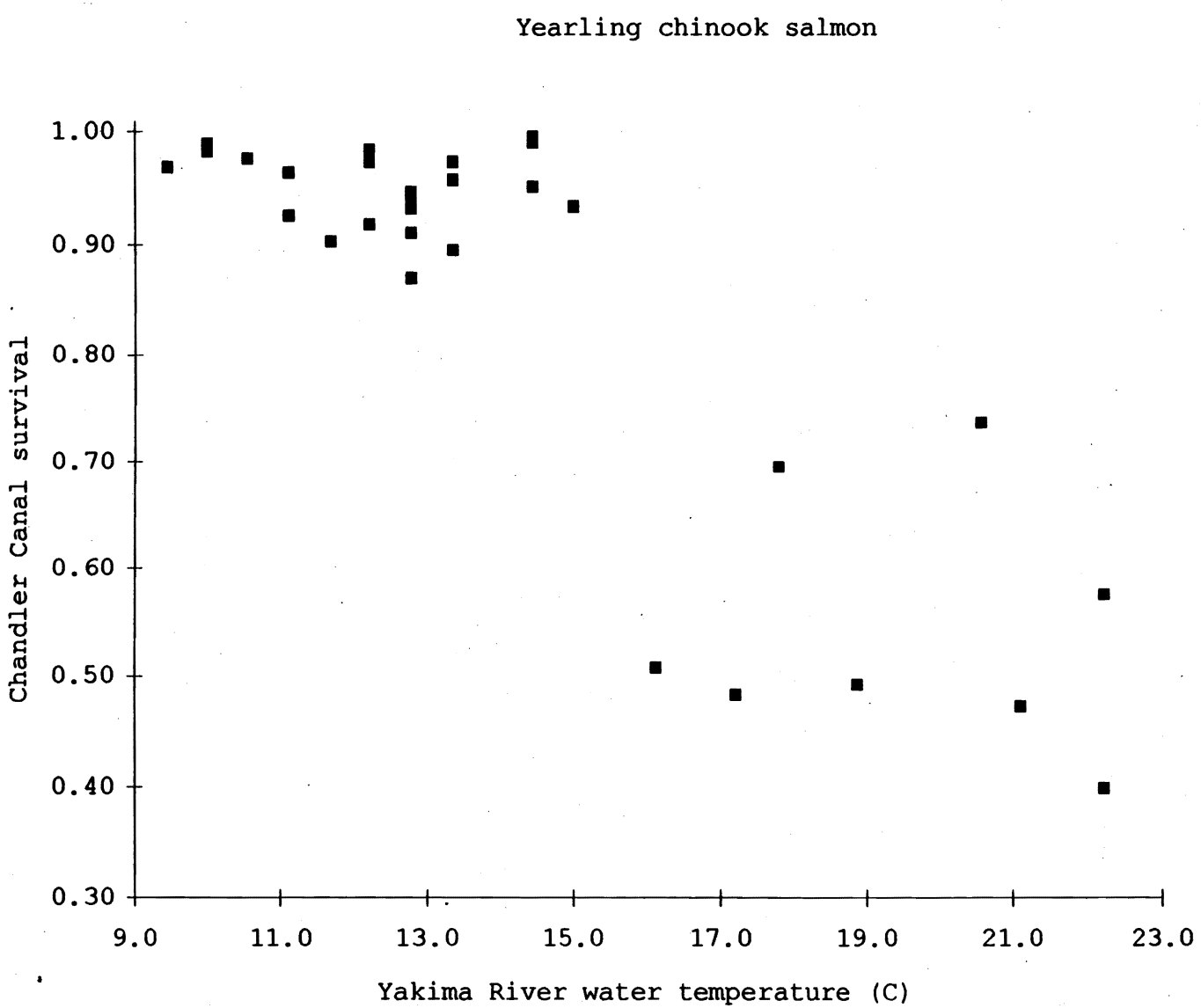

Figure 4. Yakima River water temperature versus estimated Chandler Canal survival in 1991 and 1992.

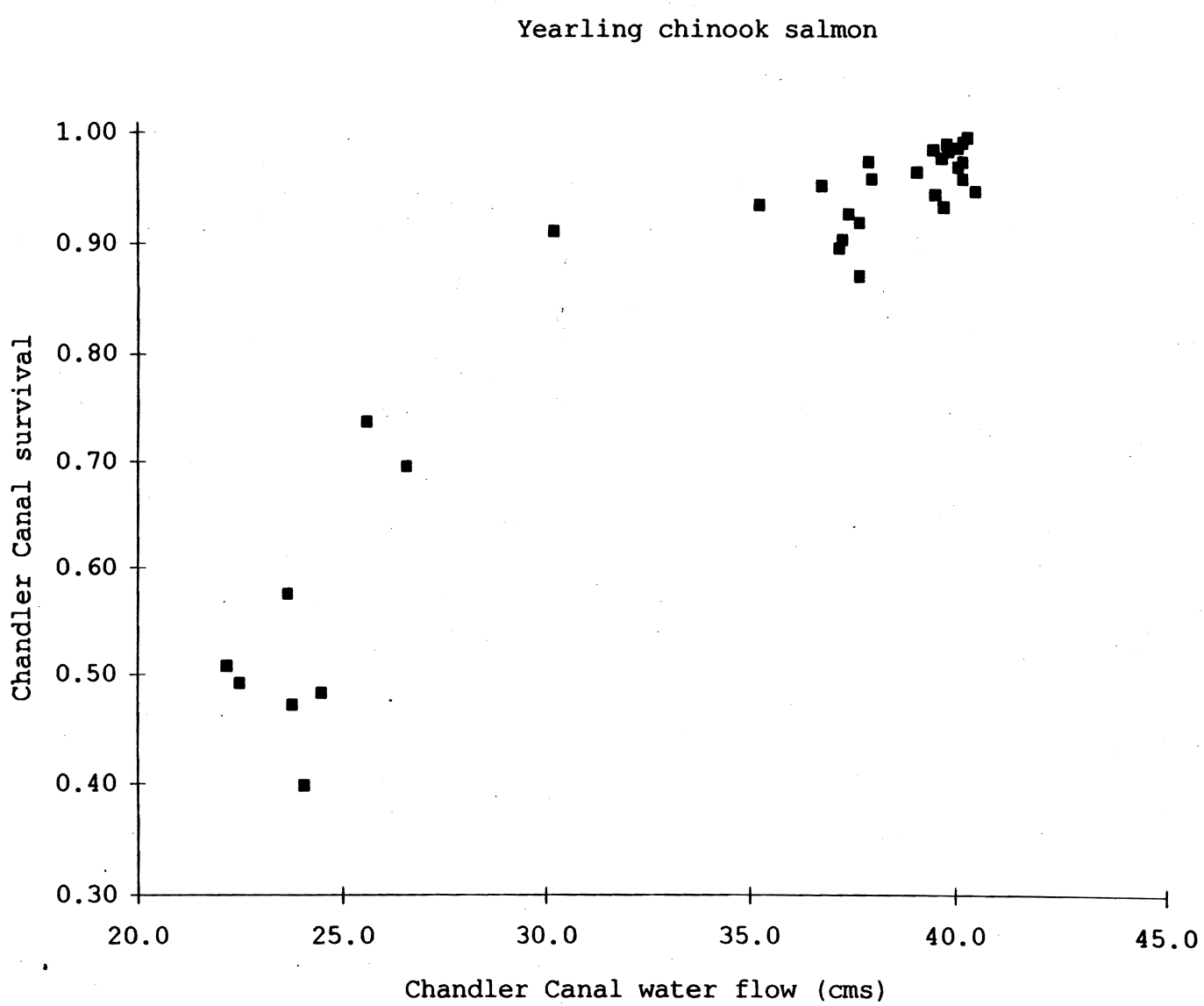

Figure 5. Chandler Canal water flow versus estimated Chandler Canal survival in 1991 and 1992.

Canal to the facility occurred after 12 May when water temperatures exceeded 15°C (59°F) and canal water flow was less than 30.0 cms (1060 cfs).

Survival estimates through the Chandler facility for yearling chinook salmon were also substantially lower after 12 May 1992 and were associated with high water temperatures and low water flows in the Yakima River (Figs. 6-8). (The discussion in the preceding paragraph regarding the choice of appropriate statistical models also applied to the observed relationships between release date, river water temperature, and survival through the Chandler facility). Survival appeared random and quite variable over release dates and water temperatures of 9-16°C (48-61°F) but decreased after 12 May when water temperature was above 17°C (63°F). Survival appeared random and quite variable over the observed flow range of 12.4-105.7 cms (438-3732 cfs) until after 12 May 1992, when it dropped substantially. Yet, it was still within the flow range observed before 12 May.

Chandler Canal Water Flow versus Fish Entrainment

The proportion of water diverted on test days and the MLEs of the proportion of fish entrained into the Chandler Canal (Tables 11 and 12) are shown in Figures 9 and 10. Individual standard errors based on multinomial sampling error for the MLEs are listed in Appendix Tables 8 and 9. For yearling chinook salmon, the best-fitting regression curve was estimated as:

$$Fi = 1.368 - 0.234/Fl$$

with a 95% prediction interval of:

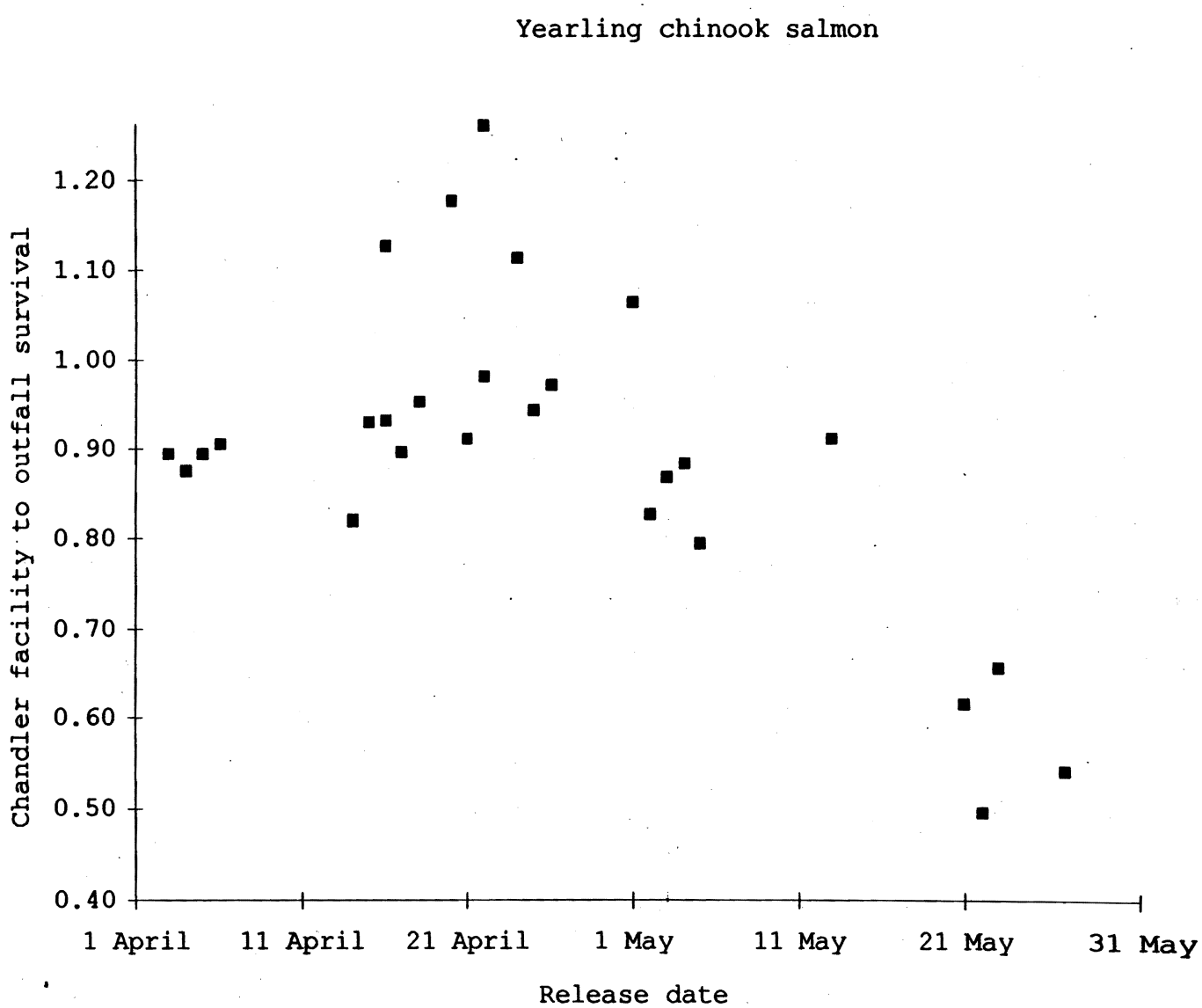

Figure 6. Release date versus estimated Chandler facility to outfall survival in 1991 and 1992.

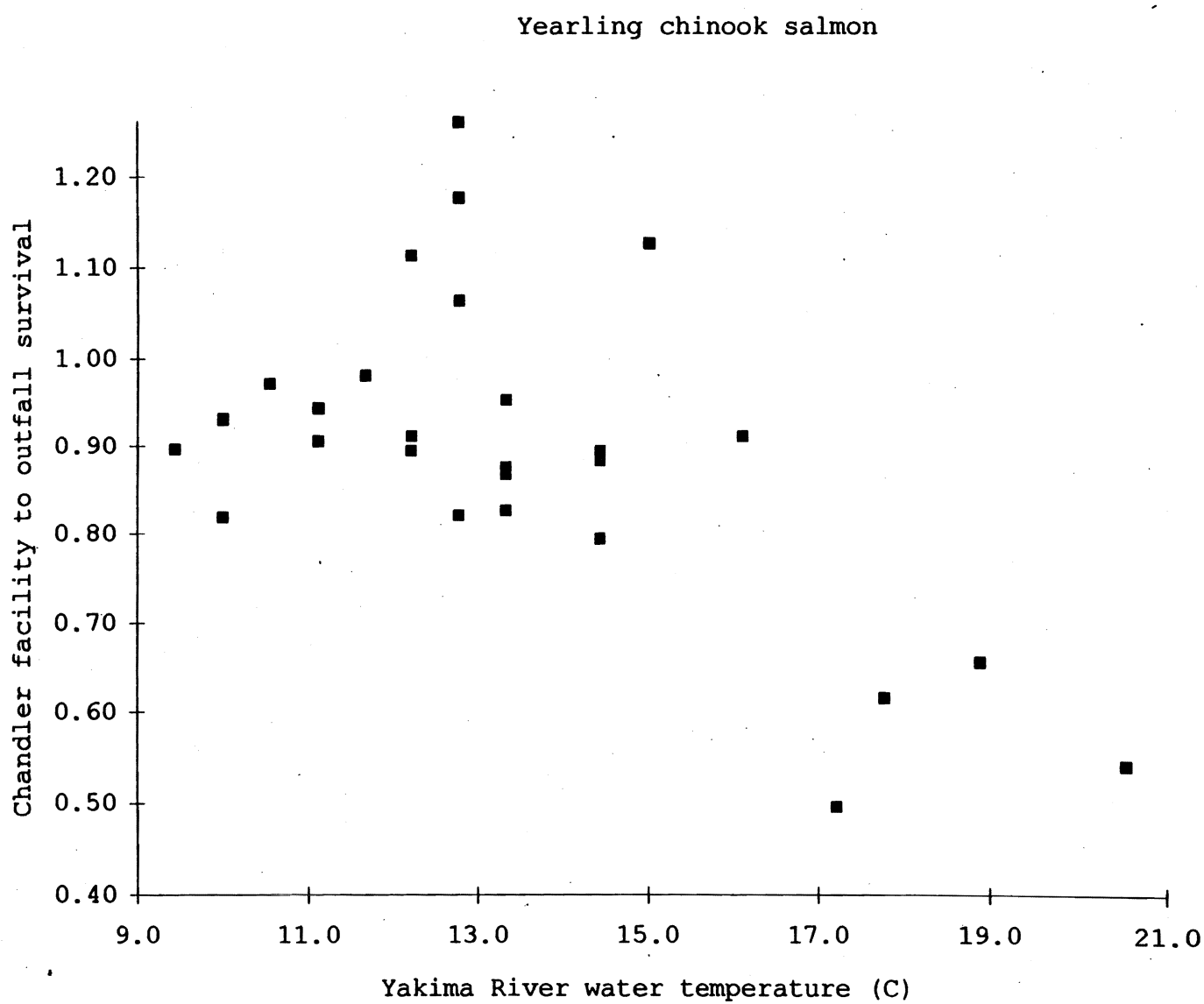

Figure 7. Yakima River water temperature versus estimated Chandler facility to outfall survival in 1991 and 1992.

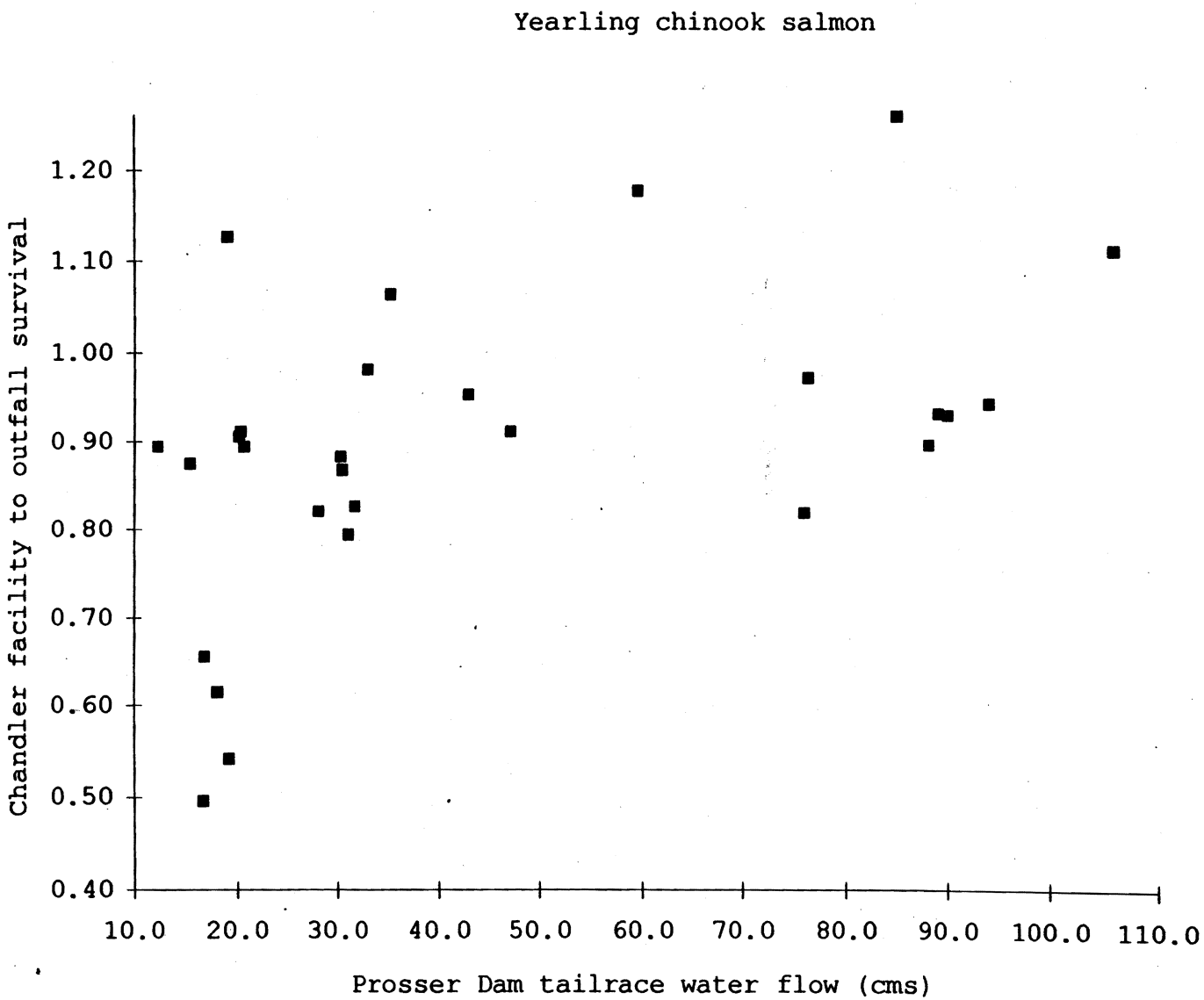

Figure 8. Prosser Dam tailrace water flow versus estimated Chandler facility to outfall survival in 1991 and 1992.

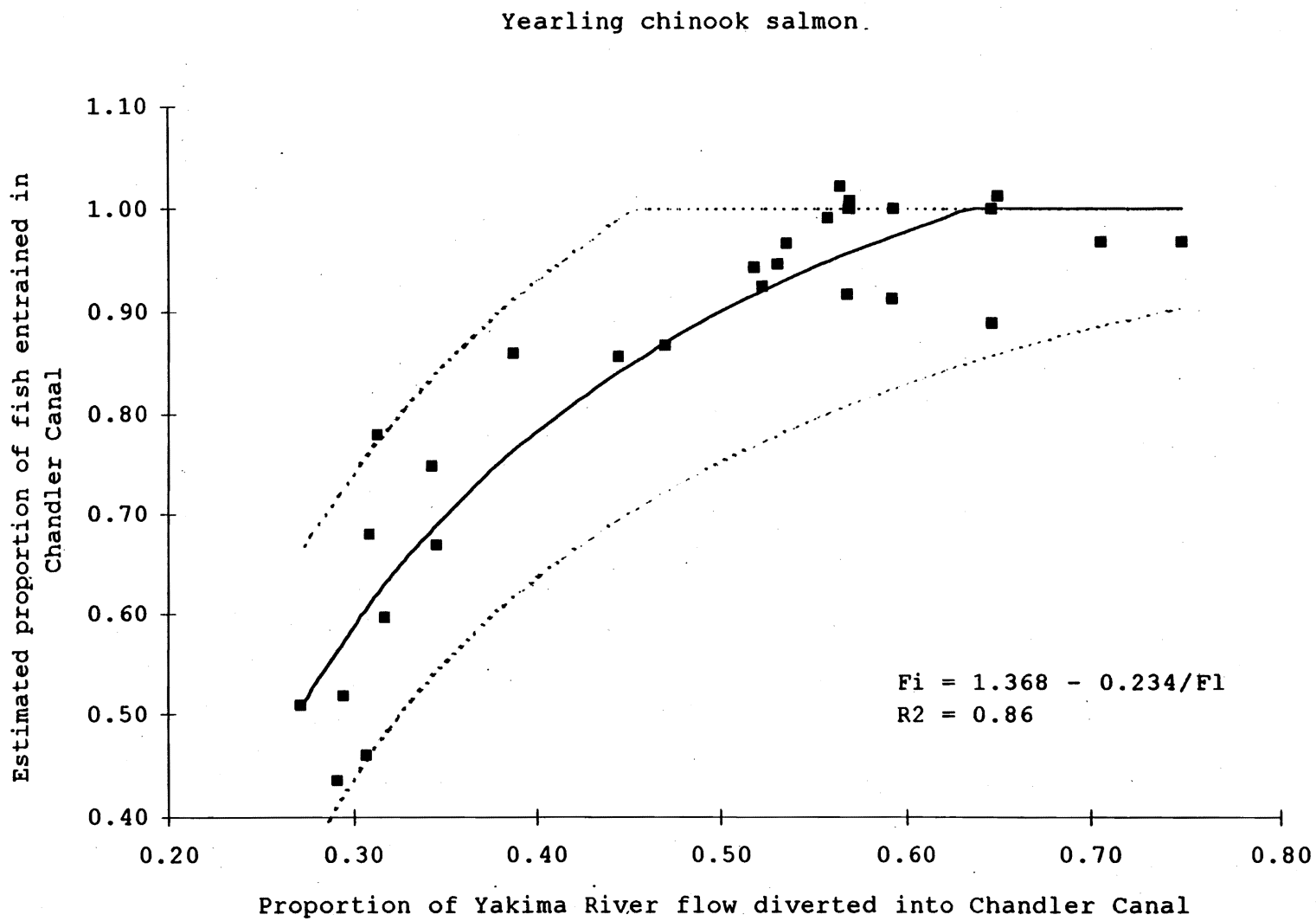

Figure 9. Relationship between the proportion of Yakima River flow diverted (Fl) and yearling chinook salmon entrained (Fi) into the Chandler Canal in 1991 and 1992. The solid line is the estimated regression prediction curve and the dashed lines are 95% prediction interval curves.

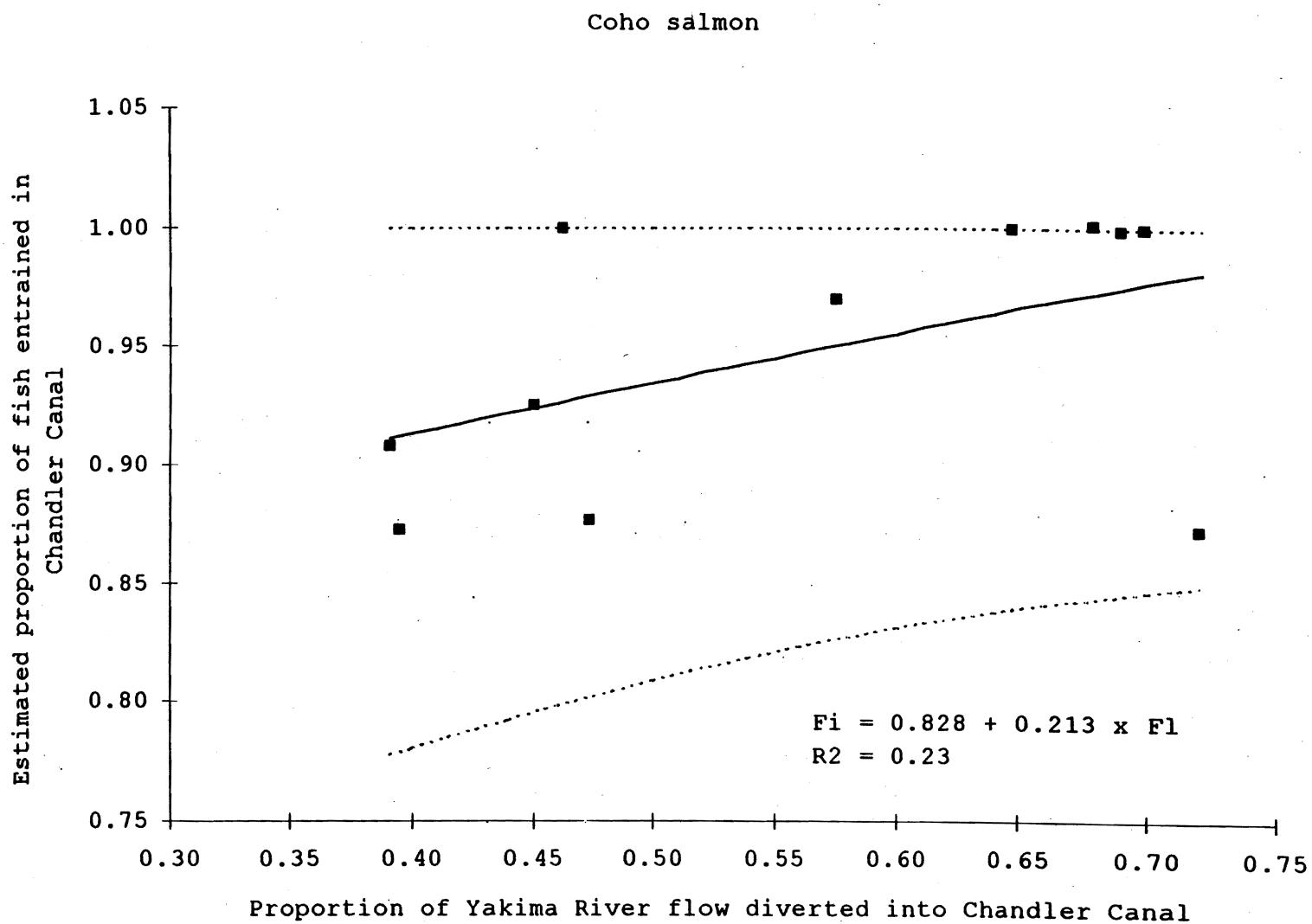

Figure 10. Relationship between the proportion of Yakima River flow diverted (Fl) and coho salmon entrained (Fi) into the Chandler Canal in 1991 and 1992. The solid line is the estimated regression prediction curve and the dashed lines are 95% prediction interval curves.

$$Fi \pm 0.1443\left[1.0345 + \frac{\left(\frac{1}{Fl} - 2.2447\right)^2}{15.0275}\right]^{\frac{1}{2}}$$

where Fi is the predicted proportion of fish entrained in Chandler Canal and Fl is the proportion of flow diverted into the canal. This regression model accounted for 86% of variation in the proportion of fish entrained in the canal (i.e., $R^2 = 0.86$). The model residuals, predicted minus actual values, appeared fairly random around zero and normally distributed. However, some "lack-of-fit" of the curve was apparent from visual inspection of the data shown in Fig. 9 (i.e., the curve didn't seem to bend quite as sharply as the data scatterplot suggested). This primarily resulted from having many more flow proportion diverted values on the ends of the range (around 0.3 and 0.5-0.7) than in the middle (0.35-0.5). That is, these middle values were less able to "shape" the curve in their neighborhood.

For coho salmon, the best-fitting curve was estimated as:

$$Fi = 0.828 + 0.213 \times Fl$$

with a 95% prediction interval of:

$$Fi \pm 0.1189\left[1.0909 + \frac{(Fl - 0.5616)^2}{0.1680}\right]^{\frac{1}{2}}$$

This regression model accounted for only 23% of the variation in the proportion of fish entrained in the canal (i.e., $R^2 = 0.23$). Curve estimation and regression diagnostics (e.g., residual plots) were difficult to interpret from this small data set (n = 11). For example, the largest value for the

proportion of flow diverted was associated with nearly the lowest value for the proportion of fish entrained, and this value also had the largest regression-model residual. This data point had strong influence on how the flow-diversion/fish-entrainment relationship was determined both from the standpoint of fitting a regression model and from visual inspection of the data scatterplot. Removal of this value from the regression considerably changed the prediction equation to $Fi = 0.766 + 0.345 \times Fl$ and increased R^2 to 0.64.

The above prediction curves can be used to expand future fish counts at the Chandler facility into Prosser Dam passage numbers (for tagged and untagged fish). However, several caveats should be noted:

1. The precision of such estimates, as calculated from the prediction intervals above, will be fairly low. For yearling chinook and coho salmon, predicted fish entrainment estimates could vary by a minimum of 14.7 and 12.4%, respectively (e.g., given a percentage of flow diverted of 45%, a researcher would predict that 85% of yearling chinook salmon would be entrained but could only say with 95% confidence that the true percentage of fish entrained was between 70.3 and 99.7%).
2. These prediction curves should only be used for flow entrainment proportions observed in this study. Flow proportions greater than those observed most likely imply 100% fish entrainment, but the relationship for flow proportions less than those observed is unknown. If data were available over the entire range of possible flow diversion proportions, it is possible that a different predictor function would be appropriate.

3. Expansion estimates using these curves need to be adjusted for Chandler Canal to facility estimated survival and facility main PIT-tag detector efficiency. Estimates at "low" canal flow volumes would be highly variable.

4. The accuracy of the coho salmon prediction curve is somewhat tenuous due to small sample size.

Maximum Likelihood vs Expanded Detection Proportion and Relative Recapture

The mean ratio of MLE to EDP estimates of Chandler Canal survival over years and species was 0.996 (SE = 0.003; Table 14). Individual values ranged from 0.966 to 1.033. Therefore, the average estimates from the two methods were not significantly different. Furthermore, individual estimates were not highly variable. The EDP method can be used to obtain Chandler Canal survival estimates in the future as long as the Chandler facility main PIT-tag detector efficiency can be estimated.

The mean ratio of the MLE to RR estimates of the proportion of fish entrained into Chandler Canal over years and species was 1.003 (SE = 0.008, Table 14). Individual values ranged from 0.894 to 1.154. Therefore, average estimates from the two methods were not significantly different. Furthermore, individual estimates were not highly variable. The RR method can be used to obtain entrainment estimates in the future as long as 100% survival from the R1 release point to the Chandler Canal can be assumed.

Chandler Facility Main PIT-tag Detector Efficiency

MLEs of the PIT-tag detection efficiency of the Chandler facility exceeded 94% for all release days over both years and species, with means and standard errors ranging from 97.4 to

Table 14. Comparison of the 1991 and 1992 expanded detection proportion (EDP) Chandler Canal survival estimates and the relative recapture (RR) Chandler Canal fish entrainment proportion estimates with the maximum likelihood (MLE) estimates.

Release	Chandler Canal survival			Entrainment proportion		
Date	MLE	EDP	MLE/EDP	MLE	RR	MLE/RR
14 April 1991	0.987	0.987	1.000	0.670	0.639	1.049
15 April 1991	0.984	0.960	1.025	0.460	0.474	0.970
16 April 1991	0.990	1.003	0.987	0.681	0.702	0.970
17 April 1991	0.969	0.979	0.990	0.779	0.753	1.035
22 April 1991	0.945	0.954	0.990	0.597	0.603	0.990
23 April 1991[a]		0.925			0.435	
24 April 1991	0.986	0.984	1.002	0.509	0.518	0.983
25 April 1991	0.964	0.974	0.990	0.518	0.507	1.022
26 April 1991	0.977	0.973	1.005	0.748	0.728	1.027
1 May 1991	0.947	0.960	0.986	0.966	0.995	0.971
2 May 1991	0.973	0.990	0.983	0.991	0.968	1.024
3 May 1991	0.958	0.958	0.999	0.916	0.937	0.978
4 May 1991	0.992	0.972	1.021	1.008	0.971	1.038
5 May 1991	0.997	0.966	1.032	1.022	1.011	1.011
7 May 1991[b]						
16 May 1991	0.978	1.004	0.974	0.925	0.917	1.009
17 May 1991	0.985	0.985	1.000	0.877	0.888	0.988
18 May 1991	0.980	0.975	1.005	1.000	0.979	1.021
21 May 1991	1.005	1.030	0.976	0.873	0.813	1.074
23 May 1991	0.988	0.975	1.014	0.908	0.870	1.044
3 April 1992	0.952	0.936	1.018	0.968	0.915	1.058
4 April 1992	0.896	0.928	0.966	0.968	1.006	0.962
5 April 1992	0.974	0.987	0.987	0.888	0.827	1.074
6 April 1992	0.928	0.911	1.018	1.012	1.030	0.983
7 April 1992[b]						
14 April 1992	0.912	0.909	1.004	0.942	0.938	1.004
16 April 1992	0.935	0.964	0.971	1.000	0.931	1.074
18 April 1992	0.958	0.928	1.033	0.867	0.836	1.037
20 April 1992	0.871	0.889	0.980	0.860	0.870	0.989
21 April 1992	0.919	0.931	0.987	0.857	0.887	0.966
22 April 1992	0.904	0.888	1.018	0.946	0.820	1.154
28 April 1992	0.952	0.968	0.984	0.873	0.899	0.971
29 April 1992	0.941	0.968	0.972	1.001	1.073	0.933
30 April 1992	0.984	0.984	1.000	0.970	0.967	1.003
5 May 1992	0.976	0.990	0.986	1.000	1.000	1.000
6 May 1992	0.978	0.967	1.011	0.999	0.966	1.034
7 May 1992	0.976	0.984	0.992	1.000	0.983	1.017
12 May 1992[b]						
13 May 1992	0.508	0.508	1.000	0.925	0.937	0.987
21 May 1992	0.696	0.708	0.983	0.912	1.000	0.912
22 May 1992	0.484	0.484	1.000	1.000	1.119	0.894
23 May 1992	0.492	0.507	0.970	1.000	1.119	0.894
27 May 1992	0.738	0.738	1.000	1.000	1.033	0.968
2 June 1992[c]		0.569				
3 June 1992[c]		0.468				
4 June 1992[c]		0.395				
Mean			0.996			1.003
SE[d]			0.003			0.008

[a] No MLE estimates calculated due to poor mixing at McNary Dam.
[b] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[c] No MLE or RR estimates calculated due to very small sample sizes or no assumption of 100% Prosser Dam forebay survival.
[d] SE = Standard Error of the Mean.

97.9% and 0.4 to 0.6%, respectively (Tables 11 and 12). Model-based individual standard errors are listed in Appendix Tables 8 and 9. However, in 22 of the 39 tests, the efficiency was not estimable by the full likelihood model and was assumed to be 100% due to 0 detections at McNary Dam of fish not previously detected at the Chandler facility.

Estimates of the Chandler facility main PIT-tag detector efficiency based on sample PIT-tag detector detections of R1 and R2 releases exceeded 95% for all release days over both years and species with means and standard errors ranging from 98.0 to 99.0% and 0.2 to 0.9%, respectively (Table 15). Estimates were obtained by this approach for all release days, with sample sizes in excess of 30 sample detections, except in June 1992. Sample sizes for the June 1992 releases ranged from 8 to 19, with detector efficiency estimates at 100%.

Travel Time

Chandler Facility

In 1991, the fastest travel times to the Chandler facility for fish released in the Chandler Canal averaged 0.7 (SE = 0.1) and 0.5 hours (SE = 0.1) for yearling chinook and coho salmon, respectively (Table 16). For both species, this was an average of about 0.8 hours (SE = 0.1) faster than the minimum travel time for fish released in the Prosser Dam forebay. In 1992, the fastest travel times to the Chandler facility for fish released in the Chandler Canal averaged 1.7 (SE = 0.2) and 1.8 hours (SE = 0.1) for yearling chinook and coho salmon, respectively (Table 17). This averaged 1.1 (SE = 0.1) and 0.6 hours (SE = 0.1) faster than the minimum travel time for forebay-released yearling chinook and coho salmon, respectively. Within both years, minimum travel times of individual release days were fairly consistent.

Table 15. Estimated Chandler facility main PIT-tag detector (MD) efficiency based on sample PIT-tag detector (SD) detections of Prosser Dam forebay and Chandler Canal yearling chinook and coho salmon releases in 1991 and 1992.

1991				1992			
Release date	SD detections	SD and MD detections	Estimated MD efficiency	Release date	SD detections	SD and MD detections	Estimated MD efficiency
Yearling chinook salmon							
14 April	58	58	1.000	3 April	63	63	1.000
15 April	50	50	1.000	4 April	87	84	0.966
16 April	79	78	0.987	5 April	77	76	0.987
17 April	134	130	0.970	6 April	74	72	0.973
22 April	104	103	0.990	7 April[a]			
23 April	88	88	1.000	14 April	70	69	0.986
24 April	112	111	0.991	16 April	68	66	0.971
25 April	209	207	0.990	18 April	56	56	1.000
26 April	252	251	0.996	20 April	50	49	0.980
1 May	218	215	0.986	21 April	78	77	0.987
2 May	181	178	0.983	22 April	65	65	1.000
3 May	144	142	0.986	12 May[a]			
4 May	142	142	1.000	13 May	46	46	1.000
5 May	46	45	0.978	21 May	60	59	0.983
7 May[a]				22 May	31	31	1.000
				23 May	43	41	0.953
Total/Mean	1817	1798	0.990	27 May	34	34	1.000
SE[b]			0.002	2 June	19	19	1.000
				3 June	17	17	1.000
Coho salmon				4 June	8	8	1.000
16 May	115	110	0.957				
17 May	117	117	1.000	Total/Mean	946	932	0.988
18 May	136	136	1.000	SE			0.003
21 May	77	74	0.961				
23 May	64	63	0.984	Coho salmon			
				28 April	62	61	0.984
Total/Mean	509	500	0.980	29 April	67	64	0.955
SE			0.009	30 April	48	48	1.000
				5 May	72	71	0.986
				6 May	63	62	0.984
				7 May	61	60	0.984
				Total/Mean	373	366	0.982
				SE			0.006

[a] No estimates made due to Chandler facility PIT-tag detector malfunction.
[b] SE = Standard Error of the Mean.

Table 16. Minimum and median travel time (TT) to the Chandler facility for yearling chinook and coho salmon released 1 km above Prosser Dam (Forebay) or at the headworks of the Chandler Canal (Canal) in 1991.

Release date	Forebay Minimum TT (hours)	Canal Minimum TT (hours)	Forebay - Canal (hours)	Forebay Median TT (hours)	Canal Median TT (hours)	Forebay - Canal (hours)
Yearling chinook salmon						
14 April	0.2	0.6	-0.4	2.7	2.1	0.7
15 April	1.3	0.5	0.8	2.7	2.0	0.7
16 April	1.5	0.6	1.0	3.2	2.3	0.9
17 April	2.3	1.2	1.1	4.1	3.8	0.4
22 April	2.4	1.1	1.4	3.5	3.5	-0.1
23 April	1.2	0.8	0.5	3.1	3.2	0.0
24 April	1.4	0.8	0.6	2.7	2.0	0.7
25 April	1.2	0.9	0.3	3.3	2.8	0.5
26 April	1.3	0.6	0.7	3.4	2.1	1.3
1 May	2.0	0.7	1.3	6.1	5.3	0.8
2 May	1.7	0.8	0.8	4.6	3.9	0.7
3 May	1.5	0.6	0.9	5.5	5.5	0.1
4 May	1.1	0.7	0.4	4.5	2.0	2.5
5 May	1.3	0.7	0.6	4.2	2.0	2.3
7 May[a]						
Mean	1.5	0.7	0.7	3.8	3.0	0.8
SE[b]	0.1	0.1	0.1	0.3	0.3	0.2
Coho salmon						
16 May	1.2	0.5	0.7	2.6	2.0	0.5
17 May	1.6	0.3	1.3	3.1	2.3	0.8
18 May	1.2	0.4	0.8	2.6	2.2	0.5
21 May	1.1	0.7	0.5	2.3	1.8	0.6
23 May	1.3	0.4	0.9	2.1	1.5	0.6
Mean	1.3	0.5	0.8	2.6	2.0	0.6
SE	0.1	0.1	0.1	0.2	0.1	0.1

[a] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[b] SE = Standard Error of the Mean.

Table 17. Minimum and median travel time (TT) to the Chandler facility for yearling chinook and coho salmon released 1 km above Prosser Dam (Forebay) or at the headworks of the Chandler Canal (Canal) in 1992.

Release date	Forebay Minimum TT (hours)	Canal Minimum TT (hours)	Forebay - Canal (hours)	Forebay Median TT (hours)	Canal Median TT (hours)	Forebay - Canal (hours)
Yearling chinook salmon						
3 April	2.1	1.0	1.0	13.5	13.6	-0.2
4 April	2.3	1.0	1.3	14.3	14.3	0.0
5 April	1.7	1.0	0.6	11.2	15.2	-4.1
6 April	1.9	1.1	0.9	14.9	14.8	0.1
7 April[a]						
14 April	3.4	1.7	1.6	39.7	37.3	2.3
16 April	2.6	1.5	1.1	10.8	8.8	1.9
18 April	2.4	1.5	0.9	4.3	3.4	0.9
20 April	2.5	1.5	1.0	4.6	4.3	0.3
21 April	2.3	2.0	0.3	5.0	5.2	-0.1
22 April	2.9	2.0	0.9	5.3	6.1	-0.9
12 May[a]						
13 May	6.0	4.1	1.9	7.4	7.8	-0.4
21 May	4.2	1.5	2.6	6.7	4.8	1.9
22 May	3.2	2.8	0.4	9.5	9.1	0.4
23 May	3.1	1.6	1.5	13.9	68.3	-54.4
27 May	2.3	1.2	1.1	5.8	6.4	-0.5
2 June	3.7	2.5	1.2	7.5	8.9	-1.4
3 June	2.1	1.3	0.8	6.4	7.3	-1.0
4 June	2.4	1.9	0.5	4.7	5.3	-0.5
Mean	2.8	1.7	1.1	9.5	8.1	-0.1
SE[b]	0.2	0.2	0.1	2.0	1.9	0.4
Coho salmon						
28 April	2.5	1.6	0.8	4.1	3.8	0.2
29 April	2.6	1.7	1.0	6.0	5.5	0.5
30 April	2.3	1.8	0.4	3.6	3.5	0.0
5 May	2.4	1.9	0.5	3.9	3.3	0.6
6 May	2.4	1.9	0.5	3.8	3.3	0.5
7 May	2.3	1.8	0.4	3.9	3.6	0.4
Mean	2.4	1.8	0.6	4.2	3.9	0.4
SE	0.1	0.1	0.1	0.4	0.3	0.1

[a] No estimates calculated due to Chandler facility PIT-tag detector malfunction.
[b] SE = Standard Error of the Mean.

In 1991, the median Chandler Canal-released yearling chinook and coho salmon reached the Chandler facility main PIT-tag detector with means of 3.0 (SE = 0.3) and 2.0 hours (SE = 0.1), respectively. This was a mean of 0.8 (SE = 0.2) and 0.6 hours (SE = 0.1) faster than the median Prosser Dam forebay-released fish (Table 16). Median travel time for Chandler Canal-released coho salmon in 1992 averaged 3.9 hours (SE = 0.3) which was 0.4 hours (SE = 0.1) faster than Prosser Dam forebay-released fish (Table 17). Median travel time characteristics for 1992 yearling chinook salmon were more complex. Between R1 and R2 releases, the median travel time was nearly the same to get to the Chandler facility (the median travel time difference averaged 0.4 hours (SE = 0.4)). However, average travel times changed over the migration season, as early in April both groups took 11-15 hours, but from mid-April through early June both groups mostly took 3-10 hours. Also, on two occasions median travel times were unexplainably much longer than usual, at nearly 40 hours for both 14 April groups and at 14 and 68 hours for R1 and R2 groups, respectively, on 23 May. Close examination of the PIT-tag observation data for these groups did not adequately reveal any data errors (such as the PIT-tag detector problems described in Appendix 2).

The time between minimum and median detection at the Chandler facility main PIT-tag detector was generally only a few hours. Also, on average, fish released to the Prosser Dam forebay passed the Chandler facility up to an hour or so later than fish released to the Chandler Canal. Therefore, any period of time in the hours following release in which the PIT-tag detector was inoperative or malfunctioned would have affected the R1 and R2 groups differently. This was evidenced for the three release days described in Appendix 2. The observation of significant

bias in statistical estimates as a result of non-random PIT-tag detection problems underscored the need for highly reliable and stable PIT-tag detection systems and careful documentation of detector problems.

McNary Dam

In 1991, median travel times from release to primary detection at McNary Dam were fairly similar between releases within days but varied substantially over time and between species (Table 18). Median travel time for yearling chinook salmon in April and May averaged 10.7 (SEs averaged 0.5 days) and 6.2 days (SEs averaged 0.2 days), respectively, while median travel time for coho salmon later in May averaged 3.2 days (SEs all 0.1 days). The maximum difference between groups released on the same day ranged from 0.4 to 2.9 days. Only two median travel time maximum differences were in excess of 2 days: the R2 release group median travel time was over 2 days longer than all groups on 22 April, and both the R1 and R2 group median travel times were over 2 days longer than the R3 group on 23 April.

McNary Dam 1991 passage distributions for yearling chinook salmon were quite protracted in April, encompassing 3 to 4 weeks; they were somewhat shorter in early May at around 2 weeks. Coho salmon passage distributions later in May were quite compact, with most fish passing in 3 to 4 days (Appendix Tables 3a-3d).

Median travel times from release to primary detection at McNary Dam in 1992 were somewhat variable between releases within days and varied considerably over time and between species (Table 19). For yearling chinook salmon in early April, median travel times were fairly consistent and averaged 16.6 days (SEs averaged 0.2 days). Maximum differences between groups released on the same day ranged from 0.8 to 2.0 days, but the groups with the longest and

Table 18. Median travel time (TT) to McNary Dam in 1991 of yearling chinook and coho salmon released approximately one km upstream from Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4).

Release date	R1 Median TT (days)	R2 Median TT (days)	R3 Median TT (days)	R4 Median TT (days)	Maximum Difference (days)
Yearling chinook salmon					
14 April	11.8	12.9	11.8	12.9	1.1
15 April	10.2	11.0	11.9	10.9	1.7
16 April	11.2	11.9	10.9	11.8	1.0
17 April	10.7	11.3	10.5	11.3	0.8
22 April	6.9	9.7	7.3	6.8	2.9
23 April	9.8	10.3	7.5	8.8	2.8
24 April	10.9	10.7	10.4	11.4	1.0
25 April	11.7	11.7	10.0	11.2	1.7
26 April	11.0	11.8	10.9	11.8	0.9
Mean	10.5	11.2	10.1	10.8	1.5
SE[a]	0.5	0.3	0.6	0.6	0.3
1 May	7.4	7.2	6.8	6.8	0.6
2 May	6.8	6.9	6.8	6.1	0.8
3 May	6.3	6.1	5.9	5.4	0.9
4 May	6.0	5.9	5.8	5.6	0.4
5 May	6.6	6.0	5.4	5.0	1.6
7 May	5.8	6.6	5.4	6.0	1.2
Mean	6.5	6.4	6.0	5.8	0.9
SE	0.2	0.2	0.3	0.3	0.2
Coho salmon					
16 May	3.8	3.8	3.1	3.1	0.7
17 May	3.4	3.7	3.3	3.2	0.5
18 May	3.3	3.4	2.6	2.7	0.8
21 May	3.4	3.2	3.0	2.6	0.8
23 May	3.1	3.5	2.9	2.8	0.7
Mean	3.4	3.5	3.0	2.9	0.7
SE	0.1	0.1	0.1	0.1	0.1

[a] SE = Standard Error of the Mean.

Table 19. Median travel time (TT) to McNary Dam in 1992 of yearling chinook and coho salmon released approximately one km upstream from Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), at the I-82 bridge, or immediately below the main PIT-tag detector in the Chandler facility (R6).

Release date	R1 Median TT (days)	R2 Median TT (days)	R3 Median TT (days)	R4 Median TT (days)	R5 Medain TT (days)	R6 Median TT (days)	Maximum Difference (days)
Yearling chinook salmon							
3 April	16.6	16.8	16.7	16.0	16.7	[a]	0.8
4 April	17.4	16.8	16.9	15.7	15.8		1.7
5 April	16.4	17.7	15.7	16.0	17.0		2.0
6 April	16.9	15.9	16.9	17.0	17.0		1.1
7 April	15.9	17.8	16.9	16.7	16.8		1.9
Mean	16.6	17.0	16.6	16.3	16.7		1.5
SE[b]	0.3	0.3	0.2	0.2	0.2		0.2
14 April	11.7	14.0	11.2	11.7	12.0		2.8
16 April	11.6	12.9	9.7	11.9	10.0		3.2
18 April	9.0	8.9	8.4	9.9	10.5		2.1
20 April	10.2	10.7	9.9	10.4	10.6	9.8	0.9
21 April	9.9	10.7	9.8	9.9	9.8	10.8	1.0
22 April	9.8	9.9	9.8	9.4	9.7	9.9	0.5
Mean	10.4	11.2	9.8	10.6	10.4	10.2	1.8
SE	0.4	0.8	0.4	0.4	0.3	0.3	0.5
12 May	31.1	32.5	20.8	28.7	30.5		11.7
13 May	28.9	30.0	27.8	29.2	29.4		2.2
21 May	23.7	25.1	23.8	22.5	25.5		3.0
22 May	27.0	21.7	24.5	23.3	22.9		5.1
23 May	21.2	35.1	21.3	22.8	24.3		14.1
27 May	26.1	22.3	18.5	17.9	21.7		8.2
Mean	26.3	27.8	22.8	24.1	25.7		7.4
SE	1.4	2.3	1.3	1.7	1.4		2.0
28 April	4.7	4.6	4.5	4.5	4.7	4.8	0.3
29 April	5.7	5.7	4.9	4.8	5.4	5.6	0.9
30 April	4.8	4.8	4.6	4.6	4.6	4.7	0.2
5 May	5.8	6.0	5.8	5.7	5.6	5.9	0.4
6 May	5.6	5.9	5.2	5.3	5.0	5.0	0.9
7 May	5.6	5.8	5.4	4.9	5.0	5.1	0.9
Mean	5.3	5.5	5.1	5.0	5.0	5.2	0.6
SE	0.2	0.2	0.2	0.2	0.2	0.2	0.1

[a] Blanks indicate no releases were made.
[b] SE = Standard Error of the Mean.

shortest median travel times varied daily. Median travel times for the same species in mid-April decreased to an average of 10.4 days (SEs averaged 0.4 days). Maximum differences ranged between 0.5 and 3.2 days, with R2 and R3 groups typically having the longest and shortest median travel times, respectively. Median travel times for the other groups were very similar and generally midway between the R2 and R3 groups. In late April to early May, median travel times for coho salmon were very consistent over time and release locations (range of all groups was only 4.5-6.0 days) and averaged 5.2 days (SEs averaged 0.2 days). Maximum differences between median travel times within a release day ranged from 0.2 to 0.9 days. Finally, yearling chinook salmon in May had quite long and highly variable median travel times (range 17.9-35.1 days), averaging 25.3 days (SEs averaged 1.7 days). Maximum differences between same-day release groups ranged from 2.2 to 14.1 days, with the R1 and R2 groups generally having the longest median travel times. The highly variable and lengthy median travel times were the result of small sample sizes and unusual passage distributions at McNary Dam (Appendix Table 3i). There were very few detections recorded for these groups in late May and early June.

McNary Dam 1992 passage distributions for yearling chinook salmon were quite protracted in April, encompassing over 2 to 3 weeks. Coho salmon passage distributions in late April and early May were fairly compact but heavily right-tailed, with most fish passing in 4 to 5 days but with the rest spread over more than an additional week later. The two yearling chinook salmon early May passage distributions were nearly bimodal with about half of the detections between 18 and 31 May and most of the rest after 10 June. The final May groups had scattered McNary Dam passage distributions with most detections after 10 June (Appendix Tables 3e-3i).

SUMMARY

1. In general, assumptions of the statistical methodology used in the 1991 and 1992 studies were not violated, and maximum likelihood estimates (MLEs) derived were deemed valid.
2. For yearling chinook and coho salmon in 1991 and 1992, significant mortality occurred in the Prosser Dam and Chandler facility system only for fish passing through the Chandler Canal and facility. For much of the time and for most conditions tested, this mortality was estimated at approximately 7-16 and 11% for yearling chinook and coho salmon, respectively. However, after mid-May 1992, when Chandler Canal water temperatures exceeded 15°C (59°F) and water flow was less than 30.0 cms (1060 cfs), yearling chinook salmon mortality increased significantly to 63%. Avian predation at the Chandler facility outfall may have contributed to this mortality (personal observations of the authors and Chandler facility staff) but its effect was not assessed in these studies. Only 5 valid tests were conducted in this time period for yearling chinook salmon and only 11 total tests were conducted for coho salmon.
3. The relationship between proportion of water flow diverted into the Chandler Canal (Fl) and proportion of fish entrained into the canal (Fi) for yearling chinook salmon was high ($R^2 = 0.86$), but for coho salmon was low ($R^2 = 0.23$). Further, predicted entrainment estimates had fairly low precision, did not cover all possible flows, and required adjustment for expected Chandler Canal-to-facility survival.

4. Expanded detection proportion estimates of Chandler Canal survival were quite similar to the maximum likelihood estimates, and the EDP method can be used in future studies as long as the efficiency of the Chandler facility main PIT-tag detector can be estimated.

5. Relative recapture estimates of the Chandler Canal fish entrainment proportion were quite similar to the maximum likelihood estimates, and the RR method can be used in future studies as long as 100% survival can be assumed in the Prosser Dam forebay.

6. The efficiency of the Chandler facility main PIT-tag detector was estimated as exceeding 95% over both studies. However, there were at least three occasions when the detector was apparently inoperative for several hours, and these malfunctions seriously compromised detection data for study fish released during those times.

7. Most of the PIT-tagged fish released in the Prosser Dam forebay and the Chandler Canal passed the Chandler facility in a few hours. Median travel times to McNary Dam decreased over time from as long as 17 days in early April to as short as 6 days in early May for yearling chinook salmon and from 5 days in early May to 3 days in late May for coho salmon.

RECOMMENDATIONS

1. If precise survival estimates in the Yakima River system are required, additional survival studies over broad ranges of environmental conditions should be conducted to clarify and substantiate the results obtained in the 1991 and 1992 studies. A primary objective should be assessment of mortality factors related to passage through the Chandler Canal and facility.

2. Further Chandler Canal fish entrainment proportion estimates are necessary to improve the precision and accuracy of the estimated fish/flow entrainment relationship.

3. High efficiency of the Chandler facility PIT-tag detection system should be maintained and detector malfunctions or downtime should be fully documented.

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APPENDIX 1

Initial estimates for the iterative likelihood models used in these studies were obtained using method-of-moment (MOM) estimators. MOM estimators were derived by setting the detection history totals equal to their expected values and then solving the equations simultaneously for the various parameters (Hogg and Craig 1978). The MOM estimators presented below applied to the 1991 experimental design. Some of the 1992 MOM estimators were identical to the 1991 estimators, while others were somewhat different as they incorporated information from additional release locations R5 and R6 (as defined in the text). The resulting MOM estimates from the observed data are presented in Appendix Tables 6 and 7.

The parameter notation for the following equations were defined in the text. Parameters were uppercase while MOM estimators were lowercase. The detection history totals were defined as x_{ijk}, where ijk were the detection histories defined in the text. Although the sizes of the release groups on the same day were not always equal (i.e., due to slightly different tagging and mortality numbers), they were similar enough that they were assumed equal for algebraic simplicity in solving the MOM equations, and the average release number, R, was used.

The following equations were used to obtain MOM estimators for 1991 (Note that detection totals x_{i00} were not needed to obtain the solutions):

$$
\begin{aligned}
x_{111} &= R\, S_1\, D\, S_2\, P\, S_a\, S_{m1} \\
x_{110} &= R\, S_1\, D\, S_2\, P\, (1 - S_a\, S_{m1}) \\
x_{101} &= R\, S_1\, S_{m1}\, (D\, S_2\, (1\text{-}P)\, S_a + (1\text{-}D)\, S_3) \\
x_{211} &= R\, S_2\, P\, S_a\, S_{m1} \\
x_{210} &= R\, S_2\, P\, (1 - S_a\, S_{m1}) \\
x_{201} &= R\, S_2\, (1 - P)\, S_a\, S_{m1} \\
x_{31} &= R\, S_3\, S_{m1} \\
x_{41} &= R\, S_{m1}
\end{aligned}
$$

The MOM estimators for the initial 1991 maximum likelihood iterative estimates were then derived as:

$$
\begin{aligned}
s_{m1} &= x_{41} / R \\
s_3 &= x_{31} / x_{41} \\
p &= x_{211} / (x_{201} + x_{211}) \\
s_2 &= (x_{210} + x_{211}) / Rp \\
s_a &= x_{211} / ((x_{210} + x_{211})\, s_{m1}) \\
d &= 1 / ((((x_{101} + x_{111})/x_{111}) - (1 / p))\,(x_{211} / x_{31}) + 1) \\
s_1 &= (x_{110} + x_{111}) / D\,(x_{210} + x_{211})
\end{aligned}
$$

APPENDIX 2

Maximum Likelihood estimates for S1, S2, P, and Chandler facility travel times for 7 May 1991, 7 April 1992, and 12 May 1992 were different from the estimates for all other release days. The differences were substantial and similar between days. PIT-tag detections through time at the Chandler facility main PIT-tag detector were examined for these three and adjacent days. In all three cases, initial detections for R1 and R2 releases were much later than other days. Also, the two groups were detected together while on other release days, R2 fish were generally detected ahead of R1 fish. Following are detailed descriptions of the differences discussed above for the three affected release days. Comparisons involve only yearling chinook salmon releases.

7 May 1991

1. The average S1 estimate was 0.99. The 7 May S1 estimate was 1.12 and was the only estimate over 1.03. The average S2 estimate was 0.97. The 7 May S2 estimate was 0.77 and was the only estimate below 0.90. The average P estimate was 0.98. The 7 May P estimate was 0.60 and was the only estimate below 0.95.
2. For R1 and R2 fish released on 7 May, 88 and 108 were not detected at the Chandler facility, respectively. The maximums for other R1 and R2 releases in May were 23 and 15, respectively.
3. Minimum travel times for R1 and R2 fish released on 7 May were 2.4 and 2.7 hours, respectively. Other release days averaged 1.5 and 0.7 hours, respectively. The difference

between median travel times for R1 and R2 fish released on 7 May was -0.6 hours. Other release days averaged 0.8 hours.

7 April 1992

1. The average April S1 estimate was 0.98. The 7 April S1 estimate was 1.12 and was the only estimate over 1.03. The average April S2 estimate was 0.93. The 7 April S2 estimate was 0.82 and was the only estimate below 0.87. The average April P estimate was 0.97. The 7 April P estimate was 0.72 and was the only estimate below 0.95.
2. For R1 and R2 fish released on 7 April, 47 and 61 were not detected at the Chandler facility, respectively. The maximums for other R1 and R2 releases in April were 31 and 17, respectively.
3. Minimum travel times for R1 and R2 fish released on 7 April were 8.4 and 8.8 hours, respectively. Other release days averaged 2.8 and 1.7 hours, respectively. The difference between median travel times for R1 and R2 fish released on 7 April was -55.9 hours. Other release days averaged 0.4 hours.

12 May 1992

1. The average May S1 estimate was 1.06. The 12 May S1 estimate was 1.45 and was the only estimate over 1.11. The average May S2 estimate was 0.58. The 12 May S2 estimate was 0.31 and was the only estimate below 0.48. There were no May P estimates.
2. For R1 and R2 fish released on 12 May, 76 and 84 were not detected at the Chandler facility, respectively. The maximums for other R1 and R2 releases in May were 65 and 63, respectively.

3. Minimum travel times for R1 and R2 fish released on 12 May were 6.0 and 6.2 hours, respectively. Other release days averaged 2.8 and 1.7 hours, respectively. The difference between median travel times for R1 and R2 fish released on 12 May was -5.3 hours. Other release days averaged 0.4 hours.

Appendix Table 1a. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam in April 1991 and detected (D) or not detected (ND) at the Chandler facility.

Passage Date	Release Date 14 April D	14 April ND	15 April D	15 April ND	16 April D	16 April ND	17 April D	17 April ND	22 April D	22 April ND	23 April D	23 April ND	24 April D	24 April ND	25 April D	25 April ND	26 April D	26 April ND
18 April	2																	
19 April	2			1														
20 April			1	4	1													
21 April		1	1	2	1													
22 April			6	5	4	3		2										
23 April	4	3	5	7	3		2	4										
24 April	1	1	2	2	5	5	4	1										
25 April	4	4	3	3	5	2	6	1	3									
26 April	6	2	2	6	3		7	3	6	7	1	1						
27 April	1	2	3	2	6	1	4	2	6	5	2	4						
28 April	2	1	1	2	3	1	5	1	12	5	7	7	2					
29 April	1	1		1	1	2	4	1	4	2	1	4	1	2		1		
30 April				1	2	2		1	3	1		1			3			
1 May	1	2	1	2	1	3	2	1	6	3	3	6	1	2	1	2		
2 May	2			2	1		3	2		1	1	3	3	5	3	1	4	
3 May			1		3	1	2	1	3	2	7	2	6	8	7	2	3	1
4 May	1		1	8	1	1	3	2	3	2	5	4	7	6	11	7	10	3
5 May	1	2	1	1	2	3	2		3	2	4	4	5	4	3	3	14	1
6 May			1	1	2			1	3	2	1	2	3	3	6	7	7	2
7 May		2				2	1		3	1	2	1	4	5	8	5	9	6
8 May			1	1			2			1		6	3	3	10	7	13	3
9 May					1	1				3	1	1	8	4	3	3	9	2
10 May			1				2				1	1	5	3		6	4	4
11 May			1								1		1		3	1		2
12 May													2		1		1	1
13 May			1			1		1	1		1	2			3	2	1	3
14 May	1													2	1	3	1	1
15 May														1			2	
16 May																	1	
17 May																	1	
18 May					1		2								1			
19 May	2													1				
20 May											1					1		
21 May																		
22 May																		
23 May																		
24 May																		
25 May									1									
Total	31	21	33	51	46	28	51	24	57	37	39	49	51	49	64	51	80	29

Appendix Table 1b. McNary Dam passage dates for yearling chinook and coho salmon released one km above Prosser Dam in May 1991 and detected (D) or not detected (ND) at the Chandler facility.

Passage Date	Release Date 1 May D	1 May ND	2 May D	2 May ND	3 May D	3 May ND	4 May D	4 May ND	5 May D	5 May ND	7 May D	7 May ND	16 May D	16 May ND	17 May D	17 May ND	18 May D	18 May ND	21 May D	21 May ND	23 May D	23 May ND
5 May	1																					
6 May	6		4		1																	
7 May	24	1	11		6																	
8 May	18	1	19		9	2	4	1	2													
9 May	15	1	15	1	21	1	27		11													
10 May	10	1	9		8	1	22		15		2	2										
11 May	7		8		10	1	9		11	1	13	4										
12 May	3		9		2	1	4		9		8	2										
13 May	5		3		3		8		10		10	6										
14 May	1		2		1	1	2		5		7	3										
15 May	2						6		3	1	5	3										
16 May	2		3		1	1	6		4		4	2										
17 May	1				3		1		2		2											
18 May	1		1						2			2										
19 May			1				1		6				15	4								
20 May						1							19		27	4	10					
21 May	2		1		2						1		6	2	13	2	22					
22 May											1		1		7		23					
23 May													3		2		4		3	1		
24 May													1				1		17	4		
25 May															1				19	2	5	2
26 May																			8	1	12	2
27 May										1					1					6	1	
28 May																	1				6	
29 May																						
30 May																					1	
31 May												1										
1 June																						
2 June																						
3 June					1																	
4 June																						
5 June													1		1							
6 June															2							
7 June															1				1			
28 June							1															
Total	98	4	86	1	68	9	91	1	80	2	54	25	46	6	54	7	61	0	48	8	30	5

Appendix Table 1c. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam in April 1992 and detected (D) or not detected (ND) at the Chandler facility.

Passage Date	Release Date 3 April D	3 April ND	4 April D	4 April ND	5 April D	5 April ND	6 April D	6 April ND	7 April D	7 April ND	14 April D	14 April ND	16 April D	16 April ND	18 April D	18 April ND	20 April D	20 April ND	21 April D	21 April ND	22 April D	22 April ND
8 April	1																					
9 April																						
10 April	1																					
11 April																						
12 April																						
13 April																						
14 April			4																			
15 April	5		5	2	3			1														
16 April	9		3		5		1		1													
17 April	4		1		4	1																
18 April	3		6		1		3															
19 April	3	1	3		4		2			1												
20 April	9	1	7		9		12		6	3												
21 April	3		4	1	8	2	2		5	2			1									
22 April	5		4		7	3	6		8	1	8	1	1		1							
23 April	2		3		8	2	11	1	9	3	7	3	12		8	2						
24 April	4		5		3		6		4		7	1	8		4							
25 April			3		2		3		3		1		3		6	2	3	1				
26 April	3				3	2	4				6		3		4	1	3					
27 April	1		3		4		2		4		1		2		2	2	3				2	
28 April			2				2			1	3		1		2	1	4		4		1	
29 April	1	1	4		1		5				2		5		3		8		8		2	
30 April			3				2		1	1	2		1		1		6	1	5	1	4	3
1 May			2		2		1			1	4		5		4		2	3	12	2	5	
2 May			2		1		2		3		7		3		1	2	5	2	3	3	9	
3 May			2		1		2		3	1	2		2		3		2	1	4		4	
4 May			1		1						1		4				4		2		5	
5 May										1			4		3		1		3	1	4	
6 May	1		1		2		1				1		1						1		1	
7 May									2		3				2		2		2	1		
8 May			1								1		1		4	1						
9 May										1			2						1		2	1
10 May															2		2	2	2		1	
11 May																					1	
12 May													2							1		
13 May															1							
18 May																	1					
19 May											1											
20 May															1							
Total	55	3	69	3	69	10	67	2	49	16	57	5	61	0	52	11	46	10	47	9	41	4

Appendix Table 1d. McNary Dam passage dates for coho salmon released one km above Prosser Dam in April and May 1992 and detected (D) or not detected (ND) at the Chandler facility.

Passage Date	Release Date 28 April D	28 April ND	29 April D	29 April ND	30 April D	30 April ND	5 May D	5 May ND	6 May D	6 May ND	7 May D	7 May ND
1 May	2						2					
2 May	14	3	3				5					
3 May	18	3	7		1		5		6			
4 May	8		17		15		7		8		2	
5 May	6		11		35	1	3		7		16	
6 May	3	1	11	1	13		2		2		9	
7 May	1		1		1		1		2		1	
8 May			4			1	2				2	
9 May	1		2		2				1			
10 May			3		1							
11 May	2	1	3		1							
12 May			4		1							
13 May												
14 May	1		1		1							
15 May												
16 May												
17 May									1		2	
18 May											2	
19 May											1	
20 May												
21 May							1		1		2	
22 May												
23 May										1	1	
24 May			1								1	
25 May												
26 May												
27 May											1	
28 May							1		1			
Total	56	8	68	1	71	2	29	0	29	1	40	0

Appendix Table 1e. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam in May and June 1992 and detected (D) or not detected (ND) at the Chandler facility.

Passage	Release Date 12 May		13 May		21 May		22 May		23 May		27 May		2 June		3 June		4 June	
Date	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
19 May																		
20 May		1	2			1												
21 May																		
22 May		1	1	1														
23 May		1																
24 May																		
25 May				1														
26 May			1															
27 May																		
28 May					1													
29 May																		
30 May - 7 June																		
8 June																		
9 June			1															
10 June		1	1															
11 June	4	1	1															
12 June	3	1	1	1					1									
13 June	1	1	2	1	2	1			2									
14 June	1				1		1											
15 June	2				1													
16 June			2															
17 June									1						1			
18 June	1	1			1		2											
19 June	1								1		1							
20 June	1		1		1										1			
21 June															1			
22 June															1			
23 June					1													
24 June																		
25 June															1			
26 June																		
27 June																		
28 June															1		1	
29 June																		
30 June																		
1 July																		
2 July													1				1	
3 July													1			1		
4 July															1			
Total	14	8	13	4	8	2	3	0	5	0	1	0	2	0	7	1	2	0

Appendix Table 2a. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in April 1991 and sampled (S) or not sampled (NS) at the Chandler facility.

Passage	Release Date 14 April		15 April		16 April		17 April		22 April		23 April		24 April		25 April		26 April	
Date	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
18 April		4																
19 April		4																
20 April		3		3		1												
21 April		2	1	4		2												
22 April	1	1	2	12	3	5	1	2										
23 April	3	4		11	4	7	1	3										
24 April	1	3	1	9	4	9	1	5										
25 April	1	10	1	11		9	3	10		4								
26 April	2	8	2	7	5	8	8	9	1	9		1						
27 April		3	3	6		9	4	6	4	12		7						
28 April	1	7	1	3	2	7	2	6	8	11	5	7		2				
29 April	2	2	1	3	1	4	5	3	3	7	1	3	1	6	1	1		
30 April	1	1	1	4	1	2		1	1	4	1	2	1		3	2		
1 May	3	6		7	3	2	3	5	4	8	4	5	4	6	2	1		1
2 May	1	2		1	1	3	1	4	2	2	5	4	4	5	5	3	4	
3 May	1	2		5	2	6		4	4	5	7	9	4	12	11	2	8	5
4 May	1	3	1	3	1	1	5	2	6	5	7	8	6	9	12	10	16	4
5 May	1			2		5	1	7	3	7	3	7	8	12	9	2	16	7
6 May		1	1	2	1	6	2	1	1	4	3	5	2	10	9	3	11	9
7 May			1			4		3	1	4	3	5	2	6	15	12	11	9
8 May				1		3		2	1	3	2		7	5	11	9	22	9
9 May		1			1	1	1	1		1		3	3	8	6	6	19	8
10 May				1		1	2		1			3	3	6	2	1	10	4
11 May				2				1				2		1	3	3	1	1
12 May						1							1	2	3		1	1
13 May				2						2		1	1		4	1	4	1
14 May		1					1		1	1					2		1	2
15 May				1										1	1		3	
16 May		1		1						1	1	1					1	
17 May				1													1	1
18 May						1	1	1							1	1		
19 May	1	1														1		
20 May												1						
21 May													1					
22 May																		
23 May																		
24 May																		
25 May										1								
Total	20	70	16	102	29	97	42	76	41	91	42	74	48	91	100	58	129	62

Appendix Table 2b. McNary Dam passage dates for yearling chinook and coho salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in May 1991 and sampled (S) or not sampled (NS) at the Chandler facility.

	Release Date																					
Passage	1 May		2 May		3 May		4 May		5 May		7 May		16 May		17 May		18 May		21 May		23 May	
Date	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
5 May	1																					
6 May	8	4		7		2																
7 May	20	28	6	18	1	11		1														
8 May	21	22	13	22	8	16	2	16		2												
9 May	11	17	20	16	15	25	13	37	1	19												
10 May	13	15	12	11	13	10	12	27	3	27		2										
11 May	8	4	5	12	7	10	5	18	4	20	1	15										
12 May	4	1	8	7	2	2	8	6	1	15	3	8										
13 May	6	4	2	3	3	5	5	8	4	10	2	18										
14 May	3	2		3		4	2	8	1	7	4	8										
15 May	2	2		1	1		3	7		12	5	4										
16 May	3		2	1	1	1	4	5	1	6	3	5										
17 May	1	1		2	1	3	1			4	1	3										
18 May	2			1		1			1	2												
19 May				1				2	2	4		2		38								
20 May				1								1	20	18	4	39		21				
21 May		2		2		2		1				1	13	3	19	19	1	38				
22 May												1	1	1	4	7	19	20				
23 May	1												1	4	4	3	6	1		12		
24 May													2	2	4		4	3	1	45		
25 May															1	1	1	1	12	26		6
26 May																	1		7	13		26
27 May												1										12
28 May																		1			12	2
29 May																					2	
30 May																					2	
31 May																						
1 June																						
2 June																						
3 June																						
4 June																						
5 June														1		1						
6 June															1	1			1			
7 June													1			1				1		
8 June																						
9 June															1							
10 June																						
11 June																		1				
16 June																						1
28 June								1														
Total	104	102	68	108	52	92	55	137	18	128	19	69	38	67	38	72	32	86	21	97	16	47

Appendix Table 2c. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in April 1992 and sampled (S) or not sampled (NS) at the Chandler facility.

Passage	Release Date																					
	3 April		4 April		5 April		6 April		7 April		14 April		16 April		18 April		20 April		21 April		22 April	
Date	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
8 April		1																				
9 April																						
10 April		4																				
11 April		1																				
12 April	2																					
13 April		2		1																		
14 April		2	2	3		1																
15 April	2	7	4	7	3	3		2														
16 April	5	10	1	6	1	5		2		1												
17 April	4	3	1	2	3	3	1	2														
18 April	2	1	3	5	1	1	2	2														
19 April	1	2	2	5	2	9		6														
20 April	5	10	3	16	3	11	5	17	2	3				1								
21 April	2	6	3	8	2	7	3	6	3	5		1		1								
22 April	2	9	3	14	5	10	2	11	2	11	3	10	1	6	1	2						
23 April		4	4	7	6	11	3	16	6	7	3	11	5	10	3	13						
24 April	1	6	1	5	1	4	4	8	2	3	3	9	5	6		8		1				
25 April		1	1	3	1	5	2	4	2	4		2	1	4	2	8		5				
26 April	4	1			4	1	3	4		1	3	6		12	5	10	3	2		1		1
27 April	2			3	2	2	1	1	3	4	1	1		4	1	6	1	3	1	2		2
28 April		1	1	2	1		1	1	1	1	2	3		3		6		7	2	5		3
29 April		2	1	4		2	4	2			1	5	2	6	3	4	1	8	4	8	1	5
30 April			1	3		3		3		1	2	4	2	2	1	3	2	13	4	9	2	8
1 May				2	2	3	2	2		2	3	5	3	8	2	4	2	12	7	15	5	6
2 May	1		1	3	1	2		2		4	4	5	1	6	2	3	3	6	4	12	9	11
3 May	1			2	2	1	3	2	1	4	2	2	2	1	2	4	1	4	4	4	3	11
4 May				1		2		1		1		2	1	3			2	3	1	3	2	4
5 May		1			1					2		2	3	6	1	3		5	2	5	1	8
6 May	1			1		2	1					1		2			1	1		2		2
7 May										3	1	2		3		4		3		3		2
8 May				1							1			1	2	3		1		2		1
9 May													2	1			1			2		3
10 May											1			3		2		4	2	1	1	1
11 May									1			1						1		2		2
12 May												1		2	1			2			1	1
13 May																1						
14 May																						1
15 May																1				1		
16 May												1										
17 May																						
18 May																		1				
19 May											1											
20 May															1							
11 June												1										
Total	35	74	32	104	41	88	37	94	23	57	31	75	28	91	27	85	17	82	31	77	25	72

Appendix Table 2d. McNary Dam passage dates for coho salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in April and May 1992 and sampled (S) or not sampled (NS) at the Chandler facility.

Passage	Release Date 28 April		29 April		30 April		5 May		6 May		7 May	
Date	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
1 May		3										
2 May	6	24		3								
3 May	8	23	2	14		3						
4 May	4	12	9	23	3	30						
5 May	6	6	6	17	14	34						
6 May		5	6	10	3	20						
7 May	1		2		2	4						
8 May	1		4	4		1		3				
9 May		1		3	1	2		7				
10 May		1		4		2	6	6		10		
11 May	1	1	3	4		1	10	10	2	20		5
12 May			2	4		1	2	8	5	9	3	25
13 May				1			3	2	3	4	6	13
14 May		1		1		1	1	1	1	3		2
15 May							1	1	1		4	
16 May									1		2	2
17 May										1		3
18 May											1	3
19 May									1		1	
20 May												1
21 May						1		2	1			3
22 May												1
23 May									1			2
24 May				1		1			1	1		1
25 May												
26 May								1				1
27 May												2
28 May							1			1		
29 May										1		
6 June												1
7 June												2
8 June									1			
Total	27	77	34	89	23	101	24	41	18	50	17	67

Appendix Table 2e. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam or at the headworks of the Chandler Canal in May and June 1992 and sampled (S) or not sampled (NS) at the Chandler facility.

Passage	Release Date																			
	12 May		13 May		21 May		22 May		23 May		27 May		2 June		3 June		4 June	
Date	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
20 May				2														
21 May	1																	
22 May			1	1														
23 May																		
24 May	1		1															
25 May																		
26 May				1														
27 May				1														
28 May				1														
29 May		1																
30 May						1		1										
31 May																		
1-8 June			1															
9 June			1															
10 June				2	1													
11 June	1	3	1	2														
12 June	1	2	2	2						1								
13 June	1	2	2	5		4	1		1	1								
14 June		2		1	1	1		2										
15 June	1	1				2								1				
16 June			1	2		1												
17 June	1	1				1			1			1				1		
18 June		1				2		2										
19 June	1									1		1						
20 June		1		1	1							1				1		
21 June		1														1		
22 June						1								1		1		
23 June				1		1												
24 June																		
25 June																2		
26 June												1						
27 June																1		
28 June						1									1	1		1
29 June																2		
30 June														1				1
1 July																		
2 July														1				1
3 July														1				1
4 July																2		
18 July														1				
21 July														1				
Total	8	15	10	22	3	15	1	5	2	3	0	4	0	7	1	12	0	4

Appendix Table 3a. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4) from 14-17 April 1991. Medians are in bold.

Passage Date	Release Date 14 April R1	R2	R3	R4	15 April R1	R2	R3	R4	16 April R1	R2	R3	R4	17 April R1	R2	R3	R4
18 April	2	2	2													
19 April	2	2			1			2								
20 April		3	4		5	2	4	1	1							
21 April	1	2	3	2	3	4	4	3	1	1	1	4			1	
22 April		2	3	5	11	8	6	11	7	4		7	2	3	4	3
23 April	7	3	6	7	12	6	12	7	3	8	12	1	6	2	14	9
24 April	2	3	7	4	4	8	4	12	10	8	5	5	5	2	5	6
25 April	8	7	5	7	**6**	10	6	7	7	5	9	9	7	7	4	11
26 April	**8**	4	**6**	4	**8**	7	8	7	3	10	10	4	10	12	15	6
27 April	3	**2**	4	**8**	5	6	**4**	7	7	3	**8**	9	6	6	9	4
28 April	3	6	4	6	3	3	5	5	4	**6**	5	**3**	**6**	**3**	**11**	**4**
29 April	2	3	4		1	4	10	3	3	4	3	4	5	4	9	6
30 April		2	4	1	1	5		3	4	1		2	1	1		6
1 May	3	8		2	3	6	2	2	4	3	4	5	3	6	10	1
2 May	2	1	1	5	2	1	1	2	1	3	5	4	5	2	4	
3 May		3	4	4	1	4	2	9	4	5	1	2	3	2	4	7
4 May	1	3	4	2	9	3	4	3	2	1	4	2	5	4		5
5 May	3		1	2	2	1	5	3	5	3	3	4	2	6	4	6
6 May		1	1	4	2	2	3	2	2	5	2	7	1	3	4	1
7 May	2		2	1		2	3	1	2	4	3	1	1	2	2	2
8 May					2		2	1		3	3	1	2		4	2
9 May		1		2			2		2	1	1	3		2	2	1
10 May			1	2	1		1	1		1	2	1	2			2
11 May				1	1	1	1					2		1		1
12 May			1				1	1		1						1
13 May					1	1			1				1		1	1
14 May	1													1		
15 May						1						1			1	
16 May		1				1									1	
17 May				1		1										
18 May								1	1				2			
19 May	2															
Total	52	59	67	70	84	87	90	94	74	80	81	81	75	69	109	85

Appendix Table 3b. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4) from 22-26 April 1991. Medians are in bold.

Passage Date	Release Date 22 April R1	R2	R3	R4	23 April R1	R2	R3	R4	24 April R1	R2	R3	R4	25 April R1	R2	R3	R4	26 April R1	R2	R3	R4
25 April	3	1	3	2																
26 April	13	4	14	9	2		**8**	3												
27 April	11	10	12	13	6	5	11	6												
28 April	17	7	8	10	14	5	15	10	2		4	3			1					
29 April	**6**	6	**10**	7	5	3	6	10	3	6	4	3	1	2	2	3				
30 April	4	3	2	1	1	3	**3**	3		1	2	2	3	2	2	1				
1 May	9	6	8	6	9	6	**4**	7	3	9	8	7	3	2	6			1	5	
2 May	1	**4**	10	4	4	8	3	**14**	8	6	10	4	4	5	6	10	4		5	4
3 May	5	6	4	6	**9**	**9**	9	10	14	10	12	7	9	6	14	13	4	10	3	6
4 May	5	8	8	4	9	10	5	8	13	8	**8**	10	18	12	14	10	13	10	9	15
5 May	5	7	2	4	**8**	6	7	6	**9**	**15**	**12**	8	6	8	**11**	15	15	9	14	7
6 May	5	2	1	1	3	7	2	2	6	9	3	**9**	13	6	14	**8**	9	13	13	7
7 May	4	2	1		3	6	7	2	9	4	9	9	**13**	**19**	10	12	**15**	11	**17**	13
8 May	1	4	3	2	6	2		5	6	9	9	7	17	10	10	19	16	**19**	19	**22**
9 May	3	1	1	1	2	2	5		12	4	8	11	6	9	5	10	11	18	14	8
10 May		1	1		2	2			8	4	1	3	6	4	5	3	8	10	6	9
11 May			1		1	1		3	1		2	1	4	3	1	1	2	2	1	7
12 May			1	1					2	1	1	3	1	2	1	1	2	2	4	5
13 May	1	1			3					1		1	5	2	1	2	4	4	3	4
14 May		2	1						2		1		4	1	1	6	2	2	1	1
15 May									1	1				1	2	2	2	1		2
16 May		1				2						1					1			1
17 May											2					1	1	1	1	2
18 May							1						1	1						1
19 May				1					1					1	1					2
20 May					1								1						1	1
21 May				1						1										
22 May																				
23 May																				
24 May																				
25 May	1																			
Total	94	76	91	73	88	77	86	89	100	89	96	89	115	96	107	117	109	113	116	117

Appendix Table 3c. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4) from 1-7 May 1991. Medians are in bold.

Passage	Release Date 1 May				2 May				3 May				4 May				5 May				6 May			
Date	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
4 May																								
5 May	1		8	5																				
6 May	6	6	13	17	4	3	8	13	1	1	1	3												
7 May	25	24	30	17	11	13	17	26	6	6	17	21		1	2	6								
8 May	**19**	**25**	**19**	**21**	19	16	27	**23**	11	15	17	23	5	14	20	17	2		3	2				
9 May	**16**	14	12	18	**16**	**21**	**23**	16	**22**	**19**	**19**	**25**	27	23	28	32	11	9	23	24				
10 May	11	18	9	9	9	14	18	13	9	16	17	11	**22**	**18**	**20**	**21**	15	16	20	**25**	4	1	3	8
11 May	7	5	4	7	8	9	3	6	11	7	6	4	9	15	14	9	12	**13**	**16**	9	17	3	23	16
12 May	3	2	3	1	9	6	5	4	3	2	7	3	4	10	8	8	**9**	8	7	10	10	11	22	14
13 May	5	5	4	2	3	2	6	3	3	5	3	3	8	5	7	2	10	4	7	4	**16**	**18**	**10**	**14**
14 May	1	4	2	1	2	1	1	3	2	3		1	2	8	7	7	5	3	7	6	10	**9**	8	16
15 May	2	2	6	3		1	3	5		1	1	1	6	4	6	5	4	10	4	9	8	9	11	9
16 May	2	1	1		3		2	1	2	1	1		6	3	1	2	4	3	3	3	6	9	10	5
17 May	1	1	2	1		2	2	1	3	1	1		1		2	2	2	2	1	2	2	3	4	5
18 May	1	1			1		1	1		1						3	2	1		1	2	1		6
19 May				1	1								1	1		1	6			1		2	2	1
20 May			1			1			1						2			1		1		1	1	
21 May	2			1	1	1	1	1	2					1				1	1		1		2	2
22 May								1													1			
23 May		1													1									1
24 May																							1	1
25 May																			1					1
26 May																								
27 May																					1			
28 May																								
29 May																								
30 May																								
31 May																					1			
1 June																								
2 June																								
3 June											1													
28 June													1											
Total	102	109	114	104	87	90	117	117	76	78	91	95	92	103	118	115	82	71	93	97	79	67	97	99

Appendix Table 3d. McNary Dam passage dates for coho salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4) from 16-23 May 1991. Medians are in bold.

	Release Date																			
Passage	16 May				17 May				18 May				21 May				23 May			
Date	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
18 May		1	8	8																
19 May	19	23	**45**	**42**			1													
20 May	**19**	**19**	8	16	**31**	16	**28**	**33**	10	12	23	20								
21 May	8	10	2	6	15	**25**	20	16	**22**	**17**	**42**	**30**								
22 May	1		1		7	4	2	3	23	**16**	3	12								
23 May	3	2	1		2	5	3		4	3	4	4	4	9	11	24				
24 May	1	3	2			4	1	1	1	6	1		21	**29**	**30**	**39**				
25 May		1			1	1		1		2			**21**	20	15	9	7	1	11	8
26 May			1							1		1	9	12	5	3	**14**	15	**28**	**18**
27 May					1												7	**6**	8	8
28 May									1								6	**8**		
29 May							1											2		
30 May																	1	1		
31 May			1					1												
1 June			1																	
2 June																				
3 June																				
4 June																				
5 June	1				1															
6 June					2									1						
7 June		1			1								1							
8 June																				
9 June						1														
10 June																				
11 June										1										
12 June																				
13 June																				
14 June																				
15 June																				
16 June																		1		
28 June																				
Total	52	60	70	72	61	56	56	55	61	58	73	67	56	71	61	75	35	34	47	34

Appendix Table 3e. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), or at the I-82 bridge (R5) from 3-7 April 1992. Medians are in bold.

Passage	Release Date 3 April					4 April					5 April					6 April					7 April				
Date	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
8 April	1																								
9 April			2	1						2															
10 April	1	3		1	2				2	3															
11 April		1			1			1												1					
12 April		2	1	1						1															
13 April		2	2	1	1		1						1												
14 April		2	3	5	3	4	1	3	3	2		1	4	1	1			1							1
15 April	5	4	9	7	8	7	6	5	7	7	3	3	7	4	8	1	2	1		1				1	1
16 April	9	6	2	10	9	3	4	5	5	8	5	1	5	6	7	1	1	4	2	5	1		2		1
17 April	4	3	3	2	2	1	2	4	2	4	5	2	3	2	3		3	1	1	2			3	1	2
18 April	3		3	2	4	6	2	2	5	4	1	1	4	4	1	3	1	2	1	1				1	2
19 April	4		7	6	2	3	4	8	9	8	4	7	3	4	5	2	5	4	8	5	1	1	1	5	7
20 April	**10**	**6**	**10**	6	**10**	7	12	12	**16**	**10**	9	5	18	15	8	12	10	6	8	6	9	4	7	6	7
21 April	3	5	10	4	4	**5**	7	**12**	10	2	10	1	**3**	**5**	7	2	7	6	5	3	7	6	1	7	8
22 April	5	6	4	7	8	4	13	12	4	3	**10**	8	6	9	**6**	6	7	15	8	7	9	6	6	8	6
23 April	2	3	4	4	5	3	8	9	5	14	8	**11**	20	8	9	**12**	10	**10**	**14**	**8**	**12**	9	12	11	10
24 April	4	3	1	1		5	1	6	3	7	3	2	2	2	6	6	6	13	6	5	4	4	**10**	**4**	**6**
25 April		1	2		1	3	1	3	2	2	2	4				3	3	1	4	2	3	**5**	6	3	3
26 April	3	2	1	1	3			1	2	3	5	2	6		4	4	3	6		5		1	5	5	7
27 April	1	1	1	1		3		3	1	2	4		1		6	2	1		3	1	4	5	1	8	6
28 April		1		1		2	1	1	3	2		1	2	1	1	2		2	1	2	1	5	5	3	2
29 April	2	1	1	1	2	4	1		3	2	1	1		3	5	5	1	3	2	1		1	3	2	1
30 April			2	2	1	3	1			3		3		1	3	2	1	1	5	5	2	3	3	3	4
1 May			1	3	1	2		1	2	2	2	3	2	4	2	1	3	2	2	2	1	2	6	5	5
2 May		1			1	2	2	2	1		1	2		5	4	2		4	5	6	3	2	2	5	8
3 May		1		1	1	2		1		1	1	2		2	1	2	3	2	1	3	4	2	1	2	3
4 May					2	1					1	1	2	1	1		1	1	2	3		2	2	1	2
5 May		1	1		1			1	1	2		1	1		2			3	2	2	1	3	1	4	2
6 May	1					1			1		2			1	1	1			1				1		2
7 May																					2	1	1		2
8 May						1							1	1									2		
9 May																					1		1		
10 May																									
11 May																						1		1	
12 May																									
13 May													1										1		
Total	58	55	70	68	72	72	67	92	87	94	77	62	92	79	91	69	68	88	81	76	65	63	83	86	98

Appendix Table 3f. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), at the I-82 bridge (R5), or immediately below the main PIT-tag detector in the Chandler facility (R6) from 14-22 April 1992. Medians are in bold.

Passage	Release Date 14 April					16 April					18 April					20 April						21 April						22 April					
Date	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
17 April																																	
18 April				1																													
19 April			1	1	1																												
20 April		1	2	2			1		1																								
21 April		1	2	2	3	1		1	1	3			1																				
22 April	9	5	4	8	3	1	6	3	1	4	1	2	7	2	3																		
23 April	10	7	9	12	6	12	3	9	10	13	10	8	7	9	4						2												
24 April	8	5	11	3	7	8	3	6	4	3	4	4	5	5	7		1	2	5	1	3					2							
25 April	1	1	6	8	7	3	2	7	4	9	8	4	10	5	7	4	2	5	5	4	6			1	1	1	1						
26 April	6	3	4	11	4	3	9	9	7	5	5	11	6	6	9	3	2	7	6	6	7		1	2	7	3	1		1				1
27 April	1	1	3	3	3	2	2	1		5	4	5	7	7	1	3	1	4	6	3	4		3	2	5	4	2	2		2	3	3	3
28 April	3	2	2	1	2	1	2	4	1	4	3	4	1	3	8	4	3	4	3	5	7	4	3	3		2	2	1	2	1	3	5	3
29 April	2	4	1	3	3	5	3	2	5	5	3	4	5	6	6	8	1	11	2	8	7	8	4	8	12	6	4	2	4	4	4	2	4
30 April	2	4	5	3	3	1	3	6	2	3	1	4	8	4	5	7	10	3	3	7	10	6	8	12	6	11	6	7	7	6	6	2	7
1 May	4	4	1	5	2	5	6	2	6	1	4	2	4	7	5	5	12	7	9	13	4	14	10	4	7	15	8	5	6	14	18	8	8
2 May	7	2	3	4	5	3	4	1	3	3	3	4	2	5	5	7	4	6	9	4	7	6	13	7	12	10	9	9	11	9	12	18	9
3 May	2	3	2	2	1	2	1	1	2	2	3	3	2	3	4	3	3	4	2	3	3	4	4	5	7	5	6	4	10	9	6	10	7
4 May	1	1	2	1		4		3	2	2			1	3	2	4	1	3	1	4	6	2	2	4	2	5	4	5	1	3	3	7	3
5 May		2	1	1		4	5	1	2	4	3	1	2	2	3	1	4	5		2	1	4	4	2	2	3	3	4	5	4	6	1	5
6 May	1		4		5	1	1	3	1	2			3		2		2	1	3	3	3	1	1	3	3	4	3	1	1	5	4		6
7 May	3		1	1	1		3			1	2	2		1		2	1	1	6	2	3	3	1	1	3	1			2	5	1	4	3
8 May	1		2	1	3	1			1		5	1	1		1		1			1			2	2	1	2			1		2	1	2
9 May				1	1	2	1		1					2	2		1			3	2	1	1		2			3	1	1			
10 May		1	2	1	1		3	1	1	2	2				4	4	2	2			2	2	1	1	1	1	1	1	1	1		2	1
11 May		1		2					1	1							1	2	1	1	1		2		2	1		1	1			1	1
12 May		1	1			2		1				2					2		2	1	1	1		1			1		2			2	1
13 May											1								1					1			2			1			
14 May				1				1																1	1				1	1		1	
15 May			1									1											1			1							1
16 May		1							1	1											1			1		1							
17 May																									1							1	
18 May														1		1		1								1							
19 May	1																									1							
20 May											1																						
11 June		1																															
Total	62	51	70	78	61	61	58	62	57	73	63	62	72	71	78	56	54	68	64	71	80	56	61	61	75	80	60	45	57	66	69	68	65

Appendix Table 3g. McNary Dam passage dates for coho salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), at the I-82 bridge (R5), or immediately below the main PIT-tag detector in the Chandler facility (R6) from 28-30 April 1992. Medians are in bold.

Passage	Release Date 20 April						21 April						22 April					
Date	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
30 April												1						
1 May	2	1	3	2	2	1												
2 May	17	16	18	19	14	18	3		4	8	6	3					1	
3 May	**21**	**13**	**24**	**22**	**14**	**19**	7	9	13	18	9	9	1	2	4	7	8	3
4 May	8	8	3	8	10	7	17	15	**18**	**18**	14	12	15	18	21	23	22	10
5 May	6	6	7	3	5	5	**11**	**12**	7	7	**12**	**11**	**36**	**13**	**24**	**14**	**16**	**9**
6 May	4	2	2	3	3	5	12	5	4	8	4	8	13	10	8	10	12	8
7 May	1		1			1	1	1	1	1	1		1	5	4	3	2	
8 May		1	1	1	2		4	5	1		3	2	1	1	1	3	4	
9 May	1		1			1	2	1		1	2	1	2	1	1	2		
10 May		1		1		2	3	1	1		1	4	1	1			1	
11 May	3			1	1	1	3	4	1	3	3	2	1		1	1	1	3
12 May					1	2	4	2	4	2	3	1	1		1	3	2	2
13 May					2			1			1	1				1		
14 May	1						1						1				1	1
15 May						1												
16 May					1													
17 May				1	1				1							1		
18 May																		
19 May										1							1	
20 May																		
21 May												1		1				
22 May																		
23 May									2									
24 May							1							1				1
25 May																		
26 May			1															
27 May									1									
28 May																		
29 May																		
30 May															1			
11 June																		
Total	64	48	61	61	56	63	69	56	58	67	59	56	73	53	66	68	71	37

Appendix Table 3h. McNary Dam passage dates for coho salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), at the I-82 bridge (R5), or immediately below the main PIT-tag detector in the Chandler facility (R6) from 5-7 May 1992. Medians are in bold.

	Release Date																	
Passage	5 May						6 May						7 May					
Date	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
8 May	2	1	1		1													
9 May	5	2	13	11	13	10					3	1						
10 May	5	7	7	10	10	6	6	4	10	6	11	5			1			
11 May	**7**	**13**	**14**	**8**	**12**	**10**	8	14	**25**	**21**	**17**	**18**	2	3	7	8	13	10
12 May	3	7	9	8	8	7	7	7	14	14	16	7	16	13	**18**	**32**	**22**	**28**
13 May	2	3	2	5	3	3	2	5	6	3	1	5	**9**	**10**	9	6	8	16
14 May	1	1		1	1	3	2	2	1				1	1	3		2	1
15 May	2				1	1		1		1		1	2	2	2	1	1	1
16 May					1		1				1			4	4	1		1
17 May					1		1			1		1	2	1	2			2
18 May										1	1	1	2	2	3		1	
19 May					1	1		1		1			1			1		1
20 May			1											1		1	3	
21 May	1	1	2		1	3	1						2	1	1	1	1	
22 May			2	1										1				
23 May			1				1	1	1				1	1				1
24 May								2					1			1		1
25 May				1				1	1							1		
26 May		1				1			1					1				
27 May												1	1	1				
28 May	1						1											
29 May								1										
30 May									1									
31 May																		
1- 5 June																		
6 June										1				1				
7 June														2	1			
8 June																		
9 June								1										
10 June																1		
27 June												1						
Total	29	36	52	45	53	45	30	40	60	49	50	41	40	45	51	54	51	62

Appendix Table 3i. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), or at the I-82 bridge (R5) from 12-27 May 1992. Medians are in bold.

Passage	Release Date 12 May					13 May					21 May					22 May					23 May					27 May				
Date	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
18 May				1																										
19 May				1	1			1		1																				
20 May	1			2	1	2		2																						
21 May		1	1	3	2			1		3																				
22 May	1		2	1	3	2	1	3	3	1																				
23 May	1		2	2	1			3	4	4																				
24 May		1		3			1	2	2																					
25 May			1			1		5	2																					
26 May				2		1		1		4																				
27 May					1		1	4												1										
28 May				1	1		1	1																						
29 May					1			1							1															
30 May										1		1		1	1		1							1						
31 May			1										1	1									1							
1 June										1				1																
2 June											1			1																
3 June			1																											
4 June								1						1				1												
5 June							1											1												
6 June									1																					
7 June								1		1																				1
8 June									1																			1		
9 June					1	1			1					1				1												
10 June	1		2	3	4	1	1	2	3	4	1		1	1																
11 June	5		3	5	1	1	2	3	1	6			3		1			1	1				1	1					1	
12 June	4		7	3	2	2	3	2	5	4			1	2	2						1		1						1	1
13 June	2	2	6	2	7	3	5	4	4	7	3	2	4	2			1			2	2		2	1	1			2		
14 June	1	1	3	2	5		1	5		4	1	1		2	2	1	1		5	4								1	1	
15 June	2		1	2	2			5	1	2	1	1	5	2					2	1				3	1					1
16 June				1		2	1	2	1	1		1	1	1	3			3	1	1			2	1	2					
17 June		2		1				2		1		1	1	1	1			2			1		2				1			
18 June	2				1			1	2	1	1	1		1	2	2			1	2				1				1	1	1
19 June	1		2	1					1	2			2	1	1				1		1			1	1	1				1
20 June	1					1		1	2		1		1	1	1										1		1			
21 June		1			1				1					1																1
22 June												1																	1	1
23 June							1		1	1	1																			
24 June			1																	1										
25 June																												1		
26 June																														
27 June																						1			1					
28 June										1		1							1											
Total	22	8	33	36	35	17	19	53	36	50	10	10	20	21	15	3	3	9	12	12	5	1	9	9	7	1	2	6	5	7

Appendix Table 3j. McNary Dam passage dates for yearling chinook salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), or at the I-82 bridge (R5) in June 1992.

Passage Date	Release Date 2 June R1	R2	R3	R4	R5	3 June R1	R2	R3	R4	R5	4 June R1	R2	R3	R4	R5
14 June															
15 June		1													
16 June							1								
17 June						1									
18 June															
19 June															
20 June						1									
21 June						1									
22 June		1				1									
23 June															
24 June															
25 June		1				1	1			1					
26 June															
27 June							1								
28 June						1	1				1				
29 June							2								
30 June		1										1			
1 July														1	
2 July	1										1				
3 July	1					1						1			
4 July						1	1								
5 July															
6 July								1							
7 July														1	
8 July															
18 July		1													
21 July		1													
Total	2	6	0	0	0	8	7	1	0	1	2	2	0	2	0

Appendix Table 4. Detection history totals for PIT-tagged yearling chinook and coho salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), or at the Chandler facility outfall (R4) in 1991. Abbreviations: CHF-Chandler facility; MCN-McNary Dam; Det-Detected.

	R1				R2				R3		R4	
Release Date	Not Det	Det at CHF	Det at MCN	Det at Both	Not Det	Det at CHF	Det at MCN	Det at Both	Not Det	Det at MCN	Not Det	Det at MCN
Yearling chinook salmon												
14 April	35	63	21	31	2	88	0	59	83	67	80	70
15 April	58	58	51	33	6	107	2	85	110	90	106	94
16 April	34	92	27	47	2	118	0	80	118	82	119	81
17 April	33	92	24	51	9	122	1	68	91	109	115	85
22 April	49	57	37	57	11	113	0	76	109	91	127	73
23 April	71	41	49	39	15	107	0	77	113	87	111	89
24 April	50	50	49	51	4	107	1	88	103	97	112	89
25 April	64	46	51	64	8	121	0	96	117	108	107	118
26 April	37	78	29	80	6	105	1	112	109	116	108	117
1 May	9	114	4	98	12	104	0	109	111	114	121	104
2 May	13	125	1	86	6	129	0	90	108	117	108	117
3 May	14	110	9	67	10	112	1	77	106	94	105	95
4 May	13	145	1	91	5	142	2	101	132	118	135	115
5 May	7	111	2	80	7	122	4	67	107	93	103	97
7 May	63	58	25	54	80	53	28	39	103	97	101	99
Coho salmon												
16 May	15	108	6	46	6	109	1	59	107	69	103	72
17 May	18	121	7	54	3	141	0	56	144	56	145	55
18 May	9	130	0	61	4	138	1	57	127	73	133	67
21 May	31	113	8	48	1	128	1	70	139	61	125	75
22 May	28	137	5	30	7	159	1	33	153	47	166	34

Appendix Table 5. Detection history totals for PIT-tagged yearling chinook and coho salmon released one km above Prosser Dam (R1), at the headworks of the Chandler Canal (R2), immediately below Prosser Dam (R3), at the Chandler facility outfall (R4), at the I-82 bridge (R5), or immediately below the main PIT-tag detector in the Chandler facility (R6) in 1992. Abbreviations: CHF-Chandler facility; MCN-McNary Dam; Det-Detected.

	R1				R2				R3		R4		R5		R6	
Release Date	Not Det	Det at CHF	Det at MCN	Det at Both	Not Det	Det at CHF	Det at MCN	Det at Both	Not Det	Det at MCN	Not Det	Det at MCN	Not Det	Det at MCN	Not Det	Det at MCN
Yearling chinook salmon																
3 April	14	52	3	55	7	63	1	54	55	70	57	68	53	72	0	0
4 April	16	87	3	69	18	88	0	67	83	92	87	87	81	94	0	0
5 April	16	57	10	67	4	88	0	62	56	92	71	79	59	91	0	0
6 April	11	70	2	67	14	68	3	65	62	88	69	81	74	76	0	0
7 April	31	54	16	49	44	42	17	46	66	83	64	86	52	98	0	0
14 April	14	48	5	57	12	62	1	50	55	70	47	78	63	61	0	0
16 April	15	47	0	61	8	58	0	58	60	62	65	57	51	73	0	0
18 April	17	45	11	52	7	56	2	60	52	72	54	71	47	78	0	0
20 April	21	48	10	46	16	54	0	54	51	68	61	64	54	71	45	80
21 April	14	55	9	47	10	53	0	61	64	61	50	75	45	80	65	60
22 April	23	50	4	41	13	55	1	56	56	66	56	69	57	68	60	65
12 May	68	31	8	15	84	29	0	8	78	33	85	36	84	35	0	0
13 May	61	46	4	13	61	44	0	19	72	53	89	36	71	50	0	0
21 May	35	79	2	8	38	77	0	10	101	20	104	21	103	15	0	0
22 May	58	63	0	3	63	56	0	3	114	9	112	12	107	12	0	0
23 May	58	61	0	5	62	59	1	0	115	9	115	9	118	7	0	0
27 May	32	91	0	2	32	88	0	2	119	6	119	5	118	7	0	0
2 June	63	58	0	2	52	65	1	5	123	0	122	0	114	0	121	0
3 June	66	47	1	7	65	52	1	6	118	1	122	0	122	1	119	0
4 June	83	27	0	2	72	45	0	2	112	0	112	2	118	0	123	0
Coho salmon																
28 April	9	51	8	56	6	71	0	48	64	61	64	61	68	56	62	63
29 April	6	50	1	68	8	55	1	55	65	58	58	67	65	59	68	56
30 April	1	48	2	71	2	70	0	53	58	66	57	68	51	71	47	37
5 May	3	93	0	29	3	86	0	36	73	52	80	45	72	53	80	45
6 May	9	86	1	29	5	80	1	39	65	60	76	49	75	50	84	41
7 May	6	79	0	40	3	77	1	44	74	51	71	54	74	51	63	62

Appendix Table 6. Method-of-moment initial parameter estimates for iterative maximum likelihood analyses in 1991. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; SM1-Chandler facility outfall to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility.

Release Date	S1	S2	S3	SM1	D	SA	P
Yearling chinook salmon							
14 April	1.021	0.987	0.957	0.467	0.626	0.860	1.000
15 April	1.155	0.983	0.957	0.470	0.410	0.942	0.977
16 April	1.095	0.990	1.012	0.405	0.641	0.998	1.000
17 April	0.967	0.964	1.282	0.425	0.779	0.842	0.986
22 April	0.930	0.945	1.247	0.365	0.648	1.102	1.000
23 April	0.918	0.925	0.978	0.445	0.473	0.940	1.000
24 April	0.964	0.986	1.090	0.443	0.537	1.019	0.989
25 April	0.866	0.964	0.915	0.524	0.585	0.844	1.000
26 April	0.977	0.977	0.991	0.520	0.746	0.993	0.991
1 May	1.034	0.947	1.096	0.462	0.962	1.107	1.000
2 May	0.977	0.973	1.000	0.520	0.991	0.790	1.000
3 May	1.030	0.957	0.989	0.475	0.910	0.858	0.987
4 May	0.964	0.991	1.026	0.460	1.008	0.904	0.981
5 May	0.985	1.001	0.959	0.485	1.026	0.731	0.944
7 May	1.093	0.790	0.980	0.495	1.114	0.856	0.582
Coho salmon							
16 May	1.006	0.976	0.958	0.411	0.912	0.854	0.983
17 May	1.003	0.985	1.018	0.275	0.885	1.034	1.000
18 May	0.966	0.992	1.090	0.335	1.014	0.873	0.983
21 May	0.955	1.004	0.813	0.375	0.851	0.943	0.986
22 May	0.953	0.989	1.382	0.170	0.913	1.011	0.971

Appendix Table 7. Method-of-moment initial parameter estimates for iterative maximum likelihood analyses in 1992. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; S4-Chandler facility outfall to the I-82 bridge survival; SM2-I-82 bridge to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility.

Release Date	S1	S2	S3	S4	SM2	D	SA	P
Yearling chinook salmon								
3 April	0.940	0.953	1.029	0.944	0.576	0.973	0.848	0.982
4 April	1.038	0.896	1.057	0.926	0.537	0.969	0.865	1.000
5 April	0.910	0.974	1.165	0.868	0.607	0.909	0.785	1.000
6 April	1.018	0.928	1.086	1.066	0.507	1.012	0.905	0.956
7 April	1.130	0.813	0.965	0.878	0.653	1.024	0.901	0.730
14 April	0.983	0.914	0.897	1.279	0.492	0.954	0.715	0.980
16 April	0.931	0.935	1.088	0.781	0.589	1.000	1.070	1.000
18 April	0.960	0.959	1.014	0.910	0.624	0.871	0.911	0.968
20 April	1.021	0.871	1.063	0.901	0.568	0.853	0.977	1.000
21 April	1.057	0.927	0.813	0.938	0.640	0.839	0.884	1.000
22 April	0.875	0.904	0.957	1.015	0.544	0.937	0.914	0.982
12 May	1.399	0.306	0.944	1.029	0.294	0.889	0.727	1.000
13 May	1.040	0.508	1.472	0.720	0.413	0.901	1.047	1.000
21 May	1.125	0.696	0.952	1.400	0.127	0.889	0.684	1.000
22 May	1.119	0.484	0.750	1.000	0.101	1.000	0.525	1.000
23 May	1.100	0.492	1.000	1.286	0.056	1.000	0.230	1.000
27 May	1.033	0.738	1.200	0.714	0.056	1.000	0.551	1.000
2 June[a]								
3 June[a]								
4 June[a]								
Coho salmon								
28 April	1.000	0.952	1.000	1.089	0.452	0.899	0.827	1.000
29 April	1.040	0.941	0.866	1.136	0.476	1.003	0.933	0.982
30 April	1.011	0.984	0.971	0.958	0.582	0.978	0.792	1.000
5 May	1.000	0.976	1.156	0.849	0.424	1.000	0.820	1.000
6 May	0.972	0.976	1.224	0.980	0.400	0.994	0.836	0.975
7 May	0.964	0.990	0.944	1.059	0.408	1.020	0.842	0.978

[a] No estimates calculated due to very small sample sizes.

Appendix Table 8. Sampling error precision of the daily parameter estimates (i.e., model-based standard errors) for maximum likelihood analyses in 1991. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; SM1-Chandler facility outfall to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility.

Release Date	S1	S2	S3	SM1	D	SA	P
Yearling chinook salmon							
14 April	0.062	0.009	0.121	0.041	0.057	0.097	--[a]
15 April	0.073	0.016	0.104	0.035	0.049	0.091	0.017
16 April	0.055	0.007	0.122	0.035	0.049	0.103	--
17 April	0.040	0.017	0.134	0.035	0.041	0.093	0.014
22 April	0.060	0.016	0.151	0.034	0.049	0.137	--
23 April[b]							
24 April	0.063	0.011	0.118	0.035	0.048	0.106	0.011
25 April	0.060	0.012	0.086	0.033	0.046	0.079	--
26 April	0.040	0.012	0.090	0.033	0.041	0.080	0.009
1 May	0.023	0.015	0.107	0.033	0.017	0.092	--
2 May	0.020	0.011	0.091	0.033	0.009	0.068	--
3 May	0.031	0.017	0.105	0.035	0.031	0.082	0.013
4 May	0.018	0.012	0.098	0.032	0.015	0.077	0.014
5 May	0.024	0.021	0.101	0.035	0.028	0.078	0.025
7 May[c]							
Mean	0.044	0.014	0.110	0.035	0.037	0.091	0.015
Coho salmon							
16 May	0.035	0.018	0.124	0.037	0.037	0.096	0.018
17 May	0.043	0.009	0.164	0.032	0.043	0.150	--
18 May	0.018	0.010	0.149	0.033	--	0.115	--
21 May	0.045	0.011	0.114	0.034	0.048	0.104	0.015
23 May	0.050	0.027	0.279	0.027	0.050	0.200	0.028
Mean	0.038	0.015	0.166	0.033	0.045	0.133	0.020

[a] Dashes indicate no standard error as parameter estimate was assumed to be 1.000.
[b] No estimates calculated due to poor mixing at McNary Dam.
[c] No estimates calculated due to Chandler facility PIT-tag detector malfunction.

Appendix Table 9. Sampling error precision of the daily parameter estimates (i.e., model-based standard errors) for maximum likelihood analyses in 1992. Abbreviations: S1-Prosser Dam forebay survival; S2-Chandler Canal survival; S3-Prosser Dam to the Chandler facility outfall survival; S4-Chandler facility outfall to the I-82 bridge survival; SM2-I-82 bridge to McNary Dam survival and detection at McNary Dam; D-diversion proportion into the Chandler Canal; SA-Chandler facility to outfall survival; P-detection proportion at the Chandler facility.

Release Date	S1	S2	S3	S4	SM2	D	SA	P
Yearling chinook salmon								
3 April	0.038	0.022	0.117	0.106	0.044	0.029	0.096	0.017
4 April	0.037	0.023	0.110	0.096	0.038	0.018	0.087	--[a]
5 April	0.032	0.013	0.119	0.088	0.040	0.033	0.090	--
6 April	0.037	0.027	0.111	0.118	0.041	0.026	0.088	0.025
7 April[b]								
14 April	0.045	0.028	0.095	0.145	0.045	0.034	0.077	0.018
16 April	0.039	0.022	0.143	0.097	0.044	--	0.131	--
18 April	0.044	0.023	0.112	0.095	0.043	0.047	0.094	0.022
20 April	0.053	0.030	0.132	0.106	0.044	0.041	0.108	--
21 April	0.048	0.024	0.095	0.093	0.043	0.044	0.075	--
22 April	0.051	0.029	0.114	0.117	0.045	0.036	0.088	0.018
12 May[b]								
13 May	0.122	0.045	0.258	0.124	0.045	0.037	0.188	--
21 May	0.103	0.041	0.281	0.413	0.031	0.060	0.184	--
22 May	0.139	0.045	0.319	0.372	0.028	--	0.240	--
23 May	0.135	0.045	0.454	0.632	0.021	--	0.336	--
27 May	0.076	0.040	0.705	0.412	0.021	--	0.358	--
April Mean	0.042	0.024	0.115	0.106	0.043	0.034	0.093	0.020
May Mean	0.115	0.043	0.403	0.391	0.029	0.049	0.261	--
Coho salmon								
28 April	0.041	0.019	0.130	0.146	0.045	0.042	0.105	--
29 April	0.035	0.025	0.111	0.142	0.045	0.025	0.093	0.017
30 April	0.017	0.011	0.115	0.105	0.045	0.021	0.090	--
5 May	0.020	0.014	0.184	0.134	0.044	--	0.119	--
6 May	0.032	0.026	0.178	0.153	0.044	0.024	0.106	0.026
7 May	0.024	0.014	0.140	0.157	0.044	--	0.112	--
Mean	0.028	0.018	0.143	0.140	0.045	0.028	0.104	0.022

[a] Dashes indicate no standard error as parameter estimate was assumed to be 1.000.

[b] No estimates calculated due to Chandler facility PIT-tag detector malfunction.

Appendix Table 10. Yakima River water temperature and flow on test dates when survival parameters were estimated in 1991 and 1992.

Release date	Yakima River water temperature (°C)	Prosser Dam Forebay water flow (cms)	Prosser Dam Tailrace water flow (cms)	Chandler Canal water flow (cms)
14 April 1991	10.0	115.9	75.9	40.0
15 April 1991	10.0	129.7	89.9	39.8
16 April 1991	10.0	128.7	88.9	39.8
17 April 1991	9.4	128.1	88.0	40.0
22 April 1991	12.8	124.6	85.1	39.5
23 April 1991	12.8	136.4	96.7	39.7
24 April 1991	12.2	145.1	105.7	39.4
25 April 1991	11.1	133.0	93.9	39.1
26 April 1991	10.6	115.9	76.2	39.6
1 May 1991	12.8	75.7	35.2	40.5
2 May 1991	13.3	71.9	31.8	40.2
3 May 1991	13.3	70.7	30.5	40.2
4 May 1991	14.4	70.4	30.3	40.1
5 May 1991	14.4	71.3	31.0	40.2
16 May 1991	14.4	90.1	49.5	40.6
17 May 1991	13.9	85.5	45.0	40.5
18 May 1991	13.9	87.9	47.3	40.6
21 May 1991	15.0	104.4	63.2	41.2
23 May 1991	16.1	105.9	64.5	41.4
3 April 1992	14.4	49.1	12.4	36.8
4 April 1992	13.3	52.7	15.5	37.2
5 April 1992	12.2	58.6	20.7	37.9
6 April 1992	11.1	57.6	20.2	37.4
14 April 1992	12.8	58.3	28.1	30.2
16 April 1992	15.0	54.4	19.2	35.2
18 April 1992	13.3	80.9	42.9	38.0
20 April 1992	12.8	97.3	59.6	37.7
21 April 1992	12.2	84.8	47.1	37.7
22 April 1992	11.7	70.3	33.0	37.3
28 April 1992	16.7	48.9	13.8	35.2
29 April 1992	17.2	52.4	16.9	35.5
30 April 1992	16.1	63.8	27.1	36.7
5 May 1992	17.8	56.1	19.8	36.3
6 May 1992	18.3	51.1	15.9	35.2
7 May 1992	20.0	49.2	14.9	34.4
13 May 1992	16.1	42.5	20.3	22.2
21 May 1992	17.8	44.8	18.3	26.5
22 May 1992	17.2	41.3	16.8	24.5
23 May 1992	18.9	39.4	17.0	22.5
27 May 1992	20.6	44.9	19.3	25.6
2 June 1992	22.2	31.3	7.6	23.6
3 June 1992	21.1	31.7	7.9	23.8
4 June 1992	22.2	34.2	10.1	24.1