# SURVIVAL ESTIMATES FOR THE PASSAGE OF JUVENILE SALMONIDS THROUGH SNAKE RIVER DAMS AND RESERVOIRS, 1996


Prepared by:

Steven G. Smith
William D. Muir
Eric E. Hockersmith
Stephen Achord
Matthew B. Eppard
Thomas E. Ruehle
and
John G. Williams

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Seattle, WA 98 112-2097



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U. S. Department of Energy
Bonneville Power Administration
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Portland, OR 97208-362 1

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## EXECUTIVE SUMMARY

In 1996, the National Marine Fisheries Service and the University of Washington completed the fourth year of a multi-year study to estimate Survival of juvenile salmonids (*Oncorhynchus spp.*) passing through dams and reservoirs on the Snake River. Actively migrating smolts were collected near the head of Lower Granite Reservoir and at Lower. Granite Dam, tagged with passive integrated transponder (PIT) tags, and released to continue their downstream migration. Individual smolts were subsequently detected at PIT-tag detection facilities at Lower Granite, Little Goose, Lower Monumental, McNary, John Day and Bonneville Dams. Survival estimates were calculated using the Single-Release (SR) and Paired-Release (PR) Models. Timing of releases of tagged hatchery steelhead (0. *mykiss*) from the head of Lower Granite Reservoir and yearling chinook salmon (0. *tshawytscha*) from Lower Granite Dam in 1996 spanned the major portion of their juvenile migrations.

Specific research objectives in 1996 were to 1) estimate reach and project survival in the Snake River using the Single-Release and Paired-Release Models throughout the yearling chinook salmon and steelhead migrations, 2) evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) synthesize results from the 4 years of the study to investigate relationships between survival probabilities, travel times, and environmental factors such as flow levels and water temperature.

Two primary release sites were used in 1996: Couse Creek in the free-flowing Snake River and the Port of Wilma at the head of Lower Granite Reservoir, about 81 and 49 km upstream from Lower Granite Dam, respectively. Hatchery chinook salmon were collected by beach seine at Couse Creek and hatchery steelhead were collected by purse seine at the Port of Wilma. We used the SR Model to estimate survival from the point of release to the tailrace of Lower Monumental Dam and for smaller segments within the larger reach.

We attempted to capture and release hatchery yearling chinook salmon from the Port of Wilma during 1996, but we were unable to capture target numbers, due to the small number of fish released in the Snake River Basin compared to previous years and high flows during their migration. The total number released was only 580 over 5 days; too few to reliably estimate survival through the Lower Granite Reservoir.

Paired releases of hatchery steelhead were made at Lower Granite Dam during 1996 to evaluate survival through the new surface bypass collector. Fish for these releases were collected in the juvenile collection facility at Lower Granite Dam.

As in 1995, we also estimated survival of PIT-tagged yearling chinook salmon released in the tailrace of Lower Granite Dam throughout the migration season, using fish tagged and released for an experiment to compare the adult return rate of chinook salmon transported by barge below Bonneville Dam to that of fish migrating through the Snake and Columbia River hydropower system. Because of the large number of fish released in this evaluation, we were able to estimate survival of both wild and hatchery yearling chinook salmon through two additional reaches with the SR Model: from Lower Monumental Dam tailrace to McNary Dam tailrace and from McNary Dam tailrace to John Day Dam tailrace. However, post-detection mortality has not been evaluated at McNary or John Day Dams. We pooled all fish known to be alive in the tailrace of Lower Granite Dam throughout the season into a single "release group" to estimate survival to John Day Dam tailrace.

Tests of assumptions of the SR and PR Models generally indicated that: 1) detecting a fish at an upstream site did not influence the probability of its subsequent detection downstream; 2) detection did not influence subsequent survival; and 3) for paired releases, treatment and reference groups were mixed at subsequent detection sites. There were a few significant assumption violations in 1996, similar to those observed during 1995. Assumption violations were probably due to large spill volumes that occurred at many dams throughout large portions of the migration season. The most common assumption violation was a lack of downstream mixing between fish detected and those not detected at a dam. Detected fish, which passed via the juvenile bypass systems, often arrived more than a day later at the next downstream dam than nondetected fish, which passed via the spillway or turbines. However, tests designed to determine whether the lack of mixing between detected and nondetected invalidated model-based estimates indicated that the effect on survival estimates was small.

Precise survival estimates were obtained for large portions of the 1996 migrations of hatchery and wild yearling chinook salmon and hatchery steelhead. Survival estimates from the head of Lower Granite Reservoir to the tailrace of Lower Granite Dam (49 km) averaged 93.9% for hatchery steelhead. Survival estimates from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 92.1% for yearling chinook salmon and 91.2 % for hatchery steelhead. From Little Goose Dam tailrace to Lower Monumental Dam tailrace, survival estimates averaged 93.3 % and 98.2% for yearling chinook salmon and hatchery steelhead, respectively.

Survival estimates in each of the reaches above Lower Monumental Dam during 1996 were generally higher for both yearling chinook salmon and hatchery steelhead than in previous years. We attribute this increase in part to improved migration conditions due to higher flows and a higher proportion of smolts passing via non-turbine routes due to the spill program.

A total of 68,106 PIT-tagged yearling chinook salmon were released in the tailrace at Lower Granite Dam to compare against transported fish. With this large number of tagged fish, there were sufficient detections at John Day and Bonneville Dams to estimate survival to McNary Dam tailrace for groups released through most of the migration season (16 April through 20 May). Survival estimates for wild yearling chinook salmon were similar to estimates for hatchery fish. Survival estimates from Lower Monumental tailrace to McNary Dam tailrace (two dams and two reservoirs) averaged 73.3 % for yearling chinook salmon (wild and hatchery combined). From Lower Granite Dam tailrace to McNary Dam tailrace (four dams and four reservoirs), survival estimates averaged 62.8%. For yearling chinook salmon, survival was lower from Lower Monumental Dam to McNary Dam in 1996 than in 1995. For the pooled group made up of all yearling chinook salmon known to be alive in the tailrace of Lower Granite Dam throughout the season, we estimated that 93.5 % survived from McNary Dam tailrace to John Day Dam tailrace, but this estimate was relatively imprecise (i.e. large error bounds). From Lower Granite Dam tailrace to John Day Dam tailrace, the estimated survival of yearling chinook salmon was 56.4%, or 89.2 % per reservoir/dam.

No mortality was detected for hatchery steelhead that passed through the surface bypass collector at Lower Granite Dam. The weighted average survival estimate for five replicates was 1.0 (some computed estimates were greater than 1.0; i.e. some treatment groups had higher survival estimates than corresponding control groups).

An appendix is included to provide revised survival and detection probability estimates for previous years' releases of PIT-tagged fish. Estimates for earlier years were revised because we refined the method of construction of capture histories from records of detections in 1996. Specifically, for analyses of 1996 tag groups, we implemented a better method of dealing with apparent "mis-reads" of PIT-tag codes, and then applied the method to the previous years' groups. In addition, the appendix includes tables of data from previous years' releases that have not been published previously, but that were requested for use in the region's ongoing Plan for Analyzing and Testing Hypotheses (PATH) process.

To investigate relationships among travel times, survival probabilities, and environmental factors, we used two multi-year data sets each for yearling chinook salmon and steelhead. The data sets were 1) primary release groups of fish collected by purse seine in Lower Granite Reservoir and 2) fish that were detected and returned to the tailrace of Lower Granite Dam, grouped by the day of detection ("daily Lower Granite Dam release groups").

For all release groups, we estimated the median travel time and the probability of survival from the release site to Lower Monumental Dam. We also computed indices of environmental exposures for each group to quantify the factors that potentially influenced the survival and travel time estimates. We performed correlation and regression analyses both within years (using release groups from only a single year at a time) and between years (using release groups from all years in a single analysis).

The strength of conclusions regarding relationships between environmental exposures and survival and travel time varied among the different data sets and environmental factors. For both species, results for primary release groups were less reliable than for daily Lower Granite Dam groups, because there were fewer release groups and because the shorter time span provided less contrast in the exposure levels. Nevertheless, the following patterns were apparent:

**1) The within-year relationship between flow exposure and travel time was relatively strong and consistent between years for both species.** For both species, higher flow levels were associated with shorter travel times (higher velocities), and the same linear equation could be used to describe the relationship for all years.

**2) Travel times were also influenced by the level of spill, though not as strongly as by flow volumes.**

**3) There was a decreasing trend in travel time throughout the season (i.e. later migrating fish traveled faster) that could not be explained by changes in flow and spill volumes or water temperature.** This trend may be related to changes in fish physiology, which were not quantified.

**4) For both species, within-year relationships between survival probabilities and flow volumes and other exposures were not consistent between years.**

**5) Relationships observed within years, if any, were not consistent with those observed in the multiple-year analyses.** For example, we found no statistically significant relationships between flow and survival estimates when the analysis was restricted to a single year's release groups. The relationship was non-significant even in years with a wide range of flow exposures. However, when the data points for all years were combined into a single analysis, a significant positive relationship between flow and survival was found. In another case the slope of the regression line between survival and spill exposure was negative, though nonsignificant, in each within-year data set, but positive and significant when data points from all years were combined.

Explaining the observed difference between within-year and combined-year survival relationships is difficult. The ranges of exposures observed within years, particularly for the daily Lower Granite Dam release groups, should have been great enough to detect relationships, assuming they existed and that we quantified the exposures in a biologically meaningful manner. Two possible explanations are:

(1) There were differences in annual mean survival that were not directly related to any of the quantified exposure variables we used. These differences could be related to factors such as the quality of fish released from hatcheries or environmental factors that occur before migration but influence survivability of the fish once they enter the impounded section of the river. To explain the significant correlations observed when data from all years were combined, these annual factors would have had to be either coincidentally or only indirectly related to annual differences in the mean levels of the factors we did quantify--i.e. flow and spill levels and water temperature.

(2) The within-year analyses were incapable of detecting the relationships that were apparent in the multiple-year analyses. The most logical extension of this argument would be that the environmental exposures we computed are not sensitive enough to describe differences within a single season. However, the relatively strong and consistent relationships observed

between the exposure indices and travel times suggest that the indices represent biologically meaningful information.

In light of the difference in within- and multiple-year linear regression results, two types of multiple regression models were investigated. In the first, the data were first adjusted for differences in annual means (i.e. the models included parameters that effectively gave each year an independent intercept in the regression equation). In the second type of models, the year from which each data point came was ignored.

When data were adjusted for annual means, no environmental exposures had a significant correlation with survival of primary release groups of yearling chinook salmon. For primary release groups of steelhead, spill rates had a negative correlation with survival (i.e. within a particular year, higher spill exposure indices were associated with lower survival). For daily Lower Granite Dam release groups, adjusted for annual means, warmer water temperatures were associated with lower survival of yearling chinook salmon, and survival of steelhead tended to decrease throughout the season (i.e. survival negatively correlated with date of release).

Without adjusting for differences in annual means, the same pair of exposure variables, spill and water temperature, resulted in the model with greatest explanatory power for survival probabilities in 3 out of 4 (2 species-by-2 release sites) cases. For all data sets but daily Lower Granite Dam release groups of steelhead, the best model had a positive slope for percentage of flow spilled (more spill for higher survival) and a negative slope for temperature (warmer temperatures for lower survival). In all three cases, if spill exposure was replaced with flow exposure in the model, the slope for flow was significant, but not as highly significant as spill exposure. Sims and Ossiander (1981) also found that spill had a more significant effect on survival than flow. For daily Lower Granite Dam releases of steelhead, the best model had slope parameters for release date (survival decreasing through the season) and flow exposure (higher flow for higher survival). When the data were not adjusted for differences in annual means, the analysis was analogous to regression using the annual means of the independent and dependent variables as points, and ignoring patterns observed within years.

Previous attempts to quantify the relationship between flow and survival (Raymond 1979, Sims and Ossiander 1981) have essentially correlated annual average survival with annual average flow. The results of our multiple-year analyses are comparable to those of the earlier analyses based on annual averages. Releases of PIT-tagged fish allowed us for the first time to move beyond annual averages to investigate relationships within years, and the results suggest that correlations apparent in annual means are not necessarily present within a single migration season. Any meaningful explanatory model would have to explain both within-year and between-year relationships between flow and survival.

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# INTRODUCTION

Survival estimates for juvenile chinook salmon (*Oncorhynchus tshawytscha)* and steelhead (0. *mykiss*) that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential to develop effective strategies to recover depressed stocks. Many management strategies, however, rely upon outdated estimates of system survival (Raymond 1979, Sims and Ossiander 1981) that lacked statistical precision and that were derived in a river system considerably different from today's (Williams and Matthews 1995). Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions, and under conditions projected for the future, are necessary to develop strategies that will optimize smolt survival.

From 1993 through 1995, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) demonstrated the feasibility of using three statistical models to estimate survival of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996). Evaluation of assumptions for these models indicated that all were generally satisfied, and accurate and precise survival estimates were obtained for a portion of the 1993 and most of the 1994 and 1995 migrations of hatchery yearling chinook salmon, and for most of the 1994 and 1995 migrations of hatchery steelhead.

In 1996, NMFS and UW completed the fourth year of the study. Specific research objectives were to 1) estimate reach and project survival in the Snake River using the Single-Release and Paired-Release Models throughout the yearling chinook and steelhead migrations,

2) evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) synthesize results from the 4 years of the study to investigate relationships between survival probabilities, travel times, and environmental factors such as flow levels and water temperature.

## METHODS

### Experimental Design

Two statistical models were used to estimate survival from PIT-tag data in 1996: the Single-Release (SR) (Cormack 1964, Jolly 1965, Seber 1965) and Paired-Release (PR) Models (Burnham et al. 1987). Background information and statistical theory underlying these models were presented by Iwamoto et al. (1994).

During the 1996 migration season, automatic PIT-tag detectors (Prentice et al. 1990a; 1990b; 1990c) were operational in the juvenile bypass systems at Lower Granite (Rkm 695), Little Goose (Rkm 635), Lower Monumental (Rkm 589), and McNary Dams (Rkm 470) (Fig. 1). Further, the majority of PIT-tagged fish detected were diverted back to the river by slide gates (rather than being barged or trucked downstream), which allowed the possibility of detection of a particular fish at more than one site downstream from release. At John Day and Bonneville Dams, a relatively small portion of the passing smolts were interrogated for PIT tags.

Primary releases were made using PIT-tagged hatchery steelhead juveniles purse-seined near the head of Lower Granite Reservoir (Rkm 744). Too few yearling chinook salmon were captured to make reliable survival estimates. Hatchery yearling chinook salmon were beach seined near Couse Creek (Rkm 776), PIT tagged, and released into the free-flowing Snake River. Survival probabilities were also estimated for groups of PIT-tagged chinook salmon released from hatcheries, traps, and into the tailrace at Lower Granite Dam (as part of an evaluation of transportation). No secondary paired releases were conducted in 1996 to estimate post-detection mortality in bypass systems since releases in previous years at Lower Granite, Little Goose, and Lower Monumental Dams had found little or no such mortality. Therefore, the SR Model was used to estimate survival for all release groups in 1996.

Hatchery steelhead were released in paired groups at Lower Granite Dam to evaluate passage survival through the new surface collector being evaluated during 1996. Data from these releases were analyzed using the PR Model.

**Primary Release Groups in Lower Granite Reservoir**

Primary release groups ($R_P$) of hatchery steelhead were captured at the head of Lower Granite Reservoir (Table 1) using two purse-seine vessels fished simultaneously. Seining was conducted near the Port of Wilma and, on several occasions, just upstream from Silcott Island. Fish were PIT tagged on an 1 l-m marking barge moored at the Port of Wilma Dock (see Muir et al. 1995 for details on fish collection, handling, and tagging). There were 14 releases of hatchery steelhead over the course of the spring migration. We were unsuccessful in purse-seining sufficient numbers of hatchery yearling chinook salmon for PIT tagging during 1996. Recapture histories from each group were used in the SR Model to estimate survival for three river sections: from release to Lower Granite Dam tailrace ($S_{R1}$), from Lower Granite Dam tailrace to Little Goose Dam tailrace ($S_{R2}$), and from Little Goose Dam tailrace to Lower Monumental Dam tailrace (S,,) (Tables 2, 3, and Fig. 2).

Most steelhead PIT tagged and released in the reservoir in primary release groups were kept in net-pens (1.8 x 0.9 x 0.7 m) (Rottiers 1991) for approximately 24 hours prior to release. However, when insufficient numbers of fish were captured to complete a release group on a single day, additional fish were captured and tagged the following day. Fish captured on the second day to complete a release group were held less than 24 hours prior to release. The net-pens were secured beneath the Port of Wilma dock in a protected, shaded area, out of the main current. For release, they were towed offshore and into the main current several hundred meters downstream from the dock. Mortalities were removed, and the net-pens were rolled over to permit fish to escape. All releases were made between 1100 and 1400 hours.

**Beach Seining in Free-Flowing Snake River**

Hatchery yearling chinook salmon for the primary release groups in the free-flowing section of the Snake River above Lower Granite Reservoir ($R_{BS}$) were collected by beach seine from 4 April through 15 May 1996. Releases were made on a total of 23 days during this period. Beach seining was conducted between 0800 and 1600 hours. Mean daily Snake River discharge at the United States Geological Survey (USGS) gauge at Anatone, WA (Rkm 792) ranged from 56.7 to 105.0 kcfs and mean daily water temperature below Couse Creek ranged from 9.0 to 13 .0°C during this time. Twenty sites were sampled between RAMS 770 and 790. Prior to beach seining each day, each site was evaluated to determine if it could be sampled under existing flow conditions.

The beach seine had a weighted multistrand mudline, 0.48 cm mesh, and was 30.5 m x 1.8 m long with a 3.9 $m^3$ bag (Connor et al. 1993). Each end of the seine was fitted with a brail weighted at the bottom and attached to 15.2 m lead ropes. The seine was set parallel to shore from the stern platform of a 6.1 m jet boat and then hauled straight into shore by the lead ropes. The net sampled approximately 465 $m^2$ to a depth of 1.8 m. When necessary, this approach was modified based on the physical features of the site. Sites were seined continually until hatchery chinook salmon were no longer present in the catch; the next site was then sampled. Juvenile hatchery chinook salmon were removed from the seine and held in a live-well filled with 75.7 L of river water on board the boat. To reduce stress and maintain water quality, 80 g of NaCl,

10 ml of Polyaqua, and oxygen were added to the live-well. Density was kept to less than 100 fish in the live-well. Non-target species were removed from the seine, counted, and returned to the river as quickly as possible.

Fish sorting and marking were conducted adjacent to the Snake River at Couse Creek. Fish were transported from sampling locations to the tagging site and immediately transferred via sanctuary dip-net to 68 L containers provided with flow-through river water. Fish were held in these containers at densities of 35 fish/container or less until processing, then anesthetized with MS 222, sorted, and transferred to a 5-L dish pan for PIT tagging.

Fish were rejected for tagging for the following reasons: non-target species, race, or rearing type, previously PIT tagged, and obvious deformities or abnormalities. Rejected fish were counted and held in a net-pen and released after a minimum of l-hour recovery period.

PIT-tagged fish were held in a net-pen (1.2 x 0.5 x 0.6 m) for 1 to 4 hours prior to release. At the time of release, mortalities were removed and the net-pen was rolled over approximately 10 m from shore to permit fish to escape. All releases were made just below the mouth of Couse Creek, between 1100 and 1700 hours.

**Surface Collector Paired Release Groups**

Five replicated sets of releases were made at Lower Granite Dam ($R_{C1}$ and Cc,) to estimate surface collector mortality for hatchery steelhead (Table 1). We had proposed using hatchery yearling chinook salmon for this evaluation; however, the small numbers of yearling chinook salmon arriving at Lower Granite Dam would have required sorting through too many steelhead to obtain the number needed, so hatchery steelhead were used instead. Collection and marking procedures were generally the same as those used in 1995 for paired releases at Lower Granite Dam (Muir et al. 1996). Only hatchery steelhead, determined by the absence of either adipose or ventral fins, were used. Large hatchery steelhead were not PIT tagged so that survival estimates would be more applicable to yearling chinook salmon which are generally smaller in size. Five pairs of releases were completed. Treatment groups ($R_{C1}$) were released through hoses directly into the surface collector using the apparatus installed by RMC Environmental Services for surface collector research using balloon tags (Normandeau Associates, Inc. et al. 1996). Tailrace reference groups ($C_{C1}$) were released downstream of the dam, from tanks (1.8 x 1.2 x 0.6 m) on a barge.

The surface collector release hose (10.2 cm x 24.3 m) entered the surface collector near its end at spillbay 1 (Fig. 3). Emergency deck water was used to flush the hose continually during and after all releases. Releases were made each day between 0900 and 1600 hours.

Estimates of surface collector survival were obtained using the PR Model for the treatment and reference groups. In addition, using the separation-by-code system at Little Goose Dam, fish from each of the release groups were sampled for descaling or other signs of injury related to surface-collector passage.

## Lower Granite Dam Tailrace Release Groups

As in 1995, both hatchery and wild yearling chinook salmon were PIT tagged and released daily in the tailrace of Lower Granite Dam as part of a study to compare the rates of adult returns for fish migrating in the river versus those transported (trucked or barged) downstream for release below Bonneville Dam. The goal was to PIT tag a constant proportion of migrants arriving at Lower Granite Dam throughout the migration season. To estimate survival probabilities for juvenile migration using these releases, daily tailrace releases were pooled into weekly release groups. Survival probabilities were estimated for the river section from Lower Granite Dam tailrace to Little Goose Dam tailrace, and from Little Goose Dam tailrace to Lower Monumental Dam tailrace using the SR Model. When releases were pooled on a weekly basis, some pooled groups had sufficient detections at John Day and Bonneville Dams to allow estimation of survival from the tailrace of Lower Monumental Dam to the tailrace of McNary Dam. When all fish known to be alive in Lower Granite Dam tailrace during the season were pooled into a single group (including fish tagged and released at Lower Granite Dam and those tagged above Lower Granite Dam and known to have been returned to the river after detection at Lower Granite Dam), there were sufficient detections at both John Day and Bonneville dams to allow estimation of survival from the tailrace of McNary Dam to the tailrace of John Day Dam.

Methods for collecting, tagging, and releasing yearling chinook salmon for the transportation evaluation were similar to those used for our secondary paired releases (Marsh et al. 1996).

## Project Operations

### Slide-Gate Operation

To divert PIT-tagged fish back to the river, slide-gate systems were operated at Lower Granite, Little Goose, Lower Monumental, and McNary Dams (Achord et al. 1992) for the duration of the study. Operations began at Lower Granite Dam on 27 March and at Little Goose and Lower Monumental Dams on 1 April. At McNary Dam, mechanical problems delayed the start-up of the juvenile fish bypass system until 19 April. Slide-gate or diversion efficiency (through the end of June) was determined by comparing the number of PIT-tagged smolts detected in the bypass system upstream from the slide gate with the number detected downstream in the same bypass system.

## Data Analysis

Tagging and detection data were retrieved from the PIT Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission (PSMFC).[1] Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. For each remaining PIT-tag code, a record ("capture history") was

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[1]Pacific States Marine Fisheries Commission, PIT Tag Operations Center, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97207.

constructed to indicate at which dams the tagged fish was detected and at which it was not detected. Methods for data retrieval and database quality assurance/control were the same as those used in 1994 (Muir et al. 1995).

For 1996, we refined the method used to construct capture histories. As a PIT-tagged fish passes through a juvenile bypass system, it passes multiple PIT-tag detectors. Each detector has several detecting “coils, " and each coil generates a record in the database as it reads the PIT-tag code. Thus, in the vast majority of cases, each PIT-tagged fish passing through the bypass system generates multiple detection records (“hits”), one for each coil that reads the code. However, there exist in the PTAGIS database records that ‘indicate that some PIT-tagged fish were read by only a single coil as they passed through a bypass system. These records are sometimes referred to as “single-coil hits.”

In past years, we treated single-coil hits as legitimate detection records. That is, we used the information contained in the record to construct the capture history for the fish. However, over the years we noticed that single-coil hits were disproportionately involved in data anomalies, such as a fish being detected at a lower dam prior to an upper one, or detected before its release date. In past years, we eliminated from analysis any fish that had such an anomalous record. An article in the November 1996 “PTAGIS Newsletter” indicated that most single-coil hits in the database are caused by “mis-reads” of PIT-tags, or “bit-shifts,” and are not reliable records. Specifically, detector coils occasionally mis-read the code from a PIT-tagged fish. The most common error is a change of a single digit of the PIT-code (e.g. the tag code is programmed as 7F7F9601A4, but the detector coil reports the code as 7F7F9611A4).

If the mis-read code happens to be a valid code for another PIT-tagged fish, the detection record for that fish will include a single-coil hit.

For 1996, we did not use single-coil hits as legitimate records. Instead, we ignored single-coil hits in constructing capture histories. In addition, we revised our estimates for releases in previous years. The revised estimates are included in an appendix to this report.

**Tests of Assumptions**

As in previous years, an objective of the studies in 1996 was to test the statistical validity of the SR and PR Models as applied to the data generated from PIT-tagged juvenile salmonids in the Snake River. Validity of the models was tested by evaluating critical assumptions. Details of the methods used to test assumptions are in Appendix A.

**Survival Estimation**

As in 1995, the slide gate operated at McNary Dam to return detected PIT-tagged fish to the river. In addition, one or sometimes two gatewells were sampled for PIT-tagged fish at John Day Dam and a flat-plate PIT-tag detector was tested at Bonneville Dam in the First Powerhouse in 1996. For groups with sufficient detections at John Day and Bonneville Dams, the capture histories for individual fish were extended by two digits to indicate detection at John Day and Bonneville Dams. Thus, survival could be estimated from Lower Monumental Dam tailrace to McNary Dam tailrace, and from McNary Dam tailrace to John Day Dam tailrace. The SR Model was used to estimate survival. Because no paired releases were made to evaluate post-detection mortality at McNary or John Day Dams, post-detection survival was assumed to be 100% at these two sites.

Because there were multiple detection sites downstream from Lower Granite Dam, the "complete capture history" protocol (Burnham et al. 1987) was used to analyze paired releases from Lower Granite Dam. Under the complete capture history protocol, the probability of survival for the passage route was estimated by applying the SR Model independently to test and reference groups. For reference groups released in Lower Granite Dam tailrace, survival probability from the point of release to the tailrace of Little Goose Dam was defined as $S_{R2}$, and for test groups it was defined as the product of $S_{R2}$ and the probability of surviving surface-collector passage $(S_{C1})$ . Thus, survival probability for surface-collector passage was estimated as the ratio of the estimated survival probability for the test group to that for the reference group.

Estimates of survival probabilities under the SR and PR Models are random variables, subject to sampling variability. When true survival probabilities are close to 1.0 and/or when sampling variability is high, it is possible for estimates of survival probabilities to exceed 1.0. For practical purposes estimates should be considered equal to 1 .O in these cases.

When estimates for a particular river section or passage route were available from more than one release or pairs of releases, the estimates were often combined using a weighted average. Weights were inversely proportional to the respective estimated variances, thus providing a weighted average with minimum standard error (Hunter et al. 1982). The formula for the weighted average was:

$$S_w = \frac{\sum_{i=1}^{I} w_i \hat{S}_i}{\sum_{i=1}^{I} w_i} \qquad (1)$$

where $\hat{S}_i$ is the ith of a series of I survival estimates and $w_i$ is the respective weight. Weighting by the inverse variance of a series of estimates gives the appropriate mean parameter estimate when all of the estimates in the series are thought to be estimating the same parameter value (i.e. a stationary process). When the parameter value changes over time, the unweighted arithmetic mean is more appropriate.

The variance of the weighted average was estimated using the formula:

$$\hat{Var}(S_w) = \frac{\sum_{i=1}^{I} w_i(\hat{S}_i - S_w)^2}{(I - 1)\sum_{i=1}^{I} w_i} \qquad (2)$$

A statistical computer program for analyzing release-recapture data was used to perform all survival analyses. This program was developed at the University of Washington and named SURPH, for “Survival with Proportional Hazards,” (Skalski et al. 1993, Smith et al. 1994). This program extends the standard Single-Release Models (Cormack 1964, Jolly 1965, Seber 1965) to allow simultaneous analysis of release-recapture data from multiple release groups.

## Hatchery Releases

In 1996, most hatcheries in the Snake River Basin released PIT-tagged fish for experiments designed at the hatcheries. Data from hatchery releases of PIT-tagged fish were analyzed to demonstrate survival estimation methods using the PIT-tag detection and slide-gate systems for automatic data collection. In addition, these analyses helped to evaluate the extent to which hatchery releases corroborated the results from our primary and secondary releases. In the course of characterizing the various hatchery releases, preliminary analyses were performed to determine whether data from multiple releases could be pooled to increase sample sizes. We neither intended nor attempted to analyze the experiments for which the hatchery releases were made.

Detections of PIT-tagged yearling chinook salmon and steelhead were analyzed from the following hatcheries (Table 4):

1) Dworshak National Fish Hatchery (United States Fish and Wildlife Service (USFWS)): One group of about 200 and one group of about 1,000 yearling chinook salmon were tagged at Dworshak Hatchery on 14 February. Another group of about 3,800 yearling chinook salmon were tagged on 13 March. All three groups were released in the North Fork Clearwater River on 11 April. Four groups of PIT-tagged steelhead were released at various locations and dates: about 300 each in Clear Creek and the Clearwater River on 23 April, approximately 2,900 at Dworshak NFH on 29 April, and about 1,500 from the hatchery between 30 April and 3 May.

2) Kooskia National Fish Hatchery (USFWS): Ten groups of about 200 yearling chinook salmon each were PIT tagged at the hatchery in late February. In mid-March, three

groups of about 5,000 yearling chinook salmon each were tagged. All these groups were released into Clear Creek on 12 April.

3) Clearwater Hatchery (Idaho Department of Fish and Game (IDFG)): PIT-tagged yearling chinook salmon were released into three different rearing ponds: one group of 500 into Crooked River Pond and 3 groups of about 400 each into Red River Pond on 10 April, and 2.0 groups of various sizes on 11 April into Powell River Pond. In addition, a “feed experiment” involved the release of 16 groups of 100 yearling chinook salmon each into Crooked River Pond on 10 April.

Three groups of about 300 PIT-tagged steelhead each were released at several sites on the South Fork Clearwater River on 17 and 18 April. Six groups of about 300 each were released into Crooked River on 15 April, four groups averaging about 1,000 each into Red River on 17 April, one group of 300 into Clear Creek on 18 April, and two groups of 150 each into Clear Creek on 24 April.

4) Lookingglass Hatchery (Oregon Department of Fish and Wildlife (ODFW)): Releases of PIT-tagged yearling chinook salmon were made at the Imnaha Weir on 2 April (24 groups totalling about 4,700 fish), and from the hatchery on 4 April (23 groups totalling about 7,150 fish).

5) McCall Hatchery (IDFG): Eighteen groups totalling over 27,000 yearling chinook salmon were released on 11 April, and a single group of about 2,000 on 13 April, all at Knox Bridge.

6) Rapid River Hatchery (IDFG): Thirteen groups of yearling chinook salmon totalling over 17,000 fish were released from the hatchery on 19 March. Four groups of 500 yearling

chinook salmon each were released from the hatchery from 2 to 5 April as part of a study of bacterial kidney disease.

7) Sawtooth Hatchery (IDFG): Approximately 1,250 PIT-tagged yearling chinook salmon were released in 5 groups on 26 March in the Salmon River. Seven groups of 200 steelhead each were released from the hatchery on 16 May.

For each hatchery, each set of releases was examined to determine suitability for survival analysis, and release groups were pooled where appropriate. The Single-Release Model was applied to each pooled data set to estimate the same probabilities as for our primary releases

(Fig. 2, Tables 2 and 3). Survival estimates were not calculated for releases of hatchery and wild chinook salmon PIT tagged as parr because release and detection numbers were not sufficient.

**Fish Trap Releases**

During the 1996 juvenile salmonid migration season, fish traps were operated for the Smolt Monitoring Program at sites on the Salmon (Rkm 928), Snake (Rkm 747), and Imnaha (Rkm 756) Rivers. Throughout the season, samples of daily catches of hatchery and wild chinook salmon and steelhead at the traps were PIT tagged and released. We retrieved data from PTAGIS on fish of each species and rearing type released from each trap throughout the migration season. We pooled the trap-released hatchery yearling chinook salmon into weekly groups for comparison with the fish we beach-seined from the free-flowing Snake River. In addition, all fish of each species and rearing type released at traps in the period during which we made our primary releases at the Port of Wilma were pooled into a single group. Survival probabilities were estimated for the pooled groups.

### Travel Time

Travel times were calculated for hatchery steelhead from primary releases through four river sections: 1) Port of Wilma to Lower Granite Dam, 2) Lower Granite Dam to Little Goose Dam, 3) Little Goose Dam to Lower Monumental Dam, and 4) Lower Monumental Dam to McNary Dam. Travel time from the Port of Wilma to Lower Granite Dam was calculated for each fish detected at Lower Granite Dam as the number of days between the time of release and the time of first detection at Lower Granite Dam. Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam and first detection at the downstream dam. Travel time included the time required to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay before entry into the bypass system. Travel times were not calculated for primary releases of hatchery chinook salmon because of the small number released and detected downstream.

To facilitate comparisons among the four river sections, rate of migration in each section (kilometers per day) was also calculated. Lengths of the river sections are 49 km from Port of Wilma to Lower Granite Dam, 60 km from Lower Granite Dam to Little Goose Dam, 43 km from Little Goose Dam to Lower Monumental Dam, and 119 km from Lower Monumental Dam to McNary Dam. Rate of migration through a river section was calculated as the length of the section (km) divided by the travel time (days) (which included any delay at dams as noted above). The minimum, 20th percentile, median, 80th percentile, and maximum travel times and migration rates were determined from the distributions for each release group.

The complete set of travel times for a release group includes travel times of both detected and nondetected fish. However, using PIT tags, travel times cannot be determined for fish that traverse a river section but are not detected at one or both ends of the section. Thus, travel time statistics were computed from travel times for detected fish only, representing a sample of the complete set.

During 1996, substantial spill volumes occurred at all dams, resulting in lower detection rates. Some release groups had fish passing detector dams both before and after large spill volumes began. For these groups, the faster migrants were sampled more heavily than the slower migrants because detection rates were higher under lighter spill. Thus, the distributions of observed travel times for these groups were biased toward shorter travel times, or faster migration rates.

**Survival, Travel Time, and Environmental Factors**

**Data sets--For** each species (yearling spring/summer chinook salmon and steelhead), two series of data extending over multiple years were available for investigating relationships between survival and travel time and environmental factors. One data set was composed of our primary release groups from near the head of Lower Granite Reservoir; 1993-1995 for yearling chinook salmon and 1994-1996 for steelhead. A second time series was constructed by creating daily groups of PIT-tagged yearling chinook salmon and steelhead released into the tailrace at Lower Granite Dam. Daily release groups from Lower Granite Dam for 1994, 1995, and 1996 were constructed from two categories of PIT-tagged fish: (1) fish that were collected and tagged in the Lower Granite juvenile bypass facility and then released into the tailrace as reference groups for transportation or passage-route-survival research, and (2) fish that were tagged above Lower Granite Dam and subsequently detected at the dam and returned to the river. The second category included fish PIT tagged anywhere above Lower Granite Dam: at hatcheries, at fish traps, in spawning streams, for our reservoir releases, etc. Hatchery and wild/natural fish were combined for these analyses. By constructing daily "release" groups in this way, we identified groups of fish known to be actively migrating, and which had all passed an identifiable point within the same 24-hour period.

**Environmental exposures--The** following potential environmental influences on survival and travel time were considered: flow volume (kcfs), percentage of flow spilled, and water temperature ("C) at each dam between Lower Granite and McNary Dams. We obtained the mean daily value of each variable measured at each dam from pages on the World Wide Web maintained by the Columbia Basin Research group of the University of Washington School of Fisheries ("Data Access in Real Time," http: //www .cqs. washington.edu/dart/dart , html) and by the Fish Passage Center (http://www.teleport.com/ ~ fpc).

Identifying and quantifying relationships between environmental variables and survival and travel times of release groups of PIT-tagged migrant juvenile salmonids have presented difficult challenges. Chief among these is that fish from a single release group do not migrate as a group, but spread out over time. If conditions change over a short period of time relative to the time it takes for the bulk of a release group to migrate through a particular river section, then different fish from the group experience different levels of various environmental factors.

In this situation, estimated survival probabilities (defined for the entire release group) are usually valid estimates of average survival for the group. However, it is difficult to accurately quantify the environmental conditions to which the entire release group was exposed and to relate them to the survival estimates. Moreover, if a series of releases is made and migrations are protracted, the various release groups may have considerable overlap in passage distributions, further clouding the relationship between survival probabilities and environmental variables by decreasing the contrast in the levels of exposures among the various groups.

Despite the difficulties outlined above, we were able to calculate for each release group (primary release group or Lower Granite daily release group) indices of exposure to each factor, based on the passage distribution at each dam. We first calculated the dates of the 25th and 75th percentiles of the group's distribution of detections at a particular dam. The exposure index for the release group was then calculated as the mean of the daily values of the variable during the period that the "middle 50%" of the group was passing the dam.

**Statistical techniques--For** each release group, median travel times were calculated as described above in the travel time methods section. For Lower Granite Dam daily release groups, the "release time" for calculation of median travel times to Little Goose Dam was taken to be noon. Survival estimates for each reach possible were calculated using the SR Model. The longest reach for which survival could be estimated every year from 1994 to 1996 is from release (reservoir or Lower Granite Dam tailrace) to Lower Monumental Dam tailrace. For daily release groups from Lower Granite Dam, we used all daily groups from which at least 5 fish were detected below Lower Monumental Dam.

The primary analytical tools were descriptive and exploratory. For each year individually and for all years combined, we plotted survival (or travel time) over a relevant reach against each index of exposure in an X-Y scatterplot, and superimposed simple linear regression lines to describe the relationship between the exposure and estimated survival. In addition, running-average lines were calculated using the “Super Smoother” function of the S-Plus statistical software package. The super smoother is a running-average smoother with a variable-sized “averaging window” (Statistical Sciences, Inc. 1993, Friedman 1984). The smoother was used strictly as a display tool to help visualize the nature of the relationship of the X and Y variables. Regression analyses used the unsmoothed estimates and exposure indices. For survival estimates, each point was weighted by the inverse of the estimated variance of the survival estimate in both the linear regression and the smoother. For median travel times, weights were equal for all points. We calculated the product-moment correlation coefficient and Spearman’s coefficient of rank correlation (Sokal and Rohlf, 1981) between survival estimates and median travel times and each exposure index. Finally, we explored multiple regression models to explain variation in survival estimates and median travel times as functions of multiple exposure indices.

In the multiple regression analyses we also included variables for “year effects” to account for differences between years not quantified by the exposure variables, and a Julian date variable to investigate time trends. In particular, using the year-effect variables we estimated and calculated significance tests among the regression models described in the table below for each environmental exposure index (flow, etc.) and each response variable:

| | | Intercept parameter | |
|---|---|---|---|
| | | $\beta_0$ same in all years | $\beta_0$ different in different years |
| Slope parameter | $\beta_1 = 0$ all years | Grand Mean Model (no year effect, no covariate effect) | Annual Means Model (no covariate effect, survival depends only on year) |
| | $\beta_1$ same in all years | Identical Regressions Model (baseline survival and covariate effect identical in all years) | Parallel Regressions Model (baseline survival depends on year, covariate effect identical in all years) |
| | $\beta_1$ different in different years | N/A | Independent Regressions Model (baseline survival and covariate effect both depend on year) |

We evaluated the models using the following sequence of tests (the restricted, or null model is listed first in each pair):

(1) Test Parallel vs. Independent Models -- If null model rejected (different slopes required for each year), the Independent Regressions Model best fit the data. Otherwise, we proceeded to (2).

(2) Test Annual Means vs. Parallel Models -- If null model rejected (common slope for all years significant), we proceeded to (3). Otherwise, we proceeded to (4).

(3) Test Identical vs. Parallel Models -- If null model rejected (different intercepts required for each year), the Parallel Regressions Model best fit the data. Otherwise, the Identical Regressions Model was best.

(4) Test Grand Mean vs. Annual Means Model -- If null model rejected (different average survival required for each year), the Annual Means Model best fit the data. Otherwise, the Grand Mean Model was best.

We computed and reported results for each test (1) through (4) for all data sets and exposure indices, whether or not all the tests were indicated by the above rules.

# RESULTS

## Logistics and Feasibility

### Lower Granite Reservoir

Purse seining in Lower Granite Reservoir near the Port of Wilma began on 6 April and continued until 15 May, with one to eight sets made each day by two purse seiner vessels (Table 5). Species composition varied by time of day, with the highest percentage of chinook salmon captured near dawn. Steelhead were the predominant species during daylight hours. The time of purse-seining effort was adjusted to target whichever species was needed for tagging each day. When fish in excess of those needed for tagging were captured, they were released without handling.

A total of 1,180 yearling chinook salmon were captured and handled in Lower Granite Reservoir, and 82.9% of these were fin clipped, indicating hatchery origin. Of the 14,246 juvenile steelhead captured and handled, 94.3 % were of hatchery origin (Table 5). An additional 27 adult steelhead were also captured (Table 6). The number of nonsalmonids (64) captured by purse seine in the reservoir was small (Table 6) compared to the number of salmonids (15,544).

A total of 550 hatchery yearling chinook salmon and 8,161 hatchery steelhead were tagged for the primary release groups. There were 14 groups of hatchery steelhead released between 22 April and 12 May (Table 7). Insufficient numbers of hatchery yearling chinook salmon were captured and PIT tagged to estimate survival from the Port of Wilma during 1996.

Overall mortality in the reservoir (handling and post-tagging combined) averaged 0.2% for hatchery yearling chinook salmon and 0.06% for hatchery steelhead (Table 5). One or 2 days -of purse seining were needed to capture hatchery steelhead for each release group. After PIT tagging, fish were held from 4 to 29 hours before release.

## Free-Flowing Snake River

Beach seining in the free-flowing section of the Snake River began on 4 April and continued through 15 May, with 5 to 26 sets made each day of sampling (Table 8). Species composition varied by location and date, but did not vary significantly by time of day. A total of 2,878 yearling chinook salmon were captured by beach seine; 87.1% were fin clipped, indicating hatchery origin. The number of nonsalmonids and whitefish captured by beach seine (1,687) was small compared to the number of juvenile salmonids captured (4,350) (Table 9).

A total of 2,304 hatchery yearling chinook salmon were PIT tagged for the 23 primary release groups (Table 10). Of the 202 hatchery yearling chinook salmon collected but not PIT tagged, 114 (4.5%) were previously PIT tagged, 74 (3.0%) were hatchery yearling fall chinook as indicated by a blue elastomer VI tag, and 8 (0.3%) were rejected due to injuries or abnormalities. Only one post-tagging mortality was observed. Overall mortality from beach seining and tagging for hatchery yearling chinook salmon was 0.4% (9 fish).

## Lower Granite Dam

Because of a lack of fish availability due to needs of other concurrently conducted research, hatchery steelhead were substituted for hatchery yearling chinook salmon for evaluation of the surface collector. These releases were made during the early part of the hatchery steelhead migration. Hatchery steelhead were PIT tagged at Lower Granite Dam from 23 to 28 April. A total of 14,959 fish were PIT tagged and released (Table 11). Mortality from handling and tagging averaged 0.1% .

Between 9 April and 17 June, a total of 68,106 yearling chinook salmon were PIT tagged at Lower Granite Dam and released in Lower Granite Dam tailrace as part of a study to compare adult returns of fish that migrated through the hydropower system to those that were transported around it. Information on the number of fish handled and marking/handling mortality can be found in the transportation evaluation annual report (Marsh et al. 1996).

## Project Operations

### Slide-Gate Operation

Between 28 March and 1 July, 47,482 PIT-tagged salmonids (all species) were detected at Lower Granite Dam. Of these, 42,457 (89.4%) were bypassed back to the Snake River by the slide-gate diverter system (Table 12). The remainder were either missed by the slide gate and transported (7.2%), removed prior to reaching the slide gate for the Smolt Monitoring Program (SMP) sample (2.1%), or were not detected again in the bypass system, leaving their fate unknown (1.3%).

At Little Goose Dam, 63,225 PIT-tagged salmonids were detected, with 55,680 (88.1%) bypassed back to the Snake River by the slide-gate diverter system (Table 12). The remainder were either missed by the slide gate and transported (4.8 %), removed prior to passing the slide gate as part of the SMP sample (1.3 %), or were not detected again in the bypass system, leaving their fate unknown (5.9%).

At Lower Monumental Dam, 65,011 PIT-tagged salmonids were detected, with 61,793 (95.1%) bypassed back to the Snake River by the slide-gate diverter system (Table 12). The remainder were either missed by the slide gate and transported (3.1%), removed prior to passing the slide gate as part of the SMP sample (0.7%), or were not detected again in the bypass system, leaving their fate unknown (1.1%).

At McNary Dam, 28,314 PIT-tagged salmonids were detected, with 20,987 (74.1%) bypassed back to the Columbia River by the slide-gate diverter system (Table 12). The remainder were either missed by the slide gate and transported (0.3%) or removed prior to passing the slide gate as part of the SMP sample (1.5 %), or were not detected again and their fate unknown (24.1%).

## Data Analysis

### Tests of Assumptions

While assumptions of the SR and MSR Models were generally met by most releases, there were a few significant assumption violations in 1996, similar to those observed in 1995 (see Appendix A for detailed results). The problems appeared related to a difference in time required to pass dams for detected and nondetected fish. Nondetected fish passed via spillways and turbines and, thus, did not have delays associated with passage through the bypass systems. Travel time data suggested that fish that passed via the bypass system traveled slower than fish that passed through other routes at Lower Granite Dam, and especially at Little Goose Dam.

## Survival Estimation

**Primary** Releases--Survival estimates for primary releases of hatchery steelhead purse seined and released at the Port of Wilma to Lower Granite Dam tailrace ranged from 0.842 to greater than 1.0, with a weighted average of 0.939 (s.e. 0.010) (Table 13). The weighted average survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace and from Little Goose Dam tailrace to Lower Monumental Dam tailrace were 0.912 (s.e. 0.024) and 0.982 (s.e. 0.030), respectively.

To estimate survival for release groups of hatchery yearling chinook salmon beach seined and released at Couse Creek, daily releases were pooled into 6 weekly groups. Survival estimates for the pooled groups from release to Lower Granite Dam tailrace ranged from 0.776 to greater than 1.0 (Table 14). The weighted average of the 6 survival estimates was 0.829 (s.e. 0.027). The weighted average survival estimate from Lower Granite Dam tailrace to Little Goose Dam tailrace was 0.887 (s.e. 0.030). The weighted average survival estimate from Little Goose Dam tailrace to Lower Monumental Dam tailrace was 0.879 (s.e. 0.041).

The product of the three survival probability estimates provided an estimate of the probability of overall survival from release at Couse Creek (hatchery yearling chinook salmon) and the Port of Wilma (hatchery steelhead) to Lower Monumental Dam tailrace. The weighted average estimates were 0.660 (s.e. 0.030) and 0.856 (s.e. 0.022) for hatchery yearling chinook salmon and hatchery steelhead, respectively (Tables 13 and 14).

Detection rates at all dams were affected in 1996 by the spill program (Tables 15 and 16). The chief effect of decreased detection rates on the SR Model was decreased precision in estimating survival probabilities.

**Surface Collector** Releases--Survival estimates of hatchery steelhead that passed through the surface collector at Lower Granite Dam relative to those released in the tailrace ranged from 0.956 (s.e. 0.034) to 1.072 (s.e. 0.052). The weighted average relative survival estimate was 1.010 (s.e. 0.019) (Table 17). That is, the average survival for fish that passed through the surface collector was higher than for those that were released below the dam, though not statistically significantly higher.

From 43 to 186 hatchery steelhead from each release group were sampled at Little Goose Dam using the separation-by-code system (Table 18). In all, a total of 582 test and 517 reference fish were sampled. Of these, 2 treatment and 2 control fish had patchy descaling, and none from either group had severe descaling or any other injury.

**Lower Granite Dam Tailrace** Releases--Daily groups of hatchery and wild yearling chinook salmon released into the tailrace of Lower Granite Dam were pooled by week for 10 consecutive weeks from 9 April through 17 June. For the pooled groups, survival estimates (weighted average for wild and hatchery yearling chinook salmon combined) from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.92 1 (s .e. 0.005) (Table 19). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, survival averaged 0.932 (s.e. 0.014). Pooled estimates of survival for hatchery yearling chinook salmon were lower than for wild chinook salmon to Little Goose Dam tailrace, but higher through the lower reaches and overall (Tables 20 and 21).

Sufficient numbers of PIT-tagged fish were detected at John Day and/or Bonneville Dams to estimate survival from Lower Monumental Dam tailrace to McNary Dam tailrace for 5 weeks of pooled daily releases (16 April through 20 May). Survival averaged 0.734

(se. 0.021) (Table 19). Survival estimates for Lower Granite Dam tailrace to McNary Dam tailrace averaged 0.629 (s.e. 0.023).

Finally, when all fish known to be alive in Lower Granite Dam tailrace during the season were pooled into a single group (including fish tagged and released at Lower Granite Dam and those tagged above Lower Granite Dam and known to have been returned to the river after detection at Lower Granite Dam), there were sufficient detections at both John Day and Bonneville Dams to allow estimation of survival from the tailrace of McNary Dam to the tailrace of John Day Dam. The estimated survival of the pooled group was 0.935 (s.e. 0.165) from McNary Dam tailrace to John Day Dam tailrace. From Lower Granite Dam tailrace to John Day Dam tailrace, the estimated survival of yearling chinook salmon was 0.564 (s.e. 0.097), or 0.892 per reservoir/dam.

**Hatchery** Releases--Preliminary analyses to determine the composition of pooled release groups are summarized below.

1) Dworshak National Fish Hatchery (NFH): The two groups of yearling chinook salmon tagged in February did not differ significantly and were pooled into a single group of 1,204 fish. The group of yearling chinook salmon tagged in March differed significantly, and was analyzed separately. Release groups of steelhead were classified by release location and release date (4 days for "Fish Passage Center" releases from the hatchery), producing 4 pooled release groups. The releases into Clear Creek and Clearwater River did not differ significantly, possibly due to low sample sizes.

2) Kooskia National Fish Hatchery: Among the groups of yearling chinook salmon tagged in February, two release groups totalling 503 fish identified in PTAGIS as

“supplementation study” groups, differed from the other 8 groups released into Clear Creek on 12 April. Thus, the set of 10 release groups was divided into one pooled group of 503 fish and one of 1,607. The three large groups of yearling chinook salmon tagged in March did not differ significantly among themselves, and did not differ significantly from the supplementation study groups. However, because of differences in tagging time and purpose, the groups were not pooled for survival estimation.

3) Clearwater Hatchery: Survival estimates are not presented for the “feed experiment” (16 releases of 100 yearling chinook salmon each on 10 April). The remaining releases of yearling chinook salmon were analyzed in three pooled groups, depending on release location. Releases of steelhead were classified by release location and release date (2-day period for releases in the South Fork Clearwater River), producing 5 pooled release groups, each with significant differences from the others.

4) Lookingglass Hatchery: Release groups of yearling chinook salmon were classified according to release site and release date, producing two release groups, though differences in the respective parameter estimates were not significant.

5) McCall Hatchery: Parameter estimates for yearling chinook salmon releases from Knox Bridge on 11 and 13 April have marginally significant differences and are reported separately.

6) Rapid River Hatchery: There were no significant differences among the groups of yearling chinook salmon released for the BKD study, and the pooled BKD group did not differ from the 19 March releases from the hatchery. Parameters were estimated separately for the two groups because of the difference in release dates.

7) Sawtooth Hatchery: Parameters for the five release groups of yearling chinook salmon in the Salmon River did not differ; releases were pooled into a single group of 1,257 fish. Similarly, the seven groups of steelhead released from the hatchery were pooled into a single group of 1,399 fish.

For hatchery-released fish, estimated survival probabilities from the point of release to Lower Granite Dam tailrace ranged from 0.121 (Sawtooth) to 0.803 (Dworshak) for chinook salmon and from 0.409 (Clearwater) to 0.804 (Clearwater) for steelhead (Table 22). In 1996 as in past years, the survival estimates generally appeared to be inversely proportional to the distance from the release point to Lower Granite Dam.

Because the river section is the same, survival probability estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace and from Little Goose Dam tailrace to Lower Monumental Dam tailrace for hatchery releases are directly comparable to those for our releases. The weighted average estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace were 0.915 (s.e. 0.008) for hatchery-released chinook salmon and 0.912 (s.e. 0.016) for steelhead; compared to the weighted average estimates of 0.921 (s.e. 0.005) for our chinook salmon releases from Lower Granite Dam tailrace and 0.912 (s.e. 0.024) for our releases of purse-seined steelhead.

**Fish Trap** Releases--Survival estimates were calculated for Smolt Monitoring Program (SMP) releases of PIT-tagged hatchery yearling chinook salmon from the Snake (8 April to 19 May) and Salmon River (18 March to 19 May) traps (Table 23). For the weekly pooled groups of hatchery yearling chinook salmon, survival estimates from release to Lower Granite Dam ranged from 0.654 to 0.908 for the Salmon River trap and from 0.856 to greater than 1.0

for the Snake River trap. The survival estimates for groups pooled throughout the period during which we made beach-seine releases were 0.775 (s.e. 0.034) for the Salmon River trap and 0.989 (s.e. 0.037) for the Snake River trap (Table 24). Survival estimates for wild yearling chinook salmon were 0.882 (s.e. 0.043) and 0.964 (s.e. 0.039) for the Salmon and Snake River traps, respectively.

For pooled trap-release groups of hatchery steelhead, survival estimates from the Salmon River and Snake River traps (15 April to 15 May for both traps) to Lower Granite Dam tailrace were 0.851 (s.e. 0.022) and 0.929 (s.e. 0.018), respectively (Table 24). Survival estimates for wild steelhead were 0.967 (s.e. 0.059) and 0.945 (s.e. 0.029) for the Salmon and Snake River traps, respectively.

**Travel Time**

Travel time and migration rate statistics are given for all primary releases of hatchery steelhead in Appendix Tables D. 1 through D.5.

For the 14 primary releases of PIT-tagged hatchery steelhead, migration rates from the Port of Wilma to Lower Granite Dam ranged from 19.8 to 39.8 km/day (Fig. 4). From Lower Granite to Little Goose Dam, median migration rates ranged from 10.7 to 35.7 km/day (Fig. 5). From Little Goose to Lower Monumental Dam, median migration rates ranged from 15.3 to 39.3 km/day (Fig. 6). From Lower Monumental to McNary Dam, median migration rates ranged from 27.1 to 43.3 km/day (Fig. 7). For the entire river section from release at the Port of Wilma to the final PIT-tag detector at McNary Dam, median migration rates ranged from 19.7 to 43.6 km/day (Fig. 8). Travel times and migration rates were not calculated for primary releases of hatchery yearling chinook salmon because of the small numbers PIT tagged and released.

For hatchery steelhead, migration rates were highest in the lower river sections. Migration rates generally increased over time as flows, water temperatures, and levels of spill increased, and as fish presumably became more smolted. With this study, we were unable to differentiate between time spent migrating through individual reservoirs and delays before passing dams.

During most of the migration season, wild yearling chinook salmon released into the tailrace at Lower Granite Dam had slower travel times between Lower Granite and McNary Dams than their hatchery-reared counterparts (Fig. 9).

**Comparison of Survival Estimates, 1993-1996**

During the 1995 and 1996 transportation evaluations, an attempt was made to PIT tag a constant proportion of migrant yearling chinook salmon arriving at Lower Granite Dam so that survival estimates would be representative of the entire migration. For the survival study, the goal was to PIT tag sufficient numbers of migrants for each release to estimate survival (with minimal standard error) during the major portion of the migration. During 1995, survival estimates were similar in downstream reaches for hatchery yearling chinook salmon from the two studies. Insufficient numbers of hatchery chinook salmon were released from the Port of Wilma during 1996. Furthermore, there was little within-year variation in estimates of survival for both hatchery yearling chinook salmon and steelhead each year. Although the survival estimates from this study do not represent the entire migration each year, their similarity to the transportation evaluation survival estimates (which do), and lack of within-year variability make between-year comparisons reasonable.

Primary groups were released near the head of Lower Granite Reservoir from Nisqually John Landing in 1993 (Rkm 726), from Silcott Island in 1994 (Rkm 732), and from the Port of Wilma in 1995 and 1996 (Rkm 744). Seven groups of hatchery yearling chinook salmon were released in 1993, 10 groups in 1994, and 12 groups in 1995. No groups of sufficient size of purse-seined hatchery yearling chinook salmon were released in 1996. For comparison across years, releases from the tailrace at Lower Granite Dam for transportation evaluation were used in 1996. For hatchery yearling chinook salmon, average survival in all reaches was higher in 1995 and 1996 than in 1993 and 1994 (Fig. 10).

Hatchery steelhead were released from Silcott Island in 1994 (9 groups) and from the Port of Wilma in 1995 and 1996 (11 and 14 groups, respectively). Hatchery steelhead had the highest survival in all reaches in 1996 (Fig. 11).

Survival was estimated for releases of PIT-tagged hatchery chinook salmon from Snake River Basin hatcheries from release to Lower Granite Dam tailrace from 1993 to 1996. When more than one group of PIT-tagged smolts were released from a particular hatchery in a given year, the survival estimate for the release group most representative of the production release was used. Estimates of survival from Snake River Basin hatcheries was generally consistent within hatcheries across years, and inversely related to migration distance (Fig. 12). There was significant negative correlation between migration distance and survival (R squared = 93.8 % , $P < 0.001$). Survival was highest in 1995 for 6 of the 8 hatcheries investigated. For yearling chinook salmon, the lowest survival each year was for those released from Sawtooth National Fish Hatchery, which had the longest distance to travel to Lower Granite Dam of any hatchery fish. Their survival from release to Lower Granite Dam tailrace ranged from 12 to 26% each year. Survival was highest for yearling chinook salmon migrating the shortest distance, from Dworshak National Fish Hatchery to Lower Granite Dam tailrace, ranging from 74 to 84% each year.

Flows (seasonal average) over the 4-year period were highest during 1996 and lowest during 1994 (Fig. 13). Flows in 1993 and 1995 were similar throughout much of April, but flow in May was much higher in 1993. The proportion of total flow spilled (Fig. 14) during the peak of hatchery yearling chinook salmon migration was highest in 1996, which might account for the increased survival observed during that year. Spill was also high in 1993 through 1995, but occurred later in the season, after most fish had passed Lower Granite Dam. Spill could increase survival by increasing the proportion of fish that avoid turbine passage, the route associated with highest mortality.

## Survival, Travel Time, and Environmental Factors

**Yearling Chinook Salmon--Of** the two data sets used, one was composed of 22 primary release groups in Lower Granite Reservoir from 1994 and 1995 and the other of 139 daily release groups into the tailrace of Lower Granite Dam in April and May of 1994, 1995, and 1996 (Table 25). The primary release groups totaled almost 21,000 PIT-tagged fish and the daily release groups totaled over 277,000. Survival estimates were possible for daily groups from Lower Granite Dam in June and July of 1995, but these were excluded from the analyses to preserve comparability with the time frame of the 1994 and 1996 data series.

The correlation between median travel time and flow exposure index for primary release groups in 1995 was negative (Fig. 15, Table 26); i.e. higher flows were associated with shorter travel times, with a range of flow exposure indices from 92.1 to 113.9 kcfs. In 1994, higher flows were associated with longer travel times, but the range of flows was narrow: from 70.7 to 85.3 kcfs. When the data from the 2 years were analyzed together, the $R^2$ value was O.O%--absolutely no correlation between flow exposure and median travel time.

When we tested the sequence of yearly regression models (Table 27), we found no models that involved flow, spill % , or temperature exposures alone that were significantly better than the Grand Mean model. For the independent variable release date, however, we found that the Independent Regressions model fit the data best; travel times decreased significantly with later release in both years, and a separate regression model was required for each year. The Independent Regressions model for release date had $R^2$ of 88.7%. Using multiple regression analysis, we found a better model with $R^2$ of 91.2%, including release date, temperature exposure index, and different intercepts for the 2 years. The equation for median travel time (days) from Lower Granite Reservoir to Lower Monumental Dam was:

$$TT = \text{Intercept} - 0.604 * \text{jdate} + 2.40 * \text{temp}.$$

with intercepts 55.28 for 1994 and 59.38 for 1995. Thus, when adjusted for the generally warmer temperatures in 1994 than in 1995, the same slope parameter for release date described the decrease in travel times throughout a single migration season.

For daily release groups from Lower Granite Dam, the correlation between median travel time and flow exposure index was relatively strong and the linear regression lines were very consistent from year to year (Fig. 16, Table 28). Testing the sequence of yearly regression models for flow exposure (Table 29), we found that the Identical Regression model fit the data best; i.e. the same regression equation for Lower Granite Dam to Lower Monumental Dam travel time (days) could be used for all 3 years (see also Table 28):

$$TT = 11.95 - 0.033 * flow.$$

This model had $R^2$ of 30.2 % .

Spill% exposure had very low correlation with travel time at lower spill levels (less than 25 % of total flow spilled) observed in 1994 and 1995 and the relationship did not appear linear (Fig. 17, Table 28). In both 1994 and 1995, some of the longest travel times were for groups with high spill exposure. In 1996 exposure levels were mostly above 25 %, and a stronger correlation was observed, but the relationship still appeared to be curved. The highest spill exposures were not always associated with short travel times (Fig. 17).

A multiple regression model for median travel time with all coefficients significant and $R^2$ of 37.3 % was found, including predictor variables Julian release date, flow exposure, spill% exposure, and different intercepts for each of the 3 years. The intercepts were 9.89, 10.50, and 10.83 for 1994, 1995, and 1996, respectively and the equation was:

$$TT = Intercept + 0.039 * jdate - 0.049 * flow - 0.152 * spill\%.$$

Within individual years, the correlation between survival estimates and flow exposure was weak and inconsistent from year to year (Figs. 18 and 19, Tables 30 through 33). The correlation was positive within some years and negative within others; none were statistically significant. For both primary release groups and daily groups from Lower Granite Dam, combining the points from all years resulted in a significant positive correlation between flow exposures and survival estimates (Tables 30 and 32). For daily Lower Granite Dam release groups, the large number of data points resulted in a highly significant positive correlation but $R^2$ of only 18.1% . Also for Lower Granite Dam release groups, the scatterplot smoother suggested slight curvature of the relationship; the slope of the relationship flattened slightly at higher levels of flow exposure (Fig. 19).

Testing the sequences of yearly regression models for flow exposure (Tables 31 and 33), we found that the Annual Means regression model best fit the data from both series of releases. That is, the best model in the sequence had a different average survival for each year, and no relationship of survival to flow either between or within years. This model had $R^2$ of 75.5% for primary release groups and 56.3 % for daily Lower Granite Dam release groups.

In multiple regression analyses for survival estimates of primary release groups, no exposure variable was significant in any model that adjusted for differences in annual mean survival. The best model not adjusted for annual means had the following equation for survival from release in Lower Granite Reservoir to the tailrace of Lower Monumental Dam:

$$S = 1.082 + 0.005 * \text{spill\%} - 0.039 * \text{temperature}.$$

Both slope parameters were highly statistically significant (P value $< 0.001$) and the model had $R^2$ of 75.8%.

In multiple regression analyses for daily Lower Granite Dam release groups, among models with all slope parameters significant at the 0.05 level, the greatest $R^2$ was 57.9%. This model had different annual mean survival for each year and a coefficient of -0.0012 for Julian date of release. A model with different annual means and a temperature exposure coefficient of -0.010 was nearly as good ($R^2$ = 57.6%, P value for temperature = 0.04). The intercepts for this model were 0.803, 0.919, and 0.944 for 1994, 1995, and 1996, respectively. Without adjusting for different annual means, the best model for survival from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam had the same independent variables as the model for primary release groups:

$$S = 0.946 + 0.004 * \text{spill\%} - 0.021 * \text{temperature}.$$

Both slope parameters were highly statistically significant (P value $< 0.001$) and the model had $R^2$ of 48.2%. If the spill% exposure was replaced by flow exposure in this model, the $R^2$ dropped to 39.6%, though the slope for flow exposure (0.0013 * flow) was highly significant (P value $< 0.001$).

Results were similar for correlations between survival estimates and temperature and spill exposures (Tables 30 through 33, Figs. 20 and 21). The only significant within-season correlations were weak ($R^2$ = 9.5 % in 1995 and 7.8% in 1996) negative correlations between temperature and survival for daily Lower Granite Dam release groups. As with flow, combining the points from all years into a single analysis resulted in statistically significant correlations with much greater $R^2$ values (Tables 30 and 32). For both multi-year data sets, higher spill exposures were correlated with higher survival estimates and higher temperature exposures were correlated with lower survival estimates. However, as with flow exposure, correlations between survival and spill% and temperature were not significant if the regression model included adjustment for differences in annual mean survival.

For primary release groups, there was no correlation between median travel time for a release group and its estimated survival, either within years or by combining years (Fig. 22, Tables 30 and 31). For daily release groups from Lower Granite Dam, there were no significant correlations between survival and travel time within years (Fig. 23, Table 32), but the large number of data points in the multi-year data set made the negative (longer travel times associated with lower survival) correlation significant (P value = 0.023), though the model had almost no predictive value ($R^2$ = 3.7%).

**Steelhead--Of** the two data sets used, one was composed of 34 primary release groups in Lower Granite Reservoir between 1994 and 1996 and the other of 125 daily release groups into the tailrace of Lower Granite Dam in April and May of 1994. 1995, and 1996 (Table 34). These releases totaled over 30,000 PIT-tagged fish released in the reservoir and almost 83,000 released from Lower Granite Dam.

For primary release groups, there was not sufficient range in flow exposures in 1994 (69.1 to 84.6 kcfs) or 1995 (102.0 to 115.4 kcfs) to effectively study the relationship between flow exposure and median travel time within those years (Fig. 24). A wider range of exposures occurred in 1996 (88.1 to 189.7 kcfs), and a significant correlation was observed (Table 35). The relationship evident in the multi-year data set (Fig. 24) was largely determined by the 1996 points, though the 1994 points, with low flow and long travel times, also influenced the regression. Patterns found in the within- and multi-year relationship of travel time with spill% exposure were similar to those with flow, and the correlations were a bit stronger (Table 35). As with chinook salmon, travel times for steelhead decreased (fish migrated faster) as the migration season progressed in all years, though the relationship was not significant in the multi-year data set, and only for 1995 in the within-year analyses.

Testing the sequence of yearly regression models (Table 36), we found that the Independent Regressions model best fit the data for both spill% and flow exposure, but this was probably because the narrow ranges of exposures in 1994 and 1995 led to widely divergent slope estimates. The Independent Regressions model for spill% exposure had an $R^2$ of 83.6%, but was not a very useful model, because of unreliability in the slopes for 1994 and 1995, again because of the narrow range of exposures.

Because of the consistency of travel time relationships seen in the chinook salmon data and the coherent scatterplot for the multi-year data set for primary release groups of steelhead (Fig. 24), we limited multiple regression analyses to models that did not adjust for annual differences in means. The best such model was provided by the single predictor variable spill % exposure. This model had $R^2$ of 55.5% and was highly significant (P value $< 0.001$), with equation for median travel time (days) from Lower Granite Reservoir to Lower Monumental Dam:

$$TT = 14.70 - 0.218 * \text{spill\%}.$$

The model with the single predictor variable flow exposure had $R^2$ of 50.6% and was also highly significant:

$$TT = 17.29 - 0.070 * \text{flow}.$$

No model with more than one predictor variable had all predictors significant.

For daily release groups of steelhead from Lower Granite Dam, within-year ranges of flow exposures were much wider (Fig. 25). The correlation between median travel time and flow exposure was relatively strong and linear regression lines were consistent from year to year (Table 37). Testing the sequence of yearly regression models for flow exposure (Table

38), we found that the Parallel Regressions model best fit the data. This model had the same slope parameter for the flow/travel time relationship for all 3 years, with a different intercept for each year. Under this model, the equation for travel time from Lower Granite Dam to Lower Monumental Dam (days) was:

$$TT = intercept - 0.039 * flow.$$

The intercepts were 11.08, 12.19, and 11.33 for 1994, 1995 and 1996, respectively. The model had $R^2$ of 36.7% (P value for flow exposure $< 0.001$. This model could be improved slightly by adding the Julian date of release ($R^2 = 38.6\%$, P value for jdate = 0.059):

$$TT = intercept - 0.031 * flow - 0.025 * jdate,$$

with intercepts 13.75, 14.62, and 13.52, for 1994, 1995, and 1996, respectively.

For daily release groups of steelhead from Lower Granite Dam, spill% exposure had very low correlation with travel time at lower spill levels (less than 25% of total flow spilled) observed in 1994 and 1995 and the relationship did not appear linear (Fig. 26, Table 37). In 1994, both the longest and shortest travel times were for groups with high spill exposure. In 1996 exposure levels were mostly above 25 % , and a strong linear correlation was observed, with greater exposure levels associated with shorter travel times (Table 37).

For both primary release groups of steelhead and daily release groups from Lower Granite Dam, as with chinook salmon, the correlation between survival estimates and flow exposures within year was weak and inconsistent from year to year (Figs. 27 and 28, Tables 39 through 42). The correlation was positive within some years and negative within others; none were statistically significant. With both series of releases, combining the points from all years resulted in highly significant (P value $< 0.001$) positive correlations between flow exposure and survival estimates (Tables 39 and 41). The $R^2$ value was 51.5 % for primary release groups, but only 16.8 % for daily Lower Granite Dam release groups. For both series of releases, the scatterplot smoother suggested a curvilinear relationship; the slopes of the regressions flattened at higher levels of flow exposure (Figs. 27 and 28).

For primary release groups, within each year the correlation between spill% exposure and survival estimates was negative, though not significantly so (Fig. 29, Table 39). However, the correlation was positive and highly significant when the 3 years were combined. A similar result obtained for daily release groups from Lower Granite Dam (Fig. 30, Table 41), where within-year regressions showed two essentially flat relationships and one highly significant negative correlation (1994), but the combined data set showed a highly significant positive correlation.

Testing the sequences of yearly regression models for flow exposure (Tables 40 and 42), we found that the Annual Means regression model best fit the data for both series of releases. That is, the best model in the sequence had a different average survival for each year, and no relationship of survival with flow either between or within years. The model with different annual means and no relationship of survival and flow had $R^2$ of 85.5 % for primary release groups and 30.0% for daily Lower Granite Dam release groups.

In multiple regression analyses for primary release groups, only spill% exposure was significant when added to the model that adjusted for differences in annual mean survival. The P value for spill% was 0.049 and the model had $R^2$ of 87.3 % . The equation for survival from Lower Granite Reservoir to the tailrace of Lower Monumental Dam was:

S = Intercept - 0.0029 * spill%;

i.e. higher levels of spill% exposure were associated with lower survival. The intercepts were 0.604, 0.848, and 0.948 for 1994, 1995, and 1996, respectively.

Among models that did not have adjustment for differences in annual means, the best model of survival had the same predictors as models reported above for survival of chinook salmon:

$$S = 1.189 + 0.006 * \text{spill\%} - 0.051 * \text{temperature}.$$

Both slope parameters were highly significant (P value $< 0.001$) and $R^2$ was 73.8%. If spill% exposure was replaced by flow exposure in this model, the $R^2$ dropped to 61.7 % , though the slope for flow exposure (0.0027 * flow) was significant (P value $< 0.001$).

In multiple regression analyses for survival of daily Lower Granite Dam release groups, among models with all slope parameters significant at the 0.05 level, the greatest $R^2$ was 43.6%. This model had different annual mean survival for each year, and a coefficient of -0.0060 for Julian date of release. The intercepts were 1.464, 1.612, and 1.590 for 1994, 1995, and 1996, respectively. Without adjusting for annual means, the best model had the following equation for survival from Lower Granite Dam tailrace to Lower Monumental tailrace:

$$S = 1.226 - 0.0055 * \text{jdate} + 0.0026 * \text{flow}.$$

Both slope parameters were highly significant (P value $< 0.001$) and $R^2$ was 29.2%.

The model with spill% and temperature exposure, which was the best unadjusted model for all other instances reported above for chinook salmon and steelhead, had $R^2$ of 23.5%, both predictors significant (P value $< 0.01$), and the equation:

$$S = 1.138 + 0.0019 * \text{spill\%} - 0.0324 * \text{temperature}.$$

If spill % exposure was replaced by flow exposure in this model, the $R^2$ increased to 26.3 % and the slope for flow exposure (0.0015 * flow) was highly significant (P value $< 0.001$).

For primary release groups, there were no significant within-year correlations between median travel time for a release group and its estimated survival (Fig. 3 1. Table 39). When the 3 years were combined, there was a highly significant negative correlation ($R^2$ = 40.3 % , P value < 0.001). That is, longer travel times were associated with lower probability of survival. From the sequence of yearly regression models (Table 40), the Annual Means model best fit the data. That is, the best model ($R^2$ = 85.5%, P value $< 0.001$) in the sequence had a different average survival for each year, and no relationship of survival with travel time either between or within years.

For daily release groups from Lower Granite Dam, the within-year correlations between survival estimates and median travel times were consistently negative, but not significant (Fig. 32, Table 41). When the 3 years were combined, there was a highly significant negative correlation ($R^2$ = 20.9 % , P value $< 0.001$). Testing the sequence of yearly regression models (Table 42), we found that the Parallel Regressions model best fit the data, indicating that after adjusting for differences in annual means, there was a significant (P value = 0.002) negative correlation between survival and travel time (longer travel times associated with lower survival). The $R^2$ for this model was 35.6% and the equation was

S = Intercept - 0.0207 * travel time,

with intercepts 0.912, 1.008, and 0.992 for 1994, 1995, and 1996, respectively.

## DISCUSSION

Results of the 1996 NMFS/UW survival study generally met the following specific research objectives: 1) estimate reach and project survival in the Snake River using the Single-Release and Paired-Release Models throughout the yearling chinook and steelhead migrations, 2) evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) synthesize results from the 4 years of the study to investigate relationships between survival probabilities, travel times, and environmental factors such as flow levels and water temperature. However, ‘we were unable to capture targeted numbers of hatchery yearling chinook salmon for PIT tagging at the Port of Wilma using purse seines.

Beach seining at Couse Creek proved an effective method for capturing yearling chinook salmon in the free-flowing Snake River, especially considering the small number of fish released from hatcheries and high flows in 1996. We originally planned to compare estimates of survival for fish released in the free-flowing Snake River to estimates for fish released at the Port of Wilma to partition survival above and below the transition area between reservoir and free-flowing river. Unfortunately, we were not able to capture sufficient numbers of yearling chinook salmon at the Port of Wilma for comparison. The pooled estimates of survival to Lower Monumental Dam tailrace from the Salmon River trap (18 March to 19 May) was 0.716 (s.e. 0.025), from Couse Creek was 0.828 (s.e. 0.027), and from the Snake River trap (same dates as Salmon River trap) was 0.975 (s.e. 0.023).

Tests of assumptions of the Single-Release and Paired-Release Models showed a few statistically significant (P value < 0.10) violations in 1996, similar to those observed in 1995. The most common violation was lack of downstream mixing between fish detected and those not detected at a dam. Detected fish, which passed via the bypass system, often arrived more than a day later at the next downstream dam than nondetected fish, which passed via either the turbines or the spillway.

Mixing of detected and nondetected fish is a sufficient, but not necessary, condition for model validity. Delays of up to a day or two generally do not result in appreciably different conditions for survival or detection downstream. Tests designed to assess lack of model fit of the type that could result from lack of mixing showed few significant violations. In general, the results indicated that 1) detection at an upstream site did not influence the probability of subsequent detection downstream, 2) detection did not influence subsequent survival, and 3) treatment and reference fish were mixed at subsequent detection sites.

Paired post-detection bypass releases in previous years indicated no significant mortality between detection in the bypass system and remixing with fish using other passage routes at Lower Granite, Little Goose, and Lower Monumental Dams. Accordingly, the Single-Release Model was used to estimate survival probabilities for the primary release groups.

Survival estimates for hatcheries upstream from Lower Granite Dam, our releases at Couse Creek, Smolt Monitoring Program traps, and our releases from the Port of Wilma indicated that most of the mortality documented between the hatcheries and Lower Granite

Dam forebay probably occurred soon after release, in river sections upstream from Lower Granite Reservoir.

The river sections over which survival probabilities were estimated for primary release groups (i.e. Port of Wilma to Lower Monumental Dam tailrace) represent about 30% of the total length of the hydrosystem (510 km from the head of Lower Granite Reservoir to Bonneville Dam). The estimated survival probability from the Port of Wilma to Lower Monumental Dam tailrace (155 km) averaged 86% for hatchery steelhead. For yearling chinook salmon released in the tailrace of Lower Granite Dam, the average survival probability to McNary Dam (225 km) tailrace was 62.9%. This reach represents 49% of the distance from Lower Granite Dam to Bonneville Dam and 44% of the entire hydrosystem. Although the survival estimate had low precision, the reach from McNary Dam tailrace to John Day tailrace (123 km) increases the total proportion of the hydrosystem for which we estimated survival to 68 % . The estimated survival probability from Lower Granite Dam tailrace to John Day Dam tailrace for yearling chinook salmon (hatchery and wild combined) was 56.4%, or 89.2 % per reservoir and dam.

Survival estimates from Lower Monumental Dam tailrace to McNary Dam tailrace (two reservoirs and two hydroelectric projects) for yearling chinook salmon released in Lower Granite Dam tailrace averaged 73 % . This was lower than the estimate for this reach in 1995 (85%). One hypothesized, though untested, cause of this difference was high levels of involuntary spill at Ice Harbor Dam during 1996.

Survival estimates from Lower Granite Dam tailrace to McNary Dam tailrace (225 km) in 1996 averaged 65 % and 52 % for hatchery and wild yearling chinook salmon, respectively, compared to 71% and 70% average survival through this reach in 1995. In both years, these estimates were derived using the Single-Release Model without post-detection bypass survival estimates at McNary Dam. Post-detection bypass survival was assumed to be 100% at McNary Dam. If mortality actually occurred between detection and the zone of remixing with nondetected fish, then the SR Model overestimated survival from Lower Monumental Dam tailrace to McNary Dam tailrace.

System survival estimates from this study have been consistently higher than those reported by Raymond (1979) and Sims and Ossiander (198 1). From 1966 to 1968, Raymond (1979) estimated an average survival rate of 89% for yearling chinook salmon migrating from trap sites on the Salmon River to Ice Harbor Dam, then the uppermost dam on the Snake River. From 1970 to 1975, Raymond (1979) estimated an average survival rate of 68 % from the Salmon River to the uppermost dam (Little Goose Dam from 1970 to 1974 and Lower Granite Dam in 1975). Raymond's earlier estimates were predominately for wild yearling chinook salmon, while his later estimates were for 43 % to 75 % hatchery fish. On a per-project basis (one reservoir and dam combined), Raymond's survival estimates from 1966-1968 and 1970-1975 ranged from 35% to 71%. Estimates of per-project survival for hatchery yearling chinook salmon in our studies have ranged from 86% in 1993 to 92% in 1996.

Raymond's estimates were made using less sophisticated methods, and in a river system substantially different from today's (Williams and Matthews 1995). Management strategies should not rely on outdated system survival estimates. Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions and under conditions projected for the future is essential to develop strategies for optimizing smolt survival.

Hatchery steelhead increased their rate of migration as the season progressed, especially in the upstream reaches. A combination of increasing flow, spill, water temperature, and smolt development likely contributed to this behavior. Berggren and Filardo (1993) found an increase in migration rate in the Snake and Columbia Rivers as these variables increased. They found that flow was the most influential variable followed by a surrogate variable for smolt development. Smolt development increases in hatchery salmonids after release from a hatchery, and continues to increase as they migrate downstream (Beeman et al. 1991, Muir et al. 1994, Zaugg et al. 1985).

Survival estimates in each of the reaches from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam during 1996 were higher for hatchery steelhead than in previous years. We attribute this increase, in part, to improved migration conditions caused by higher flows, and to a higher proportion of smolts passing via non-turbine routes due to the spill program. We saw no evidence of increased mortality for hatchery steelhead caused by the voluntary spill program downstream to the tailrace of Lower Monumental Dam. We did not estimate survival below Lower Monumental Dam for hatchery steelhead because there were insufficient numbers of detections at John Day and Bonneville Dams. However, survival from Lower Monumental Dam to McNary Dam was lower for yearling chinook salmon released in the tailrace at Lower Granite Dam in 1996 than in 1995.

Our series of tests of yearly regression models showed that the relationship between flow and travel time was strong and consistent from year to year. The points for a single year's release groups fell on the same or nearly the same line as the points for other years. The regression line that we calculated when combining data from all years was nearly the same as those we calculated using data from only a single year. However, this was not true for the relationship between flow and survival. When all years' data were combined, we observed positive correlations between flow exposures and survival estimates. However, the points for single years did not fall on the same line calculated in the combined-year analysis.

Explaining the observed difference between within-year and combined-year survival relationships is difficult. The ranges of exposures observed within years, particularly for the daily Lower Granite Dam release groups, should have been great enough to detect relationships, assuming they existed and that we quantified the exposures in a biologically meaningful manner. We have two possible explanations:

(1) There were annual differences in mean survival that were not directly related to any of the quantified exposure variables we used. These differences relate to factors such as the quality of fish released from hatcheries or environmental factors that occur before migration but influence survivability of the fish once they enter the impounded section of the river. To explain the significant correlations observed when all years' data are combined, these annual factors were either coincidentally or only indirectly related to annual differences in the mean levels of the factors we did quantify, i.e. flow and spill levels and water temperature.

(2) The within-year analyses are incapable of detecting the relationship that is apparent in the multiple-year analyses. The most logical extension of this argument suggests that the environmental exposures we computed are not sensitive enough to describe differences within a single season. However, the relatively strong and consistent relationships observed between the exposure indices and travel times suggest that the indices carry at least some biologically meaningful information.

Previous attempts to quantify the relationship between flow and survival (Raymond 1979, Sims and Ossiander 1981) have essentially correlated annual average survival with annual average flow. Our combined-year analyses are comparable to the earlier annual-average analyses, and give similar results regarding the flow-survival relationship. Releases of PIT-tagged fish allowed us for the first time to move beyond annual averages to investigate relationships within years, and the results suggest that patterns apparent in annual means are not necessarily present within a single migration season.

The results of this study provide additional evidence of a relatively strong relationship between flow and travel time, as reported by other researchers (e.g. Berggren and Filardo 1993). This relationship was strong within single migration years and consistent from year to year. However, despite a large data base collected over several years using contemporary techniques, relationships between flow and survival and between travel time and survival were neither strong (within- or between-years) nor consistent from year to year.

Nevertheless, higher flows may provide survival benefits in other portions of the salmonid life cycle and in free-flowing sections of the river both upstream and downstream of the hydropower system, even though there was no relationship within seasons between flow and survival through impounded sections of the Snake and Columbia Rivers. Other researchers have found increased adult returns following high flow years (Petrosky 1993). Higher flows might provide the greatest survival benefit to juvenile salmonids migrating through the estuary or the Columbia River plume. Yearling chinook salmon and steelhead have adapted to migrate during the spring, suggesting that over the evolutionary time scale, spring conditions, including higher in-river flows, provide an adaptive advantage for survival.

## SUMMARY AND CONCLUSIONS

1) The SR, MSR, and PR Models were useful tools to estimate survival probabilities through reservoirs and dams on the Snake River.

2) Insufficient numbers of hatchery yearling chinook salmon for PIT tagging were collected in 1996 at the Port of Wilma by purse seining and at Lower Granite Dam for release into the surface collector. Target numbers of hatchery steelhead were PIT tagged and released at the Port of Wilma and for surface collector releases at Lower Granite Dam.

3) Precise survival estimates were obtained for primary releases of hatchery steelhead from the Port of Wilma to the tailraces of Lower Granite, Little Goose, and Lower Monumental Dams. Survival probabilities from the Port of Wilma to Lower Granite Dam tailrace averaged approximately 94% for hatchery steelhead. Survival averaged approximately 91% from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam and 98% from Little Goose Dam tailrace to Lower Monumental Dam tailrace for hatchery steelhead.

4) Survival estimates from the Port of Wilma to Lower Monumental Dam tailrace (weighted average) for hatchery steelhead averaged 85.6%. The migration corridor from Port of Wilma to Lower Monumental Dam tailrace represents about 69% of the distance from the head of Lower Granite Reservoir to the confluence of the Snake and Columbia Rivers.

5) Survival was estimated for hatchery and wild yearling chinook salmon migrating from Lower Granite Dam tailrace. Estimates were calculated for weekly groups of fish released into Lower Granite Dam tailrace throughout the 1996 migration. Survival from

Lower Granite Dam tailrace to McNary Dam tailrace averaged 65 % and 52 % for hatchery and wild yearling chinook salmon, respectively.

6) The large number of PIT-tagged chinook salmon released into Lower Granite Dam tailrace for comparison to transported smolts resulted in sufficient detections downstream at John Day and Bonneville Dams to estimate survival to McNary Dam tailrace for the peak of the yearling chinook salmon migration (16 April through 20 May). Weighted average survival estimates from Lower Monumental Dam tailrace to McNary Dam tailrace (two reservoirs and dams) for hatchery and wild yearling chinook salmon was 73%. This extends available survival estimates downstream an additional 119 km and through two additional dams. Survival from Lower Granite Dam tailrace to McNary Dam tailrace (225 km) was 63% for yearling chinook salmon (hatchery and wild combined).

7) Survival and travel time data collected during this study can be used as baseline data for evaluation of future reservoir drawdowns or other management strategies.

8) Beach seines successfully collected yearling chinook salmon from the free-flowing Snake River even though relatively small numbers of fish were released from hatcheries during 1996.

9) The relationship between flow levels and travel times was relatively strong and consistent between years for both species. For both species, higher flow levels were associated with shorter travel times (higher velocities), and the same linear equation could be used to describe the relationship for all years.

10) Travel times were also influenced by the level of spill, though not as strongly as by flow volumes.

11) There was a decreasing trend in travel speed (i.e. later migrating fish traveled faster) that was not explained by changes in flow and spill volumes or water temperature. Such trends may have been related to changes in fish physiology, which we did not quantify.

12) Within-year relationships between survival probabilities and flow volumes and other exposures were not consistent between years. Furthermore, relationships observed within years, if any, were not consistent with those observed in the between-year analyses. For example, we found no statistically significant relationships between flow and survival estimates when the analysis was restricted to a single year's release groups. The relationship was non-significant even when the range of flow exposures was wide. However, when the data points for all years were combined into a single analysis, a significant positive relationship between flow and survival was found.

The single, multi-year analysis may nor may not have confounded effects of flow on survival with other interannual variation in smolt quality or environmental factors. Further studies are required to sort out the observed differences in the intra- and interannual relationships between flow and survival.

# RECOMMENDATIONS

Successful validation of field and statistical methodologies in 1996 formed the basis for the following recommendations for 1997 and future years:

1) Continue to use PIT tags and the SR (MSR when appropriate) and PR methodologies to estimate survival of migrating juvenile salmonids in future years to confirm results from the past 4 years and to get information under lower flow conditions if they occur. Future studies should evaluate the effects of seasonal and environmental variation, and use expanded study areas and additional salmonid stocks.

2) Provide hatcheries with minimum release-size requirements for their PIT-tag studies to evaluate survival estimates from hatcheries to detection sites at dams with known precision.

3) Coordinate future survival studies with other inriver projects to maximize the data-collection effort and minimize study effects on salmonid resources.

4) Maximize the return of detected PIT-tagged juveniles to the river through increased detector and diverter efficiency to maximize statistical precision of survival estimates.

5) Make additional releases of PIT-tagged yearling chinook salmon in the free-flowing Snake River between the hatcheries and the head of Lower Granite Reservoir to help determine where mortality occurs. This is crucial, as little mortality has been found in Lower Granite Reservoir and other reservoirs investigated to date, whereas estimates of survival from hatcheries to Lower Granite Dam have indicated that substantial mortality occurs upstream from the Snake and Clearwater River confluence area.

6) Increase the number of detection facilities in the Columbia River Basin to improve survival investigations. Install detectors and diversion systems at John Day, The Dalles, Bonneville, and Priest Rapids Dams. The development of flat plate detector technology in bypass systems will greatly enhance the ability to study survival.

7) Update the within- and multi-year analyses of the relationships between environmental exposures and survival and travel times of groups of PIT-tagged fish each year.

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Table 1. Release groups of PIT-tagged yearling chinook salmon and steelhead for 1996 survival studies.

| Release | Definition |
|---|---|
| $R_{BS}$ | Release groups of hatchery fish beach seined in Snake River |
| $R_P$ | Primary release groups of hatchery fish, Lower Granite Reservoir |
| $R_{C1}$ | Surface collector treatment release groups, Lower Granite Dam |
| $C_{C1}$ | Surface collector reference release groups, Lower Granite Dam |
| $C_{T1}$ | Inriver releases (tailrace) for transportation study at Lower Granite Dam |
| $R_{D1}$ | PIT-tagged fish detected and diverted back to river at Lower Granite Dam, used as "daily release groups" from Lower Granite Dam |
| $R_T$ | Trap release groups |
| $R_H$ | Hatchery release groups |

Table 2. Definition of parameters estimated from releases.

| Parameter | Definition |
|---|---|
| $S_{R1}$ | Probability of survival from point of primary release to tailrace of Lower Granite Dam (Lower Granite Dam "reach" survival). |
| $S_{C1}$ | Probability of survival from release in surface collector to tailrace at Lower Granite Dam. |
| $P_1$ | Probability of detection at Lower Granite Dam, given that fish survived to Lower Granite Dam. |
| $\underline{\beta}_1$ | Vector of slope parameters for covariates affecting survival from primary release point to Lower Granite Dam tailrace. |
| $S_{R2}$ | Probability of survival from Lower Granite Dam tailrace to Little Goose Dam tailrace (Little Goose Dam "reach" survival). |
| $P_2$ | Probability of detection at Little Goose Dam, given that fish survived to Little Goose Dam. |
| $\underline{\beta}_2$ | Vector of slope parameters for covariates affecting survival from Lower Granite Dam tailrace to Little Goose Dam tailrace. |
| $S_{R3}$ | Probability of survival from Little Goose Dam tailrace to Lower Monumental Dam tailrace (Lower Monumenta! Dam "reach" survival). |
| $P_3$ | Probability of detection at Lower Monumental Dam, given that fish survived to Lower Monumental Dam. |
| $\underline{\beta}_3$ | Vector of slope parameters for covariates affecting survival from Little Goose Dam tailrace to Lower Monumental Dam tailrace. |
| $\lambda$ | Probability that a fish surviving to Lower Monumental Dam tailrace is eventually detected at McNary Dam (includes McNary Dam "reach" survival and probability of detection at McNary Dam). |
| $S_T$ | Probability of survival from release at trap to tailrace of Lower Granite Dam. |
| $S_H$ | Probability of survival from release at hatchery to tailrace of Lower Granite Dam. |

Table 3. Parameters estimated from each set of releases.

| Set of releases | Parameters estimated | Model for analysis |
|---|---|---|
| $R_P$, $R_{BS}$ | $S_{R1}$, $P_1$, $S_{R2}$, $P_2$, $S_{R3}$, $P_3$ $\beta_1$, $\beta_2$, $\beta_3$ | Single-release |
| $R_{C1}$, $C_{C1}$ | $S_{C1}$ | Paired-release (Complete capture history) |
| $R_T$ | $S_T$ | Single-release |
| $R_H$ | $S_H$ | Single-release |

Table 4. Releases of PIT-tagged yearling chinook salmon and steelhead from Snake River hatcheries in 1996.

| Hatchery | Release site | Release Date | Species | Number of releases | Number per release* | Total number released* |
|---|---|---|---|---|---|---|
| Dworshak | N. Fork Clearwater R. | 11 Apr | Chinook | 2 | 200/1,000 | 1,200 |
| | N. Fork Clearwater R. | 11 Apr | Chinook | 1 | 3,800 | 3,800 |
| Dworshak | Clear Creek | 23 Apr | Steelhead | 1 | 325 | 325 |
| | Clear-water R. | 23 Apr | Steelhead | 1 | 325 | 325 |
| | Dworshak NFH | 29 Apr | Steelhead | 9 | 325 | 2,900 |
| | Dworshak NFH | 30 Apr-3 May | Steelhead | 6 | 250 | 1,500 |
| Kooskia | Clear Creek | 12 Apr | Chinook | 10 | 200 | 2,000 |
| | Clear Creek | 12 Apr | Chinook | 3 | 5,000 | 15,000 |
| Clear-water | Crooked R. Pond | 10 Apr | Chinook | 1 | 500 | 500 |
| | Red R. Pond | 10 Apr | Chinook | 3 | 400 | 1,200 |
| | Powell R. Pond | 11 Apr | Chinook | 20 | various | 9,300 |
| | Crooked R. Pond | 10 Apr | Chinook | 16 | 100 | 1,600 |
| Clearwater | S. Fork Clear-water R. | 17-18 Apr | Steel head | 3 | 300 | 900 |
| | Crooked R. | 15 Apr | Steelhead | 6 | 300 | 1,800 |
| | Red R. | 17 Apr | Steelhead | 4 | various | 4,000 |
| | Clear Creek | 18 Apr | Steelhead | 1 | 300 | 300 |
| | Clear Creek | 24 Apr | Steelhead | 2 | 150 | 300 |

Table 4. Continued.

| Hatchery | Release site | Date | Species | Number of releases | Number per release* | Total number released* |
|---|---|---|---|---|---|---|
| Lookingglass | Imnaha Weir | 2 Apr | Chinook | 23 | various | 4,700 |
| | Lookingglass H | 4 Apr | Chinook | 24 | various | 7,150 |
| McCall | Knox Bridge | 11 Apr | Chinook | 18 | various | 27,600 |
| | Knox Bridge | 13 Apr | Chinook | 1 | 2,000 | 2,000 |
| Rapid River | Rapid River H. | 19 Mar | Chinook | 13 | various | 17,000 |
| | Rapid River H. | 2-5 Apr | Chinook | 4 | 500 | 2,000 |
| Sawtooth | Salmon R. | 26 Mar | Chinook | 5 | various | 1,250 |
| Sawtooth | Sawtooth H. | 16 May | Steelhead | 7 | 200 | 1,400 |

* Approximate numbers.

Table 5. Number of juvenile salmonids captured by purse seine in Lower Granite Reservoir near Clarkston, Washington, 1996. Handling and tagging mortality are also shown. Abbreviations: H-Hatchery; W-Wild.

| | | Chinook Salmon | | Steelhead | | Sockeye | Coho | |
|---|---|---|---|---|---|---|---|---|
| Date | Sets | H | W | H | W | Salmon | Salmon | Total |
| 6 April | 3 | 7 | 0 | 16 | 0 | 0 | 0 | 26 |
| 8 April | 1 | 12 | 2 | 9 | 1 | 1 | 0 | 26 |
| 9 April | 2 | 8 | 6 | 18 | 15 | 0 | 0 | 49 |
| 10 April | 2 | 15 | 16 | 8 | 8 | 0 | 0 | 49 |
| 11 April | 7 | 35 | 40 | 204 | 117 | 2 | 0 | 405 |
| 12 April | 4 | 69 | 39 | 181 | 48 | 0 | 0 | 341 |
| 13 April | 5 | 277 | 12 | 58 | 18 | 0 | 0 | 370 |
| 14 April | 3 | 38 | 3 | 134 | 17 | 0 | 0 | 195 |
| 15 April | 5 | 101 | 10 | 159 | 26 | 2 | 0 | 301 |
| 16 April | 5 | 65 | 8 | 250 | 27 | 0 | 0 | 355 |
| 17 April | 2 | 23 | 0 | 35 | 0 | 0 | 0 | 60 |
| 18 April | 6 | 2 | 1 | 875 | 44 | 1 | 0 | 929 |
| 19 April | 4 | 95 | 13 | 1,285 | 0 | 0 | 0 | 1,397 |
| 20 April | 4 | 13 | 9 | 103 | 4 | 0 | 0 | 133 |
| 21 April | 5 | 22 | 6 | 527 | 31 | 0 | 0 | 591 |
| 22 April | 8 | 29 | 4 | 691 | 41 | 0 | 0 | 773 |
| 23 April | 4 | 38 | 4 | 1,100 | 0 | 0 | 0 | 1,146 |
| 24 April | 2 | 10 | 3 | 46 | 2 | 1 | 0 | 64 |
| 25 April | 5 | 66 | 13 | 633 | 46 | 0 | 0 | 763 |
| 26 April | 4 | 9 | 0 | 591 | 45 | 0 | 0 | 649 |
| 27 April | 1 | 6 | 0 | 125 | 0 | 0 | 0 | 132 |
| 28 April | 3 | 11 | 3 | 600 | 29 | 0 | 0 | 646 |
| 29 April | 2 | 2 | 3 | 77 | 0 | 1 | 0 | 85 |
| 30 April | 3 | 2 | 1 | 1,039 | 12 | 0 | 1 | 1,058 |
| 2 May | 2 | 2 | 1 | 658 | 19 | 3 | 0 | 685 |
| 6 May | 4 | 3 | 0 | 699 | 31 | 1 | 0 | 738 |
| 8 May | 3 | 2 | 0 | 821 | 52 | 1 | 0 | 879 |
| 10 May | 2 | 4 | 1 | 777 | 63 | 1 | 0 | 848 |
| 13 May | 1 | 4 | 2 | 976 | 78 | 2 | 0 | 1,063 |
| 15 May | 1 | 8 | 2 | 736 | 41 | 0 | 0 | 788 |
| Total | 103 | 978 | 202 | 13,431 | 815 | 16 | 1 | 15,544 |
| % Mortality | | 0.2 | 0.0 | 0.06 | 0.0 | 12.5 | 0.0 | 0.05 |

Table 6. Number of nonsalmonids and adult steelhead captured by purse seine in Lower Granite Reservoir near Clarkston, Washington, 1996.

| Species | Catch |
|---|---|
| Adult Steelhead | 27 |
| Chislemouth | 14 |
| Peamouth | 10 |
| Northern Squawfish | 14 |
| Crappie | 3 |
| Sucker | 8 |
| Carp | 14 |
| Channel Catfish | 1 |
| Smallmouth bass | 2 |
| Yellow Perch | 1 |
| Total all species | 91 |

Table 7. Number of hatchery steelhead PIT tagged and released in Lower Granite Reservoir near the Port of Wilma, 12 April-16 May 1996. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

| Release | $R_{P1}$ | $R_{P2}$ | $R_{P3}$ | $R_{P4}$ | $R_{P5}$ | $R_{P6}$ | $R_{P7}$ | $R_{P8}$ | $R_{P9}$ | $R_{P10}$ | $R_{P11}$ | $R_{P12}$ | $R_{P13}$ | $R_{P14}$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release date | 12 Apr | 19 Apr | 21 Apr | 23 Apr | 25 Apr | 27 Apr | 29 Apr | 1 May | 3 May | 7 May | 9May | 11 May | 14May | 16May | |
| Total fish in tagging files | 383 | 599 | 598 | 599 | 599 | 589 | 600 | 599 | 600 | 600 | 599 | 599 | 598 | 599 | 8,161 |
| Handling mortality (#) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (% | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| Total rejected (#) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total fish in analysis | 383 | 599 | 598 | 599 | 599 | 589 | 600 | 599 | 600 | 600 | 599 | 599 | 598 | 599 | 8.161 |

Table 8. Number of juvenile salmonids captured by beach seine in the free-flowing Snake River above Lower Granite Reservoir, 1996. The number of mortalities is in parentheses. Abbreviations: H-Hatchery; W-Wild.

| | | Yearling Chinook Salmon | | Sub-yearling Chinook Salmon | |
|---|---|---|---|---|---|
| Date | Sets | H | W | W | Steelhead |
| 4 April | 11 | 0 | 2 | 1 | 6 |
| 5 April | 15 | 11 | 3 | 4 | 6 |
| 8 April | 17 | 295 (1) | 56 | 16 | 44 |
| 9 April | 5 | 79 | 5 | 0 | 6 |
| 11 April | 21 | 191 (2) | 22 | 4 | 7 |
| 12 April | 19 | 43 | 9 | 0 | 6 |
| 15 April | 26 | 212 (1) | 18 | 4 | 30 |
| 16 April | 20 | 182 | 14 | 7 | 37 |
| 17 April | 22 | 120 (2) | 20 | 3 | 70 |
| 18 April | 15 | 126 (2) | 14 | 5 | 28 |
| 23 April | 23 | 207 | 18 | 11 | 48 |
| 24 April | 17 | 144 | 24 (1) | 3 | 83 |
| 29 April | 17 | 118 | 15 | 3 | 122 |
| 30 April | 19 | 71 | 15 | 6 | 46 |
| 1 May | 19 | 99 | 24 | 2 | 287 |
| 2 May | 15 | 96 | 16 | 5 | 117 |
| 6 May | 16 | 69 | 21 | 22 | 24 |
| 7 May | 21 | 61 | 5 | 15 | 34 |
| 8 May | 7 | 12 | 6 | 23 | 38 |
| 9 May | 12 | 50 | 14 | 21 | 26 |
| 13 May | 14 | 31 | 12 | 52 | 18 |
| 14 May | 22 | 204 | 28 | 29 | 67 |
| 15 May | 17 | 85 | 11 | 34 | 52 |
| Total | 390 | 2,506 (8) | 372 (1) | 270 (0) | 1,202 (0) |

Table 9. Number of nonsalmonids, whitefish, and adult steelhead captured by beach seine in the free-flowing Snake River above Lower Granite Reservoir, 1996.

| Species | Catch |
|---|---|
| Adult Steelhead | 1 |
| Chislemouth | 38 |
| Dace | 4 |
| Northern Squawfish | ‘307 |
| Shiner | 68 |
| Sucker | 152 |
| Whitefish | 1,118 |
| Total all species | 1,688 |

Table 10. Number of hatchery yearling chinook salmon beach seined in the free-flowing Snake River and released near Couse Creek, 9 April-5 May 1996. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

| Release dates | | 05 - 12 Apr | 15 - 18 Apr | 23 - 24 Apr | 29 Apr - 02 May | 06 - 09 May | 13 - 15 May | Total |
|---|---|---|---|---|---|---|---|---|
| Total fish in tagging files | | 581 | 534 | 335 | 369 | 178 | 307 | 2,304 |
| Handling mortality | (#) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total rejected | (#) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total fish in analysis | | 581 | 534 | 335 | 369 | 178 | 307 | 2,304 |

Table 11. Number of hatchery steelhead PIT tagged and released at Lower Granite Dam to evaluate surface collector survival in 1996. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

| Release | $R_{C11}$ | $C_{C11}$ | $R_{C12}$ | $C_{C12}$ | $R_{C13}$ | $C_{C13}$ | $R_{C14}$ | $C_{C14}$ | $R_{C15}$ | $C_{C15}$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Release date | 24 Apr | 24 Apr | 25 Apr | 25 Apr | 26 Apr | 26 Apr | 27 Apr | 27 Apr | 29 Apr | 29 Apr | |
| Total fish in tagging files | 1,505 | 1,499 | 1,505 | 1,498 | 1,498 | 1,491 | 1,496 | 1,496 | 1,491 | 1,495 | 14,974 |
| Chinook salmon | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Wild steelhead | 0 | 0 | 1 | 2 | 0 | 6 | 0 | 1 | 0 | 0 | 10 |
| Detected at Lower Granite Dam | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Handling mortality (number) | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| Handling mortality (%) | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Total rejected (number) | 2 | 0 | 1 | 3 | 0 | 6 | 0 | 1 | 1 | 1 | 15 |
| Total rejected (%) | 0.1 | 0.0 | 0.1 | 0.2 | 0.0 | 0.4 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total fish in analysis | 1,503 | 1,499 | 1,504 | 1,495 | 1,498 | 1,485 | 1,496 | 1,495 | 1,490 | 1,494 | 14,959 |

Table 12. Number of PIT-tagged juvenile salmonids detected and diverted at Lower Granite (LGR), Little Goose (LGO), Lower Monumental (LMO), and McNary (MCN) Dams during the 1996 migration (up to 1 July). Diverted fish were returned to the Snake River; fish in the raceways and sample were transported out of the study area.

| | Total | Diverted | | Raceways | | Sample | | Unknown | |
|---|---|---|---|---|---|---|---|---|---|
| Dam | detected | Number | (%) | Number | (%) | Number | (%) | Number | (%) |
| Yearling Chinook salmon | | | | | | | | | |
| LGR | 29,212 | 25,932 | (88.8) | 2,359 | (8.1) | 516 | (1.8) | 405 | (1.4) |
| LGO | 42,735 | 38,179 | (89.3) | 1,880 | (4.4) | 500 | (1.2) | 2,176 | (5-l) |
| LMO | 45,866 | 43,558 | (95.0) | 1,508 | (3.3) | 347 | (0.8) | 453 | (1.0) |
| MCN | 20,439 | 16,246 | (79.5) | 41 | (0.2) | 221 | (1.1) | 3,931 | (19.2) |
| Steelhead | | | | | | | | | |
| LGR | 16,263 | 14,915 | (91.7) | 955 | (5.9) | 358 | (2.2) | 35 | (0.2) |
| LGO | 19,177 | 16,435 | (85.7) | 1,087 | (5.7) | 264 | (1.4) | 1,391 | (7.3) |
| LMO | 17,660 | 16,925 | (95.8) | 490 | (2.8) | 114 | (0.6) | 131 | (0.7) |
| MCN | 7,137 | 4,314 | (60.4) | 39 | (0.5) | 104 | (1.5) | 2,680 | (37.6) |
| All species | | | | | | | | | |
| LGR | 47,482 | 42,457 | (89.4) | 3,433 | (7.2) | 996 | (2.1) | 596 | (1.3) |
| LGO | 63,225 | 55,680 | (88.1) | 3,015 | (4.8) | 800 | (1.3) | 3,730 | (5.9) |
| LMO | 65,011 | 61,793 | (95.1) | 2,042 | (3.1) | 478 | (0.7) | 698 | (1.1) |
| MCN | 28,314 | 20,987 | (74.1) | 88 | (0.3) | 417 | (1.5) | 6,822 | (24.1) |

Table 13. Estimates of survival probabilities for hatchery steelhead released near the Port of Wilma in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Release | Date | Release to LGR ($S_{R1}$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| $R_{P1}$ | 12 Apr | 1.0[a] | (0.103) | 0.733 | (0.081) | 1.0[a] | (0.141) | 0.934 | (0.113) |
| $R_{P2}$ | 19 Apr | 0.989 | (0.028) | 1.0[a] | (0.054) | 0.925 | (0.117) | 0.959 | (0.113) |
| $R_{P3}$ | 21 Apr | 0.969 | (0.032) | 0.906 | (0.045) | 0.964 | (0.090) | 0.846 | (0.074) |
| $R_{P4}$ | 23 Apr | 0.940 | (0.016) | 0,938 | (0.041) | 0.962 | (0.096) | 0.849 | (0.078) |
| $R_{P5}$ | 25 Apr | 0.940 | (0.017) | 0.917 | (0.056) | 1.0[a] | (0.102) | 0.879 | (0.073) |
| $R_{P6}$ | 27 Apr | 0.959 | (0.019) | 0.934 | (0.042) | 1.0[a] | (0.107) | 0.922 | (0.089) |
| $R_{PI}$ | 29 Apr | 0.945 | (0.025) | 0.836 | (0.045) | 1.0[a] | (0.115) | 0.797 | (0.085) |
| $R_{P8}$ | 1 May | 0.921 | (0.03 1) | 0.743 | (0.054) | 1.0[a] | (0.157) | 0.823 | (0.097) |
| $R_{P9}$ | 3 May | 0.854 | (0.032) | 0.897 | (0.068) | 1.0[a] | (0.265) | 1.0[a] | (0.189) |
| $R_{P10}$ | 7 May | 0.842 | (0.036) | 1.0[a] | (0.083) | 1.0[a] | (0.183) | 1.0[a] | (0.155) |
| $R_{P11}$ | 9 May | 0.954 | (0.028) | 0.921 | (0.055) | 0.912 | (0.115) | 0.802 | (0.093) |
| $R_{P12}$ | 11 May | 0.955 | (0.029) | 0.899 | (0.054) | 0.866 | (0.101) | 0.743 | (0.079) |
| $R_{P13}$ | 14 May | 0.916 | (0.029) | 1.0[a] | (0.092) | 0.799 | (0.129) | 0.776 | (0.1 OS) |
| $R_{P14}$ | 16 May | 0.894 | (0.045) | 0.983 | (0.088) | 1.0[a] | (0.227) | 0.968 | (0.186) |
| Weighted Average[b] | | 0.939 | (0.010) | 0.912 | (0.024) | 0.982 | (0.030) | 0.856 | (0.022) |

[a] Model-based estimate greater than 1.0 (see pages 10-l 1). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 14. Estimates of survival probabilities for hatchery yearling chinook salmon beach seined in the free-flowing Snake River and released near Couse Creek (Rkm 254). Estimates based on the Single-Release Model. Releases are pooled weekly. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Release dates | Number released | Release to LGR | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| 05 Apr - 12 Apr | 581 | 0.776 | (0.042) | 0.915 | (0.087) | 1.0[a] | (0.177) | 0.743 | (0.113) |
| 15 Apr - 18 Apr | 534 | 0.792 | (0.043) | 0.902 | (0.088) | 0.824 | (0.126) | 0.589 | (0.077) |
| 23 Apr - 24 Apr | 335 | 0.957 | (0.070) | 1.0[a] | (0.156) | 0.759 | (0.181) | 0.743 | (0.146) |
| 29 Apr - 02 May | 369 | 0.918 | (0.080) | 0.919 | (0.155) | 0.896 | (0.255) | 0.756 | (0.186) |
| 06 May - 09 May | 178 | 0.839 | (0.106). | 0.758 | (0.175) | 0.907 | (0.3 14) | 0.577 | (0.168) |
| 13 May - 15May | 307 | 1.0[a] | (0.155) | 0.694 | (0.151) | 1.0[a] | (0.576) | 0.957 | (0.398) |
| Weighted Average[b] | 2,304 | 0.829 | (0.027) | 0.887 | (0.030) | 0.879 | (0.041) | 0.660 | (0.03 1) |

[a] Model-based estimate greater than 1 .O (see pages 1 O-l 1). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 15. Estimates of detection probabilities for hatchery steelhead released near the Port of Wilma in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Release | Date | LGR ($P_1$) | | LGO ($P_2$) | | LMO ($P_3$) | |
|---|---|---|---|---|---|---|---|
| $R_{P1}$ | 12 Apr | 0.195 | (0.025) | 0.401 | (0.035) | 0.449 | (0.060) |
| $R_{P2}$ | 19 Apr | 0.402 | (0.023) | 0.534 | (0.031) | 0.336 | (0.045) |
| $R_{P3}$ | 21 Apr | 0.393 | (0.024) | 0.517 | (0.029) | 0.520 | (0.050) |
| $R_{P4}$ | 23 Apr | 0.776 | (0.021) | 0.494 | (0.030) | 0.477 | (0.049) |
| $R_{P5}$ | 25 Apr | 0.804 | (0.021) | 0.296 | (0.027) | 0.430 | (0.042) |
| $R_{P6}$ | 27 Apr | 0.673 | (0.023) | 0.500 | (0.030) | 0.431 | (0.047) |
| $R_{P7}$ | 29 Apr | 0.609 | (0.026) | 0.500 | (0.032) | 0.412 | (0.049) |
| $R_{P8}$ | 1 May | 0.598 | (0.028) | 0.327 | (0.031) | 0.376 | (0.049) |
| $R_{P9}$ | 3 May | 0.525 | (0.028) | 0.323 | (0.031) | 0.269 | (0.048) |
| $R_{P10}$ | 7 May | 0.339 | (0.025) | 0.301 | (0.028) | 0.393 | (0.063) |
| $R_{P11}$ | 9 May | 0.537 | (0.026) | 0.418 | (0.030) | 0.510 | (0.063) |
| $R_{P12}$ | 11 May | 0.535 | (0.026) | 0.424 | (0.031) | 0.528 | (0.060) |
| $R_{P13}$ | 14 May | 0.580 | (0.027) | 0.291 | (0.031) | 0.414 | (0.062) |
| $R_{P14}$ | 16 May | 0.357 | (0.027) | 0.356 | (0.034) | 0.273 | (0.056) |

Table 16. Estimates of detection probabilities for hatchery yearling chinook salmon beach seined in the free-flowing Snake River and released near Couse Creek (Rkm 254). Estimates based on the Single-Release Model. Releases are pooled weekly. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Release dates | Number released | LGR ($P_1$) | | LGO ($P_2$) | | LMO ($P_3$) | |
|---|---|---|---|---|---|---|---|
| 05 Apr - 12 Apr | 581 | 0.415 | (0.03 1) | 0.327 | (0.035) | 0.298 | (0.050) |
| 15 Apr - 18Apr | 534 | 0.423 | (0.032) | 0.342 | (0.037) | 0.425 | (0.061) |
| 23 Apr - 24 Apr | 335 | 0.362 | (0.037) | 0.255 | (0.042) | 0.345 | (0.074) |
| 29 Apr - 02 May | 369 | 0.334 | (0.038) | 0.243 | (0.043) | 0.283 | (0.074) |
| 06 May - 09 May | 178 | 0.362 | (0.059) | 0.252 | (0.063) | 0.412 | (0.127) |
| 13 May - 15 May | 307 | 0.216 | (0.039) | 0.248 | (0.048) | 0.249 | (0.107) |

Table 17. Survival estimates for hatchery steelhead released in the surface collector at Lower Granite Dam. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam.

| Releases | Treatment group survival LGR to LGO tailrace | Reference group survival LGR to LGO tailrace | Treatment relative to Reference ($S_{C1}$) |
|---|---|---|---|
| ($R_{C11}$, $C_{C11}$) | 0.999 (0.024) | 0.984 (0.023) | 1.015 (0.034) |
| ($R_{C12}$, $C_{C12}$) | 0.947 (0.024) | 0.904 (0.019) | 1.048 (0.034) |
| ($R_{C13}$, $C_{C13}$) | 0.947 (0.027) | 0.954 (0.027) | 0.993 (0.040) |
| ($R_{C14}$, $C_{C14}$) | 1 .o (0.037) | 0.954 (0.03 1) | 1.072 (0.052) |
| ($R_{C15}$, $C_{C15}$) | 0.870 (0.023) | 0.910 (0.021) | 0.956 (0.034) |
| Weighted Average' | | | 1.010 (0.019) |

[a] Model-based estimate greater than 1 .0 (see pages 10-l 1). Actual estimated value was used for relative survival.

[b] Weighted average of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 18. Descaling results for hatchery steelhead released in the surface collector at Lower Granite Dam and sampled at Little Goose Dam.

| Releases | Treatment Group | | | Reference Group | | |
|---|---|---|---|---|---|---|
| | Number sampled | Number descaled | Pct. descaled | Number sampled | Number descaled | Pct. descaled |
| ($R_{C11}$, $C_{C11}$) | 65 | 0 | 0.0 | 71 | 1 | 1.4 |
| ($R_{C12}$, $C_{C12}$) | 155 | 0 | 0.0 | 186 | 0 | 0.0 |
| ($R_{C13}$, $C_{C13}$) | 43 | 1 | 2.3 | 43 | 0 | 0.0 |
| ($R_{C14}$, $C_{C14}$) | 127 | 0 | 0.0 | 136 | 0 | 0.0 |
| ($R_{C15}$, $C_{C15}$) | 127 | 1 | 0.8 | 146 | 1 | 0.7 |
| Total | 517 | 2 | 0.4 | 582 | 2 | 0.3 |

Table 19. Estimates of survival probabilities for yearling chinook salmon (hatchery and wild combined) released into the tailrace of Lower Granite Dam in 1996 for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Dates | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LMO to MCN ($S_{R4}$) | LGR to MCN |
|---|---|---|---|---|---|
| 9-15 Apr | 638 | 0.877 (0.048) | 0.867 (0.100) | ----- | ----- |
| 16-22 Apr | 9,773 | 0.914 (0.013) | 0.971 (0.031) | 0.705 (0.086) | 0.626 (0.075) |
| 23-29 Apr | 13,280 | 0.931 (0.012) | 0.897 (0.022) | 0.726 (0.049) | 0.606 (0.039) |
| 30 Apr-6 May | 13,669 | 0,917 (0.013) | 0.945 (0.025) | 0.717 (0.055) | 0.621 (0.046) |
| 7-13 May | 17,164 | 0.912 (0.013) | 0.982 (0.032) | 0.882 (0.104) | 0.790 (0.090) |
| 14-20 May | 11,542 | 0.963 (0.024) | 0.889 (0.044) | 0.716 (0.125) | 0.613 (0.104) |
| 21-27 May | 805 | 0.928 (0.134) | 1.0[a] (0.287) | ----- | ----- |
| 28 May-3 Jun | 692 | 0.908 (0.154) | 0.582 (0.216) | ----- | ----- |
| 4-10 Jun | 393 | 0.891 (0.261) | ----- | ----- | ----- |
| 11-17 Jun | 136 | 0.473 (0.122) | 0.881 (0.395) | ----- | ----- |
| Weighted Average[b] | 68,092 | 0.921 (0.005) | 0.932 (0.014) | 0.734 (0.021) | 0.629 (0.023) |

[a] Model-based estimate greater than 1.0 (see pages 10-11). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 20. Estimates of survival probabilities for hatchery yearling chinook salmon released into the tailrace of Lower Granite Dam in 1996 for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Dates | Number released | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | LMO to MCN ($S_{R4}$) | | LGR to MCN | |
|---|---|---|---|---|---|---|---|---|---|
| 9-15 Apr | 347 | 0.809 | (0.063) | 1.0[a] | (0.292) | ----- | | ----- | |
| 16-22 Apr | 4,045 | 0.881 | (0.020) | 0.975 | (0.052) | 0.643 | (0.114) | 0.552 | (0.095) |
| 23-29 Apr | 9,017 | 0.924 | (0.015) | 0.910 | (0.026) | 0.786 | (0.062) | 0.661 | (0.050) |
| 30 Apr-6 May | 12,464 | 0.915 | (0.013) | 0.956 | (0.026) | 0.728 | (0.060) | 0.637 | (0.050) |
| 7-13 May | 15,907 | 0.910 | (0.014) | 0.979 | (0.034) | 0.881 | (0.110) | 0.785 | (0.094) |
| 14-20 May | 10,418 | 0.960 | (0.025) | 0.916 | (0.049) | 0.697 | (0.132) | 0.613 | (0.112) |
| 21-27 May | 655 | 0.947 | (0.169) | 1.0[a] | (0.452) | ----- | | ----- | |
| 28 May-3 Jun | 618 | 0.967 | (0.198) | 0.436 | (0.165) | ----- | | ----- | |
| 4-10 Jun | 324 | 0.762 | (0.235) | | | | | | |
| 11-17 Jun | 93 | 0.968 | (0.854) | ----- | | ----- | | ----- | |
| Weighted Average[b] | 53,888 | 0.914 | (0.009) | 0.941 | (0.022) | 0.754 | (0.033) | 0.651 | (0.030) |

[a] Model-based estimate greater than 1.0 (see pages 10-11). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 2 1 Estimates of survival probabilities for wild yearling chinook salmon released into the tailrace of Lower Granite Dam in 1996 for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Dates | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LMO to MCN ($S_{R4}$) | LGR to MCN |
|---|---|---|---|---|---|
| 9-15 Apr | 291 | 0.955 (0.072) | 0.681 (0.091) | ----- | ----- |
| 16-22 Apr | 5,728 | 0.937 (0.016) | 0.961 (0.038) | 0.758 (0.127) | 0.683 (0.112) |
| 23-29 Apr | 4,263 | 0.937 (0.022) | 0.867 (0.040) | 0.582 (0.077) | 0.473 (0.059) |
| 30 Apr-6 May | 1,205 | 0.944 (0.041) | 0.831 (0.067) | 0.618 (0.145) | 0.485 (0.109) |
| 7-13 May | 1,257 | 0.947 (0.044) | 1.0[a] (0.116) | 0.868 (0.337) | 0.833 (0.311) |
| 14-20 May | 1,124 | 0.993 (0.070) | 0.742 (0.090) | 0.840 (0.388) | 0.619 (0.279) |
| 21-27 May | 150 | 0.951 (0.229) | 0.755 (0.305) | ----- | ----- |
| 28 May-3 Jun | 74 | | | ----- | ----- |
| 4-10 Jun | 69 | ----- | ----- | ----- | ----- |
| 11-17 Jun | 43 | | | | |
| Weighted Average[b] | 14,204 | 0.940 (0.008) | 0.882 (0.041) | 0.639 (0.064) | 0.522 (0.070) |

[a] Model-based estimate greater than 1.0 (see pages 10-11). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 22. Survival estimates for yearling chinook salmon and steelhead released from hatcheries in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Ch-yearling chinook; St-steelhead; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Hatchery | Release site | Sp. | Rel. Date | Rel. size | Release to LGR ($S_H$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dworshak | NF Clearwater R | Ch | 11 Apr | 1,204 | 0.691 | (0.041) | 1.0[a] | (0.129) | 0.640 | (0.112) | 0.487 | (0.069) |
| | NF Clear-water R | Ch | 11 Apr | 3,853 | 0.803 | (0.019) | 0.923 | (0.039) | 0.938 | (0.070) | 0.695 | (0.046) |
| Dworshak | Clear Creek | St | 23 Apr | 322 | 0.636 | (0.037) | 0.861 | (0.072) | 1.0[a] | (0.291) | 0.686 | (0.156) |
| | Clear-water R. | St | 23 Apr | 336 | 0.669 | (0.035) | 0.811 | (0.059) | 0.903 | (0.150) | 0.490 | (0.081) |
| | Dworshak NFH | St | 29 Apr | 2,926 | 0.762 | (0.012) | 0.914 | (0.032) | 1.0[a] | (0.080) | 0.721 | (0.051) |
| | Dworshak NFH | St | 30 Apr-3 May | 1,504 | 0.754 | (0.018) | 0.880 | (0.044) | 0.931 | (0.076) | 0.618 | (0.043) |
| Kooskia | Clear Creek | Ch | 12 Apr | 1,607 | 0.730 | (0.032) | 0.915 | (0.067) | 0.946 | (0.114) | 0.632 | (0.067) |
| | Clear Creek | Ch | 12Apr | 503 | 0.498 | (0.047) | 0.905 | (0.117) | 1.0[a] | (0.226) | 0.488 | (0.094) |
| | Clear Creek | Ch | 12 Apr | 14,551 | 0.746 | (0.010) | 0.932 | (0.020) | 0.874 | (0.029) | 0.608 | (0.017) |
| Clear-water | Crooked R. Pond | Ch | 10 Apr | 500 | 0.236 | (0.033) | 1.0[a] | (0.240) | 0.759 | (0.260) | 0.191 | (0.056) |
| | Red R. Pond | Ch | 10 Apr | 1,211 | 0.344 | (0.038) | 0.809 | (0.152) | 1.0[a] | (0.488) | 0.358 | (0.125) |
| | Powell R. Pond | Ch | 11 Apr | 9,285 | 0.588 | (0.016) | 0.842 | (0.036) | 0.981 | (0.071) | 0.486 | (0.032) |
| Clear-water | SF Clear-water R. | St | 17-18 Apr | 900 | 0.804 | (0.024) | 0.962 | (0.046) | 1.0[a] | (0.118) | 0.885 | (0.086) |
| | Crooked R. | St | 15 Apr | 1,798 | 0.408 | (0.019) | 0.912 | (0.072) | 0.858 | (0.118) | 0.320 | (0.039) |
| | Red R. | St | 17 Apr | 3,999 | 0.442 | (0.012) | 0.930 | (0.041) | 1.0[a] | (0.091) | 0.422 | (0.035) |
| | Clear Creek | St | 18 Apr | 300 | 0.660 | (0.044) | 1.0[a] | (0.091) | 1.0[a] | (0.091) | 0.886 | (0.272) |
| | Clear Creek | St | 24 Apr | 300 | 0.781 | (0.032) | 1.0[a] | (0.104) | 0.879 | (0.145) | 0.701 | (0.094) |

Table 22. Continued.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | Release to LMO |
|---|---|---|---|---|---|---|---|---|
| Lookingglass | Imnaha Weir | Ch | 2 Apr | 4,714 | 0.568 (0.014) | 0.894 (0.037) | 0.912 (0.061) | 0.463 (0.028) |
| | Lookingglass H. | Ch | 4 Apr | 7,154 | 0.598 (0,011) | 0.916 (0.027) | 0.939 (0.042) | 0.515 (0.020) |
| McCall | Knox Bridge | Ch | 11 Apr | 27,527 | 0.533 (0.007) | 0.936 (0.022) | 0.979 (0.043) | 0.498 (0.020) |
| | | Ch | 13 Apr | 2,000 | 0.570 (0.031) | 0.856 (0.078) | 0.730 (0.098) | 0.356 (0.040) |
| Rapid River | Rapid River H. | Ch | 19 Mar | 17,181 | 0.588 (0.007) | 0.907 (0.019) | 0.914 (0.030) | 0.487 (0.014) |
| | Rapid River H. | Ch | 2-5 Apr | 2,003 | 0.565 (0.023) | 0.916 (0.059) | 0.974 (0.107) | 0.504 (0.050) |
| Sawtooth | Salmon R. | Ch | 26 Mar | 1,257 | 0.121 (0.017) | 1.0” (0.246) | 0.738 (0.244) | 0.093 (0.025) |
| Sawtooth | Sawtooth H. | St | 16 May | 1,399 | 0.481 (0.024) | 0.975 (0.087) | 1.0[a] (0.488) | 0.770 (0.221) |
| Weighted Average[b] | | Ch | | 94,550 | ----- | 0.915 (0.008) | 0.911 (0.017) | ----- |
| Weighted Average” | | St | | 13,084 | ----- | 0.915 (0.016) | 0.994 (0.038) | ----- |

[a] Model-based estimate greater than 1 .O (see pages 10-l 1). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 23. Estimates of survival probabilities for hatchery yearling chinook salmon PIT tagged and released at Salmon River and Snake River traps in 1996. Estimates based on the Single-Release Model. Releases are pooled weekly. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Release dates | Number released | Release to LGR | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| Salmon River Trap | | | | | | | | | |
| 18 Mar - 24 Mar | 198 | 0.661 | (0.088) | 0.779 | (0.148) | 1.0[a] | (0.274) | 0.527 | (0.127) |
| 25 Mar- 31 Mar | 300 | 0.654 | (0.072) | 0.802 | (0.128) | 1.0[a] | (0.301) | 0.532 | (0.148) |
| 01 Apr-07Apr | 670 | 0.694 | (0.041) | 0.920 | (0.087) | 0.995 | (0.161) | 0.635 | (0.093) |
| 08 Apr - 14Apr | 199 | 0.807 | (0.106) | 0.869 | (0.171) | 0.727 | (0.156) | 0.510 | (0.088) |
| 15 Apr - 21 Apr | 452 | 0.908 | (0.086) | 0.835 | (0.134) | 1.0[a] | (0.395) | 0.996 | (0.274) |
| 22 Apr - 28 Apr | 419 | 0.707 | (0.059) | 0.904 | (0.130) | 1.0[a] | (0.292) | 0.666 | (0.172) |
| 29 Apr - 05 May | 137 | 0.803 | (0.135) | 1.0[a] | (0.389) | 0.490 | (0.188) | 0.434 | (0.104) |
| 06 May - 12 May | 128 | 0.671 | (0.095) | 1.0[a] | (0.348) | 1.0[a] | (0.657) | 0.865 | (0.497) |
| 13 May - 19May | 50 | 0.767 | (0.300) | 0.696 | (0.378) | 0.885 | (0.656) | 0.472 | (0.313) |
| Weighted Average[b] | 2,553 | 0.716 | (0.025) | 0.874 | (0.029) | 0.852 | (0.079) | 0.554 | (0.038) |
| Snake River Trap | | | | | | | | | |
| 08 Apr - 14Apr | 131 | 0.871 | (0.082) | 1.0” | (0.162) | 0.798 | (0.183) | 0.719 | (0.137) |
| 15 Apr - 21 Apr | 445 | 1.0[a] | (0.061) | 0.918 | (0.100) | 0.959 | (0.174) | 0.889 | (0.141) |
| 22 Apr - 28 Apr | 325 | 0.995 | (0.064) | 0.905 | (0.116) | 0.756 | (0.124) | 0.680 | (0.085) |
| 29 Apr - 05 May | 80 | 0.856 | (0.128) | 1.0[a] | (0.338) | 0.426 | (0.155) | 0.440 | (0.122) |
| 06 May - 12May | 48 | 1.0[a] | (0.251) | 0.561 | (0.270) | 0.600 | (0.359) | 0.389 | (0.186) |
| 13 May - 19 May | 422 | 1.0[a] | (0.097) | 0.953 | (0.176) | 0.857 | (0.313) | 0.842 | (0.278) |
| Weighted Average[b] | 1,451 | 0.975 | (0.023) | 0.927 | (0.038) | 0.724 | (0.064) | 0.652 | (0.056) |

[a] Model-based estimate greater than 1.0 (see pages 10-11). Actual estimated value was used for weighted average.

[b] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances.

Table 24. Estimates of survival probabilities for juvenile salmonids released from fish traps in Snake River Basin during same period as primary releases in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Trap | Release dates | Number released | Release to LGR | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | Release to LMO |
|---|---|---|---|---|---|---|
| Hatchery chinook salmon | | | | | | |
| Salmon | 5 Apr - 15May | 1,674 | 0.775 (0.034) | 0.897 (0.066) | 0.996 (0.121) | 0.692 (0.075) |
| Snake | 8 Apr - 15May | 1,376 | 0.989 (0.037) | 0.907 (0.062) | 0.784 (0.079) | 0.703 (0.059) |
| Imnaha | 5 Apr - 15 May | 663 | 0.726 (0.052) | 0.857 (0.102) | 0.659 (0.101) | 0.410 (0.051) |
| Wild chinook salmon | | | | | | |
| Salmon | 5 Apr - 15 May | 791 | 0.882 (0.043) | 0.868 (0.066) | 0.989 (0.122) | 0.757 (0.084) |
| Snake | 5 Apr - 15May | 787 | 0.964 (0.039) | 0.980 (0.066) | 1.0[a] (0.122) | 0.963 (0.103) |
| Imnaha | 5 Apr - 15 May | 844 | 0.854 (0.035) | 0.918 (0.064) | 0.946 (0.112) | 0.742 (0.078) |
| Hatchery steelhead | | | | | | |
| Salmon | 15 Apr - 15 May | 1,255 | 0.851 (0.022) | 0.909 (0.048) | 0.853 (0.077) | 0.660 (0.052) |
| Snake | 15 Apr - 15 May | 1,141 | 0.929 (0.018) | 0.957 (0.039) | 1.0[a] (0.101) | 0.954 (0.084) |
| Imnaha | 19 Apr - 14May | 534 | 0.696 (0.035) | 1.0[a] (0.102) | 0.904 (0.192) | 0.649 (0.126) |
| Wild steelhead | | | | | | |
| Salmon | 15 Apr - 15 May | 221 | 0.967 (0.059) | 0.848 (0.105) | 1.0[a] (0.540) | 1.0[a] (0.424) |
| Snake | 15 Apr - 15May | 565 | 0.945 (0.029) | 0.976 (0.062) | 1.0[a] (0.140) | 0.951 (0.118) |
| Imnaha | 16 Apr - 14May | 1,274 | 0.862 (0.020) | 0.889 (0.036) | 1.0[a] (0.075) | 0.789 (0.052) |

[a] Model-based estimate greater than 1.0 (see pages 10-11).

Table 25. Data sets used to study relationships of survival and travel time from release to Lower Monumental Dam with environmental factors for yearling chinook salmon.

| Year | Release dates | Number of groups | Range of release sizes | Total number of PIT-tagged fish |
|---|---|---|---|---|
| Primary release groups in Lower Granite Reservoir | | | | |
| 1994 | 16 Apr - 11 May | 10 | 542-1,196 | 9,889 |
| 1995 | 9 Apr - 5 May | 12 | 119-1,259 | 11,012 |
| Total | | 22 | 119-1,259 | 20,901 |
| Daily "release" groups from Lower Granite Dam | | | | |
| 1994 | 17 Apr - 24 May | 38 | 11-2,921 | 27,763 |
| 1995 | 9 Apr - 31 May | 53 | 190-9,355 | 160,589 |
| 1996 | 10 Apr - 30 May | 48 | 31-5,555 | 88,774 |
| Total | | 139 | 11-9,355 | 277,126 |

Table 26. Summary of correlation and simple linear regression results for median travel times (Rel-LMO) of primary release groups of yearling chinook salmon from Lower Granite Reservoir.

| Exposure Index | Year | Linear regression $R^2$ | P value | intercept | slope | Rank correlation $R^2$ | P value |
|---|---|---|---|---|---|---|---|
| Flow (LMO) | 1994 | 37.2 | 0.061 | -11.12 | 0.337 | 3.5 | 0.585 |
| | 1995 | 15.9 | 0.199 | 47.39 | -0.290 | 1.8 | 0.651 |
| | 1994-1995 | 0.2 | 0.837 | 14.90 | 0.013 | 0.0 | 0.988 |
| Spill% (LMO) | 1994 | 50.3 | 0.022 | 17.31 | -0.207 | 57.0 | 0.023 |
| | 1995 | 0.9 | 0.769 | 22.92 | -0.304 | 0.6 | 0.790 |
| | 1994-1995 | 0.9 | 0.683 | 16.79 | -0.046 | 4.5 | 0.330 |
| Temperature (LMO) | 1994 | 44.1 | 0.036 | 3 1.63 | -1.290 | 49.1 | 0.034 |
| | 1995 | 18.3 | 0.165 | 151.99 | -12.760 | 48.7 | 0.020 |
| | 1994-1995 | 9.4 | 0.165 | 27.47 | -0.992 | 9.1 | 0.166 |
| Release Date (Julian) | 1994 | 76.1 | 0.001 | 45.51 | -0.260 | 70.9 | 0.011 |
| | 1995 | 90.7 | co.00 1 | 82.04 | -0.579 | 89.1 | 0.002 |
| | 1994-1995 | 78.9 | co.00 1 | 66.55 | -0.442 | 80.4 | <0.001 |

Table 27. Comparison of yearly linear regression models for median travel times (Rel-LMO) of primary release groups of yearling chinook salmon from Lower Granite Reservoir.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{1,18} = 3.33$ | 0.085 |
| | Annual Means vs. Parallel | $F_{1,19} = 0.83$ | 0.373 |
| | Identical vs. Parallel | $F_{1,19} = 1.16$ | 0.294 |
| Spill% (LMO) | Parallel vs. Independent | $F_{1,18} = 0.01$ | 0.905 |
| | Annual Means vs. Parallel | $F_{1,19} = 1.73$ | 0.204 |
| | Identical vs. Parallel | $F_{1,19} = 1.94$ | 0.179 |
| Temperature (LMO) | Parallel vs. Independent | $F_{1,18} = 2.84$ | 0.109 |
| | Annual Means vs. Parallel | $F_{1,19} = 2.11$ | 0.163 |
| | Identical vs. Parallel | $F_{1,19} = 0.48$ | 0.497 |
| Release Date (Julian) | Parallel vs. Independent | $F_{1,18} = 15.69$ | <0.001 |
| | Annual Means vs. Parallel | $F_{1,19} = 69.34$ | co.00 1 |
| | Identical vs. Parallel | $F_{1,19} = 0.003$ | 0.956 |
| | Grand Mean vs. Annual Means | $F_{1,20} = 0.38$ | 0.545 |

Table 28. Summary of correlation and simple linear regression results for median travel times (LGR-LMO) of daily release groups of yearling chinook salmon from Lower Granite Dam.

| | | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| Exposure Index | Year | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 5.3 | 0.164 | 11.97 | -0.037 | 0.3 | 0.273 |
| | 1995 | 21.5 | co.00 1 | 12.08 | -0.034 | 17.8 | 0.002 |
| | 1996 | 36.0 | co.00 1 | 13.73 | -0.046 | 30.4 | co.00 1 |
| | 1994-1996 | 30.2 | <0.001 | 11.95 | -0.033 | 27.9 | <0.001 |
| Spill% (LMO) | 1994 | 0.8 | 0.602 | 9.38 | -0.017 | 0.1 | 0.846 |
| | 1995 | 4.0 | 0.152 | 9.67 | -0.061 | 5.8 | 0.083 |
| | 1996 | 18.7 | 0.002 | 11.67 | -0.117 | 18.7 | 0.003 |
| | 1994-1996 | 16.0 | <0.001 | 9.80 | -0.063 | 13.8 | <0.001 |
| Temperature (LMO) | 1994 | 11.8 | 0.034 | 16.07 | -0.545 | 21.0 | 0.005 |
| | 1995 | 2.9 | 0.220 | 10.22 | -0.141 | 12.8 | 0.010 |
| | 1996 | 5.5 | 0.107 | 11.74 | -0.406 | 7.6 | 0.059 |
| | 1994-1996 | 0.0 | 0.821 | 8.23 | 0.020 | 10.0 | 0.996 |
| Release Date (Julian) | 1994 | 0.5 | 0.676 | 7.89 | 0.015 | 0.2 | 0.767 |
| | 1995 | 16.1 | 0.003 | 13.90 | -0.043 | 14.1 | 0.007 |
| | 1996 | 0.2 | 0.749 | 6.83 | 0.007 | 0.4 | 0.685 |
| | 1994-1996 | 1.1 | 0.213 | 10.27 | -0.015 | 1.3 | 0.183 |

Table 29. Comparison of yearly linear regression models for median travel times (LGR-LMO) of daily release groups of yearling chinook salmon from Lower Granite Dam.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,133} = 0.40$ | 0.670 |
| | Annual Means vs. Parallel | $F_{1,135} = 42.59$ | <0.001 |
| | Identical vs. Parallel | $F_{2,135} = 1.41$ | 0.247 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,133} = 2.33$ | 0.102 |
| | Annual Means vs. Parallel | $F_{1,135} = 9.95$ | 0.002 |
| | Identical vs. Parallel | $F_{2,135} = 0.14$ | 0.870 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,133} = 1.21$ | 0.301 |
| | Annual Means vs. Parallel | $F_{1,135} = 6.30$ | 0.013 |
| | Identical vs. Parallel | $F_{2,135} = 10.98$ | <0.001 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,133} = 2.66$ | 0.073 |
| | Annual Means vs. Parallel | $F_{1,135} = 1.98$ | 0.162 |
| | Identical vs. Parallel | $F_{2,135} = 7.75$ | 0.001 |
| | Grand Mean vs. Annual Means | $F_{2,136} = 7.56$ | 0.001 |

Table 30. Summary of correlation and simple linear regression results for survival estimates (Rel-LMO) of primary release groups of yearling chinook salmon from Lower Granite Reservoir.

| | | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| Exposure Index | Year | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 23.0 | 0.160 | 0.944 | -0.003 8 | 26.5 | 0.118 |
| | 1995 | 1.6 | 0.690 | 0.684 | 0.0009 | 4.4 | 0.494 |
| | 1994-1995 | 65.1 | <0.001 | 0.335 | 0.0040 | 48.7 | 0.001 |
| Spill% (LMO) | 1994 | 3.6 | 0.602 | 0.649 | -0.0008 | 0.1 | 0.912 |
| | 1995 | 0.0 | 0.977 | 0.772 | 0.0003 | 3.8 | 0.524 |
| | 1994- 1995 | 53.5 | <0.001 | 0.639 | 0.0056 | 54.3 | <0.001 |
| Temperature (LMO) | 1994 | 4.2 | 0.572 | 0.714 | -0.0058 | 0.1 | 0.913 |
| | 1995 | 1.9 | 0.673 | 1.697 | -0.0870 | 6.6 | 0.388 |
| | 1994-1995 | 33.9 | 0.005 | 1.228 | -0.047 1 | 60.7 | <0.001 |
| Median travel time (Rel-LMO) | 1994 | 0.6 | 0.835 | 0.618 | 0.0017 | 1.3 | 0.744 |
| | 1995 | 0.2 | 0.895 | 0.786 | -0.0004 | 0.8 | 0.935 |
| | 1994-1995 | 0.0 | 0.891 | 0.710 | -0.0007 | 0.3 | 0.784 |
| Release Date (Julian) | 1994 | 2.9 | 0.638 | 0.738 | -0.0008 | 0.1 | 0.913 |
| | 1995 | 3.2 | 0.578 | 0.643 | 0.0012 | 0.0 | 0.991 |
| | 1994-l 995 | 2.1 | 0.519 | 0.506 | 0.0017 | 0.7 | 0.700 |

Table 3 1. Comparison of yearly linear regression models for survival estimates (Rel-LMO) of primary release groups of yearling chinook salmon from Lower Granite Reservoir.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{1,18}$ = 1.61 | 0.220 |
| | Annual Means vs. Parallel | $F_{1,19}$ = 0.04 | 0.842 |
| | Identical vs. Parallel | $F_{1,19}$ = 8.07 | 0.010 |
| Spill% (LMO) | Parallel vs. Independent | $F_{1,18}$ = 0.01 | 0.904 |
| | Annual Means vs. Parallel | $F_{1,19}$ = 0.20 | 0.658 |
| | Identical vs. Parallel | $F_{1,19}$ = 17.42 | 0.001 |
| Temperature (LMO) | Parallel vs. Independent | $F_{1,18}$ = 0.20 | 0.657 |
| | Annual Means vs. Parallel | $F_{1,19}$ = 0.29 | 0.598 |
| | Identical vs. Parallel | $F_{1,19}$ = 32.98 | <0.001 |
| Median travel time (Rel-LMO) | Parallel vs. Independent | $F_{1,18}$ = 0.05 | 0.829 |
| | Annual Means vs. Parallel | $F_{1,19}$ = 0.01 | 0.929 |
| | Identical vs. Parallel | $F_{1,19}$ = 58.38 | <0.001 |
| Release Date (Julian) | Parallel vs. Independent | $F_{1,18}$ = 0.54 | 0.471 |
| | Annual Means vs. Parallel | $F_{1,19}$ = 0.04 | 0.852 |
| | Identical vs. Parallel | $F_{1,19}$ = 56.93 | <0.001 |
| | Grand Mean vs. Annual Means | $F_{1,20}$ = 61.50 | <0.001 |

Table 32. Summary of correlation and simple linear regression results for survival estimates (LGR-LMO) of daily release groups of yearling chinook salmon from Lower Granite Dam.

| Exposure Index | Year | Linear regression $R^2$ | P value | intercept | slope | Rank correlation $R^2$ | P value |
|---|---|---|---|---|---|---|---|
| Flow (LMO) | 1994 | 2.9 | 0.308 | 0.842 | -0.0020 | 2.4 | 0.349 |
| | 1995 | 2.5 | 0.260 | 0.849 | -0.0004 | 2.5 | 0.253 |
| | 1996 | 1.4 | 0.427 | 0.814 | 0.0003 | 3.2 | 0.224 |
| | 1994-1996 | 18.1 | <0.001 | 0.641 | 0.0015 | 9.0 | <0.001 |
| Spill% (LMO) | 1994 | 0.0 | 0.878 | 0.685 | 0.0003 | 3.4 | 0.263 |
| | 1995 | 0.6 | 0.568 | 0.828 | -0.0008 | 2.5 | 0.256 |
| | 1996 | 0.2 | 0.767 | 0.862 | -0.0005 | 0.0 | 0.893 |
| | 1994-1996 | 40.4 | <0.001 | 0.705 | 0.0048 | 14.2 | <0.001 |
| Temperature (LMO) | 1994 | 1.0 | 0.545 | 0.587 | 0.0085 | 5.2 | 0.164 |
| | 1995 | 9.5 | 0.025 | 0.939 | -0.0119 | 1.8 | 0.336 |
| | 1996 | 7.8 | 0.055 | 1.075 | -0.0238 | 4.0 | 0.173 |
| | 1994-1996 | 25.0 | <0.001 | 1.163 | -0.0349 | 12.3 | <0.001 |
| Median travel time (LGR-LMO) | 1994 | 0.2 | 0.782 | 0.706 | -0.0021 | 0.0 | 0.952 |
| | 1995 | 3.5 | 0.179 | 0.783 | 0.0038 | 2.0 | 0.307 |
| | 1996 | 0.0 | 0.863 | 0.842 | 0.0007 | 0.0 | 0.882 |
| | 1994-1996 | 3.7 | 0.023 | 0.851 | -0.0075 | 0.5 | 0.412 |
| Release Date (Julian) | 1994 | 1.7 | 0.431 | 0.851 | -0.0014 | 1.6 | 0.442 |
| | 1995 | 7.8 | 0.043 | 0.948 | -0.0011 | 2.4 | 0.262 |
| | 1996 | 1.9 | 0.356 | 0.990 | -0.0012 | 2.4 | 0.290 |
| | 1994-1996 | 0.2 | 0.592 | 0.740 | 0.0004 | 0.2 | 0.608 |

Table 33. Comparison of yearly linear regression models for survival estimates (LGR-LMO) of daily release groups of yearling chinook salmon from Lower Granite Dam.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,133}$ = 1.47 | 0.233 |
| | Annual Means vs. Parallel | $F_{1,135}$ = 0.17 | 0.683 |
| | Identical vs. Parallel | $F_{2,135}$ = 59.07 | <0.001 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,133}$ = 0.12 | 0.885 |
| | Annual Means vs. Parallel | $F_{1,135}$ = 0.14 | 0.706 |
| | Identical vs. Parallel | $F_{2,135}$ = 24.56 | <0.001 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,133}$ = 1.91 | 0.152 |
| | Annual Means vs. Parallel | $F_{1,135}$ = 4.32 | 0.039 |
| | Identical vs. Parallel | $F_{2,135}$ = 51.89 | <0.001 |
| Median travel time (LGR-LMO) | Parallel vs. Independent | $F_{2,133}$ = 0.41 | 0.664 |
| | Annual Means vs. Parallel | $F_{1,135}$ = 0.82 | 0.366 |
| | Identical vs. Parallel | $F_{2,135}$ = 82.02 | co.00 1 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,133}$ = 0.02 | 0.984 |
| | Annual Means vs. Parallel | $F_{1,135}$ = 5.13 | 0.025 |
| | Identical vs. Parallel | $F_{2,135}$ = 92.39 | <0.001 |
| | Grand Mean vs. Annual Means | $F_{2,136}$ = 87.50 | co.00 1 |

Table 34. Data sets used to study relationships of survival and travel time from release to Lower Monumental Dam with environmental factors for steelhead.

| Year | Release dates | Number of groups | Range of release sizes | Total number of PIT-tagged fish |
|---|---|---|---|---|
| Primary release groups in Lower Granite Reservoir | | | | |
| 1994 | 23 Apr - 12 May | 9 | 1,002-4,009 | 13.772 |
| 1995 | 22 Apr - 12May | 11 | 148-1,250 | 11,114 |
| 1996 | 12 Apr - 16 May | 14 | 383-600 | 8,161 |
| Total | | 34 | 148-4,009 | 30,047 |
| Daily "release" groups from Lower Granite Dam | | | | |
| 1994 | 21 Apr-26May | 36 | 28-2,865 | 31,501 |
| 1995 | 13 Apr - 30 May | 47 | 26-2,649 | 23,255 |
| 1996 | 12 Apr - 26 May | 42 | 18-3,768 | 28,155 |
| Total | | 125 | 18-3,768 | 82,911 |

Table 35. Summary of correlation and simple linear regression results for median travel times (Rel-LMO) of primary release groups of steelhead from Lower Granite Reservoir.

| | | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| Exposure Index | Year | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 4.5 | 0.582 | 9.77 | 0.037 | 16.0 | 0.268 |
| | 1995 | 29.2 | 0.086 | -26.2 1 | 0.332 | 25.9 | 0.111 |
| | 1996 | 57.7 | 0.002 | 12.91 | -0.045 | 54.9 | 0.007 |
| | 1994-1996 | 50.6 | co.00 1 | 17.29 | -0.070 | 37.7 | co.00 1 |
| Spill% (LMO) | 1994 | 2.2 | 0.700 | 12.84 | -0.018 | 1.0 | 0.759 |
| | 1995 | 60.9 | 0.005 | -21.71 | 1.514 | 55.5 | 0.019 |
| | 1996 | 73.4 | co.00 1 | 14.38 | -0.224 | 77.6 | 0.001 |
| | 1994-1996 | 55.5 | <0.001 | 14.70 | -0.218 | 46.2 | co.00 1 |
| Temperature (LMO) | 1994 | 15.2 | 0.299 | 16.91 | -0.33 1 | 21.2 | 0.185 |
| | 1995 | 23.6 | 0.130 | 28.63 | -1.680 | 36.1 | 0.055 |
| | 1996 | 24.4 | 0.073 | 20.62 | -1.416 | 20.7 | 0.099 |
| | 1994-1996 | 23.2 | 0.004 | -0.58 | 0.928 | 25.9 | 0.004 |
| Release Date (Julian) | 1994 | 3.1 | 0.649 | 15.65 | -0.025 | 1.8 | 0.689 |
| | 1995 | 88.5 | <0.001 | 56.60 | -0.380 | 84.3 | 0.004 |
| | 1996 | 24.4 | 0.453 | 12.58 | -0.045 | 3.5 | 0.496 |
| | 1994-1996 | 23.2 | 0.135 | 21.77 | -0.100 | 7.1 | 0.126 |

Table 36. Comparison of yearly linear regression models for median travel times (Rel-LMO) of primary release groups of steelhead from Lower Granite Reservoir.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,28}$ = 4.91 | 0.015 |
| | Annual Means vs. Parallel | $F_{1,30}$ = 6.72 | 0.015 |
| | Identical vs. Parallel | $F_{2,30}$ = 5.43 | 0.010 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,28}$ = 18.48 | co.00 1 |
| | Annual Means vs. Parallel | $F_{1,30}$ = 4.97 | 0.033 |
| | Identical vs. Parallel | $F_{2,30}$ = 2.55 | 0.095 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,28}$ = 1.11 | 0.343 |
| | Annual Means vs. Parallel | $F_{1,30}$ = 6.31 | 0.018 |
| | Identical vs. Parallel | $F_{2,30}$ = 16.40 | <0.001 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,28}$ = 8.44 | 0.001 |
| | Annual Means vs. Parallel | $F_{1,30}$ = 7.58 | 0.001 |
| | Identical vs. Parallel | $F_{2,30}$ = 24.44 | co.00 1 |
| | Grand Mean vs. Annual Means | $F_{2,31}$ = 19.42 | co.00 1 |

Table 37. Summary of correlation and simple linear regression results for median travel times (LGR-LMO) of daily release groups of steelhead from Lower Granite Dam.

| | | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| Exposure Index | Year | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 21.6 | 0.006 | 12.86 | -0.063 | 0.1 | 0.861 |
| | 1995 | 6.4 | 0.085 | 10.99 | -0.027 | 2.6 | 0.278 |
| | 1996 | 46.7 | co.00 1 | 11.65 | -0.041 | 46.4 | <0.001 |
| | 1994-1996 | 30.7 | <0.001 | 11.28 | -0.036 | 22.0 | <0.001 |
| Spill% (LMO) | 1994 | 1.2 | 0.541 | 8.03 | 0.017 | 0.0 | 0.923 |
| | 1995 | 0.3 | 0.739 | 7.62 | 0.022 | 0.4 | 0.679 |
| | 1996 | 65.9 | <0.001 | 12.91 | -0.196 | 65.3 | <0.001 |
| | 1994-1996 | 22.5 | <0.001 | 9.30 | -0.082 | 18.1 | co.00 1 |
| Temperature (LMO) | 1994 | 0.2 | 0.795 | 7.49 | 0.057 | 1.0 | 0.562 |
| | 1995 | 11.1 | 0.022 | 12.26 | -0.358 | 15.4 | 0.008 |
| | 1996 | 2.9 | 0.282 | 10.43 | -0.424 | 1.8 | 0.384 |
| | 1994-1996 | 2.3 | 0.096 | 5.71 | 0.159 | 2.0 | 0.121 |
| Release Date (Julian) | 1994 | 9.8 | 0.077 | 2.55 | 0.045 | 2.8 | 0.346 |
| | 1995 | 27.5 | <0.001 | 17.59 | -0.075 | 20.5 | 0.002 |
| | 1996 | 21.5 | 0.002 | 14.49 | -0.066 | 23.0 | 0.002 |
| | 1994-1996 | 7.4 | 0.003 | 12.87 | -0.043 | 7.0 | 0.004 |

Table 38. Comparison of yearly linear regression models for median travel times (LGR-LMO) of daily release groups of steelhead from Lower Granite Dam.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,116} = 0.83$ | 0.437 |
| | Annual Means vs. Parallel | $F_{1,118} = 33.38$ | <0.001 |
| | Identical vs. Parallel | $F_{2,118} = 5.59$ | 0.005 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,116} = 12.79$ | <0.001 |
| | Annual Means vs. Parallel | $F_{1,118} = 8.52$ | 0.004 |
| | Identical vs. Parallel | $F_{2,118} = 1.34$ | 0.265 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,116} = 1.02$ | 0.363 |
| | Annual Means vs. Parallel | $F_{1,118} = 5.88$ | 0.017 |
| | Identical vs. Parallel | $F_{2,118} = 15.52$ | <0.001 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,116} = 6.82$ | 0.002 |
| | Annual Means vs. Parallel | $F_{1,118} = 18.11$ | <0.001 |
| | Identical vs. Parallel | $F_{2,118} = 18.64$ | <0.001 |
| | Grand Mean vs. Annual Means | $F_{2,119} = 13.77$ | <0.001 |

Table 39. Summary of correlation and simple linear regression results for survival estimates (Rel-LMO) of primary release groups of steelhead from Lower Granite Rservoir.

| Exposure Index | Year | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| | | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 12.9 | 0.343 | 0.319 | 0.0034 | 4.7 | 0.556 |
| | 1995 | 10.9 | 0.321 | 1.095 | -0.0028 | 13.2 | 0.243 |
| | 1996 | 10.6 | 0.255 | 0.955 | -0.0008 | 2.4 | 0.568 |
| | 1994-1996 | 51.5 | <0.001 | 0.334 | 0.0038 | 29.9 | 0.002 |
| Spill% (LMO) | 1994 | 20.6 | 0.220 | 0.603 | -0.0026 | 7.1 | 0.437 |
| | 1995 | 4.8 | 0.517 | 0.903 | -0.0055 | 1.1 | 0.730 |
| | 1996 | 10.8 | 0.252 | 0.972 | -0.0036 | 2.0 | 0.601 |
| | 1994-1996 | 54.7 | co.00 1 | 0.590 | 0.0075 | 48.3 | co.00 1 |
| Temperature (LMO) | 1994 | 16.0 | 0.287 | 0.778 | -0.0158 | 3.4 | 0.586 |
| | 1995 | 0.0 | 0.935 | 0.808 | -0.0018 | 7.9 | 0.367 |
| | 1996 | 0.5 | 0.810 | 0.776 | 0.0081 | 1.1 | 0.704 |
| | 1994-1996 | 43.4 | <0.001 | 1.508 | -0.0720 | 58.1 | co.00 1 |
| Travel time (Rel-LMO) | 1994 | 0.0 | 0.941 | 0.565 | 0.0020 | 3.3 | 0.621 |
| | 1995 | 12.8 | 0.837 | 0.837 | -0.0046 | 5.8 | 0.437 |
| | 1996 | 1.6 | 0.666 | 0.820 | 0.0052 | 0.7 | 0.763 |
| | 1994-1996 | 40.2 | <0.001 | 1.011 | -0.0276 | 37.0 | <0.001 |
| Release Date (Julian) | 1994 | 24.4 | 0.176 | 1.013 | -0.0036 | 4.4 | 0.832 |
| | 1995 | 9.3 | 0.362 | 0.582 | 0.0017 | 0.1 | 0.943 |
| | 1996 | 17.9 | 0.132 | 1.307 | -0.0038 | 4.5 | 0.437 |
| | 1994-1996 | 3.4 | 0.295 | 0.307 | 0.0033 | 2.4 | 0.371 |

Table 40. Comparison of yearly linear regression models for survival estimates (Rel-LMO) of primary release groups of steelhead from Lower Granite Reservoir.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,28} = 1.27$ | 0.295 |
| | Annual Means vs. Parallel | $F_{1,30} = 1.07$ | 0.310 |
| | Identical vs. Parallel | $F_{2,30} = 36.88$ | co.00 1 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,28} = 0.09$ | 0.917 |
| | Annual Means vs. Parallel | $F_{1,30} = 4.21$ | 0.049 |
| | Identical vs. Parallel | $F_{2,30} = 38.33$ | <0.001 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,28} = 0.32$ | 0.732 |
| | Annual Means vs. Parallel | $F_{1,30} = 1.17$ | 0.288 |
| | Identical vs. Parallel | $F_{2,30} = 61.51$ | <0.001 |
| Median travel time (Rel-LMO) | Parallel vs. Independent | $F_{2,28} = 0.32$ | 0.728 |
| | Annual Means vs. Parallel | $F_{1,30} = 0.44$ | 0.510 |
| | Identical vs. Parallel | $F_{2,30} = 47.68$ | co.00 1 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,28} = 2.27$ | 0.122 |
| | Annual Means vs. Parallel | $F_{1,30} = 1.56$ | 0.221 |
| | Identical vs. Parallel | $F_{2,30} = 89.92$ | <0.001 |
| | Grand Mean vs. Annual Means | $F_{2,31} = 91.19$ | co.00 1 |

Table 41. Summary of correlation and simple linear regression results for survival estimates (LGR-LMO) of daily release groups of steelhead from Lower Granite Dam.

| | | Linear regression | | | | Rank correlation | |
|---|---|---|---|---|---|---|---|
| Exposure Index | Year | $R^2$ | P value | intercept | slope | $R^2$ | P value |
| Flow (LMO) | 1994 | 1.7 | 0.465 | 0.533 | 0.0024 | 2.2 | 0.405 |
| | 1995 | 1.0 | 0.515 | 0.93 1 | -0.0007 | 1.9 | 0.347 |
| | 1996 | 0.1 | 0.820 | 0.827 | 0.0002 | 3.9 | 0.206 |
| | 1994-1996 | 16.8 | <0.001 | 0.612 | 0.0020’ | 11.6 | co.00 1 |
| Spill% (LMO) | 1994 | 30.3 | <0.001 | 0.778 | -0.0083 | 22.5 | 0.007 |
| | 1995 | 0.1 | 0.809 | 0.842 | 0.0009 | 1.7 | 0.375 |
| | 1996 | 0.9 | 0.545 | 0.790 | 0.0017 | 2.5 | 0.317 |
| | 1994-1996 | 12.8 | <0.001 | 0.762 | 0.0028 | 3.7 | 0.023 |
| Temperature (LMO) | 1994 | 21.0 | 0.007 | 1.343 | -0.0510 | 23.9 | 0.006 |
| | 1995 | 0.7 | 0.586 | 0.914 | -0.0048 | 0.4 | 0.658 |
| | 1996 | 0.6 | 0.640 | 0.712 | 0.0139 | 0.2 | 0.780 |
| | 1994-1996 | 18.1 | <0.001 | 1.250 | -0.0399 | 7.1 | 0.003 |
| Median travel time (Rel-LMO) | 1994 | 2.9 | 0.346 | 0.886 | -0.0207 | 2.4 | 0.381 |
| | 1995 | 2.4 | 0.297 | 0.923 | -0.0085 | 0.6 | 0.601 |
| | 1996 | 5.1 | 0.150 | 0.960 | -0.0181 | 4.8 | 0.160 |
| | 1994-1996 | 20.9 | <0.001 | 1.048 | -0.033 1 | 3.6 | 0.037 |
| Release Date (Julian) | 1994 | 39.9 | co.00 1 | 1.922 | -0.0098 | 23.9 | 0.006 |
| | 1995 | 0.2 | 0.753 | 0.911 | -0.0004 | 0.8 | 0.539 |
| | 1996 | 0.5 | 0.647 | 0.719 | 0.0011 | 5.6 | 0.129 |
| | 1994-1996 | 4.0 | 0.028 | 1.163 | -0.0030 | 0.0 | 0.926 |

Table 42. Comparison of yearly linear regression models for survival estimates (LGR-LMO) of daily release groups of steelhead from Lower Granite Dam.

| Exposure Index | Test | F statistic | P value |
|---|---|---|---|
| Flow (LMO) | Parallel vs. Independent | $F_{2,116} = 1.78$ | 0.174 |
| | Annual Means vs. Parallel | $F_{1,118} = 0.39$ | 0.534 |
| | Identical vs. Parallel | $F_{2,118} = 11.33$ | <0.001 |
| Spill% (LMO) | Parallel vs. Independent | $F_{2,116} = 10.64$ | <0.001 |
| | Annual Means vs. Parallel | $F_{1,118} = 12.22$ | 0.001 |
| | Identical vs. Parallel | $F_{2,118} = 22.11$ | <0.001 |
| Temperature (LMO) | Parallel vs. Independent | $F_{2,116} = 9.74$ | <0.001 |
| | Annual Means vs. Parallel | $F_{1,118} = 5.21$ | 0.024 |
| | Identical vs. Parallel | $F_{2,118} = 13.02$ | <0.001 |
| Median travel time (LGR-LMO) | Parallel vs. Independent | $F_{2,116} = 0.45$ | 0.640 |
| | Annual Means vs. Parallel | $F_{1,118} = 10.21$ | 0.002 |
| | Identical vs. Parallel | $F_{2,118} = 13.38$ | <0.001 |
| Release Date (Julian) | Parallel vs. Independent | $F_{2,116} = 16.49$ | <0.001 |
| | Annual Means vs. Parallel | $F_{1,118} = 28.39$ | co.00 1 |
| | Identical vs. Parallel | $F_{2,118} = 41.39$ | co.00 1 |
| | Grand Mean vs. Annual Means | $F_{2,119} = 25.48$ | <0.001 |

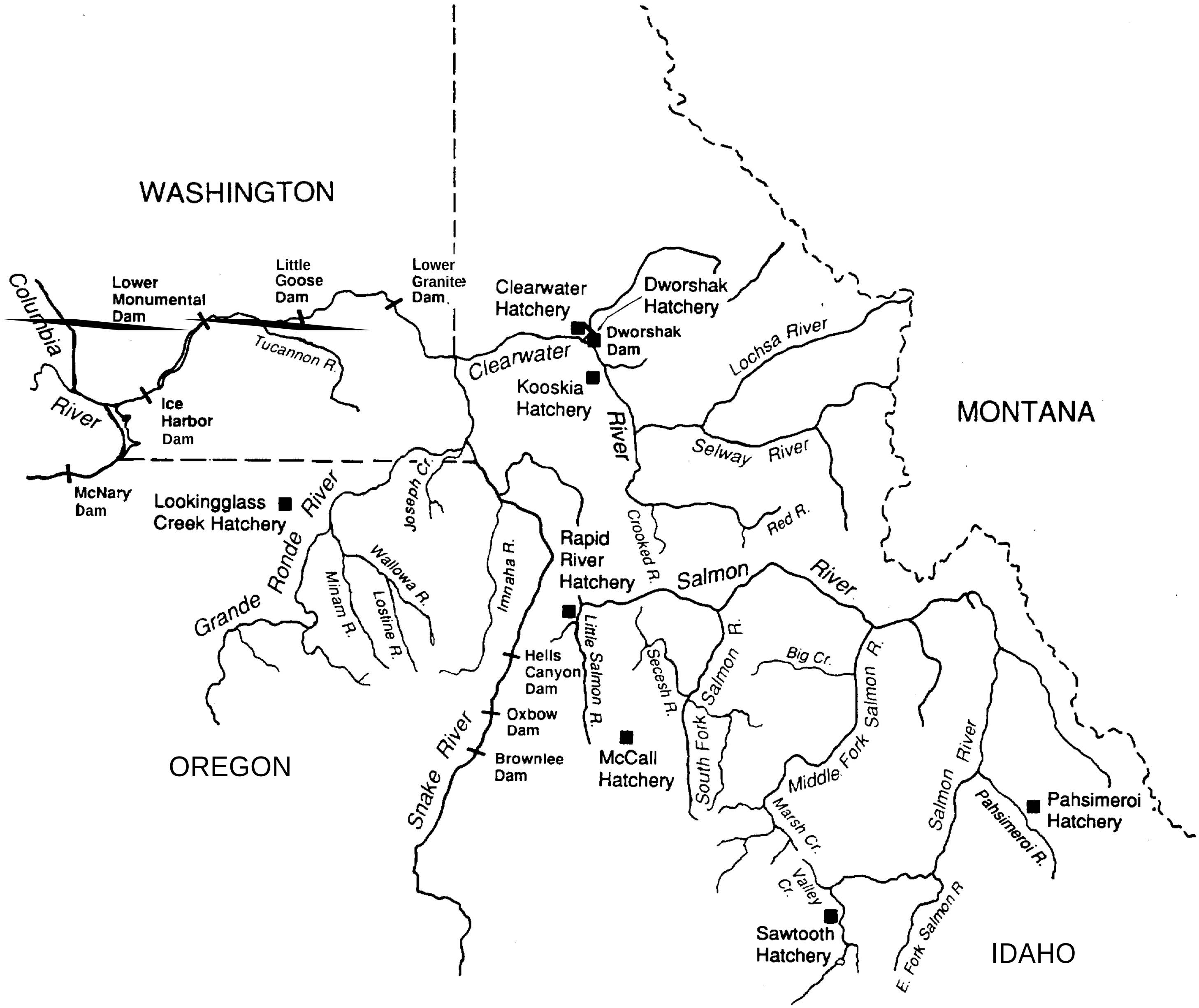


Figure 1. Study area showing release and detection sites.

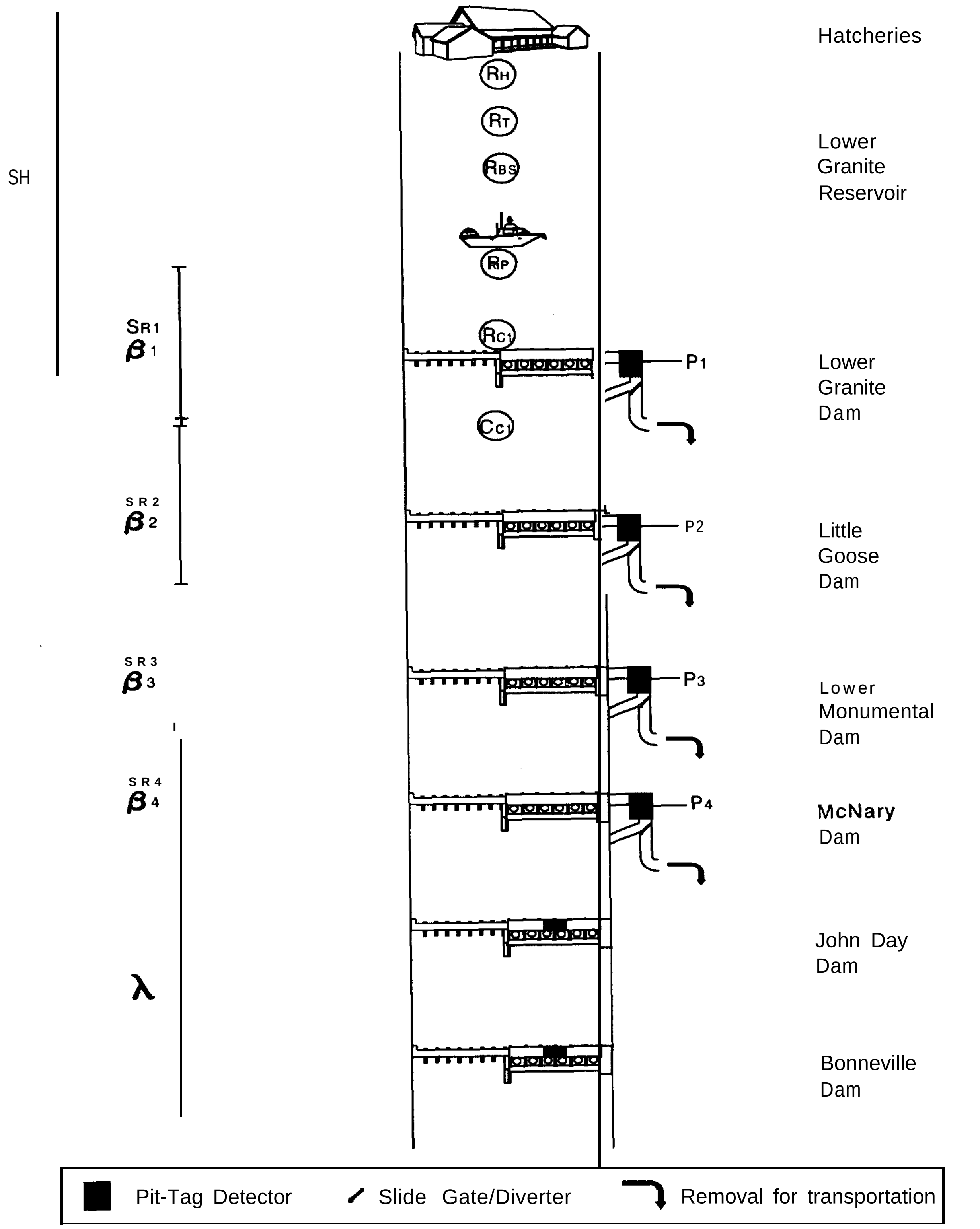


Figure 2. Schematic of study area showing location of study sites, release groups (circled), and estimated parameters. (See Tables 1 and 2 for release group and parameter definitions).

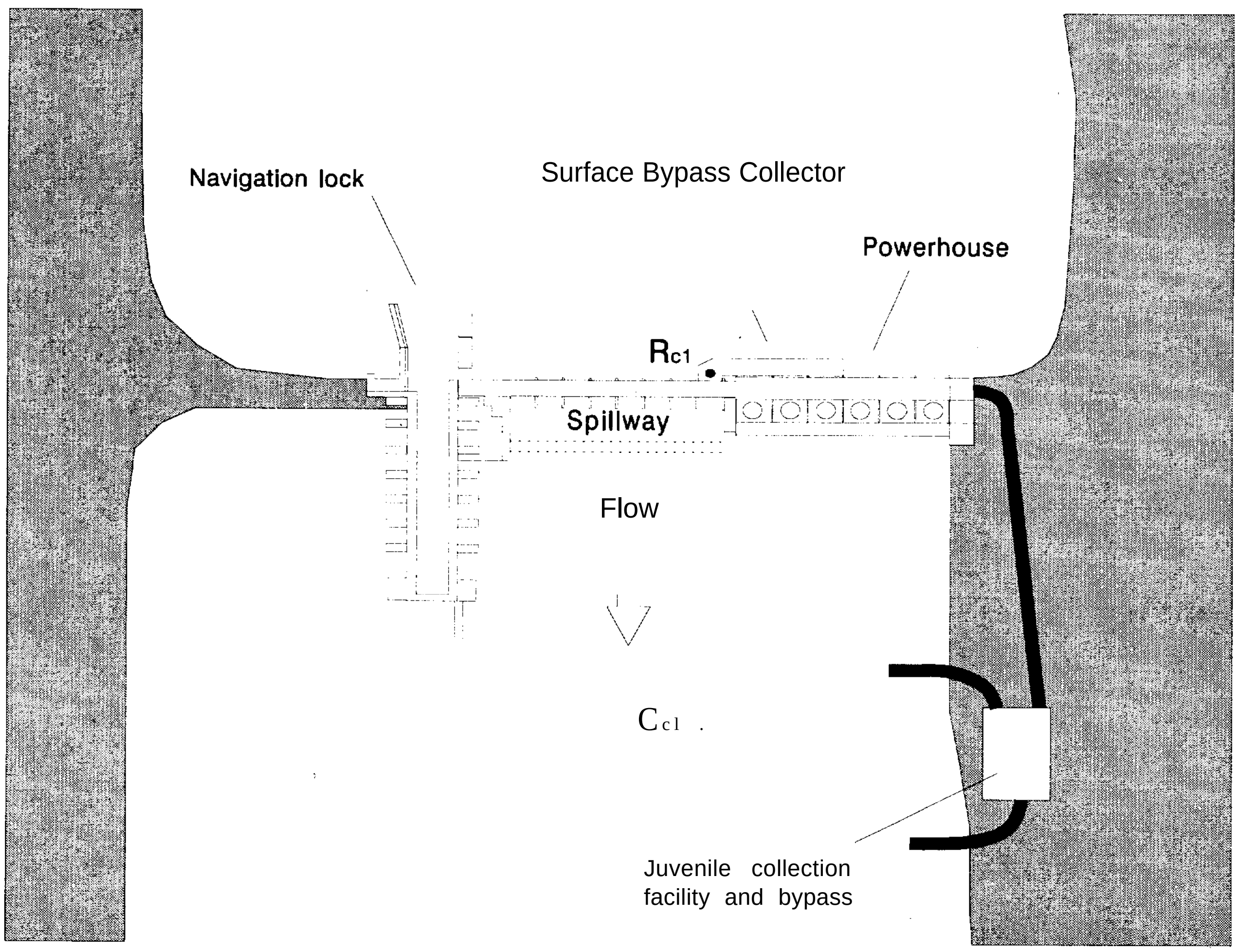


Figure 3. Schematic of Lower Granite Dam showing locations of surface collector test ($R_{C1}$) and reference releases ($C_{C1}$).

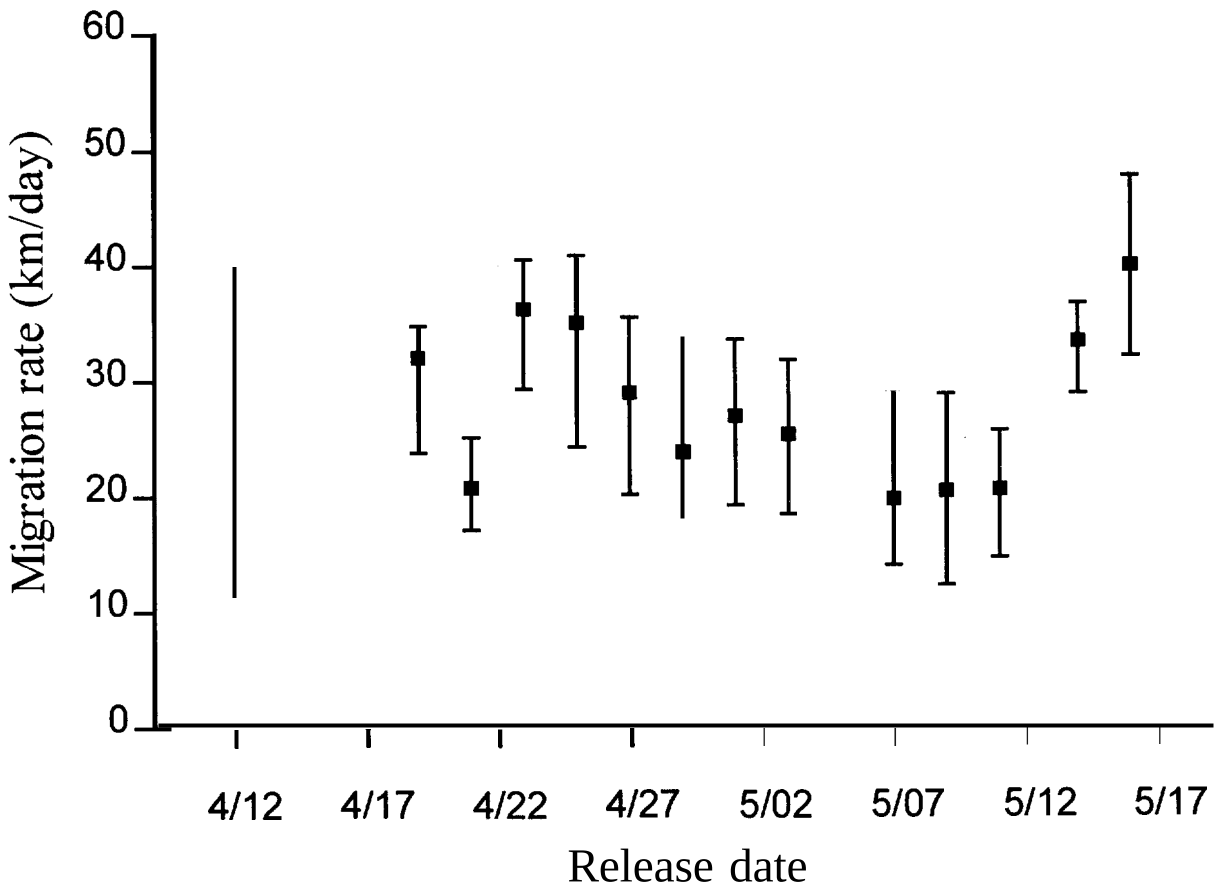


Figure 4. Median migration rate (km/day) from release at the Port of Wilma to Lower Granite Dam (49 km) for PIT-tagged hatchery steelhead. Ends of thin lines show the 20th and 80th percentiles.

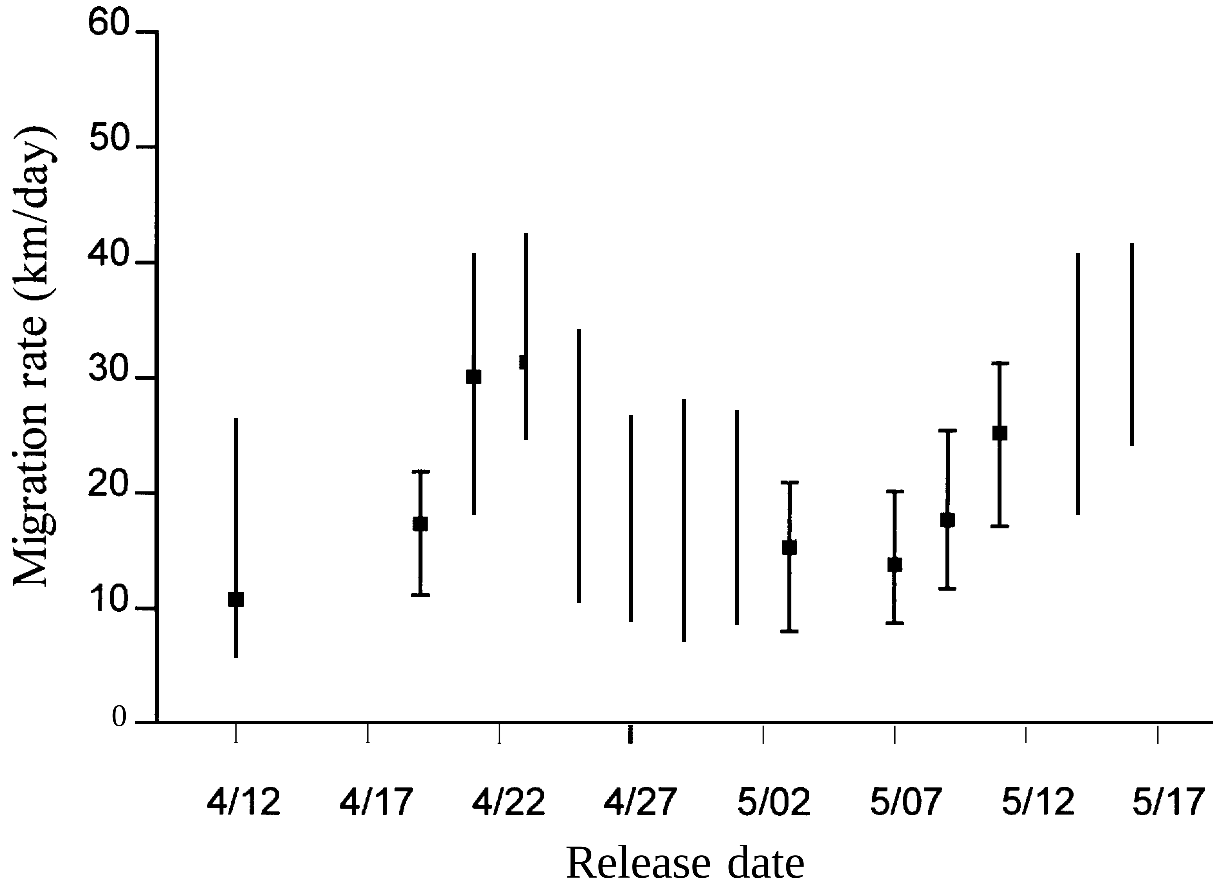


Figure 5. Median migration rate (km/day) from Lower Granite Dam to Little Goose Dam (60 km) for PIT-tagged hatchery steelhead. Ends of thin lines show the 20th and 80th percentiles.

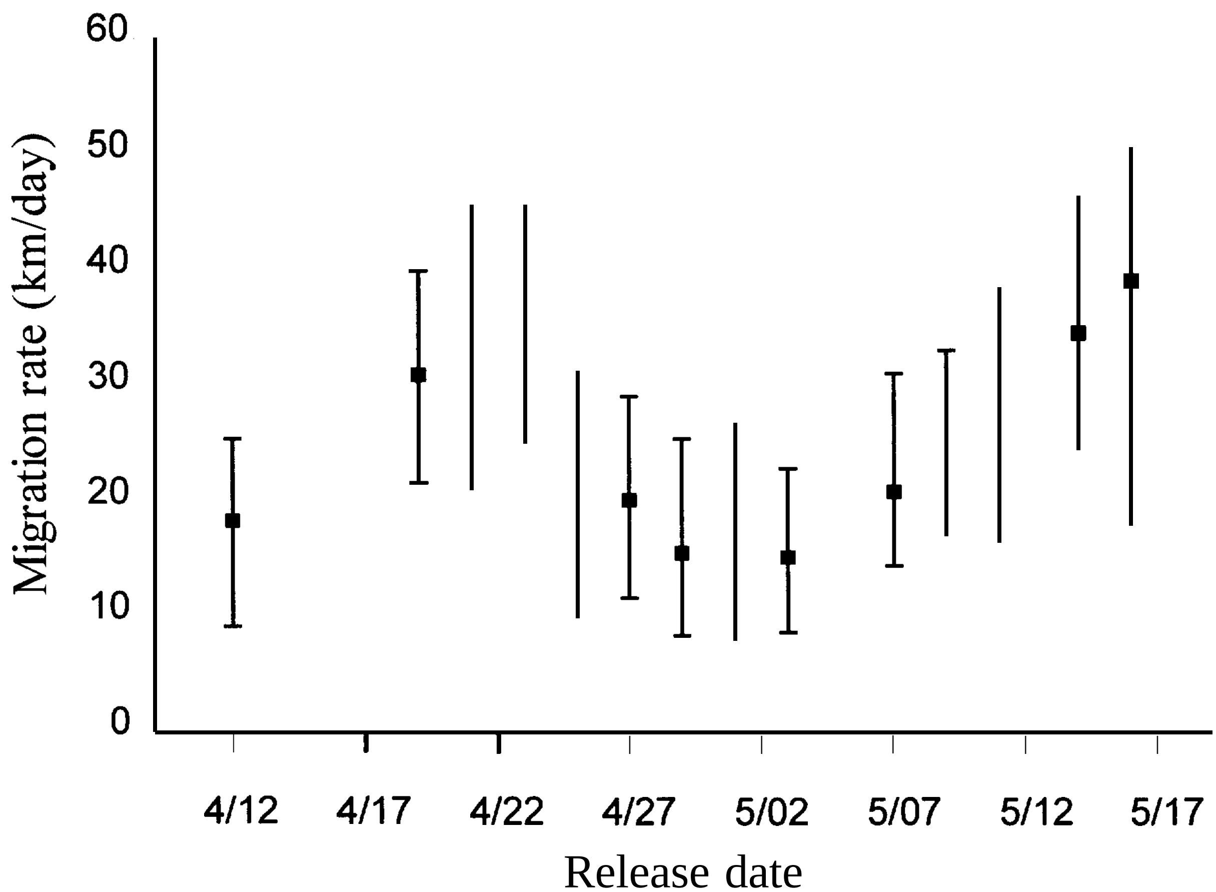


Figure 6. Median migration rate (km/day) from Little Goose Dam to Lower Monumental Dam (46 km) for PIT-tagged hatchery steelhead. Ends of thin lines show the 20th and 80the percentiles.

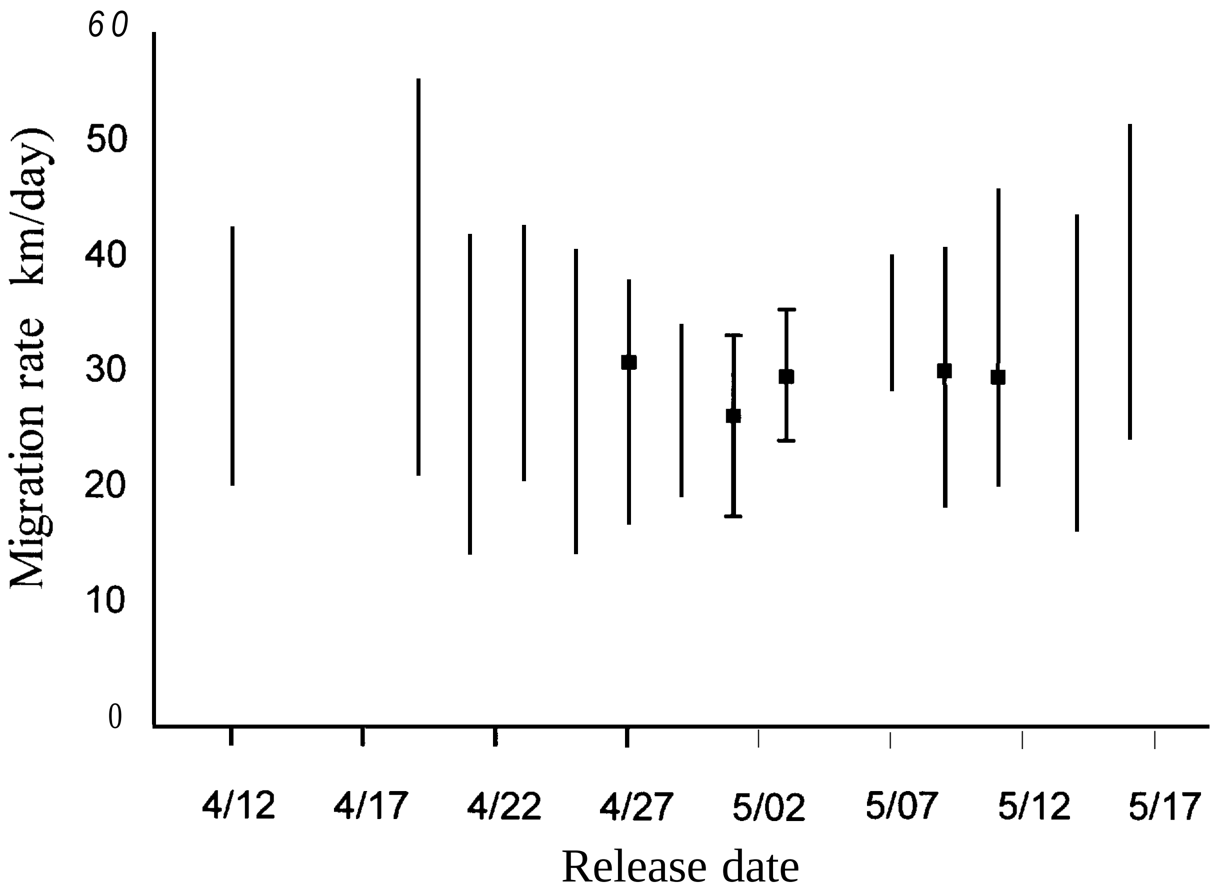


Figure 7. Median migration rate (km/day) from Lower Monumental Dam to McNary Dam (119 km) for PIT-tagged hatchery steelhead. Ends of thin lines show the 20th and 80th percentiles.

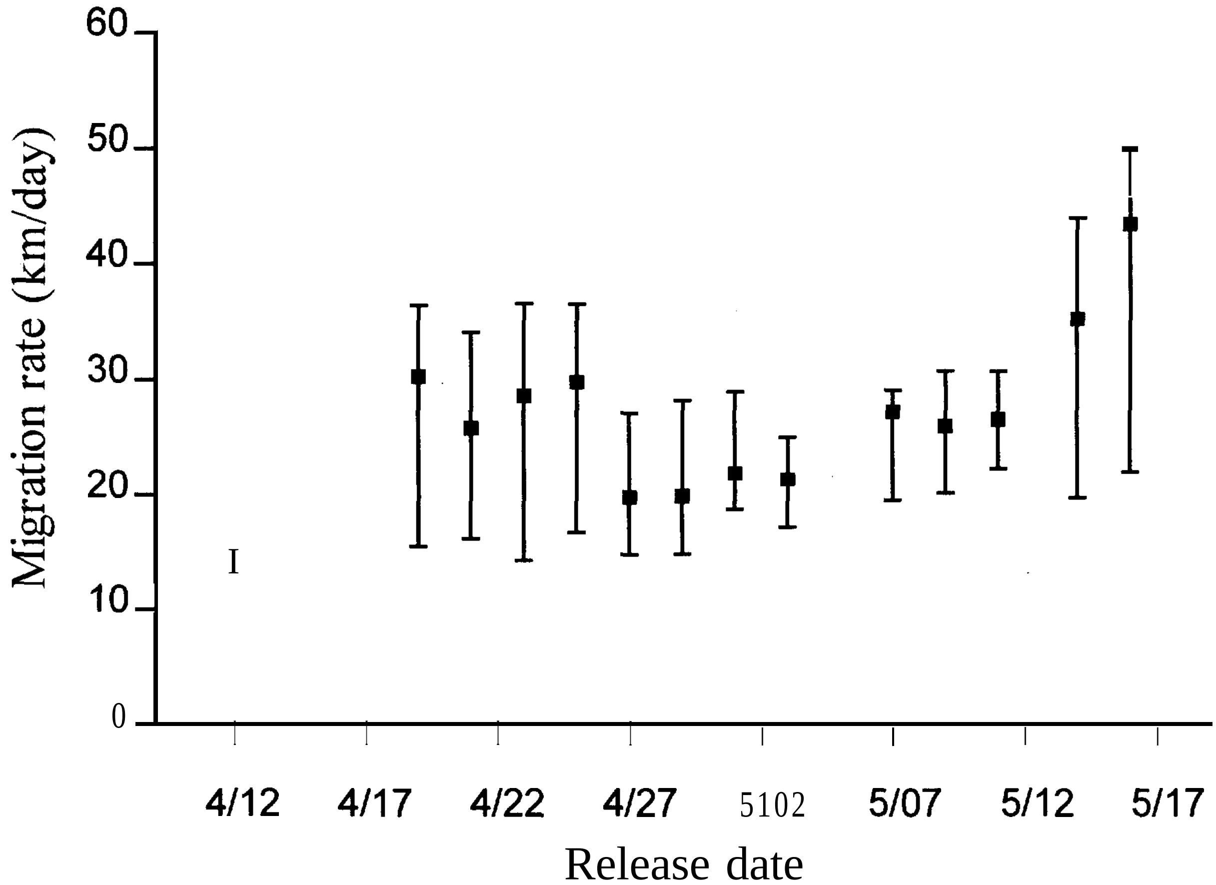


Figure 8. Median migration rate (km/day) from release at the Port of Wilma to McNary Dam (274 km) for PIT-tagged hatchery steelhead. Ends of thin lines show the 20th and 80th percentiles.

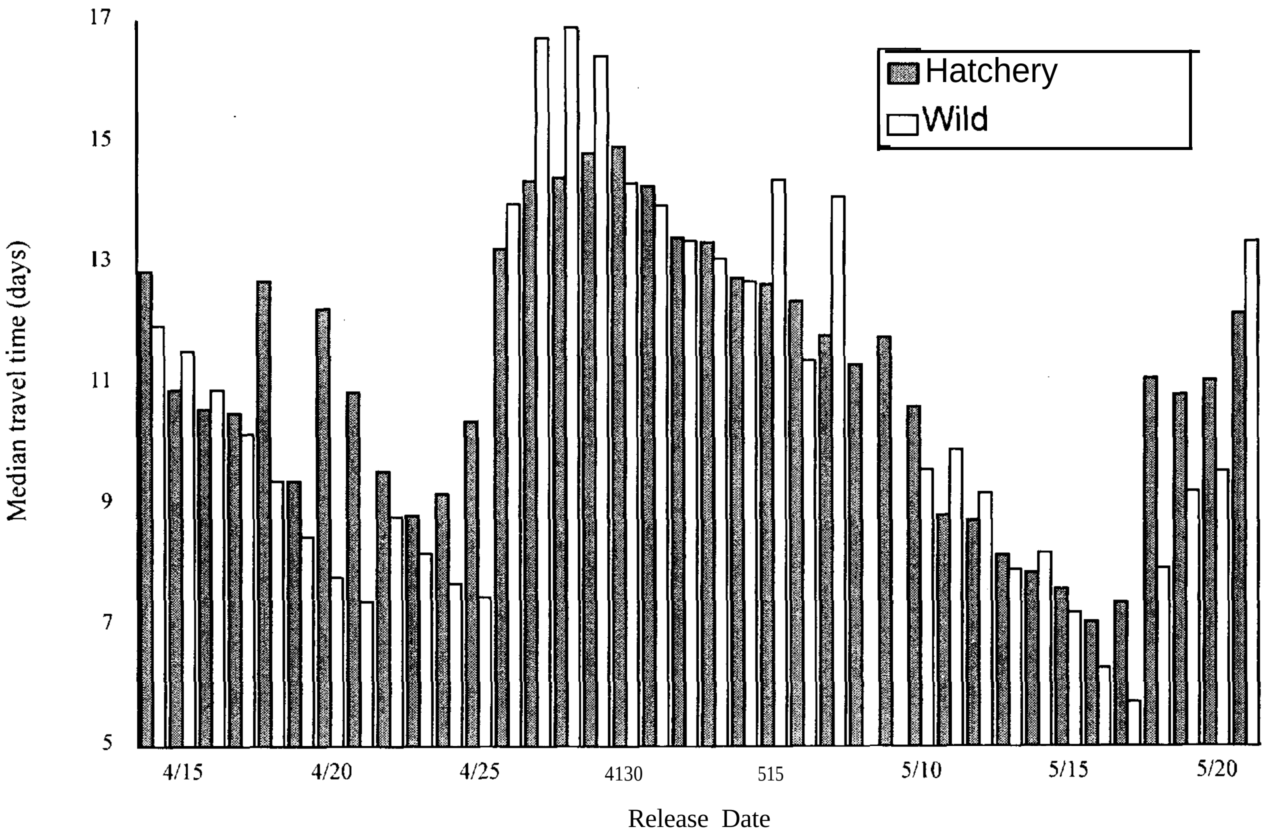


Figure 9. Median travel times (days) between Lower Granite and McNary Dams for daily releases of wild and hatchery yearling chinook salmon into Lower Granite Dam tailrace.

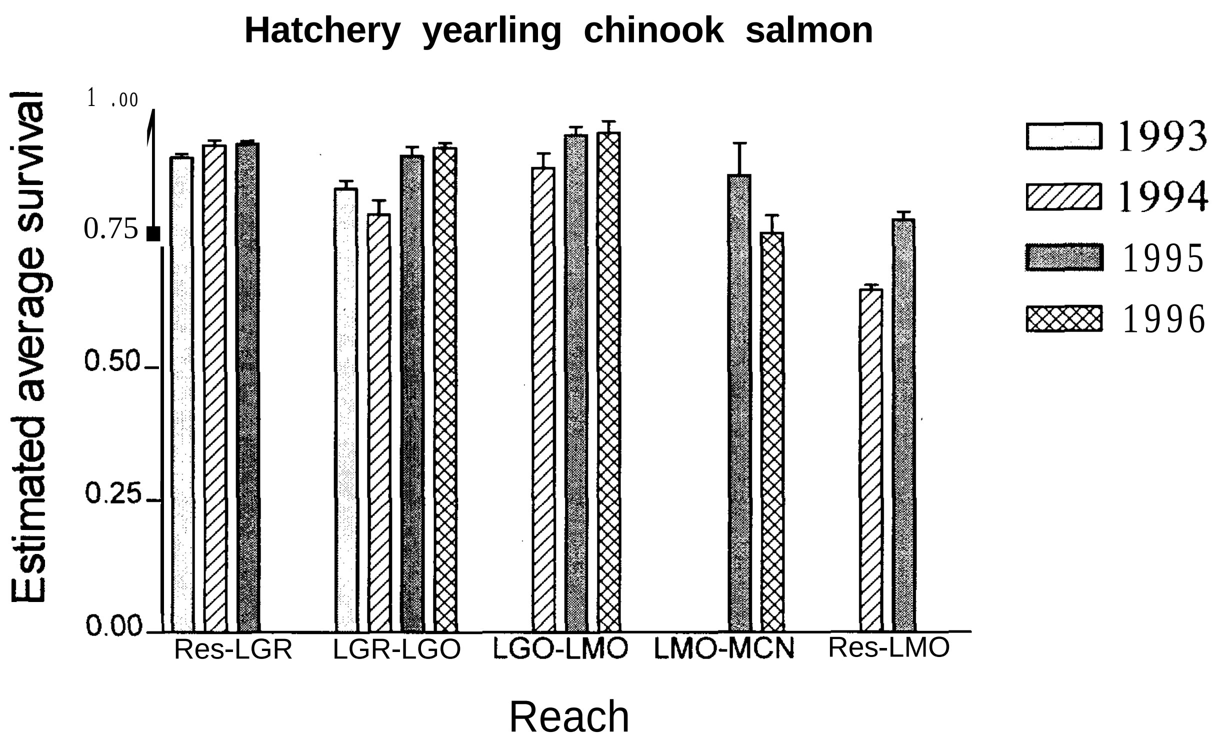


Figure 10. Annual average survival estimates for PIT-tagged hatchery yearling chinook salmon from Lower Granite Reservoir (Res; 1993-Nisqually John, 1994-Silcott Island, 1995 the Port of Wilma) and Lower Granite Dam (1996) to Lower Granite (LGR), Little Goose (LGO), Lower Monumental (LMO), and McNary (MCN) Dam tailraces. Standard errors are also shown.

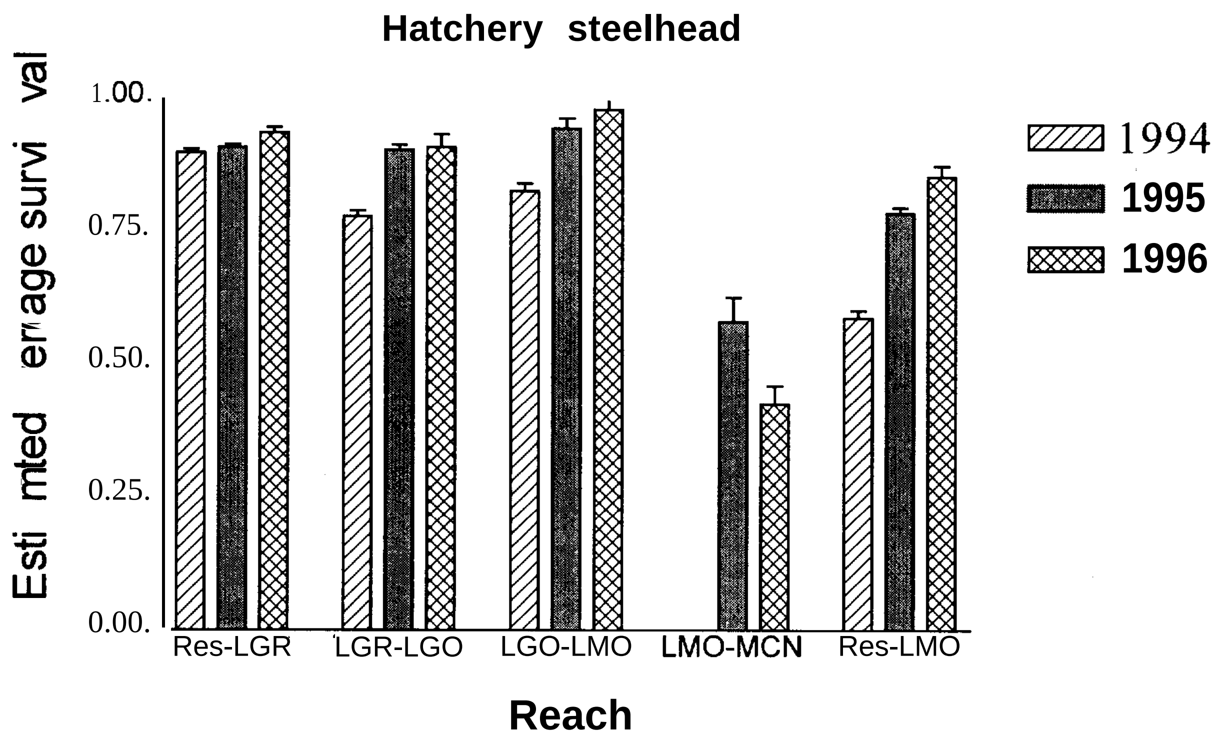


Figure 11. Annual average survival estimates for PIT-tagged hatchery steelhead from Lower Granite Reservoir (Res; 1994-Silcott Island, 1995 and 1996-the Port of Wilma) to Lower Granite (LGR), Little Goose (LGO), Lower Monumental (LMO), and McNary (MCN) Dam tailraces. Standard errors are also shown.

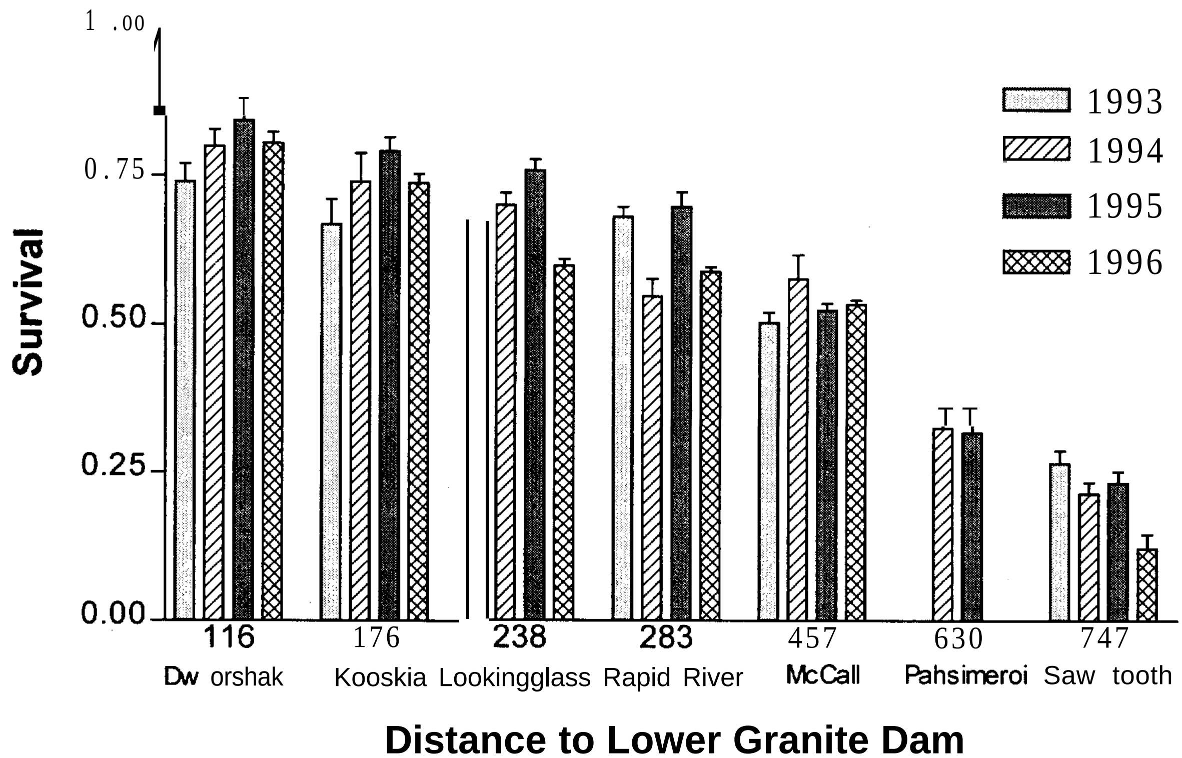


Figure 12. Estimated survival to Lower Granite Dam **tailrace** for yearling chinook salmon released from Snake River Basin hatcheries. Distance from release to Lower Granite Dam (km) and standard errors are also shown.

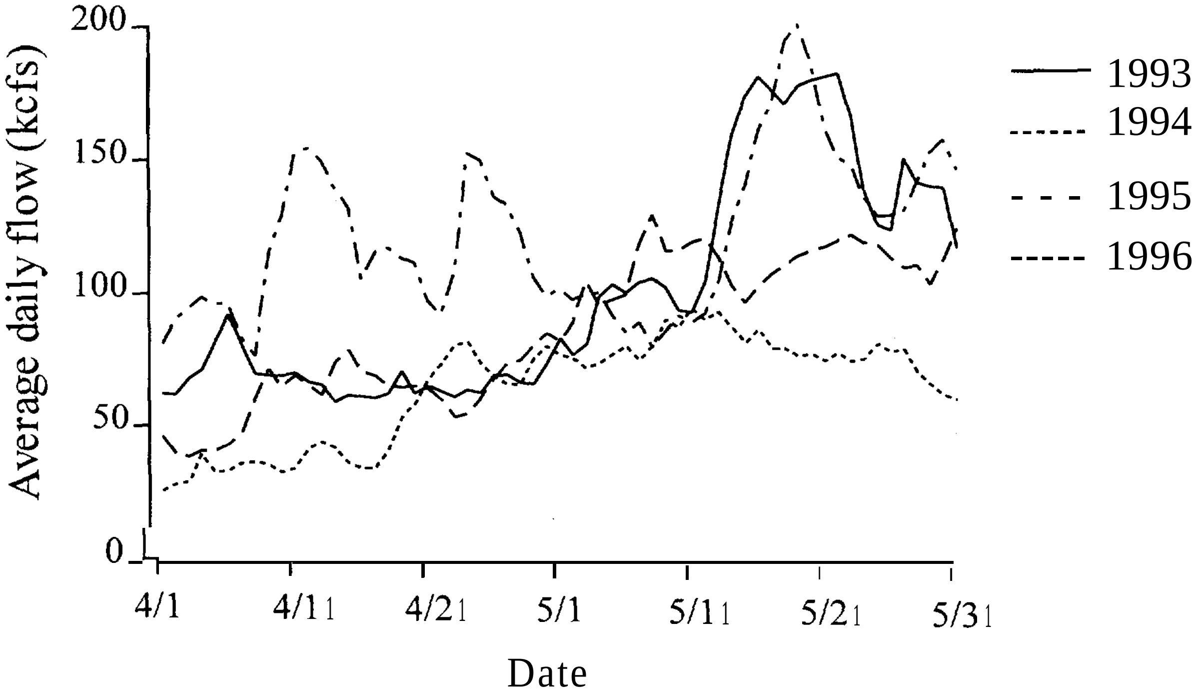


Figure 13. Average daily flow at Lower Granite Dam from 1 April through 31 May, 1993-1996.

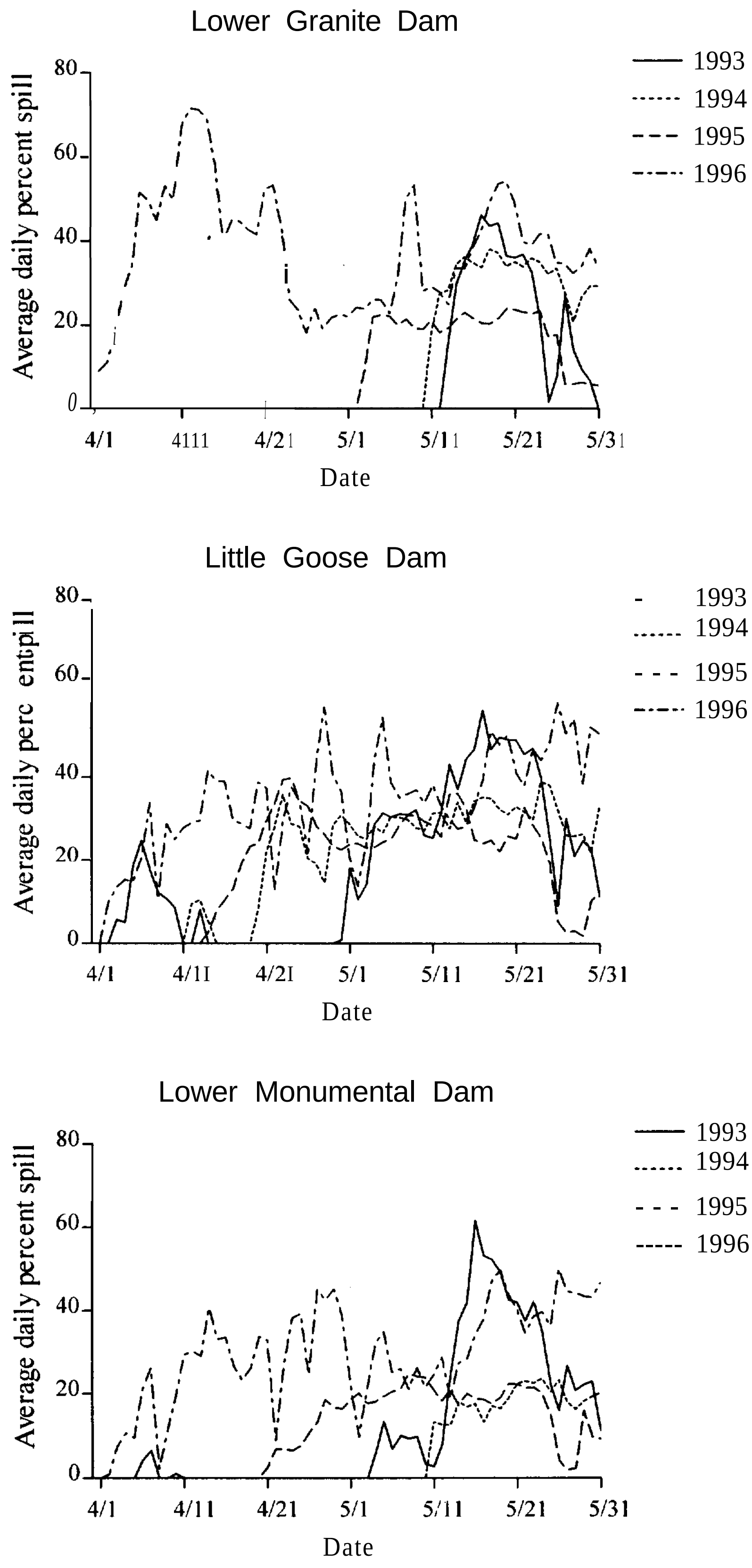


Figure 14. Average daily percent spill at Lower Granite, Little Goose, and Lower Monumental Dams from 1 April through 3 1 May, 1993-1996.

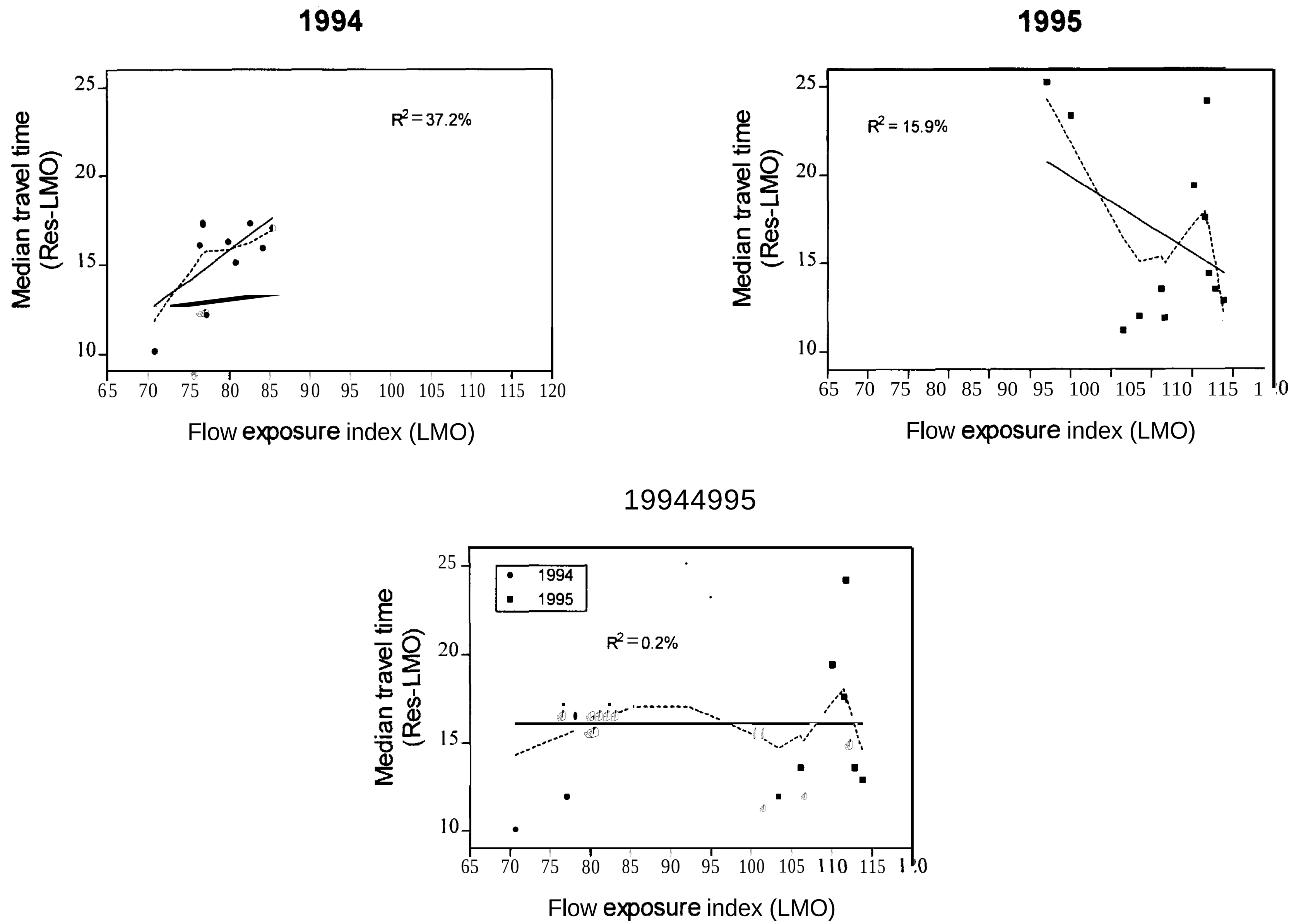


Figure 15. Median travel time (Res-LMO) plotted against flow exposure index at Lower Monumental Dam for primary release groups of yearling chinook salmon from Lower Granite Reservoir, 1994-1995. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

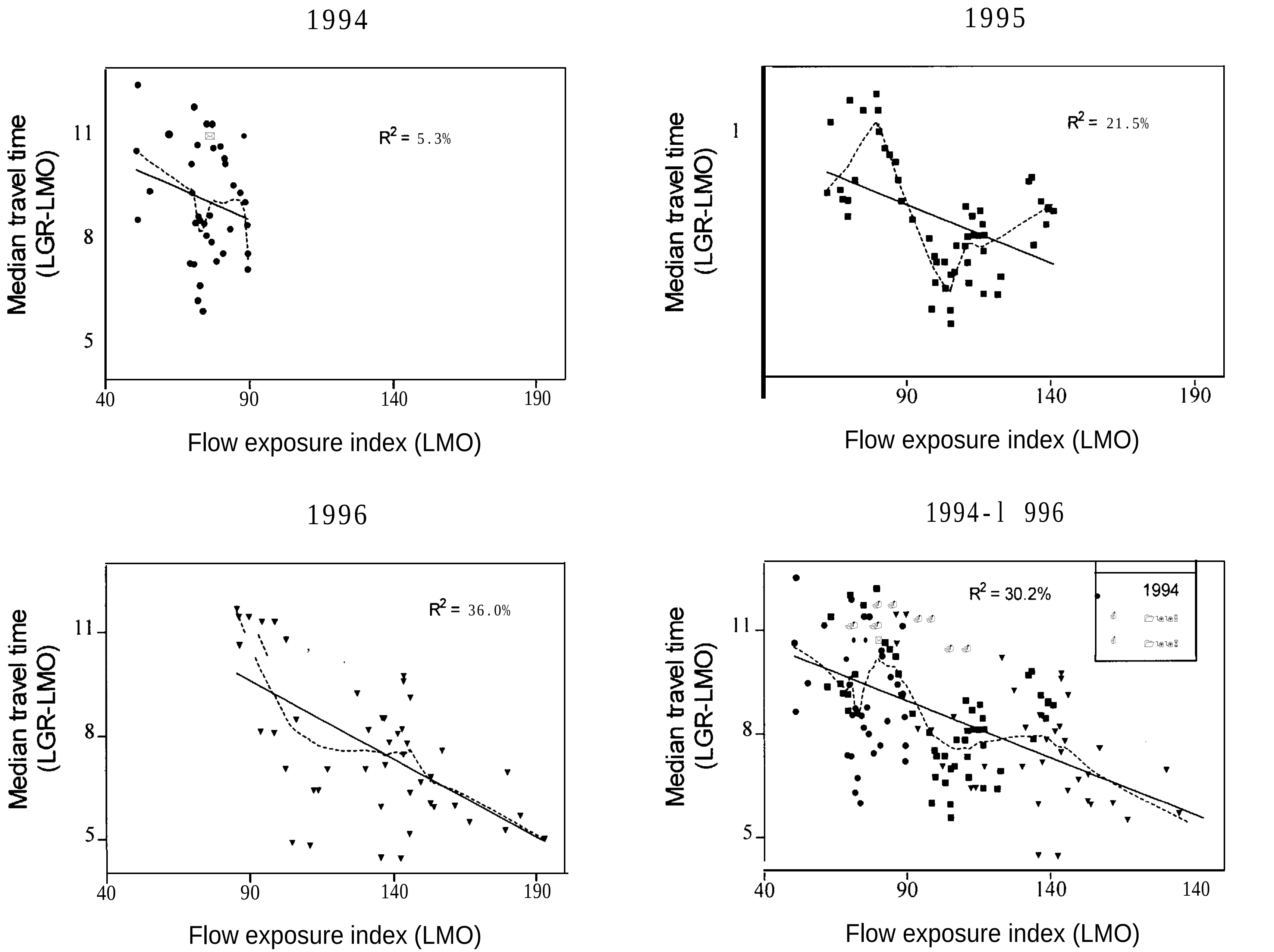


Figure 16. Median travel time (LGR-LMO) plotted against flow exposure index at Lower Monumental Dam for daily release groups of yearling chinook salmon from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

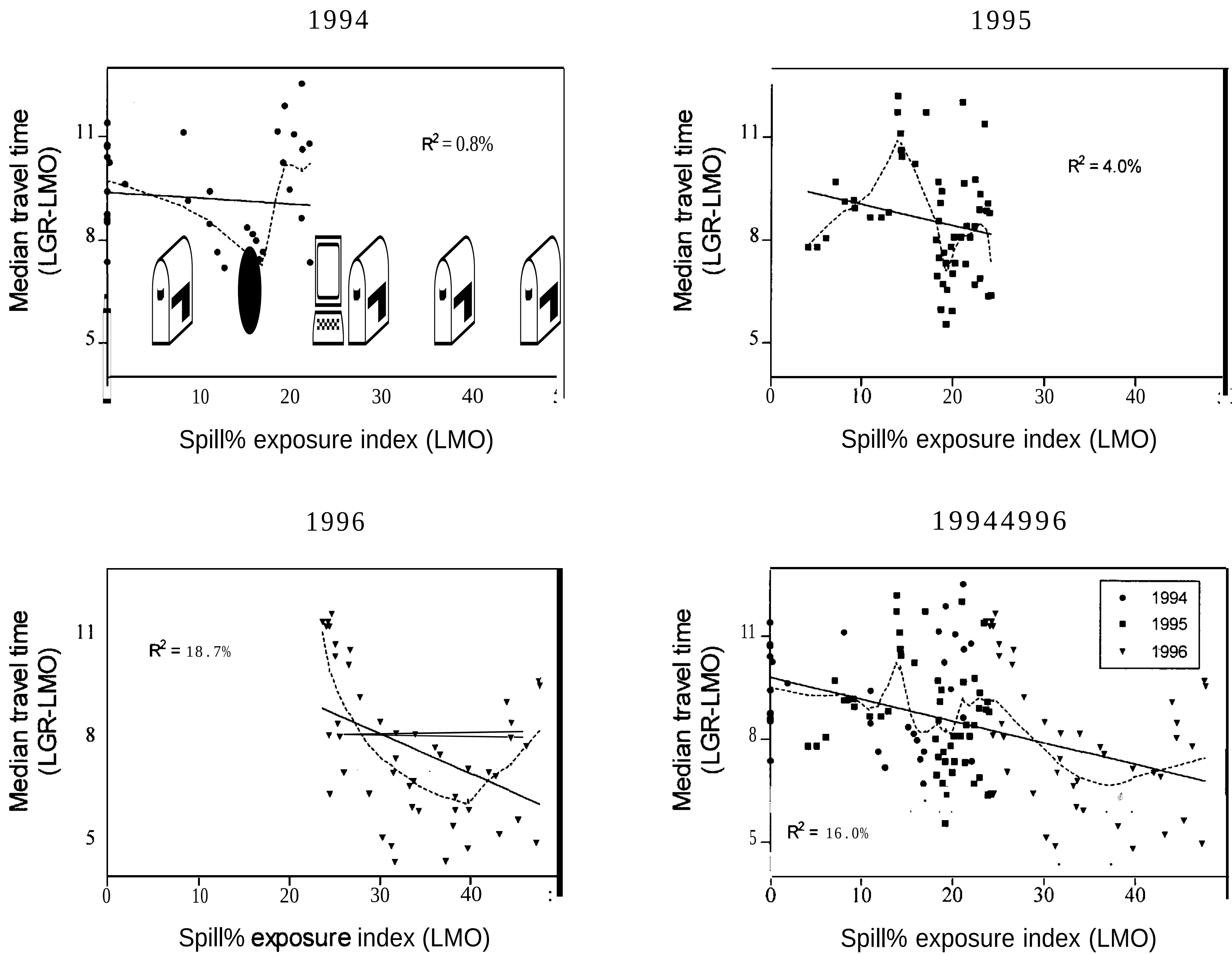


Figure 17. Median travel time (LGR-LMO) plotted against spill% exposure index at Lower Monumental Dam for daily release groups of yearling chinook salmon from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

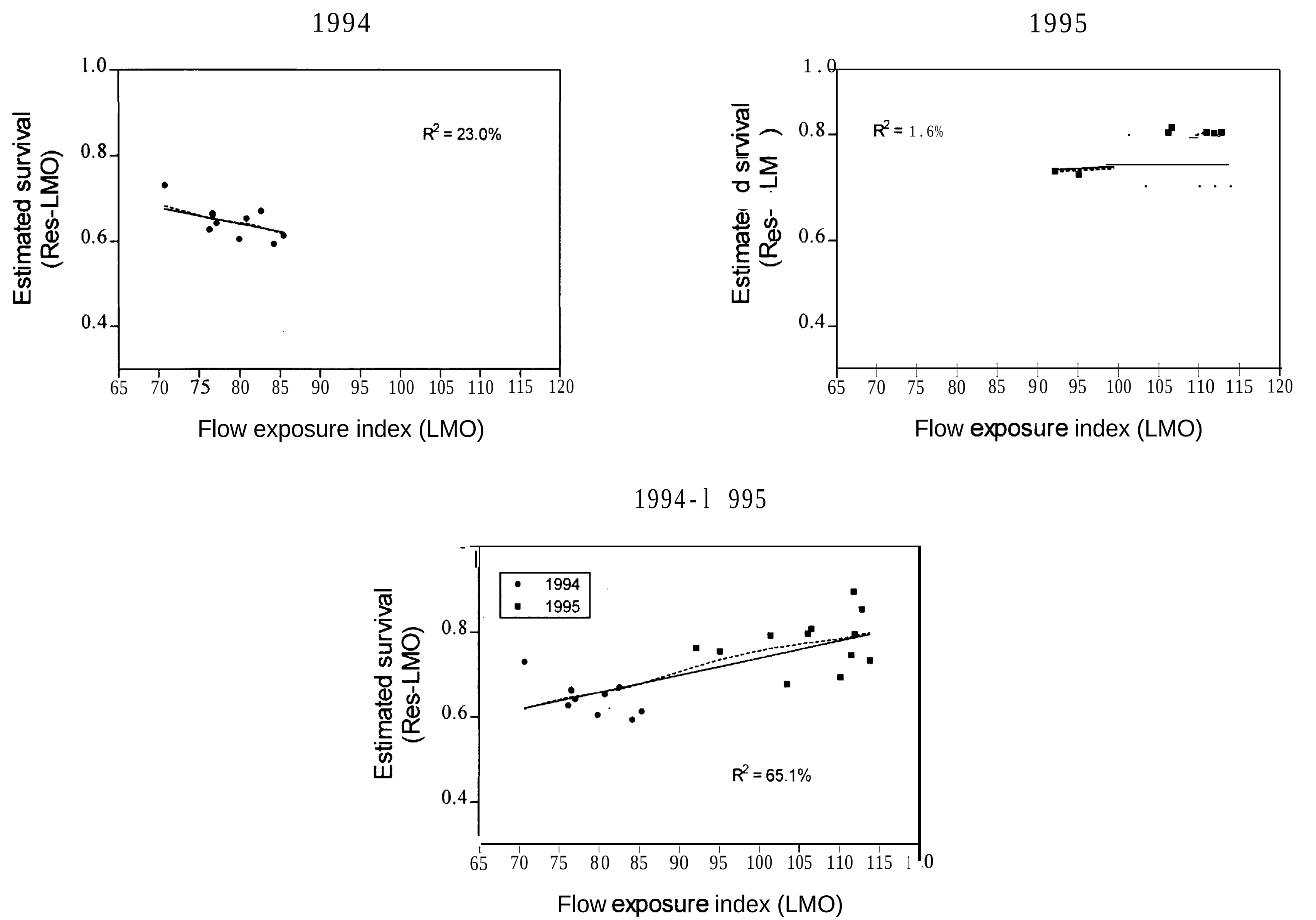


Figure 18. Estimated survival probability (Res-LMO) plotted against flow exposure index at Lower Monumental Dam for primary release groups of yearling chinook salmon from Lower Granite Reservoir, 1994- 1995. Solid and dashed lines are weighted linear regression and weighted scatter-plot smoother lines, respectively.

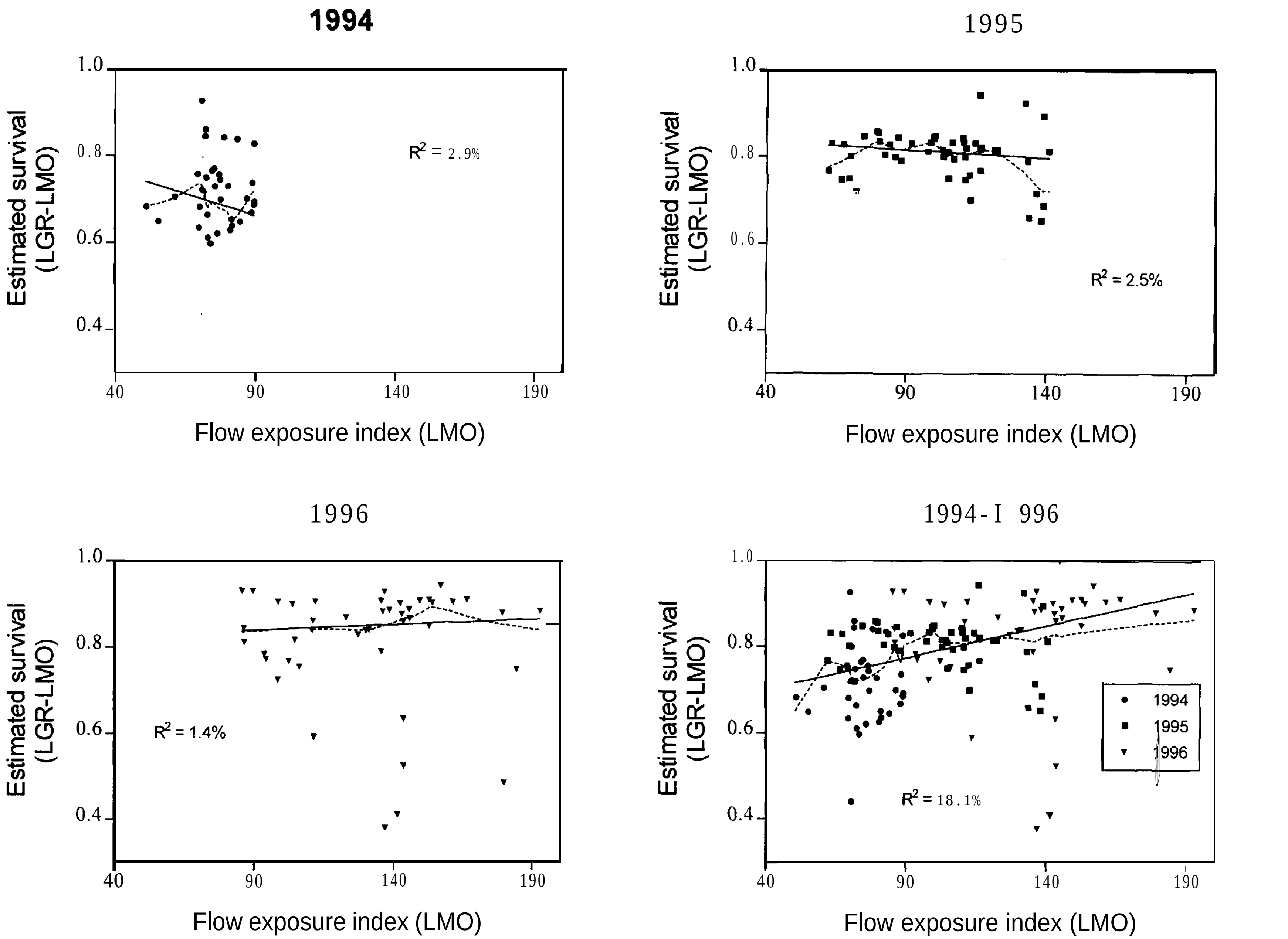


Figure 19. Estimated survival probability (LGR-LMO) plotted against flow exposure index at Lower Monumental Dam for daily release groups of yearling chinook salmon from Lower Granite Dam, 1994- 1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

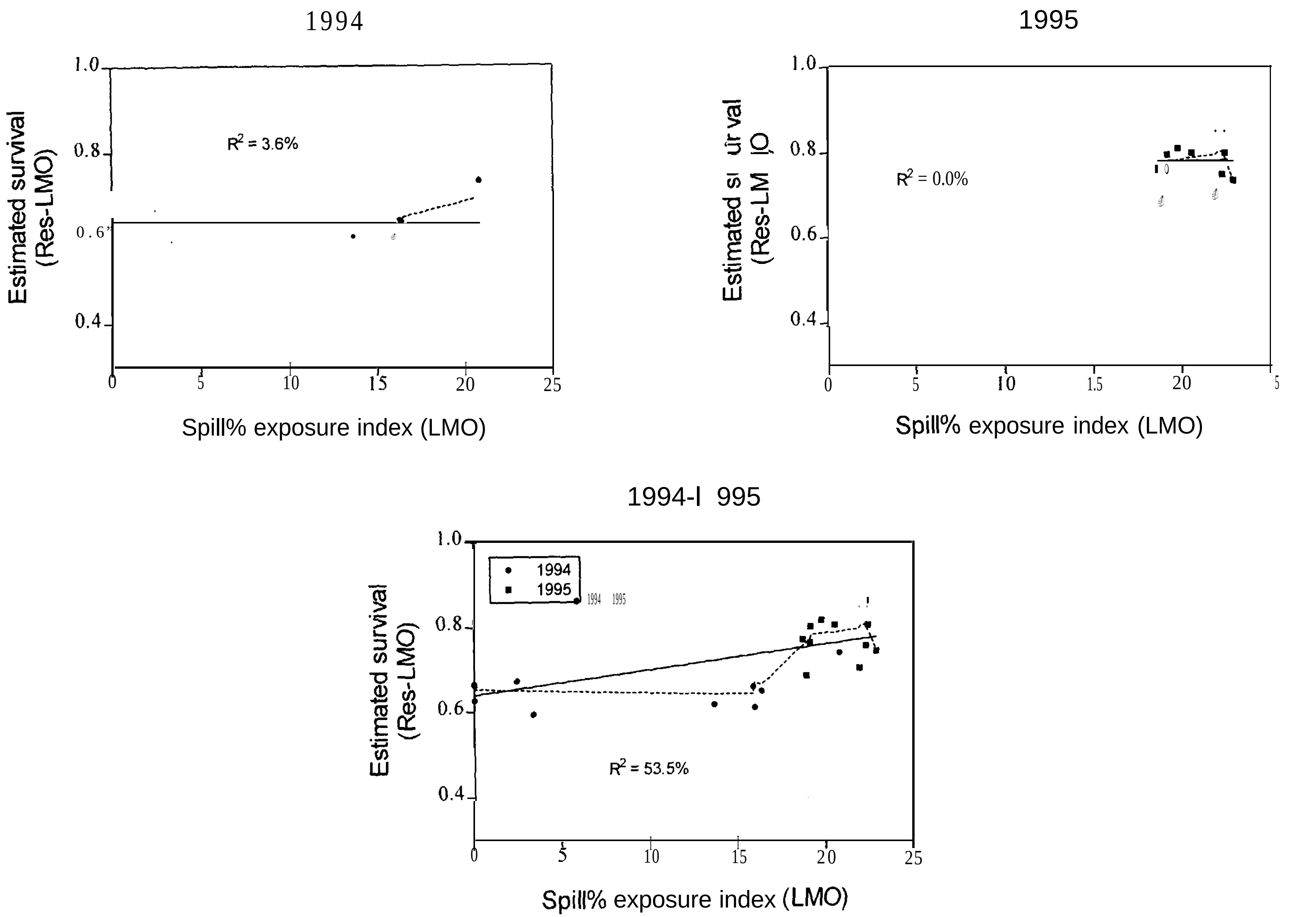


Figure 20. Estimated survival probability (Res-LMO) plotted against spill% exposure index at Lower Monumental Dam for primary release groups of yearling chinook salmon from Lower Granite Reservoir, 1994-1995. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

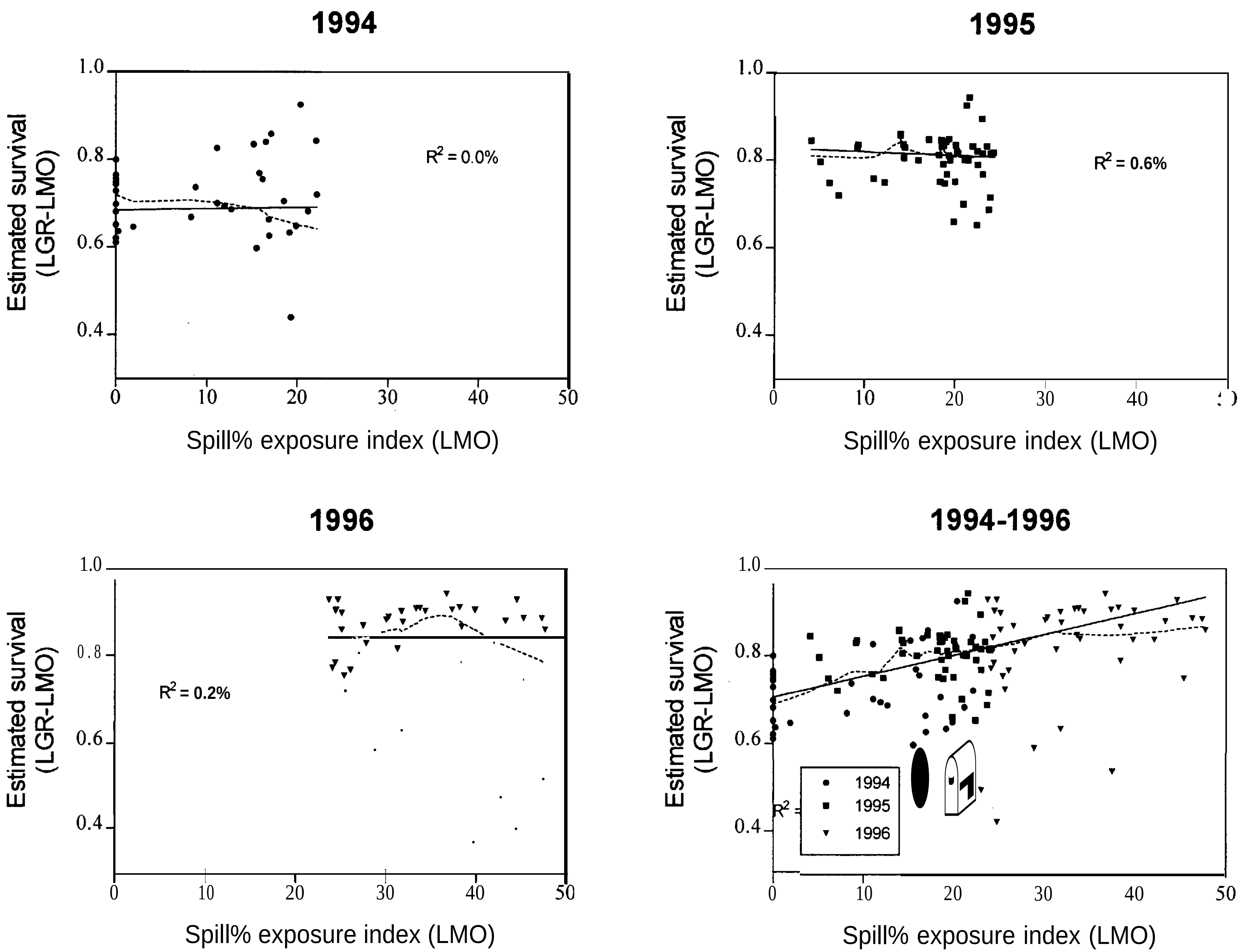


Figure 2 1. Estimated survival probability (LGR-LMO) plotted against spill% exposure index at Lower Monumental Dam for daily release groups of yearling chinook salmon from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted-linear regression and weighted scatterplot smoother lines, respectively.

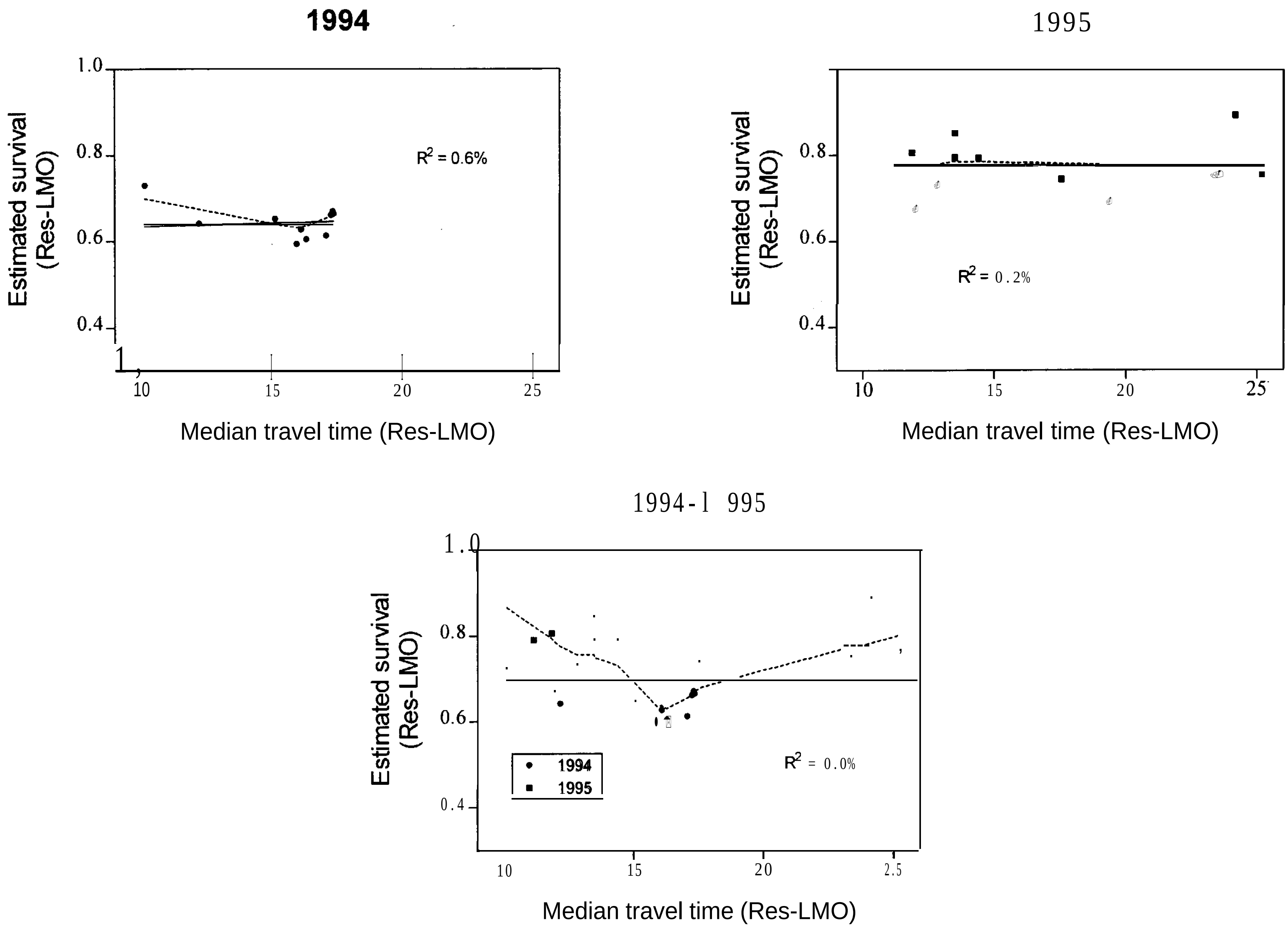


Figure 22. Estimated survival probability (Res-LMO) plotted against median travel time (Res-LMO) for primary release groups of yearling chinook salmon from Lower Granite Reservoir, 1994-1995. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

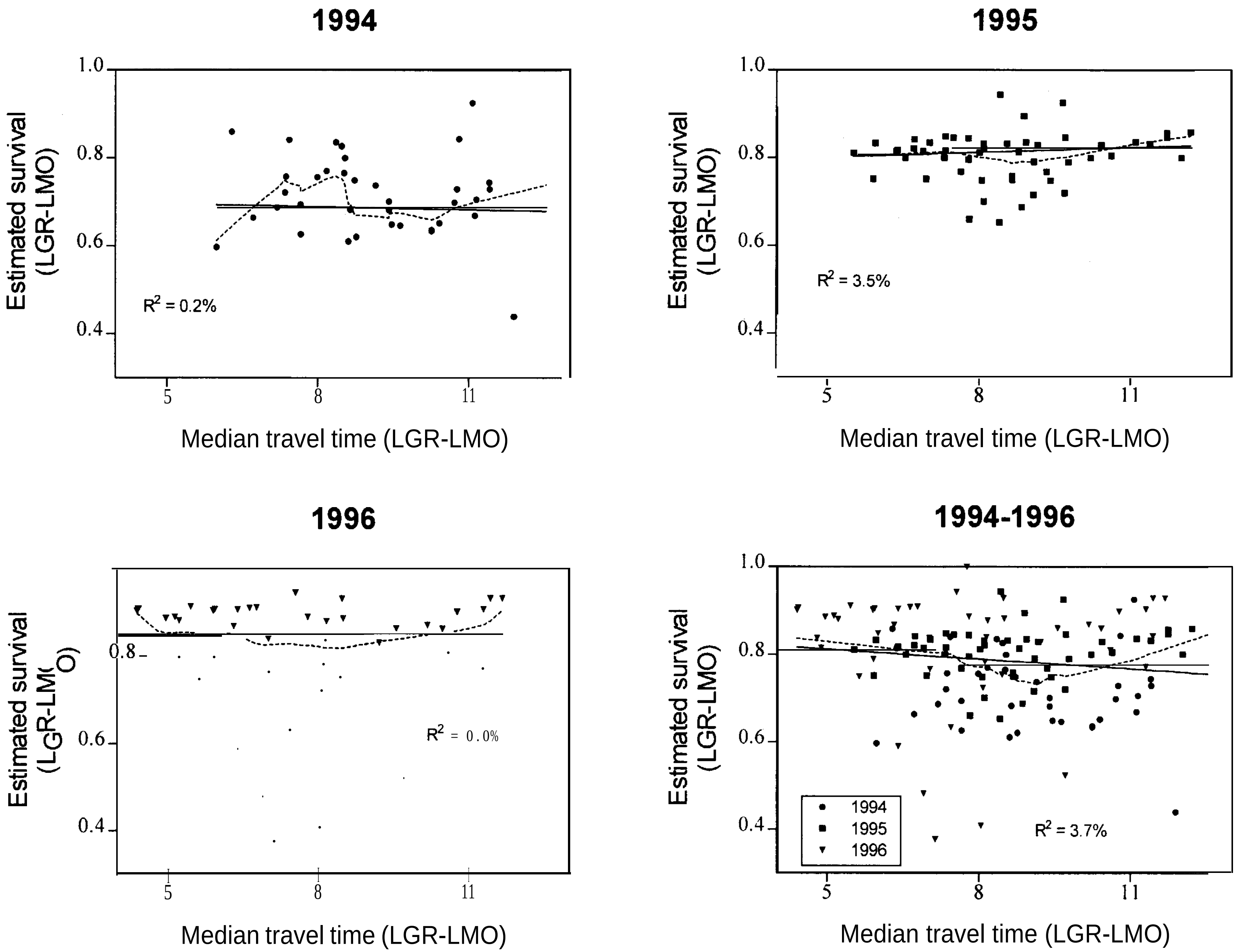


Figure 23. Estimated survival probability (LGR-LMO) plotted against median travel time (LGR-LGO) for daily release groups of yearling chinook salmon from Lower Granite Dam, 1994-l 996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

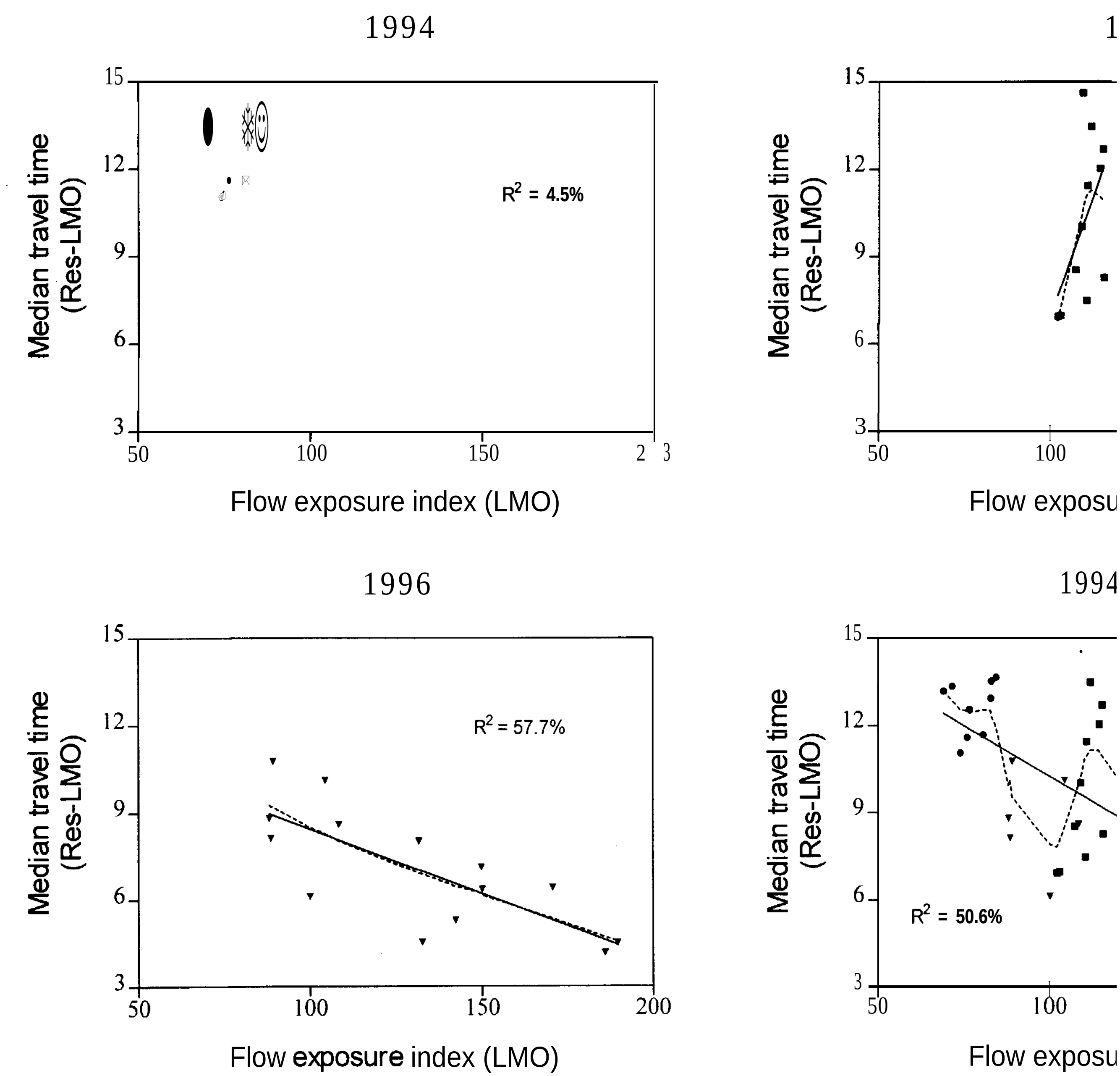


Figure 24. Median travel time (Res-LMO) plotted against flow exposure index at Lower Monumental Da
of steelhead from Lower Granite Reservoir, 1994-1996. Solid and dashed lines are weighted
scatterplot smoother lines, respectively.

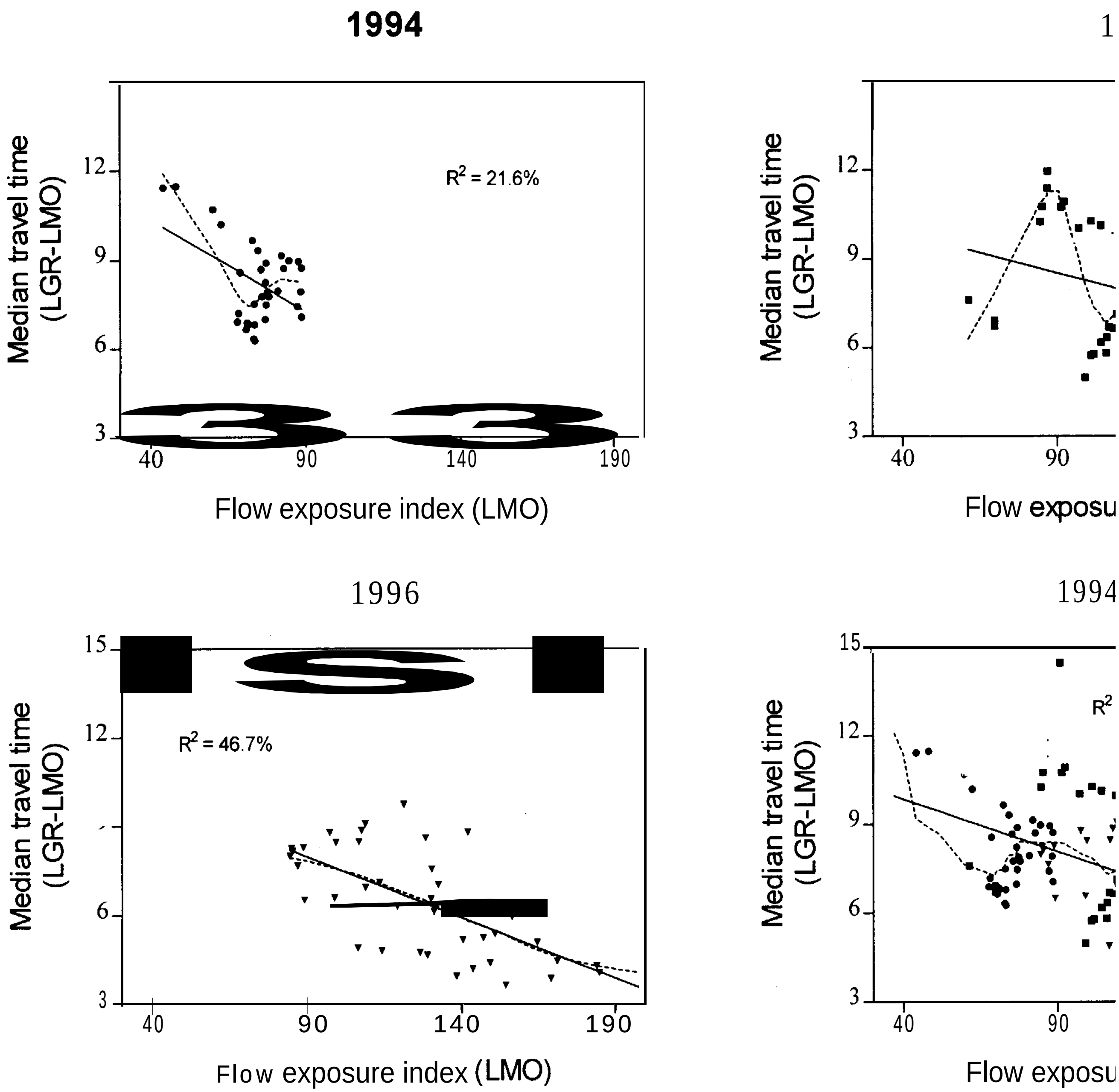


Figure 25. Median travel time (LGR-LMO) plotted against flow exposure index at Lower Monumental I of steelhead from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linea scatterplot smoother lines, respectively.

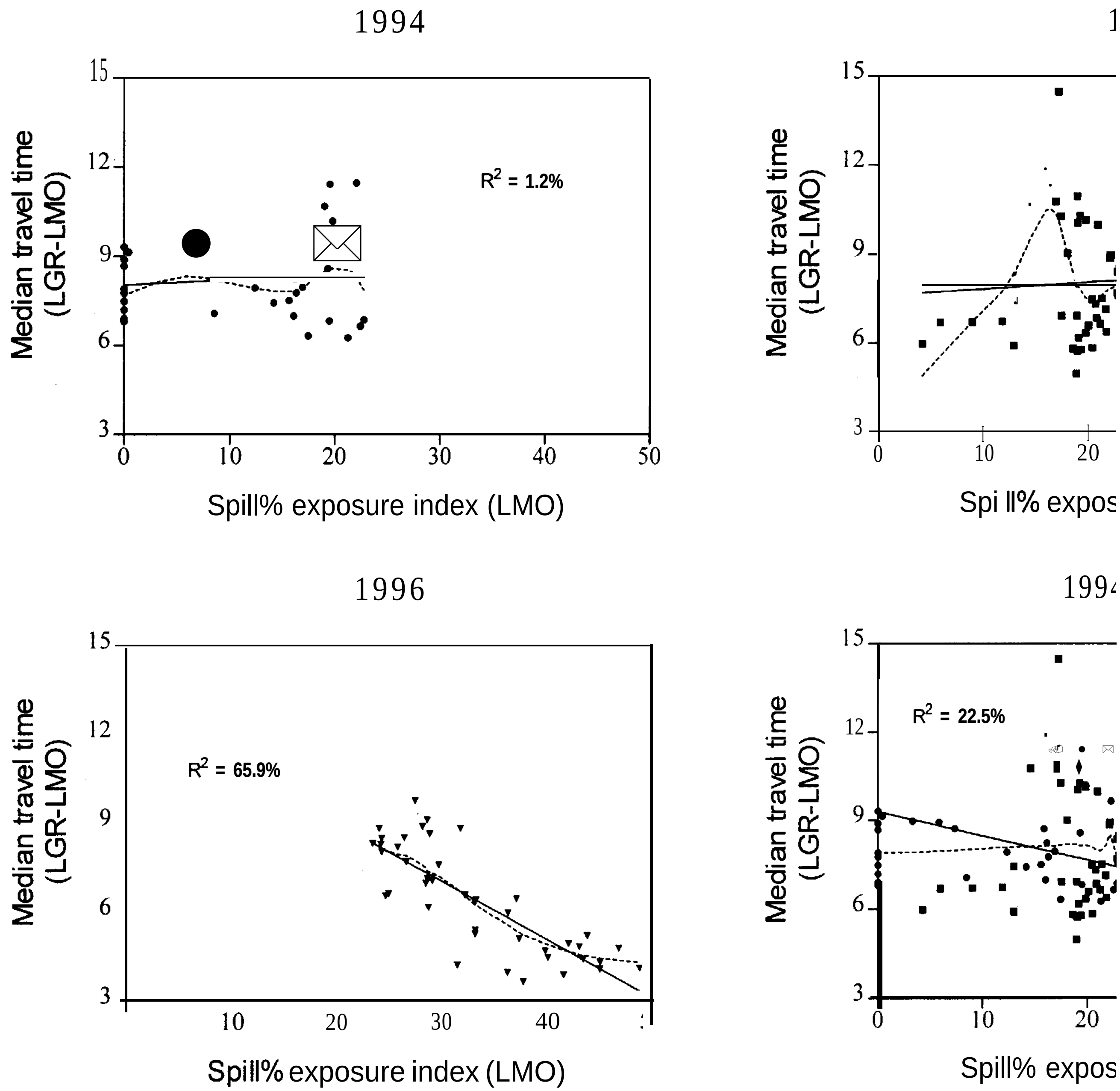


Figure 26. Median travel time (LGR-LMO) plotted against spill% exposure index at Lower Monumental of steelhead from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linea scatterplot smoother lines, respectively.

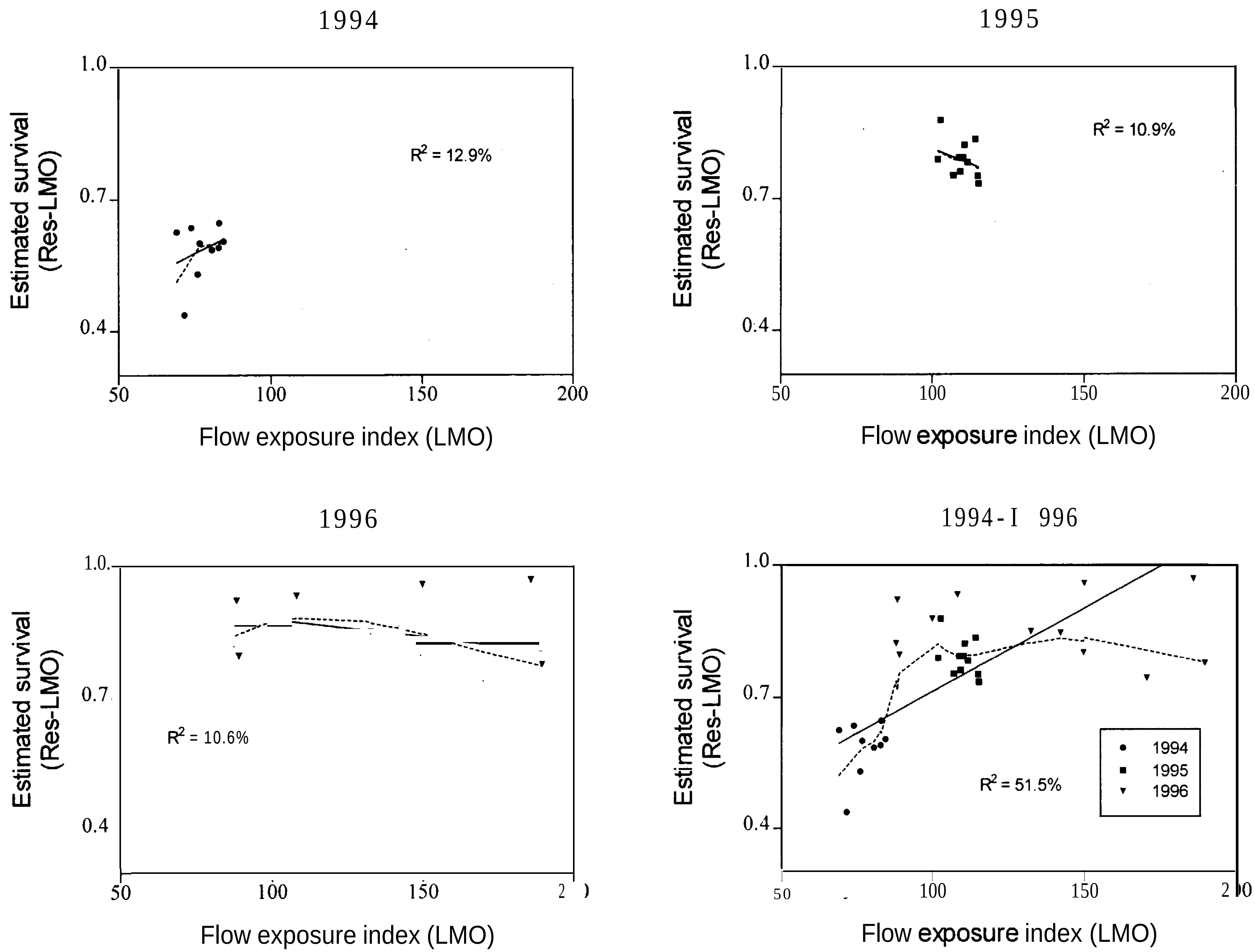


Figure 27. Estimated survival probability (Res-LMO) plotted against flow exposure index at Lower Monumental Dam for primary release groups of steelhead from Lower Granite Reservoir, 1994- 1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

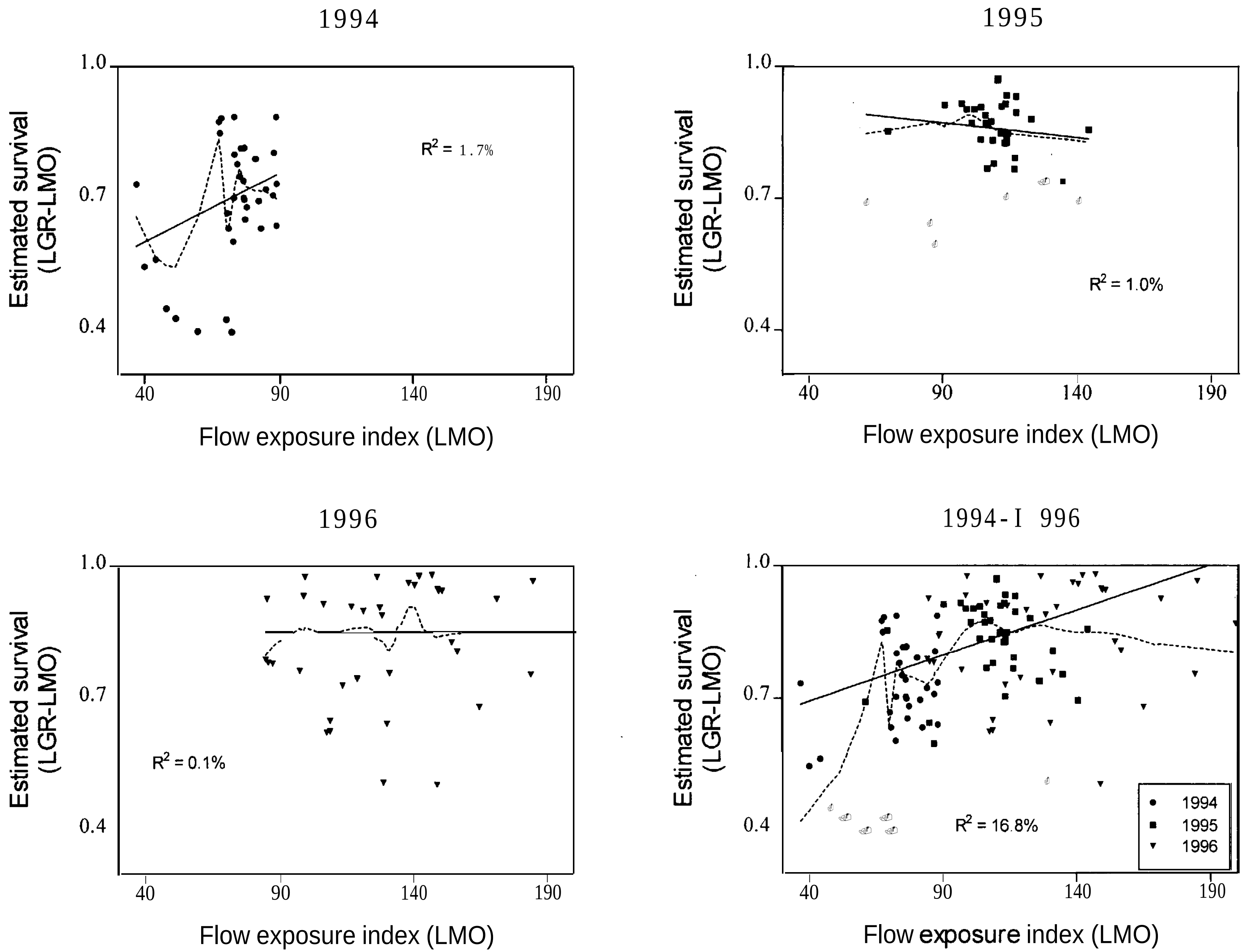


Figure 28. Estimated survival probability (LGR-LMO) plotted against flow exposure index at Lower Monumental Dam for daily release groups of steelhead from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

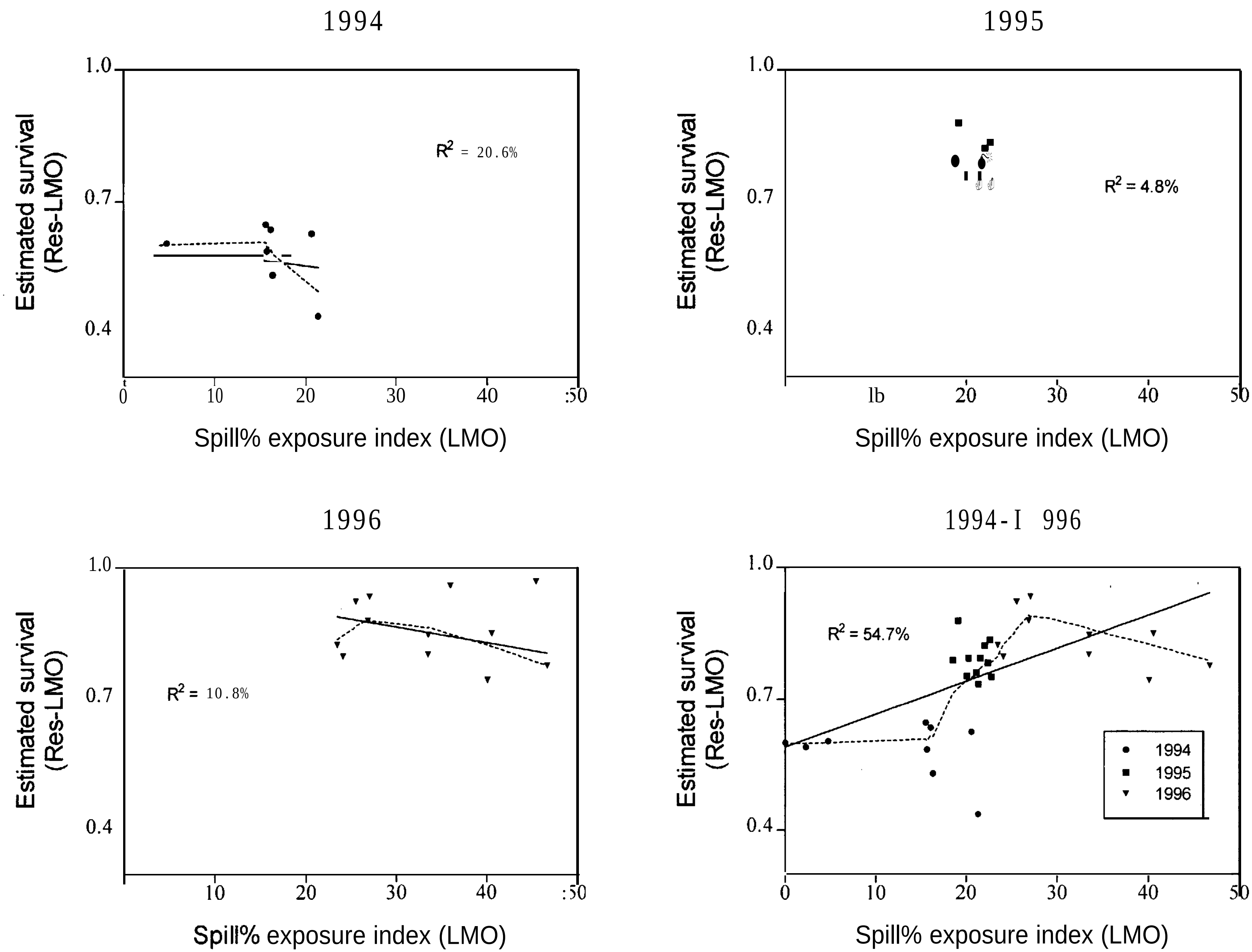


Figure 29. Estimated survival probability (Res-LMO) plotted against spill% exposure index at Lower Monumental Dam for primary release groups of steelhead from Lower Granite Reservoir, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

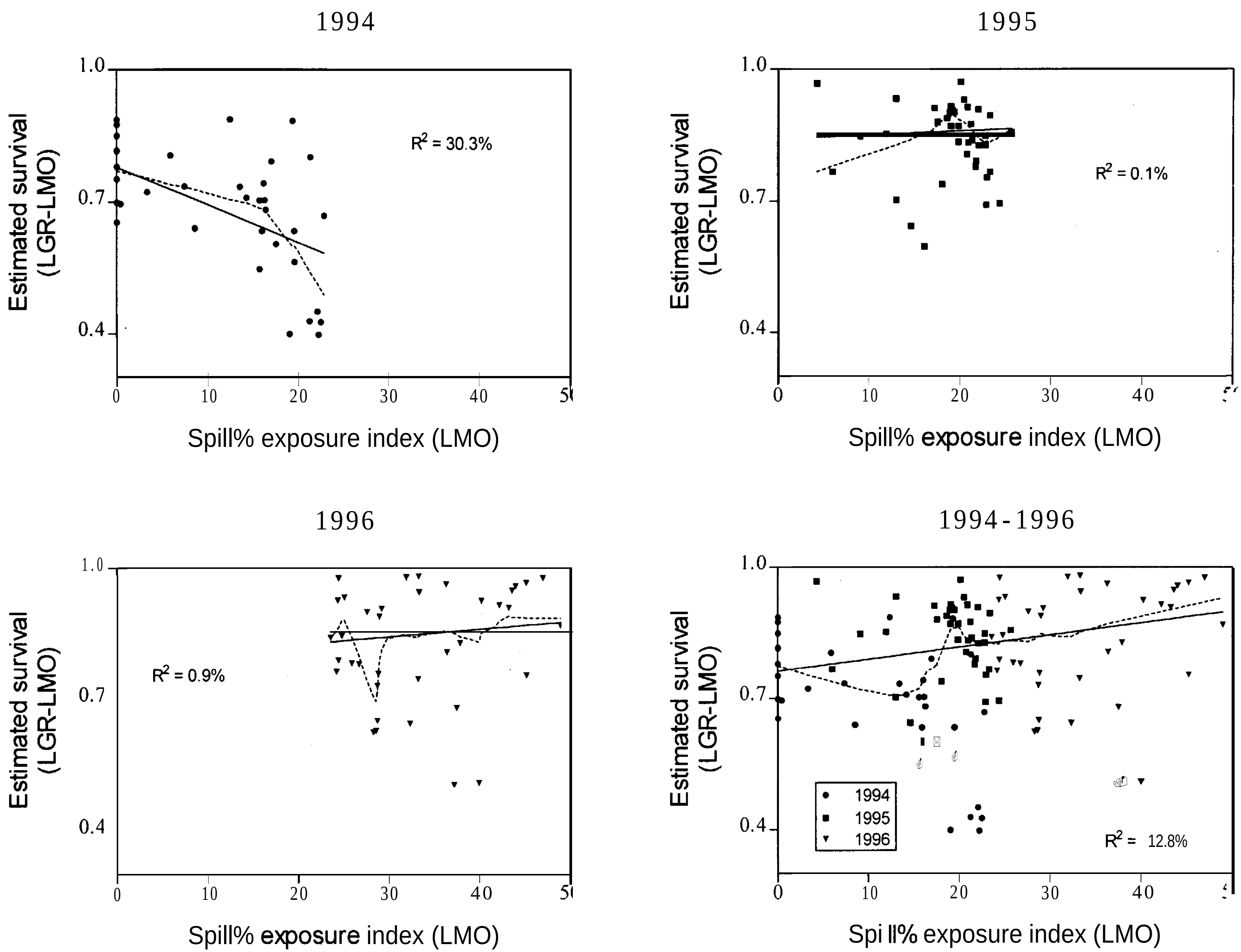


Figure 30. Estimated survival probability (LGR-LMO) plotted against spill% exposure index at Lower Monumental Dam for daily release groups of steelhead from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

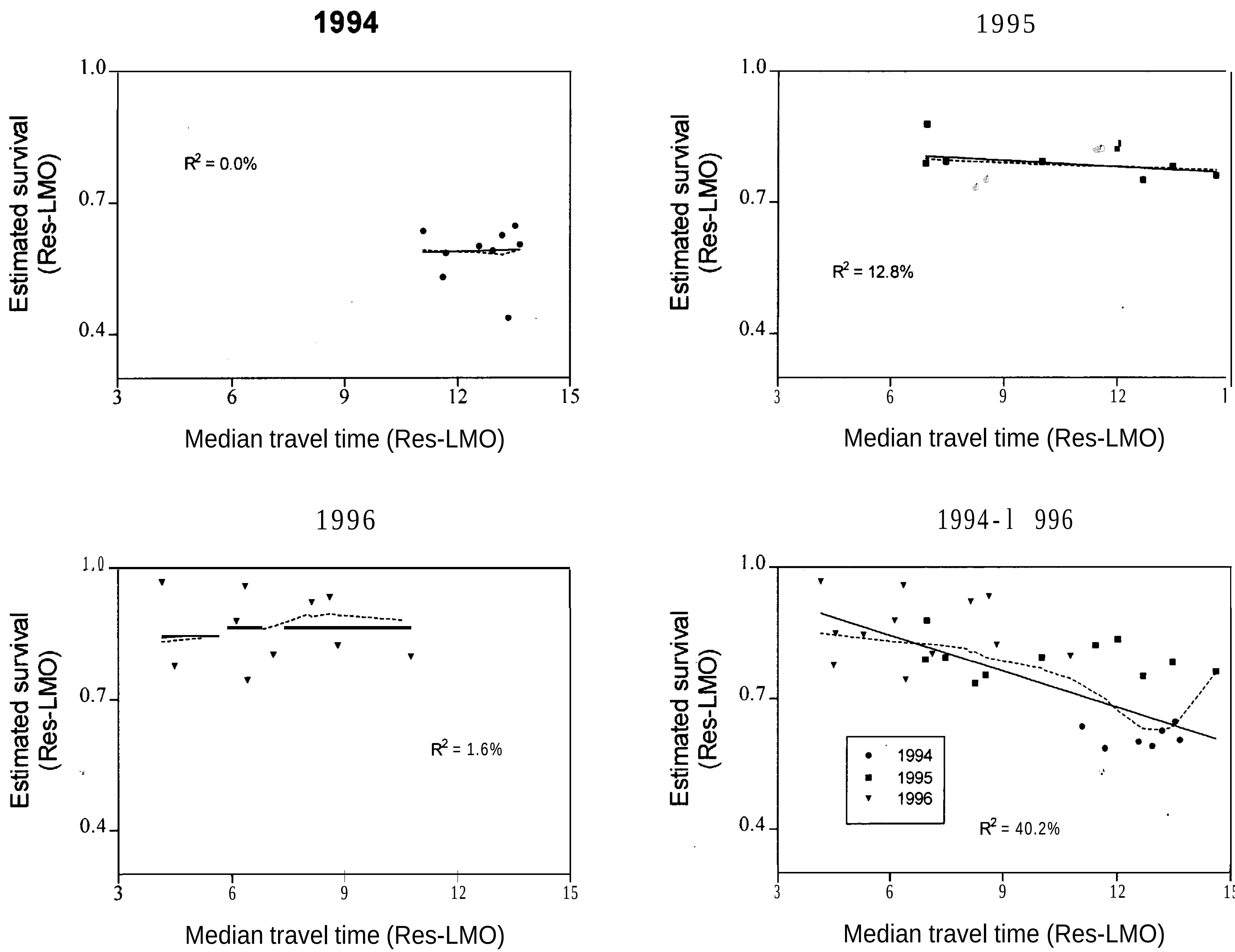


Figure 3 1. Estimated survival probability (Res-LMO) plotted against median travel time (Res-LMO) for primary release groups of steelhead from Lower Granite Reservoir, 1994-l 996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

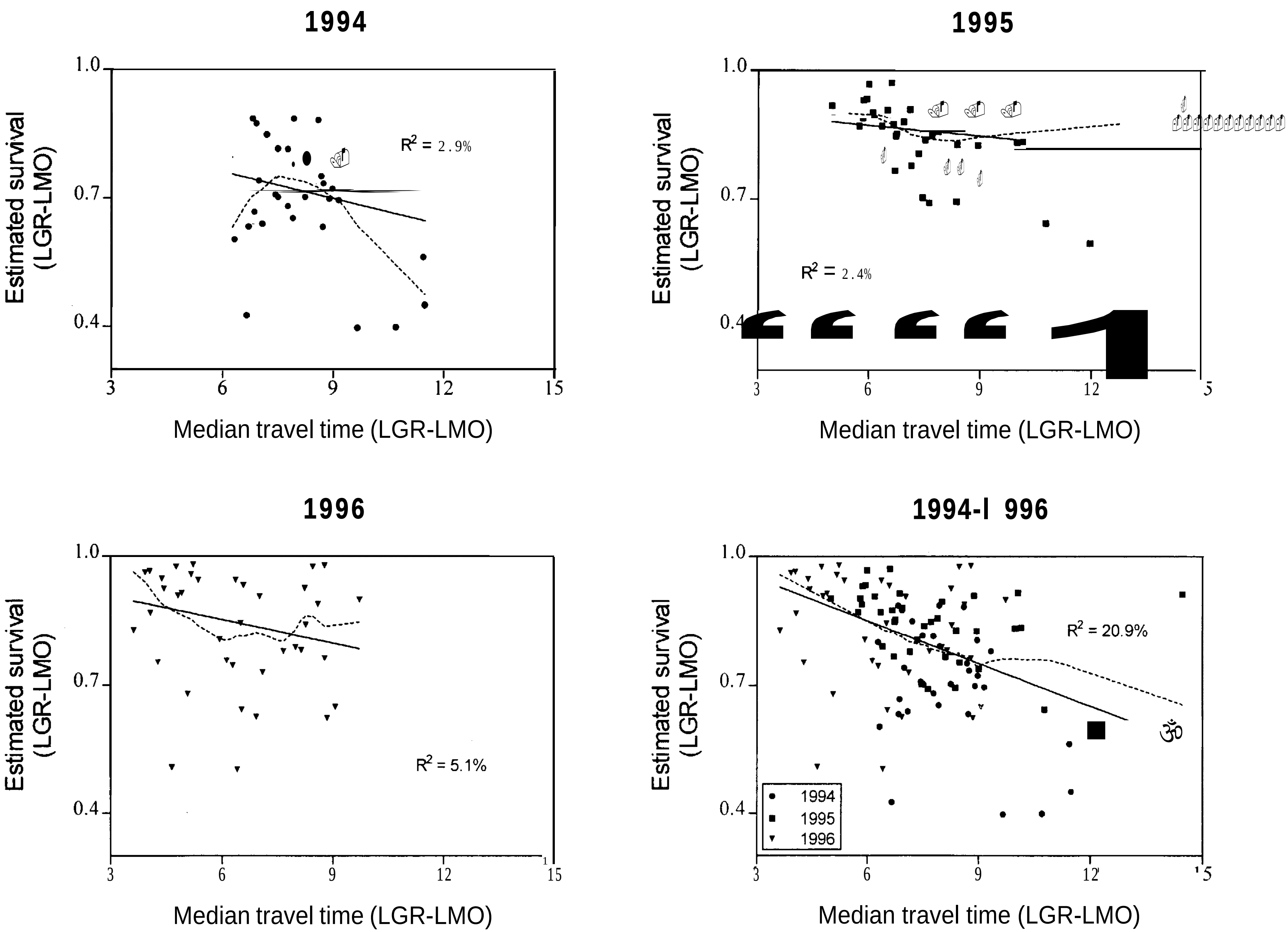


Figure 32. Estimated survival probability (LGR-LMO) plotted against median travel time (LGR-LMO) for daily release groups of steelhead from Lower Granite Dam, 1994-1996. Solid and dashed lines are weighted linear regression and weighted scatterplot smoother lines, respectively.

## APPENDIX A -- TESTS OF MODEL ASSUMPTIONS

### Methods

For the SR Model the critical assumptions are:

Al) A fish's detection at a PIT-tag detection site does not affect its probability of subsequent detection at downstream sites.

A2) A fish's detection at a PIT-tag detection site does not affect its probability of subsequent survival through downstream river reaches.

A3) Detected fish suffer no significant post-detection mortality in the bypass system before remixing with non-detected fish.

If Assumption A3 failed, the MSR Model was used in place of the SR Model to analyze the primary releases. Each release under the MSR Model is assumed to satisfy Assumptions Al and A2. There is one additional critical assumption for the paired surface-collector release groups :

A4) Treatment release groups and their corresponding reference groups mix evenly and travel together downstream from the source of mortality under investigation.

The PR Model shares the assumptions of the MSR Model.

Taken together, tests of Assumptions Al and A2 are general tests of the "goodness of fit" of the SR Model to the data. Burnham et al. (1987) gave a series of goodness-of-fit tests to be used for the SR Model (TESTs 2 and 3, Burnham et al. 1987, p. 7 l-77) and noted that factors that lead to rejection of the tests include heterogeneity of parameters across individuals, failure of the assumption of independent fish fates, and behavioral response to capture and subsequent release (i.e., behavioral changes after passage through a juvenile bypass facility).

The same goodness-of-fit tests (Tables Al and A2) were conducted in 1996 as in previous years. Tests were conducted for primary releases of hatchery steelhead and for paired releases of hatchery steelhead for evaluation of the surface collector at Lower Granite Dam. Details of the tests were presented by Muir et al., 1995.

## Results

**Assumptions Al and A2**--A fish's detection at a PIT-tag detection site does not affect its probability of subsequent survival in downstream reaches or of subsequent detection at downstream sites.

For primary release groups of hatchery steelhead, significant differences in Little Goose Dam passage distributions between fish detected and not detected at Lower Granite Dam occurred throughout the season, especially toward the end of the season (Table A3). Passage distributions at Lower Monumental Dam also differed among subgroups for several release groups (Table A4). Differences in passage distributions were due to faster passage through Lower Granite and Little Goose Dams for nondetected than for detected fish. Median travel times between the primary release site and Lower Monumental Dam averaged 1.1 days longer for fish detected at both Lower Granite and Little Goose Dams than for fish not detected at either. The average delay for detected fish at each dam appeared to be roughly equal.

Finally, as in 1995, passage distributions at McNary Dam for subgroups of the primary release groups did not differ significantly (Table A5). This suggested that hatchery chinook salmon that were delayed in bypass systems at Lower Granite and Little Goose Dams caught up with their nondetected counterparts by the time they reached McNary Dam. Lower numbers of fish in each subgroup lowered the power to detect differences in passage distributions. However, absolute differences among subgroups in average travel times to McNary Dam were generally less than the differences in average travel times to Lower Monumental Dam.

Despite frequent differences in passage distributions for detected and nondetected fish, the tests designed to detect heterogeneity of survival and detection probabilities among the subgroups found few assumption violations; i.e. there was little lack of fit of the SR Model to the primary releases of hatchery chinook salmon (Table A6). Only $R_{P13}$ had a significant overall lack of fit. The most significant test for $R_{P13}$ was TEST 2.C2--i.e. significant differences in the first detection location below Lower Granite Dam depending on detection at that dam, consistent with the differences in passage distributions found at Little Goose and Lower Monumental Dams (Tables A3 and A4).

For paired surface-collector release groups of steelhead at Lower Granite Dam, the first treatment ($R_{C11}$) and reference releases (Cc,,) both had significant lack of fit to the SR Model (Table A7). For these release groups, detection at Little Goose Dam influenced the next detection site downstream (TEST 2.C2). Later paired releases did not show this pattern.

**Assumption A3--Detected** fish suffer no significant post-detection bypass mortality before remixing with non-detected fish.

No tests of this assumption were conducted in 1996. Paired post-detection bypass releases in previous years indicated no significant mortality for hatchery yearling chinook salmon or hatchery steelhead between detection in the bypass system and remixing with fish using other passage routes at Lower Granite, Little Goose, and Lower Monumental Dams. Accordingly, the Single-Release Model was used to estimate survival probabilities for the primary release groups.

**Assumption A4--Treatment** release groups and their corresponding reference groups mix evenly and travel together downstream from the source of mortality under investigation.

Tests of homogeneity of passage distributions for paired surface-collector releases of steelhead from Lower Granite Dam showed that fish from the two groups generally appeared to remain mixed as they moved downstream (Table A8).

Appendix Table Al. Tests of goodness of tit to the Single-Release Model that can be calculated for releases above Lower Granite Dam (notation of Burnham et al. 1987). Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Test | Tests homogeneity of | Degrees of freedom |
|---|---|---|
| TEST 2.C2 | First detection location below LGR for two subgroups of a primary release group defined by capture history at LGR. | 2 |
| TEST 2.C3 | First detection location below LGO for two subgroups of a primary release group defined by capture history at LGO. | 1 |
| TEST 2 | Sum of TEST 2.C2 and TEST 2.C3. | 3 |
| TEST 3.SR3 | "Seen again versus not seen again" for two subgroups of a primary release group detected at LGO, defined by capture history at LGR. | 1 |
| TEST 3.Sm3 | "Seen next at LMO versus seen next at MCN" for two subgroups of a primary release group detected at LGO, defined by capture history at LGR. | 1 |
| TEST 3.SR4 | "Seen again versus not seen again" for two subgroups of a primary release group detected at LMO, defined by "seen at LGR or LGO "versus not seen at LGR or LGO." | 1 |
| TEST 3 | Sum of TEST 3.SR3, TEST 3.Sm3, and TEST 3.SR4 | 3 |
| Overall | Sum of TEST 2 and TEST 3 | 6 |

Appendix Table A2. Tests of goodness of fit to the Single-Release Model that can be calculated for releases at Lower Granite Dam (notation of Burnham et al. 1987). Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Test | Tests homogeneity of | Degrees of freedom |
|---|---|---|
| TEST 2.C2 | First detection location below LGO for two subgroups of a LGR releas group defined by capture history at LGO. | 1 |
| TEST 3.SR3 | "Seen again versus not seen again" for two subgroups of a LGR release group detected at LMO, defined by capture history at LGO. | 1 |
| Overall | Sum of TEST 2.C2 and TEST 3.SR3. | 2 |

Appendix Table A3. Tests of homogeneity of Little Goose Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite Dam. P values calculated Monte Carlo approximation of the exact method.

| Release | $\chi^2$ | Degrees of freedom | P value |
|---|---|---|---|
| $R_{P1}$ | 24.68 | 21 | 0.149 |
| $R_{P2}$ | 23.14 | 17 | 0.068 |
| $R_{P3}$ | 24.92 | 19 | 0.045 |
| $R_{P4}$ | 16.87 | 15 | 0.220 |
| $R_{P5}$ | 20.29 | 23 | 0.533 |
| $R_{P6}$ | 16.46 | 20 | 0.681 |
| $R_{P7}$ | 29.27 | 18 | 0.022 |
| $R_{P8}$ | 20.16 | 19 | 0.307 |
| $R_{P9}$ | 13.89 | 15 | 0.534 |
| $R_{P10}$ | 28.38 | 15 | 0.003 |
| $R_{P11}$ | 35.77 | 10 | $<0.001$ |
| $R_{P12}$ | 24.49 | 15 | 0.011 |
| $R_{P13}$ | 19.63 | 14 | 0.049 |
| $R_{P14}$ | 11.63 | 8 | 0.103 |

Appendix Table A4. Tests of homogeneity of Lower Monumental Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite and Little Goose Dams. P values calculated using Monte Carlo approximation of the exact method.

| Release | $\chi^2$ | Degrees of freedom | P value |
|---|---|---|---|
| $R_{P1}$ | 91.95 | 69 | 0.002 |
| $R_{P2}$ | 83.15 | 75 | 0.017 |
| $R_{P3}$ | 72.68 | 60 | 0.003 |
| $R_{P4}$ | 94.05 | 63 | <0.001 |
| $R_{P5}$ | 61.84 | 66 | 0.373 |
| $R_{P6}$ | 55.32 | 60 | 0.438 |
| $R_{P7}$ | 55.36 | 66 | 0.791 |
| $R_{P8}$ | 62.35 | 51 | 0.025 |
| $R_{P9}$ | 52.78 | 51 | 0.216 |
| $R_{P10}$ | 56.15 | 48 | 0.050 |
| $R_{P11}$ | 32.64 | 36 | 0.574 |
| $R_{P12}$ | 57.87 | 48 | 0.025 |
| $R_{P13}$ | 49.20 | 30 | 0.001 |
| $R_{P14}$ | 32.91 | 36 | 0.543 |

Appendix Table A5. Tests of homogeneity of McNary Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite, Little Goose, and Lower Monumental Dams. P values calculated using Monte Carlo approximation of the exact method.

| Release | $\chi^2$ | Degrees of freedom | P value |
|---|---|---|---|
| $R_{P1}$ | 153.1 | 126 | 0.491 |
| $R_{P2}$ | 139.3 | 140 | 0.826 |
| $R_{P3}$ | 116.4 | 133 | 0.868 |
| $R_{P4}$ | 158.3 | 154 | 0.840 |
| $R_{P5}$ | 161.5 | 154 | 0.744 |
| $R_{P6}$ | 114.4 | 126 | 0.819 |
| $R_{P7}$ | 112.9 | 119 | 0.310 |
| $R_{P8}$ | 89.6 | 91 | 0.660 |
| $R_{P9}$ | 91.1 | 84 | 0.374 |
| $R_{P10}$ | 65.4 | 54 | 0.146 |
| $R_{P11}$ | 55.8 | 56 | 0.832 |
| $R_{P12}$ | 51.4 | 49 | 0.474 |
| $R_{P13}$ | 67.9 | 63 | 0.118 |
| $R_{P14}$ | 80.9 | 63 | 0.542 |

Appendix Table A6. Results of tests of goodness of fit to the Single-Release Model for primary releases of hatchery steelhead from the Port of Wilma (TEST 2 and TEST 3 of Burnham et al. 1987).

| | Overall | | TEST 2 | | TEST 2.C2 | | TEST 2.C3 | |
|---|---|---|---|---|---|---|---|---|
| Release | $\chi^2$ | P value | $\chi^2$ | P value | $\chi^2$ | P value | $\chi^2$ | P value |
| $R_{P1}$ | 5.777 | 0.449 | 4.297 | 0.231 | 0.221 | 0.895 | 4.076 | 0.043 |
| $R_{P2}$ | 8.202 | 0.224 | 3.631 | 0.304 | 1.124 | 0.570 | 2.507 | 0.113 |
| $R_{P3}$ | 9.478 | 0.148 | 4.651 | 0.199 | 1.604 | 0.448 | 3.047 | 0.081 |
| $R_{P4}$ | 3.130 | 0.792 | 1.746 | 0.627 | 0.696 | 0.706 | 1.050 | 0.306 |
| $R_{P5}$ | 1.417 | 0.965 | 1.268 | 0.737 | 1.193 | 0.551 | 0.075 | 0.784 |
| $R_{P6}$ | 9.744 | 0.136 | 2.832 | 0.418 | 2.821 | 0.244 | 0.011 | 0.916 |
| $R_{P7}$ | 8.190 | 0.225 | 1.106 | 0.776 | 0.909 | 0.635 | 0.197 | 0.657 |
| $R_{P8}$ | 4.526 | 0.606 | 2.515 | 0.473 | 1.378 | 0.502 | 1.137 | 0.286 |
| $R_{P9}$ | 8.423 | 0.209 | 7.136 | 0.068 | 1.773 | 0.412 | 5.363 | 0.021 |
| $R_{P10}$ | 6.307 | 0.390 | 5.500 | 0.139 | 2.780 | 0.249 | 2.720 | 0.099 |
| $R_{P11}$ | 7.076 | 0.314 | 5.716 | 0.126 | 1.942 | 0.379 | 3.774 | 0.052 |
| $R_{P12}$ | 7.683 | 0.262 | 6.488 | 0.090 | 5.972 | 0.050 | 0.516 | 0.473 |
| $R_{P13}$ | 15.936 | 0.014 | 13.592 | 0.004 | 11.924 | 0.003 | 1.668 | 0.197 |
| $R_{P14}$ | 8.442 | 0.207 | 7.268 | 0.064 | 2.048 | 0.359 | 5.220 | 0.022 |

Appendix Table A6. Continued.

| Release | TEST 3 | | TEST 3.SR3 | | TEST 3.Sm3 | | TEST 3.SR4 | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ | P value | $\chi^2$ | P value | $\chi^2$ | P value | $\chi^2$ | P value |
| $R_{P1}$ | 1.480 | 0.687 | 0.022 | 0.882 | 0.05 1 | 0.821 | 1.407 | 0.236 |
| $R_{P2}$ | 4.571 | 0.206 | 0.006 | 0.938 | 0.745 | 0.388 | 3.820 | 0.05 1 |
| $R_{P3}$ | 4.827 | 0.185 | 2.53 1 | 0.112 | 1.110 | 0.292 | 1.186 | 0.276 |
| $R_{P4}$ | 1.384 | 0.709 | 0.054 | 0.816 | 0.545 | 0.460 | 0.785 | 0.376 |
| $R_{P5}$ | 0.149 | 0.985 | 0.064 | 0.800 | 0.03 1 | 0.860 | 0.054 | 0.816 |
| $R_{P6}$ | 6.912 | 0.075 | 2.120 | 0.145 | 3.659 | 0.056 | 1.133 | 0.287 |
| $R_{P7}$ | 7.084 | 0.069 | 5.860 | 0.015 | 0.671 | 0.413 | 0.553 | 0.457 |
| $R_{P8}$ | 2.011 | 0.570 | 0.003 | 0.956 | 2.000 | 0.157 | 0.008 | 0.929 |
| $R_{P9}$ | 1.287 | 0.732 | 0.099 | 0.753 | 0.003 | 0.956 | 1.185 | 0.276 |
| $R_{P10}$ | 0.807 | 0.848 | 0.551 | 0.458 | 0.034 | 0.854 | 0.222 | 0.638 |
| $R_{P11}$ | 1.360 | 0.715 | 0.934 | 0.334 | 0.358 | 0.550 | 0.068 | 0.794 |
| $R_{P12}$ | 1.195 | 0.754 | 0.371 | 0.542 | 0.762 | 0.383 | 0.062 | 0.803 |
| $R_{P13}$ | 2.344 | 0.504 | 2.023 | 0.155 | 0.282 | 0.595 | 0.039 | 0.843 |
| $R_{P14}$ | 1.174 | 0.759 | 0.654 | 0.419 | 0.036 | 0.850 | 0.484 | 0.487 |

Appendix Table A7. Results of tests of goodness of fit to the Single-Release Model for surface collector test and reference releases of hatchery steelhead from Lower Granite Dam (TEST 2 and TEST 3 of Burnham at al 1987).

| | Overall | | TEST 2.C2 | | TEST 3.SR3 | |
|---|---|---|---|---|---|---|
| Release | $\chi^2$ | P value | $\chi^2$ | P value | $\chi^2$ | P value |
| $R_{C11}$ | 11.158 | 0.004 | 10.934 | 0.001 | 0.224 | 0.636 |
| $C_{C11}$ | 17.75 1 | <0.001 | 17.426 | <0.001 | 0.325 | 0.569 |
| $R_{C12}$ | 4.234 | 0.120 | 0.637 | 0.425 | 3.597 | 0.058 |
| $C_{C12}$ | 1.575 | 0.455 | 0.183 | 0.669 | 1.392 | 0.238 |
| $R_{C13}$ | 4.739 | 0.094 | 4.617 | 0.032 | 0.122 | 0.727 |
| $C_{C13}$ | 0.506 | 0.776 | 0.210 | 0.647 | 0.296 | 0.586 |
| $R_{C14}$ | 3.355 | 0.187 | 3.198 | 0.074 | 0.157 | 0.692 |
| $C_{C14}$ | 2.332 | 0.312 | 1.174 | 0.279 | 1.158 | 0.282 |
| $R_{C15}$ | 2.079 | 0.354 | 1.143 | 0.285 | 0.936 | 0.333 |
| $C_{C15}$ | 4.037 | 0.133 | 2.265 | 0.132 | 1.772 | 0.183 |

Appendix Table A8. Tests of homogeneity of passage distributions at downstream dams for Lower Granite Dam paired surface collector releases of hatchery steelhead. P values calculated using Monte Carlo approximation of the exact method.

| Passage distribution | Releases | $\chi^2$ | Degrees of freedom | P value |
|---|---|---|---|---|
| Little Goose Dam | $(R_{C11}, C_{C11})$ | 20.32 | 26 | 0.823 |
| | $(R_{C12}, C_{C12})$ | 33.88 | 22 | 0.007 |
| | $(R_{C13}, C_{C13})$ | 27.14 | 23 | 0.167 |
| | $(R_{C14}, C_{C14})$ | 25.13 | 25 | 0.410 |
| | $(R_{C15}, C_{C15})$ | 21.60 | 26 | 0.721 |
| Lower Monumental Dam | $(R_{C11}, C_{C11})$ | 29.26 | 28 | 0.359 |
| | $(R_{C12}, C_{C12})$ | 35.68 | 26 | 0.059 |
| | $(R_{C13}, C_{C13})$ | 39.06 | 26 | 0.024 |
| | $(R_{C14}, C_{C14})$ | 20.79 | 23 | 0.594 |
| | $(R_{C15}, C_{C15})$ | 31.92 | 27 | 0.181 |
| McNary Dam | $(R_{C11}, C_{C11})$ | 20.10 | 25 | 0.762 |
| | $(R_{C12}, C_{C12})$ | 26.90 | 24 | 0.256 |
| | $(R_{C13}, C_{C13})$ | 21.64 | 25 | 0.665 |
| | $(R_{C14}, C_{C14})$ | 21.45 | 25 | 0.685 |
| | $(R_{C15}, C_{C15})$ | 28.00 | 23 | 0.168 |

Appendix Table B 1. Estimates of survival probabilities for yearling chinook salmon (hatchery and wild combined) released daily into the tailrace of Lower Granite Dam for comparison with transported smolts in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Date | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LGR to LMO |
|---|---|---|---|---|
| 9 Apr | 11 | 1.182 (0.423) | 0.833 (0.614) | 0.985 (0.594) |
| 10 Apr | 27 | 0.889 (0.165) | 1.750 (1.491) | 1.556 (1.302) |
| 11 Apr | 45 | 0.600 (0.123) | 0.875 (0.277) | 0.525 (0.149) |
| 12 Apr | 75 | 0.884 (0.130) | 0.892 (0.303) | 0.789 (0.242) |
| 13 Apr | 115 | 0.778 (0.090) | 1.022 (0.306) | 0.795 (0.225) |
| 14 Apr | 157 | 0.918 (0.114) | 0.741 (0.183) | 0.680 (0.146) |
| 15 Apr | 207 | 0.946 (0.094) | 0.824 (0.158) | 0.780 (0.127) |
| 16 Apr | 405 | 0.988 (0.068) | 0.785 (0.115) | 0.775 (0.099) |
| 17 Apr | 924 | 0.991 (0.044) | 1.028 (0.116) | 1.019 (0.105) |
| 18 Apr | 1,481 | 0.923 (0.029) | 1.032 (0.086) | 0.952 (0.074) |
| 19 Apr | 1,212 | 0.821 (0.028) | 1.031 (0.097) | 0.847 (0.075) |
| 20 Apr | 1.515 | 0.909 (0.031) | 0.883 (0.068) | 0.803 (0.056) |
| 21 Apr | 2,358 | 0.913 (0.026) | 0.979 (0.063) | 0.894 (0.051) |
| 22 Apr | 1,860 | 0.909 (0.034) | 0.966 (0.073) | 0.878 (0.058) |
| 23 Apr | 1,184 | 0.966 (0.041) | 0.930 (0.077) | 0.898 (0.063) |
| 24 Apr | 1,764 | 0.915 (0.032) | 0.912 (0.063) | 0.835 (0.050) |
| 25 Apr | 2,950 | 0.963 (0.027) | 0.854 (0.044) | 0.823 (0.036) |
| 26 Apr | 2,303 | 0.910 (0.032) | 0.825 (0.047) | 0.750 (0.034) |
| 27 Apr | 2,157 | 0.944 (0.030) | 0.862 (0.049) | 0.814 (0.039) |
| 28 Apr | 1,056 | 0.907 (0.043) | 1.132 (0.111) | 1.022 (0.088) |
| 29 Apr | 1.833 | 0.892 (0.033) | 0.937 (0.061) | 0.836 (0.045) |
| 30 Apr | 2,714 | 0.933 (0.030) | 0.965 (0.055) | 0.901 (0.042) |
| 1 May | 1,177 | 0.886 (0.041) | 0.841 (0.063) | 0.745 (0.044) |
| 2 May | 1,444 | 0.922 (0.040) | 0.970 (0.077) | 0.894 (0.060) |
| 3 May | 2,617 | 0.912 (0.029) | 0.985 (0.059) | 0.899 (0.045) |
| 4 May | 2,013 | 0.929 (0.034) | 0.970 (0.074) | 0.901 (0.060) |
| 5 May | 1.360 | 0.866 (0.035) | 0.945 (0.081) | 0.819 (0.063) |
| 6 May | 2,336 | 0.932 (0.031) | 0.889 (0.061) | 0.828 (0.049) |
| 7 May | 2,297 | 0.970 (0.033) | 0.933 (0.070) | 0.905 (0.061) |
| 8 May | 1,450 | 0.777 (0.037) | 1.197 (0.159) | 0.930 (0.117) |
| 9 May | 233 | 0.679 (0.078) | 0.805 (0.182) | 0.546 (0.112) |
| 10 May | 1,462 | 1.006 (0.048) | 0.899 (0.099) | 0.904 (0.089) |
| 11 May | 3,047 | 0.916 (0.030) | 0.972 (0.078) | 0.890 (0 066) |
| 12 May | 4,287 | 0.915 (0.026) | 1.018 (0.067) | 0.932 (0.055) |
| 13 May | 4,384 | 0.916 (0.031) | 0.965 (0.069) | 0.885 (0.056) |
| 14 May | 2,902 | 0.982 (0.048) | 0.936 (0.089) | 0.918 (0.075) |
| 15 May | 1,516 | 1.014 (9.072) | 0.746 (0.085) | 0.756 (0.067) |
| 16 May | 1,466 | 0.869 (0.055) | 1.056 (0.141) | 0.918 (0.109) |
| 17 May | 912 | 0.903 (0.065) | 1.047 (0.207) | 0.946 (0.174) |
| 18 May | 608 | 1.040 (0.111) | 0.687 (0.139) | 0.715 (0.122) |
| 19 May | 2,776 | 0.987 (0.053) | 0.822 .089 | 0.811 (0.075) |
| 20 May | 1,341 | 0.950 (0.075) | 0.920 (0.168) | 0.874 (0.144) |
| 21 May | 340 | 1.018 (0.166) | 1.767 (0.842) | 1.799 (0.804) |
| 22 May | 101 | 0.631 (0.241) | 0.549 (0.345) | 0.347 (0.177) |
| 23 May | 106 | Insufficient detections. | | |
| 24 May | 83 | 1.614 (1440) | 0.223 (0.216) | 0.360 (0.127) |
| 25 May | 86 | Insufficient detections | | |
| 26 May | 89 | Insufficient detections. | | |
| 27 May | No fish released. | | | |
| 28 May | 59 | Insufficient detections. | | |
| 29 May | 72 | Insufficient detections. | | |
| 30 May | 203 | 0.963 (0.404) | 0.279 (0 154) | 0.268 (0.095) |
| 31 May | 181 | 0.735 (0.164) | 0.352 (0.158) | 0.258 (0.100) |
| 1 Jun | 111 | Insufficient detections. | | |
| 2 Jun | 66 | Insufficient detections. | | |
| 3 Jun | No tish released. | | | |
| 4 Jun | 54 | Insufficient detections | | |
| 5 Jun | 58 | Insufficient detections. | | |
| 6 Jun | 70 | Insufficient detections. | | |
| 7 Jun | 67 | Insufficient detections. | | |
| 8 Jun | 88 | Insufficient detections. | | |
| 9 Jun | 57 | Insufficient detections. | | |
| 10 Jun | No fish released. | | | |
| 11 Jun | 31 | Insufficient detections. | | |
| 12 Jun | 32 | Insufficient detections. | | |
| 13 Jun | 21 | Insufficient detections. | | |
| 14 Jun | 32 | Insufficient detections. | | |
| 15 Jun | 20 | Insufficient detections. | | |

Appendix Table B2. Estimates of survival probabilities for hatchery yearling chinook salmon released daily into the tailrace of Lower Granite Dam for comparison with transported smolts in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Date | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LGR to LMO |
|---|---|---|---|---|
| 9 Apr | No fish released | | | |
| 10 Apr | 4 | Insufficient detections | | |
| 11 Apr | 34 | 0.529 (0.118) | 1.333 (0.621) | 0.706 (0.324) |
| 12 Apr | 54 | 0.791 (0.118) | 1.233 (0.535) | 0.976 (0.406) |
| 13 Apr | 68 | 0.748 (0.120) | 2.428 (2.156) | 1.815 (1.595) |
| 14 Apr | 94 | 0.907 (0.159) | 1.066 (0.446) | 0.967 (0.368) |
| 15 Apr | 93 | 0.881 (0.142) | 1.394 (0.684) | 1.228 (0.571) |
| 16 Apr | 202 | 1.103 (0.138) | 0.565 (0.123) | 0.623 (0.107) |
| 17 Apr | 419 | 0.909 (0.060) | 1.102 (0.185) | 1.001 (0.155) |
| 18 Apr | 723 | 0.856 (0.039) | 1.135 (0.133) | 0.971 (0.107) |
| 19 Apr | 611 | 0.847 (0.050) | 0.856 (0.114) | 0.725 (0.088) |
| 20 Apr | 548 | 0.835 (0.052) | 1.056 (0.192) | 0.881 (0.152) |
| 21 Apr | 858 | 0.849 (0.044) | 1.062 (0.127) | 0.901 (0.098) |
| 22 Apr | 684 | 0.953 (0.068) | 0.841 (0.107) | 0.802 (0.084) |
| 23 Apr | 597 | 0.977 (0.065) | 0.802 (0.086) | 0.784 (0.065) |
| 24 Apr | 1,139 | 0.856 (0.036) | 1.032 (0.085) | 0.884 (0.064) |
| 25 Apr | 1.886 | 0.940 (0.033) | 0.869 (0.056) | 0.817 (0.044) |
| 26 Apr | 1,484 | 0.873 (0.035) | 0.894 (0.059) | 0.780 (0.042) |
| 27 Apr | 1,571 | 0.998 (0.038) | 0.855 (0.057) | 0.853 (0.047) |
| 28 Apr | 736 | 0.912 (0.051) | 1.108 (0.124) | 1.011 (0.099) |
| 29 Apr | 1,604 | 0.915 (0.037) | 0.907 (0.063) | 0.830 (0.047) |
| 30 Apr | 2,393 | 0.923 (0.031) | 1.011 (0.062) | 0.934 (0.048) |
| 1 May | 1.087 | 0.900 (0.045) | 0.811 (0.063) | 0.729 (0.044) |
| 2 May | 1,296 | 0.934 (0.043) | 0.976 (0.083) | 0.911 (0.065) |
| 3 May | 2,405 | 0.928 (0.032) | 0.965 (0.061) | 0.896 (0.048) |
| 4 May | 1,860 | 0.908 (0.034) | 0.995 (0.078) | 0.903 (0.062) |
| 5 May | 1,258 | 0.857 (0.036) | 0.949 (0.085) | 0.813 (0.065) |
| 6 May | 2,165 | 0.920 (0.032) | 0.921 (0.066) | 0.848 (0.054) |
| 7 May | 2.179 | 0.969 (0.034) | 0.912 (0.069) | 0.883 (0.060) |
| 8 May | 1,337 | 0.784 (0.039) | 1.177 (0.161) | 0.922 (0.119) |
| 9 May | 221 | 0.679 (0.079) | 0.753 (0.165) | 0.511 (0.101) |
| 10 May | 1,347 | 1.012 (0.051) | 0.899 (0.105) | 0.910 (0.096) |
| 11 May | 2,825 | 0.908 (0.030) | 0.995 (0.084) | 0.903 (0.070) |
| 12 May | 3,985 | 0.905 (0.027) | 1.033 (0.072) | 0.935 (0.059) |
| 13 May | 4,013 | 0.922 (0.033) | 0.943 (0.071) | 0.870 (0.057) |
| 14 May | 2,776 | 0.985 (0.049) | 0.934 (0.091) | 0.919 (0.077) |
| 15 May | 1,427 | 1.022 (0.075) | 0.757 (0.090) | 0.774 (0.072) |
| 16 May | 1,395 | 0.876 (0.057) | 1.043 (0.145) | 0.914 (0.112) |
| 17 May | 838 | 0.926 (0.073) | 1.048 (0.228) | 0.971 (0.197) |
| 18 May | 541 | 1.004 (0.113) | 0.793 (0.196) | 0.795 (0.174) |
| 19 May | 2,317 | 0.960 (0.057) | 0.881 (0.112) | 0.846 (0.095) |
| 20 May | 1.124 | 0.956 (0.087) | 1.049 (0.240) | 1.003 (0.210) |
| 21 May | 236 | 1.082 (0.249) | 4.004 (3.954) | 4.331 (4.155) |
| 22 May | 89 | 0.548 (0.202) | 0.697 (0.591) | 0.382 (0.296) |
| 23 May | 97 | Insufficient detections | | |
| 24 May | 75 | 1.453 (1.274) | 0.265 (0.255) | 0.386 (0.140) |
| 25 May | 79 | Insufficient detections. | | |
| 26 May | 79 | Insufficient detections. | | |
| 27 May | No fish released | | | |
| 28 May | 56 | Insufficient detections. | | |
| 29 May | 68 | Insufficient detections. | | |
| 30 May | 189 | 1.392 (0.887) | 0.167 (0.123) | 0.233 (0.082) |
| 31 May | 157 | 0.706 (0.163) | 0.373 (0.171) | 0.263 (0.104) |
| 1 Jun | 92 | Insufficient detections | | |
| 2 Jun | 56 | Insufficient detections. | | |
| 3 Jun | No fish released. | | | |
| 4 Jun | 46 | Insufficient detections | | |
| 5 Jun | 47 | Insufficient detections. | | |
| 6 Jun | 57 | Insufficient detections | | |
| 7 Jun | 55 | Insufficient detections. | | |
| 8 Jun | 68 | Insufficient detections. | | |
| 9 Jun | 51 | Insufficient detections. | | |
| 10 Jun | No fish released. | | | |
| 11 Jun | 25 | Insufficient detections. | | |
| 12 Jun | 22 | Insufficient detections. | | |
| 13 Jun | 10 | Insufficient detections. | | |
| 14 Jun | 24 | Insufficient detections. | | |
| 15 Jun | 12 | Insufficient detections. | | |

Appendix Table B3. Estimates of survival probabilities for wild yearling chinook salmon released daily into the tailrace of Lower Granite Dam for comparison with transported smolts in 1996. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

| Date | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LGR to LMO |
|---|---|---|---|---|
| 9 Apr | 11 | 1.182 (0.423) | 0.833 (0.614) | 0.985 (0.594) |
| 10 Apr | 23 | 0.888 (0.152) | 1.762 (1.471) | 1.565 (1.290) |
| 11 Apr | 11 | 0.727 (0.290) | 0.500 (0.250) | 0.364 (0.145) |
| 12 Apr | 21 | 1.381 (0.672) | 0.357 (0.248) | 0.493 (0.221) |
| 13 Apr | 47 | 0.820 (0.136) | 0.765 (0.227) | 0.628 (0.162) |
| 14 Apr | 63 | 0.905 (0.152) | 0.536 (0.158) | 0.485 (0.120) |
| 15 Apr | 114 | 1.000 (0.127) | 0.701 (0.145) | 0.701 (0.112) |
| 16 Apr | 203 | 0.927 (0.074) | 0.993 (0.199) | 0.921 (0.170) |
| 17 Apr | 505 | 1.063 (0.065) | 0.967 (0.147) | 1.028 (0.141) |
| 18 Apr | 758 | 0.982 (0.042) | 0.946 (0.112) | 0.929 (0.102) |
| 19 Apr | 601 | 0.815 (0.034) | 1.192 (0.160) | 0.971 (0.126) |
| 20 21 Apr | 967 | 0.944 (0.038) | 0.857 (0.072) | 0.809 (0.059) |
| Apr | 1,500 | 0.949 (0.033) | 0.930 (0.069) | 0.883 (0.058) |
| 22 Apr | 1,176 | 0.891 (0.039) | 1.031 (0.09X) | 0.918 (0.078) |
| 23 Apr | 587 | 0.960 (0.052) | 1.137 (0.155) | 1.092 (0.137) |
| 24 Apr | 625 | 0.990 (0.059) | 0.755 (0.095) | 0.748 (0.083) |
| 25 Apr | 1,064 | 1.001 (0.045) | 0.828 (0.072) | 0.829 (0.061) |
| 26 Apr | 819 | 0.987 (0.066) | 0.689 (0.075) | 0.680 (0.058) |
| 27 Apr | 586 | 0.809 (0.047) | 0.854 (0.092) | 0.691 (0.065) |
| 28 Apr | 320 | 0.878 (0.076) | 1.076 (0.209) | 0.945 (0.166) |
| 29 Apr | 229 | 0.766 (0.066) | 1.126 (0.221) | 0.862 (0.157) |
| 30 Apr | 321 | 1.024 (0.108) | 0.695 (0.108) | 0.712 (0.078) |
| 1 May | 90 | 0.776 (0.095) | 1.461 (0.56')) | 1.134 (0.427) |
| 2 May | 148 | 0.823 (0.103) | 0.875 (0.196) | 0.720 (0.138) |
| 3 May | 212 | 0.832 (0.061) | 1.083 (0.182) | 0.901 (0.141) |
| 4 May | 153 | 1.268 (0.215) | 0.686 (0.220) | 0.870 (0.231) |
| 5 May | 102 | 0.981 (0.114) | 0.832 (0.242) | 0.816 (0.218) |
| 6 May | 171 | 1.079 (0.146) | 0.599 (0.130) | 0.647 (0.107) |
| 7 May | 118 | 0.999 (0.128) | 1.495 (0.627) | 1.494 (0.594) |
| 8 May | 113 | 0.700 (0.113) | 1.556 (0.933) | 1.089 (0.636) |
| 9 May | 12 | Insufficient detections | | |
| 10 May | 115 | 0.950 (0.137) | 0.913 (0.293) | 0.868 (0.249) |
| 11 May | 222 | 1.038 (0.138) | 0.703 (0.195) | 0.730 (0.176) |
| 12 May | 302 | 1.052 (0.095) | 0.874 (0.175) | 0.919 (0.163) |

| Date | Number released | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | LGR to LMO |
|---|---|---|---|---|
| 13 May | 371 | 0.893 (0.079) | 1.1b9 (0.264) | 1.044 (0.218) |
| 14 May | 126 | 0.938 (0.180) | 0.965 (0.383) | 0.906 (0.315) |
| 15 May | 89 | 0.882 (0.250) | 0.656 (0.255) | 0.579 (0.155) |
| 16 May | 71 | 0.724 (0.164) | 1.361 (0.650) | 0.986 (0.427) |
| 17 May | 74 | 0.782 (0.126) | 1.109 (0.484) | 0.866 (0.359) |
| 18 May | b7 | 1.349 (0.438) | 0.436 (0.186) | 0.588 (0.150) |
| 19 May | 459 | 1.107 (0.141) | 0.687 (0.140) | 0.760 (0.119) |
| 20 May | 217 | 0.957 (0.150) | 0.668 (0.194) | 0.639 (0.155) |
| 21 May | 104 | 0.973 (0.219) | 1.008 (0.499) | 0.981 (0.432) |
| 22 May | 12 | Insufficient detections. | | |
| 23 May | 9 | Insufficient detections. | | |
| 24 May | 8 | Insufficient detections. | | |
| 25 May | 7 | Insufficient detections. | | |
| 26 May | 10 | Insufficient detections. | | |
| 27 May | No fish released. | | | |
| 28 May | 3 | Insufficient detections | | |
| 29 May | 4 | Insufficient detections. | | |
| 30 May | 14 | Insufficient detections. | | |
| 31 May | 24 | Insufficient detections | | |
| 1 Jun | 19 | Insufficient detections | | |
| 2 Jun | 10 | Insufficient detections. | | |
| 3 Jun | No fish released. | | | |
| 4 Jun | 8 | Insufficient detections. | | |
| 5 Jun | 11 | Insufficient detections | | |
| 6 Jun | 13 | Insufficient detections | | |
| 7 Jun | 11 | Insufficient detections | | |
| 8 Jun | 20 | Insufficient detections. | | |
| 9 Jun | 6 | Insufficient detections | | |
| 10 Jun | No fish released. | | | |
| 11 Jun | 6 | 1.000 (0.577) | 0.500 (0.354) | 0.500 (0.204) |
| 12 Jun | 10 | Insufficient detections | | |
| 13 Jun | 11 | Insufficient detections. | | |
| 14 Jun | 8 | 0.833 (0.201) | 0.600 (0.219) | 0.500 (0.177) |
| 15 Jun | 8 | Insufficient detections. | | |

Appendix Table C1. Travel times and migration rates between the Port of Wilma and Lower Granite Dam (49 km) for primary releases of hatchery steelhead.

| | | | Travel time (days) | | | | | Migration rate (km/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release | Date | Number | Minimum | 20% | Median | 80% | Maximum | Minimum | 20% | Median | 80% | Maximum |
| $R_{P1}$ | 12 Apr | 90 | 1.0 | 1.2 | 1.6 | 4.4 | 17.6 | 2.8 | 11.2 | 30.6 | 40.2 | 51.6 |
| $R_{P2}$ | 19 Apr | 238 | 1.1 | 1.4 | 1.5 | 2.1 | 8.4 | 5.8 | 23.8 | 32.0 | 34.8 | 44.1 |
| $R_{P3}$ | 21 Apr | 228 | 1.5 | 2.0 | 2.4 | 2.9 | 28.7 | 1.7 | 17.1 | 20.8 | 25.1 | 32.2 |
| $R_{P4}$ | 23 Apr | 437 | 0.7 | 1.2 | 1.4 | 1.7 | 28.7 | 1.7 | 29.3 | 36.3 | 40.5 | 74.2 |
| $R_{P5}$ | 25 Apr | 453 | 0.9 | 1.2 | 1.4 | 2.0 | 26.6 | 1.8 | 24.3 | 35.0 | 40.8 | 52.7 |
| $R_{P6}$ | 27 Apr | 380 | 1.1 | 1.4 | 1.7 | 2.4 | 21.4 | 2.3 | 20.2 | 29.0 | 35.5 | 45.8 |
| $R_{P7}$ | 29 Apr | 345 | 1.1 | 1.4 | 2.1 | 2.7 | 37.2 | 1.3 | 17.9 | 23.9 | 34.0 | 44.5 |
| $R_{P8}$ | 1 May | 330 | 0.6 | 1.5 | 1.8 | 2.6 | 28.1 | 1.7 | 19.2 | 26.9 | 33.6 | 83.1 |
| $R_{P9}$ | 3 May | 269 | 1.3 | 1.5 | 1.9 | 2.7 | 34.4 | 1.4 | 18.5 | 25.4 | 31.8 | 38.3 |
| $R_{P10}$ | 7 May | 171 | 1.4 | 1.7 | 2.5 | 3.5 | 11.7 | 4.2 | 14.0 | 19.8 | 29.2 | 34.0 |
| $R_{P11}$ | 9 May | 307 | 1.4 | 1.7 | 2.4 | 4.0 | 18.4 | 2.7 | 12.3 | 20.4 | 28.8 | 35.8 |
| $R_{P12}$ | 11 May | 306 | 1.4 | 1.9 | 2.4 | 3.3 | 19.0 | 2.6 | 14.7 | 20.6 | 25.7 | 36.3 |
| $R_{P13}$ | 14 May | 318 | 1.1 | 1.3 | 1.5 | 1.7 | 13.7 | 3.6 | 28.8 | 33.3 | 36.6 | 45.8 |
| $R_{P14}$ | 16 May | 191 | 0.9 | 1.0 | 1.2 | 1.5 | 12.5 | 3.9 | 32.0 | 39.8 | 47.6 | 54.4 |

Appendix Table C2. Travel times and migration rates between Lower Granite Dam and Little Goose Dam (60 km) for primary releases of hatchery steelhead.

| Release | Date | Number | Travel time (days) | | | | | Migration rate (km/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Minimum | 20% | Median | 80% | Maximum | Minimum | 20% | Median | 80% | Maximum |
| $R_{P1}$ | 12 Apr | 24 | 1.8 | 2.3 | 5.6 | 10.7 | 18.7 | 3.2 | 5.6 | 10.8 | 26.7 | 33.5 |
| $R_{P2}$ | 19 Apr | 113 | 1.8 | 2.7 | 3.5 | 5.4 | 28.3 | 2.1 | 11.2 | 17.4 | 21.9 | 32.6 |
| $R_{P3}$ | 21 Apr | 95 | 1.1 | 1.5 | 2.0 | 3.3 | 22.5 | 2.7 | 18.0 | 30.2 | 41.1 | 54.5 |
| $R_{P4}$ | 23 Apr | 180 | 0.9 | 1.4 | 1.9 | 2.4 | 23.0 | 2.6 | 24.6 | 31.4 | 42.9 | 66.7 |
| $R_{P5}$ | 25 Apr | 114 | 1.1 | 1.7 | 2.4 | 5.8 | 29.8 | 2.0 | 10.4 | 25.1 | 34.5 | 53.1 |
| $R_{P6}$ | 27 Apr | 175 | 1.5 | 2.2 | 3.3 | 6.9 | 21.8 | 2.8 | 8.7 | 18.3 | 26.9 | 39.2 |
| $R_{P7}$ | 29 Apr | 133 | 1.3 | 2.1 | 3.0 | 8.6 | 17.1 | 3.5 | 7.0 | 19.9 | 28.4 | 46.2 |
| $R_{P8}$ | 1 May | 81 | 1.4 | 2.2 | 3.6 | 7.1 | 24.7 | 2.4 | 8.5 | 16.6 | 27.4 | 43.5 |
| $R_{P9}$ | 3 May | 72 | 1.6 | 2.9 | 3.9 | 7.5 | 16.6 | 3.6 | 8.0 | 15.3 | 21.0 | 37.0 |
| $R_{P10}$ | 7 May | 54 | 1.8 | 3.0 | 4.3 | 6.9 | 12.0 | 5.0 | 8.7 | 13.8 | 20.1 | 33.0 |
| $R_{P11}$ | 9 May | 103 | 1.5 | 2.4 | 3.4 | 5.1 | 11.9 | 5.0 | 11.8 | 17.7 | 25.4 | 40.8 |
| $R_{P12}$ | 11 May | 99 | 1.3 | 1.9 | 2.4 | 3.5 | 16.1 | 3.7 | 17.1 | 25.2 | 31.3 | 45.8 |
| $R_{P13}$ | 14 May | 109 | 1.2 | 1.5 | 2.0 | 3.3 | 13.1 | 4.6 | 18.0 | 30.0 | 41.1 | 52.2 |
| $R_{P14}$ | 16 May | 58 | 1.0 | 1.4 | 1.7 | 2.5 | 12.8 | 4.7 | 24.0 | 35.7 | 42.0 | 58.3 |

Appendix Table C3. Travel times and migration rates between Little Goose Dam and Lower Monumental Dam (46 km) for primary releases of hatchery steelhead.

| | | | Travel time (days) | | | | | Migration rate (km/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release | Date | Number | Minimum | 20% | Median | 80% | Maximum | Minimum | 20% | Median | 80% | Maximum |
| $R_{P1}$ | 12 Apr | 63 | 0.9 | 1.8 | 2.5 | 5.0 | 15.1 | 3.1 | 9.2 | 18.3 | 25.4 | 50.0 |
| $R_{P2}$ | 19 Apr | 100 | 0.8 | 1.2 | 1.5 | 2.1 | 18.8 | 2.4 | 21.7 | 31.1 | 40.0 | 58.2 |
| $R_{P3}$ | 21 Apr | 130 | 0.7 | 1.0 | 1.4 | 2.2 | 20.1 | 2.3 | 20.9 | 33.1 | 46.0 | 67.6 |
| $R_{P4}$ | 23 Apr | 109 | 0.8 | 1.0 | 1.3 | 1.8 | 15.9 | 2.9 | 25.0 | 36.8 | 46.0 | 59.0 |
| $R_{P5}$ | 25 Apr | 61 | 1.1 | 1.5 | 2.1 | 4.7 | 19.5 | 2.4 | 9.8 | 22.3 | 31.7 | 43.8 |
| $R_{P6}$ | 27 Apr | 104 | 0.9 | 1.6 | 2.3 | 3.9 | 17.7 | 2.6 | 11.7 | 20.3 | 29.3 | 54.1 |
| $R_{P7}$ | 29 Apr | 85 | 0.9 | 1.8 | 2.9 | 5.4 | 13.8 | 3.3 | 8.5 | 15.6 | 25.6 | 53.5 |
| $R_{P8}$ | 1 May | 55 | 1.0 | 1.7 | 2.6 | 5.8 | 14.3 | 3.2 | 7.9 | 18.0 | 27.2 | 48.4 |
| $R_{P9}$ | 3 May | 54 | 0.8 | 2.0 | 3.0 | 5.2 | 12.2 | 3.8 | 8.8 | 15.3 | 23.0 | 57.5 |
| $R_{P10}$ | 7 May | 72 | 1.0 | 1.5 | 2.2 | 3.2 | 6.7 | 6.9 | 14.5 | 21.0 | 31.3 | 47.4 |
| $R_{P11}$ | 9 May | 89 | 0.8 | 1.4 | 1.7 | 2.7 | 7.0 | 6.5 | 16.9 | 26.4 | 33.3 | 60.5 |
| $R_{P12}$ | 11 May | 91 | 0.8 | 1.2 | 1.5 | 2.8 | 12.7 | 3.6 | 16.4 | 29.9 | 39.0 | 61.3 |
| $R_{P13}$ | 14 May | 49 | 0.7 | 1.0 | 1.3 | 1.9 | 4.5 | 10.2 | 24.6 | 34.8 | 46.9 | 66.7 |
| $R_{P14}$ | 16 May | 60 | 0.7 | 0.9 | 1.2 | 2.6 | 50.3 | 0.9 | 18.0 | 39.3 | 51.1 | 68.7 |

Appendix Table C4. Travel times and migration rates between Lower Monumental Dam and McNary Dam (119 km) for primary releases of hatchery steelhead.

| | | | Travel time (days) | | | | | Migration rate (km/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release | Date | Number | Minimum | 20% | Median | 80% | Maximum | Minimum | 20% | Median | 80% | Maximum |
| $R_{P1}$ | 12 Apr | 26 | 2.0 | 2.7 | 3.8 | 5.7 | 20.9 | 5.7 | 20.8 | 31.2 | 43.6 | 58.9 |
| $R_{P2}$ | 19 Apr | 27 | 1.6 | 2.1 | 3.0 | 5.5 | 26.6 | 4.5 | 21.6 | 40.3 | 56.4 | 74.4 |
| $R_{P3}$ | 21 Apr | 41 | 1.9 | 2.8 | 4.3 | 8.0 | 13.4 | 8.9 | 14.8 | 27.6 | 43.0 | 64.3 |
| $R_{P4}$ | 23 Apr | 38 | 2.3 | 2.7 | 3.5 | 5.6 | 9.2 | 13.0 | 21.3 | 33.8 | 43.8 | 52.2 |
| $R_{P5}$ | 25 Apr | 45 | 2.5 | 2.9 | 3.6 | 8.0 | 15.5 | 7.7 | 15.0 | 32.8 | 41.8 | 47.4 |
| $R_{P6}$ | 27 Apr | 36 | 2.3 | 3.0 | 3.8 | 6.8 | 9.3 | 12.8 | 17.4 | 31.7 | 39.1 | 52.0 |
| $R_{P7}$ | 29 Apr | 30 | 2.9 | 3.4 | 4.1 | 6.0 | 12.1 | 9.9 | 19.9 | 28.9 | 35.3 | 40.5 |
| $R_{P8}$ | 1 May | 26 | 2.6 | 3.5 | 4.4 | 6.5 | 11.4 | 10.5 | 18.4 | 27.1 | 34.1 | 46.3 |
| $R_{P9}$ | 3 May | 15 | 2.1 | 3.3 | 3.9 | 4.8 | 10.8 | 11.0 | 25.0 | 30.5 | 36.4 | 56.9 |
| $R_{P10}$ | 7 May | 13 | 2.1 | 2.9 | 3.2 | 4.1 | 6.1 | 19.6 | 29.1 | 37.5 | 41.3 | 57.8 |
| $R_{P11}$ | 9 May | 19 | 2.0 | 2.8 | 3.8 | 6.2 | 6.6 | 17.9 | 19.1 | 31.1 | 42.0 | 60.4 |
| $R_{P12}$ | 11 May | 14 | 2.0 | 2.5 | 3.9 | 5.7 | 8.7 | 13.6 | 21.0 | 30.6 | 47.2 | 60.1 |
| $R_{P13}$ | 14 May | 13 | 1.8 | 2.6 | 3.4 | 7.0 | 10.3 | 11.6 | 17.0 | 34.9 | 45.2 | 67.2 |
| $R_{P14}$ | 16 May | 9 | 1.9 | 2.3 | 2.8 | 4.8 | 5.1 | 23.5 | 25.1 | 43.3 | 52.9 | 63.3 |

Appendix Table C5. Travel times and migration rates between the Port of Wilma and McNary Dam (274 km) for primary releases of hatchery steelhead.

| | | | Travel time (days) | | | | | Migration rate (km/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release | Date | Number | Minimum | 20% | Median | 80% | Maximum | Minimum | 20% | Median | 80% | Maximum |
| $R_{P1}$ | 12 Apr | 56 | 6.2 | 9.4 | 13.9 | 20.5 | 34.4 | 8.0 | 13.4 | 19.7 | 29.2 | 44.1 |
| $R_{P2}$ | 19 Apr | 89 | 6.7 | 7.5 | 9.1 | 17.6 | 33.9 | 8.1 | 15.5 | 30.3 | 36.4 | 41.1 |
| $R_{P3}$ | 21 Apr | 83 | 5.7 | 8.0 | 10.6 | 16.9 | 39.8 | 6.9 | 16.2 | 25.9 | 34.2 | 48.1 |
| $R_{P4}$ | 23 Apr | 81 | 5.9 | 7.5 | 9.6 | 19.1 | 29.8 | 9.2 | 14.3 | 28.6 | 36.6 | 46.8 |
| $R_{P5}$ | 25 Apr | 104 | 6.3 | 7.5 | 9.2 | 16.3 | 32.1 | 8.5 | 16.8 | 29.9 | 36.6 | 43.8 |
| $R_{P6}$ | 27 Apr | 81 | 7.4 | 10.1 | 13.8 | 18.5 | 25.5 | 10.7 | 14.8 | 19.9 | 27.2 | 37.1 |
| $R_{P7}$ | 29 Apr | 71 | 7.6 | 9.7 | 13.7 | 18.4 | 35.9 | 7.6 | 14.9 | 20.0 | 28.3 | 36.3 |
| $R_{P8}$ | 1 May | 69 | 7.6 | 9.4 | 12.4 | 14.5 | 23.9 | 11.5 | 18.9 | 22.0 | 29.1 | 36.1 |
| $R_{P9}$ | 3 May | 62 | 7.8 | 10.9 | 12.8 | 15.9 | 22.9 | 11.9 | 17.3 | 21.5 | 25.1 | 35.4 |
| $R_{P10}$ | 7 May | 34 | 7.6 | 9.4 | 10.0 | 13.9 | 16.7 | 16.4 | 19.7 | 27.4 | 29.2 | 36.3 |
| $R_{P11}$ | 9 May | 29 | 7.6 | 8.9 | 10.5 | 13.5 | 20.9 | 13.1 | 20.3 | 26.1 | 30.9 | 36.1 |
| $R_{P12}$ | 11 May | 31 | 7.3 | 8.9 | 10.3 | 12.2 | 16.5 | 16.6 | 22.5 | 26.7 | 30.9 | 37.5 |
| $R_{P13}$ | 14 May | 29 | 5.3 | 6.2 | 7.7 | 13.7 | 21.1 | 13.0 | 19.9 | 35.5 | 44.2 | 51.3 |
| $R_{P14}$ | 16 May | 39 | 4.9 | 5.5 | 6.3 | 12.4 | 21.5 | 12.8 | 22.2 | 43.6 | 50.3 | 55.9 |

Appendix Table D1. Survival and travel time estimates and environmental exposure indices used in correlation and regression analyses for primary release groups of hatchery yearling chinook salmon.

| Year | Rel. Date | Survival Rel-LMO Est. | s.e. | Travel Time (med. days) | Exposure Indices Flow | Spill% | Temperature |
|---|---|---|---|---|---|---|---|
| 1994 | 16 Apr | 0.665 | 0.028 | 17.36 | 76.54 | 0.00 | 11.20 |
| | 17 Apr | 0.662 | 0.029 | 17.26 | 76.57 | 0.00 | 11.15 |
| | 18 Apr | 0.627 | 0.028 | 16.11 | 76.18 | 0.00 | 11.15 |
| | 21 Apr | 0.671 | 0.040 | 17.33 | 82.53 | 2.44 | 11.55 |
| | 23 Apr | 0.594 | 0.047 | 15.94 | 84.14 | 3.36 | 11.71 |
| | 26 Apr | 0.613 | 0.047 | 17.07 | 85.32 | 13.63 | 13.14 |
| | 29 Apr | 0.605 | 0.068 | 16.31 | 79.85 | 15.93 | 13.73 |
| | 1 May | 0.653 | 0.054 | 15.12 | 80.72 | 15.86 | 13.70 |
| | 4 May | 0.642 | 0.090 | 12.20 | 77.03 | 16.33 | 13.89 |
| | 11 May | 0.731 | 0.106 | 10.15 | 70.73 | 20.79 | 13.89 |
| 1995 | 9 Apr | 0.762 | 0.052 | 25.25 | 92.13 | 18.69 | 10.45 |
| | 11 Apr | 0.755 | 0.056 | 23.34 | 95.09 | 19.11 | 10.56 |
| | 15 Apr | 0.894 | 0.069 | 24.16 | 111.84 | 22.02 | 10.56 |
| | 18 Apr | 0.694 | 0.065 | 19.37 | 110.19 | 21.90 | 10.56 |
| | 20 Apr | 0.746 | 0.055 | 17.56 | 111.51 | 22.29 | 10.56 |
| | 23 Apr | 0.795 | 0.043 | 14.40 | 111.96 | 22.43 | 10.56 |
| | 25 Apr | 0.733 | 0.040 | 12.86 | 113.85 | 22.87 | 10.56 |
| | 27 Apr | 0.853 | 0.055 | 13.51 | 112.83 | 22.32 | 10.56 |
| | 29 Apr | 0.796 | 0.053 | 13.53 | 106.15 | 20.55 | 10.56 |
| | 1 May | 0.807 | 0.048 | 11.88 | 106.57 | 19.79 | 10.56 |
| | 3 May | 0.792 | 0.087 | 11.19 | 101.43 | 19.18 | 10.68 |
| | 5 May | 0.678 | 0.142 | 12.00 | 103.49 | 18.87 | 11.14 |

Appendix Table D2. Survival and travel time estimates and environmental exposure indices used in correlation and regression analyses for primary release groups of hatchery steelhead.

| | | Survival Rel.-LMO | | Travel Time | Exposure Indices | | |
|---|---|---|---|---|---|---|---|
| Year | Rel. Date | Est. | s.e. | (med. days) | Flow | Spill% | Temperature |
| 1994 | 23 Apr | 0.600 | 0.021 | 12.56 | 76.77 | 0.00 | 11.11 |
| | 25 Apr | 0.590 | 0.029 | 12.93 | 82.96 | 2.28 | 11.54 |
| | 26 Apr | 0.604 | 0.038 | 13.66 | 84.56 | 4.73 | 11.86 |
| | 1 May | 0.646 | 0.068 | 13.53 | 83.10 | 15.53 | 13.50 |
| | 3 May | 0.585 | 0.073 | 11.68 | 80.68 | 15.69 | 13.68 |
| | 5 May | 0.530 | 0.066 | 11.61 | 76.14 | 16.31 | 13.89 |
| | 7 May | 0.635 | 0.104 | 11.08 | 74.08 | 16.06 | 13.89 |
| | 10 May | 0.437 | 0.064 | 13.35 | 71.59 | 21.35 | 13.71 |
| | 12 May | 0.625 | 0.084 | 13.18 | 69.11 | 20.60 | 13.33 |
| 1995 | 22 Apr | 0.761 | 0.043 | 14.62 | 109.33 | 21.15 | 10.56 |
| | 24 Apr | 0.783 | 0.053 | 13.46 | 111.68 | 22.39 | 10.56 |
| | 26 Apr | 0.751 | 0.039 | 12.68 | 115.15 | 22.79 | 10.56 |
| | 28 Apr | 0.835 | 0.058 | 12.02 | 114.26 | 22.62 | 10.56 |
| | 30 Apr | 0.822 | 0.050 | 11.43 | 110.61 | 22.08 | 10.56 |
| | 2 May | 0.793 | 0.053 | 10.01 | 108.86 | 21.59 | 10.56 |
| | 4 May | 0.753 | 0.051 | 8.52 | 107.11 | 20.06 | 10.56 |
| | 6 May | 0.879 | 0.062 | 6.96 | 102.76 | 19.09 | 10.56 |
| | 9 May | 0.789 | 0.046 | 6.93 | 101.99 | 18.57 | 11.09 |
| | 11 May | 0.793 | 0.050 | 7.46 | 110.24 | 20.26 | 12.19 |
| | 12 May | 0.734 | 0.143 | 8.25 | 115.39 | 21.38 | 12.85 |

Appendix Table D2. Continued.

| Year | Rel. Date | Survival Rel-LMO Est. | s.e. | Travel Time (med. days) | Exposure Indices Flow | Spill% | Temperature |
|---|---|---|---|---|---|---|---|
| 1996 | 12Apr | 0.934 | 0.113 | 8.60 | 108.30 | 27.06 | 10.07 |
| | 19 Apr | 0.959 | 0.113 | 6.34 | 150.06 | 35.98 | 10.40 |
| | 21 Apr | 0.846 | 0.074 | 5.28 | 142.29 | 33.55 | 10.42 |
| | 23 Apr | 0.849 | 0.078 | 4.54 | 132.61 | 40.58 | 10.35 |
| | 25 Apr | 0.879 | 0.073 | 6.11 | 99.97 | 26.88 | 10.63 |
| | 27 Apr | 0.922 | 0.089 | 8.13 | 88.47 | 25.55 | 9.59 |
| | 29 Apr | 0.797 | 0.085 | 10.76 | 89.14 | 24.13 | 8.77 |
| | 1 May | 0.823 | 0.097 | 8.82 | 88.08 | 23.48 | 8.57 |
| | 3 May | 1.132 | 0.189 | 10.12 | 104.33 | 25.29 | 8.65 |
| | 7 May | 1.033 | 0.155 | 8.03 | 131.66 | 28.96 | 9.08 |
| | 9 May | 0.802 | 0.093 | 7.11 | 149.78 | 33.52 | 9.54 |
| | 11 May | 0.743 | 0.079 | 6.40 | 170.55 | 40.09 | 9.75 |
| | 14 May | 0.776 | 0.108 | 4.49 | 189.65 | 46.74 | 9.55 |
| | 16 May | 0.968 | 0.186 | 4.15 | 185.99 | 45.51 | 8.69 |

Appendix Table D3. Survival and travel time estimates and environmental exposure indices used in correlation and regression analyses for daily release groups of yearling chinook salmon from Lower Granite Dam. Shaded survival estimates were based on fewer than 5 detections below the end of the reach. These were not used in correlation analyses but are included for PATH process documentation.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 15 Apr 94 | 0.667 | 0,272 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | NA | NA | NA |
| 16 Apr 94 | 0.857 | 0,512 | 0.333 | 0.272 | NA | NA | 0.286 | 0.171 | NA | NA | | | | | | NA | NA | NA |
| 17 Apr 94 | 0.955 | 0.335 | 0.714 | 0.298 | NA | NA | 0.682 | 0.166 | NA | NA | 7.91 | 1.75 | 5.08 | 9.41 | 15.61 | 69.98 | 0.00 | 11.47 |
| 18 Apr 94 | 0.763 | 0.161 | 0.982 | 0.320 | NA | NA | 0.749 | 0.213 | NA | NA | 7.55 | 2.84 | 4.64 | 8.73 | 15.13 | 72.15 | 0.00 | 11.36 |
| 19 Apr 94 | 0.889 | 0.132 | 0.687 | 0.130 | NA | NA | 0.611 | 1.000 | NA | NA | 6.79 | 4.68 | 6.09 | 8.61 | 14.93 | 72.78 | 0.00 | 11.46 |
| 20 Apr94 | 0.842 | 0.045 | 0.950 | 0.068 | NA | NA | 0.800 | 0.050 | NA | NA | 5.80 | 3.33 | 5.95 | 8.54 | 14.98 | 71.07 | 0.00 | 11.65 |
| 21 Apr94 | 0.827 | 0.021 | 0.916 | 0.033 | NA | NA | 0.757 | 0.023 | NA | NA | 4.56 | 3.25 | 5.69 | 7.37 | 13.47 | 69.18 | 0.00 | 11.67 |
| 22 Apr 94 | 0.866 | 0.031 | 0.883 | 0.045 | NA | NA | 0.765 | 0.031 | NA | NA | 5.73 | 2.89 | 5.35 | 8.52 | 14.97 | 74.25 | 0.00 | 11.39 |
| 23 Apr 94 | 0.782 | 0.016 | 0.794 | 0.023 | NA | NA | 0.621 | 0.015 | NA | NA | 5.11 | 3.67 | 5.78 | 8.76 | 16.12 | 76.15 | 0.00 | 11.25 |
| 24 Apr 94 | 0.829 | 0.027 | 0.880 | 0.040 | NA | NA | 0.729 | 0.026 | NA | NA | 6.75 | 3.80 | 6.12 | 11.41 | 17.85 | 75.13 | 0.00 | 11.11 |
| 25 Apr 94 | 0.866 | 0.033 | 0.860 | 0.044 | NA | NA | 0.744 | 0.028 | NA | NA | 8.03 | 3.65 | 5.56 | 11.40 | 19.64 | 76.99 | 0.00 | 11.14 |
| 26 Apr 94 | 0.758 | 0.027 | 0.922 | 0.046 | NA | NA | 0.699 | 0.027 | NA | NA | 7.97 | 3.60 | 5.45 | 10.71 | 17.84 | 77.40 | 0.00 | 11.13 |
| 27 Apr 94 | 0.815 | 0.061 | 0.895 | 0.091 | NA | NA | 0.729 | 0.053 | NA | NA | 8.06 | 2.98 | 5.39 | 10.76 | 18.95 | 79.83 | 0.00 | 11.25 |
| 28 Apr 94 | 0.822 | 0.031 | 0.775 | 0.038 | NA | NA | 0.637 | 0.020 | NA | NA | 7.89 | 3.24 | 4.96 | 10.25 | 17.66 | 81.54 | 0.26 | 11.35 |
| 29 Apr 94 | 1.009 | 0.111 | 0.646 | 0.083 | NA | NA | 0.652 | 0.039 | NA | NA | 8.16 | 3.47 | 5.27 | 10.41 | 17.04 | 81.29 | 0.00 | 11.32 |
| 30 Apr 94 | 0.930 | 0.067 | 0.695 | 0.063 | NA | NA | 0.647 | 0.033 | NA | NA | 7.77 | 2.83 | 4.88 | 9.63 | 16.07 | 84.41 | 1.94 | 11.62 |
| 1 May 94 | 0.988 | 0.109 | 0.678 | 0.090 | NA | NA | 0.669 | 0.048 | NA | NA | 8.35 | 2.85 | 4.74 | 11.12 | 17.51 | 88.50 | 8.18 | 12.39 |
| 2 May 94 | 0.886 | 0.042 | 0.832 | 0.053 | NA | NA | 0.737 | 0.031 | NA | NA | 7.74 | 2.56 | 4.46 | 9.14 | 15.13 | 88.61 | 8.68 | 12.43 |
| 3 May 94 | 0.974 | 0.157 | 0.719 | 0.138 | NA | NA | 0.701 | 0.070 | NA | NA | 8.70 | 3.23 | 4.35 | 9.41 | 15.58 | 86.82 | 11.11 | 12.81 |
| 4 May 94 | 0.878 | 0.111 | 0.942 | 0.175 | NA | NA | 0.827 | 0.112 | NA | NA | 7.94 | 3.10 | 4.40 | 8.47 | 14.72 | 89.24 | 11.08 | 12.63 |
| 5 May 94 | 1.096 | 0.187 | 0.633 | 0.127 | NA | NA | 0.694 | 0.069 | NA | NA | 7.63 | 7.47 | 4.75 | 7.65 | 13.39 | 89.51 | 11.91 | 12.70 |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR- | LGO- | LMO- | LGR- | LGR- | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | LGO | LMO | MCN | LMO | MCN | Flow | Spill% | Temp. |
| 6 May 94 | 0.940 | 0.111 | 0.730 | 0.116 | NA | NA | 0.687 | 0.072 | NA | NA | 6.68 | 2.69 | 4.60 | 7.19 | 13.03 | 89.40 | 12.67 | 12.78 |
| 7 May 94 | 0.909 | 0.095 | 0.919 | 0.141 | NA | NA | 0.836 | 0.093 | NA | NA | 6.03 | 2.94 | 4.66 | 8.36 | 12.82 | 83.22 | 15.18 | 13.41 |
| 8 May 94 | 0.938 | 0.090 | 0.668 | 0.086 | NA | NA | 0.627 | 0.052 | NA | NA | 5.52 | 2.84 | 4.55 | 7.66 | 12.15 | 80.77 | 16.91 | 13.77 |
| 9 May 94 | 0.984 | 0.103 | 0.855 | 0.128 | NA | NA | 0.841 | 0.089 | NA | NA | 5.71 | 2.63 | 4.49 | 7.43 | 12.28 | 78.40 | 16.51 | 13.89 |
| 10 May 94 | 0.759 | 0.053 | 0.996 | 0.105 | NA | NA | 0.756 | 0.061 | NA | NA | 5.96 | 2.92 | 4.34 | 7.99 | 12.19 | 76.74 | 16.15 | 13.89 |
| 11 May 94 | 0.930 | 0.097 | 0.828 | 0.126 | NA | NA | 0.770 | 0.085 | NA | NA | 5.57 | 2.93 | 4.65 | 8.17 | 12.29 | 74.99 | 15.79 | 13.89 |
| 12 May 94 | 0.860 | 0.086 | 0.693 | 0.092 | NA | NA | 0.597 | 0.052 | NA | NA | 3.93 | 2.50 | 4.16 | 5.98 | 11.07 | 73.77 | 15.52 | 13.89 |
| 13 May 94 | 0.898 | 0.134 | 0.740 | 0.146 | NA | NA | 0.664 | 0.086 | NA | NA | 5.05 | 2.52 | 4.41 | 6.72 | 11.83 | 72.77 | 16.84 | 13.89 |
| 14 May 94 | 0.700 | 0.084 | 1.227 | 0.259 | NA | NA | 0.859 | 0.154 | NA | NA | 5.30 | 2.70 | 3.89 | 6.29 | 11.12 | 71.98 | 17.10 | 13.89 |
| 15 May 94 | 0.870 | 0.136 | 0.829 | 0.204 | NA | NA | 0.721 | 0.138 | NA | NA | 5.23 | 3.24 | 4.55 | 7.35 | 11.86 | 70.59 | 22.12 | 13.89 |
| 16 May 94 | 0.899 | 0.161 | 0.938 | 0.349 | NA | NA | 0.844 | 0.273 | NA | NA | 6.10 | 4.52 | 5.09 | 10.80 | 12.03 | 71.86 | 22.05 | 13.66 |
| 17 May 94 | 0.856 | 0.187 | 1.046 | 0.544 | NA | NA | 0.926 | 0.441 | NA | NA | 5.97 | 4.25 | 6.20 | 11.07 | 15.12 | 70.41 | 20.32 | 13.31 |
| 18 May 94 | 0.805 | 0.184 | 0.546 | 0.167 | NA | NA | 0.440 | 0.086 | NA | NA | 6.10 | 3.23 | 5.76 | 11.89 | 15.66 | 70.72 | 19.30 | 13.05 |
| 19 May94 | 0.970 | 0.213 | 0.653 | 0.205 | NA | NA | 0.634 | 0.141 | NA | NA | 5.74 | 3.11 | 6.79 | 10.25 | 15.20 | 69.70 | 19.13 | 12.96 |
| 20 May 94 | 0.888 | 0.205 | 0.795 | 0.304 | NA | NA | 0.706 | 0.215 | NA | NA | 7.32 | 4.21 | 6.52 | 11.15 | 16.79 | 61.15 | 18.51 | 12.83 |
| 21 May 94 | 0.783 | 0.136 | 1.567 | 0.786 | NA | NA | 1.227 | 0.580 | NA | NA | 7.37 | 3.41 | 6.95 | 10.63 | 14.06 | 50.82 | 21.26 | 13.71 |
| 22 May 94 | 0.733 | 0.158 | 0.885 | 0.266 | NA | NA | 0.649 | 0.140 | NA | NA | 6.80 | 10.27 | 4.32 | 9.46 | 14.99 | 55.42 | 19.85 | 13.19 |
| 23 May 94 | 0.643 | 0.104 | 2.481 | 2.049 | NA | NA | 1.596 | 1.310 | NA | NA | 5.92 | 8.42 | 5.92 | 12.54 | 17.90 | 51.32 | 21.19 | 13.48 |
| 24 May 94 | 0.793 | 0.263 | 0.862 | 0.529 | NA | NA | 0.683 | 0.361 | NA | NA | 5.21 | NA | 6.35 | 8.64 | 15.44 | 51.25 | 21.19 | 13.48 |
| 26 May 94 | 1.298 | 0.689 | **0.514** | 0,376 | NA | NA | 0.667 | 0.312 | NA | NA | | | | | | | | |
| 27 May 94 | 0.627 | 0.174 | **1.295** | **0.863** | NA | NA | 0.812 | 0,518 | NA | NA | | | | | | | | |
| 28 May 94 | 0.727 | 0.311 | **1.318** | 1,174 | NA | NA | 0.959 | 0.743 | NA | NA | | | | | | | | |
| 29 May 94 | 0.682 | 0.280 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 30 May 94 | 0.893 | 0.313 | **0.703** | **0.447** | NA | NA | 0.628 | 0,324 | NA | NA | | | | | | | | |
| 1 Jun 94 | 0.750 | 0.292 | **1.879** | **1.608** | NA | NA | 1.409 | 1.102 | NA | NA | | | | | | | | |
| 2 Jun 94 | **0.235** | **0.103** | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 3 Jun 94 | 0.206 | 0.069 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 4 Jun 94 | 0.356 | 0.071 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 15 Jun94 | 0.667 | 0.430 | 0.500 | 0,354 | NA | NA | 0,333 | 0.136 | NA | NA | | | | | | | | |
| 16 Jun94 | 0.800 | 0.343 | 0.750 | 0.525 | NA | NA | 0.600 | 0.350 | NA | NA | | | | | | | | |
| 17 Jun94 | 0.562 | 0.124 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 23 Jun 94 | 0.743 | 0.266 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 2 Jul 94 | 0,273 | 0.134 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 3 Jul 94 | 0.300 | 0.145 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 7 Jul 94 | 0.429 | 0.281 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 9 Jul 94 | 0.140 | 0.049 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 10 Jun 94 | 0.413 | 0.117 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 11 Jul 94 | 0.278 | 0.191 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 12 Jul 94 | 0,417 | 0.219 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 14 Jul 94 | 0.692 | 0.398 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 9 Apr 95 | 0.911 | 0.049 | 0.791 | 0.082 | NA | NA | 0.720 | 0.061 | NA | NA | 6.76 | 2.79 | 6.65 | 9.71 | 18.11 | 72.05 | 7.15 | 9.30 |
| 10 Apr 95 | 0.806 | 0.034 | 1.324 | 0.185 | NA | NA | 1.067 | 0.146 | NA | NA | 6.08 | 2.90 | 6.06 | 9.13 | 18.14 | 69.57 | 8.19 | 9.39 |
| 11 Apr 95 | 0.864 | 0.027 | 0.960 | 0.069 | 0.857 | 0.592 | 0.830 | 0.055 | 0.711 | 0.488 | 5.74 | 3.00 | 7.04 | 9.17 | 16.69 | 67.70 | 9.17 | 9.44 |
| 12 Apr 95 | 0.788 | 0.024 | 0.951 | 0.057 | 1,734 | 1,472 | 0.750 | 0.040 | 1.300 | 1.101 | 6.01 | 3.11 | 6.96 | 8.67 | 17.56 | 69.60 | 12.21 | 9.44 |
| 13 Apr 95 | 0.862 | 0.034 | 0.868 | 0.059 | 1.153 | 0.435 | 0.748 | 0.041 | 0.862 | 0.322 | 6.23 | 2.86 | 6.45 | 9.44 | 17.36 | 66.83 | 18.78 | 9.44 |
| 14 Apr 95 | 0.886 | 0.045 | 0.868 | 0.071 | 0.744 | 0.217 | 0.769 | 0.046 | 0.572 | 0.163 | 7.13 | 2.89 | 6.31 | 9.36 | 17.07 | 62.30 | 22.99 | 9.44 |
| 15 Apr 95 | 0.870 | 0.048 | 0.958 | 0.081 | 1.143 | 0.522 | 0.833 | 0.051 | 0.951 | 0.430 | 7.76 | 2.66 | 6.10 | 11.40 | 16.34 | 63.46 | 23.44 | 9.44 |
| 16 Apr 95 | 0.953 | 0.069 | 0.842 | 0.085 | 0.991 | 0.379 | 0.802 | 0.052 | 0.795 | 0.299 | 8.21 | 2.99 | 5.65 | 12.03 | 16.36 | 70.15 | 21.03 | 9.44 |
| 17 Apr 95 | 0.846 | 0.044 | 1.002 | 0.076 | 1.142 | 0.351 | 0.848 | 0.045 | 0.969 | 0.293 | 9.20 | 2.97 | 5.79 | 11.74 | 16.27 | 74.91 | 17.04 | 9.47 |
| 18 Apr 95 | 0.796 | 0.024 | 1.081 | 0.049 | 0.623 | 0.103 | 0.860 | 0.029 | 0.536 | 0.087 | 11.06 | 2.89 | 5.41 | 12.21 | 15.99 | 79.52 | 13.95 | 9.59 |
| 19 Apr 95 | 0.930 | 0.032 | 0.922 | 0.045 | 0.860 | 0.199 | 0.858 | 0.028 | 0.738 | 0.169 | 11.13 | 2.99 | 5.33 | 11.74 | 15.72 | 80.16 | 13.92 | 9.67 |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LCO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR- | LGO- | LMO- | LGR- | LGR- | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | LGO | LMO | MCN | LMO | MCN | Flow | Spill% | Temp. |
| 20 Apr 95 | 0.880 | 0.026 | 0.951 | 0.043 | 0.985 | 0.236 | 0.837 | 0.028 | 0.825 | 0.196 | 10.23 | 2.85 | 5.24 | 11.12 | 15.22 | 80.39 | 14.26 | 9.85 |
| 21 Apr 95 | 0.852 | 0.023 | 0.946 | 0.042 | 0.767 | 0.157 | 0.806 | 0.028 | 0.618 | 0.125 | 9.39 | 2.79 | 5.22 | 10.64 | 15.02 | 82.44 | 14.36 | 9.98 |
| 22 Apr 95 | 0.850 | 0.019 | 0.976 | 0.037 | 0.702 | 0.139 | 0.830 | 0.025 | 0.582 | 0.114 | 8.74 | 2.92 | 5.09 | 10.45 | 15.14 | 84.10 | 14.40 | 10.12 |
| 23 Apr 95 | 0.871 | 0.022 | 0.921 | 0.039 | 0.953 | 0.267 | 0.801 | 0.028 | 0.764 | 0.213 | 8.19 | 2.87 | 4.88 | 10.24 | 15.08 | 86.20 | 15.87 | 10.29 |
| 24 Apr 95 | 0.859 | 0.022 | 0.987 | 0.048 | 0.686 | 0.185 | 0.847 | 0.035 | 0.581 | 0.155 | 7.16 | 2.69 | 4.86 | 9.72 | 14.15 | 87.09 | 18.40 | 10.39 |
| 25 Apr 95 | 0.832 | 0.020 | 0.952 | 0.042 | 0.844 | 0.263 | 0.792 | 0.030 | 0.668 | 0.207 | 6.47 | 2.63 | 4.81 | 9.10 | 13.34 | 88.17 | 18.63 | 10.46 |
| 26 Apr 95 | 0.855 | 0.017 | 0.974 | 0.040 | 0.645 | 0.144 | 0.833 | 0.030 | 0.537 | 0.118 | 5.81 | 2.64 | 4.98 | 8.57 | 12.68 | 91.88 | 18.46 | 10.56 |
| 27 Apr 95 | 0.901 | 0.018 | 0.902 | 0.035 | 0.798 | 0.251 | 0.813 | 0.027 | 0.648 | 0.203 | 5.50 | 2.57 | 4.75 | 8.02 | 12.14 | 97.77 | 18.16 | 10.56 |
| 28 Apr 95 | 0.887 | 0.015 | 0.955 | 0.031 | 0.879 | 0.192 | 0.846 | 0.023 | 0.744 | 0.161 | 5.32 | 2.33 | 4.41 | 7.50 | 11.54 | 99.63 | 18.46 | 10.56 |
| 29 Apr 95 | 0.898 | 0.013 | 0.946 | 0.026 | 0.839 | 0.185 | 0.849 | 0.020 | 0.713 | 0.156 | 5.27 | 2.15 | 4.25 | 7.34 | 11.60 | 100.20 | 19.27 | 10.56 |
| 30 Apr95 | 0.892 | 0.013 | 0.916 | 0.025 | 0.863 | 0.173 | 0.817 | 0.019 | 0.705 | 0.141 | 5.65 | 2.02 | 4.28 | 7.34 | 11.58 | 103.06 | 20.27 | 10.56 |
| 1 May 95 | 0.888 | 0.011 | 0.902 | 0.020 | 0.845 | 0.123 | 0.801 | 0.015 | 0.677 | 0.098 | 5.56 | 1.97 | 4.28 | 7.32 | 11.16 | 110.99 | 21.39 | 10.56 |
| 2 May 95 | 0.892 | 0.011 | 0.915 | 0.020 | 0.849 | 0.138 | 0.816 | 0.016 | 0.694 | 0.112 | 5.38 | 1.80 | 4.21 | 6.90 | 11.00 | 122.56. | 22.99 | 10.56 |
| 3 May 95 | 0.917 | 0.018 | 0.890 | 0.028 | 1.326 | 0.356 | 0.816 | 0.021 | 1.082 | 0.290 | 5.36 | 1.78 | 4.04 | 6.38 | 10.37 | 121.51 | 23.87 | 10.56 |
| 4 May 95 | 0.907 | 0.011 | 0.902 | 0.020 | 0.896 | 0.125 | 0.818 | 0.015 | 0.733 | 0.101 | 5.11 | 1.81 | 4.02 | 6.40 | 10.20 | 116.62 | 24.18 | 10.56 |
| 5 May 95 | 0.908 | 0.014 | 0.906 | 0.024 | 0.856 | 0.136 | 0.822 | 0.017 | 0.703 | 0.111 | 5.76 | 1.95 | 4.20 | 6.72 | 10.91 | 111.41 | 22.39 | 10.56 |
| 6 May 95 | 0.902 | 0.017 | 0.925 | 0.033 | 1.028 | 0.234 | 0.835 | 0.025 | 0.858 | 0.194 | 5.54 | 1.92 | 4.26 | 7.04 | 11.17 | 106.50 | 20.01 | 10.56 |
| 7 May 95 | 0.895 | 0.013 | 0.895 | 0.023 | 1.173 | 0.219 | 0.801 | 0.017 | 0.940 | 0.174 | 4.79 | 1.84 | 4.14 | 6.56 | 10.70 | 103.36 | 19.39 | 10.56 |
| 8 May 95 | 0.847 | 0.014 | 0.888 | 0.026 | 1.208 | 0.286 | 0.752 | 0.018 | 0.909 | 0.214 | 4.18 | 1.85 | 4.13 | 5.93 | 10.03 | 105.00 | 19.95 | 10.56 |
| 9 May 95 | 0.879 | 0.016 | 0.924 | 0.029 | 0.941 | 0.203 | 0.812 | 0.021 | 0.764 | 0.164 | 3.65 | 1.77 | 4.08 | 5.54 | 9.70 | 105.16 | 19.25 | 10.56 |
| 10 May 95 | 0.877 | 0.025 | 0.951 | 0.040 | 0.912 | 0.252 | 0.834 | 0.026 | 0.761 | 0.209 | 4.10 | 1.95 | 3.86 | 5.97 | 9.24 | 98.61 | 18.68 | 10.61 |
| 11 May95 | 0.840 | 0.023 | 1.004 | 0.044 | 3.689 | 2.518 | 0.843 | 0.028 | 3.111 | 2.121 | 5.20 | 2.19 | 4.08 | 6.73 | 9.82 | 99.90 | 18.93 | 10.93 |
| 12 May 95 | 0.840 | 0.028 | 0.895 | 0.051 | 1.234 | 0.643 | 0.752 | 0.035 | 0.928 | 0.482 | 5.60 | 2.11 | 4.14 | 6.97 | 10.92 | 105.20 | 18.28 | 11.53 |
| 13 May 95 | 1.000 | 0.069 | 0.701 | 0.073 | 1.149 | 0.709 | 0.701 | 0.053 | 0.806 | 0.494 | 6.64 | 2.28 | 4.11 | 8.11 | 11.38 | 113.07 | 20.89 | 12.52 |
| 14 May 95 | 0.943 | 0.038 | 0.884 | 0.067 | 0.462 | 0.185 | 0.833 | 0.052 | 0.385 | 0.152 | 6.09 | 1.99 | 3.95 | 8.10 | 11.52 | 114.74 | 21.88 | 12.78 |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 15 May 95 | 0.860 | 0.043 | 1.098 | 0.122 | NA | NA | 0.944 | 0.094 | NA | NA | 7.02 | 2.21 | 4.18 | 8.43 | 13.55 | 116.32 | 21.50 | 13.22 |
| 16 May 95 | 0.896 | 0.038 | 0.918 | 0.075 | 0.721 | 0.449 | 0.822 | 0.057 | 0.593 | 0.367 | 7.03 | 2.36 | 4.28 | 8.11 | 12.87 | 116.93 | 20.14 | 13.33 |
| 17 May 95 | 0.845 | 0.042 | 0.910 | 0.084 | NA | NA | 0.769 | 0.059 | NA | NA | 6.56 | 2.34 | 4.13 | 7.65 | 12.99 | 116.54 | 19.05 | 13.34 |
| 18 May 95 | 0.863 | 0.049 | 0.879 | 0.094 | NA | NA | 0.759 | 0.068 | NA | NA | 7.03 | 2.56 | 3.95 | 8.67 | 13.39 | 112.57 | 10.99 | 13.59 |
| 19 May 95 | 0.838 | 0.051 | 0.894 | 0.102 | 0.562 | 0.308 | 0.749 | 0.073 | 0.421 | 0.227 | 6.21 | 2.58 | 3.66 | 8.07 | 12.89 | 110.96 | 6.12 | 13.88 |
| 20 May 95 | 0.868 | 0.038 | 0.974 | 0.094 | 0.536 | 0.201 | 0.845 | 0.075 | 0.453 | 0.165 | 6.17 | 2.68 | 4.11 | 7.80 | 12.03 | 110.16 | 4.12 | 13.99 |
| 21 May 95 | 0.861 | 0.054 | 0.925 | 0.109 | NA | NA | 0.797 | 0.083 | NA | NA | 6.00 | 2.68 | 3.67 | 7.81 | 11.87 | 107.15 | 5.12 | 14.17 |
| 22 May 95 | 0.836 | 0.054 | 0.999 | 0.149 | 0.722 | 0.579 | 0.836 | 0.117 | 0.603 | 0.477 | 6.08 | 2.91 | 3.27 | 8.95 | 13.27 | 110.45 | 9.30 | 14.44 |
| 23 May 95 | 0.905 | 0.048 | 2.399 | 0.853 | NA | NA | 2.172 | 0.766 | NA | NA | 5.84 | 2.88 | 3.28 | 8.82 | 12.03 | 115.42 | 13.01 | 14.44 |
| 24 May 95 | 0.861 | 0.047 | 1.076 | 0.183 | NA | NA | 0.926 | 0.153 | NA | NA | 6.19 | 2.33 | 3.36 | 9.67 | 12.81 | 132.18 | 21.20 | 14.44 |
| 25 May95 | 0.924 | 0.033 | 0.856 | 0.067 | 0.323 | 0.093 | 0.791 | 0.054 | 0.256 | 0.071 | 7.09 | 2.17 | 3.24 | 9.79 | 12.01 | 133.26 | 22.42 | 14.44 |
| 26 May 95 | 0.831 | 0.052 | 0.862 | 0.117 | 0.782 | 0.660 | 0.716 | 0.087 | 0.559 | 0.468 | 7.88 | 1.99 | 3.08 | 9.09 | 11.70 | 136.48 | 23.83 | 14.52 |
| 27 May 95 | 0.790 | 0.045 | 0.871 | 0.112 | NA | NA | 0.688 | 0.081 | NA | NA | 6.99 | 1.98 | 3.05 | 8.87 | 11.41 | 138.94 | 23.68 | 14.62 |
| 28 May 95 | 0.864 | 0.073 | 0.943 | 0.183 | NA | NA | 0.814 | 0.145 | NA | NA | 6.83 | 2.02 | 2.85 | 8.80 | 10.96 | 140.84 | 24.01 | 14.68 |
| 29 May 95 | 0.817 | 0.036 | 1.097 | 0.130 | NA | NA | 0.896 | 0.101 | NA | NA | 7.73 | 2.11 | 3.49 | 8.91 | 11.73 | 139.12 | 22.91 | 14.93 |
| 30 May 95 | 0.868 | 0.044 | 0.752 | 0.074 | NA | NA | 0.653 | 0.056 | NA | NA | 6.57 | 2.12 | 3.40 | 8.42 | 10.89 | 138.30 | 22.38 | 14.99 |
| 31 May 95 | 0.898 | 0.067 | 0.736 | 0.110 | NA | NA | 0.661 | 0.086 | NA | NA | 5.90 | 2.06 | 4.10 | 7.82 | 11.13 | 133.80 | 19.83 | 14.99 |
| 1 Jun 95 | 0.795 | 0.069 | 0.829 | 0.145 | NA | NA | 0.659 | 0.104 | NA | NA | | | | | | | | |
| 2 Jun 95 | 0.818 | 0.046 | 0.949 | 0.133 | 0.606 | 0.534 | 0.776 | 0.102 | 0.471 | 0.410 | | | | | | | | |
| 3 Jun 95 | 0.957 | 0.067 | 0.784 | 0.100 | NA | NA | 0.750 | 0.079 | NA | NA | | | | | | | | |
| 4 Jun 95 | 0.873 | 0.035 | 0.834 | 0.068 | 0.637 | 0,529 | 0.728 | 0.054 | 0.463 | 0.384 | | | | | | | | |
| 5 Jun 95 | 0.906 | 0.029 | 0.934 | 0.083 | 0.575 | 0.498 | 0.846 | 0.071 | 0.486 | 0.420 | | | | | | | | |
| 6 Jun 95 | 0.925 | 0.029 | 0.893 | 0.069 | NA | NA | 0.826 | 0.060 | NA | NA | | | | | | | | |
| 7 Jun 95 | 0.884 | 0.023 | 0.876 | 0.061 | 0.406 | 0.277 | 0.774 | 0.053 | 0.314 | 0.214 | | | | | | | | |
| 8 Jun 95 | 0.888 | 0.027 | 0.806 | 0.054 | 0.562 | 0.386 | 0.715 | 0.046 | 0.402 | 0.275 | | | | | | | | |
| 9 Jun 95 | 0.850 | 0.033 | 0.963 | 0.113 | NA | NA | 0.819 | 0.095 | NA | NA | | | | | | | | |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 10 Jun 95 | 0.819 | 0.040 | 0.969 | 0.149 | NA | NA | 0.794 | 0.119 | NA | NA | | | | | | | | |
| 11 Jun 95 | 0.882 | 0.047 | 0.711 | '0.082 | NA | NA | 0.627 | 0.067 | NA | NA | | | | | | | | |
| 12 Jun 95 | 0.873 | 0.043 | 0.903 | 0.121 | NA | NA | 0.788 | 0.102 | NA | NA | | | | | | | | |
| 13 Jun 95 | 0.902 | 0.057 | 0.695 | 0.086 | NA | NA | 0.627 | 0.069 | NA | NA | | | | | | | | |
| 14 Jun 95 | 0.904 | 0.081 | 0.716 | 0.125 | NA | NA | 0.647 | 0.099 | NA | NA | | | | | | | | |
| 15 Jun95 | 0.883 | 0.072 | 0.721 | 0.109 | NA | NA | 0.636 | 0.088 | NA | NA | | | | | | | | |
| 16 Jun95 | 0.842 | 0.070 | 0.803 | 0.186 | NA | NA | 0.676 | 0.153 | NA | NA | | | | | | | | |
| 17 Jun95 | 1.015 | 0.088 | 0.751 | 0.191 | NA | NA | 0.762 | 0.180 | NA | NA | | | | | | | | |
| 18 Jun95 | 0.860 | 0.074 | 0.696 | 0.126 | NA | NA | 0.599 | 0.100 | NA | NA | | | | | | | | |
| 19 Jun95 | 0.998 | 0.087 | 0.665 | 0.102 | NA | NA | 0.664 | 0.083 | NA | NA | | | | | | | | |
| 20 Jun 95 | 0.844 | 0.045 | 0.838 | 0.123 | NA | NA | 0.707 | 0.101 | NA | NA | | | | | | | | |
| 21 Jun 95 | 0.781 | 0.055 | 0.749 | 0.086 | 0.583 | 0.403 | 0.585 | 0.062 | 0.341 | 0.235 | | | | | | | | |
| 22 Jun 95 | 0.817 | 0.048 | 0.780 | 0.069 | NA | NA | 0.637 | 0.051 | NA | NA | | | | | | | | |
| 23 Jun 95 | 0.768 | 0.043 | 1.052 | 0.131 | NA | NA | 0.808 | 0.102 | NA | NA | | | | | | | | |
| 24 Jun 95 | 0.763 | 0.046 | 0.772 | 0.078 | NA | NA | 0.589 | 0.061 | NA | NA | | | | | | | | |
| 25 Jun 95 | 0.815 | 0.063 | 0.707 | 0.101 | NA | NA | 0.576 | 0.081 | NA | NA | | | | | | | | |
| 26 Jun 95 | 0.646 | 0.071 | 0.996 | 0.155 | NA | NA | 0.644 | 0.116 | NA | NA | | | | | | | | |
| 27 Jun 95 | 0.868 | 0.151 | 0.926 | 0.342 | NA | NA | 0.804 | 0.266 | NA | NA | | | | | | | | |
| 28 Jun 95 | 0.871 | 0.096 | 0.950 | 0.284 | NA | NA | 0.827 | 0.234 | NA | NA | | | | | | | | |
| 29 Jun 95 | 0.658 | 0.073 | 0.735 | 0.141 | NA | NA | 0.484 | 0.089 | NA | NA | | | | | | | | |
| 30 Jun 95 | 0.674 | 0.066 | 0.756 | 0.096 | NA | NA | 0.509 | 0.065 | NA | NA | | | | | | | | |
| 1 Jul 95 | 0.840 | 0.103 | 0.814 | 0.189 | NA | NA | 0.684 | 0.141 | NA | NA | | | | | | | | |
| 2 Jul 95 | 0.903 | 0.110 | 0.726 | 0.163 | NA | NA | 0.655 | 0.136 | NA | NA | | | | | | | | |
| 3 Jul 95 | 0.905 | 0.105 | 0.966 | 0.249 | NA | NA | 0.874 | 0.208 | NA | NA | | | | | | | | |
| 4 Jul 95 | 0.705 | 0.082 | 0.733 | 0.158 | NA | NA | 0.517 | 0.117 | NA | NA | | | | | | | | |
| 5 Jul 95 | 0.639 | 0.088 | 1.056 | 0.218 | NA | NA | 0.674 | 0.155 | NA | NA | | | | | | | | |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 6 Jul 95 | 0.786 | 0.098 | 1.456 | 0.578 | NA | NA | 1.144 | 0.453 | NA | NA | | | | | | | | |
| 7 Jul 95 | 0.853 | 0.092 | 0.896 | 0.141 | NA | NA | 0.765 | 0.120 | NA | NA | | | | | | | | |
| 8 Jul 95 | 0.933 | 0.133 | 0.801 | 0.233 | NA | NA | 0.748 | 0.193 | NA | NA | | | | | | | | |
| 9 Jul 95 | 0.786 | 0.101 | 0.838 | 0.141 | NA | NA | 0.659 | 0.112 | NA | NA | | | | | | | | |
| 10 Jul 95 | 0.944 | 0.115 | 0.969 | 0.302 | NA | NA | 0.915 | 0.268 | NA | NA | | | | | | | | |
| 11 Jul 95 | 0.855 | 0.116 | 1.354 | 0.971 | NA | NA | 1.158 | 0.830 | NA | NA | | | | | | | | |
| 12 Jul 95 | 0.988 | 0.134 | 0.750 | 0.192 | NA | NA | 0.741 | 0.159 | NA | NA | | | | | | | | |
| 13 Jul 95 | 0.593 | 0.185 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 14 Jul 95 | 1.083 | 0.275 | 0.667 | 0.333 | NA | NA | 0.722 | 0.290 | NA | NA | | | | | | | | |
| 23 15 Jul 95 | 0.833 | 0.366 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| | 0.667 | 0.192 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 24 Jul 95 | 0.800 | 0.438 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 25 Jul 95 | 0.500 | 0.250 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 9 Apr 96 | 1.182 | 0.423 | 0.833 | 0.614 | NA | NA | 0.985 | 0.594 | NA | NA | | | | | | | | |
| 10 Apr 96 | 0.968 | 0.192 | 1.167 | 0.659 | NA | NA | 1.129 | 0.600 | NA | NA | 3.18 | 2.90 | 2.75 | 7.02 | 9.36 | 116.92 | 31.51 | 9.71 |
| 11 Apr 96 | 0.855 | 0.208 | 0.690 | 0.259 | NA | NA | 0.590 | 0.168 | NA | NA | 4.13 | 2.17 | 5.09 | 6.41 | 12.37 | 113.80 | 28.86 | 9.63 |
| 12 Apr 96 | 0.979 | 0.153 | 0.925 | 0.339 | NA | NA | 0.905 | 0.298 | NA | NA | 4.12 | 2.60 | 5.36 | 6.40 | 12.41 | 112.13 | 24.49 | 9.53 |
| 13 Apr 96 | 0.798 | 0.090 | 0.961 | 0.270 | NA | NA | 0.767 | 0.201 | NA | NA | 5.99 | 2.52 | 4.36 | 7.03 | 12.33 | 102.36 | 26.02 | 9.98 |
| 14 Apr 96 | 0.881 | 0.086 | 0.823 | 0.177 | NA | NA | 0.724 | 0.140 | NA | NA | 6.15 | 2.53 | 3.71 | 8.08 | 12.81 | 98.43 | 25.61 | 10.05 |
| 15 Apr 96 | 0.916 | 0.073 | 0.823 | 0.125 | 1.554 | 1.438 | 0.754 | 0.098 | 1.172 | 1.074 | 6.46 | 2.42 | 3.49 | 8.46 | 12.13 | 106.17 | 25.38 | 10.64 |
| 16 Apr 96 | 0.949 | 0.052 | 0.886 | 6.110 | 1.212 | 1.101 | 0.840 | 0.094 | 1.019 | 0.919 | 6.12 | 2.29 | 3.12 | 8.15 | 11.37 | 131.20 | 33.92 | 10.91 |
| 17 Apr 96 | 0.970 | 0.040 | 1.031 | 0.106 | 0.569 | 0.199 | 1.000 | 0.094 | 0.569 | 0.191 | 6.22 | 1.74 | 3.19 | 7.76 | 10.41 | 144.87 | 36.18 | 10.67 |
| 18 Apr 96 | 0.916 | 0.027 | 1.028 | 0.082 | 1.006 | 0.371 | 0.943 | 0.070 | 0.948 | 0.342 | 5.77 | 1.48 | 3.26 | 7.55 | 9.84 | 157.05 | 36.70 | 10.40 |
| 19 Apr 96 | 0.843 | 0.028 | 1.079 | 0.099 | 0.642 | 0.175 | 0.910 | 0.079 | 0.584 | 0.151 | 5.41 | 1.35 | 3.04 | 6.78 | 9.07 | 153.04 | 33.75 | 10.44 |
| 20 Apr 96 | 0.899 | 0.027 | 0.945 | 0.067 | 0.721 | 0.202 | 0.849 | 0.055 | 0.612 | 0.167 | 4.70 | 1.17 | 3.20 | 6.01 | 8.47 | 152.91 | 33.59 | 10.44 |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 21 Apr 96 | 0.920 | 0.026 | 0.966 | 0.060 | 0.734 | 0.176 | 0.889 | 0.049 | 0.652 | 0.153 | 4.04 | 1.24 | 3.32 | 5.13 | 9.68 | 145.63 | 30.28 | 10.48 |
| 22 Apr 96 | 0.899 | 0.032 | 1.003 | 0.073 | 0.685 | 0.236 | 0.902 | 0.058 | 0.618 | 0.209 | 3.76 | 1.21 | 3.78 | 4.41 | 9.11 | 142.57 | 31.72 | 10.45 |
| 23 Apr 96 | 0.973 | 0.037 | 0.933 | 0.069 | 0.532 | 0.118 | 0.907 | 0.057 | 0.483 | 0.103 | 3.55 | 1.38 | 3.95 | 4.43 | 8.62 | 135.57 | 37.36 | 10.38 |
| 24 Apr 96 | 0.908 | 0.028 | 0.923 | 0.058 | 0.997 | 0.267 | 0.838 | 0.046 | 0.835 | 0.219 | 2.98 | 1.44 | 3.93 | 4.80 | 8.57 | 110.83 | 39.76 | 10.43 |
| 25 Apr 96 | 0.957 | 0.023 | 0.853 | 0.037 | 0.924 | 0.149 | 0.816 | 0.029 | 0.754 | 0.119 | 2.58 | 1.62 | 4.84 | 4.88 | 9.05 | 104.67 | 31.30 | 10.52 |
| 26 Apr 96 | 0.935 | 0.029 | 0.839 | 0.043 | 0.765 | 0.117 | 0.784 | 0.033 | 0.600 | 0.089 | 6.87 | 2.83 | 5.26 | 8.12 | 13.90 | 93.76 | 24.39 | 10.49 |
| 27 Apr 96 | 0.970 | 0.029 | 0.836 | 0.044 | 0.744 | 0.097 | 0.811 | 0.035 | 0.603 | 0.074 | 6.61 | 2.72 | 5.12 | 10.61 | 15.00 | 86.40 | 26.67 | 9.38 |
| 28 Apr 96 | 0.907 | 0.034 | 1.024 | 0.074 | 0.519 | 0.074 | 0.929 | 0.058 | 0.483 | 0.062 | 7.26 | 2.58 | 5.01 | 11.67 | 15.40 | 85.61 | 24.67 | 8.75 |
| 29 Apr 96 | 0.883 | 0.027 | 0.955 | 0.052 | 0.914 | 0.156 | 0.843 | 0.038 | 0.770 | 0.127 | 8.20 | 2.65 | 4.89 | 11.44 | 15.19 | 86.23 | 24.28 | 8.64 |
| 30 Apr 96 | 0.917 | 0.026 | 1.012 | 0.054 | 0.735 | 0.102 | 0.929 | 0.041 | 0.683 | 0.090 | 9.06 | 2.52 | 4.93 | 11.44 | 14.93 | 89.62 | 23.67 | 8.54 |
| 1 May 96 | 0.878 | 0.034 | 0.880 | 0.057 | 0.884 | 0.202 | 0.772 | 0.041 | 0.683 | 0.152 | 9.08 | 2.33 | 4.53 | 11.30 | 14.53 | 94.30 | 24.11 | 8.54 |
| 2 May 96 | 0.938 | 0.033 | 0.963 | 0.063 | 0.789 | 0.158 | 0.904 | 0.050 | 0.713 | 0.137 | 9.32 | 2.32 | 4.37 | 11.30 | 13.77 | 98.71 | 24.43 | 8.54 |
| 3 May 96 | 0.940 | 0.027 | 0.956 | 0.051 | 0.544 | 0.074 | 0.899 | 0.040 | 0.489 | 0.063 | 9.21 | 2.25 | 4.14 | 10.78 | 13.58 | 103.91 | 25.10 | 8.59 |
| 4 May 96 | 0.955 | 0.031 | 0.901 | 0.058 | 1.022 | 0.284 | 0.860 | 0.048 | 0.879 | 0.239 | 9.19 | 2.05 | 3.97 | 10.43 | 12.98 | 111.16 | 25.09 | 8.65 |
| 5 May 96 | 0.892 | 0.032 | 0.974 | 0.078 | 0.596 | 0.199 | 0.869 | 0.063 | 0.518 | 0.168 | 8.66 | 1.95 | 3.99 | 10.18 | 12.91 | 122.97 | 26.53 | 8.88 |
| 6 May 96 | 0.942 | 0.029 | 0.880 | 0.055 | 1.056 | 0.285 | 0.829 | 0.045 | 0.875 | 0.231 | 7.92 | 1.80 | 3.59 | 9.22 | 12.38 | 127.36 | 27.83 | 8.99 |
| 7 May 96 | 0.964 | 0.031 | 0.916 | 0.064 | 1.110 | 0.371 | 0.883 | 0.055 | 0.980 | 0.321 | 7.42 | 1.69 | 3.28 | 8.50 | 11.90 | 136.00 | 30.05 | 9.19 |
| 8 May 96 | 0.797 | 0.035 | 1.102 | 0.130 | 0.643 | 0.249 | 0.878 | 0.097 | 0.564 | 0.209 | 6.92 | 1.62 | 3.24 | 8.17 | 11.30 | 143.09 | 31.81 | 9.37 |
| 9 May 96 | 0.744 | 0.059 | 0.852 | 0.151 | 0.944 | 0.872 | 0.634 | 0.104 | 0.598 | 0.544 | 6.32 | 1.66 | 3.34 | 7.44 | 10.87 | 143.54 | 31.76 | 9.40 |
| 10 May 96 | 0.971 | 0.038 | 0.936 | 0.090 | 0.660 | 0.204 | 0.909 | 0.080 | 0.600 | 0.178 | 5.55 | 1.48 | 3.05 | 6.64 | 10.52 | 149.56 | 33.31 | 9.53 |
| 11 May 96 | 0.951 | 0.028 | 0.950 | 0.069 | 0.870 | 0.239 | 0.903 | 0.060 | 0.786 | 0.209 | 5.12 | 1.34 | 3.28 | 5.91 | 9.68 | 154.05 | 34.36 | 9.60 |
| 12 May 96 | 0.915 | 0.024 | 0.997 | 0.060 | 0.684 | 0.130 | 0.912 | 0.050 | 0.624 | 0.114 | 4.66 | 1.29 | 3.26 | 5.46 | 8.79 | 166.51 | 38.14 | 9.79 |
| 13 May 96 | 0.915 | 0.027 | 0.963 | 0.062 | 1.072 | 0.265 | 0.881 | 0.050 | 0.945 | 0.227 | 4.31 | 1.32 | 3.16 | 5.22 | 8.57 | 179.16 | 43.30 | 9.77 |
| 14 May 96 | 0.960 | 0.039 | 0.923 | 0.074 | 1.044 | 0.352 | 0.886 | 0.061 | 0.925 | 0.305 | 4.23 | 1.34 | 3.06 | 4.96 | 8.38 | 192.82 | 47.34 | 9.40 |
| 15 May 96 | 0.979 | 0.048 | 0.766 | 0.064 | 1.603 | 0.766 | 0.750 | 0.050 | 1.202 | 0.569 | 4.78 | 1.47 | 3.12 | 5.64 | 8.12 | 184.34 | 45.35 | 8.71 |
| 16 May 96 | 0.916 | 0.045 | 0.989 | 0.104 | 0.538 | 0.187 | 0.906 | 0.084 | 0.487 | 0.164 | 4.52 | 1.59 | 3.02 | 5.94 | 7.73 | 161.49 | 39.87 | 8.53 |

Appendix Table D3. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 17 May 96 | 0.907 | 0.049 | 0.957 | 0.126 | 0.344 | 0.154 | 0.868 | 0.104 | 0.299 | 0.128 | 4.30 | 2.10 | 3.20 | 6.32 | 8.57 | 145.80 | 38.41 | 8.55 |
| 18 May 96 | 1.058 | 0.081 | 0.746 | 0.116 | 0.479 | 0.254 | 0.790 | 0.106 | 0.379 | 0.194 | 4.30 | 2.24 | 3.72 | 5.92 | 10.52 | 135.61 | 38.39 | 8.69 |
| 19 May 96 | 0.998 | 0.050 | 0.840 | 0.087 | 0.523 | 0.186 | 0.838 | 0.076 | 0.438 | 0.150 | 5.45 | 2.50 | 3.42 | 7.02 | 10.56 | 130.13 | 42.09 | 9.03 |
| 20 May 96 | 0.942 | 0.068 | 0.985 | 0.173 | 1.242 | 1.223 | 0.929 | 0.149 | 1.154 | 1.120 | 6.15 | 2.48 | 3.39 | 8.49 | 10.84 | 136.82 | 44.58 | 9.68 |
| 21 May 96 | 1.013 | 0.145 | 1.580 | 0.673 | 0.117 | 0.082 | 1.600 | 0.640 | 0.188 | 0.107 | 7.45 | 1.97 | 3.72 | 9.09 | 13.15 | 146.04 | 44.04 | 10.29 |
| 22 May 96 | 0.813 | 0.243 | 0.644 | 0.3 15 | NA | NA | 0.523 | 0.203 | NA | NA | 8.10 | 2.44 | 2.59 | 9.71 | 14.86 | 143.73 | 47.58 | 11.87 |
| 23 May 96 | 2.440 | 2.286 | 0.353 | 0.398 | NA | NA | 0.861 | 0.53 l | NA | NA | 7.81 | 1.95 | 3.51 | 9.56 | 11.31 | 143.61 | 47.70 | 11.91 |
| 24 May 96 | 0.806 | 0.312 | 0.508 | 0.247 | NA | NA | 0.409 | 0.118 | NA | NA | 6.32 | 1.47 | 3.04 | 8.04 | 11.56 | 141.45 | 44.55 | 12.14 |
| 26 May 96 | 0.745 | 0.228 | 1.191 | 0.799 | NA | NA | 0.887 | 0.533 | NA | NA | 5.13 | 2.22 | 3.33 | 7.80 | 10.03 | 138.47 | 46.27 | 12.66 |
| 28 May96 | 1.575 | 1.454 | 0.240 | 0.259 | NA | NA | 0.378 | 0.209 | NA | NA | 7.96 | 3.21 | 2.64 | 7.14 | 8.28 | 137.00 | 39.79 | 12.87 |
| 30 May96 | 1.109 | 0.381 | 0.435 | 0.223 | NA | NA | 0.482 | 0.181 | NA | NA | 5.79 | 2.17 | 2.49 | 6.91 | 9.71 | 179.86 | 42.85 | 13.28 |
| 31 May 96 | 0.739 | 0.137 | 0.377 | 0.163 | NA | NA | 0.279 | 0.108 | NA | NA | | | | | | | | |
| 1 Jun 96 | 1.579 | 0.677 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 2 Jun 96 | 0.838 | 0.378 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 3 Jun 96 | 0.420 | 0.175 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 4 Jun 96 | 1.134 | 0.685 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 5 Jun 96 | 0.433 | 0.155 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 6 Jun 96 | 1.239 | 1.117 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 8 Jun 96 | 0.975 | 0.460 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 11 Jun 96 | 0.882 | 0.476 | 0,556 | 0.451 | NA | NA | 0.490 | 0.293 | NA | NA | | | | | | | | |
| 12 Jun96 | 0.714 | 0.601 | 0.400 | 0.439 | NA | NA | 0.286 | 0.205 | NA | NA | | | | | | | | |
| 13 Jun96 | 0.583 | 0.395 | 0,786 | 0,693 | NA | NA | 0.458 | 0.282 | NA | NA | | | | | | | | |
| 14 Jun 96 | 0.500 | 0.194 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |
| 15 Jun 96 | 0.217 | 0.086 | NA | NA | NA | NA | NA | NA | NA | NA | | | | | | | | |

Appendix Table D4. Survival and travel time estimates and environmental exposure indices used in correlation and regression analyses for daily release groups of steelhead from Lower Granite Dam. Shaded survival estimates were based on fewer than 5 detections below the end of the reach. These were not used in correlation analyses but are included for PATH process documentation.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 21 Apr 94 | 0.878 | 0.099 | 0.997 | 0.159 | NA | NA | 0.875 | 0.123 | NA | NA | 4.01 | 2.72 | 6.83 | 6.91 | 12.84 | 67.43 | 0.00 | 11.62 |
| 22 Apr 94 | 0.896 | 0.030 | 0.947 | 0.036 | NA | NA | 0.849 | 0.034 | NA | NA | 4.71 | 2.71 | 4.82 | 7.19 | 12.16 | 67.86 | 0.00 | 11.67 |
| 23 Apr 94 | 0.951 | 0.021 | 0.932 | 0.033 | NA | NA | 0.886 | 0.028 | NA | NA | 4.34 | 2.50 | 4.69 | 6.81 | 11.96 | 73.06 | 0.00 | 11.67 |
| 24 Apr 94 | 0.910 | 0.019 | 0.897 | 0.029 | NA | NA | 0.816 | 0.025 | NA | NA | 4.32 | 2.61 | 4.60 | 7.48 | 11.96 | 76.83 | 0.00 | 11.36 |
| 25 Apr 94 | 0.890 | 0.019 | 0.915 | 0.026 | NA | NA | 0.815 | 0.022 | NA | NA | 4.97 | 2.73 | 4.68 | 7.76 | 12.56 | 75.45 | 0.00 | 11.16 |
| 26 Apr 94 | 0.869 | 0.020 | 0.897 | 0.029 | NA | NA | 0.779 | 0.023 | NA | NA | 5.74 | 3.05 | 5.02 | 9.32 | 14.09 | 74.20 | 0.00 | 11.11 |
| 27 Apr94 | 0.830 | 0.030 | 0.906 | 0.044 | NA | NA | 0.751 | 0.034 | NA | NA | 5.50 | 3.17 | 4.48 | 8.67 | 13.82 | 75.13 | 0.00 | 11.11 |
| 28 Apr 94 | 0.822 | 0.022 | 0.849 | 0.031 | NA | NA | 0.698 | 0.023 | NA | NA | 6.33 | 2.89 | 4.70 | 8.89 | 13.94 | 76.77 | 0.00 | 11.11 |
| 29 Apr 94 | 0.819 | 0.028 | 0.798 | 0.042 | NA | NA | 0.653 | 0.030 | NA | NA | 6.07 | 2.91 | 4.62 | 7.91 | 13.39 | 77.15 | 0.00 | 11.11 |
| 30 Apr 94 | 0.811 | 0.024 | 0.858 | 0.048 | NA | NA | 0.695 | 0.035 | NA | NA | 7.09 | 2.96 | 4.83 | 9.14 | 13.89 | 81.92 | 0.43 | 11.38 |
| 1 May 94 | 0.797 | 0.029 | 0.905 | 0.069 | NA | NA | 0.722 | 0.052 | NA | NA | 7.07 | 2.82 | 4.10 | 8.97 | 13.90 | 84.39 | 3.36 | 11.72 |
| 2 May 94 | 0.863 | 0.039 | 0.932 | 0.095 | NA | NA | 0.805 | 0.075 | NA | NA | 6.71 | 2.94 | 4.48 | 8.95 | 14.12 | 87.40 | 5.85 | 12.11 |
| 3 May 94 | 0.792 | 0.043 | 0.927 | 0.124 | NA | NA | 0.734 | 0.092 | NA | NA | 6.55 | 2.80 | 4.60 | 8.73 | 15.98 | 88.37 | 7.35 | 12.29 |
| 4 May 94 | 0.832 | 0.026 | 0.768 | 0.049 | NA | NA | 0.639 | 0.036 | NA | NA | 5.42 | 2.59 | 4.17 | 7.08 | 13.20 | 88.43 | 8.48 | 12.39 |
| 5 May 94 | 0.797 | 0.039 | 1.112 | 0.143 | NA | NA | 0.886 | 0.108 | NA | NA | 6.06 | 2.89 | 4.51 | 7.92 | 14.78 | 88.11 | 12.36 | 12.88 |
| 6 May 94 | 0.833 | 0.028 | 0.849 | 0.068 | NA | NA | 0.708 | 0.052 | NA | NA | 5.31 | 2.74 | 4.82 | 7.43 | 13.60 | 87.11 | 14.19 | 13.12 |
| 7 May 94 | 0.842 | 0.044 | 0.752 | 0.075 | NA | NA | 0.633 | 0.054 | NA | NA | 5.84 | 2.62 | 4.38 | 8.71 | 15.10 | 82.65 | 15.87 | 13.56 |
| 8 May 94 | 0.793 | 0.032 | 0.996 | 0.103 | NA | NA | 0.791 | 0.076 | NA | NA | 5.21 | 2.79 | 4.50 | 7.94 | 14.06 | 80.80 | 16.90 | 13.77 |
| 9 May 94 | 0.774 | 0.029 | 0.880 | 0.084 | NA | NA | 0.681 | 0.061 | NA | NA | 5.26 | 2.89 | 4.41 | 7.77 | 13.87 | 77.72 | 16.28 | 13.89 |
| 10 May 94 | 0.760 | 0.037 | 0.925 | 0.105 | NA | NA | 0.703 | 0.073 | NA | NA | 6.04 | 2.62 | 4.79 | 8.24 | 14.70 | 76.58 | 16.14 | 13.89 |
| 11 May 94 | 0.779 | 0.034 | 0.951 | 0.115 | NA | NA | 0.741 | 0.084 | NA | NA | 4.69 | 2.40 | 5.08 | 6.98 | 14.01 | 76.56 | 16.04 | 13.89 |
| 12 May 94 | 0.850 | 0.048 | 0.825 | 0.117 | NA | NA | 0.702 | 0.091 | NA | NA | 4.52 | 2.82 | 4.87 | 7.50 | 13.70 | 72.95 | 15.61 | 13.89 |
| 13 May 94 | 0.770 | 0.041 | 0.784 | 0.098 | NA | NA | 0.603 | 0.069 | NA | NA | 4.18 | 2.63 | 4.82 | 6.32 | 12.83 | 72.73 | 17.45 | 13.89 |

Appendix Table D4. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 14 May 94 | 0.816 | 0.079 | 0.775 | 0.134 | NA | NA | 0.633 | 0.090 | NA | NA | 5.43 | 2.94 | 4.74 | 6.83 | 13.90 | 71.05 | 19.45 | 13.89 |
| 15 May 94 | 0.721 | 0.040 | 0.590 | 0.079 | NA | NA | 0.426 | 0.052 | NA | NA | 4.43 | 2.78 | 5.37 | 6.66 | 12.75 | 70.25 | 22.44 | 13.89 |
| 16 May 94 | 0.686 | 0.087 | 0.579 | 0.153 | NA | NA | 0.397 | 0.093 | NA | NA | 5.24 | 3.03 | 7.84 | 9.66 | 18.22 | 72.25 | 22.17 | 13.86 |
| 17 May94 | 0.694 | 0.033 | 0.964 | 0.182 | NA | NA | 0.668 | 0.122 | NA | NA | 4.23 | 2.68 | 5.16 | 6.86 | 14.56 | 70.54 | 22.76 | 13.89 |
| 18 May 94 | 0.592 | 0.075 | 3.756 | 3.588 | NA | NA | 2.222 | 2.107 | NA | NA | 5.96 | 2.49 | 6.19 | 10.20 | 19.75 | 62.22 | 19.75 | 13.15 |
| 19 May 94 | 0.730 | 0.042 | 1.097 | 0.255 | NA | NA | 0.801 | 0.180 | NA | NA | 3.75 | 2.61 | 5.07 | 6.27 | 17.14 | 73.16 | 21.24 | 13.45 |
| 20 May 94 | 0.593 | 0.080 | 1.490 | 0.675 | NA | NA | 0.883 | 0.384 | NA | NA | 5.63 | 2.48 | 4.07 | 8.58 | 21.41 | 68.31 | 19.25 | 12.99 |
| 21 May 94 | 0.631 | 0.109 | 0.632 | 0.242 | NA | NA | 0.399 | 0.136 | NA | NA | 5.97 | 3.14 | 6.62 | 10.70 | 19.68 | 59.65 | 18.99 | 13.02 |
| 22 May 94 | 0.874 | 0.407 | 0.515 | 0.505 | NA | NA | 0.450 | 0.383 | NA | NA | 6.25 | 3.82 | 4.99 | 11.49 | 28.60 | 47.99 | 22.04 | 14.06 |
| 23 May94 | 0.562 | 0.142 | 1.000 | 0.638 | NA | NA | 0.562 | 0.328 | NA | NA | 6.05 | 2.73 | 8.26 | 11.44 | 23.89 | 44.00 | 19.50 | 14.59 |
| 24 May94 | 0.584 | 0.166 | 1.255 | 1.172 | NA | NA | 0.733 | 0.655 | NA | NA | 6.96 | 5.04 | 4.20 | 28.04 | 22.92 | 36.95 | 13.44 | 15.76 |
| 25 May 94 | 0.789 | 0.235 | 0.543 | 0.293 | NA | NA | 0.428 | 0.190 | NA | NA | 6.33 | 4.08 | 7.86 | 29.78 | 20.70 | 51.32 | 21.19 | 13.48 |
| 26 May 94 | 0.956 | 0.467 | 0.571 | 0.559 | NA | NA | 0.546 | 0.459 | NA | NA | 6.18 | 2.34 | 6.11 | 25.52 | 24.90 | 39.96 | 15.62 | 15.28 |
| 13 Apr 95 | 0.883 | 0.056 | 0.966 | 0.123 | NA | NA | 0.853 | 0.111 | NA | NA | 4.52 | 2.37 | 5.02 | 6.74 | 12.02 | 69.55 | 11.93 | 9.44 |
| 15 Apr 95 | 0.778 | 0.137 | 0.889 | 0.351 | NA | NA | 0.691 | 0.235 | NA | NA | 5.51 | 3.33 | 6.40 | 7.62 | 14.75 | 61.24 | 22.85 | 9.44 |
| 16 Apr 95 | 0.774 | 0.098 | 1.354 | 0.393 | NA | NA | 1.048 | 0.296 | NA | NA | 5.11 | 2.26 | 4.53 | 6.93 | 11.53 | 69.50 | 18.97 | 9.51 |
| 17 Apr 95 | 0.732 | 0.138 | 1.423 | 0.750 | NA | NA | 1.042 | 0.523 | NA | NA | 6.46 | 3.90 | 4.02 | 10.26 | 12.97 | 84.57 | 17.44 | 10.01 |
| 18 Apr 95 | 1.222 | 0.634 | 1.100 | 0.837 | NA | NA | 1.344 | 0.739 | NA | NA | 5.92 | 3.49 | 5.47 | 11.40 | 12.03 | 86.94 | 16.50 | 10.09 |
| 19 Apr 95 | 0.798 | 0.246 | 1.143 | 0.524 | NA | NA | 0.912 | 0.322 | NA | NA | 7.35 | 3.64 | 7.15 | 14.47 | 14.65 | 90.57 | 17.21 | 10.19 |
| 20 Apr 95 | 1.547 | 1.268 | 0.385 | 0.345 | NA | NA | 0.596 | 0.172 | NA | NA | 6.83 | 4.05 | 4.95 | 11.96 | 12.75 | 86.96 | 16.08 | 10.11 |
| 21 Apr 95 | 0.586 | 0.133 | 1.097 | 0.403 | NA | NA | 0.643 | 0.202 | NA | NA | 12.09 | 3.35 | 4.93 | 10.76 | 11.84 | 85.22 | 14.63 | 10.17 |
| 22 Apr 95 | 0.903 | 0.157 | 1.198 | 0.360 | NA | NA | 1.082 | 0.263 | NA | NA | 9.03 | 4.07 | 5.01 | 10.75 | 14.69 | 91.23 | 16.95 | 10.38 |
| 23 Apr 95 | 1.074 | 0.190 | 0.937 | 0.270 | NA | NA | 1.006 | 0.223 | NA | NA | 8.24 | 2.15 | 6.15 | 10.93 | 14.76 | 92.15 | 18.92 | 10.47 |
| 24 Apr 95 | 0.812 | 0.078 | 1.126 | 0.197 | 0.467 | 0.249 | 0.915 | 0.139 | 0.427 | 0.219 | 6.59 | 3.11 | 4.37 | 10.04 | 12.90 | 96.89 | 19.02 | 10.56 |
| 25 Apr 95 | 0.848 | 0.057 | 1.209 | 0.181 | NA | NA | 1.025 | 0.140 | NA | NA | 6.57 | 3.09 | 4.37 | 10.28 | 13.85 | 100.87 | 19.24 | 10.56 |

Appendix Table D4. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 26 Apr 95 | 0.858 | 0.047 | 0.972 | 0.100 | NA | NA | 0.834 | 0.075 | NA | NA | 7.98 | 3.03 | 4.02 | 10.13 | 14.53 | 104.00 | 19.80 | 10.56 |
| 27 Apr 95 | 0.888 | 0.038 | 0.937 | 0.083 | 0.603 | 0.244 | 0.832 | 0.066 | 0.502 | 0.199 | 6.39 | 2.96 | 4.17 | 9.97 | 13.15 | 108.45 | 20.91 | 10.56 |
| 28 Apr 95 | 0.936 | 0.027 | 0.971 | 0.055 | 1.042 | 0.330 | 0.909 | 0.045 | 0.947 | 0.297 | 5.78 | 2.78 | 4.26 | 8.86 | 12.56 | 111.78 | 22.01 | 10.56 |
| 29 Apr 95 | 0.899 | 0.032 | 0.919 | 0.068 | 0.872 | 0.379 | 0.826 | 0.055 | 0.720 | 0.310 | 5.86 | 3.01 | 4.16 | 8.94 | 12.07 | 113.00 | 22.08 | 10.56 |
| 30 Apr 95 | 0.921 | 0.037 | 0.832 | 0.060 | 0.799 | 0.335 | 0.766 | 0.047 | 0.612 | 0.255 | 5.43 | 2.39 | 3.98 | 8.09 | 11.74 | 116.34 | 23.28 | 10.56 |
| 1 May 95 | 0.861 | 0.021 | 1.040 | 0.060 | 1.306 | 0.542 | 0.895 | 0.048 | 1.168 | 0.481 | 5.53 | 2.53 | 4.21 | 7.99 | 11.36 | 117.08 | 23.30 | 10.56 |
| 2 May 95 | 0.870 | 0.015 | 0.974 | 0.037 | 0.943 | 0.214 | 0.848 | 0.029 | 0.800 | 0.180 | 5.18 | 2.33 | 4.15 | 7.70 | 11.54 | 114.02 | 22.77 | 10.56 |
| 3 May 95 | 0.912 | 0.019 | 0.906 | 0.039 | 0.899 | 0.234 | 0.827 | 0.032 | 0.743 | 0.191 | 5.45 | 2.24 | 3.84 | 8.37 | 12.56 | 113.59 | 22.77 | 10.56 |
| 4 May 95 | 0.922 | 0.035 | 0.844 | 0.055 | 1.676 | 0.892 | 0.778 | 0.043 | 1.304 | 0.691 | 5.41 | 1.89 | 4.08 | 7.13 | 12.02 | 108.87 | 21.69 | 10.56 |
| 5 May95 | 0.868 | 0.025 | 1.008 | 0.057 | 0.692 | 0.163 | 0.875 | 0.043 | 0.605 | 0.140 | 4.32 | 2.27 | 4.12 | 6.66 | 11.35 | 107.87 | 21.19 | 10.56 |
| 6 May 95 | 0.953 | 0.048 | 0.915 | 0.083 | 1.053 | 0.466 | 0.871 | 0.065 | 0.917 | 0.401 | 4.33 | 2.38 | 4.33 | 6.34 | 11.03 | 105.77 | 19.82 | 10.56 |
| 7 May 95 | 0.846 | 0.036 | 1.071 | 0.096 | 3.417 | 3.304 | 0.907 | 0.074 | 3.098 | 2.984 | 4.21 | 2.17 | 4.11 | 6.18 | 9.97 | 104.03 | 19.16 | 10.56 |
| 8 May 95 | 0.905 | 0.023 | 0.997 | 0.056 | 1.025 | 0.408 | 0.902 | 0.046 | 0.925 | 0.365 | 3.98 | 2.04 | 4.41 | 5.79 | 10.36 | 101.61 | 19.38 | 10.59 |
| 9 May 95 | 0.922 | 0.016 | 0.945 | 0.042 | 1.095 | 0.439 | 0.871 | 0.036 | 0.954 | 0.381 | 3.46 | 2.01 | 4.13 | 5.73 | 10.05 | 100.65 | 19.02 | 10.64 |
| 10 May 95 | 0.919 | 0.020 | 0.982 | 0.049 | 0.587 | 0.169 | 0.902 | 0.040 | 0.529 | 0.151 | 2.87 | 2.02 | 4.22 | 4.99 | 9.00 | 98.85 | 18.93 | 10.82 |
| 11 May 95 | 0.866 | 0.039 | 1.027 | 0.083 | 2.245 | 2.135 | 0.889 | 0.061 | 1.996 | 1.894 | 3.76 | 2.16 | 3.73 | 5.83 | 9.71 | 105.61 | 18.61 | 11.51 |
| 12 May 95 | 0.958 | 0.043 | 1.013 | 0.100 | NA | NA | 0.971 | 0.085 | NA | NA | 4.03 | 2.64 | 3.64 | 6.59 | 10.33 | 110.37 | 20.07 | 12.09 |
| 13 May 95 | 0.956 | 0.032 | 0.956 | 0.070 | 0.450 | 0.167 | 0.914 | 0.060 | 0.412 | 0.151 | 4.38 | 2.46 | 3.35 | 6.85 | 9.96 | 113.16 | 20.83 | 12.54 |
| 14 May 95 | 0.917 | 0.035 | 0.914 | 0.090 | NA | NA | 0.838 | 0.078 | NA | NA | 4.37 | 2.83 | 3.28 | 7.52 | 9.40 | 113.67 | 21.32 | 12.63 |
| 15 May 95 | 0.891 | 0.055 | 0.888 | 0.134 | NA | NA | 0.791 | 0.111 | NA | NA | 3.97 | 2.22 | 3.53 | 6.39 | 7.98 | 116.55 | 21.77 | 13.11 |
| 16 May 95 | 0.902 | 0.067 | 1.209 | 0.334 | NA | NA | 1.091 | 0.292 | NA | NA | 4.44 | 2.14 | 4.38 | 7.49 | 13.84 | 116.65 | 20.39 | 13.31 |
| 17 May 95 | 0.885 | 0.025 | 1.052 | 0.082 | 0.507 | 0.248 | 0.931 | 0.068 | 0.472 | 0.228 | 3.03 | 2.46 | 3.62 | 5.85 | 9.69 | 117.04 | 20.44 | 13.33 |
| 18 May 95 | 1.055 | 0.088 | 0.886 | 0.193 | NA | NA | 0.934 | 0.184 | NA | NA | 3.83 | 2.21 | 3.81 | 5.93 | 8.79 | 113.53 | 13.01 | 13.53 |
| 19 May 95 | 0.938 | 0.058 | 0.750 | 0.095 | NA | NA | 0.703 | 0.077 | NA | NA | 4.76 | 2.33 | 3.52 | 7.45 | 11.96 | 113.49 | 13.02 | 13.53 |
| 20 May 95 | 0.953 | 0.082 | 1.016 | 0.332 | NA | NA | 0.968 | 0.305 | NA | NA | 3.79 | 2.36 | 3.03 | 5.98 | 10.98 | 110.27 | 4.26 | 13.97 |
| 21 May 95 | 0.833 | 0.045 | 0.921 | 0.157 | NA | NA | 0.767 | 0.129 | NA | NA | 3.88 | 2.81 | 2.89 | 6.70 | 10.39 | 106.43 | 5.98 | 14.19 |

Appendix Table D4. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 22 May 95 | 0.878 | 0.047 | 0.965 | 0.143 | NA | NA | 0.848 | 0.121 | NA | NA | 3.90 | 2.65 | 3.01 | 6.72 | 10.75 | 111.51 | 9.07 | 14.38 |
| 23 May 95 | 0.855 | 0.049 | 1.029 | 0.181 | NA | NA | 0.880 | 0.153 | NA | NA | 4.47 | 2.82 | 3.75 | 6.92 | 10.77 | 122.76 | 17.53 | 14.44 |
| 24 May 95 | 0.882 | 0.055 | 0.837 | 0.136 | NA | NA | 0.738 | 0.117 | NA | NA | 4.07 | 2.49 | 3.10 | 9.00 | 11.57 | 126.13 | 18.05 | 14.44 |
| 25 May 95 | 0.857 | 0.049 | 0.941 | 0.208 | NA | NA | 0.806 | 0.178 | NA | NA | 4.70 | 2.26 | 3.26 | 7.33 | 11.31 | 131.19 | 20.73 | 14.44 |
| 26 May 95 | 0.883 | 0.062 | 0.853 | 0.226 | NA | NA | 0.753 | 0.196 | NA | NA | 4.29 | 2.34 | 2.59 | 8.47 | 10.10 | 134.77 | 22.92 | 14.46 |
| 27 May 95 | 0.957 | 0.083 | 0.725 | 0.136 | NA | NA | 0.694 | 0.116 | NA | NA | 4.71 | 2.04 | 2.71 | 8.36 | 10.68 | 140.36 | 24.35 | 14.68 |
| 28 May 95 | 0.859 | 0.065 | 1.208 | 0.359 | NA | NA | 1.037 | 0.303 | NA | NA | 4.93 | 2.33 | 3.72 | 8.01 | 8.74 | 142.28 | 24.74 | 14.76 |
| 29 May 95 | 0.920 | 0.065 | 0.930 | 0.190 | NA | NA | 0.856 | 0.165 | NA | NA | 4.88 | 2.33 | 2.88 | 7.87 | 8.76 | 144.10 | 25.65 | 14.83 |
| 30 May 95 | 0.930 | 0.085 | 1.460 | 0.759 | NA | NA | 1.357 | 0.694 | NA | NA | 4.05 | 2.63 | 2.67 | 7.26 | 8.84 | 141.47 | 24.12 | 14.97 |
| | | | | | | | | | | | | | | | | | | |
| 12 Apr 96 | 0.900 | 0.219 | 0.692 | 0.233 | NA | NA | 0.623 | 0.156 | NA | NA | 4.39 | 4.40 | 3.98 | 8.84 | 12.45 | 107.62 | 28.27 | 9.67 |
| 13 Apr 96 | 0.849 | 0.145 | 1.270 | 0.534 | NA | NA | 1.078 | 0.419 | NA | NA | 6.46 | 3.18 | 3.58 | 8.46 | 14.22 | 106.78 | 26.54 | 10.05 |
| 14 Apr96 | 0.729 | 0.121 | 1.000 | 0.386 | NA | NA | 0.729 | 0.278 | NA | NA | 7.46 | 2.15 | 4.27 | 7.10 | 11.80 | 113.51 | 28.71 | 10.10 |
| 15 Apr 96 | 0.956 | 0.185 | 0.679 | 0.239 | NA | NA | 0.649 | 0.191 | NA | NA | 6.09 | 2.06 | 2.52 | 9.06 | 11.78 | 108.80 | 28.72 | 10.37 |
| 16 Apr 96 | 0.973 | 0.198 | 0.643 | 0.264 | NA | NA | 0.626 | 0.219 | NA | NA | 4.84 | 1.38 | 3.59 | 6.92 | 12.00 | 108.78 | 28.58 | 10.39 |
| 17 Apr 96 | 0.877 | 0.127 | 1.154 | 0.527 | NA | NA | 1.012 | 0.439 | NA | NA | 3.74 | 1.46 | 2.95 | 7.54 | 8.74 | 130.46 | 29.79 | 10.59 |
| 18 Apr96 | 0.861 | 0.127 | 0.745 | 0.284 | NA | NA | 0.642 | 0.228 | NA | NA | 4.19 | 2.52 | 3.21 | 6.53 | 13.40 | 130.18 | 32.32 | 10.67 |
| 19 Apr96 | 1.016 | 0.128 | 0.495 | 0.107 | NA | NA | 0.503 | 0.086 | NA | NA | 4.85 | 1.67 | 2.67 | 6.41 | 9.05 | 149.08 | 37.20 | 10.59 |
| 20 Apr 96 | 0.938 | 0.061 | 0.859 | 0.152 | 0.665 | 0.381 | 0.806 | 0.133 | 0.536 | 0.294 | 4.60 | 1.75 | 2.62 | 5.92 | 7.96 | 156.58 | 36.41 | 10.40 |
| 21 Apr96 | 1.067 | 0.087 | 0.698 | 0.134 | 1.088 | 0.939 | 0.745 | 0.128 | 0.810 | 0.686 | 4.40 | 1.50 | 4.87 | 6.28 | 11.06 | 119.13 | 33.24 | 10.48 |
| 22 Apr 96 | 1.084 | 0.102 | 0.904 | 0.214 | NA | NA | 0.980 | 0.209 | NA | NA | 3.81 | 1.26 | 3.20 | 5.21 | 9.73 | 147.07 | 33.26 | 10.43 |
| 23 Apr 96 | 1.033 | 0.062 | 1.014 | 0.174 | 0.299 | 0.140 | 1.048 | 0.166 | 0.313 | 0.138 | 3.07 | 1.24 | 2.82 | 4.17 | 9.53 | 143.72 | 31.60 | 10.46 |
| 24 Apr 96 | 0.988 | 0.015 | 0.973 | 0.036 | 0.833 | 0.163 | 0.962 | 0.032 | 0.801 | 0.155 | 2.88 | 1.24 | 3.69 | 3.91 | 9.12 | 138.40 | 36.31 | 10.38 |
| 25 Apr 96 | 0.931 | 0.015 | 0.976 | 0.041 | 1.125 | 0.250 | 0.908 | 0.035 | 1.021 | 0.223 | 2.83 | 1.33 | 3.22 | 4.78 | 8.88 | 114.15 | 43.22 | 10.42 |
| 26 Apr 96 | 0.934 | 0,017 | 0.979 | 0.034 | 0.758 | 0.100 | 0.914 | 0.027 | 0.693 | 0.089 | 3.14 | 1.76 | 3.51 | 4.89 | 8.22 | 106.32 | 42.18 | 10.45 |
| 27 Apr 96 | 0.983 | 0.022 | 0.948 | 0.039 | 0.737 | 0.106 | 0.932 | 0.031 | 0.686 | 0.096 | 3.89 | 2.55 | 3.16 | 6.58 | 9.29 | 98.78 | 25.04 | 10.63 |

Appendix Table D4. Continued.

| | Survival Estimates | | | | | | | | | | Median Travel Times (days) | | | | | Exposure Indices | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR-LGO | | LGO-LMO | | LMO-MCN | | LGR-LMO | | LGR-MCN | | LGR-LGO | LGO-LMO | LMO-MCN | LGR-LMO | LGR-MCN | | | |
| Rel. Date | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | Est. | s.e. | | | | | | Flow | Spill% | Temp. |
| 28 Apr 96 | 0.873 | 0.051 | 0.967 | 0.136 | NA | NA | 0.844 | 0.111 | NA | NA | 4.34 | 2.24 | 4.45 | 6.50 | 12.42 | 89.07 | 24.77 | 9.92 |
| 29 Apr 96 | 0.895 | 0.015 | 0.870 | 0.037 | 0.796 | 0.118 | 0.779 | 0.030 | 0.620 | 0.089 | 4.52 | 2.71 | 4.34 | 7.66 | 12.11 | 86.90 | 26.71 | 9.36 |
| 30 Apr 96 | 0.806 | 0.057 | 0.970 | 0.153 | 1.568 | 1.436 | 0.781 | 0.115 | 1.225 | 1.109 | 3.67 | 2.44 | 3.95 | 8.14 | 11.41 | 85.26 | 25.91 | 9.15 |
| 1 May 96 | 0.905 | 0.044 | 0.870 | 0.106 | 0.596 | 0.204 | 0.788 | 0.089 | 0.469 | 0.152 | 3.73 | 2.75 | 4.48 | 7.99 | 13.19 | 84.49 | 24.41 | 8.85 |
| 2 May 96 | 0.856 | 0.050 | 1.080 | 0.141 | 0.773 | 0.346 | 0.925 | 0.109 | 0.715 | 0.308 | 3.87 | 3.14 | 4.64 | 8.24 | 12.02 | 84.96 | 24.32 | 8.67 |
| 3 May 96 | 0.827 | 0.066 | 1.016 | 0.137 | 3.499 | 3.413 | 0.840 | 0.093 | 2.938 | 2.848 | 5.13 | 2.73 | 4.24 | 8.26 | 11.36 | 88.79 | 23.53 | 8.55 |
| 4 May 96 | 0.805 | 0.054 | 0.946 | 0.122 | 0.587 | 0.246 | 0.762 | 0.085 | 0.447 | 0.181 | 5.87 | 2.64 | 4.18 | 8.78 | 11.97 | 97.31 | 24.17 | 8.54 |
| 5 May 96 | 0.830 | 0.057 | 1.175 | 0.165 | 1.107 | 0.595 | 0.976 | 0.120 | 1.080 | 0.564 | 5.23 | 2.62 | 4.62 | 8.45 | 10.92 | 99.23 | 24.41 | 8.55 |
| 6 May 96 | 0.917 | 0.079 | 0.980 | 0.161 | 1.347 | 1.270 | 0.899 | 0.125 | 1.211 | 1.129 | 5.61 | 2.73 | 3.46 | 9.72 | 11.43 | 121.41 | 27.58 | 8.90 |
| 7 May 96 | 0.705 | 0.071 | 1.260 | 0.297 | 1.070 | 1.014 | 0.888 | 0.196 | 0.950 | 0.875 | 6.74 | 2.14 | 3.17 | 8.59 | 10.82 | 128.32 | 28.94 | 9.02 |
| 8 May96 | 0.846 | 0.076 | 1.156 | 0.243 | NA | NA | 0.978 | 0.190 | NA | NA | 6.39 | 2.25 | 3.59 | 8.77 | 10.39 | 142.16 | 31.89 | 9.32 |
| 9 May 96 | 1.015 | 0.103 | 0.893 | 0.198 | NA | NA | 0.906 | 0.178 | NA | NA | 5.40 | 2.26 | 3.43 | 7.01 | 8.81 | 132.52 | 29.19 | 9.10 |
| 10 May 96 | 1.083 | 0.106 | 0.698 | 0.138 | NA | NA | 0.757 | 0.128 | NA | NA | 4.85 | 1.75 | 3.15 | 6.12 | 8.99 | 131.08 | 28.82 | 9.11 |
| 11 May 96 | 0.993 | 0.065 | 0.950 | 0.199 | NA | NA | 0.944 | 0.187 | NA | NA | 4.34 | 1.83 | 2.82 | 6.36 | 8.87 | 149.66 | 33.37 | 9.53 |
| 12 May 96 | 1.058 | 0.106 | 0.892 | 0.244 | NA | NA | 0.944 | 0.239 | NA | NA | 3.56 | 1.74 | 2.71 | 5.35 | 7.43 | 150.84 | 33.30 | 9.54 |
| 13 May 96 | 0.952 | 0.063 | 0.714 | 0.101 | NA | NA | 0.679 | 0.086 | NA | NA | 3.44 | 1.55 | 3.07 | 5.06 | 9.18 | 164.85 | 37.48 | 9.77 |
| 14 May 96 | 1.052 | 0.099 | 0.878 | 0.213 | 0.307 | 0.198 | 0.924 | 0.205 | 0.283 | 0.172 | 3.45 | 1.27 | 1.99 | 4.42 | 7.50 | 171.38 | 40.20 | 9.81 |
| 15 May 96 | 0.931 | 0.061 | 0.809 | 0.119 | 0.788 | 0.524 | 0.753 | 0.099 | 0.594 | 0.387 | 3.24 | 1.23 | 2.51 | 4.26 | 6.51 | 184.05 | 45.19 | 9.71 |
| 16 May 96 | 0.902 | 0.058 | 0.962 | 0.144 | 0.441 | 0.174 | 0.868 | 0.118 | 0.383 | 0.142 | 3.29 | 1.14 | 2.46 | 4.05 | 6.67 | 199.25 | 48.92 | 9.21 |
| 17 May 96 | 0.901 | 0.057 | 1.070 | 0.181 | 0.740 | 0.401 | 0.965 | 0.152 | 0.714 | 0.370 | 2.93 | 1.31 | 2.46 | 4.03 | 6.27 | 184.85 | 45.16 | 8.66 |
| 18 May 96 | 0.906 | 0.060 | 1.972 | 0.695 | 0.132 | 0.083 | 1.786 | 0.619 | 0.236 | 0.123 | 2.45 | 1.16 | 4.89 | 3.84 | 5.73 | 169.24 | 41.70 | 8.59 |
| 19 May 96 | 0.896 | 0.079 | 0.922 | 0.226 | NA | NA | 0.827 | 0.191 | NA | NA | 2.41 | 1.41 | 2.31 | 3.62 | 5.48 | 154.40 | 37.88 | 8.55 |
| 21 May 96 | 0.775 | 0.118 | 0.655 | 0.194 | NA | NA | 0.508 | 0.138 | NA | NA | 3.18 | 1.39 | 2.68 | 4.63 | 7.02 | 128.91 | 39.97 | 8.89 |
| 23 May 96 | 0.881 | 0.114 | 1.109 | 0.428 | NA | NA | 0.976 | 0.357 | NA | NA | 3.30 | 1.57 | 2.53 | 4.74 | 7.03 | 126.59 | 46.96 | 9.38 |
| 24 May 96 | 0.968 | 0.211 | 0.989 | 0.594 | NA | NA | 0.957 | 0.534 | NA | NA | 3.38 | 2.04 | 2.15 | 5.15 | 8.60 | 140.44 | 43.96 | 9.75 |
| 26 May 96 | 0.985 | 0.203 | 0.961 | 0.441 | NA | NA | 0.947 | 0.387 | NA | NA | 3.12 | 1.20 | 2.52 | 4.37 | 5.81 | 149.23 | 43.51 | 9.94 |

Appendix Table El. Revised estimates of survival probabilities for hatchery yearling chinook salmon released in Lower Granite Reservoir, 1993- 1995. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Year | Date | Release to LGR ($S_{R1}$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | 15 Apr | 0.930 | (0.027) | 0.853 | (0.041) | NA | NA | NA | NA |
| | 16 Apr | 0.895 | (0.020) | 0.875 | (0.031) | NA | NA | NA | NA |
| | 17 Apr | 0.913 | (0.024) | 0.802 | (0.034) | NA | NA | NA | NA |
| | 18 Apr | 0.892 | (0.024) | 0.808 | (0.036) | NA | NA | NA | NA |
| | 19 Apr | 0.897 | (0.024) | 0.798 | (0.039) | NA | NA | NA | NA |
| | 20 Apr | 0.863 | (0.024) | 0.908 | (0.046) | NA | NA | NA | NA |
| | Apr | 0.885 | (0.021) | 0.834 | (0.037) | NA | NA | NA | NA |
| | weighted avg.” | 0.895 | (0.007) | 0.837 | (0.015) | NA | NA | NA | NA |
| **1994** | 16 Apr | 0.895 | (0.026) | 0.873 | (0.040) | 0.850 | (0.046) | 0.665 | (0.028) |
| | 17 Apr | 0.938 | (0.030) | 0.739 | (0.038) | 0.956 | (0.052) | 0.662 | (0.029) |
| | 18 Apr | 0.926 | (0.030) | 0.785 | (0.046) | 0.862 | (0.055) | 0.627 | (0.028) |
| | 21 Apr | 0.929 | (0.034) | 0.714 | (0.046) | 1.013 | (0.077) | 0.671 | (0.040) |
| | 23 Apr | 1.028 | (0.061) | 0.741 | (0.091) | 0.780 | (0.103) | 0.594 | (0.047) |
| | 26 Apr | 0.922 | (0.040) | 0.940 | (0.108) | 0.707 | (0.093) | 0.613 | (0.047) |
| | 29 Apr | 0.907 | (0.048) | 0.728 | (0.079) | 0.916 | (0.130) | 0.605 | (0.068) |
| | 1 May | 0.893 | (0.038) | 0.968 | (0.101) | 0.756 | (0.096) | 0.653 | (0.054) |
| | 4 May | 0.912 | (0.074) | 0.690 | (0.110) | 1.020 | (0.196) | 0.642 | (0.090) |
| | 11 May | 0.829 | (0.080) | 1.043 | (0.151) | 0.846 | (0.153) | 0.731 | (0.106) |
| | weighted avg.[a] | 0.918 | (0.010) | 0.788 | (0.027) | 0.875 | (0.028) | 0.645 | (0.009) |

Appendix Table E 1. Continued

| Year | Date | Release to LGR ($S_{R1}$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| **1995** | 9 Apr | 0.965 | (0.030) | 0.790 | (0.042) | 0.999 | (0.078) | 0.762 | (0.052) |
| | 11 Apr | 0.936 | (0.031) | 0.847 | (0.055) | 0.952 | (0.086) | 0.755 | (0.056) |
| | 15 Apr | 0.922 | (0.027) | 0.967 | (0.053) | 1.002 | (0.091) | 0.894 | (0.069) |
| | 18 Apr | 0.888 | (0.037) | 0.885 | (0.073) | 0.883 | (0.102) | 0.694 | (0.065) |
| | 20 Apr | 0.897 | (0.027) | 0.929 | (0.054) | 0.895 | (0.079) | 0.746 | (0.055) |
| | 23 Apr | 0.916 | (0.019) | 0.958 | (0.039) | 0.905 | (0.058) | 0.795 | (0.043) |
| | 25 Apr | 0.912 | (0.021) | 0.900 | (0.037) | 0.894 | (0.056) | 0.733 | (0.040) |
| | 27 Apr | 0.906 | (0.023) | 0.915 | (0.040) | 1.029 | (0.075) | 0.853 | (0.055) |
| | 29 Apr | 0.942 | (0.031) | 0.859 | (0.045) | 0.984 | (0.075) | 0.796 | (0.053) |
| | 1 May | 0.939 | (0.028) | 0.942 | (0.049) | 0.913 | (0.067) | 0.807 | (0.048) |
| | 3 May | 0.928 | (0.060) | 0.955 | (0.105) | 0.894 | (0.127) | 0.792 | (0.087) |
| | 5 May | 0.997 | (0.127) | 0.743 | (0.136) | 0.916 | (0.218) | 0.678 | (0.142) |
| | weighted avg.[a] | 0.921 | (0.006) | 0.898 | (0.017) | 0.938 | (0.015) | 0.779 | (0.015) |

[a] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances

Appendix Table E2. Revised estimates of survival probabilities for hatchery steelhead released in Lower Granite Reservoir, 1994-1995. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Year | Date | Release to LGR ($S_{R1}$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|
| **1994** | 23 Apr | 0.922 | (0.012) | 0.789 | (0.022) | 0.825 | (0.031) | 0.600 | (0.021) |
| | 25 Apr | 0.906 | (0.012) | 0.801 | (0.028) | 0.813 | (0.045) | 0.590 | (0.029) |
| | 26 Apr | 0.913 | (0.011) | 0.796 | (0.027) | 0.831 | (0.056) | 0.604 | (0.038) |
| | 1 May | 0.911 | (0.016) | 0.814 | (0.041) | 0.872 | (0.099) | 0.646 | (0.068) |
| | 3 May | 0.868 | (0.016) | 0.747 | (0.045) | 0.903 | (0.123) | 0.585 | (0.073) |
| | 5 May | 0.863 | (0.018) | 0.750 | (0.051) | 0.819 | (0.114) | 0.530 | (0.066) |
| | 7 May | 0.874 | (0.020) | 0.773 | (0.054) | 0.940 | (0.166) | 0.635 | (0.104) |
| | 10 May | 0.871 | (0.068) | 0.702 | (0.082) | 0.716 | (0.121) | 0.437 | (0.064) |
| | 12 May | 0.911 | (0.052) | 0.683 | (0.055) | 1.003 | (0.146) | 0.625 | (0.084) |
| | weighted avg.[a] | 0.901 | (0.007) | 0.782 | (0.011) | 0.830 | (0.014) | 0.590 | (0.014) |
| **1995** | 22 Apr | 0.905 | (0.012) | 0.884 | (0.032) | 0.951 | (0.061) | 0.761 | (0.043) |
| | 24 Apr | 0.922 | (0.013) | 0.904 | (0.034) | 0.940 | (0.070) | 0.783 | (0.053) |
| | 26 Apr | 0.918 | (0.011) | 0.906 | (0.027) | 0.903 | (0.052) | 0.751 | (0.039) |
| | 28 Apr | 0.901 | (0.012) | 0.881 | (0.029) | 1.052 | (0.078) | 0.835 | (0.058) |
| | 30 Apr | 0.889 | (0.013) | 0.911 | (0.029) | 1.015 | (0.067) | 0.822 | (0.050) |
| | 2 May | 0.924 | (0.020) | 0.874 | (0.036) | 0.983 | (0.074) | 0.793 | (0.053) |
| | 4 May | 0.898 | (0.021) | 0.934 | (0.045) | 0.898 | (0.073) | 0.753 | (0.051) |
| | 6 May | 0.907 | (0.018) | 0.921 | (0.035) | 1.051 | (0.082) | 0.879 | (0.062) |
| | 9 May | 0.944 | (0.021) | 0.904 | (0.039) | 0.925 | (0.066) | 0.789 | (0.046) |
| | 11 May | 0.936 | (0.020) | 0.981 | (0.039) | 0.864 | (0.064) | 0.793 | (0.050) |
| | 12 May | 0.910 | (0.049) | 0.959 | (0.098) | 0.841 | (0.183) | 0.734 | (0.143) |
| | weighted avg.[a] | 0.911 | (0.005) | 0.907 | (0.009) | 0.947 | (0.019) | 0.788 | (0.011) |

[a] Weighted averages of the independent estimates, with weights inversely proportional to respective estimated variances,

Appendix Table E3. Revised estimates of detection probabilities for hatchery yearling chinook salmon released in Lower Granite Reservoir, 1993-1995. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Year | Date | LGR | ($P_1$) | LGO | ($P_2$) | LMO | ($P_3$) |
|---|---|---|---|---|---|---|---|
| **1993** | 15 Apr | 0.448 | (0.020) | 0.512 | (0.025) | NA | NA |
| | 16 Apr | 0.486 | (0.018) | 0.557 | (0.022) | NA | NA |
| | 17 Apr | 0.469 | (0.019) | 0.552 | (0.023) | NA | NA |
| | 18 Apr | 0.476 | (0.019) | 0.484 | (0.023) | NA | NA |
| | 19 Apr | 0.530 | (0.021) | 0.460 | (0.025) | NA | NA |
| | 20 Apr | 0.522 | (0.023) | 0.462 | (0.028) | NA | NA |
| | 21 Apr | 0.524 | (0.018) | 0.450 | (0.023) | NA | NA |
| **1994** | 16 Apr | 0.394 | (0.018) | 0.360 | (0.020) | 0.540 | (0.027) |
| | 17 Apr | 0.398 | (0.019) | 0.319 | (0.020) | 0.475 | (0.026) |
| | 18 Apr | 0.416 | (0.020) | 0.254 | (0.019) | 0.478 | (0.027) |
| | 21 Apr | 0.402 | (0.020) | 0.243 | (0.020) | 0.344 | (0.026) |
| | 23 Apr | 0.329 | (0.026) | 0.163 | (0.023) | 0.313 | (0.032) |
| | 26 Apr | 0.399 | (0.023) | 0.132 | (0.018) | 0.261 | (0.026) |
| | 29 Apr | 0.426 | (0.030) | 0.194 | (0.026) | 0.195 | (0.029) |
| | 1 May | 0.379 | (0.022) | 0.152 | (0.019) | 0.227 | (0.024) |
| | 4 May | 0.310 | (0.032) | 0.130 | (0.025) | 0.178 | (0.032) |
| | 11 May | 0.130 | (0.017) | 0.146 | (0.020) | 0.110 | (0.020) |

Appendix Table E3. Continued.

| Year | Date | LGR | $(P_1)$ | LGO | $(P_2)$ | LMO | $(P_3)$ |
|---|---|---|---|---|---|---|---|
| 1995 | 9 Apr | 0.423 | (0.019) | 0.363 | (0.022) | 0.367 | (0.029) |
| | 11 Apr | 0.490 | (0.024) | 0.316 | (0.026) | 0.390 | (0.035) |
| | 15 Apr | 0.415 | (0.019) | 0.319 | (0.021) | 0.348 | (0.031) |
| | 18 Apr | 0.489 | (0.029) | 0.303 | (0.031) | 0.411 | (0.045) |
| | 20 Apr | 0.519 | (0.025) | 0.377 | (0.028) | 0.472 | (0.041) |
| | 23 Apr | 0.511 | (0.018) | 0.375 | (0.020) | 0.462 | (0.029) |
| | 25 Apr | 0.502 | (0.018) | 0.406 | (0.021) | 0.473 | (0.030) |
| | 27 Apr | 0.434 | (0.018) | 0.383 | (0.021) | 0.438 | (0.032) |
| | 29 Apr | 0.374 | (0.019) | 0.385 | (0.022) | 0.443 | (0.034) |
| | 1 May | 0.366 | (0.018) | 0.341 | (0.021) | 0.472 | (0.032) |
| | 3 May | 0.298 | (0.029) | 0.268 | (0.033) | 0.426 | (0.053) |
| | 5 May | 0.295 | (0.056) | 0.395 | (0.069) | 0.653 | (0.142) |

Appendix Table E4. Revised estimates of detection probabilities for hatchery steelhead released in Lov
Reservoir, 1994-1995. Estimates based on the Single-Release Model. Standard e
Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower

| Year | Date | LGR | ($P_1$) | LGO | ($P_2$) | LMO | ($P_3$) |
|---|---|---|---|---|---|---|---|
| **1994** | 23 Apr | 0.826 | (0.014) | 0.531 | (0.021) | 0.803 | (0.026) |
| | 25 Apr | 0.832 | (0.014) | 0.474 | (0.022) | 0.705 | (0.035) |
| | 26 Apr | 0.881 | (0.012) | 0.521 | (0.023) | 0.624 | (0.041) |
| | 1 May | 0.795 | (0.018) | 0.455 | (0.028) | 0.438 | (0.049) |
| | 3 May | 0.833 | (0.017) | 0.390 | (0.028) | 0.389 | (0.052) |
| | 5 May | 0.785 | (0.019) | 0.371 | (0.029) | 0.325 | (0.044) |
| | 7 May | 0.739 | (0.020) | 0.368 | (0.030) | 0.302 | (0.052) |
| | 10 May | 0.201 | (0.019) | 0.299 | (0.029) | 0.247 | (0.039) |
| | 12 May | 0.159 | (0.011) | 0.294 | (0.018) | 0.155 | (0.022) |
| **1995** | 22 Apr | 0.841 | (0.014) | 0.386 | (0.021) | 0.579 | (0.036) |
| | 24 Apr | 0.810 | (0.015) | 0.420 | (0.023) | 0.573 | (0.042) |
| | 26 Apr | 0.848 | (0.013) | 0.449 | (0.020) | 0.643 | (0.036) |
| | 28 Apr | 0.845 | (0.013) | 0.441 | (0.021) | 0.507 | (0.038) |
| | 30 Apr | 0.765 | (0.015) | 0.446 | (0.021) | 0.577 | (0.038) |
| | 2 May | 0.544 | (0.018) | 0.412 | (0.022) | 0.538 | (0.039) |
| | 4 May | 0.541 | (0.020) | 0.361 | (0.023) | 0.571 | (0.042) |
| | 6 May | 0.532 | (0.018) | 0.432 | (0.021) | 0.542 | (0.042) |
| | 9 May | 0.524 | (0.020) | 0.401 | (0.023) | 0.673 | (0.042) |
| | 11 May | 0.501 | (0.020) | 0.434 | (0.024) | 0.680 | (0.046) |
| | 12 May | 0.542 | (0.050) | 0.486 | (0.062) | 0.609 | (0.125) |

Appendix Table E5. Revised estimates of median travel times (days) and median arrival dates at downstream dams for hatchery yearling chinook salmon released in Lower Granite Reservoir, 1993-1995. Number of fish used in calculations in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| | | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Date | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| 1993 | 15 Apr | 9.1 (432) | 6.6 (140) | 3.7 (104) | 20.1 (211) | 113.4 (437) | 120.1 (389) | 124.3 (232) | 125.7 (195) |
| | 16 Apr | 9.2 (582) | 6.5 (215) | 2.6 (155) | 18.3 (290) | 114.5 (587) | 120.7 (535) | 123.5 (317) | 126.2 (248) |
| | 17 Apr | 9.3 (509) | 6.0 (162) | 2.6 (141) | 17.3 (266) | 115.6 (514) | 120.9 (438) | 123.8 (302) | 126.5 (194) |
| | 18 Apr | 9.1 (534) | 6.0 (146) | 2.5 (134) | 16.5 (279) | 116.4 (539) | 121.2 (394) | 123.9 (302) | 126.9 (211) |
| | 20 Apr | 9.2 (548) | 5.9 (138) | 2.5 (109) | 16.3 (251) | 117.4 (553) | 122.0 (336) | 124.4 (274) | 127.5 (181) |
| | Apr | 8.0 (376) | 5.5 (107) | 2.5 (82) | 15.1 (177) | 117.0 (379) | 121.6 (261) | 124.3 (196) | 127.0 (157) |
| | 21 Apr | 7.0 (670) | 5.1 (190) | 2.4 (119) | 14.1 (277) | 117.1 (679) | 121.8 (423) | 124.3 (302) | 127.0 (245) |
| 1994 | 16 Apr | 7.2 (420) | 6.2 (109) | 3.9 (125) | 17.4 (380) | 112.6 (420) | 118.1 (321) | 122.7 (380) | 130.1 (318) |
| | 17 Apr | 7.1 (446) | 6.3 (83) | 3.8 (96) | 17.3 (334) | 113.5 (446) | 118.6 (251) | 123.6 (334) | 130.4 (358) |
| | 18 Apr | 6.8 (460) | 7.0 (77) | 3.6 (77) | 16.1 (320) | 114.2 (460) | 119.3 (209) | 123.3 (320) | 130.3 (353) |
| | 21 Apr | 7.8 (445) | 8.3 (60) | 3.4 (55) | 17.3 (247) | 118.0 (445) | 124.4 (182) | 127.9 (247) | 135.2 (343) |
| | 23 Apr | 7.2 (263) | 7.8 (23) | 3.8 (20) | 15.9 (136) | 119.5 (263) | 127.3 (92) | 128.3 (136) | 135.4 (217) |
| | 26 Apr | 10.0 (380) | 6.1 (40) | 2.7 (16) | 17.1 (155) | 125.2 (380) | 131.0 (110) | 132.4 (155) | 137.8 (299) |
| | 29 Apr | 8.2 (249) | 4.8 (31) | 2.6 (12) | 16.3 (71) | 126.5 (249) | 131.2 (78) | 134.9 (71) | 138.9 (196) |
| | 1 May | 8.2 (363) | 5.3 (45) | 3.3 (22) | 15.1 (147) | 127.6 (363) | 133.1 (134) | 134.4 (147) | 139.5 (308) |
| | 4 May | 5.5 (153) | 5.3 (09) | 3.0 (11) | 12.2 (59) | 128.8 (153) | 134.4 (43) | 135.6 (59) | 139.8 (148) |
| | 11 May | 5.3 (113) | 4.9 (17) | 2.7 (13) | 10.2 (83) | 134.6 (113) | 138.6 (131) | 139.2 (83) | 144.1 (271) |

Appendix Table E5. Continued.

| Year | Date | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| **1995** | 9 Apr | 16.0 (504) | 6.4 (126) | 2.6 (119) | 25.3 (325) | 113.9 (509) | 120.9 (328) | 123.3 (330) | 127.1 (270) |
| | 11 Apr | 14.3 (357) | 5.0 (80) | 2.6 (66) | 23.3 (209) | 114.3 (362) | 121.0 (184) | 123.4 (210) | 127.5 (195) |
| | 15 Apr | 15.2 (452) | 6.1 (120) | 2.4 (112) | 24.2 (344) | 119.1 (461) | 125.6 (321) | 128.1 (347) | 131.3 (242) |
| | 18 Apr | 10.4 (246) | 5.5 (58) | 2.3 (49) | 19.4 (152) | 117.3 (248) | 124.5 (129) | 126.3 (154) | 129.2 (121) |
| | 20 Apr | 9.3 (319) | 5.2 (104) | 2.2 (84) | 17.6 (223) | 118.2 (325) | 124.4 (204) | 126.6 (225) | 130.5 (156) |
| | 23 Apr | 7.4 (580) | 4.9 (187) | 2.2 (155) | 14.4 (426) | 119.3 (590) | 125.2 (390) | 126.3 (430) | 130.5 (297) |
| | 25 Apr | 5.9 (576) | 4.6 (193) | 2.0 (170) | 12.9 (413) | 119.9 (584) | 124.9 (396) | 126.9 (416) | 130.5 (281) |
| | 27 Apr | 5.4 (481) | 4.8 (148) | 2.0 (148) | 13.5 (421) | 121.3 (487) | 127.2 (373) | 129.5 (421) | 132.8 (241) |
| | 29 Apr | 6.5 (374) | 4.8 (106) | 1.8 (133) | 13.5 (348) | 124.4 (382) | 129.6 (321) | 131.5 (349) | 135.4 (219) |
| | 1 May | 5.9 (415) | 3.9 (96) | 1.9 (135) | 11.9 (415) | 125.9 (430) | 129.9 (347) | 131.8 (415) | 135.6 (240) |
| | 3 May | 5.6 (126) | 4.3 (26) | 1.9 (38) | 11.2 (139) | 127.5 (136) | 131.1 (106) | 133.1 (139) | 136.7 (85) |
| | 5 May | 6.6 (35) | 4.9 (08) | 2.2 (14) | 12.0 (45) | 130.3 (37) | 131.5 (34) | 135.9 (45) | 137.8 (13) |

Appendix Table E6. Revised estimates of median travel times (days) and median arrival dates at downstream dams for hatchery steelhead released in Lower Granite Reservoir, 1994- 1995. Number of fish used in calculations in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| | | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Date | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| 1994 | 23 Apr | 3.7 (910) | 5.6 (352) | 3.3 (261) | 12.6 (507) | 116.0 (910) | 122.4 (435) | 124.9 (507) | 129.8 (201) |
| | 25 Apr | 3.9 (904) | 6.2 (322) | 3.3 (199) | 12.9 (437) | 118.3 (904) | 125.8 (383) | 127.4 (437) | 132.5 (161) |
| | 26 Apr | 4.2 (978) | 5.8 (380) | 3.0 (198) | 13.7 (401) | 119.6 (978) | 127.2 (431) | 128.9 (401) | 135.3 (139) |
| | 1 May | 5.2 (726) | 5.0 (248) | 2.9 (105) | 13.5 (248) | 125.6 (726) | 131.3 (315) | 133.9 (248) | 142.7 (102) |
| | 3 May | 4.2 (862) | 4.9 (226) | 3.0 (98) | 11.7 (243) | 126.5 (863) | 131.3 (277) | 134.2 (244) | 143.6 (90) |
| | 5 May | 3.5 (819) | 4.7 (216) | 2.9 (67) | 11.6 (192) | 128.0 (819) | 133.6 (273) | 135.9 (192) | 143.1 (116) |
| | 7 May | 3.6 (790) | 4.5 (214) | 2.7 (74) | 11.1 (212) | 129.9 (790) | 134.7 (288) | 137.3 (212) | 143.9 (84) |
| | 10 May | 4.7 (266) | 4.7 (53) | 3.1 (47) | 13.4 (154) | 134.1 (266) | 138.8 (273) | 142.6 (154) | 152.4 (123) |
| | 12 May | 5.6 (581) | 4.9 (118) | 3.5 (105) | 13.2 (371) | 137.0 (581) | 140.2 (721) | 144.4 (371) | 157.4 (304) |
| 1995 | 22 Apr | 5.2 (861) | 5.4 (274) | 2.9 (166) | 14.6 (456) | 116.1 (870) | 123.1 (327) | 125.6 (457) | 129.2 (178) |
| | 24 Apr | 4.4 (751) | 5.8 (252) | 2.6 (170) | 13.5 (413) | 117.3 (755) | 123.9 (326) | 126.4 (413) | 130.3 (132) |
| | 26 Apr | 4.2 (943) | 4.7 (362) | 2.7 (233) | 12.7 (535) | 119.3 (946) | 125.3 (424) | 127.6 (537) | 131.1 (154) |
| | 28 Apr | 3.7 (909) | 4.3 (327) | 2.5 (197) | 12.0 (465) | 120.8 (914) | 126.1 (395) | 128.9 (465) | 133.6 (167) |
| | 30 Apr | 3.0 (850) | 4.6 (302) | 2.3 (232) | 11.4 (515) | 122.1 (865) | 127.8 (409) | 130.3 (516) | 133.6 (162) |
| | 2 May | 2.9 (595) | 3.3 (206) | 2.0 (175) | 10.0 (449) | 124.2 (605) | 128.3 (370) | 130.9 (449) | 135.2 (152) |
| | 4 May | 2.9 (510) | 3.0 (157) | 2.8 (142) | 8.5 (407) | 126.1 (522) | 129.6 (303) | 131.5 (407) | 135.9 (126) |
| | 6 May | 2.3 (598) | 2.7 (201) | 2.5 (188) | 7.0 (483) | 127.2 (618) | 130.0 (409) | 132.1 (483) | 136.8 (146) |
| | 9 May | 2.1 (432) | 2.5 (150) | 2.4 (147) | 6.9 (417) | 130.1 (436) | 132.2 (295) | 135.0 (417) | 138.2 (117) |
| | 11 May | 1.8 (387) | 3.4 (152) | 2.6 (147) | 7.5 (386) | 131.9 (392) | 135.2 (321) | 137.5 (386) | 141.3 (99) |
| | 12 May | 2.2 (73) | 4.0 (27) | 2.4 (23) | 8.3 (55) | 134.3 (73) | 137.0 (60) | 140.0 (55) | 143.5 (12) |

Appendix Table E7. Revised estimates of survival probabilities for juvenile salmonids released from fish traps in Snake River Basin, 1993. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Trap | Release dates | Number released | Release to LGR | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hatchery chinook salmon** | | | | | | | | | | |
| Salmon | 11 Apr- 12May | 3,119 | 0.782 | (0.019) | 0.844 | (0.039) | NA | NA | NA | NA |
| Clearwater | 09 Apr - 04 May | 1,619 | 0.712 | (0.026) | 0.890 | (0.064) | NA | NA | NA | NA |
| Snake | 09 Apr - 16 Jun | 3,186 | 0.822 | (0.015) | 0.917 | (0.035) | NA | NA | NA | NA |
| **Wild chinook salmon** | | | | | | | | | | |
| Salmon | 26 Mar - 12 May | 2,155 | 0.832 | (0.014) | 0.869 | (0.030) | NA | NA | NA | NA |
| Clearwater | 09 Apr - 29 Jul | 314 | 0.826 | (0.049) | 0.884 | (0.100) | NA | NA | NA | NA |
| Snake | 09 Apr - 23 Jul | 1,117 | 0.839 | (0.022) | 0.905 | (0.055) | NA | NA | NA | NA |
| **Hatchery steelhead** | | | | | | | | | | |
| Salmon | 15 Apr - 12May | 1,638 | 0.875 | (0.011) | 0.881 | (0.026) | NA | NA | NA | NA |
| Clear-water | 12 Apr - 04 May | 1,102 | 0.853 | (0.012) | 0.908 | (0.023) | NA | NA | NA | NA |
| Snake | 13 Apr - 16Jun | 2,516 | 0.920 | (0.007) | 0.879 | (0.016) | NA | NA | NA | NA |
| **Wild steelhead** | | | | | | | | | | |
| Salmon | 30 Mar - 12 May | 905 | 0.832 | (0.019) | 0.759 | (0.035) | NA | NA | NA | NA |
| Clear-water | 09 Apr - 04 May | 844 | 0.904 | (0.014) | 0.929 | (0.028) | NA | NA | NA | NA |
| Snake | 09 Apr - 13 May | 2,850 | 0.898 | (0.009) | 0.878 | (0.019) | NA | NA | NA | NA |

Appendix Table ES. Revised estimates of survival probabilities for juvenile salmonids released from fish traps in Snake River Basin, 1994. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Trap | Release dates | Number released | Release to LGR | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hatcher-v chinook salmon | | | | | | | | | | |
| Salmon | 31 Mar - 16 Jun | 3,633 | 0.75 1 | (0.023) | 0.8 14 | (0.043) | 0.815 | (0.050) | 0.498 | (0.023) |
| Clearwater | 05 Apr- 11 Jul | 1,998 | 0.837 | (0.032) | 0.8 18 | (0.054) | 0.918 | (0.073) | 0.630 | (0.038) |
| Snake | 13 Apr - 06 Jul | 2,844 | 0.950 | (0.029) | 0.754 | (0.040) | 0.797 | (0.048) | 0.571 | (0.026) |
| Imnaha | 13 Apr - 17May | 612 | 0.666 | (0.056) | 0.755 | (0.103) | 0.866 | (0.137) | 0.436 | (0.053) |
| Wild chinook salmon | | | | | | | | | | |
| Salmon | 31 Mar - 16 Jun | 2,913 | 0.788 | (0.017) | 0.752 | (0.028) | 0.879 | (0.039) | 0.521 | (0.019) |
| Clear-water | 05 Apr - 24 Jul | 761 | 0.842 | (0.029) | 0.844 | (0.050) | 0.798 | (0.053) | 0.567 | (0.029) |
| Snake | 13 Apr - 06 Jul | 934 | 0.894 | (0.036) | 0.796 | (0.06 1) | 0.815 | (0.074) | 0.580 | (0.039) |
| Imnaha | 23 Mar - 18 May | 959 | 0.760 | (0.026) | 0.863 | (0.052) | 0.824 | (0.061) | 0.541 | (0.03 1) |
| Hatcher-v steelhead | | | | | | | | | | |
| Salmon | 19 Apr - 16Jun | 2,596 | 0.635 | (0.017) | 0.628 | (0.033) | 0.767 | (0.069) | 0.306 | (0.025) |
| Clearwater | 12 Apr - 08 Jul | 1,250 | 0.777 | (0.016) | 0.802 | (0.028) | 0.769 | (0.046) | 0.479 | (0.027) |
| Snake | 13 Apr - 08 Jul | 3,239 | 0.633 | (0.014) | 0.692 | (0.027) | 0.799 | (0.055) | 0.35 1 | (0.022) |
| Imnaha | 23 Apr - 21 Jun | 2,313 | 0.541 | (0.028) | 0.710 | (0.078) | 1.072 | (0.326) | 0.412 | (0.118) |
| Wild steelhead | | | | | | | | | | |
| Salmon | 02 Apr - 14Jun | 532 | 0.750 | (0.028) | 0.823 | (0.058) | 0.698 | (0.063) | 0.43 1 | (0.03 1) |
| Clearwater | 05 Apr - 08 Jul | 1,297 | 0.882 | (0.0 11) | 0.928 | (0.015) | 0.934 | (0.02 1) | 0.765 | (0.017) |
| Snake | 13 Apr - 05 Jul | 2,840 | 0.836 | (0.011) | 0.835 | (0.021) | 0.738 | (0.026) | 0.515 | (0.015) |
| Imnaha | 21 Apr - 08 Jun | 1,450 | 0.632 | (0.020) | 0.803 | (0.048) | 0.708 | (0.069) | 0.359 | (0.03 1) |

Appendix Table E9. Revised estimates of survival probabilities for juvenile salmonids released from fish traps in Snake River Basin, 1995. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Trap | Release dates | Number released | Release to LGR | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|
| <u>Hatchery chinook salmon</u> | | | | | | | | | | |
| Salmon | 16 Mar - 23 May | 5,077 | 0.802 | (0.012) | 0.899 | (0.024) | 0.872 | (0.033) | 0.628 | (0.020) |
| Clearwater | 21 Mar - 31 May | 2,467 | 0.901 | (0.019) | 0.857 | (0.030) | 1.028 | (0.057) | 0.794 | (0.040) |
| Snake | 31 Mar - 31 May | 3,927 | 0.886 | (0.013) | 0.916 | (0.024) | 0.898 | (0.036) | 0.729 | (0.025) |
| Imnaha | 05 Apr - 28 Apr | 747 | 0.721 | (0.032) | 0.969 | (0.068) | 1.194 | (0.170) | 0.833 | (0.110) |
| <u>Wild chinook salmon</u> | | | | | | | | | | |
| Salmon | 16 Mar - 23 May | 3,937 | 0.863 | (0.011) | 0.912 | (0.019) | 0.994 | (0.035) | 0.782 | (0.025) |
| Clearwater | 21 Mar - 31 May | 1,051 | 0.879 | (0.024) | 0.879 | (0.042) | 1.048 | (0.090) | 0.810 | (0.063) |
| Snake | 31 Mar - 31 May | 2,067 | 0.944 | (0.015) | 0.927 | (0.028) | 0.964 | (0.047) | 0.844 | (0.036) |
| Imnaha | 05 Apr - 14 Jun | 421 | 0.909 | (0.034) | 0.923 | (0.059) | 0.971 | (0.103) | 0.814 | (0.078) |
| <u>Hatchery steelhead</u> | | | | | | | | | | |
| Salmon | 10 Apr - 23 May | 1,555 | 0.882 | (0.013) | 0.890 | (0.025) | 0.963 | (0.055) | 0.756 | (0.040) |
| Clearwater | 08 Apr - 31 May | 867 | 0.903 | (0.015) | 0.918 | (0.034) | 0.998 | (0.081) | 0.827 | (0.062) |
| Snake | 31 Mar-31 May | 2,245 | 0.936 | (0.011) | 0.830 | (0.021) | 0,968 | (0.049) | 0.752 | (0.035) |
| Imnaha | 02 May - 14 Jun | 1,289 | 0.777 | (0.017) | 0.846 | (0.030) | 0.922 | (0.084) | 0.606 | (0.054) |
| <u>Wild steelhead</u> | | | | | | | | | | |
| Salmon | 17 Mar - 23 May | 437 | 0.892 | (0.025) | 0.955 | (0.053) | 0.939 | (0.106) | 0.800 | (0.082) |
| Clearwater | 21 Mar - 31 May | 273 | 0.903 | (0.033) | 0.859 | (0.054) | 0.804 | (0.073) | 0.623 | (0.051) |
| Snake | 31 Mar - 31 May | 1,536 | 0.955 | (0.013) | 0.884 | (0.026) | 0.936 | (0.052) | 0.790 | (0.040) |
| Imnaha | 24 Apr - 14 Jun | 227 | 0.839 | (0.036) | 0.873 | (0.068) | 1.089 | (0.172) | 0.798 | (0.119) |

Appendix Table E 10. Revised estimates of median travel times (days) and median arrival dates for juvenile salmonids released from fish traps in Snake River Basin, 1993. Number of fish used in calculations in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| | | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trap | Release dates | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| Hatchery chinook salmon | | | | | | | | | |
| Salmon | 11 Apr- 12May | 10.5 (1126) | 4.7 (201) | 2.3 (186) | 17.2 (523) | 125.5 (1126) | 128.7 (572) | 129.2 (523) | 135.7 (371) |
| Clear-water | 09 Apr - 04 May | 14.4 (551) | 5.1 (91) | 2.4 (79) | 20.6 (219) | 124.4 (551) | 128.4 (280) | 129.0 (219) | 134.0 (154) |
| Snake | 09 Apr - 16 Jun | 5.4 (1317) | 5.0 (285) | 2.2 (231) | 12.2 (598) | 124.5 (1317) | 127.0 (757) | 127.8 (598) | 132.8 (382) |
| Wild chinook salmon | | | | | | | | | |
| Salmon | 26 Mar - 12 May | 11.3 (1096) | 5.3 (295) | 2.2 (169) | 17.0 (371) | 119.7 (1096) | 121.4 (572) | 125.8 (371) | 126.4 (311) |
| Clearwater | 09 Apr - 29 Jul | 9.1 (130) | 5.5 (28) | 2.5 (27) | 15.3 (63) | 123.1 (132) | 124.5 (70) | 126.4 (63) | 131.5 (42) |
| Snake | 09 Apr - 23 Jul | 5.7 (558) | 5.6 (128) | 2.4 (59) | 13.0 (150) | 130.2 (562) | 135.9 (274) | 134.3 (152) | 136.8 (130) |
| Hatchery steelhead | | | | | | | | | |
| Salmon | 15 Apr - 12May | 6.3 (1196) | 3.9 (481) | 2.0 (229) | 13.0 (422) | 125.4 (1196) | 127.2 (594) | 129.3 (422) | 131.0 (88) |
| Clear-water | 12 Apr - 04 May | 5.6 (SOS) | 5.3 (384) | 2.0 (209) | 12.4 (343) | 121.2 (808) | 125.0 (462) | 127.1 (343) | 130.3 (63) |
| Snake | 13 Apr - 16 Jun | 2.9 (1918) | 3.6 (885) | 2.1 (463) | 8.7 (733) | 127.8 (1918) | 128.8 (1114) | 130.8 (733) | 130.7 (162) |
| Wild steelhead | | | | | | | | | |
| Salmon | 30 Mar - 12 May | 4.2 (573) | 2.4 (208) | 1.7 (120) | 7.3 (227) | 128.2 (573) | 129.6 (280) | 130.6 (227) | 133.0 (43) |
| Clear-water | 09 Apr - 04 May | 3.6 (555) | 3.0 (237) | 1.8 (186) | 7.5 (343) | 122.8 (555) | 125.3 (344) | 127.1 (343) | 129.7 (90) |
| Snake | 09 Apr - 13 May | 2.4 (1969) | 2.4 (731) | 1.8 (462) | 6.1 (915) | 126.5 (1969) | 127.9 (988) | 129.6 (915) | 130.4 (219) |

Appendix Table E11. Revised estimates of median travel times (days) and median arrival dates for juvenile salmonids released from fish traps in Snake River Basin, 1994. Number of fish used in calculations in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| | | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trap | Release dates | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| Hatchery chinook salmon | | | | | | | | | |
| Salmon | 31 Mar- 16 Jun | 12.5 (870) | 5.5 (120) | 3.3 (105) | 20.5 (486) | 126.5 (870) | 135.0 (444) | 133.4 (486) | 141 .1 (792) |
| Clearwater | 0.5 Apr - 11 Jul | 15.6 (497) | 7.3 (75) | 3.7 (54) | 25.6 (306) | 127.2 (497) | 133.8 (270) | 134.4 (306) | 141.5 (521) |
| Snake | 13 Apr - 06 Jul | 7.4 (883) | 5.7 (124) | 3.3 (108) | 16.2 (444) | 126.5 (883) | 132.7 (456) | 132.5 (444) | 138.7 (754) |
| Imnaha | 13 Apr - 17 May | 14.0 (127) | 8.7 (20) | 3.6 (15) | 23.6 (73) | 127.4 (127) | 133.7 (66) | 133.8 (73) | 141.0 (115) |
| Wild chinook salmon | | | | | | | | | |
| Salmon | 31 Mar - 16 Jun | 13.0 (1113) | 4.9 (237) | 3.6 (193) | 21.5 (576) | 116.7 (1113) | 120.5 (525) | 124.5 (576) | 136.5 (652) |
| Clearwater | 05 Apr - 24 Jul | 13.1 (311) | 5.5 (83) | 3.1 (71) | 21.5 (219) | 116.3 (308) | 119.8 (177) | 124.1 (219) | 135.2 (190) |
| Snake | 13 Apr-06Jul | 5.8 (354) | 5.6 (68) | 3.6 (51) | 14.7 (198) | 119.4 (354) | 129.6 (166) | 128.8 (198) | 137.5 (226) |
| Imnaha | 23 Mar- 18 May | 17.2 (348) | 5.2 (82) | 3.2 (63) | 26.3 (216) | 113.2 (348) | 117.4 (196) | 121.1 (216) | 131.4 (225) |
| Hatcher-v steelhead | | | | | | | | | |
| Salmon | 19 Apr - 16Jun | 7.7 (1009) | 5.6 (246) | 3.3 (135) | 15.9 (318) | 128.7 (1009) | 134.7 (414) | 135.0 (318) | 143.5 (161) |
| Clear-water | 12 Apr - 08 Jul | 5.7 (728) | 5.2 (302) | 2.8 (186) | 13.6 (347) | 126.2 (728) | 130.3 (421) | 129.7 (347) | 133.6 (143) |
| Snake | 13 Apr-08 Jul | 4.1 (1314) | 5.0 (388) | 3.0 (215) | 12.8 (484) | 126.5 (1314) | 130.4 (603) | 130.3 (484) | 142.6 (231) |
| Imnaha | 23 Apr - 21 Jun | 11.4 (528) | 6.4 (109) | 3.5 (33) | 29.3 (119) | 148.6 (528) | 149.9 (271) | 172.0 (119) | 168.0 (78) |
| Wild steelhead | | | | | | | | | |
| Salmon | 02 Apr- 14 Jun | 5.2 (260) | 3.4 (91) | 2.3 (55) | 10.9 (140) | 121.1 (260) | 122.9 (135) | 124.5 (140) | 128.8 (80) |
| Clearwater | 05 Apr - 08 Jul | 4.4 (823) | 3.4 (419) | 2.5 (361) | 10.4 (677) | 113.4 (823) | 116.5 (568) | 119.4 (677) | 123.9 (362) |
| Snake | 13 Apr - 05 Jul | 3.3 (1564) | 3.5 (545) | 2.6 (391) | 9.5 (900) | 120.6 (1564) | 124.0 (867) | 124.3 (900) | 129.7 (462) |
| Imnaha | 21 Apr - 08 Jun | 6.6 (543) | 4.0 (154) | 2.7 (94) | 13.5 (242) | 128.1 (543) | 132.6 (284) | 133.2 (242) | 137.4 (109) |

Appendix Table E12. Revised estimates of median travel times (days) and median arrival dates for juvenile salmonids released from fish traps in Snake River Basin, 1995. Number of fish used in calculations in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| | | Median Travel Time (days) | | | | Median Arrival Date (Julian) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trap | Release dates | Rel-LGR | LGR-LGO | LGO-LMO | Rel-LMO | LGR | LGO | LMO | MCN |
| Hatcherv chinook salmon | | | | | | | | | |
| Salmon | 16 Mar - 23 May | 19.8 (1789) | 5.0 (500) | 2.1 (461) | 25.5 (1313) | 123.3 (1789) | 130.3 (1246) | 132.4 (1313) | 134.5 (890) |
| Clearwater | 21 Mar - 31 May | 12.1 (952) | 5.1 (269) | 2.3 (273) | 19.9 (709) | 120.2 (952) | 128.7 (690) | 131.1 (709) | 131.5 (468) |
| Snake | 3 1 Mar - 3 1 May | 8.2 (1634) | 5.0 (497) | 2.2 (431) | 14.7 (1176) | 120.0 (1634) | 126.8 (1137) | 129.5 (1176) | 131.4 (807) |
| Imnaha | 05 Apr - 28 Apr | 16.8 (214) | 6.0 (57) | 2.3 (70) | 26.2 (181) | 122.6 (214) | 129.6 (185) | 132.4 (181) | 134.9 (104) |
| Wild chinook salmon | | | | | | | | | |
| Salmon | 16 Mar - 23 May | 13.3 (1789) | 4.7 (558) | 2.1 (546) | 19.0 (1277) | 120.4 (1789) | 127.0 (1246) | 130.1 (1277) | 130.8 (811) |
| Cleat-water | 21 Mar - 3 1 May | 11.2 (464) | 6.3 (127) | 2.4 (119) | 20.6 (287) | 111.2 (464) | 122.9 (305) | 125.5 (287) | 125.8 (198) |
| Snake | 31 Mar - 3 1 May | 5.4 (1020) | 4.8 (306) | 2.2 (288) | 11.5 (718) | 122.5 (1020) | 130.3 (673) | 132.4 (718) | 132.6 (449) |
| Imnaha | 05 Apr - 14 Jun | 10.5 (184) | 4.7 (65) | 2.1 (64) | 16.8 (145) | 120.1 (184) | 126.3 (145) | 127.7 (145) | 131.1 (90) |
| Hatcherv steelhead | | | | | | | | | |
| Salmon | 10 Apr - 23 May | 6.4 (952) | 3.4 (366) | 2.3 (277) | 13.6 (637) | 125.6 (952) | 130.2 (544) | 132.1 (637) | 136.2 (187) |
| Clearwater | 08 Apr - 31 May | 4.9 (601) | 4.0 (229) | 2.2 (158) | 12.4 (372) | 120.5 (601) | 128.4 (299) | 130.3 (372) | 131.2 (107) |
| Snake | 31 Mar - 31 May | 3.2 (1475) | 3.8 (499) | 2.7 (387) | 10.3 (910) | 123.7 (1475) | 132.4 (732) | 134.7 (910) | 136.2 (237) |
| Imnaha | 02 May - 14Jun | 6.4 (668) | 3.7 (270) | 2.5 (220) | 14.0 (418) | 149.9 (668) | 152.9 (413) | 155.5 (418) | 155.2 (71) |
| Wild steelhead | | | | | | | | | |
| Salmon | 17 Mar- 23 May | 4.5 (253) | 2.4 (101) | 1.6 (81) | 7.9 (185) | 123.3 (253) | 128.5 (157) | 129.8 (185) | 130.4 (59) |
| Clearwater | 21 Mar - 3 1 May | 4.2 (155) | 3.0 (64) | 2.2 (52) | 9.8 (106) | 106.4 (155) | 108.2 (110) | 110.8 (106) | 116.0 (45) |
| Snake | 31 Mar - 3 1 May | 2.5 (963) | 2.7 (360) | 1.8 (300) | 6.7 (642) | 122.5 (963) | 126.3 (555) | 128.3 (642) | 130.0 (225) |
| Imnaha | 24 Apr - 14Jun | 4.9 (129) | 2.7 (46) | 1.9 (40) | 9.6 (84) | 121.3 (129) | 127.5 (72) | 128.5 (84) | 130.4 (37) |

Appendix Table E13. Revised survival estimates for yearling chinook salmon and steelhead released from hatcheries, 1993. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Ch-yearling chinook; St-steelhead; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | | LGR to LGO ($S_{R2}$) | | Release to LGO | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dworshak | Dworshak NFH | Ch | 8 Apr | 1,474 | 0.646 | (0.028) | 0.727 | (0.049) | 0.470 | (0.023) |
| | | | 22 Apr | 1,462 | 0.726 | (0.031) | 0.791 | (0.067) | 0.575 | (0.040) |
| | | | 6 May | 1,446 | 0.836 | (0.063) | 0.606 | (0.075) | 0.507 | (0.044) |
| Dworshak | Dworshak NFH | St | 3 May | 975 | 0.808 | (0.014) | 0.981 | (0.043) | 0.793 | (0.036) |
| Kooskia | Kooskia H | Ch | 19 Apr | 1,171 | 0.689 | (0.047) | 0.662 | (0.084) | 0.456 | (0.044) |
| Lookingglass | Lookingglass H | Ch | 7 Apr | 998 | 0.665 | (0.023) | 0.869 | (0.042) | 0.578 | (0.024) |
| Lookingglass | Imnaha Weir | Ch | 12 Apr | 1,991 | 0.660 | (0.025) | 0.767 | (0.048) | 0.507 | (0.025) |
| McCall | S. Fork Salmon | Ch | 3 Apr | 3,000 | 0.499 | (0.017) | 0.819 | (0.047) | 0.408 | (0.020) |
| McCall | Knox Bridge | Ch | 9 Apr-5 May | 1,513 | 0.552 | (0.028) | 0.729 | (0.052) | 0.403 | (0.021) |
| Rapid River | Rapid River H | Ch | 17 Apr | 2,985 | 0.670 | (0.017) | 0.898 | (0.044) | 0.602 | (0.026) |
| Pahsimeroi | Pahsimeroi Pon | Ch | 14 Apr | 600 | 0.456 | (0.032) | 0.975 | (0.130) | 0.444 | (0.055) |
| Pahsimeroi | Pahsimeroi Pon | St | 19-22 Apr | 600 | 0.683 | (0.023) | 0.891 | (0.057) | 0.609 | (0.040) |

Appendix Table E 13. Continued.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | LGR to LGO ($S_{R2}$) | Release to LGO |
|---|---|---|---|---|---|---|---|
| Sawtooth | Salmon R | Ch | 20 Apr | 799 | 0.255 (0.023) | 1.186 (0.206) | 0.303 (0.050) |
| Sawtooth | E Fork Salmon | Ch | 20 Apr | 350 | 0.177 (0.077) | 1.458 (1.499) | 0.258 (0.230) |
| Weighted average[a] | | Ch | | | ----- | 0.797 (0.027) | ----- |

[a] Weighted average of the independent estimates from releases of yearling chinook salmon, with weights inversely proportional to the respective estimated variances.

Appendix Table E14. Revised survival estimates for yearling chinook salmon and steelhead released from hatcheries, 1994. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Ch-yearling chinook; St-steelhead; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dworshak | Dworshak NFH | Ch | 8 Apr | 5,987 | 0.692 | (0.017) | 0.818 | (0.034) | 0.871 | (0.041) | 0.494 | (0.017) |
| | | | 14 Apr | 1,198 | 0.778 | (0.028) | 0.841 | (0.054) | 0.865 | (0.059) | 0.565 | (0.027) |
| | | | 15 Apr | 1,200 | 0.776 | (0.030) | 0.794 | (0.062) | 0.994 | (0.091) | 0.612 | (0.040) |
| | | | 22 Apr | 5,996 | 0.822 | (0.022) | 0.847 | (0.043) | 0.822 | (0.049) | 0.572 | (0.024) |
| | | | 6 May | 1,993 | 0.815 | (0.029) | 0.837 | (0.043) | 0.910 | (0.056) | 0.621 | (0.031) |
| Dworshak | Dworshak NFH | St | 2-5 May | 1,468 | 0.742 | (0.016) | 0.826 | (0.041) | 0.887 | (0.112) | 0.543 | (0.065) |
| | | | 4-6 May | 2,309 | 0.683 | (0.013) | 0.787 | (0.029) | 0.916 | (0.078) | 0.492 | (0.040) |
| Dworshak | Clear C. and Clear-water R. | St | 22 Apr | 499 | 0.746 | (0.022) | 0.957 | (0.050) | 0.673 | (0.065) | 0.480 | (0.041) |
| Kooskia | Kooskia H | Ch | 18 Apr | 600 | 0.752 | (0.053) | 0.784 | (0.103) | 0.963 | (0.165) | 0.567 | (0.077) |
| Lookingglass | Lookingglass H | Ch | 10 Apr | 1,993 | 0.757 | (0.025) | 0.765 | (0.038) | 0.970 | (0.059) | 0.562 | (0.029) |
| Lookingglass | Imnaha Weir | Ch | 11 Apr | 2,973 | 0.685 | (0.021) | 0.851 | (0.049) | 0.876 | (0.065) | 0.511 | (0.029) |
| McCall | Knox Bridge | Ch | 9-14 Apr | 1,295 | 0.581 | (0.041) | 0.733 | (0.077) | 1.081 | (0.171) | 0.461 | (0.065) |
| | | | 11 Apr” | 1,498 | 0.425 | (0.028) | 0.944 | (0.111) | 0.744 | (0.115) | 0.298 | (0.036) |
| | | | 11 Apr[b] | 1,499 | 0.669 | (0.046) | 0.902 | (0.107) | 0.640 | (0.089) | 0.387 | (0.039) |
| | | | 22-28 Apr | 797 | 0.450 | (0.056) | 0.714 | (0.123) | 0.931 | (0.215) | 0.299 | (0.062) |

Appendix Table E14. Continued.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rapid River | Rapid River H | Ch | 12 Apr[a] | 999 | 0.549 | (0.031) | 0.848 | (0.112) | 0.670 | (0.111) | 0.312 | (0.036) |
| | | | 12 Apr[b] | 990 | 0.512 | (0.039) | 0.781 | (0.130) | 0.811 | (0.184) | 0.324 | (0.056) |
| Pahsimeroi | Pahsimeroi Pon | Ch | 12 Apr | 997 | 0.324 | (0.028) | 0.701 | (0.130) | 0.776 | (0.163) | 0.176 | (0.024) |
| Sawtooth | Sawtooth H | Ch | 8-11 Apr | 2,155 | 0.216 | (0.016) | 0.794 | (0.117) | 0.690 | (0.105) | 0.118 | (0.010) |
| Weighted average[c] | | Ch | | | ----- | | 0.816 | (0.011) | 0.860 | (0.023) | ----- | |

[a] Hand-injected PIT tags.

[b] Auto-injected PIT tags.

[c] Weighted average of the independent estimates from releases of yearling chinook salmon, with weights inversely proportional to the respective estimated variances.

Appendix Table E15. Revised survival estimates for yearling chinook salmon and steelhead released from hatcheries, 1995. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Ch-yearling; chinook; St-steelhead; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | LGR to LGO ($S_{R2}$) | LGO to LMO ($S_{R3}$) | Release to LMO |
|---|---|---|---|---|---|---|---|---|
| Dworshak | Dworshak NFH | Ch | 14 Apr | 799 | 0.838 (0.035) | 0.898 (0.064) | 0.911 (0.094) | 0.685 (0.059) |
| Dworshak | Clear C. and Cleat-water R. | St | 17 Apr | 644 | 0.728 (0.019) | 0.958 (0.054) | 1.055 (0.117) | 0.736 (0.073) |
| Dworshak | Dworshak NFH | St | 24-28 Apr | 4,234 | 0.771 (0.007) | 0.919 (0.014) | 0.961 (0.032) | 0.681 (0.021) |
| Kooskia | Kooskia H | Ch | 12 Apr | 1,201 | 0.787 (0.024) | 0.869 (0.042) | 0.899 (0.061) | 0.615 (0.036) |
| Kooskia | Clear C. | Ch | 12 Apr | 497 | 0.582 (0.045) | 0.784 (0.080) | 1.005 (0.129) | 0.459 (0.054) |
| Lookingglass[a] | Imnaha Weir | Ch | 28 Mar | 2,494 | 0.618 (0.015) | 0.926 (0.037) | 0.908 (0.059) | 0.519 (0.029) |
| | | Ch | 5 Apr | 493 | 0.467 (0.037) | 0.775 (0.092) | 0.864 (0.144) | 0.312 (0.047) |
| | | Ch | 24-26 Apr | 987 | 0.475 (0.032) | 0.839 (0.078) | 0.951 (0.123) | 0.379 (0.043) |
| Lookingglass[b] | Lookingglass H | Ch | 6 Apr | 1,990 | 0.753 (0.018) | 0.925 (0.038) | 0.908 (0.057) | 0.632 (0.035) |
| Lookingglass[c] | Big Canyon | Ch | 21 Apr | 114 | 0.800 (0.055) | 0.876 (0.125) | 0.890 (0.224) | 0.624 (0.137) |
| McCall | Knox Bridge | Ch | 6-7 Apr | 6,298 | 0.523 (0.011) | 0.893 (0.026) | 0.873 (0.036) | 0.408 (0.015) |
| | | | 19 Apr | 800 | 0.472 (0.031) | 0.852 (0.073) | 0.904 (0.113) | 0.364 (0.042) |
| | | | 24 Apr | 400 | 0.469 (0.041) | 0.951 (0.124) | 1.024 (0.288) | 0.456 (0.120) |

Appendix Table E 15. Continued.

| Hatchery | Release site | Sp. | Date | Rel. size | Release to LGR ($S_H$) | | LGR to LGO ($S_{R2}$) | | LGO to LMO ($S_{R3}$) | | Release to LMO | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rapid River | Rapid River H | Ch | 31 Mar[d] | 999 | 0.316 | (0.033) | 0.953 | (0.152) | 0.666 | (0.137) | 0.200 | (0.033) |
| | | | 31 Mar[e] | 990 | 0.697 | (0.023) | 0.927 | (0.047) | 0.899 | (0.066) | 0.580 | (0.038) |
| Rapid River | Hell's Canyon | Ch | 30 Mar | 499 | 0.750 | (0.026) | 0.852 | (0.048) | 0.806 | (0.059) | 0.515 | (0.032) |
| Pahsimeroi | Pahsimeroi Pon | Ch | 12 Apr | 493 | 0.578 | (0.029) | 1.024 | (0.093) | 0.957 | (0.151) | 0.566 | (0.078) |
| Sawtooth | Sawtooth H | Ch | 5-7 Apr | 1,499 | 0.230 | (0.015) | 0.916 | (0.071) | 1.040 | (0.113) | 0.219 | (0.022) |
| Sawtooth | Salmon R and E. Fork Salmon | Ch | 27-28 Mar | 1,289 | 0.087 | (0.013) | 0.999 | (0.233) | 0.699 | (0.188) | 0.061 | (0.012) |
| Weighted average[f] | | Ch | | | ----- | | 0.896 | (0.011) | 0.885 | (0.016) | ----- | |

[a] Imnaha stock.

[b] Rapid River stock.

[c] Irrigon stock.

[d] Hand-injected PIT tags.

[e] Auto-injected PIT tags.

[f] Weighted average of the independent estimates from releases of yearling chinook salmon, with weights inversely proportional to the respective estimated variances.

Bonneville Power Administration

PO Box 3621 Portland, Oregon 97208-3621

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