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The Effect of Bypass Passage on Adult Returns of Salmon and Steelhead: An Analysis of PIT-Tag Data Using the Program ROSTER

Final Report

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Prepared for
the U.S. Army Corps of Engineers, Walla Walla District
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Abstract

Battelle, Pacific Northwest Division, conducted a study for the U.S. Army Corps of Engineers, Walla Walla District, to ascertain whether the juvenile bypass systems at some dams in the Federal Columbia River Power System (FCRPS) may have a detrimental effect on the return rates of adult salmonids, relative to other routes of downstream passage. Battelle investigated the history of bypass operations at five hydropower dams in the FCRPS to determine whether changes in the configuration or operation of bypass systems at these dams was related to adult return rates. Passive integrated transponder (PIT)-tag data were used to identify the history of bypass system use by individual juvenile fish and compare the observed numbers of adults that returned with specific juvenile passage histories to the numbers of adults expected in the absence of any bypass effects. Fish that were never bypassed were found to return at higher than expected rates under the null hypothesis of homogeneous survival. Adult return rates tended to decline the more often a fish was bypassed during outmigration. The perceived bypass effects depended on both dam and stock. Furthermore, preliminary tests of competing hypotheses failed to conclusively explain why bypass at some dams was associated with reduced adult return rates.. These results contribute to the growing understanding of bypass effects and potential causative factors, but important hypotheses will remain unresolved until additional data accrue or focused studies are completed.

Executive Summary

This study evaluated the influence of passage through bypass systems on juvenile salmonids by comparing adult return rates among groups of fish with differing passage histories through the dams of the Federal Columbia River Power System (FCRPS). The analysis relied on passive integrated transponder (PIT)-tag detections to assign fish to passage through a bypass system and, in some cases, through a particular bypass route. Each individual's passage history comprised a series of dams where it was detected, and that history culminated with detection in the adult fish ladder at Lower Granite Dam, denoting adult return. By comparing the adult return rates of groups of fish with different bypass passage histories, it was possible to identify patterns of bypass locations and configurations associated with low adult return rates relative to other passage histories. Bypass systems that are consistently associated with reduced adult return rates may be worthy of further study to identify the mechanisms behind the differences.

Based on the observational data available, we could not distinguish between mechanistic effects of passing through the bypass system and selectivity of the system among fish passing the dam. Thus, we use the term "perceived bypass effect" to describe the relative difference in adult return rate between bypassed and non-bypassed fish.

ES.1 Methods

The primary analysis consisted of testing the hypothesis that non-bypassed fish returned as adults to Lower Granite Dam at higher rates than bypassed fish. We tested this hypothesis using 11 years of PIT-tag data, comparing the observed numbers of adults that returned with specific juvenile passage histories to the numbers of adults expected in the absence of any bypass effects. The expected number of adults for each passage history was estimated using the ROSTER (River-Ocean Survival and Transportation Effects Routine) release-recapture model, which uses the assumption that bypassed and non-bypassed fish have a common probability of survival and adult return. A negative effect of bypass would result in non-bypassed fish consistently producing more adults than expected under the assumption of no bypass effects, while bypassed fish would consistently produce fewer than expected adults. The residuals of the ROSTER model were analyzed to determine whether certain juvenile passage histories were associated with higher (or lower) adult return rates than would be expected by assuming no influence of juvenile passage history. Meta-analysis techniques were used to combine results over multiple release years. In addition to examining model residuals for long-term patterns related to bypass events, we also examined residuals for patterns relating to changes in bypass operations or through particular bypass routes. Supplemental model-independent analyses were also performed, comparing adult return rates across detection histories upstream of McNary Dam, conditional on bypass at McNary.

One working hypothesis suggests that perceived bypass effects are due to smaller fish being more likely to be bypassed and having lower survival than larger fish (Zabel et al. 2005). If this is the case, then a perceived bypass effect would be the result of differential detection (capture) probabilities, rather than a deleterious effect of the bypass system itself. On the other hand, if both small and large fish are being bypassed in comparable numbers, then it is more likely that any perceived bypass effects (if they exist) are the cause of the bypass system itself. Thus, it is important to determine whether fish size is associated with bypass probabilities. We addressed this question by relating the probability of bypass to fish length at tagging, the only measure of fish size we had available.

ES.2 Results

The juvenile/adult PIT-tag meta-analysis using Program ROSTER found strong evidence that bypass events are associated with reduced adult return rates of Chinook salmon and steelhead smolts. In general, fish that migrated through the hydrosystem without detection in any bypass system had higher adult return rates than fish that were bypassed at least once.

For yearling Chinook salmon, smolts with one or more bypass events tended to have lower adult return rates than non-bypassed smolts. With multiple bypass events, the adult return rate of yearling Chinook salmon declined further. Steelhead smolts that were bypassed at only a single dam exhibited no noticeable decrease in adult returns. However, two or more bypass events for steelhead smolts reduced the rate of adult returns. In addition to simple perceived effects of bypass at individual dams, some pairs of dams appeared to have synergistic effects, where the effect on adult returns from joint detection at the two dams was more than the sum of the perceived effects of bypass at the two dams separately.

ES.2.1 Dam-Specific Results

The PIT-tag analyses found little evidence that spring or summer Chinook salmon bypassed at Lower Granite Dam returned at lower rates than other inriver fish, even if they were also bypassed at other dams downstream (Table ES.1). For steelhead, however, bypass at Lower Granite combined with bypass at downstream dams was associated with reduced adult return rates compared to other inriver steelhead. Spring/summer Chinook salmon that were bypassed at Lower Granite and then transported from Little Goose Dam tended to return as adults at lower than expected rates. Lower than expected adult returns for summer Chinook salmon and steelhead detected in the bypass systems at both Lower Granite and McNary dams suggest a negative synergistic effect of that combination of bypass systems, that is, fewer adult returns than would have been expected from the perceived effects of bypass at those two dams singly. This suggests that there may be a weak effect of bypass at Lower Granite Dam that is exhibited only if bypassed fish experience other bypass or stressful experiences downstream. There was no compelling evidence that smaller fish were more likely to enter the bypass system at Lower Granite Dam than larger fish.

Bypass at Little Goose Dam was consistently associated with a reduced adult return rate compared to other inriver smolts for both spring and summer Chinook salmon, regardless of whether they were detected elsewhere downstream (Table ES.1). On average, between 27% and 33% fewer adults than expected were detected from the groups of PIT-tagged Chinook smolts that were bypassed at Little Goose Dam over the 11 years of the study. Lower than expected adult returns for spring Chinook salmon detected in the bypass systems at both Little Goose and Bonneville dams suggest a negative synergistic effect of that combination of bypass systems, indicative of a possible latent effect of bypass at Little Goose. Steelhead bypassed at Little Goose demonstrated no obvious reduction in adult returns compared to other inriver fish. The bypass system at Little Goose underwent an operational change in 2002, when wider conveyance pipes and a new three-way diversion-by-code gate were installed. Perceived bypass effects did not appear to diminish significantly after these modifications.

Table ES.1. Summary of Dam-Specific Findings by Stock. A synergistic effect of bypass at a pair of dams implies that fewer adults returned from joint bypass at those dams than expected from single-dam effects (paired dam is identified).

		Dam					
		Lower Granite	Little Goose	Lower Monumental	McNary	John Day*	Bonneville*
Negative Perceived Bypass Effect	Bypassed nowhere else		SP SU	SP ST		SU	
	Also bypassed elsewhere	ST	SP SU	SP SU ST	SP SU ST	SP SU	SP
	Synergistic effect with other dam	SU: MCN ST: LGS, MCN	SP: BON ST: LGR		SP: BON SU:LGR ST: LGR, JDA	ST: MCN	SP: LGS, MCN
Significant changes with bypass operations		na	None	na	None	na	None*
Significant effect of bypass route		na	na	na	None*	na	None*

SP = Spring Chinook; SU = Summer Chinook; ST = Steelhead
BON = Bonneville Dam; JDA = John Day Dam; LGR = Lower Granite Dam; LGS= Little Goose Dam; LMN = Lower Monumental Dam; MCN = McNary Dam.
* = limited data available (low power to detect an effect).
na = not tested for lack of data.

Bypass at Lower Monumental Dam appeared to be associated with reduced adult return rates for both spring Chinook and steelhead, with a slightly less obvious effect on summer Chinook (Table ES.1). Spring Chinook salmon that were detected at Lower Monumental produced from 2% to 36% fewer adults than expected on average, while summer Chinook detected at Lower Monumental produced an average of 2% to 28% fewer adults than expected from other inriver fish, depending on where else the smolts were detected downstream. Steelhead detected at Lower Monumental produced from 11% to 41% fewer adults than expected.

Ice Harbor Dam had juvenile PIT-tag detections beginning in 2005. With only 2 years of data available, there was low power to detect any possible effect of bypass at Ice Harbor on adult returns for both Chinook and steelhead. Furthermore, because nearly all fish that were bypassed at Ice Harbor passed through primary ("full-flow") bypass, it was not possible to compare primary and facility bypass.

Fish that were bypassed at McNary Dam tended to return as adults at lower than expected rates, but only if they were also detected at another dam (Table ES.1). In particular, bypass at McNary combined with bypass at either Lower Monumental or John Day consistently produced fewer returning adults than expected, for all three stocks. Bypass at McNary alone did not appear to reduce the number of returning adults. Lower than expected adult returns for spring Chinook salmon detected in the bypass routes at both McNary and Bonneville dams, and for steelhead detected in the bypass routes at both McNary and John Day dams, indicate a negative synergistic effect of those combinations of bypass systems. This suggests that there may be a possible latent effect of bypass at McNary that requires other potentially stressful experiences in order to be exhibited. The return-to-river lines at the McNary bypass system were replaced in 2002, but did not appear to result in increased adult returns. It was also not clear that fish length was related to the probability of being bypassed at McNary. Primary bypass became available at McNary Dam in 2003, but there was no evidence that fish using the primary bypass had higher adult return rates than fish that used the facility bypass. Only 1 year of data was available to compare adult returns of fish that passed through the sort-by-code holding tank with those that passed through the facility bypass directly, and there was no significant difference in adult returns between these two routes.

Bypass at John Day Dam appeared to be associated with reduced adult return rates for both spring and summer Chinook salmon, in particular if the fish had been bypassed previously at an upriver dam (Table ES.1). Steelhead did not appear to return at lower rates after passing John Day through the bypass. However, because John Day is relatively far downriver from the release sites and tends to have low detection probability (<0.20 over all release groups), few fish were detected at John Day over the duration of the study, and so the power to detect a bypass effect was relatively low compared to the dams further upriver. Chinook that were detected at John Day produced from 10% to 42% fewer adults than expected, depending on where else the fish were detected.

There was little evidence from the PIT-tag data of a bypass effect at Bonneville Dam for any stock (Table ES.1). Chinook that were detected both at Bonneville and another upstream dam (i.e., Little Goose, Lower Monumental, or McNary) tended to return in fewer numbers than expected. However, it should be noted that with relatively low detection numbers at Bonneville and the resulting low expected numbers of adults, there was low statistical power to detect an effect on adult returns at Bonneville, especially for steelhead. The bypass system operations at Bonneville changed radically in 2000, when the bypass system at the first powerhouse was discontinued, and operational priority was switched to the second powerhouse. There was no evidence of improved adult return rates after that change, although once again there was low power to detect an effect. In 2006, PIT-tag detection became available in both

the primary bypass and the corner collector at Bonneville Dam second powerhouse (B2CC). Based on this single year of juvenile detection data, there was no significant difference in adult return rates between fish that passed via B2CC and those that passed via the facility bypass.

ES.2.2 Size-Selectivity of the Bypass System

Analysis of hatchery releases of spring Chinook salmon found no consistent evidence that bypass systems were size-selective for smaller fish. Although meta-analyses at Little Goose, Lower Monumental, McNary, and John Day dams found that smaller fish were on average more likely to be detected or bypassed ($P<0.0001$), individual tests were equivocal. A total of 50 tests found smaller fish had a significantly lower probability of being bypassed, while another 36 tests found smaller fish had a significantly higher probability of being bypassed ($\alpha = 0.05$). While size-selectivity may play some role in the perceived bypass effects, its exact role remains unclear. The long lag time between fish being PIT-tagged at the hatchery and subsequent detection events reduces the ability of any analysis to assess size-related bypass effects using the data available at this time.

ES.2.3 Statistical Power

The statistical power of the tests performed to assess perceived bypass effects on adult returns increases with more years of data, larger numbers of expected adult returns, and larger reductions in the adult return rate (i.e., larger effects). Reasonable statistical power ($1-\beta \geq 0.70$) was attainable for effect sizes $\geq 30\%$ and expected number of adults ≥ 7 ($\alpha=0.05$, 1-tailed). While expected adult returns of ≥ 7 were commonplace for spring Chinook salmon and for capture histories with detections at upper river dams, this threshold was not as often attained for steelhead or summer Chinook salmon, capture histories with multiple dam detections, or bypass events at Bonneville Dam. Low statistical power may explain why certain tests were nonsignificant, as well as why comparisons of adult return rates between operational eras or alternative bypass routes were generally nonsignificant.

ES.3 Discussion

The pattern we observed of reduced adult return rates for smolts that were bypassed one or more times has been observed by other researchers (e.g., Bouwes et al. 1999; Sandford and Smith 2002). These researchers observed that the smolt-to-adult return rate (SAR) of inriver smolts decreased as the number of bypass events increased. Our results go further and pinpoint the dams with bypass systems that are consistently associated with lower than expected adult return rates. We also identified the dams with bypass systems that appear to have no effect on Snake River salmonids. Furthermore, we established that different species and stocks have different patterns of post-bypass survival at different dams. Although we cannot identify the reason for the reduction in adult returns for bypassed fish, our results suggest future investigations are warranted.

ES.3.1 Latent vs. Direct Effects

Our modeling results detected a reduced adult return rate for smolts that passed through some bypass systems. However, it is not clear whether the associated mortality occurred immediately after dam passage (i.e., perceived direct effect) or farther downstream (i.e., perceived latent effect). The downstream migration through the hydrosystem has previously been compared between PIT-tagged smolts that have passed a dam through the bypass system and those that passed through a non-bypass

route. Smith et al. (1998) found a lack of mixing between bypassed and non-bypassed smolts during periods of high spill, with bypassed smolts taking longer to pass the dam than other fish. However, no significant difference in survival was observed as a result (Smith et al. 1998). Skalski et al. (1998) also found no difference in subsequent juvenile survival and detection between bypassed and non-bypassed smolts. However, Skalski et al. (1998) focused on survival only to Little Goose Dam, and Smith et al. (1998) focused on survival only to Lower Monumental Dam. If differences in survival occurred only after passing the last Snake River dam or entering the estuary or ocean, they would not have been observed in their analyses, but would be detectable using our approach focusing on adult return rates.

The synergistic effects we observed, reflecting a larger reduction in the adult return rate from joint bypass at some pairs of dams than expected from bypass at either dam alone, suggest that there may be a latent or delayed effect of bypass. This may occur if, for example, bypass at an upstream dam produces injury or stress that, while not lethal by itself, may become lethal when combined with the additional stress of bypass at a downstream dam. This hypothesis for a latent bypass effect has been suggested by Budy et al. (2002). Our supplemental model-independent analysis, comparing adult return rates from McNary Dam to Lower Granite Dam across bypass histories upstream of McNary, also demonstrated possible latent effects of bypass. Thus, it appears that at least some of the mortality associated with bypass occurs well after the bypass event. However, our analysis was not intended to determine whether it occurs within the hydrosystem or in the ocean.

ES.3.2 Hypotheses to Explain Results

Several competing hypotheses have been proposed to explain our results. Injury from encounters with fish guidance screens has been reported (Coutant and Whitney 2000), and Muir et al. (2001) observed higher relative survival through spill bays than through bypass systems. However, Marmorek and Peters (1998) found no difference in survival between the spillway and the bypass system. Furthermore, some non-bypassed fish pass through the turbines, which are well documented to have lower survival rates than the bypass system (Marmorek and Peters 1998; Muir et al. 2001). However, small differences in survival during dam passage through the various routes are unlikely to explain all of the differences we observed in adult returns.

Differences in survival soon after dam passage may be related to encounters with predators, affected by factors such as travel time past a dam or the location of the bypass outfall. As mentioned above, downstream differences in survival may be caused by stress associated with the bypass system, which in turn may increase disease incidence or impair reaction time and the ability to evade predators (Budy et al. 2002). None of these possibilities was distinguishable using the available PIT-tag data.

Another possible explanation for the survival differences we observed between bypassed and non-bypassed fish is a selectivity of the bypass system. This hypothesis is that fish using the bypass system tend to be smaller or weaker than fish that pass using other routes (Zabel et al. 2005). Thus, the observed survival differences reflect the inherent lower survival of fish likely to use the bypass system rather than a mechanistic impact of the bypass system. Our analysis of length-at-tagging data in relation to detection (i.e., bypass) probability was inconclusive, with a possible relationship apparent for some release groups and some dams but not for others. This contrasts with Zabel et al. (2005), who found more consistent evidence that smaller fish have a higher detection probability than larger fish at Little Goose and Lower Monumental dams. This difference in results may be partially explained by differences in the timing of tagging, measurement, and release of the study fish. In the Zabel et al. analysis (2005), fish were tagged, measured, and released shortly thereafter at Lower Granite Dam. The fish in our analyses were tagged at

hatcheries and released weeks or months later, upstream of Lower Granite. Consequently, variation in fish growth between the time of tagging and migration may have obscured any regression relationship between fish size and the probability of detection that we may otherwise have seen.

Zabel et al. (2005) examined the relationship between fork length and detection probability at Little Goose and Lower Monumental dams for eight release groups of wild or hatchery spring/summer Chinook salmon or steelhead, released from 1998 to 2002. Only two of these release groups had analogues in our study: the 1998 and 1999 release groups of hatchery spring/summer Chinook salmon. For these two release groups, we observed a significant negative relationship between fork length at tagging and detection probability at both Little Goose and Lower Monumental. Thus, in the cases where direct comparison was possible, our findings agreed with Zabel et al. (2005). However, in addition to finding the negative relationships between length and detection at Little Goose and Lower Monumental in 1998 and 1999, we also observed significant positive relationships at these dams in other years (e.g., 2002). Furthermore, we observed significant positive relationships between length and detection at both Lower Granite and McNary dams in 1998 and 1999. Thus, it appears that making inferences from only a few dams and a few years may be inadequate. Instead, the variability in the relationship between fish length and detection probability that we observed suggests that any relationship between fish size and bypass entry is complicated by other, unknown factors.

It may be worthwhile to investigate the selectivity of the bypass system further using data on fish condition that are taken at the time of migration. In addition to fish size, the condition factor (K), degree of smolting, and appearance of injury or disease may be important factors in determining the passage route used at a dam. These data should be taken at the time of dam passage, if possible.

A second hypothesis unrelated to mechanistic bypass effects is that there is dependency in route selection at the various dams. This hypothesis holds that some fish are "bypass-oriented," while others are "spillway-oriented" or "turbine-oriented." With some fish inherently more likely than others to be detected at any dam, the release-recapture model may produce residuals similar to those we observed from the ROSTER model even if survival does not vary among fish oriented to different passage routes. We tested this hypothesis in two ways. First, we tested it directly using Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic-tag data from yearling Chinook smolts and steelhead migrating past John Day and Bonneville dams in 2008. The acoustic-tag detections provided detailed information about passage routes used at both dams. We found no evidence of route dependency ($P \geq 0.1721$). We also tested the hypothesis of route dependency indirectly in our model-independent analysis, comparing adult return rates from McNary to Lower Granite across upstream juvenile detection histories. This assumption-free approach would not be affected by route dependency, yet it produced results similar to our model-based results. Thus, it does not appear that route dependency explains our results. However, our analyses into this question were limited in scope, and it may be worthwhile to investigate this question further using active tags. Such an investigation could shed light both on the question of route dependency and on the question of selectivity of the various passage routes.

ES.3.3 Scope of Investigation

Interpretation of the results presented in this report must necessarily be limited by the scope of our investigation. As stated above, our objective was to determine whether bypassed smolts returned at lower rates than non-bypassed smolts. The limitations of the available data prevented us from being able to determine whether reduced adult return rates might be due to particular aspects of the bypass system (e.g., flow rate within the bypass system) or to dam operating conditions (e.g., spillway conditions or

turbine outages). Similarly, although we can determine whether bypassed fish have reduced adult return rates compared to non-bypassed fish, we cannot definitively distinguish between reductions caused by passing through the bypass system and lower survival of bypassed fish caused by selectivity of the bypass system. Thus, any "bypass effects" we observed were more correctly termed "perceived bypass effects" because we cannot attribute them directly to the bypass system.

Because we were asked to assess possible bypass effects at the Snake River dams, including Lower Granite Dam, we used release groups of Snake River fish tagged and released upstream of Lower Granite. Furthermore, because the ROSTER model is inappropriate for use with juveniles that cease migrating prior to entering the ocean and remain within the hydrosystem, we omitted subyearling Chinook salmon from our analysis, and focused instead on yearling Chinook salmon and steelhead. The patterns of residuals we observed demonstrated that different stocks and species may experience different (perceived) bypass effects at the same dam. Thus, it would be inappropriate to make inferences from our results either to Snake River populations not studied here, or to populations from other regions, such as the Mid-Columbia or John Day rivers.

One complication in interpreting results of any tagging study is the difference in experiences between tagged and untagged individuals. PIT-tagged and untagged salmon smolts from the Snake River tend to experience different juvenile migrations through the hydrosystem. Most untagged smolts that enter the bypass systems at Lower Granite, Little Goose, or Lower Monumental dams are collected for transportation at those dams, and travel through the remainder of the hydrosystem in a barge or truck. PIT-tagged fish, on the other hand, are routinely returned to the river from the bypass systems at these dams, except for those diverted to transport for a transportation study. Thus, PIT-tagged fish may be returned to the river throughout the migration season, while untagged fish are returned to the river only when transportation is not operational, generally early in the season. If bypass effects have a seasonal component, then the perceived effects observed for PIT-tagged fish may not be applicable to untagged fish. Similarly, if post-bypass survival depends on the number of fish being bypassed (i.e., either attracting or swamping predators), then untagged fish may have different adult return rates after bypass than most PIT-tagged fish.

These are valid concerns that apply not just to our assessment of bypass effects, but to all tagging studies using PIT-tagged fish passing the Snake River dams. As long as tagged and untagged fish have different experiences, there will be uncertainty in making inferences from tagged fish to untagged fish. This is also true for the survival studies that are regularly performed to monitor juvenile survival through the hydrosystem. However, it is not practical to study either hydrosystem survival or potential bypass effects using untagged fish. Thus, we must rely on tagged fish while also bearing in mind the differences between tagged and untagged smolts.

Another factor in interpreting results is the statistical power available to detect potential bypass effects. The power to detect a difference in adult return rates between bypassed and non-bypassed fish was highest for the upstream dams where the greatest number of tagged fish were available for detection. This translated into decreased power to detect potential bypass effects downriver at dams such as Bonneville and John Day. Thus, the fact that we did not find a perceived bypass effect at Bonneville may be related to the low number of PIT-tag detections at that location. To adequately assess bypass effects at Bonneville with PIT tags, a carefully designed study would require releases of PIT-tagged fish either at Bonneville or at one of the nearby dams upriver to ensure sufficient numbers of fish detected in the bypass system at Bonneville.

An alternative approach to assessing bypass effects at downriver dams is to use active tags such as acoustic-telemetry tags. Active tags have the benefit of providing detailed route information not only through the bypass system but also through other passage routes. This allows researchers to compare survival in the river after passage through the bypass route to survival after passage over the spillway, for example, without having to pool the spillway and turbine passage routes. Also, the flexibility in receiver placement for active tags enables assessment of relatively short-term survival effects, rather than the long-term effects on adult returns observable with PIT tags. This ability to detect differences in short-term survival, coupled with detection probabilities approaching 100%, boosts the power to detect possible bypass effects, especially for downstream dams. On the other hand, PIT tags are more suitable for exploring long-term survival differences.

McMichael et al. (2010) used double tagging with PIT and JSATS acoustic tags to measure survival from Bonneville Dam through the estuary to the mouth of the Columbia River, and were able to relate survival to passage routes at John Day and Bonneville dams. In particular, they found significantly higher survival through the estuary for juvenile steelhead that passed John Day through the deep spill route and Bonneville through the B2CC compared to steelhead that passed both dams through the juvenile bypass systems. The higher statistical power of that study exemplifies the benefits of using a combination of tagging technologies to study complicated questions such as bypass effects.

Another consequence of relying only on PIT tags is that large release groups were necessary to achieve reasonable statistical power. This study focused on hatchery fish because of the relatively large release groups available compared to wild fish. Because of the smaller releases of tagged wild fish, only the largest survival differences would be reliably detectable for wild fish, and only for the common juvenile detection histories. As more years of PIT-tag data from wild stocks become available, it will become easier to detect some survival differences for bypassed smolts, but it will remain difficult to detect small effects.

ES.3.4 Outstanding Questions

Some gaps in the analysis remain. Certain bypass routes are either unmonitored by PIT-tag detectors or only recently monitored, with incomplete adult return data available at the time of analysis. Primary bypass is one such route. In addition, more information is needed about the condition of migrating smolts as they approach the dam, in order to separate true bypass effects from selectivity of the bypass system. One glaring omission is the ability to compare bypassed fish with those passing through turbines. While the bypass system at some dams may not be benign compared to the spillway, it is likely to be superior to the alternative of turbine passage. However, PIT-tag data are currently incapable of distinguishing whether fish passed via turbine or spillway. The biological and managerial consequences of mortality associated with bypass must be interpreted in the context of hydroproject operations that include spillway, bypass, and turbine passage mortality. The best measurement of this integrated response is the overall SAR that takes all passage options and their relative proportions into account.

ES.4 Recommendations and Management Implications

This study related differences in adult returns to smolt passage through the bypass systems in the FCRPS. We compared observed adult return rates with those expected under the null hypothesis of no bypass effects. We found fish that were never bypassed returned at higher than expected rates under the null hypothesis of homogeneous survival. Furthermore, we found that adult return rates tended to decline

the more often a fish was bypassed during outmigration. In some cases, there also appeared to be a significant synergistic effect of multiple bypass experiences, suggesting a latent effect of bypass. We also demonstrated that different stocks react differently to bypass at the same dam, and performed preliminary tests of competing hypotheses that may explain why fish that were bypassed at some dams tend to have reduced adult return rates compared to non-bypassed fish. However, there is more work to be done to address the question of bypass effects.

Our study used Snake River fish to study the possibility of bypass effects at the Snake River dams, as well as downstream. The result of using Snake River fish was that most of our detections occurred at the Snake River dams, with relatively few detections at McNary, John Day, and Bonneville dams. Consequently, we had low statistical power to detect any but the largest potential bypass effects at the downstream dams, where bypass is the main alternative to turbine passage. Bypass at these dams may be further studied using PIT-tagged fish from the Mid-Columbia, or using fish tagged and released downstream from Lower Granite Dam.

One limitation of our study was imposed by limitations in the PIT-tag detections at some dams. Over the past decade, more and more PIT-tag detectors have been installed throughout the hydrosystem, and detailed data are available on bypass passage at most dams. However, additional information is needed at some dams. For example, at Lower Monumental Dam, fish coming from the holding tanks cannot be distinguished from those exiting the bypass system from other routes, while at John Day Dam, fish coming directly from the sort-by-code separator cannot be distinguished from those exiting the sample room. Although PIT-tag detection has recently been implemented in the full-flow bypass at Ice Harbor Dam, very few fish have been detected compared to detections at other dams.

This study used PIT-tag data to focus on long-term survival differences between bypassed and non-bypassed inriver fish. A complementary study would use acoustic tags to study short-term, near-field effects on survival of passage through different routes (e.g., McMichael et al. 2010). Depending on only a single tag technology limits the study results. PIT-tag data permit assessment of overall survival differences, both near- and far-field, but at a coarser level of treatment. Acoustic-tag data permit comparison of finer-scale passage histories, but only for near-field effects. Both types of information should be used in a comprehensive analysis to identify sources of mortality that might be mitigated to improve overall adult return rates. This report should be viewed as just one step in that overall assessment process.

The mechanism behind the perceived bypass effects identified by this study should be investigated further. It is not clear whether the bypass systems themselves are causing reduced adult return rates at some dams, or whether it is the selectivity of the bypass system or dependency in route selection among individual fish that are producing our results. More work is needed to clarify these issues. Active tags may be used to study selectivity and route dependency, as well as short-term survival differences across the various passage routes. Releases made directly into various routes may be used to distinguish between the selectivity of the bypass system or other routes, and true effects of passage routes on subsequent survival.

The results presented in this report indicate where additional work should be focused. In particular, bypass at Lower Granite Dam should be studied further for hatchery-raised steelhead, while bypass at Little Goose Dam should be studied further for hatchery-raised yearling Chinook. Additional years of PIT-tag data may shed light on possible bypass effects at Lower Monumental and McNary dams for

Snake River fish. PIT-tag data from Mid-Columbia fish may be necessary to study potential bypass effects at the downstream dams on the Columbia River. Active tags may be used to study short-term bypass effects, complementing the long-term analysis available with PIT tags.

A glaring omission in this analysis was the ability to compare bypassed fish with those passing through turbines. There is an old adage, "getting old beats the alternative." While some bypass systems may not be benign compared to the spillway, they likely beat the alternative of turbine passage. However, PIT-tag data are incapable of providing that comparison. The biological and managerial consequences of bypass mortality must be interpreted in the context of hydroproject operation that includes spillway, bypass, and turbine passage mortality. The best measurement of this integrated response is the overall SAR that takes all passage options and their relative proportions into account.

Abbreviations and Acronyms

ANOVA	analysis of variance
B2CC	Bonneville Dam powerhouse 2 corner collector
BGS	behavioral guidance structure
CJS	Cormack-Jolly-Seber
ESBS	extended-length submersible bar screen
FCRPS	Federal Columbia River Power System
JBS	juvenile bypass system
JFF	juvenile fish facility
JSATS	Juvenile Salmon Acoustic Telemetry System
mm	millimeter(s)
MSL	mean sea level
PIT	passive integrated transponder
PTAGIS	PIT Tag Information System
RSW	removable spillway weir
ROSTER	River-Ocean Survival and Transportation Effects Routine
SAR	smolt-to-adult return
SBC	surface bypass and collector
SbyC	sort-by-code
STS	submersible traveling screen
SURPH	Survival Under Proportional Hazards
SWI	simulated wells intake
VBS	vertical barrier screen

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1.0 Introduction

Each year, large numbers of juvenile salmonids pass the eight hydropower projects in the Federal Columbia River Power System (FCRPS) on the lower Snake and Columbia rivers. Seven of these hydropower dams include juvenile bypass systems that divert juvenile salmonids away from the turbines and return them to the river downstream of the dam. Each juvenile bypass system has a unique history and a configuration, tailored to the design of the dam, as well as the river geomorphology and hydrology at the dam. With so many salmonids passing through the FCRPS annually, the configuration of the bypass systems and the performance of salmonids after passing through the bypass systems may influence overall smolt-to-adult return rates. There is concern that the bypass systems at some dams may have a detrimental effect on adult return rates. The purpose of the study reported herein was to investigate the history of bypass operations at the hydropower dams in the FCRPS, and to determine the extent to which passage through the bypass systems at these dams may be related to adult return rates. Battelle summarized the history of changes in the configuration or operation of bypass systems. The University of Washington was contracted by Battelle to model adult return rates and evaluate differences relative to juvenile passage histories. The Corps of Engineers, Walla Walla District (USACE), funded Battelle to do the study and contributed much information on history of the the bypass systems.

1.1 Purpose and Scope

Several researchers have previously observed lower SAR rates for salmonids that pass dams through the bypass system than for other inriver, non-bypassed fish (e.g., Sandford and Smith 2002; Schaller et al. 2007). It is unclear whether this perceived “bypass effect” is present across multiple years and for all dams, and whether it is influenced by structural modifications at the dams. Our primary objective in this study was to determine the extent of possible bypass effects within the FCRPS on adult return rates. Detections of salmonid smolts tagged with passive integrated transponder (PIT) tags within the bypass systems were used to indicate bypass, and detection within the adult fish ladder at Lower Granite Dam indicated adult return. We used a migratory life-cycle release-recapture model to look for evidence that bypassed smolts consistently had a lower adult return rate than non-bypassed, inriver smolts. We explored whether the number of bypass events a smolt experiences is related to the adult return rate, and also whether bypass at individual dams is consistently related to adult return rate. Changes were made both to the bypass systems throughout the study period, and to non-bypass routes. Thus, we also explored whether perceived bypass effects were reduced by structural modifications to the bypass systems. Finally, we investigated whether particular bypass routes at dams were associated with higher adult return rates than other routes. In all cases, the emphasis was on characterizing patterns of perceived bypass effects across juvenile migration years, rather than identifying small-scale, single-year anomalies.

In addition to uncertainty about the extent of possible bypass effects, the mechanism behind the perceived bypass effect is not well understood. One hypothesis is that passing through the bypass causes stress to migrating juvenile salmonids, resulting in lowered long-term survival. An alternative hypothesis is that fish that enter the bypass systems are generally smaller or weaker than fish that pass dams via other routes, such that bypassed fish have inherently lower survival than non-bypassed fish. This hypothesis implies that what may be perceived as a bypass effect on survival is actually a reflection of the fact that bypassed fish are not a random sample of the fish passing the dam (Zabel et al. 2005). In addition to looking for patterns of perceived bypass effects on adult return rates, we also explored whether fish

condition, measured by fish length at tagging, was consistently related to the probability of bypass among fish that arrived at the dam, and in particular, whether smaller fish were more likely to enter the bypass system than larger fish.

Our overall objective was to determine whether juvenile bypass has a negative effect on adult return rates relative to non-bypass routes, so we focused primarily on whether bypass could be associated with lower adult return rates, with less attention paid to positive effects. Furthermore, because our objective included exploring bypass effects at Lower Granite Dam, it was necessary to use data that indicated bypass at Lower Granite. Thus, we used PIT-tag data only from fish tagged and released upstream of Lower Granite Dam. These fish were generally not part of a planned bypass study, but were tagged and released for other reasons, with the majority tagged as part of the Comparative Survival Study (Schaller et al. 2007). The result is that the detection data available to us were opportunistic data that allowed identification of adult return patterns associated with bypass history, but did not allow us to differentiate between a true mechanistic effect of passing through the bypass system and selectivity of the bypass system. Thus, we can make inference only about perceived bypass effects on adult returns, rather than the actual causes of those perceived effects.

A second limitation of any sort of analysis such as this is the availability of PIT-tag detections. The dual phenomena of smolt inriver mortality and removal for transport mean that most of the PIT-tag detections available to us were from dams on the Snake River. With fewer detections available at John Day and Bonneville dams, we had less statistical power to detect the perceived effects of bypass at those dams. Thus, most of our analysis necessarily focused on the transport dams. The availability of PIT-tag detections also depended on the PIT-tag detection system at each dam. PIT-tag detection within the Ice Harbor Dam bypass system became available only in 2005, and even then, very few fish were detected there. For these reasons, Ice Harbor Dam was excluded from most analyses. Analysis of individual routes through the bypass system at a dam required being able to distinguish among those routes using PIT-tag coil detections. At some dams, routes of passage could not be distinguished from each other, or could be identified only for later release years. Furthermore, comparisons of routes depended on observing enough fish using each route, which meant that lesser-used routes could typically not be analyzed alone.

This type of large-scale analysis of detection data over multiple life stages requires large quantities of data. To find large enough release groups of tagged smolts, we used annual release groups of hatchery fish, pooled across the Snake River Basin upstream of Lower Granite Dam. Release groups of the necessary size were available starting in 1996. Complete adult returns were available through the 2006 release groups by the time of analysis, so our results are based on 11 years of migration data (1996–2006).

1.2 Report Contents and Organization

This report is divided into several sections. Section 2.0 gives a history of the juvenile bypass systems at each dam passed by juvenile salmonids migrating from the Snake River Basin, from Lower Granite Dam to Bonneville Dam. The configuration of each of the bypass systems and major modifications are described. Section 3.0 presents our analysis of the relationship between passing through the bypass systems and routes and adult return rate to Lower Granite Dam, including a discussion of the statistical power available to detect effects. Section 4.0 presents our conclusions, and Section 5.0 contains a discussion of our findings. References are listed in Section 6.0, and extra details about the data and analyses are provided in the appendices (A–E).

2.0 Bypass System Configurations and Changes Through Time

Juvenile fish bypass systems have been developed and installed at most dams in the FCRPS in an effort to divert migrants away from turbine passage and provide a passage route with higher survival than passage through turbines. In addition to providing an alternate passage route, these bypass systems provide a way to collect fish for sampling or barging downstream. Although bypass systems share many characteristics, differences in how these systems are configured or operated may influence the conditions fish experience. This section first describes the major types of bypass passage that are possible, then describes each bypass system, and notes major changes to those systems through time.

When juvenile salmon arrive at the forebay of a dam, dam structures and water flow can influence their route of passage to the tailrace side of the dam. At least four main types of passage route exist: bypass, turbine, spillway, and surface outlet. The bypass route is intended to intercept downstream migrating juvenile salmonids as they approach the turbine intakes from the forebay (upstream) side of the dam. Upon entering the turbine intakes, fish travelling in the upper portion of the water column encounter the guidance screens installed in the upper portion of the intake and are guided into the JBS (Figure 2.1). Screens divert water and fish into a gatewell slot that has been modified for fish passage by the addition of a vertical barrier screen (VBS). The VBS allows some of the water entering the gatewell to return to the turbine intake, but retains fish in the gatewell. Holes in the concrete walls, called orifices, allow water and fish to pass into a collection channel that is fed by the orifices from all of the turbine intakes. From the collection channel, fish move into a juvenile fish facility where they can be sampled, collected for transport downstream in barges, or released back into the river downstream of the dam. Fish that approach the powerhouse but are not guided by the screens (e.g., fish traveling at greater depths) will pass through the turbine and then the draft tube before arriving at the tailrace of the dam. Fish passing through typical spillway gates will have to dive as deep as 50 feet to enter a spillgate opening before traveling down the spillway chute to the tailrace. Surface outlets allow water and fish to pass over a structure such as a weir before traveling down the spillway chute or other structure before arriving at the tailrace.

2.1 Types of Passage Through a Bypass System

Individual juvenile salmon that enter a bypass system will pass one of several possible routes through the facility prior to continuing their migration downstream. Because this work is concerned with the conditions that fish experience, it is important to account for more than one possible route type that those fish might take through a particular bypass system and how conditions might differ among bypass systems across dams.

Figure 2.1 illustrates how migrating juvenile fish approaching a dam from the forebay upstream might enter the turbine intakes and be diverted into a JBS. Guidance screens divert a proportion of fish upward into a gatewell. Gatewells have been modified to support fish passage by the addition of VBSs that provide dewatering, and orifices that allow fish to pass from the gatewell into a transportation or collection channel. Fish entering the collection channel are usually routed into a juvenile fish facility or returned to the river.

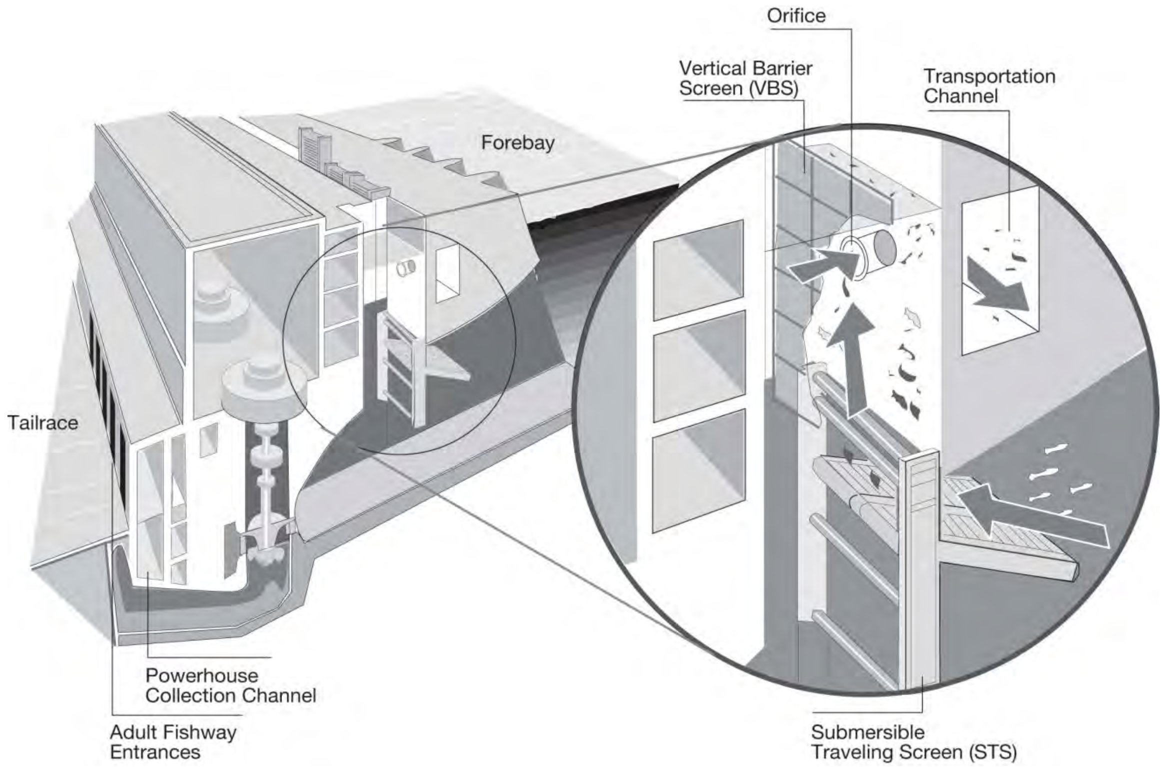

Figure 2.1. Diagram of the Cross-Section of a Dam. The inset shows the major components for entry into the JBS (image: U.S. Army Corps of Engineers. 2010. Fish Passage Plan: Corps of Engineers Projects. U.S. Army Corps of Engineers, Northwestern Division , Portland, OR.)

Figure 2.2 is a schematic of a generalized and simplified juvenile fish facility. In this illustration, fish arriving can either enter the fish and debris separator or be returned directly to the river without passing through additional structures. Fish exiting the separator can have three possible fates: 1) be diverted based on PIT-tag detection into sort-by-code holding tank or exit to river; 2) enter the sample room for examination and possible sampling; or 3) enter the raceways in preparation for barge loading. A more complex universe of routes is possible at real facilities than this simplified figure suggests, but route types can be compared only if individual fish can be reliably assigned to the route types. Multiple PIT-tag detection points within the juvenile fish bypass system allow PIT-tagged fish to be assigned to a route type. Some route types exist at a dam, but cannot be evaluated because detection does not support unequivocal assignment of a fish to that route type.

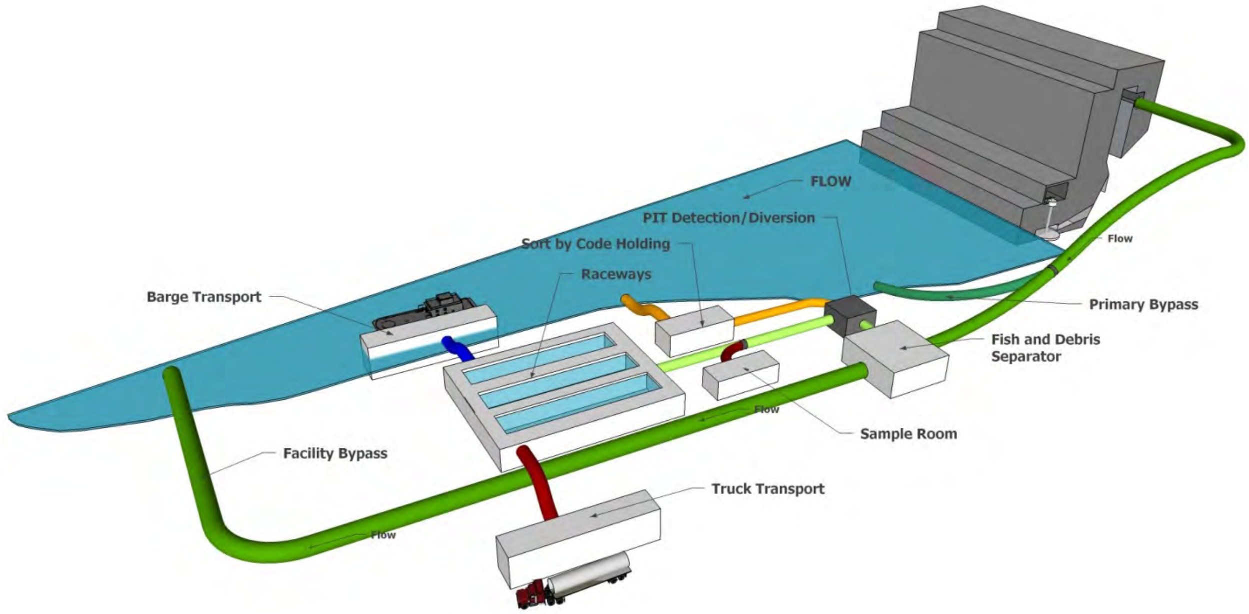

Figure 2.2. Major Routes Through a Juvenile Bypass System

Juvenile bypass systems share many similarities among dams, but most of them have been tailored to fit the needs of each dam structure and the fish passage needs because they vary from location to location. These differences have a potential to influence how well each system performs. All dams on the Snake River (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and all but one dam on the Columbia River (McNary, John Day, and Bonneville) have intake guidance screens. The Dalles Dam on the Columbia River has no intake guidance screens and no JBS. All of the dams have orifices (ranging in diameter from 6 to 14 inches) in the gatewells that lead to a collection channel. The collection channels (bypasses) of all the other dams connect to pipes, pass through dewatering structures, and then pass through a fish sampling facility and/or exit to the river. All dams except The Dalles and Ice Harbor have separators that separate adult fish from juvenile fish; the separators at Little Goose, Lower Monumental, and McNary are also able to separate smaller juveniles from larger ones. All bypass facilities (except at Ice Harbor) are capable of diverting specific PIT-tagged fish using the separation by code system. The default routing option for PIT-tagged fish has typically been to return them to the river, but some studies have specified that certain tag codes be transported or sampled. Four of the eight dams—Lower Granite, Little Goose, Lower Monumental, and McNary—have transportation facilities. In addition to being sampled or returned to the river, fish at these dams may be diverted to raceways and held for transport or they may be directly loaded onto transportation barges.

2.2 Dam-Specific Bypass Configurations

Bypass systems are tailored to the requirements of individual dams. Many components are similar among dams, but it is important to recognize the differences when evaluating their performance. The following sections provide details on how bypass systems differ among dams.

2.2.1 Lower Granite Dam

Fish guidance screens divert a portion of the juvenile migrating salmon entering the turbine intakes away from turbine passage and into the juvenile fish bypass and transportation systems. Lower Granite Dam was the first main-stem Snake River dam to have submersible traveling screens (STSs), a type of fish guidance screen, included in its original design. In the original system, fish diverted by guidance screens entered a gatewell that included VBSs to allow for partial dewatering, 8-inch-diameter orifices that led to a collection gallery and additional dewatering structures, and a pressurized pipe at the south end of the powerhouse. The pipe led down the tailrace into a fish and water separator, holding ponds, an evaluation and monitoring facility, a transport loading dock, and an outfall. Fish entering the facility could either be returned to the river through the outfall or loaded into barges for transportation downstream.

In the 1980s, juvenile bypass and transportation systems were overhauled. Gatewell orifices were increased to 10-inch diameters, the dry fish/water separator was replaced by a wet separator, and additional raceways were installed. In the 1990s, emergency gates were raised from their storage positions in the gatewells in a successful effort to improve the number of fish guided into the bypass system. In 1996, the STSs were replaced with new extended-length submersible bar screens (ESBSs) that extended deeper in the water column and new VBSs were installed in the gatewells.

Several major configuration changes occurred at Lower Granite Dam through the study period that may have influenced how many fish were entering the bypass facility. A prototype surface bypass and collector (SBC) was installed in 1996 in front of turbine units 4, 5, and 6 (Figure 2.3) to test surface passage concepts. The SBC was a fish-collection channel with four upstream-facing entrances and a single outfall located at spillbay 1. It was 18 meters (59 feet) high, 6 meters (19.7 feet) deep, and 100 meters (328 feet) long and had large flotation chambers so that it could move vertically as forebay elevations changed. The configuration of the SBC changed over several years of testing and development, but the structure was not intended to be a complete, permanent, or final design. In 1998, the simulated wells intake (SWI) was fitted to the bottom of the SBC (Figure 2.4). The purpose of the SWI, which extended the bottom of the SBC by 6 meters (19.7 feet), was to reduce the downward flow near the SBC (i.e., within 30 meters [98 feet]) and allow the fish to find the SBC entrances. During 1998, a prototype behavioral guidance structure (BGS) was deployed to divert fish away from the south powerhouse (turbine units 1–3) and direct them toward the SBC. The BGS was a steel wall 335 meters (1100 feet) long that extended from the south end of the SBC (near turbine unit 4) upstream to within 20 meters (66 feet) of the south shore. The BGS was 24 meters (78 feet) deep where it attached to the SBC and tapered to a depth of 17 meters (56 feet) at its upstream end. The prototype BGS did not extend to the upstream shoreline, but the plan was to close that gap in the final implementation. To provide a surface passage route for juvenile fish, a removable spillway weir (RSW) was installed in 2001 at Lower Granite Dam. The SBC structure was removed in 2003. After removal of the SBC, a new BGS attachment point was added between turbine units 5 and 6. The BGS also was reduced in depth at the downstream end to a maximum of 17 meters (55 feet) instead of 24 meters (78 feet) prior to testing in 2006, prior to removal of the BGS, and prior to the 2007 migration year. During 2006 testing of the BGS, the presence of the BGS influenced fish guidance efficiency, which is the proportion of fish passing into turbine intakes that are guided into the bypass.

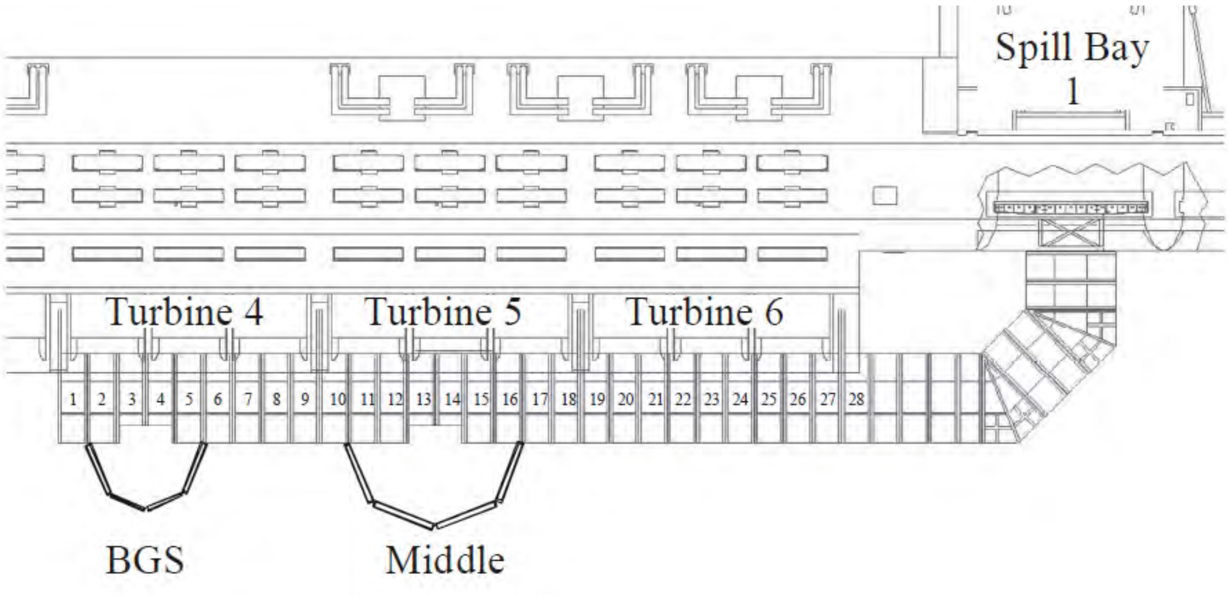

Figure 2.3. Plan View of Surface Bypass and Collector Upstream of Turbine Units 4–6 Showing Outfall Through Spillbay 1

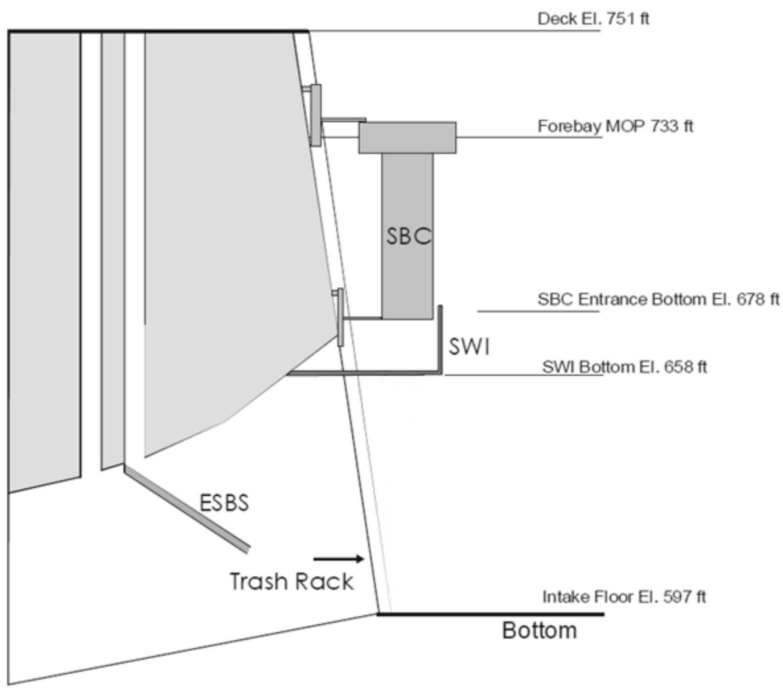

Figure 2.4. Cross Section of Surface Bypass and Collector Upstream of Turbine Intake and Illustrating Simulated Wells Intake

2.2.2 Little Goose Dam

Juvenile fish facilities at Little Goose Dam include a JBS and juvenile transportation facilities, which became operational in 1980 and were replaced in 1990. In the early 1990s, turbine intake emergency gates also were raised to increase fish guidance efficiency. The new facilities featured a modified collection channel, a new dewatering structure, a corrugated flume, a new “wet” separator, a new evaluation facility, holding ponds, and a loading and/or outfall structure. In 2002, the USACE modified the PIT-tag diversion system at Little Goose Dam to improve passage conditions for juvenile salmonids. The modifications consisted of removing the PIT-tag head boxes and fish counting tunnels, adding a new secondary dewatering system downstream from the slide gate, installing a new sort-by-code sampling system, replacing two 6-inch-diameter conveyance pipes with a single 8-inch-diameter pipe between the slide gate and diversion river-exit PIT-tag monitor, and replacing the 6-inch-diameter river-exit conveyance pipe with a 10-inch-diameter pipe. The JBS now includes ESBSs with flow vanes, VBSs, thirty-five 12-inch gatewell orifices and one 14-inch gatewell orifice, a bypass channel running the length of the powerhouse, a metal flume mounted on the face of the dam and the upper end of the adult fish ladder, a dewatering structure to eliminate excess water, two emergency bypass systems, and a corrugated metal flume to convey the fish to either the transportation facilities or the river. The transportation facilities include a separator structure, raceways for holding fish, a system for distributing the fish among the raceways, a sampling and marking building, truck- and barge-loading facilities, and PIT-tag detection and diversion systems. A trash-shear boom was added to the forebay to divert floating debris away from the powerhouse in August 1998.

2.2.3 Lower Monumental Dam

Juvenile fish facilities at Lower Monumental Dam consist of standard length STSs, VBSs, 12-inch orifices, a collection gallery, a dewatering structure, and a bypass flume to the tailrace below the project. These components are referred to collectively as the JBS. Transportation facilities consist of a separator (to sort juvenile fish by size and to separate them from adult fish), sampling facilities, raceways, office and sampling building, truck- and barge-loading facilities, and PIT-tag detection systems. The JBS at Lower Monumental Dam became operational on May 3, 1993, and PIT-tag detection capabilities became operational in 1994. Two bypass pipes are installed—for primary and secondary bypass

A number of changes have been made since 2000 to improve operations. The STSs were overhauled to improve their efficiency, spill deflectors were installed in bays 1 and 8 so they could be used in spill patterns and minimize total dissolved gas (which would reduce powerhouse flow as well as the proportion of fish entering the bypass), and barge-loading and JBS dewatering facilities were improved. Parapet walls were added to end bays to enable spill through end bays, and PIT-tag detection was initiated for the main transport flume to improve the ability to monitor or study transportation.

2.2.4 Ice Harbor Dam

Facilities for juvenile fish passage consist of standard-length STSs, VBSs in the gatewells, two 12-inch gatewell orifices, collection channel and dewatering structures, sampling facilities, an adult/ juvenile separator, and a bypass flume/pipe that transports fish to the sampling facilities and the tailrace below the dam. In April 2005, PIT-tag detectors were activated in the full-flow segment of the JBS just downstream of the primary dewatering system. The PIT-tag system allows detection of PIT tags in fish

as they are returned to the river downstream, thereby allowing for tag detection to occur for fish that are not collected at the juvenile fish facility (JFF). A RSW was installed before the spring juvenile salmonid migration period of 2005. At Ice Harbor Dam, spill deflectors are at an elevation of 338 feet above mean sea level (MSL), with a length of 12.5 feet.

2.2.5 McNary Dam

The original JBS completed in 1981 included 20-foot STSs, VBSs, and a pressure pipe system for carrying fish to a JFF on the north tailrace deck to allow for transportation of juvenile salmonids. In 1994, a new JFF was completed with open channel passage from the collection channel to the JFF. In 1996, ESBSs were installed in turbine units 1–4, prototypes were placed in units 5–6, and new VBSs were installed across the entire powerhouse. In 1997, ESBSs were installed in turbine units 5–14. Implementation of PIT-tag detection began in 1986. In 2002, a system to detect PIT tags was installed in the full-flow bypass pipe to allow fish to be returned to the river without passing through the sampling and collection apparatus in the JFF. The system was tested in 2002 and was fully functional for the 2003 fish passage season. Prototype VBSs were tested in 2004 and 2005 in preparation for turbine modernization activities that would increase the flow per unit. This modernization has yet to be implemented.

Juvenile transportation facilities at McNary Dam include a separator to sort juvenile fish by size and remove any adult fish, a flume system for distributing fish among the raceways and sample facilities, covered raceways for holding fish, sampling facilities, a wet lab, an office and sampling building with fish-marking facilities, barge- and truck-loading facilities, and PIT-tag detection and deflection systems.

2.2.6 John Day Dam

A major reconstruction of the John Day Dam bypass system occurred from 1984 to 1986 when gatewell orifices were enlarged to 12 inches in diameter, the collection channel was enlarged, VBSs and STSs were installed, and a transportation channel to carry fish from the bypass gallery to the river was constructed. A second major reconstruction occurred during the 1996–1998 timeframe. A new pipe was added between the collection channel and the JFF. After primary dewatering, fish travel through a flume that leads to a switch gate. The switch gate can be set to return fish to the river or divert them to the separator. Unlike separators at other dams, which are designed to sort fish for transportation, the wetted separator at John Day Dam has only one size of bar spacing (32 mm). Fish are not collected for transport at John Day Dam, so the bypass system does not include raceways or barge-loading facilities.

Beyond the separator, fish pass through a switch gate normally set to pass fish back to the river. The gate can be triggered to divert a sample of fish or a specific fish with a PIT-tag code designated for collection into a holding tank. After handling and recovery, fish are returned to the river via a pipe that empties into the exit channel and then the existing outfall flume.

2.2.7 The Dalles Dam

In contrast to other dams in the FCRPS, turbine intake screens have not been installed at The Dalles Dam, which means that migrating juveniles are not diverted into a bypass system. Turbine intake screens and a JBS for The Dalles Dam, analogous to those of other JBSs at other USACE main-stem Columbia

and Snake River dams, has been designed, but it was not implemented because a suitable outfall location was not evident, fish guidance efficiencies for subyearling Chinook salmon were not acceptable, and the cost to outfit 66 intakes would be high (Johnson et al. 2007). Gatewell orifices are present that would allow fish entering the gatewell to exit via the sluiceway, but in the absence of guidance screens in the turbine intakes, the number of fish entering the gatewells is assumed to be very low. In 1971, changes to the ice and trash sluiceway allowed gates to be opened in order to skim juvenile fish from the forebay and deposit them into the tailrace

2.2.8 Bonneville Dam

Bonneville Dam includes two powerhouses separated by islands and a spillway. These powerhouses differ in their configuration and operation, including those of their JBS. The operations and configurations have also changed through time. In 2000, the flows through the gatewells at powerhouse 2 were increased by installing a turning vane to the support structure of the STS near the entrance of the gatewell. A gap-closure device was installed on the intake ceiling downstream from the top edge of the STS. To accommodate the increased flow resulting from these changes, the size of the VBS was increased by removing a portion of the concrete beam below it. In 2002, powerhouse priority was changed from powerhouse 1 to powerhouse 2. In 2003, the B2CC was installed at powerhouse 2. Fish entering the B2CC pass into a flume that extends several hundred feet west on the south side of the powerhouse 2 tailrace and empties at the tip of Cascades Island. The ice-trash sluiceway channel at Bonneville Dam powerhouse 2 was modified and lengthened so that water was discharged downstream from the tip of Cascades Island to mitigate concerns about predation at the previous outfall location. Prior to the 2004 migration, screens at powerhouse 1 were removed given concerns about low survival associated with the bypass system. Turbine intake extensions, which had been installed in alternating turbine units prior to the study period, were removed at units 11–14 and left in place at units 15–18. The sluiceway at powerhouse 1 remains an effective non-turbine passage route. An ice and trash sluiceway and STSs are still in use at Bonneville Dam powerhouse 2 during juvenile fish migration.

2.3 Bypass Configuration Eras

Bypass configurations at most dams have changed since the original installation of the bypass systems. It would be ideal to analyze each change to evaluate its influence on survival, but that is not possible for a number of reasons. The primary reason is that there are too few fish to evaluate each change with statistical rigor, if at all. Fortunately, major changes have typically occurred as more extensive renovations at a given dam. Because renovations typically happened in between operations for annual migration seasons, these renovations create a break between eras of operation within which configurations are relatively similar. By consulting with biologists at the dams, we were able to identify which alterations to the bypass constitute a major change. With that information, we were able to differentiate eras for evaluation of bypass configurations. A brief description of the eras of operation is provided in Table 2.1. The changes underlying those eras are defined in greater detail in Appendix E: Juvenile Fish Bypass Improvements.

Table 2.1. Summary of Eras by Dams and PIT-Tag Data Availability. Data are PIT-tag detections from Snake River hatchery spring Chinook, Snake River hatchery summer Chinook, and Snake River hatchery steelhead.

Dam	Era	Years	Description	Data Available
Lower Granite	1	1994	Permanent holding tank; mid-river outfall pipe	-
	2	1995	2-way, 3-way fish diversion gates	-
	3	1996–2009	New ESBSs and VBSs installed	1996–2006
Little Goose	1	1990–1995		-
	2	1996	New VBSs; prototype diversion-by-code gates	1996
	3	1997–2001	New ESBSs in all units; mid-river outfall pipes	1997–2001
	4	2002–2008	Wider conveyance pipes; new 3-way diversion-by-code gate	2002–2006
	5	2009	Relocation of full flow juvenile outfall	-
Lower Monumental	1	1992–1994	Submersible screens and VBSs installed; new JBS system	-
	2	1995	Improvements to primary dewatering structure, separator exits	-
	3	1996–2009	New release line in PIT-tag diversion system	1996–2006
Ice Harbor	1	1996–2009	New JBSinstalled	2005–2006
McNary	1	1994–1995	New JFF	-
	2	1996	New ESBSs installed in units 1–6; new VBSs installed	1996
	3	1997–2001	ESBSs installed in units 7–14; VBSs installed	1997–2001
	4	2002–2009	Replace return-to-river lines	2002–2006
John Day	1	1984–1997	JBS system installed	-
	2	1998–2009	New JBS installed	1998–2006
Bonneville	1	1994–1999	Powerhouse 1 JFF was primary JBS	1996–1999[a]
	2	2000–2009	Powerhouse 2 JFF was primary JBS	2000–2006

(a) Depends on stock.
ESBS = extended-length submersible bar screen; JBS = juvenile bypass system; JFF = juvenile fish facility; VBS = vertical barrier screen.

3.0 Assessment of Bypass Effects

Our primary objective in this analysis was to determine whether dam passage through the bypass system was associated with reduced adult return rates to Lower Granite Dam. We explored whether both the number of bypass events and bypasses at individual dams were related to adult return rates. We also explored whether perceived negative bypass effects were lessened by structural changes to the bypass systems, and whether the different bypass routes at a dam influenced adult return rates. Finally, we explored whether the probability of being bypassed was related to fish length at tagging. In each analysis, smolts that were collected for transport or that entered a sampling room were omitted from the group of bypassed fish.

Although other researchers have previously observed higher adult return rates for non-bypassed smolts than for bypassed smolts (e.g., Williams et al. 2005; Schaller et al. 2007), it is unclear whether the return rates were adjusted for different incidence rates of the juvenile detection histories. For example, the probability of a smolt being bypassed just once at Lower Granite Dam is different from the probability of a smolt being bypassed just once at Lower Monumental Dam, both because of different bypass efficiencies at the two dams and because of different survival rates to the two dams. To properly compare the adult return rates of these two groups of fish, the incidence rates of the juvenile detection history must be correctly incorporated. The analysis in this report accounts for different incidence rates among the juvenile detection histories by using the ROSTER (River-Ocean Survival and Transportation Effects Routine) model, a migratory life-cycle release-recapture model, as the basis of analysis. This section describes the methods and data used in our analysis of bypass effects, and provides a detailed description of our results. We also address issues of statistical power to detect effects.

3.1 Statistical Methods

An overview of analytical methods is presented first below, followed by a description of the scope of analysis, data used, use of the ROSTER model, and analysis of Anscombe residuals from the ROSTER model. Then the analysis of the effect of the number of bypass events, dam-specific bypass events, bypass operations, alternative routes within a dam, length effects on detection probability, and of statistical power are described.

3.1.1 Overview of Methods

Detection data from PIT-tagged hatchery spring/summer Chinook and steelhead from the Snake River Basin were analyzed using the ROSTER release-capture model, and the model residuals were analyzed for patterns relating to bypass events. The ROSTER model uses both juvenile and adult PIT-tag detection data from the same tagged individuals to estimate reach survival, detection probabilities, and multiplicative transportation effects for salmonids migrating through the FCRPS. The model uses data from all bypass routes through each dam. A key assumption of the model is that detection within the JBS at any dam has no effect on subsequent survival. We assessed whether possible bypass effects exist by comparing the number of adults observed for each juvenile detection history with the number of adults expected based on the assumption of no bypass effect using the ROSTER model. A consistent pattern of observing more adult returns than expected from smolts that were not detected as juveniles would suggest that non-bypassed smolts have a higher probability of returning as adults than bypassed smolts.

Similarly, a consistent pattern of observing fewer adult returns than expected from smolts that were detected at one or more bypass dams would suggest that bypassed smolts have a lower probability of returning as adults than non-bypassed, inriver smolts. We compared the number of observed and expected adult returns by examining residuals from the ROSTER model. Although smolts collected for transport were not included in the bypass groups, we also examined ROSTER residuals for fish that were transported from Little Goose Dam to determine whether previous bypass at Lower Granite Dam was associated with lower adult return rates of transported smolts.

In addition to examining model residuals for long-term patterns related to bypass events, we examined residuals for patterns related to bypass operations or through particular bypass routes. As modifications were made to the bypass system over time (e.g., installing or updating screens), smolts may have experienced bypass differently, with corresponding changes in post-bypass survival. We used ROSTER model residuals to determine whether these structural modifications were associated with changes in adult returns. Another question was whether the particular bypass route used through a dam affected subsequent adult returns. For example, a facility bypass diverts smolts away from the turbines and into a series of holding tanks and raceways where they may be handled or otherwise stressed. On the other hand, a primary ("full-flow") bypass sends smolts directly back to the river downstream of the dam without sending them through the fish facilities at the dam. By comparing model residuals for smolts that passed via a facility bypass to those that passed via a primary bypass, we examined whether the type of bypass affects adult returns. Other routes of interest were the B2CC at Bonneville Dam and the sort-by-code holding tanks at McNary Dam.

One working hypothesis suggests that perceived bypass effects are due to smaller fish being more likely to be bypassed and having lower survival than larger fish (Zabel et al. 2005). If this is the case, then a perceived bypass effect would be the result of differential detection (capture) probabilities, rather than a deleterious effect of the bypass system itself. On the other hand, if both small and large fish are being bypassed in comparable numbers, then it is more likely that any perceived bypass effects (if they exist) are the cause of the bypass system itself. Thus, it is important to determine whether fish size is associated with bypass probabilities. We addressed this question by relating the probability of bypass to fish length at tagging, the only measure of fish size we had available.

3.1.2 Scope of Analysis

Our analysis focused on looking for possible negative effects of bypass passage on adult return rates, because of preexisting concern that bypass may not be the optimal dam passage route. Thus, our methods and results pertain especially to negative effects. We also looked for effects that were consistent over multiple years, rather than those limited to a single year. Analysis of the effect of structural changes to the bypass system was limited by the availability of PIT-tag data, with the result that only large structural changes could be assessed.

Sample size considerations led us to analyze release groups of hatchery fish rather than wild fish, because most PIT-tagged fish come from hatcheries. The detailed juvenile detection histories and low adult return rates meant that we could not perform separate analyses for each hatchery group, but instead pooled data across hatchery groups for each stock (species and run) and for each migration year. Because survival to Lower Granite Dam is accounted for in the analysis methods, differential survival across the hatchery groups has little, if any, effect on model results. Analysis of a possible effect of smolt length on bypass probability was performed at the level of hatchery group.

The opportunistic nature of the PIT-tag detection data limits the inference of the results of this analysis, and of any similar analysis of these data. Depending on observational data prevents us from distinguishing between mechanistic effects of going through the bypass system and selectivity of the bypass system among fish passing the dam, although we explored the possibility of a size-selectivity of the bypass system among different hatchery groups. The relative nature of the analysis means that evidence of a negative effect of bypass is more likely to be found if other routes performed well, and vice versa. Thus, our analysis is of perceived bypass effects, representing differences in observed and expected numbers of adults if no bypass effect (or selectivity) existed. No conclusions are possible about the actual cause of the perceived effects.

3.1.3 Data Used

PIT-tag detection data were downloaded from the PIT Tag Information System (PTAGIS) database for Snake River hatchery spring Chinook salmon, summer Chinook salmon, and steelhead that were tagged and released in the Snake River Basin upstream of Lower Granite Dam from 1996 through 2006. Both juvenile and adult detections were used from all fish in the release groups, as available. Juvenile releases after 2006 were not used in this report because adult returns were incomplete at the time of this writing.

All fish used in these analyses came from hatcheries in the Snake River Basin, and were PIT-tagged and released upstream of Lower Granite Dam. We omitted fish that were tagged and released at Lower Granite Dam because of concerns regarding potential bias from tagging effects associated with intercepting, handling, and tagging fish during the smolting process. In addition, analysis of potential bypass effects at Lower Granite Dam required fish to be released upstream of the dam. Fish from the Mid-Columbia were omitted because they could not be used to assess potential bypass effects at the Snake River dams.

Low adult return rates demand large release groups to complete any detailed analysis of adult returns, whether the ROSTER model or another analysis tool is used. This made it necessary to pool fish from individual releases made at separate hatchery sites to form the annual release groups. Heterogeneous survival across hatchery groups has little effect on the fit of release-recapture models, with estimated survival probabilities representing the average survival across the entire release group (Lebreton et al. 1992). Thus, we pooled all releases across the Snake River Basin by stock (i.e., species and run) for each migration year to form the annual release groups (Table 3.1). No distinction was made among fish from different hatcheries in either fitting the ROSTER model or examining patterns of different juvenile detection histories (e.g., undetected, or detected once).

The hatchery spring Chinook salmon release groups came from several hatcheries throughout the Snake River Basin, with most coming from Rapid River Fish Hatchery, Lookingglass Fish Hatchery, and Dworshak National Fish Hatchery. For each release year except 1997, over 93% of the hatchery summer Chinook salmon came from the McCall Fish Hatchery. In 1997, 62% of the summer Chinook salmon came from McCall, and 37% came from Pahsimeroi Fish Hatchery. The steelhead release groups were composed of fish released at numerous locations throughout the Snake River Basin, including sites in the Clearwater, Imnaha, Salmon, and Grande Ronde river watersheds.

Wild fish were not used in these analyses because there were generally fewer wild fish tagged than hatchery fish (c.f. Table 3.1, Table 3.2). While it would have been possible to fit the ROSTER model using annual release groups of wild Chinook salmon and steelhead tagged upstream of Lower Granite Dam (Buchanan et al. 2008), the smaller release groups meant that statistical power to detect differences in adult return rate between bypass and non-bypass passage routes would be low. Thus, to maximize statistical power, we restricted our analysis to hatchery fish.

Table 3.1. Sizes of Annual PIT-Tagged Release Groups of Hatchery Yearling Chinook Salmon and Steelhead Used in Bypass Effects Analysis with Program ROSTER

Release Year	Spring Chinook Salmon	Summer Chinook Salmon	Steelhead
1996	67,496	NA	28,174
1997	115,057	85,020	33,754
1998	161,693	50,261	30,312
1999	180,085	51,172	38,697
2000	131,833	58,479	36,197
2001	162,255	NA	NA
2002	303,302	68,484	30,903
2003	304,850	87,654	31,863
2004	171,050	85,167	38,475
2005	167,260	87,190	43,008
2006	297,253	63,540	35,737

NA = not applicable.

Table 3.2. Sizes of Annual Release Groups of PIT-Tagged Wild Yearling Chinook Salmon and Steelhead Available for Analysis with Program ROSTER

Release Year	Yearling Chinook Salmon	Steelhead
1996	18,908	5,393
1997	9,601	6,409
1998	30,615	8,003
1999	73,319	15,632
2000	62,780	24,712
2001	44,372	23,384
2002	59,025	25,524
2003	92,304	23,809
2004	89,077	24,688

For each release year, juvenile detections were available from Lower Granite, Little Goose, Lower Monumental, and McNary dams. Juvenile detections were also consistently available from John Day and Bonneville dams starting in 1999. Before 1999, John Day and Bonneville detections were available for some release groups, but were too few in number to be included in the ROSTER analysis for other

groups. Detections from these dams were included when possible. Although juvenile detections from Ice Harbor Dam began in 2005, we did not include them in analyses with other dams because with only 2 years of detections at Ice Harbor, we did not have sufficient power to detect a bypass effect. For each bypass system analyzed, smolts that were collected for transport or that entered a sampling room were omitted from the group of bypassed fish.

Detections of PIT-tagged adults were available from Lower Granite Dam for all release years. Adult detections at Bonneville Dam began in 1999, and at McNary and Ice Harbor dams in 2002. All adult detections were used to fit the ROSTER model. However, residuals were defined based on the number of adults that were observed and predicted to return to Lower Granite Dam. Age-1-ocean fish were counted as adults for both Chinook salmon and steelhead.

3.1.4 ROSTER Model

Each data set was analyzed with a statistical release-recapture likelihood model (i.e., the ROSTER model) that jointly analyzes juvenile and adult PIT-tag data to estimate juvenile survival, ocean return probabilities, perceived adult survival, and transportation probabilities (Buchanan and Skalski 2007). The ROSTER model incorporates PIT-tag detection and juvenile transportation and accounts for known removals of tagged fish from the migrating population. Smolts were collected for transportation at Lower Granite, Little Goose, Lower Monumental, and McNary dams during all release years. For each transport dam and annual release group, a unique probability of adult return was estimated for smolts transported from the dam if at least 5000 smolts were collected for transportation from the dam during the outmigration year. If fewer than 5000 smolts were collected for transportation at the dam, then the detection records of transported smolts were right-censored at the dam, and the transported smolts were not used to estimate survival downstream of the dam. Similarly, detection records of smolts that entered a sampling room at a dam were right-censored at the dam. Smolts that were collected for transport or that entered a sampling room were excluded from the bypass groups compared in the residual analysis.

The ROSTER model was implemented by Program ROSTER, software that was developed by the University of Washington and is publicly available online at http://www.cbr.washington.edu/paramest/roster/. Program ROSTER fits the likelihood model using numerical estimation techniques, and provides maximum likelihood estimates and standard errors of model parameters.

Program ROSTER depends on many assumptions to model the entire hydrosystem migration between passing Lower Granite Dam as a smolt and returning there as an adult. Some of these modeling assumptions are that all non-transported smolts have common probabilities of survival, common age-specific ocean return probabilities, and common age-specific adult survival and detection probabilities, regardless of detection at previous juvenile sites. Because detection of migrating juveniles occurs within the bypass system at dams, this assumption includes the assumption that the event of passing through the bypass system at a dam has no effect on subsequent survival or detection. If, on the other hand, dam passage through the bypass is associated with lower near-dam or long-term survival compared to the average survival from all other passage routes, then this assumption will be violated, and the model will predict fewer adult detections from smolts that were undetected at bypass dams than were actually observed. Likewise, the model will predict more adult detections from bypassed smolts than were observed. This expected pattern of residuals (i.e., differences between observed and expected adult returns) in the presence of a bypass effect on adult returns allows us to use residuals from the ROSTER

model to assess whether bypass lowers subsequent survival relative to other routes. It is important to note, however, that alternative hypotheses exist to explain why smolts that avoided the bypass system might have higher adult return rates than bypassed smolts. In addition to the hypothesis that the bypass system itself is harmful (Bouwes et al. 1999), it has been suggested that smolts that enter the bypass system tend to be smaller than smolts that avoid it, resulting in inherently lower survival among those fish that are more likely to be bypassed (Zabel et al. 2005). These two hypotheses are not necessarily mutually exclusive.

Another inherent assumption of the ROSTER model is that all smolts that are detected at a given dam have the same subsequent survival and detection probability, regardless of the route they took through the bypass system at the dam. At dams with both primary and facility bypasses, this assumption will be violated if one route has a differential survival effect. Likewise, if the B2CC at Bonneville Dam has a differential effect on survival compared to other bypass routes past the dam, this assumption will be violated. It is possible to test for bypass route effects using a process that is similar to testing for bypass effects, using the residuals from the ROSTER model. In this case, residuals will be compared between the various bypass passage routes past a dam.

3.1.5 Analysis of Residuals

For each annual release group, Anscombe residuals from the ROSTER model comparing the observed and expected number of adult returns were calculated for smolts, characterized by their juvenile detection histories. While all possible detection and transport histories were analyzed in the ROSTER analysis, only specific detection histories were the focus of this analysis because of our interest in assessing bypass effects. Specific groups of interest are defined below.

For each juvenile detection history or group of histories i and annual release group j, the Anscombe residual, z_{ij}, was computed as follows (Collett 1991:330–331):

$$z_{ij} = \sqrt{R_j}\,\frac{B\left(\frac{A_{ij}}{R_j},\frac{2}{3},\frac{2}{3}\right) - B\left(\hat{p}_{ij},\frac{2}{3},\frac{2}{3}\right)}{\left[\hat{p}_{ij}\left(1-\hat{p}_{ij}\right)\right]^{1/6}}, \tag{3.1}$$

where R_j = size of release group j,

A_{ij} = number of adults detected at Lower Granite Dam from detection group i and release group j,

p_{ij} = probability of being in detection group i and also being detected at Lower Granite Dam as an adult (estimated using the ROSTER model) for release group j, and

$$B(x,a,b) = \int_0^x t^{a-1}(1-t)^{b-1}\,dt, \text{ for } 0 \le x \le 1.$$

The statistic z_{ij} has an asymptotic standard normal distribution, N(0,1). This *Z*-statistic was used because it attains its asymptotic distribution more quickly than the more familiar *Z* statistic,

$$z_{ij} = \frac{A_{ij} - R_j p_{ij}}{\sqrt{R_j p_{ij}\left(1 - p_{ij}\right)}}.$$

Under the null hypothesis that bypass has no effect on adult returns, the Anscombe residual $\left(z_{ij}\right)$ for any given detection history is normally distributed with expected value 0. Thus, in the absence of a bypass effect on adult returns, we expect the Anscombe residual for any given detection history or detection group to be within -2 to 2 about 95% of the time. An observed *Z*-statistic outside this range indicates that a bypass effect on adult return rates may exist. Anscombe residuals for the various juvenile detection history groups within each annual release group were plotted to identify significant residuals. In addition, residuals from separate annual releases were combined across release years in a meta-analysis to assess bypass effects. For juvenile detection history group i and annual release group j, define the statistic T_i (Kulinskaya et al. 2008):

$$T_i = \frac{\sum_{j=1}^{J} \sqrt{R_j}\, z_{ij}}{\sqrt{\sum_{j=1}^{J} R_j}}. \qquad (3.2)$$

Under the null hypothesis that juvenile detection (i.e., bypass) has no effect on adult returns, T_i has a standard normal distribution, N(0,1). The *T*-statistic was used to assess overall significance across years. The *T*-statistic essentially weighted individual results proportional to the square root of release size. Consequently, large releases were given more weight in the overall assessment than smaller release groups. A negative *T*-value would indicate that fewer adults returned than expected under the null hypothesis of no bypass effects. A positive *T*-value would indicate that more adults returned than expected under the null hypothesis of no bypass effects. Statistical significance was inferred at the $\alpha \leq 0.05$ level.

3.1.6 Effect of Number of Bypass Events

The first analysis evaluated whether the number of times smolts were bypassed had an increasingly severe effect on adult returns. If the experience of being bypassed lowers survival, then we would expect to see a greater effect on smolts that were bypassed at more dams, and a smaller effect on smolts that were bypassed at fewer dams. We computed Anscombe residuals from the ROSTER model for smolts that were not detected at any bypass dam, and for smolts that were bypassed at one, two, or three dams. For each group, we compared the observed distribution of residuals to the standard normal distribution using the T_i statistic (Eq. [3.2]). For the undetected group, we tested whether T_i was greater than 0. For groups with one or more detections (bypass events), we tested whether T_i was less than 0.

For each group, we calculated both the number of expected adults in the absence of a bypass effect, and the relative difference between observed and expected adults, i.e., the relative effect:

$$\text{Relative Effect} = \left(\frac{O-E}{E}\right)\times 100\%, \tag{3.3}$$

where O and E are the numbers of observed and expected adult returns, respectively. Across years, the relative effect was expressed as

$$\left(\frac{\overline{O}}{\overline{E}}-1\right)\times 100\%. \tag{3.4}$$

3.1.7 Dam-Specific Bypass Effects

The effect of bypass at a particular dam or pair of dams was analyzed by computing model residuals for smolts that were bypassed at only one or two specific dams. For example, we computed model residuals for smolts that were bypassed (i.e., detected) only at Lower Monumental Dam or only at Lower Granite Dam as juveniles, as well as for smolts that were bypassed only at both Lower Monumental and Lower Granite dams. All bypass dams with juvenile PIT-tag detection were considered. For each annual detection group, the Anscombe residual from the ROSTER model was calculated. The distribution of residuals across all release years was compared to the standard normal distribution using the T_i statistic (Eq. [3.2]). In all cases, a one-sided test was used to determine whether the T_i statistic was less than 0. In those cases where the T_i statistic was found to be significantly less than 0 (P<0.05), it was concluded that a bypass effect on adult returns may have existed for the particular dam or combination of dams, relative to other, unmonitored passage routes (e.g., spillway, turbines, surface passage). Both the number of expected adults and the relative difference (i.e., relative effect; Eq. [3.3]) between expected and observed adults were calculated. Bypass effects were examined both over all release years (1996–2006), and limited to the most recent operations era (see Section 3.1.8). For Little Goose and McNary dams, the most recent operations era was 2002–2006, and for Bonneville Dam, the most recent era was 2000–2006. For all other dams, the most recent operations era was 1996–2006.

We also investigated whether the relative effect of joint bypass at pairs of dams was both negative and larger than expected from the relative effect of bypass at the individual dams separately, i.e., larger than the sum of the relative effects of bypass at the individual dams alone. Such synergistic effects were investigated using linear contrasts L_{ij} of the relative effects (Eq. [3.3]):

$$L_{ij} = D_{ij} - D_{i0} - D_{0j},$$

where D_{ij} is the relative effect of joint bypass at dams i, j [Eq. 3.4], D_{i0} is the relative effect of bypass at dam i alone, and D_{0j} is the relative effect of bypass at dam j alone. Standard errors of D_{ij}, D_{i0}, and D_{0j} were estimated using the formula for the standard error of a ratio estimator (Cochran 1977). Each linear contrast was compared to a normal distribution using a one-sided test to determine whether

L_{ij} was less than 0. In cases where L_{ij} was found to be significantly less than 0 (P<0.05), it was concluded that bypass at dams i and j interacted synergistically rather than additively. Perceived synergistic effects may reflect latent effects of bypass at the upriver dam.

Detections at Ice Harbor Dam were not included in this analysis because juvenile PIT-tag detectors were not installed there until 2005. The effects of bypass at Ice Harbor Dam were analyzed separately for the 2 years (2005 and 2006) with PIT-tag detection in the primary bypass system.

We also examined the effects of bypass at Lower Granite Dam for smolts that were later transported at Little Goose Dam. This provided a way of estimating bypass effects for a group of fish that were omitted from the groups of bypassed fish analyzed elsewhere in this report. We computed model residuals for fish that were transported from Little Goose Dam, either with or without previous detection at Lower Granite Dam. For both groups, the distribution of model residuals was compared to the standard normal distribution using the T_i statistic, and the relative effect and expected number of adults were computed. Too few smolts were transported from either Lower Monumental or McNary dams from the Chinook release groups for analysis, and too few steelhead were transported at any transport dam for analysis.

3.1.8 Analysis of Bypass Operations Eras

A variety of structural modifications have been made to the JBSs within the FCRPS over the years. Over time, these modifications defined bypass operations eras, within which the bypass system across the FCRPS was relatively stable (Figure 3.1). Bypass operations eras were defined both for specific dams and for the FCRPS as a whole. The changes used to define eras are presented in detail in Appendix E. Although changes were also being made to other passage routes during this time, and may have affected adult return rates, we were able to investigate only major changes of the bypass systems.

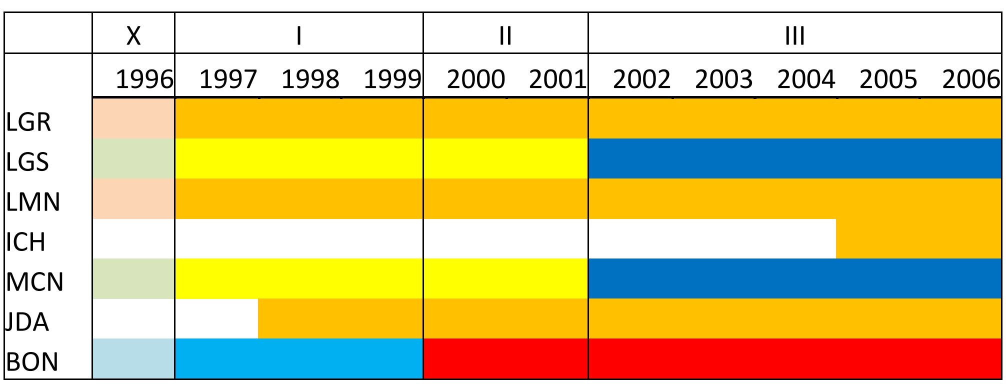

Figure 3.1. Bypass Operations Eras. Eras of common bypass operations for each dam are color-coded. System-wide bypass operations eras are numbered at the top (I–III). Release groups from 1997 were omitted from the analysis to avoid confounding an era effect with an effect of unidentified bypass at John Day Dam.

Complete juvenile and adult PIT-tag data are available only for some of the bypass era changes at some dams (Figure 3.1). For example, Lower Granite Dam has had three bypass eras (1994, 1995, and 1996–2009), but all available PIT-tag data come from a single era (1996–2009). Similarly, Lower

Monumental, Ice Harbor, and John Day dams each have had only a single bypass era during the study years (i.e., 1996–2006). At both Little Goose and McNary dams, PIT-tag data are available for three different eras, which coincide at the two dams (Table 2.1; Figure 3.1). The first era is a single year (1996) when Little Goose Dam received new VBSs and diversion-by-code gates, and McNary Dam received new ESBSs and VBSs. Because this era is only a single year, any effect of the new screens and gates at these two dams may be confounded with a year effect. The second era (1997–2001) defines the time when new ESBSs and a new mid-river outfall pipe were installed at Little Goose Dam, and new ESBSs and VBSs were installed at McNary Dam. The third era (data available 2002–2006) defines the time of wider conveyance pipes and a new three-way diversion-by-code gate at Little Goose, and when new return-to-river lines were installed at McNary. Changes in SAR rate, reflected by changes in model residuals, during these two eras may be related to the change in bypass operations between the eras at the two dams.

Bonneville Dam also had multiple operations eras, with some years of PIT-tag detection in each era. The primary operational change at Bonneville occurred in 2000, when the primary bypass route switched from powerhouse 1 to powerhouse 2 (Table 2.1). Thus, we have PIT-tag data for two eras at Bonneville: 1997–1999 and 2000–2006. We omitted 1996 from the first Bonneville era because relatively few PIT-tagged fish were detected at Bonneville in 1996. In addition to the dam-specific bypass eras, we defined a system-wide bypass era by the intersection of the individual eras for Little Goose, McNary, and Bonneville dams: I = 1997–1999, II = 2000–2001, and III = 2002–2006 (Figure 3.1). However, we omitted 1997 from the analysis to avoid confounding a possible era effect with unidentified bypass at John Day Dam, where PIT-tag detection became available only after 1997. Thus, the first eras analyzed for each dam and system-wide all began in 1998.

The effect of operational changes at Little Goose, McNary, and Bonneville dams on adult returns was analyzed by comparing Anscombe residuals from the ROSTER model for the different eras. If the operational change distinguishing two eras was beneficial to salmon survival, then we would expect the later era to have greater model residuals than the earlier era. The effect of bypass era was analyzed for those fish that were bypassed at only one or two dams, at least one of which must have been Little Goose, McNary, or Bonneville dam. Dams were assessed singly and in pairs to capture any synergistic effects of multiple bypasses. For the pairing of either Little Goose or McNary dams with Bonneville Dam, the first and last system-wide eras were compared (1998–1999 vs. 2002–2006). For each pair of dams, the change in model residuals from one era to the next was analyzed using an independent two-sample *t*-test.

In addition to the *t*-tests used for each pair of dams, we also assessed bypass era effects across all pairs of dams using analysis of variance (ANOVA), for detection histories with either one or two bypass events. For each stock, a multi-way weighted ANOVA was performed relating the ROSTER residual to bypass era while also accounting for the effect of individual bypass dams. Weights were proportional to release size, and F-tests were used to assess the significance of the bypass era effect. The ANOVA model used to test era effects had the form

$$z_{ij} = \beta_0 + \beta_1 Dam_{1i} + \beta_2 Dam_{2i} + \beta_3 Era_j,$$

for residuals z_{ij} for detection history *i* in year *j*. The covariate Dam_{1i} is the dam where the first bypass event occurred in detection history *i*, and Dam_{2i} is the dam where the second bypass event occurred, if

any. The covariate Era_j is the bypass operations era for year *j*. The Little Goose-McNary era and Bonneville era were considered separately, as well as the system-wide eras (1998–1999, 2000–2001, and 2002–2006).

3.1.9 Analysis of Alternative Bypass Routes Within a Dam

The routes used through each dam by fish that entered the bypass system were catalogued for each release group, including primary and facility bypass, sample room, adult routes, and raceway. In addition to identifying how often each route was used by PIT-tagged fish, we also analyzed the model residuals from fish that took different routes to determine whether some routes have lower subsequent adult return rates than other routes. In particular, we compared primary bypass to facility bypass, sort-by-code or other holding tanks to other forms of facility bypass ("direct facility bypass", aka "secondary bypass"), and the B2CC to facility bypass at Bonneville Dam. This residual analysis excluded juvenile fish that entered sample rooms, adult routes, or raceways.

We first identified the route taken through each dam by PIT-tagged fish that were detected at the dam. Routes were identified by the sequence of PIT-tag interrogation coils on which the tagged fish were detected at the dam. In most cases, only the final coil detection was necessary to determine the route. In other cases, it was necessary to look at earlier detections during dam passage in order to determine the route. At some dams, the configuration of interrogation coils did not provide sufficient information to identify the route. For example, at Lower Monumental Dam, the coil configuration did not distinguish between direct facility bypass and sort-by-code facility bypass, while at John Day Dam, some coils were shared by fish coming from both the sample room and the sort-by-code holding tank. Indeterminate detection at a dam meant that no information was available on the bypass route at that dam for some tagged fish. Site configuration files from the PTAGIS database and incorporated by PitPro were used to map the interrogation coils to the various routes. The bypass routes analyzed were the following (also see Table 3.3):

- primary bypass (i.e., full-flow bypass). Primary bypass PIT-tag detection was available only at Ice Harbor Dam beginning in 2005, McNary Dam beginning in 2003, and Bonneville Dam beginning in 2006. Primary bypass detection was unavailable at the other dams during the study years (1996–2006), but became available atLower Monumental and John Day dams in 2007, and at Little Goose Dam in 2009.

- facility bypass (i.e., through the facility, but omitting the sample room, raceways, or adult routes)
  - direct facility bypass (i.e., not through the sort-by-code route or holding tanks)
  - sort-by-code or holding tanks (excluding sample rooms)
  - direct or sort-by-code/holding tanks (in cases where the two routes were not distinguishable)

- sample room
  - sample room (i.e., known to go through the Sample Room)
  - sample room or sort-by-code (in cases where the two routes were not distinguishable)

- Other
  - raceway (i.e., collection for transportation), available at Lower Granite, Little Goose, Lower Monumental, and McNary dams
  - adult route (i.e., adult fish ladder or adult fish return)
  - flat plate detector at Bonneville
  - B2CC at Bonneville.

Table 3.3. Bypass Routes Identifiable by Each PIT-Tag Detection (marked by "X") and the First Year the Route Was Available (in parentheses). If no year is given, the route was identifiable for all study years with detection data (1996–2006).

		Facility			Sample Room			Other			
Dam	Primary	Direct Facility	SbyC/Holding Tank	Direct Facility or SbyC/Holding Tank	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector
Lower Granite		X	X (2000)		X		X	X	X (2006)		
Little Goose		X	X (2002)		X		X		X (2006)		
Lower Monumental				X	X		X		X (2006)		
Ice Harbor	X (2005)							X			
McNary	X (2003)	X	X (2000)		X		X		X (2003)		
John Day		X	X (2000)		X (1998)	X			X (2005)		
Bonneville	X (2006)	X	X (2000)		X					X	X (2006)

SbyC = sort-by-code.

Pairs of bypass routes were analyzed for their relative effect on adult returns within each release year. Anscombe residuals were computed for both routes under the modeling assumption that neither bypass nor bypass route (e.g., primary vs. facility) affects subsequent adult return to Lower Granite Dam. To test whether one route had higher adult return rates than the other, we used the test statistic

$$z_{12} = \frac{z_1 - z_2}{\sqrt{2}},$$

where z_1 and z_2 are the Anscombe residuals (Eq. [3.1]) for the two routes (Collett 1991). We compared z_{12} to 0 using a two-sided alternative hypothesis $\left(H_{A2} : z_{12} \neq 0\right)$ to test whether there was any difference in adult return rates between the two routes within each year. Such individual *Z*-tests were performed for each release group. The primary and facility bypass routes at McNary Dam were analyzed in this way for release years 2003–2006, as well as the B2CC and facility bypass at Bonneville Dam for the 2006 release groups. In addition, the sort-by-code holding tank was compared to other types of facility bypass ("direct facility bypass") at McNary Dam for the 2001 release group of spring Chinook salmon. Too few fish from other release groups were detected in the holding tank at McNary for this analysis, while records of fish passing through the sort-by-code facilities at other dams are censored by Program PitPro, and thus are unavailable for analysis.

In addition to the year-specific analyses, if detections from both routes were available over multiple years, we then combined the z_{12} statistics from all available release years in a meta-analysis to test for a difference between the two routes across years. The meta-analysis compared the test statistic *T* (Eq. [3.2]) to the standard normal distribution (Kulinskaya et al. 2008), where *T* was defined as

$$T = \frac{\sum_{j=2003}^{2006} \sqrt{R_j} z_{12,j}}{\sqrt{\sum_{j=2003}^{2006} R_j}},$$

with R_j equal to the size of the release group in year j. We compared *T* to 0 using a two-sided alternative $(H_A : T \neq 0)$ to test whether there was any difference in adult return rates between the two routes over years. The primary and facility bypass routes at McNary Dam were analyzed in this way for release years 2003–2006.

3.1.10 Analysis of Length Effects on Detection Probability

The effect of fish length on the probability of being detected (i.e., bypassed) was analyzed using individual-based covariate models for detection probabilities in Program SURPH (Survival Under Proportional Hazards). Fish length at tagging was used as a surrogate for fish length at the time of dam passage. To reduce noise in the length-at-tagging data arising from differences in tagging times and feeding regimes, this analysis was performed separately for different hatchery release groups, and restricted to fish that were tagged less than 100 days before release. Analysis focused on release groups of spring Chinook salmon from Dworshak, Lookingglass, and Rapid River hatcheries, because these release groups were the largest and provided the best prospects for detecting a size effect.

For each juvenile bypass dam i $(i = 1, \ldots, 6)$, the complete juvenile detection data from a release group were analyzed using the Cormack-Jolly-Seber (CJS; Cormack 1964; Jolly 1965; Seber 1965) model, with the probability of survival in the reach above the dam (S_i) and the probability of detection at the dam (p_i), both modeled as a function of fish length. Survival was modeled using a proportional hazard link, and the probability of detection was modeled using the logit link:

$$\log\left(\frac{\hat{p}_{ij}}{1-\hat{p}_{ij}}\right) = \alpha_i + \beta_i L_j,$$

where p_{ij} is the detection probability at dam i for fish j and L_j is fork length at time of tagging for fish j. The standardized regression coefficient of the length covariate,

$$z_\beta \equiv \frac{\hat{\beta}_i}{SE\left(\hat{\beta}_i\right)},$$

is asymptotically normally distributed. Under the null hypothesis that length has no effect on detection (bypass) probability, $z_\beta \sim N(0,1)$. Negative values of z_β would indicate that smaller fish have a higher probability of being bypassed, while a positive value of z_β would indicate a lower probability of bypass. The z_β statistic was calculated for each dam and release group, characterized by migration year and hatchery. Results were combined over migration years using meta-analysis methods (Kulinskaya et al. 2008) as follows:

$$T_i = \frac{\sum_{j=1}^{J} \sqrt{R_j} z_{\beta_{ij}}}{\sqrt{\sum_{j=1}^{J} R_j}},$$

where R_j is the number of fish in release group j $(j = 1, \ldots, J)$ for which length-at-tagging data were available, and $z_{\beta_{ij}}$ is the standardized regression coefficient for fish length at dam i and release group j. Under the null hypothesis, that length has no effect on bypass probability, $T_i \sim N(0,1)$. The T_i statistics were compared with the one-sided alternative $H_A : T_i < 0$. Detection processes at each dam were analyzed separately.

3.1.11 Analysis of Statistical Power

Statistical power was calculated for varying levels of the relative error between the number of adults observed and expected at Lower Granite Dam with a given juvenile bypass history (e.g., undetected, or detected only at Little Goose Dam). If O is the number of adults observed at Lower Granite Dam that had a particular juvenile bypass history, and E is the number of adults expected from that bypass history, then the relative error is

$$\Delta = \frac{O - E}{E}.$$

If R is the size of the tagged release group and p is the probability of reaching Lower Granite Dam as an adult with the given juvenile detection history under the null hypothesis (i.e., bypass does not affect adult return rates), then O is distributed as a binomial random variable with binomial parameter p and number of trials R:

$$O \sim Bin(R, p).$$

That is, $E = Rp$. This gives

$$\Delta = \frac{O - Rp}{Rp}.$$

Under the alternative hypothesis that detection affects adult return rates to Lower Granite Dam, O is still distributed as a binomial random variable with *R* independent trials, but the binomial parameter is now $p(\Delta+1)$:

$$O \sim Bin\left(R, p(\Delta+1)\right). \tag{3.5}$$

The test of whether the observed number of adults was different than expected used the residual (z) calculated from the ROSTER model for the given juvenile detection history. This residual was approximately equal to

$$z = \frac{O-E}{\sqrt{Var(O)}}.$$

The statistic z is defined under the null hypothesis that bypass does not affect adult returns, that is

$$\begin{aligned} z &= \frac{O-Rp}{\sqrt{Rp(1-p)}} \\ &= \frac{\Delta Rp}{\sqrt{Rp(1-p)}}. \end{aligned} \tag{3.6}$$

Because the probability of returning as an adult with any particular juvenile detection history (p) is very small, 1- p is approximately equal to 1, which gives

$$z \approx \Delta\sqrt{Rp}\ . \tag{3.7}$$

Under the null hypothesis that there is no error between the observed and expected number of adults, z has expected value 0 and variance 1. Under the alternative hypothesis that detection (i.e., bypass) affects adult return rates, *z* has expected value $\Delta_E\sqrt{Rp}$, where Δ_E is the expected relative error (non-zero under the alternative hypothesis), and variance (from Eq. [3.5] and Eq.[3.6]):

$$\begin{aligned} Var(z) &= \frac{Rp(\Delta_E+1)\left(1-p(\Delta_E+1)\right)}{Rp(1-p)} \\ &\approx \Delta_E+1. \end{aligned}$$

The test of whether juvenile detection affects adult return rates to Lower Granite Dam uses the test statistic $T=\bar{z}$, the mean of the observed z statistics over n years. Under the null hypothesis $H_0: T=0$, T is normally distributed with mean 0 and variance $1/n$. Under the alternative hypothesis $H_A: T \neq 0$, T is normally distributed with mean $\Delta_E\sqrt{Rp}=\Delta_E\sqrt{E}$ and variance $(\Delta_E+1)/n$. Thus, the power of the test is

$$1-\beta = \Pr\left(\sqrt{n}\left|T\right| > z_{1-\alpha/2} \mid \Delta\right).$$

Under the null hypothesis, this is α. For the one-sided alternative $H_A : T < 0$ that fewer adults are observed than expected (i.e., $\Delta < 0$, as in tests for detection histories with one or more detections), power is

$$1-\beta = \Phi\left(\frac{z_\alpha - \Delta_E\sqrt{En}}{\sqrt{\Delta_E + 1}}\right).$$

Statistical power under this alternative hypothesis was calculated for varying values of *E*, the expected number of adults observed, and for values of the relative error ranging from -1.0 to 2.0. The number of years of data n =2 to n =15, and the significance level was fixed at $\alpha = 0.05$.

3.2 Results

The results of the ROSTER residual analysis are presented in terms of comparisons of SAR rate between inriver smolts that were bypassed at particular dams and inriver smolts that passed those dams using other routes. Finding a perceived bypass effect at a given dam means that smolts that were bypassed at that dam had a different adult return rate than smolts that passed the dam through other routes (e.g., spillway, turbines). We use the term "perceived bypass effects" because we cannot distinguish between the mechanistic effects of going through the bypass system and the selectivity of the bypass system among fish passing the dam. We make no conclusions about the actual cause of the perceived effects.

3.2.1 All Juvenile Detection Histories

For each annual release group, plots of Anscombe residuals were examined. Residuals for the spring Chinook salmon release in 2003 illustrate a common pattern (Figure 3.2). Residuals are arranged by order of number of detections, starting with capture history 000000 (i.e., the undetected group), followed by all possible capture histories with one detection, then all capture histories with two detections, etc., through to the single capture history with detections at all six juvenile PIT-tag detection dams (111111). The dispersion of the *Z*-values generally declines as the number of downstream detections increases, with capture histories with four or more detections often having residuals (i.e., *Z*) near zero. This pattern occurs because the observed and expected number of adult returns is each near zero for capture histories with low probabilities of occurrence. The implication is that PIT-tagged adult return data are insufficient to assess multiple bypass events beyond three occurrences with any reasonable prospect of statistical power. For this reason, this report focuses on adult returns for fish with three or fewer bypass events.

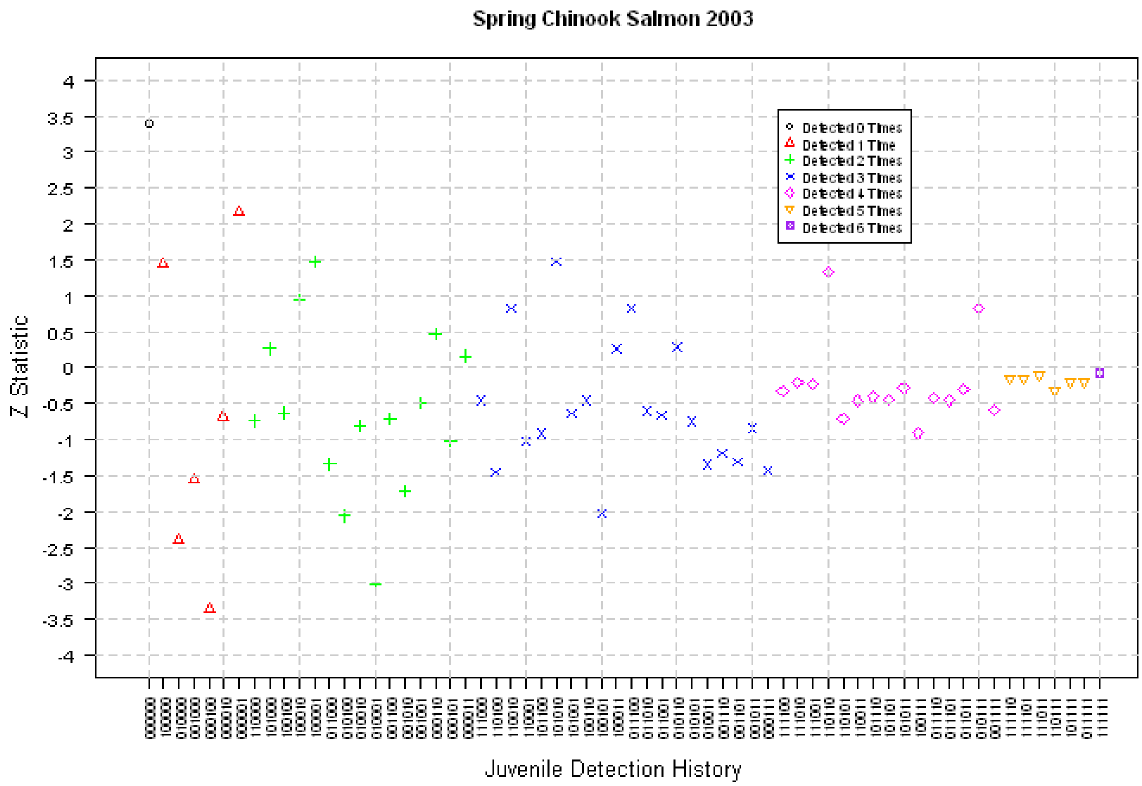

Figure 3.2. Anscombe Residual for Each Juvenile Detection History for Snake River Hatchery Spring Chinook Salmon Released Upstream of Lower Granite Dam in 2003

3.2.2 Statistical Power of the PIT-Tag Analysis to Detect Effects on Adult Returns

Interpretation of the comparisons of SAR rates between bypassed and non-bypassed smolts depends in part on the statistical power of the tests performed. The statistical power of the meta-analysis tests (using the *T* statistic) performed to assess perceived bypass effects on adult returns from the meta-analysis depends on several factors:

- α-level (1- or 2-tailed tests)
- percent reduction in the adult return rate
- years of data
- expected number of adult returns.

All tests were performed at $\alpha = 0.05$, and, in most cases, 1-tailed tests were used to test the hypothesis that bypassed fish had reduced adult return rates compared to non-bypassed fish. Most of the meta-analyses had 10 years of adult return data. The statistical power to detect a significant reduction in the adult return rate increases as the number of years of data increases, the expected number of adults increases, and the size of the effect increases (Figure 3.3–Figure 3.6).

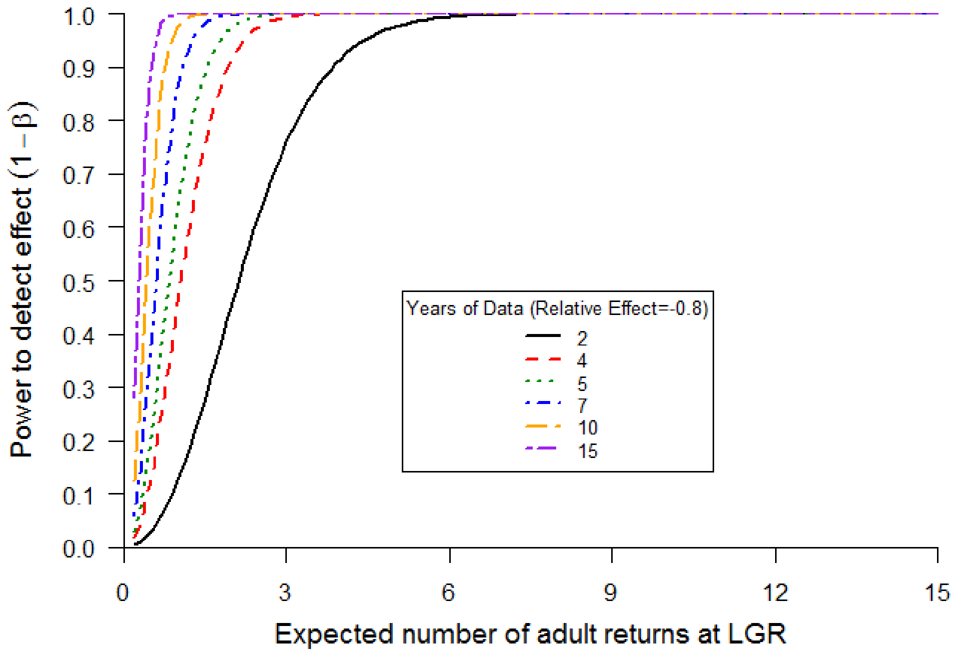

Figure 3.3. Power to Detect 80% Reduction in Adult Returns for $\alpha = 0.05$, 1-Tailed

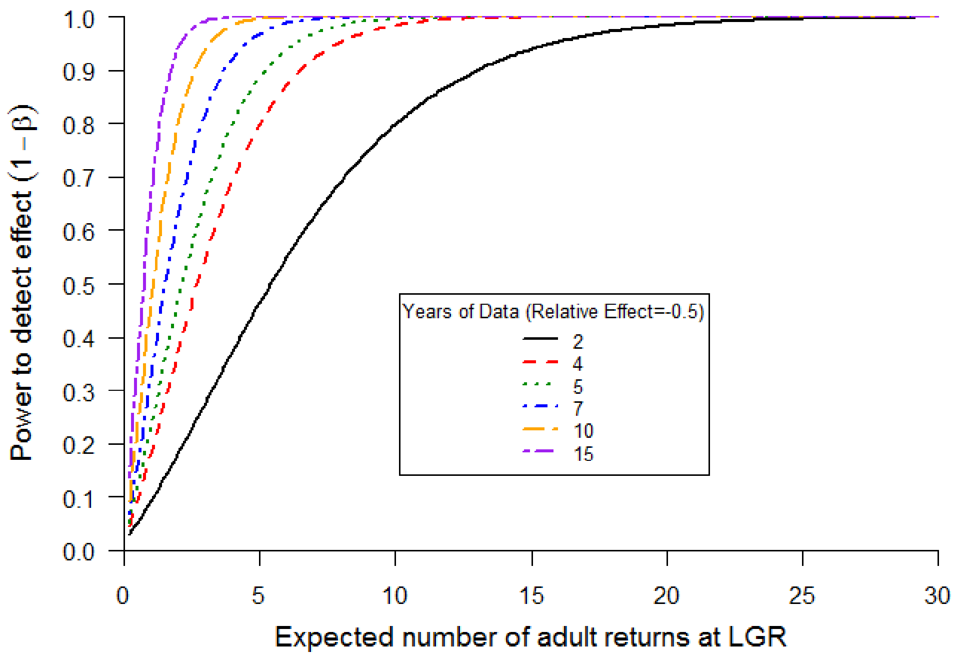

Figure 3.4. Power to Detect 50% Reduction in Adult Returns for $\alpha = 0.05$, 1-Tailed

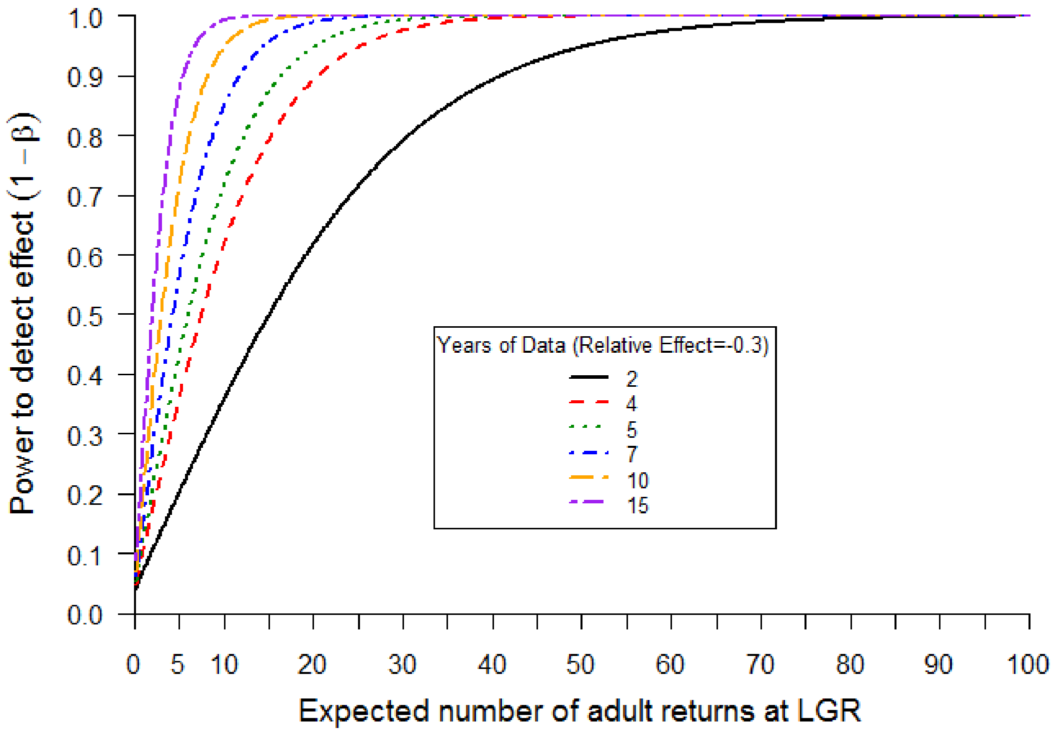

Figure 3.5. Power to Detect 30% Reduction in Adult Returns for $\alpha = 0.05$, 1-Tailed

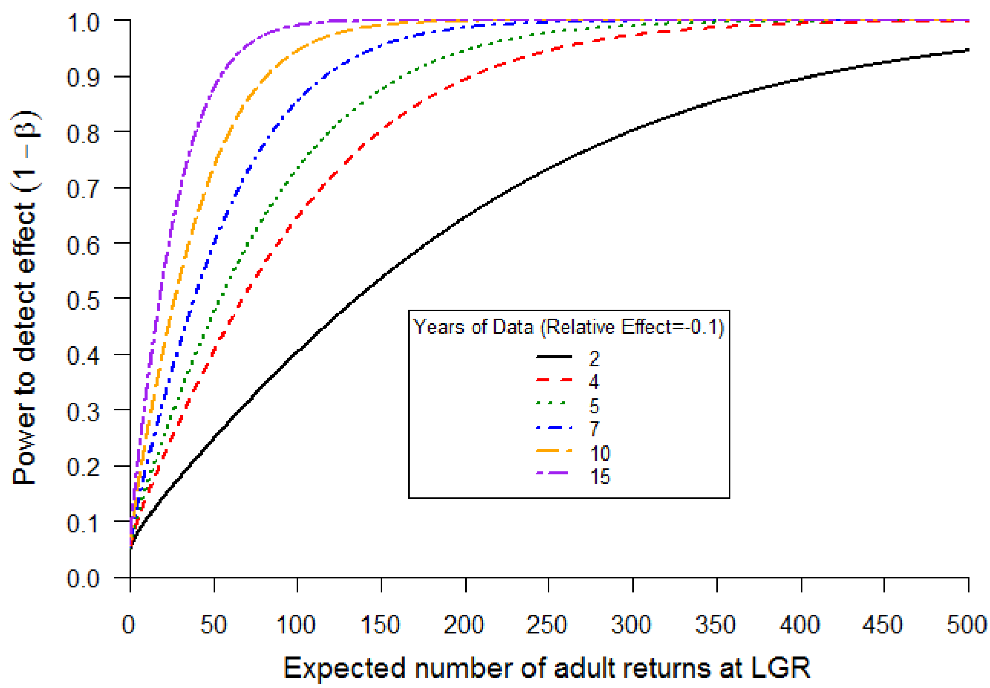

Figure 3.6. Power to Detect 10% Reduction in Adult Returns for $\alpha = 0.05$, 1-Tailed

In order to detect a 50% reduction in the number of adults with 90% power, approximately 15 adult returns are needed if only 2 years of data are available, while approximately 6 adult returns are needed if 4 years of data are available (Figure 3.4). With 10 years available, only about 3 expected adult returns are required. To detect a 30% reduction in the number of adult returns with 90% power, approximately 9 expected adults are required per year if 10 years of data are available, while approximately 41 expected adults are required per year if only 2 years of data are available (Figure 3.5). In order to detect a 10% reduction in the number of adult returns with 90% power, approximately 85 adults are required per year if 10 years of data are available, while approximately 410 adults are required per year if only 2 years of data are available (Figure 3.6). Therefore, it is impractical to expect to detect very small bypass effects.

For many of the statistical analyses performed, we will present estimates of the relative effect size and expected number of adult returns. In general, statistical significance ($P < 0.05$) was found when effect sizes were ≥30% and the average expected number of adults was ≥7. These values are a good rule of thumb for the thresholds for reasonable statistical power for the analyses performed in this report. Bypass histories that had an expected number of 7 or more adults tended to include detection only at the transport dams, while bypass histories including John Day and Bonneville dams rarely had large numbers of expected adults. For this reason, only large reductions in SAR rates could be detected in relation to bypass at John Day and Bonneville dams, while smaller reductions could generally be detected at the upstream dams. Similarly, the relatively small release groups of steelhead, compared to Chinook salmon, often resulted in low numbers of expected steelhead adults and low power to detect small reductions in adult return rates for steelhead. However, in some cases, relatively small (e.g., 30%) perceived bypass effects were found to be significant even though only very few adults were expected. This may happen if the true bypass effect is actually more extreme than the measured effect. We will return to the results of the power analysis as we discuss specific findings related to possible bypass effects at the individual dams.

3.2.3 Effect of the Number of Bypass Events on Adult Returns

The number of observed adults at Lower Granite Dam that migrated completely undetected as juveniles was significantly higher than expected for all three of the fish stocks considered ($P<0.0001$ for each stock; Figure 3.7–Figure 3.9). These results strongly suggest that non-bypassed smolts had a higher probability of adult return than bypassed smolts. Over the 11 release years of analysis (1996–2006), non-bypassed spring Chinook salmon smolts returned at a rate that was 49% higher than expected had there been no bypass effect (Figure 3.7), non-bypassed summer Chinook salmon smolts returned at a rate that was 22% higher than expected (Figure 3.8), and non-bypassed steelhead smolts returned at a rate that was 71% higher than expected (Figure 3.9). Significantly fewer spring Chinook salmon returned as adults than expected from smolts that were bypassed one, two, or three times ($P<0.0072$; Figure 3.7). Summer Chinook salmon showed a slightly different pattern, with only a slight difference between observed and expected adult returns from smolts that were bypassed at only one dam ($P=0.0872$), but with significantly fewer observed adults than expected from smolts that were bypassed at two ($P<0.0001$) or three dams ($P=0.0001$; Figure 3.8). Steelhead showed a pattern similar to summer Chinook salmon. There was no apparent trend in model residuals over time for any stock. We omitted residuals from juvenile detection histories that included four or more detections because the expected number of adults for these detection histories was too low to achieve reasonable statistical power.

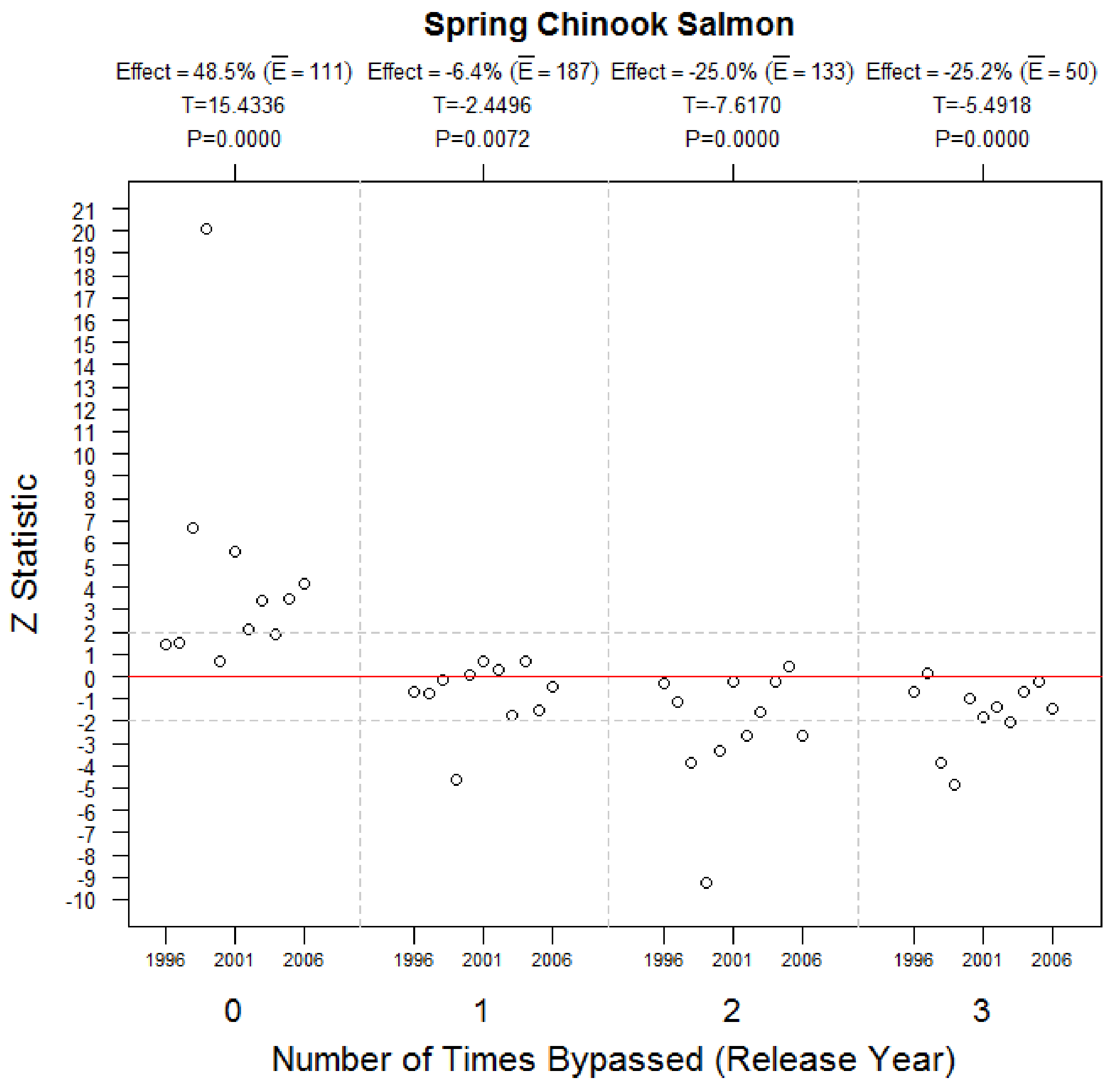

Figure 3.7. Anscombe Residuals of Number of Adults Observed at Lower Granite Dam vs. the Number of Times Fish Were Bypassed as Juveniles (smolts) for Snake River Hatchery Spring Chinook Salmon. Release year is indicated along the horizontal axis. T = meta-analysis test statistic. P-value: HA:$T>0$ for 0 times bypassed; HA:$T<0$ for 1 or more times bypassed. Effect = relative difference between observed and expected adults at Lower Granite (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years).

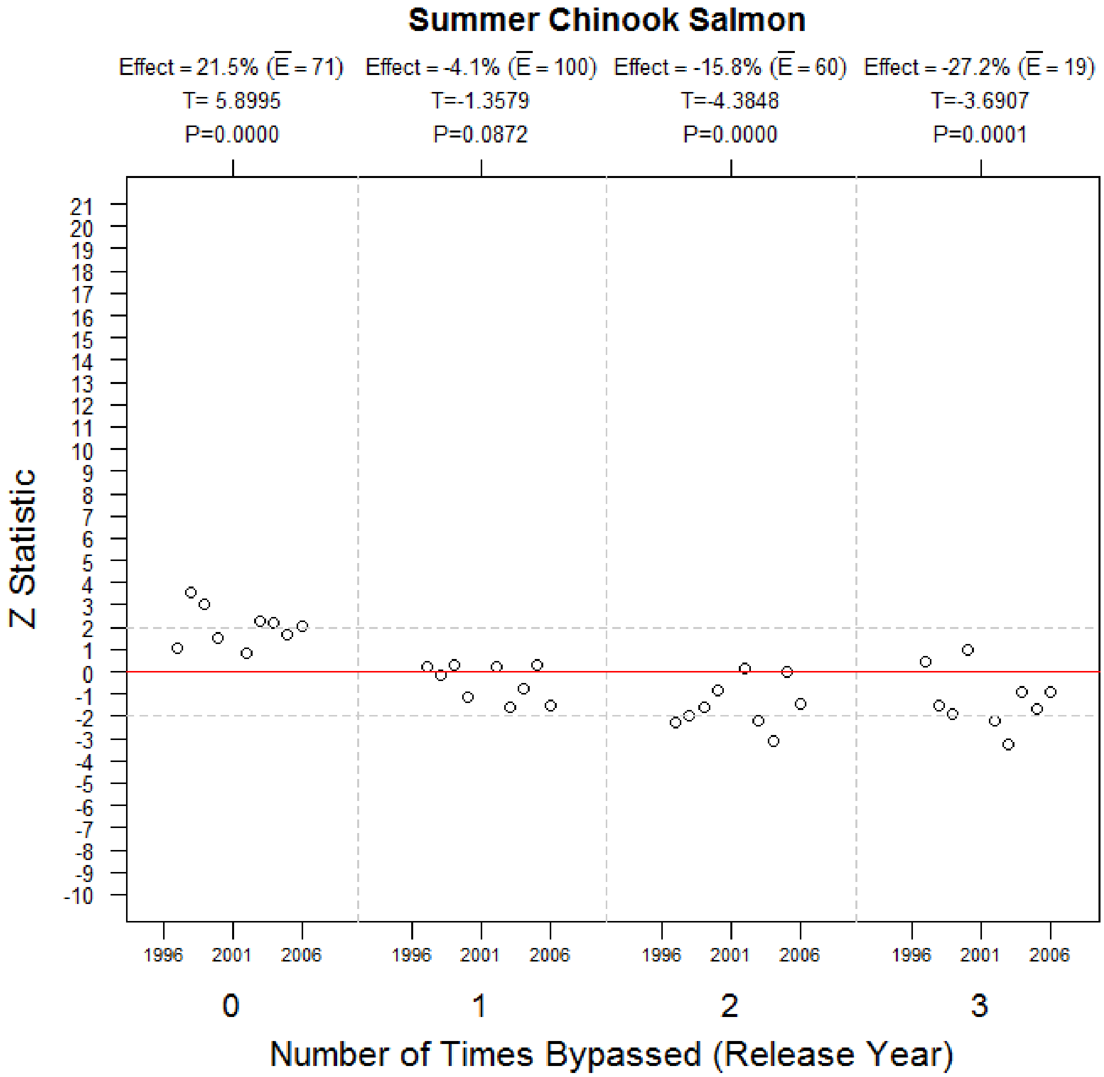

Figure 3.8. Anscombe Residuals of Number of Adults Observed at Lower Granite Dam vs. the Number of Times Fish Were Bypassed as Juveniles (smolts) for Snake River Hatchery Summer Chinook Salmon. Release year is indicated along the horizontal axis. T = meta-analysis test statistic. P-value: HA:T>0 for 0 times bypassed; HA:T<0 for 1 or more times bypassed. Effect = relative difference between observed and expected adults at Lower Granite (averaged over release years), and $\bar{E}$ = number of expected adults at Lower Granite (averaged over release years).

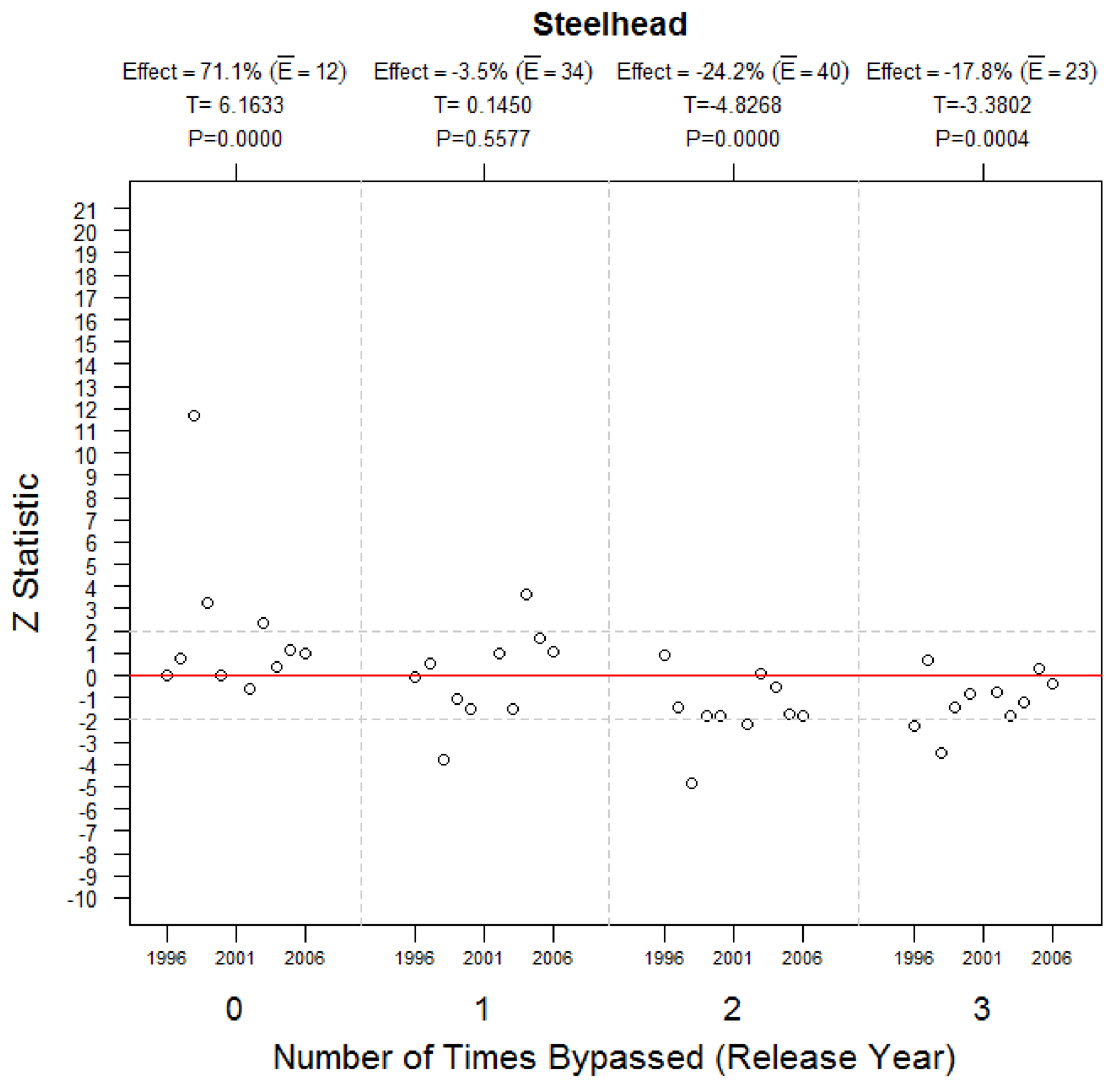

Figure 3.9. Anscombe Residuals of Number of Adults Observed at Lower Granite Dam vs. the Number of Times Fish Were Bypassed as Juveniles (smolts) for Snake River Hatchery Steelhead. Release year is indicated along the horizontal axis. T = meta-analysis test statistic. P-value: HA:T>0 for 0 times bypassed; HA:T<0 for 1 or more times bypassed. Effect = relative difference between observed and expected adults at Lower Granite (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years).

In summary, the following patterns were observed in the PIT-tag data:

- Undetected fish consistently returned at higher than expected rates.
- Yearling Chinook with one or more bypass events generally returned at significantly lower than expected rates.
- Steelhead
  - One bypass event: no noticeable difference in adult return rates.
  - Two or more bypass events: lower adult return rates compared to non-bypassed smolts.

3.2.4 Dam-Specific Bypass Effects on Adult Returns

The results of the examination of perceived dam-specific bypass effects on adult returns are presented by dam, starting with Lower Granite Dam. Figures related to each dam discussed below are provided at the end of this section.

3.2.4.1 Perceived Effects of Bypass at Lower Granite Dam on Adult Returns

Spring and summer Chinook salmon that were detected at Lower Granite Dam as smolts generally showed no difference between the observed and expected number of adults returns, whether they were detected only at Lower Granite Dam as juveniles or at both Lower Granite Dam and a downstream dam ($P \geq 0.05$; Figure 3.10, Figure 3.11). Only summer Chinook salmon bypassed at both Lower Granite and McNary dams showed a reduction in adult return rate relative to other inriver fish ($P=0.0169$; Figure 3.11). Spring Chinook salmon bypassed at both Lower Granite and Lower Monumental dams produced slightly fewer adults than other inriver smolts, but the reduction was not significant at the 5% level ($P=0.0602$; Figure 3.10). In some cases, only a few (e.g., three) adults were expected on average from the fish bypassed at both Lower Granite and downstream dams, thus making only large bypass effects detectable.

Several bypass histories including Lower Granite Dam produced more smolts than expected. In particular, both spring and summer Chinook salmon bypassed at Lower Granite Dam alone produced higher SARs than the average of all other inriver fish ($P<0.0051$; Figure 3.10, Figure 3.11). Likewise, spring Chinook salmon bypassed at both Lower Granite and Bonneville dams produced higher SARs than expected, relative to other inriver fish ($P=0.0462$; Figure 3.10). However, this positive result appears to be driven by the 1998 release group, and is no longer significant when only the most recent operations era at Bonneville Dam is considered (i.e., release years 2000–2006; $P=0.1153$).

In some cases, being bypassed at both Lower Granite and a second dam had negative effects that were larger than the sum of the effects of bypass at each dam alone. This perceived synergistic effect was seen for summer Chinook salmon detected at both Lower Granite and McNary dams (Figure 3.11), which produced fewer adults than expected from return rates of fish detected only at Lower Granite or only at McNary ($P=0.0335$). Thus, although bypass at Lower Granite alone is not associated with reduced adult return rates, these findings suggest the possibility of a latent effect of bypass at Lower Granite that is expressed only after a second bypass at McNary.

Other evidence of possible bypass effects at Lower Granite Dam were seen for fish that were detected at Lower Granite Dam and then transported from Little Goose Dam. These fish had an adult return rate that was approximately 50% to 60% lower than expected had there been no bypass effects ($P<0.0001$; Figure 3.12). This contrasts with fish that passed Lower Granite Dam without detection and then were transported from Little Goose Dam, which showed no declines in adult return rate (Figure 3.12). Thus, it appears that prior bypass at Lower Granite Dam may reduce the benefit of transportation from Little Goose Dam.

Steelhead smolts that were bypassed only at Lower Granite Dam showed no difference between observed and expected adult returns ($P>0.05$; Figure 3.13). However, steelhead smolts that were bypassed at both Lower Granite and a downstream dam tended to produce fewer than expected adult returns ($P \leq 0.03$ in each case; Figure 3.13). In two cases, these perceived bypass effects were simple

additive effects from being bypassed at either dam alone. In two other cases, however, there were apparent synergistic effects between Lower Granite Dam and another dam. Joint detection at Lower Granite and either Little Goose or McNary dams resulted in a more extreme reduction in adult return rate than expected from single detections at these individual dams (Figure 3.13). The patterns of additive and synergistic effects were observed whether all release years were used in the meta-analysis, or whether analysis was restricted to the most recent operations era.

3.2.4.2 Perceived Effects of Bypass at Little Goose Dam on Adult Returns

Spring and summer Chinook salmon that were first bypassed at Little Goose Dam tended to produce fewer adult returns than expected, whether they were bypassed only at Little Goose Dam or also at a downstream dam ($P \leq 0.0043$; Figure 3.10, Figure 3.11). In addition to simple additive effects from bypass at multiple dams, there were perceived synergistic effects from bypass at both Little Goose Dam and Bonneville Dam, with fewer spring Chinook salmon adults produced from smolts with this capture history than expected from the individual perceived bypass effects at Little Goose and Bonneville dams (Figure 3.10). However, when analysis was restricted to the most recent operations era at Little Goose Dam (2002–2006), the perceived effect of bypass was not significant at the 5% level for capture histories with bypass at both Little Goose and either John Day ($P=0.0571$) or Bonneville ($P=0.0592$) for spring Chinook salmon. For summer Chinook salmon, the effect of joint bypass at Little Goose and Lower Monumental dams was no longer significant at the 5% level ($P=0.0541$). With *P*-values nearly at the significance level, it is possible that the analyses restricted to the most recent operations era, with only 5 years of data, lacked statistical power to detect all but the largest differences in adult return rates.

Steelhead smolts that were bypassed at Little Goose generally produced the expected number of adult returns, unless they were also bypassed at either Lower Granite or Lower Monumental dams (Figure 3.13). Reductions in adult returns in those cases appear to be related more to perceived bypass effects at Lower Granite and Lower Monumental dams, rather than to bypass effects at Little Goose Dam for steelhead smolts. However, the low numbers of steelhead adults expected from smolts bypassed both at Little Goose and either McNary, John Day, or Bonneville dams limit the statistical power available to detect reductions in the adult return rate associated with those bypass histories. The same patterns were observed whether all release years were included in the analysis, or whether only the most recent operations era was analyzed (2002–2006).

3.2.4.3 Perceived Effects of Bypass at Lower Monumental Dam on Adult Returns

Both spring Chinook salmon and steelhead smolts that were bypassed at Lower Monumental Dam tended to produce fewer adult returns than expected, relative to other inriver smolts ($P \leq 0.0184$; Figure 3.10; Figure 3.13). The pattern is not as obvious for summer Chinook salmon. Although all capture histories involving bypass at Lower Monumental produced fewer adult returns than expected when averaged over all study years, the reduction in adult return rate was not consistently statistically significant for summer Chinook salmon (Figure 3.11). Furthermore, when only the most recent operations era at Little Goose and McNary (2002–2006) or Bonneville (2000–2006) was analyzed, the reduction in adult return rate for summer Chinook salmon smolts detected at both Lower Monumental and any of these dams was no longer significant at the 5% level ($P \geq 0.0541$). We cannot determine whether the lack of significance is due to reduced statistical power from the shorter time series, or to a true absence of a bypass effect.

3.2.4.4 Perceived Effects of Bypass at Ice Harbor Dam on Adult Returns

Perceived bypass effects at Ice Harbor Dam were analyzed separately from bypass considerations at other dams for 2005 and 2006, the 2 years when PIT-tag detection was available in the primary bypass system at Ice Harbor. Passage through the bypass system at Ice Harbor was not associated with a statistically significant decrease in survival to adult return to Lower Granite Dam for any stock (Figure 3.14). However, the power to detect an effect of bypass at Ice Harbor was low, both because few fish were observed in the bypass system at Ice Harbor (with the exception of spring Chinook salmon in 2006; Table B.1–Table B.3 in Appendix B), and because there are only 2 years of data available.

3.2.4.5 Perceived Effects of Bypass at McNary Dam on Adult Returns

For all stocks, smolts that were bypassed only at McNary Dam showed no difference between observed and expected numbers of adult returns when averaged across all release years ($P>0.0792$; Figure 3.10, Figure 3.11, Figure 3.13). However, when only the most recent operations era at McNary Dam was considered (2002–2006), spring Chinook salmon that were bypassed only at McNary had a lower than expected adult return rates, compared to all other inriver fish ($P=0.0369$). Smolts that were bypassed both at McNary and at a second dam tended to produce fewer than expected adult returns, relative to other inriver fish. This was particularly observable for spring and summer Chinook salmon (Figure 3.10, Figure 3.11), and was less consistent for steelhead (Figure 3.13). However, the smaller release groups of steelhead meant that the power to detect perceived bypass effects at downstream dams was consistently lower for steelhead than for Chinook release groups. Despite the small release groups and resulting low power, there appeared to be a synergistic effect between bypass at McNary Dam and bypass at Bonneville Dam for spring Chinook salmon (Figure 3.10), and between bypass at McNary and bypass at John Day for steelhead (Figure 3.13).

3.2.4.6 Perceived Effects of Bypass at John Day Dam on Adult Returns

Spring Chinook salmon smolts bypassed at John Day Dam alone produced slightly but non-significantly fewer adult returns than expected ($P=0.0549$; Figure 3.10), while smolts bypassed at John Day after a previous detection at an upstream dam tended to produce fewer than expected adults (Figure 3.10). However, the largest perceived effects of joint bypass at John Day and either Little Goose or McNary dams were observed for release groups prior to 2002. When analysis was restricted to the most recent operations era at Little Goose and McNary dams (2002–2006), spring Chinook salmon smolts bypassed at either of these dams along with John Day showed no significant reduction in adult return rate relative to other inriver fish ($P\geq0.0571$). Summer Chinook salmon bypassed at John Day Dam showed a more consistent pattern of reduction in adult return rates compared to other inriver fish than spring Chinook salmon (Figure 3.11), and limiting analysis to the most recent operations era at the upstream dams had no effect on results. For steelhead, most juvenile capture histories involving John Day Dam showed insignificant ($P\geq0.05$) reductions in adult returns; however, few adult returns were expected for steelhead, and the power to detect a significant effect was low (Figure 3.13).

3.2.4.7 Perceived Effects of Bypass at Bonneville Dam on Adult Returns

A reduction in adult returns for fish bypassed at Bonneville Dam was detected only for spring Chinook salmon smolts that were also bypassed at either Little Goose Dam (P=0.0110) or McNary Dam (P=0.0142) (Figure 3.10), and for summer Chinook salmon that were bypassed at Lower Monumental dam (P=0.0255; Figure 3.11). These results may be explained by a possible bypass effect at the upriver dams rather than at Bonneville Dam, per se. Neither run of Chinook salmon showed a negative effect of bypass at Bonneville for smolts detected only at Bonneville as juveniles (Figure 3.10, Figure 3.11), whether data from all release years were considered or whether only the most recent operations era at Bonneville was considered (2000–2006). On the other hand, spring Chinook bypassed at Bonneville alone tended to produce more adult returns than all other inriver fish (P=0.0308; Figure 3.10). Using all data from 1996–2006, steelhead smolts bypassed at Bonneville Dam showed no difference between observed and expected numbers of adult returns, regardless of where else they may have been bypassed (Figure 3.13). When restricted to data from the most recent operation era at Bonneville Dam (2000–2006), steelhead smolts bypassed only at Bonneville tended to produce more than expected adults relative to other passage routes (P=0.0291). In general, however, the average number of steelhead adults expected from Bonneville detections was consistently very low (1–3), resulting in low statistical power to detect any but the largest difference in adult return rate between bypassed and non-bypassed smolts.

3.2.4.8 Conclusions: Dam-Specific Bypass Effects on Adult Return Rates

In summary, the following patterns were observed in the PIT-tag data for bypass at specific dams, reflecting trends of significant results across multiple detection histories:

- Lower Granite Dam
  - Chinook:
    - No obvious reduction in adult return rates for inriver migrants
    - Higher adult return rate for smolts bypassed only at Lower Granite Dam compared to other passage routes
    - Reduction in adult return rate for fish transported from Little Goose Dam if previously bypassed at Lower Granite Dam
    - Perceived synergistic effect of bypass at Lower Granite and McNary dams
  - Steelhead:
    - Reduction in adult return rate if also bypassed elsewhere
    - Perceived synergistic effect of bypass at Lower Granite and Little Goose, or Lower Granite and McNary dams
- Little Goose Dam
  - Chinook:
    - Reduction in adult returns compared to other inriver fish
    - Perceived synergistic effect of bypass at Little Goose and Bonneville dams
  - Steelhead: No obvious reduction in adult returns

- Lower Monumental Dam
  - Chinook: Reduction in adult returns (stronger for spring Chinook salmon)
  - Steelhead: Reduction in adult returns
- Ice Harbor Dam: No obvious reduction in adult returns
- McNary Dam
  - Chinook:
    - Reduction in adult returns if also bypassed elsewhere
    - Perceived synergistic effect of bypass at McNary and Bonneville dams
  - Steelhead:
    - Reduction in adult returns if also bypassed elsewhere
    - Perceived synergistic effect of bypass at McNary and John Day dams
- John Day Dam
  - Chinook:
    - Reduction in adult returns if also bypassed elsewhere
    - Perceived effect lessened or absent in recent years
  - Steelhead: No obvious reduction in adult returns
- Bonneville Dam
  - Chinook: No obvious effect on adult returns
  - Steelhead:
    - No obvious effect on adult returns over 1996–2006
    - Increase in adult returns from 2000–2006.

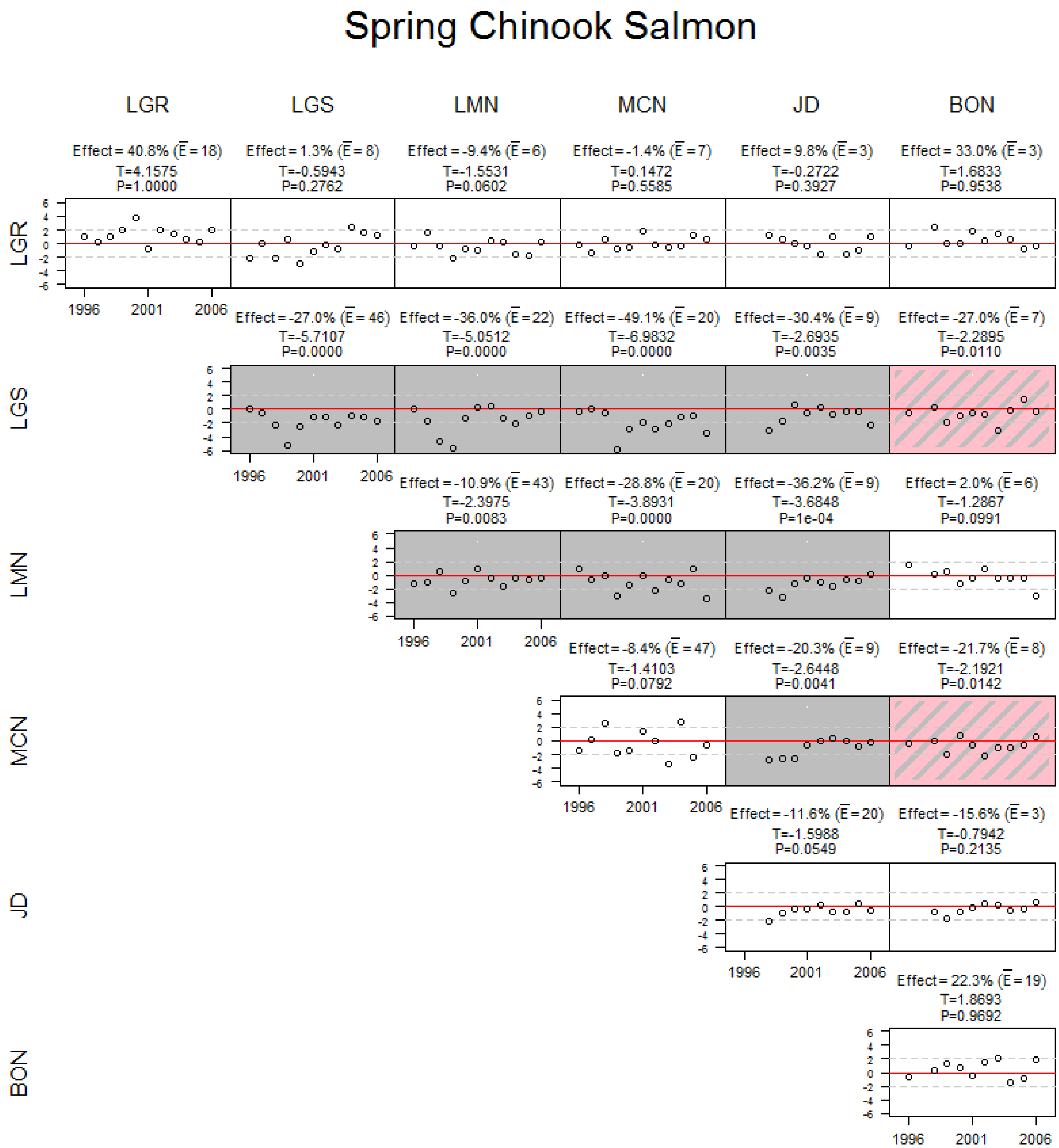

Figure 3.10. Anscombe Residuals and Meta-Analysis *T*-Statistic and *P*-Value (HA:$T<0$) for Snake River Hatchery Spring Chinook Salmon Detected at One or Two Dams as Juveniles. Only non-transported detection histories are represented. Effect = relative difference between observed and expected adults at Lower Granite Dam (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years). Solid shading indicates statistical significance at $P \leq 0.05$, and striped shading indicates synergism between effects at two dams.

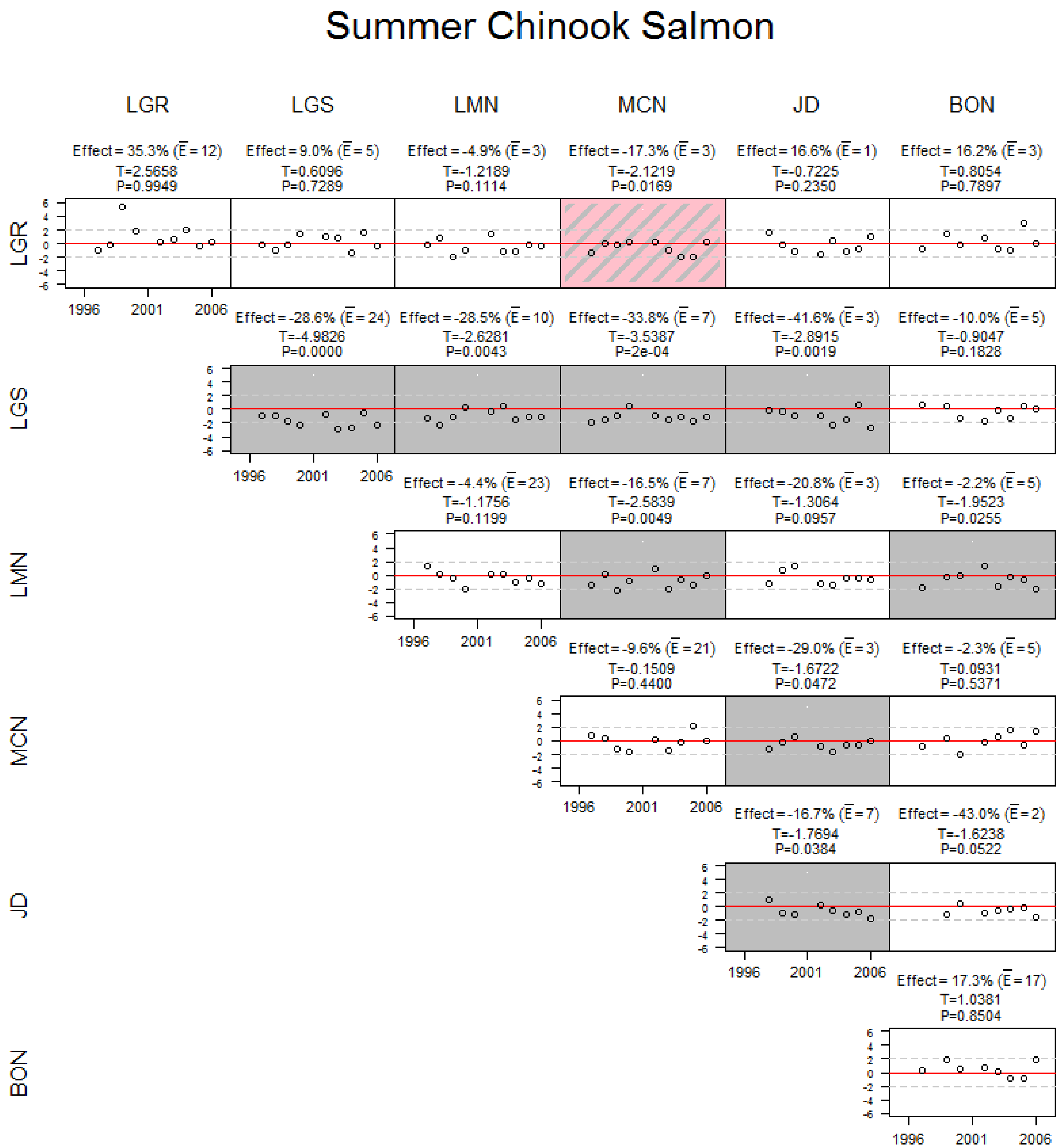

Figure 3.11. Anscombe Residuals and Meta-Analysis *T*-Statistic and *P*-Value (HA:*T*<0) for Snake River Hatchery Summer Chinook Salmon Detected at One or Two Dams as Juveniles. Only nontransported detection histories are represented. Effect = relative difference between observed and expected adults at Lower Granite Dam (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years). Solid shading indicates statistical significance at $P \leq 0.05$, and striped shading indicates synergism between effects at two dams.

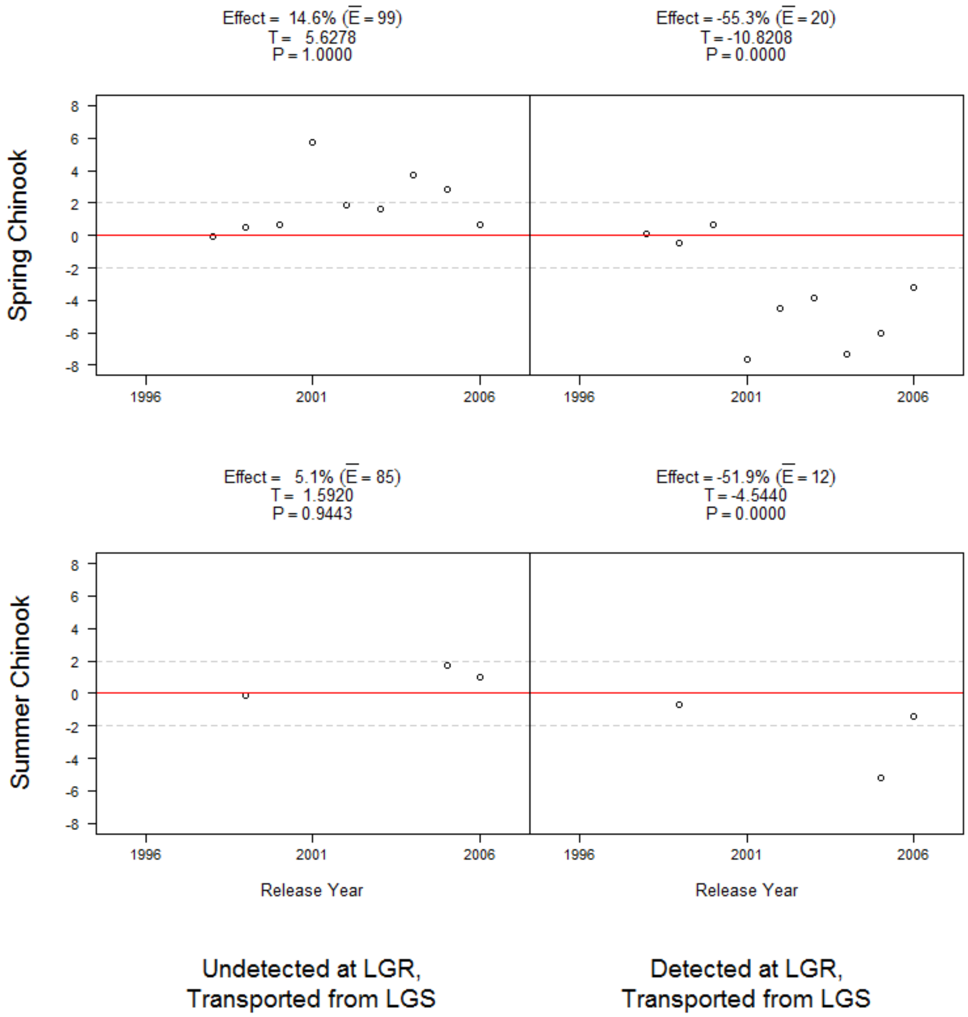

Figure 3.12. Anscombe Residuals with Meta-Analysis *T*-Statistic and *P*-Value (HA:*T*<0) for Snake River Hatchery Spring and Summer Chinook Salmon Transported at Little Goose Dam (1996–2006). Effect = relative difference between observed and expected adults at Lower Granite (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years).

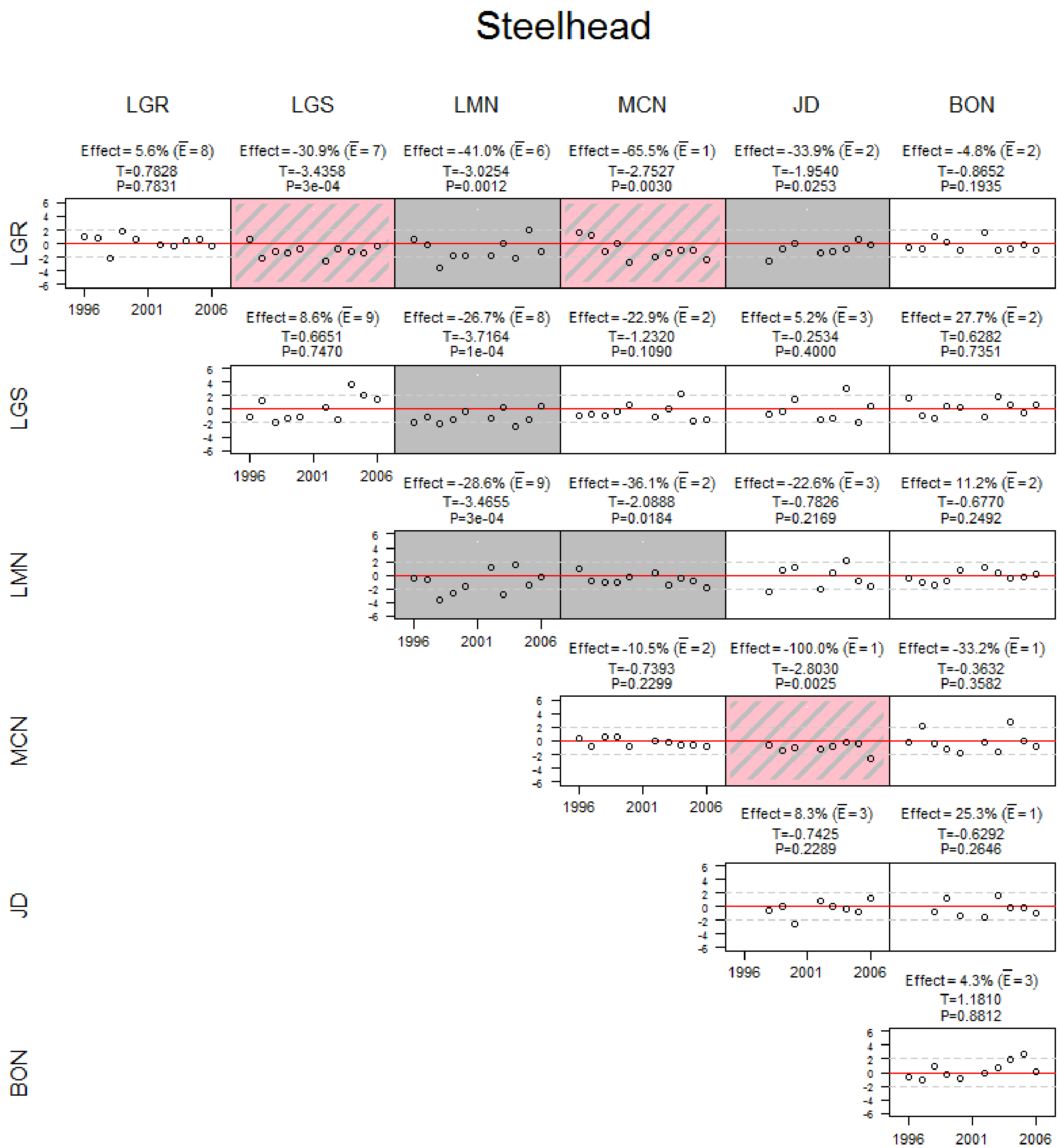

Figure 3.13. Anscombe Residuals and Meta-Analysis *T*-Statistic and *P*-Value (HA:$T<0$) for Snake River Hatchery Steelhead Detected at One or Two Dams as Juveniles. Only nontransported detection histories are represented. Effect = relative difference between observed and expected adults at Lower Granite Dam (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years). Solid shading indicates statistical significance at $P \leq 0.05$, and striped shading indicates synergism between effects at two dams.

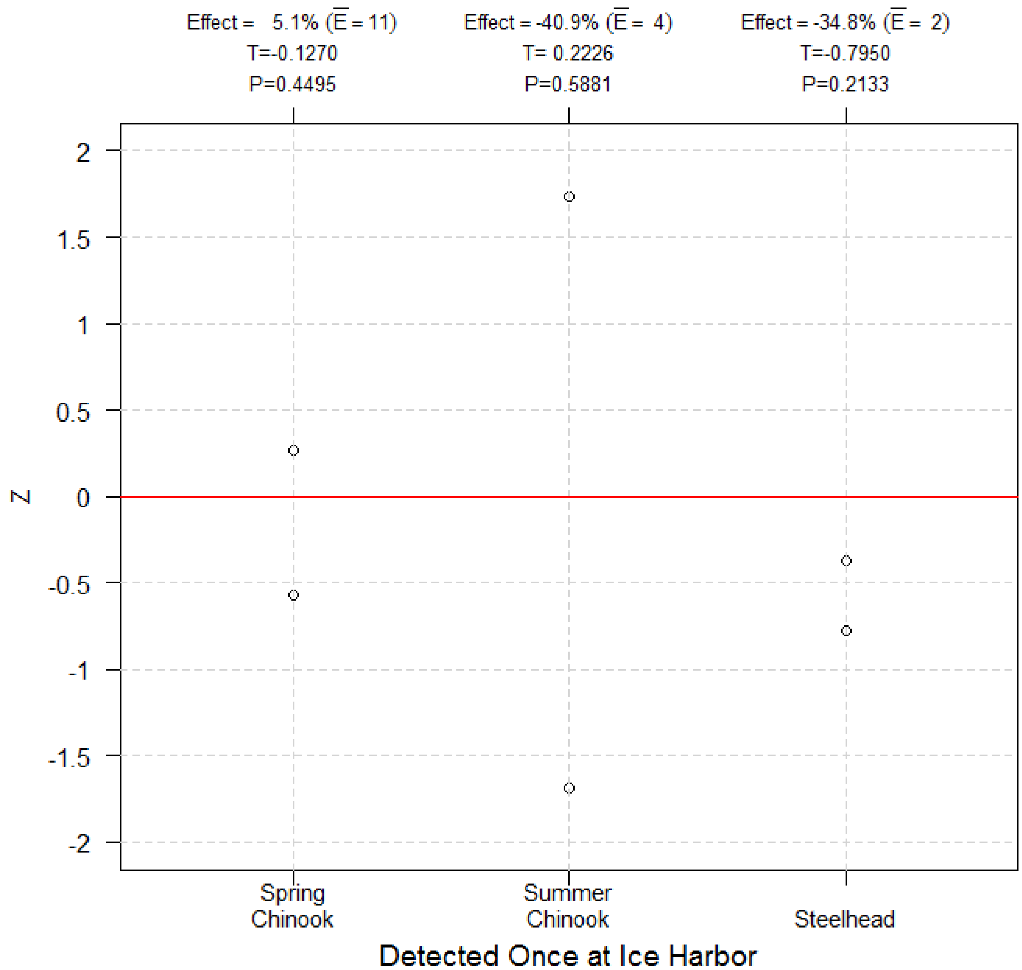

Figure 3.14. Anscombe Residual of Number of Adults Observed at Lower Granite Dam from Fish that Were Detected Only at Ice Harbor Dam as Juveniles. T = meta-analysis test statistic. P-value: HA:T<0 for detected once. Only the 2005 and 2006 release groups are represented, based on available data. Effect = relative difference between observed and expected adults at Lower Granite (averaged over release years), and $\overline{E}$ = number of expected adults at Lower Granite (averaged over release years).

3.2.5 Effects of Changes in Bypass Operations on Adult Returns

Bypass operations eras were analyzed for operational changes at Little Goose, McNary, and Bonneville dams (Table 2.1; Figure 3.1). Although changes were being made to all passage routes throughout the study period, our analysis focused only on changes to the bypass system. Overall, there was very little evidence of improvement in adult returns from operational changes at the hydroprojects. Only 4 out of 39 tests (i.e., 10.3%) found significant improvements between eras. Figures related to each dam discussed below are provided at the end of this section.

3.2.5.1 Effects of Operational Changes at Little Goose Dam on Adult Returns

The widening of the conveyance pipes and installation of a new three-way diversion-by-code gate at Little Goose Dam in 2002 appeared to have little effect on adult return rates. Although spring Chinook salmon smolts that were bypassed at Little Goose Dam from 2002 onward had slightly higher adult return rates (compared to other inriver fish) than migrants from earlier years, the increase was insignificant (P>0.1045) except for fish that were also bypassed at Lower Granite Dam (P=0.0272, Figure 3.15). Furthermore, summer Chinook salmon that were bypassed at Little Goose Dam from 2002 onward had no significant change in adult return rates (Figure 3.16), while for steelhead, only those that were bypassed at Little Goose alone had a significant increase in adult return rate after the changes to the system (P=0.0166, Figure 3.17). ANOVA found a significant effect of bypass era at Little Goose on ROSTER model residuals for spring Chinook salmon (P=0.0347) and for steelhead (P=0.0212), but this effect could not be separated from effects of coincident changes at McNary Dam, and may reflect a year effect rather than an effect of operational changes. Thus, with only 2 of 17 individual *t*-tests showing significant results, there is little evidence to suggest that the changes at Little Goose Dam in 2002 resulted in higher adult returns.

3.2.5.2 Effects of Operational Changes at McNary Dam on Adult Returns

At McNary Dam, bypass operations eras were separated by the replacement of return-to-river lines in 2002. For spring Chinook salmon, smolts that were bypassed at both McNary Dam and John Day Dam had a higher adult return rate (compared to other inriver fish) from 2002 onward (P=0.0091), but no other capture histories involving McNary Dam had significant changes in adult return rate (Figure 3.15). ANOVA found a significant ($P \leq 0.05$) effect of bypass era defined by operational changes at both Little Goose and McNary dams on adult return rates, but the effect for McNary Dam alone could not be isolated. In addition, it is possible that the ANOVA results may reflect year effects rather than effects of operational changes at either dam.

Summer Chinook salmon bypassed at McNary Dam showed no evidence of changes in the adult return rate (compared to other inriver fish) from 2002 onward (Figure 3.16), and ANOVA found no effect of bypass era on adult return rates (P>0.05). Similarly, there was no change in adult return rates between bypass eras for steelhead bypassed at McNary Dam either (Figure 3.17). As with spring Chinook salmon, ANOVA found a significant increase in adult returns from early to late eras defined by operational changes at Little Goose and McNary dams (P=0.0212), but effects of operational changes at McNary could not be distinguished from either effects of changes at Little Goose or year effects.

3.2.5.3 Effects of Operational Changes at Bonneville Dam on Adult Returns

The main bypass route past Bonneville Dam changed from powerhouse 1 to powerhouse 2 in 2000, and bypass at powerhouse 1 was discontinued. There was no significant increase in adult return rates (compared to other inriver fish) after this change for spring Chinook salmon (Figure 3.15). On the contrary, the results indicate a significant decline (P=1-0.9663 =0.0337) in the relative adult return rate for spring Chinook salmon smolts that were bypassed at both Lower Monumental and Bonneville dams. Because adult return rates of bypassed fish are estimated relative to other inriver fish, it is possible that this decline reflects an improvement in non-bypass routes at Bonneville rather than new problems in the Bonneville bypass system. ANOVA detected a significant effect of bypass era at Bonneville Dam on the

relative adult return rates of bypassed spring Chinook salmon compared to other inriver fish (*P*=0.0014), but again, this result may reflect year effects rather than operational changes. Sparse detection data of summer Chinook salmon in the early bypass era at Bonneville precluded analyzing the effect of operational changes there for summer Chinook salmon.

Among steelhead bypassed at Bonneville Dam, there was a significant increase in adult return rate (compared to other inriver fish) after smolt passage switched to powerhouse 2 only for those steelhead that were also bypassed at Lower Monumental Dam (*P*=0.0055; Figure 3.17). For other steelhead bypassed at Bonneville, there was no significant change in the relative adult return rate between bypass eras at Bonneville (*P*>0.1980). ANOVA found no significant effect of bypass era at Bonneville on adult return rates for steelhead.

3.2.5.4 Conclusions: Effects of Bypass Era on Adult Return Rate

In summary, the following patterns were observed with respect to bypass operations eras:

- very slight evidence of an increase in adult returns (compared to non-bypassed smolts) after operational changes at Little Goose and McNary dams for spring Chinook salmon and steelhead
- conflicting evidence for improved adult returns after operational changes at Bonneville Dam
- over all stocks and dams, only 4 out of 39 tests (10.3%) showed significant increase in adult returns after operation changes.

With few years of data available both before and after operational changes, there was low power to detect any but the largest increases in relative adult return rates from one bypass era to the next. Even as more years of data become available in the later eras, the relatively small amount of data available prior to operational changes will make detecting differences in adult return rates difficult. This is particularly true for Bonneville Dam, where only 3 years of data were available before the change from the first powerhouse to the second powerhouse.

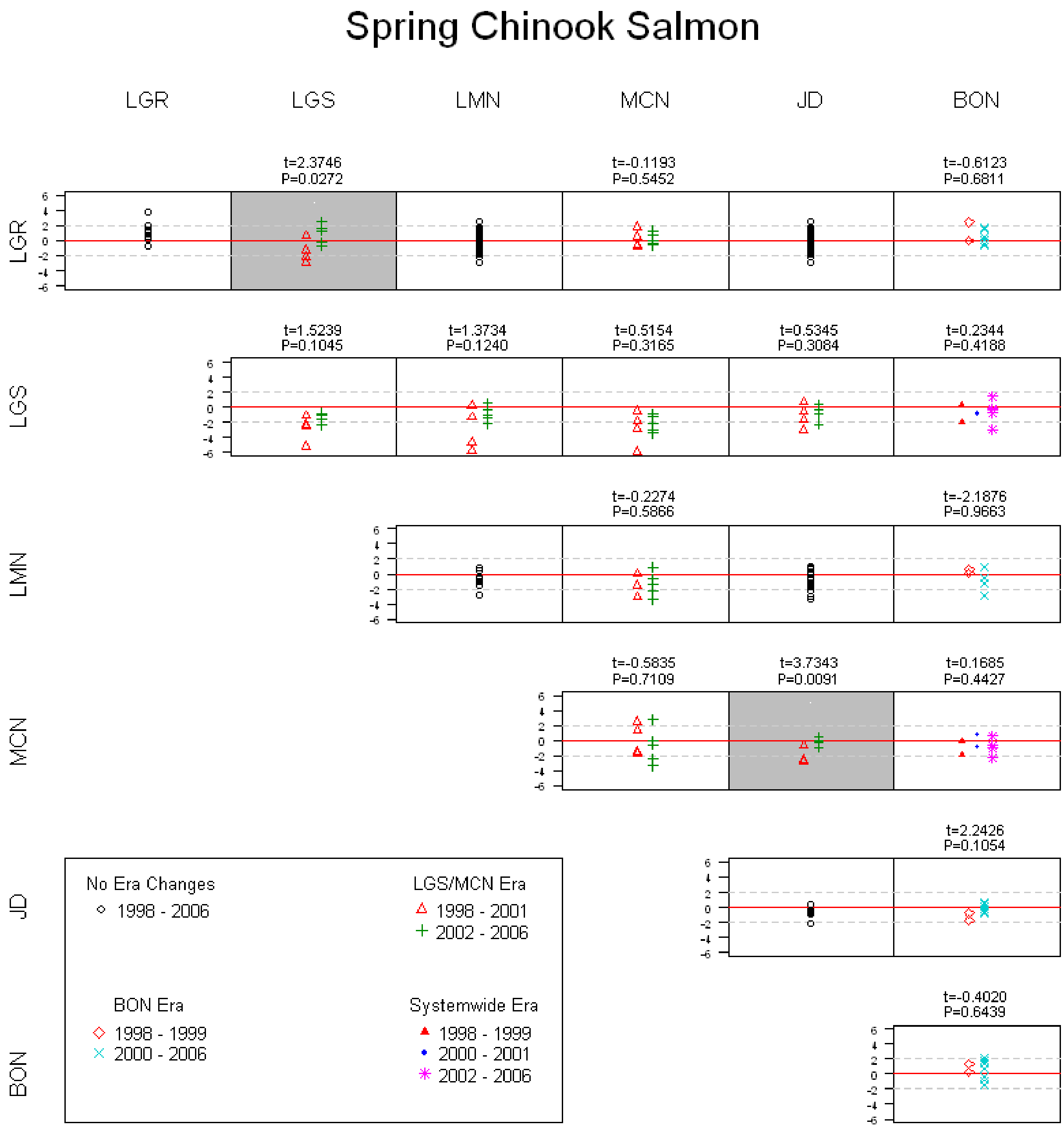

Figure 3.15. Anscombe Residuals from Different Dam-Specific Bypass Operation Eras for Snake River Hatchery Spring Chinook Salmon Detected at One or Two Dams as Juveniles, and Results of One-Sided *t*-Test Comparing Residuals from First and Last Eras (HA:t>0). Only nontransported detection histories are represented. Shading indicates statistical significance at $P \leq 0.05$.

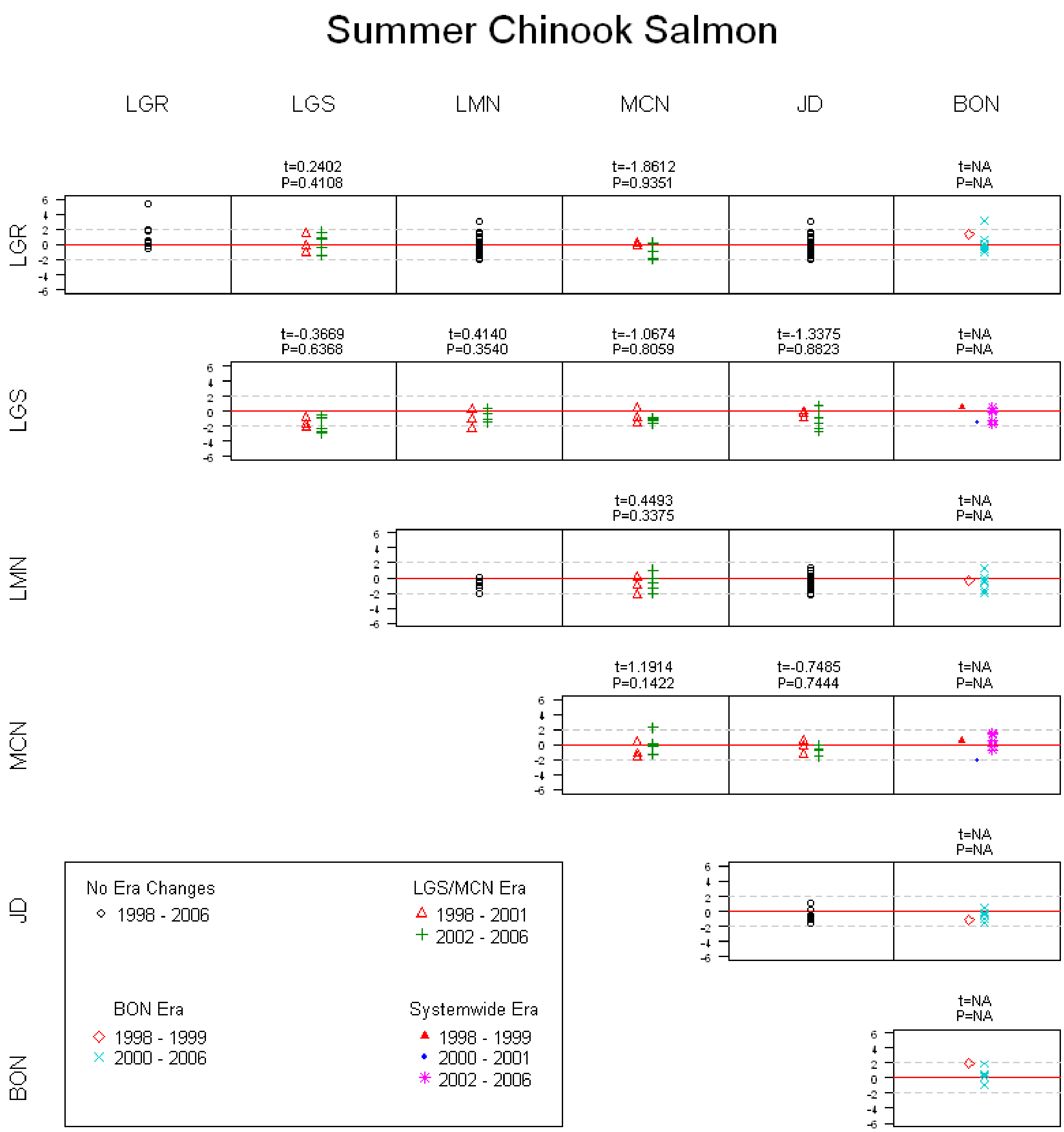

Figure 3.16. Anscombe Residuals from Different Dam-Specific Bypass Operation Eras for Snake River Hatchery Summer Chinook Salmon Detected at One or Two Dams as Juveniles, and Results of One-Sided *t*-Test Comparing Residuals from First and Last Eras (HA:t>0). Only nontransported detection histories are represented. Shading indicates statistical significance at $P \leq 0.05$.

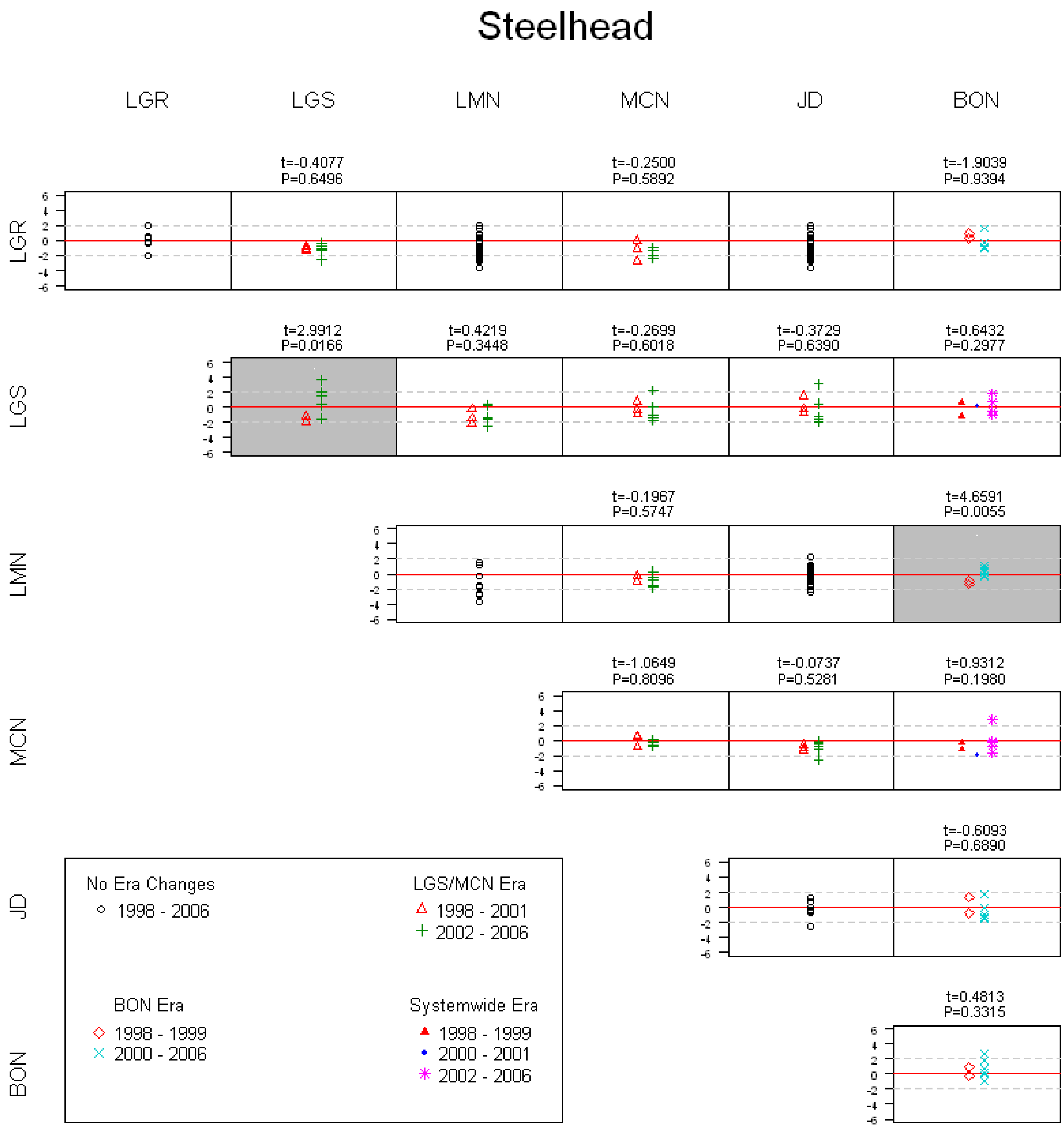

Figure 3.17. Anscombe Residuals from Different Dam-Specific Bypass Operation Eras for Snake River Hatchery Steelhead Detected at One or Two Dams as Juveniles, and Results of One-Sided *t*-Test Comparing Residuals from First and Last Eras (HA:t>0). Only nontransported detection histories are represented. Shading indicates statistical significance at $P \leq 0.05$.

3.2.6 Patterns in Bypass Route Use and Effects of Different Bypass Routes at a Dam on Adult Returns

The examination of patterns in bypass route use at the different dams is described below, starting with Lower Granite Dam. The effects of different bypass routes on adult returns at McNary Dam are also described. The emphasis here is on fish returned to the river, and the large numbers of fish transported from these dams were not included in this analysis or discussion. Figures related to each dam discussed below are provided at the end of this section.

3.2.6.1 Bypass Routes at Lower Granite Dam

In most years, the majority of the PIT-tagged spring Chinook salmon passing through the bypass system at Lower Granite Dam were collected for transport, and most of the remainder passed through direct facility bypass (see Table C.1 in Appendix C). Other routes included the sample room, sort-by-code holding tank, and adult return. The annual release groups included between 1 (2004 release group) and 6822 (2006 release group) spring Chinook salmon passing Lower Granite Dam through the sort-by-code holding tank. Similar passage patterns were observed for PIT-tagged summer Chinook salmon and steelhead (Tables C.2 and C.3). PIT-tag monitoring of primary bypass at Lower Granite Dam was not available during the study period.

3.2.6.2 Bypass Routes at Little Goose Dam

Most PIT-tagged spring Chinook salmon passing through Little Goose Dam passed either via the direct facility bypass route or through the raceway, with the remainder passing through the sort-by-code facility or the sample room (Table C.1). The same was true for PIT-tagged summer Chinook salmon and steelhead (Tables C.2 and C.3). Primary bypass at Little Goose Dam was not monitored by PIT-tag detection during the study period.

3.2.6.3 Bypass Routes at Lower Monumental Dam

In most migration years, the large majority of PIT-tagged spring and summer Chinook and steelhead passing through Lower Monumental Dam passed through the direct facility bypass (Tables C.1, C.2, and C.3). It was impossible to distinguish between direct facility bypass and sort-by-code bypass at Lower Monumental Dam. The remainder of the PIT-tagged fish passing through Lower Monumental passed through the raceway or sample room. PIT-tag monitoring of the primary bypass system at Lower Monumental Dam began did not begin until 2007. Thus, no analysis of primary bypass at Lower Monumental was possible.

3.2.6.4 Bypass Routes at Ice Harbor Dam

PIT-tag monitoring of the primary bypass system at Ice Harbor Dam began in 2005. The other monitored route at Ice Harbor is the adult fish ladder. Nearly all tagged fish at Ice Harbor Dam were detected in the primary bypass, with just a few fish detected in the adult fish ladder (2005–2006). Thus, it was not possible to compare primary and direct facility bypass routes at Ice Harbor (Table 3.4).

3.2.6.5 Bypass Routes at McNary Dam

PIT-tag monitoring of the primary bypass system at McNary Dam began in 2003. Before then, the majority of tagged yearling Chinook salmon and steelhead smolts used in this study passed McNary through direct facility bypass (Tables C.1, C.2, and C.3). Since 2003, direct facility bypass and primary

bypass have been used nearly evenly (Table 3.4). Tagged fish also passed through the holding tanks at McNary, as well as through the sample room, raceway, or adult fish return (Tables C.1, C.2, and C.3).

Primary vs. Facility Bypass at McNary Dam

Four years of data were available from each species and run combination (stock) for comparison of the primary and facility bypass routes at McNary Dam, from 2003 to 2006. During those years, from 6,568 to 15,577 PIT-tagged spring Chinook salmon passed through the primary bypass route, with 6,859 to 13,696 passing through the facility bypass route (Table 3.4). Between 1596 and 4082 PIT-tagged summer Chinook salmon passed through the primary bypass during those years, with 1691 to 3517 passing through the facility bypass (Table 3.4). Between 764 and 1761 PIT-tagged steelhead used the primary bypass route, while 605 to 1511 used the facility bypass route (Table 3.4). There was a significant difference in adult returns between the primary and facility route for the 2006 release group of spring Chinook salmon, but in this case, fish that had taken the facility route at McNary had higher adult returns (P=0.0402; Table 3.5). For all other release groups, there was no evidence that the two routes had different adult return rates (Table 3.5). Furthermore, no evidence of a difference in adult returns between the two routes was found over the four release years (Figure 3.18).

Sort-by-Code Holding Tank vs. Direct Facility Bypass at McNary Dam

Only the 2001 release group of spring Chinook salmon had sufficient numbers of fish passing through the holding tanks at McNary Dam to warrant comparing the adult return rates of fish that passed through the holding tank to that of fish that passed through other facility bypass routes (i.e., “direct facility bypass”). In 2001, 10,440 PIT-tagged spring Chinook salmon passed McNary through the direct facility bypass route, while 10,479 passed through the holding tank. The test statistic comparing the adult returns of fish using these two routes was z_{12} =0.9050 (route 1 = holding tank, route 2 = direct facility bypass), which was not significantly different from 0 (P=0.3655). Thus, there was no observed difference in adult returns to Lower Granite Dam between fish that took these two routes in 2001.

3.2.6.6 Bypass Routes at John Day Dam

In most years, the majority of PIT-tagged yearling Chinook salmon and steelhead smolts detected at John Day Dam passed through direct facility bypass, with most of the remaining passing tagged fish passing through the sample room or sort-by-code facility (Tables C.1, C.2, and C.3). In 1998 and 1999, the site configuration did not provide precise information on passage route for the majority of the tagged smolts detected at John Day. PIT-tag monitoring of the primary bypass at John Day Dam began in 2007, so no complete PIT-tag adult return data were available for analysis of the John Day primary bypass at the time of this writing.

3.2.6.7 Bypass Routes at Bonneville Dam

At Bonneville Dam, most PIT-tagged yearling Chinook salmon and steelhead smolts passed through direct facility bypass (Tables C.1, C.2, and C.3). Sizeable numbers of tagged fish also passed through the sort-by-code facility or over the flat plate detector. Monitoring of both the primary bypass and B2CC at Bonneville began in 2006. However, no tagged fish were detected on the primary bypass monitors during 2006, so it is not possible to relate adult returns to primary vs. facility bypass for Bonneville Dam (Table 3.4).

Table 3.4. Summary of PIT-Tag Detection Data Available for Primary vs. Facility Bypass. Counts are the number of tagged smolts detected for PIT-tagged Snake River hatchery spring Chinook, summer Chinook, and steelhead. Facility bypass includes sort-by-code holding tanks.

Dam	Stock	Era	Year	Primary Bypass	Facility Bypass
Ice Harbor	Spring Chinook	1	2005	1,294	2
			2006	13,422	5
	Summer Chinook	1	2005	513	1
			2006	1,692	0
	Steelhead	1	2005	1,381	10
			2006	3,484	5
McNary	Spring Chinook	4	2003	15,577	13,696
			2004	6,568	6,859
			2005	6,670	6,961
			2006	12,492	12,949
	Summer Chinook	4	2003	4,082	3,517
			2004	1,926	2,051
			2005	2,978	3,030
			2006	1,596	1,691
	Steelhead	4	2003	771	605
			2004	764	679
			2005	1,761	1,511
			2006	1,556	1,415
Bonneville	Spring Chinook		2006	0	7,617
	Summer Chinook		2006	0	1,136
	Steelhead		2006	0	334

Table 3.5. Test Statistic and *P*-Value Comparing Facility Bypass (route 1 = "F") and Primary Bypass (route 2 = "P") at McNary Dam (using two-tailed *Z*-tests of alternative hypothesis H_A: fish taking the primary and facility bypass routes at McNary had common adult return rates)

Stock	Year	z_{FP}	P
Spring Chinook	2003	0.3857	0.6997
	2004	-1.5434	0.1227
	2005	0.3766	0.7065
	2006	2.0519	0.0402
Summer Chinook	2003	0.5705	0.5684
	2004	0.5421	0.5878
	2005	-1.1304	0.2583
	2006	0.2526	0.8006
Steelhead	2003	0.3374	0.7358
	2004	1.9358	0.0529
	2005	-0.1398	0.8888
	2006	0.0562	0.9552

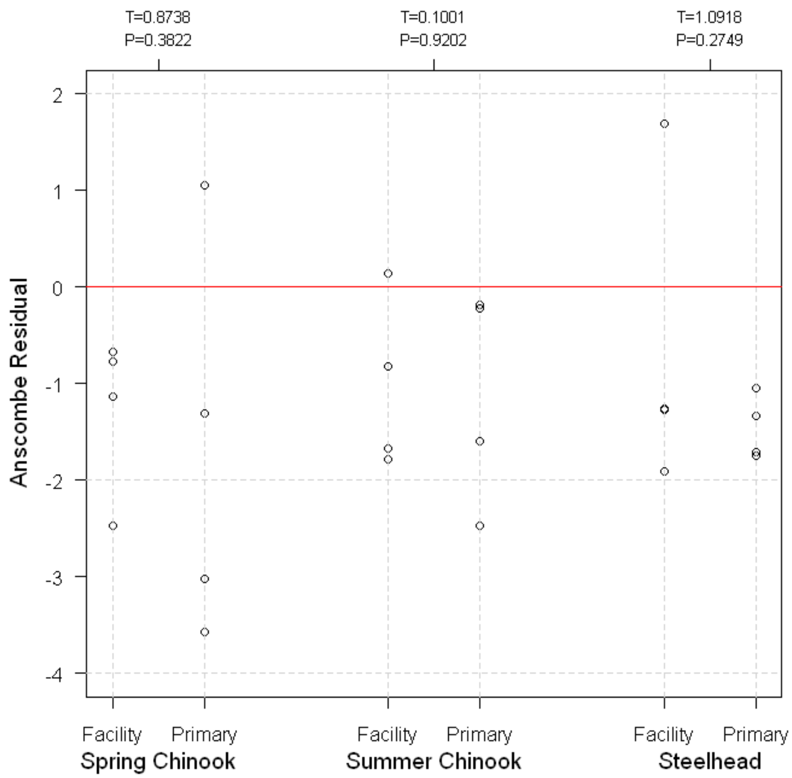

Figure 3.18. Anscombe Residual of Number of Adults Observed at Lower Granite Dam from Fish that Passed McNary Dam as Juveniles Either Through the Direct Facility Bypass or Primary ("Full-Flow") Bypass Systems as Juveniles (smolts). *T* = meta-analysis statistic. *P*-value: $H_A : T \neq 0$.

Over 4000 spring Chinook salmon from the 2006 release group were detected passing Bonneville Dam through the facility bypass at the second powerhouse (site B2J), while only 324 were detected at the B2CC (Figure 3.19). There was no significant difference in adult returns from either bypass route (P=0.9341, Figure 3.19). Fewer tagged summer Chinook salmon were detected at Bonneville passing either through the facility bypass (1133) or through the B2CC (54; Figure 3.20). None of the juveniles detected passing through the B2CC were subsequently observed as adults at Lower Granite, while 16 of 1133 (14%) of those that passed via the facility bypass were later detected at Lower Granite Dam as adults. This difference in adult returns was not significant at the $\alpha = 0.05$ (P=0.0952; Figure 3.20). Few steelhead were detected at either the B2CC (89) or the facility bypass (332) as juveniles, with no more than 5 adults subsequently detected from either juvenile bypass route (Figure 3.21). There was an insignificant difference in adult returns to Lower Granite between the two routes (P=0.1004; Figure 3.21).

3.2.6.8 Conclusions: Effects of Different Bypass Routes on Adult Returns

In summary, no differences in bypass route use nor any effects of different bypass routes at a dam on adult returns were noted:

- facility vs. primary bypass at McNary: No difference (2003–2006)
- holding tank vs. other facility bypass at McNary: No difference (2001)
- B2CC vs. facility bypass at Bonneville: No difference for any stock (2006).

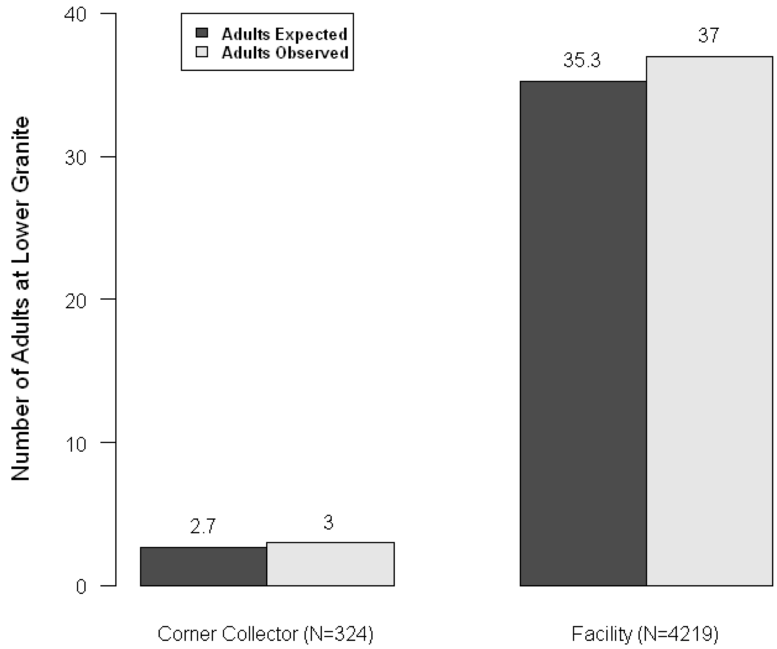

Figure 3.19. Number of Juvenile Spring Chinook Salmon Detected at the Bonneville Corner Collector (route 1 = "C") and Facility Bypass (route 2 = "F") at Bonneville Dam in 2006 and Later Detected as Adults at Lower Granite Dam. No significant differences in adult return rate were found (Z=0.0827, P=0.9341).

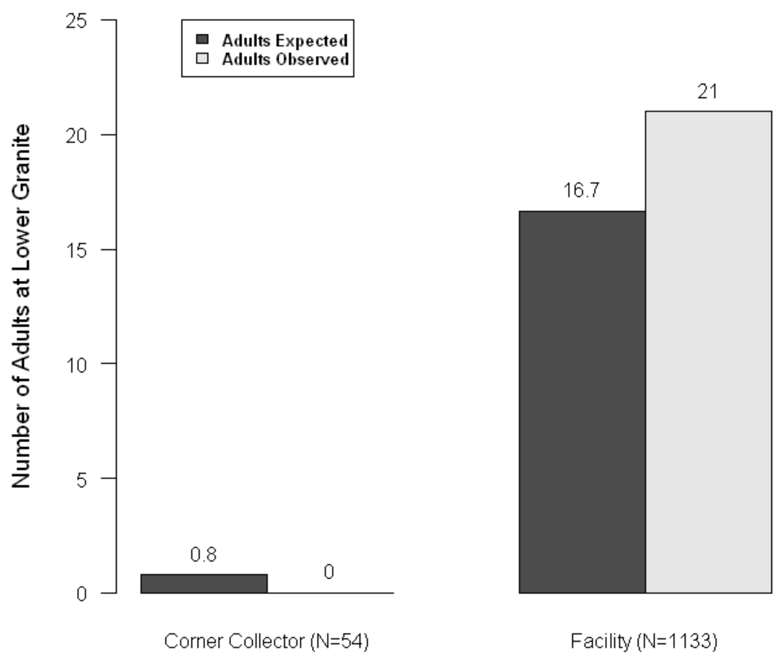

Figure 3.20. Number of Juvenile Summer Chinook Salmon Detected at the Bonneville Corner Collector (route 1 = "C") and Facility Bypass (route 2 = "F") at Bonneville Dam in 2006 and Later Detected as Adults at Lower Granite Dam. No significant differences in adult return rate were found (Z=1.6686, P=0.0952).

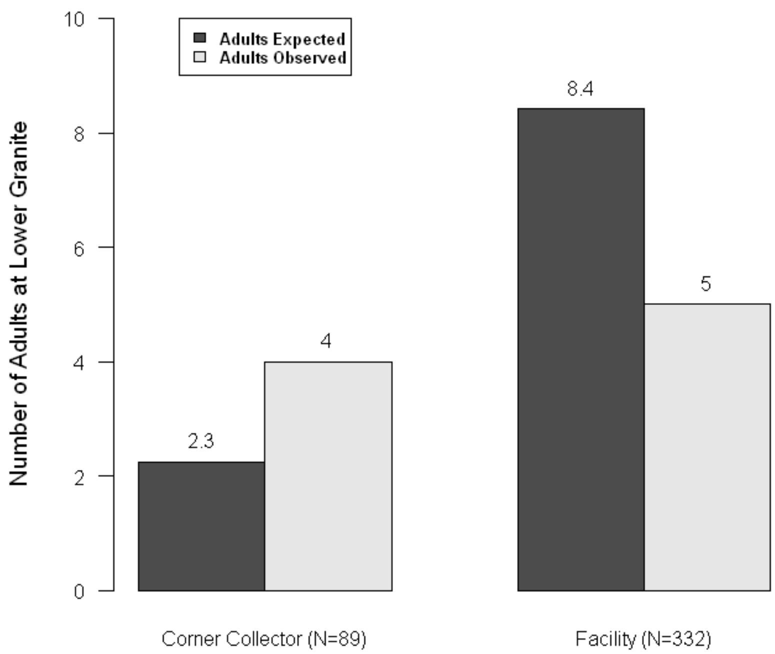

Figure 3.21. Number of Juvenile Steelhead Detected at the Bonneville Corner Collector (route 1 = "C") and Facility Bypass (route 2 = "F") at Bonneville Dam in 2006 and Later Detected as Adults at Lower Granite Dam. No significant differences in adult return rate were found (Z=1.6430, P=0.1004).

3.2.7 Model-Independent Assessment of Bypass Effects on Adult Returns

The residual analysis reported above is based on certain modeling assumptions. One is that there are no bypass effects, and this is the assumption being tested with the residual analysis. Another assumption is that all fish have the same probability of passing a dam through the bypass system, regardless of their previous bypass history. Implicit in this assumption is the criterion that there are no fish that are "bypass-oriented" or "spillway-oriented," for example, so that there is no dependency in route selection at the different dams. Violations of this modeling assumption may produce ROSTER model residuals similar to those seen in the residual analysis. For this reason, we performed a complementary analysis of the relationship between bypass history and adult return rates, independent of any modeling assumptions. We compared adult return rates from McNary Dam back to Lower Granite Dam across juvenile detection histories upstream of McNary. If there were no bypass effects from the upstream dams (i.e., Lower Granite, Little Goose, and Lower Monumental), then all smolts present at McNary Dam should have the same adult return rate to Lower Granite Dam, regardless of their previous detection histories. We performed a similar analysis comparing adult return rates from Lower Monumental back to Lower Granite across upstream juvenile detection histories. This assumption-free approach is unaffected by route dependency. Finding results from this model-independent analysis that agree with the results from our model-based residual analysis would provide more support for our model-based results, and also indicate that route-dependency is unlikely to be the reason for our model-based results.

For the model-independent analysis, the number of adult returns to Lower Granite Dam were counted for each possible upstream juvenile detection history from tagged smolts that were detected at McNary Dam. A total of eight detection histories were possible, ranging from detection at each of Lower Granite, Little Goose, and Lower Monumental dams to detection at none of them. Detection at Ice Harbor Dam

was not considered. Detection histories were compared using contingency tables (chi-square tests, α = 0.05) to determine whether being detected upstream of McNary Dam affected adult return rates, and whether the pattern of upstream detections affected adult return rates. In addition to particular patterns of detections, detection histories were grouped by the number of detections (bypass events) to assess whether being detected multiple times had a different effect than being detected only once or never. Counts of smolts and adults for each detection history were pooled across release years (1996–2006) to increase sample size.

These tests are less sensitive than the ROSTER analyses for detecting the effects of bypass on adult returns for several reasons:

1. Acute effects of bypass that are expressed before the last common downstream detection location will not be discernible.
2. Only bypass effects that are expressed after the last common downstream detection location are subject to detection.
3. The effect of detection/bypass at the last detection location cannot be evaluated.
4. A true undetected class of fish cannot be evaluated against fish with a history of bypass.
5. Sample sizes are smaller than those used in the ROSTER analysis.

Consequently, these tests of homogeneous survival are not exactly equivalent to the ROSTER residual analyses. However, if these tests detect a pattern of reduced adult return rates with repeated bypass events, it would provide a model-free confirmation of the ROSTER results.

The same analysis was conducted for fish that were detected as juveniles at Lower Monumental Dam, with examination of patterns in adult return rates for different bypass histories at Lower Granite and Little Goose dams. This analysis was used to look for consistency among the patterns observed in the model-independent McNary analysis described above, and in the ROSTER analyses.

3.2.7.1 Adult Return Rates for Fish Detected at McNary Dam

A total of 205,661 PIT-tagged spring Chinook salmon were observed in the bypass system at McNary Dam from 1996 to 2006; of these, 1,305 were subsequently detected as adults at Lower Granite Dam (Table 3.6). The most common upstream juvenile detection history at Lower Granite, Little Goose, and Lower Monumental dams for these returning adults was that with no detections, followed by histories with detection only at Lower Monumental Dam. Only 19 smolts detected at each of Lower Granite, Little Goose, Lower Monumental, and McNary dams were later detected as adults (Table 3.6).

Among spring Chinook salmon smolts that were detected at McNary Dam, the pattern of the juvenile bypass history upstream of McNary was associated with different adult return rates (P<0.0001; Table 3.6). In particular, the smolts not detected upstream of McNary Dam had a different adult return rate than those detected at least once upstream of McNary (P<0.0001). Smolts detected only at Little Goose before McNary had a significantly different adult return rate than those undetected upstream of McNary (P=0.0053), while there was no significant difference in adult return rates for undetected smolts and those detected only at Lower Granite (P=0.1934) or Lower Monumental (P=0.8843; Table 3.7). This is consistent with the model-based findings that spring Chinook detected at Little Goose tended to have lower adult return rates than expected.

Table 3.6. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite, Little Goose, and Lower Monumental Dams for Spring Chinook Salmon Bypassed at McNary Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_7^2 \geq 108.8093\right) < 0.0001$.

Bypass History	000	001	010	011	100	101	110	111	Total
Return	618 (0.75%)	213 (0.76%)	168 (0.59%)	118 (0.70%)	100 (0.65%)	28 (0.38%)	41 (0.26%)	19 (0.17%)	1,305 (0.63%)
No Return	81,741	27,759	28,428	16,716	15,307	7,364	15,768	11,273	204,356

Table 3.7. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Spring Chinook Salmon Bypassed at McNary Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	*P*
Compare all 8 bypass histories	108.8093	7	<0.0001
Compare bypass history with 0 events to those with 1 or more events	28.9272	1	<0.0001
Compare bypass histories with 1 event to those with 2 or more events	38.0518	1	<0.0001
Compare all bypass histories with exactly 1 bypass event	6.5570	2	0.0377
Compare 0 bypass events to bypass at LGR alone	1.6912	1	0.1934
Compare 0 bypass events to bypass at LGS alone	7.776	1	0.0053
Compare 0 bypass events to bypass at LMO alone	0.0212	1	0.8843

LGR = Lower Granite Dam; LGS = Little Goose Dam; LMO = Lower Monumental Dam.

On a coarser scale, the adult return rate of spring Chinook salmon detected at McNary Dam varied significantly (α=0.05) with the number of juvenile bypass events upstream of McNary Dam (*P*<0.0001), with lower return rates associated with larger numbers of bypass events (Table 3.8). This agrees with the model-based results, which found larger and more significant reductions in the adult return rate as the number of bypass events increased (Figure 3.7).

Table 3.8. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Number of Detections Upstream of McNary Dam, for Spring Chinook Salmon Bypassed at McNary Dam, 1996–2006. $P\left(\chi_3^2 \geq 75.5674\right) < 0.0001$.

Number of Bypass Events	0	1	2	3	Total
Return	618 (0.75%)	481 (0.67%)	187 (0.47%)	19 (0.17%)	1,305 (0.63%)
No Return	81,741	71,494	39,848	11,273	204,356

Over 46,000 PIT-tagged summer Chinook salmon smolts were detected in the bypass system at McNary Dam from 1996 to 2006 and returned to the river there, with 450 subsequently detected as adults at Lower Granite Dam (Table 3.9). The majority of the returning adults (230) were not detected upstream of McNary Dam as juveniles.

Table 3.9. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite, Little Goose, and Lower Monumental Dams for Summer Chinook Salmon Bypassed at McNary Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_7^2 \geq 85.5883\right) < 0.0001$.

Bypass History	000	001	010	011	100	101	110	111	Total
Return	230 (1.30%)	73 (1.40%)	54 (0.95%)	27 (0.88%)	34 (0.76%)	8 (0.44%)	18 (0.32%)	6 (0.18%)	450 (0.96%)
No Return	17,418	5,139	5,606	3,041	4,433	1,805	5,571	3,397	46,410

Summer Chinook salmon smolts that were detected at McNary Dam without prior detection had a significantly different adult return rate than those that were detected upstream of McNary as well as at McNary (*P*<0.0001; Table 3.10). Significant differences in adult return rates were observed between fish that were undetected upstream of McNary and those that were detected only at Lower Granite Dam (*P*=0.0037) or Little Goose Dam (*P*=0.04410), but not between undetected smolts and those detected only at Lower Monumental Dam (*P*=0.6376; Table 3.10).

Table 3.10. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Summer Chinook Salmon Bypassed at McNary Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	*P*
Compare all 8 bypass histories	85.5883	7	<0.0001
Compare bypass history with 0 events to those with 1 or more events	34.4342	1	<0.0001
Compare bypass histories with 1 event to those with 2 or more events	37.1576	1	<0.0001
Compare all bypass histories with exactly 1 bypass event	10.2594	2	0.0059
Compare 0 bypass events to bypass at LGR alone	8.4286	1	0.0037
Compare 0 bypass events to bypass at LGS alone	4.0565	1	0.0440
Compare 0 bypass events to bypass at LMO alone	0.2219	1	0.6376

LGR = Lower Granite Dam; LGS = Little Goose Dam; LMO = Lower Monumental Dam.

As with spring Chinook salmon, the adult return rate of summer Chinook salmon smolts detected at McNary Dam varied with the number of juvenile bypass events upstream of McNary Dam (*P*<0.0001), with those fish that were bypassed more often having lower adult return rates (Table 3.11). This was consistent with the model-based results, which found larger reductions in the adult return rates for summer Chinook salmon with more bypass events (Figure 3.8).

Table 3.11. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Number of Upstream Detections, for Summer Chinook Salmon Bypassed at McNary Dam, 1996–2006. $P\left(\chi_3^2 \geq 67.8034\right) < 0.0001$.

Number of Bypass Events	0	1	2	3	Total
Return	230 (1.30%)	161 (1.05%)	53 (0.51%)	6 (0.18%)	450 (0.96%)
No Return	17,418	15,178	10,417	3,397	46,410

A total of 20,121 PIT-tagged juvenile steelhead were detected in the bypass system at McNary Dam from 1996 to 2006, of which 146 adults subsequently returned to Lower Granite Dam (Table 3.12). The number of returning adults that had no juvenile detections upstream of McNary Dam was nearly equal to the number of fish that were detected either at Little Goose Dam alone or at both Little Goose and Lower Monumental dams before being detected at McNary Dam (Table 3.12). There was no apparent relationship between the adult return rate of PIT-tagged steelhead smolts detected at McNary Dam and either the pattern of upstream juvenile detection history (P>0.1614; Table 3.13) or the number of juvenile bypass events upstream of McNary Dam (P=0.1651; Table 3.14).

Table 3.12. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite, Little Goose, and Lower Monumental Dams for Steelhead Bypassed at McNary Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_7^2 \geq 8.8622\right) = 0.2627$.

Bypass History	000	001	010	011	100	101	110	111	Total
Return	24 (0.81%)	20 (0.95%)	23 (0.94%)	22 (0.83%)	12 (0.59%)	13 (0.81%)	16 (0.59%)	16 (0.45%)	146 (0.73%)
No Return	2,952	2,090	2,429	2,630	2,031	1,587	2,712	3,544	19,975

Table 3.13. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Steelhead Bypassed at McNary Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	P
Compare all 8 bypass histories	8.8622	7	0.2627
Compare bypass history with 0 events to those with 1 or more events	0.1988	1	0.6557
Compare bypass histories with 1 event to those with 2 or more events	1.9609	1	0.1614
Compare all bypass histories with exactly 1 bypass event	2.1573	2	0.3401
Compare 0 bypass events to bypass at LGR alone	0.5378	1	0.4633
Compare 0 bypass events to bypass at LGS alone	0.1395	1	0.7088
Compare 0 bypass events to bypass at LMO alone	0.1466	1	0.7018

LGR = Lower Granite Dam; LGS = Little Goose Dam; LMO = Lower Monumental Dam.

Although the adult return rate for steelhead detected at McNary Dam declined as the number of bypass events upstream of McNary increased from one to three, there was no statistically significant difference in adult return rate between the smolts detected once upstream of McNary and those that were not detected upstream (Table 3.14). Overall there was no significant difference in adult return rate across the number of upstream bypass events (P=0.1651). The pattern of adult return rates for steelhead agreed with the model-based results, which found that steelhead bypassed only once during their outmigration returned as adults at expected rates, but that steelhead that were bypassed two or three times had lower than expected adult return rates (Figure 3.9). However, the model-based patterns of adult return rates were significant at the 5% level, whereas the model-independent results shown here were not.

Table 3.14. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Number of Upstream Detections, for Steelhead Bypassed at McNary Dam, 1996–2006. $P\left(\chi_3^2 \geq 5.0934\right) = 0.1651$.

Number of Bypass Events	0	1	2	3	Total
Return	24 (0.81%)	55 (0.83%)	51 (0.73%)	16 (0.45%)	146 (0.73%)
No Return	2,952	6,550	6,929	3,544	19,975

Conclusions for Fish Detected at McNary Dam

The following conclusions were derived from the model-independent analysis of fish detected at McNary Dam:

- The adult return rate for both spring and summer Chinook salmon depends on the number and locations of detections upstream of McNary Dam.
- There is no difference in the adult return rate for spring Chinook salmon between smolts bypassed only at Lower Granite Dam or Lower Monumental Dam and those undetected upstream of McNary Dam.
- Spring Chinook salmon that were bypassed only at Little Goose Dam had a different adult return rate than those undetected upstream of McNary Dam.
- Summer Chinook salmon that were bypassed only at either Lower Granite or Little Goose had a different adult return rate than those undetected upstream of McNary.
- There was no difference in the summer Chinook salmon adult return rate between smolts bypassed only at Lower Monumental and those undetected upstream of McNary.
- The adult return rate for steelhead detected at McNary Dam is apparently unrelated to upstream detections.

3.2.7.2 Adult Return Rates for Fish Detected at Lower Monumental Dam

A total of 219,221 PIT-tagged spring Chinook salmon were observed in the bypass system at Lower Monumental Dam from 1996 to 2006. Of these, 1274 were subsequently detected as adults at Lower Granite Dam (Table 3.15). The majority of the returning adults had not been detected upstream of Lower Monumental Dam as juveniles. Of those that were detected upstream as juveniles, most had been detected only at Little Goose Dam (Table 3.15).

Table 3.15. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite and Little Goose Dams for Spring Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_3^2 \geq 126.5773\right) < 0.0001$.

Bypass History	00	01	10	11	Total
Return	757 (0.72%)	349 (0.59%)	115 (0.46%)	53 (0.18%)	1,274 (0.58%)
No Return	104,165	59,206	24,618	29,958	217,947

Among spring Chinook salmon smolts detected at Lower Monumental Dam, the pattern of juvenile bypass upstream of Lower Monumental was associated with different adult return rates (P<0.0001; Table 3.16). Those smolts not detected upstream of Lower Monumental Dam had a different adult return rate than those detected at either Lower Granite Dam (P<0.0001) or Little Goose Dam (P=0.0014; Table 3.16).

Table 3.16. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Spring Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	P
Compare all 4 bypass histories	126.5773	3	<0.0001
Compare bypass history with 0 events to those with 1 or more events	68.1328	1	<0.0001
Compare bypass histories with 1 event to those with 2 events	67.8815	1	<0.0001
Compare all bypass histories with exactly 1 event	4.4587	1	0.0347
Compare 0 bypass events to bypass at LGR alone	19.3334	1	<0.0001
Compare 0 bypass events to bypass at LGS alone	10.2377	1	0.0014

LGR = Lower Granite Dam; LGS = Little Goose Dam.

The number of times a fish was bypassed upstream of Lower Monumental Dam was associated with the adult return rate (P<0.0001), with higher adult return rates seen for fish detected fewer times upstream of Lower Monumental (Table 3.17). This was consistent with model-based results, which found that smolts with more juvenile detections had lower than expected adult return rates (Figure 3.7).

Table 3.17. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Spring Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006 $P\left(\chi_2^2 \geq 122.1454\right) < 0.0001$.

Number of Bypass Events	0	1	2	Total
Return	757 (0.72%)	464 (0.55%)	53 (0.18%)	1,274 (0.58%)
No Return	104,165	83,824	29,958	217,947

A total of 55,733 PIT-tagged summer Chinook salmon smolts were observed in the bypass system at Lower Monumental from 1996 to 2006, out of which 505 were subsequently detected as adults at Lower Granite Dam (Table 3.18). Most of these returning adults had not been detected upstream of Lower Monumental as juveniles, while the majority of those that had been detected upstream had been detected at Little Goose Dam alone (Table 3.18).

Table 3.18. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite and Little Goose Dams for Summer Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_3^2 \geq 95.5875\right) < 0.0001$.

Bypass History	00	01	10	11	Total
Return	326 (1.29%)	110 (0.82%)	43 (0.63%)	26 (0.26%)	505 (0.91%)
No Return	24,994	13,328	6,817	10,089	55,228

Among the summer Chinook salmon that were detected at Lower Monumental Dam as juveniles, the adult return rate was associated with the pattern of detections upstream of Lower Monumental Dam (P<0.0001; Table 3.19). Smolts not detected upstream of Lower Monumental Dam had a different adult return rate than those detected at either Lower Granite Dam (P<0.0001) or Little Goose Dam (P<0.0001; Table 3.19). The number of times a fish was detected upstream of Lower Monumental Dam was associated with the adult return rate (P<0.0001), with higher adult return rates seen for fish detected fewer times upstream of Lower Monumental Dam (Table 3.20). However, there was no discernible difference in the adult return rate between smolts detected at Lower Granite alone and those detected at Little Goose alone before bypass at Lower Monumental Dam (P=0.1590; Table 3.19).

Table 3.19. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Summer Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	P
Compare all 4 bypass histories	95.5875	3	<0.0001
Compare bypass history with 0 events to those with 1 or more events	74.4004	1	<0.0001
Compare bypass histories with 1 event to those with 2 events	27.6257	1	<0.0001
Compare all bypass histories with exactly 1 event	1.9832	1	0.1590
Compare 0 bypass events to bypass at LGR alone	20.2074	1	<0.0001
Compare 0 bypass events to bypass at LGS alone	16.9378	1	<0.0001

LGR = Lower Granite Dam; LGS = Little Goose Dam.

The adult return rate of summer Chinook salmon smolts detected at Lower Monumental Dam depended on the number of juvenile detections at Lower Granite and Little Goose dams (P<0.0001, Table 3.20). In particular, the adult return rate decreased as the number of juvenile detections upstream of Lower Monumental increased (Table 3.20). This is consistent with the model-based results (Figure 3.8).

Table 3.20. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Summer Chinook Salmon Bypassed at Lower Monumental Dam, 1996–2006. $P\left(\chi_2^2 \geq 93.7278\right) < 0.0001$.

Number of Bypass Events	0	1	2	Total
Return	326 (1.29%)	153 (0.75%)	26 (0.26%)	505 (0.91%)
No Return	24,994	20,145	10,089	55,228

A total of 83,534 juvenile PIT-tagged steelhead were detected at Lower Monumental Dam from 1996 to 2006, with 404 of these fish subsequently detected as adults at Lower Granite Dam (Table 3.21). Nearly equal numbers of returning adults that were detected at Lower Monumental had been previously detected Little Goose alone as those that were not detected upstream of Lower Monumental as juveniles (Table 3.21).

Table 3.21. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for Bypass Histories at Lower Granite and Little Goose Dams for Steelhead Bypassed at Lower Monumental Dam, 1996–2006. "0" = no detection, "1" = detection. $P\left(\chi_3^2 \geq 15.8031\right) = 0.0012$.

Bypass History	00	01	10	11	Total
Return	126 (0.59%)	110 (0.55%)	73 (0.47%)	95 (0.36%)	404 (0.48%)
No Return	21,338	19,772	15,456	26,564	83,130

Among the steelhead that were detected at Lower Monumental Dam as juveniles, the adult return rate differed from the juvenile bypass history upstream of Lower Monumental (*P*=0.0012; Table 3.22). While the number of juvenile bypass events upstream of Lower Monumental was associated with the adult return rate (*P*=0.0007; Table 3.23), the primary difference occurred between steelhead with either zero or one upstream detection and those with two upstream detections (*P*=0.0003; Table 3.22). This was consistent with the model-based results, which found that steelhead smolts detected only once had adult return rates as expected while those detected two or three times returned at lower than expected rates (Figure 3.9). There was no discernible difference in the adult return rate between those steelhead undetected upstream of Lower Monumental and those detected only at Lower Granite (*P*=0.1483) or only at Little Goose (*P*=0.6965) prior to bypass at Lower Monumental (Table 3.22).

Table 3.22. Tests of Independence of Adult Return Rates Among Upstream Bypass Histories for Steelhead Bypassed at Lower Monumental Dam, 1996–2006. Significance level = 0.05.

Test	X^2	DF	*P*
Compare all 4 bypass histories	15.8031	3	0.0012
Compare bypass history with 0 events to those with 1 or more events	6.1302	1	0.0133
Compare bypass histories with 1 event to those with 2 events	8.4238	1	0.0037
Compare bypass histories with at most 1 event to that with 2 events	12.7944	1	0.0003
Compare all bypass histories with exactly 1 event	1.0171	1	0.3132
Compare 0 bypass events to bypass at LGR alone	2.0895	1	0.1483
Compare 0 bypass events to bypass at LGS alone	0.1521	1	0.6965

LGR = Lower Granite Dam; LGS = Little Goose Dam.

Table 3.23. Contingency Table of Adult Returns, and Percentage of Juveniles Returning as Adults, for the Steelhead Bypassed at Lower Monumental Dam, 1996–2006. $P\left(\chi_2^2 \geq 14.5499\right) = 0.0007$.

Number of Bypass Events	0	1	2	Total
Return	126 (0.59%)	183 (0.52%)	95 (0.36%)	404 (0.48%)
No Return	21,338	35,228	26,564	83,130

Conclusions for Fish Detected at Lower Monumental Dam

The following conclusions were derived from the model-independent analysis of fish detected at Lower Monumental Dam:

- The pattern of detections upstream of Lower Monumental Dam during juvenile migration is related to adult return rates for both spring and summer Chinook salmon and steelhead.
- Adult return rates for spring Chinook salmon depend on both the number and locations of upstream detections.
- Adult return rates for summer Chinook salmon depend on the number of upstream detections, but not the location of upstream detections.
- The adult return rate for steelhead is related to the number of bypass events upstream of Lower Monumental.
- There is no difference in adult return rates between steelhead bypassed only once upstream of Lower Monumental and those undetected upstream of Lower Monumental.

3.2.7.3 Conclusions from Model-Independent Analysis

Overall, the model-independent analysis supported the findings from the model-based residual analysis. Spring and summer Chinook salmon consistently had lower adult return rates as the number of juvenile detections increased, which is what we observed using the residual analysis. The pattern for steelhead was not as strong, with a significant relationship between detection history and adult return rate observed only for those steelhead detected at Lower Monumental, and not for those detected at McNary. However, there were considerably more steelhead detected at Lower Monumental than at McNary, so there was more statistical power to detect an effect of upstream juvenile detection history among fish detected at Lower Monumental. Furthermore, the pattern of adult return rates observed for steelhead detected at Lower Monumental was consistent with the model-based results, with little difference in the adult return rate between steelhead detected once upstream of Lower Monumental and those undetected upstream, and lower adult return rates observed for those steelhead detected twice upstream. Because of the similarity in our model-based results and these model-independent results, we feel confident that our model-based results are not reflecting a dependency on route selection.

3.2.8 Effects of Smolt Length on Detection Probabilities

For some hatchery groups of spring Chinook salmon, length at tagging was seen to have a negative effect on the probability of detection (i.e., bypass) at several dams. For example, smaller fish from the 2001 Dworshak National Fish Hatchery release group had a greater probability of bypass at McNary Dam than larger fish from the same release group (Figure 3.22). For other groups, length at tagging apparently had the opposite effect. For example, smaller fish from the 1997 Rapid River Hatchery release group had a lower probability of bypass at Lower Granite than larger fish (Figure 3.23). When evaluating results over release groups and release years, there is evidence that smaller fish tend to be bypassed more than larger fish (Figure 3.24) at Little Goose, Lower Monumental, McNary, and John Day dams. However, the evidence is equivocal, with highly variable results over multiple release groups (Figure 3.24). If the bypass systems were truly size-selective, then we might expect that the preponderance of release groups would show more small fish than large fish bypassed, which is not the case. Thus, while there may be a

size-selection process that acts at some dams under some conditions, we cannot conclude from these analyses that bypassed fish are smaller than non-bypassed fish in general. It is possible that analysis using fish length measured at the time of dam passage, rather than at the time of tagging, may produce different results.

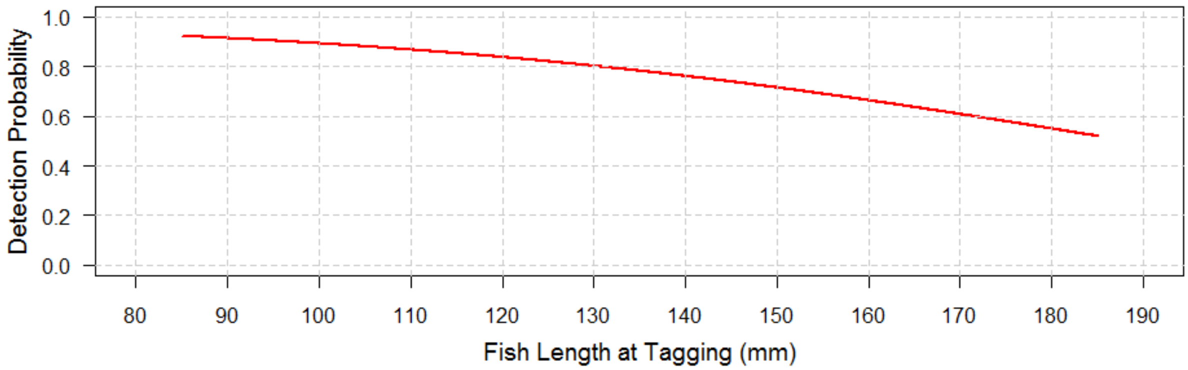

Figure 3.22. Predicted Probability of Detection (i.e., bypass) at McNary Dam for Spring Chinook Salmon Released from Dworshak National Fish Hatchery in 2001, as a Function of Fish Length at Tagging

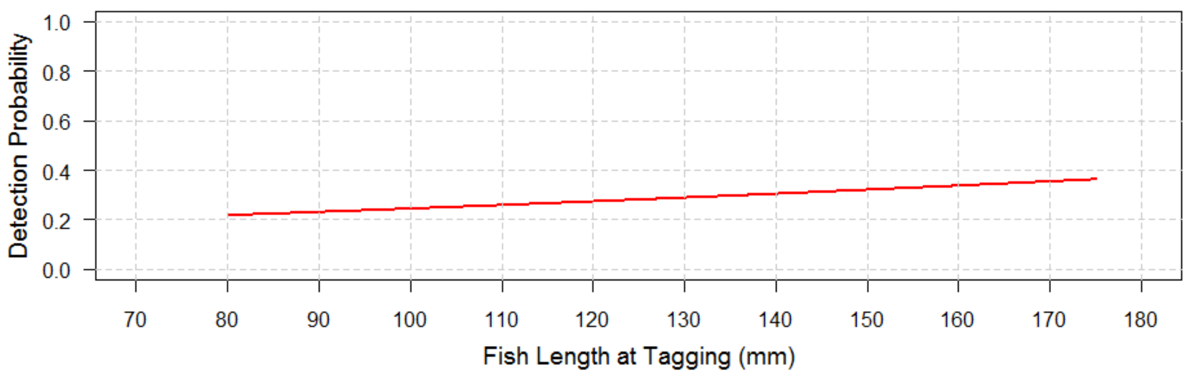

Figure 3.23. Predicted Probability of Detection (i.e., bypass) at Lower Granite Dam for Spring Chinook Salmon Released from Rapid River Hatchery in 1999, as a Function of Fish Length at Tagging

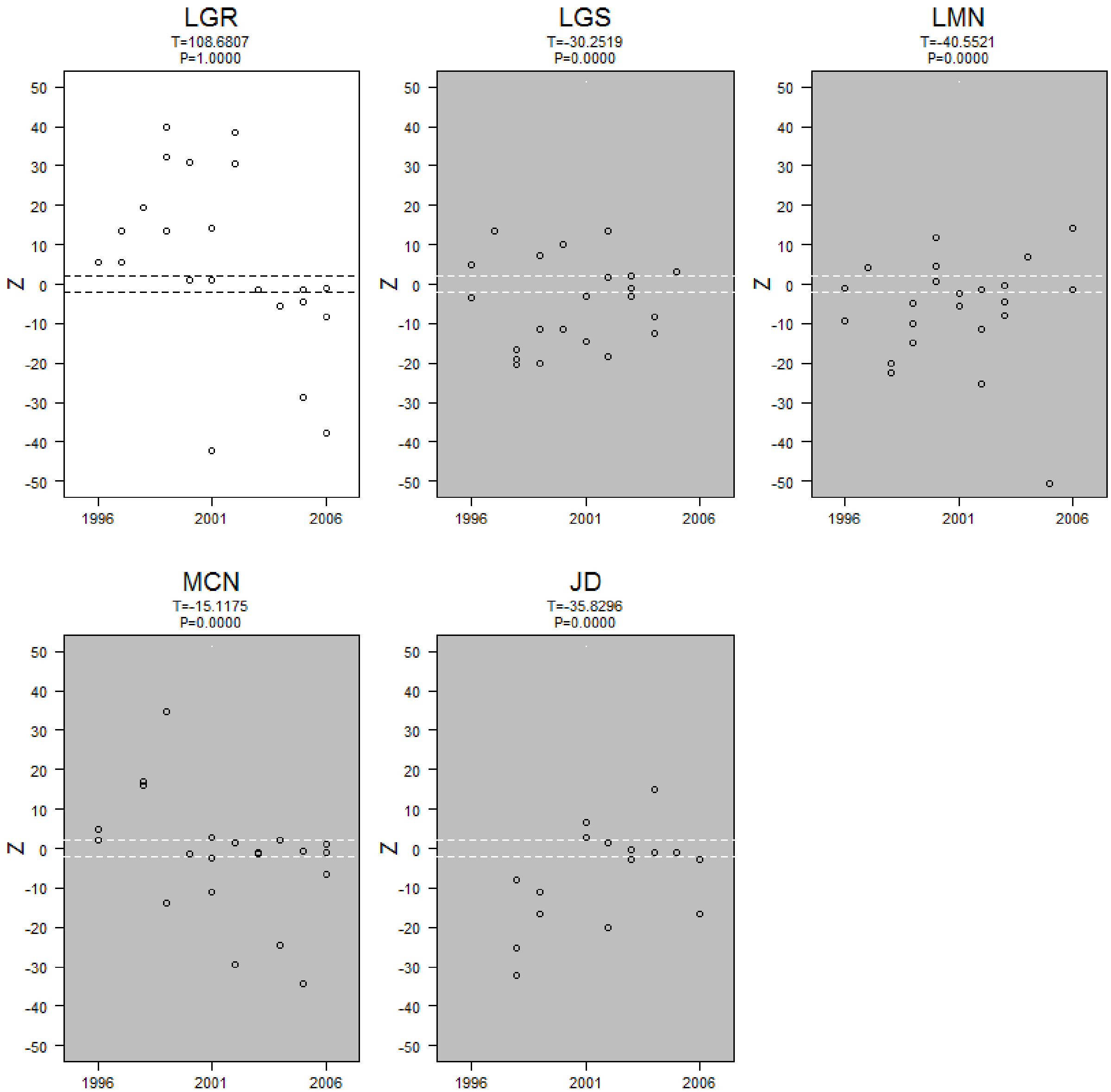

Figure 3.24. Standardized Regression Coefficients for Fish Length at Tagging vs. Detection (i.e., bypass) Probability from Fitted Logistic Models for Snake River Hatchery Spring Chinook Salmon That Were Tagged no More Than 100 Days Before Release (meta-analysis *T*-statistic and *P*-value [HA:$T<0$]). Shading indicates statistical significance at $P \leq 0.05$.

4.0 Conclusions

This juvenile/adult PIT-tag meta-analysis using Program ROSTER found strong evidence that bypass events are associated with reduced adult return rates of Chinook salmon and steelhead smolts. In general, fish that migrated through the hydrosystem without being detected in a bypass system had higher adult return rates than fish that were bypassed at least once (Figure 3.7–Figure 3.9). Based on the observational data available, we could not distinguish between mechanistic effects of passing through the bypass system and selectivity of the system among fish passing the dam. Adult return rates of fish detected in bypass systems were evaluated relative to all other inriver juvenile detection histories. The relative nature of the evaluation means that the performance of any group will appear higher if other groups (including those using other passage routes) perform poorly, and vice versa. Thus, we use the term “perceived bypass effect” to describe the relative difference in adult return rate between bypassed and non-bypassed fish.

For yearling Chinook salmon, smolts with one or more bypass events tended to have lower adult return rates than non-bypassed smolts (Figure 3.7, Figure 3.8). With multiple bypass events, the adult return rate of yearling Chinook salmon declined further. Steelhead smolts that were bypassed at only a single dam exhibited no noticeable decrease in adult returns (Figure 3.9). However, two or more bypass events for steelhead smolts reduced the rate of adult returns (Figure 3.9). In addition to simple perceived effects of bypass at individual dams, some pairs of dams appeared to have synergistic effects, where the effect on adult returns from joint detection at the two dams was more than the sum of the perceived effects of bypass at the two dams separately.

The PIT-tag analyses found little evidence that spring or summer Chinook salmon bypassed at Lower Granite returned at lower rates than expected from all inriver fish, even if they were bypassed at other dams downstream (Figure 3.10, Figure 3.11). For steelhead, however, bypass at Lower Granite Dam combined with bypass at downstream dams was associated with reduced adult return rates (Figure 3.13). Spring/summer Chinook salmon that were bypassed at Lower Granite and then transported from Little Goose Dam tended to return as adults at lower than expected rates. Lower than expected adult returns for summer Chinook and steelhead detected in the bypass systems at both Lower Granite and McNary dams suggest a negative synergistic effect of that combination of bypass systems, that is, fewer adult returns than would have been expected from the perceived effects of bypass at those two dams singly. This suggests that there may be a weak effect of bypass at Lower Granite Dam that is exhibited only if bypassed fish experience other bypass or stressful experiences downstream. There was no compelling evidence that smaller fish were more likely to enter the bypass system at Lower Granite Dam than larger fish.

Bypass at Little Goose Dam was consistently associated with a reduced adult return rate compared to other inriver smolts for both spring and summer Chinook salmon, regardless of whether they were detected elsewhere downstream. On average, between 27% and 33% fewer adults than expected were detected from the groups of PIT-tagged Chinook smolts that were bypassed at Little Goose Dam over the 11 years of the study. Lower than expected adult returns for spring Chinook salmon detected in the bypass routes at both Little Goose and Bonneville dams suggest the presence of a negative synergistic effect of that combination of dams, indicative of a possible latent effect of bypass at Little Goose. Steelhead bypassed at Little Goose demonstrated no obvious reduction in adult returns compared to other inriver fish. The bypass system at Little Goose underwent an operational change in 2002, when wider

conveyance pipes and a new three-way diversion-by-code gate were installed. Perceived bypass effects did not appear to diminish significantly after these modifications.

Bypass at Lower Monumental Dam appeared to be associated with reduced adult return rates for both spring Chinook salmon and steelhead, with a slightly less obvious effect on summer Chinook. Spring Chinook salmon that were detected at Lower Monumental produced from 2% to 36% fewer adults than expected on average, while summer Chinook detected at Lower Monumental produced an average of 2% to 28% fewer adults than expected from other inriver fish, depending on where else the smolts were detected downstream. Steelhead detected at Lower Monumental produced from 11% to 41% fewer adults than expected.

Ice Harbor Dam had juvenile PIT-tag detections beginning in 2005. With only 2 years of data available, there was low power to detect any possible effect of bypass at Ice Harbor on adult returns for both Chinook and steelhead. Furthermore, because nearly all fish that were bypassed at Ice Harbor passed through primary ("full-flow") bypass, it was not possible to compare primary and facility bypass.

Fish that were bypassed at McNary Dam tended to return as adults at lower than expected rates, but only if they were also detected at another dam. In particular, bypass at McNary combined with bypass at either Lower Monumental or John Day consistently produced fewer returning adults than expected, for all three stocks. Bypass at McNary alone did not appear to reduce the number of returning adults. Lower than expected adult returns for spring Chinook salmon detected in the bypass systems at both McNary and Bonneville dams, and for steelhead detected in the bypass systems at both McNary and John Day dams, suggest that a negative synergistic effect may exist for those combinations of bypass systems. This indicates that there may be a possible latent effect of bypass at McNary. The return-to-river lines at the McNary bypass system were replaced in 2002, but did not appear to result in increased adult returns. It was also not clear that fish length was related to the probability of being bypassed at McNary. Primary bypass became available at McNary Dam in 2003, but there was no evidence that fish using the primary bypass route had higher adult return rates than fish that used the facility bypass route. Only 1 year of data was available to compare adult returns of fish that passed through the sort-by-code holding tank with those that passed through facility bypass directly, and there was no significant difference in adult returns between these two routes.

Bypass at John Day Dam appeared to be associated with reduced adult return rates for both spring and summer Chinook salmon, in particular if the fish had been bypassed previously at an upriver dam. Steelhead did not appear to return at lower rates after passing John Day Dam through the bypass system. However, because John Day is relatively far downriver from the release sites and tends to have low detection probability (<0.20 over all release groups), few fish were detected at John Day over the duration of the study, and so the power to detect a bypass effect was relatively low compared to the dams further upriver. Chinook that were detected at John Day produced from 10% to 42% fewer returning adults than expected, depending on where else the fish were detected.

There was little evidence from the PIT-tag data of a bypass effect at Bonneville Dam for any stock. Chinook that were detected both at Bonneville and another upstream dam (i.e., Little Goose, Lower Monumental, or McNary) tended to return in fewer numbers than expected. However, it should be noted that with relatively low detection numbers at Bonneville and the resulting low expected numbers of returning adults, there was low statistical power to detect an effect on adult returns at Bonneville, especially for steelhead. The bypass system operations at Bonneville changed radically in 2000, when the

bypass system at the first powerhouse was discontinued and operational priority was switched to the second powerhouse. There was no evidence of improved adult return rates after that change, although once again there was low power to detect an effect. In 2006, PIT-tag detection became available in both the primary bypass and the B2CC. Based on this single year of juvenile detection data, there was no significant difference in adult return rates between fish that passed via the B2CC and those that passed via facility bypass.

Analysis of hatchery releases of spring Chinook salmon found no consistent evidence that bypass systems were size-selective for smaller fish. Although meta-analyses at Little Goose, Lower Monumental, McNary, and John Day dams (Figure 3.24) found that smaller fish were on average more likely to be detected or bypassed ($P<0.0001$), individual tests were equivocal. A total of 50 tests found smaller fish had a significantly lower probability of being bypassed while another 36 tests found smaller fish had a significantly higher probability of being bypassed ($\alpha = 0.05$). While size-selectivity may play some role in the perceived bypass effects, its exact role remains unclear. The long lag time between fish being PIT-tagged at the hatchery and subsequent detection events reduces the ability of any analysis to assess size-related bypass effects using the available data at this time.

5.0 Discussion

The pattern we observed of reduced adult return rates for smolts that were bypassed one or more times has been observed by other researchers (e.g., Bouwes et al. 1999; Sandford and Smith 2002). These researchers observed that the SAR rate of inriver smolts decreased as the number of bypass events increased. Our results go further and pinpoint the dams with bypass systems that are consistently associated with lower than expected adult return rates. We also identified those dams with bypass systems that appear to have no effect on Snake River salmonids. Furthermore, we established that different species and stocks have different patterns of post-bypass survival at different dams. Although we cannot identify the reason for the reduction in adult returns for bypassed fish, our results suggest future investigations are warranted.

5.1 Latent vs. Direct Effects

Our modeling results detected a reduced adult return rate for smolts that passed through some bypass systems. However, it is not clear whether the associated mortality occurred immediately after dam passage (i.e., perceived direct effect) or farther downstream (i.e., perceived latent effect). The downstream migration through the hydrosystem of PIT-tagged smolts that have passed a dam through the bypass system and those that passed through a non-bypass route has previously been compared. Smith et al. (1998) found a lack of mixing between bypassed and non-bypassed smolts during periods of high spill, with bypassed smolts taking longer to pass the dam than other fish. However, no significant difference in survival was observed as a result (Smith et al. 1998). Skalski et al. (1998) also found no difference in subsequent juvenile survival and detection between bypassed and non-bypassed smolts. However, Skalski et al. (1998) focused on survival only to Little Goose Dam, and Smith et al. (1998) focused on survival only to Lower Monumental Dam. If differences in survival occurred only after passing the last Snake River Dam or entering the estuary or ocean, they would not have been observed in their analyses, but would be detectable using our approach that focuses on adult return rates.

The synergistic effects we observed, reflecting a larger reduction in the adult return rate from joint bypass at some pairs of dams than expected from bypass at either dam alone, suggest that there may be a latent or delayed effect of bypass. This may occur if, for example, bypass at an upstream dam produces injury or stress that, while not lethal by itself, may become lethal when combined with the additional stress of bypass at a downstream dam. This hypothesis for a latent bypass effect has been suggested by Budy et al. 2002. Our supplemental model-independent analysis (Section 3.2.7), comparing adult return rates from McNary to Lower Granite across bypass histories upstream of McNary, also demonstrated possible latent effects of bypass. Thus, it appears that at least some of the mortality associated with bypass occurs well after the bypass event. However, our analysis was not intended to determine whether it occurs within the hydrosystem or in the ocean.

5.2 Hypotheses to Explain Results

Several competing hypotheses have been proposed to explain our results. Injury from encounters with fish guidance screens has been reported (Coutant and Whitney 2000), and Muir et al. (2001) observed higher relative survival through spill bays than through bypass systems. However, Marmorek and Peters (1998) found no difference in survival between the spillway and the bypass system.

Furthermore, some non-bypassed fish pass through the turbines, which are well documented to have lower survival rates than the bypass system (Marmorek and Peters 1998; Muir et al. 2001). However, differences in survival during dam passage through the various routes are unlikely to explain all of the differences we observed in adult returns.

Differences in survival soon after dam passage may be related to encounters with predators, affected by factors such as travel time past a dam or the location of the bypass outfall. As mentioned above, downstream differences in survival may be caused by stress associated with the bypass system, which in turn may increase disease incidence or impair reaction time and the ability to evade predators (Budy et al. 2002). None of these possibilities was distinguishable using the available PIT-tag data.

Another possible explanation for the survival differences we observed between bypassed and non-bypassed fish is selectivity of the bypass system. This hypothesis is that fish using the bypass system tend to be smaller or weaker than fish that pass using other routes. Thus, the observed survival differences reflect the inherent lower survival of fish likely to use the bypass system rather than a mechanistic impact of the bypass system. Zabel et al. (2005) suggest that smaller fish are less able than larger fish to avoid the strong flows directed to the turbines and bypass system, and are more likely to be surface-oriented and thus enter the bypass system rather than the turbines. They also suggest that fish that are more smolted may be more likely to enter the bypass system, because they are more surface-oriented. Weaker fish may also be less able to evade flows directed to the powerhouse, although it is unclear whether fish impaired by disease or injury would be more likely to enter the bypass system or to pass through the turbines.

Our analysis of length-at-tagging data in relation to detection (i.e., bypass) probability was inconclusive, with a possible relationship apparent for some release groups and some dams but not for others. This contrasts with Zabel et al. (2005), who found more consistent evidence that smaller fish have a higher detection probability than larger fish at Little Goose and Lower Monumental dams. This difference in results may be partially explained by differences in the timing of tagging, measurement, and release of the study fish. In the Zabel et al. analysis (2005), fish were tagged and measured, then released shortly thereafter at Lower Granite. The fish in our analyses were tagged at hatcheries and released weeks or months later, upstream of Lower Granite. Consequently, variation in fish growth between the time of tagging and migration may have obscured any regression relationship between fish size and the probability of detection that we might otherwise have seen.

Zabel et al. (2005) examined the relationship between fork length and detection probability at Little Goose and Lower Monumental dams for eight release groups of wild or hatchery spring/summer Chinook salmon or steelhead, released from 1998 to 2002. Only two of these release groups had analogues in our study: the 1998 and 1999 release groups of hatchery spring/summer Chinook salmon. For these two release groups, we observed a significant negative relationship between fork length at tagging and detection probability at both Little Goose and Lower Monumental dams. Thus, in the cases where direct comparison was possible, our findings agreed with Zabel et al. (2005). However, in addition to finding the negative relationships between length and detection at Little Goose and Lower Monumental in 1998 and 1999, we also observed significant positive relationships at these dams in other years (e.g., 2002). Furthermore, we observed significant positive relationships between length and detection at Lower Granite and McNary dams in 1998 and 1999. Thus, it appears that making inferences from only a few dams and a few years may be inadequate. Instead, the variability in the relationship between fish length

and detection probability that we observed suggests that any relationship between fish size and bypass entry is complicated by other, unknown factors.

It may be worthwhile to investigate the selectivity of the bypass system further using data on fish condition that are taken at the time of migration. In addition to fish size, the condition factor (K), degree of smolting, and appearance of injury or disease may be important factors in determining the passage route used at a dam. These metrics should be measured at or near the time of dam passage, if possible.

A second hypothesis unrelated to mechanistic bypass effects is that there is dependency in route selection at the various dams. This hypothesis holds that some fish are “bypass-oriented,” while others are “spillway-oriented” or “turbine-oriented.” With some fish inherently more likely than others to be detected at any dam, the release-recapture model may produce residuals similar to those produced by the ROSTER model even if survival does not vary among fish oriented to different passage routes. We tested this hypothesis in two ways. First, we tested it directly using Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic-tag data from yearling Chinook smolts and steelhead migrating past John Day and Bonneville dams in 2008 (Appendix D). The acoustic-tag detections provided detailed information about passage routes used at both dams. We found no evidence of route dependency. In particular, there was no indication that smolts that passed John Day through the bypass system were more likely to use the Bonneville bypass than other smolts ($P \geq 0.1721$). We also tested the hypothesis of route dependency indirectly in our model-independent analysis, comparing adult return rates from McNary to Lower Granite across upstream juvenile detection histories. This assumption-free approach would not be affected by route dependency, yet it produced results similar to our model-based results. Thus, it does not appear that route dependency explains our results. However, our analyses into this question were limited in scope, and it may be worthwhile to investigate this question further using active tags. Such an investigation could shed light both on the question of route dependency and on the question of selectivity of the various passage routes.

5.3 Scope of Investigation

Interpretation of the results presented in this report must necessarily be limited by the scope of our investigation. As stated above, our objective was to determine whether bypassed smolts returned at lower rates than non-bypassed smolts. The limitations of the available data prevented us from being able to determine whether reduced adult return rates might be caused by particular aspects of the bypass system (e.g., flow rate within the bypass system) or dam operating conditions (e.g., spillway conditions or turbine outages). Similarly, although we can determine whether bypassed fish have reduced adult return rates compared to non-bypassed fish, we cannot definitively distinguish between reductions caused by passing through the bypass system and lower survival of bypassed fish caused by the selectivity of the bypass system. Thus, any “bypass effects” we observed were more correctly termed “perceived bypass effects” because we cannot attribute them directly to the bypass system.

Because we were asked to assess possible bypass effects at the Snake River dams, including Lower Granite Dam, we used release groups of Snake River fish tagged and released upstream of Lower Granite. Furthermore, because the ROSTER model is inappropriate for use with juveniles that residualize within the hydrosystem, we omitted subyearling Chinook salmon from our analysis, and focused instead on yearling Chinook salmon and steelhead. The patterns of residuals we observed demonstrated that different stocks and species may experience different (perceived) bypass effects at the same dam. Thus, it

would be inappropriate to make inferences from our results either to Snake River populations not studied here, or to populations from other regions, such as the Mid-Columbia or John Day rivers.

One complication in interpreting results of any tagging study is the difference in experiences between tagged and untagged individuals. PIT-tagged and untagged salmon smolts from the Snake River tend to experience different juvenile migrations through the hydrosystem. Most untagged smolts that enter the bypass systems at Lower Granite, Little Goose, or Lower Monumental dams are collected for transportation at those dams, and travel through the remainder of the hydrosystem in a barge or truck. PIT-tagged fish, on the other hand, are routinely returned to the river from the bypass systems at these dams, except for those diverted to transport for a transportation study. Thus, PIT-tagged fish may be returned to the river throughout the migration season, while untagged fish are returned to the river only when transportation is not operational, generally early in the season. If bypass effects have a seasonal component, then the perceived effects observed for PIT-tagged fish may not be applicable to untagged fish. Similarly, if post-bypass survival depends on the number of fish being bypassed (i.e., either attracting or swamping predators), then untagged fish may have different adult return rates after bypass than most PIT-tagged fish.

These are valid concerns that apply not just to our assessment of bypass effects, but to all tagging studies using PIT-tagged fish passing the Snake River dams. As long as tagged and untagged fish have different experiences, there will be uncertainty in making inference from tagged fish to untagged fish. This is also true for the survival studies that are regularly performed to monitor juvenile survival through the hydrosystem. However, it is not practical to study either hydrosystem survival or potential bypass effects using untagged fish. Thus, we must rely on tagged fish while also bearing in mind the differences between tagged and untagged smolts.

Another factor in interpreting results is the statistical power available to detect potential bypass effects. The power to detect a difference in adult return rates between bypassed and non-bypassed fish was highest for the upstream dams where the greatest number of tagged fish were available for detection. This translated into decreased power to detect potential bypass effects downriver at dams such as Bonneville and John Day. Thus, the fact that we did not find a perceived bypass effect at Bonneville may be related to the low number of PIT-tag detections at that location. To adequately assess bypass effects at Bonneville with PIT tags, a carefully designed study would require releases of PIT-tagged fish either at Bonneville or at one of the nearby dams upriver to ensure sufficient numbers of fish detected in the bypass system at Bonneville.

An alternative approach to assessing bypass effects at downriver dams is to use active tags such as acoustic-telemetry tags. Active tags have the benefit of providing detailed route information not only through the bypass system but also through other passage routes. This allows researchers to compare survival in the river after passage through the bypass route to survival after passage over the spillway, for example, without having to pool the spillway and turbine passage routes. Also, the flexibility in receiver placement for active tags enables assessment of relatively short-term survival effects, rather than the long-term effects on adult returns observable with PIT tags. This ability to detect differences in short-term survival, coupled with detection probabilities approaching 100%, boosts the power to detect possible bypass effects, especially for downstream dams. On the other hand, PIT tags are more suitable for exploring long-term survival differences.

McMichael et al. (2010) used double tagging with PIT and JSATS acoustic tags to measure survival from Bonneville Dam through the estuary to the mouth of the Columbia River, and were able to relate survival to passage routes at John Day and Bonneville. In particular, they found significantly higher survival through the estuary for juvenile steelhead that passed John Day through the deep spill route and Bonneville through the B2CC compared to steelhead that passed both dams through the JBSs. The higher statistical power of that study exemplifies the benefits of using a combination of tagging technologies to study complicated questions such as bypass effects.

Another consequence of relying only on PIT tags is that large release groups were necessary to achieve reasonable statistical power. This study focused on hatchery fish because of the relatively large release groups available compared to wild fish. The hatchery spring Chinook salmon release groups ranged in size from 67,496 to 304,850, with an average of 187,467. Hatchery summer Chinook salmon release groups were somewhat smaller (average 70,774), and hatchery steelhead release groups were smaller still (average 34,712), with resulting reductions in statistical power. The power to detect survival differences for steelhead in particular was especially small. Available release groups of wild Snake River yearling Chinook and steelhead ranged in size from 9,601 to 92,304 (average 53,333) for Chinook salmon, and from 5,393 to 25,524 (average 17,584) for steelhead for the migration years 1996–2006. Because of the small release groups, only the largest survival differences would be reliably detectable for wild fish, and only for the common juvenile detection histories. As more years of PIT-tag data from wild stocks become available, it will become easier to detect some survival differences for bypassed smolts, but it will remain difficult to detect small effects.

6.0 Recommendations and Management Implications

This study related differences in adult returns to smolt passage through the bypass systems in the FCRPS. We compared observed adult return rates with those expected under the null hypothesis of no bypass effects. We found fish that were never bypassed returned at higher than expected rates under the null hypothesis of homogeneous survival. Furthermore, we found that adult return rates tended to decline the more often a fish was bypassed during outmigration. In some cases, there also appeared to be a significant synergistic effect of multiple bypass experiences, suggesting a latent effect of bypass. We also demonstrated that different stocks react differently to bypass at the same dam, and performed preliminary tests of competing hypotheses that may explain why fish that were bypassed at some dams tend to have reduced adult return rates compared to non-bypassed fish. However, there is more work to be done on the question of bypass effects.

Our study used Snake River fish to study the possibility of bypass effects at the Snake River dams, as well as downstream. The result of using Snake River fish was that most of our detections occurred at the Snake River dams, with relatively few detections at McNary, John Day, and Bonneville dams. Consequently, we had low statistical power to detect any but the largest potential bypass effects at the downstream dams. Bypass at these dams may be further studied using PIT-tagged fish from the Mid-Columbia, or using fish tagged and released downstream from Lower Granite Dam.

One limitation of our study was imposed by limitations in the PIT-tag detections at some dams. Over the past decade, more and more PIT-tag detectors have been installed throughout the hydrosystem, and detailed data are available on bypass passage at most dams. However, additional information is needed at some dams. For example, at Lower Monumental Dam, fish coming from the holding tanks cannot be distinguished from those exiting the bypass system from other routes, while at John Day Dam, fish coming directly from the sort-by-code separator cannot be distinguished from those exiting the sample room. Although PIT-tag detectors have recently been installed in the full-flow bypass at Ice Harbor Dam, very few fish have been detected passing this dam compared to multiple years of detections at other dams.

This study used PIT-tag data to focus on long-term survival differences between bypassed and non-bypassed inriver fish. A complementary study would use acoustic tags to study short-term, near-field effects on survival of passage through different routes (e.g., McMichael et al. 2010). Depending on only a single tag technology limits the study results. PIT-tag data permit assessment of overall survival differences, both near- and far-field, but at a coarser level of treatment. Acoustic-tag data permit comparison of finer-scale passage histories, but only for near-field effects. Both types of information should be used in a comprehensive analysis to identify sources of mortality that might be mitigated to improve overall adult return rates. This report should be viewed as just one step in that overall assessment process.

The mechanism behind the perceived bypass effects identified by this study should be investigated further. It is not clear whether the bypass systems themselves are causing reduced adult return rates at some dams, or whether the selectivity of the bypass system or dependency in route selection among individual fish are producing our results. More work is needed to clarify these issues. Active tags may be used to study both selectivity and route dependency, as well as short-term survival differences

across the various passage routes. Releases made directly into various routes may be used to distinguish between the selectivity of the bypass system or other routes, and true effects of passage routes on subsequent survival.

The results presented in this report indicate where additional work should be focused. In particular, bypass at Lower Granite Dam should be studied further for hatchery-raised steelhead, while bypass at Little Goose Dam should be studied further for hatchery-raised yearling Chinook. Additional years of PIT-tag data may shed light on possible bypass effects at Lower Monumental and McNary dams for Snake River fish. PIT-tag data from Mid-Columbia fish may be necessary to study potential bypass effects at the downstream dams on the Columbia River. Active tags may be used to study short-term bypass effects, complementing the long-term analysis available with PIT tags.

A glaring omission in this analysis was the ability to compare bypassed fish with those passing through turbines. There is an old adage, "getting old beats the alternative." While some bypass systems may not be benign compared to the spillway, they likely beat the alternative of turbine passage. However, PIT-tag data are incapable of providing that comparison. The biological and managerial consequences of bypass mortality must be interpreted in the context of hydroproject operation that includes spillway, bypass, and turbine passage mortality. The best measurement of this integrated response is the overall smolt-to-adult ratio that takes all passage options and their relative proportions into account.

7.0 References

Bouwes N, H Schaller, P Budy, C Petrosky, R Kiefer, P Wilson, O Langness, E Weber, and E Tinus. 1999. *An Analysis of Differential Delayed Mortality Experienced by Stream-Type Chinook Salmon of the Snake River: A Response by State, Tribal, and USFWS Technical Staff to the 'D' Analysis and Discussion in the Draft Anadromous Fish Appendix to the U.S. Army Corps of Engineers' Lower Snake River Juvenile Salmonid Migration Feasibility Study/Environmental Impact Statement*. Tech. Rep. Oregon Department of Fish and Wildlife, Portland, Oregon.

Buchanan RA and JR Skalski. 2007. "A Migratory Life-Cycle Release-Recapture Model for Salmonid PIT-Tag Investigations." *Journal of Agricultural, Biological, and Environmental Statistics* 12:325–345.

Buchanan, RA, JR Skalski, and K Broms. 2008. *Survival and transportation effects for migrating Snake River wild Chinook salmon and steelhead: Historical estimates from 1996-2004 and comparison to hatchery results*. Volume XVIII in Monitoring and Evaluation of Smolt Migration in the Columbia Basin. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Available at http://pisces.bpa.gov/release/documents (accessed 6 August 2009).

Budy P, GP Thiede, N Bouwes, CE Petrosky, and H Schaller. 2002. "Evidence Linking Delayed Mortality of Snake River Salmon to Their Earlier Hydrosystem Experience." *North American Journal of Fisheries Management* 22:35–51.

Cochran WG. 1977. "Sampling Techniques." In *Probability and Mathematical Statistics,* John Wiley & Sons, Inc., New York.

Collett D. 1991. *Modelling Binary Data*. Chapman & Hall/CRC, New York.

Cormack RM. 1964. "Estimates of survival from the sighting of marked animals." *Biometrika* 51:429–438.

Coutant CC and RR Whitney. 2000. "Fish Behavior in Relation to Passage through Hydropower Turbines: A Review." *Transactions of the American Fisheries Society* 129:351–380.

Downing SL and GA Axel. 2007. *Evaluation of the Full-Flow PIT-Tag Interrogation System at Ice Harbor Dam, 2005*. Report to the U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Seattle, Washington, by National Marine Fisheries Service, Seattle, Washington. Contract 22361, Project No. 200100300, 31 pp.

USACE. 2010. Fish Passage Plan: Corps of Engineers Projects. U.S. Army Corps of Engineers, Northwestern Division , Portland, OR.

Johnson GE, JW Beeman, IN Duran, and AL Puls. 2007. *Synthesis of Juvenile Salmonid Passage Studies at The Dalles Dam, Volume II, 2001-2005*. PNNL-16443, report submitted to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington, and the U.S. Geological Survey Biological Resources Division, Cook, Washington.

Jolly GM. 1965. "Explicit estimates from capture-recapture data with both death and immigration - Stochastic model." *Biometrika* 52:225–247.

Kulinskaya E, S Morgenthaler, and RG Staudte. 2008. "Meta Analysis: A Guide to Calibrating and Combining Statistical Evidence." Wiley Series in *Probability and Statistics*, John Wiley & Sons, Ltd., Chichester, England.

Lebreton J-D, KP Burnham, J Clobert, and DR Anderson. 1992. "Modeling Survival and Testing Biological Hypotheses Using Marked Animals: A Unified Approach with Case Studies." *Ecological Monographs* 62:67–118.

Marmorek DR and CN Peters (eds.). 1998. *Plan for Analyzing and Testing Hypotheses (PATH): Final Report for Fiscal Year 1998*. ESSA Technologies, Ltd, Vancouver, British Columbia.

McMichael GA, RA Harnish, BJ Bellgraph, JA Carter, KD Ham, PS Titzler, and MS Hughes. 2010. *Migratory Behavior and Survival of Juvenile Salmonids in the Lower Columbia River and Estuary in 2009*. Draft Final Report to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Available at http://www.nwp.usace.army.mil/pm/e/draftreports.asp.

Muir WD, SG Smith, JG Williams, and BP Sandford. 2001. "Survival of Juvenile Salmonids Passing through Bypass Systems, Turbines, and Spillways with and without Flow Deflectors at Snake River Dams." *North American Journal of Fisheries Management* 21:135–146.

Sandford BP and SG Smith. 2002. "Estimation of Smolt-to-Adult Return Percentages for Snake River Basin Anadromous Salmonids, 1990–1997." *Journal of Agricultural, Biological, and Environmental Statistics* 7:243–263.

Schaller H, P Wilson, S Haeseker, C Petrosky, E Tinus, T Dalton, R Woodin, E Weber, N Bouwes, T Berggren, J McCann, S Rassk, H Franzoni, and P McHugh. 2007. *Comparative Survival Study (CSS) of PIT-Tagged Spring/Summer Chinook and Steelhead in the Columbia River Basin: Ten-Year Retrospective Analyses Report*. BPA Contract #19960200, Bonneville Power Administration, Portland, Oregon.

Seber GAF. 1965. "A note on the multiple recapture census." *Biometrika* 52:249–259.

Skalski JR, SG Smith, RN Iwamoto, JG Williams, and A Hoffman. 1998. "Use of Passive Integrated Transponder Tags to Estimate Survival of Migrant Juvenile Salmonids in the Snake and Columbia Rivers." *Canadian Journal of Fisheries and Aquatic Sciences* 55:1484–1493.

Smith SG, WD Muir, EE Hockersmith, S Achord, MP Eppard, TE Ruehle, and JG Williams. 1998. *Survival Estimates for the Passage of Juvenile Salmonids through Snake River Dams and Reservoirs, 1996*. Technical report prepared for U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon. Project #93-29, Contract #DE-AI79-93BP10891

Williams, JG, SG Smith, RW Zabel, WD Muir, MD Scheuerell, BP Sandford, DM Marsh, RA McNatt, and S Achord. 2005. "Effects of the Federal Columbia River Power System on Salmonid Populations." National Oceanic and Atomospheric Administration Technical Memo NMFS-NWFSC-63, U.S. Department of Commerce, Seattle, Washington.

Zabel RW, T Wagner, JL Congleton, SG Smith, and JG Williams. 2005. "Survival and Selection of Migrating Salmon from Capture-Recapture Models with Individual Traits." *Ecological Applications* 15:1427–1439.

Appendix A

Release Groups Used in Bypass Effects Analysis

Appendix A

Release Groups Used in Bypass Effects Analysis

Table A.1. Release Sites of the PIT-Tagged Chinook Salmon and Steelhead in the Annual Release Groups Used in the Bypass Effects Analysis. All fish were tagged and released in the Snake River Basin upstream of Lower Granite Dam. River kilometer (RKM) is measured from the confluence of the Snake River with the Columbia River (i.e., RKM 522 from the mouth of the Columbia River). Release sites are ordered by total RKM. "Percentage" refers to the percentage of the release group released at the given release site.

Stock	Year	Release Site	RKM	Number Released	Percentage
Spring Chinook	1996	Powell Rearing Pond	224.120.037.113	11,402	16.7
		Red River Rearing Pond	224.120.101.027	1,212	1.8
		Rapid River Hatchery	303.140.007.006	19,169	28.0
		Crooked River Pond	224.120.094.015	2,095	3.1
		Lookingglass Hatchery	271.137.003	6,758	9.9
		Imnaha River Weir	308.074	4,715	6.9
		Clear Creek	224.120.004	16,464	24.1
		Salmon River	303	1,257	1.8
		Dworshak NFH (NF Clearwater)	224.065	4,067	5.9
		North Fork Clearwater River	224.065	1,002	1.5
		Other		233	0.3
		Total		68,374	100
Spring Chinook	1997	Rapid River Hatchery	303.140.007.006	40,959	34.6
		Lookingglass Hatchery	271.137.003	40,404	34.2
		Imnaha River Weir	308.074	13,378	11.3
		Selway River	224.120.037	1,427	1.2
		Kooskia NFH	224.120.004.001	4,075	3.4
		Dworshak NFH (NF Clearwater)	224.065	14,080	11.9
		Other		3,954	3.2
		Total		118,277	99.8
Spring Chinook	1998	Powell Rearing Pond	224.120.037.113	1,675	1.0
		Rapid River Hatchery	303.140.007.006	48,339	29.1
		Lookingglass Hatchery	271.137.003	44,788	27.0
		Imnaha River Weir	308.074	19,827	11.9
		Dworshak NFH (NF Clearwater)	224.065	47,704	28.7
		Other		3,655	2.2
		Total		165,988	99.9

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
Spring Chinook	1999	Sawtooth Trap	303.617	2,966	1.6
		Rapid River Hatchery	303.140.007.006	49,288	27.1
		Lookingglass Hatchery	271.137.003	44,554	24.5
		Imnaha River Weir	308.074	23,426	12.9
		Lostine River	271.131.042	4,959	2.7
		Dworshak NFH (NF Clearwater)	224.065	47,845	26.3
		Grande Ronde River	271	1,772	1.0
		Other		7,236	3.9
		Total		182,046	100
Spring Chinook	2000	Catherine Creek Pond	271.232.048	3,980	3.0
		Rapid River Hatchery	303.140.007.006	47,748	35.4
		Lostine River Pond	271.131.042.021	7,922	5.9
		Imnaha River Weir	308.074	20,819	15.4
		Dworshak NFH (NF Clearwater)	224.065	47,745	35.4
		Grande Ronde River	271	1,397	1.0
		Other		5,209	3.7
		Total		134,820	99.8
Spring Chinook	2001	Catherine Creek Pond	271.232.048	20,915	12.4
		Rapid River Hatchery	303.140.007.006	55,091	32.6
		Lostine River Pond	271.131.042.021	7,886	4.7
		Imnaha River Weir	308.074	20,922	12.4
		Dworshak NFH (MS Clearwater)	224.065	51,196	30.3
		Grande Ronde River	271	1,628	1.0
		Clearwater River	224	3,946	2.3
		Other		7,208	4.3
		Total		168,792	100
Spring Chinook	2002	Catherine Creek Pond	271.232.048	20,796	6.7
		Rapid River Hatchery	303.140.007.006	183,923	59.7
		Lostine River Pond	271.131.042.021	16,001	5.2
		Imnaha River Weir	308.074	20,920	6.8
		Dworshak NFH (NF Clearwater)	224.065	54,726	17.8
		Other		11,824	3.8
		Total		308,190	100
Spring Chinook	2003	Catherine Creek Pond	271.232.048	20,628	6.7
		Rapid River Hatchery	303.140.007.006	184,473	59.9
		Lostine River Pond	271.131.042.021	15,901	5.2
		Imnaha River Weir	308.074	20,904	6.8
		Dworshak NFH (NF Clearwater)	224.065	51,787	16.8
		Other		14,451	4.7
		Total		308,144	100.1

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
Spring Chinook	2004	Catherine Creek Pond	271.232.048	20,994	12.0
		Rapid River Hatchery	303.140.007.006	51,969	29.8
		Lostine River Pond	271.131.042.021	15,928	9.1
		Lookingglass Hatchery	271.137.003	5,193	3.0
		Imnaha River Weir	308.074	20,910	12.0
		Dworshak NFH (NF Clearwater)	224.065.000	51,616	29.6
		Other		7,789	4.6
		Total		174,399	100.1
Spring Chinook	2005	Catherine Creek Pond	271.232.048	20,839	12.2
		Rapid River Hatchery	303.140.007.006	52,021	30.4
		Lostine River Pond	271.131.042.021	13,340	7.8
		Meadow Creek, Selway River	224.120.037.031	5,098	3.0
		Imnaha River Weir	308.074	20,917	12.2
		Dworshak NFH (NF Clearwater)	224.065.000	51,819	30.3
		Other		7,077	4.2
		Total		171,111	100.1
Spring Chinook	2006	Catherine Creek Pond	271.232.048	20,963	7.0
		Powell Rearing Pond	224.120.037.113	15,274	5.1
		Red River Rearing Pond	224.120.101.027	15,273	5.1
		Lostine River Pond	271.131.042.021	14,256	4.7
		Rapid River Hatchery	303.140.007.006	97,053	32.2
		Crooked River	224.120.094	15,278	5.1
		Imnaha River Weir	308.074	20,632	6.8
		Dworshak NFH (NF Clearwater)	224.065	92,548	30.7
		Dworshak NFH	224.065	4,843	1.6
		Other		5,130	1.8
		Total		301,250	100.1
Summer Chinook	1996	Knox Bridge	303.215.112	29,595	97.7
		Imnaha Trap	308.007	698	2.3
		Total		30,293	100
Summer Chinook	1997	Pahsimeroi Pond	303.489.011	31,442	36.9
		Knox Bridge	303.215.112	52,655	61.9
		Imnaha Trap	308.007	999	1.2
		Total		85,096	100
Summer Chinook	1998	Pahsimeroi Pond	303.489.011	993	2.0
		Knox Bridge	303.215.112	47,343	93.9
		Imnaha Trap	308.007	2,000	4.0
		Other		72	0.2
		Total		50,408	100.1

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
Summer Chinook	1999	Pahsimeroi Pond	303.489.011	500	1.0
		Knox Bridge	303.215.112	48,577	94.7
	1999	Imnaha Trap	308.007	1,453	2.8
		Other		787	1.5
		Total		51,317	100
Summer Chinook	2000	Knox Bridge	303.215.112	48,305	80.9
		Johnson Creek	303.215.060.024	8,045	13.5
		Imnaha Trap	308.007	2,421	4.1
		Other		969	1.6
		Total		59,740	100.1
Summer Chinook	2001	Pahsimeroi Pond	303.489.011	1,000	1.7
		Knox Bridge	303.215.112	55,727	93.3
		Imnaha Trap	308.007	3,008	5.0
		Other		4	0.0
		Total		59,739	100
Summer Chinook	2002	Pahsimeroi Pond	303.489.011	992	1.4
		Knox Bridge	303.215.112	55,432	79.8
		Johnson Creek	303.215.060.024	9,987	14.4
		Imnaha Trap	308.007	2,962	4.3
		Other		79	0.1
		Total		69,452	100
Summer Chinook	2003	Pahsimeroi Pond	303.489.011	982	1.1
		Knox Bridge	303.215.112	74,314	84.7
		Johnson Creek	303.215.060.024	12,132	13.8
		Other		323	0.4
		Total		87,751	100
Summer Chinook	2004	Pahsimeroi Pond	303.489.011	970	1.1
		Knox Bridge	303.215.112	72,116	84.5
		Johnson Creek	303.215.060.024	12,186	14.3
		Other		24	0.0
		Total		85,296	99.9
Summer Chinook	2005	Knox Bridge	303.215.112	74,719	85.5
		Johnson Creek	303.215.060.024	12,050	13.8
		Other		602	0.7
		Total		87,371	100.0
Summer Chinook	2006	Knox Bridge	303.215.112	51,904	80.5
		Johnson Creek	303.215.060.024	12,058	18.7
		Other		545	0.8
		Total		64,507	100.0

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
Steelhead	1996	Sawtooth Hatchery	303.617	1,799	6.3
		Sawtooth Trap	303.617	903	3.1
		East Fork Salmon River Weir	303.552.030	300	1.0
		Pahsimeroi River Trap	303.489.002	1,697	5.9
		Lemhi River	303.416	299	1.0
		North Fork Salmon River	303.381	300	1.0
		Herd Creek	303.301	300	1.0
		Hazard Creek	303.140.031	304	1.1
		Red River	224.120.101	3,999	13.9
		Crooked River Trap	224.120.094.001	310	1.1
		Crooked River	224.120.094	3,005	10.5
		Big Canyon Facility	271.131.018.001	995	3.5
		Salmon Trap	303.103	1,410	4.9
		Hells Canyon Dam	397	300	1.0
		Little Sheep Facility	308.032.005.008	1,518	5.3
		Clear Creek	224.120.004	920	3.2
		South Fork Clearwater River	224.120	898	3.1
		Imnaha Trap	308.007	1,346	4.7
		Salmon River	303	1,505	5.2
		Dworshak NFH	224.065	4,425	15.4
		Grande Ronde River	271	287	1.0
		Snake Trap	225	1,453	5.1
		Clearwater River	224	336	1.2
		Other		81	0.3
		Total		28,690	99.8
Steelhead	1997	Sawtooth Hatchery	303.617	2,595	7.6
		Pahsimeroi Weir	303.489.002	798	2.4
		Hazard Creek	303.140.031	899	2.6
		Wallowa Hatchery	271.131.063.001	1,650	4.9
		Crooked River Pond	224.120.094.015	2,394	7.1
		Red River	224.120.101	1,000	2.9
		Big Canyon Facility	271.131.018.001	2,210	6.5
		Salmon Trap	303.103	1,252	3.7
		Little Sheep Facility	308.032.005.008	812	2.4
		Clear Creek	224.120.004	991	2.9
		South Fork Clearwater River	224.120	900	2.7
		Imnaha Trap	308.007	6,118	18.0
		Salmon River	303	1,500	4.4
		Dworshak NFH	224.065	4,874	14.4
		Grande Ronde River	271	2,356	6.9
		Snake Trap	225	1,459	4.3

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
		Other		2,119	6.3
		Total		33,927	100
Steelhead	1998	Sawtooth Hatchery	303.617	1,200	4.0
		East Fork Salmon River Weir	303.552.030	300	1.0
		Squaw Creek Acclimation Pond	303.564.001	899	3.0
		Pahsimeroi River Trap	303.489.002	300	1.0
		Herd Creek	303.301	1,205	4.0
		Hazard Creek	303.140.031	900	3.0
		Wallowa Hatchery	271.131.063.001	1,108	3.6
		Red River	224.120.101	4,116	13.6
		Big Canyon Facility	271.131.018.001	1,202	4.0
		Twentymile Creek	224.120.069	326	1.1
		Salmon Trap	303.103	1,117	3.7
		Hells Canyon Dam	397	300	1.0
		Little Sheep Facility	308.032.005.008	862	2.8
		Clear Creek	224.120.004	303	1.0
		South Fork Clearwater River	224.120	300	1.0
		Imnaha Trap	308.007	3,859	12.7
		Salmon River	303	1,499	4.9
		Dworshak NFH	224.065	3,497	11.5
		Grande Ronde River	271	2,730	9.0
		Snake Trap	225	4,274	14.1
		Other		78	0.3
		Total		30,375	100.3
Steelhead	1999	Sawtooth Hatchery	303.617	2,399	6.2
		Squaw Creek Acclimation Pond	303.564.001	1,496	3.9
		Wallowa Hatchery	271.131.063.001	1,354	3.5
		Red River	224.120.101	5,000	12.9
		Little Salmon River	303.140	599	1.5
		Big Canyon Facility	271.131.018.001	2,330	6.0
		Salmon Trap	303.103	2,266	5.8
		Little Sheep Facility	308.032.005.008	761	2.0
		Clear Creek	224.120.004	1,498	3.9
		South Fork Clearwater River	224.120	1,198	3.1
		Imnaha Trap	308.007	6,387	16.5
		Salmon River	303	924	2.4
		Dworshak NFH (MS Clearwater)	224.065	2,108	5.4
		Grande Ronde River	271	3,116	8.0
		Snake Trap	225	3,990	10.3
		Clearwater River	224	1,921	5.0
		Other		1,427	3.7
		Total		38,774	100.1

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
Steelhead	2000	Sawtooth Hatchery	303.617	2,408	6.6
		Squaw Creek Acclimation Pond	303.564.001	1,791	4.9
		Wallowa Hatchery	271.131.063.001	1,195	3.3
		Little Salmon River	303.140	599	1.6
		Big Canyon Facility	271.131.018.001	3,509	9.6
		Salmon Trap	303.103	2,126	5.8
		Little Sheep Facility	308.032.005.008	756	2.1
		Clear Creek	224.120.004	1,200	3.3
		South Fork Clearwater River	224.120	1,200	3.3
		Cottonwood Acclimation Pond	271.046	354	1.0
		Imnaha Trap	308.007	5,742	15.8
		Salmon River	303	597	1.6
		Dworshak NFH (MS Clearwater)	224.065	4,208	11.6
		North Fork Clearwater River	224.065	782	2.1
		Grande Ronde River	271	2,951	8.1
		Snake Trap	225	3,698	10.2
		Clearwater River	224	699	1.9
		Other		2,574	6.9
		Total		36,389	99.7
Steelhead	2001	Sawtooth Hatchery	303.617	500	1.6
		Yankee Fork (Salmon River)	303.591	597	1.9
		Squaw Creek Acclimation Pond	303.564.001	900	2.9
		Squaw Creek (Salmon River)	303.564	600	1.9
		Pahsimeroi River Trap	303.489.002	302	1.0
		Lemhi River	303.416	300	1.0
		Red River Rearing Pond	224.120.101.027	299	1.0
		Wallowa Hatchery	271.131.063.001	890	2.9
		Crooked River Pond	224.120.094.015	598	1.9
		American River	224.120.101	295	1.0
		Little Salmon River	303.140	900	2.9
		Newsome Creek	224.120.084	300	1.0
		Big Canyon Facility	271.131.018.001	2,068	6.7
		Salmon Trap	303.103	3,084	10.0
		Hells Canyon Dam	397	300	1.0
		Little Sheep Facility	308.032.005.008	747	2.4
		Clear Creek	224.120.004	903	2.9
		South Fork Clearwater River	224.120	1,199	3.9
		Cottonwood Acclimation Pond	271.046	346	1.1
		Imnaha Trap	308.007	3,463	11.2
		Lolo Creek	224.087	318	1.0
		Salmon River	303	1,300	4.2
		Dworshak NFH (MS Clearwater)	224.065	4,205	13.6

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
		North Fork Clearwater River	224.065	663	2.1
		Grande Ronde River	271	2,216	7.2
		Snake Trap	225	2,940	9.5
		Clearwater River	224	665	2.1
		Other		86	0.3
		Total		30,984	100.2
Steelhead	2002	Sawtooth Hatchery	303.617	599	1.9
		Squaw Creek Acclimation Pond	303.564.001	1,200	3.9
		Squaw Creek (Salmon River)	303.564	600	1.9
		Pahsimeroi River Trap	303.489.002	300	1.0
		Lemhi River	303.416	594	1.9
		Red River Rearing Pond	224.120.101.027	298	1.0
		Wallowa Hatchery	271.131.063.001	737	2.4
		Crooked River Pond	224.120.094.015	601	1.9
		Little Salmon River	303.140	599	1.9
		Big Canyon Facility	271.131.018.001	3,852	12.4
		Salmon Trap	303.103	2,060	6.6
		Hells Canyon Dam	397	298	1.0
		Little Sheep Facility	308.032.005.008	751	2.4
		Clear Creek	224.120.004	900	2.9
		South Fork Clearwater River	224.120	1,202	3.9
		Imnaha Trap	308.007	2,153	6.9
		Salmon River	303	2,099	6.8
		Dworshak NFH (MS Clearwater)	224.065	4,213	13.6
		Grande Ronde River Trap	271.002	2,418	7.8
		Snake Trap	225	5,031	16.2
		Other		498	1.6
		Total		31,003	99.9
Steelhead	2003	Yankee Fork (Salmon River)	303.591	596	1.9
		Squaw Creek Acclimation Pond	303.564.001	599	1.9
		Lemhi River	303.416	597	1.9
		Wallowa Hatchery	271.131.063.001	493	1.5
		Crooked River Pond	224.120.094.015	648	2.0
		American River	224.120.101	526	1.6
		Red River	224.120.101	535	1.7
		Little Salmon River	303.140	1,175	3.7
		Crooked River	224.120.094	841	2.6
		Newsome Creek	224.120.084	519	1.6
		Big Canyon Facility	271.131.018.001	3,967	12.4
		Salmon Trap	303.103	2,444	7.6
		Mill Creek, SF Clearwater River	224.120.052	526	1.6
		Little Sheep Facility	308.032.005.008	772	2.4

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
		South Fork Clearwater River	224.120	883	2.8
		Imnaha Trap	308.007	5,227	16.3
		Lolo Creek	224.087	535	1.7
		Salmon River	319 - 489	900	2.8
		Dworshak NFH (MS Clearwater)	224.065	1,500	4.7
		Grande Ronde River Trap	271.002	2,210	6.9
		Snake Trap	225	4,177	13.0
		Other		2,338	7.1
		Total		32,008	99.7
Steelhead	2004	Yankee Fork (Salmon River)	303.591	595	1.5
		Squaw Creek Acclimation Pond	303.564.001	2,300	6.0
		Lemhi River	303.416	599	1.6
		Red River Rearing Pond	224.120.101.027	7,412	19.2
		Wallowa Hatchery	271.131.063.001	530	1.4
		Crooked River	224.120.094	598	1.5
		Little Salmon River	303.140	1,482	3.8
		Big Canyon Facility	271.131.018.001	3,756	9.7
		Salmon Trap	303.103	2,241	5.8
		Meadow Creek, SF Clearwater River	224.120.053	1,061	2.7
		Mill Creek, SF Clearwater River	224.120.052	1,505	3.9
		Little Sheep Facility	308.032.005.008	732	1.9
		Imnaha Trap	308.007	4,487	11.6
		Salmon River	319 - 489	588	1.5
		Dworshak NFH (MS Clearwater)	224.065	1,496	3.9
		Grande Ronde River Trap	271.002	1,539	4.0
		Snake Trap	225	4,843	12.5
		Other		2,877	7.7
		Total		38,641	100.2
Steelhead	2005	Squaw Creek Acclimation Pond	303.564.001	1,809	4.2
		Squaw Creek (Salmon River)	303.564	499	1.2
		Lemhi River	303.416	597	1.4
		Salmon River	489 – 650	597	1.4
		Red River Rearing Pond	224.120.101.027	7,488	17.3
		Wallowa Hatchery	271.131.063.001	7,556	17.5
		Crooked River Pond	224.120.094.015	597	1.4
		Little Salmon River	303.140	1,796	4.2
		Big Canyon Facility	271.131.018.001	503	1.2
		Meadow Creek, SF Clearwater River	224.120.053	1,302	3.0
		Salmon Trap	303.103	2,625	6.1
		Mill Creek, SF Clearwater River	224.120.052	1,293	3.0

Table A.1. (contd)

Stock	Year	Release Site	RKM	Number Released	Percentage
		Little Sheep Facility	308.032.005.008	499	1.2
		Salmon River	319 - 489	596	1.4
		Imnaha Trap	308.007	6,570	15.2
		Dworshak NFH (MS Clearwater)	224.065	1,247	3.9
		Grande Ronde River Trap	271.002	1,417	3.3
		Snake Trap	225	3,356	7.8
		Other		2,860	6.7
		Total		43,207	100.4
Steelhead	2006	Yankee Fork (Salmon River)	303.591	592	1.6
		Squaw Creek Acclimation Pond	303.564.001	984	2.7
		Lemhi River	303.416	599	1.7
		Salmon River	489 – 650	797	2.2
		Red River Rearing Pond	224.120.101.027	7,253	20.2
		Wallowa Hatchery	271.131.063.001	7,144	19.9
		Little Salmon River	303.140	1,487	4.1
		Big Canyon Facility	271.131.018.001	591	1.6
		Meadow Creek, SF Clearwater River	224.120.053	1,297	3.6
		Salmon Trap	303.103	1,225	3.4
		Mill Creek, SF Clearwater River	224.120.052	1,289	3.6
		Salmon River	319 - 489	597	1.7
		Imnaha Trap	308.007	1,494	4.2
		Dworshak NFH (MS Clearwater)	224.065	1,494	4.2
		Grande Ronde River Trap	271.002	3,606	10.1
		Snake Trap	225	2,148	6.0
		Other		3,282	8.8
		Total		35,879	99.6

NF = North Fork; NFH = National Fish Hatchery; MS = main stem.

Appendix B

Estimates of Residuals for Juvenile Detection History Groups

Appendix B

Estimates of Residuals for Juvenile Detection History Groups

Tables B.1 through B.4 list the observed and expected number of adults for juvenile detection histories with a given number of juvenile detections, with only one detection, with detections at exactly two dams, and with transportation from Little Goose Dam with or without previous detection, respectively.

Table B.1. Observed and Expected Number of Adults for Juvenile Detection Histories with Given Number of Juvenile Detections (pooled over detection histories) (cf Figure 3.7, Figure 3.8, Figure 3.9). *P*-values for each year are from two-tailed tests of H0: $Z=0$. Values after individual years are from meta-analysis; *P*-value from meta-analysis are from one-tailed tests: HA:$T>0$ for 0 juvenile detections, HA:$T<0$ for 1 or more detections. Absolute difference = Observed – Expected. Relative difference = (Observed/Expected – 1).

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	0	19	13.46	5.54	0.4116	1.4219	0.1551
	1997	115057	0	80	67.345	12.655	0.1879	1.4979	0.1342
	1998	161693	0	166	94.047	71.953	0.7651	6.7016	0.0000
	1999	180085	0	531	192.921	338.079	1.7524	20.1013	0.0000
	2000	131833	0	313	300.891	12.109	0.0402	0.6943	0.4875
	2001	162255	0	6	0.226	5.774	25.5487	5.6316	0.0000
	2002	303302	0	276	242.132	33.868	0.1399	2.1296	0.0332
	2003	304850	0	179	137.481	41.519	0.3020	3.3840	0.0007
	2004	171050	0	19	11.924	7.076	0.5934	1.8867	0.0592
	2005	167260	0	14	4.630	9.370	2.0238	3.5216	0.0004
	2006	297253	0	213	157.729	55.271	0.3504	4.1785	0.0000
Overall				1816	1222.786	593.214	0.4851	15.4336	0.0000
Spring Chinook	1996	67496	1	18	21.018	-3.018	-0.1436	-0.6753	0.4995
	1997	115057	1	83	90.027	-7.027	-0.0781	-0.7509	0.4527
	1998	161693	1	175	177.204	-2.204	-0.0124	-0.1660	0.8682
	1999	180085	1	387	484.454	-97.454	-0.2012	-4.5969	0.0000
	2000	131833	1	305	303.397	1.603	0.0053	0.0921	0.9266
	2001	162255	1	3	1.966	1.034	0.5259	0.6843	0.4938
	2002	303302	1	508	500.311	7.689	0.0154	0.3432	0.7315
	2003	304850	1	144	165.87	-21.87	-0.1319	-1.7383	0.0822
	2004	171050	1	38	34.071	3.929	0.1153	0.6609	0.5087
	2005	167260	1	12	18.003	-6.003	-0.3334	-1.5080	0.1316
	2006	297253	1	254	261.818	-7.818	-0.0299	-0.4858	0.6271
Overall				1927	2058.139	-131.139	-0.0637	-2.4496	0.0072

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	2	11	12.118	-1.118	-0.0923	-0.3262	0.7442
	1997	115057	2	32	38.677	-6.677	-0.1726	-1.1074	0.2681
	1998	161693	2	87	128.141	-41.141	-0.3211	-3.8646	0.0001
	1999	180085	2	279	463.469	-184.469	-0.3980	-9.2801	0.0000
	2000	131833	2	86	120.552	-34.552	-0.2866	-3.3218	0.0009
	2001	162255	2	6	6.514	-0.514	-0.0789	-0.2043	0.8381
	2002	303302	2	341	391.938	-50.938	-0.1300	-2.6338	0.0084
	2003	304850	2	62	75.292	-13.292	-0.1765	-1.5811	0.1139
	2004	171050	2	32	33.47	-1.47	-0.0439	-0.2560	0.7980
	2005	167260	2	26	23.654	2.346	0.0992	0.4748	0.6349
	2006	297253	2	137	170.810	-33.810	-0.1979	-2.6815	0.0073
Overall				1099	1464.635	-365.635	-0.2496	-7.6170	0.0000
Spring Chinook	1996	67496	3	2	3.093	-1.093	-0.3534	-0.6653	0.5059
	1997	115057	3	6	5.702	0.298	0.0523	0.1238	0.9015
	1998	161693	3	22	45.388	-23.388	-0.5153	-3.8704	0.0001
	1999	180085	3	146	212.826	-66.826	-0.3140	-4.8642	0.0000
	2000	131833	3	19	23.781	-4.781	-0.2010	-1.0167	0.3093
	2001	162255	3	5	10.28	-5.28	-0.5136	-1.8351	0.0665
	2002	303302	3	132	147.984	-15.984	-0.1080	-1.3392	0.1805
	2003	304850	3	9	16.653	-7.653	-0.4596	-2.060	0.0394
	2004	171050	3	12	14.49	-2.49	-0.1718	-0.6744	0.5001
	2005	167260	3	13	13.803	-0.803	-0.0582	-0.2182	0.8273
	2006	297253	3	45	55.338	-10.338	-0.1868	-1.4371	0.1507
Overall				411	549.338	-138.338	-0.2518	-5.4918	0.0000

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	4	0	0.312	-0.312	-1.0000	-0.8379	0.4021
	1997	115057	4	1	0.252	0.748	2.9683	1.1357	0.2561
	1998	161693	4	4	8.412	-4.412	-0.5245	-1.7001	0.0891
	1999	180085	4	41	48.597	-7.597	-0.1563	-1.1205	0.2625
	2000	131833	4	1	2.393	-1.393	-0.5821	-1.0232	0.3062
	2001	162255	4	8	7.85	0.15	0.0191	0.0533	0.9575
	2002	303302	4	27	28.793	-1.793	-0.0623	-0.3378	0.7356
	2003	304850	4	2	1.895	0.105	0.0554	0.0755	0.9398
	2004	171050	4	2	2.869	-0.869	-0.3029	-0.5431	0.5871
	2005	167260	4	3	3.706	-0.706	-0.1905	-0.3797	0.7042
	2006	297253	4	11	9.235	1.765	0.1911	0.5636	0.5730
Overall				100	114.314	-14.314	-0.1252	-1.0853	0.1389
Spring Chinook	1996	67496	5	0	0.005	-0.005	-1.0000	-0.1080	0.9140
	1998	161693	5	0	0.782	-0.782	-1.0000	-1.3264	0.1847
	1999	180085	5	4	5.175	-1.175	-0.2271	-0.5382	0.5905
	2000	131833	5	0	0.112	-0.112	-1.0000	-0.5009	0.6164
	2001	162255	5	0	2.598	-2.598	-1.0000	-2.4177	0.0156
	2002	303302	5	3	2.781	0.219	0.0787	0.1295	0.8969
	2003	304850	5	0	0.104	-0.104	-1.0000	-0.4848	0.6278
	2004	171050	5	2	0.255	1.745	6.8431	2.2342	0.0255
	2005	167260	5	0	0.410	-0.410	-1.0000	-0.9603	0.3369
	2006	297253	5	0	0.737	-0.737	-1.0000	-1.2881	0.1977
Overall				9	12.959	-3.959	-0.3055	-1.6575	0.0487

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1998	161693	6	0	0.029	-0.029	-1.0000	-0.254	0.7995
	1999	180085	6	0	0.195	-0.195	-1.0000	-0.6632	0.5072
	2000	131833	6	0	0.002	-0.002	-1.0000	-0.0635	0.9493
	2001	162255	6	1	0.302	0.698	2.3113	1.0059	0.3145
	2002	303302	6	0	0.106	-0.106	-1.0000	-0.4875	0.6259
	2003	304850	6	0	0.002	-0.002	-1.0000	-0.0692	0.9448
	2004	171050	6	0	0.008	-0.008	-1.0000	-0.1348	0.8927
	2005	167260	6	0	0.014	-0.014	-1.0000	-0.1802	0.8570
	2006	297253	6	0	0.021	-0.021	-1.0000	-0.2182	0.8276
Overall				1	0.679	0.321	0.4728	-0.4059	0.3244
Summer Chinook	1997	85020	0	85	75.847	9.153	0.1207	1.0314	0.3024
	1998	50261	0	54	31.877	22.123	0.6940	3.5673	0.0004
	1999	51172	0	133	101.151	31.849	0.3149	3.0236	0.0025
	2000	58479	0	248	225.371	22.629	0.1004	1.4861	0.1372
	2002	68484	0	74	67.255	6.745	0.1003	0.8098	0.4181
	2003	87654	0	85	65.664	19.336	0.2945	2.2831	0.0224
	2004	85167	0	8	3.240	4.760	1.4691	2.2323	0.0256
	2005	87190	0	7	3.430	3.570	1.0408	1.6914	0.0908
	2006	63540	0	85	37.206	17.794	0.2648	2.0857	0.0370
Overall				779	611.041	137.959	0.2258	5.8995	0.0000
Summer Chinook	1997	85020	1	96	93.867	2.133	0.0227	0.2195	0.8263
	1998	50261	1	68	68.999	-0.999	-0.0145	-0.1207	0.9039
	1999	51172	1	203	198.456	4.544	0.0229	0.3219	0.7475
	2000	58479	1	192	207.815	-15.815	-0.0761	-1.1134	0.2655
	2002	68484	1	135	132.286	2.714	0.0205	0.2354	0.8139
	2003	87654	1	74	88.811	-14.811	-0.1668	-1.6196	0.1053
	2004	85167	1	11	13.568	-2.568	-0.1893	-0.7213	0.4708
	2005	87190	1	14	12.956	1.044	0.0806	0.2863	0.7746
	2006	63540	1	70	83.385	-13.385	-0.1605	-1.5090	0.1313
Overall				863	900.143	-37.143	-0.0413	-1.3579	0.0872

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	2	25	38.029	-13.029	-0.3426	-2.2570	0.0240
	1998	50261	2	38	51.298	-13.298	-0.2592	-1.9487	0.0513
	1999	51172	2	134	153.188	-19.188	-0.1253	-1.5869	0.1125
	2000	58479	2	68	75.001	-7.001	-0.0933	-0.8221	0.4110
	2002	68484	2	100	98.261	1.739	0.0177	0.1750	0.8610
	2003	87654	2	33	47.079	-14.079	-0.2991	-2.1713	0.0299
	2004	85167	2	7	18.473	-11.473	-0.6211	-3.0712	0.0021
	2005	87190	2	17	16.884	0.116	0.0069	0.0281	0.9776
	2006	63540	2	33	41.938	-8.938	-0.2131	-1.4350	0.1513
Overall				455	540.151	-85.151	-0.1576	-4.3848	0.0000
Summer Chinook	1997	85020	3	7	5.877	1.123	0.1911	0.4495	0.6531
	1998	50261	3	10	15.65	-5.65	-0.3610	-1.5319	0.1255
	1999	51172	3	45	58.668	-13.668	-0.2330	-1.8630	0.0625
	2000	58479	3	17	13.228	3.772	0.2852	0.9933	0.3206
	2002	68484	3	23	35.39	-12.39	-0.3501	-2.2287	0.0258
	2003	87654	3	3	12.528	-9.528	-0.7605	-3.2622	0.0011
	2004	85167	3	7	9.753	-2.753	-0.2823	-0.9292	0.3528
	2005	87190	3	5	9.768	-4.768	-0.4881	-1.6884	0.0913
	2006	63540	3	8	10.908	-2.908	-0.2666	-0.9251	0.3549
Overall				125	171.77	-46.77	-0.2723	-3.6907	0.0001
Summer Chinook	1997	85020	4	1	0.373	0.627	1.6810	0.8518	0.3943
	1998	50261	4	0	2.079	-2.079	-1.0000	-2.1629	0.0306
	1999	51172	4	7	11.52	-4.52	-0.3924	-1.4390	0.1502
	2000	58479	4	3	1.149	1.851	1.6110	1.4412	0.1495
	2002	68484	4	3	6.577	-3.577	-0.5439	-1.5674	0.1170
	2003	87654	4	2	1.756	0.244	0.1390	0.1801	0.8571
	2004	85167	4	2	2.258	-0.258	-0.1143	-0.1750	0.8610
	2005	87190	4	3	2.551	0.449	0.1760	0.2732	0.7847
	2006	63540	4	3	1.543	1.457	0.9443	1.0395	0.2986
Overall				24	29.806	-5.806	-0.1948	-0.3493	0.3635

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	5	0	0.008	-0.008	-1.0000	-0.1336	0.8937
	1998	50261	5	0	0.1	-0.1	-1.0000	-0.4748	0.6349
	1999	51172	5	0	1.072	-1.072	-1.0000	-1.5532	0.1204
	2000	58479	5	0	0.042	-0.042	-1.0000	-0.3075	0.7585
	2002	68484	5	3	0.602	2.398	3.9834	2.2311	0.0257
	2003	87654	5	0	0.121	-0.121	-1.0000	-0.5220	0.6017
	2004	85167	5	0	0.235	-0.235	-1.0000	-0.7265	0.4676
	2005	87190	5	0	0.263	-0.263	-1.0000	-0.7696	0.4416
	2006	63540	5	0	0.112	-0.112	-1.0000	-0.5026	0.6152
Overall				3	2.555	0.445	0.1742	-0.8868	0.1876
Summer Chinook	1999	51172	6	0	0.037	-0.037	-1.0000	-0.2871	0.7741
	2000	58479	6	0	0	0	NaN	-0.0282	0.9775
	2002	68484	6	0	0.021	-0.021	-1.0000	-0.2195	0.8263
	2003	87654	6	0	0.003	-0.003	-1.0000	-0.0834	0.9335
	2004	85167	6	0	0.009	-0.009	-1.0000	-0.1418	0.8872
	2005	87190	6	0	0.009	-0.009	-1.0000	-0.1424	0.8868
	2006	63540	6	0	0.003	-0.003	-1.0000	-0.0859	0.9315
Overall				0	0.082	-0.082	-1.0000	-0.3657	0.3573
Steelhead	1996	28174	0	5	4.94	0.06	0.0121	0.0271	0.9784
	1997	33754	0	5	3.547	1.453	0.4096	0.7267	0.4674
	1998	30312	0	68	11.178	56.822	5.0834	11.7027	0.0000
	1999	38697	0	23	10.754	12.246	1.1387	3.2472	0.0012
	2000	36197	0	26	25.974	0.026	0.0010	0.0052	0.9959
	2002	30903	0	21	23.798	-2.798	-0.1176	-0.5856	0.5582
	2003	31863	0	26	15.896	10.104	0.6356	2.3224	0.0202
	2004	38475	0	1	0.664	0.336	0.5060	0.3830	0.7017
	2005	43008	0	2	0.797	1.203	1.5094	1.1334	0.2581
	2006	35737	0	26	21.112	4.888	0.2315	1.0268	0.3045
Overall				203	118.660	84.340	0.7108	6.1633	0.0000

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Steelhead	1996	28174	1	10	10.177	-0.177	-0.0174	-0.0556	0.9556
	1997	33754	1	11	9.415	1.585	0.1683	0.5032	0.6148
	1998	30312	1	14	32.98	-18.98	-0.5755	-3.7503	0.0002
	1999	38697	1	32	38.292	-6.292	-0.1643	-1.0473	0.295
	2000	36197	1	64	76.782	-12.782	-0.1665	-1.5041	0.1326
	2002	30903	1	60	52.745	7.255	0.1375	0.9783	0.3279
	2003	31863	1	22	30.005	-8.005	-0.2668	-1.5362	0.1245
	2004	38475	1	18	6.71	11.29	1.6826	3.6164	0.0003
	2005	43008	1	13	7.907	5.093	0.6441	1.6578	0.0974
	2006	35737	1	85	75.782	9.218	0.1216	1.0396	0.2985
Overall				329	340.795	-11.795	-0.0387	0.1450	0.5577
Steelhead	1996	28174	2	10	7.425	2.575	0.3468	0.8977	0.3693
	1997	33754	2	5	8.947	-3.947	-0.4412	-1.4427	0.1491
	1998	30312	2	11	35.754	-24.754	-0.6923	-4.8837	0.0000
	1999	38697	2	40	52.464	-12.464	-0.2376	-1.7985	0.0721
	2000	36197	2	64	79.862	-15.862	-0.1986	-1.8415	0.0656
	2002	30903	2	32	45.954	-13.954	-0.3037	-2.1812	0.0292
	2003	31863	2	23	22.671	0.329	0.0145	0.0689	0.945
	2004	38475	2	18	20.167	-2.167	-0.1075	-0.4918	0.6228
	2005	43008	2	14	21.583	-7.583	-0.3613	-1.7471	0.0806
	2006	35737	2	83	100.730	-17.730	-0.1760	-1.8253	0.0680
Overall				300	395.557	-95.557	-0.2416	-4.8268	0.0000

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Steelhead	1996	28174	3	0	2.224	-2.224	-1.0000	-2.2369	0.0253
	1997	33754	3	5	3.554	1.446	0.4069	0.7225	0.4700
	1998	30312	3	5	17.242	-12.242	-0.7100	-3.5005	0.0005
	1999	38697	3	27	35.228	-8.228	-0.2336	-1.4474	0.1478
	2000	36197	3	34	39.072	-5.072	-0.1298	-0.8305	0.4063
	2002	30903	3	17	20.19	-3.19	-0.1580	-0.7302	0.4653
	2003	31863	3	4	8.706	-4.706	-0.5405	-1.7907	0.0733
	2004	38475	3	13	17.768	-4.768	-0.2683	-1.1891	0.2344
	2005	43008	3	24	22.579	1.421	0.0629	0.2961	0.7672
	2006	35737	3	59	62.171	-31.171	-0.0510	-0.4060	0.6847
Overall				188	228.734	-68.734	-0.3005	-3.3802	0.0004
Steelhead	1996	28174	4	0	0.23	-0.23	-1.0000	-0.7187	0.4723
	1997	33754	4	0	0.515	-0.515	-1.0000	-1.0764	0.2817
	1998	30312	4	3	3.565	-0.565	-0.1585	-0.3076	0.7584
	1999	38697	4	14	12.313	1.687	0.1370	0.4705	0.638
	2000	36197	4	8	9.593	-1.593	-0.1661	-0.5299	0.5962
	2002	30903	4	7	4.701	2.299	0.4890	0.9887	0.3228
	2003	31863	4	1	1.774	-0.774	-0.4363	-0.6343	0.5259
	2004	38475	4	0	5.02	-5.02	-1.0000	-3.3611	0.0008
	2005	43008	4	9	8.883	0.117	0.0132	0.0391	0.9688
	2006	35737	4	22	18.329	3.671	0.2003	0.8312	0.4058
Overall				64	64.923	-0.923	-0.0142	-1.3810	0.0836

Table B.1. (contd)

Stock	Year	Release Size	Juvenile Detections	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	5	0	0.006	-0.006	-1.0000	-0.1182	0.9059
	1997	33754	5	0	0.024	-0.024	-1.0000	-0.2322	0.8164
	1998	30312	5	0	0.28	-0.28	-1.0000	-0.7936	0.4274
	1999	38697	5	2	2.138	-0.138	-0.0645	-0.0954	0.924
	2000	36197	5	3	1.118	1.882	1.6834	1.4768	0.1397
	2002	30903	5	0	0.544	-0.544	-1.0000	-1.1068	0.2684
	2003	31863	5	0	0.18	-0.18	-1.0000	-0.6361	0.5247
	2004	38475	5	0	0.555	-0.555	-1.0000	-1.1177	0.2637
	2005	43008	5	1	1.227	-0.227	-0.1850	-0.2122	0.8319
	2006	35737	5	4	2.267	1.733	0.7644	1.0393	0.2987
Overall				10	8.339	1.661	0.1992	-0.5318	0.2974
Steelhead	1998	30312	6	0	0.007	-0.007	-1.0000	-0.1243	0.9011
	1999	38697	6	0	0.144	-0.144	-1.0000	-0.5702	0.5686
	2000	36197	6	0	0.048	-0.048	-1.0000	-0.3289	0.7422
	2002	30903	6	0	0.024	-0.024	-1.0000	-0.2322	0.8164
	2003	31863	6	0	0.007	-0.007	-1.0000	-0.1262	0.8996
	2004	38475	6	0	0.021	-0.021	-1.0000	-0.2162	0.8288
	2005	43008	6	0	0.025	-0.025	-1.0000	-0.2370	0.8126
	2006	35737	6	0	0.065	-0.065	-1.0000	-0.3834	0.7014
Overall				0	0.341	-0.341	-1.0000	-0.7935	0.2137

Table B.2. Observed and Expected Number of Adults for Juvenile Detection Histories with Only One Detection. *P*-values for each year are from one-tailed tests of HA:*Z*<0. Values after individual years are from meta-analysis; *P*-value from meta-analysis are from one-tailed tests: HA:*T*<0. Absolute difference = Observed – Expected. Relative difference = (Observed/Expected – 1)*100%.

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	LGR	7	4.7024	2.2976	0.4886	0.9880	0.8384
	1997	115057	LGR	6	5.3617	0.6383	0.1190	0.2705	0.6066
	1998	161693	LGR	25	20.1041	4.8959	0.2435	1.0519	0.8536
	1999	180085	LGR	24	15.7549	8.2451	0.5233	1.9287	0.9731
	2000	131833	LGR	97	63.7759	33.2241	0.5209	3.8648	0.9999
	2001	162255	LGR	0	0.3030	-0.3030	-1.0000	-0.8257	0.2045
	2002	303302	LGR	48	35.5224	12.4776	0.3513	1.9870	0.9765
	2003	304850	LGR	22	15.8856	6.1144	0.3849	1.4495	0.9264
	2004	171050	LGR	9	7.5070	1.4930	0.1989	0.5283	0.7014
	2005	167260	LGR	4	3.6154	0.3846	0.1064	0.1988	0.5788
	2006	297253	LGR	35	24.2583	10.7417	0.4428	2.0454	0.9796
Overall				277	196.7907	80.2093	0.4076	4.1574	1.0000
Spring Chinook	1996	67496	LGS	6	5.608	0.392	0.0699	0.1636	0.565
	1997	115057	LGS	35	37.5598	-2.5598	-0.0682	-0.4226	0.3363
	1998	161693	LGS	38	53.8869	-15.8869	-0.2948	-2.2878	0.0111
	1999	180085	LGS	104	166.3074	-62.3074	-0.3747	-5.2003	0.0000
	2000	131833	LGS	41	59.906	-18.906	-0.3156	-2.5939	0.0047
	2001	162255	LGS	0	0.5249	-0.5249	-1.0000	-1.0867	0.1386
	2002	303302	LGS	58	66.4001	-8.4001	-0.1265	-1.0540	0.1459
	2003	304850	LGS	8	16.755	-8.755	-0.5225	-2.3892	0.0084
	2004	171050	LGS	13	16.2567	-3.2567	-0.2003	-0.8375	0.2012
	2005	167260	LGS	6	9.0329	-3.0329	-0.3358	-1.0762	0.1409
	2006	297253	LGS	61	74.9328	-13.9328	-0.1859	-1.6643	0.0480
Overall				370	507.1705	-137.171	-0.2705	-5.7107	0.0000

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	*P*
Spring Chinook	1996	67496	LMN	4	7.1507	-3.1507	-0.4406	-1.2880	0.0989
	1997	115057	LMN	31	36.7156	-5.7156	-0.1557	-0.9697	0.1661
	1998	161693	LMN	61	57.0180	3.9820	0.0698	0.5215	0.6990
	1999	180085	LMN	93	121.7832	-28.7832	-0.2363	-2.7244	0.0032
	2000	131833	LMN	18	22.3474	-4.3474	-0.1945	-0.9524	0.1704
	2001	162255	LMN	1	0.3500	0.6500	1.8570	0.8994	0.8158
	2002	303302	LMN	150	155.5237	-5.5237	-0.0355	-0.4457	0.3279
	2003	304850	LMN	3	6.5503	-3.5503	-0.5420	-1.5580	0.0596
	2004	171050	LMN	1	1.5788	-0.5788	-0.3666	-0.4947	0.3104
	2005	167260	LMN	1	1.8937	-0.8937	-0.4719	-0.7156	0.2371
	2006	297253	LMN	59	362.5381	-3.5381	-0.0566	-0.4518	0.3257
Overall				422	773.4495	-51.4495	-0.0665	-2.3975	0.0083
Spring Chinook	1996	67496	MCN	1	3.2822	-2.2822	-0.6953	-1.4871	0.0685
	1997	115057	MCN	11	10.3904	0.6096	0.0587	0.1873	0.5743
	1998	161693	MCN	30	18.2216	11.7784	0.6464	2.5249	0.9942
	1999	180085	MCN	82	98.6835	-16.6835	-0.1691	-1.7312	0.0417
	2000	131833	MCN	74	87.399	-13.399	-0.1533	-1.4731	0.0704
	2001	162255	MCN	2	0.6473	1.3527	2.0896	1.3532	0.912
	2002	303302	MCN	165	166.3745	-1.3745	-0.0083	-0.1067	0.4575
	2003	304850	MCN	41	66.3184	-25.3184	-0.3818	-3.3508	0.0004
	2004	171050	MCN	14	5.9191	8.0809	1.3652	2.8291	0.9977
	2005	167260	MCN	0	2.5053	-2.5053	-1.0000	-2.3742	0.0088
	2006	297253	MCN	55	58.9461	-3.9461	-0.0669	-0.5199	0.3016
Overall				475	518.6874	-43.6874	-0.0842	-1.4103	0.0792

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Spring Chinook	1998	161693	JD	9	16.8547	-7.8547	-0.4660	-2.1051	0.0176
	1999	180085	JD	39	45.3144	-6.3144	-0.1393	-0.9614	0.1682
	2000	131833	JD	9	9.8707	-0.8707	-0.0882	-0.2814	0.3892
	2001	162255	JD	0	0.0707	-0.0707	-1.0000	-0.3989	0.3450
	2002	303302	JD	45	42.9998	2.0002	0.0465	0.3027	0.6190
	2003	304850	JD	24	27.485	-3.485	-0.1268	-0.6797	0.2484
	2004	171050	JD	1	1.9195	-0.9195	-0.4790	-0.7327	0.2319
	2005	167260	JD	1	0.6507	0.3493	0.5369	0.4014	0.6559
	2006	297253	JD	28	31.2964	-3.2964	-0.1053	-0.6001	0.2742
Overall				156	176.4619	-20.4619	-0.1160	-1.5988	0.0549
Spring Chinook	1996	67496	BON	0	0.2747	-0.2747	-1.0000	-0.7862	0.2159
	1998	161693	BON	12	11.1188	0.8812	0.0793	0.2609	0.6029
	1999	180085	BON	45	36.6104	8.3896	0.2292	1.3385	0.9096
	2000	131833	BON	66	60.0976	5.9024	0.0982	0.7496	0.7733
	2001	162255	BON	0	0.0703	-0.0703	-1.0000	-0.3978	0.3454
	2002	303302	BON	42	33.4901	8.5099	0.2541	1.4144	0.9214
	2003	304850	BON	46	32.8759	13.1241	0.3992	2.1588	0.9846
	2004	171050	BON	0	0.8899	-0.8899	-1.0000	-1.4150	0.0785
	2005	167260	BON	0	0.3046	-0.3046	-1.0000	-0.8279	0.2039
	2006	297253	BON	16	9.8567	6.1533	0.6249	1.7988	0.9640
Overall				227	185.589	41.421	0.2232	1.8693	0.9692

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	LGR	5	7.5777	-2.5777	-0.3402	-0.9996	0.1587
	1998	50261	LGR	6	6.5692	-0.5692	-0.0866	-0.2254	0.4108
	1999	51172	LGR	28	8.3539	19.6461	2.3517	5.3752	1.0000
	2000	58479	LGR	62	48.3851	13.6149	0.2814	1.8762	0.9697
	2002	68484	LGR	8	7.3952	0.6048	0.0818	0.2195	0.5869
	2003	87654	LGR	13	11.1427	1.8573	0.1667	0.5420	0.7061
	2004	85167	LGR	9	4.3262	4.6738	1.0803	1.9645	0.9753
	2005	87190	LGR	2	2.7342	-0.7342	-0.2685	-0.4667	0.3203
	2006	63540	LGR	10	9.1858	0.8142	0.0886	0.2649	0.6044
Overall				143	105.670	37.330	0.3533	2.5658	0.9949
Summer Chinook	1997	85020	LGS	38	43.6379	-5.6379	-0.1292	-0.8732	0.1913
	1998	50261	LGS	21	25.2067	-4.2067	-0.1669	-0.8633	0.1940
	1999	51172	LGS	40	51.987	-11.987	-0.2306	-1.7348	0.0414
	2000	58479	LGS	23	35.4403	-12.4403	-0.3510	-2.2367	0.0127
	2002	68484	LGS	12	15.0354	-3.0354	-0.2019	-0.8119	0.2084
	2003	87654	LGS	3	11.1278	-8.1278	-0.7304	-2.9157	0.0018
	2004	85167	LGS	1	6.5805	-5.5805	-0.8480	-2.7522	0.0030
	2005	87190	LGS	5	6.1860	-1.1860	-0.1917	-0.4936	0.3108
	2006	63540	LGS	10	18.9380	-8.9380	-0.4720	-2.2634	0.0118
Overall				115	170.5017	-55.5017	-0.3255	-4.9826	0.0000
Summer Chinook	1997	85020	LMN	39	31.8345	7.1655	0.2251	1.2268	0.8901
	1998	50261	LMN	28	27.6757	0.3243	0.0117	0.0615	0.5245
	1999	51172	LMN	50	53.4463	-3.4463	-0.0645	-0.4769	0.3167
	2000	58479	LMN	9	16.6983	-7.6983	-0.4610	-2.0703	0.0192
	2002	68484	LMN	51	50.1686	0.8314	0.0166	0.1171	0.5466
	2003	87654	LMN	4	3.868	0.132	0.0341	0.0668	0.5266
	2004	85167	LMN	0	0.4816	-0.4816	-1.0000	-1.0409	0.1490
	2005	87190	LMN	1	1.4096	-0.4096	-0.2906	-0.3643	0.3578
	2006	63540	LMN	13	18.4884	-5.4884	-0.2969	-1.3499	0.0885
Overall				195	204.071	-9.071	-0.0445	-1.1756	0.1199

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	MCN	10	7.487	2.513	0.3356	0.8735	0.8088
	1998	50261	MCN	5	4.3077	0.6923	0.1607	0.3252	0.6275
	1999	51172	MCN	33	40.483	-7.483	-0.1848	-1.2161	0.112
	2000	58479	MCN	38	49.0168	-11.0168	-0.2248	-1.6399	0.0505
	2002	68484	MCN	34	33.1689	0.8311	0.0251	0.1437	0.5571
	2003	87654	MCN	23	29.9325	-6.9325	-0.2316	-1.3221	0.0931
	2004	85167	MCN	1	1.3166	-0.3166	-0.2405	-0.2884	0.3865
	2005	87190	MCN	6	2.0243	3.9757	1.9639	2.2695	0.9884
	2006	63540	MCN	19	19.1474	-0.1474	-0.0078	-0.0340	0.4864
Overall				169	186.8842	-17.8842	-0.0957	-0.1509	0.4400
Summer Chinook	1998	50261	JD	8	5.24	2.76	0.5267	1.1190	0.8684
	1999	51172	JD	10	13.4116	-3.4116	-0.2544	-0.9765	0.1644
	2000	58479	JD	1	2.6392	-1.6392	-0.6211	-1.1609	0.1229
	2002	68484	JD	10	9.1824	0.8176	0.0890	0.2660	0.6049
	2003	87654	JD	12	14.1749	-2.1749	-0.1534	-0.5936	0.2764
	2004	85167	JD	0	0.5277	-0.5277	-1.0000	-1.0897	0.1379
	2005	87190	JD	0	0.2587	-0.2587	-1.0000	-0.7629	0.2228
	2006	63540	JD	6	10.9641	-4.9641	-0.4528	-1.6439	0.0501
Overall				47	56.3986	-9.3986	-0.1667	-1.7694	0.0384
Summer Chinook	1997	85020	BON	4	3.3299	0.6701	0.2013	0.3559	0.6390
	1999	51172	BON	42	30.7746	11.2254	0.3648	1.9177	0.9724
	2000	58479	BON	59	55.6354	3.3646	0.0605	0.4469	0.6725
	2002	68484	BON	20	17.3358	2.6642	0.1537	0.6246	0.7339
	2003	87654	BON	19	18.5647	0.4353	0.0234	0.1007	0.5401
	2004	85167	BON	0	0.3352	-0.3352	-1.0000	-0.8684	0.1926
	2005	87190	BON	0	0.3430	-0.3430	-1.0000	-0.8786	0.1898
	2006	63540	BON	12	6.6601	5.3399	0.8018	1.8610	0.9686
Overall				156	132.9787	23.0213	0.1731	1.0381	0.8504

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Steelhead	1996	28174	LGR	6	3.7403	2.2597	0.6041	1.0744	0.8587
	1997	33754	LGR	4	2.5957	1.4043	0.5410	0.8076	0.7903
	1998	30312	LGR	5	11.1452	-6.1452	-0.5514	-2.0733	0.0191
	1999	38697	LGR	10	5.1275	4.8725	0.9503	1.9056	0.9716
	2000	36197	LGR	40	36.7128	3.2872	0.0895	0.5350	0.7037
	2002	30903	LGR	7	7.3125	-0.3125	-0.0427	-0.1164	0.4537
	2003	31863	LGR	4	4.9362	-0.9362	-0.1897	-0.4360	0.3314
	2004	38475	LGR	3	2.4492	0.5508	0.2249	0.3400	0.6331
	2005	43008	LGR	2	1.3401	0.6599	0.4924	0.5313	0.7024
	2006	35737	LGR	8	8.9602	-0.9602	-0.1072	-0.3268	0.3719
Overall				89	84.3197	4.6803	0.0555	0.7828	0.7831
Steelhead	1996	28174	LGS	1	2.7314	-1.7314	-0.6339	-1.2104	0.1131
	1997	33754	LGS	5	2.8187	2.1813	0.7739	1.172	0.8794
	1998	30312	LGS	3	7.8177	-4.8177	-0.6163	-1.9795	0.0239
	1999	38697	LGS	8	12.0893	-4.0893	-0.3383	-1.2551	0.1047
	2000	36197	LGS	7	10.634	-3.634	-0.3417	-1.1902	0.1170
	2002	30903	LGS	11	9.8362	1.1638	0.1183	0.3642	0.6421
	2003	31863	LGS	3	6.4383	-3.4383	-0.5340	-1.5186	0.0644
	2004	38475	LGS	12	3.4495	8.5505	2.4788	3.6105	0.9998
	2005	43008	LGS	10	5.0089	4.9911	0.9965	1.9658	0.9753
	2006	35737	LGS	37	28.4742	8.5258	0.2994	1.5277	0.9367
Overall				97	89.2982	7.7018	0.0862	0.6651	0.7470

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	LMN	2	2.891	-0.891	-0.3082	-0.5555	0.2893
	1997	33754	LMN	2	3.186	-1.186	-0.3723	-0.7145	0.2375
	1998	30312	LMN	1	9.6783	-8.6783	-0.8967	-3.6394	0.0001
	1999	38697	LMN	4	11.5511	-7.5511	-0.6537	-2.5844	0.0049
	2000	36197	LMN	8	13.6456	-5.6456	-0.4137	-1.6599	0.0485
	2002	30903	LMN	23	17.7656	5.2344	0.2946	1.1881	0.8826
	2003	31863	LMN	1	6.5877	-5.5877	-0.8482	-2.7546	0.0029
	2004	38475	LMN	2	0.5505	1.4495	2.6330	1.5173	0.9354
	2005	43008	LMN	0	1.0503	-1.0503	-1.0000	-1.5373	0.0621
	2006	35737	LMN	20	21.3384	-1.3384	-0.0627	-0.2929	0.3848
Overall				63	88.2445	-25.2445	-0.2861	-3.4655	0.0003
Steelhead	1996	28174	MCN	1	0.6084	0.3916	0.6436	0.4595	0.6771
	1997	33754	MCN	0	0.3516	-0.3516	-1.0000	-0.8895	0.1869
	1998	30312	MCN	1	0.5167	0.4833	0.9354	0.5963	0.7245
	1999	38697	MCN	3	2.144	0.856	0.3993	0.5514	0.7093
	2000	36197	MCN	3	4.6548	-1.6548	-0.3555	-0.8216	0.2056
	2002	30903	MCN	6	5.8029	0.1971	0.0340	0.0814	0.5324
	2003	31863	MCN	2	2.3274	-0.3274	-0.1407	-0.2200	0.4129
	2004	38475	MCN	0	0.1157	-0.1157	-1.0000	-0.5101	0.305
	2005	43008	MCN	0	0.2129	-0.2129	-1.0000	-0.6921	0.2444
	2006	35737	MCN	4	5.6242	-1.6242	-0.2888	-0.7230	0.2348
Overall				20	22.3586	-2.3586	-0.1055	-0.7393	0.2299

Table B.2. (contd)

Stock	Year	Release Size	Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Steelhead	1998	30312	JD	2	2.8607	-0.8607	-0.3009	-0.5386	0.2951
	1999	38697	JD	4	3.9699	0.0301	0.0076	0.0151	0.506
	2000	36197	JD	0	2.7248	-2.7248	-1.0000	-2.4761	0.0066
	2002	30903	JD	4	2.6234	1.3766	0.5247	0.7890	0.7849
	2003	31863	JD	2	1.8824	0.1176	0.0625	0.0848	0.5338
	2004	38475	JD	0	0.0559	-0.0559	-1.0000	-0.3548	0.3614
	2005	43008	JD	0	0.2756	-0.2756	-1.0000	-0.7875	0.2155
	2006	35737	JD	15	10.5360	4.4640	0.4237	1.2931	0.9020
Overall				27	24.9287	2.0713	0.0831	-0.7425	0.2289
Steelhead	1996	28174	BON	0	0.2058	-0.2058	-1.0000	-0.6805	0.2481
	1997	33754	BON	0	0.4626	-0.4626	-1.0000	-1.0203	0.1538
	1998	30312	BON	2	0.9616	1.0384	1.0800	0.9258	0.8227
	1999	38697	BON	3	3.4097	-0.4097	-0.1202	-0.2266	0.4104
	2000	36197	BON	6	8.4105	-2.4105	-0.2866	-0.8771	0.1902
	2002	30903	BON	9	9.404	-0.404	-0.0430	-0.1327	0.4472
	2003	31863	BON	10	7.8328	2.1672	0.2767	0.7425	0.7711
	2004	38475	BON	1	0.0894	0.9106	10.1795	1.7944	0.9636
	2005	43008	BON	1	0.0194	0.9806	50.4239	2.6834	0.9964
	2006	35737	BON	1	0.8493	0.1507	0.1774	0.1590	0.5632
Overall				33	31.6451	1.3549	0.0428	1.1810	0.8812

BON = Bonneville Dam; JD = John Day Dam; LGR = Lower Granite Dam; LGS = Little Goose Dam; LMN = Lower Monumental Dam; MCN = McNary Dam.

Table B.3. Observed and Expected Number of Adults for Juvenile Detection Histories with Detections at Exactly Two Dams (cf Figure 3.10, Figure 3.11, Figure 3.13). *P*-values for each year are from one-tailed tests of HA:*Z*<0. Values after individual years are from meta-analysis; *P*-value from meta-analysis are from one-tailed tests: HA:*T*<0. Absolute difference = Observed – Expected. Relative difference = (Observed/Expected – 1)*100%.

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	LGR	LGS	0	1.9592	-1.9592	-1.0000	-2.0996	0.0179
	1997	115057	LGR	LGS	3	2.9903	0.0097	0.0032	0.0056	0.5022
	1998	161693	LGR	LGS	5	11.5192	-6.5192	-0.5659	-2.1725	0.0149
	1999	180085	LGR	LGS	16	13.5815	2.4185	0.1781	0.6382	0.7383
	2000	131833	LGR	LGS	4	12.6975	-8.6975	-0.6850	-2.8705	0.0020
	2001	162255	LGR	LGS	0	0.7030	-0.7030	-1.0000	-1.2577	0.1043
	2002	303302	LGR	LGS	9	9.7414	-0.7414	-0.0761	-0.2407	0.4049
	2003	304850	LGR	LGS	1	1.9360	-0.9360	-0.4835	-0.7435	0.2286
	2004	171050	LGR	LGS	19	10.2347	8.7653	0.8564	2.4498	0.9929
	2005	167260	LGR	LGS	12	7.0530	4.9470	0.7014	1.6938	0.9549
	2006	297253	LGR	LGS	16	11.5244	4.4756	0.3884	1.2451	0.8935
Overall					85	83.9402	1.0598	0.0126	-0.5943	0.2762
Spring Chinook	1996	67496	LGR	LMN	2	2.4981	-0.4981	-0.1994	-0.3267	0.3720
	1997	115057	LGR	LMN	6	2.9231	3.0769	1.0526	1.5775	0.9427
	1998	161693	LGR	LMN	11	12.1886	-1.1886	-0.0975	-0.3462	0.3646
	1999	180085	LGR	LMN	4	9.9454	-5.9454	-0.5978	-2.1530	0.0157
	2000	131833	LGR	LMN	3	4.7367	-1.7367	-0.3666	-0.8569	0.1957
	2001	162255	LGR	LMN	0	0.4688	-0.4688	-1.0000	-1.0270	0.1522
	2002	303302	LGR	LMN	25	22.8164	2.1836	0.0957	0.4502	0.6737
	2003	304850	LGR	LMN	1	0.7569	0.2431	0.3212	0.2663	0.6050
	2004	171050	LGR	LMN	0	0.9939	-0.9939	-1.0000	-1.4955	0.0674
	2005	167260	LGR	LMN	0	1.4786	-1.4786	-1.0000	-1.8240	0.0341
	2006	297253	LGR	LMN	10	9.6182	0.3818	0.0397	0.1223	0.5487
Overall					62	68.4247	-6.4247	-0.0939	-1.5531	0.0602

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (z)	P
Spring Chinook	1996	67496	LGR	MCN	1	1.1467	-0.1467	-0.1279	-0.1401	0.4443
	1997	115057	LGR	MCN	0	0.8272	-0.8272	-1.0000	-1.3643	0.0862
	1998	161693	LGR	MCN	5	3.8952	1.1048	0.2836	0.5362	0.7041
	1999	180085	LGR	MCN	6	8.0590	-2.0590	-0.2555	-0.7603	0.2235
	2000	131833	LGR	MCN	16	18.5248	-2.5248	-0.1363	-0.6009	0.2740
	2001	162255	LGR	MCN	3	0.8670	2.1330	2.4602	1.7985	0.9640
	2002	303302	LGR	MCN	24	24.4083	-0.4083	-0.0167	-0.0829	0.4670
	2003	304850	LGR	MCN	6	7.6630	-1.6630	-0.2170	-0.6249	0.2660
	2004	171050	LGR	MCN	3	3.7265	-0.7265	-0.1949	-0.3898	0.3484
	2005	167260	LGR	MCN	4	1.9562	2.0438	1.0448	1.2819	0.9001
	2006	297253	LGR	MCN	11	9.0657	1.9343	0.2134	0.6215	0.7329
Overall					79	80.1396	-1.1396	-0.0142	0.1472	0.5585
Spring Chinook	1998	161693	LGR	JD	6	3.6030	2.3970	0.6653	1.1530	0.8755
	1999	180085	LGR	JD	5	3.7006	1.2994	0.3511	0.6411	0.7393
	2000	131833	LGR	JD	2	2.0922	-0.0922	-0.0440	-0.0642	0.4744
	2001	162255	LGR	JD	0	0.0947	-0.0947	-1.0000	-0.4617	0.3222
	2002	303302	LGR	JD	3	6.3084	-3.3084	-0.5244	-1.4721	0.0705
	2003	304850	LGR	JD	5	3.1758	1.8242	0.5744	0.9445	0.8276
	2004	171050	LGR	JD	0	1.2085	-1.2085	-1.0000	-1.6490	0.0496
	2005	167260	LGR	JD	0	0.5081	-0.5081	-1.0000	-1.0692	0.1425
	2006	297253	LGR	JD	7	4.8133	2.1867	0.4543	0.9334	0.8247
Overall					28	25.5046	2.4954	0.0978	-0.2722	0.3927

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	LGR	BON	0	0.0960	-0.0960	-1.0000	-0.4647	0.3211
	1998	161693	LGR	BON	7	2.3768	4.6232	1.9451	2.4389	0.9926
	1999	180085	LGR	BON	3	2.9898	0.0102	0.0034	0.0059	0.5024
	2000	131833	LGR	BON	13	12.7381	0.2619	0.0206	0.0731	0.5292
	2001	162255	LGR	BON	1	0.0942	0.9058	9.6169	1.7634	0.9611
	2002	303302	LGR	BON	6	4.9132	1.0868	0.2212	0.4738	0.6822
	2003	304850	LGR	BON	7	3.7987	3.2013	0.8427	1.4707	0.9293
	2004	171050	LGR	BON	1	0.5602	0.4398	0.7850	0.5294	0.7017
	2005	167260	LGR	BON	0	0.2379	-0.2379	-1.0000	-0.7316	0.2322
	2006	297253	LGR	BON	1	1.5144	-0.5144	-0.3397	-0.4462	0.3277
Overall					39	29.3193	9.6807	0.3302	1.6833	0.9538
Spring Chinook	1996	67496	LGS	LMN	3	2.9792	0.0208	0.0070	0.0120	0.5048
	1997	115057	LGS	LMN	13	20.4770	-7.4770	-0.3651	-1.7740	0.0380
	1998	161693	LGS	LMN	10	32.6702	-22.6702	-0.6939	-4.6800	0.0000
	1999	180085	LGS	LMN	52	104.9831	-52.9831	-0.5047	-5.7491	0.0000
	2000	131833	LGS	LMN	2	4.4493	-2.4493	-0.5505	-1.3074	0.0955
	2001	162255	LGS	LMN	1	0.8121	0.1879	0.2314	0.2012	0.5797
	2002	303302	LGS	LMN	46	42.6495	3.3505	0.0786	0.5066	0.6938
	2003	304850	LGS	LMN	0	0.7983	-0.7983	-1.0000	-1.3402	0.0901
	2004	171050	LGS	LMN	0	2.1524	-2.1524	-1.0000	-2.2007	0.0139
	2005	167260	LGS	LMN	2	3.6943	-1.6943	-0.4586	-0.9680	0.1665
	2006	297253	LGS	LMN	28	29.7102	-1.7102	-0.0576	-0.3169	0.3957
Overall					157	245.3756	-88.3756	-0.3602	-5.0512	0.0000

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	LGS	MCN	1	1.3675	-0.3675	-0.2687	-0.3303	0.3706
	1997	115057	LGS	MCN	6	5.7949	0.2051	0.0354	0.0847	0.5337
	1998	161693	LGS	MCN	9	10.4406	-1.4406	-0.1380	-0.4568	0.3239
	1999	180085	LGS	MCN	37	85.0700	-48.0700	-0.5651	-5.8941	0.0000
	2000	131833	LGS	MCN	7	17.4007	-10.4007	-0.5977	-2.8475	0.0022
	2001	162255	LGS	MCN	0	1.5019	-1.5019	-1.0000	-1.8383	0.0330
	2002	303302	LGS	MCN	27	45.6251	-18.6251	-0.4082	-2.9905	0.0014
	2003	304850	LGS	MCN	3	8.0823	-5.0823	-0.6288	-2.0619	0.0196
	2004	171050	LGS	MCN	5	8.0698	-3.0698	-0.3804	-1.1642	0.1222
	2005	167260	LGS	MCN	3	4.8873	-1.8873	-0.3862	-0.9210	0.1785
	2006	297253	LGS	MCN	12	28.0037	-16.0037	-0.5715	-3.4262	0.0003
Overall					110	216.2438	-106.2440	-0.4913	-6.9832	0.0000
Spring Chinook	1998	161693	LGS	JD	2	9.6574	-7.6574	-0.7929	-3.0298	0.0012
	1999	180085	LGS	JD	29	39.0632	-10.0632	-0.2576	-1.6888	0.0456
	2000	131833	LGS	JD	3	1.9652	1.0348	0.5266	0.6851	0.7534
	2001	162255	LGS	JD	0	0.1641	-0.1641	-1.0000	-0.6076	0.2717
	2002	303302	LGS	JD	13	11.7919	1.2081	0.1025	0.3461	0.6354
	2003	304850	LGS	JD	2	3.3496	-1.3496	-0.4029	-0.7987	0.2122
	2004	171050	LGS	JD	2	2.6170	-0.6170	-0.2358	-0.3982	0.3452
	2005	167260	LGS	JD	1	1.2693	-0.2693	-0.2122	-0.2484	0.4019
	2006	297253	LGS	JD	7	14.8681	-7.8681	-0.5292	-2.2835	0.0112
Overall					59	84.7458	-25.7457	-0.3038	-2.6935	0.0035

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	LGS	BON	0	0.1144	-0.1144	-1.0000	-0.5075	0.3059
	1998	161693	LGS	BON	7	6.3709	0.6291	0.0988	0.2453	0.5969
	1999	180085	LGS	BON	21	31.5600	-10.5600	-0.3346	-2.0042	0.0225
	2000	131833	LGS	BON	9	11.9651	-2.9651	-0.2478	-0.8972	0.1848
	2001	162255	LGS	BON	0	0.1632	-0.1632	-1.0000	-0.6059	0.2723
	2002	303302	LGS	BON	7	9.1840	-2.1840	-0.2378	-0.7528	0.2258
	2003	304850	LGS	BON	0	4.0066	-4.0066	-1.0000	-3.0025	0.0013
	2004	171050	LGS	BON	1	1.2132	-0.2132	-0.1757	-0.1997	0.4208
	2005	167260	LGS	BON	2	0.5943	1.4057	2.3655	1.4405	0.9251
	2006	297253	LGS	BON	4	4.6779	-0.6779	-0.1449	-0.3215	0.3739
Overall					51	69.8496	-18.8496	-0.2699	-2.2895	0.0110
Spring Chinook	1996	67496	LMN	MCN	3	1.7436	1.2564	0.7205	0.8633	0.8060
	1997	115057	LMN	MCN	4	5.6647	-1.6647	-0.2939	-0.7391	0.2299
	1998	161693	LMN	MCN	11	11.0472	-0.0472	-0.0043	-0.0142	0.4943
	1999	180085	LMN	MCN	40	62.2949	-22.2949	-0.3579	-3.0279	0.0012
	2000	131833	LMN	MCN	3	6.4912	-3.4912	-0.5378	-1.5372	0.0621
	2001	162255	LMN	MCN	1	1.0016	-0.0016	-0.0015	-0.0016	0.4994
	2002	303302	LMN	MCN	84	106.8640	-22.8640	-0.2140	-2.2996	0.0107
	2003	304850	LMN	MCN	2	3.1597	-1.1597	-0.3670	-0.7007	0.2417
	2004	171050	LMN	MCN	0	0.7837	-0.7837	-1.0000	-1.3279	0.0921
	2005	167260	LMN	MCN	2	1.0246	0.9754	0.9520	0.8531	0.8032
	2006	297253	LMN	MCN	9	23.3716	-14.3716	-0.6149	-3.4134	0.0003
Overall					159	223.4468	-64.4468	-0.2884	-3.8931	0.0000

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1998	161693	LMN	JD	4	10.2186	-6.2186	-0.6086	-2.2292	0.0129
	1999	180085	LMN	JD	13	28.6051	-15.6051	-0.5455	-3.2806	0.0005
	2000	131833	LMN	JD	0	0.7331	-0.7331	-1.0000	-1.2843	0.0995
	2001	162255	LMN	JD	0	0.1094	-0.1094	-1.0000	-0.4962	0.3099
	2002	303302	LMN	JD	22	27.6192	-5.6192	-0.2035	-1.1093	0.1337
	2003	304850	LMN	JD	0	1.3095	-1.3095	-1.0000	-1.7165	0.0430
	2004	171050	LMN	JD	0	0.2541	-0.2541	-1.0000	-0.7562	0.2248
	2005	167260	LMN	JD	0	0.2661	-0.2661	-1.0000	-0.7738	0.2195
	2006	297253	LMN	JD	13	12.4087	0.5913	0.0476	0.1665	0.5661
Overall					52	81.5238	-29.5238	-0.3622	-3.6848	0.0001
Spring Chinook	1996	67496	LMN	BON	1	0.1459	0.8541	5.8525	1.4943	0.9324
	1998	161693	LMN	BON	7	6.7410	0.2590	0.0384	0.0991	0.5395
	1999	180085	LMN	BON	26	23.1107	2.8893	0.1250	0.5892	0.7221
	2000	131833	LMN	BON	2	4.4635	-2.4635	-0.5519	-1.3134	0.0945
	2001	162255	LMN	BON	0	0.1088	-0.1088	-1.0000	-0.4948	0.3104
	2002	303302	LMN	BON	26	21.5111	4.4889	0.2087	0.9370	0.8256
	2003	304850	LMN	BON	1	1.5664	-0.5664	-0.3616	-0.4854	0.3137
	2004	171050	LMN	BON	0	0.1178	-0.1178	-1.0000	-0.5149	0.3033
	2005	167260	LMN	BON	0	0.1246	-0.1246	-1.0000	-0.5295	0.2982
	2006	297253	LMN	BON	0	3.9041	-3.9041	-1.0000	-2.9638	0.0015
Overall					63	61.7939	1.2061	0.0195	-1.2867	0.0991
Spring Chinook	1998	161693	MCN	JD	0	3.2656	-3.2656	-1.0000	-2.7107	0.0034
	1999	180085	MCN	JD	12	23.1793	-11.1793	-0.4823	-2.5657	0.0051
	2000	131833	MCN	JD	0	2.8671	-2.8671	-1.0000	-2.5399	0.0055
	2001	162255	MCN	JD	0	0.2024	-0.2024	-1.0000	-0.6748	0.2499
	2002	303302	MCN	JD	29	29.5462	-0.5462	-0.0185	-0.1008	0.4599
	2003	304850	MCN	JD	15	13.2583	1.7417	0.1314	0.4684	0.6803
	2004	171050	MCN	JD	1	0.9528	0.0472	0.0495	0.0479	0.5191
	2005	167260	MCN	JD	0	0.3521	-0.3521	-1.0000	-0.8900	0.1867
	2006	297253	MCN	JD	11	11.6960	-0.6960	-0.0595	-0.2056	0.4186
Overall					68	85.3198	-17.3198	-0.2030	-2.6448	0.0041

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1996	67496	MCN	BON	0	0.0670	-0.0670	-1.0000	-0.3882	0.3489
	1998	161693	MCN	BON	2	2.1543	-0.1543	-0.0716	-0.1064	0.4576
	1999	180085	MCN	BON	11	18.7271	-7.7271	-0.4126	-1.9385	0.0263
	2000	131833	MCN	BON	21	17.4564	3.5436	0.2030	0.8218	0.7944
	2001	162255	MCN	BON	0	0.2012	-0.2012	-1.0000	-0.6729	0.2505
	2002	303302	MCN	BON	13	23.0119	-10.0119	-0.4351	-2.2784	0.0114
	2003	304850	MCN	BON	12	15.8587	-3.8587	-0.2433	-1.0133	0.1555
	2004	171050	MCN	BON	0	0.4417	-0.4417	-1.0000	-0.9969	0.1594
	2005	167260	MCN	BON	0	0.1648	-0.1648	-1.0000	-0.6090	0.2713
	2006	297253	MCN	BON	5	3.6799	1.3201	0.3587	0.6525	0.7430
Overall					64	81.7630	-17.7630	-0.2173	-2.1921	0.0142
Spring Chinook	1998	161693	JD	BON	1	1.9927	-0.9927	-0.4982	-0.7803	0.2176
	1999	180085	JD	BON	4	8.5993	-4.5993	-0.5348	-1.7580	0.0394
	2000	131833	JD	BON	1	1.9715	-0.9715	-0.4928	-0.7666	0.2217
	2001	162255	JD	BON	0	0.0220	-0.0220	-1.0000	-0.2224	0.4120
	2002	303302	JD	BON	7	5.9475	1.0525	0.1770	0.4198	0.6627
	2003	304850	JD	BON	7	6.5725	0.4275	0.0650	0.1650	0.5655
	2004	171050	JD	BON	0	0.1432	-0.1432	-1.0000	-0.5677	0.2851
	2005	167260	JD	BON	0	0.0428	-0.0428	-1.0000	-0.3104	0.3781
	2006	297253	JD	BON	3	1.9538	1.0462	0.5355	0.6939	0.7561
Overall					23	27.2453	-4.2453	-0.1558	-0.4942	0.2135

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	LGR	LGS	4	4.3598	-0.3598	-0.0825	-0.1748	0.4306
	1998	50261	LGR	LGS	3	5.1946	-2.1946	-0.4225	-1.0479	0.1473
	1999	51172	LGR	LGS	4	4.2935	-0.2935	-0.0684	-0.1433	0.4430
	2000	58479	LGR	LGS	12	7.6087	4.3913	0.5771	1.4686	0.9290
	2002	68484	LGR	LGS	3	1.6533	1.3467	0.8146	0.9407	0.8266
	2003	87654	LGR	LGS	3	1.8883	1.1117	0.5887	0.7452	0.7719
	2004	85167	LGR	LGS	5	8.7861	-3.7861	-0.4309	-1.3929	0.0818
	2005	87190	LGR	LGS	9	4.9305	4.0695	0.8254	1.6441	0.9499
	2006	63540	LGR	LGS	2	2.5885	-0.5885	-0.2273	-0.3812	0.3515
Overall					45	41.3033	3.6967	0.0895	0.6096	0.7289
Summer Chinook	1997	85020	LGR	LMN	3	3.1805	-0.1805	-0.0568	-0.1022	0.4593
	1998	50261	LGR	LMN	8	5.7035	2.2965	0.4027	0.9066	0.8177
	1999	51172	LGR	LMN	1	4.4141	-3.4141	-0.7735	-1.9803	0.0238
	2000	58479	LGR	LMN	2	3.5850	-1.5850	-0.4421	-0.9154	0.1800
	2002	68484	LGR	LMN	9	5.5165	3.4835	0.6315	1.3595	0.9130
	2003	87654	LGR	LMN	0	0.6564	-0.6564	-1.0000	-1.2153	0.1121
	2004	85167	LGR	LMN	0	0.6430	-0.6430	-1.0000	-1.2028	0.1145
	2005	87190	LGR	LMN	1	1.1235	-0.1235	-0.1099	-0.1188	0.4527
	2006	63540	LGR	LMN	2	2.5270	-0.5270	-0.2086	-0.3443	0.3653
Overall					26	27.3495	-1.3495	-0.0493	-1.2189	0.1114
Summer Chinook	1997	85020	LGR	MCN	0	0.7480	-0.7480	-1.0000	-1.2973	0.0973
	1998	50261	LGR	MCN	1	0.8877	0.1123	0.1265	0.1168	0.5465
	1999	51172	LGR	MCN	3	3.3434	-0.3434	-0.1027	-0.1912	0.4242
	2000	58479	LGR	MCN	11	10.5234	0.4766	0.0453	0.1458	0.5580
	2002	68484	LGR	MCN	4	3.6472	0.3528	0.0967	0.1819	0.5722
	2003	87654	LGR	MCN	3	5.0793	-2.0793	-0.4094	-1.0008	0.1585
	2004	85167	LGR	MCN	0	1.7579	-1.7579	-1.0000	-1.9888	0.0234
	2005	87190	LGR	MCN	0	1.6135	-1.6135	-1.0000	-1.9053	0.0284
	2006	63540	LGR	MCN	3	2.6173	0.3827	0.1462	0.2312	0.5914
Overall					25	30.2177	-5.2177	-0.1727	-2.1220	0.0169

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1998	50261	LGR	JD	3	1.0799	1.9201	1.7781	1.5217	0.9360
	1999	51172	LGR	JD	1	1.1076	-0.1076	-0.0972	-0.1040	0.4586
	2000	58479	LGR	JD	0	0.5666	-0.5666	-1.0000	-1.1291	0.1294
	2002	68484	LGR	JD	0	1.0097	-1.0097	-1.0000	-1.5073	0.0659
	2003	87654	LGR	JD	3	2.4054	0.5946	0.2472	0.3691	0.6440
	2004	85167	LGR	JD	0	0.7046	-0.7046	-1.0000	-1.2591	0.1040
	2005	87190	LGR	JD	0	0.2062	-0.2062	-1.0000	-0.6811	0.2479
	2006	63540	LGR	JD	3	1.4986	1.5014	1.0019	1.0805	0.8600
Overall					10	8.5786	1.4241	0.1657	-0.7225	0.2350
Summer Chinook	1997	85020	LGR	BON	0	0.3327	-0.3327	-1.0000	-0.8652	0.1935
	1999	51172	LGR	BON	5	2.5416	2.4584	0.9672	1.3632	0.9136
	2000	58479	LGR	BON	11	11.9444	-0.9444	-0.0791	-0.2770	0.3909
	2002	68484	LGR	BON	3	1.9062	1.0938	0.5738	0.7311	0.7676
	2003	87654	LGR	BON	2	3.1503	-1.1503	-0.3651	-0.6958	0.2433
	2004	85167	LGR	BON	0	0.4475	-0.4475	-1.0000	-1.0035	0.1578
	2005	87190	LGR	BON	3	0.2734	2.7266	9.9721	3.0885	0.9990
	2006	63540	LGR	BON	1	0.9103	0.0897	0.0985	0.0925	0.5369
Overall					25	21.5064	3.4936	0.1624	0.8054	0.7897
Summer Chinook	1997	85020	LGS	LMN	13	18.3157	-5.3157	-0.2902	-1.3117	0.0948
	1998	50261	LGS	LMN	12	21.8847	-9.8847	-0.4517	-2.3166	0.0103
	1999	51172	LGS	LMN	22	27.4691	-5.4691	-0.1991	-1.0819	0.1397
	2000	58479	LGS	LMN	3	2.6259	0.3741	0.1425	0.2257	0.5893
	2002	68484	LGS	LMN	10	11.2156	-1.2156	-0.1084	-0.3699	0.3557
	2003	87654	LGS	LMN	1	0.6555	0.3445	0.5256	0.3950	0.6536
	2004	85167	LGS	LMN	0	0.9780	-0.9780	-1.0000	-1.4834	0.0690
	2005	87190	LGS	LMN	1	2.5419	-1.5419	-0.6066	-1.1075	0.1340
	2006	63540	LGS	LMN	3	5.2098	-2.2098	-0.4242	-1.0541	0.1459
Overall					65	90.8962	-25.8962	-0.2849	-2.6281	0.0043

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	LGS	MCN	1	4.3076	-3.3076	-0.7679	-1.9373	0.0264
	1998	50261	LGS	MCN	1	3.4063	-2.4063	-0.7064	-1.5456	0.0611
	1999	51172	LGS	MCN	17	20.8065	-3.8065	-0.1829	-0.8624	0.1942
	2000	58479	LGS	MCN	9	7.7080	1.2920	0.1676	0.4533	0.6748
	2002	68484	LGS	MCN	5	7.4152	-2.4152	-0.3257	-0.9438	0.1726
	2003	87654	LGS	MCN	2	5.0725	-3.0725	-0.6057	-1.5619	0.0592
	2004	85167	LGS	MCN	1	2.6739	-1.6739	-0.6260	-1.1796	0.1191
	2005	87190	LGS	MCN	1	3.6504	-2.6504	-0.7261	-1.6571	0.0488
	2006	63540	LGS	MCN	3	5.3959	-2.3959	-0.4440	-1.1285	0.1296
Overall					40	60.4363	-20.4363	-0.3382	-3.5388	0.0002
Summer Chinook	1998	50261	LGS	JD	4	4.1436	-0.1436	-0.0346	-0.0709	0.4717
	1999	51172	LGS	JD	6	6.8930	-0.8930	-0.1296	-0.3480	0.3639
	2000	58479	LGS	JD	0	0.4150	-0.4150	-1.0000	-0.9663	0.1669
	2002	68484	LGS	JD	1	2.0528	-1.0528	-0.5129	-0.8186	0.2065
	2003	87654	LGS	JD	0	2.4022	-2.4022	-1.0000	-2.3249	0.0100
	2004	85167	LGS	JD	0	1.0717	-1.0717	-1.0000	-1.5529	0.0602
	2005	87190	LGS	JD	1	0.4664	0.5336	1.1440	0.6789	0.7514
	2006	63540	LGS	JD	0	3.0896	-3.0896	-1.0000	-2.6366	0.0042
Overall					12	20.5343	-8.5343	-0.4156	-2.8915	0.0019
Summer Chinook	1997	85020	LGS	BON	3	1.9158	1.0842	0.5659	0.7235	0.7653
	1999	51172	LGS	BON	18	15.8168	2.1832	0.1380	0.5371	0.7044
	2000	58479	LGS	BON	5	8.7488	-3.7488	-0.4285	-1.3814	0.0836
	2002	68484	LGS	BON	1	3.8756	-2.8756	-0.7420	-1.7562	0.0395
	2003	87654	LGS	BON	3	3.1461	-0.1461	-0.0464	-0.0830	0.4669
	2004	85167	LGS	BON	0	0.6807	-0.6807	-1.0000	-1.2376	0.1079
	2005	87190	LGS	BON	1	0.6186	0.3814	0.6165	0.4452	0.6719
	2006	63540	LGS	BON	2	1.8767	0.1233	0.0657	0.0890	0.5355
Overall					33	36.6791	-3.6791	-0.1003	-0.9047	0.1828

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1997	85020	LMN	MCN	1	3.1425	-2.1425	-0.6818	-1.4197	0.0779
	1998	50261	LMN	MCN	4	3.7400	0.2600	0.0695	0.1330	0.5529
	1999	51172	LMN	MCN	12	21.3905	-9.3905	-0.4390	-2.2190	0.0132
	2000	58479	LMN	MCN	2	3.6318	-1.6318	-0.4493	-0.9381	0.1741
	2002	68484	LMN	MCN	30	24.7424	5.2576	0.2125	1.0229	0.8468
	2003	87654	LMN	MCN	0	1.7632	-1.7632	-1.0000	-1.9918	0.0232
	2004	85167	LMN	MCN	0	0.1957	-0.1957	-1.0000	-0.6635	0.2535
	2005	87190	LMN	MCN	0	0.8318	-0.8318	-1.0000	-1.3681	0.0856
	2006	63540	LMN	MCN	5	5.2678	-0.2678	-0.0508	-0.1177	0.4531
Overall					54	64.7057	-10.7057	-0.1655	-2.5839	0.0049
Summer Chinook	1998	50261	LMN	JD	2	4.5494	-2.5494	-0.5604	-1.3497	0.0886
	1999	51172	LMN	JD	9	7.0865	1.9135	0.2700	0.6899	0.7549
	2000	58479	LMN	JD	1	0.1955	0.8045	4.1140	1.3056	0.9042
	2002	68484	LMN	JD	4	6.8496	-2.8496	-0.4160	-1.1831	0.1184
	2003	87654	LMN	JD	0	0.8350	-0.8350	-1.0000	-1.3707	0.0852
	2004	85167	LMN	JD	0	0.0784	-0.0784	-1.0000	-0.4201	0.3372
	2005	87190	LMN	JD	0	0.1063	-0.1063	-1.0000	-0.4890	0.3124
	2006	63540	LMN	JD	2	3.0162	-1.0162	-0.3369	-0.6242	0.2663
Overall					18	22.7169	-4.7169	-0.2076	-1.3064	0.0957
Summer Chinook	1997	85020	LMN	BON	0	1.3976	-1.3976	-1.0000	-1.7733	0.0381
	1999	51172	LMN	BON	15	16.2608	-1.2608	-0.0775	-0.3169	0.3757
	2000	58479	LMN	BON	4	4.1222	-0.1222	-0.0296	-0.0605	0.4759
	2002	68484	LMN	BON	18	12.9317	5.0683	0.3919	1.3306	0.9083
	2003	87654	LMN	BON	0	1.0936	-1.0936	-1.0000	-1.5686	0.0584
	2004	85167	LMN	BON	0	0.0498	-0.0498	-1.0000	-0.3348	0.3689
	2005	87190	LMN	BON	0	0.1410	-0.1410	-1.0000	-0.5632	0.2867
	2006	63540	LMN	BON	0	1.8322	-1.8322	-1.0000	-2.0304	0.0212
Overall					37	37.8289	-0.8289	-0.0219	-1.9523	0.0255

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1998	50261	MCN	JD	0	0.7081	-0.7081	-1.0000	-1.2622	0.1034
	1999	51172	MCN	JD	5	5.3677	-0.3677	-0.0685	-0.1606	0.4362
	2000	58479	MCN	JD	1	0.5740	0.4260	0.7422	0.5090	0.6946
	2002	68484	MCN	JD	3	4.5286	-1.5286	-0.3375	-0.7664	0.2217
	2003	87654	MCN	JD	3	6.4615	-3.4615	-0.5357	-1.5268	0.0634
	2004	85167	MCN	JD	0	0.2144	-0.2144	-1.0000	-0.6946	0.2437
	2005	87190	MCN	JD	0	0.1526	-0.1526	-1.0000	-0.5860	0.2789
	2006	63540	MCN	JD	3	3.1240	-0.1240	-0.0397	-0.0706	0.4719
Overall					15	21.1309	-6.1309	-0.2901	-1.6722	0.0472
Summer Chinook	1997	85020	MCN	BON	0	0.3287	-0.3287	-1.0000	-0.8600	0.1949
	1999	51172	MCN	BON	14	12.3168	1.6832	0.1367	0.4694	0.6806
	2000	58479	MCN	BON	6	12.1003	-6.1003	-0.5041	-1.9492	0.0256
	2002	68484	MCN	BON	8	8.5498	-0.5498	-0.0643	-0.1901	0.4246
	2003	87654	MCN	BON	10	8.4626	1.5374	0.1817	0.5137	0.6963
	2004	85167	MCN	BON	1	0.1362	0.8638	6.3422	1.5376	0.9379
	2005	87190	MCN	BON	0	0.2024	-0.2024	-1.0000	-0.6749	0.2499
	2006	63540	MCN	BON	4	1.8976	2.1024	1.1079	1.3307	0.9084
Overall					43	43.9944	-0.9944	-0.0226	0.0931	0.5371
Summer Chinook	1999	51172	JD	BON	2	4.0804	-2.0804	-0.5099	-1.1464	0.1258
	2000	58479	JD	BON	1	0.6515	0.3485	0.5349	0.4003	0.6555
	2002	68484	JD	BON	1	2.3669	-1.3669	-0.5775	-1.0084	0.1566
	2003	87654	JD	BON	3	4.0076	-1.0076	-0.2514	-0.5272	0.2990
	2004	85167	JD	BON	0	0.0546	-0.0546	-1.0000	-0.3505	0.3630
	2005	87190	JD	BON	0	0.0259	-0.0259	-1.0000	-0.2412	0.4047
	2006	63540	JD	BON	0	1.0865	-1.0865	-1.0000	-1.5636	0.0590
Overall					7	12.2734	-5.2734	-0.4230	-1.6238	0.0522

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	LGR	LGS	3	2.0682	0.9318	0.4505	0.6070	0.7281
	1997	33754	LGR	LGS	0	2.0628	-2.0628	-1.0000	-2.1544	0.0156
	1998	30312	LGR	LGS	5	7.7947	-2.7947	-0.3585	-1.0731	0.1416
	1999	38697	LGR	LGS	3	5.7642	-2.7642	-0.4796	-1.2713	0.1018
	2000	36197	LGR	LGS	12	15.0308	-3.0308	-0.2016	-0.8108	0.2087
	2002	30903	LGR	LGS	0	3.0225	-3.0225	-1.0000	-2.6079	0.0046
	2003	31863	LGR	LGS	1	1.9993	-0.9993	-0.4998	-0.7845	0.2164
	2004	38475	LGR	LGS	9	12.7142	-3.7142	-0.2921	-1.1005	0.1356
	2005	43008	LGR	LGS	5	8.4191	-3.4191	-0.4061	-1.2773	0.1007
	2006	35737	LGR	LGS	11	12.0848	-1.0848	-0.0898	-0.3170	0.3756
Overall					49	70.9606	-21.9606	-0.3095	-3.4358	0.0003
Steelhead	1996	28174	LGR	LMN	3	2.1891	0.8109	0.3704	0.5189	0.6981
	1997	33754	LGR	LMN	2	2.3316	-0.3316	-0.1422	-0.2227	0.4119
	1998	30312	LGR	LMN	1	9.6499	-8.6499	-0.8964	-3.6320	0.0001
	1999	38697	LGR	LMN	2	5.5077	-3.5077	-0.6369	-1.7286	0.0419
	2000	36197	LGR	LMN	12	19.2875	-7.2875	-0.3778	-1.7870	0.0370
	2002	30903	LGR	LMN	2	5.4590	-3.4590	-0.6336	-1.7104	0.0436
	2003	31863	LGR	LMN	2	2.0457	-0.0457	-0.0223	-0.0321	0.4872
	2004	38475	LGR	LMN	0	2.0290	-2.0290	-1.0000	-2.1367	0.0163
	2005	43008	LGR	LMN	5	1.7653	3.2347	1.8323	1.9967	0.9771
	2006	35737	LGR	LMN	6	9.0563	-3.0563	-0.3375	-1.0836	0.1393
Overall					35	59.3211	-24.3211	-0.4100	-3.0254	0.0012

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	LGR	MCN	2	0.4607	1.5393	3.3414	1.6913	0.9546
	1997	33754	LGR	MCN	1	0.2573	0.7427	2.8859	1.1199	0.8686
	1998	30312	LGR	MCN	0	0.5152	-0.5152	-1.0000	-1.0766	0.1408
	1999	38697	LGR	MCN	1	1.0223	-0.0223	-0.0218	-0.0221	0.4912
	2000	36197	LGR	MCN	1	6.5794	-5.5794	-0.8480	-2.7519	0.0030
	2002	30903	LGR	MCN	0	1.7831	-1.7831	-1.0000	-2.0030	0.0226
	2003	31863	LGR	MCN	0	0.7227	-0.7227	-1.0000	-1.2752	0.1011
	2004	38475	LGR	MCN	0	0.4263	-0.4263	-1.0000	-0.9794	0.1637
	2005	43008	LGR	MCN	0	0.3579	-0.3579	-1.0000	-0.8973	0.1848
	2006	35737	LGR	MCN	0	2.3870	-2.3870	-1.0000	-2.3175	0.0102
Overall					5	14.5119	-9.5119	-0.6555	-2.7527	0.0030
Steelhead	1998	30312	LGR	JD	0	2.8523	-2.8523	-1.0000	-2.5334	0.0056
	1999	38697	LGR	JD	1	1.8929	-0.8929	-0.4717	-0.7151	0.2373
	2000	36197	LGR	JD	4	3.8513	0.1487	0.0386	0.0753	0.5300
	2002	30903	LGR	JD	0	0.8061	-0.8061	-1.0000	-1.3468	0.0890
	2003	31863	LGR	JD	0	0.5845	-0.5845	-1.0000	-1.1468	0.1257
	2004	38475	LGR	JD	0	0.2062	-0.2062	-1.0000	-0.6811	0.2479
	2005	43008	LGR	JD	1	0.4633	0.5367	1.1584	0.6842	0.7531
	2006	35737	LGR	JD	4	4.4716	-0.4716	-0.1055	-0.2272	0.4102
Overall					10	15.1282	-5.1282	-0.3390	-1.9540	0.0253
Steelhead	1996	28174	LGR	BON	0	0.1558	-0.1558	-1.0000	-0.5922	0.2769
	1997	33754	LGR	BON	0	0.3386	-0.3386	-1.0000	-0.8728	0.1914
	1998	30312	LGR	BON	2	0.9587	1.0413	1.0861	0.9292	0.8236
	1999	38697	LGR	BON	2	1.6258	0.3742	0.2302	0.2833	0.6115
	2000	36197	LGR	BON	9	11.8880	-2.8880	-0.2429	-0.8759	0.1905
	2002	30903	LGR	BON	6	2.8897	3.1103	1.0764	1.6003	0.9452
	2003	31863	LGR	BON	1	2.4323	-1.4323	-0.5889	-1.0460	0.1478
	2004	38475	LGR	BON	0	0.3297	-0.3297	-1.0000	-0.8613	0.1945
	2005	43008	LGR	BON	0	0.0327	-0.0327	-1.0000	-0.2712	0.3931
	2006	35737	LGR	BON	0	0.3605	-0.3605	-1.0000	-0.9006	0.1839
Overall					20	21.0118	-1.0118	-0.0482	-0.8616	0.1935

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	LGS	LMN	0	1.5986	-1.5986	-1.0000	-1.8966	0.0289
	1997	33754	LGS	LMN	1	2.5319	-1.5319	-0.6050	-1.1020	0.1352
	1998	30312	LGS	LMN	2	6.7688	-4.7688	-0.7045	-2.1715	0.0149
	1999	38697	LGS	LMN	8	12.9856	-4.9856	-0.3839	-1.4920	0.0679
	2000	36197	LGS	LMN	5	5.5867	-0.5867	-0.1050	-0.2528	0.4002
	2002	30903	LGS	LMN	4	7.3430	-3.3430	-0.4553	-1.3537	0.0879
	2003	31863	LGS	LMN	3	2.6682	0.3318	0.1244	0.1992	0.5789
	2004	38475	LGS	LMN	0	2.8578	-2.8578	-1.0000	-2.5358	0.0056
	2005	43008	LGS	LMN	3	6.5982	-3.5982	-0.5453	-1.5749	0.0576
	2006	35737	LGS	LMN	31	28.7797	2.2203	0.0771	0.4089	0.6587
Overall					57	77.7185	-20.7185	-0.2666	-3.7164	0.0001
Steelhead	1996	28174	LGS	MCN	0	0.3364	-0.3364	-1.0000	-0.8700	0.1921
	1997	33754	LGS	MCN	0	0.2794	-0.2794	-1.0000	-0.7929	0.2139
	1998	30312	LGS	MCN	0	0.3614	-0.3614	-1.0000	-0.9017	0.1836
	1999	38697	LGS	MCN	2	2.4102	-0.4102	-0.1702	-0.2724	0.3927
	2000	36197	LGS	MCN	3	1.9057	1.0943	0.5742	0.7315	0.7678
	2002	30903	LGS	MCN	1	2.3985	-1.3985	-0.5831	-1.0266	0.1523
	2003	31863	LGS	MCN	1	0.9427	0.0573	0.0608	0.0585	0.5233
	2004	38475	LGS	MCN	3	0.6004	2.3996	3.9967	2.2348	0.9873
	2005	43008	LGS	MCN	0	1.3376	-1.3376	-1.0000	-1.7348	0.0414
	2006	35737	LGS	MCN	4	7.5855	-3.5855	-0.4727	-1.4349	0.0757
Overall					14	18.1578	-4.1578	-0.2290	-1.2320	0.1090

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1998	30312	LGS	JD	1	2.0007	-1.0007	-0.5002	-0.7854	0.2161
	1999	38697	LGS	JD	4	4.4629	-0.4629	-0.1037	-0.2231	0.4117
	2000	36197	LGS	JD	3	1.1156	1.8844	1.6892	1.4795	0.9305
	2002	30903	LGS	JD	0	1.0843	-1.0843	-1.0000	-1.5620	0.0591
	2003	31863	LGS	JD	0	0.7624	-0.7624	-1.0000	-1.3098	0.0951
	2004	38475	LGS	JD	3	0.2904	2.7096	9.3319	3.0260	0.9988
	2005	43008	LGS	JD	0	1.7317	-1.7317	-1.0000	-1.9739	0.0242
	2006	35737	LGS	JD	16	14.2102	1.7898	0.1260	0.4654	0.6792
Overall					27	25.6582	1.3418	0.0523	-0.2534	0.4000
Steelhead	1996	28174	LGS	BON	1	0.1138	0.8862	7.7866	1.6487	0.9504
	1997	33754	LGS	BON	0	0.3677	-0.3677	-1.0000	-0.9095	0.1815
	1998	30312	LGS	BON	0	0.6725	-0.6725	-1.0000	-1.2301	0.1093
	1999	38697	LGS	BON	5	3.8332	1.1668	0.3044	0.5692	0.7154
	2000	36197	LGS	BON	4	3.4434	0.5566	0.1616	0.2924	0.6150
	2002	30903	LGS	BON	2	3.8870	-1.8870	-0.4855	-1.0584	0.1449
	2003	31863	LGS	BON	7	3.1725	3.8275	1.2065	1.8566	0.9683
	2004	38475	LGS	BON	1	0.4644	0.5356	1.1535	0.6824	0.7525
	2005	43008	LGS	BON	0	0.1222	-0.1222	-1.0000	-0.5243	0.3000
	2006	35737	LGS	BON	2	1.1455	0.8545	0.7459	0.7224	0.7650
Overall					22	17.2222	4.7778	0.2774	0.6282	0.7351
Steelhead	1996	28174	LMN	MCN	1	0.3561	0.6439	1.8084	0.8866	0.8124
	1997	33754	LMN	MCN	0	0.3159	-0.3159	-1.0000	-0.8430	0.1996
	1998	30312	LMN	MCN	0	0.4474	-0.4474	-1.0000	-1.0033	0.1579
	1999	38697	LMN	MCN	1	2.3030	-1.3030	-0.5658	-0.9710	0.1658
	2000	36197	LMN	MCN	2	2.4454	-0.4454	-0.1822	-0.2943	0.3843
	2002	30903	LMN	MCN	5	4.3321	0.6679	0.1542	0.3132	0.6229
	2003	31863	LMN	MCN	0	0.9645	-0.9645	-1.0000	-1.4732	0.0704
	2004	38475	LMN	MCN	0	0.0958	-0.0958	-1.0000	-0.4643	0.3212
	2005	43008	LMN	MCN	0	0.2805	-0.2805	-1.0000	-0.7944	0.2135
	2006	35737	LMN	MCN	2	5.6845	-3.6845	-0.6482	-1.7941	0.0364
Overall					11	17.2252	-6.2252	-0.3614	-2.0888	0.0184

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1998	30312	LMN	JD	0	2.4769	-2.4769	-1.0000	-2.3608	0.0091
	1999	38697	LMN	JD	6	4.2642	1.7358	0.4071	0.7920	0.7858
	2000	36197	LMN	JD	3	1.4315	1.5685	1.0957	1.1444	0.8738
	2002	30903	LMN	JD	0	1.9585	-1.9585	-1.0000	-2.0992	0.0179
	2003	31863	LMN	JD	1	0.7801	0.2199	0.2819	0.2385	0.5943
	2004	38475	LMN	JD	1	0.0463	0.9537	20.5803	2.1800	0.9854
	2005	43008	LMN	JD	0	0.3631	-0.3631	-1.0000	-0.9039	0.1830
	2006	35737	LMN	JD	6	10.6490	-4.6490	-0.4366	-1.5559	0.0599
Overall					17	21.9696	-4.9696	-0.2262	-0.7826	0.2169
Steelhead	1996	28174	LMN	BON	0	0.1205	-0.1205	-1.0000	-0.5206	0.3013
	1997	33754	LMN	BON	0	0.4156	-0.4156	-1.0000	-0.9670	0.1668
	1998	30312	LMN	BON	0	0.8325	-0.8325	-1.0000	-1.3687	0.0856
	1999	38697	LMN	BON	2	3.6626	-1.6626	-0.4539	-0.9529	0.1703
	2000	36197	LMN	BON	6	4.4186	1.5814	0.3579	0.7134	0.7622
	2002	30903	LMN	BON	10	7.0204	2.9796	0.4244	1.0572	0.8548
	2003	31863	LMN	BON	4	3.2461	0.7539	0.2322	0.4037	0.6568
	2004	38475	LMN	BON	0	0.0741	-0.0741	-1.0000	-0.4083	0.3415
	2005	43008	LMN	BON	0	0.0256	-0.0256	-1.0000	-0.2401	0.4051
	2006	35737	LMN	BON	1	0.8584	0.1416	0.1649	0.1489	0.5592
Overall					23	20.6744	2.3256	0.1125	-0.6770	0.2492
Steelhead	1998	30312	MCN	JD	0	0.1322	-0.1322	-1.0000	-0.5455	0.2927
	1999	38697	MCN	JD	0	0.7915	-0.7915	-1.0000	-1.3345	0.0910
	2000	36197	MCN	JD	0	0.4883	-0.4883	-1.0000	-1.0482	0.1473
	2002	30903	MCN	JD	0	0.6397	-0.6397	-1.0000	-1.1997	0.1151
	2003	31863	MCN	JD	0	0.2756	-0.2756	-1.0000	-0.7875	0.2155
	2004	38475	MCN	JD	0	0.0097	-0.0097	-1.0000	-0.1480	0.4412
	2005	43008	MCN	JD	0	0.0736	-0.0736	-1.0000	-0.4070	0.3420
	2006	35737	MCN	JD	0	2.8068	-2.8068	-1.0000	-2.5131	0.0060
Overall					0	5.2174	-5.2174	-1.0000	-2.8030	0.0026

Table B.3. (contd)

Stock	Year	Release Size	First Dam	Second Dam	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Steelhead	1996	28174	MCN	BON	0	0.0254	-0.0254	-1.0000	-0.2388	0.4056
	1997	33754	MCN	BON	1	0.0459	0.9541	20.8024	2.1859	0.9856
	1998	30312	MCN	BON	0	0.0444	-0.0444	-1.0000	-0.3162	0.3759
	1999	38697	MCN	BON	0	0.6798	-0.6798	-1.0000	-1.2368	0.1081
	2000	36197	MCN	BON	0	1.5073	-1.5073	-1.0000	-1.8416	0.0328
	2002	30903	MCN	BON	2	2.2931	-0.2931	-0.1278	-0.1980	0.4215
	2003	31863	MCN	BON	0	1.1468	-1.1468	-1.0000	-1.6064	0.0541
	2004	38475	MCN	BON	1	0.0156	0.9844	63.2298	2.8146	0.9976
	2005	43008	MCN	BON	0	0.0052	-0.0052	-1.0000	-0.1081	0.4570
	2006	35737	MCN	BON	0	0.2263	-0.2263	-1.0000	-0.7135	0.2378
Overall					4	5.9898	-1.9898	-0.3322	-0.3632	0.3582
Steelhead	1998	30312	JD	BON	0	0.2461	-0.2461	-1.0000	-0.7441	0.2284
	1999	38697	JD	BON	3	1.2587	1.7413	1.3833	1.3199	0.9066
	2000	36197	JD	BON	0	0.8823	-0.8823	-1.0000	-1.4090	0.0794
	2002	30903	JD	BON	0	1.0367	-1.0367	-1.0000	-1.5273	0.0633
	2003	31863	JD	BON	3	0.9276	2.0724	2.2342	1.7149	0.9568
	2004	38475	JD	BON	0	0.0075	-0.0075	-1.0000	-0.1302	0.4482
	2005	43008	JD	BON	0	0.0067	-0.0067	-1.0000	-0.1230	0.4512
	2006	35737	JD	BON	0	0.4239	-0.4239	-1.0000	-0.9766	0.1644
Overall					6	4.7895	1.2105	0.2527	-0.6292	0.2646

BON = Bonneville Dam; JD = John Day Dam; LGR = Lower Granite Dam; LGS= Little Goose Dam; LMN = Lower Monumental Dam; MCN = McNary Dam.

Table B.4. Observed and Expected Number of Adults for Juvenile Detection Histories with Transportation from Little Goose Dam, with or Without Previous Detection (cf Figure 3.12). *P*-values for each year are from one-tailed tests of HA:*Z*<0. Values after individual years are from meta-analysis; *P*-value from meta-analysis are from one-tailed tests: HA:*T*<0.

Stock	Year	Release Size	Previous Detection	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Spring Chinook	1998	161693	NA	49	49.4332	-0.4332	-0.0088	-0.0617	0.4754
	1999	180085	NA	253	245.0262	7.9738	0.0325	0.507	0.6939
	2000	131833	NA	179	170.7536	8.2464	0.0483	0.6265	0.7345
	2001	162255	NA	49	19.2233	29.7767	1.5490	5.6959	1.0000
	2002	303302	NA	129	108.7616	20.2384	0.1861	1.8853	0.9703
	2003	304850	NA	106	90.1665	15.8335	0.1756	1.6224	0.9476
	2004	171050	NA	63	37.8296	25.1704	0.6654	3.7369	0.9999
	2005	167260	NA	35	20.8480	14.1520	0.6788	2.8257	0.9976
	2006	297253	NA	154	145.7711	8.2289	0.0565	0.6755	0.7503
Overall				1017	887.8131	129.1869	0.1455	5.6278	1.0000
Spring Chinook	1998	161693	LGR	11	10.5672	0.4328	0.041	0.1323	0.5526
	1999	180085	LGR	18	20.0101	-2.0101	-0.1005	-0.4573	0.3237
	2000	131833	LGR	40	36.1924	3.8076	0.1052	0.6224	0.7332
	2001	162255	LGR	0	25.7466	-25.7466	-1.0000	-7.6115	0.0000
	2002	303302	LGR	2	15.9561	-13.9561	-0.8747	-4.4912	0.0000
	2003	304850	LGR	1	10.4186	-9.4186	-0.904	-3.8267	0.0001
	2004	171050	LGR	0	23.8164	-23.8164	-1.0000	-7.3206	0.0000
	2005	167260	LGR	0	16.2784	-16.2784	-1.0000	-6.0521	0.0000
	2006	297253	LGR	9	22.4192	-13.4182	-0.5986	-3.2374	0.0006
Overall				81	181.4050	-100.4040	-0.5535	-10.8208	0.0000
Summer Chinook	1999	51172	NA	174	176.0293	-2.0293	-0.0115	-0.1535	0.4390
	2005	87190	NA	22	14.9153	7.0847	0.4750	1.7136	0.9567
	2006	63540	NA	73	65.0411	7.9589	0.1224	0.9683	0.8335
Overall				269	255.9857	13.0143	0.0508	1.5920	0.9443

Table B.4. (contd)

Stock	Year	Release Size	Previous Detection	Adults Observed	Adults Expected	Absolute Difference	Relative Difference	Residual (*z*)	*P*
Summer Chinook	1999	51172	LGR	12	14.538	-2.538	-0.1746	-0.6868	0.2461
	2005	87190	LGR	0	11.8880	-11.8880	-1.0000	-5.1721	0.0000
	2006	63540	LGR	5	8.8899	-3.8899	-0.4376	-1.4251	0.0771
Overall				17	35.3159	-18.3159	-0.5186	-4.5440	0.0000

LGR = Lower Granite Dam; NA = not applicable.

Appendix C

Summary of Bypass Route Passage

Appendix C

Summary of Bypass Route Passage

Table C.1. Bypass Routes Taken by Hatchery Spring Chinook Salmon from the Snake River Basin, 1996–2006

			Facility Bypass			Sample Room		Other						
Dam	Year	Primary	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Granite	1996		12,973			221		981	5				174	14,354
	1997		4,019			249		13,807	9				488	18,572
	1998		15,227			641		36,537	8				641	53,054
	1999		8,748			295		19,770	17				373	29,203
	2000		12,261	704		302		24,080					375	37,722
	2001		38,416	654		1,112		40,561	4				257	81,004
	2002		25,859	3,827		594		12,139	1				94	42,514
	2003		15,437	184		497		48,149	30				109	64,406
	2004		28,456	1		520		33,624	260				101	62,962
	2005		30,088	2		504		38,195	28				75	68,892
	2006		23,434	6,822		402		23,824	17	313			41	54,853
Little Goose	1996		9,372			116		314					214	10,016
	1997		14,463			206		498					23	15,190
	1998		25,678			265		8,284					141	34,368
	1999		40,595			410		11,752					284	53,041
	2000		8,158			214		12,284					69	20,725
	2001		37,410			883		9,007					435	47,735
	2002		38,259	6		454		12,325					162	51,206
	2003		11,979	15		1,869		21,809					193	35,865
	2004		33,899	41		291		16,266					118	50,615
	2005		32,762	31		311		13,514					132	46,750
	2006		40,471	25		303		25,146		422			146	66,513

Table C.1. (contd)

			Facility Bypass			Sample Room		Other						
Dam	Year	Primary	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Monumental	1996				9,862	63		426					100	10,451
	1997				11,294	49		346					14	11,703
	1998				21,078	168		1,297					9	22,552
	1999				33,095	1,666		1,337					158	36,256
	2000				3,149	703		4,663					33	8,548
	2001				26,078	854		1,481					91	28,504
	2002				67,257	260		3,286					10	70,813
	2003				4,310	259		3,466					5	8,040
	2004				5,785	161		1,451					15	7,412
	2005				12,379	123		1,680					13	14,195
	2006				30,498	167		11,536		587			9	42,797
Ice Harbor	2005	1,294							2					1,296
	2006	13,422							5					13,427
McNary	1996		3,910			39		4					741	4,694
	1997		3,723			6		4					191	3,924
	1998		7,258			847		155					6,366	14,626
	1999		22,795			63		41					1,090	23,989
	2000		8,400	88		161		21					61	8,731
	2001		10,440	10,479		247		225					15	21,406
	2002		55,051	8		634		1,997					8	57,864
	2003	15,577	13,681	15		165		720					206	30,364
	2004	6,568	6,857	2		322		299		199			16	14,263
	2005	6,670	6,754	207		71		128		124			17	13,971
	2006	12,492	12,945	4		406				302			30	26,179

Table C.1. (contd)

Dam	Year	Primary	Facility Bypass: Direct	Facility Bypass: SbyC or Holding Tank	Facility Bypass: Direct or SbyC	Sample Room: Sample	Sample Room: Sample or SbyC	Other: Raceway	Other: Adult Fish Ladder	Other: Adult Fish Return	Other: Flat Plate	Other: Corner Collector	Other: Unknown	Total
John Day	1996													
	1997													
	1998					75							5,303	5,378
	1999		39			372							11,988	12,399
	2000		1,013	204		39	380							1,636
	2001		5,353			33	175							5,561
	2002		20,968	3		77	954						8	22,010
	2003		13,850			12	234						8	14,104
	2004		4,629	4		20	240						2	4,895
	2005		3,920			11	187			2			3	4,123
	2006		13,571			3	117			10			2	13,703
Bonneville	1996					15					441			456
	1997													
	1998					2,275					1,560			3,835
	1999		6,304								3,645			9,949
	2000		3,689	296							1,963		59	5,896
	2001		4,008	519		52					14		2	4,595
	2002		12,959	8,483		175					1,824		20	23,461
	2003		13,050	122		130					1,016		25	14,343
	2004		2,168	2		447							2	2,619
	2005		2,473			448								2,921
	2006		4,219	3,398		362						324	4	8,307

SbyC = sort-by-code.

Table C.2. Bypass Routes Taken by Hatchery Summer Chinook Salmon from the Snake River Basin, 1996–2006

			Facility Bypass			Sample Room		Other						
Dam	Year	Primary	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Granite	1996													
	1997		2,722			141		10,360	19				441	13,683
	1998		4,343			127		9,171	4				203	13,848
	1999		2,100			79		4,977	2				113	7,271
	2000		4,667	217		135		8,662					154	13,835
	2002		3,315	231		139		4,217					25	7,927
	2003		5,388	81		95		9,379	5				27	14,975
	2004		13,955			201		19,032	221				47	33,456
	2005		12,854			234		20,079	9				50	33,226
	2006		3,518	41		48		6,874	2	55			4	10,542
Little Goose	1996													
	1997		9,122			165		382					16	9,685
	1998		7,931			72		1,064					28	9,095
	1999		6,787			94		5,367					105	12,353
	2000		2,806			115		3,194					29	6,144
	2002		5,115	1		68		4,146					33	9,363
	2003		4,239	7		417		4,560					33	9,256
	2004		12,896	24		99		4,624					41	17,684
	2005		13,093	12		132		6,447					59	19,743
	2006		4,301	4		46		5,899		64			24	10,338

Table C.2. (contd)

			Facility Bypass			Sample Room		Other						
Dam	Year	Primary	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Monumental	1996													
	1997				6,461	27		173					8	6,669
	1998				6,630	53		373					5	7,061
	1999				6,434	288		178					19	6,919
	2000				1,214	229		876					8	2,327
	2002				11,623	13		297					1	11,934
	2003				1,367	67		1,050						2,484
	2004				2,414	68		307					8	2,797
	2005				5,197	68		814					5	6,084
	2006				3,298	36		2,889		68			2	6,293
Ice Harbor	2005	513							1					514
	2006	1,692												1,692
McNary	1996													
	1997		2,120			11		4					165	2,300
	1998		1,522			111		31					1,311	2,975
	1999		4,791			7		3					122	4,923
	2000		3,153	95		61		18					76	3,403
	2002		7,110	2		79		246					24	7,461
	2003	4,082	3,517			43		191		1			153	7,987
	2004	1,926	2,051			97		105		34			2	4,215
	2005	2,978	3,013	17		31		63		47			9	6,158
	2006	1,596	1,690	1		44				25			2	3,358

Table C.2. (contd)

Dam	Year	Primary	Facility Bypass: Direct	Facility Bypass: SbyC or Holding Tank	Facility Bypass: Direct or SbyC	Sample Room: Sample	Sample Room: Sample or SbyC	Other: Raceway	Other: Adult Fish Ladder	Other: Adult Fish Return	Other: Flat Plate	Other: Corner Collector	Unknown	Total
John Day	1998					28							1,755	1,783
	1999					64							2,135	2,199
	2000		222	64		2	72							360
	2002		2,770	3		4	131						2	2,910
	2003		4,047			1	62						3	4,113
	2004		1,680	2		9	98							1,789
	2005		1,047	73		5	68							1,193
	2006		1,679				20			2			1	1,702
Bonneville	1997					316					503			819
	1998													
	1999		1,891								837			2,728
	2000		1,903	108							763		31	2,805
	2002		3,259	247		30					406		6	3,948
	2003		4,359	66		28					380		11	4,844
	2004		841			170							1	1,012
	2005		1,137	13		208							1	1,359
	2006		1,133	3		57						54		1,247

SbyC = sort-by-code.

Table C.3. Bypass Routes Taken by Hatchery Steelhead from the Snake River Basin, 1996–2006

			Facility Bypass			Sample Room		Other						
Dam	**Year**	**Primary**	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Granite	1996		8,734			180		502					14	9,430
	1997		11,024			289		1,156					31	12,500
	1998		11,924			177		564					38	12,703
	1999		9,024			156		706					33	9,919
	2000		15,326	59		160		308					56	15,909
	2002		5,148	17		86		65					3	5,319
	2003		4,977	1		79		2,066	41				5	7,169
	2004		21,731			156		348	377				27	22,639
	2005		18,742			246		3,873	51				18	22,930
	2006		7,731	77		81		1,743		24			9	9,665
Little Goose	1996		4,401			82		276					422	5,181
	1997		8,886			124		451					33	9,494
	1998		7,420			96		648					15	8,179
	1999		13,211			172		292					5	13,680
	2000		5,169			93		106					13	5,381
	2002		5,714	1		51		58					3	5,827
	2003		5,225	3		72		1,510					26	6,836
	2004		20,011	29		128		248					56	20,472
	2005		22,301	11		159		1,708					44	24,223
	2006		12,719	5		66		2,495		33			19	15,337

Table C.3. (contd)

			Facility Bypass			Sample Room		Other						
Dam	Year	Primary	Direct	SbyC or Holding Tank	Direct or SbyC	Sample	Sample or SbyC	Raceway	Adult Fish Ladder	Adult Fish Return	Flat Plate	Corner Collector	Unknown	Total
Lower Monumental	1996				4,796	36		196					49	5,077
	1997				8,124	44		362					19	8,549
	1998				6,898	83		457					6	7,444
	1999				11,290	493		315					26	12,124
	2000				4,839	200		183					7	5,229
	2002				8,061	21		160						8,242
	2003				4,607	50		890					1	5,548
	2004				9,369	206		239					16	9,830
	2005				12,110	108		903					5	13,126
	2006				9,167	52		1,271		158			1	10,649
Ice Harbor	2005	1,381							10					1,391
	2006	3,484							5					3,489
McNary	1996		1,106			16		9					318	1,449
	1997		1,296			4		5					112	1,417
	1998		528			46		24					1,048	1,646
	1999		2,797			3		5					149	2,954
	2000		1,459	144		32		22					179	1,836
	2002		1,938	3		36		33					11	2,021
	2003	771	599	6		6		24					31	1,437
	2004	764	665	14		53		23		57			1	1,577
	2005	1,761	1,498	13		3		63		93			7	3,438
	2006	1,556	1,415			49				93			5	3,118

Table C.3. (contd)

Dam	Year	Primary	Facility Bypass: Direct	Facility Bypass: SbyC or Holding Tank	Facility Bypass: Direct or SbyC	Sample Room: Sample	Sample Room: Sample or SbyC	Other: Raceway	Other: Adult Fish Ladder	Other: Adult Fish Return	Other: Flat Plate	Other: Corner Collector	Other: Unknown	Total
John Day	1998					21							2,563	2,584
	1999					63							4,655	4,718
	2000		660			5	170							835
	2002		951			1	41							993
	2003		1,110				15						1	1,126
	2004		741			7	41							789
	2005		2,485			11	116			17			1	2,630
	2006		4,451				59			18			1	4,529
Bonneville	1996					18					341			359
	1997					265					865			1,130
	1998					788					760			1,548
	1999		1,698								1,109			2,807
	2000		656	6							735		15	1,412
	2002		1,693	11		27					124		2	1,857
	2003		2,233	67		18					157		6	2,481
	2004		230			37								267
	2005		228			51								279
	2006		332	2		15						89		438

SbyC = sort-by-code.

Appendix D

Dependencies in Route Selection

Appendix D

Dependencies in Route Selection

The release-recapture model underlying the bypass effects analysis and all models used to estimate survival from passive integrated transponder (PIT)-tag data uses the assumption that detection is independent across detection sites. For PIT-tagged salmonids in the Federal Columbia River Power System (FCRPS), this means that fish that are detected in the bypass system at one dam are no more or less likely to be detected at the next dam than other fish. If, on the other hand, there is dependence in route selection at multiple dams, with some fish more likely to consistently pass dams via the bypass system and other fish more likely to consistently pass dams over the spillway, then this assumption will be violated.

In response to concern that some PIT-tagged fish are more likely to be bypassed than other fish because of fish condition or other reasons, we explored whether there is evidence of dependence in route selection using Juvenile Salmon Acoustic Telemetry System (JSATS) data for juvenile spring Chinook salmon and steelhead migrating past John Day and Bonneville dams in 2008. The routes analyzed included the spillway and powerhouse, with the powerhouse routes further subdivided into juvenile bypass system (JBS), turbines, and B2CC (at Bonneville). We computed contingency tables representing the number of fish observed to take each combination of routes at John Day and Bonneville, and performed chi-square tests of independence across the routes. A significant result (α=0.05) would suggest that fish differentially select routes upon encountering a dam, thus violating the assumption of independent route selection.

D.1 Spring Chinook Salmon Released at Lower Granite

Detections of Lower Granite spring Chinook salmon from the Bonneville spillway were not available, so only detections from the powerhouse routes available at both dams (JBS, turbine) are shown. No evidence of dependence in route selection between these two routes was found (*P*=0.9027; Table D.1).

Table D.1. Contingency Table of Detections of Spring Chinook Salmon (released at Lower Granite Dam in 2008) in the Juvenile Bypass System and Turbines at John Day and Bonneville Dams, 2008. Numbers in parentheses are the expected counts under independence of route selection. $P\left(\chi_1^2 \geq 0.0149\right) = 0.9027$.

		Bonneville		
		JBS	Turbine	Total
John Day	JBS	6 (6.7)	28 (27.3)	34
	Turbine	6 (5.3)	21 (21.7)	27
	Total	12	49	61

D.2 Spring Chinook Salmon Released at Arlington

Detections of spring Chinook salmon released at Arlington were available from both the spillway and powerhouse at both John Day and Bonneville dams. When the JBS and turbine were analyzed separately and detections from the Bonneville corner collector omitted, there was very slight evidence of dependency in route selection at the two dams (*P*=0.1076; Table D.2). When all powerhouse routes were considered (including the B2CC), there was stronger evidence of dependency in route selection (*P*=0.0040; Table D.3).

However, for all routes, we observed fewer fish using common routes at the two dams than expected under the assumption that fish select routes independently. For example, at John Day and Bonneville, 18 fish were expected to use the JBS to pass both dams. However, we observed only 15 fish using the JBS at both dams (Table D.2). With all powerhouse routes pooled (i.e., JBS, turbines, and B2CC; Table D.3), we observed 110 fish using powerhouse routes at both dams, but we would expect approximately 134 fish using powerhouse routes at both dams if fish selected routes independently. With fewer than expected juvenile Chinook salmon using a common route at both dams, there is no evidence that some Chinook salmon are inherently more likely than others to use the bypass systems at all dams encountered.

Table D.2. Contingency Table of Detections of Spring Chinook Salmon (released at Arlington in 2008) in the Spillway, Juvenile Bypass System, and Turbines at John Day and Bonneville Dams, 2008. Numbers in parentheses are the expected counts under the assumption of independent route selection. $P\left(\chi_4^2 \geq 7.5950\right) = 0.1076$.

		Bonneville			Total
		Spillway	JBS	Turbine	
John Day	Spillway	831 (848.0)	91 (86.9)	152 (139.2)	1,074
	JBS	186 (175.3)	15 (18.0)	21 (28.8)	222
	Turbine	86 (79.7)	7 (8.2)	8 (13.1)	101
	Total	1,103	113	181	1,397

Table D.3. Contingency Table of Detections of Spring Chinook Salmon (released at Arlington in 2008) in the Spillway and Powerhouse (including B2CC) at John Day and Bonneville Dams, 2008. Numbers in parentheses are the expected counts under the assumption of independent route selection. $P\left(\chi_1^2 \geq 8.2882\right) = 0.0040$.

		Bonneville		Total
		Spillway	Powerhouse	
John Day	Spillway	831 (855.1)	487 (462.9)	1,318
	Powerhouse	272 (247.9)	110 (134.1)	382
	Total	1,103	597	1,700

D.3 Steelhead Released at Arlington

Steelhead were detected in both the spillway and powerhouse routes at both John Day and Bonneville dams in 2008 (Table D.4). Because of insufficient detections in the turbines at John Day, the counts from the powerhouse routes were pooled, with counts from the B2CC included in the Bonneville powerhouse count (Table D.5). A significant dependency in route selection was found between the spillway and powerhouse routes at John Day and Bonneville (*P*=0.0021; Table D.5). However, as was the case for spring Chinook salmon, we observed fewer than expected steelhead using a common route at both John Day and Bonneville if fish select routes independently at the two dams. For example, we observed 130 steelhead passing both dams through the powerhouse routes, but expected approximately 157 steelhead to use the powerhouse routes under the assumption of independence (Table D.5). Thus, there is no evidence that some steelhead are more likely than others to use a particular type of passage route at all dams.

Table D.4. Contingency Table of Detections of Steelhead (released at Arlington in 2008) in the Spillway, Juvenile Bypass System, and Turbines at John Day and Bonneville Dams, 2008. Numbers in parentheses are the expected counts under independence of route selection.

		Bonneville			
		Spillway	JBS	Turbine	Total
John Day	Spillway	768 (770.6)	58 (53.1)	67 (69.3)	893
	JBS	255 (251.1)	12 (17.3)	24 (22.6)	291
	Turbine	22 (23.3)	2 (1.6)	3 (2.1)	27
	Total	1,045	72	94	1,211

Table D.5. Contingency Table of Detections of Steelhead (released at Arlington in 2008) in the Spillway and Powerhouse (including B2CC) at John Day and Bonneville Dams, 2008. Numbers in parentheses are the expected counts under independence of route selection. $P\left(\chi_1^2 \geq 9.4448\right) = 0.0021$.

		Bonneville		
		Spillway	Powerhouse	Total
John Day	Spillway	768 (794.8)	525 (498.2)	1,293
	Powerhouse	277 (250.2)	130 (156.8)	407
	Total	1,045	655	1,700

Appendix E

Juvenile Fish Bypass Improvements

Appendix E

Juvenile Fish Bypass Improvements

Table E.1. Juvenile Fish Passage Improvements Made at Lower Granite Dam

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
Pre-1994	Configured for "sort-by-code" (SbyC) at separator exit.	System installed to support National Marine Fisheries Service (NMFS) system survival study; used by other parties for additional studies.	PTOC 2010; Dave Hurson, USACE Retired (Personal Communication)	x				
1994	Part of the passive integrated transponder (PIT)-tag deflector system was rebuilt to install a permanent holding tank and a mid-river outfall pipe.	Provide improved outfall release conditions for diverted test fish.	Hurson et al. 1996; Dave Hurson (Personal Communication)			?	x	
	A mid-river facility bypass pipe was installed alongside the PIT-tag outfall pipe.	Improve release conditions for bypassed fish when not transporting or for tagged fish released for research purposes.	Hurson et al. 1996; Dave Hurson (Personal Communication)			?	X	
	A new dewatering system was installed in the barge direct loading line.		Hurson et al. 1996					x
1995	NMFS installed a prototype SbyC system on the PIT-tag diversion system between the PIT-tag head tank and the PIT-tag holding tank.		Baxter et al. 1994	x		x		
	Two PIT-tag detectors for mortalities were installed, one for each set of race ways (but later removed)		Baxter et al. 1995	x				
	A roof was constructed over the PIT-tag holding tank.	Improve holding conditions for subyearling Chinook during summer transport operations.	Baxter et al. 1996; Dave Hurson (Personal Communication)			x		

Table E.1. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
	Prototype extended-length submersible bar screens (ESBSs) and new vertical barrier screens (VBSs) (traveling screens in A and C slots and a bar Screen in B slot) were installed in unit 4 on 4/06/95 for research.	Test ESBSs for improving fish guidance efficiency (FGE).	Baxter et al. 1996; Dave Hurson (Personal Communication)			x	x	x
	Installed 2-way and 3-way fish diversion gates (part of SbyC system) in September to allow PIT-tagged fish to be diverted during periods of 100% sampling.	Allowed individual PIT-tagged juveniles to be sampled or examined as part of SbyC system	Baxter et al. 1995; Ham et al. 2009; Dave Hurson (Personal Communication)	x		X	X	
	Closure screens were installed at the bottom of the fish screen slots.	Prevent fish from entering the slots	Baxter et al. 1996					
	A loading line was constructed from the sample room to the mini-tanker.	To replace the process of having to haul fish in buckets	Baxter et al. 1996			x		
1996	Prior to the 1996 juvenile fish season, new ESBSs and VBSs were installed in all six units.	Reduce fish stress and injury in JBS	Ham et al. 2009; USACE 2007; Spurgeon et al. 1997			x	x	x
	SbyC experimental sub-site; Lower Granite Dam-Experimental (GRX; 02/27/96 to 09/01/99); SbyC improvements.	Decrease stress.	PTOC 2010	x				
	An additional water line with spray bar was added to the direct barge load line dewater.		Spurgeon et al. 1997					x
1997	A new tail screen for the separator was fabricated and installed.		Hetherman et al. 1998			x	x	x
2000	ISO installation complete (01/03/00).		PTOC 2010	x				
	The barge-loading pipe was retrofitted with a new extension (Winter 1999–2000).		John Bailey (USACE, Personal Communication)					x
	A new water-supply pipe was installed at the base of the separator (Winter 1999–2000).		John Bailey (USACE, Personal Communication)			x	x	x

Table E.1. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
2001	Installed a new PIT-tag headbox		John Bailey (USACE, Personal Communication)					
	Installed a new dewatering system in the truck-loading flume		John Bailey (USACE, Personal Communication)					x
2004	Installed new 72-in. and 42-in. valve controllers on the separator		Mike Halter (Lower Granite Dam [LGR] project Biologist, Personal Communication)			x	x	x
2005	NMFS installed a new raceway fish-tagging facility.	Improve ability to tag large numbers of fish for research	Ham et al. 2009			x		
2006	Added Adult Fish Return to site: tag detection to the separator adult fish release chute.		PTOC 2010; Mike Halter (LGR project Biologist, Personal Communication)	x				
2007	Added new East Raceway-10, Bypass River Exit, and Raceway-10 Diversion.		PTOC 2010	x				
	Added a new slide gate system to the flume/pipe that supplies water to the upstream raceways and bypass outfall pipe (Winter 2006–2007).		John Bailey (USACE, Personal Communication)				x	x
	Replaced frost-damaged polyvinyl chloride (PVC) pipes to eliminate low spots	Allow for late season PIT-tag monitoring off the separator	Mike Halter (LGR project Biologist, Personal Communication)	x		x	x	x

Table E.1. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
2008	Rerouted barge-loading hoses to eliminate extra hose and allow for easier direct loading of fish.		Mike Halter (LGR project Biologist, Personal Communication)					x

References:

Baxter R, D Hurson, T Wik, M Halter, D Ross, P Verhey, T Goffredo, J Bailey, T Hillson, J Kamps, W Spurgeon, P Wagner, M Price, S Lind, P Hoffarth, R Tudor, S Caromile, and C Hampton. 1996. *Juvenile Fish Transportation Program: 1995 Annual Report*. U.S. Army Corps of Engineers, Walla Walla, Washington.

Ham KD, JP Duncan, CII Arimescu, MA Chamness, MA Simmons, and A Solcz. 2009. *Synthesis of Biological Research on Juvenile Fish Passage and Survival 1990-2006: Lower Granite Dam*. PNWD-4059, final report prepared by Battelle, Pacific Northwest Division for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Hurson D, M Halter, P Verhey, T Goffredo, D Ross, C Morrill, R Baxter, J Bailey, T Hillson, G Christofferson, W Spurgeon, P Wagner, M Price, B Eby, C. Hampton, S. Richards, P. Hoffarth. 1996. *Juvenile Fish Transportation Program: 1994 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

PTOC (PIT Tag Operation Center). 2010. "PIT Tag Interrogation Site Configuration History" Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

Spurgeon W, D Hurson, T Wik, M Halter, D Ross, P Verhey, R Baxter, M Jensen, J Kamps, P Wagner, M Price, S Lind, M Plummer, B Eby, P Hoffarth, R Tudor, and S Caromile. 1997. *Juvenile Fish Transportation Program: 1996 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

USACE (U.S. Army Corps of Engineers). 2007. "Structural and operational changes at FCRPS dams to improve fish survival." U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, Oregon. 26 pp. Available from: http://www.salmonrecovery.gov/Biological_Opinions/FCRPS/biop_remand_2004/Docs/2007/Overhaul_of_the_System_final_draft%20.pdf

Table E.2. Juvenile Fish Passage Improvements Made at Little Goose Dam

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
1990	Combined separator monitors into separator gates (04/01/90)		PTOC 2010	x		
	The Pacific States Marine Fisheries Commission (PSMFC) installed new electronic controls for the slide gates in the passive integrated transponder (PIT)-tag diversion system.		Hurson et al. 1996	x		
1994	The three (75-gallon) fish recovery tanks (also referred to as bypass/control tanks) in the wet lab were outfitted with larger exits and a deeper exit trough with more slope.	Fish would more readily exit tanks while being less likely to jump out of troughs.	Hurson et al. 1996			
	All 4-in. flush lines for the various flumes were re-oriented.	Decease the chance that water from flush lines would affect fish passing down flumes.	Hurson et al. 1996		x	x
	Flexible hoses were installed in the PIT-tag diversion holding tank, connecting the fish entrance valves to the fish exit valves.	This was done so that fish could be bypassed through the tank to the river as they were collected.	Hurson et al. 1996			
	A new release pipe was installed in the PIT-tag diversion system, connecting the holding tank to the facility bypass line downstream of the truck- and barge-loading dewatering structure.		Hurson et al. 1996			x
	New prototype extended-length submersible bar screens (ESBSs) in turbine units 4 and 5 were evaluated (4/24/94 to 6/02/94); possibly new vertical barrier screens (VBSs) for test slots, also.	Prototype testing of longer screens for increasing fish guidance efficiency (FGE).	Hurson et al. 1996; Dave Hurson (Personal Communication)		x	x
1995	A PIT-tag detector for mortalities was installed. For various reasons, the detector was used only briefly. In the future the detector will be used for all mortalities.	PSMFC ended up removing these to use as spare parts for other detectors.	Baxter et al. 1995; Dave Hurson (Personal Communication)	x		
	Smooth, downward sloping jumper screens were installed at the upstream ends of all raceways.	Jumping fish can now slide back into the raceways, rather than getting stranded on flat screens.	Baxter et al. 1996			

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
	A new dewatering screen was installed on the fish sample line that enters the wet lab.	The new bar screen prevents smaller salmonids (<50 mm) from falling through and passing through a drain to the river.	Baxter et al. 1996			
	A 4-in. pipe and hose were installed for loading fish from the wet lab to the mini-tanker.		Baxter et al. 1996			
	In mid-April, prototype ESBSs were installed in turbine intakes 4A and 4B and an extended-length submerged traveling screen was installed in 4C.	Increase FGE and reduce turbine entrainment of juvenile fish.	Baxter et al. 1996		x	x
1996	Sprinklers were installed at the flume/bypass pipe outfall.	To discourage predation by gulls	Spurgeon et al. 1997		x	x
	New modified balanced flow VBSs were installed (March 26 to May 9) in all intakes to accommodate new ESBSs. Operation of new ESBSs was delayed to 1997 due to installation problems	New VBSs with porosity control behind screen were installed to accommodate and balance increased flows up the gatewell from ESBSs. .	Spurgeon et al. 1997; Dave Hurson (Personal Communication)		x	x
	A jumper screen was installed at the upstream end of raceway 1.		Spurgeon et al. 1997			
	The 6-in. pipe for bypassing PIT-tagged fish was extended beyond an aluminum box, designed for direct barge loading and reconnected to the 10-in. bypass pipe.	This was done to allow for simultaneous barge loading and bypassing of fish.	Spurgeon et al. 1997			x
	The National Marine Fisheries Service (NMFS) installed removable perforated plates in both PIT-tag head tanks to reduce the volume of water available to fish.	Encourage fish to exit to the river more readily.	Spurgeon et al. 1997			x
	NMFS also installed two prototype diversion-by-code gates in the PIT-tag holding tank. The A-side was outfitted with a horizontally sliding gate and the B-side with a rotating gate.		Spurgeon et al. 1997			
	An air flush system for removing impinged debris was installed under the downstream third of the primary dewatering screen.		Spurgeon et al. 1997			x
	A floating indicator rod was installed in the head tank for monitoring water levels.		Spurgeon et al. 1997			

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
1997	New ESBSs were installed in all turbine units in March (4/27/97).	Increase FGE.	Hetherman 1998		x	x
	The air bubbler system under the primary dewatering screen was extended 40 ft upstream. A total of 80 ft of screen now has the air bubbler system for removing fine debris.		Hetherman 1998		x	x
	Several 4-in. flush valves were redirected.	Reduce the likelihood that fish passing down small flumes would be affected by water jets	Hetherman 1998			
	In the wet lab, a small flume was constructed for distributing sample fish to any of the three indoor recovery tanks.		Hetherman 1998			
	Two new 10-in. fish bypass pipes that terminate in the middle of the river were constructed to replace the original pipes that terminated near the shoreline at the outfall of the corrugated metal flume.		Hetherman 1998		x	x
1998	Larger holes were drilled in both full sprinklers at the end of the A- and B-side bypass pipes to increase the range of effectiveness.	Reduce gull predation	Hurson et al. 1999		x	x
	Debris chutes were constructed at the separator and holding tanks.	More efficiently dispose of debris.	Hurson et al. 1999			x
	The angle of each sample gate was adjusted to ease fish around the corner to the raceways and river.		Hurson et al. 1999			x
	A short flume was constructed to divert A-side fish into the A-pipe to accommodate direct barge loading.	The flume worked well but water flows beyond the flume, near the barge dock, were unstable and judged to be unacceptable for fish passage. As a result, no A-side fish were direct loaded.	Hurson et al. 1999			

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
	Orifice 1 in slot A of turbine 1 was increased in diameter from 12 in. to 14 in. as a prototype test to minimize debris blockage. A prototype debris shear was also installed to cut through debris lodged in the orifice.	Reduce debris.	Hurson et al. 1999; Dave Hurson (Personal communication)		x	x
	A gull-deterrent structure consisting of a pipe with ropes trailing in the current was installed at the end of the 10-in. bypass pipes.	Reduce predation.	Hurson et al. 1999		x	x
2000	Installed a trash-shear boom	Reduce debris entering gatewell, thereby reducing fish injury and mortality	PTOC 2010		x	x
	ISO installation complete (01/10/00).			x		
	An automated air back-flush system was installed for removing debris from the orifices. The system was operated manually throughout the season, because integration of the automation was not completed.		John Bailey (USACE, Personal Communication)		x	x
	A new adult fish release gate was installed at the separator.	The gate has a rubber strip to prevent nose injuries to adult fish.	John Bailey (USACE, Personal Communication)			x
	The sloping jump plates at the upstream ends of the raceways were “painted” with a plastic material.	Jumping fish now slide back into the raceways on a smoother surface.	John Bailey (USACE, Personal Communication)			
	A larger pump and sprinkler were installed.	To deter gull predation at the bypass pipe outfall	John Bailey (USACE, Personal Communication)		x	x
2001	The lower edges of the separator exit gates were covered with split hose.	To avoid fish injury	John Bailey (USACE, Personal Communication)			x
	“Tops” were installed on two curved gates at the raceway corners.	To keep fish from splashing out	John Bailey (USACE, Personal Communication)			

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
	Flat screens on pre-anesthetic chamber overflow drains were replaced with upright conical screens.	To prevent fish impingement	John Bailey (USACE, Personal Communication)			
	A funnel-like insert was installed entering the direct barge-loading hose.	To provide a smoother transition for fish entering the direct barge-loading hose	John Bailey (USACE, Personal Communication)			
	Netting over the A-side flume at the barge dock was replaced with nylon mesh.	To prevent fish from falling out of the flume in the event that water backs up the direct barge loading hose	John Bailey (USACE, Personal Communication)			
	"Ramps" were installed in the sample tanks.	To guide fish toward the electronic counting tunnels	John Bailey (USACE, Personal Communication)			
2002	Added a new secondary dewatering system downstream from the slide gate (PIT-tag diversion system was replaced to eliminate counter tube head tanks and provide more efficient dewatering and transitioning to bypass pipes).	Modifications were designed to reduce fish holding areas, delays, stress, predation.	PTOC 2010; Dave Hurson (Personal communication)			
	Modified PIT-tag diversion system by removing the PIT-tag head boxes and fish counting tunnels.	Improve passage performance and maintain PIT-tag reading efficiency.	Hockersmith et al. 2002; Ham et al. 2009; PTOC 2010			
	Installed a new sort-by-code (SbyC) sampling system.	Reduce bycatch.	Hockersmith et al. 2002 ;Ham et al. 2009; PTOC 2010	x		
	Replaced two 6-in.-diameter conveyance pipes with a single 8-in.-diameter pipe between the slide gate and diversion river-exit PIT-tag monitor.		Hockersmith et al. 2002; Ham et al. 2009; PTOC 2010			x
	Replaced the 6-in.-diameter river exit conveyance pipe with a 10-in.-diameter pipe.		Hockersmith et al. 2002' Ham et al. 2009			x

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
	A- and B-side PIT-tag diversion-by-code gates were replaced by a single 3-way diversion-by-code gate		John Bailey (USACE, Personal Communication)Dave Hurson (Personal communication)			x
2003	A new adult release gate was installed and the adult fish return trough was modified.	To prevent fish entrapment at the end of the separator	John Bailey (USACE, Personal Communication)			x
	Four new counting tunnels were installed.		John Bailey (USACE, Personal Communication)			
	A-side direct-loading crossover flume was removed from the truck platform.	A-side fish now enter a bypass or loading pipe via a new curved gate upstream of truck platform.	John Bailey (USACE, Personal Communication)			
2004	The EBSBs were modified.	Required due to the interaction of dissimilar metals	USACE 2004		x	x
2005	Completed modifications to the ESBSs	Required due to the interaction of dissimilar metals	USACE 2005		x	x
2006	Added adult fish return monitor to site (01/01/06).		PTOC 2010	x		
	Installed an additional perforated plate to the wet lab/sample dewatering trough.	To prevent injury to fry and escapement	John Bailey (USACE, Personal Communication)			
	Replaced two right-angle (90°) polyvinyl chloride sections of the wet laboratory sample fish routing pipes with 90° sweeps.	The sweeps have a less sharp right angle and allow easier passage of fish to holding tanks.	John Bailey (USACE, Personal Communication)			

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF
	Removed and refurbished PIT-tag gates with new slide gates, air cylinders, and shock absorbers.	The entire PIT-tag gates were sent to PSMFC personnel for upgrades with installation of gate sensors to provide real-time gate position for more accurate detection of gate malfunction and to improve programming.	John Bailey (USACE, Personal Communication)			
	Sample holding tanks were fitted with new lightweight covers, making them easier to use.	The covers prevent fish from jumping out of the tanks.	John Bailey (USACE, Personal Communication)			
2008	Detection was added upstream of primary bypass gate			x		
2009–2010	The full flow (corrugated flume) juvenile outfall was relocated.	This modification, along with the following PIT-tag detection modification, allowed fish to pass through the large bypass flume and PIT-tag detection (full-flow detection) during nontransport periods. Prior to this, fish had to be passed through the separator and out 10-in. lines in order for researchers to collect PIT tag information.	Dave Hurson (Personal communication)		x	x
	The PIT-tag monitoring facilities on the main transportation flume were modified: installed four PIT-tag detectors on the “Full Flow Bypass Flume” (03/06/09).	Improve detection of migrating PIT-tagged juveniles.	USACE 2008; PTOC 2009, 2010	x		

References:

Baxter R, D Hurson, T Wik, M Halter, D Ross, P Verhey, T Goffredo, J Bailey, T Hillson, J Kamps, W Spurgeon, P Wagner, M Price, S Lind, P Hoffarth, R Tudor, S Caromile, and C Hampton. 1996. *Juvenile Fish Transportation Program: 1995 Annual Report.* U.S. Army Corps of Engineers, Walla Walla, Washington.

Ham KD, JP Duncan, CII Armescu, MA Chamness, MA Simmons, and A Solcz. 2009. *Synthesis of Biological Research on Juvenile Fish Passage and Survival 1990-2006: Little Goose Dam*. PNWD-4065, final report prepared by Battelle, Pacific Northwest Division, for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.

Hetherman L, D Hurson, M Halter, D Ross, P Verhey, S Witalis, R Baxter, J Bailey, J Firman, R Madden, W Spurgeon, P Wagner, M Price, S Lind, B Eby, B Johnson, P Hoffarth, R Tudor, T Hillson. 1998. *Juvenile Fish Transportation Program: 1997 Annual Report*. U.S. Army Corps of Engineers, Walla Walla

Table E.2. (contd)

Year	Major Passage Modifications	Passage Improvement Purpose	Reference	Detection	Primary Bypass	River via JBF

District, Walla Walla, Washington.

Hockersmith EE, SL Downing, and DB Dey. 2003. *Post-Construction Evaluation of the Modified PIT-Tag Diversion and Bypass System at Little Goose Dam, 2002*. Research report prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington, by the Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, and National Oceanic and Atmospheric Administration, Seattle, Washington.

Hurson D, M Halter, D Curuso, C Morrill, D Ross, P Verhey, S Witalis, R Baxter, J Bailey, S Moyers, S Rapp, W Spurgeon, P Wagner, M Price, S Lind, B Ebby, B Johnson, P Hoffarth, R Tudor, and L Spencer. 1999. *Juvenile Fish Transportation Program: 1998 Annual Report*. U.S. Army Corps of Engineers, Walla Walla, Washington.

Hurson D, M Halter, P Verhey, T Goffredo, D Ross, C Morrill, R Baxter, J Bailey, T Hillson, G Christofferson, W Spurgeon, P Wagner, M Price, B Eby, C Hampton, S Richards, P Hoffarth. 1996. *Juvenile Fish Transportation Program: 1994 Annual Report*. U.S. Army Corps of Engineers. Walla Walla District, Walla Walla, Washington.

PTOC (PIT Tag Operation Center). 1997. "Little Goose full flow completion." Pacific Marine Fisheries Commission, PTAGIS Newsletter 2(1): 2. Available from: http://php.ptagis.org/wiki/index.php/PTAGIS_Newsletter

PTOC (PIT Tag Operation Center). 2009. "New PIT tag system transition plan." Pacific Marine Fisheries Commission, PTAGIS Newsletter 9(1): 2. Available from: http://php.ptagis.org/wiki/index.php/PTAGIS_Newsletter

PTOC (PIT Tag Operation Center). 2010. "PIT Tag Interrogation Site Configuration History" Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

Spurgeon W, D Hurson, T Wik, M Halter, D Ross, P Verhey, R Baxter, M Jensen, J Kamps, P Wagner, M Price, S Lind, M Plummer, B Eby, P Hoffarth, R Tudor, and S Caromile. 1997. *Juvenile Fish Transportation Program: 1996 Annual Report*. U.S. Army Corps of Engineers. Walla Walla District, Walla Walla, Washington.

USACE (U.S. Army Corps of Engineers). 2004. *Annual Report of the Secretary of the Army on Civil Works Activities for Fiscal Year 2004*. Department of the Army Corps of Engineers Extract Report of the Walla Walla District, Walla Walla, Washington.

USACE (U.S. Army Corps of Engineers). 2005. *Annual Report of the Secretary of the Army on Civil Works Activities for Fiscal Year 2005*. Department of the Army Corps of Engineers Extract Report of the Walla Walla District, Walla, Walla, Washington.

USACE (U.S. Army Corps of Engineers). 2007. "Structural and operational changes at FCRPS dams to improve fish survival." U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, Oregon. 26 pp. Available from: http://www.salmonrecovery.gov/Biological_Opinions/FCRPS/biop_remand_2004/Docs/2007/Overhaul_of_the_System_final_draft%20.pdf

USACE (U.S. Army Corps of Engineers). 2008. *Annual Report of the Secretary of the Army on Civil Works Activities for Fiscal Year 2008*. Department of the Army Corps of Engineers Extract Report of the Walla Walla District, Wall Walla, Washington.

Table E.3. Juvenile Fish Passage Improvements Made at Lower Monumental Dam

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
1992	Standard length submersible screens and fvertical barrier screens (VBSs) were installed.		Diverts fish away from turbine passage and into juvenile bypass system (JBS)			USACE 2007; Ham et al. 2009; Dave Hurson (Personal Communication)		x	x	x	x
	New JBS was constructed and began operation.		Provide state-of-the-art JBS to divert juvenile fish from turbine intakes and bypass them to tailrace.			Dave Hurson (Personal Communication)					
1993				Passive integrated transponder (PIT)-tag detection system included in new facility construction	Allowed detection of PIT tags in collected fish	PTOC 2010; Dave Hurson (Personal Communication)	x				
		New juvenile fish transportation facilities were constructed and began operation.	Allowed transporting of juvenile fish from Lower Monumental Dam								
1994				A PIT-tag diversion system was constructed.	Configuration conforms to 1995 PIT-tag spec document (01/01/94). Allowed the diversion of PIT-tagged fish for research and other purposes.	PTOC 2010	x				

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
		Jump/barrier shade screens were installed over all holding, sample, and PIT-tag diversion system tanks.				Hurson et al. 1996			x		
		A mini-tanker loading line was installed from the platform outside the sample room door to the truck-loading area.				Hurson et al. 1996					x
		Jump barriers were installed at the flume outfall of raceway 1 and raceway 4.				Hurson et al. 1996					x
		The recirculating anesthetic system tank was modified with a sloping bottom.	To allow complete draining and drying between sampling events			Hurson et al. 1996			x		
	The porosity control unit on the separator was modified.		To prevent water surging			Hurson et al. 1996			x	x	x
	The separator release gate was modified to open wider.		To allow adult fish to pass beneath it more easily			Hurson et al. 1996			x	x	x
1995		Roofs were installed over raceways and the PIT-tag facility holding tank.	To provide shading for fish during summer transport operations			Baxter et al. 1996			x		x
		The primary dewatering structure was modified.	To prevent recurrence of the			Baxter et al. 1996		x	x	x	x

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
		This included lowering the elevations of both internal walls, lowering the positions of the overflow weirs, and installing screens in the upwell chamber. Also included in this work was increasing the height of the transport flume at the secondary dewaterer and at the transition/bypass area upstream of the separator.	flooding problem experienced in 1993.								
	An air bubbler system was installed under the trapezoidal section of the inclined screen of the primary dewatering structure.		To help prevent plugging by debris			Baxter et al. 1996		x	x	x	x
	Pneumatic acuators were installed on the separator exits.		To allow quick closing in the event of sudden water loss			Baxter et al. 1996			x	x	x
		Piping was installed from the sample trough to the mini-tanker holding hopper.	To eliminate the need for bucketing fish			Baxter et al. 1996			x		x

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
1996				Coils at the A & B "separator" and "separator gate" were merged to form 4-coil A & B separator gate monitors.		PTOC 2010	x				
	The river release line of the PIT-tag diversion system was modified by extending the pipe and intersecting the release line downstream of its prior location.		This eliminated the potential for overflow during bypass of the small fish side of the separator.			Spurgeon et al. 1997				x	
	An air bubbler system was installed under the inclined screen of the primary dewaterer.		To help prevent plugging			Spurgeon et al. 1997		x	x	x	x
		The recirculating anesthetic tank was insulated to reduce the rate of temperature increase.				Spurgeon et al. 1997			x		
		Flume covers were installed over the flumes between the separator exits and PIT-tag detectors.	To reduce the number of PIT-tag diversion system misses			Spurgeon et al. 1997			x	x	x

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
		A new hopper was installed to hold fish for mini-tanker transport.				Spurgeon et al. 1997					x
1999	The porosity unit was changed from bar screen to perforated plate.		This solved the surging water problem of the past.			Spurgeon et al. 1999		x	x	x	x
2000				ISO installation was completed (01/26/00).		PTOC 2010	x				
	Major overhaul (maintenance) of submersible traveling screen (STS) was performed in 2000 and 2001.		Ensures STS efficacy and reliability			USACE 2007; Ham et al. 2009; Dave Hurson (Personal Communication)		x	x	x	x
		A new dewatering device was fabricated and installed upstream of the sample trough.	To reduce split fins on fish in the sample			Spurgeon et al. 2000; Dave Hurson (Personal Communication)			x		
		Guards to keep fish from hitting the separator bar support frames were installed.				Spurgeon et al. 2000			x	x	x
		The raceway tailscreens were rebuilt.				Spurgeon et al. 2000					x
2002	Modified the primary emergency bypass exit.		Fish can be bypassed through it during dewatering.			John Bailey (USACE, Personal Communication)		x			

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection Primary Bypass	Sampled	River via JBF	Transported
	An insert was installed in the "A" side of the separator to reduce the area under the bars where fish could delay.		This was intended to reduce delay in the separator and it appeared to work.			John Bailey (USACE, Personal Communication)		x	x	x
		Resized the late season holding tank in which sample fish recover prior to loading into the midi-tanker	The new size (315 gallons) will hold the maximum fish capacity of the midi-tanker (150 pounds).			John Bailey (USACE, Personal Communication)		x		
2004		Covers were installed on flumes 1 and 2 between the sample gates and raceways to reduce light.	Reduce stress on fish.			Spurgeon et al. 2004				x
	The "A" separator insert was permanently mounted in the separator.					Spurgeon et al. 2004		x	x	x
	The "B" side of the separator was modified to duplicate the design of the "A" side.		To eliminate the down-well at the separator exit and reduce separator residence time			Spurgeon et al. 2004		x	x	x

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
	Baffles were added to the bottom of the "B" separator.		To more evenly disperse the flow of separator supply water up through the supply screens			Spurgeon et al. 2004			x	x	x
2005	Improved barge-loading and JBS dewatering facilities: new barge-loading pipe with less slope to the barge dock was installed. A new barge-loading flume dewaterer was installed to maintain the flume water level without the need of an operator.		Improve juvenile transportation system.			USACE 2007; Ham et al. 2009; Spurgeon et al. 2005; Dave Hurson (Personal Communication)					x
		Raceway exit chamber floors were sloped to the exit hole.	This was done to eliminate areas where fish hold after the raceway has drained.			Spurgeon et al. 2005					x
		Flume covers were installed on flumes 1 and 2 to provide shade.	Reduce fish stress.			Spurgeon et al. 2005					
2006				Added adult fish return monitor to site (01/01/06)		PTOC 2010	x				

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
2007				Added new full-flow bypass monitor, antennas 01-04; renumbered B-exit antennas to 61-62. The full-flow PIT-tag detector system was constructed on the transport flume from the primary dewaterer to the juvenile fish facility.	Provide full flow P|IT tag detection. It allows detection of PIT tags when in non-transport modes without passing fish through the separator system.	PTOC 2010; Spurgeon et al. 2007; Dave Hurson (Personal Communication)	x				
	The B-side separator bars were modified into two sets of permanently attached bars with a hatch to allow for easy cleaning of the exit slot from the east side set.					Spurgeon et al. 2007			x	x	x
	A river release system for the avian predation study was fabricated and installed from the truck-loading holding tank to the downstream (river) end of flume 5.					Spurgeon et al. 2007				x	

Table E.3. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported

References:

Baxter R, D Hurson, T Wik, M Halter, D Ross, P Verhey, T Goffredo, J Bailey, T Hillson, J Kamps, W Spurgeon, P Wagner, M Price, S Lind, P Hoffarth, R Tudor, S Caromile, and C Hampton. 1996. *Juvenile Fish Transportation Program: 1995 Annual Report*. U.S. Army Corps of Engineers, Walla Walla, Washington.

Ham KD, JP Duncan, CII Armescu, MA Chamness, MA Simmons, and A Solcz. 2009. *Synthesis of Biological Research on Juvenile Fish Passage and Survival 1990-2006: Lower Monumental Dam*. PNWD-4061, final report prepared by Battelle, Pacific Northwest Division for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Hurson D, M Halter, P Verhey, T Goffredo, D Ross, C Morrill, R Baxter, J Bailey, T Hillson, G Christofferson, W Spurgeon, P Wagner, M Price, B Eby, C Hampton, S Richards, and P Hoffarth. 1996. *Juvenile Fish Transportation Program: 1994 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

PTOC (PIT Tag Operation Center). 2010. “PIT Tag Interrogation Site Configuration History” Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

Spurgeon W, D Hurson, T Wik, M Halter, D Ross, P Verhey, R Baxter, M Jensen, J Kamps, P Wagner, M Price, S Lind, M Plummer, B Eby, P Hoffarth, R Tudor, and S Caromile. 1997. *Juvenile Fish Transportation Program: 1996 Annual Report*. U.S. Army Corps of Engineers. Walla Walla District, Walla Walla, Washington. 109 pp.

Spurgeon W, P Wagner, M Price, and S Lind. 1999. *1999 Juvenile Fish Collection and Bypass Report: Lower Monumental Dam Juvenile Fish Facility*. Walla Walla District of the U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, Walla Walla, Washington.

Spurgeon W, S Lind, C Morrill, M Price, and P Wagner. 2000. *2000 Juvenile Fish Collection and Bypass Report: Lower Monumental Dam Juvenile Fish Facility*. Walla Walla District of the U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, Walla Walla, Washington.

Spurgeon W, K Fone, M Price, S Lind, and C Morrill. 2004. *2004 Juvenile Fish Collection and Bypass Report: Lower Monumental Dam Juvenile Fish Facility*. Walla Walla District U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, Walla Walla, Washington.

Spurgeon W, K Fone, M Price, S Lind, and C Morrill. 2005. *2005 Juvenile Fish Collection and Bypass Report: Lower Monumental Dam Juvenile Fish Facility*. Walla Walla District of the U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, Walla Walla, Washington.

Spurgeon W, M Price, S Lind, and C Morrill. 2007. *2007 Juvenile Fish Collection and Bypass Report: Lower Monumental Dam Juvenile Fish Facility*. Walla Walla District of the U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife, Walla Walla, Washington.

USACE (U.S. Army Corps of Engineers). 2007. “Structural and operational changes at FCRPS dams to improve fish survival.” U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, OR. 26 pp. Available from: http://www.salmonrecovery.gov/Biological_Opinions/FCRPS/biop_remand_2004/Docs/2007/Overhaul_of_the_System_final_draft%20.pdf

Table E.4. Juvenile Fish Passage Improvements Made at Ice Harbor Dam

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported
1993	14-in. orifices (holes) were drilled between gatewells and ice and trash sluiceway.		Increase egress from gatewells to ice and trash sluiceway.			Dave Hurson (Personal Communication)					
	New submersible traveling screens (STSs) and vertical barrier screens (VBSs) were installed in all turbine intakes.		Improve fish guidance efficiency (FGE) prior to construction of new juvenile by-pass system (JBS).			Dave Hurson (Personal Communication)					
1996	A new JBS was installed, including new 12-in. orifices to gatewells, juvenile fish collection channel (in old ice and trash sluiceway), primary dewatering system, sampling facilities, and a juvenile outfall pipe (see added items below). Screens and orifice drilling were done before bypass system construction took place.		Provide a state-of-the-art juvenile fish bypass at Ice Harbor Dam.			USACE 2007; Ham et al. 2009; Dave Hurson (Personal Communication)					
2005				Passive integrated transponder (PIT)-tag detection on main bypass flume was constructed and implemented. (This modification had nothing to do with the adult ladder modification; 04/01/05).	Allowed PIT tag detection of bypassed juvenile fish at Ice Harbor Dam	Ham et al. 2010; USACE 2007; PTOC 2009					

Table E.4. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBF	Transported

References:

Ham KD, JP Duncan, CII Armescu, MA Chamness, MA Simmons, and A Solcz. 2009. *Synthesis of Biological Research on Juvenile Fish Passage and Survival 1990-2006: Ice Harbor Dam*. PNWD-3976, final report prepared by Battelle, Pacific Northwest Division, for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA

PTOC (PIT Tag Operation Center). 2010. “PIT Tag Interrogation Site Configuration History” Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

USACE (U.S. Army Corps of Engineers). 2007. “Structural and operational changes at FCRPS dams to improve fish survival.” U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, Oregon. 26 pp. Available from: http://www.salmonrecovery.gov/Biological_Opinions/FCRPS/biop_remand_2004/Docs/2007/Overhaul_of_the_System_final_draft%20.pdf

Table E.5. Juvenile Fish Passage Improvements Made at McNary Dam

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
1994	Initial operation of a new juvenile fish facility commenced.			New passive integrated transponder (PIT) detection configuration (01/01/1994).		PTOC 2010	x				
	The bar screen in the separator porosity control unity was covered with a perforated plate .		To improve flow conditions across the porosity control unit and into the separator			Hurson et al. 1996			x	x	x
		The sample-holding tank pre-anesthetic gates were replaced and plastic guide seals were installed .				Hurson et al. 1996			x		
		A screen was constructed to prevent fish from jumping between raceway 9E and 9W.				Hurson et al. 1996					x
		The flush water pump for the sample trough delivery line was replaced due to load vibration noises during operations.	The replacement pump operated with less noise and a large increase in the volume of flush water.			Hurson et al. 1996			x		

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		Perforated plate screen covers were installed over the open barge-/truck-loading flume.	To prevent the spilling of fish near the switch gate			Hurson et al. 1996					x
		The collection channel's screen cleaning system was modified.				Hurson et al. 1996		x	x	x	x
	The National Marine Fisheries Service (NMFS) conducted fish guidance efficiency (FGE) tests of prototype extended-length submersible bar screens (ESBSs) and extended-length submersible traveling screens (STSs) in turbine units 5 and 6. The studies were conducted from 4/18/94 to 6/2/94 and from 6/20/94 to 7/26/94.					Hurson et al. 1996		x	x	x	x
1996				Combined separator and separator gate monitors (02/27/1996).		PTOC 2010	x				
	New ESBSs were installed in turbine units 1-6.		Increase FGE.			Spurgeon et al. 1997; Ham et al. 2009; Dave Hurson (Personal Communication)		x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
	A pneumatic (air blast) floor-screening system was installed under the rectangular floor screen.		To assist in debris removal			Spurgeon et al. 1997		x	x	x	x
	A programmable logic controller was installed.		To provide more positive control of the screen cleaners and of the water level in the collection channel.			Spurgeon et al. 1997		x	x	x	x
		Raceway shelters were added over both banks of raceways.	To improve holding conditions for summer transport operations.			Spurgeon et al. 1997; Dave Hurson (Personal Communication)					x
		The separator porosity control bar screen was replaced with 1/8th-in. perforated plate.				Spurgeon et al. 1997			x	x	x
	New VBSs installation occurred throughout the year with the last screen installed on 11/06/96					Spurgeon et al. 1997		x	x	x	x
1997	ESBSs were installed in turbine units 7-14. VBSs were installed (04/1997).		To increase FGE.			Ham et al. 2009; Hetherman et al. 1998		x	x	x	x
	A transportation flume flush line was installed from the station service units to the transport flume.		To provide flush water for fish during facility dewatering.			Hetherman et al. 1998					x
		An emergency raceway water-	This will allow fish to be held during emergencies			Hetherman et al. 1998		x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		supply line was installed from the station service units to the 42-in. facility water-supply line.	and routine collection channel dewaterings.								
	The main transport pipe carrying fish from the powerhouse to the separator was improved with the addition of this 6-in. flush line by preventing the potential loss of fish during dewatering operations. This pipe is fed from the new collection channel water-up system					Hetherman et al. 1998		x	x	x	x
		A separator water-supply back-flush and line were connected to the large fish side of the separator.	This allows water in the separator to flow down through the water-supply screen, removing debris from the screen and returning separator flow to normal.			Hetherman et al. 1998			x	x	x
		A raceway water-supply back-flush drain valve and line were connected to each raceway supply line.	This allows water in the raceway to flow down through the raceway diffuser screens removing debris and returning raceway flow to normal.			Hetherman et al. 1998					x
		Direct barge-loading lines were installed to allow fish to be				Hetherman et al. 1998					x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		directly loaded onto barges without being loaded into raceways.									
1998				McNary Juvenile Experimental (MCX): 400 kHz VS ISO 134.2 kHz, apples to apples test (02/20/98 to 12/31/98) [1]		PTOC 2010	x				
				Added ISO monitors (03/02/98).		PTOC 2010	x				
		New fish-jumping barriers (gap closure panels) were installed on the raceway loading flumes, replacing the awkward screen panels.				Hurson et al. 1999					x
		Shade covers were installed over the transition flume leading into the separator to retard algae growth.				Hurson et al. 1999			x	x	x
	Jib booms were installed at the					Hurson et al. 1999					x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
	raceways for removing tubs of debris.										
2000	Add-in water was provided just below PIT-tag slide gates in the transport flumes (Winter 1999-2000).					John Bailey (USACE, Personal Communication)					x
	The "A" transport flume's dryers were replaced with new dryers, that had bars running perpendicular to flow (Winter 1999-2000).		Results in less debris impingement			John Bailey (USACE, Personal Communication)					x
	The separator bar holders were rebuilt (Winter 1999-2000).		Easier removal of the bars			John Bailey (USACE, Personal Communication)			x	x	x
	The chamber below the "A" side of the separator was opened up (Winter 1999-2000).		To increase flow and improve back-flush cleaning			John Bailey (USACE, Personal Communication)			x	x	x
		Powerhouse ice and trash sluiceway's bulkhead replacement began (Winter 1999-2000).	This will help keep debris for the collection channel.			John Bailey (USACE, Personal Communication)		x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		A fish-evacuation slide was installed to improve fish movement from the upper ice and trash sluiceway to the lower ice and trash sluiceway during bypass and salvage operations (Winter 1999-2000).				John Bailey (USACE, Personal Communication)	x	x	x	x	x
				ISO installation complete (01/21/00).		PTOC 2010	x				
2001				The primary bypass gate position indicator switches were tied into the PIT-tag system (Winter 2000-2001).		John Bailey (USACE, Personal Communication)	x				

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		The old frequency PIT-tag detector was removed from the "B" flume and replaced with an aluminum flume (Winter 2000-2001).	Helped reduce debris blockages			John Bailey (USACE, Personal Communication)			x	x	x
		The old frequency PIT-tag detector was removed from the "B" return-to-river line and replaced with straight polyvinyl chloride (PVC) pipe (Winter 2000-2001).	Helped reduce debris blockages			John Bailey (USACE, Personal Communication)			x	x	x
	A dewatering unit was installed between the perforated plate and the head of the separator bars (Winter 2000-2001).		Allowing for more adjustment of flow into the separator			John Bailey (USACE, Personal Communication)			x	x	x
2002				A full-flow PIT tag detection system was installed on the main juvenile bypass line.	Detects tags without routing through juvenile fish facility (JFF).	PTOC 2010; Dave Hurson (Personal Communication)	x				

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		The forebay side splashguards at the unit 9 orifices were extended, which eliminated fish stranding (Winter 2001-2002).				John Bailey (USACE, Personal Communication)		x	x	x	x
		Work continued on improvements in the jump guards at the raceways (Winter 2001-2002).				John Bailey (USACE, Personal Communication)					x
				The secondary bypass slide gates were modified for PIT-tag detection, including all associated equipment and a new breaker panel (Winter 2001-2002).		John Bailey (USACE, Personal Communication)	x				
		Portions of the secondary bypass\return to river lines were replaced (Winter 2001-2002).	Reduced debris blockages in the lines			John Bailey (USACE, Personal Communication)				x	

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		A water cannon and pump were installed (Winter 2001-2002).	To detour birds from the outfall of the primary and secondary bypass lines			John Bailey (USACE, Personal Communication)		x		x	
		A flush line was added to the steelhead direct barge-loading line (Winter 2001-2002).				John Bailey (USACE, Personal Communication)					x
2003				Added full-flow bypass (formerly MCX)		Ham et al. 2009; PTOC 2010	x				
				New sort-by-code (SbyC) monitors were located prior to A-raceway and B-raceway gates.	Enabled spring testing of transport for upriver marked juvenile fish. (check date, may have been done a year earlier)	PTOC 2010; Dave Hurson (Personal Communication)	x				
2004	A prototype VBS was installed in slot A of turbines 2, 3, and 4 for testing (Winter 2003-2004).		Research for improving gatewell conditions for potential installation of higher discharge turbine unit			Ham et al. 2009; Dave Hurson (Personal Communication)	x	x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
				Permanent PIT-tag equipment was installed at the separator's adult return to river line (Winter 2003-2004) .		John Bailey (USACE, Personal Communication)	x				
2005	The prototype VBS installed the 4A slot was replaced with a different meshed, motorized version for testing (Winter 2004-2005).		Improved gatewell conditions (reducing debris accumulation) may improve fish condition (lower descaling and injury rates). Research for improving gatewell conditions for potential installation of a higher discharge turbine unit. (removed because of failure problems)			Ham et al. 2009; Gessel et al. 2006; Dave Hurson (USACE Retired, Personal Communication)		x	x	x	x
				A new orifice trap with PIT-tag detection at the 4A south orifice was installed in the collection channel (Winter 2004-2005).		John Bailey (USACE, Personal Communication)		x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
	Replaced facility 10-in. bypass pipes with improved piping and routes to eliminate debris plugging problems		Eliminate debris plugging and impacts on fish when routing fish from the separator and PIT-tag system back to the river.			Dave Hurson (USACE Retired, Personal Communication)					
2006				Added adult fish return monitor (01/01/06).		PTOC 2010	x				
	A second-generation prototype VBS and flow-control device was installed in gatewell slot 4A (Winter 2005-2006).		Designed for high unit discharge			John Bailey (USACE, Personal Communication)		x	x	x	x
	A flow-control device was installed in slot 4A as part of the VBS installation (Winter 2005-2006).					John Bailey (USACE, Personal Communication)		x	x	x	x
		A new collection channel orifice trap was installed at the south orifice in slot 5A (Winter 2005-2006).				John Bailey (USACE, Personal Communication)		x	x	x	x
		The orifice trap at the north orifice in slot 6B was removed (Winter 2005-2006).				John Bailey (USACE, Personal Communication)		x	x	x	x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		Four flume flush valves were replaced with stainless steel valves and new PVC piping (Winter 2005-2006).				John Bailey (USACE, Personal Communication)					
2007		The orifice trap at the 6B south orifice was rehabilitated (Winter 2006-2007).				John Bailey (USACE, Personal Communication)		x	x	x	x
		Netting to adult jump barrier was extended at unit 13 collection channel orifices (Winter 2006-2007).				John Bailey (USACE, Personal Communication)		x	x	x	x
	The PIT tag A side count tank outflow was modified (Winter 2006-2007).					John Bailey (USACE, Personal Communication)					
		The release line into the west sample raceway was modified (Winter 2006-2007).	To reduce fish jumping.			John Bailey (USACE, Personal Communication)			x		
2008		A funnel was built to be used when evacuating fish from the lower channel (Winter 2007-2008).				John Bailey (USACE, Personal Communication)					

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported
		A corner gasket was installed where the tip of the primary bypass gate rest when the gate is in the bypass position. (Winter 2007-2008).	This will help keep fish from getting past the gate.			John Bailey (USACE, Personal Communication)		x	x	x	x
		A down spout was installed in the inflow into the sample raceway (9 west) (Winter 2007-2008).	To reduce jumping			John Bailey (USACE, Personal Communication)			x		
		The water supplies for the wet lab tagging stations' were modified (Winter 2007-2008).	To improve fish loading and holding for U.S. Geological Survey tanks			John Bailey (USACE, Personal Communication)			x		
2009		The old water system to the upstream raceways was replaced with a new 4-in. line system from the spool piece at the base of the separator (prior to 2009 season).				John Bailey (USACE, Personal Communication)					x

Table E.5. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Transported

References:

Gessel MH, DA Brege, BP Sandford, and GM Matthews. 2006. *Effects of Turbine Operations and a Prototype Rotating Vertical Barrier Screen on Fish Condition at McNary Dam*, *2005*. Prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington, by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington, under Contract W68SBV20655422.

Ham KD, JP Duncan, CII Armescu, MA Chamness, MA Simmons, and A Solcz. 2009. *Synthesis of Biological Research on Juvenile Fish Passage and Survival 1990-2006: McNary Dam*. PNWD-4035, final report prepared by Battelle, Pacific Northwest Division, for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA

Hetherman L, D Hurson, M Halter, D Ross, P Verhey, S Witalis, R Baxter, J Bailey, J Firman, R Madden, W Spurgeon, P Wagner, M Price, S Lind, B Eby, B Johnson, P Hoffarth, R Tudor, T Hillson. 1998. *Juvenile Fish Transportation Program: 1997 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Hurson D, M Halter, P Verhey, T Goffredo, D Ross, C Morrill, R Baxter, J Bailey, T Hillson, G Christofferson, W Spurgeon, P Wagner, M Price, B Eby, C Hampton, S Richards, and P Hoffarth. 1996. *J uvenile Fish Transportation Program: 1994 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Hurson D, M Halter, D Curuso, C Morrill, D Ross, P Verhey, S Witalis, R Baxter, J Bailey, S Moyers, S Rapp, W Spurgeon, P Wagner, M Price, S Lind, B Ebby, B Johnson, P Hoffarth, R Tudor, and L Spencer. 1999. *Juvenile Fish Transportation Program: 1998 Annual Report*. U.S. Army Corps of Engineers, Walla Walla, Washington.

PTOC (PIT Tag Operation Center). 2010. "PIT Tag Interrogation Site Configuration History" Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

Spurgeon W, D Hurson, T Wik, M Halter, D Ross, P Verhey, R Baxter, M Jensen, J Kamps, P Wagner, M Price, S Lind, M Plummer, B Eby, P Hoffarth, R Tudor, and S Caromile. 1997. *Juvenile Fish Transportation Program: 1996 Annual Report*. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Table E.6. Juvenile Fish Passage Improvements Made at John Day Dam

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
1986	The first major reconstruction of the John Day Dam bypass system occurred in 1984-1986 when gatewell orifices were enlarged to 30.5-cm (12-in) in diameter, the collection channel was enlarged, vertical barrier screens and submersible traveling screens (STSs) were installed, and a transportation channel to carry fish from the bypass gallery to the river was constructed.					Absolon et al. 2000				
1993				A remote monitor was installed in gatewell air lift sample room (01/01/92 to 04/01/95).		PTOC 2010				
1995				A remote monitor was installed in gatewell air lift (04/01/95 to 05/06/96).		PTOC 2010	x			
1996	Major reconstruction of bypass system began.					Absolon et al. 2000				
				Added second air lift (05/06/96 to 03/02/98).		PTOC 20	x			
	Three extended-length submersible bar screens (ESBSs) were installed and researched in unit 7. All remaining units were installed with STSs.					Weiland and Escher 2001				

Table E.6. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
1998	The new juvenile bypass system at John Day Dam was completed in April 1998. Components of the bypass system added during the 1996-1998 construction were similar to those in use at other Snake and Columbia River hydroelectric dams, with the exception of a hydraulic jump and a wetted separator ,which are unique to this project. The components added in the 1984-1986 period were retained and remain part of the present bypass system.					Absolon et al. 2000				
				New sampling and detection configuration (1998). Made main site 3/19/99 (03/02/98 to 12/16/99).		PTOC 2010	x			
1999				ISO installation completed (12/16/99 to 03/01/05).		PTOC 2010	x			
2005				Added adult separator monitor to site configuration (03/01/05 to 03/01/07)		PTOC 2010	x			

Table E.6. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
2007				Added new full-flow bypass array with antennas 01-04 (03/01/07 to Present).		PTOC 2010	x			

References:

Absolon RF, DA Brege, and JW Ferguson. 1999. *Post-Construction Evaluation of the Juvenile Bypass System at John Day Dam, 1998*. Report to the U.S. Army Corps of Engineers, Contract W66QKZ80354028, 26 p. + Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

PTOC (PIT Tag Operation Center). 2009. "PIT Tag Interrogation Site Operations & Maintenance: Interrogation Site Configurations; Current and Historic Coil & Monitor Configurations." Pacific Marine Fisheries Commission, PTAGIS. Available from: http://www.ptoccentral.org/Ptoc_OM/

Weiland MA and C Escher. 2001. *Water Velocity Measurement on an Extended-Length Submerged Bar Screen at John Day Dam*. PNNL-13517, Pacific Northwest National Laboratory, Richland, Washington.

Table E.7. Juvenile Fish Passage Improvements Made at Bonneville Powerhouse 1

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
1992				**BVJ**[1]: Bonneville Dam downstream migrant channel 1 (DSM1) subsample site (inclined screen sampling system in the bypass channel). First configuration cloned from current configuration; dates correct, but equipment must be confirmed (05/01/92 to 01/01/94).		PTOC 2010	x			
1994				**BVJ** modified to single coil subsample monitor. Smolt Monitoring Program sub-sample in DSM channel. Made main site 03/19/99.		PTOC 2010	x			
1996				**BVX**[1]: Bonneville Powerhouse 1 (B1) juvenile site (experimental). The National Marine Fisheries Service (NMFS) pass-by (flat plate) interrogation experiment (05/06/96 to 03/06/00). Made main site 03/19/99.		PTOC 2010, www.ptoccentral.org/Ptoc_OM/event_log/Elog-Main.html; Nunnallee et al. 1998	x			
1999				**BVX** and **BVJ** made main site 03/19/99.		PTOC 2010				

Table E.7. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
	A prototype extended-length submerged bar screen (ESBS) was installed in 1999 and specifically tested in 2000 and 2001. It was still present during the 2002 studies ,but was removed in 2003 because both netting and hydroacoustic sampling revealed a significant decline in fish guidance efficiency (FGE) in summer that made the screen no more effective than the existing submersible traveling screen (STS).					Ploskey et al. 2005		x	x	x
2000				ISO installation complete at **BVX** (03/06/00 to 07/28/00).		PTOC 2010	x			
				Changed coil numbers to begin with 01 rather than 00 at **BVX** (07/28/00 to 02/20/00).		PTOC 2010	x			

Table E.7. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
				Due to a reduction in sampling effort at DSM1, use of the **BVJ** interrogation site was discontinued in 2000. 100% of the fish in the SMP condition sample were scanned for passive integrated transponder (PIT) tags, and any codes so detected were reported to the PIT Tag Information System (PTAGIS) as "recaptures." Outside of the SMP sample, all fish transiting the bypass channel at B1 passed over the "**BVX**" flat-plate detector at the base of the channel, and any detected PIT-tagged fish were reported as "interrogations" from that site.		www.ptoccentral.org/Ptoc_OM/event_log/Elog-Main.html	x			
		New minimum gap runners were installed in unit 6	Evaluate survival			Ploskey et al. 2005		x	x	x

Table E.7. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
2001	After the second power house (B2) came on line in 1982 and FGE problems were identified in 1983, subsequent fish passage plans called for B1 to be the priority powerhouse from 1984 through 2000. In general, B2 units were not operated except for research purposes unless they were needed to limit spill to 75,000 cfs during daylight hours. Units 11, 17, and 18 were the priority units during most years, after B1 units. It was not until 2001 that the fish passage plan switched the powerhouse priority from B1 to B2. This change in priority was made possible by a new switch that allowed the two powerhouses to operate independently and by new data suggesting that fish survival passing B2 was higher than previously thought.									
2003				Downstream migrant channel 1 (DSM1) trap with flat-plate detector operational (**B1J**[3]). Not detecting when trap operates (02/20/03 to 07/31/03). To replaced the previous experimental flat plate detector in PH1 downstream migrant collection channel (**BVX**).		PTOC 2010, www.ptoccentral.org/Ptoc_OM/event_log/Elog-Main.html	x			

Table E.7. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS
2004	STS not deployed and the juvenile bypass system at B1 was removed in 2004 because other routes are safer for fish.					Ploskey et al. 2005	x			

[1]BVJ = Bonneville Dam DSM1 Subsample 1992 – 1999

[2]BVX = Bonneville Dam PH1 Flat Plate (Experimental) 1996 – 2002

[3]B1J = Bonneville Dam DSM1 Flat Plate Detector 2003 – 2003

References:

Nunnallee EP, EF Prentice, BF Jonasson, and W Patten. 1998. "Evaluation of a flat-plate PIT tag interrogation system at Bonneville Dam." *Aquacultural Engineering* 17: 261-272.

Ploskey GR, GE Johnson, AE Giorgi, RL Johnson, JR Stevenson, CR Schilt, PN Johnson, and DS Patterson. 2005. *Synthesis of Biological Reports on Juvenile Fish Passage and Survival at Bonneville Dam through 2005*. PNNL-15041, Pacific Northwest National Laboratory, Richland, Washington.

PTOC (PIT Tag Operation Center). 2010. "PIT Tag Interrogation Site Configuration History" Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

Table E.8. Juvenile Fish Passage Improvements Made at Bonneville Powerhouse 2

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
1983	Juvenile fish that entered Powerhouse 2 (B2) turbines and were guided by screens into the original bypass system passed through a 0.25-m-diameter orifice and entered a 2.7-m-wide, 2.4-m-deep, 244-m-long channel that extended the length of the powerhouse and collected fish from each turbine. The collection channel is oriented such that water flow is generally from south to north. A 15.5-m-long dewatering structure located at the northern end of the collection channel removed excess water. The remaining flow (3.4–5.1 m^3/s) and bypassed fish entered a 0.9-m-diameter, pressurized, steel pipe (transportation pipe) that traveled underground for 287 m. The transportation pipe terminated at a bypass exit located in the river 78 m below B2, away from either shoreline, and from 6 to 14 m below the water surface to reduce the potential for predation.		Original bypass design.			Ferguson et al. 2007					
1993	Added three streamlined trash racks in the upper part of the turbine intake and turbine intake extensions (TIEs) to every other intake across the powerhouse.										
1996				New configuration (04/01/96 to 02/08/97).		PTOC 2010	x				

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
1997				National Marine Fisheries Service (NMFS) installation to support the Dalles Survival Study. Replaces single-coil subsample monitor (02/08/97 to 03/19/99).		PTOC 2010	x				
1999				Temporary installation at new, permanent outfall location. 400 kHz only. (03/19/99 to 12/22/99).		PTOC 2010	x				
				ISO installation complete (12/22/99 to 01/22/01).		PTOC 2010	x				

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
	Orifice diameter increased from 0.25 m to 0.30 m.		Allow debris to pass through more effectively and decrease fish injury.					x	x	x	
	The new collection channel has the same slope and dimensions as the original juvenile bypass system (JBS) system in the northern portion, but the southern-most 141 m were narrowed, tapered, and filled.		Eliminate low-velocity areas where fish could hold.			Ferguson et al. 2007		x	x	x	
	The new dewatering screen consists of two 24.4-m-long, 4.1-m-deep profile bar screens with a maximum clear opening of 1.75 mm between the bars. The screen panels are oriented vertically and arranged in a V-shaped pattern such that the screen apex terminates at the entrance to the transportation flume.		The increased flow volume capacity of the new dewatering structure allows both orifices located in each turbine intake gatewell to be operated. This results in reduced fluctuations in collection channel flow volumes as forebay water surface elevation increases or decreases with powerhouse operations, a relatively stable flow of water at the dewatering structure, and a reduction in transportation flume flow fluctuations relative to the original bypass system.			Ferguson et al. 2007			x	x	

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
	The new bypass system transportation flume uses a 1.22-m-diameter, non-pressurized, high-density polyethylene pipe to convey water flow, river debris, and bypassed fish from the dewatering structure to the bypass outfall location 2.8 km downstream from the dam. It travels below ground for 3.7 km, and water in the pipe is maintained at a depth of 0.6 m, which results in the pipe being partially full and acting similar to an open flume.					Ferguson et al. 2007		x			
	In the new bypass system, an extensive juvenile fish monitoring facility is located just upstream from the bypass exit to accommodate long-term smolt-monitoring needs and was designed so that 0–100% of the bypassed flow and fish can be diverted into the facility for examination and enumeration. The original bypass system was designed such that 10% of the bypass water flow and fish leaving the		Relocated bypass avoids predation outfall location.			Ferguson et al. 2007; USACE 2007			x	x	

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
	dewatering structure could be diverted to a facility in the powerhouse, where fish could be held and examined to evaluate fish condition and estimate migration timing, species composition, and the number of smolts passing through the bypass system. This sample did not include any potential effects on fish from passage through the down well or the pressurized transportation pipe.										
2001	After the B2 came online in 1982 and fish guidance efficiency (FGE) problems were identified in 1983, subsequent fish passage plans called for Powerhouse 1 (B1) to be the priority powerhouse from 1984 through 2000. In general, B2 units were not operated except for research purposes unless they were needed to limit spill to 75,000 cfs during daylight hours. Units 11, 17, and 18 were the priority units in most years, after B1 units. It was not until 2001 that the fish passage plan switched the powerhouse priority from B1 to B2. This change in priority was made possible by a new switch that allowed the two powerhouses to operate independently and by new data suggesting that fish survival passing B2 was higher than previously thought.					Ploskey et al. 2005					

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
				Installed sample monitor and coils (01/22/01 to 03/01/06)		PTOC 2010	x				
		Modified gatewell slots in Unit 15 (prior to 2001 migration season). Modifications consisted of expanding the surface area the of vertical barrier screens (VBSs), and adding a turning vane and gap closure device to direct more water up the slot and away from the gap between the top of the submersible traveling screen (STS) and the intake ceiling.	Improve FGE at B2 turbines.			Ploskey et al. 2003		x	x	x	

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
2002		Modified gatewell slots in unit 17 (prior to 2002 migration season). Same modifications as 2001.	Improve FGE at B2 turbines.			Ploskey et al. 2003		x	x	x	
2004	Added surface bypass corner collector (B2CC) with 0.5 mile conveyance channel.		Further increases the percentage of fish that avoid turbine passage and provided outfall in location to improve survival.			USACE 2007					x
	TIEs were removed from intakes at units 11–14. TIEs were maintained in units 15–18.		Facilitated southerly flow along the powerhouse toward the B2CC			Ploskey et al. 2006		x	x	x	
2006				Full-flow passive integrated transponder (PIT)-tag detection on bypass outfall flume (03/01/06 to Present).	Reduces need to subject juveniles to very low flow levels for PIT-tag detection, which will reduce stress levels.	PTOC 2010; USACE 2007	x				

Table E.8. (contd)

Year	Major Passage Modifications	Minor Passage Modifications	Passage Improvement Purpose	Fish Detection Modification	Fish Detection Modification Purpose	Reference	Detection	Primary Bypass	Sampled	River via JBS	Alternate Passage
				A PIT-tag antenna was installed in the B2CC outfall channel (04/08/06 to Present).	Capable of detecting tagged fish moving at high speeds down flume.	USACE 2007; PTOC 2010; Ploskey et al. 2005	x				

References:

Ferguson JW, Sandford BP, Reagan RE, Gilbreath LG, Meyer EB, et al. 2007. “Bypass system modification at Bonneville Dam on the Columbia River improved the survival of juvenile salmon.” *Trans Amer Fish Soc* 136:1487–1510.

Ploskey GR, CR Schilt, J Kim, C Escher, and JR Skalski. 2003. *Hydroacoustic Evaluation of Fish Passage Through Bonneville Dam in 2002*. PNNL-14356, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, GE Johnson, AE Giorgi, RL Johnson, JR Stevenson, CR Schilt, PN Johnson, and DS Patterson. 2005. *Synthesis of Biological Reports on Juvenile Fish Passage and Survival at Bonneville Dam through 2005*. PNNL-15041, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, MA Weiland, SA Zimmerman, JS Hughes, KE Bouchard, ES Fischer, CR Schilt, ME Hanks, J Kim, JR Skalski, J Hedgepeth, and WT Nagy. 2006. *Hydroacoustic Evaluation of Fish Passage Through Bonneville Dam in 2005*. PNNL-15944, Pacific Northwest National Laboratory, Richland, Washington.

PTOC (PIT Tag Operation Center). 2010. “PIT Tag Interrogation Site Configuration History” Pacific Marine Fisheries Commission, PTAGIS. Available from: ftp://ftp.ptagis.org/Reports/TMT/site_con_spec.txt

USACE (U.S. Army Corps of Engineers). 2007. “Structural and operational changes at FCRPS dams to improve fish survival.” U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, Oregon. 26 pp. Available from: http://www.salmonrecovery.gov/Biological_Opinions/FCRPS/biop_remand_2004/Docs/2007/Overhaul_of_the_System_final_draft%20.pdf