PNNL-14473

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Monitoring Tissue Concentrations of Chromium and Fish Condition in Juvenile Fall Chinook Salmon from the Hanford Reach of the Columbia River

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Summary

This study involved the collection of juvenile fall Chinook salmon and Columbia River water samples to assess whether fall Chinook salmon were exposed to chromium that upwells into the river from contaminated groundwater originating at the Hanford Site. Juvenile fall Chinook salmon were seined and water samples were collected from three locations in the Hanford Reach during the period of juvenile salmon freshwater residency in early May, mid-May, and mid-June 2002. The concentrations of chromium in fish and river water were measured and the overall conditions of the fish were evaluated. Sample collection focused on the 100-D and 100-H Areas, which were the locations most likely to have elevated chromium concentrations in the environment based on groundwater monitoring data. The Vernita Bridge area served as an upstream reference site for all samples.

All Columbia River water concentrations for chromium determined during this study were less than or equal to 0.1 µg/L, which were below the Washington State ambient surface-water quality criteria of 10 µg/L. Body burdens of chromium were not statistically different for fish collected at the 100-D and 100-H Areas compared to the Vernita Bridge location; thus, there was no indication of elevated exposure or uptake of Hanford sources of chromium. No gross morphological anomalies were noted in any fish collected during this effort. Histological assessments for fish examined during this study exhibited normal and healthy tissues and comparison of fish body lengths and weights from these locations revealed no evidence of physiological stress for organisms collected near the 100-D or 100-H Areas. Taken collectively, these results indicated that there was no impact to juvenile fall Chinook salmon from chromium released into the Columbia River from Hanford during 2002.

Acknowledgments

The authors wish to acknowledge the support of Paul Hoffarth and staff of the Washington State Department of Fish and Wildlife who provided the sampling boat, seining equipment, and valuable expertise for the fish collections. Rhett Zufelt assisted in preparing and categorizing the biological samples and report graphics. Brenda Lasorsa and other Marine Sciences Laboratory staff provided analytical services and technical support. Craig McKinstry assisted in data reduction and statistical analysis. Geoff McMichael provided peer review support. Launa Morasch and Jennifer Zohn provided editorial reviews and Rose Urbina provided text formatting.

Contents

Figures

Table

1.0 Introduction

The Hanford Reach of the Columbia River is an important spawning and rearing area for fall Chinook salmon (*Oncorhynchus tshawytscha*) (Dauble and Watson 1997). The Hanford Reach is also home to the U.S. Department of Energy's (DOE's) Hanford Site where production of nuclear materials for national defense resulted in the discharge of substantial amounts of contaminants to the river and the soil column adjacent to the river (Figure 1). Hexavalent chromium is a contaminant of concern for the Hanford Site because of its use as a corrosion inhibitor for cooling water systems in the nuclear reactors. Direct discharges of chromium to the river ended with the shutdown of the last single-pass reactor in 1971; however, residual chromium is still present in the soil column, groundwater, and some biota (Poston et al. 2002, Patton et al. 2003).

Monitoring of groundwater and riverbank spring water has detected concentrations of chromium above the 100 µg/L drinking water standard at the 100-D, 100-H, 100-K, and 100-N Areas (Poston et al. 2002). The maximum concentration of chromium detected in Hanford groundwater in 2002 was 5,300 µg/L at the 100-D Area (Poston et al. 2003); however, the area where this plume intersects the Columbia River has a low potential for salmon spawning (Mueller and Geist 1998). Hexavalent chromium above the Washington State ambient surface-water quality criteria of 10 µg/L has been documented in Hanford groundwater upwelling into the Columbia River (Hope and Peterson 1996). The effects of hexavalent chromium on juvenile Chinook salmon have been evaluated by several studies (Olson and Foster 1956; Buhl and Hamilton 1991; Geist et al. 1994; Farag et al. 2000; Patton et al. 2001; and Dauble et al. 2002). However, no study has assessed chromium exposure and uptake in wild juvenile salmon from areas of the Hanford shoreline near the contaminated groundwater plumes.

Juvenile fall Chinook salmon were seined and water samples were collected from three locations in the Hanford Reach during the period of the juvenile salmon residency: early May, mid-May, and mid-June 2002. Samples collected from near the Vernita Bridge area served as an upstream reference (i.e., no exposure to Hanford groundwater contaminants) for comparison with those collected from the 100-D and 100-H Areas. Fish collected from the 100-D and 100-H Areas may have spent some portion of their time in shoreline areas where chromium groundwater plumes enter the river; however, it was not possible to determine the exposure periods (if any) for fish collected at these locations.

2.0 Objectives

The objective of this study was to evaluate the concentrations of chromium in juvenile fall Chinook salmon and river water from the Hanford Reach and to assess overall condition of the organisms collected. This study will assist in determining whether the juvenile salmon are at risk from exposure to chromium entering the Columbia River from groundwater at the Hanford Site during their freshwater rearing period (approximately March through June [Becker 1973]).

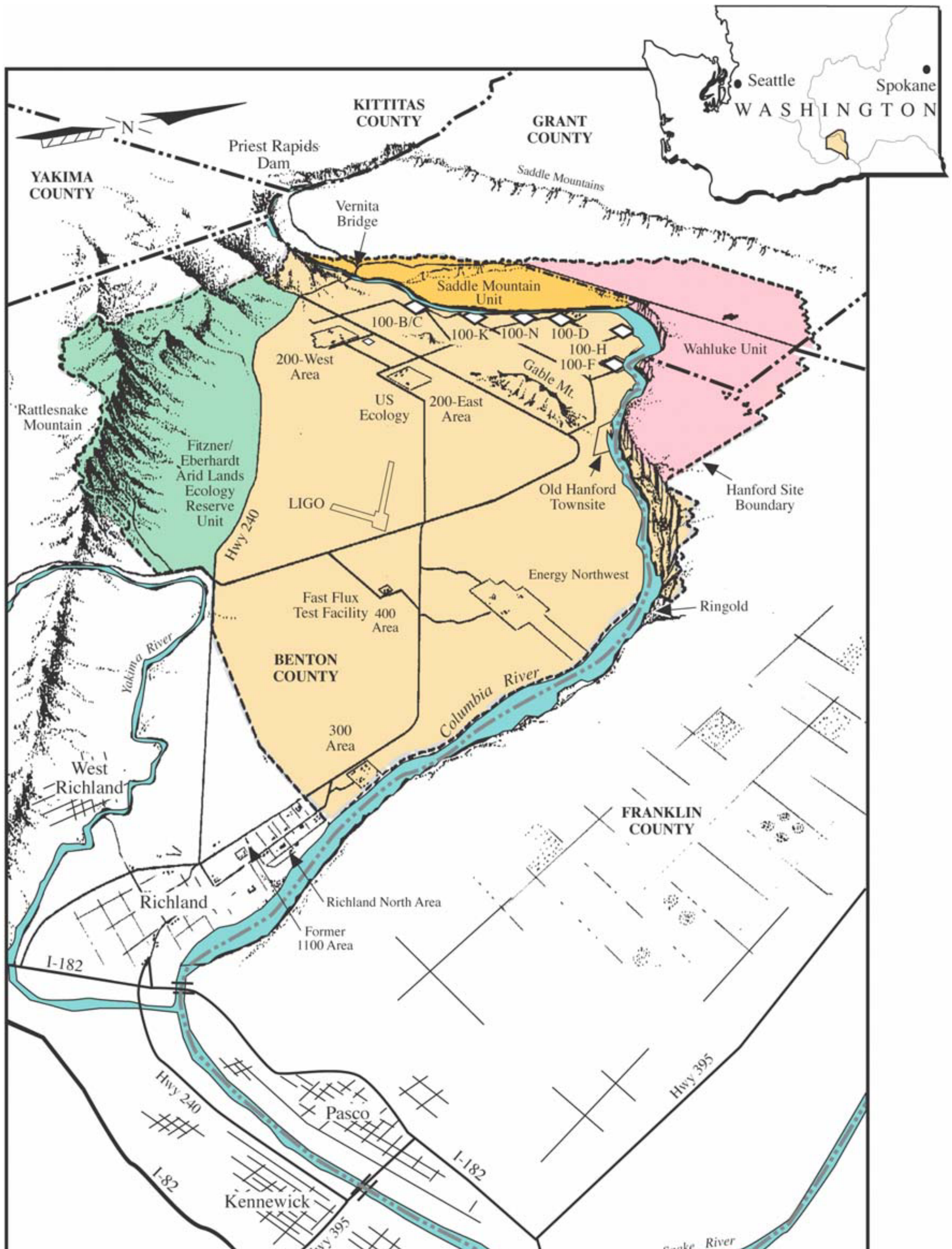

Figure 1. Hanford Site Location Map

This work was performed by Pacific Northwest National Laboratory (PNNL) at the request of DOE to address stakeholder requests and was conducted as part of the Hanford Site's Public Safety and Resource Protection Program (PSRPP). In addition, this work will support ongoing efforts for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) requirements that require assessments of potential ecological impacts from contaminated groundwater near several Superfund Sites located along the Hanford Reach of the Columbia River.

In addition, selected samples of juvenile fall Chinook salmon and river water were analyzed for a suite of metals to support PSRPP environmental assessment objectives beyond the scope of this report. These results are provided as an appendix to this report but are not discussed in detail.

3.0 Sample Collection and Analysis Methods

3.1 Sample Locations

Samples of fish and water were collected along the shorelines of the 100-D Area, 100-H Area, and upstream of the Vernita Bridge (Figure 2). The 100-D and 100-H Areas were chosen based on elevated chromium concentration measured in riverbank springs and shallow groundwater emerging into the shoreline areas of the Columbia River (Poston et al. 2002). The fish were collected in rearing areas directly downstream from the 100-D and 100-H groundwater plumes containing elevated chromium. The riparian habitat near these sites is largely comprised of a mixture of reed canary grass (*Phalaris arundinacea*) and scattered mulberry trees (*Morus alba*). River substrate consists of a mixture of sand/silt and cobble typically between 60- and 400-centimeter-size classes.

Vernita Bridge (reference area). For the May 1, 2002 and June 10, 2002 sampling events, the fish samples were collected on the Benton County shoreline approximately 1 to 2 kilometers above the Vernita Bridge. On May 17, 2002, elevated river stage (above 6,750 m^3/sec) resulted in no fish being collected at the previous location despite multiple attempts; thus, samples were collected on the Grant County shoreline approximately 500 meters above the major electrical power line crossing at Midway, Washington.

100-D Area. The sample collection location for the 100-D Area was on the Hanford shoreline, approximately 200 to 300 meters downriver from the riverbank spring (100-D Spring 110-1; Bisping 2002), near the old ferry landing at the downstream side of 100-D Island. Attempts to collect fish directly at the riverbank spring location were not successful because of the small numbers present.

100-H Area. The sample collection location for the 100-H Area was on the Hanford shoreline, approximately 50 to 400 meters downriver from the 100-H Area concrete outfall structure. Several riverbank springs (100-H Spring 145-1, 100-H Spring 152-2; Bisping 2002) emerge in the vicinity of the concrete outfall structure.

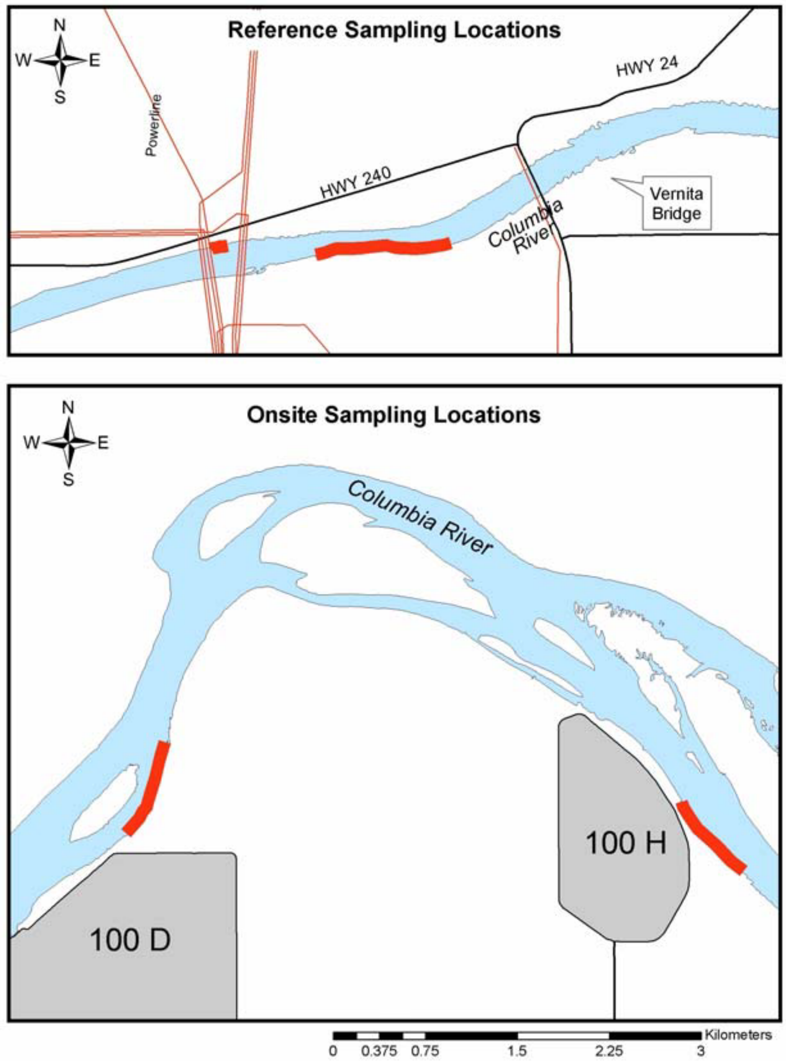

Figure 2. Fish and Water Sampling Locations

3.2 Analysis of Water Samples

Eighteen water samples (i.e., duplicate samples at three locations on three dates) were collected using a MasterFlex peristaltic pump to push water through a Geotech 0.45 µm high-volume filter and into a plastic sampling bottle. The samples were collected within 1 meter of the river shoreline. The samples were shipped to the Marine Sciences Laboratory (Sequim, Washington) for analysis. Water samples were analyzed for metals using inductively coupled plasma-mass spectrometry (ICP-MS) in accordance with Battelle Standard Operating Procedure *MSL-I-022; Determination of Elements in Aqueous and Digestate Samples by ICP/MS.* Samples were analyzed for aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, nickel, selenium, silver, thallium, uranium, and zinc. These samples provided "point-in-time" concentrations of chromium and other constituents present in river water where and when the fish were collected.

Quality control analysis for the water samples included duplicate, matrix spike, method blank, and comparison to standard reference materials (Appendix A).

3.3 Analysis of Fish Tissues

Individual fish samples were weighed, measured for fork length, rinsed with deionized water, and placed into pre-cleaned sample containers. The frozen samples were sent to the Marine Sciences Laboratory for analysis of whole-body metal concentrations. Tissue samples from the early-May collection period were digested using a nitric acid total digestion process based upon U.S. Environmental Protection Agency (EPA) Method 200.2. Tissue samples from the mid-May and mid-June collection periods were digested according to Battelle Standard Operating Procedure MSL-I-024, *Mixed Acid Tissue Digestion* using nitric and hydrochloric acids (aqua regia). For both digestion methods, the entire dried fish sample was combined with acid in glass scintillation vials and heated on a hot plate to approximately 130ºC (±10ºC). After heating and cooling, deionized water was added to the acid-digested tissue to achieve analysis volume and the digestates were submitted for analysis.

Digestates were analyzed for all metals by ICP-MS in accordance with Battelle Standard Operating Procedure *MSL-I-022; Determination of Elements in Aqueous and Digestate Samples by ICP/MS.* All samples were analyzed for chromium, with selected samples analyzed for an additional suite of metals (aluminum, antimony, arsenic, beryllium, cadmium, copper, lead, manganese, nickel, selenium, silver, thallium, thorium, uranium, and zinc).

3.4 Fish Condition Assessments

Fish collected for contaminant analyses (n=164) were inspected for gross anatomical anomalies and general condition. A condition factor index (K) was calculated using Equation 1 (Williams 2000):

$$K = 100\ W / L^3 \qquad (1)$$

where W = body weight in grams
L = body length (fork length) in mm.

The general external conditions of all fish submitted for contaminant analyses were observed and recorded immediately after the samples were obtained from the field.

When adequate numbers of fish were obtained, up to 10 additional fish per each location and time interval were retained and preserved in phosphate-buffered formalin for histological evaluation. Histological injuries observed in the gills, liver, and kidney sample may be used as an indication of impacts to the organism from excessive exposure to chromium. A total of 29 fish were collected from the Vernita Bridge, 100-D Area, and 100-H Area locations during the first sampling event (May 1-3), preserved in the field, and transported to a diagnostic laboratory at Oregon State University. These fish samples were set in paraffin, sectioned at 4 µm, stained with hemotoxylin and eosin, and evaluated by Oregon State University staff pathologists using light microscopy. Additional specimens collected during later sampling periods were archived at PNNL.

4.0 Results and Discussion

Analytical results for chromium for water and fish samples collected for this study are presented and discussed in this section. In addition, data on fish condition are also included. For other metals (i.e., non chromium), the analytical results and a limited discussion is provided in Appendix B.

4.1 Chromium Concentrations in Columbia River Water

Chromium was below the detection limit of 0.024 µg/L for all samples, except for one of two samples collected on May 1, 2002, at the 100-D Area that was 0.093 µg/L. The detection limit for chromium was well below the Washington State ambient water quality criteria of 10 µg/L (WAC 173-201A).

4.2 Chromium Concentrations in Fish Tissues

Chromium concentrations in fish tissues are provided in Appendix B and summarized in Figure 3. Chromium levels in fish ranged from 1.1 to 9.4 µg/g dry wt., with 98% of the values between 1.5 and 4.8 µg/g dry wt. Figure 4 uses a box plot to illustrate a slight increase in total chromium concentration through time and a general decrease in variation. Notches on the box plot provide an approximate (α = 0.05) significance level for pairwise comparisons, where non-overlapping notches suggest a statistical difference in medians between the data sets. Comparison of the notches in Figure 4 suggests no clear difference in chromium concentrations within or between sampling periods.

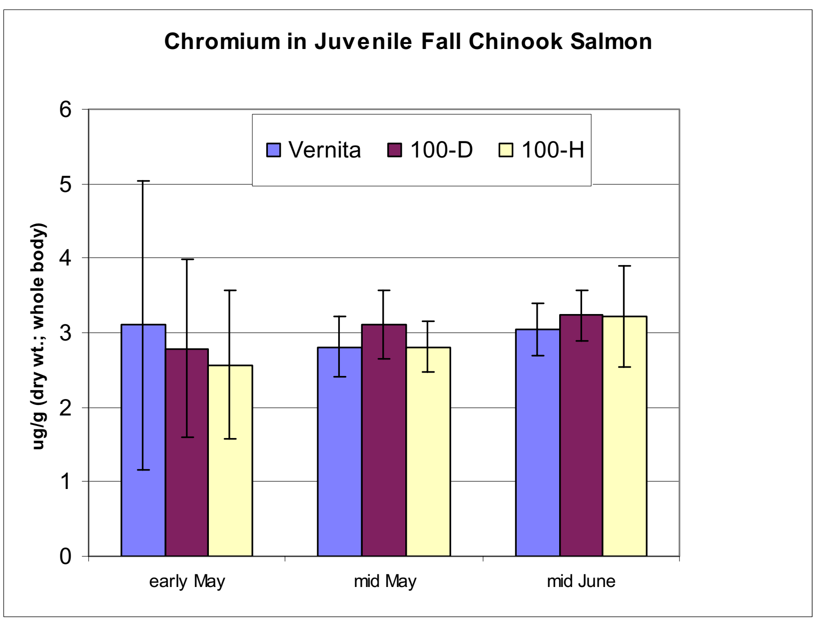

Figure 3. Average Concentrations (± 1 standard deviation) of Chromium in Whole Body Tissues of Juvenile Fall Chinook Salmon from the Hanford Reach

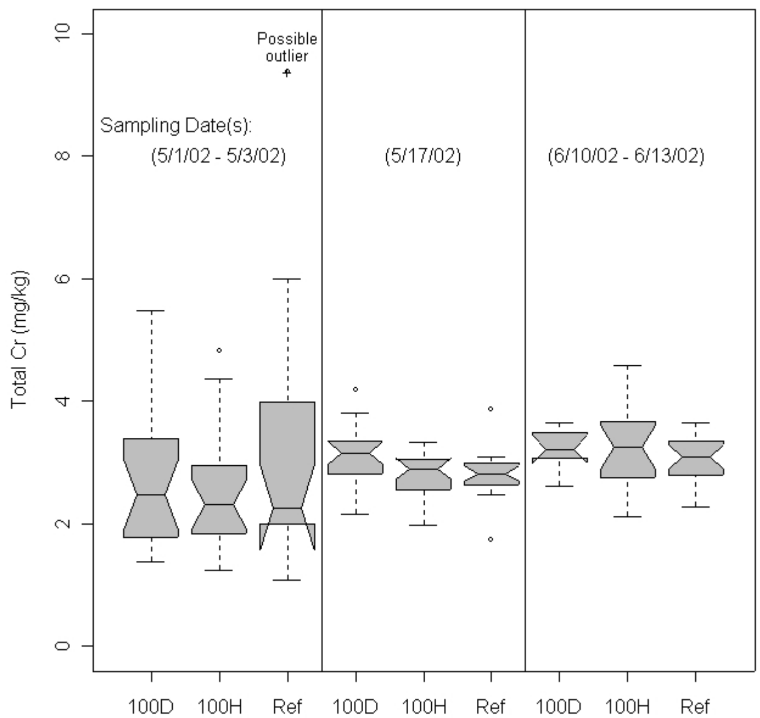

Figure 4. Box Plots Comparing Chromium Tissue Concentrations from Three Study Sites (100-D, 100-H, and an Upriver Reference Site near the Vernita Bridge). A possible outlier value is shown for the reference location in sampling period 1. Non-overlapping notches would suggest a statistically significant difference ($\alpha = 0.05$) in medians between the two distributions; however, no clear differences were observed.

Table 1 shows an analysis of variance matrix that confirms the general findings of the data shown in Figure 4. The conclusions to be drawn from this analysis are that when the effects of time have been removed, there is no evidence of systematic differences in total chromium concentrations in fish tissue among any of the three sites. This precludes the need for assessing a difference between the two study sites (100-D and 100-H Areas) taken together and the reference site.

In general, chromium concentrations (average of 3 µg/g dry wt.) reported for juvenile salmon collected at all three locations for this study were considerably higher than the levels reported for control fish (0.4 µg/g dry wt.) used during a laboratory-based early-life-stage toxicity test for chromium. The

Table 1. Analysis of Variance (ANOVA) for Total Chromium Concentration. The outlier shown in Figure 4 was omitted from the analysis. (Df = degrees of freedom.)

Model	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			163	142.22		
Sampling Period	2	2.75	161	139.47	1.58	0.21
Location	2	1.03	159	138.44	0.59	0.55

laboratory-based test used chromium contaminated groundwater from the 100-D Area and Hanford Reach fall Chinook salmon that were incubated and reared in Columbia River water taken from the 300 Area (Patton et al. 2001). The tissue chromium levels observed for the Hanford Reach fish from this study were similar to the mean concentration of 2.6 μg/g dry wt. reported for the early-life-stage fish exposed to chromium water concentrations of 266 μg/L. For the laboratory-based toxicity testing, fish were sacrificed at a younger age (fork lengths less than 40 mm) compared to the Hanford Reach fish (fork lengths between 40 and 60 mm) collected for this current study (Appendix F). The most likely reason for the elevated chromium levels in the fish collected from the Hanford Reach compared to the laboratory-based test fish was higher uptake of chromium from the fish's diet in the Columbia River. The laboratory-based test fish that were reared in the lab were not fed until swimup (i.e., transition from bottom dwelling to free swimming), and after swimup, the fish were fed a commercially produced fish food.

Chromium concentrations measured in the whole body of juvenile salmonids did not indicate elevated exposure and uptake for fish collected from near the 100-D or 100-H Areas compared to the reference location. Chromium concentrations were reported above the analytical detection limit for all fish. Fish samples collected early during the outmigration period (May 1-3, 2002) likely represented fish from local origin, whereas subsequent sampling events likely represented the juvenile Chinook populations-at-large.

4.3 Condition Assessments

Health-assessment endpoints chosen for the juvenile Chinook salmon collected during this effort included comparison of tissue (whole body) concentrations of contaminants in areas of concern; gross external examination (external condition and external morphological anomalies); physical measurements (body weights, body lengths, condition factors); and histological evaluations for early indications of target tissue damage.

The lack of elevated tissue burdens of chromium for 104 individual organisms collected near the most likely chromium exposure sites provides evidence that deleterious impact to juvenile Chinook salmon from chromium entering the Columbia River at the 100-D and 100-H Areas is not likely.

4.3.1 Gross External Examinations

No gross external morphological anomalies were observed for any fish examined during this study. No external abrasions or lesions were found for fish collected during the first sampling event (May 1, 2002). During the second sampling event (May 17, 2002), 5 of the 20 fishes collected from the 100-H Area were noted to have a red-coloration (indicative of bruising/hemorrhage of the tissue) at the base of one, or both, pectoral fins. One of those fish also exhibited red-coloration along the seam of the abdomen and four small focal abrasions along the left side of its body and appeared to extend into the subcutaneous tissues. The abrasion appeared to be a recent injury, with little evidence of activation of tissue repair mechanisms or the presence of secondary infections. One fish of 20 collected near the Vernita Bridge during the second sampling event also exhibited red-coloration in the skin near the left pectoral fin, similar to the abrasions observed in some of the fish collected near the 100-H Area. No indications of external injury were noted in any fish collected during the third sampling event (June 10, 2002).

Appearance of bruises such as these recorded for 5 of 57 (8%) juvenile Chinook salmon from the 100-H Area and 1 of 60 (2%) fish from the upstream reference sites near the Vernita Bridge were likely related to physical injury of the fish during the field sampling events. The collection technique consisted of dragging a large net through the emergent vegetation in the near shore environment during high river flows and these physical injuries most likely occurred during sampling. The sampling site near the 100-H Area was particularly difficult and fish entrapment was only successful in areas with a heavy cover of reed canary grass (*Phalaris arundinacea*).

4.3.2 Body Weights

Whole body weights were obtained from each fish collected and analyzed for contamination (Appendix C). Average and maximum body weights generally increased at all sites over the course of the three sampling periods. In early May, mean (± 1 standard error) body weights ranged from 0.66 ± 0.03 g at the 100-D Area to 0.9 ± 0.05 g at the 100-H Area. By the third sampling period (June 10, 2002), mean body weights ranged between 0.85 ± 0.06 g near the Vernita Bridge to 1.4 ± 0.15 g near the 100-D Area.

4.3.3 Body Lengths (Fork Length)

Average and maximum body lengths also increased slightly at all sites over the course of the three sampling periods (Appendix C) and closely corresponded to the organisms body weight for all fish measured (r^2=0.95, $p < 0.001$). Mean and maximum fish body lengths obtained from the upstream reference area were slightly less than, or equal to, fish obtained from the 100-D and 100-H Areas during all three sampling events. In early May, mean (±1 standard error) body lengths ranged from 42 ± 0.6 mm at the 100-D Area to 44 ± 0.7 mm at the 100-H Area. By the third sampling period (June 10, 2002), mean body lengths ranged between 44 ± 0.7 mm near the Vernita Bridge area to 51 ± 1.8 mm near the 100-D Area. The observation that fish sizes were generally larger downstream of the Vernita Bridge area is consistent with findings that 30% to 40% of the fall Chinook salmon spawn upstream of the 100-K Area (Dauble and Watson 1997).

4.3.4 Body Weight to Length Ratios and Fish Condition Factors

The ratio between fish whole body weight to body length (head to fork of tail) was examined to identify fish with anomalously high or low ratios. Specific indices of condition have been developed for assessing overall health of several species of fishes (Williams 2000). Most notably, fish measured with an exceptionally low weight-to-length ratio may indicate the organism is stressed, either by physical injury, disease, dietary limitations, or poor water quality.

The mean weight-to-length ratio observed during this study was 0.02 ± 0.006 g/mm, (±1 standard deviation). The lowest weight-to-length ratio measured during this study (0.011 g/mm) did not exceed the lower-limit (0.009 g/mm) of the 95% confidence interval around the mean. Four of the 165 organisms measured were found to exceed the upper 95% confidence interval limits (greater than 0.033 g/mm). These four individuals were also among the largest salmon collected during this study, with body weights that exceeded 2.0 g and body lengths that were at least 53 mm. Three of these fish were collected from near the 100-D Area and one was collected from near the 100-H Area during the second and third sampling events.

Condition factors for salmonids were also calculated and used as a health index of the fish collected during this study. The regression of fish condition factor versus chromium concentration suggested no systematic change in the health index associated with differences in total chromium concentrations (Figure 5). No relationship between fish condition factors and chromium body burdens were apparent within each sampling period when datasets were examined in each sampling period separately.

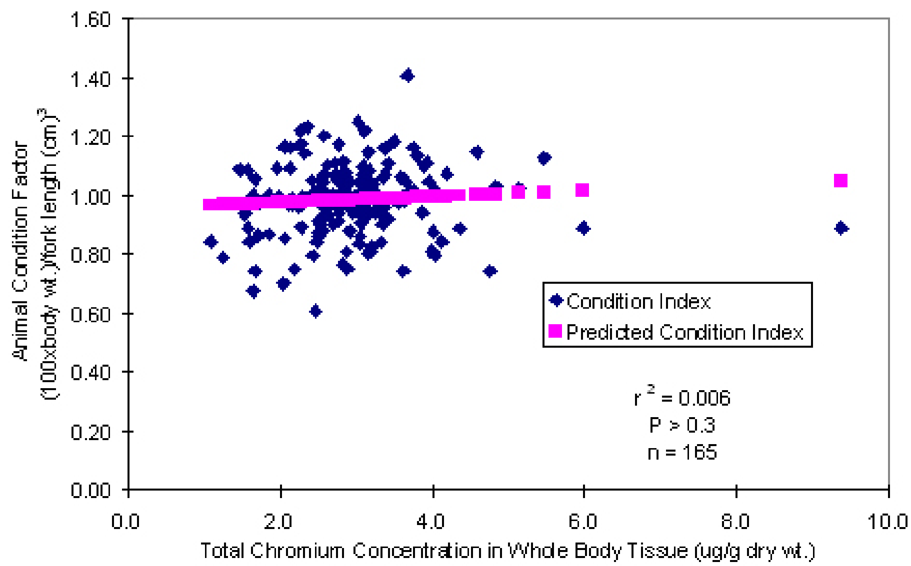

Figure 5. Regression of Fish Condition Factors and Total Chromium Body Burdens for All Sites Combined

4.3.5 Histology

Histological evaluations were performed on ten specimens obtained from each location during the first sampling event (May 1, 2002) by certified pathologists at Oregon State University. Tissues from all organs (except reproductive organs which at this life stage were too small to examine) were examined for signs of tissue injury or stress. The liver, kidneys, and gills are target organs for early indications of injury induced by heavy metal contamination (Driver 1994). There were no indications of any tissue damage in any of the specimens examined. In addition, there were also no internal parasites or infections noted in any fish evaluated.

5.0 Conclusion

All Columbia River water concentrations for chromium determined during this study were less than or equal to 0.1 µg/L and were well below the Washington State ambient surface-water quality criteria of 10 µg/L.

Chromium body burdens in fish tissues were not significantly different at the 100-D and 100-H Areas compared to the Vernita Bridge location and there was no indication of elevated exposure or uptake of chromium near the 100-D and 100-H Areas. The lack of elevated body burdens of chromium in juvenile fall Chinook salmon from near the 100-D and 100-H Areas indicate that impacts from chromium from Hanford sources released into the Columbia River are not likely. Furthermore, no gross morphological anomalies were noted in any fish collected during this effort. The histological assessments for all fish examined during this study exhibited normal and healthy tissues. Examination of the physical measurements of fish body lengths and weights revealed no excessively thin organisms were collected near the 100-D or 100-H Areas.

Signs of physical trauma (red-colorations, "bruising," and abrasions) observed on some individual specimens from the 100-D Area and from the Vernita Bridge location were noted; however, the injuries were likely directly related to the capture technique. In addition, the bruising and abrasions are not an expected manifestation of injury from excessive exposure to chromium. No other signs of injury, such as target tissue damage (histological evidence of kidney or liver damage) or compromised condition factors were apparent, as would be expected if excessive exposure to the heavy metals were the causative agents.

Collectively evaluated, ambient water concentrations, tissue body concentrations of chromium, and fish condition assessments provided in this report indicated that juvenile fall Chinook salmon found near the 100-D and 100-H Areas were not likely adversely affected as a result of chromium in Hanford groundwater entering the Columbia River.

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Appendix A

Results and Discussion for Quality Control Samples

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A.1 Quality Control Results for Water Samples

One method blank was analyzed with the water samples. The concentration of metals in the blank were below the method detection limit, with the exception of antimony, arsenic, chromium, manganese, and thorium which were less than 10 times the method detection limit. One matrix spike was analyzed with the set of water samples. The native sample was spiked at 20 µg/L for all metals. The percent recoveries for all analytes were within the quality control criterion of 75% to 125%. Two standard reference materials were analyzed with the set of samples: National Institute of Standards and Technology (NIST) 1640 (trace elements in natural water) and National Research Council Canada SLRS-3 (riverine water reference material). Analytical accuracy for each standard reference material was expressed as the percent difference between the measured and certified values. Recoveries for NIST 1640 were within the quality control criterion of ±25% for all certified analytes. The standard SLRS-3 was analyzed to provide a lower range standard reference material as well as a reference value for uranium. The recoveries for SLRS-3 were within the quality control criterion of ±25%, with the exception of antimony (30%), chromium (33%), and zinc (113%). However, acceptable accuracy for these metals was demonstrated in the recoveries for NIST 1640.

A.2 Standard Reference Materials Results for Fish Samples

A.2.1 Full Metals Suite

Three replicates of certified reference material DORM-2 (dogfish muscle) and three replicates of certified reference material DOLT-2 (dogfish liver) were analyzed with the set of samples. The analytical accuracy of the standard reference material assays was expressed as the percent difference between the measured and certified values. Recoveries for DORM-2 were within the quality control criterion of ±25% for a minimum of one replicate for arsenic, cadmium, chromium, copper, lead, manganese, nickel, selenium, silver, and zinc. Recoveries were outside of the quality control limit for all replicates for aluminum, and cadmium. The incorporation of stainless steel into the standard reference material DORM-2 complicates the analysis because stainless steel is more difficult to digest than fish tissue, thus the low recoveries of this standard reference material may be attributed to the digestion method. However, the integrity of the samples should not be compromised, as this digestion is frequently used for fish tissue.

Recoveries for DOLT-2 were within the quality control criterion of ±25% for a minimum of one replicate, with the exception of aluminum, chromium, and arsenic. Certified values for chromium, nickel, selenium, and cadmium were less than 10 times the detection limit, which enhanced the variation for these recoveries.

Chromium and Uranium Suite. Eight replicates of the certified reference material DORM-2 and eight replicates of the certified reference material DOLT-2 were analyzed for chromium with the set of samples. No certified value for uranium was provided for these standards. Recoveries for DORM-2 were within the quality control criterion of ±25% for only two samples, with low recovery for the other samples. The incorporation of stainless steel in the DORM-2 standard elevates the level of chromium above average native samples. Since stainless steel is more difficult to digest than fish tissue, the low recoveries of this standard reference material may be attributed to the digestion method. However, the integrity of the samples should not be compromised, as this digestion is frequently used for fish tissue. Recoveries for DOLT-2 were outside the quality control criterion of ±25% for all samples, as chromium is certified at 0.37 µg/g and the method detection limit was 0.34 µg/g.

A.3 Quality Control Results for Fish Samples

A.3.1 Method Blanks for Fish Samples

Full Metals Suite. Three method blanks were analyzed with the set of samples analyzed for the full suite of metals. Concentrations were either below the method detection limit or less than ten times the method detection limit for all metals, with the exception of antimony. Additional evaluation determined that the specific lot of hydrochloric acid used in the digestion was contaminated for antimony; therefore, all values are suspect. No corrective action was taken due to lack of additional sample material.

Chromium and Uranium Suite. Eight method blanks were analyzed with this set of samples with all concentrations below the method detection limits.

A.4 Spike Recovery for Fish Samples

Full Metals Suite. Three matrix spikes were analyzed with the set of samples analyzed for the full metals suite. Approximately 25 µg/g of all metals were spiked on the National Research Council Canada standard reference material DOLT-2 (dogfish liver) because of the lack of native samples. The percent recoveries for the majority of the matrix spike samples were within the quality control limits of 75% to 125%, with the exception of one matrix spike for aluminum (135%) and antimony (57%) and two matrix spikes for thorium (2% and 16%). Three laboratory control samples were spiked at 25 µg/g and analyzed with the set of samples analyzed for the full metals suites. The percent recoveries for the majority of the laboratory control samples were within the quality control limits of 75% to 125%, with the exception of one laboratory control sample for antimony (316%) and three laboratory control samples for thorium (30%, 138%, and 140%).

Chromium and Uranium Suite. Eight matrix spikes were analyzed with the set of samples. Approximately 25 µg/g of all metals were spiked on the standard reference material DOLT-2 due to lack of native samples. The percent recoveries for all analytes were within the quality control criterion of 75% to 125%. Eight laboratory control samples were spiked at 25 µg/g and analyzed with the set of samples. The percent recoveries for all analytes were within the quality control criterion of 75% to 125%.

Appendix B

Results for Chromium and Other Metals in Columbia River Water and Juvenile Fall Chinook Salmon Samples

Appendix B

Results for Chromium and Other Metals in Columbia River Water and Juvenile Fall Chinook Salmon Samples

B.1 Results and Discussion for Selected Metals (other than chromium) for Columbia River Water and Juvenile Fall Chinook Salmon Samples

B.1.1 River Water

The results for filtered water samples analyzed for aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, manganese, nickel, lead, selenium, silver, thallium, thorium uranium, and zinc are shown in Table B.1. Aluminum, antimony, arsenic, cadmium, copper, lead, manganese, nickel, selenium, thallium, uranium, and zinc were above the detection limits for the majority of samples. All detected concentrations of metals in river water were below Washington State ambient water quality criteria (WAC 173-201A). The levels of metals in river water collected for this study were similar to concentrations reported for Columbia River water samples analyzed in 2001 and 2002 (Poston et al. 2002; Poston et al. 2003). Beryllium was below the detection limit (0.028 µg/L) for all water samples. Silver was below the detection limit of 0.004 µg/L for all samples, with one exception at the 100-H Area (0.006 µg/L), which was near the detection limit. Thorium was below the detection limit of 0.042 µg/L for all samples, except for one sample at the Vernita Bridge location (0.073 µg/L), which was near the detection limit. All detection limits for metals were well below Washington State ambient water quality criteria (WAC 173-201A).

There were only minor differences in metal concentrations for water samples collected at the 100-D and 100-H Areas and the background location. For the first sampling event (May 1-3, 2002), the aluminum concentrations were roughly twice as high at the 100-H Area compared to the other locations; however, for the remaining sampling events the concentration were similar at all locations. In general, the concentrations of aluminum, manganese, and zinc were slightly elevated at the 100-H Area and more variable compared to both the 100-D Area and the background location. The background location was slightly elevated for lead compared to the other locations.

B.1.2 Fish Tissues

The results for fish samples analyzed for metals (all samples were individual whole body) are given in Tables B.2, B.3, B.4, and B.5. Fish collected during the first sampling event (May 1-3, 2002) were analyzed for a wide suite of metals, whereas the fish were only analyzed for chromium and uranium for the remaining sampling events. Uranium was analyzed for all samples to support other Hanford Site assessments. For most metals the background location above Vernita Bridge had slightly higher average and maximum concentrations in the whole body fish samples compared to the 100-D and 100-H Areas. Antinomy results are suspect because the acid used for the digestion process was contaminated (see

Table B.2). All uranium concentrations in whole body tissue were below the detection limits (0.04 to 0.05 µg/g), with the exception of one sample of 0.51 µg/g collected at the background location (Table B.3).

B.1.3 References

Poston TM, RW Hanf, RL Dirkes, and LF Morasch (eds.). 2002. *Hanford Site Environmental Report for Calendar Year 2001*. PNNL-13910, Pacific Northwest National Laboratory, Richland, Washington.

Poston TM, RW Hanf, RL Dirkes, and LF Morasch (eds). 2003. *Hanford Site Environmental Report for Calendar Year 2002*. PNNL-14295, Pacific Northwest National Laboratory, Richland, Washington.

WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." Washington Administrative Code, Olympia, Washington.

Table B.1. Metal Concentrations in Filtered Columbia River Water Samples (µg/L)

Location	Event	Date	Ag	Al	As	Be	Cd	Cr	Cu	Mn	Ni	Pb	Sb	Se	Th	Tl	U	Zn
Vernita	1	5/3/2002	**0.004**	8.12	0.528	**0.028**	0.0181	**0.024**	0.688	0.852	0.793	0.00735	0.197	0.107	**0.0423**	0.0144	0.542	2.82
Vernita	1	5/3/2002	**0.004**	9.17	0.548	**0.028**	0.0173	**0.024**	0.796	0.936	0.892	0.00638	0.212	0.115	**0.0423**	0.0142	0.561	2.61
Vernita	2	5/17/2002	**0.004**	0.465	0.607	**0.028**	0.0174	**0.024**	0.646	1.88	0.770	0.0112	0.273	0.0884	**0.0423**	0.0188	0.601	3.46
Vernita	2	5/17/2002	**0.004**	0.654	0.610	**0.028**	0.0163	**0.024**	0.674	1.54	0.745	0.0118	0.256	0.131	0.0730	0.0196	0.589	2.73
Vernita	3	6/10/2002	**0.004**	6.43	0.632	**0.028**	0.0158	**0.024**	1.090	0.975	0.663	0.0978	0.176	0.0752	**0.0423**	0.0151	0.482	2.78
Vernita	3	6/10/2002	**0.004**	6.14	0.623	**0.028**	0.0148	**0.024**	0.785	0.991	0.658	0.0300	0.180	0.127	**0.0423**	0.0160	0.475	2.59
100-D	1	5/1/2002	**0.004**	10.7	0.542	**0.028**	0.0161	0.093	0.607	0.640	0.741	**0.005**	0.201	0.107	**0.0423**	0.0138	0.554	2.86
100-D	1	5/1/2002	**0.004**	11.3	0.517	**0.028**	0.0187	**0.024**	0.610	0.691	0.823	**0.005**	0.244	0.146	**0.0423**	0.0140	0.545	2.83
100-D	2	5/17/2002	**0.004**	1.090	0.556	**0.028**	0.0189	**0.024**	0.659	1.12	0.702	0.00662	0.224	0.161	**0.0423**	0.0164	0.517	3.39
100-D	2	5/17/2002	**0.004**	0.476	0.548	**0.028**	0.0175	**0.024**	0.678	1.11	0.762	0.00932	0.226	0.109	**0.0423**	0.0167	0.531	3.46
100-D	3	6/10/2002	**0.004**	6.15	0.586	**0.028**	0.0142	**0.024**	0.701	1.020	0.625	0.0109	0.175	0.068	**0.0423**	0.0158	0.478	4.24
100-D	3	6/10/2002	**0.004**	6.92	0.632	**0.028**	0.0181	**0.024**	0.792	1.33	0.684	0.0190	0.203	0.124	**0.0423**	0.0160	0.509	3.09
100-H	1	5/1/2002	0.006	26.4	0.570	**0.028**	0.0188	**0.024**	0.632	1.16	0.808	0.0449	0.205	0.0961	**0.0423**	0.0137	0.569	4.64
100-H	1	5/1/2002	**0.004**	22.2	0.537	**0.028**	0.0184	**0.024**	0.616	1.55	0.848	0.0226	0.223	0.133	**0.0423**	0.0145	0.573	2.99
100-H	2	5/17/2002	**0.004**	0.339	0.538	**0.028**	0.0182	**0.024**	0.649	1.80	0.733	0.00749	0.238	0.116	**0.0423**	0.0163	0.557	7.52
100-H	2	5/17/2002	**0.004**	0.694	0.560	**0.028**	0.0170	**0.024**	0.648	2.05	0.718	0.00545	0.269	0.161	**0.0423**	0.0179	0.542	3.46
100-H	3	6/13/2002	**0.004**	4.96	0.615	**0.028**	0.0173	**0.024**	0.725	1.59	0.623	0.0181	0.196	0.108	**0.0423**	0.0155	0.497	2.56
100-H	3	6/13/2002	**0.004**	5.50	0.601	**0.028**	0.0172	**0.024**	0.751	2.12	0.641	0.0136	0.216	0.123	**0.0423**	0.0172	0.507	2.52

Bold = below detection limit.

Table B.2. Metals Concentrations in Whole Body Tissue of Juvenile Fall Chinook Salmon from the Hanford Reach (µg/g dry wt.)

Sample #	Sample Location	Date	Percent Dry Wt	Be	Al	Mn	Ni	Cu	Zn	As	Se	Ag	Cd	Sb[a]	Tl	Pb	Th
B14JV8	100-D	05/01/02	9.0	**0.074**	47.8	10.6	0.678	6.30	172	1.17	4.29	0.0500	0.401	*169*	0.314	0.193	0.0550
B14JV9	100-D	05/01/02	16.9	**0.074**	34.3	3.48	0.918	3.94	74.0	**0.213**	2.85	**0.036**	0.194	*8.42*	0.208	0.116	**0.021**
B14JW0	100-D	05/01/02	10.4	**0.074**	39.1	6.56	0.899	6.17	140	**0.213**	5.26	0.0660	0.385	*23.1*	0.464	0.185	**0.021**
B14JW1	100-D	05/01/02	11.3	**0.074**	37.1	5.86	1.78	5.66	125	0.600	3.16	0.0580	0.338	*23.6*	0.296	0.160	**0.021**
B14JW2	100-D	05/01/02	17.1	**0.074**	46.9	5.20	0.536	4.34	90.5	0.377	2.72	0.0420	0.231	*15.9*	0.208	0.198	0.0430
B14JW3	100-D	05/01/02	13.6	**0.074**	24.6	2.60	0.843	3.68	87.9	0.422	3.25	**0.036**	0.135	*25.9*	0.348	0.103	0.0470
B14JW4	100-D	05/01/02	15.3	**0.074**	18.6	2.61	1.12	2.89	71.7	**0.213**	3.88	**0.036**	0.0820	*36.3*	0.251	0.095	0.0310
B14JW5	100-D	05/01/02	11.5	**0.074**	38.0	3.37	0.450	4.47	109	0.939	7.55	**0.036**	0.127	*71.5*	0.282	0.195	0.0250
B14JW6	100-D	05/01/02	16.6	**0.074**	38.9	8.54	0.410	3.43	75.3	0.666	3.74	**0.036**	0.170	*55.9*	0.165	0.125	**0.021**
B14JW7	100-D	05/01/02	8.7	**0.074**	57.4	5.15	0.471	6.95	162	**0.213**	6.59	0.0430	0.299	*346*	0.475	0.289	0.0590
B14JX8	100-H	05/01/02	13.8	**0.074**	72.5	6.94	0.490	5.88	125	0.600	3.27	**0.036**	0.484	*9.15*	0.134	0.232	**0.021**
B14JX9	100-H	05/01/02	16.7	**0.074**	25.0	4.11	0.463	2.74	74.5	**0.213**	1.75	**0.036**	0.181	*2.36*	0.0890	0.0840	**0.021**
B14JY0	100-H	05/01/02	17.0	**0.074**	35.4	4.74	0.395	4.03	91.2	**0.213**	2.96	**0.036**	0.304	*2.59*	0.108	0.110	**0.021**
B14JY1	100-H	05/01/02	10.8	**0.074**	100	6.96	0.670	7.06	125	2.090	4.81	0.0490	0.406	*9.92*	0.321	0.625	**0.021**
B14JY2	100-H	05/01/02	16.0	**0.074**	17.5	1.67	0.235	1.94	37.5	**0.213**	1.24	**0.036**	0.0710	*3.46*	0.0970	0.0760	0.030
B14JY3	100-H	05/01/02	15.4	**0.074**	59.8	7.63	0.590	3.98	77.0	0.362	2.35	**0.036**	0.203	*6.83*	0.202	0.210	0.030
B14JY4	100-H	05/01/02	17.0	**0.074**	37.2	5.53	0.445	3.91	105	0.331	2.96	**0.036**	0.276	*3.89*	0.129	0.101	**0.021**
B14JY5	100-H	05/01/02	12.6	**0.074**	23.9	2.91	0.179	2.80	43.4	0.579	2.20	**0.036**	0.167	*7.42*	0.101	0.104	**0.021**
B14JY6	100-H	05/01/02	10.9	**0.074**	65.6	8.67	0.458	7.60	153	**0.213**	3.68	0.0400	0.581	*14.4*	0.231	0.209	**0.021**
B14JY7	100-H	05/01/02	11.1	**0.074**	75.7	6.59	0.457	6.25	118	2.48	5.82	**0.036**	0.304	*22.6*	0.266	0.190	**0.021**
B14K08	Vernita	05/03/02	18.1	**0.074**	27.8	3.39	0.134	4.12	88.4	0.213	2.82	**0.036**	0.238	*7.93*	0.167	0.0740	0.207
B14K09	Vernita	05/03/02	7.3	**0.074**	173	13.3	0.759	13.7	248	1.29	7.09	0.0990	0.732	*14.1*	0.438	0.539	0.152
B14K10	Vernita	05/03/02	13.7	**0.074**	60.3	6.92	1.15	6.30	124	0.705	3.57	**0.036**	0.357	*4.17*	0.139	0.219	0.0480
B14K11	Vernita	05/03/02	10.0	**0.074**	19.2	2.10	0.766	2.29	63.9	0.558	1.83	**0.036**	0.256	*5.52*	0.116	0.0770	0.0250
B14K12	Vernita	05/03/02	9.8	**0.074**	86.6	12.0	0.706	8.74	176	**0.213**	5.14	0.0460	0.791	*5.15*	0.216	0.264	0.0280
B14K13	Vernita	05/03/02	17.0	**0.074**	35.3	5.00	0.416	4.25	91.5	1.15	3.39	0.0560	0.316	*3.65*	0.143	0.0960	**0.021**
B14K14	Vernita	05/03/02	18.0	**0.074**	22.5	1.94	0.038	1.82	40.4	**0.213**	1.51	**0.036**	0.168	*2.60*	0.0550	0.0612	**0.021**
B14K15	Vernita	05/03/02	15.3	0.350	19.6	2.28	0.316	2.00	43.6	0.400	2.47	0.314	0.617	*5.31*	0.537	0.526	0.704
B14K16	Vernita	05/03/02	10.9	**0.074**	96.9	6.68	0.268	6.18	107	1.53	6.24	**0.036**	0.0970	*10.8*	0.229	0.198	0.0680
B14K17	Vernita	05/03/02	5.1	**0.074**	138	26.3	2.14	12.9	288	3.91	11.9	0.0810	0.932	*40.4*	0.663	0.360	0.0600

Bold = Value was below the listed detection limit.
(a) Contamination in analytical blank, data suspect.

Table B.3. Chromium and Uranium in Whole Body Tissues of Juvenile Fall Chinook Salmon from the Vernita Bridge Area of the Hanford Reach (µg/g, dry wt.)

Heiss #	Date	% Dry Wt	Cr	U	Heiss #	Date	% Dry Wt	Cr	U
B14K08	05/03/02	18.1	2.06	**0.053**	B14KY7	05/17/02	16.0	2.91	**0.043**
B14K09	05/03/02	7.3	5.99	**0.053**	B14KY8	05/17/02	16.2	2.72	**0.043**
B14K10	05/03/02	13.7	4.04	**0.053**	B14KY9	05/17/02	14.6	3.10	**0.043**
B14K11	05/03/02	10.0	2.13	**0.053**	B14LO0	05/17/02	14.7	2.77	**0.043**
B14K12	05/03/02	9.8	3.95	**0.053**	B14LO1	05/17/02	15.4	2.70	**0.043**
B14K13	05/03/02	17.0	2.30	**0.053**	B14LO2	05/17/02	15.0	2.73	**0.043**
B14K14	05/03/02	18.0	1.09	**0.053**	B14LO3	05/17/02	15.6	2.95	**0.043**
B14K15	05/03/02	15.3	1.58	0.508	B14LO4	05/17/02	15.2	3.87	**0.043**
B14K16	05/03/02	10.9	3.61	**0.053**	B14LO5	05/17/02	20.8	1.73	**0.043**
B14K17	05/03/02	5.1	9.37	**0.053**	B14PT7	06/10/02	15.6	2.89	**0.043**
B14JY8	05/03/02	10.7	2.88	**0.043**	B14PT8	06/10/02	17.7	3.42	**0.043**
B14JY9	05/03/02	8.5	4.03	**0.043**	B14PT9	06/10/02	17.0	2.77	**0.043**
B14K00	05/03/02	6.8	4.76	**0.043**	B14PV0	06/10/02	16.9	3.50	**0.043**
B14K01	05/03/02	18.9	1.67	**0.043**	B14PV1	06/10/02	17.4	3.65	**0.043**
B14K02	05/03/02	14.9	2.23	**0.043**	B14PV2	06/10/02	16.4	3.35	**0.043**
B14K03	05/03/02	15.5	2.04	**0.043**	B14PV3	06/10/02	16.6	2.72	**0.043**
B14K04	05/03/02	16.5	1.96	**0.043**	B14PV4	06/10/02	17.1	2.85	**0.043**
B14K05	05/03/02	13.8	2.50	**0.043**	B14PV5	06/10/02	16.1	2.28	**0.043**
B14K06	05/03/02	17.7	1.67	**0.043**	B14PV6	06/10/02	17.0	3.34	**0.043**
B14K07	05/03/02	13.0	2.15	**0.043**	B14PV7	06/10/02	16.3	3.07	**0.043**
B14KX6	05/17/02	17.3	3.07	**0.043**	B14PV8	06/10/02	43.3	2.83	**0.043**
B14KX7	05/17/02	15.6	3.03	**0.043**	B14PV9	06/10/02	14.9	3.09	**0.043**
B14KX8	05/17/02	15.6	2.97	**0.043**	B14PW0	06/10/02	16.0	3.09	**0.043**
B14KX9	05/17/02	16.8	2.48	**0.043**	B14PW1	06/10/02	16.6	2.53	**0.043**
B14KY0	05/17/02	16.5	3.07	**0.043**	B14PW2	06/10/02	15.9	3.38	**0.043**
B14KY1	05/17/02	15.9	2.87	**0.043**	B14PW3	06/10/02	15.2	2.77	**0.043**
B14KY2	05/17/02	16.6	2.58	**0.043**	B14PW4	06/10/02	15.3	3.16	**0.043**
B14KY3	05/17/02	12.6	2.91	**0.043**	B14PW5	06/10/02	15.6	3.15	**0.043**
B14KY4	05/17/02	15.8	2.70	**0.043**	B14PW6	06/10/02	16.3	3.16	**0.043**
B14KY5	05/17/02	15.8	2.54	**0.043**			Average	2.99	0.05
B14KY6	05/17/02	17.1	2.50	**0.043**			Maximum	9.37	0.51

Bold = value was below the listed detection limit.

Table B.4. Chromium and Uranium in Whole Body Tissues of Juvenile Fall Chinook Salmon from the 100-D Area of the Hanford Reach (µg/g, dry wt.)

Sample #	Date	% Dry Wt	Cr	U	Sample #	Date	% Dry Wt	Cr	U
B14JV8	05/01/02	9.0	3.44	**0.053**	B14KT2	05/17/02	16.9	3.30	**0.043**
B14JV9	05/01/02	16.9	2.19	**0.053**	B14KT3	05/17/02	18.1	3.21	**0.043**
B14JW0	05/01/02	10.4	4.12	**0.053**	B14KT4	05/17/02	16.6	3.13	**0.043**
B14JW1	05/01/02	11.3	5.47	**0.053**	B14KT5	05/17/02	15.0	3.37	**0.043**
B14JW2	05/01/02	17.1	2.53	**0.053**	B14KT6	05/17/02	14.2	3.80	**0.043**
B14JW3	05/01/02	13.6	2.98	**0.053**	B14KT7	05/17/02	16.4	3.16	**0.043**
B14JW4	05/01/02	15.3	2.83	**0.053**	B14KT8	05/17/02	17.4	2.55	**0.043**
B14JW5	05/01/02	11.5	3.99	**0.053**	B14KT9	05/17/02	18.0	3.09	**0.043**
B14JW6	05/01/02	16.6	2.44	**0.053**	B14KV0	05/17/02	17.1	2.55	**0.043**
B14JW7	05/01/02	8.7	5.14	**0.053**	B14KV1	05/17/02	16.0	3.09	**0.043**
B14JT9	05/01/02	16.8	2.47	**0.043**	B14KV2	05/17/02	17.9	3.38	**0.043**
B14JV0	05/01/02	9.9	3.32	**0.043**	B14KV3	05/17/02	14.6	3.16	**0.043**
B14JV1	05/01/02	15.0	1.85	**0.043**	B14KV4	05/17/02	16.3	2.56	**0.043**
B14JV2	05/01/02	12.8	2.43	**0.043**	B14KV5	05/17/02	15.1	3.19	**0.043**
B14JV3	05/01/02	8.9	1.59	**0.043**	B14PM7	06/10/02	17.4	3.12	**0.043**
B14JV4	05/01/02	14.4	1.71	**0.043**	B14PM8	06/10/02	16.6	3.21	**0.043**
B14JV5	05/01/02	16.2	1.65	**0.043**	B14PM9	06/10/02	15.5	3.22	**0.043**
B14JV6	05/01/02	15.3	1.39	**0.043**	B14PN0	06/10/02	16.1	3.38	**0.043**
B14JV7	05/01/02	16.1	1.54	**0.043**	B14PN1	06/10/02	17.6	3.65	**0.043**
B14KR6	05/17/02	14.4	4.19	**0.043**	B14PN2	06/10/02	16.8	3.60	**0.043**
B14KR7	05/17/02	18.7	2.15	**0.043**	B14PN3	06/10/02	15.6	3.03	**0.043**
B14KR8	05/17/02	15.1	3.43	**0.043**	B14PN4	06/10/02	16.6	2.62	**0.043**
B14KR9	05/17/02	17.7	3.34	**0.043**			Average	3.00	0.05
B14KT0	05/17/02	14.1	2.60	**0.043**			Maximum	5.47	0.05
B14KT1	05/17/02	14.7	3.01	**0.043**					

Bold = value was below the listed detection limit.

Table B.5. Chromium and Uranium in Whole Body Tissues of Juvenile Fall Chinook Salmon from the 100-H Area of the Hanford Reach (µg/g, dry wt.)

Heiss #	Date	% Dry Wt	Cr	U	Heiss #	Date	% Dry Wt	Cr	U
B14JX8	05/01/02	13.8	2.72	**0.053**	B14KW6	05/17/02	15.4	2.91	**0.043**
B14JX9	05/01/02	16.7	1.57	**0.053**	B14KW7	05/17/02	16.2	2.96	**0.043**
B14JY0	05/01/02	17.0	2.05	**0.053**	B14KW8	05/17/02	16.0	2.79	**0.043**
B14JY1	05/01/02	10.8	4.36	**0.053**	B14KW9	05/17/02	12.9	3.04	**0.043**
B14JY2	05/01/02	16.0	1.25	**0.053**	B14KX0	05/17/02	15.1	3.06	**0.043**
B14JY3	05/01/02	15.4	2.70	**0.053**	B14KX1	05/17/02	14.6	1.98	**0.043**
B14JY4	05/01/02	17.0	2.27	**0.053**	B14KX2	05/17/02	14.8	2.66	**0.043**
B14JY5	05/01/02	12.6	1.47	**0.053**	B14KX3	05/17/02	14.8	2.98	**0.043**
B14JY6	05/01/02	10.9	3.89	**0.053**	B14KX4	05/17/02	14.0	3.05	**0.043**
B14JY7	05/01/02	11.1	4.01	**0.053**	B14KX5	05/17/02	13.3	2.46	**0.043**
B14JW8	05/01/02	13.5	1.85	**0.043**	B14PP7	06/13/02	16.4	2.32	**0.043**
B14JW9	05/01/02	17.5	1.82	**0.043**	B14PP8	06/13/02	15.6	3.67	**0.043**
B14JX0	05/01/02	14.5	2.14	**0.043**	B14PP9	06/13/02	13.6	3.64	**0.043**
B14JX1	05/01/02	16.4	2.58	**0.043**	B14PR0	06/13/02	14.3	3.75	**0.043**
B14JX2	05/01/02	13.0	3.17	**0.043**	B14PR1	06/13/02	15.7	3.93	**0.043**
B14JX3	05/01/02	14.8	2.36	**0.043**	B14PR2	06/13/02	17.3	3.25	**0.043**
B14JX4	05/01/02	8.2	4.83	**0.043**	B14PR3	06/13/02	17.1	3.55	**0.043**
B14JX5	05/01/02	16.4	2.48	**0.043**	B14PR4	06/13/02	16.1	2.54	**0.043**
B14JX6	05/01/02	16.7	1.65	**0.043**	B14PR5	06/13/02	16.3	3.59	**0.043**
B14JX7	05/01/02	15.1	2.27	**0.043**	B14PR6	06/13/02	17.1	3.75	**0.043**
B14KV6	05/17/02	14.5	2.28	**0.043**	B14PR7	06/13/02	16.6	3.08	**0.043**
B14KV7	05/17/02	16.4	2.89	**0.043**	B14PR8	06/13/02	14.9	2.84	**0.043**
B14KV8	05/17/02	16.3	2.41	**0.043**	B14PR9	06/13/02	16.9	2.50	**0.043**
B14KV9	05/17/02	16.7	2.61	**0.043**	B14PT0	06/13/02	10.9	4.59	**0.043**
B14KW0	05/17/02	16.8	3.02	**0.043**	B14PT1	06/13/02	14.9	2.80	**0.043**
B14KW1	05/17/02	16.1	2.82	**0.043**	B14PT2	06/13/02	15.0	2.75	**0.043**
B14KW2	05/17/02	16.5	2.51	**0.043**	B14PT3	06/13/02	16.2	2.12	**0.043**
B14KW3	05/17/02	15.6	3.33	**0.043**			Average	2.85	0.04
B14KW4	05/17/02	14.2	3.11	**0.043**			Maximum	4.83	0.05
B14KW5	05/17/02	16.0	3.24	**0.043**					

Bold = value was below the listed detection limit.

Appendix C

Biological Data for Juvenile Fall Chinook Salmon Collected from the Hanford Reach of the Columbia River, 2002

Table C.1. Biological Data for Juvenile Fall Chinook Salmon Collected from the Hanford Reach of the Columbia River, 2002 (individual fish, whole body)

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
1	B14JT9	2002ALEVIN1	1803-1	01-May-02	100-D	1	0.45	42	
2	B14JV0	2002ALEVIN2	1803-2	01-May-02	100-D	1	0.9	45	
3	B14JV1	2002ALEVIN3	1803-3	01-May-02	100-D	1	0.74	44	
4	B14JV2	2002ALEVIN4	1803-4	01-May-02	100-D	1	0.51	40	
5	B14JV3	2002ALEVIN5	1803-5	01-May-02	100-D	1	0.77	45	
6	B14JV4	2002ALEVIN6	1803-6	01-May-02	100-D	1	0.64	42	
7	B14JV5	2002ALEVIN7	1803-7	01-May-02	100-D	1	0.5	42	
8	B14JV6	2002ALEVIN8	1803-8	01-May-02	100-D	1	0.83	44	
9	B14JV7	2002ALEVIN9	1803-9	01-May-02	100-D	1	0.8	44	
10	B14JV8	2002ALEVIN10	1803-10	01-May-02	100-D	1	0.93	43	
11	B14JV9	2002ALEVIN11	1803-11	01-May-02	100-D	1	0.73	46	
12	B14JW0	2002ALEVIN12	1803-12	01-May-02	100-D	1	0.54	40	
13	B14JW1	2002ALEVIN13	1803-13	01-May-02	100-D	1	0.62	38	
14	B14JW2	2002ALEVIN14	1803-14	01-May-02	100-D	1	0.62	41	
15	B14JW3	2002ALEVIN15	1803-15	01-May-02	100-D	1	0.62	40	
16	B14JW4	2002ALEVIN16	1803-16	01-May-02	100-D	1	0.49	40	
17	B14JW5	2002ALEVIN17	1803-17	01-May-02	100-D	1	0.56	41	
18	B14JW6	2002ALEVIN18	1803-18	01-May-02	100-D	1	0.75	42	
19	B14JW7	2002ALEVIN19	1803-19	01-May-02	100-D	1	0.52	37	
20	B14JW8	2002ALEVIN20	1803-20	01-May-02	100-H	1	1.04	47	
21	B14JW9	2002ALEVIN21	1803-21	01-May-02	100-H	1	0.9	45	
22	B14JX0	2002ALEVIN22	1803-22	01-May-02	100-H	1	1.06	45	
23	B14JX1	2002ALEVIN23	1803-23	01-May-02	100-H	1	0.77	40	
24	B14JX2	2002ALEVIN24	1803-24	01-May-02	100-H	1	0.99	45	
25	B14JX3	2002ALEVIN25	1803-25	01-May-02	100-H	1	0.98	43	
26	B14JX4	2002ALEVIN26	1803-26	01-May-02	100-H	1	0.94	45	
27	B14JX5	2002ALEVIN27	1803-27	01-May-02	100-H	1	0.78	43	
28	B14JX6	2002ALEVIN28	1803-28	01-May-02	100-H	1	1.04	47	

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
29	B14JX7	2002ALEVIN29	1803-29	01-May-02	100-H	1	1.35	48	
30	B14JX8	2002ALEVIN30	1803-30	01-May-02	100-H	1	0.91	44	
31	B14JX9	2002ALEVIN31	1803-31	01-May-02	100-H	1	1.28	49	
32	B14JY0	2002ALEVIN32	1803-32	01-May-02	100-H	1	1.21	47	
33	B14JY1	2002ALEVIN33	1803-33	01-May-02	100-H	1	0.45	37	
34	B14JY2	2002ALEVIN34	1803-34	01-May-02	100-H	1	0.72	45	
35	B14JY3	2002ALEVIN35	1803-35	01-May-02	100-H	1	0.67	42	
36	B14JY4	2002ALEVIN36	1803-36	01-May-02	100-H	1	1.22	47	
37	B14JY5	2002ALEVIN37	1803-37	01-May-02	100-H	1	0.75	41	
38	B14JY6	2002ALEVIN38	1803-38	01-May-02	100-H	1	0.94	44	
39	B14JY7	2002ALEVIN39	1803-39	01-May-02	100-H	1	0.65	42	
40	B14JY8	2002ALEVIN40	1803-40	03-May-02	Vernita	1	0.48	40	
41	B14JY9	2002ALEVIN41	1803-41	03-May-02	Vernita	1	0.68	44	
42	B14K00	2002ALEVIN42	1803-42	03-May-02	Vernita	1	0.55	42	
43	B14K01	2002ALEVIN43	1803-43	03-May-02	Vernita	1	0.9	44	
44	B14K02	2002ALEVIN44	1803-44	03-May-02	Vernita	1	0.82	44	
45	B14K03	2002ALEVIN45	1803-45	03-May-02	Vernita	1	0.52	42	
46	B14K04	2002ALEVIN46	1803-46	03-May-02	Vernita	1	0.81	42	
47	B14K05	2002ALEVIN47	1803-47	03-May-02	Vernita	1	0.95	47	
48	B14K06	2002ALEVIN48	1803-48	03-May-02	Vernita	1	0.55	42	
49	B14K07	2002ALEVIN49	1803-49	03-May-02	Vernita	1	0.79	43	
50	B14K08	2002ALEVIN50	1803-50	03-May-02	Vernita	1	0.59	41	
51	B14K09	2002ALEVIN51	1803-51	03-May-02	Vernita	1	0.57	40	
52	B14K10	2002ALEVIN52	1803-52	03-May-02	Vernita	1	0.99	46	
53	B14K11	2002ALEVIN53	1803-53	03-May-02	Vernita	1	0.51	36	
54	B14K12	2002ALEVIN54	1803-54	03-May-02	Vernita	1	1.02	46	
55	B14K13	2002ALEVIN55	1803-55	03-May-02	Vernita	1	0.74	42	
56	B14K14	2002ALEVIN56	1803-56	03-May-02	Vernita	1	0.72	44	
57	B14K15	2002ALEVIN57	1803-57	03-May-02	Vernita	1	0.57	40	
58	B14K16	2002ALEVIN58	1803-58	03-May-02	Vernita	1	0.59	43	
59	B14K17	2002ALEVIN59	1803-59	03-May-02	Vernita	1	0.57	40	

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
60	B14KR6	2002ALEVIN60	1803-60	17-May-02	100-D	2	0.59	38	
61	B14KR7	2002ALEVIN61	1803-61	17-May-02	100-D	2	1.53	54	
62	B14KR8	2002ALEVIN62	1803-62	17-May-02	100-D	2	0.59	40	
63	B14KR9	2002ALEVIN63	1803-63	17-May-02	100-D	2	1.58	53	
64	B14KT0	2002ALEVIN64	1803-64	17-May-02	100-D	2	0.85	45	
65	B14KT1	2002ALEVIN65	1803-65	17-May-02	100-D	2	0.64	40	
66	B14KT2	2002ALEVIN66	1803-66	17-May-02	100-D	2	1.36	52	
67	B14KT3	2002ALEVIN67	1803-67	17-May-02	100-D	2	0.53	40	
68	B14KT4	2002ALEVIN68	1803-68	17-May-02	100-D	2	1.68	56	
69	B14KT5	2002ALEVIN69	1803-69	17-May-02	100-D	2	2.15	57	
70	B14KT6	2002ALEVIN70	1803-70	17-May-02	100-D	2	1.69	53	
71	B14KT7	2002ALEVIN71	1803-71	17-May-02	100-D	2	1.45	52	
72	B14KT8	2002ALEVIN72	1803-72	17-May-02	100-D	2	1.2	49	
73	B14KT9	2002ALEVIN73	1803-73	17-May-02	100-D	2	1.83	55	
74	B14KV0	2002ALEVIN74	1803-74	17-May-02	100-D	2	1.39	51	
75	B14KV1	2002ALEVIN75	1803-75	17-May-02	100-D	2	1.04	46	
76	B14KV2	2002ALEVIN76	1803-76	17-May-02	100-D	2	1.78	55	
77	B14KV3	2002ALEVIN77	1803-77	17-May-02	100-D	2	0.64	43	
78	B14KV4	2002ALEVIN78	1803-78	17-May-02	100-D	2	0.7	43	
79	B14KV5	2002ALEVIN79	1803-79	17-May-02	100-D	2	0.52	40	
80	B14KV6	2002ALEVIN80	1803-80	17-May-02	100-H	2	0.77	43	
81	B14KV7	2002ALEVIN81	1803-81	17-May-02	100-H	2	0.88	45	
82	B14KV8	2002ALEVIN82	1803-82	17-May-02	100-H	2	0.78	42	Red coloration at base of both pectoral fins
83	B14KV9	2002ALEVIN83	1803-83	17-May-02	100-H	2	1.25	51	
84	B14KW0	2002ALEVIN84	1803-84	17-May-02	100-H	2	2.08	55	Red coloration at base of both pectoral fins and 4 small lacerations in abdominal area
85	B14KW1	2002ALEVIN85	1803-85	17-May-02	100-H	2	1.36	52	Red coloration at base of both pectoral fins
86	B14KW2	2002ALEVIN86	1803-86	17-May-02	100-H	2	0.97	48	Red coloration at base of both pectoral fins

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
87	B14KW3	2002ALEVIN87	1803-87	17-May-02	100-H	2	0.99	49	
88	B14KW4	2002ALEVIN88	1803-88	17-May-02	100-H	2	0.97	43	
89	B14KW5	2002ALEVIN89	1803-89	17-May-02	100-H	2	0.86	45	
90	B14KW6	2002ALEVIN90	1803-90	17-May-02	100-H	2	0.75	44	
91	B14KW7	2002ALEVIN91	1803-91	17-May-02	100-H	2	1.43	53	
92	B14KW8	2002ALEVIN92	1803-92	17-May-02	100-H	2	1.07	48	
93	B14KW9	2002ALEVIN93	1803-93	17-May-02	100-H	2	0.62	42	
94	B14KX0	2002ALEVIN94	1803-94	17-May-02	100-H	2	1.08	47	
95	B14KX1	2002ALEVIN95	1803-95	17-May-02	100-H	2	1.25	50	
96	B14KX2	2002ALEVIN96	1803-96	17-May-02	100-H	2	0.77	43	
97	B14KX3	2002ALEVIN97	1803-97	17-May-02	100-H	2	0.85	44	
98	B14KX4	2002ALEVIN98	1803-98	17-May-02	100-H	2	0.51	39	
99	B14KX5	2002ALEVIN99	1803-99	17-May-02	100-H	2	0.92	45	Red coloration at base of both pectoral fins, red belly seam and vent
100	B14KX6	2002ALEVIN101	1803-101	17-May-02	Vernita	2	0.96	46	
101	B14KX7	2002ALEVIN102	1803-102	17-May-02	Vernita	2	0.75	43	
102	B14KX8	2002ALEVIN103	1803-103	17-May-02	Vernita	2	0.84	44	
103	B14KX9	2002ALEVIN104	1803-104	17-May-02	Vernita	2	0.77	45	
104	B14KY0	2002ALEVIN105	1803-105	17-May-02	Vernita	2	0.87	45	
105	B14KY1	2002ALEVIN106	1803-106	17-May-02	Vernita	2	0.6	42	
106	B14KY2	2002ALEVIN107	1803-107	17-May-02	Vernita	2	0.91	44	
107	B14KY3	2002ALEVIN108	1803-108	17-May-02	Vernita	2	0.71	42	
108	B14KY4	2002ALEVIN109	1803-109	17-May-02	Vernita	2	0.55	38	
109	B14KY5	2002ALEVIN110	1803-110	17-May-02	Vernita	2	1.07	48	
110	B14KY6	2002ALEVIN111	1803-111	17-May-02	Vernita	2	0.55	40	Abrasion near left pectoral fin
111	B14KY7	2002ALEVIN112	1803-112	17-May-02	Vernita	2	1.39	51	
112	B14KY8	2002ALEVIN113	1803-113	17-May-02	Vernita	2	1.77	55	
113	B14KY9	2002ALEVIN114	1803-114	17-May-02	Vernita	2	0.91	44	
114	B14L00	2002ALEVIN115	1803-115	17-May-02	Vernita	2	1	44	
115	B14L01	2002ALEVIN116	1803-116	17-May-02	Vernita	2	0.9	45	

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
116	B14L02	2002ALEVIN117	1803-117	17-May-02	Vernita	2	1.39	50	
117	B14L03	2002ALEVIN118	1803-118	17-May-02	Vernita	2	0.7	42	
118	B14L04	2002ALEVIN119	1803-119	17-May-02	Vernita	2	0.75	43	
119	B14L05	2002ALEVIN120	1803-120	17-May-02	Vernita	2	0.89	45	
120	B14PM7	2002ALEVIN141	1803-141	10-Jun-02	100-D	3	1.48	52	
121	B14PM8	2002ALEVIN142	1803-142	10-Jun-02	100-D	3	1.26	50	
122	B14PM9	2002ALEVIN143	1803-143	10-Jun-02	100-D	3	0.77	42	
123	B14PN0	2002ALEVIN144	1803-144	10-Jun-02	100-D	3	2.32	60	
124	B14PN1	2002ALEVIN145	1803-145	10-Jun-02	100-D	3	1.56	53	
125	B14PN2	2002ALEVIN146	1803-146	10-Jun-02	100-D	3	1.17	49	
126	B14PN3	2002ALEVIN147	1803-147	10-Jun-02	100-D	3	1.23	49	
127	B14PN4	2002ALEVIN148	1803-148	10-Jun-02	100-D	3	1.38	50	
128	B14PN5	Not Collected							
129	B14PN6	Not Collected							
130	B14PN7	Not Collected							
131	B14PN8	Not Collected							
132	B14PN9	Not Collected							
133	B14PP0	Not Collected							
134	B14PP1	Not Collected							
135	B14PP2	Not Collected							
136	B14PP3	Not Collected							
137	B14PP4	Not Collected							
138	B14PP5	Not Collected							
139	B14PP6	Not Collected							
140	B14PP7	2002ALEVIN149	1803-149	13-Jun-02	100-H	3	3	64	
141	B14PP8	2002ALEVIN150	1803-150	13-Jun-02	100-H	3	1.12	43	
142	B14PP9	2002ALEVIN151	1803-151	13-Jun-02	100-H	3	1.02	47	
143	B14PR0	2002ALEVIN152	1803-152	13-Jun-02	100-H	3	0.81	43	
144	B14PR1	2002ALEVIN153	1803-153	13-Jun-02	100-H	3	1.31	49	
145	B14PR2	2002ALEVIN154	1803-154	13-Jun-02	100-H	3	1.51	53	
146	B14PR3	2002ALEVIN155	1803-155	13-Jun-02	100-H	3	1.45	53	

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
147	B14PR4	2002ALEVIN156	1803-156	13-Jun-02	100-H	3	1.76	55	
148	B14PR5	2002ALEVIN157	1803-157	13-Jun-02	100-H	3	1.41	51	
149	B14PR6	2002ALEVIN158	1803-158	13-Jun-02	100-H	3	1.06	45	
150	B14PR7	2002ALEVIN159	1803-159	13-Jun-02	100-H	3	0.87	44	
151	B14PR8	2002ALEVIN160	1803-160	13-Jun-02	100-H	3	0.81	43	
152	B14PR9	2002ALEVIN161	1803-161	13-Jun-02	100-H	3	1.27	50	
153	B14PT0	2002ALEVIN162	1803-162	13-Jun-02	100-H	3	0.85	42	
154	B14PT1	2002ALEVIN163	1803-163	13-Jun-02	100-H	3	0.89	44	
155	B14PT2	2002ALEVIN164	1803-164	13-Jun-02	100-H	3	1.11	47	
156	B14PT3	2002ALEVIN165	1803-165	13-Jun-02	100-H	3	1.07	48	
157	B14PT4	2002ALEVIN166	1803-166	13-Jun-02	100-H	3	(a)	(a)	
158	B14PT5	Not Collected							
159	B14PT6	Not Collected							
160	B14PT7	2002ALEVIN121	1803-121	10-Jun-02	Vernita	3	0.98	46	
161	B14PT8	2002ALEVIN122	1803-122	10-Jun-02	Vernita	3	1.08	46	
162	B14PT9	2002ALEVIN123	1803-123	10-Jun-02	Vernita	3	0.78	44	
163	B14PV0	2002ALEVIN124	1803-124	10-Jun-02	Vernita	3	1.31	48	
164	B14PV1	2002ALEVIN125	1803-125	10-Jun-02	Vernita	3	0.69	41	
165	B14PV2	2002ALEVIN126	1803-126	10-Jun-02	Vernita	3	0.64	41	
166	B14PV3	2002ALEVIN127	1803-127	10-Jun-02	Vernita	3	0.95	46	
167	B14PV4	2002ALEVIN128	1803-128	10-Jun-02	Vernita	3	0.8	42	
168	B14PV5	2002ALEVIN129	1803-129	10-Jun-02	Vernita	3	0.71	43	
169	B14PV6	2002ALEVIN130	1803-130	10-Jun-02	Vernita	3	0.88	46	
170	B14PV7	2002ALEVIN131	1803-131	10-Jun-02	Vernita	3	0.58	40	
171	B14PV8	2002ALEVIN132	1803-132	10-Jun-02	Vernita	3	1.66	53	
172	B14PV9	2002ALEVIN133	1803-133	10-Jun-02	Vernita	3	0.64	40	
173	B14PW0	2002ALEVIN134	1803-134	10-Jun-02	Vernita	3	0.73	42	
174	B14PW1	2002ALEVIN135	1803-135	10-Jun-02	Vernita	3	0.8	45	
175	B14PW2	2002ALEVIN136	1803-136	10-Jun-02	Vernita	3	0.71	42	
176	B14PW3	2002ALEVIN137	1803-137	10-Jun-02	Vernita	3	0.75	43	
177	B14PW4	2002ALEVIN138	1803-138	10-Jun-02	Vernita	3	0.85	42	

ID	HEIS #	HEIS Sample ID	MSL Sample ID	Date	Location	Sample Group	Weight (g)	Fork Length (mm)	Physical Condition
178	B14PW5	2002ALEVIN139	1803-139	10-Jun-02	Vernita	3	0.9	44	
179	B14PW6	2002ALEVIN140	1803-140	10-Jun-02	Vernita	3	0.6	40	

HEIS = Hanford Environmental Information System.
ID = Identification.
MSL = Marine Sciences Laboratory.
(a) Value not obtained.