

**ASSESSMENT OF SMOLT CONDITION FOR
TRAVEL TIME ANALYSIS**

ANNUAL REPORT 1991 - 1992

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Prepared for:

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Project Number 87-401
Contract Number DE-AI79-87BP35245

MAY 1994

EXECUTIVE SUMMARY

Between 1988 to 1992, data were collected on physiological and environmental variables that influence the rate at which juvenile salmonids (steelhead, spring, summer and fall chinook salmon) migrate downstream through the mid Columbia and Snake rivers. This report summarizes work done in 1991 and 1992, but also contains data collected in previous years. The five chapters describe the influence of biotic and abiotic variables on smolt travel time, changes in bacterial kidney disease and several non-lethal methods developed to assess the Parr-to-smolt transformation in juvenile salmonids. The following are our most significant findings.

Travel times of juvenile spring chinook salmon were found to be dependent on river flow, smoltification, water temperature, and change in river flow. Travel times of steelhead depended on river flow alone (Chapter 1).

Average river flow was the only variable common to all regressions predicting travel times of juvenile spring chinook salmon and steelhead, indicating that increases in river flow during the spring outmigration would be the most biologically effective management action to decrease travel times of these species (Chapter 1).

Prevalence of BKD in mid-Columbia and Snake river hatchery spring chinook salmon declined from 1988 to 1992 (Chapter 2) .

BKD in hatchery spring chinook salmon may be more severe in the Snake River than the Columbia River (Chapter 2).

Non-lethal gill clips for Na^+, K^+ -ATPase determination did not affect travel time or detection rate of steelhead or spring chinook salmon in the Snake River (Chapter 3).

The results of the micro-assay for ATPase activity is directly comparable to the macro-assay used previously (Chapter 3).

The ability of skin to reflect light (skin reflectance) differed significantly between samples taken before steelhead, spring and fall chinook salmon were released and when branded migrants were tested (Chapter 4).

Skin reflectance correlated positively with gill ATPase activity and skin guanine content (Chapter 4).

The body morphology of spring chinook salmon changed during smoltification and correlated significantly with changes in gill ATPase activity (Chapter 5).

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INTRODUCTION

As a part of the Northwest Power Planning Council's Fish and Wildlife Program, the Fish Passage Center (FPC) collects information on the migrational characteristics of juvenile salmon and steelhead (Oncorhynchus sp.) in the Columbia River basin. This information is collected through the Smolt Monitoring Program, and is used as a tool in the management and evaluation of the Water Budget. The Water Budget is a volume of water used to enhance environmental conditions (flows) to aid in the seaward migration of juvenile salmon and steelhead. Implicit in the Water Budget concept is that by augmenting flows, travel time of juvenile salmonids will be decreased, thereby increasing survival via reductions in delayed migration and exposure to predators.

Since 1987, the FPC has relied on estimates of travel times of juvenile salmonids through selected index reaches of the Snake and Columbia rivers to evaluate the Water Budget. This study continues to collect physiological information on the fish used for this purpose although the emphasis has changed somewhat since 1987, reflecting the adaptive management nature of the Smolt Monitoring Program. In 1990, the emphasis shifted from relying solely on data from releases of branded fish from hatcheries with the addition of information collected from PIT-tagged releases of fish from the migration-at-large. These migrating fish are collected, tagged, and released daily at monitoring sites located at the upstream-end of index reaches. Using PIT-tagged groups in this manner allows collection of more information than from releases of branded hatchery groups, since many releases can be made from each site. In addition, fewer fish are handled in this process due to the high rate of downstream detection possible with PIT-tagged fish.

Beginning in 1993, virtually all of the fish used by the FPC will be PIT tagged as opposed to branded. This includes hatchery release groups and wild and hatchery fish collected at migration traps and dams. In addition, several stocks of Snake River salmon have been listed as threatened or endangered under the Endangered Species Act. These changes will limit possible

sampling designs and limit the ways in which smoltification and fish health can be measured. This report reflects the Assessment of Smolt Condition for Travel Time Analysis Project's response to those changes, and contains chapters that describe studies of the physiology and health of branded hatchery fish and the development of non-lethal methods of measuring smoltification. In most cases, these chapters summarize work conducted over several years from 1987 through 1992, and there is some duplication of data from earlier reports. Chapter 1 describes the relations between travel time, river flows and smoltification using data collected from 1989 through 1992. Chapter 2 describes changes in the prevalence and severity of bacterial kidney disease in spring chinook salmon from Snake and Columbia river hatcheries from 1988 through 1992. Non-lethal methods of assessing smoltification using a micro-assay for gill ATPase, changes in skin reflectance and changes in body morphology are described in Chapters 3, 4, and 5, respectively. Each chapter was written as a "stand-alone" document that will be submitted for publication to a scientific journal and each has its own list of authors. Chapters 3 and 5 have been accepted for publication. Several appendices follow the main text and include data collected in 1991 and 1992. Data collected in earlier years are contained in their respective annual reports.

Chapter 1.

Estimating the Effects of River Flow, Emoltification, and Other
Biotic and Abiotic Variables on the Travel Time of Juvenile
Salmonids in the Columbia and Snake Rivers.

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ABSTRACT

Regression techniques were used to determine the effects of several biotic and abiotic variables on the migration rates of juvenile spring chinook salmon and steelhead in the Columbia and Snake rivers. Comparisons of the effects of river flow and smoltification, assessed using gill $\text{Na}^+ - \text{K}^+$ ATPase activity, were of primary interest. Day of the year, water temperature, change in flow, condition factor, and fork length were also considered as independent variables. Groups of fish were sampled to assess smoltification 2-3 times per week during the spring outmigrations during 1989-1992. These groups were assumed to be representative of other fish which were PIT-tagged and released as a part of the Smolt Monitoring Program in the Columbia Basin. River flow, gill ATPase activity, condition factor, water temperature, and change in flow were significant variables in regressions predicting the time for juvenile spring chinook salmon to travel between specific points (travel time), whereas river flow was the only significant contributor to models describing travel times of steelhead. Predicted travel times of wild steelhead were shorter than those of hatchery steelhead. River flow was the only variable common to all regression equations. Based on this characteristic, changes in river flow would be the most logical means to decrease travel times of both juvenile spring chinook salmon and steelhead in the Columbia and Snake rivers.

INTRODUCTION

Since the completion of Rock Island Dam on the Columbia River in 1933, the Columbia and Snake rivers have undergone a transformation from free-flowing rivers with an "inexhaustible supply" of salmon, to a series of dams and reservoirs with a growing number of salmon protected under the Endangered Species Act (Nehlsen et al. 1991). Causes for the reductions in survival of Columbia Basin salmonids from hydropower development include inundation of spawning and rearing habitat, predation of juveniles by resident fishes in reservoirs, impaired upstream passage of adults, mortality of juveniles associated with

downstream passage, and delayed migration (Fulton 1968, 1970; Raymond 1968, 1979; Park 1969). Mortality due to delayed migration stems from increased availability to predators, exposure to high water temperatures, and loss of seawater tolerance. In an effort to decrease this migration delay, a specific volume of water, called the Water Budget, was allocated in the Columbia Basin to increase spring river flows, thereby aiding juvenile salmonids in their downstream migration (NPPC 1987). This action was based in part on the works of Raymond (1968, 1969, 1979) indicating a positive relation between river flow and migration rate of juvenile salmonids in the Columbia and Snake rivers, and Sims and Ossiander (1981), indicating a positive correlation between river flow and juvenile salmonid survival. The underlying premise behind the Water Budget concept is that decreasing the juvenile salmonid migration delays caused by slow moving water in reservoirs will result in increased survival to adulthood.

Recent studies to further define factors affecting the migration rates of juvenile salmonids have emphasized river flow as an important variable. Fish Passage Center (1990), using marked groups of juvenile spring chinook salmon (Oncorhynchus tshawytscha) and steelhead (O. mykiss) migrating in the Columbia and Snake rivers, found a positive relation between river flow and the time required to traverse specific river reaches (travel time). Berggren and Filardo (1993) found that in addition to flow-related variables, surrogate variables for smoltification were also required to best explain travel time of juvenile salmonids. The objective of this study was to define the roles of river flow, smoltification, and several other biotic and abiotic variables on the travel times of juvenile salmonids in selected reaches of the Columbia and Snake rivers.

METHODS

Analyses of the effects of selected factors on the travel time of juvenile salmonids were conducted using two species migrating through four reaches. Juvenile spring chinook salmon

of unknown origin, steelhead of hatchery origin, and naturally produced steelhead, hereafter referred to as wild steelhead, were sampled during their spring outmigration at the upstream ends of each reach. Hatchery and wild steelhead were separated based on adipose-fin clips of hatchery steelhead. Data were collected from fish migrating through the reaches of Rock Island Dam (river km 731) to McNary Dam (river km 471) on the Columbia River, and the Idaho Department of Fish and Game (IDFG) Snake River Trap (river km 225) to Lower Granite Dam (river km 173), IDFG Clearwater River Trap (river km 234) to Lower Granite Dam, and Little Goose Dam (river km 113) to McNary Dam reaches on the Snake River (Figure 1.1).

Fish used in this study were injected with passive integrated transponder (PIT) tags and released daily as part of the Smolt Monitoring Program (Prentice et al. 1990a; Fish Passage Center 1993). Implantation of PIT tags was performed by the Chelan County Public Utility District at Rock Island Dam, the IDFG at the Snake River and Clearwater traps, and the National Marine Fisheries Service at Little Goose Dam. Dams at the downstream ends of each reach were equipped with PIT tag detectors as described by Prentice et al. (1990b). Median travel time to the nearest 0.1 d was computed as the time from the median date of release at the upstream end of a reach through the median date of detection at the last downstream dam in the reach (Fish Passage Center 1993).

Average river flows at selected dams were used as surrogate measures of average water velocities. For the Snake River Trap and Clear-water Trap-to-Lower Granite Dam reaches, average flow was calculated as the average daily flow at Lower Granite Dam from the median date of release at the traps through the day preceding the median date of detection at Lower Granite Dam. For fish in the Rock Island Dam-to-McNary Dam and Little Goose Dam-to-McNary Dam reaches, average flows were calculated as the average daily flows at Priest Rapids Dam (Columbia River) or Ice Harbor Dam (Snake River) from the median date of release through the day preceding the median date of detection at McNary Dam. Flows at McNary Dam were not used for these reaches because

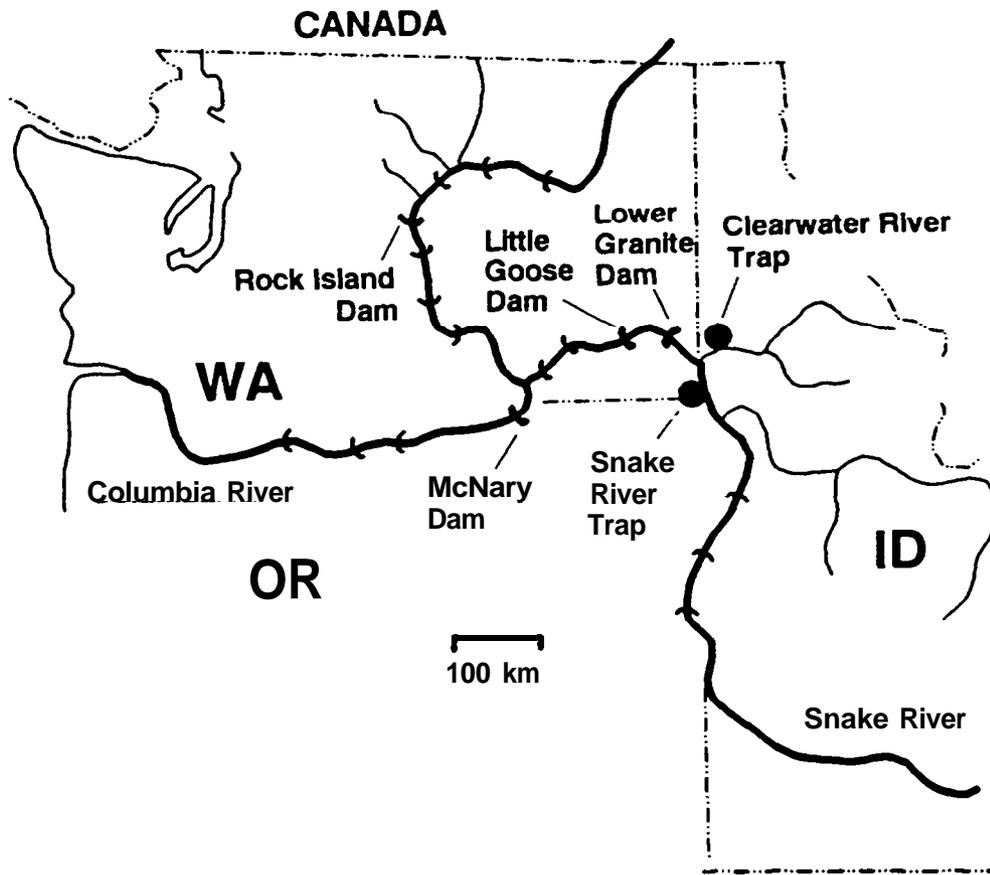


Figure 1.1. Map of Columbia River basin showing locations of fish release and recovery sites.

McNary Dam is the first dam below the confluence of the Columbia and Snake rivers and flows there reflect components from both rivers; fish migrating in these reaches migrated chiefly in the rivers above the confluence of the two rivers (Figure 1.1).

Gill $\text{Na}^+\text{-K}^+$ ATPase (ATPase) activity was measured to assess smoltification. Gill ATPase activity is involved in the ion-transport mechanism of the gill epithelium, increasing in activity preparatory to the osmoregulatory demands of life in seawater (Hoar 1976). Gill ATPase activity is one of many measures of smoltification, which is a complex process that includes physiological, morphological, and behavioral changes that accompany downstream migration.

Groups of 10 fish collected biweekly in 1989 and 1990 and three times per week in 1991 and 1992 were sacrificed in a lethal dose of tricaine methane sulfonate. Gill filaments were removed from the left gill arches for determination of gill ATPase activity using the method of Zaugg (1982). Fork length to the nearest 1.0 mm and weight to the nearest 0.1 g were also measured and the condition factor was calculated as $\text{weight} \cdot 10^5 \div \text{fork length}^3$. Fish from which these data were collected were assumed to be representative of those marked with PIT tags and released on the same day, from which travel time information was collected through the Smolt Monitoring Program (Fish Passage Center 1990, 1991, 1992, 1993).

Multiple linear regression techniques were used to analyze the data collected in 1989-1992 using SAS software for personal computers (SAS Institute 1989). Median travel time, average flow, and average gill ATPase activity variables were natural-logarithm transformed (Loge) to improve the linearity of the relations between them. In each regression, Loge median travel time (travel time) was first regressed on Loge average daily flow (flow) and Loge average gill ATPase activity (gill ATPase activity). Day of the year, surface water temperature (C) at release, condition factor, and fork length were examined for correlations with travel time. Delta flow, calculated as the maximum average flow minus the minimum average flow, was also examined for correlation with travel time, as this variable was a

significant contributor to similar models in Berggren and Filardo (1993). Variables with a significant correlation with travel time were considered as additional independent variables in the multiple regressions. Variables were considered significant contributors to a model when $P \leq 0.05$ testing the null hypothesis that the parameter estimate is equal to zero (z-tailed t -statistic). Analyses were performed for each reach and species.

Data used in each regression were checked for outliers by plotting residuals about the predicted values as well as examining several influence statistics measuring the effect of an observation on the change in predicted values when it is excluded (dffits), change in regression coefficients when each observation is excluded (dfbetas), the leverage each observation has on its own prediction (leverage), and the covariance ratio of each observation, indicating the impact of each observation on the precision of the regression estimates (SAS Institute 1989; Belsley et al. 1980). An observation was not removed from the data set unless several of the statistics were above suggested cutoff values based on the sample size and number of independent variables (Belsley et al. 1980). Multicollinearity was assessed by examining the Pearson product-moment correlations of the independent variables when there were two, and with eigenanalysis when there were more than two independent variables. When using eigenanalysis, multicollinearity was suspected when the condition index was greater than 10 (Belsley et al. 1980). Normality of residuals and presence of first-order autocorrelation were assessed using the Shapiro-Wilk and Durbin-Watson D statistics, respectively. Differences were considered statistically significant when $P \leq 0.05$.

The standardized partial slope estimates (beta weights) of the regression coefficients were used to compare the amount of variance in the dependent variable (Y) explained by each of the independent variables (X_i). These coefficients represent the average standard deviation change in Y associated with a standard deviation change in X_i , when the other independent variables are held constant, assuming the independent variables are not correlated (Lewis-Beck 1980).

Analysis of covariance was used to test the null hypotheses of equal non-zero slopes and intercepts of regressions involving steelhead of hatchery and wild origin. In these analyses, origin was the factor and flow was the covariate of travel time. If the slopes of regressions describing travel time of the two origins were not significantly different and the intercepts were significantly different, a common regression was used. This regression included a dummy variable for origin, which adjusted the intercept.

RESULTS

Rock Island Dam-to-McNary Dam Reach

Steelhead. Flow was the only significant variable explaining travel time of hatchery steelhead in the Rock Island Dam-to-McNary Dam reach, but flow and water temperature were significant predictors of travel times of wild steelhead. Gill ATPase was not correlated with the travel times of hatchery or wild steelhead in this reach. Condition factor was significantly correlated with travel times of hatchery and wild steelhead, but was not a significant contributor in models explaining variation in travel times when the flow variable was included.

Analysis of covariance indicated that slopes of the regressions describing travel times of hatchery and wild steelhead were not significantly different but there were significant differences in the intercepts. Therefore, a single regression equation with a dummy variable for origin was fitted to the pooled data, explaining 67% of the variability in steelhead travel times (Table 1.1). This equation describes a relation in which changes in flow elicit identical changes in travel time of hatchery and wild steelhead, with the wild fish having a travel time 9% shorter than hatchery fish at any given flow. Figure 1.2 depicts the predicted travel times of hatchery and wild steelhead over the range of flows in our data.

The Shapiro-Wilk statistic indicated the residuals from this regression were not normally distributed ($N = 64$, $P = 0.0463$), however, this deviation was not considered serious because the P

value was close to the 0.05 level and the skewness and kurtosis values indicated little departure from normal.

As another approach, a regression was performed with pooled hatchery and wild steelhead data. In this regression, flow, ATPase, and water temperature variables were significant predictors of travel time, explaining 72% of the variability in steelhead travel times (Table 1.1). Water temperature was the only variable other than the intercept with a positively-signed coefficient. Regression coefficients indicated that increases in water temperature prolonged the migration of steelhead, whereas increases in flow and gill ATPase activity decreased travel times in this reach. The beta weight of flow was more than twice as large as those of ATPase and water temperature, indicating it was the most influential variable determining travel times of steelhead in this reach.

Spring Chinook Salmon. Two outliers were omitted from the data prior to analysis of juvenile spring chinook salmon travel time in the Rock Island Dam-to-McNary Dam reach based on their unusually long travel times. These observations were collected on May 20 and 22, 1992 and had travel times of 24.6 and 29.5 days, respectively. Juvenile chinook salmon PIT tagged at Rock Island Dam after 18 May 1992 were believed to be predominantly late-release summer chinook salmon from mid-Columbia hatcheries, as there were releases of approximately 720,000 of these fish shortly before this time, the travel times after this date were 2-3 times longer, and the percent recoveries at McNary Dam were about 14% lower than those tagged on earlier dates under similar flow conditions (Fish Passage Center 1993).

Flow, ATPase, condition factor, and water temperature variables were significant contributors in the explanation of the travel times of spring chinook salmon in the Rock Island Dam-to-McNary Dam reach. Date and fork length were also significantly correlated with travel time of juvenile spring chinook salmon in this reach. Of these variables, date was significantly correlated with most other variables and was not considered as an independent variable, and fork length was not a significant contributor when the other variables were in the model. Gill

Table 1.1. Results of regressions using juvenile spring chinook salmon of unknown origin (Spch), steelhead of hatchery origin (Hsth), and steelhead of wild origin (Wsth). The dependent variable in each regression is LOGTRAV, the natural logarithm-transformed median travel time in days. Regressions were completed for river reaches in the Columbia River (RIS-MCN, Rock Island Dam to McNary Dam) and Snake River (SNK-LGR, Snake River Trap to Lower Granite Dam: CLW-LGR Clear-water River Trap to Lower Granite Dam).

Reach	Species	Variables	Coefficient	P	Beta coefficient	N	R ²
RIS-MCN	Hsth/Wsth ^a	Intercept	8.886	<0.01		64	0.67
		LOGFLOW	-1.350	co.01	-0.80		
		ORIGIN ^b	0.094	<0.01	0.21		
	Hsth/Wsth ^c	Intercept	7.965	<0.01		64	0.72
		LOGFLW	-1.111	<0.01	-0.66		
		LOGATPASE	-0.245	co.01	-0.29		
		TEMP	0.044	co.01	-0.27		
	Spch	Intercept	6.711	go.01		34	0.68
		LOGFLW	-0.528	co.01	-0.33		
		LDGATPASE	-0.343	<0.01	-0.54		
		TEMP	-0.054	0.04	-0.28		
	Spch	Intercept	2.545	0.06		31	0.78
LDGFLW		-0.481	<0.01	-0.33			
KFACTOR		3.332	<0.01	0.49			
TEMP		-0.086	<0.01	-0.49			
SNK-LGR	Hsth	Intercept	8.387	<0.01		57	0.81
		LOGFLOW	-1.602	<0.01			
	Usth	Intercept	5.712	co.01		40	0.76
		LDGFLW	-1.044	<0.01			
	Hsth/Wsth ^c	Intercept	7.449	<0.01		97	0.76
		LOGFLOW	-1.239	<0.01	-0.74		
		DELTAFLW	0.009	<0.01	0.21		
		LOGATPASE	-0.308	co.01	-0.19		
	Spch ^d	Intercept	6.725	<0.01		34	0.75
		LOGFLOW	-0.551	<0.01	-0.42		
		DELTAFLOW	0.012	go.01	0.30		
		LOGATPASE	-0.477	0.01	-0.31		
TEMP		-0.119	0.01	-0.30			
Spch ^e	Intercept	6.288	<0.01		23	0.81	
	LDGFLW	-1.092	co.01	-0.82			
	DELTAFLOW	0.010	0.04	0.22			
CLW-LGR	Spch	Intercept	6.678	<0.01		33	0.76
		LOGFLW	-0.506	0.02	-0.27		
		DELTAFLOW	0.015	co.01	0.39		
		LOGATPASE	-0.490	<0.01	-0.35		
		TEMP	-0.122	co.01	-0.42		

^a Origins separate

^b Hsth ORIGIN = 1, Wsth ORIGIN = 0

^c Origins pooled

^d Based on data from 1989-1992.

^e Based on data from 1990-1992 with high flow year of 1989 omitted.

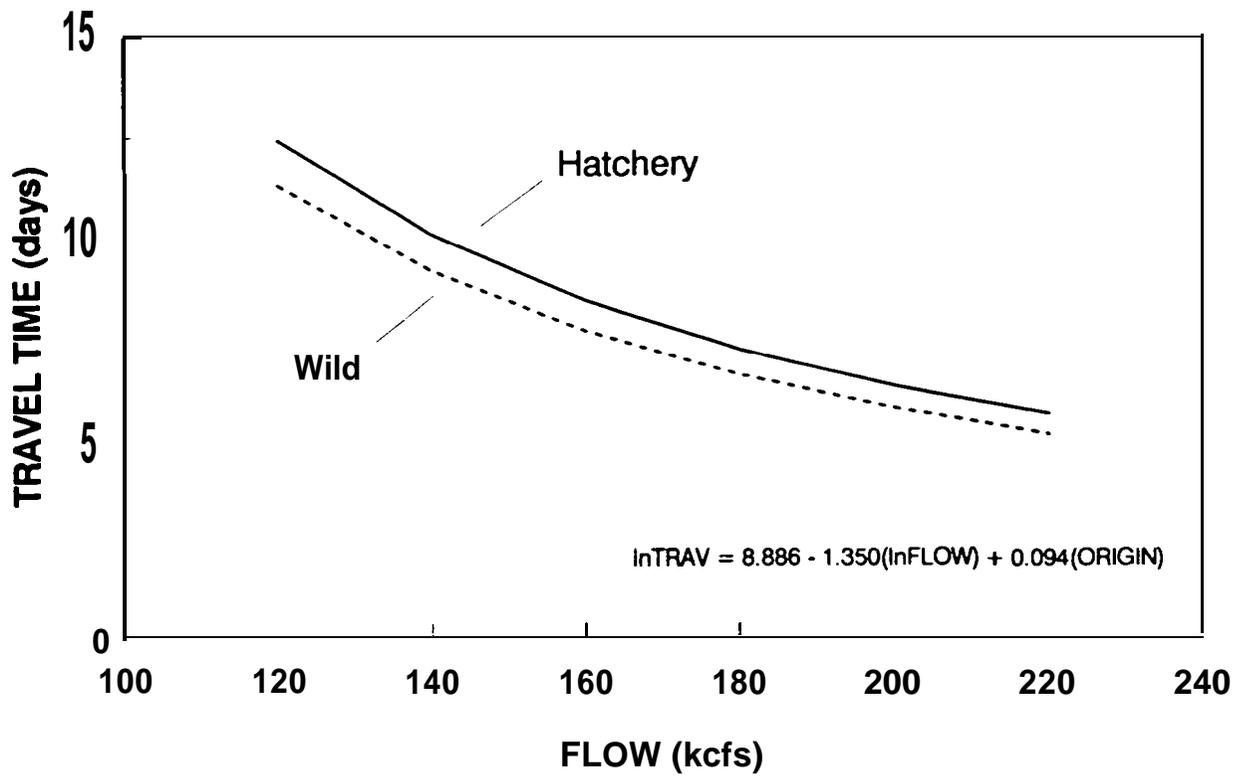


Figure 1.2. Predicted flow-travel time relations for hatchery and wild steelhead migrating between Rock Island and McNary dams based on a regression including a dummy variable for origin.

ATPase and condition factor were evaluated in separate models due to their high correlation with each other ($r = -0.77$, $N = 31$, $P = 0.0001$).

In a model containing flow and ATPase variables, water temperature was also a significant contributor explaining travel time; this model explained 68% of the variability in travel time (Table 1.1). In an alternative model with condition factor replacing ATPase, condition factor, flow and water temperature were significant contributors to the model, explaining 78% of the variation in travel time. In each of these models, increases in water temperature were predicted to decrease travel times of juvenile spring chinook salmon, indicated by the negative sign of the regression coefficients (Table 1.1). Figure 1.3 depicts the range in predicted travel times of fish with a low level of smoltification (low gill ATPase activity, high condition factor) and those with a high level of smoltification (high gill ATPase activity, low condition factor) over different levels of flow.

Eigenanalysis did not indicate the presence of multicollinearity, permitting comparison of the effects of the independent variables on travel time using the beta coefficients (Lewis-Beck 1980). The beta coefficients in the regression containing flow, ATPase, and water temperature variables were -0.33, -0.54, and -0.28, respectively, indicating ATPase explained the largest amount of the variation in travel time. The beta coefficients in the regression containing flow, condition factor, and water temperature were -0.33, 0.49, and -0.49, respectively, indicating condition factor and water temperature explained approximately equal portions of travel time, which were larger than the portion explained by the flow variable.

Snake River Trap-to-Lower Granite Dam Reach

Steelhead. The flow variable alone was the best descriptor of travel times of hatchery and wild steelhead in the Snake River Trap-to-Lower Granite Dam reach (Table 1.1). An analysis of covariance indicated the slopes of regression lines describing travel times of hatchery and wild steelhead using flow as the independent variable were significantly different, so separate

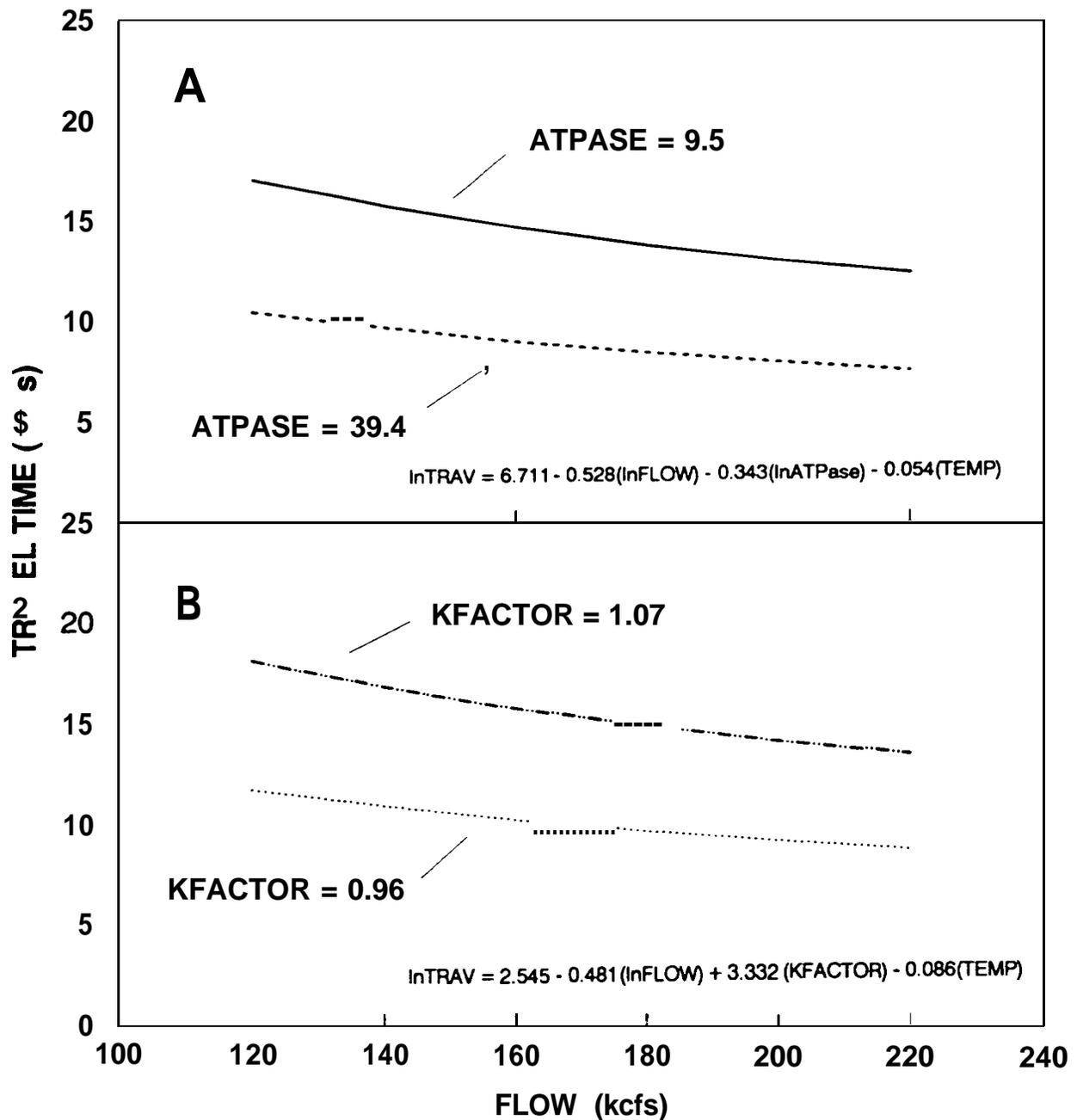


Figure 1.3. Predicted flow-travel time relations of juvenile spring chinook salmon migrating between Rock Island and McNary dams based on a multiple regression including gill ATPase activity (ATPASE; A) or condition factor (KFACTOR; B). Levels of ATPASE and KFACTOR represent minimums and maximums from data collected in 1989-1992. For the purpose of these plots the water temperature variable was held constant at its mean.

regressions were required for each group. These regressions accounted for 81% and 76% of the variability in travel times of hatchery and wild steelhead, respectively (Table 1.1; Figure 1.4a).

Gill ATPase activity of hatchery steelhead was significantly correlated with travel time, but the correlation coefficient was low ($r = -0.27$, $N = 57$, $P = 0.0423$). The correlation coefficient between gill ATPase and travel time of wild steelhead was not significant ($r = -0.27$, $N = 40$, $P = 0.0934$). The date variable was significantly correlated with travel time of hatchery steelhead ($r = -0.28$, $N = 57$, $P = 0.0364$), and fork length was significantly correlated with travel time of wild steelhead ($r = 0.35$, $N = 40$, $P = 0.0273$). However, with the flow variable already in the models, gill ATPase, fork length, and date were not significant contributors.

In a model using pooled hatchery and wild steelhead data, flow, delta flow, ATPase, and fork length were significant independent variables. However, the fork length variable was subsequently omitted from the analysis because the positive sign of the parameter estimate was believed to reflect the smaller size of the wild fish ($\text{mean}_{\text{wild}} = 176 \text{ mm}$, $\text{mean}_{\text{hatchery}} = 219 \text{ mm}$), rather than a common relation of size and travel time in fish of each origin. The resulting model containing flow, delta flow, and ATPase variables explained 76% of the variability in travel times of steelhead (Table 1.1). The beta coefficients indicated changes in flow were approximately four times as important in determining travel times of steelhead in this reach than changes in delta flow or gill ATPase activity (Table 1.1). Figure 1.4b depicts the predicted flow-travel time relation for steelhead over the range of gill ATPase activities and flows present in our data from this reach.

Spring Chinook Salmon. The flow and ATPase variables together explained 56% of the variability in travel time of juvenile spring chinook salmon in the Snake River Trap-to-Lower Granite Dam reach. The data collected on 18 May 1989 was omitted

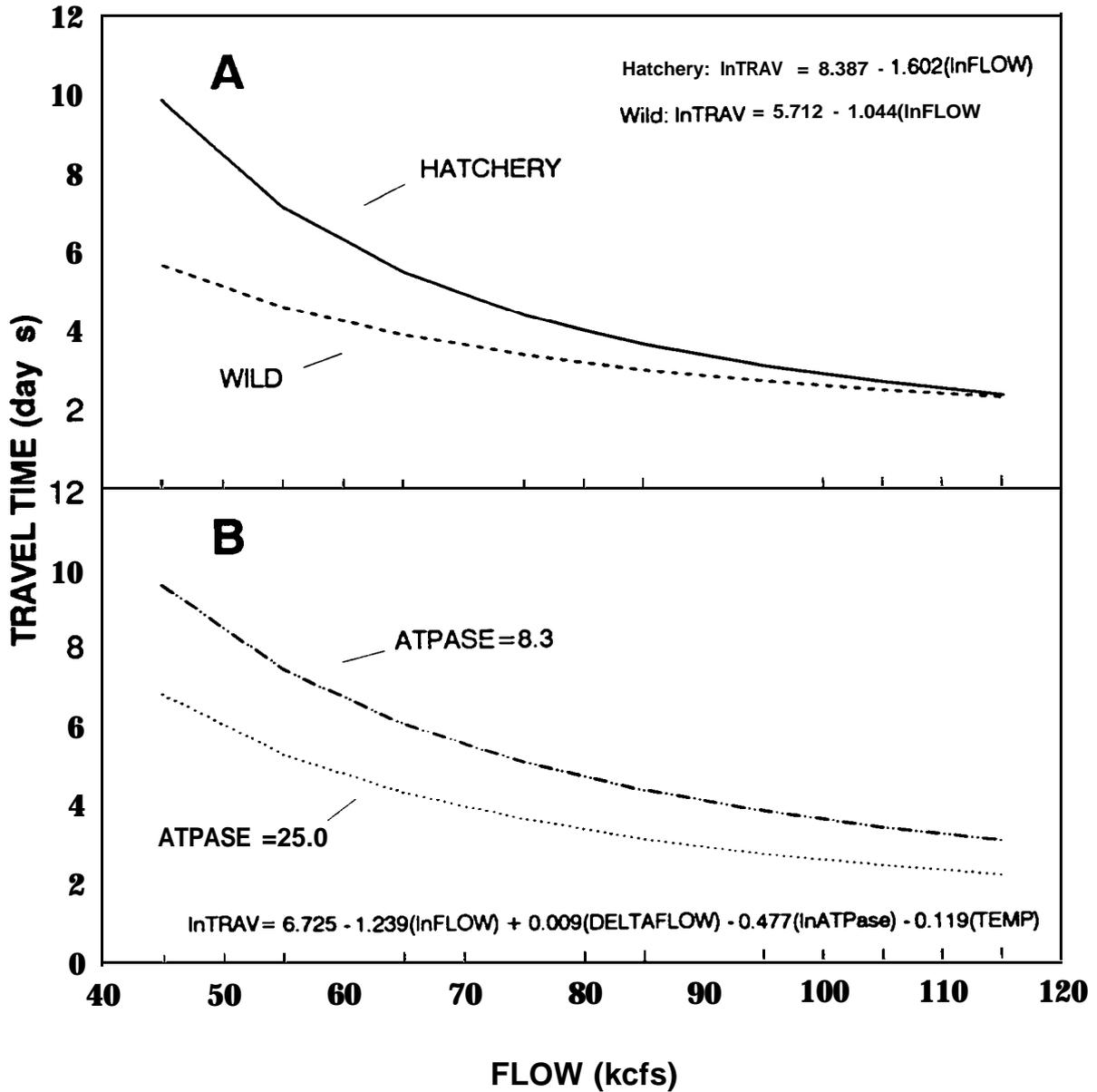


Figure 1.4. Predicted flow-travel time relations of juvenile steelhead of hatchery and wild origins migrating between the Idaho Department of Fish and Game Snake River Trap and Lower Granite Dam. Plate A depicts results based on simple regressions with hatchery and wild steelhead separate: plate B is based on a multiple regression of pooled hatchery and wild steelhead data. Levels of gill ATPase (ATPASE) in plate B represent minimums and maximums from data collected in 1989-1992. For the purpose of demonstration, the deltaflow variable was held constant at its mean in plate B.

from this analysis as these fish were predominantly subyearlings (Buettner and Nelson 1990).

In addition to flow and ATPase variables, date, delta flow, and water temperature were significantly correlated with travel time of these fish ($r = 0.37$ to -0.77 , $N = 34$, $P \leq 0.033$). However, the date variable was not considered as an independent variable as it was significantly correlated with most other variables. The addition of water temperature and delta flow to the model containing flow and ATPase variables increased the R^2 value from 0.56 to 0.75 (Table 1.1). As in models of juvenile spring chinook salmon travel time in the Rock Island Dam-to-McNary Dam reach, the regression coefficient of the water temperature variable was negative, indicating increases in water temperature decreased travel times. Figure 1.5a illustrates the flow-travel time relation predicted using this equation over the range of flows and gill ATPase activities present in our data from this reach.

Regression diagnostics did not indicate the presence of multicollinearity, so beta weights were used to compare the influence of the independent variables on spring chinook salmon travel time. These coefficients indicated flow was a slightly more important factor than the other independent variables in determining the travel time of juvenile spring chinook salmon in this reach (Table 1.1). This equation was heavily influenced by the data collected in 1989. Compared to three subsequent years, 1989 was a relatively high flow year and resulted in a different flow-travel time relation. However, the gill ATPase-travel time and water temperature-travel time relations were similar in each year. These factors resulted in a smaller flow effect and larger gill ATPase and water temperature effects in 1989 than in the other years. The flow and delta flow variables were the only significant contributors to the model without the data from 1989. ($R^2 = 0.81$; Table 1.1; Figure 1.5b).

Clearwater Trap-to-Lower Granite Dam Reach

Springs Chinook Salmon. Flow and ATPase variables together explained 49% of the variability in travel times of juvenile

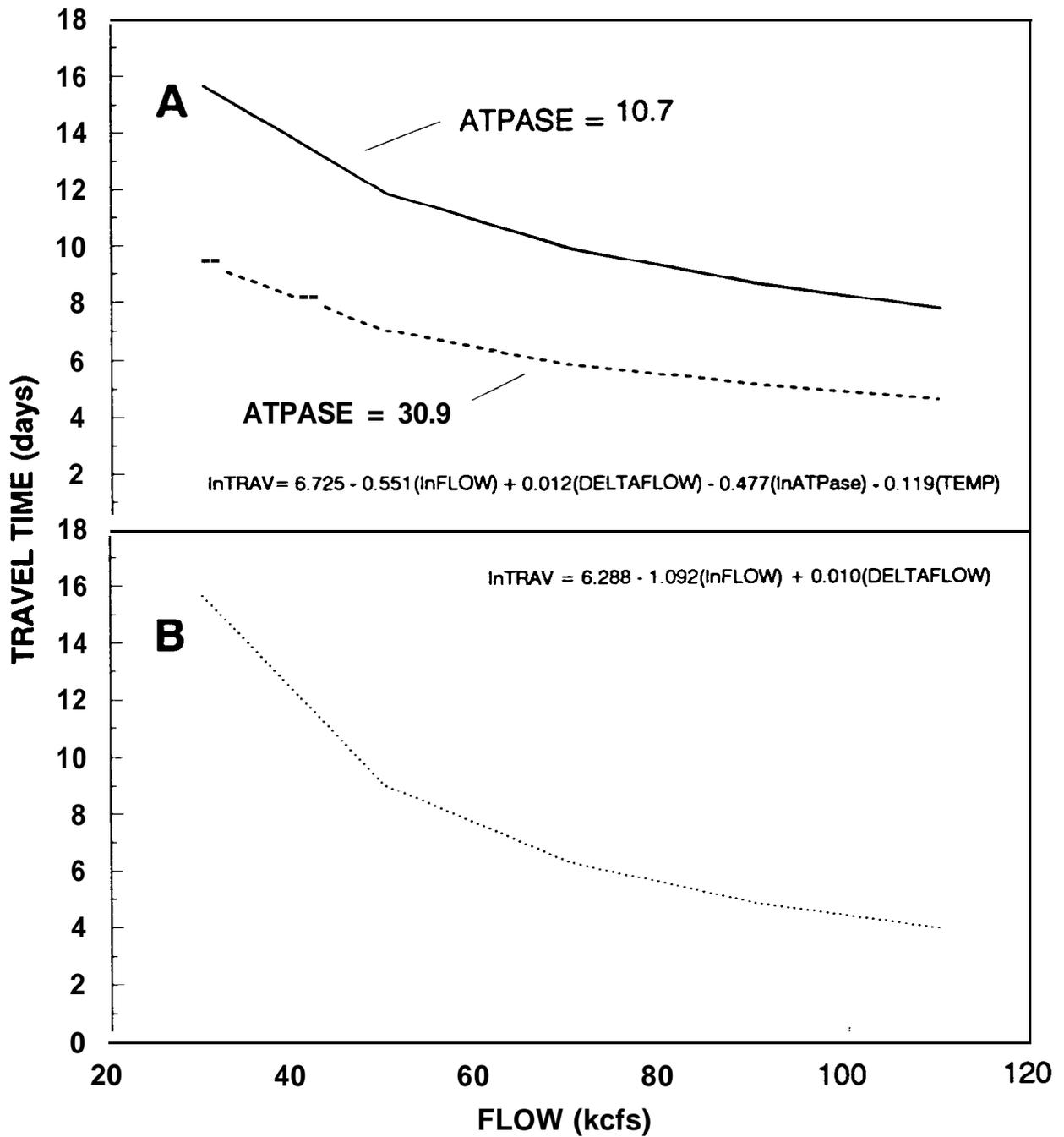


Figure 1.5. Predicted flow-travel time relations of juvenile spring chinook salmon migrating between the Idaho Department of Fish and Game Snake River Trap and bower Granite Dam based on a multiple regression of data collected in 1989-1992 including gill ATPase activity (ATPASE; A), and data collected in 1990-1992 based on river flow alone (B). For the purpose of plate A, delta flow and water temperature variables were held constant at their means.

spring chinook salmon in the Clearwater River Trap-to-Lower Granite Dam reach. The addition of delta flow and water temperature variables increased the coefficient of determination to $R^2 = 0.76$ (Table 1.1; Figure 1.6).

Multicollinearity of the independent variables was not present, so their importance in affecting the travel time in this equation was evaluated using the beta weights. These estimates for the flow, delta flow, gill ATPase, and water temperature variables were -0.27, -0.39, -0.35, and -0.42, respectively, indicating each of the independent variables explained approximately equal portions of the travel time of juvenile spring chinook salmon in this reach.

Little Goose Dam-to-McNary Dam Reach

Steelhead. Nineteen-ninety-two was the first year we collected data from juveniles during PIT tagging at Little Goose Dam. Due to the low sample rates at the juvenile fish collection facility and the timing of the migration, only six samples from hatchery steelhead and four samples from wild steelhead were obtained from 21 April to 28 May, 1992.

Median travel time of hatchery steelhead was significantly correlated with flow ($r = -0.97$, $N = 6$, $ll = 0.0011$), delta flow ($r = 0.96$, $N = 6$, $P = 0.0025$) and water temperature ($r = 0.84$, $N = 6$, $P = 0.0383$). Regression analysis was not performed due to the small sample size. Median travel times of the wild steelhead collected on the four dates were not significantly correlated with any of the measured variables.

Spring Chinook Salmon. Samples from juvenile spring chinook salmon were collected on nine dates from 21 April to 26 May, 1992. The variables collected from juvenile spring chinook salmon were not correlated with median travel time through this reach. These variables were date, gill ATPase activity, flow, delta flow, condition factor, and water temperature.

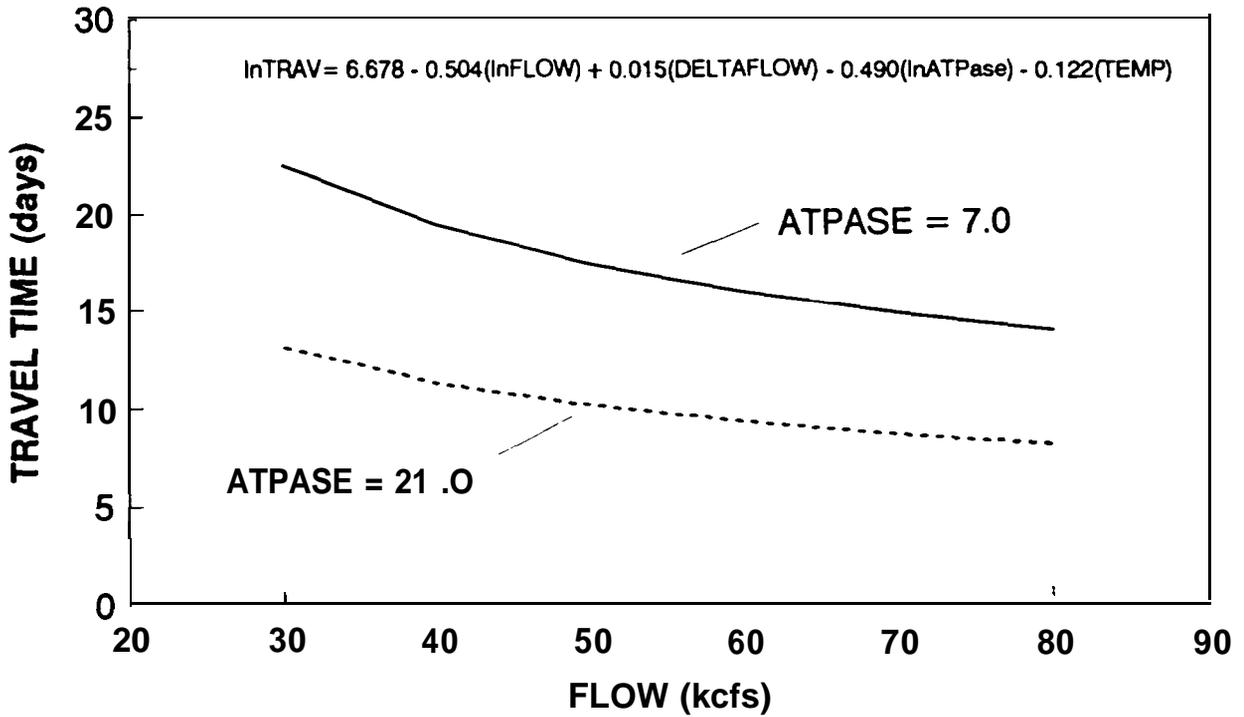


Figure 1.6. Predicted flow-travel time relations of juvenile spring chinook salmon migrating between the Idaho Department of Fish and Game Clearwater River Trap and Lower Granite Dam based on a multiple regression based on data collected in 1989-1992. Levels of gill atpase (ATPASE) represent minimums and maximums from data collected in 1989-1992. For the purpose of demonstration, the deltaflow and water temperature variables were held constant at their means.

DISCUSSION

Gill ATPase activity (i.e. smoltification), condition factor, average river flow (a surrogate measure of water velocity), delta river flow, and water temperature were significant contributors in regression models explaining the travel times of juvenile salmonids. Each of these variables was an important determinant of the travel times of juvenile spring chinook salmon, but travel times of steelhead were best explained using average flow alone. These results are similar to those of Berggren and Filardo (1993), who used surrogate variables for smoltification.

Gill ATPase activity was used as a measure of smoltification based on its relation to migratory behavior and other physiological measures of smoltification (Hart et al. 1981; Dickhoff et al. 1990). Spring chinook salmon with higher gill ATPase activities had shorter travel times. However, we agree with Ewing et al. (1980) that elevated gill ATPase activity is not a prerequisite for seaward movement of juvenile chinook salmon. The increased activity of gill ATPase in fresh water is a developmental change preparatory to the osmoregulatory demands of life in seawater (Folmar and Dickhoff 1981). Increases in gill ATPase activity are one of a suite of physiological changes occurring during smoltification, and most likely has a correlative, rather than a causative, relation with increases in migration rates during smoltification.

River flow was the only variable common to models of juvenile spring chinook salmon and steelhead travel time in every reach. Juvenile salmonid travel times decreased as river flows increased. This is consistent with the findings of other investigators (Raymond 1968, 1969; Berggren and Filardo 1993). However, flow is probably not the proximate factor initiating migration. Johnsson (1991), in a review of the influence of environmental variables on fish migration, cited photoperiod, indicating the season for migration, as the proximate factor with flow and water temperature as direct modifiers of fish migration patterns once migration has been initiated. Our analysis has also shown that in addition to flow-related variables and Water

temperature, gill ATPase activity also plays a role in the rate of migration of juvenile spring chinook salmon, although this variable has also been shown to be affected by photoperiod and water temperature.

The relative influence of the gill ATPase and river flow variables is important to managers of the juvenile salmonid migrations in the Columbia and Snake rivers, because water management strategies may be influenced by the outcome. However, we could not conclude that either flow or gill ATPase activity was consistently more important in affecting the travel times of juvenile spring chinook salmon: beta weights of these variables were similar in most cases. However, the areas we studied were in the upper reaches of the Columbia and Snake rivers, where gill ATPase activities typically increase rapidly as fish undergo the process of smoltification. The effects of gill ATPase activity farther downstream may be different, as changes in the activity of this enzyme occur rapidly during the first several weeks after hatchery release and change little afterward (Beeman and Rondorf, unpublished data, information on wild fish not available).

Gill ATPase activity was not a significant contributor to regression models predicting travel times of hatchery or wild steelhead, unless fish from both origins were pooled. However, in this context, the effects of gill ATPase activity may be expected to influence travel times of steelhead, as wild steelhead typically had higher gill ATPase activities and shorter travel times than hatchery steelhead.

Condition factor was a significant variable in the regression predicting travel time of juvenile spring chinook salmon between Rock Island and McNary dams. Travel times decreased with reductions in condition factor. Condition factor probably accounted for variability in travel times associated with differences in smoltification, as it was highly correlated with gill ATPase activity ($r = -0.77$). The streamlined appearance of smolts compared to parr and the reduced condition factors of migrants compared to non-migrants are well known (Vanstone and Markert 1968, Rodgers et al. 1987). However, we caution the use of condition factor as a measure of

smoltification, as it can be readily affected by food consumption and fish health, potentially confounding comparisons of smoltification between groups of fish.

Water temperature at release was a significant variable in four of five regressions of juvenile spring chinook salmon travel time, and in one model of the travel time of pooled hatchery and wild steelhead data. The regression coefficients for water temperature in models of juvenile spring chinook salmon were negative, i.e., as temperature at release increased the travel times decreased. This relation is contrary to findings of Bjorn (1971) and Bilby and Bisson (1987), who reported increases in numbers of migrants during periods of decreases in water temperatures of Idaho and Oregon tributaries of the Snake and Columbia rivers. However, temperatures in tributaries are often influenced by cool water from freshets and snow melt, whereas in mainstem reservoirs the effects of these factors are small due to the volume of the reservoirs. Inasmuch as gill ATPase activity and water temperature were positively correlated, increases in water temperatures may affect travel times by accelerating development of smoltification or other physiological processes. However, we expect that the relation between water temperature and travel time has some upper limit beyond which disposition to migrate is suppressed. Zaugg et al. (1972) found that above 15 C gill ATPase activity failed to develop in steelhead, and concluded the disposition to migrate may also have upper limits occurring under natural conditions.

The regression coefficients of water temperature in the models of steelhead travel time between Rock Island and McNary dams and Little Goose and McNary dams were positive, indicating increases in water temperature prolonged the migration of steelhead in these reaches. These relations are opposite from the relation in our data from juvenile chinook salmon, and the findings of Berggren and Filardo (1993). The cause of this relation may be the possible detrimental effects of water temperature on the disposition of migratory behavior of steelhead proposed by Zaugg et al. (1972), as water temperatures were as high as 14.9 C during the migration of steelhead tagged at Rock

Island Dam, and 16.5 C during the migration of those tagged at Little Goose Dam.

The models of steelhead travel time differed from those of chinook salmon travel time in that models for steelhead used only flow-related variables to predict travel time. This difference may be related to many factors including behavior in reservoirs, size, or readiness to migrate. Smith (1974), in a study of fish distribution in the Snake River above Lower Monumental Dam, found that juvenile spring chinook salmon tended to be surface-oriented at night, whereas juvenile steelhead were near the surface during the day. Ledgerwood et al. (1990) found similar results near the Columbia River estuary. Differences in distribution in the reservoir environment could place individuals in areas of different water velocities resulting in different rates of migration. Fish size may also play a role, as the juvenile steelhead in this study were considerably larger (mean fork length = 196 mm) than the spring chinook salmon (mean fork length = 129 mm). We did not measure variables indicating behavioral readiness to migrate, but steelhead in the Columbia Basin generally migrate later in the spring than spring chinook salmon, and migrate through reaches in a shorter time. Perhaps steelhead entered the mainstem rivers with higher dispositions to migrate than spring chinook salmon, and the increases in gill ATPase activities were not correlated with migration rate.

Regressions developed here predict wild steelhead have shorter travel times than their hatchery counterparts at the same river flows. This has also been documented by other investigators in the Columbia basin (Buettner and Nelson 1989, Fish Passage Center 1993). The reasons for this difference are unclear, although there were several differences between these fish. Wild steelhead typically had higher gill ATPase activities and smaller fork lengths. The differences in gill ATPase activities indicate the differences in travel times may be due to smoltification development. Gill ATPase activity is a significant contributor to models of steelhead travel time when hatchery and wild fish are pooled. This may indicate that smoltification does play a role in migration behavior of

steelhead, but the range of gill ATPase activities of hatchery or wild steelhead alone was not sufficient for this to be detected, or the larger sample size of the pooled data increased the power of the test for significance. It may also be an artifact of the known differences between hatchery and wild fish, as the highest gill ATPase activities and lowest travel times were from the wild fish. If fish size was a factor it seems logical that large fish would migrate faster than small fish. However, wild steelhead were significantly smaller (FL) than hatchery steelhead in this study, which does not support this theory. Suppression of physiological responses of hatchery steelhead from rearing in a captive environment may also be a cause of this difference, inasmuch as juvenile salmonids undergo physiological changes after release which do not occur if they remain in hatchery environments (Dickhoff et al. 1985; Rodgers et al. 1987).

We agree with Berggren and Filardo (1993), that reduction of the migration delay of juvenile salmonids in the Columbia and Snake rivers could be achieved through increases in river flows, and that smoltification should be taken into account when predicting travel times of juvenile salmonids in the Columbia Basin. The effects of smoltification on travel times of juvenile spring chinook salmon in the upper reaches of the Snake and Columbia river system of reservoirs appear as large as those of river flow. Effect of smoltification on travel times of juvenile steelhead was potentially confounded by differences between hatchery and wild fish, and thus could not be readily detected.

Manipulation of smoltification of juvenile salmonids to increase the readiness to migrate at the time of release from the hatchery may also reduce delays in migration, although these effects may be short-lived and they would not affect wild fish (Muir et al. 1992). Many observations indicate that smoltification, and perhaps the readiness of juvenile salmon in hatcheries to migrate, are not completely developed prior to release (Dickhoff et al. 1985; Zaugg and Mahnken 1991). The stimuli of in-river migration or release from captive environments has been shown to stimulate smoltification development (Zaugg et al. 1985). If a regime of altered

photoperiod and water temperature could be developed to provide the stimulation observed during the in-river migration, then the travel time of juvenile salmon from hatcheries could be reduced (Muir et al. 1992). These changes could alter the migrational tendencies of a large component of the juvenile salmon migration, as the proportion of hatchery released fish in the Columbia and Snake rivers has increased dramatically in recent years.

Based on our analyses, increases in average river flows (or water velocities) would be the most biologically-effective method to decrease travel times of juvenile salmonids in the Columbia Basin. In addition, the degree of smoltification and water temperature are important factors affecting travel times of juvenile spring chinook salmon. Of the variables we tested, average river flow is of primary importance because of the association with travel time for both chinook salmon and steelhead. Furthermore, the effects of reservoirs have been to decrease water velocities in impounded reaches, increasing travel times of juvenile salmonids relative to the water velocities under free-flowing conditions.

Chapter 2.

Epidemiology of Bacterial Kidney Disease
in Juvenile Hatchery Spring Chinook Salmon in the
Columbia and Snake Rivers

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ABSTRACT

During the years from 1988 through 1992, we assessed the prevalence and severity (based on optical density data from enzyme-linked immunosorbent assays) of bacterial kidney disease (BKD) in marked groups of Columbia River basin and Snake River basin hatchery spring chinook salmon (Oncorhynchus tshawytscha) before release and during their seaward migration. There was a decrease in prevalence of BKD (from > 90% to < 60%) in six of the eight hatchery groups studied which we attribute to changes in hatchery practices that reduced vertical and horizontal transmission. Fish from Snake River hatcheries had higher prevalence of infection when sampled at dams (mean > 90%) as compared to in the hatchery (mean c 70%), but there were no differences in similar comparisons of Columbia River fish. Although there was no correlation between prevalence and severity of BKD in the groups studied, it appears that Snake River, BKD-positive fish were more severely infected than those from the Columbia River. Some groups of Snake River fish had higher severity of infection when sampled at dams as compared to the hatchery, but infection in fish from Columbia River hatcheries did not change. These differences between Snake River and Columbia River fish may be the result of differences in river conditions and the distances from hatcheries to dams; however, unknown variables such as inriver mortality, selection biases of dam bypass systems and the removal of fish for transportation confound these analyses.

INTRODUCTION

Bacterial kidney disease (BKD) is the most serious health problem currently affecting wild (Evelyn et al. 1973) and cultured salmonids (Fryer and Sanders 1981; Fryer and Lannan 1993) in the Pacific northwest. The history of BKD (Earp et al. 1953) and reports on the affects of hatchery rearing conditions suggest that anthropogenic activities, such as the addition of unpasteurized fish flesh and viscera to fish food (Wood and Wallis, 1955) and the unavoidably stressful conditions in the aquaculture environment (Maule et al. 1989; Bank 1992), have

exacerbated fish diseases worldwide. As the factors influencing the epizootiology of BKD have become known, alterations in management practices, such as segregating gametes based on the severity of BKD in the broodstock, have decreased the prevalence and severity of BKD in salmon in hatcheries (Pascho et al. 1991).

Little is known about the health of anadromous salmon during much of their lives because their life cycle includes migrating to, living in and returning from the ocean. Pascho et al. (1991) found that 62% of the progeny of female chinook salmon with low severity of BKD infection were positive for BKD at the time of their release from Dworshak National Fish Hatchery (NFH) as compared to 85% BKD-positives among progeny of females with high BKD infection. When fish were collected at Lower Granite Dam on the Snake River, the two groups were a combined 73% positive for BKD (Pascho et al. 1993). Sanders et al. (1992) reported that 19 to 25% of chinook salmon (Oncorhynchus tshawytscha) collected at the mouth of the Columbia River tested positive for Renibacterium salmoninarum (RS), the pathogenic bacterium responsible for BKD. Banner et al. (1986) found that 11% of juvenile chinook salmon collected in the Pacific Ocean off of the Oregon and Washington coasts were positive for RS. Although the two latter studies used a different assay (fluorescent antibody test, FAT) than the two former studies (enzyme-linked immunosorbent assay, ELISA), these results suggest that changes in the prevalence and severity of BKD occur after salmon are released from hatcheries.

The goal of this study was to describe the epidemiology of BKD in spring chinook salmon in Columbia River basin hatcheries and during their seaward migration. To achieve this goal, we defined several objectives: (1) determine if there were changes in prevalence or severity of BKD in spring chinook salmon prior to their release from hatcheries between 1988 through 1992; (2) determine if there were changes in prevalence or severity of BKD in specific groups of hatchery spring chinook salmon after migrating to dams in the Snake and Columbia rivers; (3) determine if there were differences in the prevalence or severity of BKD in spring chinook salmon in hatcheries and during migration of Snake River fish as compared to Columbia River fish; (4) determine if

the prevalence or severity of BKD differed based on when spring chinook salmon from a specific hatchery arrived at a dam (i.e., early, mid, or late portion of the run for that hatchery group); and, 5) determine if changes in prevalence or severity of BKD were related to changes in hatchery practices or river environment.

METHODS

Sampling Times and Locations. During the years 1988 through 1992, groups of spring chinook salmon were sampled within two weeks prior to their release from four mid Columbia River basin and four Snake River basin hatcheries (Figure 2.1; Table 2.1). (Chinook salmon from the McCall Idaho State Hatchery (SFH) are considered a summer run of chinook salmon.) One hundred fish from each of two hatcheries from each river basin were sampled beginning in 1988; 60 fish from two additional hatcheries from each river basin were sampled beginning in 1990. Between 20,000 to 50,000 fish from each group were uniquely marked by freeze-branding (Everest and Edmundson 1967; for review see: Parker et al. 1990), and members of each group were collected when they entered fish collection facilities at Lower Granite Dam (LGR) on the Snake River and Rock Island Dam (RIS) and McNary Dam (MCN) on the Columbia River. The collection systems at LGR (Matthews et al. 1986), MCN (Maule et al. 1988) and RIS (Peven and Duree, 1990) have been described. Rock Island Dam is above, and MCN is below the confluence of the Snake and Columbia rivers (Figure 2.1); Snake River fish were sampled at LGR and MCN, and Columbia River fish were sampled at RIS and MCN, with the exception of those from Ringold Washington SFH that is located down river of RIS. Based on the number of fish in a given marked-group and estimates of travel time and total number of fish expected to be collected, we attempted to collect 20 fish at each dam during the 25th, 50th and 75th percentile of each branded group's passage at each dam. This goal was not always met because the actual percentiles could not be determined until the end of the migration; so not all hatcheries for each year and location were considered (Table 2.1). If we collected 20 fish from a particular group at each percentile (25th, 50th and 75th), we

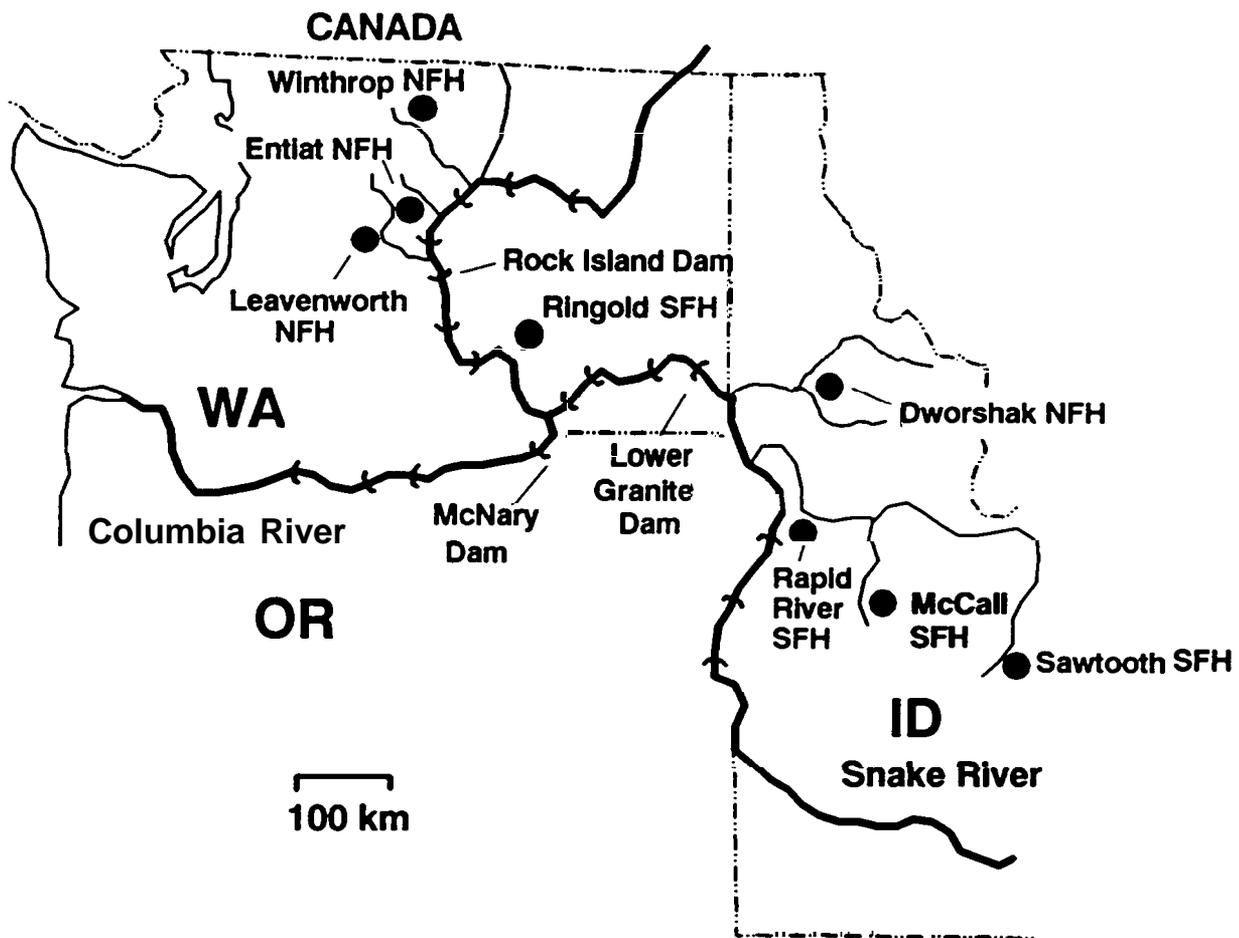


Figure 2.1. Map of the Columbia and Snake rivers showing the national fish hatcheries (NFH), state hatcheries (SFH) and dams where fish were sampled.

Table 2.1. Years in which spring chinook salmon were sampled for bacterial kidney disease analyses prior to release of the fish from national fish hatcheries (NFH), Washington and Idaho state fish hatcheries (SFH) in the Columbia and Snake river basins. Numbers in parentheses are the river km from the hatchery to Rock Island Dam (RIS), Lower Granite Dam (LGR) or McNary Dam (MCN) where freeze-branded hatchery fish were also sampled.

	Hatchery	<u>Sampling Location</u>	
		RIS or LGR	MCN
<u>Snake River Hatcheries</u>			
Dworshak NFH	1988 - 1992	1988 - 1992	1988 - 1992
McCall SFH	1990 - 1992	1990 - 1992	1990 - 1992
Rapid River SFH	1990 - 1992	1990 - 1992	1990 - 1992
Sawtooth SFH	1988 - 1992	1988 - 1992	1988, -90, -92
<u>Columbia River Hatcheries</u>			
Entiat NFH	1988, 1990-92	1988, 1990-92	1988,
Leavenworth NFH	1989 - 1992	1990 - 1992	1989 - 1992
Ringold SFH	1990 - 1992	n.a.	1990 - 1992
Winthrop NFH	1988 - 1992 1992	1988, 1990-92	1988 -

established criteria that a difference of 10% in prevalence of BKD or a statistically significant difference in mean ELISA OD Value constituted a change in BKD (not necessarily statistically significant) during the course of the migration of a group of hatchery fish past a dam.

Sample Collection and Analyses. All fish that were sampled were placed quickly into a lethal dose (200 mg/L) of tricaine methanesulfonate (MS-222). After fish were fully anesthetized, blood and gill filaments were collected from some fish and processed to address objectives not considered here. Spleens and kidneys were removed from all fish in such a manner as to avoid cross contamination (Pascho et al. 1987); samples were frozen immediately in liquid nitrogen and stored at -80 C until assayed. Assay conditions for determining the presence and severity of infection with R. salmoninarum were the same as the ELISA described by Pascho et al. (1987).

Environmental Variables and Hatchery Practices. We recorded water temperature each time that fish were sampled. We also obtained data as to river flow rates and median time required for branded fish to travel from their hatchery of origin to RIS, LGR or MCN from annual reports of the Fish Passage Center of the Columbia Basin Fish and Wildlife Authority (FPC 1989, 1990, 1991, 1992, 1993). In 1993, we sent a questionnaire to each hatchery requesting information about hatchery practices, such as brood stock segregation (Pascho et al., 1991), prophylactic or therapeutic treatments, numbers of returning adults and numbers of male and female spawners, raceway loading densities, survival to various life stages, and changes in water quantity or quality. Hatchery information was examined to detect changes that coincided with changes in BKD.

Data Analyses. Severity of R. salmoninarum infection is based on the optical density (OD) of the final reaction mixture in the ELISA system. A critical step in analyzing BKD data is determining the maximum OD value for a sample to be classified as negative (i.e., free of R. salmoninarum; Pascho et al. 1987). We determined this value independently each year and the maximum OD values for samples to be considered negative were from 0.070 to 0.074, except for about one third of the samples collected in

1990 when 0.095 was the maximum negative. Pascho et al. (1987) described a process by which ELISA OD values were classified as high, medium, or low severity of infection; this classification or the distribution of OD values has been used previously to describe the severity of BKD in a population (Pascho et al. 1991; 1993). Because we had over 200 groups to consider, we wanted a single value to describe severity of BKD infection in a group. Furthermore, we decided that a fish that was negative for BKD had no infection, so the term "severity of infection" did not apply to that individual. Therefore, we determined severity of infection based on the mean ELISA OD of only the BKD-positive samples within a group.

The distribution of ELISA OD values is skewed toward low values (i.e., to the left); therefore, OD values were squared to normalize the data for statistical analyses (Zar 1984). We used a variety of statistical methods to analyze the BKD data and to determine relations between prevalence and severity of BKD and several spatial and temporal variables. Analyses included general linear models procedure, Duncan's multiple range test for pairwise comparisons, t-tests, Cochran's t-test for samples with unequal variances, regression analyses and correlation analyses. The prevalence of BKD, in percent, was arcsin transformed prior to analyses.

RESULTS

BKD in Hatcheries. Between 1988 and 1992 the prevalence of BKD in six of the eight spring chinook salmon hatcheries declined from highs near 100% to less than 60% in Snake River hatcheries (Figure 2.2a) and less than 25% in Columbia River hatcheries (Figure 2.3a). One hatchery in each river basin (Rapid River SFH and Ringold SFH) did not show this decline. The mean severity of BKD-positive fish at Columbia River hatcheries varied from < 0.1 to 0.4 ELISA OD values (Figure 3b) while similar measurements in Snake River hatcheries varied from < 0.1 to 1.3 (Figure 2.2b). In general, there was no correlation between prevalence and mean severity of infection in BKD-positive fish (Figures 2.2b & 2.3b); however, from 1988 to 1989 prevalence and severity increased simultaneously at Dworshak National Fish Hatchery (NFH) and in

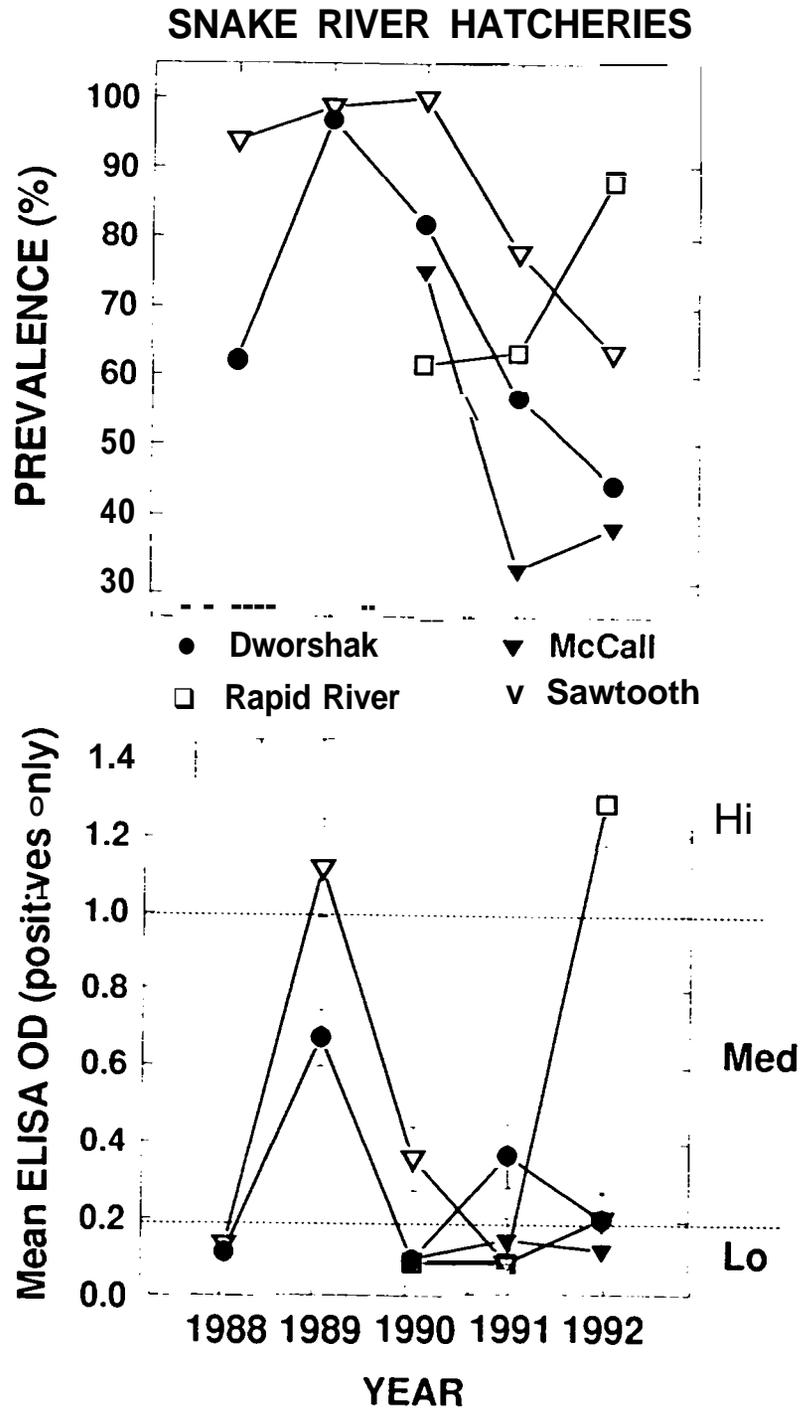


Figure 2.2. Prevalence and mean (\pm SE) ELISA optical density (OD) of BKD-positive spring chinook salmon sampled at hatcheries in the Snake River during the years indicated. The high (Hi), low (Lo) and medium (Med) lines are based on the cutoff values established by Pascho et al. (1991).

COLUMBIA RIVER HATCHERIES

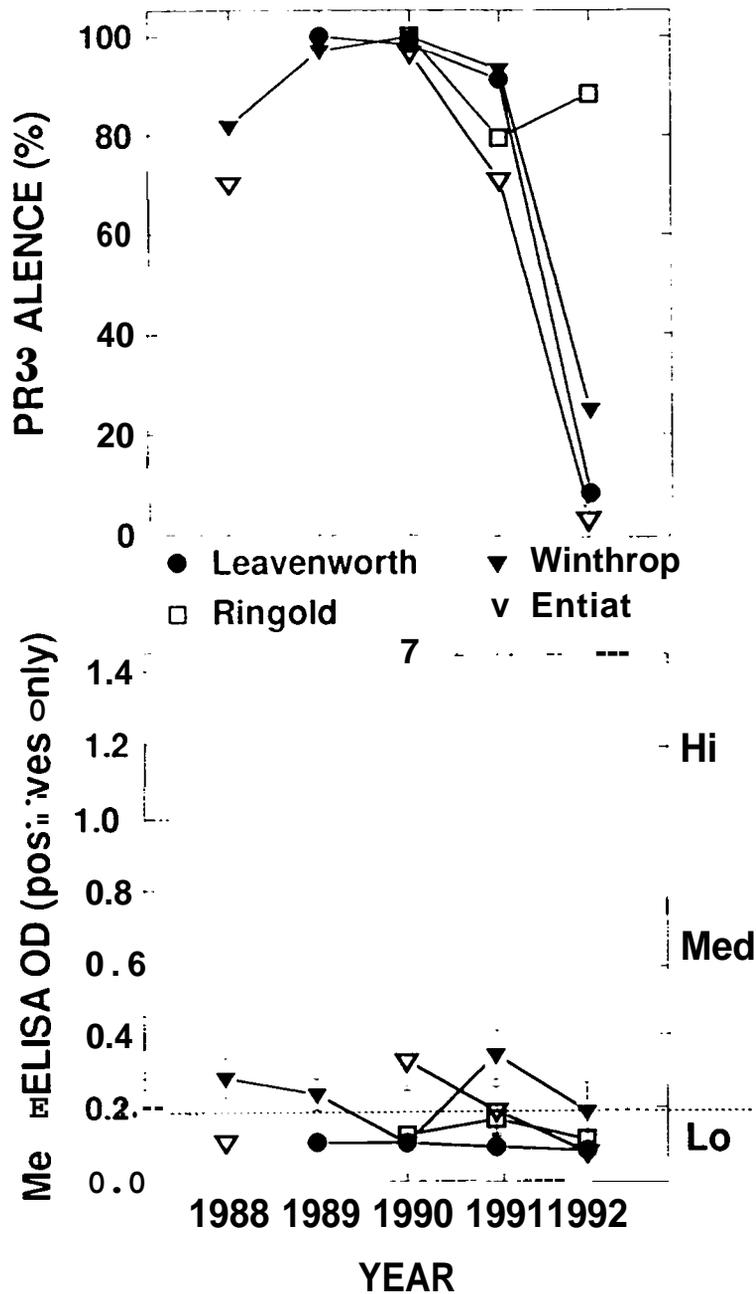


Figure 2.3. Prevalence and mean (+ SE) ELISA optical density (OD) of BKD-positive spring chinook salmon sampled at hatcheries in the Columbia River during the years indicated. The high (Hi), low (Lo) and medium (Med) lines are based on the cutoff values established by Pascho et al. (1991).

1992 similar increases occurred at Rapid River SFH (Figure 2.3).

BKD at Dams. The mean prevalences of BKD in fish collected at LGR and MCN dams throughout the study were significantly greater than when the same groups were sampled in Snake River hatcheries (Figure 2.4a). However, prevalence in fish sampled in Columbia River hatcheries did not differ significantly from those collected at RIS or MCN dams (Figure 2.4b). Seven of the 16 groups of fish released from Snake River hatcheries had significantly greater mean severity of infection when sampled at dams as compared to the hatchery (Figure 2.5). Two Snake River groups that had exceptionally high mean severity of infection (> 1.2 ELISA OD-values) in the hatchery had significantly lower values when collected at the dams (Figure 2.5). There were no differences in severity of infection in Columbia River fish sampled at the dams as compared to in the hatcheries (Figure 2.6).

Snake River Fish Versus Columbia River Fish. Several comparisons were made to determine if there were differences in BKD between fish from the Snake and Columbia rivers. There was no significant difference in mean prevalence of BKD in fish in hatcheries or in groups of hatchery fish sampled at McNary Dam, the only collection site common to fish from both rivers (Figure 2.4, comparing Snake River to Columbia River). Severity of BKD infections in fish from the two river systems was compared in two ways on an annual basis. First, BKD in all fish sampled prior to release from Snake River hatcheries was compared to that of fish sampled at Columbia River hatcheries; and second, all Snake River hatchery fish collected at MCN were compared to fish from Columbia River hatcheries also collected at MCN. In one year (1988) BKD-positive fish in Columbia River hatcheries had significantly greater mean ELISA OD values than fish in Snake River hatcheries, while in two years (1989, 1992) and for all years combined, Snake River fish had significantly greater OD values than did Columbia River hatchery fish (Table 2.2). In three of five years (1989, 1990 & 1992), and in all years combined, fish from Snake River hatcheries collected at MCN had significantly greater OD values than did fish from Columbia River hatcheries also collected at MCN (Table 2.2).

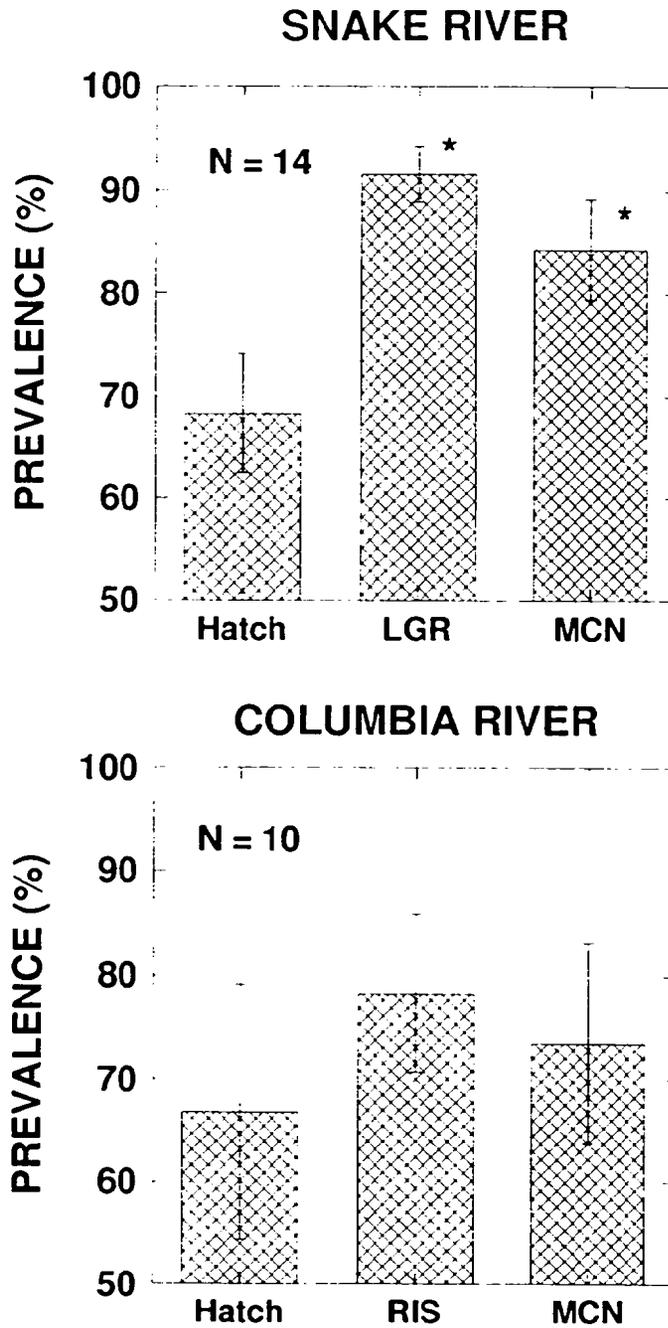


Figure 2.4. Prevalence (mean \pm SE) of BKD in groups of freeze-branded spring chinook salmon sampled at Snake River or Columbia River hatcheries (Hatch) before release and captured during their migration at Lower Granite (LGR), Rock Island (RIS) or McNary (MCN) dams during the years of 1988 to 1992. Bars marked (*) differ significantly from Hatch in the same panel ($p < 0.05$; general linear model test of arcsin-transformed percent).

SNAKE RIVER HATCHERIES

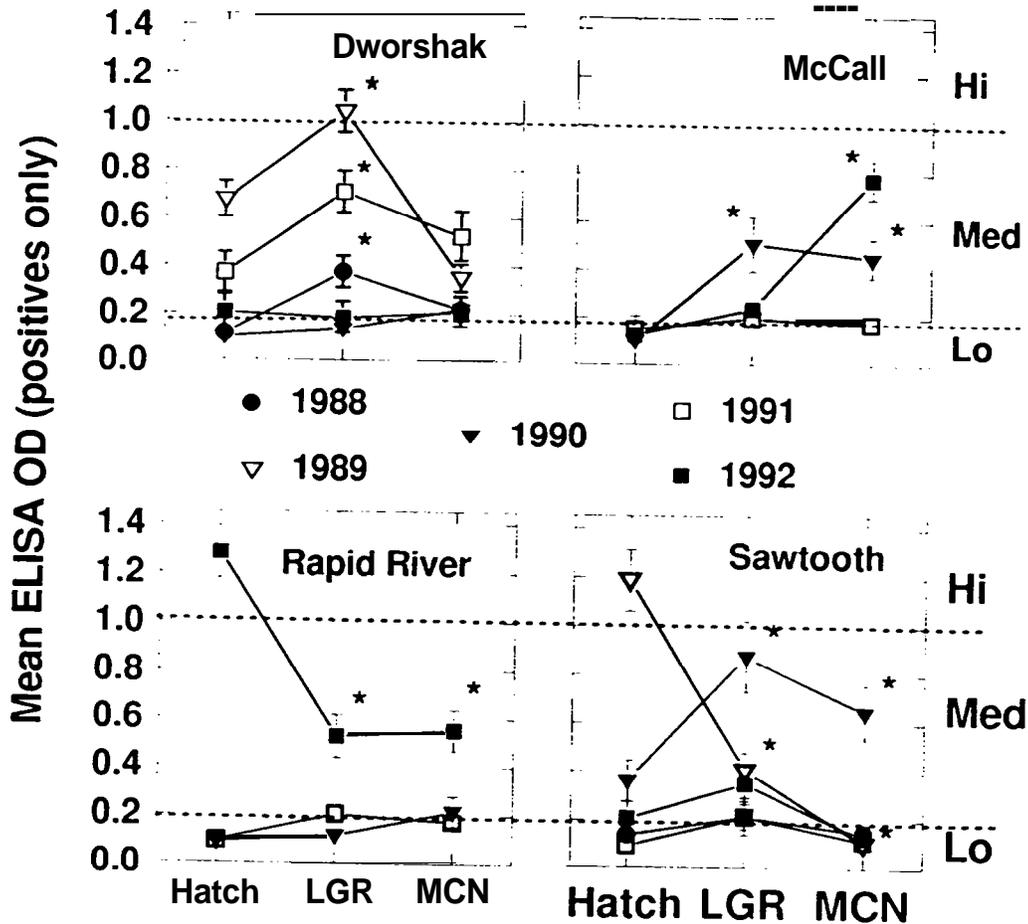


Figure 2.5. Mean (+ SE) ELISA optical density (OD) of BKD-positive spring chinook salmon sampled in Snake River hatcheries (Hatch) and after migration to Lower Granite (LGR) and McNary (MCN) dams during years indicated. The high (Hi), low (Lo) and medium (Med) lines are based on the cutoff values established by Pascho et al. (1991). Points marked (*) differ significantly from Hatch of the same line ($p < 0.05$, general linear models and Duncan's multiple range test). Sample sizes are 22 to 160.

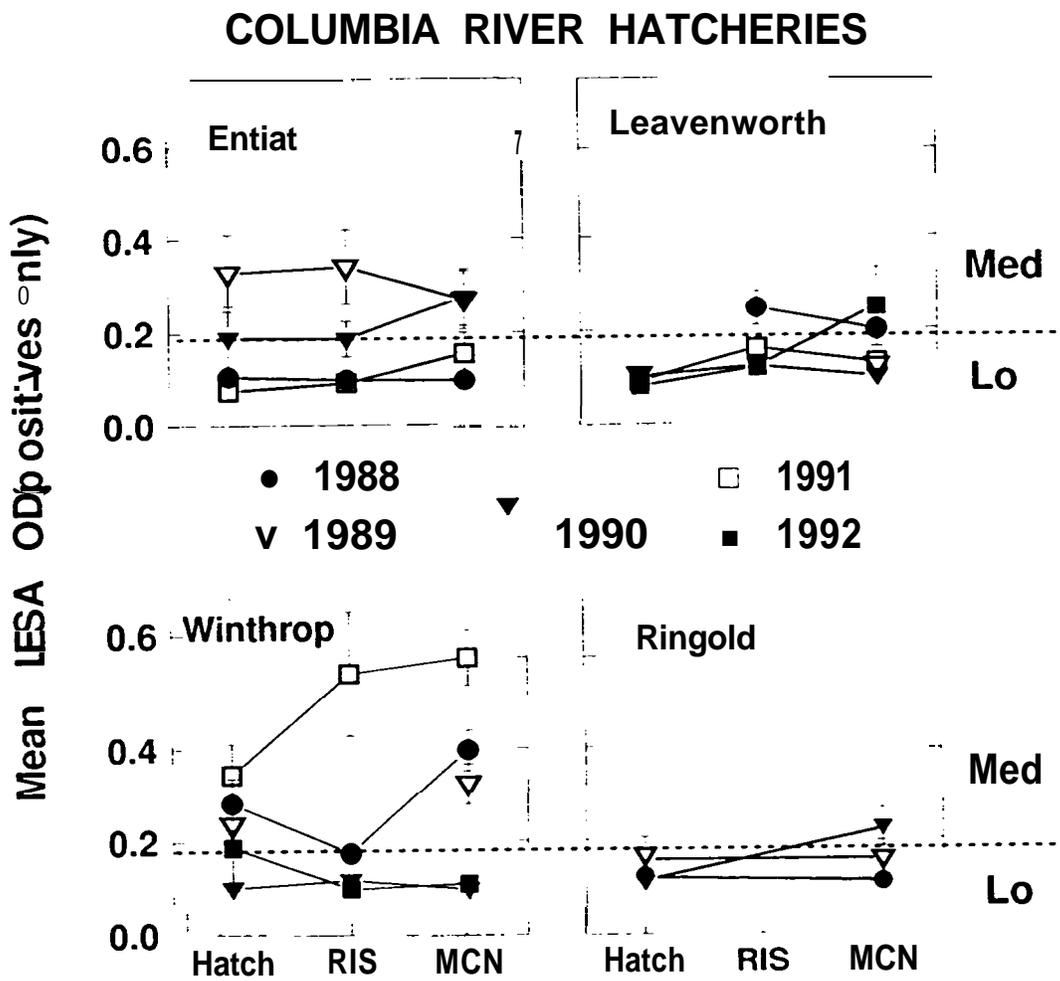


Figure 2.6. Mean (+ SE) ELISA optical density (OD) of BKD-positive spring chinook salmon sampled in Columbia River hatcheries (Hatch) and after migration to Rock Island (RIS) and McNary (MCN) dams during years indicated. The high (Hi), low (Lo) and medium (Med) lines are based on the cutoff values established by Pascho et al. (1991). Sample sizes are 18 to 175.

Table 2.2. Severity of bacterial kidney disease infection (mean ELISA OD \pm SE) in spring chinook salmon sampled at hatcheries in Columbia or Snake river basin and after migrating to McNary Dam. Data are all fish sampled from two to four hatchery groups released into each river system each year. Sample sizes are in parentheses. Statistical comparisons between fish from the Columbia and Snake rivers were done by Cochran's t-test for samples with unequal variances.

Year	Columbia River	Snake River	P
	<u>Hatcheries</u>		
1988	0.207 \pm 0.032 (142)	0.133 \pm 0.014 (143)	0.048
1989	0.169 \pm 0.022 (196)	0.883 \pm 0.073 (180)	0.0001
1990	0.170 \pm 0.025 (195)	0.181 \pm 0.028 (183)	0.805
1991	0.209 \pm 0.029 (171)	0.188 \pm 0.029 (174)	0.944
1992	0.128 \pm 0.023 (88)	0.554 \pm 0.061 (156)	0.0001
Total	0.180 \pm 0.012 (792)	0.395 \pm 0.024 (836)	0.0001
	<u>McNary Dam</u>		
1988	0.272 \pm 0.253 (271)	0.214 \pm 0.040 (92)	0.570
1989	0.214 \pm 0.023 (344)	0.349 \pm 0.056 (117)	0.090
1990	0.122 \pm 0.009 (476)	0.330 \pm 0.033 (322)	0.0001
1991	0.341 \pm 0.029 (376)	0.326 \pm 0.047 (112)	0.705
1992	0.192 \pm 0.028 (124)	0.496 \pm 0.043 (203)	0.0001
Total	0.225 \pm 0.010 (1582)	0.359 \pm 0.020 (846)	0.0001

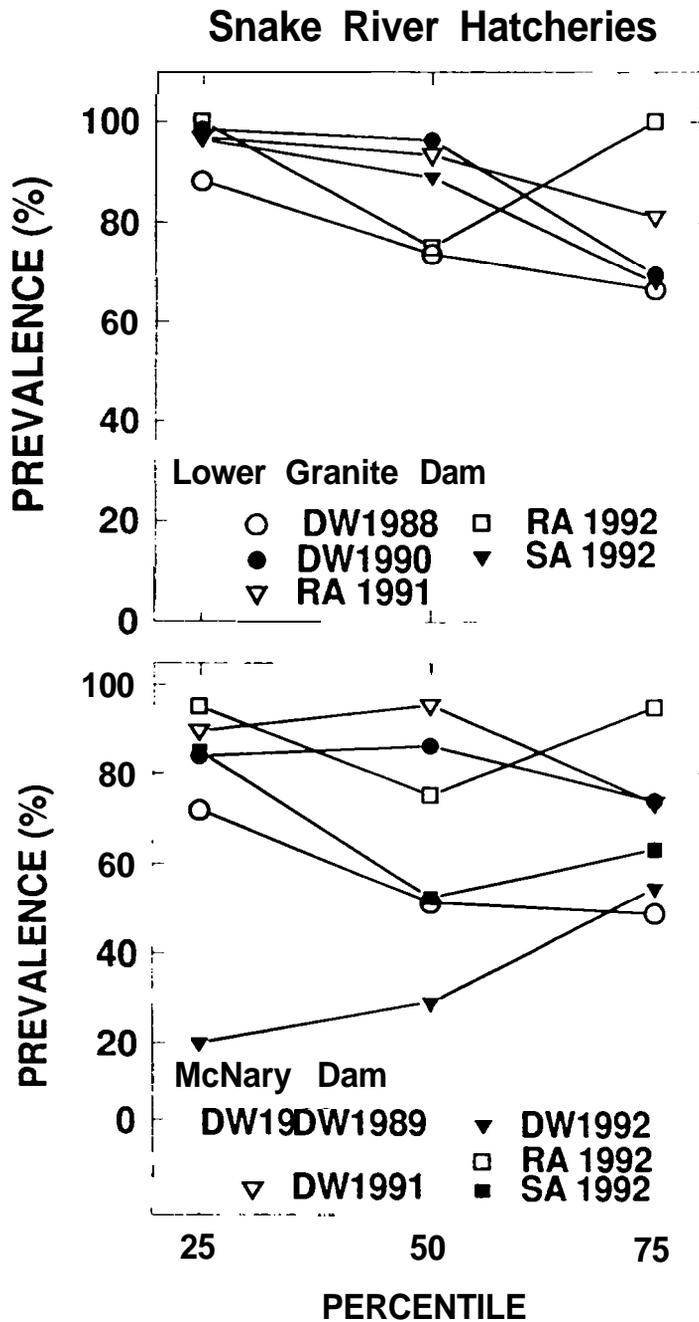


Figure 2.7. Prevalence of BKD in freeze-branded spring chinook salmon from Dworshak (DW) Rapid River (RA) and Sawtooth (SA) fish hatcheries. Data are from hatchery groups that had at least a 10% change in prevalence in fish during the 25th, 50th or 75th percentiles of fish that passed Lower Granite or McNary dams in the years indicated.

Columbia River Hatcheries

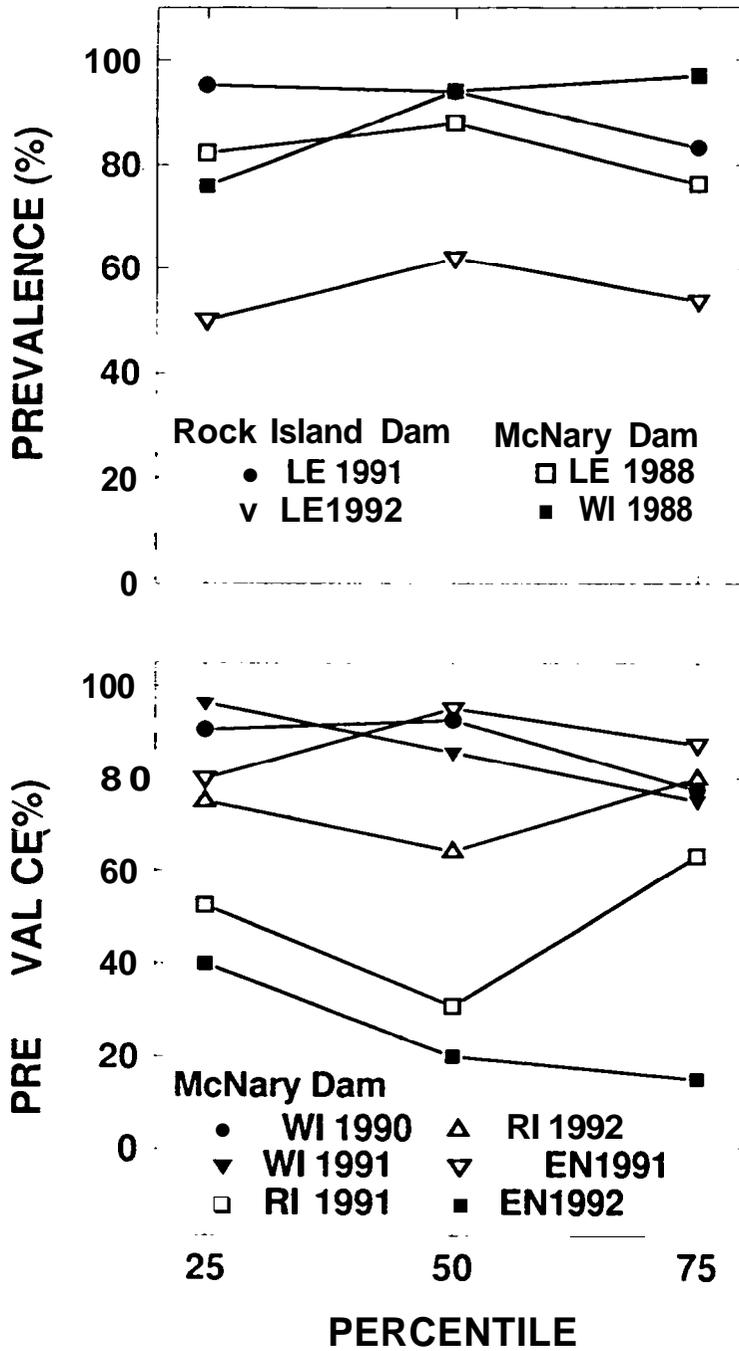


Figure 2.8. Prevalence of BKD in freeze-branded spring chinook salmon from Entiat (EN), Leavenworth (LE), Ringold (RI) and Winthrop (WI) fish hatcheries. Data are from hatchery groups that had at least a 10% change in prevalence in fish during the 25th, 50th or 75th percentiles of fish that passed Rock Island or McNary dams in the years indicated.

Thus, in five of the 10 annual comparisons and in both combined comparisons, fish from the Snake River had greater severity of BKD infection than did fish from the Columbia River (Table 2.2).

BKD Durins Emicfration. From 1988 through 1992, 21 of 34 groups of fish collected at dams met the criterion of a 10% difference in prevalence between the early, mid and late arriving fish (Figures 2.7 & 2.8). While there were variable patterns of changes in prevalence, in general, the early-arriving fish had the highest prevalence of BKD (13 of 21 groups) and those arriving late had the lowest (11 of 21). There do not appear to be any differences in this pattern based on whether the fish originated at a Snake River or Columbia River hatchery, or based on which dam the fish were passing (Figures 2.7 & 2.8).

Of the 34 groups that had sufficient numbers of fish collected at a dam, only five had significant temporal changes in severity of BKD and all of those were at McNary Dam, the furthest downstream sampling site. In two of the five groups (McCall SFH and Rapid River SFH in 1992), mean ELISA OD values were significantly higher (Duncan's multiple range test, $P < 0.05$) in later arriving fish compared to early and middle arrivals: two groups had significantly higher values in early arrivals (Leavenworth NFH, 1988 and Dworshak NFH, 1989); and, one group had significantly higher values in fish that arrived in the middle of the run (Dworshak NFH, 1988; data not shown).

Environmental Variables and Hatchery Practices. Water temperatures at hatcheries were generally 4 to 8°C (Table 2.3), except for Rapid River SFH that had the coldest water (1.0°C). Ringold SFH had the warmest water temperatures (13-16.5°C), with the highest temperatures recorded in 1992 (Table 2.3). Mean water temperatures at the dams during the times of our sampling were also at their highest in 1992 (Table 2.3).

On average, the Snake River hatcheries are farther from LGR and MCN than Columbia River hatcheries are from RIS and MCN (Table 2.4). The time (median travel time) required for fish to migrate from their hatchery to LGR and MCN is directly related to distance traveled (Table 2.4), with the exception of fish (summer chinook salmon) from McCall SFH which had the longest mean travel time to LGR (52.5 days) but were almost 300 km closer than

Table 2.3. Water temperatures (°C) at national (NFH) and state (SFH) fish hatcheries on day of sampling and the mean daily river water temperatures at dams during April 1 to May 31 for each year in which samples were taken. Dashed line indicates that no sample was taken that year at that location.

Location	<u>Year</u>				
	1988	1989	1990	1991	1992
Snake River Hatcheries					
Dworshak NFH	4.0	11.0	7.0	7.0	7.0
McCall SFH	--	--	3.0	3.5	4.0
Rapid River SFH	7.0	--	5.5	5.5	7.0
Sawtooth SFH	1.0	1.5	1.0	1.5	1.0
Mean \pm SE = 4.6 \pm 0.7 (N = 17)					
Columbia River Hatcheries					
Entiat NFH	6.0	--	6.8	8.5	9.0
Leavenworth NFH	--	4.5	6.5	6.0	6.0
Ringold NFH	--	--	13.0	13.0	16.5
Winthrop NFH	5.0	10.5	8.0	4.0	8.0
Mean \pm SE = 8.2 \pm 0.9 (N = 16)					
Dams					
Rock Island	9.6	8.5	8.6	8.6	10.3
Lower Granite	10.4	10.2	11.3	9.9	11.3
McNary	10.9	10.2	10.4	10.2	12.3

Table 2.4. Travel time (mean of yearly medians \pm SE: number of years are in parentheses) and distanced traveled of branded hatchery spring chinook salmon from their hatchery of origin to Lower Granite (LGR), Rock Island and McNary (MCN) dams. All data are from FPC (1989, 1990, 1991, 1992, 1993).

<u>River reach</u>	<u>Travel time</u>	<u>River distance</u>
Hatchery	(d)	(km)
Snake River		
Hatchery to LGR		
Dworshak NFH	24.0 \pm 1.3 (5)	118
Rapid River SFH	31.7 \pm 1.8 (3)	279
McCall SFH	52.5 \pm 4.6 (3)	457
Sawtooth SFH	46.2 \pm 4.0 (5)	<u>748</u>
Mean distance		400 \pm 135
Hatchery to MCN		
Dworshak NFH	39.4 \pm 1.5 (5)	324
Rapid River SFH	44.7 \pm 0.9 (3)	504
McCall SFH	62.7 \pm 7.4 (3)	682
Sawtooth SFH	54.2 \pm 3.0 (5)	<u>973</u>
Mean distance		621 \pm 138
Columbia River		
Hatchery to RIS		
Leavenworth NFH	n.a.	69
Entiat NFH	n.a.	66
Winthrop NFH	n.a.	<u>194</u>
Mean distance		110 \pm 42
Hatchery to MCN		
Ringold SFH	8.6 \pm 2.0 (3)	90
Leavenworth NFH	25.4 \pm 2.3 (4)	329
Entiat NFH	24.4 \pm 4.3 (4)	341
Winthrop NFH	31.0 \pm 1.9 (5)	<u>453</u>
Mean distance		303 \pm 76

n.a. - not available

were fish from Sawtooth SFH (Table 2.4). Travel times from Columbia River hatcheries to RIS are not available because of inadequate collection efficiency at RIS.

Several factors reported by hatchery personnel may have had a part in the changes in prevalence of BKD in the hatcheries. These include reduction in total number of adults returning to the hatchery, the use of therapeutics for adults and juveniles, culling eggs from adults with severe BKD, segregating juveniles based on severity of infection of the parents, and reduced loading density of juveniles in the hatchery raceways or ponds (Table 2.5).

DISCUSSION

BKD in Hatcheries. During the years of 1988 through 1992, the prevalence of BKD in spring chinook salmon in six of the eight hatcheries studied decreased from near 100% to as low as 3% (Figs. 2.2 and 2.3). We believe that there are three factors responsible for this decrease. First, the hatcheries with the greatest decline in BKD cull the eggs of severely infected females (Table 2.5). We have some concern about the practice of culling eggs because of the potential to eliminate from the population those genetic components that enable adults to survive and become sexually mature despite severe BKD infection.

River conditions may also have contributed to the culling of the weakest adults. Several managers reported up to a 78% reduction in the number of adults returning to their hatchery during the years of this study (Table 2.5). Furthermore, an experiment at Dworshak NFH had to be changed because not enough adults with high BKD returned in 1992 to create a treatment group of progeny from high-BKD adults (Ron Pascho, National Biological Survey, Seattle, WA, personal communication). The Pacific northwest was in a severe drought during this study and, in 1992 the Snake and Columbia rivers received less than 50% of the 50-year average water runoff (Fish Passage Center, 1993). Further, during the present study, water temperatures at the dams and hatcheries were highest in 1992 (Table 2.3), with temperatures in the river and at Ringold SFH at, or above 11°C - the temperature where highest BKD mortality occurs (Wood 1974;

Table 2.5. Summary of information provided by managers of Dworshak National Fish Hatchery (NFH), McCall, Rapid River and Sawtooth Idaho fish hatcheries in the Snake River basin and Entiat NFH, Leavenworth NFH, Ringold Washington Fish Hatchery and Winthrop NFH in the mid Columbia River basin.

<u>Life Stage</u>	<u>Snake River Hatcheries</u>			
	Hatchery practice	Dworshak	McCall	Rapid River	Sawtooth
Parents				
Total returns (rounded mean)	2,000	2,600 (1988-90) ^a 950 (1991-92)	6500 (1988) 3700 (1989-90) 2400 (1991-92)	1,400
Spawning ratio (males:females)	1:1	1:2 to 1.3:1	1:1	2:1
Therapeutics	erythro ^b	erythro (1991-92)	erythro (1991-92)	erythro
Eggs				
Cull eggs of high BKD adults	yes (1992)	yes - visual	no (began - 1993)	no
Juveniles				
Segregate - BKD of parents	yes	no	no	yes
Loading density index'	0.25 (1988-89) 0.30 (1990) 0.22 (1991-92)	0.20 to 0.29	0.20	0.35 (1988-90)
Therapeutics	erythro 1/yr (1988-90) 2/yr (1991-92)	erythro (1990-92)	no	erythro 2/yr (1991-92)
Survival to smolt	94+%	64-75% (1988-90) 81-88% (1991-92)	89+%	81-86% (1988-90) 89% (1991-92)

(Table 2.5 continued)

Columbia River Hatcheries

	Entiat	Leavenworth	Ringold ^d	Winthrop
Parents				
Total returns (rounded mean)	900 (1988-89) 670 (1990-91) 580 (1992)	5500 (1988-89) 3390 (1990-91) 2570 (1992)	na ^d	715 (1988-89) 1330 (1990) 158 (1991-92)
Spawning ratio (males:females)	1:2 (1988-90) 1:1.4 (1991) 1:1 (1992)	1:1.5 (on average)	na	1:2 (1988-90) 1:1.5 (1991) 1:1 (1992)
Therapeutics	erythro 1/yr	erythro 2/yr	na	no
Eggs				
Cull eggs of high BKD adults	yes (1990-92)	Yes	na	yes
Juveniles				
Segregate - BKD of parent	Yes (1990-92)	Yes	no (began 1993)	Yes (1989-92)
Loading density index ^c	0.33 (1988-90) 0.26 (1991-92)	0.18	0.40	0.30 (1988-89) 0.26 (1990-91) 0.17 (1992)
Therapeutics	no	no	Yes 3/yr	no
Survival to smolt	99+% (to swim-up)	90+%	73% (1990) 91% (1991) 75% (1992)	98+% (1988-91)

a- All dates refer to year in which fish were released: subtract 2 yr to get year in which adult fish returned to the hatchery and were spawned. Lack of dates indicates that conditions existed throughout the study (1988-92).

b- erythromycin or gallimycin treatment

c - Density index = fish weight/(fish length X water volume)

d- Ringold receives eggs or fish from other hatcheries: therefore, information on adults is not available (na).

Sanders et al.1978). Therefore, it is possible that poor river conditions caused de facto culling of juveniles after release and adults before they returned to the hatcheries.

The second factor responsible for decreasing prevalence of BKD was segregation of eggs and juveniles based on the severity of BKD in the parents (Table 2.5). Segregation would reduce possible horizontal transmission of the disease (Mitchum and Sherman 1981; Bell et al. 1984). The third factor is the reduction in loading density of juveniles in raceways or ponds at several hatcheries (Table 2.5). When R. salmoninarum is internal to a fish, it is able to depress the host's immune system (Turaga et al. 1987; Kaattari et al. 1988). However, decreasing the loading density may enhance specific immune responses of juvenile salmon (Maule et al. 1987, 1989). Therefore, the combination of segregating juveniles and reducing loading density may simultaneously reduce the severity of the R. salmoninarum challenge caused by horizontal transmission and enhance the ability of the fish to resist the pathogen.

The role that these factors played in the reduced prevalence of BKD will be tested in the next few years as Rapid River SFH began culling eggs of severely infected females and Ringold SFH began segregating juveniles in 1993 (Table 2.5). The high water temperature (13-16°C) at Ringold SFH may mask the effects of segregation (Wood 1974; Sanders et al. 1978). It will also be interesting to see if the trend toward low prevalence of BKD seen at several hatcheries continues.

BKD at Dams. The mean prevalence of BKD in groups of Snake River hatchery fish collected at LGR and MCN were significantly higher than when those groups were sampled in the hatcheries (Fig. 2.4) and there were also significant increases in the severity of infection in several groups (Fig. 2.5). There were no significant changes in prevalence or severity of BKD in fish between the Columbia River hatcheries and the dams (Fig. 2.4 and 2.6). We assume that after release from a hatchery, mortalities occur and that the most severely infected fish will be among the early mortalities. Therefore, the increases in severity of infection and prevalence suggest that internalized R. salmoninarum became more active and that horizontal transmission

occurred during the migration. The fact that increased prevalence and severity happens in the Snake River but not the Columbia River suggests that the changes are caused by the river environment and not by decreased resistance of the fish during smoltification (Maule et al. 1987). Two environmental factors that differ in the systems are (1) the distances from Snake River hatcheries to LGR and MCN are on average 2- to 4-times greater than from Columbia River hatcheries to RIS and MCN (Table 2.4), and (2) the water at LGR was about twice as warm as water at the Snake River hatcheries at the time the fish were released while water temperatures at Columbia River hatcheries were about the same as that at RIS or MCN (Table 2.3). While these factors may play a role, it is impossible to draw any cause-and-effect conclusions about the changes in prevalence or severity of BKD because of unknown sources of mortality during migration of fish, unknown sampling biases in the fish collection systems and the transportation of all fish collected at LGR and MCN.

Snake River verses Columbia River. It appears that BKD-positive fish in the Snake River basin had more severe infections than did fish from the Columbia River basin. Severity of infection in fish sampled at hatcheries was greater at Snake River than Columbia River hatcheries in three of the five years of the study and when all years were combined (Table 2.2).

Although there was no difference in the prevalence of BKD infection comparing Columbia River to Snake River fish sampled at MCN (Fig. 2.4), the severity of infections was greater in Snake River fish collected at MCN in two of the five years and in all years combined (Table 2.2). These comparisons are clouded by the fact that large numbers of Snake River fish were removed from the river at LGR and transported past MCN. The fact that the prevalence of BKD in Snake River fish collected at MCN was significantly greater than prevalence in the hatcheries but not different from fish at IGR suggests that either the collection system at LGR is not selective for high-BKD fish or that BKD continues to develop and spread among fish during their migration from LGR to MCN. Bacterial kidney disease in fish migrating from Columbia River hatcheries showed little change during this study, suggesting differences in fish or river environment. We have

already mentioned that environmental conditions appear to cause increased severity of infection in Snake River fish as compared to Columbia River fish.

BKD Durina Emigration. No definite conclusion can be made about differences in BKD in fish from branded hatchery groups during their migration passed dams. Although there were significant changes in severity of BKD in some groups (5 of 34), these included higher severity in the early (2 of 5), mid (1 of 5) and late (2 of 5) arrivals. There were also variable changes in the prevalence of BKD in groups of fish passing the dams; however, the most frequent pattern was for early migrants to have a higher prevalence than the late migrants. These results differ from those of Pascho and Elliott (1989) and Elliott and Pascho (1991, 1992) who reported an apparent increase in severity of BKD infection in spring/summer chinook salmon late in the migration after the majority of fish had passed LGR and MCN. In those reports, samples of the total population of fish were taken during most of the runs from 1988 to 1990.

Conclusion. In summary, during the five years of this study there was a decrease in the prevalence of BKD in fish at 6 of 8 hatcheries. This improvement might be the result of hatchery practices that reduced vertical and horizontal transmission. The effects of these practices will be tested in coming years as the two hatcheries that did not have reduced BKD adopted similar practices beginning with the 1992 broodstock. The severity of infection in fish infected with BKD was not correlated with prevalence, but it appeared that fish in the Snake River had higher severity of infection than fish from the Columbia River. Fish from the Snake River sampled at LGR and MCN had higher prevalence of BKD than when the same groups were sampled at the hatcheries; there was no change in prevalence in fish from the Columbia River collected at RIS or MCN. In general, fish sampled at the dams early in the migration had a higher prevalence of BKD than did fish sampled late. However, unknown sources of mortality in the rivers and unknown sampling biases of the fish collection systems at dams confound comparisons between sampling locations.

ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Frank V. Anderson, Joe Chapman, Greg Clarine, Dan Davies, Rick Lowell, Gene McPherson, Wayne Olson, Greg Pratschner, Jon Streufort, Bill Wallien and numerous past and present workers at the hatcheries without whose help this study would not have been possible. This study was funded by Bonneville Power Administration, project number 87-401 and we thank Patrick H. Poe, project manager for his continued support. Finally, we thank the numerous past and present employees of the Columbia River Research Laboratory who helped on this project. Mention of any tradenames in this report does not constitute an endorsement by the U.S government.

Chapter 3.

A Microassay for Gill Sodium, Potassium-Activated ATPase
in Juvenile Pacific Salmonids

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(This chapter has been accepted for publication in Transactions
of the American Fisheries Society)

ABSTRACT

A microassay well-plate method is described for determining Na^+, K^+ -ATPase activities of small gill sections from juvenile salmon. The method differs from the current macromethod by using much smaller tissue samples, making possible the release of fish after sampling, and by detecting inorganic phosphate in nmol, rather than μmol concentrations. Use of sonication during enzyme extraction and elimination of the need to deproteinize samples before ATPase analysis further simplify the assay. Application of the micro well-plate technique for both Na^+, K^+ -ATPase activity and protein analysis allows for the rapid processing of large numbers of samples and produces results equivalent to those of the macroassay with no significant difference between sample duplicates run by the two methods using the same enzyme extract (130.05). The coefficient of variation for microassay samples containing at least $10 \mu\text{mol P}_i/\text{mg protein/h}$ was $\leq 12\%$ for between plate comparisons and $\leq 5\%$ for same plate comparisons. Preliminary monitoring of gill-clipped fish during migration indicates that small gill clips did not cause mortality or alter migration behavior of PIT-tagged juvenile salmonids, important considerations in programs monitoring species listed under the Endangered Species Act.

INTRODUCTION

Gill sodium, potassium-activated adenosine triphosphatase levels (Na^+, K^+ -ATPase) has been used as a quantitative measurement of the level of smoltification in migrating salmon (Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985) and has been reported in association with many morphological, physiological and environmental variables of smoltification (Wedemeyer et al. 1980; Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985; Sower and Fawcett 1991). Na^+, K^+ -ATPase is one of the enzymes that plays a role in ionic transport across membranes by hydrolyzing adenosine triphosphate (ATP) as an energy source. The enzyme takes part in the absorption of NaCl across the gill epithelium of freshwater teleosts, and excretion

of NaCl in marine species (Hoar and Randall 1984, Borgatti et al. 1992).

Absolute concentrations of gill Na⁺,K⁺-ATPase vary among salmonid species and there is a characteristic enzyme profile during the seaward migration. Na⁺,K⁺-ATPase activity remains low during rearing at the hatchery, exhibiting only a gradual increase that accelerates rapidly after fish are released to the rivers to emigrate. Levels continue to rise during the migration and level off late in the migration (Beeman et al. 1991). Fish held in hatcheries for delayed release may experience a decrease in Na⁺,K⁺-ATPase activity, with a subsequent rapid increase in activity upon release and during the migration (Zaugg 1982a). Reporting gill Na⁺,K⁺-ATPase activity in migrating salmon on a weekly basis has become a routine part of smolt monitoring programs in the Columbia River Basin (Beeman et al. 1991). The increasing number of samples analyzed and the need to provide quicker turn-over time, necessitated the development of a method that would increase sample capacity while decreasing analysis time. Furthermore, listing stocks of Pacific salmon as endangered (Snake River sockeye salmon Oncorhynchus nerka, December 1991) and threatened (Snake River spring-summer chinook salmon and fall chinook salmon O. tshawytscha, April 1992) under the Endangered Species Act (Federal Register 1992), compelled us to reconsider sampling that entailed sacrificing large numbers of fish, as was necessary for the macroassay. Therefore, the objective of this study was to develop an assay for gill Na⁺,K⁺-ATPase activity that was nonlethal, increased the number of samples that could be assayed in a day and yielded results that were equivalent to those of the established procedure.

METHODS

Sample Collection. Spring chinook salmon and steelhead O. mykiss were sampled by dipnet at hatcheries shortly before release and at dams from juvenile fish passage collection systems (Matthews 1986) during the seaward migration as part of ongoing smolt monitoring programs. Fish were anaesthetized with 50-100 mg/L MS-222 (tricaine methanesulfonate) until they turned on

their sides and did not struggle when their gills were clipped. A small piece of gill filament about 2 x 3 mm (10 mg wet weight) was clipped from the center third of the first gill arch on the left side of the fish and was preserved in 0.5 mL buffer solution composed of 0.3 M sucrose, 0.02 M disodium ethylenediamine tetraacetate, and 0.1 M imidazole at Ph 7.1 (SEI; unless stated otherwise, all reagent chemicals were from Sigma Chemical Company and all solutions were made in double distilled H₂O). Samples were shaken and placed in an ice bath for 5-15 min, frozen in liquid nitrogen, and stored at -80°C. Gill-clipped fish were immediately placed in aerated water until they revived, then were released to the hatchery pond, river or juvenile transport system (15 to 120 min). Gill samples for macroassay analysis were collected according to Zaugg (1982b), and were divided before sample preparation to provide duplicate tissue pieces for method comparisons.

Sample Preparation. The extraction method of Zaugg (1982b) was adapted for the microassay with the following changes. Samples were partially thawed and ground in a #20 conical ground-glass tissue grinder (Kontes) for 10 strokes. The homogenates were centrifuged for 8 min at 2000 x gravity (g) relative centrifugal force (RCF) at room temperature (20°C). The samples were drained and the pellets suspended in 100-600 µL room temperature sucrose-disodium ethylenediamine tetraacetate-imidazole-deoxycholate (SEID), a solution of SEI at pH 7.1 with the addition of 2.4 mM deoxycholic acid sodium salt. Sample dilution brought protein concentrations between 1 and 6 µg/4 µL sample volume for analysis by the microassay Lowry method, which brought samples into the correct inorganic phosphate range for a 2 µL sample volume for the enzyme assay. Samples were kept in an ice bath during all steps of the preparation, with the exception of the SEID extraction and centrifugation steps.

The suspended pellets were sonicated with a Sonics and Materials Vibracell Model VC60 High Tech Ultrasonic Processor at output 50 for 1-3 s (pulsed 1.0 s on and 0.5 s off) with a 2-mm probe. Samples were centrifuged a second time for 6 min at 2000 x g RCF at room temperature. Immediately after centrifugation,

100 μL of the enzyme preparation supernate was withdrawn and transferred to a culture tube kept in an ice bath.

Na⁺,K⁺-ATPase Analysis. Sodium, potassium ATPase activity was determined by measuring the inorganic phosphate (P_i) concentration released during a 10 min incubation period using the Na⁺,K⁺-ATPase reaction mixtures developed by Zaugg (1982b), in combination with the P_i determination of Chan et al. (1986) as modified for the microassay by Henkel (1988). Protein concentrations were determined with a microassay adaptation of the Miller (1959) modification of the Lowry et al. (1951) protein determination. The ATPase activity was calculated as the difference between the ouabain insensitive plus ouabain sensitive Na⁺,K⁺-ATPase activity (A reaction) and the ouabain sensitive activity (B reaction), and reported as $\mu\text{mol P}_i/\text{mg protein/h}$. Individual samples were delivered to the plates for the enzyme and protein assays from the same aliquot of extracted enzyme preparation by way of a multiple dispensing, automated pipettor. Na⁺,K⁺-ATPase activity incubation plates were processed immediately through the inorganic phosphate analysis after completion of sample pipetting, while the protein plates were held at room temperature until a second set of samples were pipetted to the plate.

The following reaction mixture (Zaugg 1982b) was prepared as Solution A: 155 mM sodium chloride, 75 mM potassium chloride, 23 mM magnesium chloride, and 115 mM imidazole, adjusted to Ph 7.0. Solution B was prepared by adding 0.6 mM ouabain to Solution A. Solutions were refrigerated for periods up to three months. Adenosine 5'-triphosphate disodium salt (0.03 M Na₂ATP, pH 7.0) was prepared and frozen in 7.0 mL aliquots, and were thawed in a room temperature bath just before use.

Malachite green reagent for the P_i determination was prepared daily from the following weight/volume (g/100 mL) stock solutions at a 1:1:2:2 ratio: 5.72% ammonium molybdate, 2.32% polyvinyl alcohol, 0.0812% malachite green, and distilled water. The reagent was allowed to mature for 1 h in the light and was then kept in the dark until use. The malachite green reagent mixture was very susceptible to light conditions, and while this

did not affect final phosphate concentration values, analysts should control lighting to keep background absorbances low. All stock solutions were stored in dark bottles. Malachite green and ammonium molybdate were stored at room temperature in the dark for periods up to three months. Polyvinyl alcohol was refrigerated and kept one month.

Inorganic phosphate standards were prepared weekly in SEID from a stock standard ($25 \times 10^{-3} \text{M K}_2\text{HPO}_4$ in deionized water) at 0.05, 1.0, and 3.0 nmol/ μL . Phosphate standards kept well at room temperature for up to nine months. Two μL volumes of standards, samples, and controls were used in the microassay.

Enzyme Incubation and Inorganic Phosphate Analysis. A

96-well flat-bottomed microwell plate (Corning) was cooled on a flat ice pack and loaded with 65 μL of Solution A in all wells of columns 1-7, and 65 μL of Solution B in columns 8-12 using standard eight channel pipettors. The first column held reagents only due to consistent, unaccountable variability in first column readings. The second column held duplicates of each of the following: 2 μl SEID for background readings, and inorganic phosphate standards at 1.0, 2.0, and 6.0 nmol/2 μL . Columns 3-7 contained samples and controls treated with the Solution A reaction mixture for ouabain insensitive plus ouabain sensitive Na^+, K^+ -ATPase activity. Columns 8-12 contained samples and controls in the same order as columns 3-7, treated with the Solution B reaction mixture for ouabain sensitive Na^+, K^+ -ATPase activity.

The microwell plate was shaken for 3.5 min at room temperature, and the enzyme reaction was initiated by pipetting 10 μL of 30 mM Na_2ATP to all wells, column by column, at a rate corresponding to the speed at which the plate reader would read the plate to ensure equal incubation time for the A and B wells for an individual sample. The plate was shaken for 1 min, then incubated at $37 \pm 0.5^\circ\text{C}$ in a waterbath for exactly 10 min. The plate was moved from the waterbath to the ice pack and 225 μL of malachite green reagent was pipetted to all wells, again at a column to column rate corresponding to the rate of the plate reader. The plate was shaken for 4 min, rested for 6 min, and

then was read at 630 nm on a Titertek Multiskan Plus MKII Type 314 microwell plate reader (ICN Biomedicals Inc.) exactly 10 min after the addition of malachite green reagent to the first column.

The background absorbance of each plate was set to zero based on the mean of the two wells in column two that contained just SEID, and the slope of the standard curve for P_i was calculated from the mean of the standard duplicates. It was necessary to run standards on all plates to accommodate slight variations in temperature and time regimes. A commercial phosphorous standard was analyzed with each plate as a control to provide quality assurance of standard curve readings for individual plate accuracy.

Protein Assay. Three protein stock solutions were prepared: (1) alkaline carbonate, a solution of 0.94 M sodium carbonate plus 0.5 M sodium hydroxide; (2) 0.04 M copper sulphate, and (3) 0.07 M sodium-potassium tartrate. Solutions were stored in dark glass bottles, in the dark, at room temperature for periods up to three months. Alkaline carbonate was checked daily for turbidity and replaced as needed. A 20:1:1 reagent mixture of these solutions was prepared daily.

Bovine serum albumin was used to prepare a protein stock standard at 12.0 mg/mL in deionized water that held for one month when refrigerated. Protein standards were prepared weekly from the stock diluted with SEID at 0.25, 0.50, and 1.50 $\mu\text{g}/\mu\text{L}$ and were kept at room temperature. A protein control prepared from a commercial human serum control was diluted and run on each plate. Plate set-up duplicated that for the inorganic phosphate assay, but samples were pipetted into dry wells. Column 1 held reagents only. Duplicates of SEID at 4 μL and protein standards at 1, 2, and 6 $\mu\text{g}/4\mu\text{L}$ volume filled column 2 from top to bottom. Columns 3-7 contained protein samples from a first set of samples with a control, and columns 8-12 contained the protein samples from a second set of samples and a control.

Protein analysis was initiated by pipetting 70 μL of the protein reagent mixture to all wells; the plate was then shaken for a 5 min room temperature incubation. To all wells, 210 μL of

Folin's reagent (Folin Ciocalteu's Phenol Reagent 2.0 N , diluted 1:10 with deionized water) was quickly added. The plate was shaken for 1 min, then incubated for 5 min at $37 \pm 0.5^\circ\text{C}$. The plate was held for 30 min at room temperature in the dark, then read at 700 nm. The background absorbance of each plate was set to zero based on the mean of the two wells in column two that contained just SEID, and the standard curve for protein was constructed from the mean of the standard duplicates.

Precision, Variation and Reproducibility. Precision of the microassay was calculated using the mean standard deviation of the duplicates in the concentration range 0-40 $\mu\text{mol P}_i/\text{mg}$ protein/h. Precision of duplication was characterized at different concentrations by calculating the standard deviations of 10 duplicates in the concentration ranges 0-10, 10-20, 20-30, and 30-40 $\mu\text{mol P}_i/\text{mg}$ protein/h. The coefficient of variation for samples at the mean concentration in each range was calculated using the standard deviation of the duplicates. Ten duplicates of two different homogenates were run on the same plate to assess the reproducibility during a single run.

Validation of the Microassay. The microassay was validated by four comparisons: (1) duplicates of the same sample homogenate were analyzed by macroassay (Zaugg 1982b) in separate analytical runs, (2) microassay sample homogenates were duplicated on separate plates, (3) sample homogenates prepared for and run by the macroassay were diluted and run by microassay, and (4) separate enzyme preparations from gill tissue from unknown locations on the gills from the same fish were run by both the macroassay and microassay. Samples for validation experiments were chosen randomly from routine monitoring analyses and covered the normal range of concentrations from 0 to 52 $\mu\text{mol P}_i/\text{mg}$ protein/h.

Field Test of Non-lethal Sampling. A preliminary study of the effects of clipping a small amount of gill from migrating salmon was conducted in 1991 in conjunction with existing migration and survival studies using fish that had been intraperitoneally implanted with passive integrated transponder tags (PIT tags; Prentice et al. 1990a, 1990b). Spring chinook

salmon, hatchery steelhead (all hatchery steelhead in the Columbia River Basin had their adipose fins removed to distinguish them from wild steelhead) and wild steelhead were collected and PIT-tagged at both the Clearwater and Snake River juvenile salmon traps operated near Lewiston, Idaho by the Idaho Department of Fish and Game. The objective of their study was to determine migration rate and detection rate of salmonids at downstream PIT-tag detection stations.

Several hundred fish were PIT-tagged each day at each trap and we were allowed to clip gill tissue from a portion of those. Based on previous PIT tag releases and detection rates, we determined that 80 spring chinook salmon and 50 each hatchery and wild steelhead would be tagged, gill clipped, and released to have about 30 fish from each group detected at Lower Granite Dam (52 and 62 km downstream of the Snake and Clearwater traps, respectively). Analyses of group PIT tag detections was of arcsine-transformed data, using a parametric one-way General Linear Models procedure. Migration times from traps to Lower Granite Dam were compared using the non-parametric median test, with the chi-squared approximation (SAS Institute 1989).

RESULTS

Precision. Variation and Renroducibility. Precision of microassay duplicates in the concentration range 0-40 $\mu\text{mol P}_i/\text{mg}$ protein/h was 2.8 $\mu\text{mol P}_i/\text{mg}$ protein/h. However, precision differed at varying levels of ATPase activity (Table 3.1). The precision of the microassay (95% confidence) for a sample of 5.0 $\mu\text{mol P}_i/\text{mg}$ protein/h using the standard deviation of the range (Table 1, SD = 1.2) was 3.4 $\mu\text{mol P}_i/\text{mg}$ protein/h. Coefficient of variation was 18% for samples in the 0-10 $\mu\text{mol P}_i/\text{mg}$ protein/h range and decreased in higher concentration ranges, leveling off at about 10% in samples >20 $\mu\text{mol P}_i/\text{mg}$ protein/h (Table 3.1). Ten duplicates of two different homogenates were run on the same plate to assess reproducibility during a single run. The first sample, with a mean of 11.1, had a coefficient of variation of 5% (N = 10, SD = 0.56); the second, with a mean of 25.3, had a coefficient of variation of 4% (N = 10, SD = 1.13).

Table 3.1. Precision of duplicate gill ATPase measurements in various concentration ranges (N = 10 duplicates for each range).

Concentration range	Mean (SD) of duplicates ($\mu\text{mol P}_i/\text{mg protein/h}$)	Coefficient of variation (%)
0 - 10	6.8 (1.2)	18
10 - 20	15.4 (1.8)	12
20 - 30	25.1 (2.3)	9
30 - 40	34.2 (3.6)	10

Validation of the Microassay. Correlations of results from three of four assay comparisons resulted in correlation coefficients (r) of 0.95 or greater (Figures 3.1-3.3). The lone exception was the comparison of microassay and macroassay using different tissue preparations (Figure 3.4; $r = 0.89$). A significant difference was found between duplicates analyzed by the macroassay (Table 3.2; $P < 0.002$, t -test for paired comparisons).

Field Test of Non-lethal Sampling. Neither detection rate nor median travel times of PIT-tagged fish at Lower Granite Dam differed significantly between clipped and non-clipped fish for any of the paired groups. (Table 3.3: $P > 0.05$).

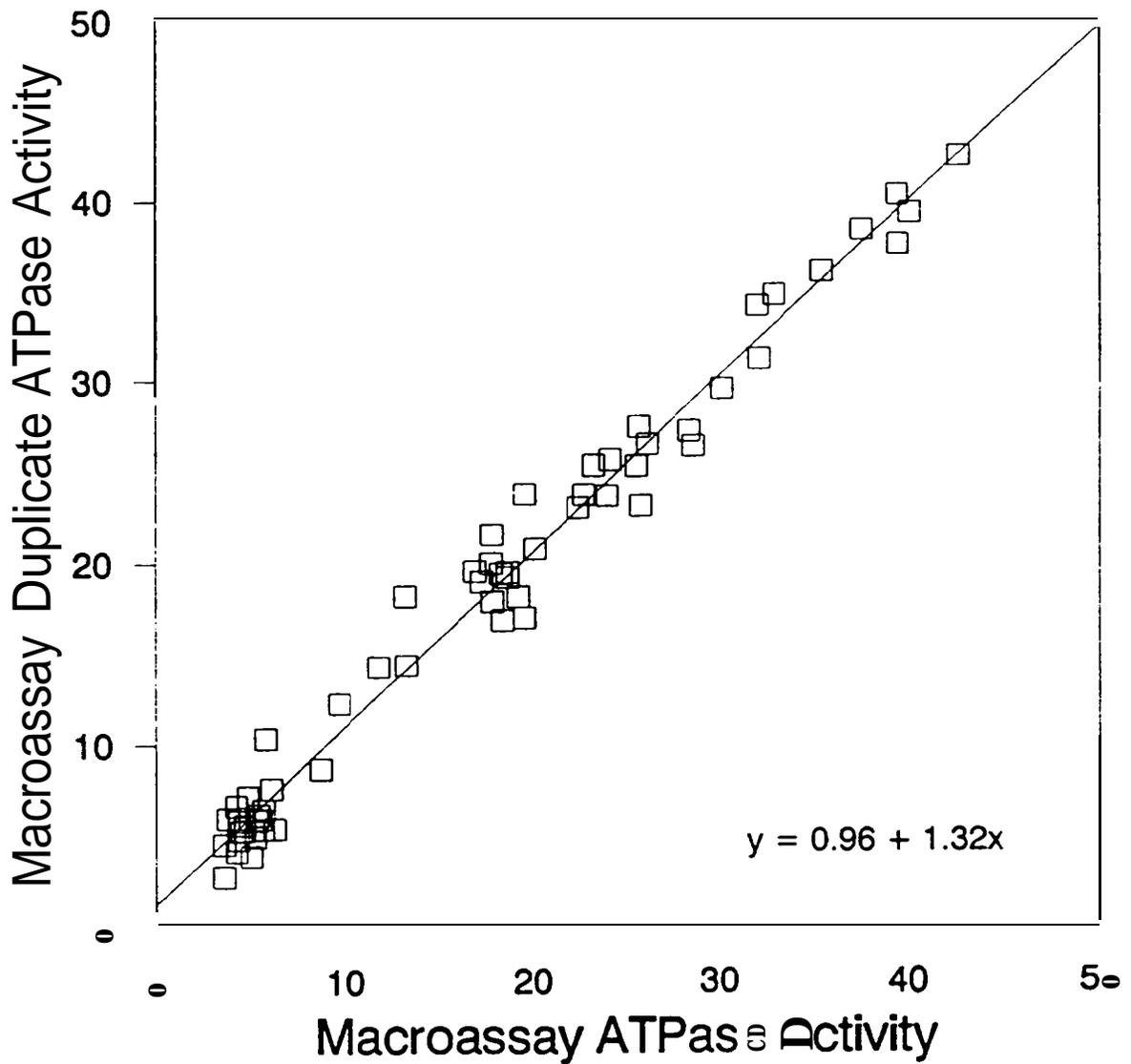


Figure 3.1. Correlation of gill Na^+, K^+ -ATPase activity ($\mu\text{mol Pi/mg protein/h}$) between duplicate assays of the same enzyme extract in separate assays by the macroassay ($N = 60$, $r = 0.99$).

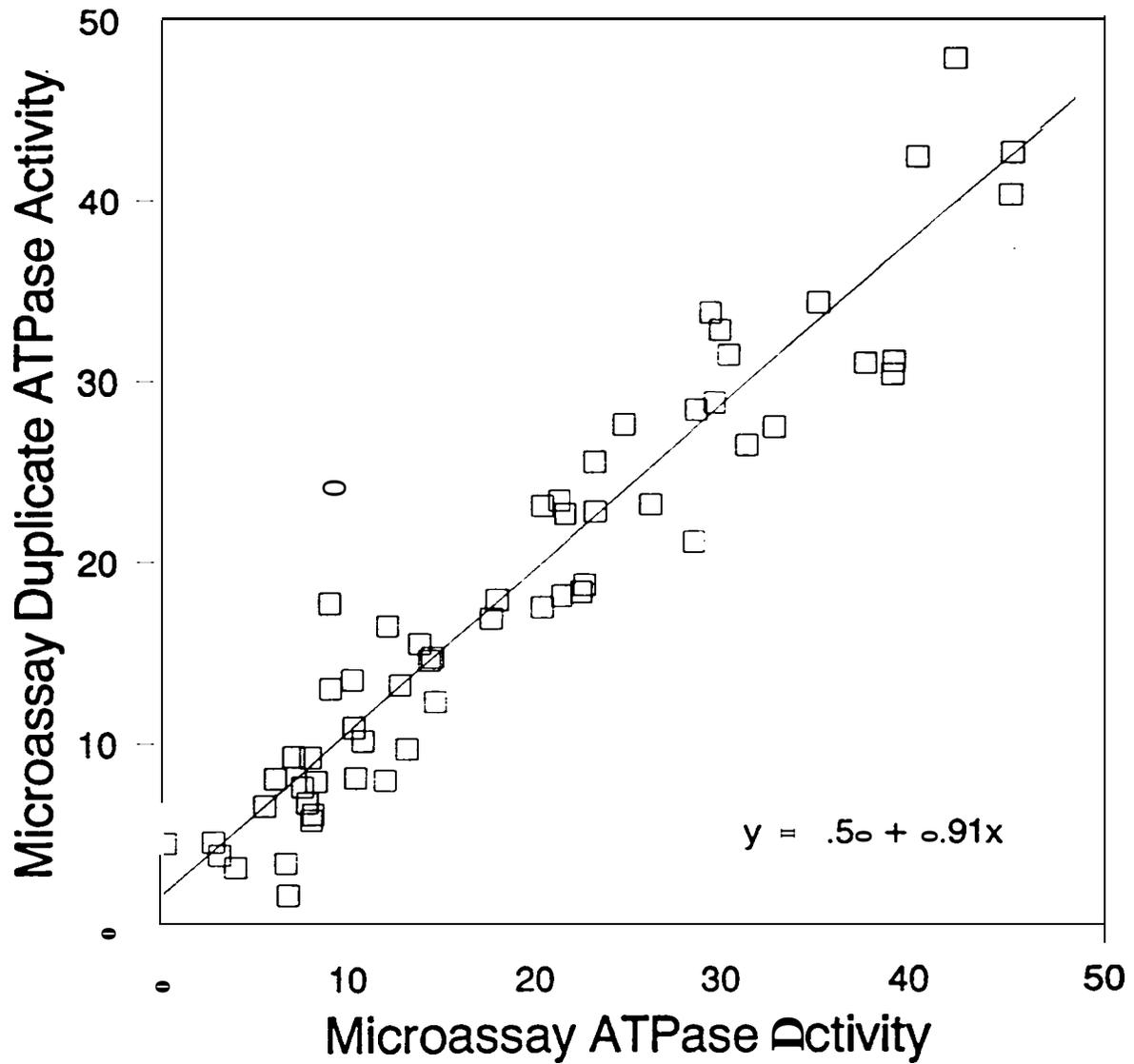


Figure 3.2. Correlation of gill Na^+, K^+ -ATPase activity ($\mu\text{mol Pi/mg protein/h}$) between duplicate assays of the same enzyme extract in separate assays by the microassay ($N = 60, r = 0.95$).

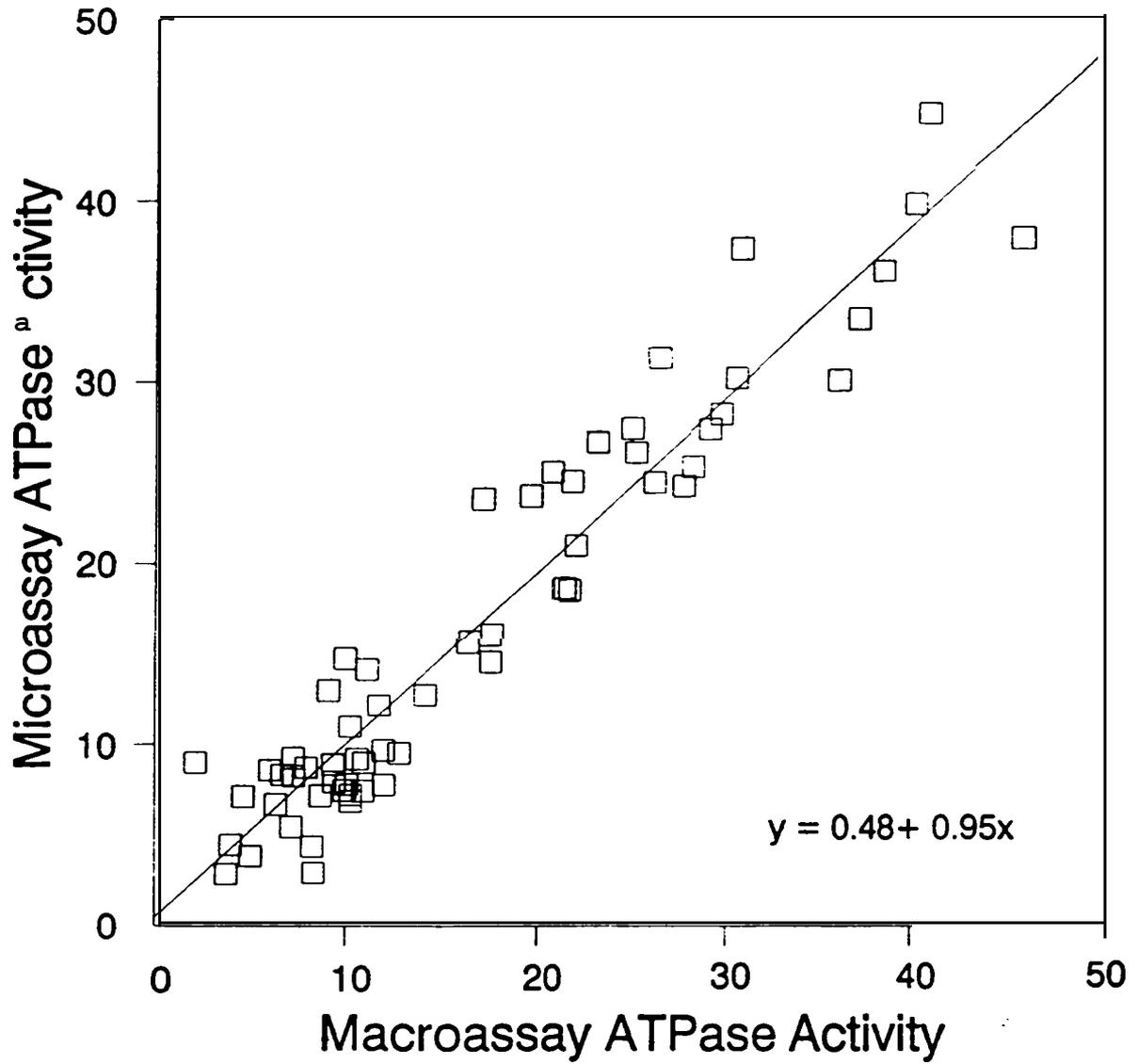


Figure 3.3. Correlation of gill Na^+, K^+ -ATPase activity ($\mu\text{mol Pi/mg protein/h}$) comparing duplicate assays of the same enzyme extract by the macroassay and the microassay ($N = 60, r = 0.95$).

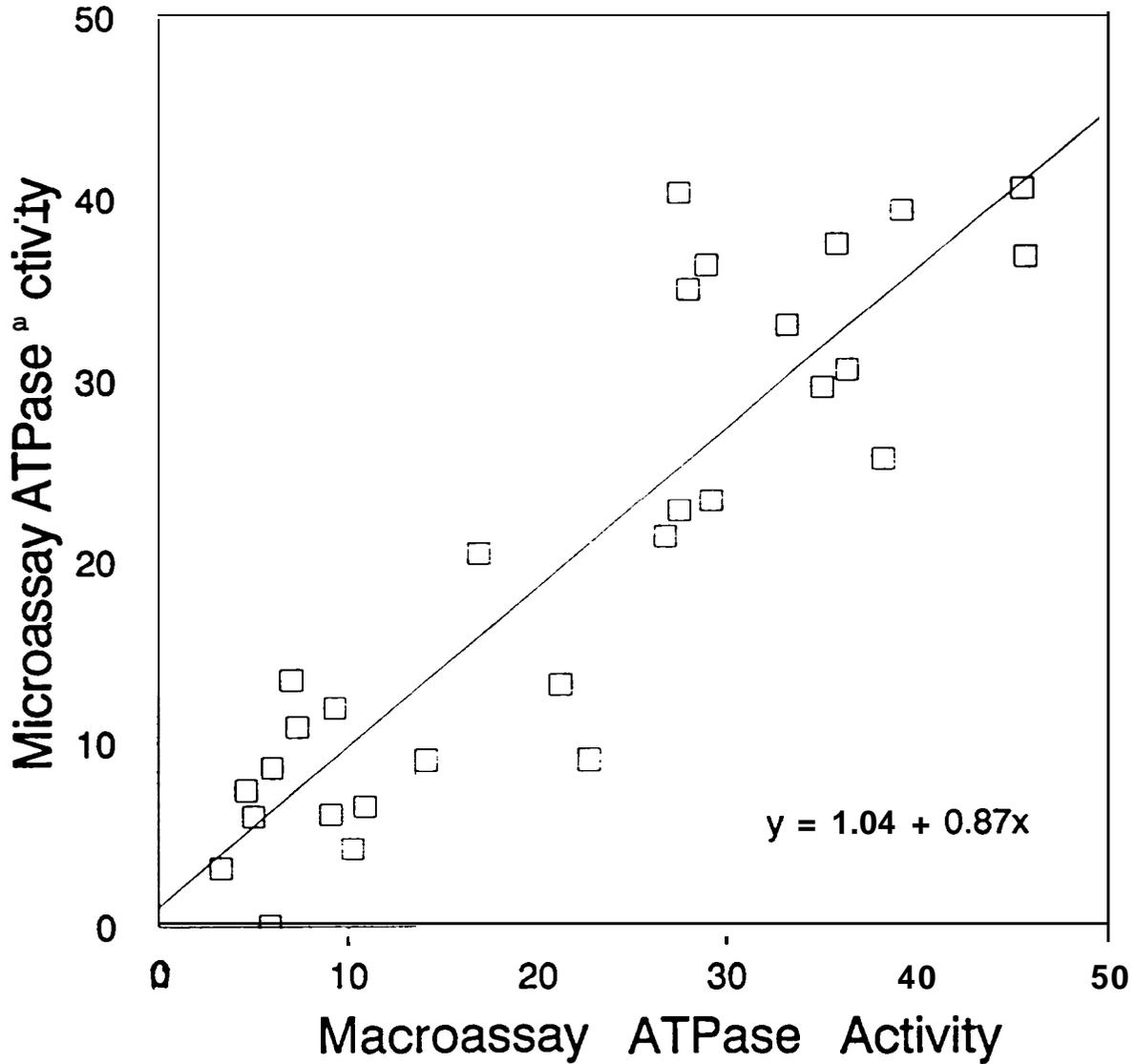


Figure 3.4. Correlation of gill Na^+, K^+ -ATPase activity ($\mu\text{mol Pi/mg protein/h}$) by the macroassay and the microassay. Separate tissue homogenates of gill tissue from a single fish were assayed by both methods ($N = 29, r = 0.89$).

Table 3.2. Student's t-test for paired comparisons of duplicate gill Na⁺,K⁺-ATPase activities. D is the mean (SE) of the mean difference between duplicates.

Duplicate comparison	N	D	<u>t</u>	<u>P</u>
Macroassay duplicates tissue extract	60	-0.68 (0.21)	3.29	CO.002 same
Microassay duplicates same tissue extract	60	0.30 (0.52)	0.57	>0.05
Macroassay-microassay duplicates same tissue extract		0.34 (0.42)	0.83	>0.05
Macroassay-microassay separate tissue extracts		1.83 (1.18)	1.58	<0.02

Table 3.3. Travel time and percent PIT-tag detection for fish with micro gill clips removed for ATPase analysis and non-clipped gill control fish, spring 1991. There were no significant differences between percent detected or median travel time in any paired release group ($P > 0.05$).

Species and date released	Number of PIT-tagged fish released		Percent detected	Median travel time (d)
	clipped	non-clipped		
Clearwater trap release site				
Spring chinook salmon				
April 11-12	79		36.7	19.7
		301	36.3	22.5
April 26	81		34.6	13.4
		151	42.4	13.3
Steelhead (hatchery)				
April 26	60		76.7	7.2
		57	78.9	7.3
Steelhead (wild)				
April 26	55		56.4	5.4
		50	58.0	5.2
Snake River trap release site				
Spring chinook salmon				
April 11-12	80		46.2	14.6
		85	37.6	12.0
Steelhead (hatchery)				
May 01-02	50		72.0	6.2
		108	74.1	7.1
Steelhead (wild)				
May 13-14	50		56.0	3.2
		207	69.1	3.1

DISCUSSION

The nonlethal sampling of gill tissue made possible by the microassay for Na^+, K^+ -ATPase activity will allow sampling of fish stocks that may be in limited supply. McCormick (1993) presented a similar microassay for determining Na^+, K^+ -ATPase activity using different reagents and verified that removing several gill filaments did not affect growth, condition or osmoregulation in Atlantic salmon (Salmo salar). The assay presented here has the advantage of being directly comparable to the method of Zaugg (1982) which has been used extensively with Pacific salmon for many years.

The Na^+, K^+ -ATPase microassay was first considered as an alternative to the Zaugg (1982) method to increase analysis capacity. The microassay has proven to be rapid and economical, and as reliable as the method it replaces. The inorganic phosphate analysis that detects P_i in nmol concentrations easily replaces the more complex protein extraction method of Zaugg and Knox (1966, 1967), modified by Zaugg (1982). While sample preparation and enzyme extraction remain the same with minor modifications, the inorganic phosphate and protein assays combined require less than a 10- μL sample.

The methods adapted for use in the microassay have been verified previously by their respective developers (Zaugg, 1982, Chan et al. 1986, Henkel et al. 1988), but observation of a strict protocol is necessary for reliable results. Several factors are of key importance in the success of the microassay. During the extraction process care must be taken to minimize sample loss. Samples should be kept in an ice bath at all times during processing except during the room temperature extraction and centrifugation. The enzyme extract should be mixed immediately before pipetting, and results are improved if the protein aliquot is pipetted at the same time, from the same aliquot as the ATPase assay subsample. We recommend running the A (ouabain insensitive) and B (ouabain sensitive) reactions for individual samples on the same micro well-plate to allow for exact timing of A and B incubation periods. Strict adherence to

consistent timing and temperature protocols is necessary for consistent, accurate results.

Our validation of the microassay by comparison to the macroassay provides quality control measurements for laboratories considering conversion to the microassay, as well as assurance that results are equivalent to results from previous years. Microassay duplicates were not significantly different. This, coupled with the agreement of the duplicate enzyme preparation analysis by the two methods, indicates that the microassay and the macroassay provide quantitatively identical values.

Significant differences in Na^+, K^+ -ATPase between gill arches in individual fish have been documented in crude homogenates that were not centrifuged (Johnson et al. 1991). The mean difference between our duplicates was greatest for the duplicate comparison between enzyme homogenate preparations from two separate tissue pieces from unknown gill locations, analyzed by the two different assay methods. To eliminate the increased variability found among samples from different gill arches in the same fish, the location of the gill-clip was standardized to the middle of the first gill arch on the left side of the fish. Our comparison of activities of tissue duplicates analyzed by the two methods did not yield significantly different results, but our method requires centrifugation of homogenates during enzyme extraction.

Comparison of detection rates and migration rates of PIT-tagged test and control fish indicate that migration performance and survival of gill-clipped fish is similar to that of control fish. The opportunity to release fish to continue their migration is important, as listing of salmon stocks as threatened or endangered increases our accountability for the numbers of fish we sacrifice.

ACKNOWLEDGMENTS

We thank individuals of the Idaho Department of Fish and Game, U.S. Fish and Wildlife Service, state and federal staff of Columbia River Basin hatcheries and dams, the Fish Passage Center, the U. S. Army Corps of Engineers, and the Bonneville Power Administration. We also thank our colleagues at the Columbia River Field Station for their assistance. Funding for this research was provided by Bonneville Power Administration under contract No. DE-AI79-87BP35245. Reference to tradenames does not imply endorsement by the U.S. government.

Chapter 4.

Skin Reflectance as a Non-lethal Measure of Smoltification
for Juvenile Salmonids

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ABSTRACT

Our efforts to find non-lethal methods of assessing development in the Parr-smolt transformation of juvenile steelhead, Oncorhynchus mykiss, and spring and fall chinook salmon, O. tshawytscha, led to the development of a video system for quantitatively measuring silvering using skin reflectance. Gill Na⁺,K⁺-ATPase activity, skin guanine concentration, and skin reflectance were collected from groups of fish marked with freeze brands at hatcheries and downstream sample sites in the Columbia River Basin. Skin reflectance increased significantly between samples collected prior to release and samples collected from migrants, while non-migrants had significantly lower skin reflectance than migrants from the same brand group. Skin reflectance correlated significantly with other measures of smoltification including gill ATPase activity and skin guanine concentration. Skin reflectance increased during the Parr-smolt transformation and could be used as a non-lethal indicator of smoltification.

INTRODUCTION

Juvenile anadromous salmonids undergo a Parr-smolt transformation (smoltification) adapting them for the marine environment (Folmar and Dickhoff 1980; Wedemeyer 1980). Smoltification is characterized by behavioral, morphological, and physiological changes including increased gill sodium, potassium-activated adenosine triphosphatase levels (gill ATPase activity), and increased silvering due to the deposition of guanine and other purines in the skin (Vanstone and Market 1968; Eales 1969; Zaugg and McLain 1972; Zaugg and Wagner 1973). Measures of these physiological characteristics have been used with varying success in research and management to assess physiological development, seawater adaptation, and behavioral disposition of juvenile salmonids to migrate (Folmar and Dickhoff 1981; Zaugg 1981; Zaugg and Mahnken 1991). Measures of smoltification have been used by managers in the Columbia River Basin as the basis for setting hatchery fish release dates and manipulating river flows with the intention of decreasing the length of time required for juveniles to migrate to the ocean (Fish Passage Center 1993; Muir et al. in press). It is assumed that decreasing this travel time will increase the proportion of juveniles that survive to adulthood (Berggren and Filardo 1993).

The change from a dark-colored parr to a silvery smolt is one of the most obvious physical changes associated with smoltification (Hoar 1976). Guanine, a product of nucleotide catabolism, is the most abundant purine associated with silvering in the skin of juvenile salmonids during smoltification (Johnston and Eales 1967; Staley and Ewing 1992). Guanine crystals are deposited in the epithelium and between scales during smoltification in regularly spaced, highly reflective platelets oriented perpendicular to the water surface of the normally swimming fish (Denton and Nicol 1965; Denton and Saunders 1972). The silvery appearance of the developing smolt is caused by increasing amounts of light reflecting from the guanine crystals deposited in the skin.

Smoltification levels have been estimated using measures of

silvering including skin guanine concentrations and visual classifications (Johnston and Eales 1968; Gorbman et al. 1982; Ewing et al. 1984). However, assessing skin guanine concentration requires sacrificing the fish to remove a skin sample and involves a complex and time-consuming laboratory assay (Staley and Ewing 1992). Visual interpretation of silvering using descriptive classifications is non-lethal, but our experience indicated it was subject to bias between observers and differences in ambient light. While various instruments have been designed to measure silvering by quantifying the amount of light reflecting from the skin (Denton and Nicol 1964; Kazakov and Kozlov 1985), these instruments were not developed or used to measure smoltification.

In our efforts to find non-lethal methods of assessing smoltification, we developed a system to quantify the silvering of juvenile salmonids without harming the fish by measuring skin reflectance. Skin reflectance is a measure of the amount of light reflecting from the surface of the fish skin. The objectives of this study were to: (1) determine if skin reflectance changes during smoltification, and (2) examine correlations between skin reflectance and other measures of smoltification including gill ATPase activity and skin guanine.

METHODS

Sample Collection and Processing

The photo reflectance video analysis system (PRVAS) was designed to illuminate a fish with diffuse, uniform light, record an image of the fish, and calculate skin reflectance. Based on the findings of Denton and Nicol (1965), we concluded that diffuse light would eliminate elevated skin reflectance values caused by bright spots from direct light sources. The PRVAS used consistent light from two photo bulbs that was diffused by an opaque plexiglass box. The diffuse light reflected from the surface of the fish and was recorded using a high resolution video camera and a video camera recorder (VCR). The image was retrieved from the VCR with a computer and skin reflectance

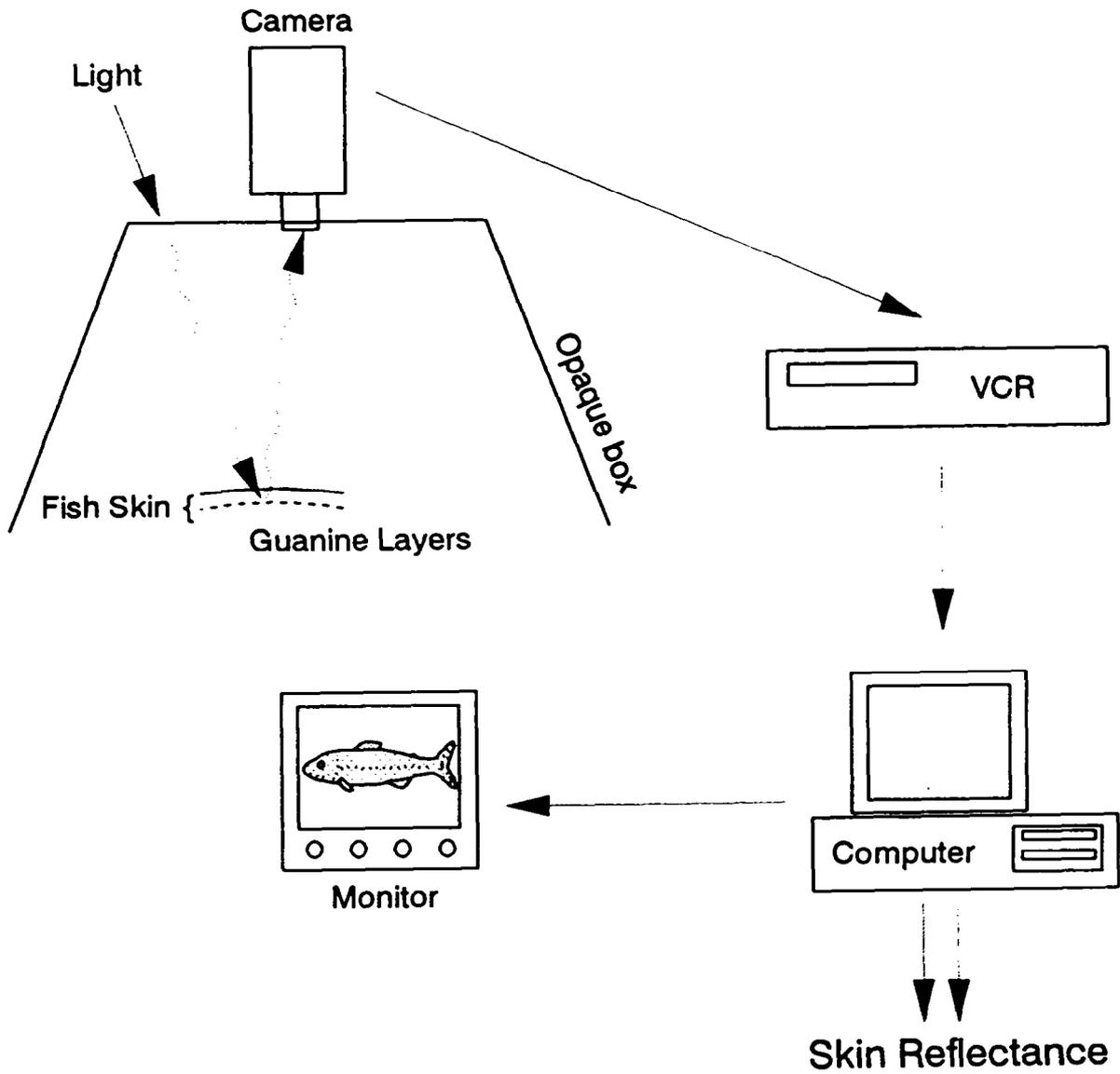


Figure 4.1. A schematic of the photo reflectance video analysis system showing the path of light and equipment used to calculate skin reflectance.

calculated as the amount of light reflected from a section of skin based on a grey scale from 0 to 10. The monitor was used by the operator to display images used in the system (Figure 4.1). The fish, a black and white calibration tab, and a sample number assigned to that fish were placed in an opaque 32 x 25 x 30-cm pyramid-shaped plexiglass box. A high resolution black and white video camera connected to a standard VHS format VCR was used to record the image for approximately 10 s. A 33-cm, black and white monitor was also connected to the video camera to display the recorded image. Skin reflectance was measured using the Java software (Jandel Scientific, San Rafael, California¹) and an IBM-compatible computer with a 640 x 512 pixel frame grabber. The video image, saved on the VCR tape, was routed to the computer and then to the monitor when played on the VCR. The Java program captured the image sent from the VCR, calibrated ambient light using operator-defined areas on the black and white calibration tab, and calculated skin reflectance using the average shade of grey for an operator-defined area-of-interest. The area-of-interest used for measuring skin reflectance was the same section that was later removed for the skin guanine concentration assay.

In 1991, an opaque 28 x 22 x 30-cm box was placed over the fish to measure skin reflectance on whole fish bodies. The video camera was lowered into the box until the lens was inside, the lights were positioned to minimize any direct light reflecting from the sample, and the image was recorded. We found this system too cumbersome to use effectively in the field, so in 1992 the design was changed to allow the camera and box to remain in a fixed position with a door added to the front of the opaque box. Using this system, the fish could be placed, or repositioned, in the chamber without lifting the video camera and box.

Skin reflectance, gill ATPase activity ($\mu\text{moles } P_i \cdot \text{mg protein}^{-1} \cdot \text{hr}^{-1}$), and skin guanine ($\text{mg guanine} \cdot \text{cm}^{-2} \text{ skin}$) were measured on juvenile steelhead (*Oncorhynchus mykiss*) and chinook

¹ Mention of trade names does not imply endorsement by the National Biological Survey.

salmon (O. tshawytscha) sampled at hatcheries and dams along the Snake and Columbia rivers (Figure 4.2). Fish were anesthetized in a lethal dose (105 ppm) of tricane methanesulfinate (MS-222), placed within the opaque box, an image recorded, gill tissue removed for gill ATPase activity determination using the method of Zaugg (1982), and a skin core sample collected for guanine content. Skin samples for guanine concentrations were collected using a 16-mm cork borer for steelhead, a 13-mm borer for spring chinook salmon, and an 8-mm borer for fall chinook salmon. Samples were taken from the left side by freezing the fish in liquid nitrogen and centering the borer on a vertical line extending ventrally from the anterior insertion of the dorsal fin, with the top of the borer just under the lateral line. The circular sample was peeled from the body using forceps, placed in a vial, and frozen in liquid nitrogen. These skin samples were then assayed for guanine concentration using methods described by Staley (1984).

Juvenile Steelhead Collection

The PRVAS was used at six locations for steelhead in 1991. Juvenile steelhead from Lyons Ferry State Fish Hatchery (SFH) of Washington State were sampled at the hatchery, acclimation ponds, locations of release on tributary rivers, and at McNary Dam (Figure 4.2). Curl Pond and Dayton Pond were used to acclimate the fish to river water prior to release. The fish were released from these ponds into the Tucannon and Touchet rivers respectively, and eventually migrated past McNary Dam (Figure 4.2). The fish released at Marengo were reared at the hatchery and released into the Tucannon River approximately five miles downstream from Curl Pond. Fish were marked with freeze brands (Mighell 1969) differentiating fish from the Marengo, Curl Pond, and Dayton Pond releases. Prior to their release in mid-April (pre-release), the Curl Pond and Dayton Pond release groups were sampled at the acclimation ponds and the Marengo release group at Lyons Ferry SFH. Fish sampled at McNary Dam (migrants) were collected when 50% of each freeze-branded release group passed the juvenile collection system at McNary Dam, approximately a

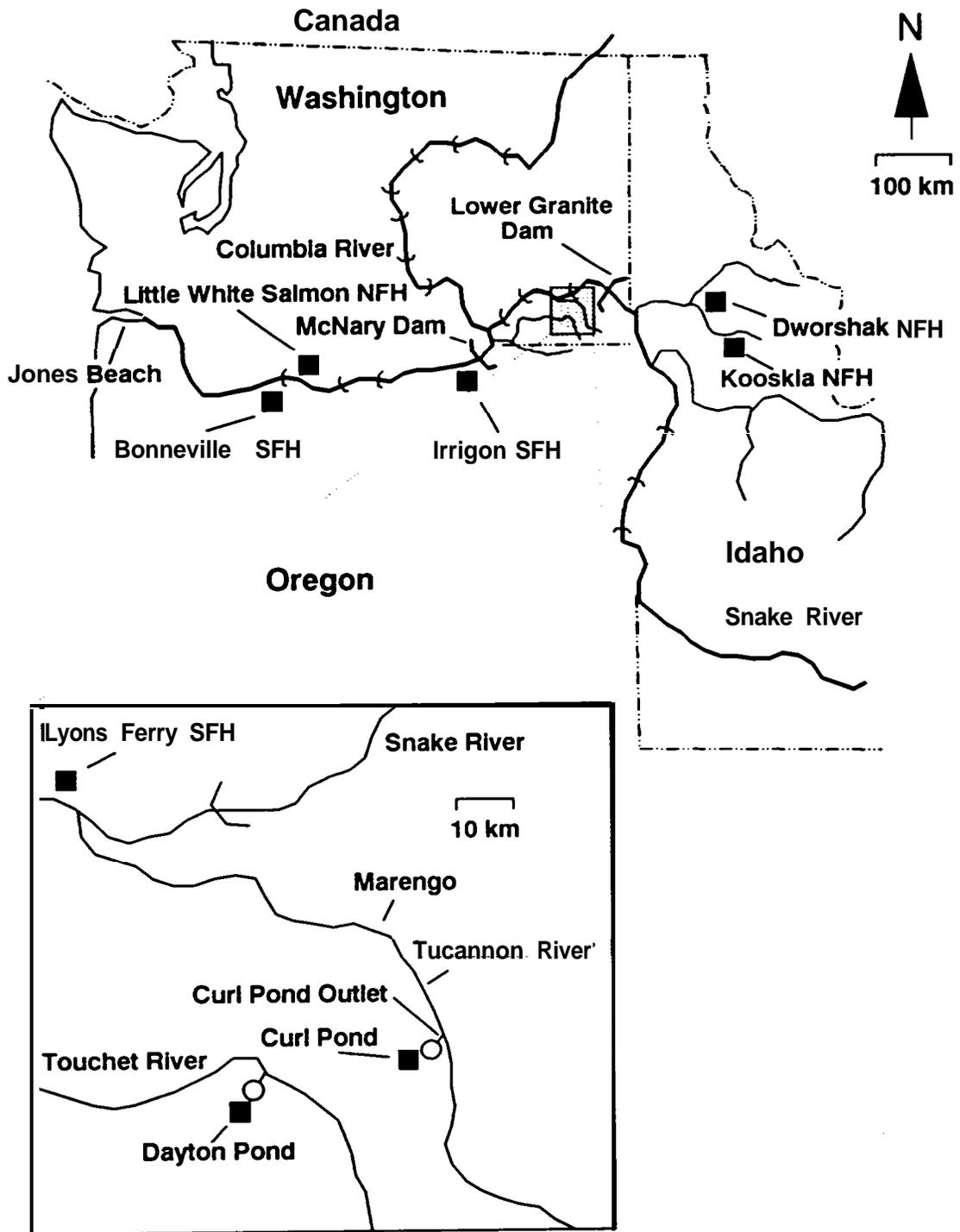


Figure 4.2. Map of study area with pre-release sampling sites marked with a solid square (■), migrant sampling sites at Lower Granite and McNary dams, and non-migrant collection sites on the Tucannon and Touchet rivers.

month after release. Fish that did not migrate after release (non-migrants) from the Curl Pond and Marengo releases were sampled in the Tucannon River and non-migrants from Dayton Pond were sampled in the Touchet River. All non-migrant fish were sampled on approximately the same date the corresponding marked migrants were sampled at McNary Dam.

In 1992, PRVAS was used to measure skin reflectance on steelhead at three hatcheries, two tributary or pond sites, and two mainstem dams. Steelhead were sampled from Lyons Ferry SFH, Irrigon SFH of Oregon, and Dworshak National Fish Hatchery (NFH). Pre-release samples of the Irrigon and Dworshak hatchery fish were sampled at the hatcheries in April, and migrants were collected at Lower Granite Dam on the Snake River (Figure 4.2) about a month after release. The Lyons Ferry SFH pre-release sampling in mid-April included release groups from Curl Pond, Curl Pond Outlet, and Marengo. The fish sampled at Curl Pond, Marengo, and McNary Dam, as well as the non-migrants from the Tucannon River, were collected in the same manner as the 1991 samples. The Curl Pond Outlet release group was treated the same as the Marengo release group except the fish were released into the Tucannon River at the outlet of Curl Pond (Figure 4.2).

Juvenile Springs Chinook Salmon Collection

Spring chinook salmon migrants of unknown origin were collected in 1991 at Lower Granite Dam. Forty migrating fish collected at Lower Granite Dam in May and June had gill samples taken and the bodies frozen. Subsequently, the bodies were thawed, reflectance images recorded, and then refrozen to remove skin samples. An additional 40 laboratory-held fish of known origin, Little White Salmon NFH, were sampled in August 1991 and January 1992 in the same manner as the migrating fish collected at Lower Granite Dam. The chinook salmon collected in 1991 were the only fish sampled for reflectance where the fish were frozen prior to recording the image.

The spring chinook salmon collected in 1992 were freeze-branded groups from Dworshak NFH and Kooskia NFH (Figure 4.2). The pre-release samples were collected at the hatcheries in April

and May and the migrants were sampled at Lower Granite Dam about a month later. Fish released from Kooskia NFH were also sampled when recaptured at McNary Dam.

Juvenile Fall Chinook Salmon Collection

The fall race of chinook salmon were collected in 1992 from groups marked with freeze brands at Little White Salmon NFH and Bonneville SFH of Oregon. Samples were collected at the hatcheries in mid-June and migrant fish were collected two weeks later by purse and beach seine at Jones Beach, Oregon, 72 km from the mouth of the Columbia River (Figure 4.2). The seines were operated by the National Marine Fisheries Service as described by Sanders et al. (1992).

Data Analysis

Mean skin reflectance for the pre-release, migrant, and non-migrant comparisons of freeze-branded groups of fish were calculated by pooling data from the same collection site when the mean skin reflectance values were not significantly different by sample date (ANOVA, $P \leq 0.05$).

Pearson correlation coefficients (r) were calculated on the mean and individual data, while only mean data were tested for normality using the Shapiro-Wilk statistic. Mean values were calculated on skin reflectance, gill ATPase activity, and skin guanine for each freeze-brand group by sample site and date to estimate Pearson's correlation coefficients. Data from fish of freeze-brand release groups containing less than five fish per day were pooled and a single mean calculated if the collection dates were within seven days of each other and the mean values were not significantly different. Correlations were also calculated on individual fish skin reflectance, gill ATPase activity, and skin guanine concentration data: these data will be referred to as individual data correlations. All statistical analyses were done, using SAS (SAS Institute 1988), with significance levels $P \leq 0.05$.

RESULTS

Pre-release, Migrant, and Non-Migrant Analyses

Skin reflectance of marked juvenile steelhead recaptured as migrants tended to be higher than pre-release samples. Six of the eight release groups of steelhead had significantly higher skin reflectance when sampled as migrants than when sampled before release. Skin reflectance of migrating steelhead recaptured at McNary Dam in 1991 increased significantly from pre-release samples collected at Lyons Ferry SFH and the acclimation ponds (Figure 4.3A). Skin reflectance of steelhead released in 1992 at Curl Pond Outlet and Marengo were significantly higher upon recapture at McNary Dam than the pre-release samples of these marked groups collected at Lyons Ferry SFH (Figure 4.4A). Freeze-branded steelhead from Dworshak NFH and Irrigon SFH also had significant increases in skin reflectance from the pre-release samples compared to samples from migrants recaptured at Lower Granite Dam (Figure 4.4B). Freeze-branded steelhead released from Dayton Pond in 1991 and Curl Pond in 1992 were the only two groups of fish, out of eight, without significant increases in skin reflectance when recaptured as migrants compared to samples collected prior to release.

Non-migrant steelhead had significantly lower skin reflectance than did migrants from the same freeze-branded release group. All steelhead groups originating from Lyons Ferry SFH and sampled in 1991 had marked fish that did not migrate after release (Figure 4.3A). Measurements of skin reflectance from these non-migrant steelhead were all significantly lower than the migrants from the same freeze-branded groups recaptured at McNary Dam on the same date. The non-migrant steelhead collected from the Tucannon River in 1992, fish released from Curl Pond, Curl Pond Outlet, and Marengo, had significantly lower skin reflectance than did the migrants of these three freeze-branded release groups recaptured at McNary Dam (Figure 4.4A).

Skin reflectance of chinook salmon migrants tended to be higher than either fish held in the laboratory or fish sampled prior to release at the hatchery. Although the 1991 spring

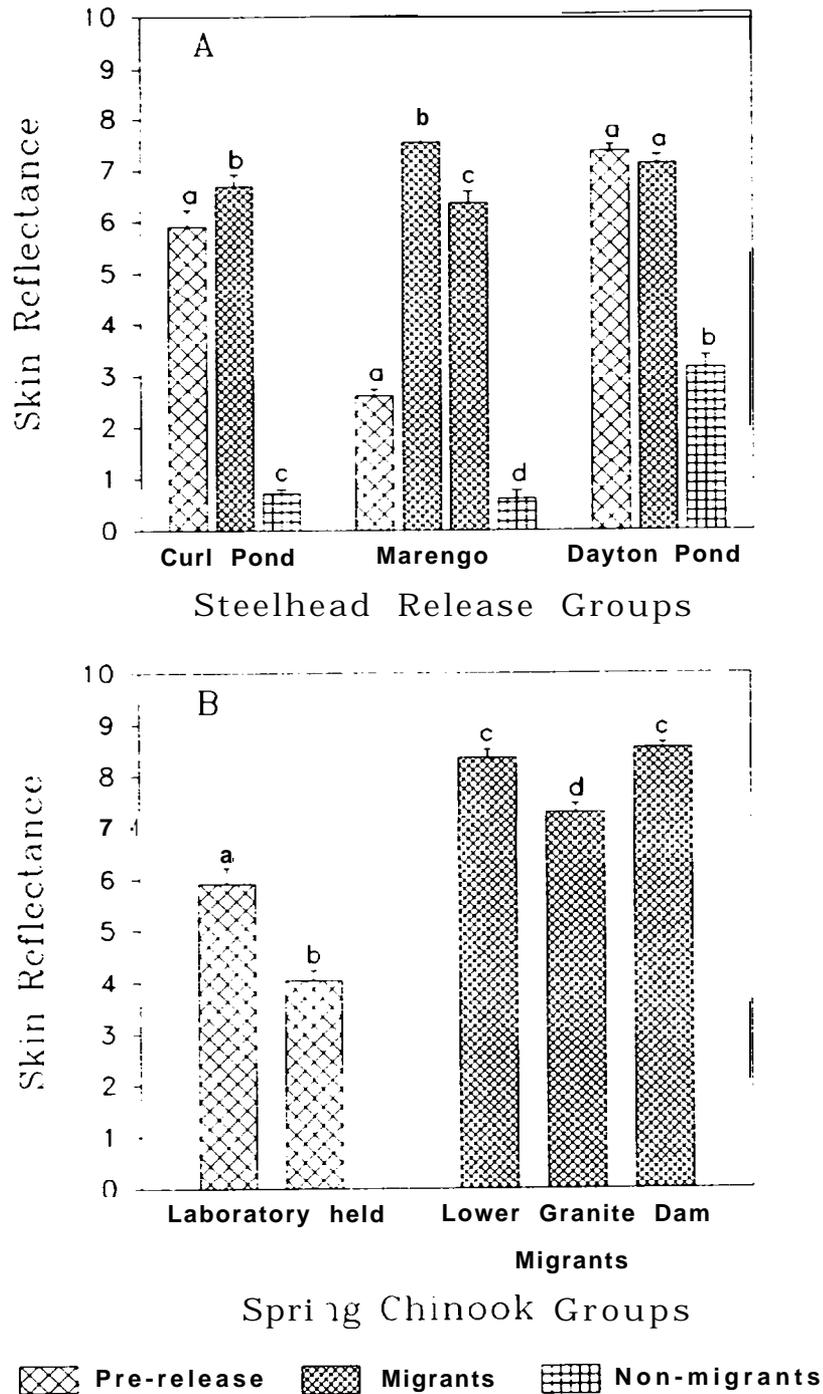


Figure 4.3. Skin reflectance (mean \pm SE) of freeze-banded juvenile steelhead and spring chinook salmon collected in 1991 prior to release or held in the laboratory (pre-release), recaptured downstream as migrants, or recaptured at the release site (non-migrants). Letters denote bars that differ significantly (ANOVA, $P \leq 0.05$) within each release group (Figure 4.3A) or between release groups (Figure 4.3B).

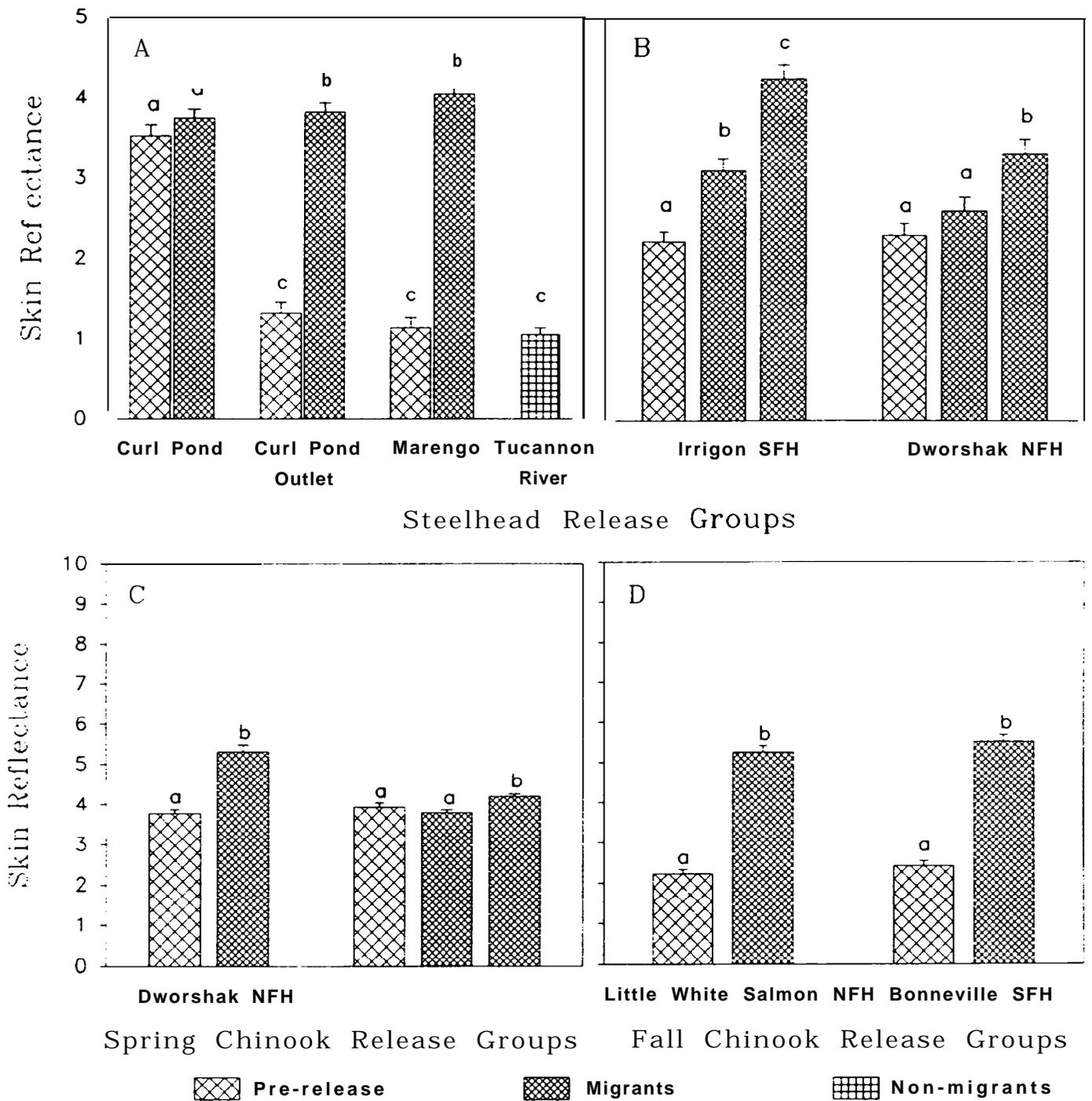


Figure 4.4. Skin reflectance (mean \pm SE) of freeze-banded juvenile steelhead, spring chinook salmon, and fall chinook salmon collected in 1992 prior to release (pre-release), recaptured downstream as migrants, or recaptured at the release site (non-migrants). Letters denote bars that differ significantly (ANOVA, $P < 0.05$) within each release group with the exception of Figure 4.4A in which the Tucannon River non-migrants were compared to the three Lyons Ferry SFH release groups.

chinook salmon data compared groups of fish of known origin, from Little White Salmon NFH, to those of unknown origin, unmarked migrating fish collected at Lower Granite Dam, the migrating fish had significantly higher skin reflectance than the fish held in a Captive environment (Figure 4.3B). The spring chinook salmon from marked releases in 1992 at Dworshak NFH and Kooskia NFH also had significantly higher reflectance as migrants recaptured at downstream sites compared to pre-release sampling at the hatcheries (Figure 4.4C). Freeze-branded groups of fall chinook salmon had significant increases in reflectance when recaptured at Jones Beach as migrants compared to samples collected prior to release at Bonneville SFH and Little White Salmon NFH in 1992 (Figure 4.4D).

Skin Reflectance, Gill ATPase Activity, and Skin Guanine

Mean skin reflectance of marked steelhead groups collected ATPase activity and mean skin guanine concentration. Significant ATPase activity in 1991 ($r = 0.56$) and 1992 ($r = 0.84$; Table 4.1). Skin reflectance and skin guanine were correlated in 1991 and 1992 ($r = 0.87$ and $r = 0.80$, respectively). Gill ATPase activity and skin guanine also correlated significantly in both years ($r = 0.47$ for 1991 and $r = 0.94$ for 1992).

Skin reflectance, gill ATPase activity, and skin guanine were correlated significantly for marked groups of spring chinook salmon sampled in 1991 (Table 4.1), but in 1992, none of the samples collected in 1991 had skin reflectance correlated with gill ATPase activity ($r = 0.98$) and skin guanine ($r = 0.84$). Skin reflectance also correlated significantly with skin guanine ($r = 0.90$). Although the mean data set for 1992 did not have significant skin reflectance data from individual spring chinook salmon were correlated significantly with gill ATPase activity ($r = 0.20$), ATPase activity correlated with skin guanine ($r = 0.36$; Table 4.1).

Table 4.1. Correlation coefficient (r), level of significance (P), and number of samples collected (N) for skin reflectance, mean reflectance, gill Na^+, K^+ -ATPase activity, mean ATPase, skin guanine concentration, and mean skin guanine concentration of steelhead and spring chinook salmon sampled in 1991 and 1992. Fall chinook salmon sampled in 1992 had correlation coefficients calculated only on the individual data.

		<u>ATPase</u>			<u>Mean ATPase</u>			<u>Guanine</u>			<u>Mean Guanine</u>		
		r	P	N	r	P	N	r	P	N	r	P	N
Steelhead													
1991	Reflectance	0.36	0.00	418				0.57	0.00	283			
	Mean Ref Lectance				0.56	0.00	23				0.87	0.00	23
	ATPase							0.25	0.00	362			
	Mean ATPase										0.47	0.02	23
1992	Reflectance	0.58	0.00	371				0.66	0.00	397			
	Mean Reflectance				0.84	0.00	21				0.80	0.00	23
	ATPase							0.64	0.00	414			
	Mean ATPase										0.94	0.00	21
Spring Chinook Salmon													
1991	Reflectance	0.83	0.00	54				0.71	0.00	80			
	Mean Reflectance				0.98	0.00	5				0.84	0.04	6
	ATPase							0.62	0.00	54			
	Mean ATPase										0.90	0.04	5
1992	Ref Lectance	0.24	0.00	132				0.20	0.01	167			
	Mean Reflectance				0.39	0.30	9				0.24	0.45	11
	ATPase							0.36	0.00	134			
	Mean ATPase										0.66	0.05	9
Fall C h i d Salmon													
1992	Ref Lectance	0.70	0.00	114				0.37	0.00	117			
	ATPase							0.28	0.00	113			

Fall chinook salmon sampled in 1992 had only four groups on which means were calculated, therefore correlations of group attributes were not examined. However, the number of skin reflectance, gill ATPase activity, and skin guanine data on individual samples collected were sufficient and did have significant correlations (Table 4.1). Individual skin reflectance values from fall chinook salmon were correlated with gill ATPase activity ($r = 0.70$) and skin guanine ($r = 0.37$). Gill ATPase activity from individual fish correlated with skin guanine ($r = 0.28$).

DISCUSSION

As juvenile salmonids undergo smoltification, several physiological indicators change including an increase in gill ATPase activity and skin guanine (Folmar and Dickhoff 1981). An increase in the level of gill ATPase activity and skin guanine is tantamount to a higher level of smoltification (Rodgers et al. 1987). As the guanine concentration in the skin increases, more light reflects from the guanine-filled platelets, and the degree of silvering increases (Denton and Saunders 1972). Techniques have been developed to determine the level of smoltification using measurements of gill ATPase activity and skin guanine concentration, however, the assays for both measurements require a tissue sample. Although a micro gill ATPase activity assay has been developed for non-lethal sampling (Schrock et al. in press), a lethal sample is required for the skin guanine assay (Staley 1984). Silvering, the reflection of light from the surface of the fish, can be easily identified visually, but very difficult to quantify. Therefore, PRVAS was designed as a non-lethal method of determining the level of smoltification by objectively quantifying the degree of silvering using measurements of skin reflectance. Although this study used a lethal dose of MS-222 to sacrifice the fish, a non-lethal dose has been effectively used on fish to measure skin reflectance.

Skin reflectance increased during smoltification in

migrating juvenile salmonids and either remained constant or decreased in fish collected after release as non-migrants. Investigators have shown that the most prevalent increase in the level of smoltification occurs from the time juvenile salmonids are released from the hatchery to approximately four weeks later when the fish are recaptured as migrants (Zaugg et al. 1985; Beeman et al. 1991). Eleven of thirteen freeze-branded groups of steelhead, spring chinook salmon, and fall chinook salmon recaptured as migrants had significantly higher mean skin reflectance compared to samples collected prior to release.

When juvenile steelhead were released from the acclimation ponds of Lyons Ferry SFH some of them did not migrate and residualized near the release site. Fessler and Wagner (1969) found that non-migrant steelhead did not undergo smoltification as the actively migrating fish did, but remained either dark-colored parr or reverted to the parr stage from the degree of smoltification at which they were released. In every case where non-migrant groups of freeze-branded steelhead were sampled, we found that skin reflectance was significantly lower in the non-migrants compared to the migrants, and either the same or lower than samples collected prior to release. Furthermore, in the two cases where skin reflectance of pre-release and migrants did not differ, skin reflectance of the non-migrants was significantly less than that of the pre-release samples.

Inasmuch as mean values have been used to describe other measures of smoltification, correlation coefficients of mean skin reflectance with mean gill ATPase activity and mean skin guanine concentration were used in this study. We found mean skin

significantly with mean gill ATPase activity and mean skin guanine concentration except for the spring chinook salmon

However, correlations on individual data were
Fall chinook salmon
had insufficient numbers of mean data available, but did have

The lack of significant correlations between mean skin reflectance and mean gill ATPase activity or mean skin guanine

concentration in spring chinook salmon in 1992, compared to 1991, may have been the result of natural variation in physiological processes between the two years. Other investigators have identified changes in physiological variables that correlated with each other during smoltification in some years but not others (Staley and Ewing 1992; Maule et al. 1993).

In 1991, neither the lights nor the opaque box were thought to be as important as they now appear to be. Photo lights were not used when the data were collected if there appeared to be enough ambient light, and the opaque box was not used when it became too cumbersome. As a result, many images saved for skin reflectance in 1991 could not be used because of bright reflective spots from direct light sources. In 1992, all images were collected using the lights and the opaque box and no images had bright spots. In 1991 at Curl Lake, the Tucannon River, and the Touchet River a portable generator was used to operate the VCR, camera, and lights (all other sites had 110 V AC available). We found that a surge suppressor must be used or the VCR records erratically. With a generator and a surge suppressor the equipment can be used at any location, even if 110 V AC is not available.

Skin reflectance can be used to objectively measure silvering of juvenile salmonids. In the past, investigators have used visual interpretations of silvering as a technique to assess the level of smoltification in juvenile salmonids, but this technique was highly subjective based on the individual assessing the coloration and the lighting conditions. We found, using PRVAS, that (1) migrating salmonids recaptured at downstream sites had significantly higher skin reflectance than samples collected either prior to release or from non-migrants, and (2) skin reflectance was significantly correlated with gill.ATPase activity and skin guanine concentration, albeit low when individual data were used, for juvenile steelhead, spring chinook salmon, and fall chinook salmon. We have demonstrated that this technique for measuring skin reflectance is an objective, non-lethal measure of silvering and can be used as an indicator of smoltification in juvenile salmonids.

ACKNOWLEDGEMENTS

We thank the individuals at the hatcheries and dams where we sampled, especially staff at Lyons Ferry SFH and Mark Schuck of the Washington Department of Wildlife. We also thank the reviewers of this manuscript for their time and expertise. Special thanks are extended to our colleagues, past and present, at the Columbia River Research Laboratory, National Biological Survey, for their help and cooperation. This project was funded by Bonneville Power Administration, Portland, Oregon, contract No. DE-AI79-87BP35245.

Chapter 5.

Assessing Smoltification of Juvenile Spring Chinook Salmon
(Oncorhynchus tshawtscha) Using Changes in Body Morphology

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(This chapter has been accepted for publication in the Canadian
Journal of Fisheries and Aquatic Sciences)

ABSTRACT

A morphometric measure of smoltification of juvenile spring chinook salmon (Oncorhynchus tshawytscha) was developed and evaluated. Fish were collected from hatcheries in Washington and Idaho prior to release and at McNary Dam on the Columbia River during their downstream migration. Distances between 15 anatomical landmarks were digitized from photographs of each fish resulting in 34 morphometric characters for analysis. The canonical variate calculated from a discriminant function based on several principal components was evaluated as a measure of smoltification. The canonical variate was significantly correlated with gill $\text{Na}^+\text{-K}^+$ ATPase activity, a commonly used measure of smoltification. Measuring the morphometric characters and calculating the canonical variate is a relatively simple procedure and can be performed with little harm to the fish. This method of smoltification assessment may be ideally suited to studies in which sacrificing fish is not possible, such as those involving threatened or endangered species, or when access to a laboratory for sample analysis is not available.

INTRODUCTION

Early in the life history of anadromous salmonids, juveniles undergo a metamorphosis, transforming from freshwater-adapted forms (Parr) to seawater-adapted forms (smolt). Associated with this process, known as smoltification, are changes in behavior, physiology, and morphology (Hoar 1976). Smoltification of juvenile salmonids has been demonstrated to affect responses to stress, susceptibility to guidance mechanisms at hydroelectric dams, swimming behavior, and migration rates (Smith 1982, Barton et al. 1985, Giorgi et al. 1988, Berggren and Filardo 1993).

Smoltification of juvenile salmonids has been described using many measures of the physiological and endocrinological changes that take place during smoltification development. Common methods include gill $\text{Na}^+\text{-K}^+$ ATPase (ATPase) activity, plasma thyroxine (T_4), and seawater challenges (Dickhoff et al. 1985). However, using these methods typically requires either

sacrificing the animal to obtain tissue samples or complicated laboratory assays to obtain results. A non-lethal alternative to such methods is a measure of the morphological changes associated with the smoltification of juvenile salmonids (Fessler and Wagner 1969; Gorbman et al. 1982).

Measures of smoltification indicate that juvenile salmonids of hatchery origin undergo smoltification during the in-river migration after release from hatcheries. Measures of smoltification from fish held in captive environments are often low or clearly suppressed compared with migrants (Zaugg et al. 1985; Patino et al. 1986). Gill ATPase activities of migrating juvenile salmonids increase rapidly after release from hatcheries, indicating rapid smoltification (Zaugg 1981; Rodgers et al. 1987). Although some physiological measures of smoltification indicate ongoing smoltification during the in-river migration, little is known about changes in morphology during this time.

Morphology of juvenile salmonids has been used to demonstrate differences among groups of fish with different rearing environments, genetic origins, and life history types (Swain and Holtby 1989; Damsgard 1991; Swain et al. 1991). Winans (1984) recognized the value of this approach and Winans and Nishioka (1987) demonstrated the useful application of this multivariate description of change in body shape during smoltification of coho salmon (Oncorhynchus kisutch) in a hatchery environment.

In this paper, we present results from analyses of morphological changes during the seaward migration of juvenile spring chinook salmon (0. tshawytscha) of hatchery origin in a large river system. The relations of these morphological changes to other measures of smoltification are described. We propose that a method of assessing smoltification using a non-lethal morphometric index could be substituted for other measures of smoltification.

METHODS

This study was conducted on populations of yearling juvenile spring chinook salmon of hatchery origin. The fish were from the Entiat National Fish Hatchery (NFH), Leavenworth NFH, Winthrop NFH (Columbia River hatcheries), Dworshak NFH, and Rapid River State Fish Hatchery (Snake River hatcheries) (Fig. 5.1). The fish reared at the Columbia River hatcheries originated from the Carson and Little White Salmon river stocks on the lower Columbia River. Fish reared at the Snake River hatcheries were of the Rapid River stock.

The fish were collected at the hatcheries and McNary Dam (river km 470) in spring 1988, 1989 and 1990. In each year, fish bearing freeze brands (Mighell 1969) were collected at each hatchery three times during the 1-month period prior to release (hatchery residents) and as they migrated past McNary Dam (migrants). Samples collected at the dam were made at approximately the 25th, 50th and 75th percentile of each branded group's passage to ensure an even sampling distribution throughout the migration. The juvenile salmon collection system at McNary Dam is equipped with submersible traveling screens to divert juvenile salmonids from the turbine intakes to intake gatewells, where they are bypassed to juvenile fish collection facilities (Matthews et al. 1986).

Sampling Methods. Fish sacrificed with a lethal dose of MS-222 were weighed, measured, and photographed immediately after immobilization. Changes in the length and weight relationship were described using Fulton's each fish by the equation $(w \cdot l^3) \cdot 10^5$, with weight (w) in grams and fork length (l) in millimeters (Ricker 1975). Photographs were taken using a 35-mm camera with black and white film (ASA 100) mounted on a copy stand. Fish were photographed with the fins held in the extended position using pins, using care to avoid altering the body shape, and a millimeter scale was placed nearby.

Morphometric data were collected from photographs by digitizing anatomical landmarks in an X and Y coordinate system using a digitizer and personal computer. Morphometric

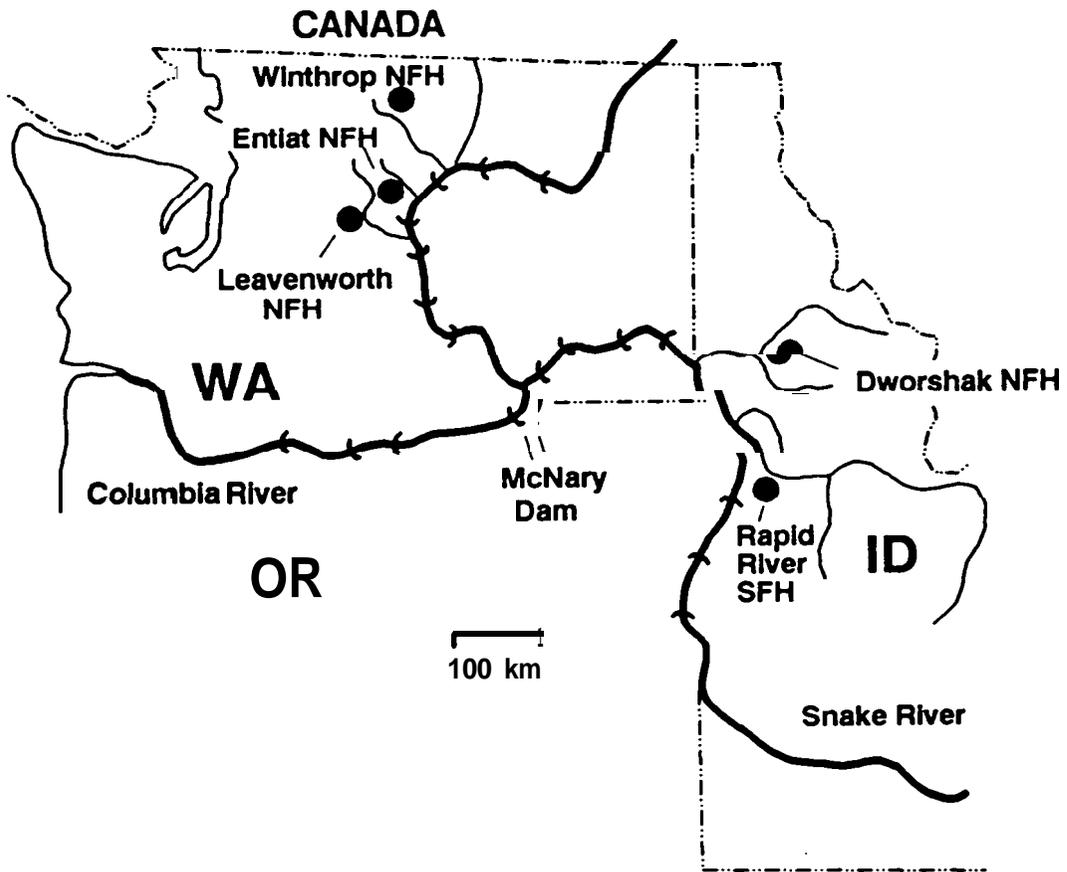


Figure 5.1. Map of study area indicating fish hatchery and McNary Dam sample sites.

characters, forming a truss network similar to that in Winans (1984), except as noted in Fig. 5.2, were calculated from the X and Y coordinates. Distances between 15 landmark locations were calculated using the Pythagorean theorem, resulting in 34 morphometric characters for analysis (Fig. 5.2). These characters were adjusted using the scale included in each photograph so that each digitized distance corresponded to the actual distance on the fish. To simplify interpretation, the principal components analysis was used as a data reduction procedure to reduce the large data set of morphological traits to several principal components for further analysis (Tabachnick and Fidell 1983).

To permit analyses of shape without the effects of allometric growth, a size-adjustment procedure was necessary because fish in the migrant group had a significantly larger mean fork length than those in the hatchery resident group. The second (PC2), third (PC3), and fourth (PC4) principal components were sheared to adjust for the effects of size using the shearing method of Humphries et al. (1981) as reformulated by Rohlf and Bookstein (1987). In this method the first principal component is used as a latent factor to represent general size. A computer program from Bookstein et al. (1985) and modified by Rohlf and Bookstein (1987) was used for this purpose after modification for use with a personal computer. Data analysis was performed using the SAS language for personal computers (SAS Institute 1989).

The correlations of sheared principal component *scores* with other measures of smoltification were analyzed using the Pearson product-moment correlation. In this analysis the number of days of in-river migration (MIGDAYS), calculated as the number of days between the date of release from the hatchery and date of recapture at McNary Dam, was used as a time variable to examine correlations of other variables with time-related migratory development. Correlations between individual scores of sheared PC2 (SPC2) sheared PC3 (SPC3), and sheared PC4 (SPC4) with MIGDAYS, K, gill ATPase activity, and plasma T_4 concentrations were examined.

Discriminant Function Analysis. Canonical discriminant function analysis was used to classify fish in the training data set ($n = 1095$) as either hatchery residents or migrants based on SPC2, SPC3, and SPC4. This data set included 485 hatchery residents and 610 migrants collected in 1989 and 1990. Homogeneity of the within-group variance-covariance matrices was tested using Bartlett's modification of the likelihood ratio test to determine whether a linear or quadratic discriminant function was appropriate (SAS Institute 1989).

Two methods were used to evaluate the performance of the discriminant function. In the first, a cross-validation morphometric characters were grouped into six cells along the anterior-posterior axis of the fish (Fig. 5.2).

Gill filaments and blood plasma were collected to assess smoltification through measurements of gill ATPase activity and plasma T₄. Gill filaments removed from the left gill arches were preserved and assayed using the method of Zaugg (1982). Blood plasma samples were assayed for plasma T₄ using the radioimmunoassay described by Dickhoff et al. (1978) and modified by Specker and Schreck (1982).

Principal Components Analysis. The variance-covariance matrix of the log-transformed (base 10) set of 34 morphometric characters was analyzed using principal components analysis. procedure was used to determine if the classification error-rate estimates of the discriminant function were biased. This procedure involved deleting an observation from the training data set, estimating a discriminant function based on those remaining, and classifying the deleted observation as to group membership. This procedure was repeated for each observation in the data set. This approach is similar to a jack-knife procedure (Efron 1982) and allows all of the fish in the training data set to be used for validation.

As a second method of verification, the percent correct classification of fish independent of those used to develop the discriminant function was examined. In this method, fish collected from the hatcheries and McNary Dam in 1988 ($n = 1022$) were classified using the discriminant function based on the

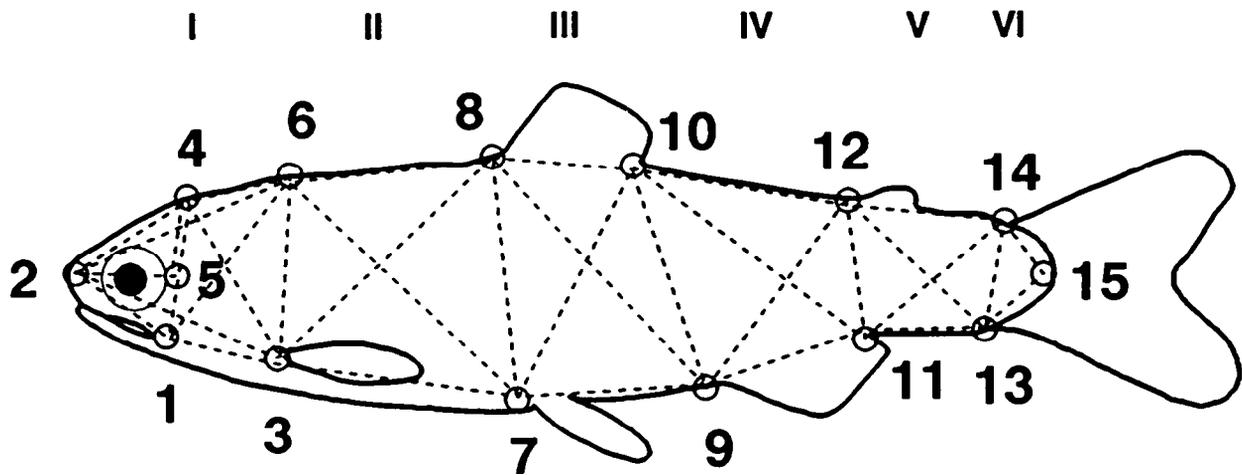


Figure 5.2. Locations of 15 landmarks (open circles) and 34 morphometric characters (dashed lines) used in the truss network. Landmark points are from Winans (1984) except the locations of (4) point on neocranium intersected by a line from point (5) perpendicular to character 2-5, (5) posteriormost aspect of eye, and (6) point on neocranium intersected by a line extended dorsally from point 3 and posteriormost aspect of the operculum. Roman numerals indicate cells.

training data set. This method was also used as a measure of the effectiveness of the discriminant function in classifying fish from other years.

The canonical variate (CAN) was evaluated as a morphological index of smoltification. Pearson product-moment correlations were used to measure the association of CAN with gill ATPase activity and plasma T_4 of fish in the training data set. Statistical results were considered significant when $P \leq 0.05$.

The sample size required to detect a difference of 0.5 units between two mean CAN values was calculated as an estimate of the sample size required when using the morphometric measure of smoltification. This number was estimated based on a 90% chance ($\beta = 0.10$) of detecting a true difference between two mean CAN values at the $\alpha = 0.05$ significance level (Zar 1984). Variability in the data was based on the sample variances of CAN values of the hatchery residents and migrants in the training data set.

RESULTS

Principal Components Analysis. Ninety percent of the variation of the 34 morphometric characters was accounted for using the first four principal components. Variable loadings of the first component (PC1), explaining 68.6% of the total variation, were of similar size and sign, indicating that PC1 was a general size component (Pimentel 1979; Bookstein et al. 1985; Table 5.1). This component was highly correlated with fork length ($r = 0.97$, $n = 1092$, $P = 0.0001$). The SPC2, SPC3, and SPC4 explained 13.0%, 4.5%, and 4.3% of the total variation, respectively. Loadings of these components were of variable sizes and signs and were interpreted as shape components. Each of the remaining principal components accounted for less than 2% of the total variation; these were not examined further.

The SPC2 was characterized by large positive loadings in cell V and large negative loadings in cell VI: it summarized variation associated with caudal peduncle shape (Table 5.1, Fig. 5.3). Variation described by this component was predominantly due to differences among Columbia and Snake river fish, although

Table 5.1. Loadings from principal components analyses of 34 morphometric characters of 1095 juvenile spring chinook salmon. Loadings are listed for principal component 1 (PCI) and the sheared second (SPC2), third (SPC3), and fourth (SPC4) principal components. Character descriptors and cells refer to Fig. 2.

Cell	Character		PC1	SPC2	SPC3	SPC4
	Number	Descriptor				
I	1	1-2	0.147	-0.060	0.258	0.057
	2	1-3	0.196	0.039	-0.061	0.288
	3	2-3	0.174	-0.011	0.090	0.164
	4	2-4	0.120	-0.026	0.152	0.090
	5	2-5	0.106	-0.013	0.078	0.082
	6	4-5	0.157	0.018	0.127	0.296
	7	4-6	0.240	0.040	0.051	0.410
	8	2-6	0.175	0.003	0.095	0.228
	9	1-6	0.170	0.003	-0.015	0.186
	10	3-4	0.181	-0.026	0.042	0.096
	11	1-4	0.133	-0.032	0.096	0.072
II	12	3-6	0.151	-0.064	-0.058	-0.082
	13	3-7	0.160	-0.042	-0.038	-0.170
	14	6-8	0.154	-0.056	-0.014	-0.235
	15	6-7	0.157	-0.057	-0.049	-0.186
	16	3-8	0.152	-0.056	-0.060	-0.192
III	17	7-8	0.150	-0.081	-0.163	-0.230
	18	7-9	0.185	-0.010	-0.018	0.001
	19	8-10	0.163	-0.050	-0.052	-0.017
	20	8-9	0.172	-0.044	-0.050	-0.087
	21	7-10	0.152	-0.071	-0.164	-0.193
IV	22	9-10	0.173	-0.046	-0.059	-0.123
	23	9-11	0.156	-0.053	-0.053	-0.031
	24	10-12	0.202	-0.029	-0.012	0.105
	25	9-12	0.162	-0.077	-0.100	-0.119
	26	10-11	0.182	-0.022	-0.006	-0.014
V	27	11-12	0.158	-0.033	-0.025	-0.217
	28	11-13	0.241	0.464	0.458	-0.086
	29	12-14	0.169	0.379	-0.218	0.057
	30	12-13	0.192	0.256	0.240	-0.202
	31	11-14	0.195	0.332	-0.272	0.121
VI	32	13-14	0.193	0.230	-0.239	-0.063
	33	14-15	0.188	-0.443	0.463	-0.085
	34	13-15	0.150	-0.397	-0.323	0.290
Variance			0.070	0.013	0.005	0.004
% of Total			68.6	13.0	4.5	4.3

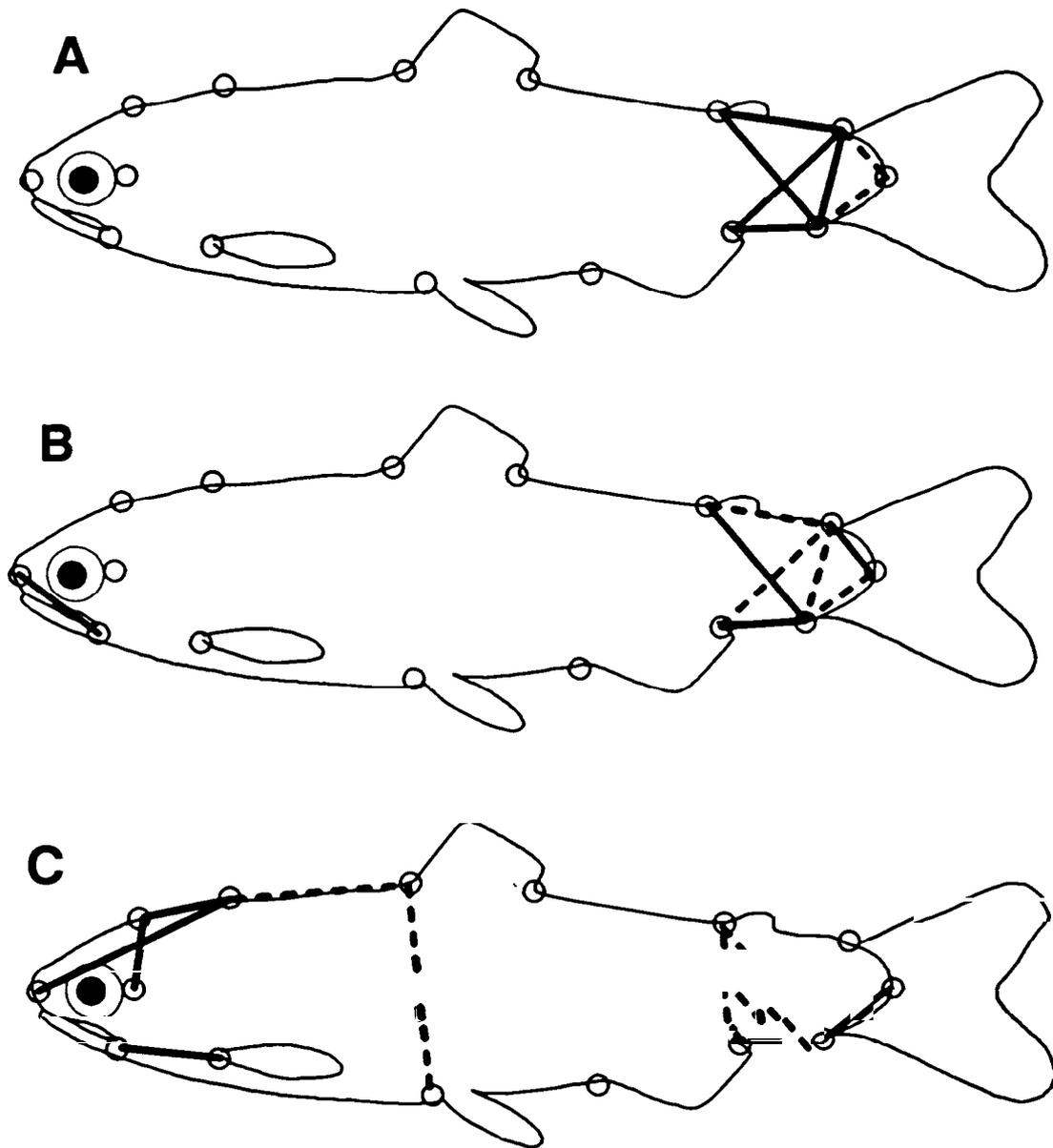


Figure 5.3. Schematic diagrams of morphometric characters with important loadings on SPC2 (A), SPC3 (B), and SPC4 (C). Solid lines denote characters with positive loadings: dashed lines denote those with negative loadings.

some differences between hatchery residents and migrants from the Columbia River hatcheries were also evident; those from the Snake River hatcheries were poorly separated using SPC2 (Fig. 5.4A,B). This component indicated fish from the Columbia River hatcheries had generally longer (cell V), but more posteriorly truncated (cell VI), caudal peduncles than those from the Snake River hatcheries. In addition, the mean SPC2 of migrants from the Columbia River hatcheries was higher than those of hatchery residents, indicating SPC2 increased during the migration of these fish.

The most important loadings of SPC3 were generally characterized by a contrast of several positive and negative values in cells V and VI, as well as one positive loading in cell I; it summarized variation associated with caudal peduncle shape apart from that described by SPC2 (Table 5.1, Fig. 5.3). This component accounted for variation between hatchery residents and migrants of both drainages (Fig. 5.4A,C).

The most important loadings of SPC4 were characterized by a contrast of several positive loadings in cell I and one positive loading in cell VI, with many, predominantly negative, loadings in all other cells (Table 5.1, Fig. 5.3). This component indicated migrants from Columbia and Snake river hatcheries had larger heads and smaller bodies compared with hatchery residents (Fig. 5.4B,C).

Individual SPC2, SPC3, and SPC4 scores were significantly correlated with gill ATPase activity, K, and MIGDAYS (Table 5.2). The significant correlations with MIGDAYS indicated that the changes in shape were associated with the time elapsed during the migration. The correlations between the principal components and gill ATPase activity were interpreted as evidence that they described shape changes associated with smoltification. The principal components were positively correlated with gill ATPase activity: they increased as smoltification development progressed during the migration. Principal components SPC2, SPC3, and SPC4 were not correlated with plasma T_4 concentrations ($P > 0.1$).

Discriminant Function Analysis. Ninety-two percent of fish in the hatchery resident and migrant groups in the training data set were correctly classified into group of origin using SPC2, SPC3, and SPC4 as variables in a quadratic discriminant function (Table 5.3). A quadratic discriminant function was selected because the within-group variance-covariance matrices were significantly different (chi-square = 65.7, $P = 0.0001$). Cross-validation error rates were identical to those in the original classification, indicating the error rate estimates from the training data set were unbiased.

Eighty percent of hatchery residents and 94% of the migrants independent of those used to develop the discriminant function were correctly classified. This indicated the results that could be expected when the discriminant function is applied to other independent samples, and that the discriminant function can be

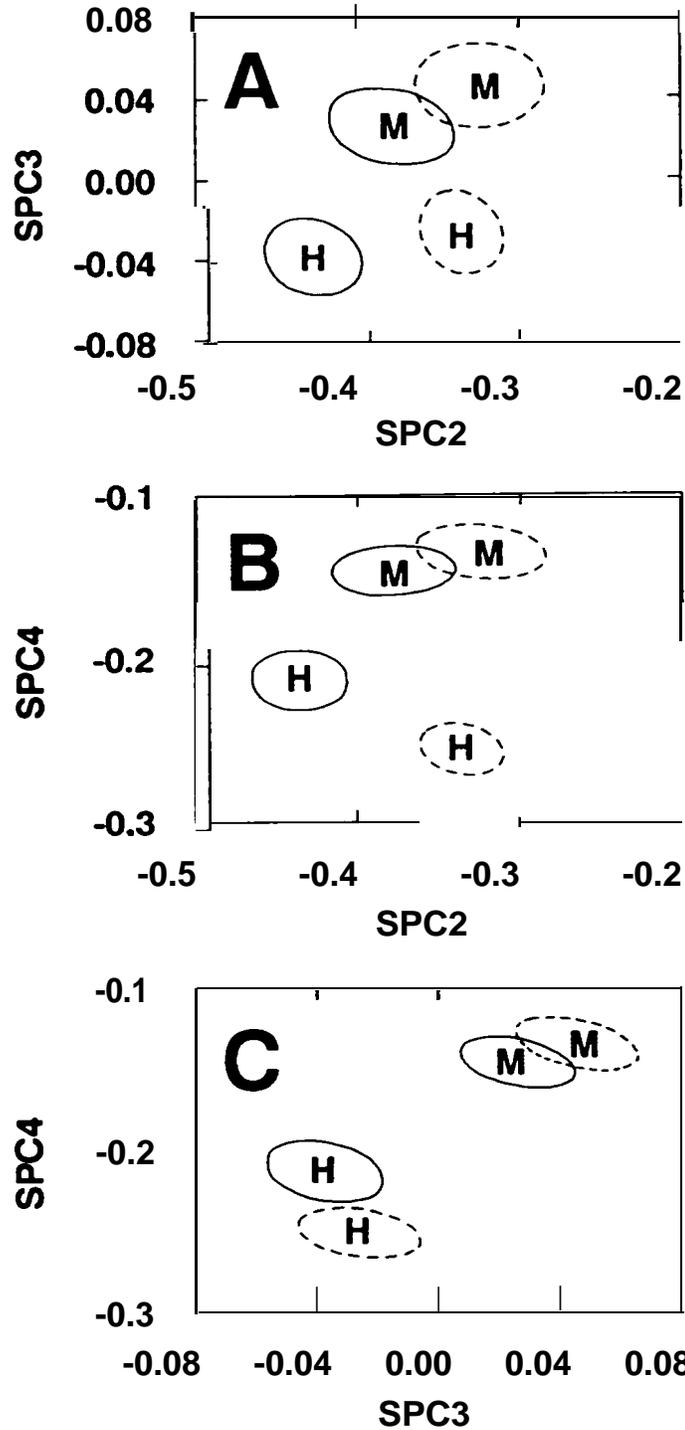


Figure 5.4. Bivariate plots of SPC2, SPC3, and SPC4 with 95% confidence ellipsoids around bivariate means from juvenile spring chinook salmon from Columbia River hatcheries (solid lines) and Snake River hatcheries (dashed lines). Letters denote sample group (H = hatchery residents, M = migrants).

Table 5.2. Correlation coefficients, significance levels (in parentheses), and sample sizes for comparisons between several variables measured in juvenile spring chinook salmon collected in 1989 and 1990, and included in the training data set used in the canonical discriminant function. Refer to text for variable definitions.

	ATPASE	SPC2	SPC3	SPC4	T4	K
MIGDAYS	0.8625 (0.0001) 1095	0.2950 (0.0001) 1095	0.4447 (0.0001) 1095	0.6147 (0.0001) 1095	-0.0336 (0.3995) 629	-0.8189 (0.0001) 946
ATPASE		0.2912 (0.0001) 1095	0.3967 (0.0001) 1095	0.6371 (0.0001) 1095	-0.0719 (0.0715) 629	-0.7130 (0.0001) 946
SPCE			0.0260 (0.3899) 1095	0.0379 (0.2102) 1095	-0.0141 (0.7239) 629	-0.1386 (0.0001) 946
SPC3				0.0496 (0.1012) 1095	0.0108 (0.7879) 629	-0.5579 (0.0001) 946
SPC4					-0.0547 (0.1707) 629	-0.5560 (0.0001) 946
T4						-0.0333 (0.4332)

555

Table 5.3. Classification results of discriminant function analyses to separate hatchery resident (H.Res.) and migrant groups of juvenile spring chinook salmon.

Actual group	Number of fish classified as		Total	Percent correct
	H.Res.	Migrant		
Training set				
H.Res.	447	38	485	92
Migrant	50	560	610	92
Cross-validation set				
H.Res.	447	38	485	92
Migrant	50	560	610	92
Independent set				
H.Res.	490	122	612	80
Migrant	24	386	410	94

successfully applied to fish collected in different years. The canonical discriminant function equation was

$$(2) \quad \text{CAN} = 5.059 + 3.294(\text{SPC2}) + 13.000(\text{SPC3}) + 18.976(\text{SPC4}),$$

where the sheared principal components are calculated as

$$(3) \quad \text{SPC}_j = \sum_{i=1}^{34} (\text{LOG}_{10} l_i * L_{ij}),$$

where i designates the character number from 1 to 34, l_i is the length of character i in millimeters, and L_{ij} is the loading of character i on the j^{th} principal component.

Fish with a CAN score less than zero were classified as hatchery residents and those with a score above zero as migrants (Figure 5.5). CAN scores were significantly correlated with gill ATPase activity ($r = 0.77$, $n = 1095$, $P = 0.0001$) but not with plasma T_4 ($n = 629$, $P = 0.2994$).

The relations between MIGDAYS, CAN, and gill ATPase activity of two representative groups collected during 1990 are illustrated in Fig. 5.6. In each instance, the trends in CAN are similar to trends in gill ATPase activity over time. Values of both variables were lower in hatchery residents (MIGDAYS ≤ 0) than in migrants (MIGDAYS > 0), with values increasing sharply after release from the hatcheries. The variability of CAN was higher than that of gill ATPase activity, indicated by the larger standard errors in Fig. 5.5.

The standard deviation of CAN of the hatchery residents in the training data set (SD = 1.04) was used to estimate the sample size required rather than the slightly smaller standard deviation of CAN of the migrants (SD = 0.97). Based on this conservative approach, the sample sizes required to detect a difference of 0.5 units between two mean CAN values was estimated as $n = 92$.

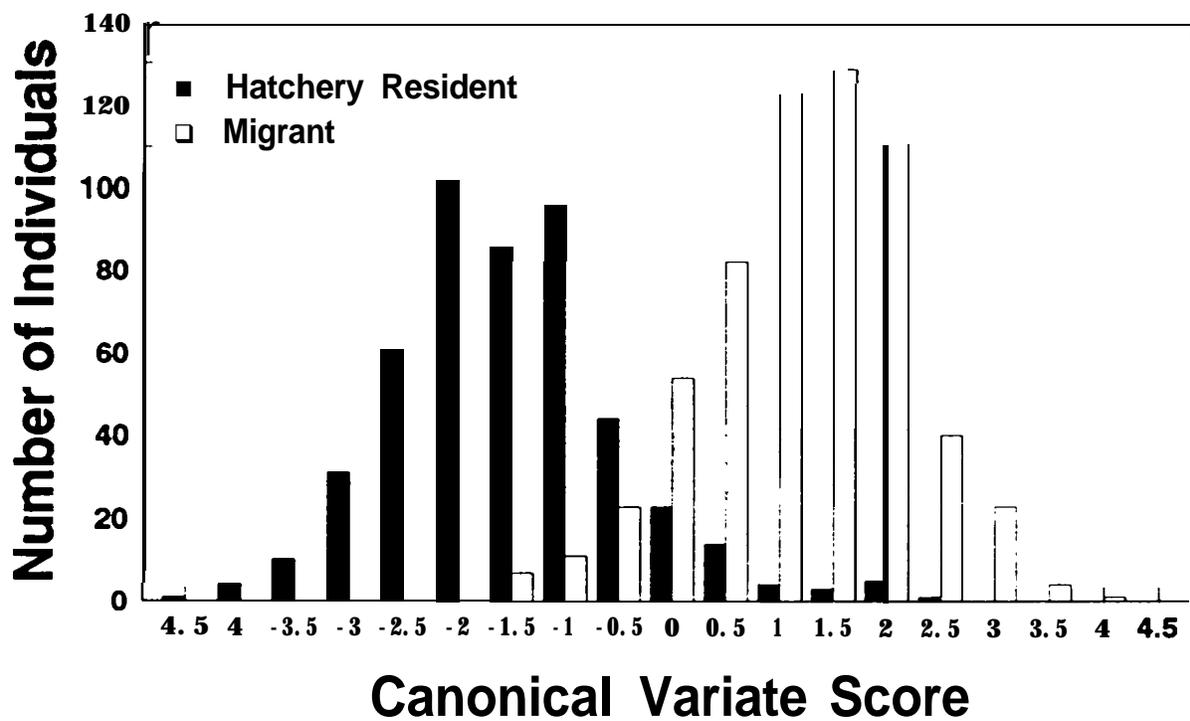


Figure 5.5. Distribution of CAN scores among hatchery residents (solid bars) and migrants (open bars) in the training data set.

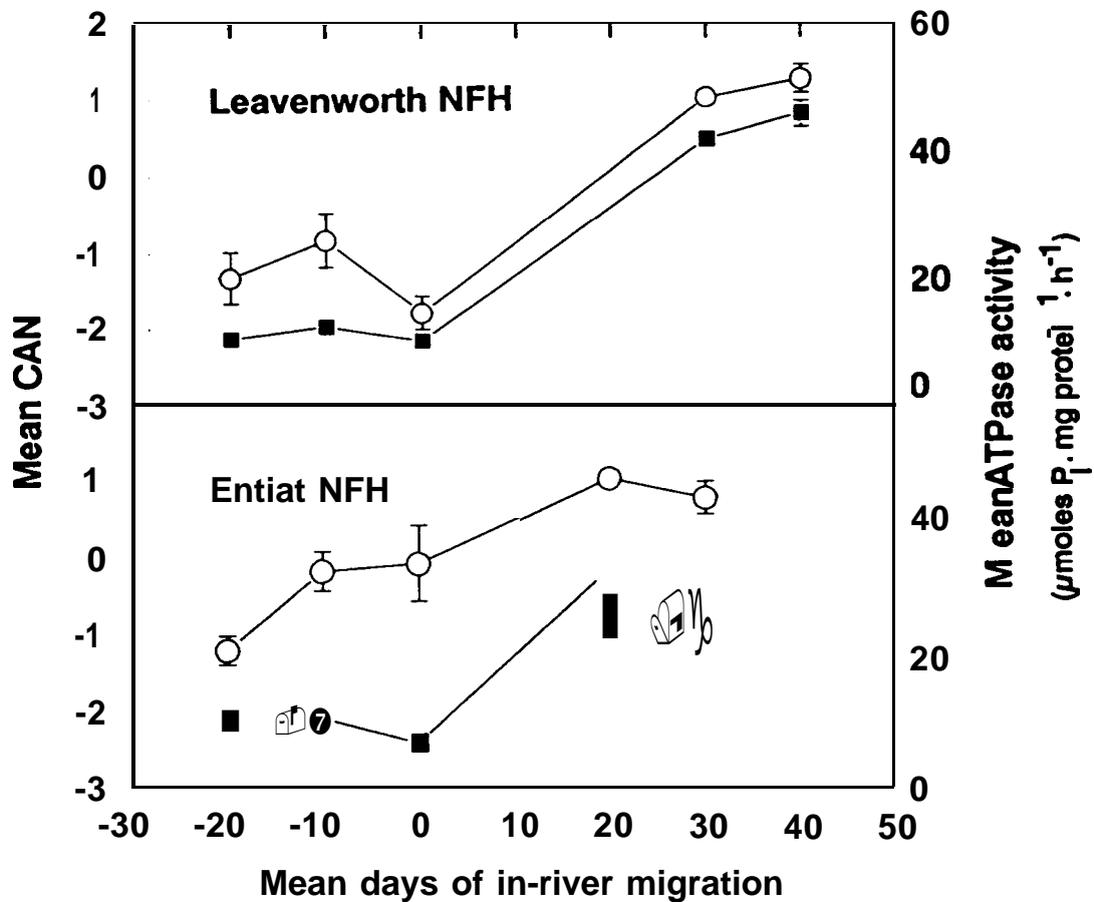


Figure 5.6. Plot of mean $\text{Na}^+\text{-K}^+$ gill ATPase activity (■) and the mean canonical variate (○) versus mean days of in-river migration of two representative groups of hatchery spring chinook salmon collected in spring 1990. Sample sizes range from 10 to 28. Vertical bars indicate ± 1 SE.

DISCUSSION

Morphological changes occur in juvenile spring chinook salmon during smoltification, and these changes can be quantified. The SPC2, SPC3, and SPC4 indicated shape changes occurred in the caudal peduncle, head, and body depth, with differential growth in these areas resulting in migrants with longer caudal peduncles, larger heads, and narrower bodies than hatchery residents. The largest amount of shape variability, accounted for by SPC2, was from landmarks 11-13 in the caudal peduncle (Table 5.1). These results are similar to those described during smoltification of hatchery-resident juvenile spring chinook salmon and coho salmon (Winans 1984; Winans and Nishioka 1987) and anadromous and resident Arctic char (Salvelinus alpinus) (Damsgard 1991).

The timing of shape changes occurring during smoltification of the groups we examined were similar to the development of gill ATPase activity. Most changes in shape occurred after release from the hatchery environment, proceeded rapidly for several weeks, then slowed. However, our data was limited to the time between one month prior to release (March and April) and sixty days afterward; there may also be changes in shape prior to or after this time. Winans and Nishioka (1987) reported cyclical changes in the caudal peduncle shape of juvenile coho salmon in a California hatchery over a several-month period.

The shape variability accounted for by each of SPC2, SPC3, and SPC4 was necessary to develop a canonical variate with optimal discriminatory power and the highest correlation with gill ATPase activity. Although most shape variation in the training data set was accounted for by SPC2, hatchery residents and migrants from the Snake River hatcheries were poorly separated along this axis, requiring the addition of the other principle components to the discriminant function. The SPC3 and SPC4 variables explained small amounts of the total variability in the training data set, but were the primary axes along which hatchery residents and migrants were separated. The discriminant function analysis was used to weight each of these principal components based on their relative discriminatory powers,

resulting in low classification error rates and a high correlation with gill ATPase activity.

The sample sizes required to result in precise estimates of CAN may vary depending on the application. The determination of appropriate sample sizes depends not only on the level of precision required, but on the variability of the data collected. Our sample size estimate was based detecting a small difference in CAN, and on the variability associated with a composite sample of hatchery residents from five hatcheries. We believe it is a conservative estimate which is probably an upper bound of the sample size required for most applications. Smaller sample sizes may be appropriate if the acceptable level of precision is lower. For example, an estimated sample size of $n = 23$ is required to detect a difference of 1.0 CAN unit. However, since changes in shape occur rapidly during the first several weeks of migration, morphological data from fish with varied migration histories collected during this time may require larger sample sizes. This may occur when morphometric data are collected from migrating fish of many different or unknown origins. The appropriate sample sizes for a specific application may be best estimated based on previous data from that application.

Other non-lethal measures of smoltification are available, such as the gill ATPase assay of McCormick (1993), which requires only a small gill biopsy. However, this method requires a laboratory with specialized equipment and technicians which are unavailable to many researchers and managers.

The morphometric measure of smoltification has the advantage of being non-lethal as well as requiring little training and having a relatively fast turn-around time from sample collection to final result. With practice, fish can be digitized at a rate of about 2 min each, requiring approximately three hours to digitize a sample of $n = 90$ fish. Using a simple computer program, results can be available as the fish are digitized. Moreover, recent developments in video technology may make it possible for images to be digitized in real time, rather than digitizing from still photographs. However, the morphometric methods to assess smoltification may be less desirable than

others in situations when samples need to be collected in a short amount of time, or when sufficient space is not available; conditions common to many juvenile fish traps.

Using a morphometric indicator as a measure of smoltification provides researchers and managers with a tool that is non-lethal to fish, requires a reasonable sample size, has relatively low equipment costs, and requires little technical training compared with laboratory assays. The morphometric method of smoltification assessment described here may be best suited to studies in which sacrificing fish is not possible, such as those involving threatened or endangered species, or when access to a laboratory for sample analysis is not available.

ACKNOWLEDGMENTS

We thank W. Nelson, A. Maule, G.R. Smith, and one anonymous reviewer for making helpful comments during review of this manuscript. We appreciate the cooperation of the staffs of the U.S. Fish and Wildlife Service at the Dworshak, Entiat, Leavenworth, and Winthrop National Fish Hatcheries, as well as the Idaho Department of Fish and Game staff at the Rapid River State Fish Hatchery. We thank our colleagues at the Columbia River Field Station and the staffs of the many agencies that participated in the Smolt Monitoring Program in the Columbia River basin. This work was funded through contract DE-AI79-87BP35245 with the Bonneville Power Administration, Portland, Oregon.

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APPENDICES

Appendix A.1. Summary of data from juvenile steelhead from Dworshak NFH branded LA-7U-1/3, LD-7U-1/3, RA-7U-1 and RD-7U-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	03APR1991	40	190.6	13.34	40	72.7	14.91	40	1.04	0.07	38	4.64	2.28
	18APR1991	39	193.4	17.02	40	74.4	23.08	39	1.04	0.09	38	5.53	2.04
	29APR1991	49	196.6	20.30	150	80.0	24.46	49	1.03	0.08	148	7.07	3.08
LGR	30APR1991	60	204.2	19.38	60	89.7	20.90	60	1.05	0.19	47	7.19	2.72
	06MAY1991	22	211.6	22.26	22	87.8	25.74	22	0.90	0.05	22	8.87	2.64
	07MAY1991	12	195.8	17.67	12	69.4	17.40	12	0.91	0.04	11	13.06	4.59
	08MAY1991	31	212.4	15.69	31	88.7	17.62	31	0.92	0.07	31	13.22	5.17
	09MAY1991	20	209.1	20.86	20	85.7	25.01	20	0.92	0.05	20	12.11	2.92
	10MAY1991	13	209.2	15.62	13	84.9	15.80	13	0.92	0.05	13	11.62	8.03
	13MAY1991	17	205.5	21.11	17	77.3	23.21	17	0.87	0.05	17	15.25	3.21
	14MAY1991	7	209.9	29.92	7	84.0	35.77	7	0.86	0.04	6	18.07	3.62
	15MAY1991	20	209.3	21.75	20	81.3	23.23	20	0.86	0.05	20	15.44	3.82
	16MAY1991	10	222.8	13.11	10	93.2	12.97	10	0.84	0.04	10	17.59	4.26
	17MAY1991	3	230.0	19.08	3	103.7	25.60	3	0.84	0.02	3	20.15	7.01
	20MAY1991	9	222.8	26.03	9	94.9	29.49	9	0.84	0.04	9	13.01	3.18
	21MAY1991	12	218.1	23.02	12	89.1	26.52	12	0.83	0.03	12	15.48	6.06
	22MAY1991	1	227.0	.	1	101.8	.	1	0.87	.	1	8.80	.
	23MAY1991	4	211.0	10.68	4	80.8	5.7;	4	0.86	0.08	4	13.00	4.8;
	24MAY1991	4	212.8	35.67	4	83.4	39.89	4	0.82	0.05	4	13.34	3.42
MCN	17MAY1991	3	209.7	16.04	3	74.3	16.75	3	0.80	0.01	1	27.97	.
	18MAY1991	1	190.0	.	1	55.9	.	1	0.81	.	1	14.48	.
	21MAY1991	2	226.5	10.61	2	98.9	16.19	2	0.85	0.0;	2	25.40	6.2;
	23MAY1991	4	226.0	21.24	4	110.4	33.67	4	0.93	0.04	4	14.76	4.62

Appendix A.2. Summary of data from juvenile spring chinook from Entiat NFH branded RA-7C-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	06MAR1991	20	122.6	13.85	20	20.9	7.03	20	1.10	0.06	20	6.60	1.20
	19MAR1991	20	115.2	9.98	20	17.1	4.90	20	1.09	0.06	20	6.56	1.24
RIS	02APR1991	60	122.2	13.89	60	20.8	7.92	60	1.09	0.07	19	7.68	2.25
	23APR1991	1	103.0	.	1	11.6	.	1	1.06	.	1	12.73	.
	28APR1991	1	135.0	.	1	25.1	.	1	1.02	.	0	.	.
	29APR1991	1	119.0	.	1	16.0	.	1	0.95	.	1	12.78	.
	01MAY1991	2	123.0	8.49	2	18.5	4.03	2	0.98	0.01	2	10.08	9.46
	05MAY1991	1	167.0	.	1	45.4	.	1	0.97	.	1	10.52	.
	07MAY1991	1	132.0	.	1	20.2	.	1	0.88	.	0	.	.
	08MAY1991	1	125.0	.	1	17.4	.	1	0.89	.	0	.	.
	09MAY1991	1	140.0	.	1	24.5	.	1	0.89	.	1	6.91	.
	13MAY1991	1	115.0	.	1	14.6	.	1	0.96	.	1	17.85	.
	14MAY1991	1	132.0	.	1	20.5	.	1	0.89	.	1	13.89	.
	17MAY1991	1	130.0	.	1	21.1	.	1	0.96	.	1	23.21	.
	MCN	11MAY1991	11	139.8	8.78	11	25.3	4.64	11	0.92	0.04	9	29.89	8.54
12MAY1991		9	130.1	11.21	9	20.3	6.12	9	0.90	0.03	8	37.05	10.22
17MAY1991		14	129.9	11.54	14	20.6	5.57	14	0.92	0.06	13	35.18	7.58
18MAY1991		6	141.3	13.57	6	26.5	8.19	6	0.92	0.04	6	37.33	9.00
23MAY1991		2	131.0	19.80	2	19.8	8.63	2	0.86	0.01	2	27.97	1.75
24MAY1991		5	141.0	10.70	5	25.2	4.85	5	0.89	0.03	4	38.20	13.01
25MAY1991		9	141.0	10.51	9	25.4	6.05	9	0.89	0.05	8	35.87	8.50
28MAY1991		6	134.3	7.53	6	22.9	3.02	6	0.94	0.06	6	33.70	6.45
29MAY1991		1	134.0	.	1	22.3	.	1	0.93	.	1	23.62	.
03JUN1991	1	151.0	.	1	32.1	.	1	0.93	.	1	27.55	.	

Appendix A.3. Summary of data from juvenile steelhead from IrrigonSFH branded LA-A-2 and RA-A-2 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	01APR1991	20	176.1	22.40	20	62.3	22.00	20	1.10	0.10	20	6.67	4.58
	15APR1991	20	186.2	26.51	20	72.1	26.30	20	1.06	0.07	17	8.09	2.28
	30APR1991	20	196.6	18.66	20	78.6	20.80	20	1.01	0.04	20	7.26	2.95
LGR	06MAY1991	2	216.5	9.19	2	108.7	17.90	2	1.07	0.04	2	9.42	3.24
	07MAY1991	2	225.5	0.71	2	105.7	0.99	2	0.92	0.01	2	7.92	0.61
	08MAY1991	9	193.3	12.88	9	68.4	14.53	9	0.93	0.03	9	11.15	2.39
	13MAY1991	24	204.3	12.97	24	77.5	16.29	24	0.90	0.05	24	15.60	3.60
	14MAY1991	16	206.6	18.77	16	79.1	23.92	16	0.88	0.04	16	13.68	2.22
	15MAY1991	18	208.7	20.52	18	83.2	25.73	18	0.89	0.05	18	17.82	3.99
	16MAY1991	7	214.0	10.31	7	84.1	13.62	7	0.85	0.04	7	16.54	2.47
	17MAY1991	7	212.4	17.79	7	87.9	25.77	7	0.89	0.04	7	17.04	4.73
	20MAY1991	18	213.7	17.88	18	84.9	25.33	18	0.85	0.06	17	17.74	4.32
	21MAY1991	20	208.4	11.21	20	77.8	14.32	20	0.85	0.07	20	18.40	6.89
	22MAY1991	19	211.5	15.09	20	79.2	24.49	19	0.87	0.05	20	14.38	4.48
	23MAY1991	7	204.7	21.34	7	75.9	22.44	7	0.86	0.06	7	14.77	4.99
	24MAY1991	6	202.2	18.48	6	72.7	25.31	6	0.85	0.07	6	14.39	5.00
MCN	21MAY1991	1	195.0	.	1	62.8	.	1	0.85	.	1	22.09	.
	23MAY1991	1	214.0	.	1	86.5	.	1	0.88	.	1	21.50	.
	24MAY1991	2	225.5	0.7;	2	93.6	8.7;	2	0.82	0.08	2	26.80	2.2;
	25MAY1991	1	221.0	.	1	87.3	.	1	0.81	.	1	26.68	.
	28MAY1991	2	233.01	7.07	2	106.8	13.58	2	0.84	0.03	2	22.90	4.00

Appendix A.4. Summary of data from juvenile spring chinook from Leavenworth NFH branded LA-7N-1/3 and RD-IN-1 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	19MAR1991	20	125.9	8.731	20	21.41	4.47	20	1.07	0.10	20	8.82	3.18
	02APR1991	2a	122.5	8.06	20	20.4	4.38	20	1.10	0.04	19	9.99	2.57
	16APR1991	60	127.7	11.90	60	24.4	7.77	60	1.14	0.06	20	14.98	2.77
RIS	20APR1991	6	125.0	11.26	6	22.8	7.00	6	1.14	0.05	6	13.59	4.13
	22APR1991	4	135.3	14.03	4	26.9	8.68	4	1.06	0.03	4	12.94	1.61
	23APR1991	2	135.0	4.24	2	27.3	2.97	2	1.11	0.01	2	15.06	4.76
	24APR1991	3	120.0	10.54	3	18.1	4.76	3	1.03	0.03	2	19.19	7.41
	28APR1991	5	126.0	7.00	5	20.5	3.53	5	1.01	0.05	3	14.54	2.63
	29APR1991	1	123.0		1	17.5		1	0.94		1	8.12	
	30APR1991	1	123.0		1	19.4		1	1.04		1	7.84	
	01MAY1991	1	119.0	5.13	23	184.83	11.74	1	0.99		2	13.67	11.3;
	05MAY1991	3	123.3				2.54	3	0.98	0.06	3	9.40	2.08
	07MAY1991	7	127.4	6.32	7	20.2	3.44	7	0.96	0.04	1	16.36	
	08MAY1991	7	124.7	10.98	7	18.4	6.85	7	0.92	0.08	1	17.11	
	09MAY1991	5	128.0	7.31	5	20.9	4.30	5	0.99	0.05	5	12.95	3.98
	12MAY1991	2	129.5	9.19	2	20.7	3.25	2	0.95	0.06	2	19.20	0.54
	13MAY1991	3	126.7	6.43	3	19.8	2.69	3	0.97	0.03	3	19.95	8.75
	14MAY1991	5	135.6	14.91	5	24.3	8.66	5	0.94	0.03	5	19.72	1.79
17MAY1991	3	140.3	13.65	3	26.5	7.92	3	0.94	0.02	3	21.08	2.03	
21MAY1991	1	147.0					1	0.90		1	17.76		
MCN	11MAY1991	12	144.9	14.8;	12	28.5	29.2	12	0.93	0.04	10	27.05	7.0;
	12MAY1991	13	137.7	11.26	13	24.7	7.76	13	0.92	0.04	4	28.51	8.33
	13MAY1991	22	140.6	15.44	22	27.2	10.67	22	0.94	0.06	1	27.73	
	14MAY1991	18	134.8	8.33	18	22.9	4.84	18	0.92	0.05	0		
	20MAY1991	30	138.4	12.68	30	24.7	8.58	30	0.91	0.04	18	35.3;	10.4;
	21MAY1991	30	141.9	11.58	30	26.1	6.97	30	0.89	0.05	1	25.73	
	24MAY1991	30	140.4	10.38	30	25.4	6.05	30	0.90	0.04	20	31.31	6.30
31MAY1991	1	137.0		1	26.2		1	1.02		0			

Appendix A.5. Summary of data from juvenile summer chinook from McCall SFH branded LA->O-1, RA->O-1 and RD->O-1 collected during spring, 1991. Fish were collected at the hatchery (RAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data include sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
IAT	21FEB1991	20	115.1	9.47	20	17.6	3.89	20	1.13	0.06	20	7.14	2.65
	06MAR1991	20	119.8	7.29	20	20.3	3.85	20	1.17	0.06	20	5.97	1.80
	19MAR1991	60	118.9	8.00	60	19.2	3.91	60	1.12	0.06	20	7.03	1.89
GR	22APR1991	1	126.0	.	1	20.4	.	1	1.02	.	1	12.52	.
	25APR1991	2	127.5	2.1	2	19.4	0.00	2	0.94	0.05	2	15.65	3.86
	26APR1991	1	139.0	.	1	27.9	.	1	1.04	.	1	7.47	.
	28APR1991	1	125.0	.	1	18.8	.	1	0.96	.	1	13.35	.
	30APR1991	3	129.0	6.00	3	20.9	4.70	3	0.96	0.09	3	17.14	0.30
	01MAY1991	4	127.8	4.03	4	19.9	2.63	4	0.95	0.05	4	18.28	6.72
	03MAY1991	1	126.0	.	1	19.6	.	1	0.98	.	1	20.56	.
	06MAY1991	5	132.2	5.26	5	21.3	2.76	5	0.92	0.03	4	18.16	5.01
	07MAY1991	2	129.0	15.56	2	21.0	7.85	2	0.96	0.02	2	23.03	9.58
	08MAY1991	5	129.4	6.77	5	21.4	3.31	5	0.98	0.03	4	17.92	0.76
	09MAY1991	10	131.5	5.68	10	21.5	2.72	10	0.94	0.03	9	16.04	4.83
	10MAY1991	3	131.0	7.00	3	21.5	3.05	3	0.95	0.05	3	24.68	4.32
	13MAY1991	3	133.3	2.08	3	22.6	0.26	3	0.95	0.05	3	22.25	6.12
	14MAY1991	2	128.0	2.83	2	20.1	4.17	2	0.95	0.14	2	25.34	8.09
	15MAY1991	5	128.6	5.55	5	21.2	2.87	5	0.99	0.02	5	20.20	3.61
	16MAY1991	3	133.7	7.09	3	23.3	2.95	3	0.97	0.03	3	24.94	7.67
	17MAY1991	7	131.3	4.82	7	22.0	2.23	7	0.97	0.03	7	25.47	5.31
	20MAY1991	4	133.5	8.23	4	22.9	3.73	4	0.96	0.03	4	22.39	5.33
	21MAY1991	13	128.8	8.75	13	20.8	3.96	13	0.96	0.05	13	21.77	5.05
22MAY1991	9	132.2	5.17	9	23.3	3.71	9	1.00	0.05	9	20.60	5.05	
23MAY1991	1	126.0	.	1	19.6	.	1	0.98	.	1	16.69	.	
24MAY1991	2	127.0	7.0	2	20.0	2.4	2	0.97	0.04	2	23.15	0.19	
24MAY1991	4	136.8	7.18	4	22.6	4.62	4	0.88	0.05	4	62.52	8.02	
25MAY1991	11	137.2	4.02	11	22.3	2.40	11	0.86	0.03	11	35.34	8.92	
28MAY1991	9	130.7	4.56	9	20.0	1.63	9	0.90	0.04	9	34.53	7.37	
29MAY1991	3	133.3	5.13	3	21.3	3.70	3	0.89	0.05	3	31.79	9.18	
31MAY1991	3	137.7	5.13	3	22.7	3.03	3	0.86	0.05	3	37.77	10.03	
03JUN1991	1	139.0	.	1	23.9	.	1	0.89	.	1	20.29	.	
12JUN1991	4	142.0	9.83	4	27.4	6.29	4	0.94	0.05	4	21.78	6.2	

Appendix A.6. Summary of data from juvenile spring chinook from Rapid River SFH branded RA->1-1 and RD->1-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	
HAT	21FEB1991	20	114.6	7.80	20	16.8	3.44	20	1.11	0.04	20	5.79	2.06	
	05MAR1991	20	114.2	6.81	20	16.5	3.22	20	1.10	0.07	18	6.66	1.73	
	20MAR1991	60	117.5	6.54	60	18.0	3.35	60	1.10	0.06	19	6.73	3.22	
LGR	18APR1991	4	122.0	13.71	4	17.5	5.27	4	0.94	0.05	4	27.77	5.96	
	19APR1991	3	131.3	4.93	3	21.8	3.04	3	0.96	0.08	3	27.28	6.79	
	22APR1991	2	132.0	5.66	2	21.7	1.34	2	0.95	0.06	2	24.34	4.54	
	23APR1991	8	127.8	11.18	8	19.9	5.33	8	0.93	0.03	5	22.16	4.40	
	24APR1991	19	122.5	6.12	19	17.1	2.63	19	0.92	0.04	14	20.35	5.86	
	01MAY1991	9	125.0	5.45	9	17.9	3.27	9	0.91	0.06	6	21.27	6.19	
	02MAY1991	1	125.0	.	1	17.4	.	.	.	.	.	.	.
	03MAY1991	3	123.3	10.69	3	17.5	5.0;	3	0.89	0.01	3	27.58	3.53	
	06MAY1991	3	123.0	3.61	3	17.5	1.85	3	0.94	0.03	3	20.57	3.07	
	08MAY1991	3	123.0	5.29	3	16.7	2.08	3	0.89	0.01	2	20.59	6.21	
	09MAY1991	6	130.2	9.15	6	19.9	4.63	6	0.89	0.03	6	22.37	7.90	
	10MAY1991	3	130.0	4.58	3	17.6	1.46	3	0.80	0.06	3	32.33	9.32	
	13MAY1991	2	120.0	14.14	2	17.1	5.37	2	0.90	0.04	2	25.00	7.56	
	14MAY1991	1	122.0	.	1	16.4	.	1	0.90	.	1	20.19	.	
	15MAY1991	1	116.0	.	1	15.7	.	1	1.01	.	1	24.72	.	
16MAY1991	1	140.0	.	1	27.0	.	1	0.98	.	1	25.56	.		
17MAY1991	1	135.0	.	1	26.0	.	1	1.06	.	1	22.83	.		
20MAY1991	1	138.0	.	1	24.0	3.71	1	0.82	0.91	0.04	1	27.34	.	
MCN	10MAY1991	5	132.0	6.89	5	19.1	.	5	.	0.04	37	49.04	44.10	
	11MAY1991	10	128.5	13.59	10	17.3	6.59	10	0.79	.	.	.	.
	12MAY1991	6	128.2	6.31	6	17.3	2.37	6	0.82	0.03	5	37.72	8.56	
	13MAY1991	2	125.5	3.54	2	15.7	1.91	2	0.79	0.03	1	29.09	.	
	17MAY1991	8	138.4	7.46	8	22.1	3.44	8	0.83	0.03	8	38.28	5.7;	
	18MAY1991	4	130.5	4.51	4	17.5	2.00	4	0.79	0.04	4	43.14	10.36	
	19MAY1991	1	130.0	.	1	17.2	.	.	.	.	.	.	.
	20MAY1991	B	130.9	6.4;	8	19.3	3.91	8	0.78	0.85	0.06	8	39.00	41.58
	25MAY1991	3	136.7	3.51	3	22.3	3.17	3	0.87	0.09	3	32.32	6.59	

Appendix A.7. Summary of data from juvenile spring chinook from Ringold SFH branded RA-7S-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	05MAR1991	20	226.9	17.26	20	133.6	24.86	20	1.13	0.07	20	11.15	4.03
	18MAR1991	20	231.0	24.38	20	138.6	39.99	20	1.09	0.05	20	15.61	6.65
	01APR1991	20	235.6	23.01	20	145.8	37.78	20	1.09	0.06	15	14.04	6.95
MCN	05APR1991	20	197.7	29.20	20	81.7	37.34	20	0.99	0.03	18	24.59	10.70
	08APR1991	20	189.6	27.71	20	71.3	35.36	20	0.98	0.04	16	25.54	9.99
	12APR1991	26	175.9	17.70	26	55.2	21.76	26	0.98	0.04	23	25.30	7.90
	19APR1991	20	178.8	17.36	20	54.9	18.95	20	0.94	0.04	20	38.12	9.31

Appendix A.8. Summary of data from juvenile spring chinook from Sawtooth SFH branded LA->1-1 and LD->1-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	20FEB1991	19	117.9	9.27	19	19.1	4.82	19	1.14	0.08	18	7.24	2.44
	07MAR1991	00	116.4	12.23	00	17.6	6.16	100	1.07	0.07	21	7.23	4.18
LGR	24APR1991	6	131.0	17.65	6	22.0	9.45	6	0.93	0.03	5	21.06	7.30
	25APR1991	11	132.4	10.90	11	21.7	6.66	11	0.92	0.06	11	17.78	6.33
	26APR1991	1	109.0	.	1	11.3	.	1	0.87	.	0	.	.
	27APR1991	4	140.5	6.81	4	27.1	3.54	4	0.98	0.03	4	16.74	11.4;
	28APR1991	2	129.5	3.54	2	19.6	4.81	2	0.90	0.15	1	10.78	.
	30APR1991	1	135.0	.	1	24.4	.	1	.	.	1	10.81	.
	01MAY1991	2	120.0	8.45	2	15.7	3.3;	2	0.90	0.00	2	18.86	1.3;
	02MAY1991	1	123.0	.	1	15.5	.	1	0.83	.	1	27.28	.
	07MAY1991	1	127.0	.	1	18.6	.	1	0.91	.	1	22.42	.
	08MAY1991	4	130.3	11.3;	4	19.5	6.69	4	0.86	0.0;	4	21.72	1.96
	09MAY1991	1	135.0	.	1	23.5	.	1	0.96	.	1	22.52	.
	10MAY1991	1	150.0	.	1	32.6	.	1	0.97	.	1	22.73	.
	13MAY1991	1	127.0	.	1	21.6	.	1	1.05	.	1	33.74	.
	22MAY1991	1	111.0	.	1	14.1	.	1	1.03	.	1	19.10	.
	MCN	07MAY1991	1	112.0	.	1	11.3	.	1	0.80	.	a	.
12MAY1991		1	124.0	.	1	15.3	.	1	0.80	.	1	42.39	.
17MAY1991		2	134.5	20.5;	2	21.4	10.68	2	0.84	0.0;	1	37.63	.
20MAY1991		1	135.0	.	1	21.6	.	1	0.88	.	1	29.78	.

Appendix A.9. Summary of data from juvenile steelhead from Wells SFH branded LD-7F-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
RIS	14MAY1991	20	210.0	19.29	20	79.5	22.74	20	0.84	0.04	20	17.57	3.51
	17MAY1991	20	204.3	10.93	20	72.5	11.91	20	0.84	0.04	20	15.16	3.44
	21MAY1991	4	210.3	16.40	4	78.8	19.41	4	0.83	0.03	4	22.08	5.99
MCN	16MAY1991	20	206.5	11.51	20	72.5	12.07	20	0.82	0.03	14	22.27	4.64
	18MAY1991	20	212.9	12.08	20	77.2	13.32	20	0.79	0.03	20	26.35	7.38
	20MAY1991	20	210.5	14.70	20	75.3	15.89	20	0.80	0.04	20	26.35	6.76

Appendix A.10. Summary of data from juvenile steelhead from Wells SFH branded RA-7F-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
RIS	14MAY1991	20	204.1	11.47	20	72.4	11.05	20	0.85	0.03	19	13.53	3.14
	17MAY1991	13	213.0	10.75	13	82.5	12.03	13	0.85	0.05	13	13.77	5.00
	18MAY1991	3	196.3	29.74	3	64.0	26.33	3	0.81	0.02	3	14.64	1.67
	21MAY1991	3	196.0	30.51	3	66.5	29.17	3	0.84	0.02	3	14.48	3.72
MCN	14MAY1991	21	203.8	12.58	21	70.4	12.63	21	0.82	0.04	17	21.78	6.43
	16MAY1991	18	212.2	17.17	18	82.4	20.77	18	0.85	0.06	16	18.76	2.19
	19MAY1991	11	212.8	15.18	11	81.9	18.73	11	0.84	0.04	11	19.50	4.20
	20MAY1991	9	204.3	11.10	9	68.3	13.06	9	0.79	0.05	9	24.18	5.68
	21MAY1991	1	207.0		1	71.7		1	0.81		1	27.87	

Appendix A.11. Summary of data from juvenile spring chinook from Winthrop NFH branded LD-7T-1 and RA-7T-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \bullet \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	06MAR1991	30	120.5	10.42	30	20.3	6.23	30	1.13	0.06	28	7.26	2.00
	20MAR1991	30	118.5	8.63	30	18.9	4.11	30	1.12	0.06	30	6.54	2.27
	10APR1991	60	126.0	8.96	60	23.0	5.34	60	1.13	0.06	25	4.56	5.09
RIS	24APR1991	1	126.0	.	1	19.3	.	1	0.96	.	1	6.59	.
	29APR1991	1	116.0	.	1	14.9	.	1	0.95	.	1	15.49	.
	30APR1991	1	120.0	.	1	17.3	.	1	1.00	.	1	12.54	.
	01MAY1991	1	143.0	.	1	28.3	.	1	0.97	.	1	8.46	.
	05MAY1991	1	129.0	.	1	19.0	.	1	0.89	.	1	10.17	.
	08MAY1991	4	129.3	10.21	4	20.4	4.97	4	0.93	0.03	2	10.36	1.34
	09MAY1991	4	127.3	9.18	4	25.6	7.77	4	1.34	0.78	4	8.44	3.02
	12MAY1991	2	128.5	0.71	2	20.1	1.27	2	0.95	0.08	2	15.50	11.56
	13MAY1991	4	127.0	10.10	4	19.0	4.35	4	0.92	0.04	4	17.38	4.90
	14MAY1991	1	131.0	.	1	21.4	.	1	0.95	.	1	18.31	.
MCN	17MAY1991	4	130.5	5.20	4	21.2	2.53	4	0.95	0.01	4	24.10	3.98
	21MAY1991	8	135.9	8.13	8	23.4	3.33	8	0.93	0.05	8	21.17	5.90
	12MAY1991	22	133.6	6.69	22	22.2	3.08	22	0.93	0.05	15	28.17	6.79
	13MAY1991	24	135.3	10.14	24	23.4	7.51	24	0.92	0.06	6	28.32	8.34
	14MAY1991	10	137.3	9.45	10	24.4	4.83	10	0.93	0.07	0	.	.
	17MAY1991	16	136.4	8.67	16	23.0	5.23	16	0.89	0.04	12	31.04	8.90
	18MAY1991	13	140.2	11.70	13	26.0	6.56	13	0.93	0.06	11	30.12	9.46
	19MAY1991	13	139.8	11.42	13	25.5	7.60	13	0.91	0.04	4	27.03	4.15
	20MAY1991	11	140.5	8.38	11	25.1	5.18	11	0.89	0.03	0	.	.
	21MAY1991	7	149.9	14.68	7	31.0	9.62	7	0.89	0.07	0	.	.
	23MAY1991	10	138.0	7.38	10	23.6	3.51	10	0.89	0.05	10	25.37	6.54
	24MAY1991	13	139.9	6.60	14	23.0	7.27	13	0.90	0.06	13	27.74	6.54
	25MAY1991	10	140.7	10.25	10	25.4	5.88	10	0.90	0.04	4	30.22	4.08
28MAY1991	18	147.6	11.77	18	29.4	7.72	18	0.90	0.05	6	29.13	4.45	
29MAY1991	4	136.8	7.46	4	23.6	4.54	4	0.91	0.03	4	34.41	9.07	
31MAY1991	4	138.3	4.43	4	23.7	2.49	4	0.90	0.08	4	27.35	0.33	
03JUN1991	3	151.0	5.29	3	30.6	1.21	3	0.89	0.07	3	24.88	11.65	

Appendix A.12. Summary of data from juvenile steelhead from Winthrop NFH branded LD-7T-1 and RA-7T-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
MCN	23MAY 1991	1	227.01	.	1	106.7	.	1	0.911	.	1	14.41	.

Appendix A.13. Summary of data from juvenile spring chinook from Dworshak NFH branded RA-1K-1 and RD-1K-1 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	05MAR1991	20	121.1	20.09	20	21.5	13.93	20	1.10	0.07	19	7.31	2.58
	21MAR1991	20	120.6	8.82	20	20.3	4.49	20	1.14	0.05	19	8.43	2.83
	02APR1991	99	126.5	9.14	100	23.0	6.04	99	1.13	0.09	20	6.71	2.16

Appendix A.14. Summary of data from juvenile fall chinook from Priest Rapids SFH branded LA-U1/2/3 and LD-U-1/3 collected during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOU			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	22MAY1991	60	74.7	8.84	60	4.4	1.40	60	1.01	0.07	58	12.32	4.15
	04JUN1991	80	84.1	9.57	80	6.6	2.47	80	1.06	0.10	79	13.17	5.34
	14JUN1991	60	94.3	7.53	60	8.9	2.15	60	1.04	0.06	21	20.59	7.50
MCN	11JUN1991	40	93.2	9.79	40	8.7	2.69	40	1.05	0.08	36	8.62	4.87
	20JUN1991	2	97.5	9.19	2	9.9	1.77	2	1.07	0.11	2	19.25	8.06
	25JUN1991	10	101.2	2.97	10	10.3	1.03	10	0.99	0.02	10	28.71	9.10
	27JUN1991	20	98.4	7.16	20	9.2	1.88	20	0.95	0.04	4	19.56	6.09
	28JUN1991	20	98.6	5.89	20	9.4	1.61	20	0.97	0.04	9	26.22	8.18
	02JUL1991	39	101.0	4.93	39	10.1	1.49	39	0.98	0.04	39	28.10	8.53
	05JUL1991	20	101.1	4.20	20	10.1	1.69	20	0.97	0.06	20	22.11	6.36
	09JUL1991	57	103.8	4.30	57	11.1	1.62	57	0.99	0.05	57	28.40	7.73
	10JUL1991	20	102.3	2.62	20	10.4	0.84	20	0.97	0.04	20	29.76	6.24
	12JUL1991	60	103.8	5.00	60	11.1	1.87	60	0.99	0.05	60	29.72	9.19
	16JUL1991	16	105.1	6.01	16	11.9	2.55	16	1.01	0.06	16	33.53	7.77

Appendix B.1. Summary of data from juvenile steelhead from Dworshak NFH branded RD-T-1/3 and LD-T-4 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	28APR1992	89	203.2	25.15	89	86.8	27.69	89	0.99	0.04	66	11.04	3.68
LGR	05MAY1992	31	210.7	15.80	31	88.1	21.04	31	0.93	0.07	0	.	.
	07MAY1992	13	214.7	20.21	14	86.4	34.83	13	0.92	0.04	0	.	.
	08MAY1992	20	206.6	16.16	20	79.0	17.00	20	0.89	0.06	0	.	.
	11MAY1992	12	206.9	14.85	12	79.2	19.53	12	0.88	0.04	12	17.18	4.10
	12MAY1992	6	208.2	13.67	6	79.4	17.91	6	0.87	0.05	6	14.43	6.13
	13MAY1992	8	214.8	18.00	8	84.3	19.10	8	0.84	0.03	8	18.68	5.16
MCN	13MAY1992	1	213.0	.	1	83.0	.	1	0.86	.	1	24.54	.
	14MAY1992	1	263.0	.	1	144.5	.	1	0.79	.	1	33.15	.
	15MAY1992	3	216.0	5.5;	3	81.2	5.9;	3	0.81	0.04	3	28.98	5.95
	22MAY 1992	2	215.0	5.66	2	75.5	3.04	2	0.76	0.03	2	29.56	16.23
	24MAY 1992	1	235.0	.	1	100.7	.	1	0.78	.	0	.	.

Appendix B.2. Summary of data from spring chinook from Entiat NFH branded RA-7N-1/3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	13APR1992	60	141.8	13.00	60	32.0	9.16	60	1.10	0.06	30	11.69	2.41
RIS	20APR1992	2	143.0	4.24	2	29.7	4.24	2	1.01	0.06	2	11.36	0.68
	21APR1992	5	142.2	18.16	5	31.5	15.06	5	1.04	0.05	4	10.95	2.02
	22APR1992	4	140.5	3.87	4	29.1	1.78	4	1.05	0.04	4	12.25	3.03
	23APR1992	1	167.0	.	1	50.4	.	1	1.08	.	1	19.87	.
	30APR1992	1	142.0	.	1	28.6	.	1	1.00	.	1	17.08	.
	01MAY1992	1	118.0	.	1	17.8	.	1	1.06	.	1	15.19	.
	06MAY1992	1	128.0	.	1	20.7	.	1	0.99	.	1	14.71	.
	07MAY1992	1	155.0	.	1	35.7	.	1	0.96	.	1	28.56	.
MCN	06MAY1992	20	150.4	17.8	20	33.2	14.06	20	0.92	0.06	20	21.64	5.71
	09MAY1992	20	147.7	8.68	20	30.1	5.69	20	0.92	0.04	20	24.52	5.80
	14MAY1992	19	148.4	8.20	19	29.6	5.12	19	0.90	0.03	19	30.18	7.22

Appendix B.3. Summary of data from juvenile steelhead from Irrigon SFH branded LD-A-3 and RD-A-3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	01APR1992	29	189.6	18.61	30	72.9	25.16	29	1.08	0.06	29	7.27	2.98
LGR	04MAY1992	2	241.0	21.21	2	118.2	31.82	2	0.84	0.01	0	.	.
	05MAY1992	4	235.3	6.40	4	111.8	14.91	4	0.86	0.06	0	.	.
	08MAY1992	4	234.0	8.52	4	106.5	9.94	4	0.83	0.03	0	.	.
	12MAY1992	1	228.0	.	1	95.7	.	1	0.81	.	1	22.78	.
	13MAY1992	3	237.7	24.54	3	108.6	27.8	3	0.80	0.06	3	17.74	6.41
	15MAY1992	6	234.2	17.72	6	108.1	28.97	6	0.83	0.08	6	24.71	6.24
	18MAY1992	7	246.3	15.40	7	127.5	23.78	7	0.85	0.03	7	24.85	6.66
	19MAY1992	6	229.2	16.39	6	100.0	21.34	6	0.82	0.02	6	20.92	7.93
	20MAY1992	6	227.8	19.38	6	96.4	22.36	6	0.81	0.05	6	18.45	3.44
	22MAY 1992	20	236.1	23.96	21	102.7	41.09	20	0.79	0.06	21	23.60	8.06
	26KAY 1992	9	221.6	17.63	9	87.1	21.78	9	0.79	0.04	9	21.13	5.24
	27MAY1992	7	226.3	16.89	7	91.5	27.48	7	0.77	0.05	7	20.05	6.27
	28MAY 1992	5	219.8	17.99	5	82.6	24.18	5	0.76	0.09	5	18.62	3.69

Appendix B.4. Summary of data from spring chinook from Leavenworth NFH branded LA-7T-1/3 and RD-7T-1 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HAT	15APR1992	100	126.5	10.88	100	22.8	7.12	100	1.10	0.06	30	9.58	2.05
RIS	22APR1992	12	131.3	9.20	12	24.6	5.30	12	1.07	0.07	9	10.32	2.84
	23APR1992	6	130.2	16.76	6	23.3	9.22	6	1.02	0.05	5	9.00	0.97
	24APR1992	4	136.0	9.83	4	28.1	6.81	4	1.10	0.04	4	10.77	2.39
	27APR1992	2	126.5	0.71	2	21.2	0.35	2	1.05	0.04	2	9.84	3.65
	28APR1992	7	130.3	7.61	7	22.4	3.78	7	1.00	0.03	7	14.64	2.41
	29APR1992	8	124.3	9.53	8	20.2	4.37	8	1.04	0.05	8	13.99	3.61
	30APR1992	3	126.0	13.11	3	21.8	7.33	3	1.06	0.03	3	14.27	2.40
	01MAY1992	3	120.0	11.00	3	16.6	4.22	3	0.95	0.05	3	13.77	3.35
	05MAY1992	3	127.3	2.52	3	22.0	4.49	3	1.06	0.15	3	21.69	2.00
	06MAY1992	12	132.9	8.86	12	24.0	6.13	12	1.00	0.09	12	21.18	5.23
	07MAY1992	16	133.7	11.11	16	23.9	6.53	16	0.98	0.04	16	21.19	4.07
	08MAY1992	11	132.5	5.41	11	23.2	3.22	11	0.99	0.05	11	20.35	4.37
	11MAY1992	2	128.5	7.78	2	20.5	2.62	2	0.97	0.05	2	21.59	0.74
	12MAY1992	5	130.0	9.62	5	21.5	4.07	5	0.97	0.04	5	22.56	5.00
	13MAY1992	2	134.5	3.54	2	25.0	1.63	2	1.03	0.01	2	24.13	0.85
	14MAY1992	3	132.7	9.07	3	22.7	5.69	3	0.96	0.05	3	25.21	2.87
	15MAY1992	1	136.0	.	1	24.8	.	1	0.99	.	1	18.24	.
MCN	13MAY1992	34	135.5	9.88	34	23.6	6.35	34	0.93	0.05	34	32.38	5.60
	17MAY1992	35	138.5	10.39	35	24.2	6.87	35	0.89	0.04	35	35.86	7.28
	19MAY1992	15	135.5	7.48	15	22.5	3.89	15	0.89	0.05	15	33.30	7.94
	20MAY1992	20	138.9	5.34	20	24.5	2.75	20	0.91	0.04	20	33.31	5.05

Appendix B.5. Summary of data from summer chinook from McCall SFH branded LD-7U-1 and RA-7U-1/3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY LGR	11HAR1992	60	123.5	7.94	60	21.7	4.67	60	1.13	0.05	29	7.88	2.15
	17APR1992	3	129.3	11.59	3	20.1	5.06	3	0.92	0.01	3	27.54	5.49
	20APR1992	3	139.0	8.89	3	24.9	5.26	3	0.92	0.02	3	21.08	4.53
	21APR1992	3	130.7	5.77	3	21.0	2.82	3	0.93	0.03	3	25.08	4.08
	22APR1992	10	129.9	8.76	10	20.6	4.76	10	0.92	0.03	10	27.90	5.08
	23APR1992	13	133.2	9.02	13	21.9	4.90	13	0.91	0.03	13	26.58	4.62
	24APR1992	3	136.3	6.66	3	25.0	4.20	3	0.98	0.03	3	23.28	12.73
	27APR1992	10	126.9	8.28	10	19.1	3.93	10	0.93	0.04	1	30.20	.
	28APR1992	16	131.8	5.83	16	21.6	3.05	16	0.94	0.04	2	27.28	3.10
	01MAY1992	20	135.4	8.45	20	22.6	4.26	20	0.90	0.03	0		
MCN	04MAY1992	3	133.7	3.79	3	21.8	2.85	3	0.91	0.05	0		
	30APR1992	1	138.0	.	1	22.0	.	1	0.87		1	34.48	.
	04MAY1992	3	140.7	5.03	3	23.8	2.86	3	0.85	0.0;	3	38.70	2.17
	05MAY1992	5	136.4	2.70	5	22.1	1.65	5	0.87	0.02	5	39.20	2.04
	06MAY1992	7	132.6	9.22	7	21.1	4.19	7	0.89	0.05	7	34.46	12.25
	09MAY1992	11	140.8	6.37	11	24.4	3.95	11	0.87	0.04	11	37.33	6.37
	10MAY1992	7	133.7	5.47	7	20.3	2.65	7	0.84	0.06	7	37.84	10.04
	11MAY1992	5	131.0	16.42	5	19.9	7.39	5	0.85	0.03	5	36.53	10.20
	12MAY1992	1	143.0	.	1	24.1	.	1	0.82		1	25.88	
	14MAY1992	16	138.4	7.1;	16	22.9	3.80	16	0.86	0.0;	16	37.02	9.3;
	15MAY1992	3	135.7	6.66	3	20.9	2.86	3	0.83	0.06	3	35.66	3.86
22MAY 1992	5	137.2	4.38	5	21.7	1.93	5	0.84	0.05	5	42.88	9.45	
28MAY1992	11	138.1	5.43	11	22.7	2.40	11	0.86	0.06	11	35.00	11.05	
31MAY1992	5	142.0	6.63	5	25.5	2.85	5	0.89	0.08	4	30.96	5.71	

Appendix B.6. Summary of data from spring chinook from Rapid River SFH branded RA-R-1/2/3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at bower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STO	N	MEAN	STO	N	MEAN	STO	N	MEAN	STO
HATCHERY	12MAR1992	60	123.6	8.87	60	22.1	5.47	60	1.15	0.07	28	6.68	1.28
LGR	13APR1992	5	130.8	10.55	5	22.4	5.24	5	0.99	0.05	5	25.06	5.86
	17APR1992	21	136.5	7.43	21	24.3	3.97	21	0.95	0.06	21	21.65	5.49
	21APR1992	12	133.3	10.76	12	23.0	4.94	12	0.96	0.07	12	23.99	5.51
	27APR1992	12	136.2	6.94	12	22.9	3.65	12	0.90	0.02	0		
	28APR1992	8	136.1	3.76	8	22.8	2.23	8	0.90	0.04	1	22.84	
	01MAY1992	20	137.4	7.30	20	23.2	3.88	20	0.89	0.04	0		
MCN	30APR1992	1	136.0		1	20.9		1	0.83		1	40.18	
	01MAY1992	9	141.4	7.50	9	24.1	4.01	9	0.85	0.04	9	33.30	7.65
	04MAY 1992	10	142.3	9.80	10	24.9	5.62	10	0.85	0.03	10	34.81	8.31
	08MAY1992	9	141.1	8.59	9	24.1	4.27	9	0.85	0.06	9	39.05	6.38
	09MAY1992	11	136.1	10.44	11	21.8	6.06	11	0.84	0.05	11	44.80	8.05
	13MAY1992	4	147.5	8.74	4	26.8	3.88	4	0.83	0.05	4	45.57	7.17
	14MAY1992	10	142.8	9.85	10	25.5	6.65	10	0.86	0.07	10	40.00	0.88
	15MAY1992	6	146.3	5.20	6	24.7	2.73	6	0.78	0.02	6	36.88	8.73

Appendix B.7. Summary of data from spring chinook from Ringold SFH branded LA-7S-1/3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STO	N	MEAN	STO	N	MEAN	STO	N	MEAN	STO
HATCHERY	31MAR1992	60	194.7	25.43	60	89.4	40.56	60	1.14	0.07	31	18.01	7.80
MCN	04APR1992	20	207.4	28.86	20	100.1	45.64	20	1.05	0.08	19	18.63	7.80
	06APR1992	19	198.7	36.30	19	89.7	59.48	19	1.01	0.13	16	14.00	7.22
	18APR1992	18	175.4	7.64	18	52.2	6.84	18	0.96	0.05	18	17.80	9.64
	27APR1992	3	162.3	19.86	3	42.8	17.01	3	0.96	0.09	3	24.46	7.24

Appendix B.8. Summary of data from spring chinook from Sawtooth SFH branded LA-T-1/2/3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	10MAR1992	60	114.1	9.39	60	17.4	4.69	60	1.14	0.07	28	6.62	1.78
LGR	13APR1992	6	128.0	13.01	6	20.5	6.64	6	0.94	0.0	6	25.25	5.20
	17APR1992	23	128.4	7.45	23	20.0	4.17	23	0.93	0.05	23	25.10	7.43
	20APR1992	8	126.1	1.73	8	18.5	0.99	8	0.91	0.05	8	26.62	8.01
	21APR1992	11	128.1	9.44	11	19.5	4.59	11	0.90	0.05	11	24.85	5.57
	22APR1992	9	129.0	5.41	9	19.5	2.41	9	0.91	0.02	9	31.10	3.90
	23APR1992	7	134.1	7.99	7	23.6	5.17	7	0.97	0.11	7	23.14	8.27
	24APR1992	2	121.0	0.00	2	16.9	0.92	2	0.95	0.06	1	32.08	
	27APR1992	5	138.6	12.42	5	25.1	5.76	5	0.93	0.03	0		
	28APR1992	5	130.4	13.26	5	20.4	7.92	5	0.89	0.08	1	30.51	
	01MAY1992	12	130.5	7.37	12	20.1	2.84	12	0.90	0.05	0		
	04MAY1992	1	135.0		1	24.5		1	1.00		0		
	07MAY1992	1	125.0		1	16.8		1	0.86		0		
	08MAY1992	2	147.0	5.66	2	29.1	6.51	2	0.91	0.10	0		
	15MAY1992	1	136.0		1	19.2		1	0.76		1	39.45	
MCN	27APR1992	5	137.2	11.34	5	24.0	5.59	5	0.92	0.04	5	25.60	3.80
	28APR1992	5	134.6	9.21	5	21.3	4.99	5	0.86	0.04	5	33.63	12.44
	29APR1992	2	152.5	41.72	2	36.3	29.34	2	0.89	0.08	2	27.59	7.37
	30APR 1992	3	136.0	12.12	3	22.9	4.38	3	0.91	0.07	3	30.12	9.06
	01MAY1992	5	133.2	13.97	5	20.6	7.60	5	0.84	0.05	5	36.18	6.35
	04MAY1992	8	136.3	8.65	8	21.1	4.10	8	0.83	0.05	8	45.76	8.73
	05MAY1992	7	131.7	4.31	7	19.3	2.09	7	0.84	0.03	7	37.16	4.14
	07MAY1992	2	124.0	16.97	2	16.6	6.01	2	0.86	0.04	2	33.49	5.56
	08MAY1992	4	133.0	4.32	4	20.2	1.86	4	0.86	0.03	4	38.57	7.84
	09MAY1992	1	122.0		1	13.8		1	0.76		1	41.12	
	10MAY1992	3	135.7	15.50	3	21.1	7.91	3	0.82	0.04	3	40.03	8.63
	11MAY1992	1	137.0		1	22.2		1	0.86		1	39.97	
	13MAY1992	3	140.0	1.00	3	22.9	2.8	3	0.83	0.11	3	36.65	10.58
	15MAY1992	1	132.0		1	17.4		1	0.76		1	36.09	
	16MAY1992	1	123.0		1	14.8		1	0.80		1	51.72	
	19MAY1992	1	142.0		1	26.8		1	0.94		1	34.48	
	21MAY1992	2	134.5	0.7	2	20.8	0.9	2	0.86	0.02	2	36.72	4.36
	22MAY 1992	1	146.0		1	29.7		1	0.95		1	41.94	
	24MAY 1992	2	146.5	27.58	2	28.5	13.86	2	0.89	0.05	2	34.16	18.81
	25MAY1992	2	138.0	8.49	2	23.4	5.30	2	0.88	0.04	2	45.14	1.36
	28MAY1992	1	133.0		1	18.8		1	0.80		1	43.82	
	29MAY1992	1	148.0		1	26.1		1	0.82		1	44.21	

Appendix B.9. Summary of data from spring chinook from Winthrop. NFH branded LA-7H-1/3 and RD-7H-1 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	14APR1992	00	136.9	14.96	100	31.3	12.94	100	1.17	0.08	30	11.40	3.14
RIS	28APR1992	2	150.5	2.12	2	32.9	0.14	2	0.97	0.05	2	11.51	0.59
	29APR1992	1	134.0	.	1	25.0	.	1	1.04	.	1	12.69	.
	30APR1992	1	161.0	.	1	45.1	.	1	.	.	1	16.94	.
	01MAY1992	2	133.5	2.12	2	24.0	1.41	2	1.08	0.01	2	18.20	1.9
	06MAY1992	3	126.3	6.43	3	19.6	2.82	3	0.96	0.01	3	24.87	2.03
	07MAY1992	3	139.3	10.02	3	26.1	4.12	3	0.96	0.06	3	28.08	2.60
	08MAY1992	3	135.0	2.65	3	23.5	2.25	3	0.95	0.07	3	30.53	4.60
	11MAY1992	2	147.0	0.00	2	30.1	0.35	2	0.95	0.01	2	27.73	0.95
	12MAY1992	1	157.0	.	1	35.1	.	1	.	.	0	.	.
	13MAY1992	3	142.3	0.58	3	26.6	0.1	3	0.91 0.92	0.01	3	23.31	3.85
	15MAY1992	5	147.4	9.45	5	30.2	6.04	5	0.93	0.04	5	27.48	2.42
	18MAY1992	3	152.0	8.89	3	34.0	7.11	3	0.96	0.06	3	36.04	7.74
	20MAY1992	2	146.0	8.49	2	31.0	5.02	2	0.99	0.01	2	34.06	6.06
MCN	10MAY1992	17	143.3	7.97	17	27.3	4.68	17	0.92	0.06	17	29.82	6.62
	11MAY1992	17	139.5	9.29	17	24.4	4.73	17	0.89	0.03	17	31.43	6.00
	12MAY1992	1	154.0	.	1	34.6	.	1	.	.	1	29.14	.
	14MAY1992	33	145.9	11.48	33	28.5	9.19	33	0.95 0.89	0.0	33	34.04	6.46
	18MAY1992	35	145.4	11.72	35	28.5	8.85	35	0.90	0.05	34	35.01	6.59

Appendix B.10. Summary of data from spring chinook from Dworshak SFH branded LA-7C-1 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY LGR	16APR1992	100	138.7	14.08	100	28.9	9.91	100	1.04	0.08	29	10.46	2.95
	04MAY1992	7	142.3	7.09	7	27.2	4.36	7	0.94	0.06	0	.	.
	07MAY1992	7	142.6	6.27	7	26.5	3.64	7	0.91	0.02	0	.	.
	08MAY1992	5	150.2	9.88	5	32.0	7.47	5	0.93	0.05	0	.	.
	11MAY1992	2	147.5	0.71	2	29.0	0.85	2	0.90	0.01	2	35.81	11.0;
	12MAY1992	5	144.0	4.24	5	25.8	3.07	5	0.86	0.05	5	31.72	8.29
	13MAY1992	1	146.0	.	1	27.8	.	1	0.89	.	1	42.86	.
	15MAY1992	8	152.0	10.0;	8	30.6	6.96	8	0.86	0.0;	8	35.18	12.40
	05MAY1992	1	155.0	.	1	36.6	.	1	0	9 8	1	46.53	.
	06MAY1992	1	163.0	.	1	35.5	.	1	0.82	.	1	37.08	.
MCN	08MAY1992	2	143.0	0.00	2	27.2	2.1;	2	0.93	0.07	2	27.95	0.25
	09MAY1992	2	146.5	9.19	2	26.9	5.30	2	0.85	0.01	2	43.84	5.54
	10MAY1992	5	150.8	12.50	5	31.7	10.05	5	0.90	0.05	5	32.61	5.78
	11MAY1992	1	146.0	.	1	25.5	.	1	0.82	.	1	44.61	.
	12MAY1992	2	133.0	9.90	2	21.6	4.7;	2	0.91	0.00	2	47.08	3.37
	13MAY1992	11	145.4	12.31	11	27.9	8.34	11	0.89	0.07	11	37.84	6.39
	14MAY1992	10	153.7	14.35	10	32.3	11.27	10	0.86	0.06	10	37.41	5.32
	16MAY1992	5	142.6	14.05	5	25.5	8.21	5	0.86	0.03	5	37.21	6.73
	18MAY1992	1	147.0	.	1	26.2	.	1	0.82	.	1	45.24	.
	19MAY1992	4	150.5	12.0;	4	29.2	5.58	4	0.85	0.04	4	39.99	5.3;
	20MAY1992	9	155.6	30.79	9	35.8	30.54	9	0.82	0.05	9	44.72	13.64
	21MAY1992	7	143.3	5.91	7	25.7	3.12	7	0.87	0.04	7	44.70	9.44
	22MAY1992	4	148.3	10.59	4	27.2	7.04	4	0.82	0.06	4	44.89	3.77
	23MAY1992	2	145.0	0.00	2	23.6	1.13	2	0.78	0.04	2	49.85	2.49
	24MAY 1992	2	158.0	18.38	2	33.7	16.76	2	0.82	0.13	2	34.57	27.44
	25MAY1992	7	150.9	5.67	7	28.8	2.44	7	0.84	0.03	7	49.68	9.07
	27MAY1992	1	153.0	.	1	27.3	.	1	0.76	.	1	43.84	.
28MAY1992	8	151.9	8.03	8	28.1	4.5;	8	0.80	0.05	8	54.45	7.7;	
29MAY1992	9	158.1	9.65	9	32.0	6.72	9	0.80	0.06	9	49.06	11.59	
31MAY1992	5	153.0	12.69	5	30.3	7.53	5	0.83	0.04	5	39.65	9.77	
05JUN1992	1	148.0	.	1	25.6	.	1	0.79	.	1	41.93	.	

Appendix B.11. Summary of data from spring chinook from Dworshak SFH branded LA-7C-3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \text{ h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	16APR1992	30	138.4	11.34	30	29.2	7.77	30	1.06	0.06	30	10.32	2.33
LGR	04MAY1992	4	145.5	3.11	4	30.2	1.52	4	0.98	0.06	0		
	05MAY1992	1	153.0		1	36.6		1	1.02		0		
	07MAY1992	2	141.0	8.49	2	25.7	6.36	2	0.91	0.06	0		
	08MAY1992	2	138.0	8.49	2	24.5	2.33	2	0.93	0.08	0		
	11MAY1992	3	142.7	4.93	3	26.2	3.96	3	0.90	0.05	3	36.3	5.5
	13MAY1992	1	145.0		1	27.2		1	0.89		1	32.25	
	15MAY1992	7	146.7	5.96	7	28.9	3.66	7	0.91	0.05	7	31.99	5.29
MCN	14MAY1992	9	150.3	11.56	9	30.2	6.57	9	0.88	0.04	9	39.55	10.00
	18MAY1992	1	139.0		1	24.4		1	0.91		1	29.06	
	19MAY1992	4	137.5	9.7	4	22.1	4.54	4	0.84	0.0	3	47.75	2.96
	20MAY1992	4	152.5	6.24	4	30.2	3.69	4	0.85	0.05	4	47.96	11.6
	21MAY1992	5	145.6	3.71	5	25.7	2.50	5	0.83	0.04	5	38.51	4.41
	22MAY1992	5	155.4	8.56	5	32.0	7.53	5	0.84	0.05	5	34.77	11.26

Appendix B.12. Summary of data from spring chinook from Dworshak SFH branded RD-7C-3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	16APR1992	29	133.7	13.92	30	27.3	10.27	29	1.15	0.08	30	6.38	1.84
LGR	04MAY1992	1	139.2	15.09	6	29.1	9.21	6	1.06	0.19	0		
	07MAY1992	2	144.5	19.09	2	32.9	9.62	2	1.09	0.11	0		
	08MAY1992	1	182.0		1	78.8		1	1.31		0		
	11MAY1992	1	142.0		1	31.1		1	1.09		1	20.44	
	12MAY1992	6	147.7	8.98	6	32.1	5.59	6	0.99	0.06	6	29.28	7.8
	13MAY1992	1	152.0		1	34.8		1	0.99		1	21.40	
	15MAY1992	10	140.1	14.56	10	27.2	9.0	10	0.96	0.09	9	25.19	8.9
MCN	14MAY1992	1	162.0		1	39.0		1	0.92		1	59.72	
	20MAY1992	2	148.5	7.78	2	28.7	4.9	2	0.87	0.0	2	44.83	0.4
	21MAY1992	2	152.0	11.31	2	31.2	8.63	2	0.88	0.05	2	47.05	4.14
	22MAY1992	1	149.0		1	29.6		1	0.89		1	54.66	
	26MAY1992	1	158.0		1	35.3		1	0.89		1	34.99	
	27MAY1992	4	152.3	14.7	4	30.5	10.94	4	0.84	0.06	4	45.81	2.06
	28MAY1992	3	151.3	4.93	3	30.0	3.61	3	0.87	0.08	3	39.29	4.62
	29MAY1992	3	142.3	8.50	3	25.5	4.49	3	0.88	0.02	3	45.65	1.13
	31MAY1992	1	162.0		1	34.6		1	0.81		1	44.39	

Appendix B.13. Summary of data from spring chinook from Kooskia SFH branded RD-W-2/4 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	27MAR1992	0			12	0.0	0.00	0			9	5.57	1.38
	07APR1992	24	122.;	10.2;	24	19.7	4.84	24	1.0;	0.08	24	9.65	2.46
LGR	17APR1992	20	129.8	15.26	20	22.3	9.20	20	0.98	0.05	20	15.78	4.70
	21APR1992	16	121.4	6.27	16	17.4	2.61	16	0.97	0.04	16	20.56	3.93
	27APR1992	21	127.2	9.66	21	20.0	5.36	21	0.95	0.04	2	22.32	3.60
MCN	01MAY1992	20	129.0	8.11	20	19.4	4.08	20	0.89	0.04	0		
	05MAY1992	10	131.0	10.71	10	19.8	4.31	10	0.87	0.05	10	31.03	5.16
	06MAY1992	8	131.1	8.17	8	19.3	4.24	8	0.84	0.04	8	47.06	12.04
	08MAY1992	21	131.7	6.91	21	19.3	3.12	21	0.84	0.05	20	42.41	8.34
	11MAY1992	7	133.0	5.51	7	20.5	2.52	7	0.87	0.02	7	39.14	12.85
	12MAY1992	13	131.2	5.89	13	19.0	2.46	13	0.84	0.04	13	47.43	9.68

Appendix B.14. Summary of data from spring chinook from Kooskia SFH branded RD-W-1 and LD-Y-4 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STO	N	MEAN	STO	N	MEAN	STD	N	MEAN	STO
HATCHERY	27MAR1992	0	.	.	12	0.0	0.00	0	.	.	10	5.49	1.14
	07APR1992	12	126.3	9.86	12	22.6	4.85	12	1.11	0.03	12	11.24	2.55
	15APR1992	12	132.2	10.94	12	26.1	5.87	12	1.12	0.07	7	10.98	3.58
	21APR1992	12	130.7	10.24	12	25.7	5.49	12	1.14	0.06	9	15.85	3.91
	05MAY1992	30	143.3	11.57	30	30.6	8.68	30	1.01	0.08	0	.	.
LGR	12MAY1992	22	142.9	11.80	22	29.2	8.00	22	0.98	0.05	22	17.14	6.76
	15MAY1992	21	145.0	11.38	21	30.0	7.40	21	0.97	0.04	21	20.76	4.25
	18MAY1992	19	141.0	7.70	19	25.7	4.72	19	0.91	0.04	19	24.71	8.96
	19MAY1992	1	138.0	.	1	24.2	.	1	0.92	.	1	24.38	.
MCN	28MAY1992	20	145.1	8.9	20	26.2	5.25	20	0.85	0.04	20	39.68	9.54
	31MAY1992	20	148.1	4.42	20	27.7	3.07	20	0.85	0.04	20	39.09	6.99
	05JUN1992	8	151.5	12.50	8	31.7	6.09	8	0.91	0.07	7	27.09	6.30
	06JUN1992	6	153.8	1.60	6	34.0	1.46	6	0.93	0.03	6	25.43	4.15
	12JUN1992	6	152.0	7.46	6	33.2	6.15	6	0.94	0.06	6	16.43	4.15

Appendix B.15. Summary of data from spring chinook from Kooskia SFH branded RD-Y-1 and LD-Y-1/2 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+ - \text{K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	21APR1992	24	129.2	10.62	24	25.9	5.41	24	1.19	0.06	16	14.06	3.47
LGR	05MAY1992	5	136.8	14.34	5	24.5	8.20	5	0.93	0.05	0		
	07MAY1992	8	135.6	5.26	8	24.0	2.31	8	0.96	0.05	0		
	08MAY1992	13	133.9	8.41	13	23.5	4.45	13	0.97	0.06	0		
	12MAY1992	5	136.4	5.18	5	24.1	3.55	5	0.94	0.04	4	27.16	5.75
	13MAY1992	2	130.5	4.95	2	20.0	2.19	2	0.90	0.01	2	25.14	4.71
MCN	14MAY1992	21	134.7	7.75	21	21.4	3.78	21	0.87	0.04	21	38.99	8.26
	18MAY1992	11	136.5	7.26	11	22.8	3.22	11	0.89	0.04	11	40.36	12.98
	19MAY1992	2	138.0	1.41	2	23.6	0.64	2	0.90	0.01	2	42.21	2.56
	20MAY1992	7	138.1	11.42	7	23.4	5.13	7	0.87	0.04	7	45.05	5.95
	27MAY1992	14	140.2	5.29	14	23.8	2.59	14	0.86	0.04	14	39.53	8.74
	29MAY1992	6	144.5	6.19	6	24.1	3.07	6	0.79	0.04	6	36.01	17.15

Appendix B.16. Summary of data from production release spring chinook from Kooskia collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+ - \text{K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	15APR1992	12	127.1	11.671	12	22.51	5.831	12	1.081	0.051	9	112.351	2.04

Appendix B.17. Summary of data from fall chinook from Priest Rapids SFH branded RA-U-2 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	11JUN1992	20	90.3	6.51	20	7.7	1.79	20	1.03	0.08	19	10.53	3.78
MCN	28JUN1992	20	105.2	3.47	20	12.0	1.28	20	1.03	0.04	19	31.53	8.70
	30JUN1992	16	104.3	3.81	16	11.9	1.63	16	1.05	0.08	16	34.06	9.66
	01JUL1992	4	105.3	2.06	4	12.2	0.83	4	1.05	0.06	4	36.06	12.48
	05JUL1992	2	107.0	7.07	2	12.8	2.33	2	1.04	0.02	2	22.25	18.87
	06JUL1992	18	105.6	4.23	18	12.4	1.63	18	1.05	0.04	18	32.35	6.62

Appendix B.18. Summary of data from fall chinook from Priest Rapids SFH branded RA-U-3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	
HATCHERY	11JUN1992	20	94.0	6.81	20	8.3	2.23	20	0.97	0.06	20	9.67	4.68	
MCN	27JUN1992	12	105.8	6.51	12	12.0	2.11	12	1.01	0.05	10	17.87	6.57	
	28JUN1992	8	100.3	1.91	8	10.3	0.52	8	1.02	0.05	8	25.49	6.59	
	30JUN1992	11	101.9	2.77	11	10.8	1.34	11	1.01	0.06	11	21.15	8.57	
	01JUL1992	9	102.8	5.33	9	10.9	1.49	9	0.99	0.03	9	20.45	10.50	
	06JUL1992	1	102.0					1	0.99		1	41.65		
	07JUL1992	5	108.4	5.0	5	10.5	12.7	5	0.99	0.0	5	34.37	7.2	
	08JUL1992	1	104.0					1	1.12		1	39.26		
	09JUL1992	8	105.5	5.26	8	12.6	13.0	2.70	8	1.10	0.19	8	30.32	8.83
	10JUL1992	1	109.0		1	13.5		1	1.04		1	24.56		
	11JUL1992	1	98.0					1	1.15		1	17.51		
	13JUL1992	2	116.0	0.00	2	10.8	17.6	1.91	2	1.13	0.1	2	17.65	2.40
	15JUL1992	1	112.0		1	16.1		1	1.15		1	9.91		

Appendix B.19. Summary of data from fall chinook from Priest Rapids SFH branded RD-U-3 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	11JUN1992	20	90.9	6.62	20	7.4	1.79	20	0.96	0.06	20	7.77	2.46
MCN	29JUN1992	3	103.3	3.06	3	11.0	1.15	3	1.00	0.02	3	21.20	5.33
	30JUN1992	17	102.5	4.71	17	11.1	1.68	17	1.03	0.05	17	28.08	7.80
	04JUL1992	14	104.1	2.68	14	11.4	1.27	14	1.01	0.04	14	29.41	7.22
	05JUL1992	6	103.2	3.37	6	11.5	1.30	6	1.04	0.06	6	32.50	9.52
	10JUL1992	1	111.0	.	1	16.0	.	1	1.17	.	1	33.50	.
	11JUL1992	1	115.0	.	1	16.5	.	1	1.08	.	1	28.99	.
	13JUL1992	5	109.0	3.3	5	15.2	1.7	5	1.17	0.0s	5	16.53	6.8
	14JUL1992	1	120.0	.	1	18.8	.	1	1.09	.	1	10.27	.
	15JUL1992	11	113.5	3.08	11	16.6	1.4	11	1.14	0.06	11	19.16	8.2

Appendix B.20. Summary of data from fall chinook from Priest Rapids SFH branded RD-U-1 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	17JUN1992	20	92.7	5.74	20	8.2	1.85	20	1.02	0.07	18	7.06	1.71
MCN	29JUN1992	1	101.0	.	1	10.0	.	1	0.97	.	1	23.64	.
	30JUN1992	9	108.3	3.8	9	13.0	1.7	9	1.02	0.0	9	23.01	6.09
	01JUL1992	10	103.6	4.53	10	11.1	1.37	10	1.00	0.04	10	23.21	10.90
	05JUL1992	3	104.3	2.52	3	11.9	0.06	3	1.05	0.07	3	39.37	13.24
	06JUL1992	17	104.1	5.58	17	11.5	1.78	17	1.01	0.04	17	35.85	9.11
	10JUL1992	3	110.0	2.65	3	14.8	0.95	3	1.11	0.05	3	26.69	11.14
	11JUL1992	1	108.0	.	1	13.3	.	1	1.06	.	1	26.37	.
	13JUL1992	3	113.7	5.86	3	16.6	2.0	3	1.13	0.0	3	18.40	2.56
	14JUL1992	1	108.0	.	1	14.0	.	1	1.11	.	1	13.36	.
	15JUL1992	13	114.9	4.94	13	17.4	2.2	13	1.14	0.04	13	18.25	5.40

Appendix B.21. Summary of data from fall chinook from Priest Rapids SFH branded RA-U-1 collected during spring, 1992. Fish were collected at the hatchery (HATCHERY) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, condition factor (KFACTOR), and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
HATCHERY	17JUN1992	20	91.8	8.58	20	8.2	2.33	20	1.03	0.08	20	10.54	3.66
MCN	30JUN1992	14	103.8	6.23	14	11.4	2.10	14	1.01	0.04	14	24.30	7.68
	01JUL1992	6	102.8	3.19	6	10.8	1.51	6	0.99	0.06	6	26.11	5.44
	06JUL1992	20	103.5	5.10	20	11.4	1.84	20	1.02	0.08	20	34.18	8.22
	10JUL1992	2	109.0	9.90	2	14.1	3.61	2	1.07	0.01	2	37.68	4.26
	11JUL1992	2	108.0	2.83	2	13.1	0.85	2	1.04	0.01	2	31.21	5.07
	13JUL1992	3	110.0	8.54	3	15.2	3.86	3	1.12	0.03	3	19.95	9.16
	15JUL1992	17	114.2	3.76	17	17.1	1.69	17	1.15	0.04	17	21.52	5.26

Appendix C.1. Summary of selected data from yearling spring/summer chinook salmon collected from the migration-at-large at the IDFG Clearwater River trap (CLW), Lower Granite Dam (LGR), Rock Island Dam (RIS) and McNary Dam (MCN), during spring, 1991. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
CLW	03APR1991	20	124.0	13.06	20	20.3	5.67	20	1.04	0.05	20	8.73	4.57
	11APR1991	49	114.2	15.13	49	15.2	6.46	49	0.97	0.05	10	17.22	6.32
	12APR1991	50	119.0	15.08	50	17.9	6.66	50	1.01	0.05	10	15.35	5.80
	18APR1991	10	114.8	40.50	10	22.e	2.51	10	0.98	0.35	10	15.90	2.97
	19APR1991	10	120.4	4.58	10	18.E	2.76	10	1.06	0.05	9	16.95	4.13
	25APR1991	10	125.4	6.74	10	20.9	3.86	10	1.05	0.05	4	8.10	6.15
	26APR1991	91	123.0	16.84	91	17.2	7.53	91	0.88	0.31	10	18.82	6.67
	02MAY1991	10	110.5	11.35	10	14.3	3.74	10	1.05	0.05	9	18.32	3.69
	03MAY1991	10	120.6	14.92	10	18.4	6.02	10	1.01	0.05	10	15.92	3.61
	09MAY1991	10	124.5	17.76	10	20.2	8.2	10	1.00	0.05	10	17.99	3.74
.EW	10MAY1991	10	123.8	9.20	10	20.1	4.26	10	1.05	0.05	10	17.49	5.82
	11APR1991	50	116.6	12.79	50	17.1	5.61	50	1.05	0.11	9	12.92	4.29
	12APR1991	50	110.8	11.54	50	14.2	4.85	50	1.01	0.15	11	15.30	6.25
	18APR1991	10	130.9	5.59	10	23.E	3.55	10	1.05	0.0	8	21.24	5.37
	19APR1991	10	126.0	5.64	10	20.1	3.06	10	1.00	0.05	10	18.88	5.24
	25APR1991	10	119.9	11.12	10	18.C	5.46	10	1.02	0.0	8	14.03	7.63
	26APR1991	10	120.3	14.12	10	0.0	0.00	10	0.00	0.00	7	14.97	7.59
	02MAY1991	10	122.2	10.04	10	18.7	3.85	10	1.01	0.06	10	23.63	5.64
	03MAY1991	9	134.2	13.20	9	24.9	7.79	9	1.00	0.06	9	24.48	5.27
	09MAY1991	10	130.1	8.24	10	22.3	6.25	10	0.99	0.14	10	22.51	8.70
	10MAY1991	10	123.3	13.00	10	19.9	5.80	10	1.04	0.05	10	21.51	2.55
	16MAY1991	10	118.1	11.07	10	17.0	4.38	10	1.01	0.03	9	22.09	4.93
	17MAY1991	10	118.7	14.16	10	17.4	5.94	10	1.00	0.06	8	21.75	4.69
	22MAY1991	30	116.7	15.45	30	17.6	9.87	30	1.04	0.11	1	41.43	.
	23MAY1991	10	111.8	10.49	10	14.8	3.54	10	1.04	0.09	9	23.88	4.91
	24MAY1991	10	113.2	9.93	10	16.1	3.86	10	1.09	0.06	9	21.09	5.00
	30MAY1991	3	106.3	12.58	3	13.0	4.55	3	1.05	0.02	3	21.47	7.81
31MAY1991	10	115.0	16.57	10	17.1	7.10	10	1.09	0.09	10	18.96	5.45	
GR	06JUN1991	10	115.9	13.63	10	16.4	6.89	10	1.02	0.12	9	24.52	6.66
	07JUN1991	2	125.5	2.12	2	19.4	1.41	2	0.99	0.02	2	21.59	5.39
	18APR1991	10	124.4	11.12	10	19.2	5.39	10	0.97	0.05	10	24.28	8.59
	19APR1991	10	121.2	13.41	10	18.4	5.52	10	1.00	0.04	10	20.09	6.61
	25APR1991	10	126.8	12.57	10	19.6	6.73	10	0.93	0.05	9	15.34	5.20
	26APR1991	10	129.6	9.52	10	20.5	4.90	10	0.93	0.04	9	14.03	4.32
	02MAY1991	10	135.4	10.61	10	23.9	6.22	10	0.94	0.05	10	24.91	7.84
	03MAY1991	10	130.9	13.67	10	21.2	7.56	10	0.91	0.04	10	24.72	6.87
	09MAY1991	10	136.2	6.97	10	23.5	3.83	10	0.92	0.04	10	20.86	7.30
	10MAY1991	10	133.2	5.14	10	21.9	2.81	10	0.92	0.05	10	21.34	4.20
17MAY1991	20	130.4	13.37	20	21.2	6.29	20	0.93	0.05	20	25.87	6.49	

Appendix C.1. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STO	N	MEAN	STO	N	MEAN	STO	N	MEAN	STD
IS	23MAY1991	10	119.2	11.97	10	16.4	4.01	10	0.96	0.06	10	25.01	5.86
	24MAY1991	9	105.8	10.15	9	12.0	3.97	9	0.99	0.04	8	25.11	6.45
	30MAY1991	10	122.5	10.66	10	18.7	4.93	10	1.00	0.04	10	23.48	5.66
	31MAY1991	10	121.7	11.80	10	18.2	4.83	10	0.99	0.04	10	23.37	7.27
	06JUN1991	10	127.4	12.95	10	21.2	6.32	10	0.99	0.05	10	23.44	7.16
	07JUN1991	10	125.0	9.36	10	19.6	4.03	10	0.99	0.03	10	26.72	9.88
	13JUN1991	10	125.8	11.63	10	20.5	4.78	10	1.02	0.09	10	15.77	3.70
	14JUN1991	10	118.8	11.56	10	16.9	4.78	10	0.99	0.06	10	23.82	4.78
	20JUN1991	11	130.0	7.40	11	23.3	4.17	11	1.05	0.05	11	26.66	11.03
	21JUN1991	10	128.1	14.67	10	22.5	8.91	10	1.03	0.06	10	24.32	7.44
	27JUN1991	10	128.9	9.16	10	22.9	5.01	10	1.00	0.06	10	29.02	8.40
	28JUN1991	10	119.6	8.81	10	18.4	4.49	10	1.00	0.05	10	29.37	5.32
	02JUL1991	10	134.6	15.60	10	26.8	11.02	10	1.05	0.07	10	20.11	5.41
	03JUL1991	10	128.1	14.65	10	23.6	8.43	10	1.05	0.05	9	20.30	7.03
	11JUL1991	20	126.0	8.09	20	22.1	4.93	20	1.05	0.06	20	28.65	7.37
	18JUL1991	7	129.0	17.40	7	25.0	10.49	7	1.10	0.06	7	26.84	6.98
	19JUL1991	13	130.4	10.58	13	25.8	7.39	13	1.13	0.07	13	30.30	7.43
	27JUL1991	20	139.1	12.31	20	33.2	8.92	20	1.21	0.07	20	12.69	5.17
	21APR1991	10	122.5	16.16	10	19.9	8.92	10	1.02	0.07	10	15.72	3.30
	22APR1991	10	140.0	16.23	10	29.8	11.93	10	1.00	0.11	10	12.48	3.49
	28APR1991	10	123.7	14.28	10	19.9	7.58	10	1.01	0.07	4	15.51	3.34
	29APR1991	12	133.6	8.06	12	23.2	4.35	12	0.90	0.06	12	11.33	3.55
	05MAY1991	10	139.9	20.38	10	28.7	14.70	10	0.90	0.06	10	15.64	4.80
	06MAY1991	10	126.2	9.95	10	19.4	4.88	10	0.90	0.05	10	16.77	4.87
	12MAY1991	10	138.7	8.06	10	25.5	4.93	10	0.95	0.05	10	14.84	5.42
	13MAY1991	10	148.6	14.20	10	32.3	8.87	10	0.90	0.05	10	16.63	6.93
	19MAY1991	10	169.7	23.06	10	50.4	19.15	10	0.91	0.07	10	16.67	6.96
	20MAY1991	10	178.4	22.14	10	59.6	20.00	10	1.01	0.03	10	12.71	4.26
	21MAY1991	1	175.0		1	58.0		1	1.00		0		
	22APR1991	20	180.3	12.78	20	54.9	12.91	20	0.90	0.04	20	40.2	13.18
29APR1991	10	162.5	15.13	10	41.9	9.71	10	0.97	0.06	10	29.47	12.14	
01MAY1991	10	164.2	28.74	10	44.5	21.17	10	0.90	0.06	6	27.94	13.70	
06MAY1991	10	145.1	19.74	10	30.4	15.20	10	0.93	0.05	10	31.51	7.12	
07MAY1991	10	141.7	14.45	10	26.5	9.13	10	0.90	0.09	0			
13MAY1991	10	137.2	10.66	10	23.8	5.28	10	0.91	0.04	10	27.8	4.8	
14MAY1991	10	142.9	9.98	10	27.1	6.61	10	0.91	0.06	10	26.31	5.24	
20MAY1991	9	146.2	17.06	9	29.5	12.74	9	0.91	0.07	9	35.47	6.56	
21MAY1991	11	138.8	9.12	11	24.5	6.95	11	0.90	0.08	11	28.02	10.35	
28MAY1991	10	168.3	29.91	10	48.2	21.36	10	0.92	0.04	10	28.21	8.40	
29MAY1991	10	153.3	26.73	10	36.5	22.51	10	0.92	0.05	10	33.47	10.86	
03JUN1991	23	169.0	20.85	23	47.6	18.09	23	0.94	0.08	23	24.39	7.79	

Appendix C.2. Summary of selected data from hatchery steelhead collected from the migration-at-large at the IDFG Clearwater River trap (CLW), Lower Granite Dam (LGR), Rock Island Dam (RIS) and McNary Dam (MCN) during Spring, 1991. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
CLW LEW	26APR1991	60	196.2	18.45	60	73.0	20.64	60	0.94	0.05	3	17.63	4.49
	25APR1991	10	213.8	11.70	10	91.9	14.41	10	0.93	0.05	9	9.93	4.60
	26APR1991	10	227.5	27.50	10	0.0	0.00	10	0.00	0.00	5	8.47	5.10
	01MAY1991	25	214.9	31.33	25	90.2	42.70	25	0.86	0.19	2	29.12	1.74
	02MAY1991	35	222.3	22.17	35	99.9	30.24	35	0.89	0.10	11	15.07	9.20
	03MAY1991	10	221.8	20.99	10	103.7	32.14	10	0.92	0.06	10	8.88	3.59
	09MAY1991	10	224.0	22.79	10	96.3	26.58	10	0.84	0.13	10	11.66	2.55
	10MAY1991	10	224.4	20.76	10	97.7	24.44	10	0.87	0.14	10	12.30	6.41
	16MAY1991	10	226.7	22.17	10	105.9	32.17	10	0.85	0.05	10	12.25	1.94
	17MAY1991	10	226.3	23.87	10	106.3	35.68	10	0.89	0.05	10	17.56	2.74
	23MAY1991	10	210.4	13.86	10	79.1	17.63	10	0.84	0.05	4	12.24	3.86
	24MAY1991	10	210.5	25.68	10	80.6	33.55	10	0.83	0.04	10	20.36	6.73
	30MAY1991	10	213.1	31.39	10	89.9	52.31	10	0.86	0.08	8	16.11	5.49
	31MAY1991	10	217.5	25.87	10	89.8	33.06	10	0.84	0.04	9	11.82	3.87
	06JUN1991	10	217.6	29.84	10	90.5	34.07	10	0.85	0.07	10	14.29	2.82
	07JUN1991	8	215.0	37.08	8	88.2	49.07	8	0.82	0.07	8	18.42	5.85
	13JUN1991	10	187.9	14.15	10	60.0	14.63	10	0.89	0.09	10	17.69	6.30
14JUN1991	10	211.7	23.96	10	88.0	28.67	10	0.90	0.06	10	18.00	7.00	
LGR	25APR1991	10	209.7	26.00	10	92.3	40.31	10	0.95	0.06	9	11.06	6.47
	26APR1991	10	211.0	12.35	10	87.6	19.07	10	0.92	0.05	7	14.30	3.32
	02MAY1991	10	210.3	23.40	10	85.5	29.80	10	0.89	0.05	10	16.67	3.93
	03MAY1991	8	225.9	21.23	8	99.1	28.29	8	0.84	0.04	8	15.74	5.38
	09MAY1991	10	207.5	22.78	10	82.8	24.64	10	0.90	0.04	10	12.96	3.95
	10MAY1991	10	235.2	25.94	10	111.8	34.66	10	0.84	0.06	10	13.09	2.17
	16MAY1991	10	233.4	24.91	10	113.9	38.18	10	0.87	0.06	10	18.75	2.57
	17MAY1991	12	217.5	25.87	12	92.4	39.32	12	0.84	0.07	12	16.73	4.90
	23MAY1991	11	244.3	27.33	11	127.6	39.20	11	0.85	0.07	11	20.83	5.90
	24MAY1991	9	232.9	29.52	9	108.4	47.10	9	0.85	0.07	9	17.36	6.85
	30MAY1991	10	224.2	24.73	10	93.1	31.08	10	0.84	0.03	10	18.58	4.56
	31MAY1991	10	231.8	20.70	10	102.3	28.58	10	0.85	0.03	10	20.19	4.22
	06JUN1991	10	214.7	12.98	10	78.5	17.53	10	0.71	0.09	10	16.07	6.88
	07JUN1991	10	219.0	27.65	10	88.9	46.80	10	0.84	0.06	10	18.85	8.04
	13JUN1991	10	230.6	28.45	10	105.7	45.29	10	0.85	0.06	10	14.00	3.47
14JUN1991	10	224.5	20.26	10	92.9	22.43	10	0.85	0.06	10	13.57	4.10	
20JUN1991	10	218.6	17.15	10	87.4	17.08	10	0.85	0.08	10	25.62	6.21	
21JUN1991	10	245.5	38.29	10	136.1	64.77	10	0.85	0.07	10	14.51	4.54	
27JUN1991	10	226.3	29.81	10	99.6	48.63	10	0.85	0.09	10	23.17	9.42	
28JUN1991	10	230.0	35.35	10	107.5	59.71	10	0.85	0.06	10	25.50	3.85	

Appendix C.2. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
RIS	02JUL1991	10	231.2	30.78	10	102.9	43.95	10	0.79	0.11	10	16.23	4.97
	03JUL1991	10	241.2	36.02	10	131.6	58.34	10	0.88	0.10	10	15.92	5.85
	11JUL1991	20	226.0	28.66	20	103.5	47.42	20	0.85	0.08	20	19.35	6.77
	18JUL1991	10	255.5	41.47	10	156.9	76.56	10	0.88	0.08	10	11.46	9.04
	19JUL1991	10	254.0	52.00	10	163.1	113.92	10	0.89	0.08	10	11.15	3.29
	27JUL1991	20	253.2	36.32	20	150.3	59.63	20	0.89	0.07	20	6.41	3.01
	28APR1991	10	190.4	22.77	10	67.1	25.52	10	0.93	0.09	10	10.28	2.45
	29APR1991	10	218.5	26.05	10	96.6	32.59	10	0.90	0.06	10	10.68	3.57
	05MAY1991	10	198.8	19.60	10	69.5	19.69	10	0.86	0.05	10	15.07	5.97
	06MAY1991	10	188.9	13.14	10	58.8	14.32	10	0.86	0.05	10	15.29	5.45
	12MAY1991	10	199.1	16.60	10	70.4	16.87	10	0.88	0.06	10	16.48	6.73
	13MAY1991	10	199.9	12.66	10	70.3	13.82	10	0.87	0.03	10	12.09	2.89
	19MAY1991	10	191.1	26.11	10	62.0	23.18	10	0.85	0.05	10	17.76	6.43
	20MAY1991	10	197.7	15.78	10	70.7	19.36	10	0.89	0.04	9	12.81	2.92
	21MAY1991	6	199.0	23.38	6	71.3	22.12	6	0.88	0.07	0	.	.
MCN	29APR1991	10	229.9	14.69	10	107.9	24.72	10	0.87	0.05	10	18.19	5.91
	01MAY1991	10	233.3	26.40	10	113.6	41.24	10	0.86	0.02	4	20.04	4.10
	06MAY1991	10	222.9	26.05	10	96.7	36.63	10	0.84	0.05	10	22.25	5.23
	07MAY1991	10	205.9	22.38	10	75.6	23.08	10	0.85	0.07	0	.	.
	13MAY1991	9	215.7	14.33	9	82.3	22.50	9	0.80	0.06	9	19.92	6.12
	14MAY1991	10	207.2	19.30	10	74.6	23.23	10	0.81	0.05	1	21.71	.
	20MAY1991	10	205.6	15.85	10	71.3	15.04	10	0.81	0.06	8	22.54	4.19
	21MAY1991	11	209.3	12.28	11	76.9	13.69	11	0.83	0.05	11	19.20	6.08
	28MAY1991	10	214.0	26.13	10	82.7	29.92	10	0.81	0.03	10	21.86	4.26
	29MAY1991	10	217.5	31.42	10	85.4	31.41	10	0.80	0.07	10	28.73	8.93
	03JUN1991	21	208.9	34.06	21	77.9	41.96	21	0.78	0.06	21	23.04	6.31
	12JUN1991	20	222.6	28.34	20	90.4	32.42	20	0.79	0.05	20	16.17	4.47
20JUN1991	11	252.1	38.31	11	130.5	58.29	11	0.76	0.05	11	18.13	4.15	

Appendix C.3. Summary of selected data from wild steelhead collected from the migration-at-large at the IDFG Clear-water River trap (CLW), Lower Granite Dam (LGR), Rock Island Dam (RIS) and McNary Dam (MCN) during spring, 1991. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
CLW	26APR1991	55	179.1	15.25	55	36.6	25.85	55	0.63	0.40	1	72.83	
LEW	25APR1991	10	181.1	15.37	10	56.6	18.09	10	0.93	0.08	5	9.73	5.88
	26APR1991	10	188.9	25.99	10	0.0	0.00	10	0.00	0.00	6	11.26	7.27
	02MAY1991	9	159.3	15.25	9	38.8	12.01	9	0.94	0.07	9	19.79	5.97
	03MAY1991	10	167.4	23.73	10	43.1	22.75	10	0.95	0.56	10	20.43	8.41
	09MAY1991	10	174.6	15.28	10	48.4	11.97	10	0.90	0.05	10	16.78	4.82
	10MAY1991	10	151.1	56.96	10	45.3	17.98	10	0.82	0.29	10	16.01	3.46
	13MAY1991	25	175.2	16.45	25	48.2	13.27	25	0.88	0.10	0		
	14MAY1991	25	181.3	14.48	25	52.9	13.81	25	0.87	0.06	2	31.98	0.51
	16MAY1991	10	171.7	16.30	10	47.5	12.20	10	0.92	0.05	10	22.35	4.95
	17MAY1991	10	179.1	22.52	10	53.9	27.23	10	0.89	0.06	10	22.56	4.38
	23MAY1991	10	166.3	24.94	10	48.3	24.67	10	0.98	0.09	10	16.28	6.20
	24MAY1991	10	171.0	14.91	10	46.7	12.52	10	0.91	0.06	10	21.13	5.67
	30MAY1991	9	162.9	16.69	9	43.7	13.59	9	0.98	0.07	9	17.39	6.78
	31MAY1991	10	168.1	17.86	10	45.8	15.85	10	0.93	0.05	10	23.99	5.80
	06JUN1991	4	180.5	5.45	4	54.8	6.19	4	0.93	0.06	4	22.19	15.29
	07JUN1991	1	172.0		1	46.1		1	0.91		1	12.78	
	13JUN1991	3	168.0	15.1	3	48.8	14.54	3	1.01	0.06	3	18.32	7.06
LGR	02MAY1991	10	184.0	27.54	10	56.4	33.86	10	0.84	0.06	10	16.22	3.85
	03MAY1991	10	190.5	27.89	10	55.0	37.06	10	0.75	0.27	10	20.24	10.28
	09MAY1991	10	199.2	18.62	10	69.8	25.81	10	0.85	0.08	10	15.73	4.24
	10MAY1991	10	189.4	22.75	10	59.5	20.78	10	0.84	0.03	10	21.38	5.72
	16MAY1991	10	181.8	22.69	10	52.1	22.67	10	0.83	0.05	10	19.12	4.42
	17MAY1991	9	188.7	21.12	9	57.9	19.54	9	0.84	0.08	9	22.53	10.00
	23MAY1991	10	181.7	23.79	10	54.1	21.62	10	0.87	0.05	10	25.76	7.98
	24MAY1991	10	170.3	27.89	10	45.6	22.38	10	0.88	0.07	9	18.50	7.90
	30MAY1991	10	177.2	15.89	10	48.9	16.58	10	0.85	0.08	10	19.65	5.12
	31MAY1991	10	163.2	10.34	10	38.7	6.37	10	0.88	0.03	10	17.13	5.33
	06JUN1991	10	175.2	16.34	10	47.5	15.01	10	0.86	0.04	10	18.44	3.63
	07JUN1991	10	164.7	12.61	10	37.8	7.75	10	0.84	0.05	10	19.48	5.23
	13JUN1991	10	168.8	17.52	10	44.3	15.68	10	0.89	0.05	10	19.68	4.81
	14JUN1991	10	178.1	11.81	10	51.7	10.84	10	0.91	0.06	10	20.44	5.16
	20JUN1991	10	182.7	14.09	10	55.0	17.61	10	0.88	0.08	10	22.38	9.93
	21JUN1991	10	180.4	23.43	10	54.1	21.78	10	0.88	0.04	10	26.39	10.61
	27JUN1991	10	187.9	25.29	10	60.6	26.56	10	0.87	0.06	10	30.36	5.52
	28JUN1991	8	177.3	28.26	8	53.9	23.01	8	0.92	0.07	8	28.19	7.57
RIS	28APR1991	10	173.9	26.81	10	50.2	31.19	10	0.87	0.06	5	16.66	5.30
	29APR1991	10	180.2	23.96	10	52.4	22.68	10	0.86	0.06	10	18.52	9.10

Appendix C.3. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
MCN	05MAY1991	10	180.2	23.83	10	54.3	27.36	10	0.87	0.05	10	15.89	2.33
	06MAY1991	10	182.8	17.20	10	52.9	15.11	10	0.84	0.05	10	20.35	6.73
	12MAY1991	10	177.3	24.16	10	49.9	22.73	10	0.85	0.05	10	17.52	5.34
	13MAY1991	10	175.3	29.60	10	50.8	32.33	10	0.86	0.05	10	18.07	6.75
	19MAY1991	10	193.5	21.35	10	63.9	21.12	10	0.85	0.04	10	27.13	a.77
	20MAY1991	10	174.0	12.66	10	46.4	11.37	10	0.87	0.04	10	15.71	5.41
	21MAY1991	9	169.0	17.06	9	44.9	15.57	9	0.91	0.06	9		
	29APR1991	10	189.9	19.91	10	63.3	27.55	10	0.87	0.10	10	22.86	4.62
	01MAY1991	10	196.3	22.83	10	64.5	18.88	10	0.84	0.07	9	15.52	0.19
	06MAY1991	10	192.7	15.40	10	59.0	16.91	10	0.81	0.10	10	32.95	2.85
	07MAY1991	10	185.9	17.26	10	54.3	18.19	10	0.82	0.08	10		
	13MAY1991	10	198.3	18.49	10	71.6	28.97	10	0.88	0.08	10	21.29	4.99
	14MAY1991	10	179.5	16.31	10	46.7	12.12	10	0.79	0.07	10	25.77	1.34
	20MAY1991	10	188.6	27.91	10	59.1	30.30	10	0.82	0.06	10	22.08	7.96
	21MAY1991	9	176.8	11.12	9	48.8	11.05	9	0.87	0.09	9	26.03	1.96
	28MAY1991	10	170.6	13.16	10	41.8	10.34	10	0.83	0.07	10	24.96	5.83
	29MAY1991	9	168.4	14.95	9	40.7	11.44	9	0.83	0.04	8	28.81	8.22
	03JUN1991	18	172.7	16.11	18	45.9	15.30	18	0.86	0.07	18	25.13	8.44
	12JUN1991	14	191.5	25.39	14	65.4	29.03	14	0.89	0.05	14	19.14	5.19
	13JUN1991	1	163.0		1	35.3		1	0.82		1	39.17	
20JUN1991	2	191.0	36.7	2	55.1	24.75	2	0.78	0.09	2	23.40	6.36	

Appendix C.4 Summary of selected data from subyearling fall chinook salmon collected from the migration-at-large at bower Granite Dam (LGR), Hanford Reach (HAN), McNary Dam (MCN), and John Day Dam (JDA) during spring, 1991. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i\text{mg prot}^{-1}\text{.h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
LGR	20JUN1991	6	108.7	3.50	6	13.1	1.52	6	1.02	0.04	6	28.36	5.72
	22JUN1991	6	114.7	3.33	6	15.9	1.48	6	1.05	0.04	6	26.24	7.63
	23JUN1991	6	115.2	1.47	6	15.9	1.84	6	1.04	0.09	5	29.11	10.05
	24JUN1991	2	114.0	0.00	2	18.2	3.39	2	1.23	0.23	2	32.18	16.94
	25JUN1991	6	107.7	9.54	6	13.7	4.04	6	1.06	0.08	6	27.07	10.28
	26JUN1991	3	109.7	3.51	3	14.2	2.21	3	1.07	0.09	3	30.10	4.43
	27JUN1991	10	109.2	4.21	10	14.1	1.25	10	1.08	0.08	10	26.24	8.59
	28JUN1991	2	105.5	0.71	2	13.c	0.35	2	1.11	0.01	2	20.15	5.42
	29JUN1991	3	114.0	5.57	3	16.E	3.58	3	1.12	0.09	3	19.64	6.61
	01JUL1991	5	111.8	9.09	5	15.3	3.25	5	1.08	0.05	5	20.94	5.94
	02JUL1991	5	112.0	9.14	5	15.2	4.86	5	1.05	0.15	4	16.91	8.12
	03JUL1991	9	115.9	9.27	9	17.c	2.94	9	1.15	0.14	8	25.82	7.38
	04JUL1991	5	115.0	8.97	5	17.3	3.71	5	1.13	0.09	5	24.07	4.36
	05JUL1991	7	113.1	7.54	7	16.2	3.80	7	1.10	0.06	7	23.51	8.85
	06JUL1991	5	114.0	7.48	5	16.1	3.2	5	1.11	0.03	5	38.47	10.39
	07JUL1991	4	117.8	7.93	4	17.8	3.56	4	1.08	0.03	4	23.14	7.13
	08JUL1991	13	118.6	4.39	13	18.:	2.2:	13	1.09	0.05	13	28.20	7.39
	09JUL1991	6	123.3	4.50	6	22.:	2.9:	6	1.18	0.04	6	29.73	7.17
	11JUL1991	6	118.8	5.71	6	20.t	3.07	6	1.18	0.07	5	24.93	9.75
	12JUL1991	10	119.7	6.02	10	20.2	3.61	10	1.17	0.08	10	33.23	8.25
	13JUL1991	8	121.6	5.68	8	22.0	4.13	8	1.21	0.08	8	31.61	4.82
	15JUL1991	12	123.8	5.99	12	22.2	3.27	12	1.17	0.06	12	34.83	8.60
	17JUL1991	4	128.0	5.35	4	24.4	4.31	4	1.15	0.08	4	24.58	7.40
	19JUL1991	4	138.8	10.69	4	33.6	8.59	4	1.24	0.05	4	37.02	8.41
	21JUL1991	7	138.6	7.79	7	32.7	7.78	7	1.21	0.13	7	37.58	11.25
	22JUL1991	7	130.3	4.96	7	27.5	3.53	7	1.23	0.04	7	37.32	8.31
	23JUL1991	5	120.8	4.15	5	22.3	3.50	5	1.26	0.10	5	25.09	8.75
	24JUL1991	7	128.7	6.45	7	26.4	4.27	7	1.23	0.04	7	26.98	8.72
	26JUL1991	4	145.5	7.77	4	41.3	7.94	4	1.33	0.10	4	18.02	8.33
	28JUL1991	5	136.4	13.67	5	35.2	12.38	5	1.34	0.08	5	22.22	13.85
	29JUL1991	7	136.4	11.03	7	35.4	7.56	7	1.38	0.11	7	21.72	8.08
	30JUL1991	5	131.0	7.97	5	29.5	7.12	5	1.29	0.08	5	29.75	6.96
	06AUG1991	1	94.0	.	1	9.2	.	1	1.11	.	1	10.55	.
	07AUG1991	2	131.5	2.12	2	30.5	0.21	2	1.34	0.06	2	28.79	12.76
HAN	06JUN1991	20	60.9	2.68	20	2.1	0.28	20	0.92	0.05	19	9.39	2.63
	13JUN1991	20	63.1	4.39	20	2.5	0.59	20	0.99	0.07	6	17.87	7.86
MCN	12JUN1991	20	100.9	7.21	20	9.9	2.46	20	0.94	0.06	20	20.35	7.35
	20JUN1991	20	98.2	10.41	20	9.3	2.98	20	0.96	0.04	19	16.14	3.11

Appendix C.4. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	25JUN1991	20	100.7	9.43	20	10.1	3.09	20	0.96	0.05	20	14.63	3.43
	02JUL1991	20	100.0	6.73	20	9.8	2.07	20	0.97	0.05	20	31.82	7.83
	10JUL1991	20	103.4	13.31	20	11.0	4.99	20	0.95	0.04	19	30.55	7.02
	16JUL1991	20	95.5	7.11	20	8.9	2.09	20	1.01	0.05	20	29.73	9.13
	23JUL1991	20	99.5	6.66	20	10.0	2.37	20	1.00	0.04	20	20.74	5.75
	30JUL1991	40	54.4	55.21	40	7.1	7.33	40	0.55	0.55	40	27.85	5.54
	06AUG1991	20	113.9	6.49	20	16.6	3.13	20	1.12	0.06	20	24.73	8.41
	13AUG1991	20	117.6	8.69	20	18.2	3.90	20	1.10	0.05	20	24.27	7.55
	20AUG1991	19	125.6	12.05	19	22.4	6.51	19	1.10	0.07	19	16.94	7.03
	27AUG1991	20	123.5	7.29	20	21.1	3.75	20	1.11	0.07	20	17.46	5.85
	04SEP1991	19	121.7	10.06	19	20.0	5.20	19	1.08	0.06	19	20.76	8.02
	10SEP1991	20	130.4	11.18	20	24.7	7.23	20	1.09	0.06	20	17.50	9.87
	26NOV1991	13	174.5	21.59	13	59.0	18.01	13	1.07	0.05	13	20.98	7.33
DA	18JUN1991	20	101.4	7.08	20	11.3	2.47	20	1.07	0.06	20	21.02	4.54
	25JUN1991	20	106.7	8.81	20	13.0	3.78	20	1.04	0.06	20	14.79	3.51
	02JUL1991	20	113.1	7.20	20	16.1	4.05	20	1.09	0.09	20	32.28	7.35
	09JUL1991	20	105.6	6.45	20	12.7	2.47	20	1.07	0.06	19	29.34	8.03
	16JUL1991	20	107.8	6.70	20	14.0	2.72	20	1.11	0.05	20	32.96	10.21
	22JUL1991	20	106.4	6.23	20	13.0	3.06	20	1.06	0.13	20	25.53	9.78
	30JUL1991	20	117.8	8.15	20	17.5	3.83	20	1.06	0.09	20	23.08	8.97
	06AUG1991	20	119.8	6.60	20	20.1	3.61	20	1.16	0.05	20	31.19	10.15
	12AUG1991	20	121.7	5.91	20	20.4	3.46	20	1.13	0.08	20	22.86	11.13
	21AUG1991	20	120.1	7.13	20	19.2	3.99	20	1.09	0.06	20	23.86	8.14
	28AUG1991	20	128.9	10.52	20	24.4	6.08	20	1.12	0.07	20	17.87	5.97
	05SEP1991	19	129.4	10.34	19	25.1	7.50	19	1.13	0.09	19	19.77	8.60

Appendix C.5. Summary of selected data from shad collected from the migration-at-large at John Day Dam (JDA), and Bonneville Dam first powerhouse (BON) during spring, 1991. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill $\text{Na}^+ - \text{K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPAS		
		N	#AN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
JDA	21AUG1991	19	51.5	3.91	19	1.5	0.36	19	1.05	0.07	19	13.45	4.72
	28AUG1991	20	53.6	8.27	20	1.9	1.36	20	1.15	0.10	20	9.39	3.35
I	05SEP1991	20	65.4	12.90	20	3.3	2.04	20	1.05	0.06	20	12.78	3.33
	11SEP1991	20	70.1	9.42	20	3.8	1.53	20	1.05	0.05	20	14.03	6.23
I	19SEP1991	20	59.8	13.11	20	2.6	1.36	20	1.08	0.06	20	17.02	3.36
	03OCT1991	20	73.1	9.55	20	4.4	1.63	20	1.08	0.08	12	12.85	2.86
I	16SEP1991	20	73.0	8.79	20	4.1	1.47	20	1.03	0.07	20	11.25	2.49
	01OCT1991	20	74.1	6.75	20	4.2	1.18	20	1.02	0.05	20	12.54	4.50
I	10OCT1991	20	74.5	8.45	20	4.5	1.99	20	1.05	0.09	20	15.20	3.99
	24OCT1991	20	81.6	5.53	20	5.4	1.21	20	0.98	0.04	20	15.27	4.80
I	07NOV1991	20	76.5	7.66	20	4.2	1.33	20	0.91	0.05	20	17.53	8.80
	26NOV1991	20	78.6	14.39	20	4.8	3.66	20	0.89	0.08	19	16.77	6.73

Appendix D.1. Summary of selected data from yearling spring/summer chinook salmon collected from the migration-at-large at the IDFG Clear-water River trap (CLW), IDFG Lewiston trap (LEW), Lower Granite Dam (LGR), Little Goose Dam (LGS), McNary Dam (MCN), and Rock Island Dam (RIS) during spring, 1992. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill Na⁺-K⁺ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
LW	06APR1992	10	121.4	12.75	10	18.4	6.56	10	0.99	0.10	10	11.53	3.84
	08APR1992	10	125.5	9.97	10	20.2	5.53	10	1.00	0.06	10	9.97	2.71
	10APR1992	10	127.2	9.28	10	21.2	5.12	10	1.01	0.03	10	10.28	2.45
	13APR1992	10	133.3	8.10	10	24.6	4.59	10	1.03	0.07	10	11.14	3.11
	14APR1992	40	129.4	10.49	40	22.1	5.50	40	1.00	0.06	0	.	.
	15APR1992	10	118.6	8.91	10	17.2	4.02	10	1.01	0.06	10	8.70	2.21
	17APR1992	10	135.8	13.35	10	26.3	8.40	10	1.02	0.07	10	9.94	1.62
	20APR1992	10	125.4	6.80	10	19.6	3.18	10	0.99	0.05	10	11.15	2.94
	22APR1992	10	129.8	13.72	10	22.9	7.79	10	1.02	0.06	10	11.41	3.15
	24APR1992	10	123.2	7.48	10	20.0	4.07	10	1.06	0.05	10	10.85	1.69
	27APR1992	10	111.5	10.42	10	14.0	3.97	10	0.98	0.12	10	9.93	3.07
	29APR1992	10	124.3	10.77	10	19.1	4.37	10	0.98	0.05	10	13.53	3.85
	01MAY1992	10	129.8	11.21	10	22.5	7.25	10	1.00	0.09	5	13.84	2.57
	06MAY1992	9	144.1	10.87	8	31.4	7.82	8	1.02	0.06	0	.	.
	18MAY1992	10	131.9	12.33	10	24.3	6.42	10	1.04	0.04	10	15.6;	5.31
	20MAY1992	10	141.0	10.09	10	30.3	8.14	10	1.06	0.07	10	16.01	3.62
	EW	08APR1992	10	126.7	11.75	10	20.9	5.38	10	1.01	0.05	10	10.99	2.69
13APR1992		7	129.3	6.92	7	21.4	3.78	7	0.98	0.04	7	14.77	4.17
14APR1992		40	126.1	7.92	40	21.8	4.26	40	1.08	0.15	0	.	.
17APR1992		10	128.2	10.90	10	22.6	5.39	10	1.05	0.07	10	15.73	4.79
20APR1992		5	123.0	14.73	5	19.6	5.49	5	1.03	0.06	5	13.11	3.86
22APR1992		10	131.4	13.55	10	24.3	9.38	10	1.02	0.09	10	20.28	4.35
24APR1992		10	125.2	9.22	10	19.1	4.25	10	0.96	0.06	10	17.20	6.78
01MAY1992	10	127.6	16.34	10	22.3	9.81	10	1.03	0.14	10	19.37	5.20	
06MAY1992	1	149.0	.	1	33.0	.	1	1.00	.	1	21.66	.	
GR	06APR1992	10	124.1	8.31	10	18.6	3.3;	10	0.97	0.05	10	17.70	5.7;
	08APR1992	10	126.5	10.34	10	19.8	4.69	10	0.96	0.05	10	27.23	4.15
	10APR1992	10	128.1	7.99	10	20.3	3.60	10	0.96	0.05	10	22.81	5.55
	13APR1992	10	128.9	10.65	10	20.7	5.48	10	0.94	0.04	10	23.31	6.62
	17APR1992	10	129.7	11.70	10	21.7	5.30	10	0.97	0.04	10	18.33	4.94
	20APR1992	10	130.7	13.95	10	21.6	6.15	10	0.95	0.07	10	19.52	7.60
	22APR1992	11	132.2	28.04	11	24.6	21.47	11	0.93	0.04	11	22.52	4.82
	24APR1992	10	141.3	29.27	10	30.0	28.36	10	0.91	0.04	10	24.75	4.90
	27APR1992	10	137.7	8.76	10	24.5	5.13	10	0.93	0.04	10	26.98	7.15
	29APR1992	10	129.7	9.29	10	20.2	4.71	10	0.91	0.06	10	27.25	9.50
	01MAY1992	10	144.9	13.76	10	29.9	11.64	10	0.95	0.08	0	.	.
04MAY1992	10	144.1	18.76	10	28.9	12.23	10	0.93	0.05	0	.	.	

Appendix D.1 continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	08MAY1992	10	137.7	14.76	10	25.5	9.36	10	0.94	0.07	0		
	11MAY1992	10	139.2	18.93	10	26.8	9.76	10	0.95	0.04	10	25.48	7.41
	13MAY1992	10	138.5	6.92	0	25.1	4.25	10	0.94	0.04	10	20.50	5.30
	15MAY1992	10	138.3	11.85	10	24.2	5.63	10	0.90	0.06	10	29.06	9.82
	18MAY1992	10	145.1	15.67	10	27.6	7.92	10	0.89	0.12	10	29.30	5.18
	20MAY1992	10	138.2	13.46	10	23.9	7.15	10	0.88	0.06	10	36.46	7.70
	22MAY1992	10	138.4	14.30	10	23.1	6.85	10	0.86	0.08	10	31.03	9.90
	25MAY1992	10	141.8	9.24	10	25.9	4.47	10	0.91	0.05	10	21.88	7.49
	27MAY 1992	10	144.1	8.75	10	26.1	4.97	10	0.87	0.08	10	26.79	12.07
.GR	29MAY1992	10	137.3	10.18	10	23.1	3.84	10	0.89	0.08	9	21.09	7.66
	01JUN1992	10	128.7	11.16	10	20.4	4.93	10	0.95	0.11	10	23.10	6.08
	03JUN1992	10	136.5	16.48	10	24.5	7.39	10	0.95	0.07	10	30.42	9.86
	05JUN1992	10	127.9	11.50	10	20.2	4.42	10	0.96	0.07	10	29.03	7.53
.GS	21APR1992	10	133.2	14.12	10	21.4	6.40	10	0.88	0.05	10	25.74	5.37
	23APR1992	10	128.0	10.21	10	18.9	4.12	10	0.89	0.04	10	24.57	6.99
	28APR1992	10	137.5	6.95	10	23.5	3.45	10	0.90	0.04	10	30.13	8.50
	30APR1992	9	136.3	4.69	9	22.0	1.59	9	0.87	0.05	9	32.13	7.54
	12MAY1992	10	137.9	10.75	10	24.0	5.65	10	0.90	0.03	10	31.19	6.82
	14MAY1992	10	134.4	10.91	10	21.7	4.77	10	0.88	0.04	10	31.96	7.14
	19MAY1992	10	134.2	8.89	10	21.3	3.91	10	0.87	0.04	10	33.72	7.81
	21MAY1992	10	140.5	10.05	10	24.8	5.83	10	0.88	0.07	10	38.79	10.31
	26MAY1992	10	145.2	13.43	10	26.7	8.06	10	0.85	0.07	10	26.37	9.67
IS	20APR1992	10	131.7	21.89	10	25.9	13.55	10	1.04	0.07	10	12.92	3.44
	22APR1992	10	128.8	9.78	10	22.3	4.67	10	1.03	0.06	10	9.03	1.74
	24APR1992	10	134.3	15.63	10	26.7	10.65	10	1.07	0.06	10	9.53	2.27
	27APR1992	10	135.1	18.44	10	24.9	9.08	10	0.98	0.12	9	14.78	5.44
	29APR1992	10	134.9	8.01	10	25.7	5.02	10	1.03	0.05	9	14.48	6.64
	01MAY1992	10	121.3	11.75	10	18.2	4.44	10	1.01	0.05	10	5.61	11.95
	04MAY1992	10	131.5	12.45	10	23.4	8.43	10	0.99	0.04	10	15.40	4.02
	06MAY1992	10	140.0	15.43	10	27.5	8.91	10	0.97	0.05	10	17.25	5.67
	08MAY1992	10	134.3	8.76	10	23.7	4.96	10	0.97	0.05	9	20.73	3.46
	11MAY1992	10	145.1	25.06	10	32.2	17.03	10	0.97	0.04	10	24.91	5.74
	13MAY1992	10	144.7	21.47	10	30.5	11.88	10	0.98	0.16	8	23.13	7.19
	15MAY1992	10	156.3	20.80	10	38.2	14.47	10	0.96	0.05	10	27.45	4.59
	18MAY1992	10	152.4	25.21	10	36.2	17.08	10	0.95	0.05	10	24.36	8.18
	20MAY1992	10	150.6	24.40	10	35.4	16.99	10	0.96	0.03	9	29.51	5.90
	22MAY1992	10	155.4	21.61	10	38.8	19.80	10	0.96	0.06	10	29.28	9.89
EN	06APR1992	10	182.1	15.25	10	60.8	17.60	10	0.98	0.11	1	10.54	
	27APR1992	10	167.4	27.31	10	49.9	26.03	10	0.97	0.08	10	19.87	4.6
	29APR1992	12	145.7	24.60	12	29.9	16.71	12	0.88	0.06	10	32.27	11.23
	01MAY1992	10	169.4	23.09	10	50.2	26.10	10	0.96	0.08	10	26.52	8.14
	04MAY1992	10	145.8	22.44	10	30.8	17.22	10	0.91	0.08	9	19.07	5.58
	06MAY1992	10	170.0	27.32	10	51.4	25.91	10	0.96	0.08	8	26.78	13.79
	08MAY1992	10	142.2	19.26	10	26.9	13.62	10	0.89	0.07	9	30.96	11.43
	11MAY1992	10	147.2	21.88	10	30.2	16.27	10	0.88	0.06	10	32.18	8.80
	13MAY1992	10	162.3	23.02	10	40.9	18.54	10	0.90	0.05	10	32.87	7.69

Appendix D.1 continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	15MAY 1992	10	143.5	18.82	10	28.4	12.75	10	0.91	0.06	10	33.97	9.36
	18MAY 1992	10	140.2	13.42	10	25.1	8.86	10	0.88	0.05	10	36.14	6.46
	20MAY 1992	10	143.7	9.98	10	26.8	5.46	10	0.90	0.06	10	33.08	8.80
	22MAY 1992	10	140.7	11.95	10	25.5	6.40	10	0.90	0.03	10	39.40	10.47
	25MAY 1992	10	150.4	12.10	10	30.7	7.95	10	0.89	0.06	10	32.88	9.32
	27MAY 1992	10	149.6	10.48	10	30.5	9.03	10	0.89	0.11	10	33.36	6.07
	29MAY 1992	10	157.8	21.06	10	37.5	21.61	10	0.88	0.10	10	35.91	8.45

Appendix D.2. Summary of selected data from hatchery steelhead collected from the migration-at-large at the IDFG Clearwater River trap (CLW), IDFG Lewiston trap (LEW), Lower Granite Dam (LGR), Little Goose Dam (LGS), McNary Dam (MCN), and Rock Island Dam (RIS) during spring, 1992. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	
CLW	05MAY1992	16	189.4	23.26	16	69.6	25.51	16	0.97	0.06	0	.	.	
	06MAY1992	34	200.0	25.41	34	78.6	31.52	34	0.93	0.06	0	.	.	
LEW	17APR1992	11	201.8	11.52	11	76.2	14.38	11	0.92	0.05	8	9.34	9.38	
	20APR1992	10	222.1	20.33	10	104.0	29.53	10	0.92	0.07	10	8.35	3.14	
	22APR1992	10	227.1	22.17	10	110.1	31.69	10	0.92	0.05	10	9.73	2.98	
	24APR1992	10	220.9	26.41	10	103.7	39.76	10	0.92	0.05	10	10.43	3.92	
	27APR1992	10	225.7	21.38	10	112.8	32.97	10	0.96	0.07	10	10.32	4.87	
	29APR1992	10	215.0	11.50	10	93.9	14.54	10	0.95	0.13	10	13.11	4.91	
	30APR1992	25	224.4	21.08	25	107.4	28.78	25	0.93	0.06	0	.	.	
	01MAY1992	10	217.6	21.52	10	100.7	30.24	10	0.95	0.09	10	12.1	5.41	
	04MAY1992	10	213.2	16.50	10	88.2	21.04	10	0.90	0.05	9	12.70	3.20	
	06MAY1992	10	221.0	10.46	10	97.4	16.97	10	0.90	0.06	9	15.94	4.54	
	08MAY1992	10	236.5	23.18	10	118.8	40.34	10	0.87	0.04	8	15.56	3.18	
	11MAY1992	10	213.4	15.12	9	81.9	19.41	9	0.81	0.04	10	15.83	6.53	
	13MY 1992	10	219.9	28.12	10	97.7	44.68	10	0.87	0.06	10	13.81	4.72	
	15MAY1992	10	214.9	24.75	10	87.2	28.97	10	0.84	0.04	10	18.91	5.30	
	20MAY1992	10	229.4	22.33	10	101.9	32.41	10	0.82	0.07	9	22.76	8.21	
	22MAY 1992	10	227.1	12.47	10	100.5	21.10	10	0.85	0.06	10	18.27	6.39	
	29MAY 1992	10	222.0	15.97	10	95.0	18.82	10	0.86	0.08	10	17.67	6.08	
	GR	20APR1992	10	230.6	25.65	10	110.1	37.04	10	0.87	0.05	10	12.94	4.25
		22APR1992	9	229.4	15.00	9	110.7	24.22	9	0.90	0.05	9	14.04	4.53
		24APR1992	10	231.2	21.90	10	112.3	37.99	10	0.88	0.05	10	14.36	3.12
27APR1992		10	224.3	17.74	10	98.2	24.01	10	0.86	0.04	8	18.12	3.23	
29APR1992		10	227.3	24.01	10	105.2	32.97	10	0.87	0.07	9	19.57	5.86	
01MAY1992		10	225.6	22.28	10	104.5	35.70	10	0.88	0.05	0	.	.	
04MAY1992		10	224.3	22.13	10	103.5	29.23	10	0.90	0.05	0	.	.	
08MAY1992		10	206.0	24.12	10	80.7	24.50	10	0.90	0.06	0	.	.	
11MAY1992		10	222.9	20.94	10	98.1	28.50	10	0.86	0.06	10	16.08	4.04	
13MAY1992		10	226.2	21.58	10	98.5	27.22	10	0.84	0.04	10	15.45	7.54	
15MAY1992		10	223.3	26.18	10	96.6	43.51	10	0.82	0.07	10	17.67	4.23	
18MAY1992		10	208.2	26.61	10	77.7	26.66	10	0.83	0.05	10	17.31	6.11	
20MAY1992		10	217.4	21.00	10	87.5	22.55	10	0.84	0.06	10	15.37	5.43	
22MAY 1992		10	228.5	17.22	10	98.1	30.72	10	0.80	0.08	10	25.16	9.21	
25MAY1992		10	226.4	14.33	10	93.8	23.56	10	0.80	0.09	10	24.79	8.99	
27MAY 1992		11	241.1	24.87	11	115.2	34.22	11	0.80	0.05	11	20.85	6.14	
29MY 1992	10	221.7	23.84	10	89.6	26.93	10	0.80	0.08	10	20.40	8.25		
01JUN1992	10	219.7	23.42	10	86.1	31.72	10	0.78	0.08	10	21.28	3.45		

Appendix D.2. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
GR	03JUN1992	10	240.2	15.271	10	105.7	19.30	10	0.76	0.08	10	15.22	6.00
	05JUN1992	10	237.9	19.76	10	100.1	26.60	10	0.73	0.06	10	15.49	7.58
	11JUN1992	15	244.2	23.71	15	108.6	44.47	15	0.71	0.09	15	11.80	7.12
	17JUN1992	15	244.3	17.70	15	110.1	27.24	15	0.74	0.10	14	12.93	7.14
	24JUN1992	15	240.9	18.25	15	103.5	32.99	15	0.72	0.12	14	6.83	3.77
	01JUL1992	16	227.4	24.08	16	83.2	26.73	16	0.69	0.07	14	5.70	1.12
	08JUL1992	13	230.7	19.88	13	105.0	29.16	13	0.86	0.21	13	6.64	1.62
	09JUL1992	1	258.0		1	141.4		1	0.82		1	9.99	
	16JUL1992	15	246.3	31.81	15	127.4	72.60	15	0.77	0.14	13	7.18	3.07
	22JUL1992	15	252.1	24.69	15	129.7	35.72	15	0.80	0.10	15	6.62	1.96
	30JUL1992	15	250.2	29.39	15	129.2	52.05	15	0.80	0.13	14	6.21	1.28
	08AUG1992	19	243.5	17.27	19	132.8	25.03	19	0.92	0.13	16	5.40	0.75
	12AUG1992	21	244.4	14.25	21	129.9	24.51	21	0.88	0.10	15	6.08	1.63
	18AUG1992	20	233.9	16.19	20	117.7	30.40	20	0.91	0.20	16	5.51	0.91
	26AUG1992	20	248.8	26.18	20	142.3	49.77	20	0.90	0.09	18	5.75	3.16
02SEP1992	20	249.3	20.09	20	136.4	37.65	20	0.87	0.13	16	5.10	0.78	
09SEP1992	20	254.3	20.33	20	141.0	31.05	20	0.85	0.12	15	5.92	1.25	
GS	12MAY1992	12	223.3	21.02	12	93.7	30.66	12	0.82	0.07	12	18.13	7.50
	14MAY1992	10	216.5	23.87	10	85.5	28.38	10	0.82	0.04	10	19.97	5.52
	19MAY1992	9	206.0	22.53	9	71.6	21.38	9	0.80	0.07	9	19.33	5.38
	21MAY1992	10	222.0	22.21	10	89.5	25.03	10	0.80	0.05	10	19.21	7.50
IS	26MAY 1992	10	222.3	27.30	10	88.5	32.34	10	0.77	0.06	10	14.66	6.70
	28MAY1992	10	240.0	21.79	10	106.8	28.36	10	0.76	0.06	10	18.65	5.64
	20APR1992	1	224.0		1	107.9		1	0.96		1	13.62	
	22APR1992	10	203.9	14.72	10	80.6	17.21	10	0.94	0.04	10	11.56	2.56
	24APR1992	10	205.7	23.16	10	85.0	29.51	10	0.94	0.06	10	12.05	4.20
	27APR1992	9	217.7	29.49	9	103.3	54.46	9	0.94	0.07	9	9.68	3.12
	29APR1992	10	218.4	15.38	10	94.2	14.52	10	0.90	0.06	9	15.91	9.60
	01MAY1992	10	215.6	27.07	10	96.6	43.05	10	0.91	0.09	7	13.18	5.64
	04MAY1992	10	207.3	23.15	10	89.5	34.55	10	0.91	0.08	10	12.65	4.87
	06MAY1992	10	211.3	19.86	10	80.8	23.22	10	0.84	0.04	6	19.2	4.11
	08MAY1992	10	191.8	16.24	10	59.7	12.73	10	0.84	0.00	7	14.91	5.21
	11MAY1992	10	193.8	22.11	10	63.8	20.07	10	0.85	0.04	10	15.41	2.92
	13MAY1992	10	205.2	36.46	10	79.6	46.50	10	0.84	0.04	10	13.99	3.98
	15MAY1992	10	193.6	26.60	10	64.1	19.45	10	0.85	0.06	10	20.46	5.51
	18MAY1992	10	186.9	16.72	10	55.4	15.13	10	0.83	0.06	10	18.06	8.07
20MAY1992	10	183.7	16.81	10	56.3	15.37	10	0.89	0.05	10	14.29	4.28	
22MAY 1992	10	190.6	26.55	10	64.2	30.81	10	0.86	0.08	10	19.42	7.06	
25MAY1992	10	195.8	20.92	10	68.0	22.56	10	0.88	0.06	10	16.59	7.86	
27MAY 1992	10	190.5	14.82	10	62.6	14.77	10	0.89	0.06	10	15.74	6.65	
29MAY 1992	10	215.3	32.15	10	96.0	46.63	10	0.90	0.06	10	17.23	5.25	
CN	27APR1992	10	252.5	28.18	10	145.0	71.63	10	0.85	0.10	7	13.71	2.81
	29APR1992	10	228.8	34.46	10	105.3	54.46	10	0.81	0.09	10	20.27	5.41
	01MAY1992	10	228.8	18.56	10	100.2	27.57	10	0.82	0.06	10	24.02	6.36
	04MAY1992	10	227.9	9.95	10	95.6	14.32	10	0.81	0.06	10	20.91	7.50
	06MAY1992	10	229.8	18.07	10	00.3	27.11	10	0.81	0.05	9	21.19	3.71

Appendix D.2. continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	08MAY1992	10	220.3	17.63	10	92.4	26.66	10	0.85	0.12	9	22.41	4.13
	11MAY1992	10	220.0	12.80	10	88.2	18.92	10	0.82	0.05	10	22.71	6.74
	13MAY1992	10	220.1	18.25	10	88.0	21.10	10	0.81	0.06	10	29.21	6.90
	15MAY1992	10	223.7	25.72	10	93.0	39.32	10	0.79	0.05	10	29.07	12.17
	18MAY1992	10	216.8	17.26	10	79.6	16.11	10	0.78	0.05	10	28.56	8.25
	20MAY1992	10	207.8	34.36	10	73.6	39.52	10	0.76	0.04	10	29.90	9.12
	22MAY 1992	10	225.2	19.31	10	87.1	23.93	10	0.74	0.06	10	24.90	7.22
	24MAY1992	10	215.6	13.38	10	77.0	13.50	10	0.76	0.04	10	31.66	6.92
	25MAY1992	10	230.4	19.76	10	96.2	24.41	10	0.77	0.03	10	25.05	5.79
	27MAY1992	10	228.6	12.19	10	91.0	18.11	10	0.75	0.05	10	30.86	9.33
	29MAY 1992	10	236.6	22.29	10	97.5	28.16	10	0.72	0.04	10	22.46	11.70
	05JUN1992	10	231.9	23.29	10	91.8	21.38	10	0.73	0.07	9	22.98	12.83
	12JUN1992	10	231.5	24.19	10	97.6	27.89	10	0.77	0.07	10	15.83	3.73
	18JUN1992	10	242.7	32.79	10	106.7	36.24	10	0.72	0.05	10	12.01	8.86
	25JUN1992	1	218.0	.	1	83.9	.	1	0.81	.	0	.	.
	26JUN1992	9	245.9	20.21	9	108.9	24.06	9	0.73	0.04	9	7.79	0.79

Appendix D.3. Summary of selected data from wild steelhead collected from the migration-at-large at the IDFG Clearwater River trap (CLW), IDFG Lewiston trap (LEW), Lower Granite Dam (LGR), Little Goose Dam (LGS), McNary Dam (MCN), and Rock Island Dam (RIS) during spring, 1992. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill $\text{Na}^+ - \text{K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
CLW	05MAY1992	2	157.0	0.00	2	34.0	1.41	2	0.90	0.04	0		
	06MAY1992	4	186.8	38.06	4	69.3	40.29	4	0.96	0.06	0		
LEW	17APR1992	10	192.1	19.66	10	65.9	24.36	10	0.89	0.07	10	13.69	6.49
	20APR1992	10	183.3	14.23	10	57.6	12.61	10	0.92	0.06	10	13.11	3.91
	22APR1992	10	189.6	19.64	10	64.3	18.87	10	0.92	0.04	10	13.71	4.65
	24APR1992	10	186.6	24.72	10	64.0	31.18	10	0.93	0.05	10	16.29	4.76
	27APR1992	2	164.0	4.24	2	40.3	4.24	2	0.91	0.03	2	20.30	1.15
	29APR1992	10	190.0	20.95	8	71.7	29.67	8	0.95	0.08	10	15.11	4.54
	30APR1992	27	186.3	14.00	27	59.2	15.20	27	0.90	0.09	0		
	01MAY1992	10	188.0	16.52	10	60.6	18.19	10	0.89	0.05	10	15.96	5.03
	04MAY1992	10	179.5	13.70	10	52.4	13.74	10	0.89	0.06	7	15.42	3.56
	06MAY1992	10	178.8	20.48	10	54.3	18.64	10	0.92	0.08	7	16.03	3.64
	08MAY1992	10	187.0	15.94	7	62.4	17.23	7	0.97	0.08	6	18.77	6.91
	11MAY1992	10	182.9	18.07	10	57.5	19.17	10	0.91	0.05	10	17.32	4.94
	13MAY1992	8	179.0	15.41	8	55.5	15.44	8	0.95	0.07	8	18.66	7.20
	15MAY1992	1	188.0		1	58.9		1	0.89		1	18.74	
	20MAY1992	3	203.3	25.9;	3	74.5	26.2;	3	0.88	0.20	3	22.07	6.69
	LGR	08APR1992	10	184.2	20.69	10	57.4	23.15	10	0.87	0.07	10	19.57	5.32
10APR1992		10	197.4	29.13	10	69.9	37.21	10	0.85	0.05	10	21.01	5.29
13APR1992		10	202.8	13.46	10	72.8	13.25	10	0.87	0.05	10	16.79	5.27
17APR1992		10	206.2	18.29	10	77.6	18.50	10	0.87	0.06	10	17.89	5.92
20APR1992		10	216.4	37.15	8	109.0	55.99	8	0.89	0.09	10	15.91	5.34
22APR1992		10	196.2	14.43	10	63.0	14.79	10	0.83	0.08	10	20.49	4.70
24APR1992		10	197.3	21.46	10	66.6	21.74	10	0.84	0.05	10	18.22	4.68
27APR1992		10	189.8	16.01	10	57.5	14.95	10	0.83	0.04	10	21.91	6.55
29APR1992		10	198.5	28.56	10	71.7	39.99	10	0.85	0.06	9	20.55	3.59
01MAY1992		10	203.4	25.83	10	73.8	31.59	10	0.84	0.06	0		
04MAY1992		10	192.3	19.90	10	63.0	22.95	10	0.85	0.07	0		
08MAY1992		10	178.1	21.40	10	49.9	17.56	10	0.86	0.06	0		
11MAY1992		10	190.5	27.17	9	55.1	17.39	9	0.86	0.06	10	19.8	4.9;
13MAY1992		10	197.3	35.57	10	74.0	50.92	10	0.87	0.04	10	22.46	4.21
15MAY1992		10	180.6	31.03	10	56.1	31.43	10	0.88	0.06	10	21.55	5.85
18MAY1992		10	184.8	18.79	10	54.3	14.94	10	0.85	0.06	10	25.21	7.56
20MAY1992		10	179.1	13.06	10	47.8	10.40	10	0.82	0.06	10	20.25	5.64
22MAY1992	10	189.1	19.73	10	56.3	17.16	10	0.82	0.09	10	22.06	8.22	
25MAY1992	10	196.2	31.95	10	73.1	39.11	10	0.90	0.07	10	21.59	6.88	
27MAY1992	9	210.6	28.70	9	80.0	34.04	9	0.82	0.06	9	21.67	10.72	
29MAY1992	10	193.5	21.89	10	64.6	26.20	10	0.85	0.06	10	21.10	10.17	
01JUN1992	10	185.0	13.35	10	54.6	12.22	10	0.85	0.07	10	20.62	5.29	

Appendix D.3 continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	03JUN1992	10	210.8	13.01	10	78.8	14.42	10	0.84	0.07	10	6.25	9.71
	05JUN1992	10	210.5	19.63	10	79.4	23.27	10	0.83	0.06	10	19.96	7.77
	11JUN1992	15	199.2	21.10	15	68.0	31.36	15	0.81	0.14	15	11.05	8.49
	17JUN1992	15	204.9	15.52	15	70.7	18.06	15	0.81	0.00	15	13.34	7.29
	24JUN1992	15	217.8	27.00	15	82.2	38.71	15	0.75	0.12	15	8.40	2.82
	01JUL1992	14	198.0	23.96	14	65.0	23.09	14	0.82	0.11	12	6.13	1.38
	08JUL1992	13	239.4	99.46	13	101.2	58.78	13	0.82	0.22	12	6.26	0.97
GR	09JUL1992	3	190.3	13.58	3	59.2	9.64	3	0.86	0.10	3	6.52	1.51
	14JUL1992	4	213.3	26.70	4	87.1	24.49	4	0.89	0.09	4	7.52	2.12
	15JUL1992	4	191.8	7.14	4	63.7	8.87	4	0.90	0.11	3	4.75	0.64
	16JUL1992	3	203.3	20.65	3	76.6	24.62	3	0.89	0.06	2	7.60	3.73
	22JUL1992	2	206.0	11.31	2	81.5	1.98	2	0.94	0.13	2	7.35	1.17
	23JUL1992	2	228.5	38.89	2	80.7	4.17	2	0.73	0.33	2	6.53	1.97
	24JUL1992	5	222.0	14.09	5	103.4	20.13	5	0.94	0.02	3	6.53	0.98
GS	21APR1992	3	181.0	17.52	3	48.7	13.20	3	0.81	0.01	3	13.24	3.16
	30APR1992	1a	188.1	18.05	10	55.5	17.68	10	0.81	0.05	1a	16.07	6.83
	12MAY1992	7	185.3	24.05	7	56.7	23.60	7	0.85	0.04	7	13.41	1.26
	19MAY1992	8	166.3	12.08	8	54.3	9.40	8	0.81	0.04	8	7.10	1.45
IS	20APR1992	11	183.4	20.56	11	57.5	19.23	11	0.90	0.06	11	6.16	5.02
	22APR1992	10	169.4	20.09	10	45.0	15.99	10	0.89	0.07	10	4.50	6.34
	24APR1992	10	177.5	27.20	10	55.0	29.32	10	0.92	0.07	10	13.55	4.29
	27APR1992	10	185.1	24.09	10	57.9	23.20	10	0.87	0.06	9	9.90	2.97
	29APR1992	1a	178.3	20.65	10	50.9	14.75	10	0.87	0.05	8	14.37	6.51
	01MAY1992	10	166.9	21.17	10	43.2	15.26	10	0.90	0.06	10	2.73	3.57
	04MAY1992	10	172.4	17.24	10	45.4	13.24	10	0.86	0.04	9	6.60	4.83
	06MAY1992	1a	185.4	17.45	10	54.4	18.07	10	0.83	0.04	9	19.99	5.26
	08MAY1992	10	174.4	10.95	10	47.0	10.11	10	0.80	0.05	8	8.19	4.03
	11MAY1992	1a	178.6	31.71	10	54.6	36.24	10	0.80	0.03	10	19.42	6.56
	13MAY1992	10	172.5	20.50	10	45.6	14.43	10	0.86	0.04	9	10.28	3.85
	15MAY1992	10	159.4	16.67	10	36.9	11.08	10	0.89	0.08	9	10.99	6.58
	18MAY1992	10	171.7	8.38	10	44.8	6.30	10	0.80	0.05	10	12.31	7.70
	20MAY1992	10	166.8	14.51	10	41.5	10.90	10	0.87	0.04	10	13.47	4.89
	22MAY1992	1a	162.7	12.16	10	37.9	8.39	10	0.87	0.08	1a	16.85	8.63
	25MAY1992	10	175.4	19.53	10	50.5	17.13	10	0.90	0.05	10	12.43	4.37
	27MAY1992	10	180.5	21.14	10	56.2	20.69	10	0.92	0.06	1a	15.62	7.05
	29MAY1992	1a	187.6	23.74	10	62.1	22.94	10	0.91	0.04	1a	13.71	10.23
ICN	27APR1992	10	189.9	29.18	10	67.3	39.52	10	0.91	0.08	9	9.68	4.42
	29APR1992	10	195.9	16.88	10	62.5	15.60	10	0.82	0.07	10	13.45	7.92
	01MAY1992	10	206.4	22.67	10	75.3	25.14	10	0.83	0.07	10	19.79	7.40
	04MAY1992	10	212.4	25.81	10	80.8	31.73	10	0.80	0.05	9	15.81	7.38
	06MAY1992	1a	186.0	13.06	10	53.5	14.24	10	0.81	0.06	9	12.12	8.93
	08MAY1992	1a	187.9	32.98	10	63.6	32.59	10	0.95	0.39	9	14.52	6.83
	11MAY1992	10	192.3	28.37	10	58.5	24.46	10	0.78	0.05	1a	16.35	7.41
	13MAY1992	1a	185.0	13.11	10	53.4	11.37	10	0.85	0.19	10	18.36	10.49

Appendix D.3 continued.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
	15MAY1992	10	189.9	18.58	10	57.1	16.73	10	0.81	0.08	10	24.36	6.99
	18MAY1992	10	182.7	25.66	10	50.5	21.46	10	0.79	0.05	10	30.95	7.86
	20MAY1992	10	184.0	14.56	10	50.9	12.58	10	0.80	0.07	10	32.04	8.06
	22MAY1992	10	187.6	26.88	10	57.8	28.66	10	0.82	0.05	9	35.81	8.52
	25MAY1992	10	189.6	21.69	10	59.0	19.38	10	0.83	0.07	10	23.00	9.55
	27MAY1992	10	183.3	13.70	10	49.5	12.22	10	0.79	0.04	10	36.86	7.04
	29MAY1992	10	196.3	24.70	10	63.4	26.29	10	0.80	0.05	9	27.83	10.58
	05JUN1992	10	198.0	28.80	10	65.4	23.98	10	0.82	0.07	10	17.39	9.73
	12JUN1992	10	211.5	41.71	10	87.5	57.45	10	0.84	0.05	10	15.61	5.15
	18JUN1992	10	216.4	21.73	10	84.2	25.15	10	0.81	0.08	10	12.18	4.92
	25JUN1992	1	218.0		1	85.1		1	0.82	.	0		.
	26JUN1992	6	231.5	35.46	6	107.8	53.6	6	0.82	0.08	6	10.56	3.91

Appendix D.4. Summary of selected data from subyearling fall chinook salmon collected from the migration-at-large at Bonneville Dam first powerhouse (BON), John Day Dam (JDA), and McNary Dam (MCN) during spring, 1992. Data includes sample size (N), mean (MEAN), and standard deviation (STD) of fork length in millimeters, wet weight in grams, and gill $\text{Na}^+\text{-K}^+$ ATPase activity in $\mu\text{moles P}_i \cdot \text{mg prot}^{-1} \cdot \text{h}^{-1}$.

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD
MCN	05JUN1992	20	99.4	20.46	20			20	1.08	0.07	20	19.98	5.57
	12JUN1992	20	117.3	8.49	20	18.0	3.86	20	1.10	0.05	20	34.96	7.43
	18JUN1992	20	109.3	7.79	20	13.8	2.96	20	1.04	0.07	20	27.23	5.52
	25JUN1992	20	105.4	3.63	20	12.8	1.42	20	1.09	0.08	16	26.98	8.62
	03JUL1992	22	104.1	5.70	22	12.1	2.22	22	1.07	0.09	20	31.36	6.71
	10JUL1992	20	108.2	7.37	20	14.4	2.62	20	1.13	0.06	20	30.83	10.30
	17JUL1992	20	112.1	4.71	20	16.0	2.13	20	1.13	0.05	20	23.16	6.63
	24JUL1992	19	119.4	5.33	19	19.8	2.79	19	1.16	0.07	19	19.25	6.90
	31JUL1992	20	125.2	7.54	20	23.1	3.64	20	1.17	0.05	20	29.45	10.24
	07AUG1992	20	126.7	6.84	20	23.6	4.26	20	1.15	0.07	20	24.67	10.64
	14AUG1992	20	133.8	7.76	20	28.9	5.34	20	1.20	0.09	20	19.44	7.01
	21AUG1992	20	130.6	9.36	20	25.3	5.75	20	1.12	0.05	20	25.28	7.99
	27AUG1992	20	135.1	10.19	20	27.1	6.56	20	1.08	0.08	20	17.26	7.09
	04SEP1992	20	138.2	13.62	20	29.9	10.66	20	1.09	0.07	20	21.30	7.50
JDA	29JUN1992	20	125.0	7.47	20	22.01	3.93	20	1.12	0.051	20	21.19	9.52
	08JUL1992	20	117.6	6.87	20	16.7	3.58	20	1.02	0.11	20	22.18	12.91
	16JUL1992	20	119.1	5.90	20	18.2	4.04	20	1.07	0.16	20	17.92	8.54
	23JUL1992	20	119.3	6.36	20	18.3	3.88	20	1.07	0.14	20	16.41	6.35
	30JUL1992	20	123.3	6.78	20	20.2	4.66	20	1.06	0.11	20	20.32	7.41
	06AUG1992	20	128.1	7.15	20	23.3	3.95	20	1.10	0.07	20	21.24	11.11
	13AUG1992	20	128.2	5.58	20	22.1	3.56	20	1.04	0.06	18	18.74	7.92
	20AUG1992	20	133.7	7.79	20	26.5	5.60	20	1.10	0.08	20	25.75	10.01
	27AUG1992	5	130.0	8.43	5	24.6	5.32	5	1.11	0.10	5	17.91	10.14
BON	13JUL1992	20	108.0	10.70	20	14.5	4.22	20	1.13	0.10	20	31.11	8.95
	20JUL1992	20	115.7	8.91	20	18.1	4.17	20	1.15	0.05	20	30.53	7.17
	27JUL1992	20	116.2	10.65	20	18.7	5.84	20	1.16	0.10	20	30.16	8.88
	03AUG1992	20	126.1	13.72	20	23.3	6.69	20	1.12	0.06	20	31.65	6.08
	10AUG1992	20	116.1	21.65	20	18.9	8.91	20	1.10	0.08	20	25.57	8.53
	17AUG1992	20	122.2	14.64	20	19.8	6.76	20	1.04	0.06	20	30.07	10.12
	24AUG1992	20	116.3	16.36	20	17.6	7.03	20	1.05	0.08	20	25.19	7.23
	31AUG1992	19	118.7	17.80	19	18.0	7.60	19	0.99	0.08	19	26.75	11.16

Appendix E.1. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Dworshak NFH sampled during spring, 1991. Fish were collected at the hatchery (BAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA OD				
		N	MEAN	STDERR	MIN	MAX
HAT	02APR1991	99	0.238	0.049	0.050	2.770
LGR	15APR1991	7	0.710	0.374	0.094	2.793
	16APR1991	1	0.158		0.158	0.158
	17APR1991	1	2.563		2.563	2.563
	18APR1991	8	0.687	0.339	0.091	2.795
	19APR1991	6	1.305	0.528	0.063	2.973
	22APR1991	2	1.205	1.133	0.071	2.338
	23APR1991	6	0.856	0.492	0.079	3.112
	24APR1991	24	0.718	0.204	0.071	2.805
	26APR1991	2	0.275	0.170	0.105	0.445
	27APR1991	13	0.693	0.303	0.070	2.952
	28APR1991	14	0.608	0.264	0.071	2.817
	30APR1991	11	0.388	0.155	0.085	1.536
	01MAY1991	3	0.089	0.015	0.072	0.119
	02MAY1991	4	1.128	0.663	0.076	2.878
	03MAY1991	5	1.174	0.589	0.120	3.126
	06MAY1991	2	0.267	0.163	0.104	0.430
	07MAY1991	2	0.079	0.001	0.078	0.080
	08MAY1991	8	0.439	0.272	0.074	2.318
	09MAY1991	8	0.466	0.180	0.097	1.422
	10MAY1991	1	0.158		0.156	0.158
	13MAY1991	1	0.573		0.573	0.573
	20MAY1991	1	0.307		0.307	0.307
MCN	10MAY1991	7	0.284	0.133	0.055	1.060
	11MAY1991	5	0.121	0.034	0.070	0.250
	12MAY1991	5	0.649	0.346	0.075	1.533
	13MAY1991	2	0.516	0.431	0.085	0.947
	14MAY1991	4	1.092	0.658	0.089	3.004
	17MAY1991	8	0.291	0.118	0.061	1.056
	18MAY1991	9	0.663	0.272	0.085	1.982
	19MAY1991	3	0.086	0.015	0.071	0.115
	20MAY1991	7	0.829	0.362	0.076	2.421
	21MAY1991	1	0.107		0.107	0.107
	23MAY1991	1	0.061		0.081	0.081
	24MAY1991	1	0.146		0.146	0.146
	25MAY1991	2	0.065	0.003	0.064	0.066

Appendix E.2. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Entiat NFH sampled during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00			
		N	MEAN	STDERR	MIN | MAX
HAT	02APR1991	55	0.153	0.049	0.052 | 2.179
RIS	23APR1991	1	0.315	.	0.315 | 0.315
	28APR1991	1	0.067	.	0.067 | 0.067
	29APR1991	1	0.141	.	0.141 | 0.141
	01MAY1991	2	0.220	0.100	0.120 | 0.320
	05MAY1991	1	0.069	.	0.069 | 0.069
	07MAY1991	1	0.069	.	0.069 | 0.069
	08MAY1991	1	0.072	.	0.072 | 0.072
	13MAY1991	1	0.121	.	0.121 | 0.121
	14MAY1991	1	0.069	.	0.069 | 0.069
	MCN	11MAY1991	11	0.091	0.003	0.039 | 0.123
12MAY1991		9	0.114	0.023	0.043 | 0.266
17MAY1991		15	0.511	0.191	0.076 | 2.560
18MAY1991		6	0.163	0.057	0.069 | 0.430
23MAY1991		2	0.170	0.097	0.073 | 0.266
24MAY1991		5	0.126	0.035	0.063 | 0.252
25MAY1991		9	0.195	0.064	0.072 | 0.627
28MAY1991		6	0.400	0.305	0.066 | 1.927
29MAY1991		1	0.110	.	0.110 | 0.110
03JUN1991		1	0.461	.	0.461 | 0.461
17MAY1991	1	0.217	.	0.217 | 0.217	

Appendix E.3. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Leavenworth NFH sampled during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	16APR1991	57	0.088	0.003	0.040	0.150
RIS	20APR1991	6	0.119	0.016	0.089	0.196
	22APR1991	4	0.095	0.009	0.072	0.114
	23APR1991	2	0.110	0.028	0.081	0.138
	24APR1991	3	0.293	0.158	0.090	0.604
	28APR1991	5	0.397	0.150	0.115	0.922
	29APR1991	1	0.159	.	0.159	0.159
	30APR1991	1	0.261	0.261	0.261	0.261
	01MAY1991	1	0.084	0.084	0.084	0.084
	05MAY1991	3	0.125	0.026	0.085	0.174
	07MAY1991	6	0.134	0.030	0.076	0.276
	08MAY1991	7	0.103	0.012	0.069	0.151
	09MAY1991	4	0.088	0.005	0.075	0.101
	12MAY1991	2	0.143	0.056	0.087	0.198
	13MAY1991	4	0.194	0.106	0.082	0.513
	14MAY1991	4	0.111	0.023	0.068	0.176
	17MAY1991	3	0.086	0.014	0.070	0.114
MCN	11MAY1991	11	0.098	0.015	0.039	0.241
	12MAY1991	13	0.112	0.010	0.044	0.194
	13MAY1991	21	0.134	0.034	0.058	0.803
	14MAY1991	12	0.121	0.012	0.075	0.196
	20MAY1991	28	0.119	0.013	0.068	0.405
	21MAY1991	28	0.132	0.012	0.058	0.271
	24MAY1991	30	0.129	0.017	0.070	0.491
	31MAY1991	1	0.094	.	0.094	0.094
	21MAY1991	1	0.070	.	0.070	0.070

Appendix E.4. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from McCall SFH sampled during spring, 1991. Fish were collected at the hatchery (RAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	19MAR1991	44	0.083	0.020	0.030	0.913
LGR	25APR1991	1	0.225		0.225	0.225
	26APR1991	1	0.082		0.082	0.082
	28APR1991	1	0.309		0.309	0.309
	30APR1991	1	0.204		0.204	0.204
	01MAY1991	4	0.129	0.014	0.097	0.159
	03MAY1991	1	0.111		0.111	0.111
	06MAY1991	5	0.256	0.11;	0.086	0.696
	07MAY1991	1	0.143		0.143	0.143
	08MAY1991	3	0.135	0.029	0.079	0.178
	09MAY1991	10	0.267	0.052	0.078	0.593
	10MAY1991	3	0.141	0.031	0.098	0.200
	13MAY1991	3	0.151	0.048	0.097	0.247
	14MAY1991	2	0.084	0.030	0.054	0.114
	15MAY1991	5	0.109	0.019	0.074	0.177
	16MAY1991	3	0.069	0.009	0.051	0.079
	17MAY1991	7	0.149	0.028	0.096	0.303
	20MAY1991	4	0.107	0.009	0.085	0.129
	21MAY1991	10	0.361	0.202	0.088	2.160
	22MAY1991	8	0.116	0.021	0.072	0.240
	23MAY1991	1	0.406		0.406	0.406
	24MAY1991	2	0.264	0.143	0.121	0.406
MCN	24MAY1991	4	0.114	0.023	0.071	0.178
	25MAY1991	8	0.200	0.081	0.076	0.752
	28MAY1991	5	0.155	0.018	0.107	0.209
	29MAY1991	2	0.094	0.006	0.088	0.100
	31MAY1991	3	0.263	0.084	0.127	0.415
	03JUN1991	1	0.272		0.272	0.272
	12JUN1991	3	0.133	0.029	0.082	0.183

Appendix E.5. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Ringold SFH sampled during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKO ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	18MAR1991	19	0.156	0.053	0.064	1.096
MCN	05APR1991	20	0.034	0.021	0.047	0.483
	08APR1991	20	0.084	0.009	0.061	0.216
	12APR1991	26	0.118	0.034	0.047	0.825
	19APR1991	19	0.160	0.080	0.062	1.602
	01APR1991	20	0.135	0.036	0.062	0.800

Appendix E.6. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Rapid River SFH sampled during spring, 1991. Fish were collected at the hatchery (RAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	20MAR1991	57	0.079	0.005	0.035	0.314
LGR	18APR1991	4	0.358	0.152	0.107	0.775
	19APR1991	3	0.172	0.056	0.075	0.268
	22APR1991	2	0.213	0.031	0.182	0.244
	23APR1991	5	0.092	0.009	0.068	0.120
	24APR1991	17	0.278	0.069	0.074	0.861
	01MAY1991	9	0.102	0.010	0.067	0.157
	02MAY1991	1	0.084		0.084	0.084
	03MAY1991	2	0.115	0.01s	0.097	0.133
	06MAY1991	3	0.161	0.071	0.073	0.302
	08MAY1991	1	0.477		0.477	0.477
	09MAY1991	6	0.111	0.01;	0.072	0.163
	10MAY1991	2	0.523	0.432	0.091	0.955
	13MAY1991	2	0.095	0.027	0.067	0.122
	14MAY1991	1	0.051		0.051	0.051
	15MAY1991	1	0.079		0.079	0.079
	16MAY1991	1	0.087		0.087	0.087
	17MAY1991	1	0.095		0.095	0.095
	20MAY1991	1	0.074		0.074	0.074
MCN	10MAY1991	5	0.093	0.00s	0.071	0.102
	11MAY1991	6	0.220	0.103	0.075	0.727
	12MAY1991	6	0.135	0.035	0.074	0.308
	13MAY1991	1	0.103		0.103	0.103
	17MAY1991	8	0.235	0.101	0.074	0.908
	18MAY1991	4	0.116	0.005	0.102	0.123
	20MAY1991	6	0.171	0.053	0.068	0.421
25MAY1991	3	0.075	0.010	0.063	0.094	

Appendix E.7. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Sawtooth SFH sampled during spring, 1991. Fish were collected at the hatchery (BAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAE) optical densities.

SITE	DATE	BKD ELISA 00					
		N	MEAN	STDERR	MIN	MAX	
BAT	20FEB1991	13	0.073	0.005	0.061	0.127	
LGR	24APR1991	5	0.134	0.032	0.071	0.252	
	25APR1991	11	0.309	0.127	0.083	1.518	
	27APR1991	4	0.186	0.074	0.097	0.407	
	28APR1991	1	0.106	.	0.106	0.106	
	30APR1991	1	0.114	.	0.114	0.114	
	01MAY1991	2	0.135	0.036	0.099	0.171	
	07MAY1991	1	0.213	.	0.213	0.213	
	08MAY1991	1	0.077	.	0.077	0.077	
	09MAY1991	1	0.134	.	0.134	0.134	
	10MAY1991	1	0.249	.	0.249	0.249	
	13MAY1991	1	0.088	.	0.088	0.088	
	MCN	12MAY1991	1	0.106	.	0.106	0.106
		17MAY1991	2	0.099	0.00;	0.096	0.102
20MAY1991		1	0.159	.	0.159	0.159	
07MAR1991		86	0.089	0.00;	0.036	0.165	

Appendix E.8. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Winthrop NFH sampled during spring, 1991. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	10APR1991	59	0.324	0.064	0.034	2.272
RIS	24APR1991	1	1.315	.	1.315	1.315
	29APR1991	1	0.600	.	0.600	0.600
	30APR1991	1	0.116	.	0.116	0.116
	01MAY1991	1	0.142	.	0.142	0.142
	05MAY1991	1	1.486	.	1.486	1.486
	08MAY1991	4	0.528	0.331	0.073	1.478
	09MAY1991	4	0.606	0.525	0.068	2.180
	12MAY1991	2	0.288	0.201	0.087	0.489
	13MAY1991	3	0.737	0.427	0.086	1.541
	14MAY1991	1	0.088	.	0.088	0.088
MCN	17MAY1991	2	0.198	0.068	0.130	0.265
	21MAY1991	7	0.545	0.333	0.079	2.472
	12MAY1991	22	0.597	0.148	0.065	2.103
	13MAY1991	23	0.650	0.162	0.072	2.721
	14MAY1991	10	0.435	0.204	0.070	1.981
	17MAY1991	14	0.616	0.191	0.074	2.118
	18MAY1991	12	0.678	0.221	0.091	2.571
	19MAY1991	12	0.433	0.207	0.041	2.421
	20MAY1991	11	0.303	0.118	0.075	1.097
	21MAY1991	6	0.642	0.357	0.093	2.293
	23MAY1991	10	0.463	0.271	0.054	2.861
	24MAY1991	14	0.245	0.152	0.037	2.213
	25MAY1991	10	0.465	0.224	0.065	2.071
	28MAY1991	17	0.564	0.198	0.065	2.771
	29MAY1991	4	0.237	0.113	0.069	0.551
31MAY1991	4	0.275	0.172	0.081	0.791	
03JUN1991	3	1.342	0.820	0.196	2.932	

Appendix F.1. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Dworshak NFH sampled during spring, 1992 Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
AT	16APR1992	00	0.126	0.033	0.042	2.906
GR	04MAY1992	7	0.153	0.044	0.055	0.359
	07MAY1992	6	0.319	0.247	0.062	1.552
	08MAY1992	5	0.099	0.011	0.070	0.125
	11MAY1992	2	0.148	0.072	0.076	0.220
	12MAY1992	5	0.079	0.008	0.063	0.110
	13MAY1992	1	0.061	.	0.061	0.061
	15MAY1992	8	0.067	0.006	0.042	0.092
CN	05MAY1992	1	0.066	.	0.066	0.066
	06MAY1992	1	0.052	.	0.052	0.052
	08MAY1992	2	0.065	0.008	0.057	0.073
	09MAY1992	2	0.058	0.008	0.050	0.065
	10MAY1992	5	0.062	0.004	0.051	0.073
	11MAY1992	1	0.064	.	0.064	0.064
	12MAY1992	2	0.061	0.003	0.058	0.064
	13MAY1992	11	0.059	0.003	0.051	0.078
	14MAY1992	10	0.258	0.194	0.055	2.002
	16MAY1992	5	0.067	0.004	0.059	0.083
	18MAY1992	1	0.052	.	0.052	0.052
	19MAY1992	4	0.069	0.00;	0.064	0.072
	20MAY1992	10	0.096	0.020	0.064	0.251
	21MAY1992	7	0.169	0.107	0.053	0.811
	22MAY1992	3	0.111	0.050	0.061	0.211
	23MAY1992	2	0.066	0.004	0.062	0.070
	24MAY1992	2	0.078	0.007	0.071	0.086
	25MAY1992	7	0.148	0.084	0.056	0.652
	27MAY1992	1	0.090	.	0.090	0.090
	28MAY1992	8	0.094	0.011	0.067	0.167
	29MAY1992	10	0.074	0.005	0.062	0.115
	31MAY1992	5	0.218	0.125	0.060	0.715

Appendix F.2. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Entiat NFH sampled during spring, 1992. Fish were collected at the hatchery (RAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	13APR1992	60	0.060	0.001	0.050	0.076
RIS	20APR1992	2	0.071	0.010	0.061	0.080
	21APR1992	5	0.064	0.003	0.057	0.074
	22APR1992	4	0.059	0.004	0.050	0.069
	23APR1992	1	0.079	.	0.079	0.079
	30APR1992	1	0.060	.	0.060	0.060
	01MAY1992	1	0.090	.	0.090	0.090
	06MAY1992	1	0.136	.	0.136	0.136
	07MAY1992	1	0.066	.	0.066	0.066
MCN	06MAY1992	20	0.098	0.023	0.060	0.533
	09MAY1992	20	0.064	0.002	0.052	0.088
	14MAY1992	20	0.091	0.030	0.052	0.654

Appendix F.3. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Leavenworth NFH sampled during spring, 1992. Fish were collected at the hatchery (BAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT RIS	15APR1992	99	0.061	0.001	0.032	0.109
	22APR1992	11	0.094	0.031	0.046	0.404
	23APR1992	6	0.077	0.013	0.058	0.144
	24APR1992	4	0.074	0.007	0.058	0.091
	27APR1992	2	0.069	0.000	0.069	0.069
	28APR1992	7	0.098	0.007	0.079	0.131
	29APR1992	8	0.070	0.003	0.057	0.082
	30APR1992	3	0.051	0.008	0.035	0.063
	01MAY1992	3	0.074	0.004	0.068	0.082
	05MAY1992	3	0.078	0.006	0.067	0.085
	06MAY1992	12	0.183	0.077	0.061	1.007
	07MAY1992	16	0.076	0.005	0.045	0.120
	08MAY1992	11	0.086	0.010	0.058	0.174
	11MAY1992	1	0.065		0.065	0.065
	12MAY1992	5	0.109	0.02	0.067	0.175
	13MAY1992	2	0.072	0.004	0.068	0.076
	14MAY1992	3	0.070	0.003	0.065	0.075
	15MAY1992	1	0.083		0.083	0.083
	MCN	13MAY1992	34	0.129	0.043	0.054
17MAY1992		34	0.170	0.074	0.051	2.375
19MAY1992		14	0.070	0.003	0.057	0.109
20MAY1992		19	0.069	0.002	0.051	0.084

Appendix F.4. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from McCall SFH sampled during spring, 1992. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	11MAR1992	58	0.087	0.009	0.047	0.459
LGR	17APR1992	3	0.238	0.118	0.110	0.473
	20APR1992	4	0.145	0.027	0.115	0.227
	21APR1992	3	0.315	0.053	0.216	0.399
	22APR1992	10	0.309	0.095	0.089	1.011
	23APR1992	13	0.107	0.009	0.072	0.183
	24APR1992	3	0.324	0.248	0.076	0.819
	27APR1992	10	0.143	0.018	0.087	0.238
	28APR1992	16	0.112	0.011	0.065	0.207
	01MAY1992	20	0.402	0.113	0.065	2.051
	04MAY1992	3	0.307	0.046	0.218	0.371
MCN	30APR1992	1	0.199	.	0.199	0.199
	04MAY1992	3	0.153	0.031	0.105	0.210
	05MAY1992	4	0.534	0.149	0.090	0.737
	06MAY1992	7	0.427	0.188	0.067	1.290
	09MAY1992	11	0.547	0.120	0.071	1.515
	10MAY1992	7	0.750	0.197	0.065	1.315
	11MAY1992	6	0.471	0.189	0.074	1.161
	12MAY1992	1	0.093	.	0.093	0.093
	14MAY1992	16	0.587	0.143	0.077	1.928
	15MAY1992	3	1.184	0.206	0.803	1.512
	22MAY1992	5	0.975	0.454	0.106	2.496
	28MY 1992	11	1.145	0.228	0.091	2: 138
	31MAY1992	5	1.906	0.515	0.080	2.718

Appendix F.5. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Ringold SFH sampled during spring, 1992. Fish were collected at the hatchery (HAT) shortly before release and at McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	31MAR1992	60	0.104	0.004	0.048	0.207
MCN	04APR1992	16	0.172	0.064	0.061	1.087
	06APR1992	19	0.114	0.016	0.064	0.334
	18APR1992	18	0.294	0.082	0.043	1.292
	27APR1992	2	0.164	0.059	0.105	0.223

Appendix F.6. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Rapid River SFH sampled during spring, 1992. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
MT	12MAR1992	59	1.140	0.108	0.058	2.898
LGR	13APR1992	5	0.457	0.276	0.076	1.554
	17APR1992	19	0.631	0.191	0.074	3.028
	21APR1992	11	0.837	0.327	0.076	2.724
	27APR1992	12	0.105	0.010	0.063	0.155
	28APR1992	8	0.120	0.034	0.066	0.346
	01MAY1992	19	0.581	0.153	0.074	2.656
MCN	30APR1992	1	0.409		0.409	0.409
	01MAY1992	9	0.278	0.11s	0.072	1.095
	04MAY1992	10	0.406	0.154	0.065	1.214
	08MAY1992	9	0.576	0.241	0.061	2.182
	09MAY1992	11	0.234	0.099	0.058	1.063
	13MAY1992	4	1.009	0.496	0.093	2.105
	14MAY1992	9	0.836	0.238	0.087	1.772
15MAY1992	6	0.477	0.230	0.071	1.439	

Appendix F.7. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Sawtooth SFH sampled during spring, 1992. Fish were collected at the hatchery (HAT) shortly before release and at Lower Granite Dam (LGR) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN); standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00					
		N	MEAN	STDERR	MIN	MAX	
HAT	10MAR1992	60	0.155	0.043	0.055	1.862	
	LGR	13APR1992	6	0.173	0.098	0.000	0.652
		17APR1992	22	0.313	0.039	0.097	0.837
		20APR1992	12	0.671	0.309	0.078	2.941
		21APR1992	11	0.220	0.057	0.073	0.691
		22APR1992	9	0.115	0.020	0.071	0.256
		23APR1992	7	0.548	0.461	0.047	3.313
		24APR1992	2	0.084	0.013	0.072	0.097
		27APR1992	5	0.067	0.002	0.062	0.070
		28APR1992	5	0.090	0.020	0.064	0.171
		01MAY1992	11	0.398	0.233	0.071	2.694
		04MAY1992	1	0	0.80	0.080	0.080
		07MAY1992	1	0.179		0.179	0.179
		08MAY1992	2	0.077	0.008	0.069	0.086
		15MAY1992	1	0.106		0.106	0.106
MCN	27APR1992	5	0.085	0.006	0.073	0.104	
	28APR1992	5	0.094	0.008	0.071	0.114	
	29APR1992	2	0.073	0.004	0.069	0.077	
	30APR1992	3	0.095	0.009	0.078	0.108	
	01MAY1992	5	0.094	0.017	0.071	0.161	
	04MAY1992	8	0.090	0.008	0.068	0.130	
	05MAY1992	7	0.069	0.004	0.061	0.092	
	07MAY1992	2	0.373	0.295	0.078	0.666	
	08MAY1992	4	0.082	0.011	0.062	0.109	
	09MAY1992	1	0.072		0.072	0.072	
	10MAY1992	3	0.063	0.00;	0.060	0.067	
	11MAY1992	1	0.064		0.064	0.064	
	13MAY1992	3	0.112	0.019	0.089	0.151	
	15MAY1992	1	0.075		0.075	0.075	
	16MAY1992	1	0	0.82	0.082	0.082	
	19MAY1992	1	0.057		0.057	0.057	
	21MAY1992	2	0.083	0.00;	0.080	0.085	
22MAY 1992	1	0.999		0.999	0.999		
24MAY 1992	2	0.071	0.00;	0.067	0.075		
25MAY1992	1	0.066		0.066	0.066		
28MAY1992	1	0.073		0.073	0.073		
29MAY 1992	1	0.079		0.079	0.079		

Appendix F.8. Bacterial kidney disease ELISA optical densities for juvenile spring chinook from Winthrop NFH sampled during spring, 1992. Fish were collected at the hatchery (HAT) shortly before release and at Rock Island Dam (RIS) and McNary Dam (MCN) during their seaward migration. Data includes sample size (N), mean (MEAN), standard error (STDERR), minimum (MIN), and maximum (MAX) optical densities.

SITE	DATE	BKD ELISA 00				
		N	MEAN	STDERR	MIN	MAX
HAT	13APR1992	84	0.098	0.024	0.052	2.016
	14APR1992	16	0.070	0.003	0.058	0.094
RIS	28APR1992	2	0.110	0.044	0.066	0.154
	29APR1992	1	0.080		0.080	0.080
	30APR1992	1	0.072		0.072	0.072
	01MAY1992	2	0.069	0.007	0.062	0.076
	06MAY1992	3	0.100	0.026	0.067	0.151
	07MAY1992	3	0.084	0.006	0.073	0.093
	08MAY1992	3	0.061	0.010	0.042	0.078
	11MAY1992	2	0.071	0.008	0.062	0.079
	12MAY1992	1	0.164		0.164	0.164
	13MAY1992	3	0.086	0.020	0.062	0.127
	15MAY1992	5	0.072	0.005	0.061	0.089
	18MAY1992	3	0.098	0.020	0.073	0.137
	20MAY1992	2	0.068	0.003	0.065	0.071
	MCN	10MAY1992	16	0.073	0.004	0.057	0.106
11MAY1992		17	0.085	0.016	0.058	0.346
12MAY1992		1	0.064		0.064	0.064
14MAY1992		32	0.076	0.008	0.051	0.300
18MAY1992		36	0.078	0.007	0.051	0.252