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**ASSESSMENT OF SMOLT CONDITION  
FOR TRAVEL TIME ANALYSIS  
SUMMARY REPORT 1999**



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# Assessment of Smolt Condition for Travel Time Analysis

## Summary Report 1999



**U. S. Department of the Interior  
U. S. Geological Survey, Biological Resources Division  
Columbia River Research Laboratory  
Western Fisheries Research Center**

**U. S. Department of Energy  
Bonneville Power Administration  
Division of Fish and Wildlife**

# **Assessment of Smolt Condition for Travel Time Analysis**

## **Summary Report**

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## EXECUTIVE SUMMARY AND RECOMMENDATIONS

The Assessment of Smolt Condition for Travel Time Analysis (ASCTTA) project has conducted monitoring and evaluation of juvenile salmonid health, condition, and emigration characteristics since 1987. The major purpose of the project was to determine how physiological condition influenced travel time or emigration rates. During the past thirteen years, major innovations in fish passage have improved mitigation for the impounded Columbia and Snake Rivers (Whitney et al. 1997). One of the most important changes has been the institution of prescribed flows to enhance the juvenile salmonid migration. Increased flows in the mainstem, spill at dams, and passage improvements have helped reduce delayed emigration caused by the decreased spring and summer flows that result from water storage in the Federal Columbia River Power System (NMFS 1999a). Because these improvements were made, physiological monitoring activities by ASCTTA in support of the Smolt Monitoring Program (SMP) of the Fish Passage Center (FPC) were completed in 1996. Changes in flow management in the rivers have resulted in a migration environment much different from 1987 (NMFS 2000a). The project now focuses on examining long-term variation in physiological and environmental factors that might explain differences in growth, migration, and survival among Columbia basin salmonid stocks. The ultimate goal is to provide information to regional fish managers to further management actions that maximize survival of Columbia basin salmonids throughout the entire life cycle.

Analysis to determine the effects of biotic and abiotic factors on travel time for the period of 1993 –1996 was conducted to conclude the long-term analysis reported previously for 1989 – 1992 (Maule et al. 1994). The earlier analysis for Columbia and Snake River juvenile spring chinook salmon and steelhead determined that river-flow, change in flow, gill  $\text{Na}^+$ ,  $\text{K}^+$ -activated ATPase activity, condition factor, and water temperature were significant variables in regressions predicting juvenile spring chinook travel times. Furthermore, river flow was the single significant variable describing travel time for steelhead, and travel times predicted for wild steelhead were shorter than for hatchery steelhead. Similar analysis for spring chinook salmon in the Snake River for 1993-1996, presented in this report, identified the reciprocal of river flow, release date, and gill ATPase activity as significant explanatory variables in the regression analysis. A decrease in travel time was identified with an increase in flow in both analyses.

Salmonid stocks in the Columbia basin have continued to decline despite massive production efforts to mitigate for losses due to degraded habitat, impoundment, and human development (Independent Science Group 1996). Greater numbers of hatchery fish compared to wild fish further endanger wild populations through competition, displacement, and predation (Swain and Ridell 1990, Ritter 1997, McMichael et al. 1999). Characterization of the physiology of wild and hatchery juvenile salmonids became an important monitoring focus to better understand differences in migration patterns and rates between the two groups. A multi-year comparison of smoltification in wild and hatchery fish at multiple in-river sites was conducted for 1990 – 1996, using gill  $\text{Na}^+$ ,  $\text{K}^+$ -activated ATPase activities as a measurement of smoltification. Results of both travel time analysis and the seasonal smoltification profiles of juvenile emigrants in this report demonstrated high variability among species, and between years, in both physiological characteristics and emigration performance. This variability is attributed to environmental variability, a factor that can be controlled in a limited fashion in production and fish passage facilities, but not in the tributaries and rivers. The greatest challenge for the future of Columbia

basin salmonids is the development of management strategies with the flexibility to accommodate differences among stocks and species in a dynamic environment.

The efforts of regional fishery researchers and managers to quantify the complex biological interactions of anadromous salmonids with their environment over the complete life cycle has been hampered by organization of the resource on a life stage basis. Different agencies are responsible for rearing juveniles, monitoring juveniles and adults, administering and monitoring harvest, managing habitat and the migration corridor, and conducting evaluations at the different life history stages. Our understanding of juvenile salmonid development and emigration behavior was gleaned primarily from the relatively limited number of marked hatchery stocks compared to total numbers of migrating fish. The ability to predict adult return numbers based on emergence, rearing, release, and migration data will require the additional understanding of the seawater transition and survival during estuary and ocean residence (NMFS 1999a). These factors combined should make coordinated and timely information exchange a priority in the region.

Marking programs in the Columbia basin were developed to primarily track and identify specific hatchery stocks to determine the success of their propagation programs (Appendix 0.1): (1) the Regional Mark Information System (RMIS) documents coded-wire tag (CWT) information, (2) the Smolt Monitoring Program tracks juvenile emigrants including freeze branded and passive integrated transponder (PIT) tagged fish, and (3) the Pacific States Marine Fisheries Commission maintains the Passive Integrated Transponder Tag Information System (PTAGIS), a database that allows users to access subsets of PIT-tag data collected in the Columbia and Snake River basins. Multiple year comparisons and coordinated management have been hampered by the cost of freeze branding, coded-wire tagging, or PIT tagging large enough numbers of fish to guarantee sufficient adult returns for statistical analysis. In the past, ASCTTA assisted the Smolt Monitoring Program evaluations of smolt condition and migration rates of marked groups of fish, as well as run-at-large sampling that allowed Water Budget adjustments during times of peak emigration in the river (<http://www.fpc.org/SMPannuals.htm>). However, run-at-large sampling often did not differentiate among wild or hatchery stocks, or stocks from different tributaries; therefore, this strategy helped the largest numbers of fish, but not necessarily those stocks needing the most assistance to navigate and survive in the impounded river.

Far-reaching changes are now proposed for the management of Columbia and Snake River salmonids to restore stocks that have been listed as threatened or endangered under the Endangered Species Act (ESA) outlined in documents by the Federal Caucus (FC 1999), Army Corps of Engineers (COE 2000), Bonneville Power Administration (BPA/BOR/COE 1999), and National Marine Fisheries Service (1999a; 2000 a,b). Proposed changes include assessments of the impacts of habitat, harvest, hydropower, and hatchery programs on salmonid populations. Many of the changes are based on data provided by monitoring, evaluation, and research programs that have focused on marked hatchery groups. Significant changes are proposed for hatchery programs, especially reorientation of production programs for conservation, restoration, and supplementation to sustain naturally producing populations (Flagg and Nash 1999, NMFS 1999 b). Research, from monitoring and evaluation projects of various scales needs to be expanded to a life cycle level to allow coordinated ecosystem management and predictive modeling to benefit the largest number of stocks. The complexity of the developmental process

in anadromous salmonids requires more extensive research models than are traditionally used to investigate individual life stages. We recommend (1) coordination of juvenile and adult life cycle studies; (2) the use of reference stocks that are studied over successive generations; (3) more extensive investigations of individual wild populations to develop an understanding of the effects of annual environmental variability on the relations between physiology, behavior, and survival; and, (4) long-term monitoring of wild and hatchery stocks to judge the efficacy of management actions under changing environmental and river passage conditions.

### *Coordinated life cycle studies*

We urge the establishment of complete life cycle studies, an approach that will require adequate marking programs to allow identification of fish as returning adults. Few studies have investigated physiological development throughout spawning, rearing, subsequent juvenile and adult migrations, adult returns and reproduction for fish of a single brood year, or for the same stock over several generations. The relation between developmental physiology and the environment has been obscured by the limitations of research design based on individual life stages. Accommodation of proposed conservation plans that integrate the effects of habitat, harvest, hydropower, and hatchery programs on all stages of the salmonid life cycle will require investigations on a larger scale than in the past. The short-term nature of many projects concealed progressive effects that occur during development, proceeding or following the period of the investigation, and did not capture the temporal and spatial variability imposed by the length of the salmonid life cycle. Variability among years is the norm, therefore, methods used to analyze and describe developmental phenomena associated with smoltification need to be sufficiently robust to identify relationships notwithstanding inherent seasonal and annual variability.

Models developed to capture the entire range of environmental and physiological variability are, therefore, necessarily very simple in their approach. Many important measurements of physiological condition and the level of smolt development at the time of release or during outmigration are recognized as being of further importance to seawater growth and adult returns. Smolt size, for example, contributes to variability in the timing of migration (Beckman et al. 1998), migration rates (Tipping et al. 1995, Giorgi et al. 1997), and adult returns (Hager and Noble 1976, Koenings et al. 1993). The year of release is also important and survival has been attributed to variations in ocean conditions (NWPPC 1999, Virtanen et al. 1991). Pre-smolt growth predicts growth in seawater (Johnsson et al. 1997), and smolt size and early growth in the ocean are related to marine survival (Holtby et al. 1990). Demonstration of the importance of individual factors to survival has been successful in these studies, however, the physical challenges of sampling during estuary transition and ocean residence have limited our knowledge at those critical life stages. A commitment to life history studies of successive generations will be necessary to address the critical uncertainties associated with prescribed management actions for anadromous species, which under the influence of environmental conditions, demonstrate tremendous variability among years.

### *Reference stocks*

When run-at-large fish are used for monitoring, wild and hatchery fish cannot be distinguished from one another, as a result, the information gained is generalized for the species. Examples of the generalized nature of results from run-at-large sampling are an assumption of similar genetic, emergence, rearing, and migration history. Therefore, we support stock-specific marking programs that allow identification of large groups of individuals repeatedly during their life history. An anomaly of the Columbia basin is that stock-specific management is used for hatchery fish and wild stocks in different habitats, but the mainstem river is managed by species or seasonal runs of a species. Seasonal runs and run-at-large species groups are made up of many separate stocks, adding increased variability to any physiological, behavioral, or response characteristics that are used to monitor and assess fish condition for the various management projects. These measurements are then used in models with environmental measurements that also vary in their precision, scale, and even the location of measurement. Individual fish's physiology and behavior differs at particular monitoring sites in response to environmental cues. Additionally, individually marked stocks used in monitoring do not represent all fish of the same species in the river because of vastly different rearing histories, especially between wild and hatchery fish. PIT tag technology, among others, offers an option to identify individuals within stocks, but a commitment to fund expanded marking and detection programs to allow adequate monitoring over the complete life cycle will be needed. Generalized assumptions for management purposes eliminate the opportunity to identify stock-specific characteristics that lead to survival at each life stage and finally to reproduction of subsequent generations.

### *Wild fish field investigations*

Identification of emerging groups of wild fish for monitoring purposes would be especially useful in determining where in their stock-specific life history conservation actions would produce the greatest benefits. Genetic and environmental factors that affect developmental biology contribute to the physiological (McCormick and Björnsson 1994, Shrimpton et al. 1994, McDonald et al. 1998), behavioral, and survival differences found between wild and hatchery fish (Swain and Riddell 1990, McMichael et al. 1999). Differences as far reaching as stress response and immunity are attributed to difference in rearing conditions (Salonius and Iwama 1993). In a 1998 review of Atlantic salmon management and biology (Canadian Journal of Fisheries and Aquatic Sciences, volume 55, supplement 1) it was recognized that two different biologies exist for wild and cultured salmonids (Gross 1998). Life cycle studies of wild Pacific salmonids in their native environment are needed to provide the biological information necessary to coordinate the activities of hatcheries, hydropower, harvest, and habitat management to reduce the impacts on ESA-listed stocks.

Our understanding of adult-to-adult survival has too often been based on experimental results collated from laboratory experiments, with different stocks or hatchery programs, an approach that has not promoted an understanding of the cumulative and progressive nature of developmental processes in the anadromous life cycle. Physiological and hormonal differences have been identified between wild and hatchery parr and smolts (McCormick and Björnsson 1994), behavioral interactions differ in juveniles of the two groups during stream residence (McMichael et al. 1999), and differences in spawning and emergence have been noted between

wild and hatchery fish of other salmonid species (Stefanik and Sandheinrich 1999). In most of these studies, wild fish were transported to research facilities, acclimated to the holding conditions, and then compared to domesticated fish in a cultured environment, rather than in their native environment. The summary of wild and hatchery migration profiles in the present report (Chapter 2) demonstrates different migration profiles for the two groups. Investigations of the developmental physiology of wild fish characterized by their natural rearing environment are needed to determine the basis for these differences, and to determine which environmental factors are responsible for the resilience of wild stocks (Reisenbichler and Rubin 1999). Because returns of both hatchery and wild fish often fluctuate together, a greater emphasis is needed to explore how long-term environmental change manifests itself as annual variability in survival. These factors might then be considered in future management actions designed to increase adult returns, especially for natural production.

### *Long-term monitoring, and evaluation*

All of the proposed regional strategies to increase Columbia basin salmonid stocks have the potential to differentially affect many salmonid stocks and species. The complicated life history of anadromous salmonids and the length of the life cycle are impediments to determining what factors throughout the fish's life history cumulatively guarantee survival to sustain reproductive populations. Despite our very detailed knowledge of individual aspects of a successful salmonid life history, maximizing the conditions that promote peak performance during each life stage for individual stocks will be the basis for any successful recovery plan. Habitat may be improved for wild stocks on a site-by-site basis, and hatchery practices can be modified at individual hatcheries, but similar accommodation needs to persist in the river where the stocks and species mix. Fish that have evolved in a natural river display alternative life histories, for example, outmigration as subyearlings or yearlings is based on the level of physiological and behavioral development that has been primed by environmental conditions during a particular year (Peven et al. 1994). Wild salmonids experience this variation in their tributary streams, but once they reach the impounded reaches of the rivers, the fish are afforded little opportunity to avoid adverse conditions. The spatial and temporal differences in environmental requirements for wild and hatchery fish, between species and between stocks of the same species will need to be resolved. Stock specific management has the potential to confer benefits on one group, and uniform management of the river confers benefits to others. By monitoring stocks over several generations we will be increasing our understanding of the life stages of the most threatened wild and hatchery stocks, and determine the lasting advantages of new management strategies. The region can move beyond generalized management actions that are based on limited monitoring and evaluation to more specific actions that target the most threatened stocks, and allow long term assessment of effects under the influence of annual environmental variability.

### *Conclusions*

This report presents a final summary of our travel time analysis findings; results that affirm findings of other related modeling analyses. It has yet to be determined if the combination of prescriptive flows used to enhance migration, and the many innovations in rearing practices and fish passage that have taken place in the past decade will show positive correlations with smolt-to-adult returns. The short term and cursory nature of the available data, compared to the

complexity of the anadromous life cycle, is an important factor that prohibits effective modeling. Using hatchery fish in the experimental model is a further limitation, especially when applying the results from artificial rearing environments toward understanding the developmental physiology and emigration behavior of wild fish. A similar level of effort needs to be made to examine wild fish in their natural habitat in order to understand why their development and migration behavior differs from that of hatchery fish. Expansion of knowledge of individual steps in the developmental process during salmonid maturation, and of environmental influences on those steps has not resulted in actions that are of a correspondingly complex nature to slow the decline of both wild and artificially produced fish. Regional coordination and tracking of marking programs to allow multiple uses of marked groups for system-wide monitoring and evaluation would create better timely exchange of information essential to conservation actions. As integrated regional management on a life cycle basis supersedes individual stock management on an annual basis, monitoring and evaluation methods will need to be redesigned to measure population response over time.

## ABSTRACT

### Objectives:

The primary objective of the Assessment of Smolt Condition for Travel Time Analysis project has been to determine the effect of developmental status in juvenile salmonids, particularly smolt condition, on emigration performance. The interaction between physiological development and environmental factors, especially flow, were used to explain migration rates of spring chinook salmon in the Snake River for 1993 - 1996. Seasonal profiles of smolt condition as measured by gill  $\text{Na}^+$ ,  $\text{K}^+$ -activated ATPase activity, were compared between wild and hatchery emigrants from 1990 – 1996.

### Results:

The analysis for 1993 – 1996 presented in this report, describes contributions of selected variables to travel time similar to those reported for 1989 – 1992 (Maule et al. 1994), including a flow variable and gill  $\text{Na}^+$ ,  $\text{K}^+$ -activated ATPase activity. However, condition factor, known to decrease during smoltification, was not a significant contributor to travel time for spring chinook salmon in the Snake River. The comparison of the regression results with a current mathematical model demonstrated a similarity between the time to peak gill ATPase in our model, and the time to 95% of a flow-independent variable (Zabel et al. 1998). Predicted travel times were lower in the regression model than in the mathematical model. Future predictive models of migration dynamics should consider the correlative nature of the relation between smoltification and migration rate, and not rely on single smoltification measurements to explain travel times.

Annual migration profiles describe consistent and repeated annual patterns of smoltification in wild and hatchery salmonids including: 1) higher ATPase levels in wild fish than hatchery fish early in the season at upper Snake River sites, 2) fewer differences in gill ATPase in wild and hatchery fish as the season progressed and at downstream sites, and 3) a similarity of temporal changes in gill ATPase at given sites that represents similar responses, although of different magnitudes, of wild and hatchery fish to seasonal changes in the river environment.

### Recommendations

Extensive data exist about rearing and migration physiology, behavior, and survival of Columbia basin salmonids, but applications to long-term management are limited by the scale of the studies. Life history scaled monitoring is needed to allow ecosystem level management and predictive modeling. The complexity of the developmental process in anadromous salmonids requires more extensive research models than are traditionally used to investigate individual life stages. We recommend (1) coordination of juvenile and adult life cycle studies; (2) tracking of reference populations over several generations; (3) more extensive investigations of wild stocks to further an understanding of the effects of annual environmental variability on the relations between physiology, behavior, and survival; and (4) long-term monitoring of wild and hatchery stocks to determine the efficacy of management actions under changing environmental and river passage conditions.

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## LIST OF ACRONYMS, UNITS, AND NOMENCLATURE

ASCTTA = Assessment of Smolt Condition for Travel Time Analysis  
BOR = Bureau of Reclamation  
BPA = Bonneville Power Administration  
BRD = Biological Resources Division of the USGS  
COE = Army Corps of Engineers  
CRI = Cumulative Risk Initiative  
CRRL = Columbia River Research Laboratory  
CWT = Coded wire tag  
DART = Columbia River Data Access Real Time  
EDT = Ecological Diagnosis and Treatment  
ESA = Endangered Species Act  
FACH = Fall Chinook Salmon  
FC = Federal Caucus  
FPC = Fish Passage Center  
IDFG = Idaho Department of Fish and Game  
kcfs = 1000 cubic feet per second  
MS-222 = Tricaine Methanesulfonate, anaesthetic  
Na<sup>+</sup>, K<sup>+</sup>-ATPase = Gill Sodium, Potassium-Activated Adenosine Triphosphatase  
NaCl = Sodium Chloride  
NFH = National Fish Hatchery  
NMFS = National Marine Fisheries Service  
NWPPC = Northwest Power Planning Council  
ODFW = Oregon Department of Fish and Wildlife  
PATH = Plan for Analyzing and Testing Hypotheses  
PTAGIS = Passive Integrated Transponder Tag Information System  
PIT-tag = Passive Integrated Transponder tag  
PSMFC = Pacific States Marine Fisheries Commission  
RMIS = Regional Mark Information System  
SE = Standard Error  
SFH = State Fish Hatchery  
SMP = Smolt Monitoring Program  
SOCK = Sockeye Salmon  
SPCH = Spring Chinook Salmon  
STHD = Steelhead  
SURPH = Survival under Proportional Hazards  
USFWS = United States Fish and Wildlife Service  
USGS = United States Geological Survey  
WDFW = Washington Department of Fish and Wildlife

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## INTRODUCTION

Survival of juvenile salmonids during emigration in the Columbia and Snake Rivers is of extreme importance as more species and stocks are listed as threatened or endangered under the amended Endangered Species Act of 1973 (16 U.S.C. 1536). Fisheries management in the basin is organized under many different groups, each specializing in specific phases of the anadromous life history or management tasks. This approach has often masked our understanding of the simultaneous, sequential, and cumulative physiological processes involved in salmonid development. Life cycle studies of salmonid development are limited in number, therefore our understanding of the salmonid life history has been gathered from data from separate investigations of divergent stocks, species, and research design. Major changes in adaptive management made to improve survival have taken place in parallel with ever increasing knowledge about the organismal complexity of physiological development in anadromous salmonids (Groot et al. 1995). A limitation on the application of research results to adaptive management has been the scope of the investigations, often restricted to short time periods or single brood years. However, despite these limitations, results have described a broad range of environmental influences on development, behavior, and survival (Wedemeyer et al 1980, Zaugg 1981a, Hoar 1988, Holtby et al. 1990, Salonius and Iwata 1993, Whalen et al. 1999). Modifications in Water Budget allotments, hydropower system fish passage facilities, artificial production, harvest management, and habitat improvements have been made based on the combined results of individual research, monitoring and evaluation projects.

Primary objectives of investigations conducted by the Columbia River Research Laboratory, U. S. Geological Survey, Biological Resources Division are to describe and understand (1) how the environment affects physiological development in juvenile salmonids and (2) how physiological condition interacts with the environment to influence juvenile emigration behavior. To further our understanding of the interactions of the environment and physiological development, regression analyses have been conducted to explain migration behavior (Maule et al. 1994). Environmental factors important to the physiological determinants of migration behavior are the source of much of the variability in that behavior. Water flow, temperature, moon phase, and social interactions have all been found to relate significantly to the migration tendency, its timing and duration (Hvidsten et al. 1995). Furthermore, rearing conditions such as high fish densities, can affect physiological changes associated with smoltification including gill  $\text{Na}^+$ ,  $\text{K}^+$ -activated ATPase activity (Schreck et al. 1985, Sower and Fawcett 1991). Researchers have recognized the differences in migration characteristics of stocks or species with different life histories, but there has been a lack of consistency in predictors, with the exception of flow, that explain travel times over years, especially between species (Berggren and Filardo 1993, Muir et al. 1994, Giorgi et al. 1994, Zabel and Anderson 1997, Giorgi et al. 1997). Extreme differences in flow among years are linked to a number of effects that influence migration rates and survival. For example, in low flow years increased travel times and poor juvenile survival have been linked to increased debris at dams, sporadic turbine operations, increased predator exposure, as well as decreased water volume in the estuary leading to prolonged entry to the ocean (Williams and Matthews 1995).

Our first approach to understanding differences among travel times considered the physiological basis of the migration tendency. Salmonid development proceeds under endocrine direction

(Barron 1986, a review) of physiological changes associated with growth that affect smoltification (Dickhoff et al. 1997). Interactions between the immune and endocrine systems (Weyts et al. 1999, a review) occurring under environmental modulation affect the range of variability seen in developmental characteristics, migration behavior, and survival. The rearing environment, especially photoperiod and temperature, affects physiological development, the basis for functional and behavioral changes (Wagner 1974, Zaugg 1981b, Muir et al. 1994). Although photoperiod is acknowledged as the initiator of physiological changes associated with smoltification and the migration tendency, other environmental and behavior factors are also involved (Jonsson 1991). Temperature, for example, plays an important role in determining the timing and magnitude of the physiological changes (Zaugg 1981a, b). The seaward migration of anadromous salmonids has long been found to coincide with changes in temperature and flow (Bjornn 1971), and development in the fish continues during the in-river migration (Zaugg 1981a, b; Zaugg et al. 1985). This view has not changed significantly in the past two decades, although more recent research has expanded our understanding of the many physiological and behavioral changes that take place during rearing and the downstream migration. Smoltification is influenced by the environment, therefore, variability in smolt development and the emigration among years is to be expected.

Physiological change allows migration to different environments, which in turn influences further physiological, functional, and behavioral change (Zaugg et al. 1985). Our understanding of the smoltification process (Wedemeyer et al. 1980, Folmar and Dickhoff 1981, Hoar 1988) has advanced with recognition that growth, more than size, may influence the timing of smoltification and migration (Beckman et al. 1998, Beckman et al. 1999). Fish with higher spring growth rates have been found to migrate earlier than slower growing fish, regardless of size (Beckman et al. 1998). Furthermore, it is recognized that environmental change governs the entire salmonid life cycle and may be the ultimate determinant of survival, despite the fishes' physiological status during smoltification (Beckman et al. 1999). Patterns of change of gill ATPase activity and plasma thyroxine during smoltification vary among years (Ewing et al. 1994); these changes have been associated with temperature (Folmar and Dickhoff 1981). Increases in gill ATPase activities are further associated with higher temperatures and water discharge (Whalen et al. 1999). Thyroid hormones, growth hormone, and cortisol are involved in smolt development and behavior related to downstream migration (Iwata 1995, a review). However, environmental differences before emigration, and differential response to conditions during emigration may influence the timing and magnitude of further development during outmigration (Muir et al. 1994). The rearing environment may also have far reaching effects on stress response, immune function, and disease resistance (Salonius and Iwama 1993). Migration profiles of gill ATPase activity for both wild and hatchery Columbia and Snake River salmonids from 1990 – 1996 presented in this report provide evidence that similar trends in development occur in wild and hatchery fish (see Chapter 2).

Modeling interactions of emigration characteristics of juvenile salmonids with environmental factors was the second objective of our investigations. The goal was to provide information to help managers adapt hydropower operations and structures to improve fish passage. Accompanying past changes in management of physical factors such as flow, have been modifications of rearing and release strategies for hatchery fish to enhance their physiological preparedness to emigrate. Regression models and mathematical models have described key

variables, especially flow, which explain variations in migration rates (Berggren and Filardo 1993, Maule et al. 1994, Giorgi et al. 1994, Giorgi et al. 1997, Zabel and Anderson 1997, Zabel et al. 1998). Physiological variables were usually not included in these models, instead surrogate variables have been used to represent the level of development of the fish. The surrogate variables capture the level of development by assuming that the timing of appearance in the river at a particular site is related to development. This recognizes how development related to smoltification, migration tendency, behavior, and survival progresses under multiple influences that in combination determine performance during the migration. Similarities of variables from different travel time migration models demonstrate that flow and the in-river experience are consistently important. The most important result of monitoring and evaluation of travel time has been acknowledgement of the environmental influence on physiological development and behavior over the course of the migration, both the longer individual fish are in the river exposed to flow, and as the season progresses.

The magnitude of inter-annual differences in the timing and duration of the juvenile migration has demonstrated that the predictive power of migration models is constrained by annual variability in effects of the environment. The environment affects physiological functioning, which in turn influences behavior, performance, and ultimately survival (Hoar 1988, Muir et al. 1994). As the ability to determine individual survival during the emigration increased with new tagging and tracking technologies, differences in smolt condition among in-river sites, between seasons and years, and among species or stocks were evident (Maule et al. 1994, Giorgi et al. 1994, Giorgi et al. 1997). Evidence of genetic components of stress and immune response (Fevolden et al. 1994, Wiegertjes et al. 1996) suggest that, having been reared in very different environments, wild and hatchery fish will experience different selection pressures. Therefore, at the time of emigration, their physiological responses will differ. Because the environmental influence can greatly influence physiological characteristics, surrogate variables that are loosely related to the juvenile developmental stage are often used with the assumption that the location and time of river residence are representative of the developmental stage. This is an especially important assumption because the diverse species, stocks, life histories and wide range of migration distances of Columbia basin salmonids confounds direct use of physiological variables that are subject to temporal and spatial variability imposed by the environment (Peven et al. 1994).

Concentrated effort on studies of biochemical changes related to smoltification, on specific life history events, and the use of hatchery fish have contributed to the treatment of salmonid development as a series of sequential steps, rather than an ongoing process. The complexity of the process and persistence of environmental effects throughout the life cycle requires broad scale monitoring and analysis to determine generalized relations that can be applied to management of juvenile salmonids. Generalizations about physiological measurements related to smoltification are difficult because fishes within a stock may demonstrate considerable variation in growth patterns and physiological characteristics (Dickhoff et al. 1995, Beckman et al 1999), and seaward migration may also occur without apparent changes in smolt characteristics (Ewing et al. 1980). Furthermore, many physiological and smoltification characteristics also affect seawater survival (Franklin et al. 1992), growth in seawater (Holtby et al 1990, Johnsson et al. 1997), and adult return numbers (Bilton et al. 1982, Virtanen et al. 1991), thus affecting survival beyond the outmigration. This report provides long-term analysis of

travel time and smoltification profiles for a number of Columbia basin wild and hatchery salmonids, information that relates migration behavior to both environmental and physiological variability.

Management of wild salmonids has focused on habitat protection and restoration, and preventing hatchery stocks from competing with native fish. Identification, therefore, of differences in physiological condition and emigration behavior between wild and hatchery fish is of extreme importance to managing hatchery production in order to minimize effects on wild fish. Furthermore, these differences are of overlying importance to management of juvenile fish passage because the physiological condition of the fish will determine their response to changing environmental conditions throughout the emigration. This report details emigration profiles of wild and hatchery salmonids for an extended period of time, and describes characteristics of the emigration that were seen in successive years.

## CHAPTER ONE

### **The Effects of Physiological and Environmental Variables on the Travel Time of Juvenile Spring Chinook Salmon in the Snake River, 1993-1996**

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#### **ABSTRACT**

We used regression techniques to determine the effects of environmental and physiological variables on the migration rates of juvenile spring chinook salmon (*Oncorhynchus tshawytscha*) in the Snake River from 1993 to 1996 and compared our results with a published mathematical model that predicts migratory behavior of these fish. Release date, the reciprocal of river flow, and gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase (ATPase) activity were significant variables in the regression. The dynamics of gill ATPase activity and a variable from the mathematical model describing a fish's flow-independent contribution to migration (migration rate was assumed to increase with in-river experience) were similar. Both increased from baseline to peak levels in about 30 d. The difference between minimum and maximum migration rate was much lower in the regression than the mathematical model. There were no significant correlations between the explanatory variables used in the regression and a variable from the mathematical model describing a fish's flow-dependent contribution to migration (fish were assumed to use more river flow to migrate as the migration season progressed). Our results are similar to past work using regression techniques in terms of explanatory variables and amounts of variability described. We believe that while regression models are statistically valid, they do have limitations. Other models describe more variability in travel time and their greater ability to predict migration dynamics in future years offers a distinct advantage over regression techniques. Further research is necessary to determine the mechanisms driving migration behavior in juvenile salmonids. Better understanding of these mechanisms will yield more accurate migration predictions thus providing better tools for management of salmon populations.

## INTRODUCTION

Columbia basin fish managers are interested in the time required for juvenile salmonids to emigrate from natal streams to the Columbia River estuary. This interest is based on a belief that impoundment of the Columbia and Snake rivers has increased travel times and decreased survival of juvenile salmonids. The evidence of these trends came largely from Raymond (1968, 1979) who indicated a positive relation between river flow and travel time, and Raymond (1979) and Sims and Ossiander (1981) who reported a positive correlation between river flow and survival. Thus, the Water Budget, a volume of water to be used as an aid to migrating juvenile salmonids in the Columbia River basin, was created with the expectation that reductions in travel times would result in increases in survival (NWPPC 1987).

This project was funded in 1987 to monitor several measures of smolt physiology to help explain variation in survival and travel times of juvenile salmonids. This was prompted by research indicating relations between smoltification and the disposition to migrate (Rodgers et al. 1987). Smoltification is the process by which juvenile salmonids prepare for the shift in their osmoregulatory environment that occurs upon ocean entry and includes changes in physiology, morphology and behavior. We measured gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase (ATPase) activity and condition factor to monitor smoltification. Our aim was to explain variability in travel time estimates by conducting multiple regression analyses that included indices of smoltification and environmental factors like river flow and water temperature as explanatory variables.

The fish marking operations of the Smolt Monitoring Program (SMP) and the ATPase assay method we used structured our analyses of travel time. The SMP marking program was designed to evaluate the effectiveness of the Water Budget using mark and recapture studies to determine survival levels and travel time. Survival estimates from this program were discontinued after violations of key assumptions were identified by this project in 1987. Before 1988, estimates of survival and travel time were based on mark and recapture of freeze-branded fish allowing analyses only at a group level. Beginning in 1988, fish were implanted with uniquely coded passive-integrated transponder (PIT) tags. This method provides precise travel times for individuals and allows for analyses at the level of the individual and group. Despite the ability to conduct analyses on individuals, travel time estimates were still largely based on data pooled by release date given the similarities of fish released at the same time. Another reason we continued to estimate travel time using data pooled by release date was the use of an ATPase assay that necessitated lethal sampling (Zaugg 1982a). In 1993 we adopted an assay method that required much smaller amounts of tissue allowing non-lethal sampling (Schrock et al. 1994). Although we were able to analyze data at the level of the individual from 1993 through 1996, we continued to pool by release date because of the similarities of fish released at the same time and to remain consistent with past analyses.

We conducted several travel time analyses that used multiple regression techniques on data collected from PIT-tagged fish. Analysis of data collected from 1988 through 1992 indicated river flow, ATPase activity, condition factor, water temperature, and change in flow were significant predictors of the travel times of juvenile spring chinook salmon (*Oncorhynchus tshawytscha*; Beeman and Rondorf 1994). In contrast to the model describing juvenile chinook salmon travel time, the only significant predictor of steelhead (*O. mykiss*) travel time was river

flow. Furthermore, we found no evidence to indicate any consistent differences in the importance of flow-related or smoltification-related variables as predictors of travel time. Other researchers have conducted regression analyses to describe the migration of juvenile salmonids with similar results. Berggren and Filardo (1993) found river flow, and for one reach, water temperature were significant predictors of steelhead travel time and that surrogate indices of smoltification (i.e., previous time in river and water temperature) were additional predictors of chinook salmon travel time. A noticeable difference from our results was their finding that flow-related variables were consistently more important than other factors as predictors of travel time. Giorgi et al. (1997) also found river flow to be the most important predictor of migration rate for sockeye salmon (*O. nerka*) and steelhead. Curiously, they found that the migration rate of spring chinook salmon was not correlated with any predictor variables including river flow, water temperature, release date, and fish size.

The range of variability explained by these multiple regression models is relatively broad. The models of Berggren and Filardo (1993) explained from 39 to 90% of the observed variability, the analyses of Beeman and Rondorf (1994) accounted for 67 to 81% of the variability, and the work of Giorgi et al. (1997) explained from 21 to 63% of travel time variability. The broad range of explained variability as well as the inconsistent inclusion of explanatory variables raises questions about the predictive power of these models.

Recently, Zabel et al. (1998) used a different approach to predict travel times of migrating juvenile salmonids. They used a nested sequence of nonlinear models to create a mathematical model describing travel time of juvenile spring chinook salmon in the Snake River. Their initial model assumed a constant migration rate and was considered inadequate because it predicted about the same travel time for all release groups. Adding river velocity, assumed to have a linear relationship with migration rate, improved the model so it explained 52% of the variability. A third model explained 80% of the variability in travel times. Inclusion of a flow-season interaction term (flow-dependent) in this model accounted for the assumption that as the season progresses, fish migrate more actively by traveling in portions of the river with higher flow or spending more of the day migrating. A migration-experience factor (flow-independent) was included in the fourth and final model to account for the assumption that independent of flow, fish migration speed increases with experience in the river. Their final model was able to explain about 90% of the variability in travel times.

The assumptions included in the final model of Zabel et al. (1998) were chosen to provide a good fit to extant migration data, but they also agree with biological data. Both the flow-season interaction and migration-experience factors are used to describe changes in migration behavior over time. Northcote (1992) and Jonsson (1991) describe similar changes in behavior during migration. Zabel et al. (1998) also assumes that 95% of a fish's flow-independent contribution to downstream migration develops over 30 days of experience in the river. The rise and plateau of gill ATPase activities (Rondorf et al. 1989; Beeman et al. 1990) and morphological indices of smoltification (Beeman et al. 1994, 1995) also develop during the first 30 days of emigration. It is important to point out that a causal relation between these indices of smoltification and the disposition to migrate has not been clearly shown (Ewing et al. 1980; Hart et al. 1981). As stated previously, we believe that changes in these indices are part of a suite of physiological changes occurring during smoltification, and probably have a correlative, rather than a causative, relation

to migration (Beeman and Rondorf 1994). The accuracy of the model described by Zabel et al. (1998) supports the theory that there is some behavioral change affecting the fish's contribution to migration. If changes in migration behavior are related to smoltification then differences in smoltification indices should exist between individuals with low and high migration rates. Our objective with these analyses was to determine if the changes in migration behavior integrated into the model of Zabel et al. (1998) could be attributed to indices of smoltification.

## METHODS

We conducted analyses of the effects of selected variables on travel time of juvenile salmon to determine if indices of smoltification correspond to changes in migration rate parameters described by Zabel et al. (1998). We used data collected from juvenile spring chinook salmon migrating from the Idaho Department of Fish and Game (IDFG) Snake River Trap to Lower Granite Dam (LGR; Figure 1.1).

Fish used in this study were implanted with PIT-tags by IDFG personnel and released on the day of capture as part of the Smolt Monitoring Program. Tagged fish were detected at LGR with PIT-tag detectors described by Prentice et al. (1990). Median travel time was calculated as the difference between the date of release and the day before the median date of detection at LGR. We calculated mean river flow as the mean daily flow at LGR from the date of release through the day before the median date of detection at the dam. Similarly, mean river temperature was calculated as the mean daily temperature at LGR from the date of release through the day before the median date of detection at the dam. We obtained flow and temperature data from the Columbia River Data Access in Real Time (DART) website ([www.cqs.washington.edu/dart/dart.html](http://www.cqs.washington.edu/dart/dart.html)) operated by the University of Washington's School of Fisheries. We extrapolated values for days lacking flow or temperature data by using the mean value of the day before and day after the missing data.

Sampling schedules varied between years. We sampled fish three days per week in 1993, 1994, and 1995 and five days per week in 1996. Fish were anesthetized in tricaine methane sulfonate (MS-222) and injected with PIT-tags by IDFG personnel. Physiological data were collected from a sub-sample of the fish that were PIT tagged on any one day. The number of fish we sampled each day varied by year. The sample size was 20 hatchery and 20 wild chinook in 1993 and 1994, 10 of each in 1995, and 15 of each in 1996. Fork length was measured to the nearest 1.0 mm and weight to the nearest 0.1 g. Condition factor was calculated as  $\text{weight} \cdot 10^5 \div \text{fork length}^3$ . A sample of gill tissue was collected from each fish and stored using the method of Schrock et al. (1994). Fish were released after a short time for recovery. The concentrations of gill  $\text{Na}^+$ ,  $\text{K}^+$  - ATPase were determined from samples of gill tissue using the colorimetric micro-assay described by Schrock et al. (1994). The fish from which we collected physiological data were assumed to be representative of all the fish PIT tagged and released on the same day.

We chose to pool data from hatchery and wild chinook salmon given that the model of Zabel et al. (1998) was developed using run-of-the-river chinook salmon. If the ratio of hatchery to wild fish we sampled on any one day was greater than 2:1 then the number of hatchery and wild fish was equalized. This was done by randomly selecting a number of fish from the larger group

equal to the size of the smaller group. Furthermore, the data from one day were pooled with that of the prior sample date if the sample size (number of gill ATPase samples) was less than 10. If after pooling the sample size was still less than 10 then data from the following sample date were also included with the middle date considered the sample date.

Data from 1993 through 1996 were analyzed with multiple linear regression techniques using SAS software for personal computers (SAS Institute 1994). Median travel times were natural logarithm transformed ( $\ln$ ) to prevent violation of the assumption of equal variation of the response variable (median travel time) for all observations in the regression. We conducted a stepwise regression which tested for the inclusion of the reciprocal of mean daily flow, mean gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity, condition factor, delta flow (maximum mean flow minus minimum mean flow), day of the year of release, and mean river temperature as explanatory variables. Following Berggren and Filardo (1993), we used the reciprocal of mean daily flow given the similarity between the travel time of fish and water through a reservoir (water travel time is calculated as reservoir volume divided by flow). Delta flow was included in the analysis due to its significance in similar models of travel time (Berggren and Filardo 1993; Beeman and Rondorf 1994). The p-value for explanatory variables to enter and stay in the model was 0.15.

We examined the data used in the regression for outliers by plotting residuals about their predicted values to identify problematic points requiring further investigation (Ramsey and Schaefer 1997). We tested for multicollinearity with eigenanalysis using a condition index of 10 or greater as an indication of dependencies (Belsley et al. 1980). Normality of residuals was tested with the Shapiro-Wilk statistic and first-order autocorrelation was assessed using the Durbin-Watson D statistic at significance levels of  $P \leq 0.05$ .

We determined the relative importance of each explanatory variable on the variance of the response variable by comparing standardized partial slope estimates (beta weights) of the regression coefficients. The beta weight describes the average change in the standard deviation of the response variable associated with a standard deviation change in an explanatory variable when the other explanatory variables are held constant (Lewis-Beck 1980).

Predicted travel times were determined by using the regression equation to calculate  $\ln$  (travel time) over the range of flows experienced by fish from 1993 through 1996 at several gill ATPase levels with release date held constant at its mean (122). Travel times were then calculated by back-transforming  $\ln$  (travel time) values to the original scale.

The relationship between gill ATPase activity and release date was examined by fitting a curve to data from 1993 through 1996 with non-linear regression techniques. Our criteria for curve selection were a good fit to the data and that the curve had to make biological sense (i.e., the shape of the curve should be similar to the expected response of the measured variable, not merely provide the highest  $R^2$  value).

Migration rates were determined by first using the regression equation to calculate  $\ln$  (travel time) over the range of release dates from 1993 through 1996 at several gill ATPase levels while holding river flow constant at its mean for the same time period (95 kcfs). Travel times were then calculated by back-transforming  $\ln$  (travel time) values to the original scale. Finally,

migration rates were calculated by dividing the distance between the Snake River Trap and LGR (52 km) by the calculated travel times.

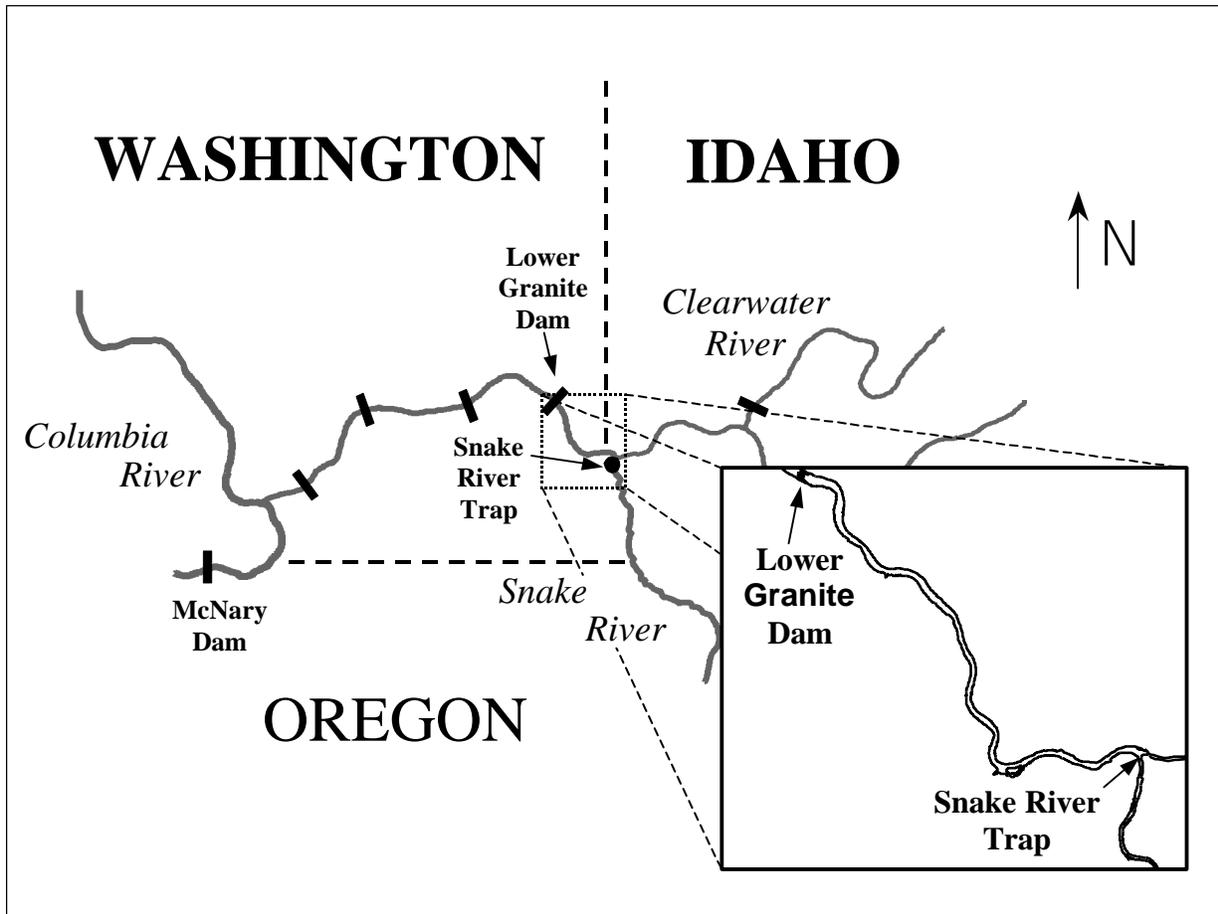


Figure 1.1. Map of the lower-Snake and mid-Columbia rivers. The inset map shows the 52-km study reach from the Idaho Fish and Game Snake River Trap to Lower Granite Dam.

## RESULTS

The regression model predicting travel time for juvenile spring chinook salmon from the Snake River Trap to LGR included the reciprocal of mean flow, gill ATPase, and release date (Table 1.1). This model explained 63% of the variation observed in the travel time of juvenile spring chinook salmon. The first variable selected in the stepwise regression was release date ( $R^2 = 0.51$ ), the reciprocal of mean flow was added second ( $R^2 = 0.61$ ), and gill ATPase was the last variable added to the model ( $R^2 = 0.63$ ). It was not necessary to remove any variables from the model (Table 1.2).

No outliers or influential data were observed in the plot of residuals versus predicted values nor was there any indication of multicollinearity (condition index  $\leq 2.3$ ). The data were distributed normally and there was no evidence of autocorrelation. The beta weights indicated that release date explained the largest amount of variation in travel time (0.44) followed by the reciprocal of flow (0.31) and gill ATPase (0.18; Table 1.1).

Predicted travel times over the range of flows experienced by fish from 1993 through 1996 ranged from a high of 10.3 d (ATPase = 7 : mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, flow = 47 kcfs) to a low of 4.3 d (ATPase = 20 : mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, flow = 175 kcfs) (Figure 1.2). Predicted travel times for fish with minimum and maximum fitted gill ATPase levels ranged from 9.3 d (ATPase = 11 : mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, flow = 47 kcfs) to 4.8 d (ATPase = 15.5 : mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, flow = 175 kcfs; Figure 1.2).

We identified three equations defining the relationship between gill ATPase and release date that maximized the amount of described variability (range of  $R^2 = 0.29$  to 0.32). An equation that used a log-normal curve to describe a peak was selected due to its similarity to the expected response of gill ATPase in migrating salmonids (Figure 1.3). The ATPase levels of juvenile salmonids are low during the parr stage, increase to a peak during the smoltification process, and then decline (Zaugg 1982b). The minimum gill ATPase activity on the fitted curve, defined as activity at the mean date of first release (102.5), was 11  $\mu$ mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>. The maximum gill ATPase level on the fitted curve was 15.5  $\mu$ moles  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup> and was reached at day 133, 30.5 d after the mean date of first release (Figure 1.3). Calculated migration rates for each release date from 1993 through 1996 ranged from a low of 5.6 km/d (ATPase = 7  $\mu$ mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, date = 100) to a high of 15.4 km/d (ATPase = 20  $\mu$ moles  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, date = 153; Figure 1.4). Migration rates calculated for each release date for fish with minimum and maximum fitted gill ATPase levels ranged from 6.3 km/d (ATPase = 11  $\mu$ mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, date = 102.5) to 10.6 km/d (ATPase = 15.5  $\mu$ mol  $P_i$  · mg protein<sup>-1</sup> · h<sup>-1</sup>, date = 133; Figure 1.4).

Table 1.1. Final multiple regression model for predicting travel time of juvenile spring chinook salmon from the Snake River Trap to Lower Granite Dam from 1993 through 1996. The dependent variable in the regression is the natural logarithm transformed median travel time in days. The model has 62 degrees of freedom and total  $R^2 = 0.63$ . Beta weights describe the relative importance each explanatory variable has on the variance of the response variable.

Variables	Coefficient	Standard Error	Sum of Squares	P	Beta Weight
Intercept	3.333	0.470	2.657	<0.001	
Reciprocal Flow	35.929	12.104	0.467	0.004	-0.440
Gill ATPase	-0.025	0.013	0.190	0.063	0.313
Release Date	-0.013	0.003	1.019	<0.001	-0.185

Table 1.2. Summary of stepwise procedure from the multiple regression model for predicting travel time of juvenile spring chinook salmon from the Snake River Trap to Lower Granite Dam from 1993 through 1996. The dependent variable in the regression is the natural logarithm transformed median travel time in days. Explanatory variables included in the analysis were release date, reciprocal flow, change in flow, gill ATPase, condition factor, and water temperature.

Variables	Number in Model	Partial $R^2$	Model $R^2$
Release Date	1	0.509	0.509
Reciprocal Flow	2	0.099	0.609
Gill ATPase	3	0.022	0.631

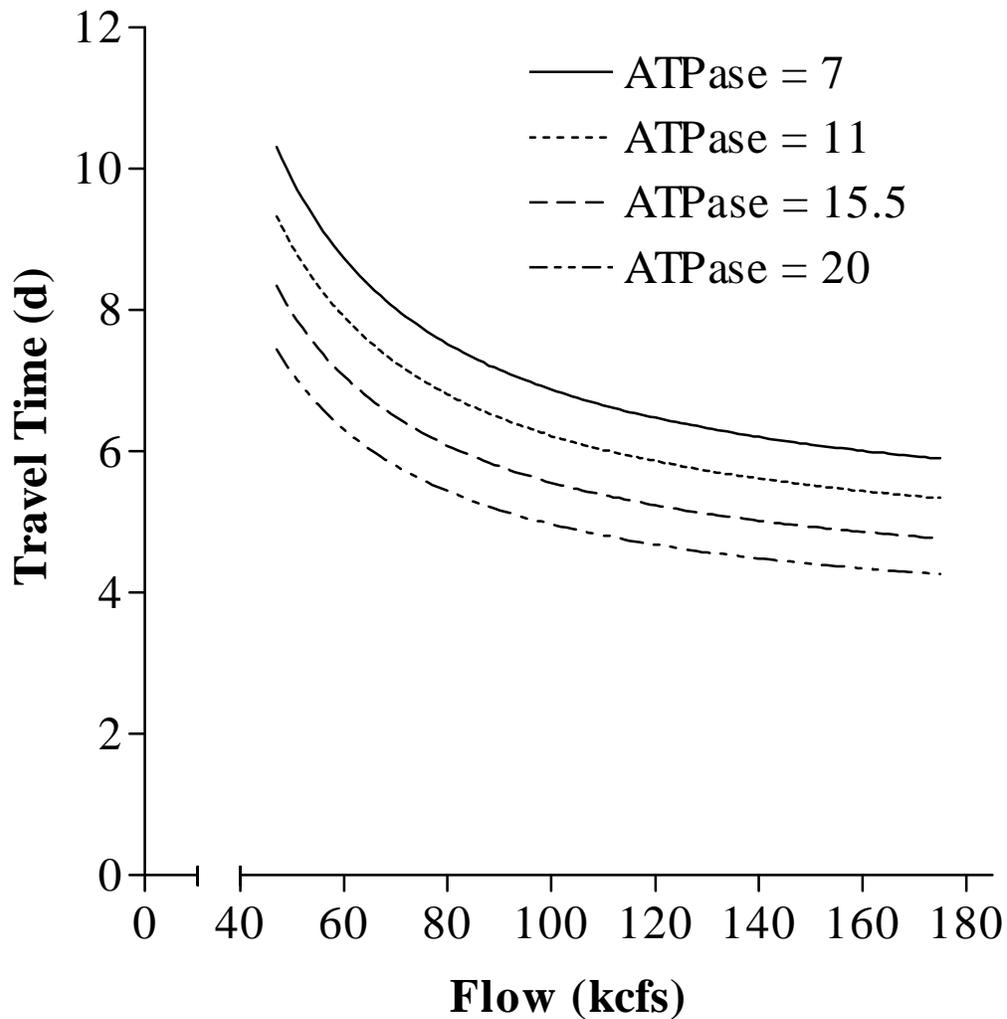


Figure 1.2. Predicted travel times for the range of flows experienced by juvenile spring chinook salmon with different levels of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase (ATPase) migrating between the Idaho Department of Fish and Game Snake River Trap and Lower Granite Dam from 1993 through 1996. Levels of 7 and 20 are the minimum and maximum measured activity levels. The other levels are the minimum (11) and maximum (15.5) levels from a fitted curve defining the relationship between gill ATPase activity and release date. Release date was held constant at its mean (122) for the purpose of visualizing the relationship between travel time and flow.

## DISCUSSION

The reciprocal of river flow, release date, and gill ATPase activity were significant explanatory variables in the regression model describing travel time of juvenile spring chinook salmon between the Snake River Trap and LGR (Table 1.1). Release date explained the largest amount of variation in travel time in our model followed by the reciprocal of flow (Table 1.2). Gill ATPase activity explained less variability in travel time than the other explanatory variables, but was the only index of smoltification that was a significant contributor in the regression model. The other indicator of smoltification we monitored was condition factor, which is known to be lower in migrant fish than in non-migrants (Rodgers et al. 1987). In our model, condition factor did not make a significant contribution in explaining the travel times of juvenile chinook salmon. A curve fit to the data indicated that gill ATPase activity reached peak levels in 30.5 d (Figure 1.3), very similar to the 30-d increase to 95% of a fish's flow-independent contribution to migration in the model of Zabel et al. (1998).

Although we found the timing to peak gill ATPase activity and the flow-independent term (Zabel et al. 1998) were very similar, changes in migration rate associated with these variables were quite different. In the model of Zabel et al. (1998) migration rates increased almost 15 km/d over the 30-d increase in a fish's flow-independent contribution. Using our regression model to predict travel time and then calculate migration rate, we found the migration rate increased by 4.3 km/d during the 30.5-d increase along the fitted curve from minimum to maximum gill ATPase levels (Figure 1.4). Even when comparing our model's rates associated with minimum ATPase and first release versus maximum ATPase and last release, the difference is still only 9.8 km/d (Figure 1.4). A possible problem with this comparison is that Zabel et al. (1998) uses a flow-independent migration rate while we had to calculate migration rates from travel times predicted by a regression model that included flow as an explanatory variable. The inclusion of flow in the process of calculating migration rates may mean that a direct comparison of this factor between models is inappropriate.

One might question the similarity between the time to peak gill ATPase activity in our curve fit and the time of increase to 95% of a fish's contribution to downstream migration due to the uncertainty of gill ATPase levels prior to our sampling. It is possible that earlier sampling may have indicated lower activity levels, thus increasing the time from basal to peak levels. Our monitoring efforts have shown however, that prior to release from hatcheries gill ATPase levels in juvenile spring chinook salmon range from 5 to 7  $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$  (Schrock et al. 1998). The lowest ATPase level at the Snake River Trap was 7  $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ , suggesting our initial samples were near baseline levels of activity.

Other factors that we did not measure may relate to the flow-dependent factor in the model of Zabel et al. (1998). A variety of indicators of smoltification are known including elevated levels of thyroid hormones, changes in body morphology, and increased silvering of the skin, (Young et al. 1989; Beeman et al. 1994, 1995; Haner et al. 1995). The dynamics of one or several of the many indices of smoltification may correspond to the 48-d increase to 95% of a fish's flow-dependent contribution to migration. Alternatively, the correlative nature of the relation between smoltification and migration rate may rule out the use of single physiological measures of smoltification to precisely explain migration in juvenile salmonids.

The results of our analyses are similar to past work using regression techniques in terms of explanatory variables and amount of variability described (Berggren and Filardo 1993; Beeman and Rondorf 1994; Giorgi et al. 1997). We believe that while these models are statistically valid, they do have limitations. The model developed by Zabel et al. (1998) describes more variability in travel time than multiple regression models and also has good predictive power. Greater ability to predict migration dynamics in future years is a distinct advantage over multiple regression techniques. We did find similarities between the timing of the dynamics of gill ATPase levels in migrating fish and the flow-independent contribution to migration used by Zabel et al. (1998) to describe changes in behavior that affect travel time of juvenile chinook salmon in the Snake River. This is not to suggest that changes in gill ATPase activity directly alter smolt behavior. As we indicated previously, we believe that the relationship between smolt indices and migration is more likely correlative than causative. We agree with Zabel et al. (1998) that further research is necessary to clarify the mechanisms driving the observed patterns of juvenile salmonid migrations. A better understanding of these mechanisms will lead to more accurate predictions of migrations and thus provide better tools for management of salmon populations.

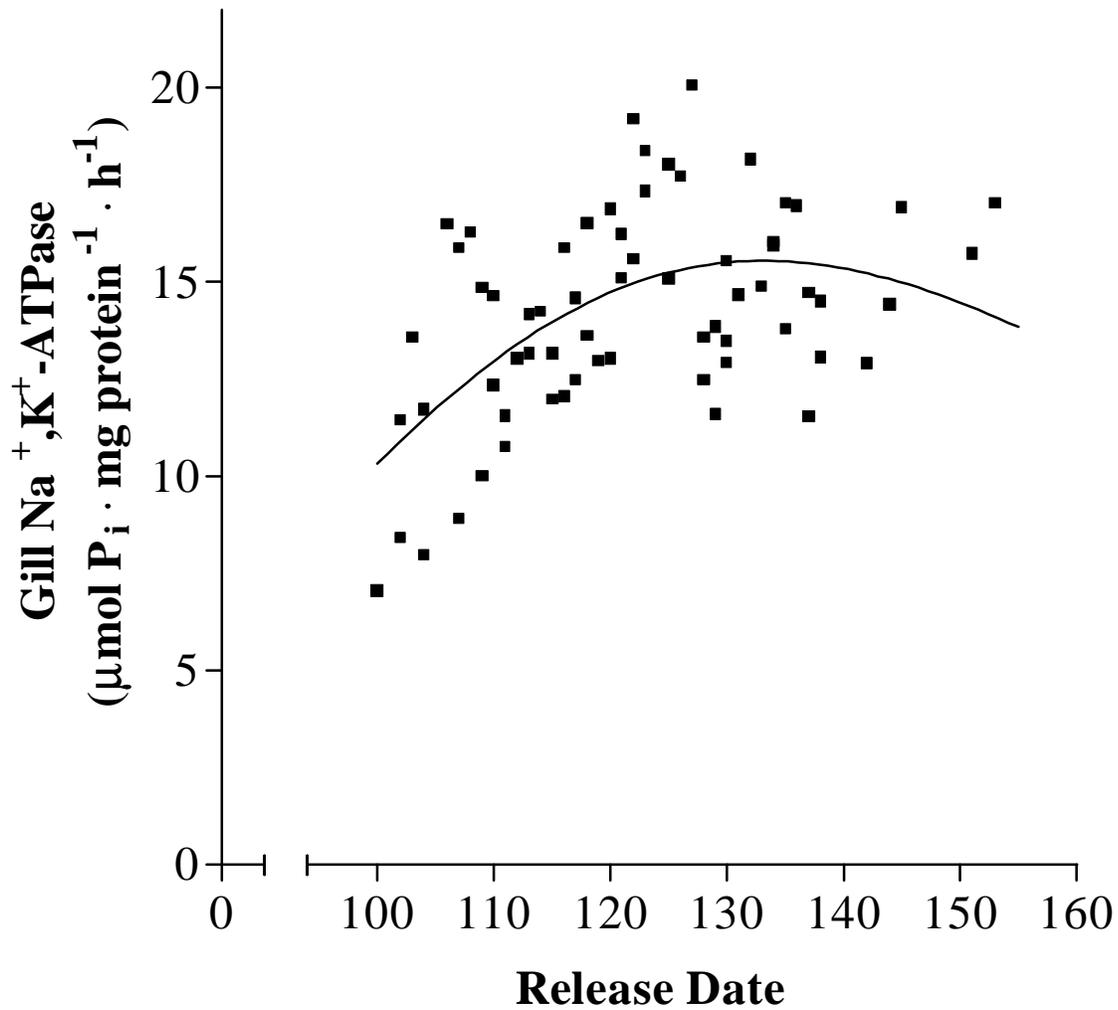


Figure 1.3. Mean gill Na<sup>+</sup>, K<sup>+</sup>-ATPase ( ) versus release date (day of year) and fitted curve (–) for spring chinook salmon captured at the Idaho Department of Fish and Game Snake River Trap from 1993 through 1996. We used non-linear regression techniques to fit an equation of a log-normal curve describing a peak to the data.

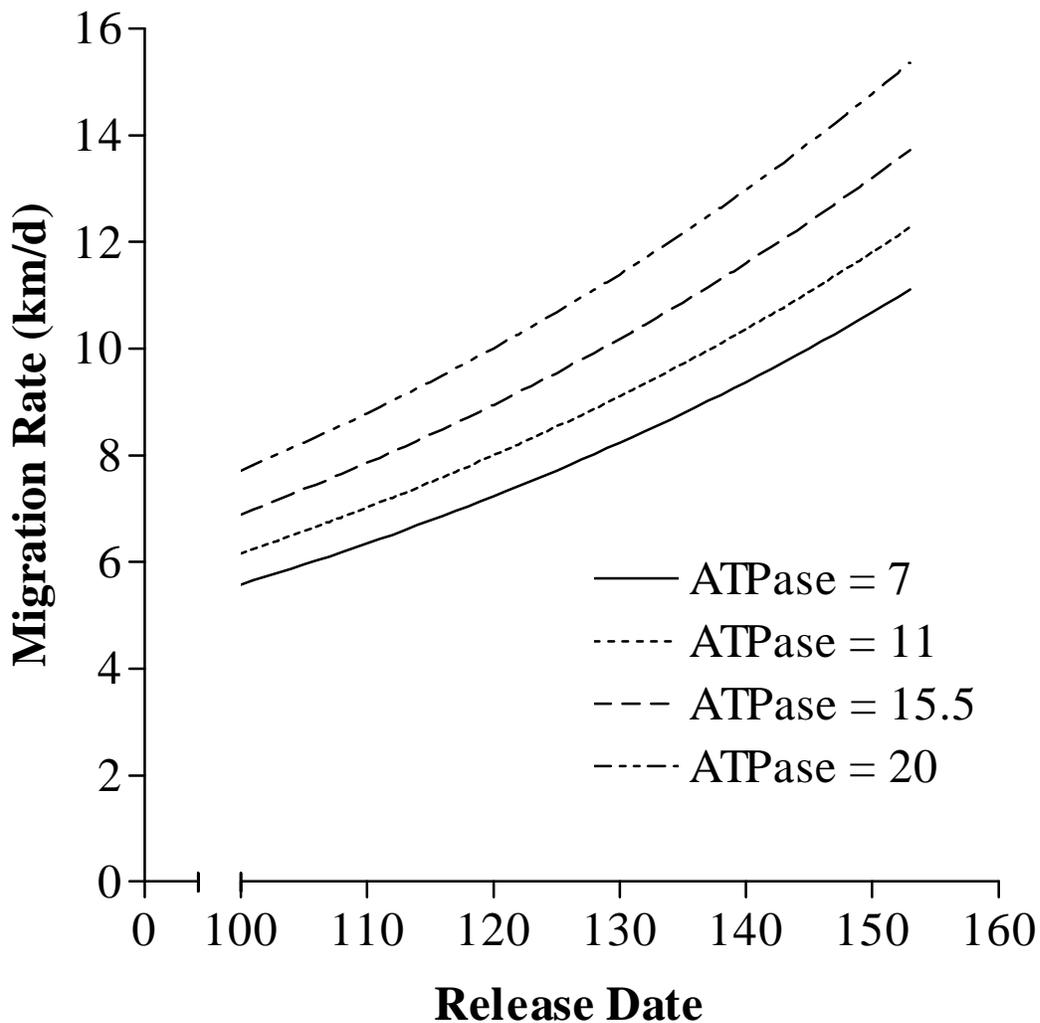


Figure 1.4. Migration rates (calculated from regression predicted travel times with flow held constant at its mean) by release date for juvenile spring chinook salmon with different levels of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase (ATPase) migrating between the Idaho Department of Fish and Game Snake River Trap and Lower Granite Dam from 1993 through 1996. Levels of 7 and 20 are the minimum and maximum measured activity levels. The other levels are the minimum (11) and maximum (15.5) levels from a fitted curve defining the relationship between gill ATPase activity and release date.

## **ACKNOWLEDGEMENTS**

We thank Ed Buettner and staff of the Idaho Department of Fish and Game, Snake River juvenile-fish trap. We thank the many colleagues at the Columbia River Research Laboratory who worked on this project. This study was funded by the Bonneville Power Administration, contract DE-AI79-87BP35245.

## CHAPTER 2

### **Gill Sodium, Potassium-Activated Adenosine Triphosphatase Activity of Wild and Hatchery Salmonids Emigrating in the Columbia and Snake River Basins, 1990 – 1996**

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#### **ABSTRACT**

Emigrating juvenile salmonids undergo physiological, behavioral, and biochemical changes (smoltification) that prepare them for successful life in the marine environment. Changes in gill sodium, potassium-activated adenosine triphosphatase ( $\text{Na}^+, \text{K}^+$ -ATPase) are among the most well documented indices of smoltification. We compared gill  $\text{Na}^+, \text{K}^+$ -ATPase activity in juvenile steelhead (*Oncorhynchus mykiss*) and chinook salmon (*O. tshawytscha*) of wild origin to that in fish of hatchery origin as they emigrated in the Columbia River Basin. Between 1990 and 1996, we made 669 daily comparisons of hatchery and wild fish collected at eight tributary and mainstem locations. Most of the time gill  $\text{Na}^+, \text{K}^+$ -ATPase activity did not differ between hatchery and wild fish. However, in 227 (33.9%) of these comparisons wild fish had higher gill  $\text{Na}^+, \text{K}^+$ -ATPase activity than did hatchery fish; while hatchery fish exceeded wild fish on only one occasion. In general, early in the migration, at upper basin collection sites (e.g., Salmon River Trap) wild fish had significantly higher gill  $\text{Na}^+, \text{K}^+$ -ATPase activity than did hatchery fish; however, there were fewer differences as the run progressed and at lower river sites (e.g., Lower Granite Dam). These results are consistent with earlier reports that differences in early rearing environment affect smoltification and that the rate of smoltification accelerates during in-river migration. Although the differences in smoltification that we report may help to explain some of the differences in post-smolt survival of wild and hatchery salmonids, the true relation is clouded by the differential mortalities of hatchery and wild fish prior to and during emigration.

## INTRODUCTION

Prior to entering the ocean, juvenile anadromous salmonids undergo a number of physiological, biochemical and behavioral changes, known as smoltification, that allow them to thrive in the saltwater environment (Hoar and Randall 1984). One of these changes involves an increase in the activity of gill sodium, potassium-activated adenosine triphosphatase ( $\text{Na}^+$ ,  $\text{K}^+$ -ATPase), an enzyme that facilitates ionic transport across cell membranes by hydrolyzing adenosine triphosphate as an energy source. This enzyme is involved in the absorption of sodium chloride (NaCl) across gill epithelium of freshwater teleosts and excretion of NaCl in marine species (Hoar and Randall 1984; Borgatti et al. 1992). Monitoring gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase is an established method of measuring the level of smoltification in juvenile salmon (Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985) and has been used frequently as an indicator of smoltification (Wedemeyer et al. 1980; Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985; Sower and Fawcett 1991). While the absolute concentration of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase varies between individuals, stocks, and species, a characteristic enzyme profile emerges during salmonids' seaward migration. Juvenile salmon in hatcheries generally have low gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity. After the fish are released into the river and during the seaward migration, however, activity increases rapidly (Zaugg et al. 1985; Beeman et al. 1991).

Gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in emigrating salmonids has been used to identify the importance of smolt development to successful emigration. Muir et al. (1994) found that advanced photoperiod increased the rate of smoltification, as determined by gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity, in chinook salmon (*Oncorhynchus tshawytscha*), and that fish from the advanced photoperiod treatment migrated faster than control fish. Similarly, during emigration, chinook salmon with the highest gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity traveled at a faster rate (Beeman et al. 1991) and were more likely to be guided into fish bypass systems (Giorgi et al. 1988). The assumption is that faster emigration can increase survival by decreasing the time that a fish is exposed to predators, high river temperatures, and lethal levels of dissolved gas supersaturated water. Reduced migration rates may also disrupt the smoltification process and the timing of the fish's physiological readiness to tolerate seawater (Zaugg et al. 1985). The importance of smolt development to long-term survival was demonstrated by Beckman et al. (1999) who found that groups of hatchery fish with the highest degree of smoltification at release (based in part on gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase) showed the highest smolt-to-adult return rates.

Because of the link between smolt migration and adult return, successful emigration of salmonids is of major concern to agencies with interests in water resource distribution in the Columbia River Basin. Information regarding the level of smoltification in emigrating fish is important to fish managers interested in maximizing smolt survival during emigration. The Assessment of Smolt Condition for Travel Time Analysis project has provided data on the physiology and condition of emigrating salmonids in the Columbia River Basin to management agencies since 1988. Our earlier studies indicated that wild and hatchery fish may differ significantly in their physiological level of smoltification during emigration (Beeman et al. 1991). Therefore, the objective of this study was to compare, on a basin-wide and multiple year basis, the level of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild and hatchery steelhead (*O. mykiss*) and spring/summer chinook salmon during emigration.

## METHODS

*Sampling Locations.* Between 1990 and 1996, fish were collected at traps operated by Idaho Department of Fish and Game on the Salmon, Clearwater, and Snake rivers (Table 2.1). Fish were also collected from traps on the Imnaha River, operated by the Nez Pierce Indian Nation, and on the Grande Ronde River, operated by the Oregon Department of Fish and Wildlife. Fish were collected at Lower Granite Dam, the first dam encountered by emigrants in the Snake River. Fish emigrating in the Columbia River were collected at Rock Island Dam and McNary Dam. Fish were held in all of these collection sites for up to 24 h before we sampled them. Not all collection sites were operated every year of our study; nor could we make comparisons between hatchery and wild fish at every site (Table 2.1).

*Fish Sampled.* During the seven years of this study, we collected gill tissue from more than 25,600 hatchery and wild fish and analyzed them for  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity. We distinguished hatchery fish from wild fish based on hatchery fish having had their adipose fin removed (adipose clipped). We were unable to distinguish between hatchery and wild spring chinook salmon in the Columbia River because not all Columbia River hatchery spring chinook salmon were adipose clipped. In the Snake River all hatchery fish were adipose clipped. There is considerable variability in our sample sizes because, although the fish traps were located at sites known to be fish migration routes, these were passive collection systems (i.e., the fish had to come to us); furthermore, during the courses of this study, changes in methodology and management needs mandated changes in our sampling. In all years and at all locations we sampled from 1 to 50 spring chinook salmon per day and 1 to 40 steelhead per day at the traps or dams. At the time of each sampling, we noted water temperature and recorded comments on the external appearance of each fish (e.g., descaling, lesions, parasites).

*Sample Collection and Assay.* Fish sampled from 1990 to 1992 were killed in a lethal dose (200 mg/L) of MS-222 and all gill filaments were removed from the left gill arches. During these years, we analyzed gill tissue for  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity using the method of Zaugg (1982b). From 1993 to 1996, fish were anesthetized lightly (80 mg/L MS-222) and sampled non-lethally by removing a small piece of gill tissue from the first arch on the left side. After this non-lethal sample was taken, the fish were revived in aerated water (15 to 120 min) then released to the river or juvenile bypass system from which they were collected. The gill tissue we obtained non-lethally was analyzed for  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity using the method of Schrock et al. (1994), who verified that the method was equivalent to that of Zaugg (1982b).

*Data analysis.* We limited our analysis to those times and locations where we have gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity for at least two wild and two hatchery fish. Although we used all of those samples in our analyses, we present representative data from various locations and years (Table 2.1). Figures containing all of the data used in these analyzes are presented in Appendices 2.1 – 2.12. Data were analyzed using general linear models for unequal sample sizes (SAS Institute, 1994) to determine differences between wild and hatchery fish of the same species sampled at a given site during a given year. Where differences were detected, we used Duncan's multiple range test ( $P < 0.10$ ) to determine differences between hatchery and wild fish sampled on the same day.

## RESULTS

During the seven years of this study, we made 669 daily comparisons of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity between wild and hatchery chinook salmon or steelhead sampled at the various locations. Of the possible comparisons, there was no difference between wild and hatchery fish on 431 occasions, wild fish had significantly higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity on 227 (33.9%) occasions, and on only one occasion did hatchery fish have higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than wild fish.

*Spring chinook salmon in the Snake River basin.* Wild spring chinook salmon in the Snake River had higher mean gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than hatchery fish on 74 (33.5 %) of the 221 daily samples; hatchery spring chinook had higher activity on one occasion. Higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild fish occurred most often early in the season. For example, in 1993 fish differed significantly on many dates at most sites (Figure 2.1) while in 1994, wild and hatchery fish differed significantly on few dates (Figure 2.2). Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild and hatchery fish seldom differed at the Clearwater River Trap (Figure 2.3a), but differed on most dates at the Salmon River Trap (Figures 2.1a, 2.3b). Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity most often differed between wild and hatchery fish in the early part of the sampling season, generally in early to mid April at the upper river basin traps, such as the Salmon River Trap (216 km from Lower Granite Dam) (Figures 2.1a, 2.2a, 2.3b, 2.4b), or late April and early May at the lower Snake River sites, such as Lower Granite Dam (Figure 2.4a).

*Steelhead sampled in the Snake River basin.* As was true with the spring chinook salmon, mean gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild steelhead sampled in the Snake River basin tended to be higher than in hatchery steelhead (106 of 283 occasions, 37.5%), most often early in the season. Gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in hatchery steelhead was never greater than that of wild fish. There was, however, annual variation in this wild-hatchery relation; in 1990 and 1993, gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity differed significantly on many dates at most sites (Figure 2.5) while in 1992 and 1994 gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild and hatchery fish seldom differed (Figure 2.6). Generally, wild and hatchery fish differed throughout the season at the upper traps, such as the Grande Ronde Trap (101 km from Lower Granite Dam) (Figure 2.7a), and early, but not late in the season at lower Snake River sites, such as Lower Granite Dam (Figure 2.7b).

*Steelhead sampled at Columbia River dams.* As in the Snake River basin, wild steelhead sampled at Columbia River sites tended to have higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity (28.5% of 165 occasions) than did hatchery fish, which never exceeded that of wild fish. Similar to fish sampled in the Snake River basin, gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity was often higher in wild steelhead as compared to hatchery steelhead sampled at Rock Island Dam early in the season; but, unlike fish collected at Lower Granite Dam, wild and hatchery steelhead sampled at Rock Island Dam also differed late in the season-- after the peak of the migration (Figure 2.8a). Fish sampled at McNary Dam could have originated in either the upper Columbia River or the Snake River, and gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity differed between wild and hatchery fish in the early part of the season (Figure 2.8b), similar to the fish in the Snake River.

## DISCUSSION

This study represents an extensive multi-year, multi-site evaluation of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild and hatchery salmonids as they emigrated to the ocean. We have shown that in 227(33.9%) of the 669 comparisons wild fish had higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than did hatchery fish of the same species collected on the same date and location. Gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in hatchery fish exceeded that of wild fish on only one occasion. Several studies have documented that hatchery rearing can inhibit the process of smoltification; fish density (Patiño et al. 1986), water velocity (McDonald et al. 1998), altered water temperature regimens (Muir et al. 1994), and other environmental factors and culture practices (Wedemeyer et al. 1980) can affect the development of smolt characteristics. So, it appears that at the time of release, the urge to migrate was less fully developed in hatchery fish than in emigrating wild fish; and that this difference was reflected in the difference in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity. This difference in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity may also be important to the survival of hatchery fish as elevated gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity has been correlated with performance capacities, such as horizontal and vertical position in the water column during migration (Giorgi et al. 1988) and rate of migration (Beeman et al. 1994). Although gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase is an important regulator of osmoregulation, Zaugg et al. (1985) reported that the levels attained by emigrants exceed that needed for osmoregulation in full strength seawater. They speculated that the excess gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity offered emigrants protection from the stress of entering and acclimating to saltwater. Therefore, the differences in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity between hatchery and wild fish may reflect differences in potential survival during emigration and seawater entry.

In the present study, wild steelhead and chinook salmon collected early in the season at upper Snake River basin sites tended to have higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than did hatchery fish (Figures 2.1b, 2.2a, 2.4a, 2.5a, 2.7b, 2.8b). As the season progressed, and at downstream sites that required fish to migrate longer distances (Figures 2.4a, 2.8b), there were fewer differences in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity between wild and hatchery fish. There are several possible reasons for this change in relative gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish. First, as the hatchery fish spent more time in the river and migrated downstream, their gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity increased at an accelerating rate (Zaugg et al. 1985; Muir et al. 1994). In another study (Hans and Maule, unpublished data) wild fish had significantly higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than did hatchery fish at the Salmon River Trap, but there was no difference when the same individual fish, which were tagged with passive integrated transponders (PIT), were re-sampled at Lower Granite Dam. Those data also showed a propensity for fish with the lowest gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity (usually hatchery fish) at the Salmon River Trap to experience the greatest proportional increase in activity during emigration to Lower Granite Dam. The second factor contributing to the convergence of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity is that the more fully smolted fish (i.e., higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity) migrated at a faster rate (Berggren and Filardo 1993; Beeman et al. 1994) and reached the downstream sampling locations before the less smolted fish. Finally, fish that were less fully developed may have residualized and not migrated at all (Viola and Schuck 1995), thus, increasing the mean gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase of the active migrants. These factors are consistent with previous studies that concluded hatchery rearing practices fail to stimulate smoltification (Folmar and Dickhoff, 1981; Nishioka et al. 1985; Muir et al. 1994), but that  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity increases rapidly as fish emigrate (Zaugg et al. 1985; Muir et al. 1994). Undoubtedly all of these factors played a role in the

differences between hatchery and wild fish, and the convergence of gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity during their emigration.

Although we have described a general trend of wild fish having higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than hatchery fish usually early in the season, this was not always the case. At the Salmon River Trap the difference between wild and hatchery fish often extended throughout the sampling season (Figures 2.1a, 2.3b), and wild and hatchery spring chinook salmon sampled at the Clearwater River Trap differed on only a few dates (Figure 2.3a). Furthermore, at Rock Island Dam, gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity in wild and hatchery steelhead differed most often late in the season, after the peak of migration (Figure 2.8a). Differences in the relations between wild and hatchery fish may have been the result of differences between the time that wild fish began emigrating and hatchery fish were released, variations in the distances fish traveled before they were sampled at traps or dams, or differences in environmental variables experienced by the fish during their migrations. Within the present study there is evidence that environmental factors can cause variation in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity during the smolt migration. Even though wild fish frequently had higher gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity than did hatchery fish, wild and hatchery fish frequently had similar temporal variation in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity (Figures 2.1b, 2.3b, 2.5, 2.6, 2.8). The increases or decreases in gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity during the migration are, at least in part, the result of changes in environment conditions, such as water temperature (Zaugg 1982a; Muir et al. 1994). Although we do not present data on changes in individual fish, the similarity of temporal changes at a given site suggests that wild and hatchery fish had similar physiological responses to changes in, for example, water temperature, flow, turbidity, or even cloud cover. An alternate explanation, however, is that the environmental changes triggered similar behavioral responses such that fish from the two groups at the same relative stage of smoltification migrated concurrently.

In this study we have examined gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity, described differences and similarities between wild and hatchery steelhead and chinook salmon, and suggested that environmental factors (in hatcheries and rivers) could account for these relations. However, these relations should be viewed with caution because the differential mortality experienced by hatchery and wild fish prior to their emigrations means that the populations are not comparable. It is common for greater than 50% of the eggs harvested in hatcheries to be released as smolts (Waples 1991); however, Bradford (1995) estimated that only about 6.4 % of wild chinook salmon survive from egg to smolt. Similarly, Achord et al. (1996) estimated that 5.6% of wild chinook salmon that were PIT-tagged in the summer or fall were detected at Lower Granite Dam the following spring--indicating either poor survival or failure to emigrate. Muir et al. (1994) and Hockersmith et al. (1999) estimated the post-release survival to Lower Granite Dam of Snake River hatchery chinook salmon to be as high as 61%. Thus, even if we make the unlikely assumption that the diversity of potential smolt genotypes was the same for the hatchery fish and wild fish at the time of hatching (see: Waples 1991), differential mortality will have altered that relation by the time the fish start emigrating. While fish spawned in the wild were exposed to in-river selection pressures throughout their egg-to-smolt development, those spawned in a hatchery will only experience those pressures after they are released as smolts. It is not known how soon, if at all, in-river selection acts to equalize the level of smolt development in wild and hatchery groups.

## TABLES

Table 2.1. Years in which hatchery and wild spring chinook salmon and steelhead were sampled at various sites in the Snake and Columbia River basins, and the representative data presented in this study.

Location	<u>Years sampled</u>		<u>Years Presented</u>	
	SPCH <sup>1</sup>	STHD <sup>2</sup>	SPCH	STHD
Snake River Basin				
Imnaha River Trap	1994-1995	1994-1995		
Grande Ronde River Trap	1994-1995	1994-1995		1994
Salmon River Trap	1993-1996	1990-1996	1993, 1994, 1995	
Clearwater River Trap	1993-1995	1993-1995	1995	
Snake River Trap	1993-1996	1990-1996	1993, 1994, 1996	1993, 1994
Lower Granite Dam	1993-1995	1990-1995	1993	1990, 1992, 1995
Columbia River Basin				
Rock Island Dam		1990-1996		1992
McNary Dam		1990-1995		1994

<sup>1</sup> SPCH represents spring chinook salmon

<sup>2</sup> STHD represents steelhead

## FIGURES

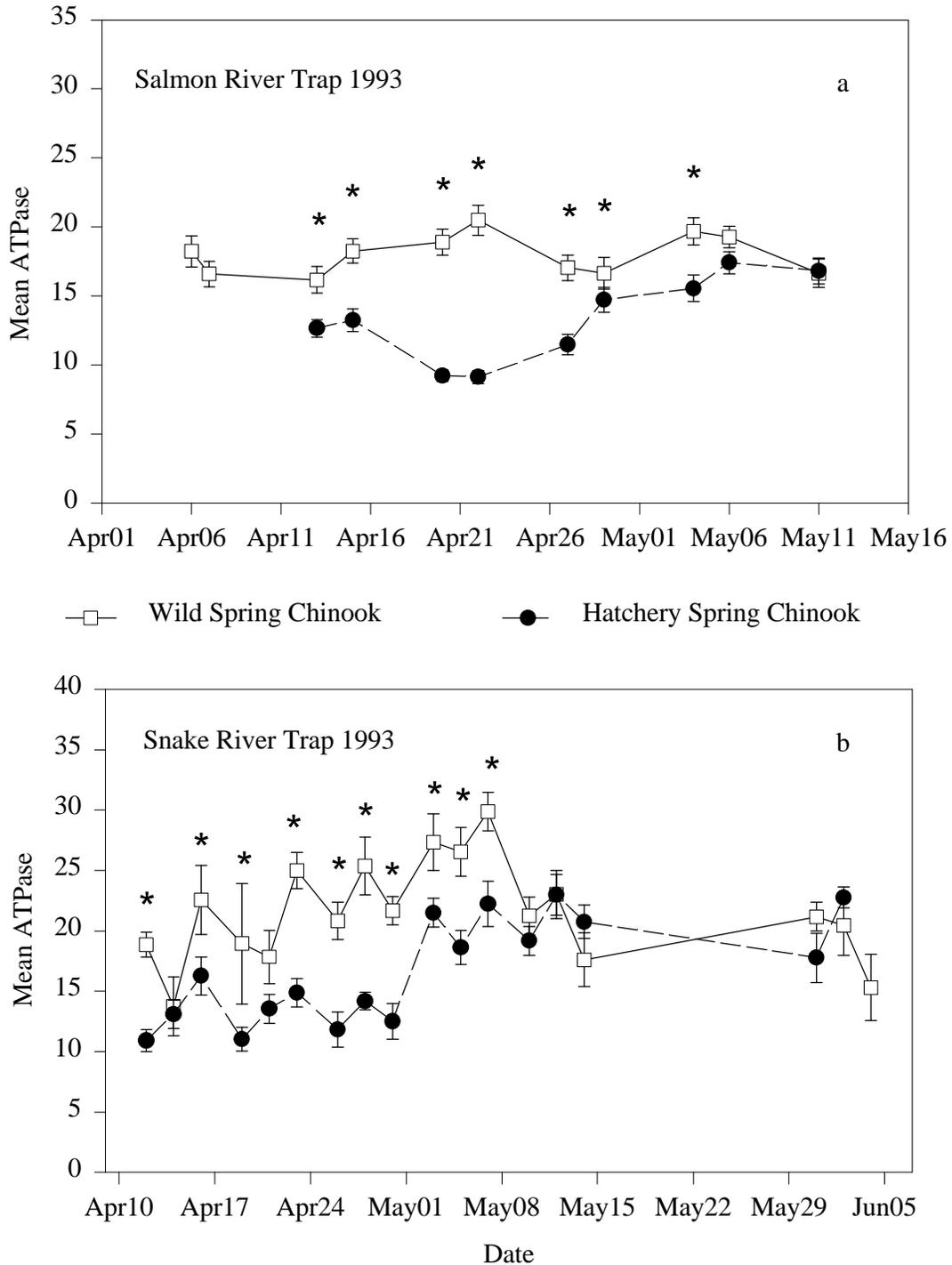


Figure 2.1. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\text{imol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of spring chinook salmon sampled from run-at-large populations captured at (a) the Salmon River Trap and (b) the Snake River Trap in 1993. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 4$  to 49).

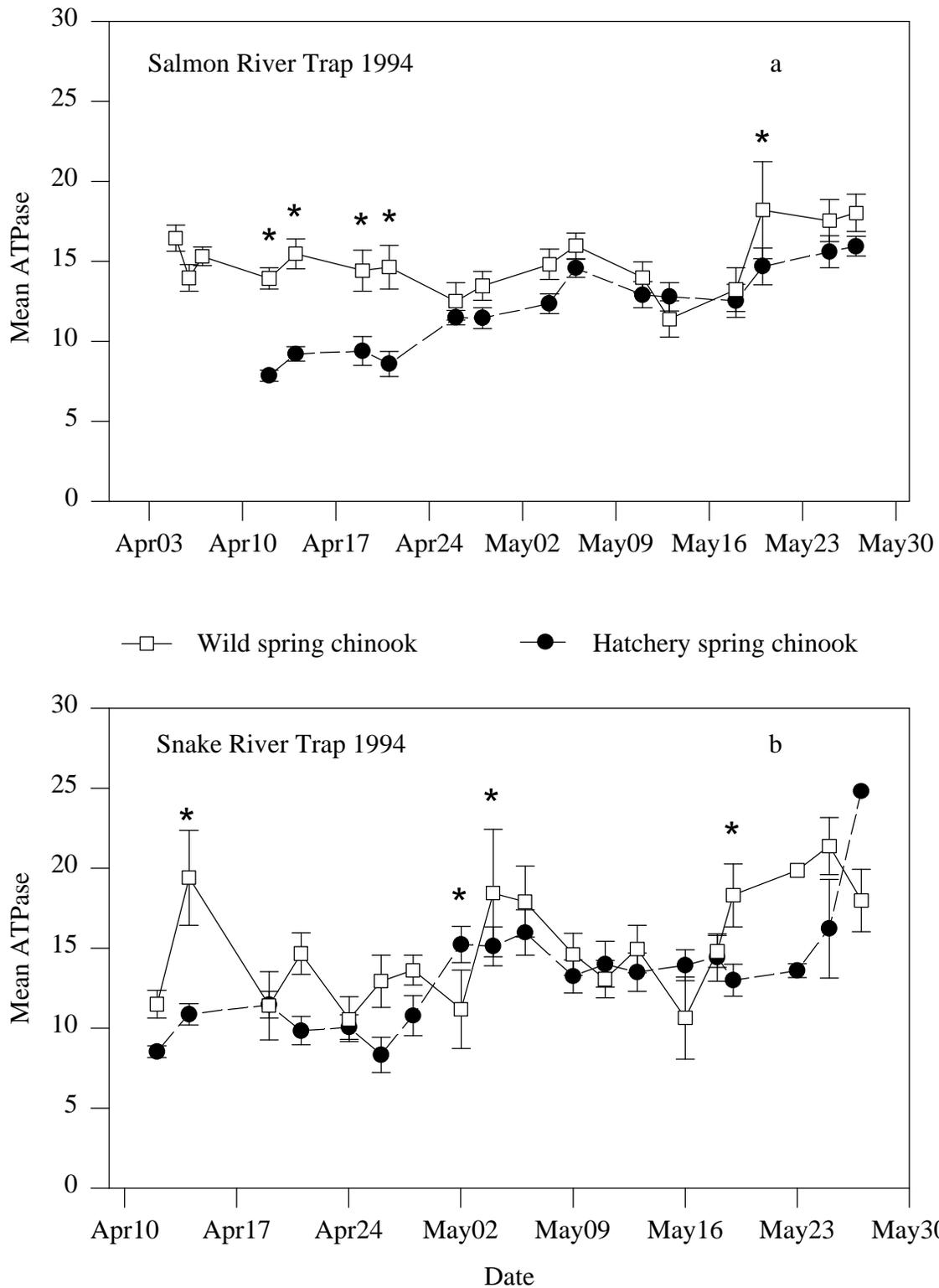


Figure 2.2. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of spring chinook salmon sampled from run-at-large populations captured at (a) the Salmon River Trap and (b) the Snake River Trap in 1994. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 2$  to 50).

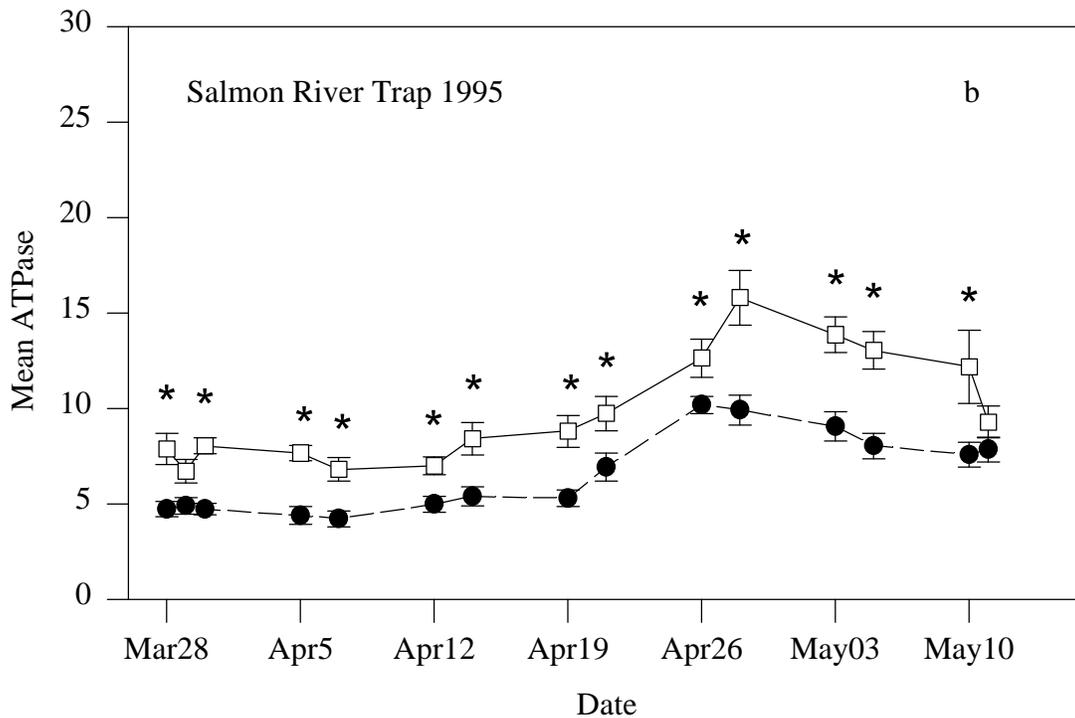
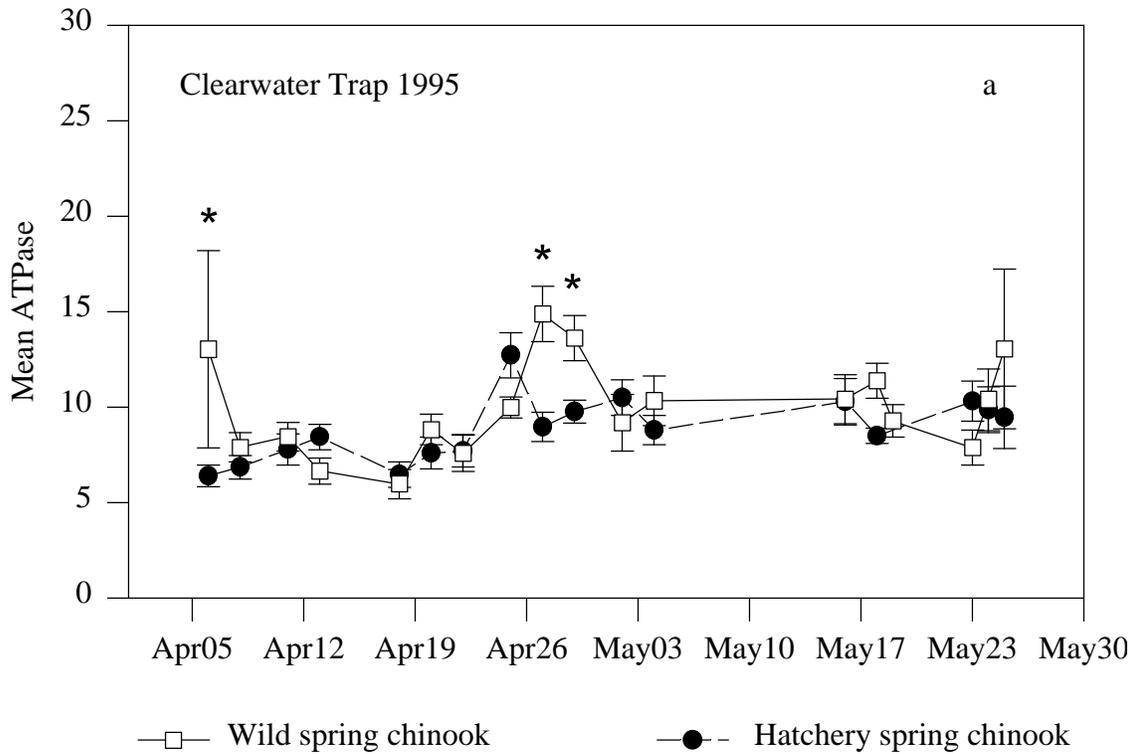


Figure 2.3. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\text{imol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of spring chinook salmon sampled from run-at-large populations captured at (a) the Clearwater River Trap and (b) the Salmon River Trap in 1995. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 2$  to 21).

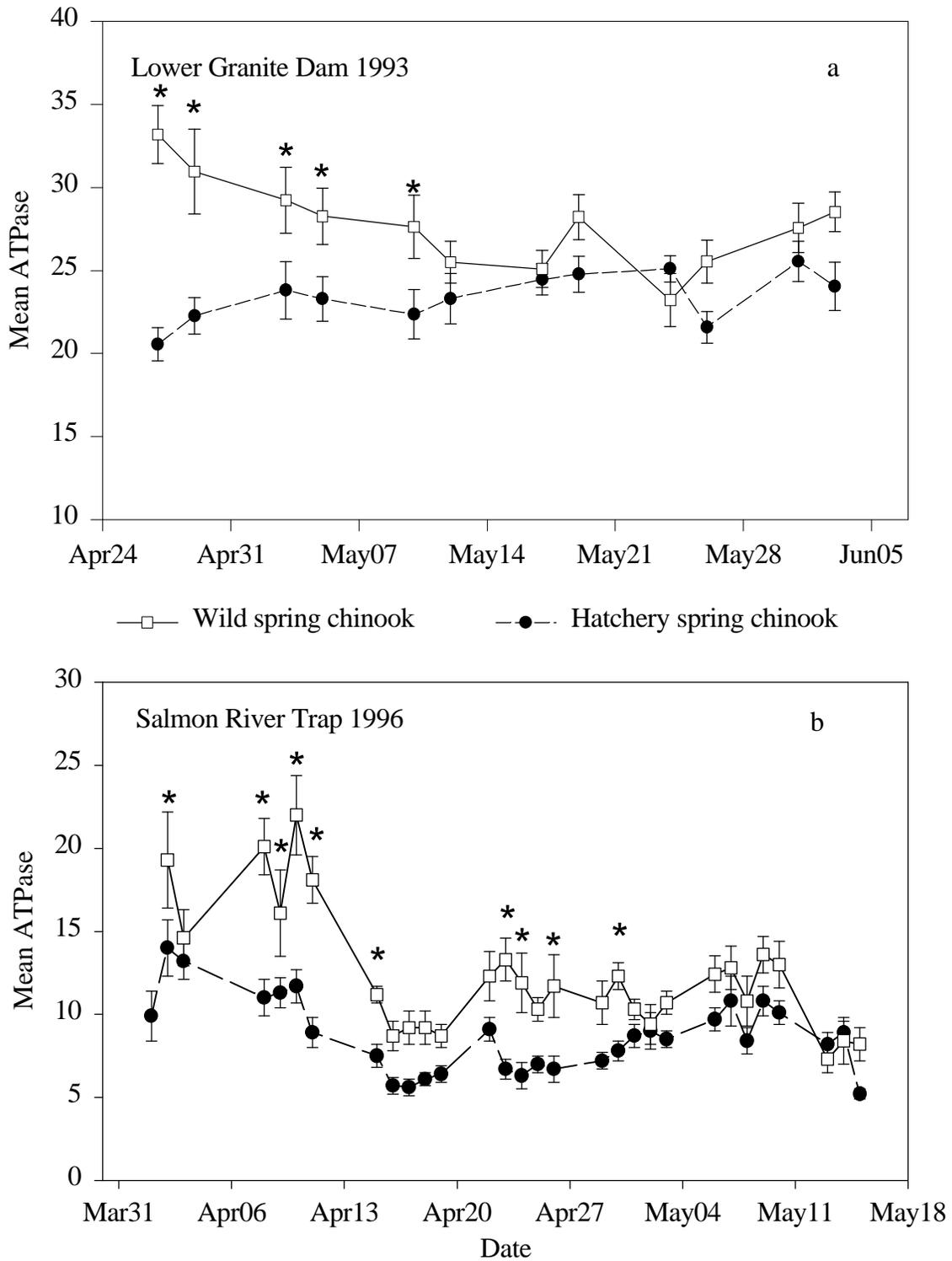


Figure 2.4. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\text{imol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of spring chinook salmon sampled from run-at-large populations captured at (a) Lower Granite Dam in 1993 and (b) the Salmon River Trap in 1996. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 3$  to 29).

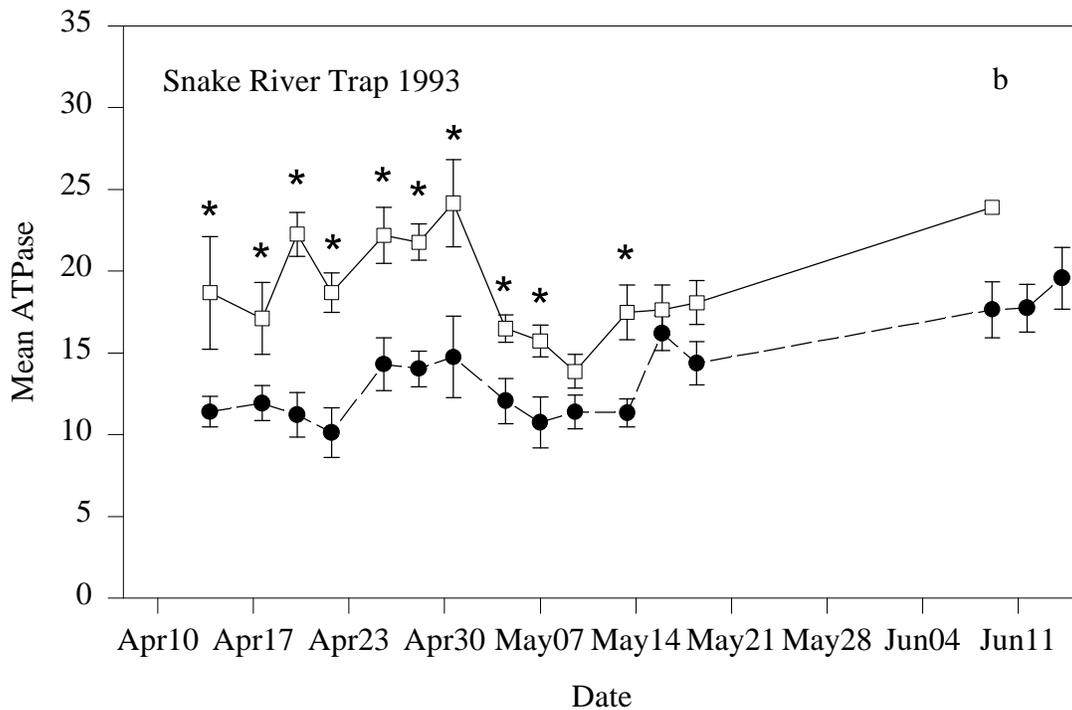
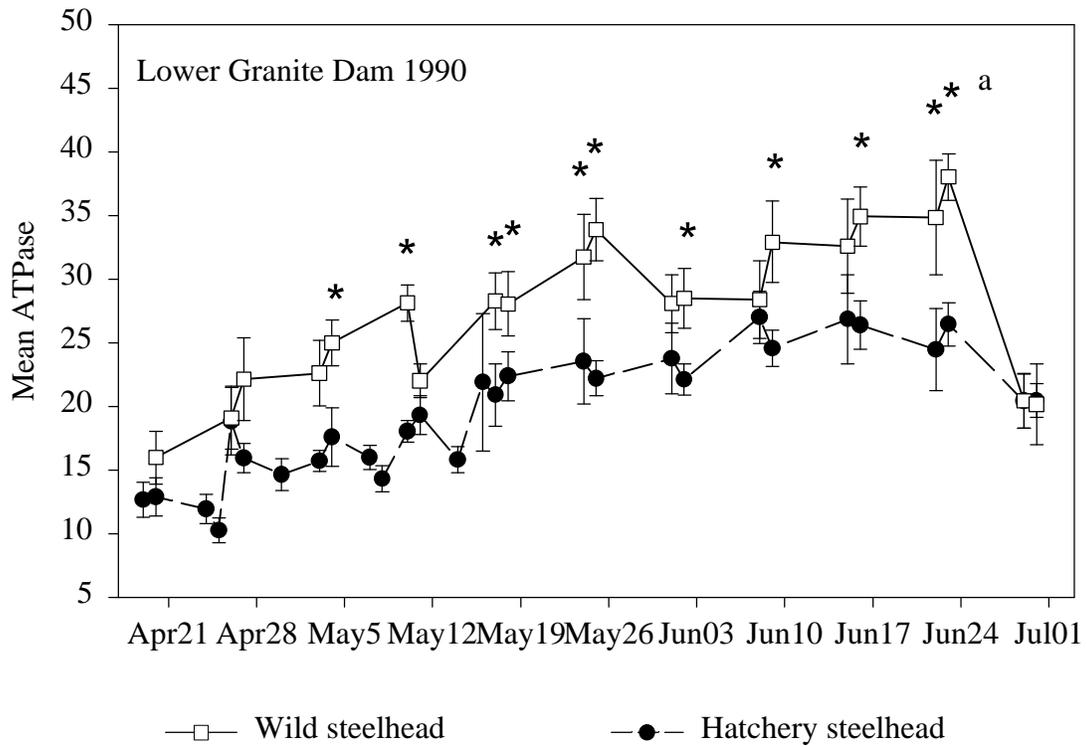


Figure 2.5. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\text{imol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of steelhead sampled from run-at-large populations captured at (a) Lower Granite Dam in 1990 and (b) the Snake River Trap in 1993. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 9$  to 30).

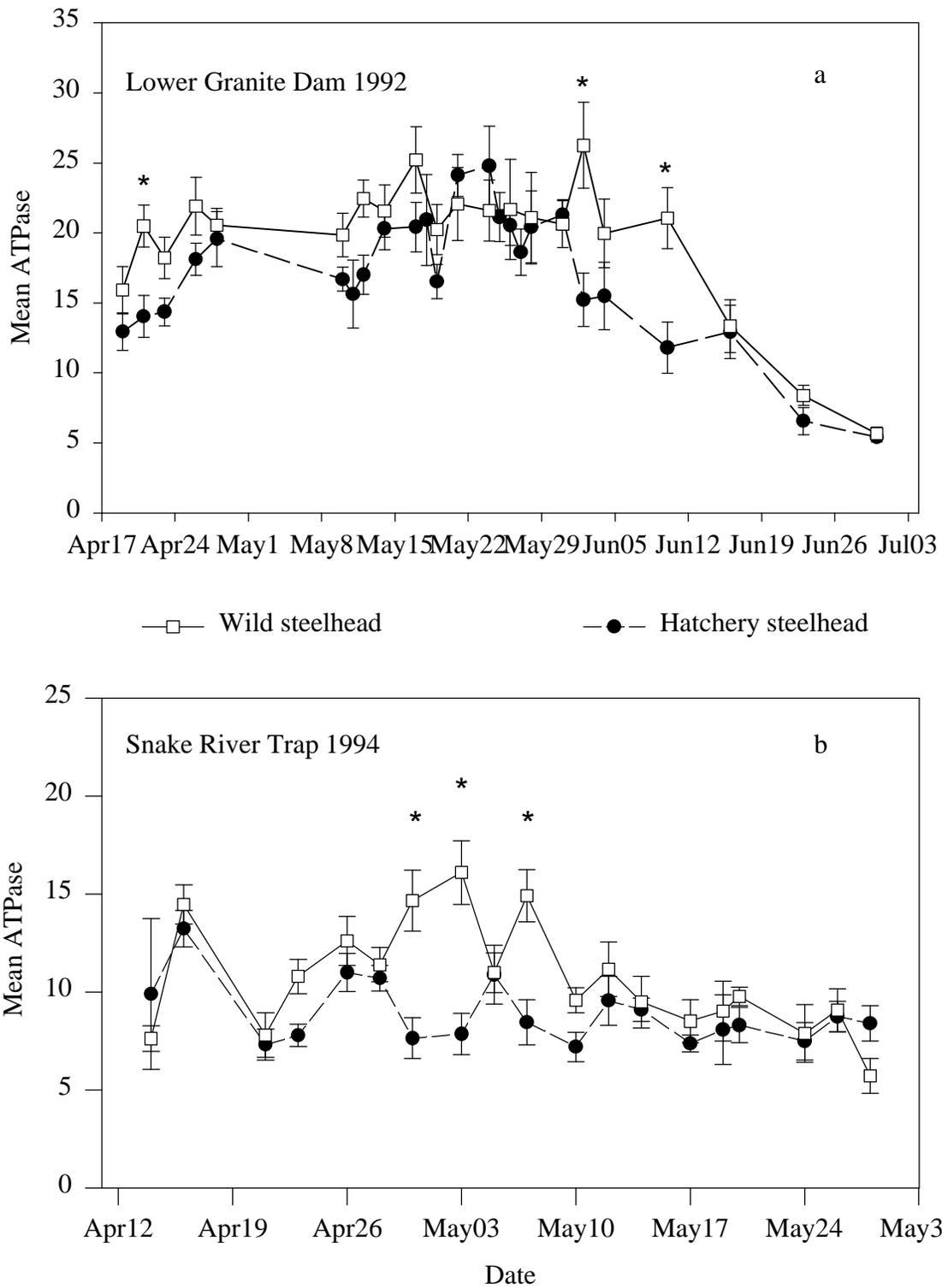


Figure 2.6. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of steelhead sampled from run-at-large populations captured at (a) Lower Granite Dam in 1992 and (b) the Snake River Trap in 1994. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 2$  to 31).

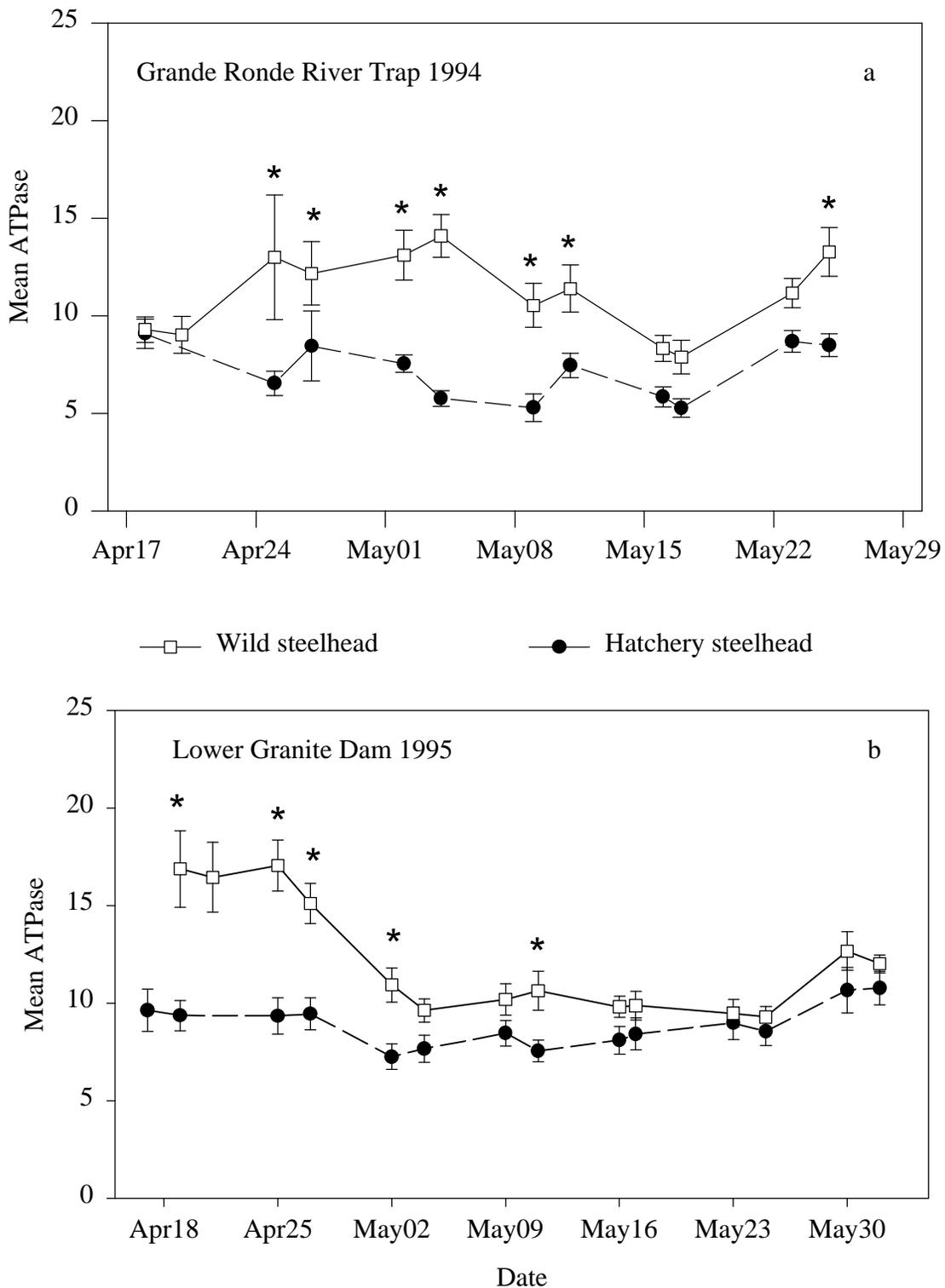


Figure 2.7. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\text{imol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of steelhead sampled from run-at-large populations captured at (a) the Grande Ronde River Trap in 1994 and (b) Lower Granite Dam in 1995. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 3$  to 25).

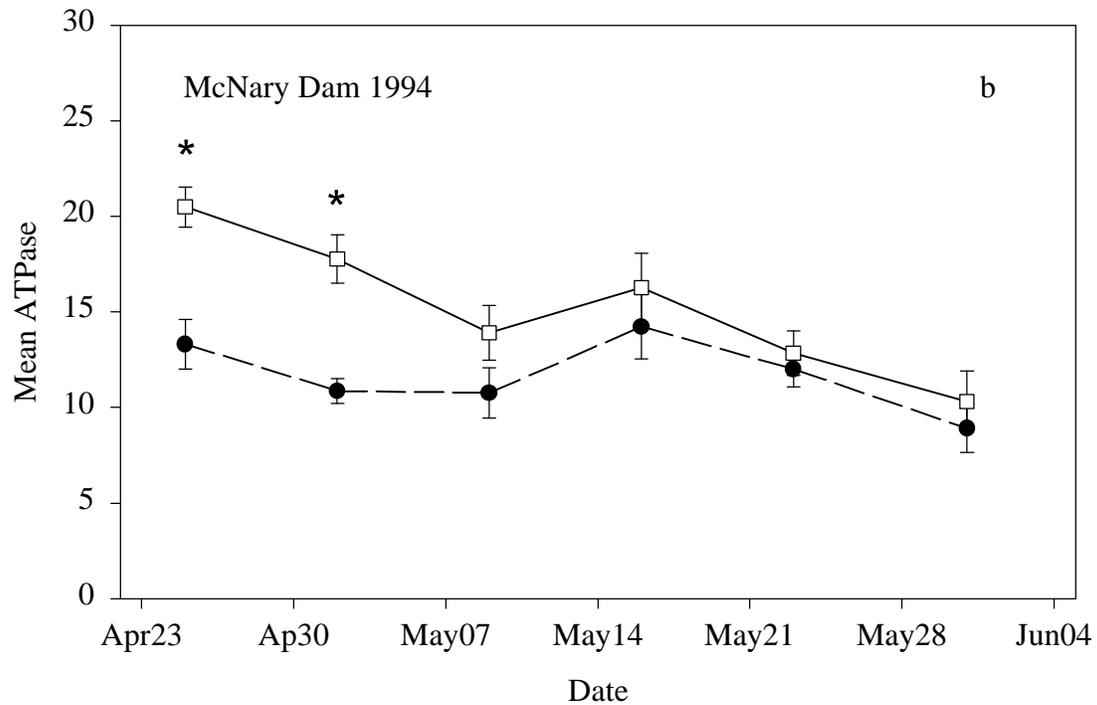
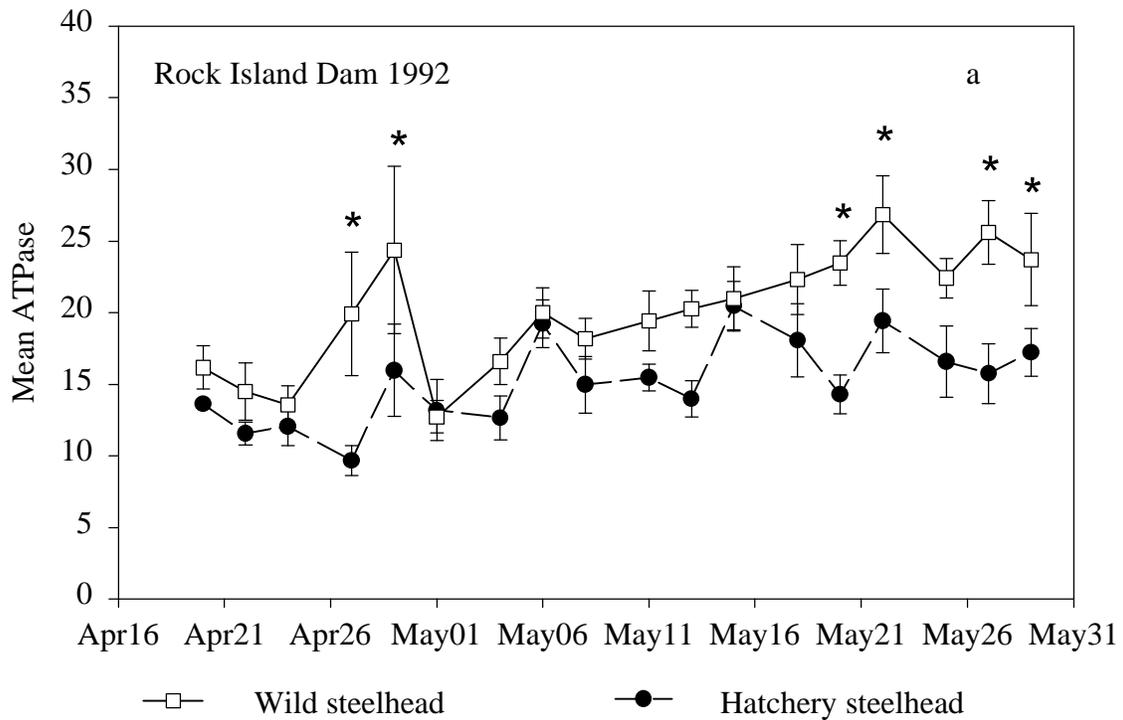


Figure 2.8. Mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase ( $\pm$ SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of steelhead sampled from run-at-large populations captured at (a) Rock Island Dam in 1992 and (b) McNary Dam in 1994. Asterisks represent dates when mean  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity of wild and hatchery fish differed significantly (Duncan's,  $P < 0.10$ ,  $n = 8$  to 21).

## CHAPTER THREE

### **Summary of Gill Sodium, Potassium-Activated Adenosine Triphosphatase Activity In Columbia and Snake River Basin Juvenile Salmonids, 1995-1996**

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#### **ABSTRACT**

Smoltification levels of run-at-large chinook, sockeye, and steelhead were determined through observing seasonal fluctuations of gill  $\text{Na}^+$ ,  $\text{K}^+$  - ATPase activity at hatcheries, traps, and dams in the Columbia and Snake River basins. Previous years data showed that wild salmonids had higher ATPase values than their hatchery counterparts and a general increase in ATPase levels in both groups as the fish migrate further down river. This pattern was again witnessed with data gathered in 1995-1996, even with unusually high flows that occurred during the spring migration period in 1996.

## INTRODUCTION

Monitoring gill sodium, potassium-activated adenosine triphosphatase ( $\text{Na}^+$ ,  $\text{K}^+$ -ATPase) activity in juvenile Pacific salmonids (*Oncorhynchus* spp.) prior to release from hatcheries and during migration can be used to make water, hydropower, and fishery management recommendations for the Columbia and Snake River basins. As salmonids transform from parr to smolt they undergo a series of behavioral, morphological, and physiological changes, including increased  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity, which allows them to adapt to the marine environment (Folmar and Dickhoff 1981). The Assessment of Smolt Condition for Travel Time Analysis (ASCTTA) project has monitored salmonid physiology in relation to environmental conditions for ten years (Schrock et al. 1998) and has supplied basin managers with pertinent data relating to travel time and smolt condition, assisting in making informed decisions. This report represents the completion of ASCTTA involvement in providing the Fish Passage Center Smolt Monitoring Program with run-of-the-river physiological information.

Gill sodium, potassium-activated ATPase is an enzyme that facilitates ionic transport across membranes by hydrolyzing adenosine triphosphate as an energy source. The enzyme is involved with the absorption of sodium chloride ( $\text{NaCl}$ ) across the gill epithelium of freshwater teleosts and excretion of  $\text{NaCl}$  in marine species (Hoar and Randall 1984; Borgatti et al. 1992). Thus, anadromous juvenile salmonids must reverse the flow of salts as they move from freshwater to saltwater habitats. Gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase is an established method of monitoring the level of smoltification in juvenile salmon (Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985) and can be used in association with other morphological, physiological and environmental indicators of smoltification (Wedemeyer et al. 1980; Folmar and Dickhoff 1981; Zaugg 1982a; Dickhoff et al. 1985; Sower and Fawcett 1991). Reporting gill ATPase activity on a seasonal basis has been a routine part of salmonid smolt programs in the Columbia River basin (Beeman et al. 1991, Maule et al. 1994, Schrock et al. 1998).

While the absolute concentration of gill ATPase varies, there is an enzyme profile characteristic among salmonids during seaward migration.  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity remains low in juveniles residing in hatcheries, showing only a gradual increase, followed by a rapid escalation in activity upon release into the river. The increase in enzyme activity continues until late in the migration (Beeman et al. 1991). If release is delayed, fish at hatcheries experience a decrease in ATPase activity followed by rapid increases upon release and during migration (Zaugg 1982a). The objective of this study was to determine the level of smoltification, as indicated by gill ATPase activity, in juvenile yearling (spring/summer) and subyearling (fall) chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*) and steelhead (*O. mykiss*) before their release from hatcheries, and in both hatchery and wild fish during seaward migration.

## METHODS

### Sample Sites

#### *Hatcheries*

In 1995 and 1996, samples were taken at the following state and federal hatcheries in Idaho, Oregon, and Washington: In Idaho, Dworshak National Fish Hatchery (Spring Chinook, Steelhead – sampled 1996 only, USFWS), Kooskia National Fish Hatchery (Spring Chinook, USFWS – sampled 1996 only), McCall Hatchery (Summer Chinook, Idaho Department of Fish and Game), Rapid River Hatchery (Spring Chinook, Idaho Department of Fish and Game), and Sawtooth Hatchery (Spring Chinook, Idaho Department of Fish and Game) were sampled (Figure 3.1). Fish were sampled in Washington at Entiat National Fish Hatchery (Spring Chinook, USFWS), Leavenworth National Fish Hatchery (Spring Chinook, USFWS), Winthrop National Fish Hatchery (Spring Chinook, USFWS), Priest Rapids Hatchery (Fall Chinook, Washington Department of Fish and Wildlife), Ringold Hatchery (Spring Chinook, Washington Department of Fish and Wildlife), and Wells Hatchery (Summer Chinook, Washington Department of Fish and Wildlife) (Figure 3.1). Lookingglass Hatchery (Spring Chinook, Oregon Department of Fish and Wildlife) was the only sample site in Oregon (Figure 3.1). Sockeye salmon were sampled from net pens in Lake Wenatchee in Washington (Washington Department of Fish and Wildlife).

#### *Traps*

In 1995, fish were sampled at traps located on the Salmon River (operated by Idaho Department of Fish and Game), Clearwater River (operated by Idaho Department of Fish and Game), Snake River (operated by Idaho Department of Fish and Game), Imnaha River (operated by Nez Perce Indian Nation), and Grande Ronde River (operated by Oregon Department of Fish and Wildlife) (Figure 3.1). In 1996, fish were captured only at the Salmon River and Snake River traps (Figure 3.1). Collected fish were held up to 24 hours, anesthetized using tricaine methanesulfonate (MS-222), tagged with passive integrated transponder (PIT) tags, and non-lethally sampled for  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity by removing a small piece of gill tissue, then released.

#### *Dams*

On the Snake River, hatchery and wild spring chinook salmon and steelhead were sampled only at Lower Granite Dam while sampling on the Columbia River took place at the juvenile bypass facilities at Rock Island Dam (1995 and 1996), McNary Dam (1995 only), and John Day Dam (1995 only) (Figure 3.1). All hatchery steelhead in the Snake and Columbia rivers were adipose fin-clipped before release to distinguish them from wild fish, which allowed comparison of ATPase activity of wild versus hatchery fish. Likewise, all hatchery chinook salmon in the Snake River were fin-clipped prior to release and could be separated from wild fish in Snake River dams and traps. However, comparisons of ATPase activity in spring and fall chinook salmon at Columbia River dams were limited to fish of hatchery origin versus unknown origin, due to incomplete marking of release groups at Columbia River hatcheries. Hatchery sockeye,

which originated from a net pen project on Lake Wenatchee operated by WDFW, were also fin-clipped allowing them to be differentiated from wild stocks. Hatchery and wild sockeye were sampled at Rock Island Dam only.

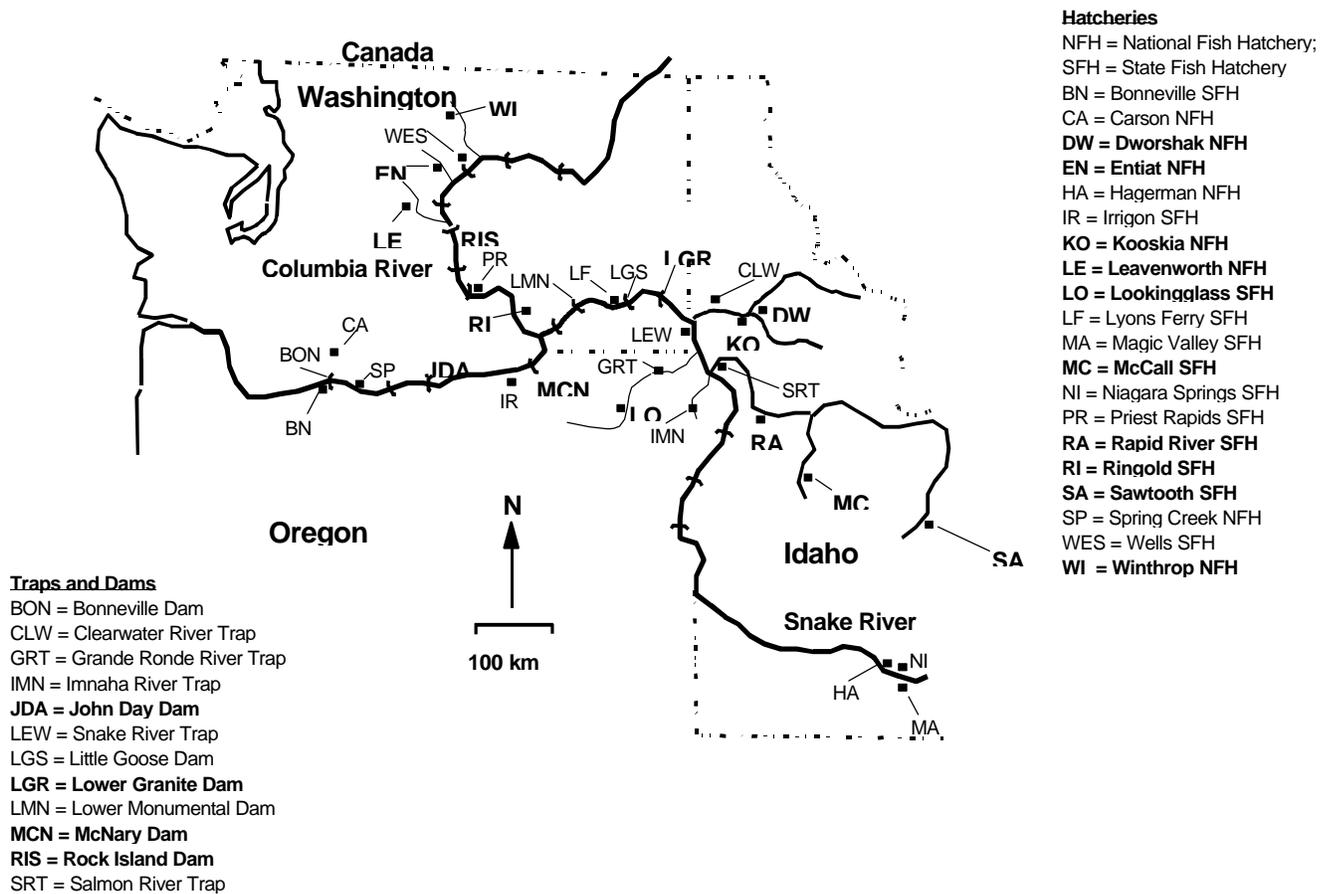


Figure 3.1. Location of sampling sites in the Columbia and Snake River basins for the Assessment of Smolt Condition for Travel Time project, 1987-1996 (BPA Project No. 87-401)

## **Sample Sizes**

In 1995 and 1996, our objective was to sample 30 fish per hatchery prior to release. At traps and dams, we attempted to sample 20 to 40 spring chinook salmon and 12 to 25 steelhead per day. The number of PIT-tagged fish we expected to detect at downstream collection sites determined the target sample size. Frequently, these sample sizes were not attained on a given day, and more fish were sampled in subsequent days in order to reach weekly goals.

## **Tissue Collection and Analysis**

Fish collected from hatcheries, traps, or dams were anaesthetized in 50 to 80 mg · L<sup>-1</sup> tricaine methanesulfonate (MS-222), weighed to the nearest 0.1 g, and measured to the nearest millimeter fork length. 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 (Schrock et al. 1994). After ATPase sampling, fish were revived in aerated water for 15 to 120 min until swimming upright and alert, then released at the site of collection. The gill tissue samples were placed in 1.5-mL microcentrifuge tubes and preserved in 0.5 mL chilled ATPase buffer solution (Schrock et al. 1994). Samples were shaken to break up filaments, bathed in icewater for at least 5 min, frozen in liquid nitrogen for transport, and later stored at -80 °C. Water temperature and external signs of disease or injury of each fish (e.g., descaling, lesions, and parasites) were noted at the time of sampling. The microassay method developed by Schrock et al. (1994) was used to determine ATPase levels in gill tissue. ATPase activity is reported in units of micromoles inorganic phosphate per milligrams protein per hour (μmoles Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>). Tables containing the data collected in 1995 and 1996 and used in the following figures are presented in Appendices 3.1 - 3.21.

# **RESULTS**

## **1995 Results**

In 1995, the ASCTTA project collected 5605 gill samples to determine relative ATPase levels using the non-lethal microassay method developed by Schrock et al. (1994). Sampling of 12 release groups was completed at 12 hatcheries in the Snake and Columbia River basins. Wild and hatchery steelhead, yearling and subyearling chinook salmon, and sockeye salmon were sampled at 5 smolt traps and 5 hydropower dams in the region.

## **Yearling Chinook Salmon**

### **Hatcheries**

In 1995, yearling spring chinook salmon sampled at Snake and Columbia River basin hatcheries showed similar mean ATPase levels, ranging between 5.3 units at Sawtooth SFH and 7.4 units at Lookingglass SFH (Figures 3.2a, 3.2b). Summer chinook salmon also had similar mean ATPase levels ranging from 7.8 units at Wells Hatchery to 5.8 units at McCall Hatchery (Figures 3.2a,b).

## **Traps**

Clearwater River Trap. At the Clearwater River Trap, mean ATPase levels for hatchery yearling chinook salmon fluctuated between 6.4 and 10.5 units except for a peak of 12.7 units on April 24 (Figure 3.3a). Mean ATPase for wild fish showed more fluctuation than hatchery fish. On April 5 the mean ATPase value was 13.0 units ( $n = 2$ ), declined to 6.0 units on April 17, and increased to 14.9 on April 26. Values ranged between 7.9 and 13.6 units during the remainder of the migration season (Figure 3.3a).

Salmon River Trap. In 1995, mean ATPase levels for yearling hatchery chinook salmon at the Salmon River Trap began at 4.7 units on March 28, remained low (between 4.2 and 6.9 units) from March 29 to April 20, rose to 10.2 units on April 25, then decreased to 7.8 units on May 10 (Figure 3.3b). Wild fish mean ATPase levels showed a gradual increase from 7.9 units to 15.8 units, then declined to 9.3 on May 10 (Figure 3.3b).

Snake River Trap. Mean ATPase levels of hatchery yearling chinook salmon captured at the Snake River Trap in 1995 increased steadily in April from 4.8 to 15.7 units, while in May levels varied between 8.9 and 14.9 units (Figure 3.3c). Mean ATPase levels for wild fish rose from 8.2 on April 10 to 17.4 units by April 28, before stabilizing in May when levels were between 12.2 and 17.7 units (Figure 3.3c).

Imnaha River Trap. Mean ATPase values for hatchery yearling chinook salmon at the Imnaha River Trap began at 14.6 units on April 18, then dropped abruptly to 4.5 units on April 25 before gradually increasing to 11.2 units on May 4, when sampling was suspended for 19 days due to high flows and debris loads. After May 23, when sampling resumed, mean ATPase levels varied between 6.2 and 9.0 units (Figure 3.4a). Wild fish began the season on April 20 at 14.5 ATPase units, dropped to 8.8 units on April 26, then fluctuated between 10.0 and 12.3 units until sampling was suspended for the same 19 day period. When sampling resumed, mean ATPase levels steadily declined from 11.3 to 8.7 units at the end of sampling May 26 (Figure 3.4a).

Grande Ronde River Trap. Hatchery yearling chinook salmon were not sampled at the Grande Ronde River Trap in 1995. Sample sizes for wild fish were small on most days ( $n \leq 15$ ). Gill ATPase levels for wild fish fluctuated between 8.9 and 9.6 units from April 13 to 20, then increased to 16.7 units by April 27, when sampling was suspended for 28 days. Mean ATPase activities on May 24 and 25 were 15.5 and 12.5 units, respectively (Figure 3.4b).

## **Snake River Dams**

Lower Granite Dam. Mean ATPase levels for hatchery yearling chinook salmon at Lower Granite Dam began at 11.7 units on April 14, dropped to 8.5 units on April 17, increased to 16.4 units on May 2, then steadily decreased to 10.9 units by the end of sampling on June 1 (Figure 3.5a). For wild fish, mean ATPase levels began at 11.9 units on April 14, increased to 19.8 units on April 25, and then gradually decreased from 17.7 on April 27 to 13.9 units at the end of sampling on May 30 (Figure 3.5a).

## **Columbia River Dams**

Rock Island Dam. Sample sizes of yearling chinook salmon of hatchery origin were small ( $n \leq 6$ ) at Rock Island Dam in 1995. During the first week of sampling, mean ATPase levels were low, less than 9.9 units, then increased to 18.1 units on April 25, declined to 5.2 units on May 11, and remained between 13.6 and 19.3 units through the end of sampling on May 25 (Figure 3.6a). Sample sizes of yearling spring chinook salmon of unknown origin (both wild and hatchery) were also small ( $n \leq 8$ ) in 1995. Mean ATPase levels showed considerable variation through

April and early May, fluctuating between 7.0 and 13.7 units, then increasing steadily from 15.7 units on May 15 to 19.9 units on May 25 when sampling was terminated (Figure 3.6a).

McNary Dam. No yearling chinook salmon of hatchery origin were sampled at McNary Dam in 1995. Yearling chinook salmon of unknown origin sampled in 1995 showed an increase in ATPase activity from 8.9 to 18.7 units between April 24 and May 1, then remained between 14.0 and 21.0 units throughout May (Figure 3.5b).

## **Subyearling Chinook Salmon**

### **Hatcheries**

Priest Rapids SFH. Priest Rapids Hatchery on the Columbia River in Washington was the sole hatchery sampled for subyearling fall chinook salmon. A mean gill ATPase activity of 8.7 units on June 13 (Figure 3.2a) was found for the 21 fish sampled.

### **Columbia River Dams**

Rock Island Dam. Mean ATPase levels for subyearling chinook salmon during the first week of sampling at Rock Island Dam were between 9.9 and 11.1 units. Mean ATPase activity remained above 14.5 units in July, peaked at 19.8 on July 28, and then steadily decreased to 11.3 at the end of sampling on August 25 (Figure 3.7a).

McNary Dam. Mean ATPase levels for subyearling chinook salmon at McNary Dam in 1995 began at 23.8 units on June 12, varied between 16.4 and 18.6 units the remainder of June, dropped to 5.9 units on July 12, increased to 18.3 units on July 19, then steadily declined to 10.9 units by August 25 (Figure 3.7b).

John Day Dam. Mean ATPase levels for subyearling chinook salmon at John Day Dam began at 19.2 units on June 24, decreased to 16.2 units on July 8, increased to 21.5 units on July 17, then declined to 8.6 units by August 27 (Figure 3.7c).

## **Steelhead**

### **Traps**

Salmon River Trap. During 1995, mean ATPase levels for hatchery steelhead at the Salmon River Trap were relatively low all season, with levels remaining between 3.4 and 8.8 units (Figure 3.8a). Wild fish began the sampling season on April 11 with a mean ATPase level of 5.7 units, increased to 14.1 units on April 18, decreased steadily to 6.4 units on May 4, then increased to 11.7 units ( $n = 1$ ) on the last day of sampling (Figure 3.8a).

Snake River Trap. During 1995, mean ATPase levels for hatchery steelhead at the Snake River Trap fluctuated between 5.3 and 8.4 units through the sampling season, except for peaks of 10.3 and 11.1 units near the end of the season (Figure 3.8b). Levels for wild fish were more variable with a mean ATPase level of 13.4 units on 4/26, dropping to 6.7 units on 5/8, raising on 5/18 to 14.0 units, and then remained between 11.6 and 9.8 the rest of the sampling period (Figure 3.8b).

Imnaha River Trap. During 1995, hatchery steelhead were sampled for ATPase at the Imnaha River Trap on May 23 only, with a mean ATPase level of 6.4 units (Figure 3.9a). Wild fish mean ATPase levels started at 6.3 on April 19 and steadily increased to 10.6 units on May 25 (Figure 3.9a).

Grande Ronde River Trap. In 1995, mean ATPase levels for hatchery steelhead at the Grande Ronde River Trap began at 7.7 units, and increased to 9.3 units at the end of the season (Figure 3.9b). Mean ATPase levels of wild fish varied between 8.2 and 12.2 units (Figure 3.9b).

### **Snake River Dams**

Lower Granite Dam. During 1995, mean ATPase levels for hatchery steelhead at Lower Granite Dam showed little variation during the sampling season, ranging between 7.3 and 10.8 (Figure 3.5b). Levels of ATPase for wild fish began at 16.9 units on April 19, decreased to 9.6 on May 4, and then remained between 9.3 and 12.7 units through the end of sampling (Figure 3.5b).

### **Columbia River Dams**

Rock Island Dam. Mean ATPase levels of hatchery steelhead at Rock Island Dam started at 15.5 on April 27, dropped to 7.6 units on May 1, and remained between 7.9 and 11.0 units until late May, when elevated activities of 14.0 to 15.6 units were seen (Figure 3.10a). Wild steelhead also began with a high mean ATPase level of 18.8 units, which dropped to 10.3 units on May 1, and fluctuated between 8.8 and 18.3 units during May (Figure 3.10a).

McNary Dam. At McNary Dam in 1995, mean ATPase levels for hatchery steelhead started at 6.1 units on April 26, then increased to 12.3 units by the end of sampling (May 24) (Figure 3.10b). Sample sizes for wild fish were low ( $n = 7$ ) resulting in large fluctuations in ATPase levels. Wild fish ATPase levels began at 14.2 units ( $n = 1$ ) on April 26, increased to 20.7 units on May 1, then fluctuated between 12.2 and 17.8 units (Figure 3.10b).

## **Sockeye Salmon**

### **Hatcheries**

Sockeye salmon sampled from the Lake Wenatchee net pens in 1995 had a mean ATPase level of 6.5 units (Figure 2.2a).

### **Columbia River Dams**

Rock Island Dam. Mean ATPase levels for hatchery sockeye salmon at Rock Island Dam fluctuated greatly during the sampling season of 1995; however, sample sizes were small ( $n \leq 9$ ). During April and early May, levels varied between 7.8 and 28.8 units. For the last two weeks of sampling, levels increased steadily from 17.9 to 38.2 units (Figure 10a). Sample sizes for wild sockeye salmon were also low ( $n \leq 9$ ). For most of the season, mean ATPase levels were between 15.0 and 20.0 units, with a low of 6.9 units on May 2 and a high of 25.7 units on May 23 (Figure 3.11a).

## **1996 Results**

In 1996, 6101 gill samples were collected using the non-lethal method. Sampling of 15 release groups was completed at 13 hatcheries while salmonid migrants of wild and hatchery origin were sampled at 2 smolt traps and 2 hydropower dams.

## Yearling Chinook Salmon

### Hatcheries

Yearling spring chinook salmon sampled at Snake and Columbia River basin hatcheries in 1996 generally showed similar mean ATPase levels, ranging between 5.5 and 11.0 ATPase units (Figures 3.12a, 3.12b). The exception was Ringold Hatchery on the mid-Columbia River, with a mean ATPase value of 15.1 units. Two release groups of summer chinook salmon were sampled at Wells Hatchery, with mean ATPase levels of 7.1 units for the yearling release group (April 8), and 11.2 units for the subyearling release group (June 5) (Figure 3.12a). At McCall Hatchery, the mean ATPase level for summer chinook salmon was 8.1 units (Figure 3.12b).

### Traps

Salmon River Trap. In 1996, mean ATPase levels for hatchery yearling chinook salmon at the Salmon River Trap started at 9.9 units on April 1 ( $n = 4$ ), peaked at 14.0 units on April 2, and decreased to 5.2 units at the end of sampling (May 15) (Figure 3.13a). Wild fish sampled early in the season exhibited mean ATPase levels between 14.6 and 22.0 units. Mean ATPase level dropped to 8.9 units on April 16, and for the next month fluctuated between 7.2 and 13.6 units (Figure 3.13a).

Snake River Trap. Mean ATPase levels for hatchery yearling chinook salmon at the Snake River Trap declined from 15.1 units on April 15 to 11.9 units on April 24, peaked at 18.9 units on May 6, and remained at around 15.0 units for the rest of the sampling season (Figure 3.13b). Wild fish mean ATPase levels were more variable than levels for hatchery fish, fluctuating between 11.7 and 19.5 units through most of the sampling season, except for a peak of 21.4 on April 23 (Figure 3.13b).

### Snake River Dams

Lower Granite Dam. Yearling hatchery spring chinook salmon at Lower Granite Dam exhibited a range of mean ATPase activities between 9.1 and 16.6 units during May, while wild fish ATPase activity ranged between 13.3 and 18.8 units during the same period.

### Columbia River Dams

Rock Island Dam. Mean ATPase levels of yearling spring chinook salmon of hatchery origin sampled at Rock Island Dam increased from 8.2 units on April 23 to a peak of 32.3 units on May 13, then fluctuated between 16.0 and 24.6 units through the end of sampling (Figure 3.14a). Yearling spring chinook salmon of unknown origin displayed a similar pattern of fluctuating ATPase levels, beginning the season with a mean of 9.3 units, increasing to 35.2 units on May 13, and ranging between 16.3 and 28.7 through the remainder of the season (Figure 3.14a).

## Subyearling Chinook Salmon

### Hatcheries

Subyearling fall chinook salmon were sampled at Priest Rapids twice during 1996, and had a mean ATPase level of 12.8 on June 6 and 10.0 units on June 18 (Figure 3.12a).

## **Columbia River Dams**

Rock Island Dam. In 1996, mean ATPase activity in subyearling chinook salmon started at 15.1 units on June 24, increased to 21.7 units on June 25, then fell sharply to 10.8 units on June 28. During July, levels ranged from 13.3 to 23.5 units (Figure 3.14b).

## **Steelhead**

### **Hatcheries**

Steelhead sampled at Dworshak National Fish Hatchery on April 17, 1996 had a mean ATPase level of 4.0 units (Figure 3.12c).

### **Traps**

Salmon River Trap. Mean ATPase levels for hatchery steelhead at the Salmon River Trap were low all season, between 3.3 and 7.0 units (Figure 3.15a). Wild fish began the 1996 sampling season on April 2 with an ATPase level of 3.0 units ( $n = 1$ ), activity remained low all season peaking at 9.1 units on May 9, and then declining to 5.0 units on May 15 ( $n = 3$ ) (Figure 3.15a). Snake River Trap. In 1996, mean ATPase levels for hatchery steelhead at the Snake River Trap were between 4.2 and 9.8 units for most of the season, and then peaked at 11.5 units on May 15 (Figure 3.15b). Levels for wild steelhead were more variable, starting at 7.6 units on April 15 and fluctuating between 5.8 and 12.4 units before increasing to 16.7 units near the end of sampling (Figure 3.15b).

### **Snake River Dams**

Lower Granite Dam. Sample sizes for hatchery steelhead at Lower Granite Dam in 1996 were small ( $n \leq 8$ ), often with only one fish per sample date. Recorded ATPase levels ranged between 6.2 and 18.9. ATPase levels for wild steelhead were also based on only one or two fish; daily values ranged from 7.3 to 13.1.

## **Columbia River Dams**

Rock Island Dam. At Rock Island Dam during 1996, hatchery steelhead mean ATPase levels started at 8.1 units on April 29, peaked at 16.7 units on May 13, then declined to 11.1 units at the end of sampling (Figure 3.16). Wild fish mean ATPase level began at 14.5 units on April 29, peaked at 28.6 on May 8, and then fluctuated between 15.3 and 26.8 units through the end of May (Figure 3.16).

## **Sockeye Salmon**

### **Hatcheries**

Sockeye salmon sampled from the Lake Wenatchee net pens on September 5, 1996 had a mean ATPase level of 6.0 units on 5/9/96 (Figure 3.12c).

## **Columbia River Dams**

Rock Island Dam. Mean ATPase levels for hatchery sockeye salmon at Rock Island Dam varied greatly during the 1996 sampling season. Sample sizes were often low and highly variable ( $n \leq$

16). Mean ATPase levels increased from 13.6 units ( $n = 1$ ) to 43.3 units ( $n = 4$ ) by May 7, dropped to 21.5 units on May 10, then fluctuated between 14.7 and 31.0 units through the end of sampling (Figure 3.11b). Wild fish sample sizes were also variable and often low ( $n \leq 17$  on most sample dates). ATPase levels began at 13.8 units on April 23, rose to 29.9 units on May 9, and then ranged between 14.4 and 30.9 during the remainder of the season (Figure 3.11b).

## DISCUSSION

The ASCTTA project was developed to monitor the effects of smoltification on travel time. Gill  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity is one method by which the physiological development of juvenile salmonids is observed as juvenile salmonids develop and migrate down river. Information gained through the monitoring of ATPase levels as salmonids pass through the river system provides regional hydro and fishery managers with valuable information allowing them to better facilitate smolt passage to the estuary.

Data gathered over past years indicate that ATPase levels are often higher in wild salmonids than their hatchery counterparts, a trend that is especially noticeable at traps and dams higher in the system. The discrepancy in ATPase levels lessens as fish migrate down river, however, at lower river dams such as McNary and Lower Granite, hatchery fish continue to exhibit lower ATPase levels. In 1996, when high water events upset the typical migration patterns resulting in an earlier migration, and decreased migration time in both hatchery and wild salmonids, ATPase values for wild fish sampled remained higher. Early run numbers are not available for comparison because traps and smolt monitoring facilities at dams were not operating when the first part of the runs were migrating.

In hatcheries, gill ATPase levels were relatively low (5.0 to 7.0 units) during 1995 and 1996, with the exception of Ringold State Fish Hatchery, which had a mean ATPase level of 15.1 units. This higher mean ATPase value may be the expression of high water temperatures during rearing as Ringold SFH had a water temperature of 12.5 °C at the time of sampling, while the other reference hatcheries had temperatures ranging from 5 to 7 °C. Water temperature has been shown to be a crucial variable affecting ATPase levels, both Zaugg et al. (1985) and Jonsson (1991) found that increased water temperatures promote smoltification in juvenile salmonids. Both hatchery and wild fish demonstrated lower ATPase levels at upper Snake River basin traps (Salmon River, Snake River, Imnaha River, and Grande Ronde traps) than at downstream dams (Lower Granite and McNary), a finding consistent with results from previous studies in which gill ATPase activity increased rapidly after release from the hatchery (Rondorf et al. 1988, 1989; Beeman et al. 1990, 1991; Maule et al. 1994).

The mean ATPase levels in migrating wild fish were generally higher than those of migrating hatchery fish. This was true for most of the sampling season for yearling chinook salmon sampled at the Salmon River Trap, Clearwater River Trap (1995), Snake River Trap, and Lower Granite Dam. Higher ATPase levels in wild versus hatchery fish were also observed for steelhead sampled at the Snake River Trap, Salmon River Trap, Lower Granite Dam, Rock Island Dam and McNary Dam (1995). Because yearling chinook salmon with intact adipose fins sampled in the Columbia River could not be distinguished as from wild or hatchery origin,

differences in ATPase activities between wild and hatchery fish sampled at Columbia River dams could not be determined.

In areas where wild and hatchery fish could be distinguished, the difference between the two groups was usually more pronounced at upper river sites, and lessened as the fish moved downriver. This supports published studies that suggest hatchery fish are often released at a different level of physiological development than their wild counterparts (Wedemeyer et al. 1980; Folmar and Dickhoff, 1981; Zaugg et al. 1985). Constant water temperature, artificial diets, high rearing densities, and artificial photoperiod may act to suppress the parr-smolt transformation (Folmar and Dickhoff 1981; Nishioka et al. 1985; Schreck et al. 1985). Differences between the mean ATPase levels of wild and hatchery spring chinook salmon on specific sample dates may be the result of differences in the timing of peak migration between hatchery and wild fish. Data from the present report and from a recapture study conducted in 1996 (Hans, unpublished data) suggest that wild spring chinook salmon were at a higher level of smoltification than hatchery fish at the same site on the same date. The difference in mean ATPase levels between wild and hatchery fish was most pronounced early in the season and at upriver sampling sites. As the season progressed, mean ATPase levels of wild and hatchery fish converged, implying that hatchery fish migrating later in the season had sufficient time to physiologically “catch up” with the wild fish through in-river residence.

Mean ATPase levels in wild versus hatchery sockeye salmon exhibited little difference. Hatchery sockeye salmon sampled at Rock Island Dam often displayed similar or higher mean ATPase levels than wild fish, which may be explained by the origin of the hatchery fish. All hatchery fish sampled at Rock Island Dam in 1995 and 1996 came from the WDFW net pen operation at Lake Wenatchee, where a wild population of sockeye salmon also exists. Hatchery sockeye salmon are transferred to the net pens as fry in April, and released from the net pens into the lake in late October. The fish then migrate volitionally the following spring along with the wild fish. Shrimpton et al. (1994) found that colonized hatchery fish, released early to overwinter, were physiologically equivalent to wild fish with respect to ATPase level and seawater tolerance at the time of migration. Differences between wild and hatchery fish are less noteworthy for Wenatchee sockeye salmon because of the colonized nature of the hatchery fish.

Salmonids sampled at dams and traps can originate from many different sources, therefore the duration of river residence varies. The diversity in rearing history and the natural variation within a population make it difficult to definitively predict smoltification level and its effect on the physiological readiness to migrate. However, data collected for this report provides useful information about the physiological smoltification level of juvenile salmonids at hatcheries and during migration. This information, when used with data on water availability, temperature, and specific dam spill conditions, can be used to make management decisions geared toward maximizing the survival of out-migrating juvenile salmonids

## FIGURES

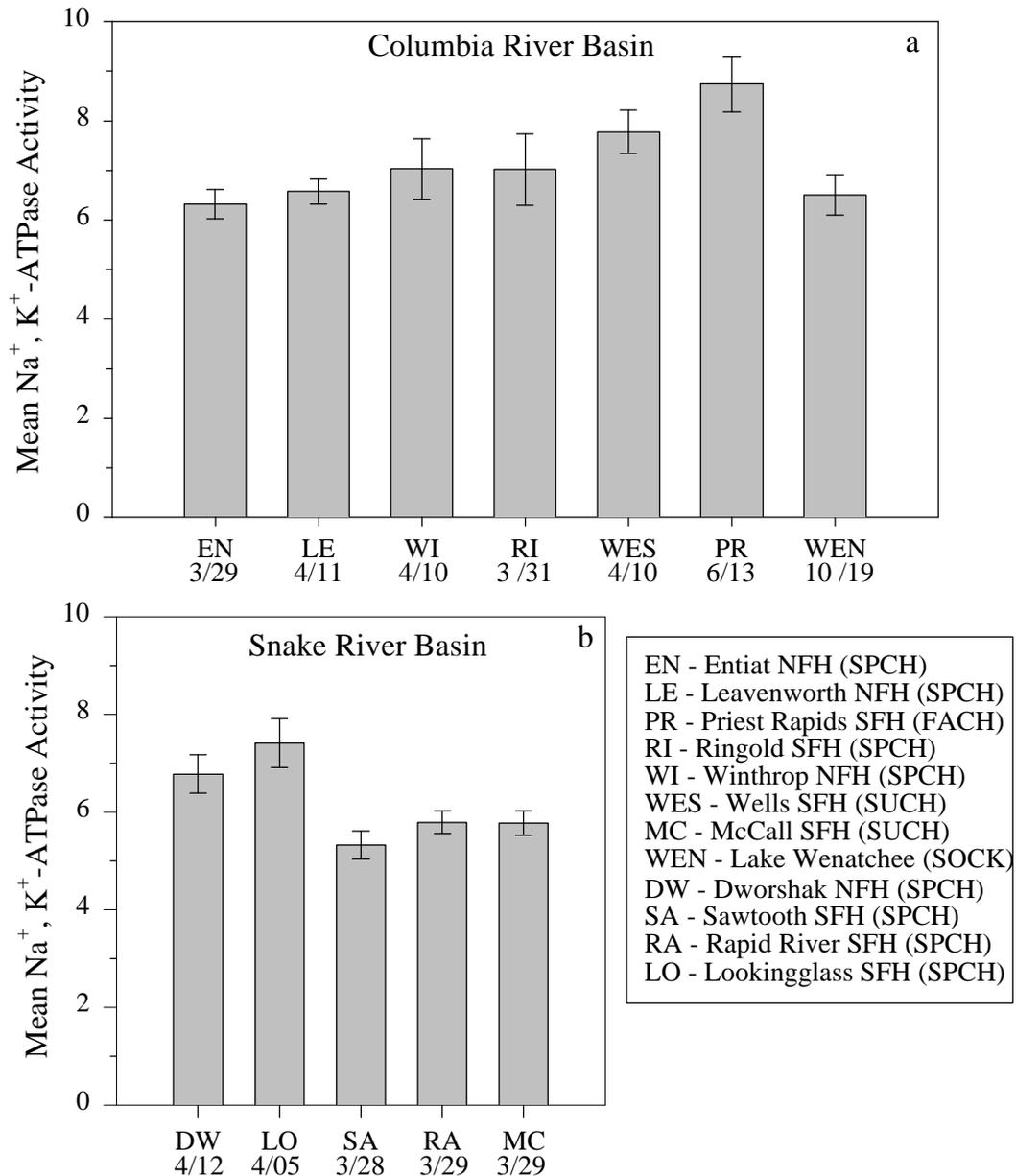


Figure 3.2. Mean ( $\pm$ SE) gill  $\text{Na}^+, \text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for yearling spring chinook salmon (SPCH), yearling summer chinook salmon (SUCH), subyearling fall chinook salmon (FACH), and sockeye salmon (SOCK) sampled before release from (a) Columbia River basin hatcheries and (b) Snake River basin hatcheries in 1995.

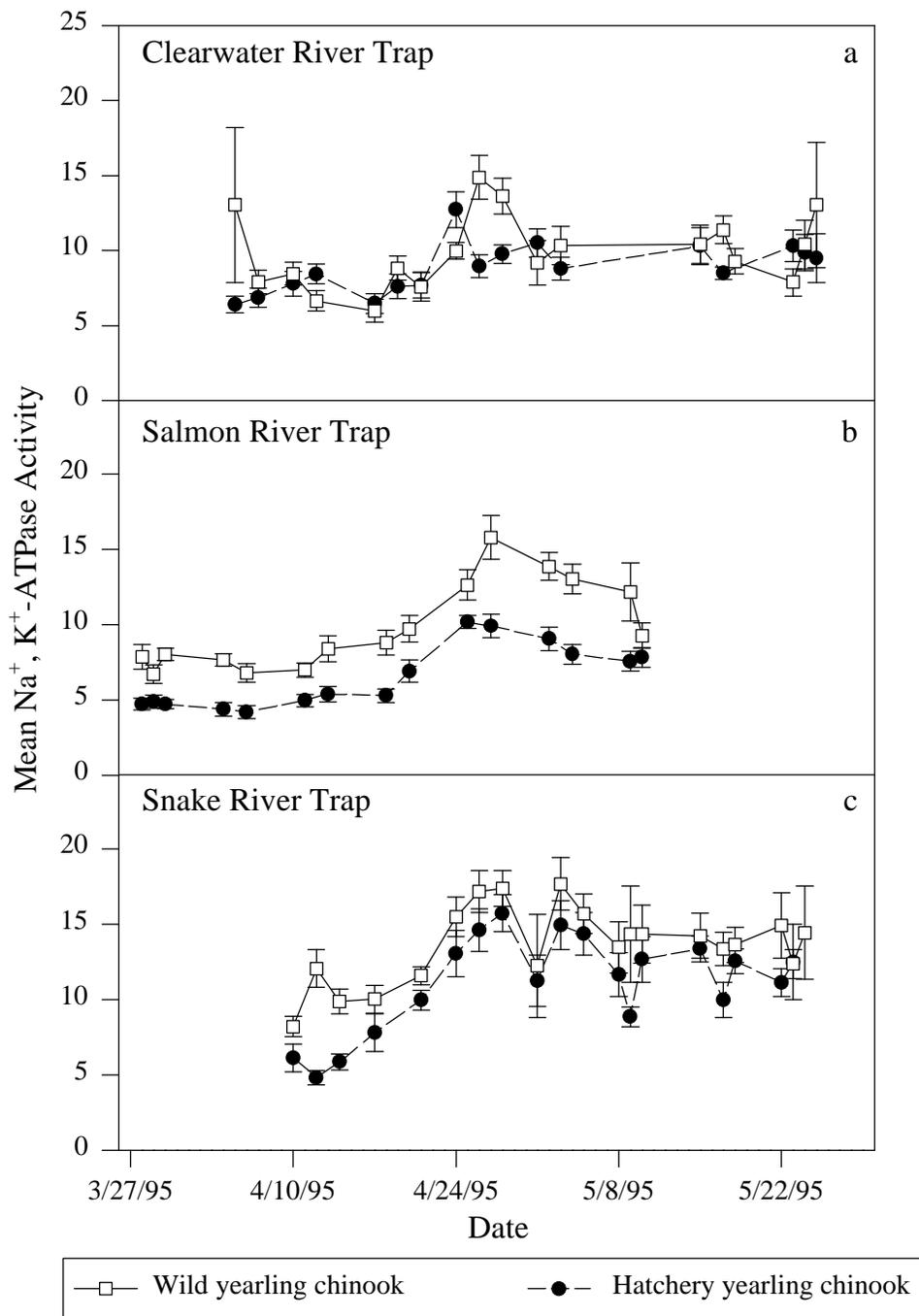


Figure 3.3. Mean ( $\pm$ SE) Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\mu$ moles Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of wild and hatchery yearling chinook salmon collected during migration at (a) the Clearwater River Trap, (b) the Salmon River Trap, and (c) the Snake River Trap in 1995

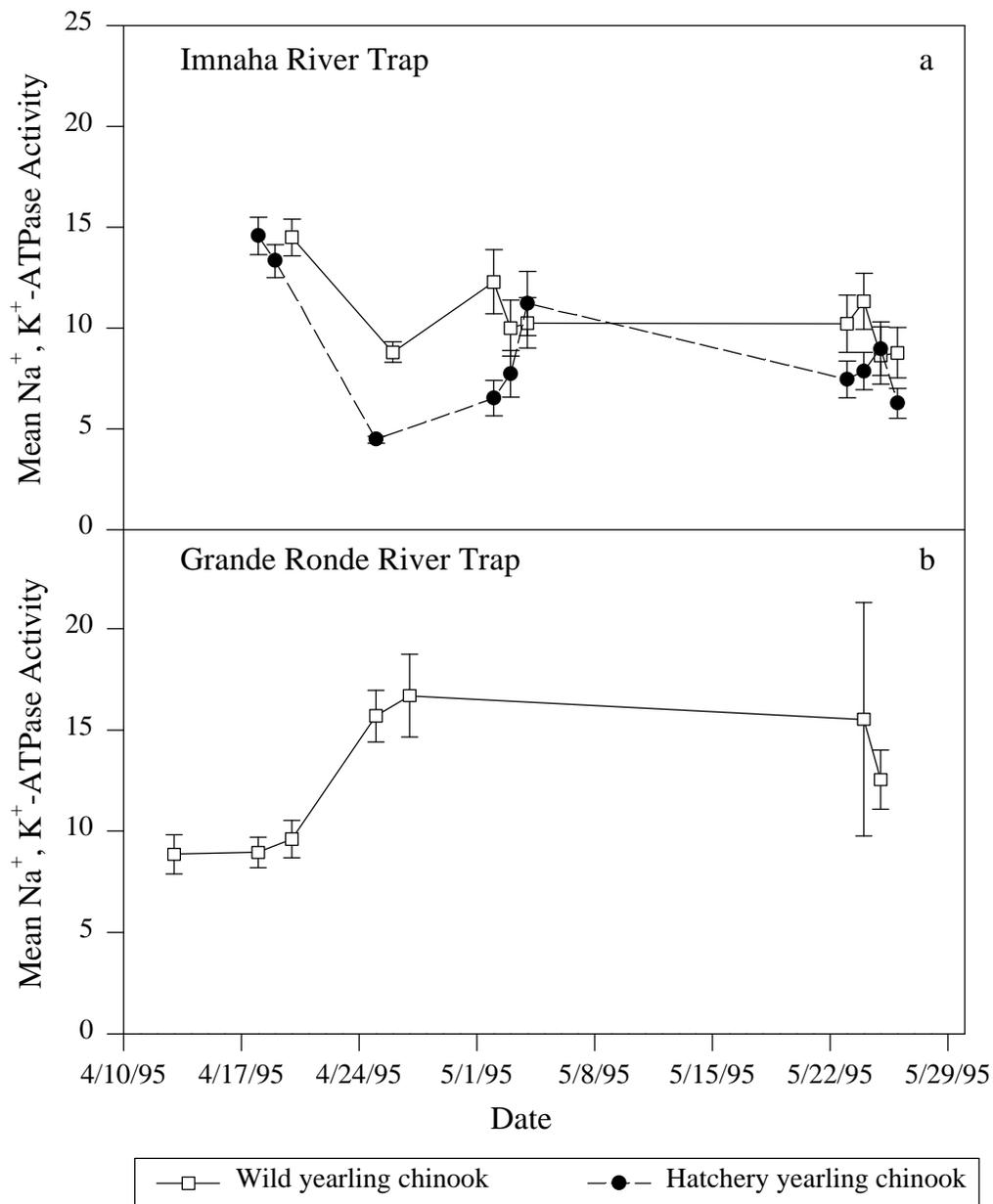


Figure 3.4. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery yearling chinook salmon collected during migration at (a) the Imnaha River Trap and (b) the Grande Ronde River Trap in 1995. Sampling ceased between May 4 and May 23 when traps were closed due to high flows.

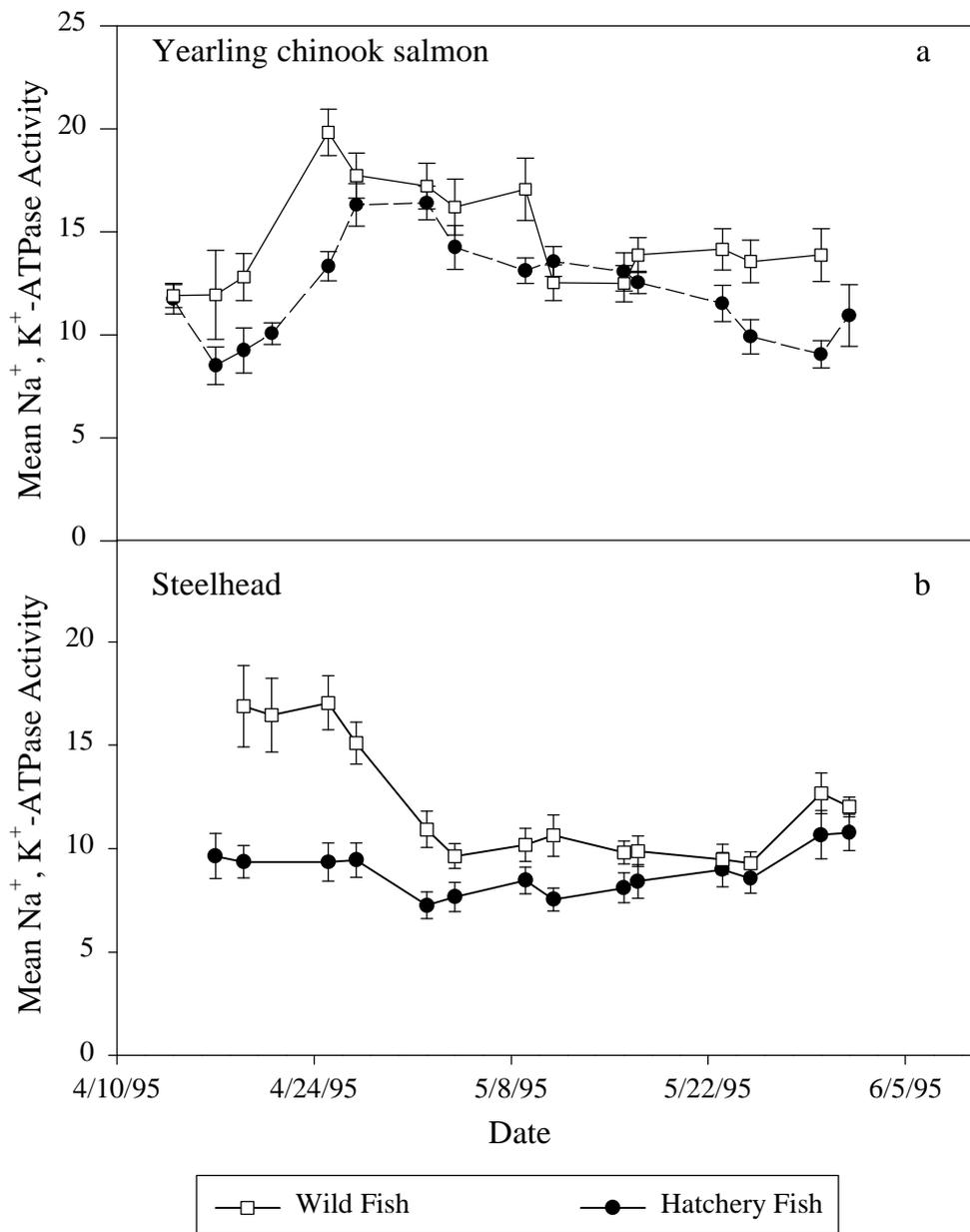


Figure 3.5. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of (a) wild and hatchery yearling chinook salmon and (b) wild and hatchery steelhead collected during migration at Lower Granite Dam on the Snake River in 1995.

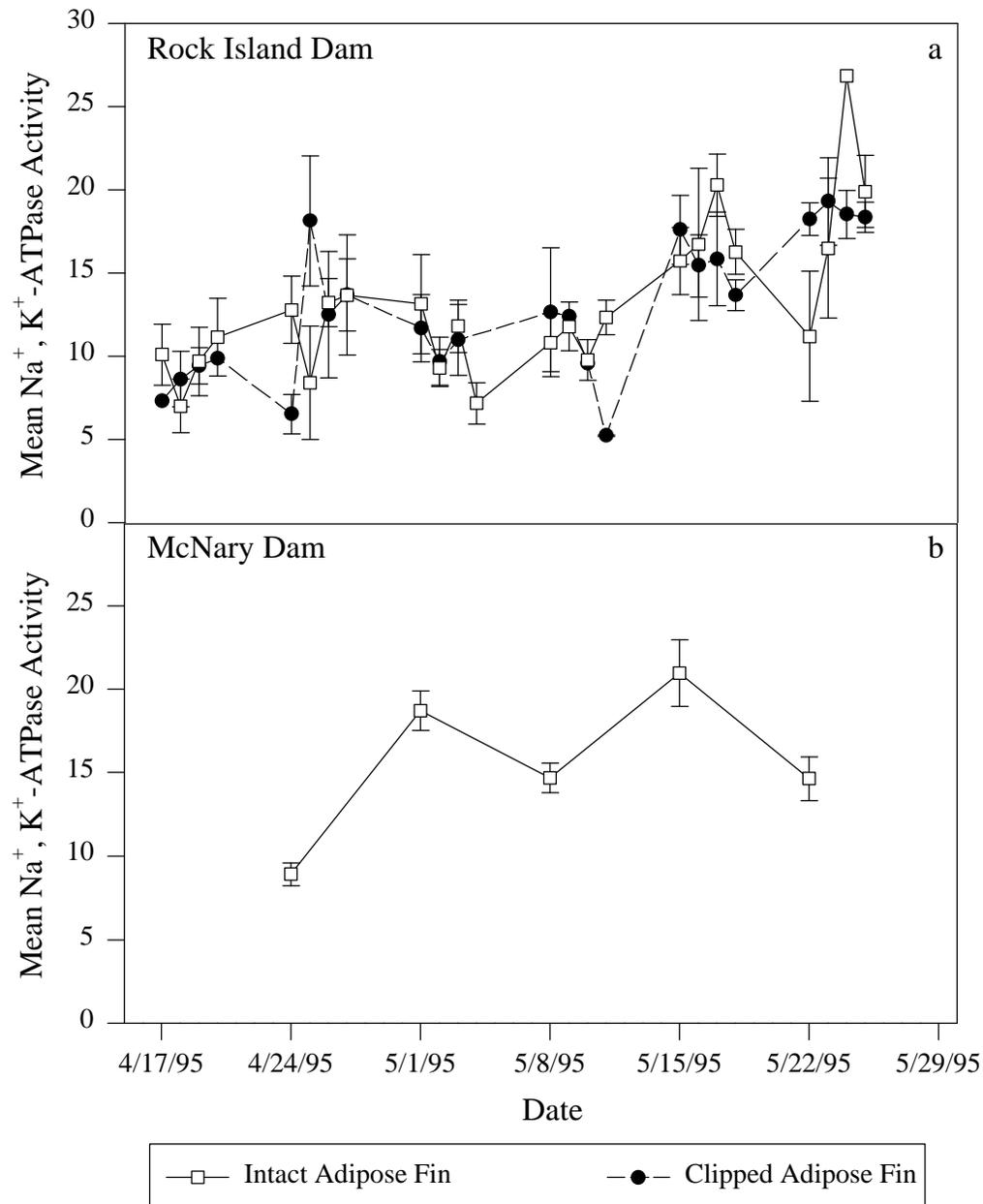


Figure 3.6. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of yearling chinook salmon with intact adipose fins and yearling hatchery chinook salmon (adipose fin-clipped) collected during migration at (a) Rock Island Dam and (b) McNary Dam on the Columbia River in 1995.

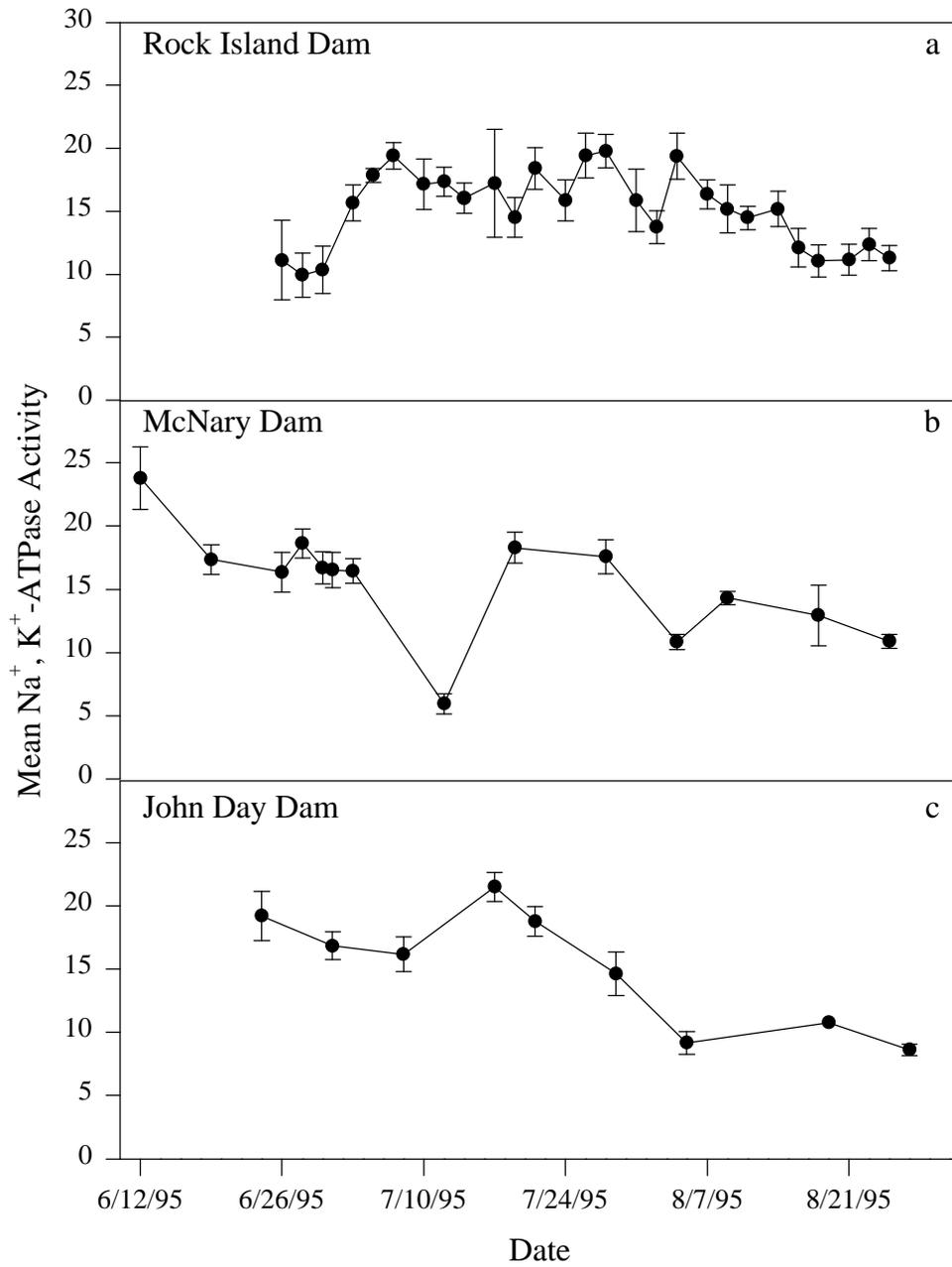


Figure 3.7. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of subyearling fall chinook salmon collected during migration at (a) Rock Island Dam, (b) McNary Dam, and (c) John Day Dam on the Columbia River in 1995.

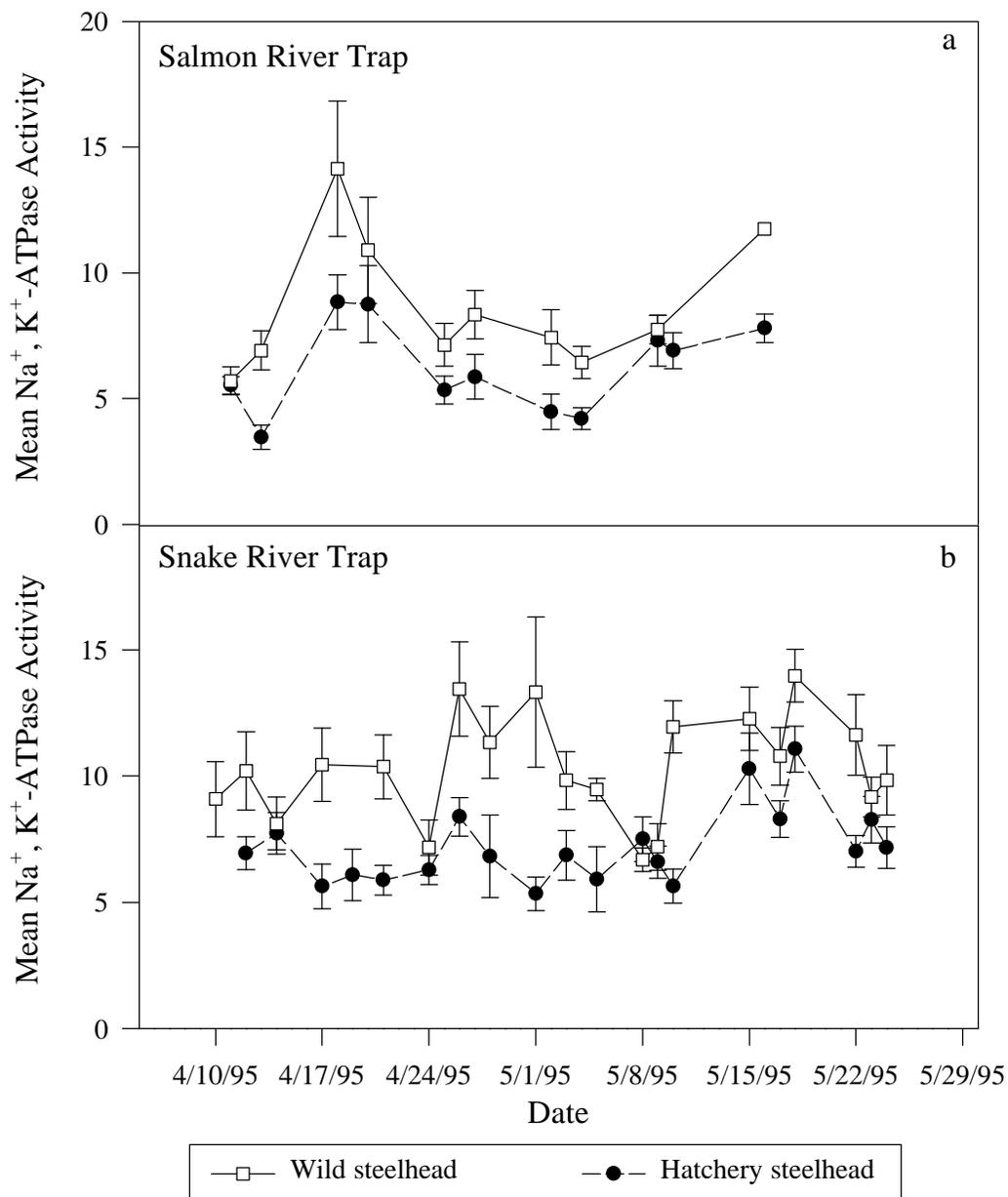


Figure 3.8. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery steelhead collected during migration at (a) the Salmon River Trap and (b) the Snake River Trap in 1995.

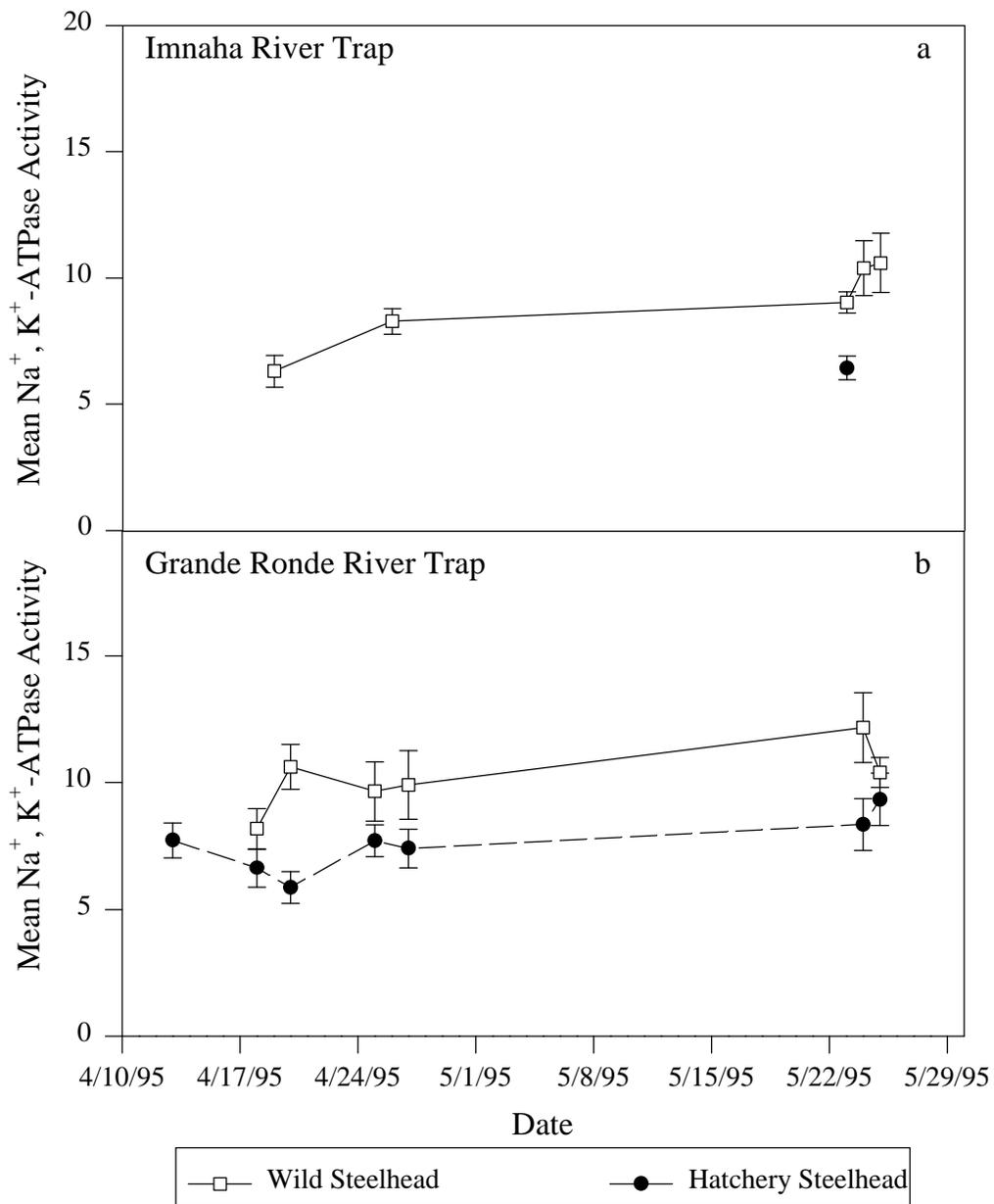


Figure 3.9. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery steelhead collected during migration at (a) the Imnaha River Trap and (b) the Grande Ronde River Trap in 1995. Traps were closed between May 4 and May 23 due to high flows.

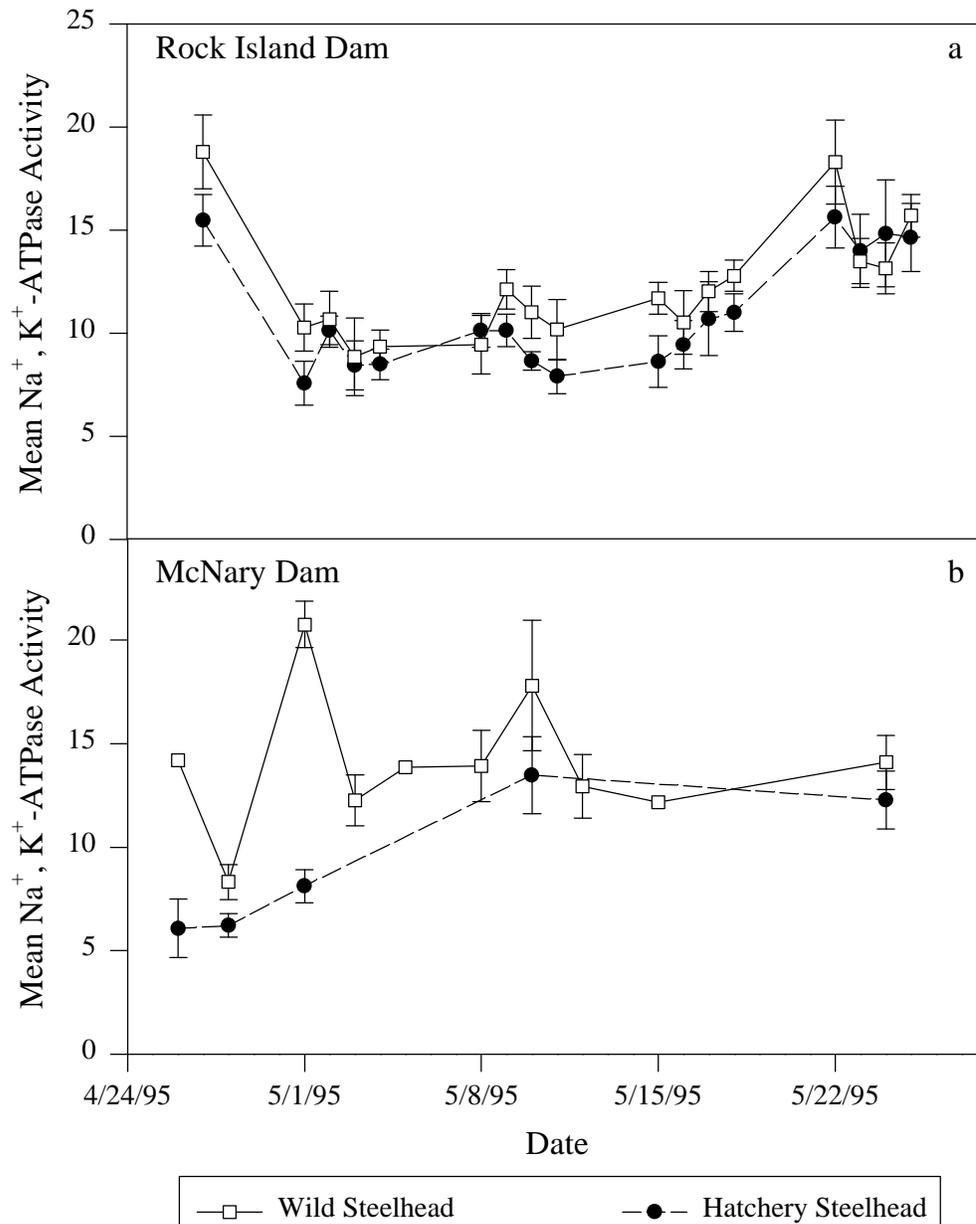


Figure 3.10. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery steelhead collected during migration at (a) Rock Island Dam and (b) McNary Dam on the Columbia River in 1995.

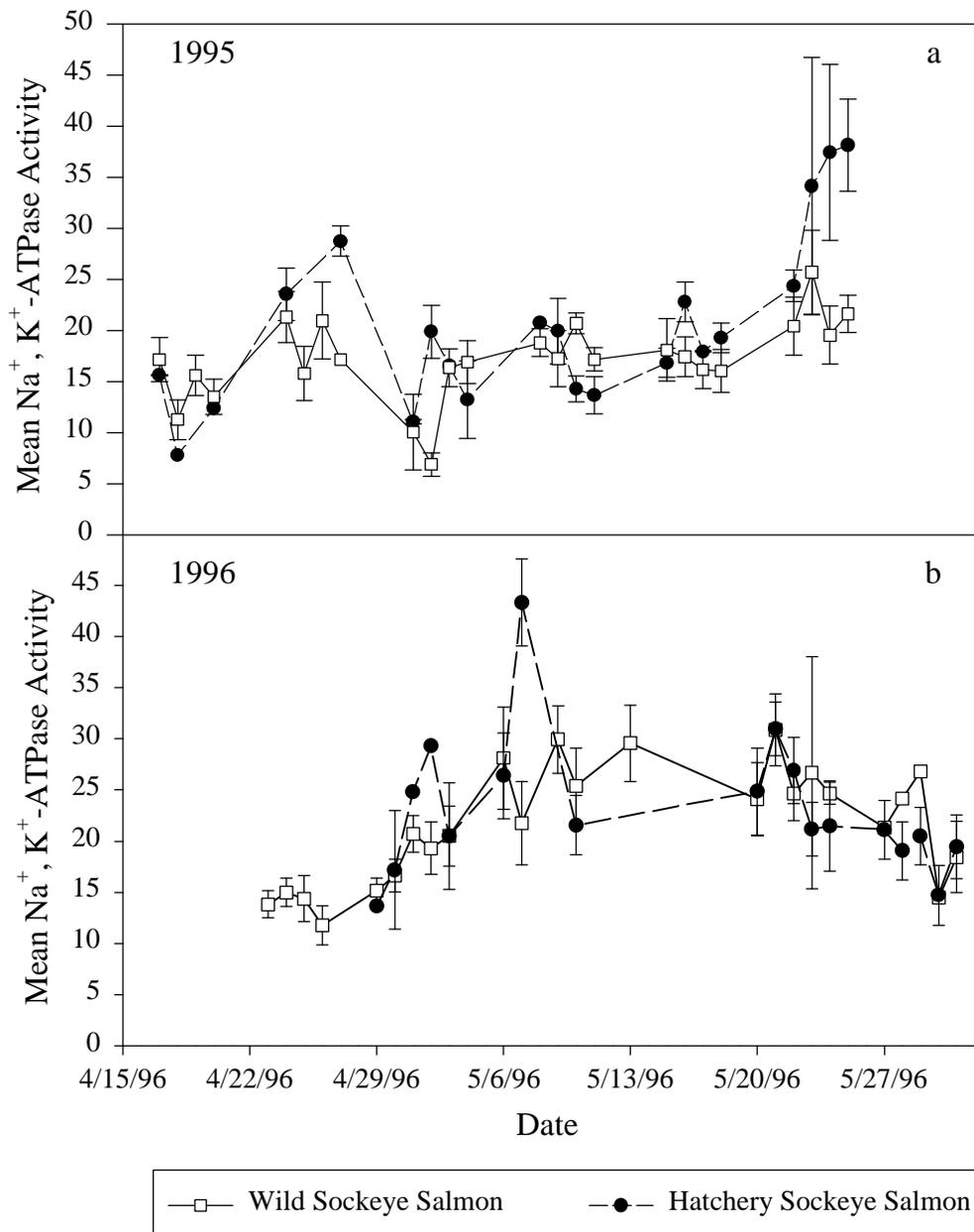


Figure 3.11. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery sockeye salmon collected during migration in (a) 1995 and (b) 1996 at Rock Island Dam on the Columbia River.

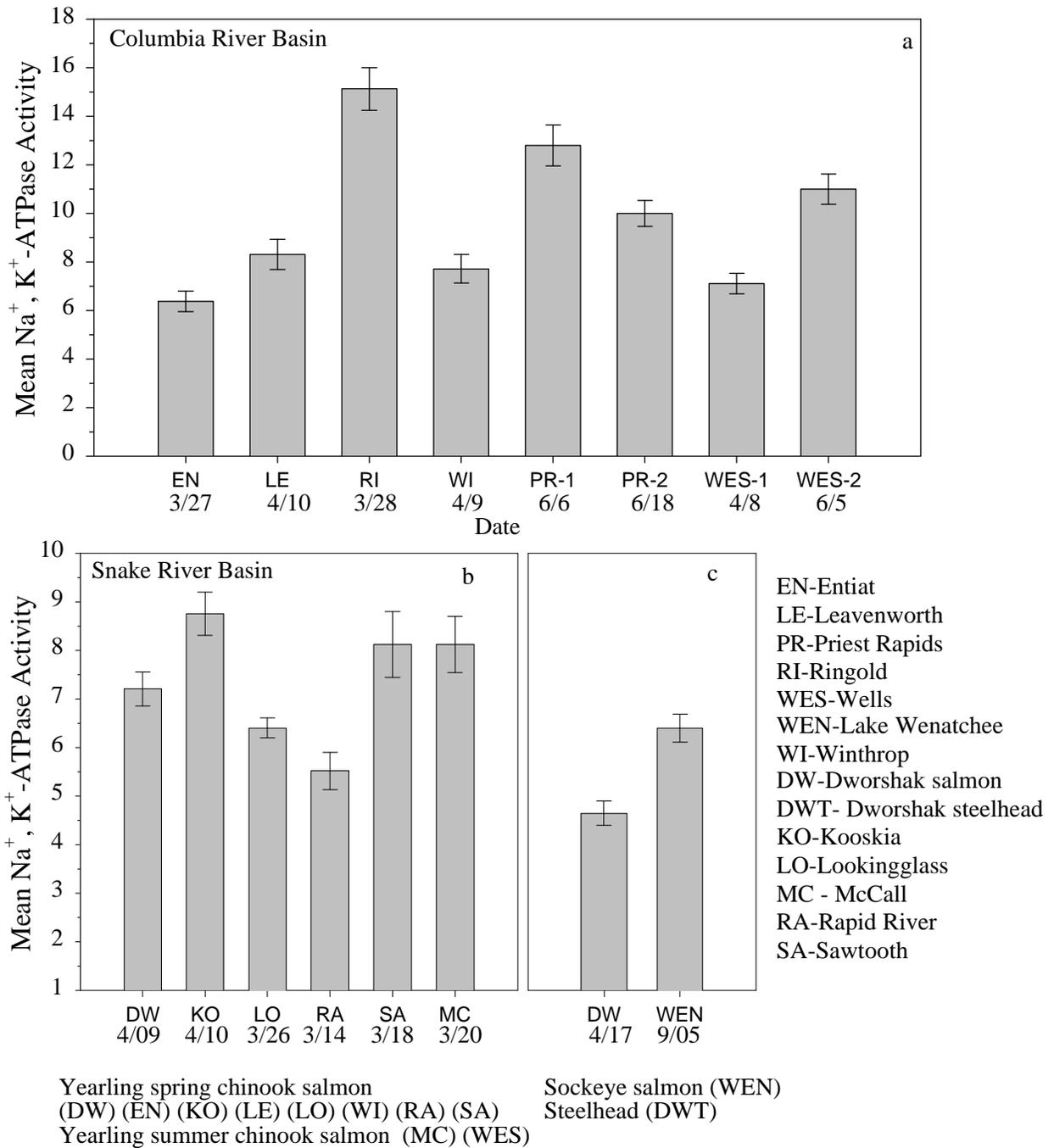


Figure 3.12. Mean ( $\pm$ SE) gill Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of yearling spring chinook salmon, yearling summer chinook salmon, and subyearling fall chinook salmon in (a) Columbia River basin hatcheries, and (b) Snake River basin hatcheries; and (c) hatchery sockeye salmon and steelhead, sampled in 1996.

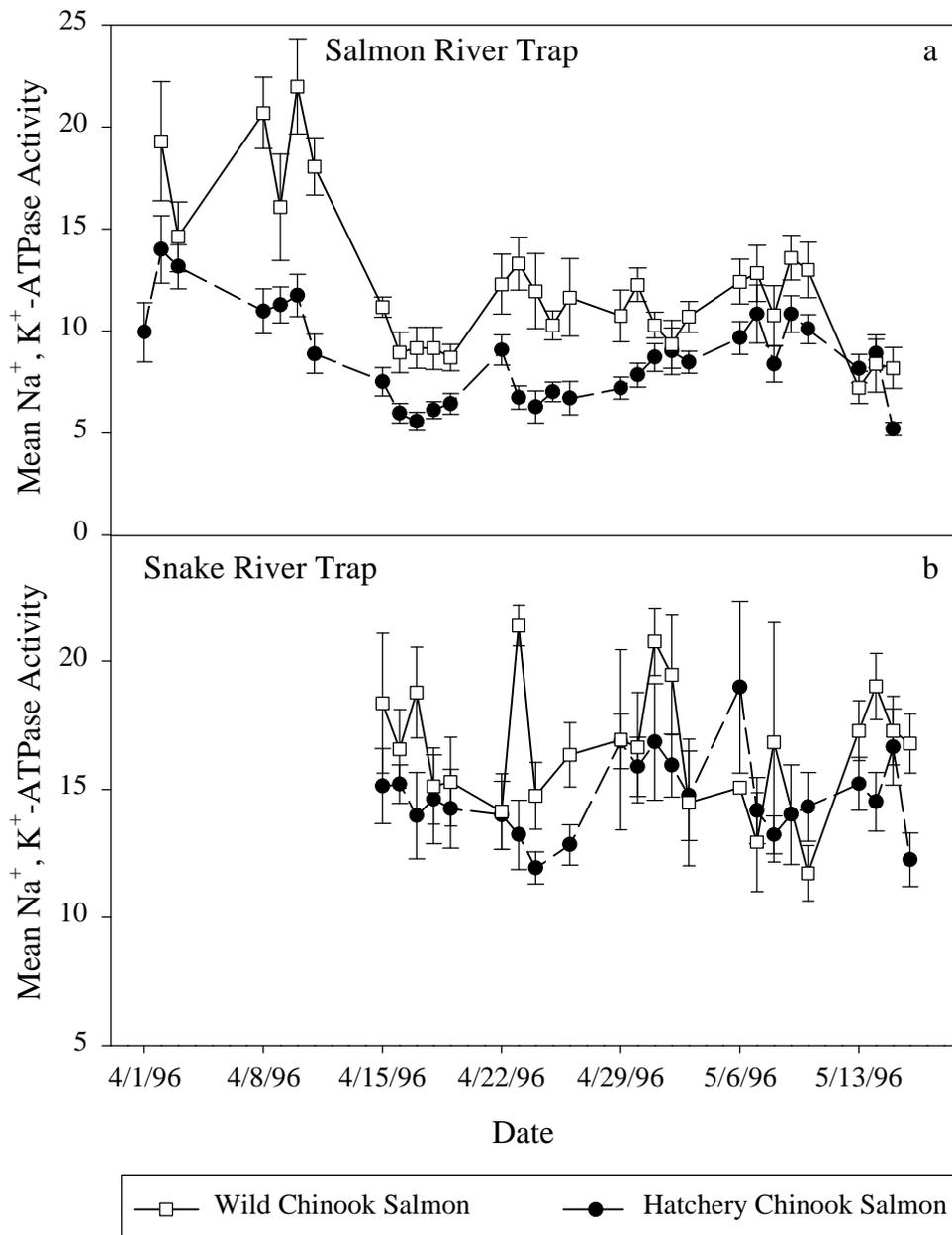


Figure 3.13. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery yearling chinook salmon collected during migration at (a) the Salmon River Trap and (b) the Snake River Trap during 1996.

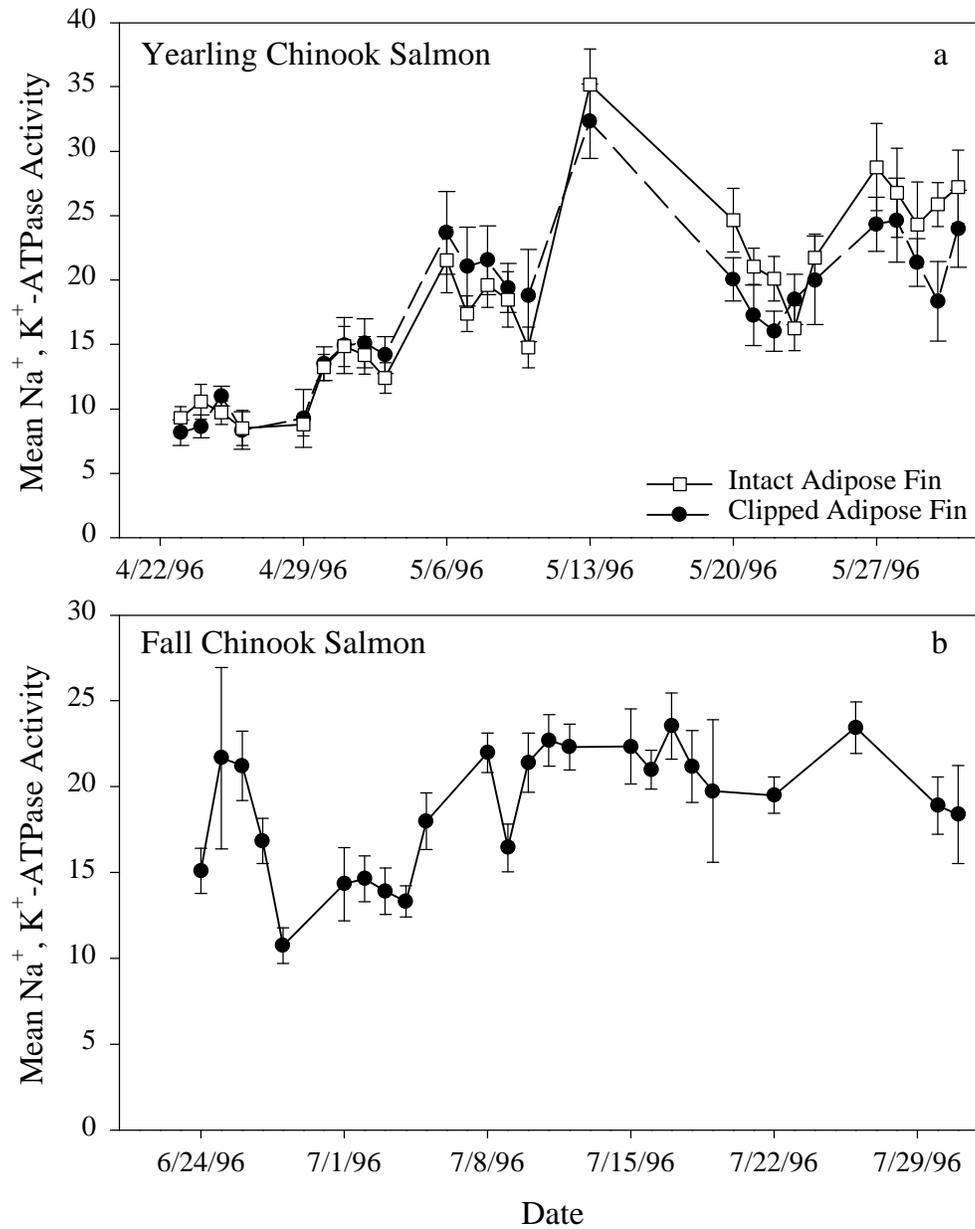


Figure 3.14. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of (a) yearling chinook salmon with intact adipose fins and yearling hatchery chinook salmon (adipose fin clipped), and (b) subyearling fall chinook salmon, collected during migration at Rock Island Dam on the Columbia River in 1996.

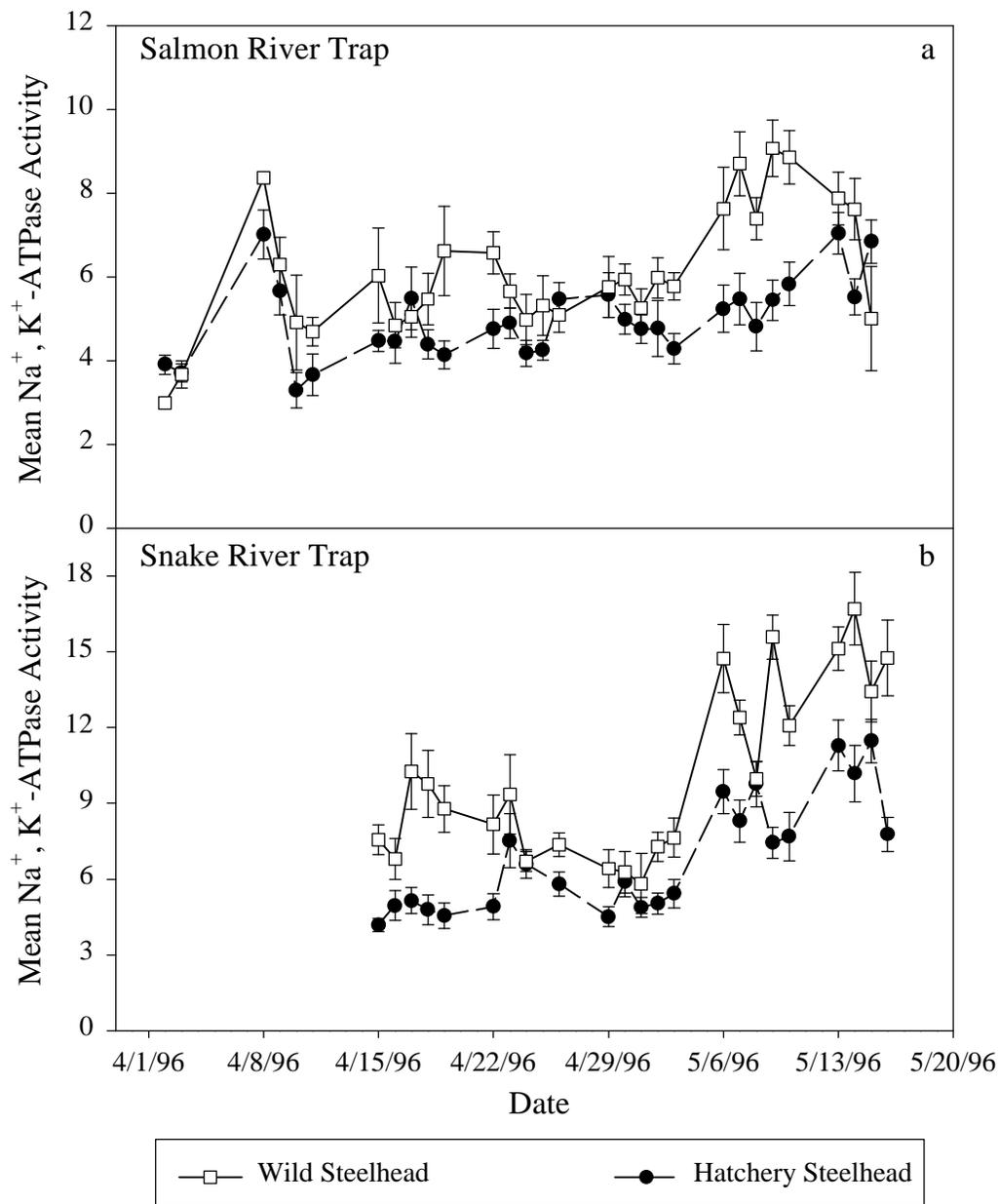


Figure 3.15. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery steelhead collected during migration at (a) the Salmon River Trap and (b) the Snake River Trap in 1996.

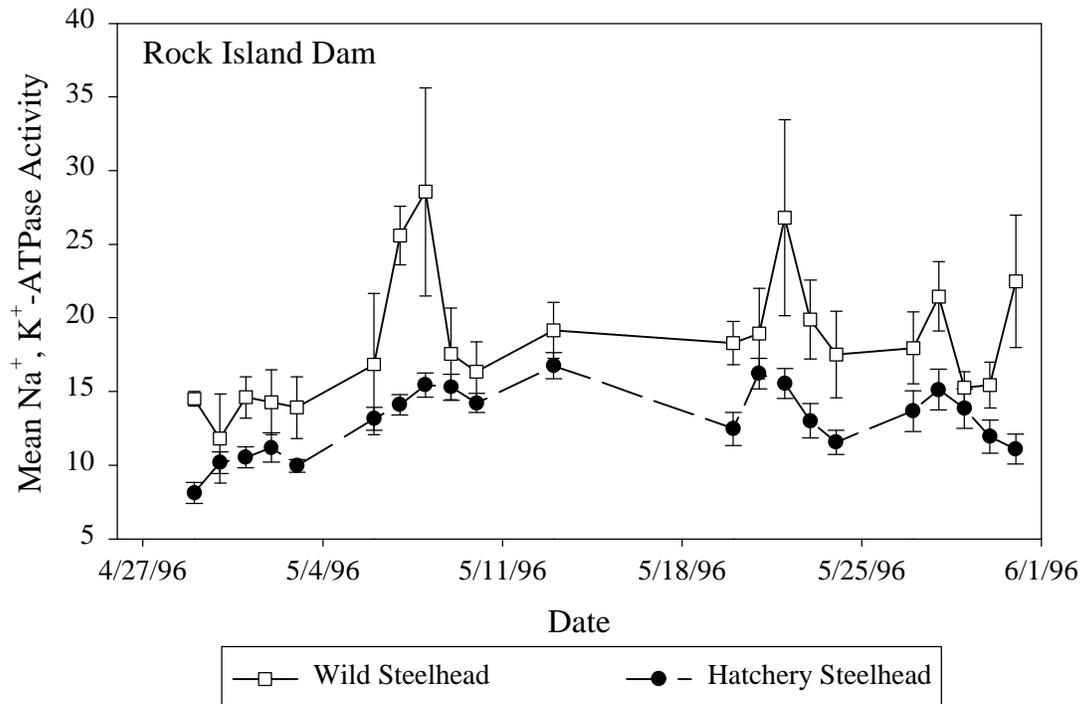


Figure 3.16. Mean ( $\pm$ SE)  $\text{Na}^+$ ,  $\text{K}^+$ -ATPase activity ( $\mu\text{moles Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of wild and hatchery steelhead collected during migration at Rock Island Dam on the Columbia River in 1996.

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## APPENDICES

### **Appendix 0.1. Internet Resources–Data Information and Modeling of Columbia River Basin Salmonids**

Analysis Tools Home Page (including CRiSP Harvest, CRiSP Passage, SURPH, etc). University of Washington, School of Fisheries: [www.cqs.washington.edu/analysis.html](http://www.cqs.washington.edu/analysis.html).

Columbia River DART (Data Access in Real Time) Home. University of Washington, School of Fisheries: [www.cqs.washington.edu/dart/dart.html](http://www.cqs.washington.edu/dart/dart.html).

Ecological Analysis (including information on EDT (Ecological Diagnosis and Treatment) and CRI (Cumulative Risk Initiative). Northwest Power Planning Council: [www.nwframework.org/ecol\\_work.html](http://www.nwframework.org/ecol_work.html).

Fish Passage Center Home Page. Fish Passage Center: [www.fpc.org](http://www.fpc.org).

Plan for Analyzing and Testing Hypotheses (PATH) Web Page. Bonneville Power Administration: [www.efw.bpa.gov/Environment/PATH](http://www.efw.bpa.gov/Environment/PATH).

PTAGIS (Passive Integrated Transponder (PIT) Tag Information System) Home Page. Pacific States Marine Fisheries Commission: [www.psmfc.org/pittag](http://www.psmfc.org/pittag).

RMIS (Regional Mark Information System) Home Page. Pacific States Marine Fisheries Commission: [www.rmis.org/index.html](http://www.rmis.org/index.html).

StreamNet Home Page. Pacific States Marine Fisheries Commission: [www.streamnet.org](http://www.streamnet.org)

**Appendix 2.1. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu$ mol Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of spring chinook salmon sampled from run-at-large populations at the Snake River Trap in 1993 and 1994.**

**1993**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/12/93	Hatchery	20	10.9	0.9	Wild	20	18.9	1.0
04/14/93	Hatchery	18	13.1	1.2	Wild	8	13.7	2.4
04/16/93	Hatchery	15	16.3	1.6	Wild	4	22.6	2.9
04/19/93	Hatchery	21	11.0	1.0	Wild	5	18.9	5.0
04/21/93	Hatchery	19	13.5	1.2	Wild	10	17.8	2.2
04/23/93	Hatchery	25	14.9	1.2	Wild	7	25.0	1.5
04/26/93	Hatchery	19	11.8	1.5	Wild	8	20.8	1.6
04/28/93	Hatchery	26	14.2	0.7	Wild	12	25.4	2.4
04/30/93	Hatchery	20	12.5	1.5	Wild	19	21.6	1.2
05/03/93	Hatchery	20	21.5	1.2	Wild	14	27.3	2.3
05/05/93	Hatchery	21	18.6	1.4	Wild	25	26.5	2.0
05/07/93	Hatchery	20	22.2	1.9	Wild	20	29.9	1.6
05/10/93	Hatchery	20	19.2	1.2	Wild	20	21.2	1.6
05/12/93	Hatchery	21	23.0	1.7	Wild	19	23.0	2.0
05/14/93	Hatchery	20	20.7	1.4	Wild	20	17.6	2.2
05/31/93	Hatchery	12	17.8	2.0	Wild	17	21.2	1.2
06/02/93	Hatchery	22	22.8	0.9	Wild	18	20.4	2.5
06/04/93	Hatchery				Wild	4	15.3	2.7

**1994**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/12/94	Hatchery	30	8.5	0.4	Wild	4	11.5	0.9
04/14/94	Hatchery	22	10.9	0.7	Wild	3	19.4	3.0
04/19/94	Hatchery	21	11.5	0.8	Wild	20	11.4	2.1
04/21/94	Hatchery	31	9.8	0.9	Wild	29	14.7	1.3
04/24/94	Hatchery	30	10.1	0.8	Wild	27	10.6	1.4
04/26/94	Hatchery	20	8.3	1.1	Wild	19	12.9	1.6
04/28/94	Hatchery	21	10.8	1.3	Wild	11	13.6	0.9
05/01/94	Hatchery	21	15.2	1.1	Wild	4	11.2	2.4
05/03/94	Hatchery	21	15.1	1.2	Wild	6	18.4	4.0
05/05/94	Hatchery	21	16.0	1.4	Wild	6	17.9	2.2
05/08/94	Hatchery	22	13.2	1.0	Wild	18	14.6	1.3
05/10/94	Hatchery	23	14.0	1.4	Wild	18	13.1	1.2
05/12/94	Hatchery	22	13.5	1.2	Wild	17	15.0	1.5
05/15/94	Hatchery	13	13.9	1.0	Wild	2	10.6	2.6
05/17/94	Hatchery	7	14.4	1.5	Wild	9	14.8	1.0
05/18/94	Hatchery	9	13.0	1.0	Wild	2	18.3	2.0
05/22/94	Hatchery	2	13.6	0.4	Wild	1	19.9	0.0
05/24/94	Hatchery	2	16.2	3.1	Wild	8	21.4	1.8
05/26/94	Hatchery	1	24.8	0.0	Wild	7	18.0	2.0

**Appendix 2.2. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of steelhead sampled from run-at-large populations at the Snake River Trap in 1993 and 1994.**

**1993**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/16/93	Hatchery	12	11.4	0.9	Wild	7	18.7	3.4
04/19/93	Hatchery	14	11.9	1.1	Wild	10	17.1	2.2
04/21/93	Hatchery	12	11.2	1.4	Wild	12	22.3	1.3
04/23/93	Hatchery	12	10.1	1.5	Wild	10	18.7	1.2
04/26/93	Hatchery	13	14.3	1.6	Wild	16	22.2	1.7
04/28/93	Hatchery	18	14.0	1.1	Wild	18	21.8	1.1
04/30/93	Hatchery	12	14.7	2.5	Wild	12	24.2	2.7
05/03/93	Hatchery	12	12.1	1.4	Wild	12	16.5	0.8
05/05/93	Hatchery	12	10.7	1.6	Wild	16	15.7	1.0
05/07/93	Hatchery	12	11.4	1.0	Wild	17	13.9	1.0
05/10/93	Hatchery	12	11.3	0.8	Wild	12	17.5	1.7
05/12/93	Hatchery	12	16.2	1.1	Wild	12	17.6	1.5
05/14/93	Hatchery	12	14.4	1.3	Wild	12	18.1	1.3
05/31/93	Hatchery	12	17.6	1.7	Wild			
06/02/93	Hatchery	12	17.7	1.5	Wild			
06/04/93	Hatchery	12	19.6	1.9	Wild	3	23.9	7.1

**1994**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/12/94	Hatchery	4	9.9	3.8	Wild	4	7.6	0.7
04/14/94	Hatchery	5	13.2	0.9	Wild	2	14.5	1.0
04/19/94	Hatchery	10	7.3	0.8	Wild	12	7.8	1.1
04/21/94	Hatchery	17	7.8	0.6	Wild	17	10.8	0.9
04/24/94	Hatchery	17	11.0	1.0	Wild	17	12.6	1.3
04/26/94	Hatchery	11	10.7	0.7	Wild	12	11.4	0.9
04/28/94	Hatchery	12	7.7	1.0	Wild	12	14.7	1.6
05/01/94	Hatchery	13	7.9	1.1	Wild	12	16.1	1.6
05/03/94	Hatchery	11	10.9	1.5	Wild	12	11.0	1.0
05/05/94	Hatchery	12	8.5	1.2	Wild	12	14.9	1.3
05/08/94	Hatchery	12	7.2	0.8	Wild	12	9.6	0.6
05/10/94	Hatchery	12	9.6	1.3	Wild	12	11.2	1.4
05/12/94	Hatchery	12	9.1	0.6	Wild	11	9.5	1.3
05/15/94	Hatchery	12	7.4	0.4	Wild	12	8.5	1.1
05/17/94	Hatchery	12	8.1	1.8	Wild	12	9.0	1.5
05/18/94	Hatchery	11	8.3	0.9	Wild	12	9.8	0.5
05/22/94	Hatchery	11	7.5	1.0	Wild	12	7.9	1.5
05/24/94	Hatchery	12	8.8	0.8	Wild	12	9.1	1.1
05/26/94	Hatchery	12	8.4	0.9	Wild	12	5.7	0.9

**Appendix 2.3. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of spring chinook salmon sampled from run-at-large populations at the Salmon River Trap in 1993 and 1994.**

**1993**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/06/93	Hatchery				Wild	40	18.2	1.1
04/07/93	Hatchery				Wild	40	16.6	0.9
04/13/93	Hatchery	40	12.6	0.6	Wild	40	16.2	1.0
04/15/93	Hatchery	42	13.2	0.8	Wild	39	18.2	0.9
04/20/93	Hatchery	42	9.2	0.4	Wild	40	18.9	0.9
04/22/93	Hatchery	40	9.1	0.5	Wild	15	20.5	1.1
04/27/93	Hatchery	48	11.5	0.7	Wild	49	17.0	0.9
04/29/93	Hatchery	42	14.7	0.9	Wild	39	16.7	1.2
05/04/93	Hatchery	40	15.5	1.0	Wild	40	19.7	1.0
05/06/93	Hatchery	41	17.4	0.8	Wild	37	19.3	0.8
05/11/93	Hatchery	40	16.8	1.0	Wild	40	16.6	1.0

**1994**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/04/94	Hatchery				Wild	40	16.5	0.8
04/05/94	Hatchery				Wild	40	14.0	0.8
04/06/94	Hatchery				Wild	40	15.3	0.6
04/11/94	Hatchery	40	7.9	0.4	Wild	38	13.9	0.7
04/13/94	Hatchery	50	9.2	0.4	Wild	40	15.5	0.9
04/18/94	Hatchery	40	9.4	0.9	Wild	38	14.4	1.3
04/20/94	Hatchery	49	8.6	0.8	Wild	40	14.6	1.4
04/25/94	Hatchery	40	11.5	0.5	Wild	33	12.5	1.2
04/27/94	Hatchery	50	11.5	0.7	Wild	40	13.5	0.9
05/02/94	Hatchery	40	12.4	0.6	Wild	18	14.8	0.9
05/04/94	Hatchery	51	14.6	0.6	Wild	39	16.0	0.8
05/09/94	Hatchery	40	12.9	0.8	Wild	40	14.0	1.0
05/11/94	Hatchery	37	12.8	0.9	Wild	20	11.4	1.1
05/16/94	Hatchery	5	12.5	1.0	Wild	7	13.2	1.4
05/18/94	Hatchery	11	14.7	1.1	Wild	4	18.2	3.0
05/23/94	Hatchery	21	15.6	1.0	Wild	17	17.6	1.3
05/25/94	Hatchery	40	15.9	0.6	Wild	20	18.0	1.2

**Appendix 2.4. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$ SE) ( $\mu$ mol Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of spring chinook salmon sampled from run-at-large populations at the Salmon River Trap in 1995.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
3/27/95	Hatchery	15	4.7	0.4	Wild	14	7.9	0.8
3/28/95	Hatchery	15	4.9	0.4	Wild	8	6.7	0.6
3/29/95	Hatchery	15	4.7	0.3	Wild	21	8.0	0.4
4/3/95	Hatchery	15	4.4	0.5	Wild	14	7.7	0.4
4/5/95	Hatchery	14	4.2	0.4	Wild	13	6.8	0.6
4/10/95	Hatchery	14	5.0	0.4	Wild	13	7.0	0.5
4/12/95	Hatchery	15	5.4	0.5	Wild	14	8.4	0.9
4/17/95	Hatchery	15	5.3	0.4	Wild	12	8.8	0.8
4/19/95	Hatchery	12	6.9	0.7	Wild	15	9.7	0.9
4/24/95	Hatchery	15	10.2	0.4	Wild	14	12.6	1.0
4/26/95	Hatchery	15	9.9	0.8	Wild	15	15.8	1.5
5/1/95	Hatchery	15	9.1	0.8	Wild	15	13.9	0.9
5/3/95	Hatchery	14	8.0	0.7	Wild	15	13.0	1.0
5/8/95	Hatchery	15	7.6	0.7	Wild	9	12.2	1.9
5/9/95	Hatchery	15	7.8	0.7	Wild	13	9.3	0.8

**Appendix 2.5. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$ SE) ( $\mu$ mol Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of spring chinook salmon sampled from run-at-large populations at the Salmon River Trap in 1996.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
03/31/96	Hatchery	4	9.9	1.5	Wild			
04/01/96	Hatchery	21	14.0	1.7	Wild	3	19.3	2.9
04/02/96	Hatchery	11	13.2	1.1	Wild	9	14.6	1.7
04/07/96	Hatchery	12	11.0	1.1	Wild	13	20.1	1.7
04/08/96	Hatchery	13	11.3	0.9	Wild	6	16.1	2.6
04/09/96	Hatchery	15	11.7	1.0	Wild	13	22.0	2.4
04/10/96	Hatchery	12	8.9	0.9	Wild	16	18.1	1.4
04/14/96	Hatchery	15	7.5	0.7	Wild	12	11.2	0.5
04/15/96	Hatchery	15	5.7	0.5	Wild	15	8.7	0.9
04/16/96	Hatchery	15	5.6	0.5	Wild	15	9.2	1.0
04/17/96	Hatchery	15	6.1	0.4	Wild	15	9.2	1.0
04/18/96	Hatchery	14	6.4	0.5	Wild	14	8.7	0.7
04/21/96	Hatchery	15	9.1	0.7	Wild	6	12.3	1.5
04/22/96	Hatchery	15	6.7	0.6	Wild	16	13.3	1.3
04/23/96	Hatchery	15	6.3	0.8	Wild	9	11.9	1.8
04/24/96	Hatchery	15	7.0	0.5	Wild	18	10.3	0.7
04/25/96	Hatchery	14	6.7	0.8	Wild	3	11.7	1.9
04/28/96	Hatchery	15	7.2	0.5	Wild	4	10.7	1.3
04/29/96	Hatchery	14	7.8	0.6	Wild	10	12.3	0.8
04/30/96	Hatchery	15	8.7	0.7	Wild	8	10.3	0.6
05/01/96	Hatchery	14	9.0	1.1	Wild	7	9.4	1.2
05/02/96	Hatchery	14	8.5	0.5	Wild	11	10.7	0.7
05/05/96	Hatchery	15	9.7	0.7	Wild	2	12.4	1.1
05/06/96	Hatchery	15	10.8	1.5	Wild	5	12.8	1.3
05/07/96	Hatchery	15	8.4	0.8	Wild	3	10.8	1.5
05/08/96	Hatchery	15	10.8	0.9	Wild	7	13.6	1.1
05/09/96	Hatchery	15	10.1	0.7	Wild	8	13.0	1.4
05/12/96	Hatchery	15	8.2	0.7	Wild	6	7.3	0.8
05/13/96	Hatchery	9	8.9	0.7	Wild	4	8.4	1.4
05/14/96	Hatchery	7	5.2	0.3	Wild	5	8.2	1.0

**Appendix 2.6. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of spring chinook salmon sampled from run-at-large populations at the Clearwater River Trap in 1995.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/04/95	Hatchery	20	8.5	1.0	Wild	2	13.0	5.2
04/06/95	Hatchery	20	7.6	0.9	Wild	14	7.9	0.8
04/09/95	Hatchery	20	12.3	0.9	Wild	10	8.5	0.8
04/11/95	Hatchery	1	9.0	0.0	Wild	8	6.6	0.7
04/16/95	Hatchery	20	13.1	0.8	Wild	9	6.0	0.8
04/18/95	Hatchery	19	11.6	1.0	Wild	10	8.8	0.8
04/20/95	Hatchery	18	14.2	0.8	Wild	6	7.6	1.0
04/23/95	Hatchery	24	11.0	1.1	Wild	7	10.0	0.6
04/25/95	Hatchery	20	13.0	1.2	Wild	10	14.9	1.4
04/27/95	Hatchery	21	17.9	1.3	Wild	3	13.6	1.2
04/30/95	Hatchery	1	15.3	0.0	Wild	9	9.2	1.5
05/02/95	Hatchery	22	9.0	0.7	Wild	10	10.3	1.3
05/14/95	Hatchery	25	10.3	0.8	Wild	10	10.4	1.3
05/16/95	Hatchery	30	11.3	0.5	Wild	8	11.4	0.9
05/17/95	Hatchery	20	12.1	1.2	Wild	11	9.3	0.8
05/22/95	Hatchery	30	6.4	0.7	Wild	8	7.9	0.9
05/23/95	Hatchery	20	11.4	1.3	Wild	8	10.4	1.6
05/24/95	Hatchery	20	9.2	0.8	Wild	3	13.0	4.2

**Appendix 2.7. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of steelhead sampled from run-at-large populations at the Grande Ronde River Trap in 1994.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/18/94	Hatchery	25	9.1	0.8	Wild	23	9.3	0.7
04/20/94	Hatchery				Wild	20	9.0	0.9
04/25/94	Hatchery	25	6.5	0.6	Wild	3	13.0	3.2
04/27/94	Hatchery	3	8.5	1.8	Wild	8	12.2	1.6
05/02/94	Hatchery	22	7.6	0.4	Wild	23	13.1	1.3
05/04/94	Hatchery	25	5.8	0.4	Wild	25	14.1	1.1
05/09/94	Hatchery	25	5.3	0.7	Wild	25	10.5	1.1
05/11/94	Hatchery	25	7.5	0.6	Wild	25	11.4	1.2
05/16/94	Hatchery	26	5.9	0.5	Wild	24	8.3	0.7
05/17/94	Hatchery	25	5.3	0.5	Wild	18	7.9	0.9
05/23/94	Hatchery	21	8.7	0.6	Wild	11	11.2	0.8
05/25/94	Hatchery	25	8.5	0.6	Wild	7	13.3	1.3

**Appendix 2.8. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol P}_i \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of spring chinook salmon sampled from run-at-large populations at Lower Granite Dam in 1993.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/27/93	Hatchery	30	20.6	1.0	Wild	22	33.2	1.8
04/29/93	Hatchery	30	22.3	1.1	Wild	20	31.0	2.6
05/04/93	Hatchery	20	23.8	1.7	Wild	20	29.2	2.0
05/06/93	Hatchery	20	23.3	1.3	Wild	20	28.3	1.7
05/11/93	Hatchery	30	22.4	1.5	Wild	21	27.6	1.9
05/13/93	Hatchery	20	23.3	1.5	Wild	20	25.5	1.3
05/18/93	Hatchery	20	24.5	0.9	Wild	18	25.1	1.1
05/20/93	Hatchery	20	24.8	1.1	Wild	20	28.2	1.4
05/25/93	Hatchery	20	25.1	0.8	Wild	20	23.2	1.6
05/27/93	Hatchery	20	21.6	1.0	Wild	19	25.5	1.3
06/01/93	Hatchery	20	25.6	1.2	Wild	19	27.6	1.5
06/03/93	Hatchery	21	24.0	1.5	Wild	18	28.5	1.2

**Appendix 2.9. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol P}_i \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) of steelhead sampled from run-at-large populations at Lower Granite Dam in 1990.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/20/90	Hatchery	10	12.9	1.5	Wild	11	16.0	2.1
04/24/90	Hatchery	15	11.9	1.2	Wild			
04/25/90	Hatchery	5	10.3	1.0	Wild			
04/26/90	Hatchery	11	18.8	2.7	Wild	10	19.1	2.5
04/27/90	Hatchery	21	15.9	1.2	Wild	10	22.2	3.3
04/30/90	Hatchery	10	14.6	1.2	Wild			
05/03/90	Hatchery	30	15.7	0.8	Wild	10	22.6	2.6
05/04/90	Hatchery	10	17.6	2.3	Wild	10	25.0	1.8
05/07/90	Hatchery	20	16.0	0.9	Wild			
05/08/90	Hatchery	20	14.3	1.0	Wild			
05/10/90	Hatchery	30	18.0	0.9	Wild	10	28.1	1.4
05/11/90	Hatchery	18	19.3	1.5	Wild	10	22.0	1.3
05/14/90	Hatchery	21	15.8	1.0	Wild			
05/16/90	Hatchery	3	21.9	5.4	Wild			
05/17/90	Hatchery	11	20.9	2.4	Wild	16	28.3	2.2
05/18/90	Hatchery	17	22.4	1.9	Wild	10	28.1	2.5
05/24/90	Hatchery	10	23.5	3.4	Wild	10	31.8	3.4
05/25/90	Hatchery	5	22.2	1.4	Wild	9	33.9	2.5
05/31/90	Hatchery	10	23.8	2.8	Wild	10	28.1	2.3
06/01/90	Hatchery	10	22.1	1.2	Wild	10	28.5	2.3
06/07/90	Hatchery	10	27.0	2.1	Wild	9	28.4	3.1
06/08/90	Hatchery	10	24.6	1.4	Wild	10	32.9	3.2
06/14/90	Hatchery	10	26.9	3.5	Wild	10	32.6	3.7
06/15/90	Hatchery	10	26.4	1.9	Wild	10	34.9	2.3
06/21/90	Hatchery	10	24.5	3.2	Wild	10	34.9	4.5
06/22/90	Hatchery	10	26.5	1.7	Wild	10	38.0	1.8
06/28/90	Hatchery	10	20.4	2.1	Wild	10	20.4	2.1
06/29/90	Hatchery	10	20.5	1.3	Wild	4	20.2	3.2

**Appendix 2.10. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$  SE) ( $\mu\text{mol P}_i \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) activity of steelhead sampled from run-at-large populations at Lower Granite Dam in 1992 and 1993.**

**1992**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/20/92	Hatchery	10	12.9	1.3	Wild	10	15.9	1.7
04/22/92	Hatchery	9	14.0	1.5	Wild	10	20.5	1.5
04/24/92	Hatchery	10	14.4	1.0	Wild	10	18.2	1.5
04/27/92	Hatchery	8	18.1	1.1	Wild	10	21.9	2.1
04/29/92	Hatchery	9	19.6	2.0	Wild	9	20.6	1.2
05/11/92	Hatchery	22	16.7	0.9	Wild	10	19.8	1.6
05/12/92	Hatchery	7	15.6	2.4	Wild			
05/13/92	Hatchery	21	17.0	1.4	Wild	10	22.5	1.3
05/15/92	Hatchery	16	20.3	1.5	Wild	10	21.6	1.9
05/18/92	Hatchery	17	20.4	1.8	Wild	10	25.2	2.4
05/19/92	Hatchery	6	20.9	3.2	Wild			
05/20/92	Hatchery	16	16.5	1.2	Wild	10	20.2	1.8
05/22/92	Hatchery	31	24.1	1.5	Wild	10	22.1	2.6
05/25/92	Hatchery	10	24.8	2.8	Wild	10	21.6	2.2
05/26/92	Hatchery	9	21.1	1.7	Wild			
05/27/92	Hatchery	18	20.5	1.4	Wild	9	21.7	3.6
05/28/92	Hatchery	5	18.6	1.6	Wild			
05/29/92	Hatchery	10	20.4	2.6	Wild	10	21.1	3.2
06/01/92	Hatchery	10	21.3	1.1	Wild	10	20.6	1.7
06/03/92	Hatchery	10	15.2	1.9	Wild	10	26.2	3.1
06/05/92	Hatchery	10	15.5	2.4	Wild	10	20.0	2.5
06/11/92	Hatchery	15	11.8	1.8	Wild	15	21.0	2.2
06/17/92	Hatchery	14	12.9	1.9	Wild	15	13.3	1.9
06/24/92	Hatchery	15	6.6	1.0	Wild	15	8.4	0.7
07/01/92	Hatchery	16	5.4	0.3	Wild	14	5.7	0.5

**1993**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/27/93	Hatchery	19	12.9	1.0	Wild	20	20.0	1.0
04/29/93	Hatchery	20	13.8	0.9	Wild	20	23.6	1.8
05/04/93	Hatchery	20	17.2	1.5	Wild	20	24.8	1.3
05/06/93	Hatchery	20	16.0	1.1	Wild	20	22.9	1.3
05/11/93	Hatchery	21	16.5	1.0	Wild	20	20.5	1.5
05/13/93	Hatchery	20	20.3	1.6	Wild	20	26.1	1.6
05/18/93	Hatchery	20	15.9	1.3	Wild	20	20.0	1.3
05/20/93	Hatchery	20	16.6	1.1	Wild	20	21.9	1.3
05/25/93	Hatchery	20	18.7	1.3	Wild	20	20.6	1.4
05/27/93	Hatchery	13	14.6	1.2	Wild	20	22.0	1.3
06/01/93	Hatchery	20	18.7	1.1	Wild	20	24.5	1.5
06/03/93	Hatchery	20	19.9	1.3	Wild	20	24.6	1.4

**Appendix 2.11. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$ SE) ( $\mu$ mol Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of steelhead sampled from run-at-large populations at Lower Granite Dam in 1995 and Rock Island Dam in 1992.**

**Lower Granite Dam**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/16/95	Hatchery	10	9.6	1.1	Wild	15	16.9	2.0
04/18/95	Hatchery	19	9.4	0.8	Wild	14	16.5	1.8
04/24/95	Hatchery	15	9.4	0.9	Wild	15	17.1	1.3
04/26/95	Hatchery	14	9.5	0.8	Wild	16	15.1	1.0
05/01/95	Hatchery	14	7.3	0.7	Wild	14	10.9	0.9
05/03/95	Hatchery	15	7.7	0.7	Wild	15	9.6	0.6
05/08/95	Hatchery	15	8.5	0.6	Wild	15	10.2	0.8
05/10/95	Hatchery	14	7.6	0.6	Wild	15	10.6	1.0
05/15/95	Hatchery	15	8.1	0.7	Wild	15	9.8	0.6
05/16/95	Hatchery	15	8.4	0.8	Wild	15	9.9	0.7
05/22/95	Hatchery	13	9.0	0.8	Wild	14	9.5	0.7
05/24/95	Hatchery	12	8.6	0.7	Wild	15	9.3	0.5
05/29/95	Hatchery	15	10.7	1.2	Wild	15	12.7	1.0
05/31/95	Hatchery	15	10.8	0.9	Wild	15	12.0	0.5

**Rock Island Dam**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/20/92	Hatchery	1	13.6	0.0	Wild	11	16.2	1.5
04/22/92	Hatchery	10	11.6	0.8	Wild	10	14.5	2.0
04/24/92	Hatchery	10	12.1	1.3	Wild	10	13.5	1.4
04/27/92	Hatchery	9	9.7	1.0	Wild	9	19.9	4.3
04/29/92	Hatchery	9	16.0	3.2	Wild	8	24.4	5.8
05/01/92	Hatchery	7	13.2	2.1	Wild	10	12.7	1.1
05/04/92	Hatchery	10	12.6	1.5	Wild	9	16.6	1.6
05/06/92	Hatchery	6	19.2	1.7	Wild	9	20.0	1.8
05/08/92	Hatchery	7	15.0	2.0	Wild	8	18.2	1.4
05/11/92	Hatchery	10	15.5	0.9	Wild	10	19.4	2.1
05/13/92	Hatchery	10	14.0	1.3	Wild	9	20.3	1.3
05/15/92	Hatchery	10	20.5	1.7	Wild	9	21.0	2.2
05/18/92	Hatchery	10	18.1	2.6	Wild	10	22.3	2.4
05/20/92	Hatchery	10	14.3	1.4	Wild	10	23.5	1.5
05/22/92	Hatchery	10	19.4	2.2	Wild	10	26.9	2.7
05/25/92	Hatchery	10	16.6	2.5	Wild	10	22.4	1.4
05/27/92	Hatchery	10	15.7	2.1	Wild	10	25.6	2.2
05/29/92	Hatchery	10	17.2	1.7	Wild	10	23.7	3.2

**Appendix 2.12. Mean Na<sup>+</sup>, K<sup>+</sup>-ATPase activity ( $\pm$ SE) ( $\mu$ mol Pi  $\cdot$  mg protein<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) of steelhead sampled from run-at-large populations McNary Dam in 1994.**

Sample Date	Origin	n	Mean ATPase	$\pm$ SE	Origin	n	Mean ATPase	$\pm$ SE
04/27/94	Hatchery	7	13.7	1.1	Wild	9	19.7	1.5
04/29/94	Hatchery	10	20.3	1.7	Wild	10	23.4	2.5
05/01/94	Hatchery	10	24.0	2.0	Wild	10	29.8	2.3
05/04/94	Hatchery	10	20.9	2.4	Wild	9	25.8	2.5
05/06/94	Hatchery	9	21.2	1.2	Wild	9	32.1	3.0
05/08/94	Hatchery	10	22.5	1.2	Wild	9	24.5	2.3
05/11/94	Hatchery	15	24.0	1.7	Wild	10	26.4	2.3
05/13/94	Hatchery	17	24.5	2.1	Wild	10	28.4	3.3
05/15/94	Hatchery	37	26.2	1.5	Wild	10	24.4	2.2
05/18/94	Hatchery	21	24.8	1.8	Wild	10	30.9	2.5
05/20/94	Hatchery	10	29.9	2.9	Wild	10	32.0	2.5
05/22/94	Hatchery	29	24.1	1.3	Wild	9	35.8	2.8
05/25/94	Hatchery	10	25.1	1.8	Wild	10	23.0	3.0
05/27/94	Hatchery	10	30.9	3.0	Wild	10	36.9	2.2
05/29/94	Hatchery	29	25.6	1.5	Wild	9	27.8	3.5
06/05/94	Hatchery	9	23.0	4.3	Wild	10	17.4	3.1
06/12/94	Hatchery	10	15.8	1.2	Wild	10	15.6	1.6
04/25/94	Hatchery	10	13.3	1.3	Wild	21	20.5	1.1
05/02/94	Hatchery	20	10.9	0.6	Wild	19	17.8	1.3
05/09/94	Hatchery	20	10.8	1.3	Wild	19	13.9	1.4
05/16/94	Hatchery	20	14.2	1.7	Wild	19	16.3	1.8
05/23/94	Hatchery	20	12.0	0.9	Wild	20	12.8	1.2
05/31/94	Hatchery	20	8.9	1.3	Wild	20	10.3	1.6

**Appendix 3.1. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for yearling spring/summer chinook salmon sampled in 1995 at Dworshak NFH (DW), Entiat NFH (EN), Leavenworth NFH (LE), Lookingglass SFH (LO), McCall SFH (MC), Rapid River SFH (RA), Ringold SFH (RI), Sawtooth SFH (SA), Wells SFH (WES), Winthrop NFH (WI).**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
DW	4/12/95	30	139	2	30	31.8	1.6	30	1.15	0.01	30	6.7	0.4
EN	3/29/95	30	136	2	30	28.9	1.2	30	1.14	0.02	27	6.3	0.3
LE	4/11/95	60	133	2	60	28.1	1.3	60	1.16	0.01	59	6.5	0.3
LO	4/5/95	29	124	1	29	20.4	0.6	29	1.07	0.01	27	7.4	0.5
MC	3/29/95	30	124	2	30	21.2	1.1	30	1.09	0.01	30	5.7	0.3
RA	3/29/95	30	127	3	29	23.5	1.6	29	1.13	0.01	29	5.7	0.2
RI	3/31/95	30	167	3	30	57.5	3.9	30	1.20	0.02	25	7.0	0.7
SA	3/28/95	29	119	2	29	19.6	1.2	29	1.12	0.01	27	5.3	0.3
WES	4/10/95	28	165	3	28	49.2	2.5	28	1.07	0.01	28	7.7	0.4
WI	4/10/95	30	131	2	30	25.1	1.3	30	1.09	0.02	30	7.0	0.6

**Appendix 3.2. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for sub-yearling chinook salmon sampled in 1995 and 1996 at Priest Rapids SFH (PR).**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
PR	6/13/95	60	92	1	60	8.7	0.3	60	1.09	0.01	21	8.7	0.6
PR	6/6/96	30	85	1	30	7.2	0.4	30	1.14	0.02	27	12.8	0.8
PR	6/18/96	60	96	1	60	10.3	0.3	60	1.16	0.01	55	10.0	0.5

**Appendix 3.3. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for sockeye salmon sampled from Lake Wenatchee net pens in 1995 and 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
WEN	10/19/95	30	109	2	30	16.1	0.8	30	1.23	0.02	25	6.5	0.4
WEN	9/5/96	32	81	1	32	6.6	0.3	32	1.23	0.02	32	6.0	0.3

**Appendix 3.4. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for steelhead sampled at Dworshak NFH in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
DW	4/17/96	30	176	6	30	59.6	5.7	30	0.97	0.02	30	4.1	0.3

**Appendix 3.5. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̑mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for yearling spring/summer chinook salmon sampled in 1996 at Dworshak NFH (DW), Entiat NFH (EN), Leavenworth NFH (LE), Lookingglass SFH (LO), McCall SFH (MC), Rapid River SFH (RA), Ringold SFH (RI), Sawtooth SFH (SA), Wells SFH (WES), Winthrop NFH (WI).**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
DW	4/9/96	30	148	4	30	41.6	3.6	30	1.20	0.01	30	7.2	0.4
EN	3/27/96	30	149	2	30	38.2	1.7	30	1.13	0.01	30	6.3	0.4
KO	4/10/96	30	125	1	30	23.7	0.6	30	1.19	0.01	30	8.7	0.4
LE	4/10/96	30	137	2	30	28.1	1.1	30	1.08	0.02	30	8.3	0.6
LO	3/26/96	60	129	1	60	25.5	0.6	60	1.17	0.01	59	6.4	0.2
MC	3/20/96	20	131	2	20	25.9	1.2	20	1.15	0.02	20	8.1	0.6
RA	3/14/96	20	125	1	20	22.8	0.8	20	1.17	0.01	20	5.5	0.4
RI	3/28/96	30	161	2	30	49.8	2.6	30	1.16	0.01	29	15.1	0.9
SA	3/18/96	20	128	3	20	25.4	2.0	20	1.17	0.02	20	11.0	0.7
WE	4/8/96	30	164	2	30	46.7	1.7	30	1.05	0.01	28	7.1	0.4
	6/5/96	30	111	1	30	16.7	0.7	30	1.20	0.01	30	11.2	0.6
WI	4/9/96	29	147	3	29	36.6	2.3	29	1.12	0.02	29	7.7	0.6

**Appendix 3.6. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̑mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for yearling hatchery spring/summer chinook salmon collected from the migration-at-large at the IDFG Clearwater River Trap (CLW), IDFG Snake River Trap (LEW), Salmon River Trap (SRT), Imnaha River Trap (IMT), and Lower Granite Dam (LGR) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
SRT	3/28/95	15	126	2	15	22.8	1.0	15	1.12	0.02	15	4.7	0.4
	3/29/95	15	128	2	15	23.4	1.1	15	1.12	0.01	15	4.8	0.4
	3/30/95	15	129	3	15	24.2	1.5	15	1.11	0.02	15	4.7	0.3
	4/4/95	15	130	3	15	23.1	1.3	15	1.03	0.01	15	4.3	0.5
	4/6/95	14	134	2	14	25.1	1.2	14	1.03	0.01	14	4.2	0.4
	4/11/95	15	131	3	15	24.2	1.7	15	1.07	0.02	14	4.9	0.4
	4/13/95	15	131	1	15	24.0	0.7	15	1.06	0.01	15	5.3	0.5
	4/18/95	15	129	2	15	22.2	1.2	15	1.03	0.01	15	5.2	0.4
	4/20/95	14	127	3	14	21.7	1.4	14	1.04	0.02	12	6.9	0.7
	4/25/95	15	128	2	15	21.4	1.2	15	1.01	0.01	15	10.1	0.4
	4/27/95	15	129	3	15	21.8	1.3	15	1.01	0.02	15	9.9	0.8
	5/2/95	15	127	3	15	21.1	1.2	15	1.02	0.01	15	9.0	0.8
	5/4/95	15	131	2	15	22.6	1.0	15	0.99	0.01	14	8.0	0.7
	5/9/95	15	128	2	15	21.9	0.9	15	1.03	0.01	15	7.5	0.6
	5/10/95	15	132	3	15	24.5	1.9	15	1.04	0.02	15	7.8	0.7
CLW	4/5/95	8	113	3	8	15.2	1.3	8	1.05	0.02	6	6.4	0.6
	4/7/95	15	110	2	15	13.8	1.0	15	1.00	0.02	15	6.8	0.6
	4/10/95	10	120	3	10	17.7	1.6	10	1.01	0.02	10	7.7	0.8
	4/12/95	12	128	2	12	20.3	1.2	12	0.96	0.02	12	8.4	0.7
	4/17/95	10	132	2	10	24.5	1.2	10	1.05	0.03	10	6.4	0.7
	4/19/95	9	126	3	8	22.9	1.8	8	1.11	0.02	9	7.6	0.8
	4/21/95	10	129	2	10	23.8	1.6	10	1.08	0.03	9	7.6	0.8

**Appendix 3.6. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
CWL	4/24/95	10	130	3	10	23.9	1.5	10	1.07	0.02	10	12.7	1.2
	4/26/95	10	129	5	9	19.5	1.4	9	0.96	0.05	10	8.9	0.8
	4/28/95	10	133	2	10	23.9	1.4	10	1.01	0.02	10	9.7	0.6
	5/1/95	9	132	4	9	23.4	1.8	9	1.01	0.04	9	10.4	0.9
	5/3/95	10	124	4	10	19.3	1.8	10	1.00	0.02	10	8.7	0.8
	5/15/95	14	128	3	14	22.8	1.5	14	1.08	0.02	14	10.2	1.2
	5/17/95	14	120	3	14	18.0	1.2	14	1.04	0.02	14	8.4	0.4
	5/23/95	15	124	5	15	21.0	2.2	15	1.06	0.02	15	10.3	1.1
	5/24/95	10	129	6	10	23.6	3.8	10	1.03	0.02	10	9.8	1.2
	5/25/95	10	127	5	10	23.7	2.9	10	1.11	0.03	10	9.4	1.6
LEW	4/10/95	11	137	9	11	28.5	7.6	11	0.98	0.01	11	6.1	0.9
	4/12/95	10	128	3	9	21.5	2.3	9	0.99	0.03	10	4.8	0.5
	4/14/95	10	129	5	10	21.1	1.9	10	0.96	0.03	9	5.8	0.5
	4/17/95	10	125	2	10	19.7	1.3	10	1.00	0.02	9	7.7	1.2
	4/21/95	20	129	2	20	20.9	1.0	20	0.96	0.01	20	9.9	0.7
	4/24/95	10	130	2	10	20.2	1.0	10	0.92	0.01	10	13.0	1.6
	4/26/95	10	132	2	10	24.4	1.4	10	1.05	0.03	10	14.6	1.4
	4/28/95	10	130	3	10	25.1	1.8	10	1.12	0.03	10	15.7	1.2
	5/1/95	4	125	1	4	19.2	1.2	4	0.97	0.03	4	11.2	1.7
	5/3/95	10	132	4	10	23.8	2.4	10	1.01	0.01	10	14.9	1.6
	5/5/95	9	129	3	9	21.9	1.7	9	1.01	0.02	9	14.3	1.4
	5/8/95	10	137	4	10	24.9	1.9	10	0.96	0.02	9	11.6	1.5
	5/9/95	10	130	3	10	24.9	2.5	10	1.12	0.03	8	8.8	0.7
	5/10/95	10	134	4	10	21.0	2.5	10	0.86	0.07	10	12.6	1.5
	5/15/95	10	133	2	10	23.7	1.4	10	1.00	0.02	9	13.3	0.9
	5/17/95	10	133	3	9	24.3	1.3	9	0.99	0.02	10	9.9	1.2
	5/18/95	10	136	3	10	24.3	1.7	10	0.96	0.03	10	12.5	0.8
5/22/95	10	129	4							10	11.1	0.9	
5/23/95	10	132	3	10	23.8	1.9	10	1.01	0.02	9	12.4	2.5	
LGR	4/14/95	30	136	2	30	26.0	1.4	30	1.00	0.01	29	11.7	0.7
	4/17/95	10	134	4	10	25.3	2.5	10	1.03	0.02	10	8.5	0.9
	4/19/95	11	146	7	11	34.5	6.6	11	1.03	0.01	10	9.2	1.1
	4/21/95	9	144	3	9	31.3	2.8	9	1.02	0.02	8	10.0	0.5
	4/25/95	15	131	3	15	23.9	1.4	15	1.04	0.02	15	13.3	0.7
	4/27/95	15	134	2	15	24.2	1.8	15	0.98	0.02	15	16.3	1.0
	5/2/95	15	138	3	15	25.5	1.4	15	0.96	0.01	15	16.4	0.8
	5/4/95	15	135	2	15	25.3	1.3	15	1.01	0.01	15	14.2	1.1
	5/9/95	15	139	2	15	26.0	1.3	15	0.97	0.01	15	13.1	0.6
	5/11/95	15	138	3	15	26.2	1.8	15	0.98	0.01	15	13.5	0.7
	5/16/95	15	134	4	15	24.7	2.2	15	0.99	0.01	15	13.0	0.9
5/17/95	15	140	3	15	26.8	1.8	15	0.97	0.01	15	12.5	0.5	
5/23/95	15	140	3	15	26.9	1.5	15	0.97	0.01	15	11.5	0.9	
5/25/95	15	138	1	15	25.3	0.9	15	0.96	0.01	15	9.9	0.8	
5/30/95	6	140	5	6	26.6	2.7	6	0.95	0.02	5	9.0	0.7	

**Appendix 3.7. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for yearling hatchery spring/summer chinook salmon collected from the migration-at-large at the IDFG Snake River Trap (LEW), Salmon River Trap (SRT), and Lower Granite Dam (LGR) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
SRT	4/1/96	6	130	3	6	24.8	1.4	6	1.12	0.03	4	9.9	1.5
	4/2/96	24	130	2	24	24.8	1.1	24	1.13	0.01	21	13.9	1.7
	4/3/96	15	133	2	15	26.8	1.1	15	1.13	0.02	11	13.1	1.1
	4/8/96	14	130	2	14	24.6	1.5	14	1.10	0.02	12	10.9	1.1
	4/9/96	14	132	3	14	26.0	1.6	14	1.11	0.02	13	11.2	0.9
	4/10/96	14	134	2	14	27.3	1.4	14	1.11	0.02	15	11.7	1.0
	4/11/96	12	132	3	12	25.9	1.5	12	1.11	0.02	12	8.8	1.0
	4/15/96	15	141	3	15	27.3	1.8	15	0.96	0.02	15	7.5	0.7
	4/16/96	15	133	3	13	27.3	2.5	13	1.17	0.14	13	5.9	0.5
	4/17/96	15	135	3	15	25.3	1.2	15	1.02	0.03	15	5.5	0.5
	4/18/96	15	133	2	15	23.3	1.1	15	0.99	0.02	15	6.1	0.4
	4/19/96	15	136	2	15	23.9	1.1	15	0.94	0.03	14	6.4	0.5
	4/22/96	15	137	2	15	25.5	1.2	15	0.99	0.03	15	9.0	0.7
	4/23/96	15	138	2	15	25.5	1.1	15	0.96	0.02	15	6.7	0.6
	4/24/96	15	140	2	15	24.6	1.1	15	0.88	0.02	15	6.2	0.8
	4/25/96	15	136	2	15	24.1	1.3	15	0.95	0.04	15	7.0	0.5
	4/26/96	15	140	2	15	26.0	1.5	15	0.93	0.02	14	6.7	0.8
	4/29/96	15	138	2	15	24.2	0.8	15	0.92	0.02	15	7.1	0.5
	4/30/96	15	136	2	15	23.3	1.0	15	0.92	0.02	14	7.8	0.6
	5/1/96	15	139	4	15	25.7	2.0	15	0.93	0.02	15	8.7	0.7
	5/2/96	14	142	2	14	28.4	2.1	14	0.99	0.06	14	9.0	1.1
	5/3/96	14	135	2	14	23.5	0.8	14	0.95	0.02	14	8.4	0.5
	5/6/96	15	138	2	15	24.0	1.4	15	0.90	0.02	15	9.6	0.8
	5/7/96	15	136	2	15	24.2	1.1	15	0.97	0.02	15	10.8	1.4
	5/8/96	15	137	3	15	25.2	1.5	15	0.97	0.02	15	8.3	0.9
	5/9/96	15	141	3	15	25.6	1.5	15	0.90	0.01	15	10.8	0.9
	5/10/96	15	141	2	5	24.7	0.8	5	0.93	0.03	15	10.0	0.7
	5/13/96	15	139	2	15	26.6	1.5	15	0.98	0.02	15	8.1	0.7
	5/14/96	9	141	2	9	29.3	1.5	9	1.03	0.03	9	8.8	0.7
	5/15/96	7	139	4	7	25.2	2.5	7	0.93	0.03	7	5.2	0.3
LEW	4/15/96	15	139	5	15	31.50	3.39	15	1.13	0.02	15	15.1	1.5
	4/16/96	15	140	5	15	31.20	3.42	15	1.10	0.02	14	15.1	0.7
	4/17/96	15	140	4	15	29.90	2.60	15	1.05	0.02	15	13.9	1.7
	4/18/96	16	127	4	16	23.60	1.74	16	1.12	0.02	16	14.6	1.7
	4/19/96	15	138	3	15	27.80	2.33	15	1.03	0.01	14	14.2	1.5
	4/22/96	16	130	2	16	22.90	1.20	16	1.04	0.02	16	13.9	1.3
	4/23/96	11	131	3	11	23.50	1.11	11	1.05	0.03	11	13.2	1.4
	4/24/96	22	137	1	22	27.10	0.85	22	1.06	0.02	22	11.9	0.6
	4/26/96	32	138	1	32	27.00	0.84	32	1.03	0.01	32	12.8	0.8
	4/29/96	15	142	3	15	28.50	1.41	15	0.98	0.01	15	16.8	1.1
4/30/96	15	135	2	15	25.90	1.30	15	1.04	0.01	13	15.8	1.2	
	5/1/96	8	140	3	8	29.40	2.66	8	1.06	0.04	8	16.8	2.3

**Appendix 3.7. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	
LEW	5/2/96	15	142	4	15	28.8	3.0	15	0.98	0.02	15	15.9	1.2	
	5/3/96	10	141	3	10	28.5	1.9	10	1.00	0.02	10	14.7	1.7	
	5/6/96	4	141	2	4	26.7	1.2	4	0.96	0.02	4	18.9	3.3	
	5/7/96	15	137	2	15	25.5	0.9	15	0.99	0.01	15	14.1	1.3	
	5/8/96	15	137	2	15	25.7	1.0	15	1.00	0.02	15	13.2	0.7	
	5/9/96	7	141	5	7	30.2	3.0	7	1.07	0.06	7	14.0	1.9	
	5/10/96	15	135	2	15	24.0	0.7	15	0.98	0.02	13	14.3	1.3	
	5/13/96	15	133	2	15	24.5	1.0	15	1.02	0.01	15	15.2	1.0	
	5/14/96	15	134	3	15	24.3	1.6	15	1.00	0.02	15	14.5	1.1	
	5/15/96	15	136	2	15	25.6	1.6	15	1.00	0.01	15	16.6	1.5	
	5/16/96	15	139	2	15	27.2	1.6	15	1.00	0.02	15	12.2	1.0	
	LGR	5/1/96	1	140	0	1	26.7	0.0	1	0.97	0.00	1	11.8	0.0
		5/2/96	4	139	4	4	27.0	2.5	4	1.00	0.01	4	13.8	2.0
5/3/96		1	139	0	1	28.6	0.0	1	1.06	0.00	1	9.1	0.0	
5/4/96		5	135	2	5	23.7	0.9	5	0.96	0.01	5	15.5	0.9	
5/5/96		3	141	2	3	27.3	0.2	3	0.98	0.05	3	14.9	0.7	
5/6/96		2	135	2	2	22.6	0.3	2	0.93	0.04	2	14.4	3.1	
5/7/96		2	140	6	2	25.6	2.4	2	0.94	0.02	2	16.9	3.7	
5/8/96		1	148	0	1	27.5	0.0	1	0.85	0.00	1	18.3	0.0	
5/10/96		1	149	0	1	27.3	0.0	1	0.83	0.00	1	15.8	0.0	
5/14/96		5	136	4	5	24.3	2.4	5	0.96	0.01	4	16.6	1.9	
5/16/96		22	142	1	22	28.6	0.7	22	1.00	0.02	22	16.7	0.9	
5/17/96		12	137	3	12	25.6	1.6	12	0.98	0.02	11	14.4	0.9	
5/18/96		6	134	2	6	24.5	1.3	6	1.02	0.02	6	14.9	0.7	
5/19/96		5	138	3	5	26.6	1.5	5	1.02	0.01	5	14.3	1.2	
5/29/96		1	148	0	1	33.4	0.0	1	1.03	0.00	1	15.2	0.0	
5/30/96		1	152	0	1	34.1	0.0	1	0.97	0.00	1	12.4	0.0	

**Appendix 3.8. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for adipose fin clipped yearling spring/summer chinook salmon collected from the migration-at-large at Rock Island Dam (RIS) in 1995 and 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	
RIS	4/17/95	2	137	12	2	29.9	9.5	2	1.13	0.08	1	7.3	0.0	
	4/18/95	5	142	9	5	28.6	4.2	5	0.97	0.04	5	8.6	1.7	
	4/19/95	5	131	5	5	24.3	1.7	5	1.08	0.05	5	9.4	1.1	
	4/20/95	1	117	0	1	16.5	0.0	1	1.03	0.00	1	9.8	0.0	
	4/24/95	3	120	3	2	18.6	2.7	2	1.08	0.01	3	6.5	1.2	
	4/25/95	4	148	6	3	29.1	4.5	3	0.95	0.01	4	18.1	3.9	
	4/26/95	4	141	5	4	30.7	3.0	4	1.08	0.02	4	12.5	3.8	
	4/27/95	2	117	19	2	18.2	7.8	2	1.08	0.02	2	13.6	3.6	
	5/1/95	4	139	13	4	29.1	8.2	4	1.00	0.03	4	11.6	2.0	
	5/2/95	3	165	14	3	47.5	9.3	3	1.04	0.05	3	9.6	1.4	
	5/3/95	2	137	9	2	25.3	1.8	2	1.00	0.12	2	10.9	2.1	
	5/8/95	3	142	3	3	28.2	2.2	3	0.99	0.03	3	12.6	3.9	
	5/9/95	1	147	0	1	28.4	0.0	1	0.89	0.00	1	12.3	0.0	
	5/10/95	1	127	0	1	20.3	0.0	1	0.99	0.00	1	9.5	0.0	
	5/11/95	2	154	2	2	35.0	2.8	2	0.96	0.04	2	5.2	0.0	
	5/15/95	2	134	6	2	24.3	1.3	2	1.02	0.07	2	17.5	2.1	
	5/16/95	6	139	7	6	24.4	5.0	6	0.89	0.12	6	15.4	1.9	
	5/17/95	4	132	3	4	23.2	0.5	4	1.01	0.05	4	15.8	2.8	
	5/18/95	2	157	14	2	37.7	10.6	2	0.95	0.02	2	13.6	0.9	
	5/22/95	5	136	2	5	25.0	0.6	5	1.00	0.03	5	18.2	1.0	
	5/23/95	5	149	8	5	31.5	5.3	5	0.93	0.02	4	19.3	2.6	
	5/24/95	5	147	7	5	32.0	5.1	5	0.98	0.01	4	18.5	1.4	
	5/25/95	5	136	5	5	26.2	2.3	5	1.03	0.04	4	18.3	0.9	
	RIS	4/23/96	10	168	3	10	45.6	2.6	10	0.95	0.01	10	8.1	1.0
		4/24/96										12	8.6	0.9
4/25/96		12	160	7	12	42.9	4.9	12	0.97	0.03	12	11.0	0.8	
4/26/96		12	162	5	12	40.4	3.5	12	0.91	0.01	12	8.3	1.5	
4/29/96		11	139	7	11	27.8	4.5	11	0.96	0.02	10	9.2	2.3	
4/30/96											14	13.5	1.3	
5/1/96		11	158	5	11	37.2	3.2	11	0.93	0.02	11	14.9	2.2	
5/2/96		14	147	6	14	32.7	3.8	14	0.98	0.02	14	15.1	1.9	
5/3/96		13	149	6	13	31.4	3.3	13	0.91	0.01	12	14.2	1.4	
5/6/96		11	137	6	11	26.5	3.2	11	1.00	0.03	11	23.6	3.2	
5/7/96		11	154	5	11	35.3	3.2	11	0.94	0.02	10	21.0	3.1	
5/8/96		11	146	5	11	32.2	3.2	11	1.01	0.02	12	21.5	2.7	
5/9/96		15	142	3	15	28.9	1.6	15	0.99	0.02	15	19.3	1.9	
5/10/96		12	146	6	12	31.2	3.5	12	0.97	0.01	9	18.7	3.6	
5/13/96		16	151	3	16	33.5	1.7	16	0.96	0.01	16	32.3	2.9	
5/14/96		15	152	3	15	33.2	2.0	15	0.94	0.01				
5/15/96		12	150	3	12	32.0	2.2	12	0.94	0.02				
5/16/96		16	150	5	16	32.5	2.6	16	0.94	0.02				
5/17/96		19	152	4										
5/20/96		17	154	4	17	36.4	2.9	17	0.98	0.02	17	20.0	1.7	

**Appendix 3.8. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	5/21/96	16	156	2	16	37.9	2.1	16	0.98	0.01	16	17.2	2.3
	5/22/96	19	155	3	18	36.5	2.5	18	0.97	0.02	18	16.0	1.6
	5/23/96	17	149	3	17	32.2	2.2	17	0.95	0.02	17	18.5	1.9
	5/24/96	13	151	3	13	31.8	1.9	13	0.92	0.01	12	20.0	3.4
	5/27/96	15	154	4	15	35.6	3.3	15	0.95	0.02	15	24.3	2.1
	5/28/96	15	156	5	15	37.0	3.0	15	0.95	0.02	10	24.6	3.3
	5/29/96	16	151	4	16	32.8	2.4	16	0.94	0.01	12	21.3	1.9
	5/30/96	17	156	4	17	37.9	2.9	17	0.97	0.01	11	18.3	3.1
	5/31/96	15	156	4	15	37.6	2.8	15	0.97	0.02	13	24.0	3.0

**Appendix 3.9. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for non-adipose fin clipped yearling spring/summer chinook salmon collected from the migration-at-large at Rock Island Dam (RIS) in 1995 and 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	4/17/95	5	111	8	5	15.1	2.4	5	1.09	0.14	5	10.1	1.8
1995	4/18/95	3	146	4	3	28.7	2.8	3	0.93	0.05	3	7.0	1.6
	4/19/95	3	122	9	3	20.6	4.8	3	1.09	0.04	3	9.7	2.1
	4/20/95	7	133	8	7	26.0	4.8	7	1.03	0.05	7	11.1	2.3
	4/24/95	5	115	7	1	15.8	0.0	1	0.99	0.00	5	12.8	2.0
	4/25/95	4	133	5	4	22.6	1.7	4	0.96	0.06	2	8.4	3.4
	4/26/95	4	125	5	4	22.0	1.9	4	1.13	0.06	4	13.2	1.4
	4/27/95	6	151	4	6	37.2	3.2	6	1.08	0.05	6	13.7	2.2
	5/1/95	4	130	5	4	21.7	1.5	4	1.00	0.05	4	13.1	3.0
	5/2/95	5	142	8	5	30.4	5.2	5	1.03	0.03	4	9.3	1.1
	5/3/95	6	129	8	6	21.1	3.3	6	1.02	0.03	6	11.8	1.6
	5/4/95	8	133	7	8	24.9	2.9	8	1.02	0.02	8	7.2	1.2
	5/8/95	5	137	5	5	26.4	2.8	5	1.01	0.01	5	10.8	1.7
	5/9/95	7	134	8	7	24.9	4.1	7	1.00	0.02	7	11.8	1.5
	5/10/95	7	138	7	7	27.6	3.9	7	1.00	0.02	7	9.8	1.2
	5/11/95	6	129	4	6	22.1	1.7	6	1.02	0.03	6	12.3	1.0
	5/15/95	6	134	7	6	23.8	3.0	6	0.98	0.02	6	15.7	2.0
	5/16/95	3	133	5	3	24.0	2.8	3	1.01	0.02	3	16.7	4.6
	5/17/95	4	131	3	4	22.6	1.4	4	1.00	0.02	4	20.3	1.9
	5/18/95	6	134	4	6	23.0	1.6	6	0.96	0.03	6	16.3	1.4
	5/22/95	2	134	16	2	26.4	11.0	2	1.02	0.09	2	11.2	3.9
5/23/95	3	141	5	3	27.7	2.8	3	0.99	0.01	2	16.5	4.2	
5/24/95	1	148	0	1	32.0	0.0	1	0.97	0.00	1	26.9	0.0	
5/25/95	4	142	9	4	29.4	5.3	4	1.00	0.03	4	19.9	2.2	
RIS	4/23/96	11	137	5	11	28.2	2.9	11	1.06	0.03	11	9.3	0.9
1996	4/24/96										14	10.5	1.4
	4/25/96	16	132	6	15	23.9	3.1	15	0.97	0.04	14	9.7	0.9
	4/26/96	16	133	4	16	24.1	1.9	16	1.00	0.01	15	8.5	1.4
	4/29/96	15	137	5	15	26.6	2.7	15	0.98	0.02	15	8.7	0.9
	4/30/96										17	13.2	1.0
	5/1/96	17	137	4	17	26.8	2.2	17	1.00	0.02	18	14.8	1.6
	5/2/96	21	140	4	21	29.3	2.4	21	1.02	0.01	21	14.1	1.5
	5/3/96	14	130	5	13	22.0	2.2	13	1.00	0.02	14	12.4	1.2
	5/6/96	20	134	3	20	24.9	1.4	20	1.02	0.02	20	21.5	2.6
	5/7/96	16	145	3	16	30.2	1.9	16	0.97	0.02	15	17.4	1.4
	5/8/96	18	139	3	18	28.2	2.2	18	1.03	0.01	17	19.6	1.7
	5/9/96	16	141	4	16	29.0	2.6	16	1.01	0.04	13	18.4	2.2
	5/10/96	17	139	3	17	26.0	1.4	17	0.97	0.02	13	14.7	1.6
	5/13/96	15	138	5	15	26.8	2.8	15	0.99	0.02	13	35.1	2.8
	5/14/96	19	133	2	19	23.3	1.0	19	0.97	0.02			
	5/15/96	17	137	3	17	26.0	1.8	17	0.99	0.01			

**Appendix 3.9. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	5/21/96	13	144	3	13	29.6	1.8	13	0.98	0.01	13	21.0	1.4
1996	5/22/96	11	139	3	11	26.1	1.4	11	0.97	0.01	11	20.1	1.7
	5/23/96	12	140	4	12	27.3	2.4	12	0.97	0.02	12	16.2	1.8
	5/24/96	17	141	3	17	27.2	1.8	17	0.95	0.02	15	21.7	1.9
	5/27/96	16	154	4	16	34.3	2.5	16	0.92	0.02	14	28.7	3.4
	5/28/96	14	146	3	14	30.1	2.1	14	0.95	0.01	12	26.7	3.5
	5/29/96	13	149	4	13	30.5	2.5	13	0.91	0.02	9	24.3	3.3
	5/30/96	11	141	4	11	28.5	2.2	11	1.00	0.02	10	25.8	1.7
	5/31/96	13	146	3	13	28.8	1.9	13	0.92	0.02	13	27.2	2.8

**Appendix 3.10. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for yearling wild spring/summer chinook salmon collected from the migration-at-large at the IDFG Clearwater River Trap (CLW), IDFG Snake River Trap (LEW), Grande Ronde River Trap (GRT), Imnaha River Trap (IMT), and Lower Granite Dam (LGR) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
IMT	4/20/95	30	101	1	30	11.4	0.4	30	1.11	0.01	25	14.4	0.9
	4/26/95	29	107	2	29	12.8	0.6	29	1.04	0.01	29	8.7	0.5
	5/2/95	5	104	3	5	13.2	1.3	5	1.17	0.02	5	12.2	1.6
	5/3/95	11	100	3	11	12.0	0.8	11	1.17	0.02	9	9.9	1.4
	5/4/95	13	106	2	13	13.5	0.7	13	1.14	0.02	12	10.2	1.2
	5/23/95	4	100	5	4	11.4	2.5	4	1.12	0.10	4	10.2	1.4
	5/24/95	10	103	6	10	13.6	2.4	10	1.17	0.05	10	11.3	1.4
	5/25/95	4	106	3	4	11.8	0.7	4	1.01	0.04	4	8.6	1.4
	5/26/95	7	100	4	7	11.5	1.0	7	1.14	0.02	6	8.7	1.2
SRT	3/28/95	15	91	3	15	8.5	0.9	15	1.07	0.02	14	7.8	0.8
	3/29/95	8	101	4	8	10.9	1.2	8	1.04	0.03	8	6.7	0.6
	3/30/95	22	96	2	22	9.6	0.7	22	1.05	0.01	21	8.0	0.4
	4/4/95	15	98	2	15	9.5	0.8	15	1.00	0.01	14	7.6	0.4
	4/6/95	14	96	2	14	8.8	0.7	14	0.98	0.01	13	6.7	0.6
	4/11/95	14	103	2	14	12.0	0.9	14	1.08	0.01	13	6.9	0.5
	4/13/95	15	95	1	15	9.2	0.4	15	1.06	0.01	14	8.4	0.9
	4/18/95	14	94	2	14	8.8	0.5	14	1.04	0.02	12	8.8	0.8
	4/20/95	15	100	2	15	10.7	0.7	15	1.06	0.02	15	9.7	0.9
	4/25/95	15	96	1	15	9.4	0.4	15	1.06	0.01	14	12.6	1.0
	4/27/95	15	98	2	15	10.2	0.7	15	1.06	0.01	15	15.7	1.4
	5/2/95	15	104	2	15	12.4	0.8	15	1.07	0.01	15	13.8	0.9
	5/4/95	15	104	3	15	12.5	1.2	15	1.06	0.01	15	13.0	1.0
	5/9/95	15	98	2	15	10.6	0.7	15	1.12	0.01	9	12.1	1.9
	5/10/95	15	99	1	15	11.0	0.4	15	1.14	0.02	13	9.2	0.8
GRT	4/13/95	6	97	6	5	9.4	1.8	5	1.09	0.03	5	8.8	1.0
	4/18/95	15	103	3	15	12.4	1.1	15	1.11	0.02	15	8.9	0.8
	4/20/95	14	111	3	14	15.7	1.4	14	1.11	0.02	13	9.6	0.9
	4/25/95	14	106	3	14	12.9	1.1	14	1.06	0.01	12	15.6	1.3
	4/27/95	15	110	3	15	14.7	1.0	15	1.09	0.01	14	16.7	2.1
	5/24/95	4	108	2	4	16.2	1.4	4	1.29	0.06	3	15.5	5.8
CLW	4/5/95	5	105	3	5	14.2	1.5	5	1.21	0.02	5	12.5	1.5
	4/7/95	2	105	2	2	13.1	1.2	2	1.14	0.06	2	13.0	5.2
	4/7/95	15	101	2	15	11.1	0.9	15	1.05	0.04	14	7.8	0.8
	4/10/95	10	99	3	10	9.9	1.0	10	1.01	0.03	10	8.4	0.8
	4/12/95	9	103	4	9	10.8	1.1	9	0.97	0.02	8	6.6	0.7
	4/17/95	10	119	4	10	18.4	1.6	10	1.06	0.02	9	5.9	0.8
	4/19/95	10	101	4	10	12.7	1.6	10	1.18	0.08	10	8.8	0.8
	4/21/95	7	94	2	7	9.4	0.7	7	1.10	0.03	6	7.5	1.0
	4/24/95	7	102	5	7	12.0	1.7	7	1.08	0.03	7	9.9	0.6
	4/26/95	10	101	4	10	11.6	1.0	10	1.10	0.05	10	14.8	1.4
	4/28/95	3	100	4	3	11.5	1.5	3	1.13	0.03	3	13.6	1.2
5/1/95	10	95	3	10	9.8	0.8	10	1.13	0.03	9	9.1	1.5	

**Appendix 3.10. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	STD	n	MEAN	STD	n	MEAN	STD	n	MEAN	STD
CLW	5/3/95	10	93	2	10	8.8	0.6	10	1.09	0.03	10	10.3	1.3
	5/15/95	10	103	2	10	11.8	0.6	10	1.10	0.04	10	10.4	1.3
	5/17/95	8	106	1	8	14.4	0.6	8	1.21	0.07	8	11.3	0.9
	5/18/95	13	102	3	13	12.4	0.9	13	1.14	0.02	11	9.2	0.8
	5/23/95	9	100	3	9	11.9	0.9	9	1.16	0.03	8	7.8	0.9
	5/24/95	9	106	2	9	14.4	1.1	9	1.20	0.02	8	10.3	1.6
	5/25/95	4	109	2	4	14.5	1.0	4	1.12	0.04	3	13.0	4.2
LEW	4/10/95	10	110	5	10	14.1	1.9	10	1.01	0.01	9	8.2	0.7
	4/12/95	10	114	11	10	19.2	8.0	10	0.99	0.02	10	12.0	1.2
	4/14/95	11	102	2	11	10.6	0.7	11	0.98	0.03	10	9.8	0.8
	4/17/95	10	100	2	10	10.0	0.5	10	0.99	0.02	9	10.0	0.9
	4/21/95	20	105	1	20	12.0	0.7	20	1.02	0.02	20	11.5	0.6
	4/24/95	10	105	3	10	11.3	0.9	10	0.96	0.02	10	15.4	1.3
	4/26/95	10	100	2	10	10.9	0.6	10	1.07	0.04	10	17.1	1.4
	4/28/95	10	100	3	10	13.0	0.7	10	1.32	0.05	9	17.3	1.2
	5/1/95	3	108	5	3	12.8	2.0	3	1.01	0.02	3	12.2	3.4
	5/3/95	10	106	2	10	12.4	0.6	10	1.05	0.03	10	17.6	1.8
	5/5/95	11	101	2	11	11.0	0.5	11	1.05	0.01	11	15.6	1.3
	5/8/95	10	103	2	10	12.1	0.7	10	1.11	0.02	8	13.4	1.7
	5/9/95	10	103	2	10	13.4	0.9	10	1.21	0.02	8	14.3	3.2
	5/10/95	10	104	1	10	11.1	0.7	10	1.00	0.06	10	14.3	1.9
	5/15/95	10	103	2	10	12.3	0.8	10	1.12	0.02	9	14.2	1.5
	5/17/95	9	103	2	9	12.5	0.7	9	1.13	0.02	9	13.3	1.1
	5/18/95	10	109	2	10	13.7	0.7	10	1.07	0.02	10	13.6	1.2
	5/22/95	10	104	2							9	14.9	2.2
	5/23/95	10	103	2	10	12.7	0.7	10	1.15	0.02	9	12.3	1.0
	5/24/95	10	108	2							9	14.4	3.1
LGR	4/14/95	29	109	2	29	13.3	0.7	29	0.99	0.01	26	11.8	0.6
	4/17/95	10	109	4	10	13.5	1.6	10	0.99	0.01	8	11.9	2.2
	4/19/95	20	105	2	20	11.6	0.6	20	0.99	0.01	19	12.8	1.1
	4/25/95	15	107	2	14	13.2	0.9	14	1.05	0.01	15	19.8	1.1
	4/27/95	15	105	2	15	11.9	0.7	15	1.01	0.01	15	17.7	1.1
	5/2/95	15	109	2	15	13.3	0.7	15	1.03	0.01	14	17.2	1.1
	5/4/95	15	102	2	15	10.9	0.6	15	1.01	0.01	15	16.1	1.4
	5/9/95	14	111	3	14	14.4	1.1	14	1.03	0.02	13	17.0	1.5
	5/11/95	15	106	2	15	12.8	0.7	15	1.05	0.01	15	12.5	0.9
	5/16/95	15	111	1	15	14.5	0.5	15	1.05	0.01	13	12.4	0.9
	5/17/95	15	106	2	15	12.4	0.7	15	1.04	0.01	14	13.8	0.9
	5/23/95	15	109	2	15	13.9	0.7	15	1.05	0.01	15	14.1	1.0
	5/25/95	15	108	2	15	13.5	0.6	15	1.06	0.02	15	13.5	1.0
5/30/95	15	107	2	15	12.7	0.6	15	1.02	0.01	14	13.8	1.3	

**Appendix 3.11. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for yearling wild spring/summer chinook salmon collected from the migration-at-large at the IDFG Salmon River Trap (CLW), IDFG Snake River Trap (LEW), and Lower Granite Dam (LGR) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
SRT	4/2/96	3	97	2	3	8.9	0.8	3	0.98	0.02	3	19.3	2.9
	4/3/96	16	100	2	16	10.0	0.7	16	0.98	0.02	9	14.6	1.7
	4/8/96	15	105	2	15	12.0	0.6	15	1.02	0.03	13	20.6	1.7
	4/9/96	15	99	2	15	10.6	0.9	15	1.07	0.01	6	16.0	2.6
	4/10/96	15	107	3	15	13.6	1.1	15	1.07	0.01	13	21.9	2.3
	4/11/96	20	103	2	20	12.0	0.8	20	1.08	0.02	16	18.0	1.4
	4/15/96	15	102	2	15	10.3	0.7	15	0.96	0.02	12	11.1	0.5
	4/16/96	15	107	3	7	13.6	2.3	7	1.00	0.03	7	8.9	1.0
	4/17/96	15	103	3	15	11.3	1.1	15	1.00	0.02	15	9.1	1.0
	4/18/96	15	97	2	15	8.8	0.6	15	0.97	0.03	15	9.1	1.0
	4/19/96	15	99	2	15	8.7	0.6	15	0.90	0.02	14	8.7	0.7
	4/22/96	6	105	2	6	11.9	0.6	6	1.03	0.01	6	12.2	1.5
	4/23/96	17	104	3	17	11.5	0.7	17	1.02	0.03	16	13.3	1.3
	4/24/96	11	102	3	11	9.6	0.8	11	0.89	0.04	9	11.9	1.8
	4/25/96	20	106	2	20	11.3	0.8	20	0.94	0.02	18	10.2	0.7
	4/26/96	3	105	4	3	11.7	1.5	3	1.00	0.01	3	11.6	1.9
	4/29/96	4	107	1	4	11.7	0.2	4	0.96	0.03	4	10.7	1.3
	4/30/96	11	104	3	11	11.3	0.8	11	0.99	0.01	10	12.2	0.8
	5/1/96	8	107	4	7	12.6	1.5	7	1.01	0.05	8	10.2	0.6
	5/2/96	7	116	5	7	15.2	1.6	7	0.95	0.04	7	9.3	1.2
	5/3/96	11	108	6	11	13.6	2.4	11	0.99	0.02	11	10.7	0.8
	5/6/96	2	115	7	2	16.3	3.9	2	1.05	0.06	2	12.4	1.1
	5/7/96	5	113	4	5	15.2	1.5	5	1.05	0.03	5	12.8	1.4
	5/8/96	3	104	8	3	12.7	2.9	3	1.09	0.02	3	10.7	1.5
	5/9/96	7	118	3	7	16.5	1.3	7	0.98	0.03	7	13.5	1.1
	5/10/96	10	110	3	4	13.1	1.6	4	1.00	0.01	8	12.9	1.4
	5/13/96	7	107	4	7	13.0	1.1	7	1.05	0.03	6	7.2	0.8
	5/14/96	4	109	3	4	13.8	1.4	4	1.07	0.07	4	8.4	1.4
	5/15/96	5	109	3	5	13.6	1.0	5	1.04	0.03	5	8.1	1.0
	LEW	4/15/96	15	102	3	15	12.3	1.0	15	1.14	0.03	11	18.3
4/16/96		15	107	2	15	13.8	0.9	15	1.11	0.01	14	16.5	1.5
4/17/96		15	101	2	15	11.0	0.5	15	1.06	0.03	14	18.7	1.8
4/18/96		14	104	2	14	12.0	0.7	14	1.04	0.02	13	15.1	1.5
4/19/96		15	103	2	15	11.5	0.8	15	1.04	0.03	9	15.2	1.7
4/22/96		13	102	2	13	11.5	0.5	13	1.08	0.03	13	14.1	1.5
4/23/96		2	112	6	2	17.0	3.2	2	1.19	0.04	2	21.3	0.8
4/24/96		17	106	2	16	12.1	1.3	16	0.97	0.05	17	14.7	1.3
4/26/96		34	106	1	34	12.6	0.5	34	1.05	0.02	32	16.3	1.3
4/29/96		9	106	2	9	12.6	1.0	9	1.05	0.02	6	16.9	3.5
4/30/96	17	102	2	17	11.7	0.6	17	1.09	0.01	11	16.6	2.2	

**Appendix 3.11. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
	5/1/96	12	109	1	12	12.9	0.7	12	1.00	0.04	12	20.7	1.3
	5/2/96	10	105	3	10	12.6	1.0	10	1.07	0.03	10	19.4	2.3
	5/3/96	6	115	5	6	16.2	2.5	6	1.04	0.04	5	14.4	2.5
	5/6/96	1	102	0	1	10.9	0.0	1	1.03	0.00	1	15.0	0.0
	5/7/96	3	112	5	3	15.0	2.1	3	1.05	0.01	3	12.9	1.9
	5/8/96	2	126	19	2	21.6	9.2	2	1.01	0.00	2	16.8	4.7
	5/10/96	8	109	3	8	13.3	0.9	8	1.03	0.04	8	11.7	1.1
	5/13/96	10	106	2	10	12.5	0.6	10	1.05	0.01	10	17.2	1.2
	5/14/96	20	110	1	20	14.4	0.5	20	1.07	0.01	19	19.0	1.3
	5/15/96	15	107	2	15	13.5	0.7	15	1.09	0.02	15	17.2	1.4
	5/16/96	18	108	2	18	13.4	0.5	18	1.05	0.01	18	16.8	1.2
LGR	5/2/96	5	103	5	5	11.2	1.4	5	1.02	0.03	5	15.9	2.2
	5/3/96	2	110	1	2	13.8	0.5	2	1.05	0.02	2	16.1	1.5
	5/4/96	2	113	2	2	15.7	0.1	2	1.09	0.05	2	17.2	0.0
	5/5/96	3	97	2	3	10.0	1.2	3	1.08	0.06	3	13.4	1.9
	5/6/96	3	116	2	3	15.8	0.4	3	1.02	0.02	3	18.1	1.2
	5/7/96	2	110	4	2	13.5	1.8	2	1.00	0.02	2	13.5	1.8
	5/14/96	4	122	8	4	19.6	4.8	4	1.02	0.02	5	18.6	1.9
	5/16/96	5	123	5	5	20.5	2.6	5	1.08	0.01	5	17.8	1.4
	5/17/96	3	114	3	3	14.6	2.2	3	0.97	0.09	3	18.4	0.4
	5/18/96	5	123	2	5	20.2	1.3	5	1.08	0.03	5	13.3	1.7
	5/19/96	2	110	1	2	13.9	0.0	2	1.04	0.03	2	14.2	2.1
	5/24/96	1	107	0	1	13.9	0.0	1	1.13	0.00	1	18.8	0.0

**Appendix 3.12. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for subyearling fall chinook salmon collected from the migration-at-large at John Day Dam (JDA), McNary Dam (MCN), and Rock Island Dam (RIS) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	
RIS	6/26/95	10	96	5	10	10.6	1.9	10	1.09	0.02	9	11.1	3.2	
	6/28/95	9	101	5	9	12.9	2.3	9	1.15	0.02	9	9.9	1.8	
	6/30/95	8	105	7	8	15.5	2.5	8	1.33	0.16	8	10.3	1.9	
	7/3/95	10	112	5	10	16.7	1.9	10	1.15	0.03	10	15.6	1.4	
	7/5/95	10	100	7	10	12.1	2.3	10	1.09	0.05	9	17.8	0.5	
	7/7/95	10	93	4	10	9.3	1.3	10	1.10	0.02	10	19.4	1.1	
	7/10/95	9	100	3	9	11.5	1.0	9	1.11	0.02	5	17.1	2.0	
	7/12/95	10	104	3	10	12.5	1.0	10	1.08	0.02	5	17.3	1.2	
	7/14/95	10	94	4	10	9.6	1.0	10	1.10	0.01	8	16.0	1.2	
	7/17/95	7	86	7	7	8.2	2.1	7	1.14	0.02	4	17.2	4.3	
	7/19/95	10	80	3	10	5.7	0.7	10	1.08	0.02	6	14.5	1.6	
	7/21/95	9	86	5	9	7.8	1.4	9	1.15	0.03	6	18.4	1.7	
	7/24/95	10	83	2	10	6.6	0.6	10	1.12	0.02	9	15.8	1.6	
	7/26/95	10	98	5	10	11.3	1.7	10	1.14	0.03	10	19.4	1.8	
	7/28/95	10	100	3	10	12.2	1.2	10	1.17	0.04	10	19.7	1.3	
	7/31/95	10	100	5	10	12.2	1.7	10	1.15	0.03	7	15.8	2.5	
	8/2/95	10	96	6	10	12.1	2.6	10	1.20	0.04	10	13.7	1.3	
	8/4/95	10	90	5	10	9.1	1.8	10	1.14	0.03	9	19.3	1.8	
	8/7/95	10	95	4	10	8.5	1.4	10	1.03	0.10	9	16.3	1.2	
	8/9/95	10	106	6	10	14.6	2.5	10	1.11	0.02	10	15.1	1.9	
	8/11/95	10	104	6	10	14.2	2.4	10	1.13	0.02	10	14.4	0.9	
	8/14/95	8	113	5	8	18.6	2.3	8	1.25	0.03	7	15.1	1.4	
	8/16/95	10	107	4	10	13.9	1.6	10	1.13	0.08	10	12.1	1.5	
	8/18/95	8	122	8	8	24.1	4.1	8	1.22	0.03	8	11.0	1.3	
	8/21/95	10	111	5	10	16.3	2.4	10	1.11	0.02	9	11.1	1.2	
	8/23/95	9	127	5	9	24.1	2.4	9	1.15	0.02	9	12.3	1.3	
	8/25/95	9	124	6	9	24.0	3.5	9	1.17	0.04	5	11.2	1.0	
	MCN	6/12/95	19	87	3	19	6.9	0.6	19	1.02	0.02	16	23.7	2.5
		6/19/95	20	91	2	20	8.0	0.5	20	1.05	0.01	15	17.3	1.2
		6/26/95	20	101	2	20	10.2	0.5	20	0.99	0.01	15	16.3	1.6
6/28/95		37	99	1	37	9.2	0.2	37	0.95	0.01	23	18.6	1.2	
6/30/95		26	100	1	26	9.7	0.3	26	0.97	0.01	12	16.7	1.3	
7/1/95		13	100	2	13	9.8	0.6	13	0.96	0.02	6	16.5	1.4	
7/3/95		30	100	1	30	10.1	0.3	30	1.00	0.01	23	16.4	1.0	
7/12/95		20	90	3							13	5.9	0.8	
7/19/95		20	95	2	20	9.9	0.5	20	1.13	0.02	18	18.2	1.2	
7/28/95		20	108	3	20	14.9	1.4	20	1.14	0.02	11	17.5	1.3	
8/4/95		20	118	3	20	19.8	1.5	20	1.16	0.02	19	10.8	0.6	
8/9/95		20	119	2	20	20.5	1.3	20	1.19	0.02	19	14.3	0.5	
8/18/95		20	120	1	20	19.5	0.7	20	1.13	0.02	3	12.9	2.4	
8/25/95	20	130	5	20	27.3	3.5	20	1.15	0.01	20	10.8	0.6		

**Appendix 3.12. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
JDA	6/24/95	20	103	2	20	11.4	0.6	20	1.04	0.01	18	19.2	2.0
	7/1/95	20	102	2	20	11.8	0.9	20	1.08	0.02	18	16.8	1.1
	7/8/95	20	99	1	20	10.6	0.6	20	1.06	0.01	20	16.1	1.4
	7/17/95	20	104	2	20	13.0	0.9	20	1.13	0.01	15	21.5	1.2
	7/21/95	20	100	2	20	11.4	0.6	20	1.12	0.02	20	18.7	1.2
	7/29/95	20	105	2	20	13.5	0.7	20	1.17	0.02	8	14.6	1.7
	8/5/95	20	114	2	20	18.1	1.2	20	1.19	0.02	20	9.1	0.9
	8/19/95	20	129	3	20	26.1	1.8	20	1.19	0.02	1	10.7	0.0
	8/27/95	20	128	1	20	25.5	1.0	20	1.21	0.03	20	8.6	0.4

**Appendix 3.13. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for subyearling fall chinook salmon collected from the migration-at-large at Rock Island Dam (RIS) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	6/24/96	12	119	2	12	18.2	1.1	12	1.07	0.02	9	15.1	1.3
	6/25/96	6	109	5	2	14.2	5.1	2	1.17	0.16	4	21.6	5.3
	6/26/96	10	122	3	10	19.6	1.3	10	1.06	0.02	10	21.2	2.0
	6/27/96	5	122	4	5	19.9	2.0	5	1.07	0.02	3	16.8	1.3
	6/28/96	29	106	1	29	14.4	0.6	29	1.19	0.01	23	10.7	1.0
	7/1/96	30	107	2	30	13.9	0.8	30	1.10	0.01	23	14.3	2.1
	7/2/96	30	114	3	30	17.3	1.2	30	1.12	0.01	28	14.6	1.3
	7/3/96	30	112	3	29	16.2	1.1	29	1.10	0.01	28	13.9	1.4
	7/4/96	30	113	2	30	16.1	0.9	30	1.09	0.01	30	13.3	0.9
	7/5/96	19	117	4	19	18.1	1.6	19	1.07	0.01	18	17.9	1.6
	7/8/96	26	110	3	26	15.2	1.3	26	1.08	0.01	21	21.9	1.1
	7/9/96	22	114	3	22	17.1	1.2	22	1.11	0.02	20	16.4	1.4
	7/10/96	24	105	3	24	12.8	1.0	24	1.06	0.01	19	21.4	1.7
	7/11/96	30	101	2	30	11.7	0.7	30	1.10	0.01	25	22.7	1.5
	7/12/96	30	105	2	30	13.1	0.9	30	1.09	0.01	25	22.3	1.3
	7/15/96	18	102	2	18	11.5	0.8	18	1.07	0.01	15	22.3	2.2
	7/16/96	21	98	3	21	10.5	0.9	21	1.08	0.01	16	20.9	1.1
	7/17/96	13	95	2	13	9.4	0.6	13	1.09	0.02	9	23.5	1.9
	7/18/96	10	101	5	10	12.2	1.8	10	1.13	0.01	10	21.1	2.1
	7/19/96	8	86	3	8	7.5	0.8	8	1.14	0.02	6	19.7	4.1
	7/22/96	25	99	2	25	11.3	0.8	25	1.13	0.01	21	19.5	1.0
	7/26/96	24	94	2	24	9.8	0.8	24	1.14	0.01	22	23.4	1.5
	7/30/96	12	102	5	12	13.7	2.2	12	1.18	0.02	12	18.9	1.7
	7/31/96	6	106	7	6	15.0	3.1	6	1.17	0.02	6	18.4	2.9

**Appendix 3.14. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for hatchery steelhead collected from the migration-at-large at the IDFG Snake River Trap (LEW), IDFG Salmon River Trap (SRT), Lower Granite Dam (LGR), Grande Ronde Trap (GRT), Imnaha River Trap (IMT), McNary Dam (MCN), and Rock Island Dam (RIS) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
IMT	5/2/95	30	210	2	30	95.1	3.5	30	1.01	0.01			
	5/23/95	29	205	4	29	80.4	4.9	29	0.90	0.01	28	6.4	0.5
SRT	4/11/95	10	219	6	10	103.1	8.2	10	0.98	0.03	10	5.5	0.3
	4/13/95	15	215	6	15	97.4	8.8	15	0.95	0.01	15	3.4	0.5
	4/18/95	15	221	6	15	107.8	8.8	15	0.96	0.01	14	8.8	1.1
	4/20/95	15	225	7	15	114.5	10.4	15	0.97	0.01	14	8.7	1.5
	4/25/95	15	220	4	15	98.9	9.2	15	0.91	0.05	15	5.3	0.6
	4/27/95	15	221	6	15	106.7	9.5	15	0.95	0.02	15	5.8	0.9
	5/2/95	15	204	7	15	84.4	9.6	15	0.94	0.01	15	4.4	0.7
	5/4/95	15	217	6	15	96.3	8.9	15	0.92	0.01	15	4.1	0.4
	5/9/95	15	202	6	15	77.1	7.1	15	0.90	0.01	14	7.3	1.0
	5/10/95	15	207	6	15	84.2	8.5	15	0.92	0.01	15	6.8	0.7
	5/16/95	24	212	5	24	87.1	6.6	24	0.88	0.01	24	7.8	0.6
GRT	4/13/95	25	214	3	23	89.6	5.7	23	0.93	0.04	23	7.7	0.7
	4/18/95	17	212	3	17	93.3	4.5	17	0.97	0.01	17	6.6	0.8
	4/20/95	13	222	5	13	111.0	7.9	13	0.99	0.01	13	5.8	0.6
	4/25/95	15	194	6	15	73.8	7.0	15	0.96	0.01	15	7.7	0.6
	4/27/95	15	192	8	15	70.2	8.4	15	0.93	0.01	14	7.4	0.8
	5/24/95	15	209	5	15	84.7	5.9	15	0.92	0.02	15	8.3	1.0
LEW	5/25/95	15	212	4	15	89.9	4.3	15	0.94	0.02	15	9.3	1.0
	4/12/95	14	217	5	13	92.2	9.4	13	0.90	0.06	14	6.9	0.7
	4/14/95	14	211	4	14	84.6	4.9	14	0.89	0.01	14	7.7	0.8
	4/17/95	10	224	10	9	77.0	8.9	9	0.82	0.09	10	5.6	0.9
	4/19/95	10	206	5	10	88.5	7.1	10	0.99	0.02	10	6.0	1.0
	4/21/95	10	208	5	10	83.3	7.2	10	0.91	0.02	10	5.8	0.6
	4/24/95	10	212	4	10	88.1	5.2	10	0.92	0.02	10	6.2	0.6
	4/26/95	9	216	4	9	98.6	8.7	9	0.95	0.04	8	8.3	0.8
	4/28/95	10	205	8	10	88.3	10.2	10	0.99	0.02	9	6.8	1.6
	5/1/95	9	217	6	9	96.0	10.0	9	0.92	0.03	9	5.3	0.7
	5/3/95	10	209	6	10	85.4	7.5	10	0.91	0.01	9	6.8	1.0
	5/5/95	10	221	11	10	105.4	15.5	10	0.92	0.02	9	5.9	1.3
	5/8/95	10	224	6	10	106.9	9.5	10	0.93	0.01	10	7.5	0.9
	5/9/95	10	206	3	10	83.6	3.9	10	0.95	0.01	10	6.6	0.6
	5/10/95	10	212	6	10	76.6	10.9	10	0.77	0.06	9	5.6	0.7
	5/15/95	10	221	8	10	99.8	10.7	10	0.89	0.01	10	10.2	1.4
	5/17/95	10	215	4	10	89.4	4.8	10	0.89	0.02	10	8.3	0.7
5/18/95	10	213	5	10	80.6	6.4	10	0.82	0.01	10	11.0	0.9	
5/22/95	11	194	5							11	7.0	0.6	
5/23/95	10	211	7	10	86.0	8.3	10	0.89	0.01	10	8.2	0.9	
5/24/95	10	191	6							10	7.1	0.8	

**Appendix 3.14. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
LGR	4/17/95	10	217	5	10	102.3	7.7	10	0.99	0.02	10	9.6	1.1
	4/19/95	19	217	4	19	99.8	5.5	19	0.96	0.01	19	9.3	0.8
	4/25/95	15	213	6	15	91.6	6.7	15	0.93	0.03	15	9.3	0.9
	4/27/95	14	199	5	14	75.9	6.0	14	0.95	0.01	14	9.4	0.8
	5/2/95	15	216	5	15	94.0	7.0	15	0.91	0.02	14	7.2	0.7
	5/4/95	15	225	6	15	108.7	8.4	15	0.92	0.01	15	7.6	0.7
	5/9/95	15	215	8	15	95.1	10.1	15	0.91	0.02	15	8.4	0.6
	5/11/95	15	226	4	15	103.8	5.2	15	0.89	0.01	14	7.5	0.6
	5/16/95	15	222	5	15	97.5	7.7	15	0.87	0.01	15	8.1	0.7
	5/17/95	15	218	6	15	94.5	7.0	15	0.89	0.01	15	8.4	0.8
	5/23/95	16	218	7	16	90.7	8.1	16	0.84	0.02	13	8.9	0.8
	5/25/95	15	222	6	14	96.2	10.1	14	0.85	0.02	12	8.5	0.7
	5/30/95	15	218	6	15	93.2	9.8	15	0.86	0.02	15	10.6	1.2
	6/1/95	15	223	8	15	101.0	13.2	15	0.85	0.02	15	10.7	0.9
	RIS	4/27/95	8	211	5	8	84.7	5.7	8	0.90	0.02	7	15.4
5/1/95		8	219	6	8	96.5	9.4	8	0.90	0.02	7	7.5	1.1
5/2/95		8	218	7	8	95.4	10.0	8	0.90	0.02	8	10.1	0.7
5/3/95		8	213	8	8	90.2	10.3	8	0.90	0.01	5	8.4	1.2
5/4/95		8	207	10	8	84.2	13.1	8	0.89	0.03	8	8.4	0.8
5/8/95		8	198	6	8	68.3	5.8	8	0.87	0.01	8	10.1	0.8
5/9/95		8	213	5	8	86.9	6.2	8	0.89	0.01	8	10.1	0.8
5/10/95		8	204	7	8	74.2	7.2	8	0.86	0.01	8	8.6	0.4
5/11/95		8	199	6	8	71.7	7.8	8	0.88	0.02	8	7.8	0.8
5/15/95		8	197	4	8	69.0	4.6	8	0.89	0.01	8	8.6	1.3
5/16/95		9	197	9	9	69.9	5.8	9	0.95	0.09	9	9.4	1.2
5/17/95		8	193	9	8	66.3	10.2	8	0.87	0.02	8	10.6	1.8
5/18/95		8	200	9	8	74.7	9.9	8	0.89	0.02	8	10.9	0.9
5/22/95		7	205	4	7	70.7	4.0	7	0.82	0.02	7	15.6	1.5
5/23/95		8	212	8	8	88.5	10.6	8	0.89	0.02	8	13.9	1.8
5/24/95	6	201	8	6	78.3	8.4	6	0.94	0.03	6	14.8	2.6	
5/25/95	7	206	8	7	82.9	11.2	7	0.91	0.03	7	14.6	1.6	
MCN	4/26/95	6	236	15	6	127.9	22.9	6	0.92	0.02	6	6.0	1.4
	4/28/95	16	238	4	16	125.3	7.6	16	0.91	0.02	16	6.2	0.6
	5/1/95	18	245	4	18	133.5	7.4	18	0.90	0.01	18	8.1	0.8
	5/10/95	18	235	4	18	117.0	5.1	18	0.90	0.02	18	13.4	1.8
5/24/95	20	237	4	20	111.1	6.3	20	0.82	0.01	16	12.2	1.4	

**Appendix 3.15. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for hatchery steelhead collected from the migration-at-large at the IDFG Snake River Trap (LEW), IDFG Salmon River Trap (SRT), Lower Granite Dam (LGR), and Rock Island Dam (RIS) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
SRT	4/2/96	30	202	3	30	77.0	3.4	30	0.92	0.01	29	3.9	0.2
	4/3/96	15	209	4	15	88.5	4.8	15	0.96	0.02	15	3.7	0.2
	4/8/96	3	201	11	3	71.3	9.3	3	0.87	0.03	3	7.0	0.6
	4/9/96	19	207	4	19	84.9	5.5	19	0.93	0.01	19	5.6	0.6
	4/10/96	9	201	4	9	76.5	5.6	9	0.93	0.01	9	3.2	0.4
	4/11/96	10	212	6	9	93.3	8.5	9	0.98	0.02	9	3.6	0.5
	4/15/96	15	220	3	15	97.8	4.8	15	0.91	0.01	15	4.4	0.3
	4/16/96	15	220	5	10	102.6	5.8	10	0.93	0.03	15	4.4	0.5
	4/17/96	15	219	4	14	97.2	6.5	14	0.92	0.02	15	5.4	0.7
	4/18/96	15	219	4	15	93.3	6.3	15	0.87	0.02	15	4.3	0.4
	4/19/96	15	228	6	15	109.1	8.5	15	0.90	0.02	15	4.1	0.3
	4/22/96	15	210	4	15	86.6	4.8	15	0.92	0.01	15	4.7	0.5
	4/23/96	15	222	7	15	101.4	9.8	15	0.88	0.01	15	4.8	0.4
	4/24/96	15	213	4	15	84.5	5.3	15	0.86	0.01	15	4.1	0.3
	4/25/96	15	206	4	15	80.2	5.5	15	0.89	0.01	15	4.2	0.2
	4/26/96	15	224	6	15	102.3	8.7	15	0.88	0.01	15	5.4	0.4
	4/29/96	15	218	6	15	96.3	7.8	15	0.90	0.01	15	5.5	0.5
	4/30/96	15	221	5	15	99.9	7.2	15	0.90	0.02	15	4.9	0.4
	5/1/96	15	217	5	15	95.6	7.7	15	0.91	0.02	15	4.7	0.3
	5/2/96	15	215	6	15	91.7	8.8	15	0.88	0.01	15	4.7	0.7
	5/3/96	15	220	7	15	105.0	7.0	15	1.06	0.15	14	4.2	0.4
	5/6/96	15	230	6	15	107.5	9.7	15	0.86	0.01	15	5.2	0.6
	5/7/96	15	221	4	15	94.6	4.7	15	0.87	0.01	15	5.4	0.6
	5/8/96	15	222	6	15	100.7	7.8	15	0.90	0.01	15	4.8	0.6
	5/9/96	15	225	5	15	97.9	6.2	15	0.84	0.01	15	5.4	0.5
	5/10/96	15	222	7	15	97.9	9.6	15	0.87	0.01	15	5.8	0.5
	5/13/96	15	217	4	15	90.3	4.9	15	0.88	0.01	15	7.0	0.5
	5/14/96	11	220	8	11	98.8	11.6	11	0.90	0.03	11	5.5	0.4
	5/15/96	21	210	4	21	79.8	4.9	21	0.84	0.01	21	6.8	0.5
	LEW	4/15/96	14	215	5	14	102.6	7.0	14	1.02	0.03	13	4.1
4/16/96		15	217	6	15	96.6	7.7	15	0.92	0.02	15	4.9	0.6
4/17/96		15	212	4	15	91.4	5.1	15	0.95	0.01	15	5.1	0.5
4/18/96		15	204	4	15	80.4	4.8	15	0.94	0.02	15	4.7	0.6
4/19/96		14	215	5	14	92.8	6.2	14	0.91	0.02	14	4.5	0.5
4/22/96		15	212	7	15	93.6	9.3	15	0.95	0.02	15	4.9	0.5
4/23/96		15	201	4	15	76.2	4.8	15	0.93	0.02	15	7.5	1.1
4/24/96		15	212	6	15	90.6	7.4	15	0.92	0.02	15	6.6	0.6
4/26/96		23	208	3	23	82.6	3.8	23	0.91	0.01	23	5.8	0.5
4/29/96		15	208	6	15	83.7	7.5	15	0.90	0.02	14	4.5	0.4
4/30/96	15	216	7	15	98.1	11.4	15	0.93	0.01	15	5.9	0.6	
5/1/96	15	204	6	15	79.0	6.7	15	0.90	0.01	16	4.8	0.4	

**Appendix 3.15. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
LEW	5/2/96	15	207	4	15	80.8	4.9	15	0.90	0.01	15	5.0	0.4
	5/3/96	14	226	5	14	106.9	7.6	14	0.91	0.01	14	5.4	0.6
	5/6/96	16	211	6	16	87.0	8.1	16	0.89	0.02	15	9.4	0.9
	5/7/96	14	219	5	14	91.2	6.3	14	0.86	0.01	15	8.3	0.8
	5/8/96	15	226	4	15	104.7	6.1	15	0.90	0.02	15	9.7	0.9
	5/9/96	14	227	4	14	109.9	6.8	14	0.93	0.02	14	7.4	0.6
	5/10/96	16	210	4	16	82.3	5.3	16	0.86	0.02	16	7.6	1.0
	5/13/96	15	221	4	15	93.7	4.7	15	0.86	0.01	15	11.2	1.0
	5/14/96	15	220	3	15	91.3	3.9	15	0.85	0.01	15	10.1	1.1
	5/15/96	15	218	5	15	90.9	5.9	15	0.87	0.01	14	11.4	0.9
	5/16/96	22	214	4	22	85.5	5.2	22	0.85	0.01	22	7.7	0.7
LGR	5/1/96	1	239	0	1	125.7	0.0	1	0.92	0.00	1	8.6	0.0
	5/3/96	2	213	7	2	82.6	9.5	2	0.85	0.01	2	11.8	0.8
	5/4/96	1	267	0	1	172.7	0.0	1	0.91	0.00	1	10.0	0.0
	5/8/96	1	269	0	1	179.7	0.0	1	0.92	0.00	1	9.8	0.0
	5/10/96	1	226	0	1	87.1	0.0	1	0.75	0.00	1	18.9	0.0
	5/14/96	1	219	0	1	95.4	0.0	1	0.91	0.00	1	11.9	0.0
	5/16/96	8	220	10	8	94.3	12.1	8	0.86	0.01	8	10.4	1.1
	5/17/96	1	216	0	1	82.2	0.0	1	0.82	0.00	1	13.5	0.0
	5/18/96	2	222	3	2	98.7	6.2	2	0.91	0.03	2	8.3	1.1
		6/4/96	1	244	0	1	114.1	0.0	1	0.79	0.00	1	6.1
RIS	4/29/96	13	204	4	12	83.0	4.7	12	0.97	0.02	11	8.1	0.7
	4/30/96										15	10.1	0.7
	5/1/96	18	211	4	18	91.7	5.1	18	0.96	0.02	19	10.5	0.7
	5/2/96	17	212	4	15	92.5	5.8	15	0.95	0.01	18	11.1	1.0
	5/3/96	21	201	3	21	78.1	3.8	21	0.94	0.01	21	9.9	0.4
	5/6/96	27	209	4	27	88.4	4.8	27	0.94	0.01	25	13.1	0.8
	5/7/96	28	211	4	28	86.6	5.5	28	0.89	0.01	28	14.1	0.7
	5/8/96	27	207	3	27	84.7	4.3	27	0.94	0.01	26	15.4	0.8
	5/9/96	24	212	5	24	87.1	6.4	24	0.88	0.01	24	15.3	0.9
	5/10/96	25	201	4	25	77.6	4.6	25	0.93	0.01	25	14.2	0.6
	5/13/96	23	208	4	22	84.5	5.8	22	0.91	0.01	23	16.7	0.9
	5/14/96	27	201	4	27	74.8	4.0	27	0.90	0.01			
	5/15/96	5	202	7	5	77.9	7.9	5	0.93	0.02			
	5/16/96	11	214	8	11	93.1	10.2	11	0.91	0.02			
	5/17/96	25	215	3									
	5/20/96	22	212	4	22	87.1	5.6	22	0.89	0.01	21	12.4	1.1
	5/21/96	17	200	4	17	72.7	4.9	17	0.89	0.01	17	16.2	1.0
	5/22/96	27	213	4	26	87.4	4.9	26	0.88	0.01	27	15.5	1.0
	5/23/96	23	212	4	23	89.5	4.8	23	0.92	0.02	23	13.0	1.2
	5/24/96	22	213	4	22	89.1	4.9	22	0.90	0.01	21	11.5	0.8
5/27/96	23	220	4	23	98.0	5.2	23	0.90	0.01	23	13.6	1.4	
5/28/96	21	219	3	21	99.6	5.2	21	0.93	0.02	21	15.1	1.4	
5/29/96	26	216	4	26	96.4	5.4	26	0.93	0.02	26	13.8	1.3	
5/30/96	22	204	5	22	79.9	5.6	22	0.92	0.02	22	11.9	1.1	
5/31/96	23	221	5	23	101.7	6.0	23	0.93	0.01	23	11.0	1.0	

**Appendix 3.16. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for wild steelhead collected from the migration-at-large at the IDFG Snake River Trap (LEW), IDFG Salmon River Trap (SRT), Grande Ronde River Trap (GRT), Imnaha River Trap (IMT), Lower Granite Dam (LGR), McNary Dam (MCN), and Rock Island Dam (RIS) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
IMT	4/19/95	30	177	3	30	52.4	2.7	30	0.93	0.01	30	6.3	0.6
	4/26/95	30	183	3	30	58.5	3.5	30	0.93	0.01	25	8.2	0.5
	5/2/95	19	182	4	19	60.3	3.9	19	0.98	0.01	0		
	5/3/95	10	170	7	10	51.7	6.5	10	0.99	0.02	0		
	5/23/95	5	177	4	5	57.0	3.9	5	1.03	0.03	4	9.0	0.4
	5/24/95	20	168	4	20	49.5	3.2	20	1.03	0.02	18	10.3	1.1
	5/25/95	5	166	5	5	42.3	4.0	5	0.92	0.02	5	10.5	1.2
	5/25/95	5	166	5	5	42.3	4.0	5	0.92	0.02	5	10.5	1.2
SRT	4/11/95	17	189	7	17	64.5	8.3	17	0.88	0.01	17	5.7	0.6
	4/13/95	8	189	12	8	65.7	12.8	8	0.89	0.02	8	6.9	0.8
	4/18/95	5	183	6	5	55.3	5.0	5	0.89	0.01	5	14.1	2.7
	4/20/95	6	187	6	6	59.1	4.9	6	0.89	0.02	5	10.8	2.1
	4/25/95	9	168	6	9	43.1	4.8	9	0.89	0.02	9	7.1	0.8
	4/27/95	15	181	3	15	52.4	2.7	15	0.88	0.01	15	8.3	1.0
	5/2/95	15	173	5	15	47.0	4.8	15	0.88	0.01	15	7.4	1.1
	5/4/95	14	170	4	14	43.7	3.0	14	0.88	0.01	14	6.4	0.6
	5/9/95	15	170	4	15	45.7	3.4	15	0.90	0.01	14	7.7	0.6
	5/16/95	1	137	0	1	24.1	0.0	1	0.94	0.00	1	11.7	0.0
GRT	4/18/95	6	180	7	6	56.4	7.9	6	0.93	0.03	6	8.1	0.8
	4/20/95	25	177	5	25	55.5	4.9	25	0.94	0.02	24	10.6	0.9
	4/25/95	15	176	6	15	53.1	6.4	15	0.93	0.02	14	9.6	1.2
	4/27/95	15	160	3	15	40.3	2.6	15	0.97	0.01	15	9.9	1.3
	5/24/95	8	167	8	8	50.1	6.8	8	1.04	0.04	8	12.1	1.4
	5/25/95	8	163	4	8	41.5	5.2	8	0.92	0.09	8	10.4	0.6
	5/25/95	8	163	4	8	41.5	5.2	8	0.92	0.09	8	10.4	0.6
LEW	4/10/95	10	172	6	10	46.9	5.1	10	0.89	0.02	10	9.1	1.5
	4/12/95	10	176	5	10	46.7	4.9	10	0.83	0.02	10	10.2	1.5
	4/14/95	9	204	16	7	55.4	10.8	7	0.82	0.03	9	8.1	1.0
	4/17/95	10	191	10	10	63.6	11.5	10	0.85	0.01	10	10.4	1.5
	4/21/95	20	192	6	20	65.8	7.6	20	0.88	0.01	19	10.3	1.3
	4/24/95	7	209	19	7	93.4	26.2	7	0.91	0.05	7	7.1	1.1
	4/26/95	11	178	8	11	55.6	8.6	11	0.92	0.02	11	13.4	1.9
	4/28/95	10	175	8	10	53.2	9.1	10	0.95	0.05	10	11.3	1.4
	5/1/95	4	180	12	4	60.5	5.4	4	1.08	0.18	4	13.3	3.0
	5/3/95	10	180	7	10	53.5	6.1	10	0.90	0.03	10	9.8	1.1
	5/5/95	10	173	6	10	49.8	5.0	10	0.93	0.02	10	9.4	0.5
	5/8/95	10	171	7	10	48.1	5.1	10	0.93	0.02	10	6.6	0.5
	5/9/95	10	178	10	10	58.7	13.6	10	0.95	0.02	10	7.2	0.9
	5/10/95	10	169	6	10	31.7	3.8	10	0.63	0.01	10	11.9	1.0
	5/15/95	10	160	4	10	41.5	3.7	10	0.99	0.03	10	12.2	1.3
	5/17/95	10	164	4	10	43.9	3.7	10	0.97	0.02	10	10.7	1.1
	5/18/95	10	170	3	10	45.9	2.7	10	0.92	0.01	10	13.9	1.0
	5/22/95	10	160	5							10	11.6	1.6
5/23/95	6	170	6	6	46.1	4.5	6	0.92	0.03	6	9.1	0.8	
5/24/95	9	175	6							9	9.8	1.4	

**Appendix 3.16. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	
LGR	4/19/95	15	186	6	15	58.0	6.6	15	0.86	0.06	15	16.8	2.0	
	4/21/95	15	203	10	15	83.2	14.9	15	0.89	0.02	14	16.4	1.8	
	4/25/95	15	181	9	15	60.4	14.2	15	0.89	0.02	15	17.0	1.3	
	4/27/95	16	195	11	16	78.3	19.12	16	0.90	0.01	16	15.1	1.0	
	5/2/95	15	194	9	15	69.0	10.2	15	0.87	0.01	14	10.9	0.9	
	5/4/95	15	179	3	15	53.7	3.3	15	0.93	0.02	15	9.6	0.6	
	5/9/95	15	178	5	15	51.8	3.7	15	0.90	0.02	15	10.1	0.8	
	5/11/95	15	181	6	15	55.4	5.8	15	0.89	0.02	15	10.6	1.0	
	5/16/95	15	174	4	15	47.8	3.7	15	0.89	0.02	15	9.8	0.5	
	5/17/95	15	175	5	15	50.7	4.5	15	0.91	0.01	15	9.8	0.7	
	5/23/95	14	174	5	14	48.5	4.6	14	0.89	0.01	14	9.4	0.7	
	5/25/95	15	175	4	15	51.5	4.2	15	0.93	0.01	15	9.3	0.5	
	5/30/95	15	180	3	15	54.1	2.8	15	0.92	0.02	15	12.6	1.0	
	6/1/95	15	179	6	15	56.2	6.1	15	0.93	0.01	15	12.0	0.5	
	RIS	4/27/95	8	186	11	8	61.0	12.1	8	0.87	0.01	7	18.7	1.8
		5/1/95	8	198	6	8	67.8	5.6	8	0.86	0.01	8	10.2	1.1
		5/2/95	9	183	6	9	53.4	5.2	9	0.86	0.01	7	10.6	1.4
5/3/95		8	163	12	8	42.8	10.5	8	0.90	0.03	7	8.8	1.9	
5/4/95		8	179	8	8	53.5	6.8	8	0.89	0.01	7	9.3	0.8	
5/8/95		8	171	12	8	52.0	13.3	8	0.92	0.02	8	9.4	1.4	
5/9/95		8	170	10	8	48.2	6.9	8	0.94	0.02	8	12.1	1.0	
5/10/95		8	176	6	8	49.5	5.1	8	0.89	0.02	8	11.0	1.3	
5/11/95		6	167	10	6	47.5	8.8	6	0.99	0.08	6	10.1	1.5	
5/15/95		7	162	4	7	40.0	3.4	7	0.92	0.02	7	11.6	0.8	
5/16/95		6	163	6	6	38.8	4.4	6	0.89	0.02	6	10.5	1.5	
5/17/95		8	167	6	8	42.7	4.2	8	0.90	0.01	8	12.0	1.0	
5/18/95		8	159	2	8	35.6	1.2	8	0.89	0.01	7	12.7	0.8	
5/22/95		9	169	3	9	43.9	2.8	9	0.90	0.02	9	18.2	2.0	
5/23/95		8	170	10	8	49.2	9.1	8	0.94	0.02	8	13.4	1.1	
5/24/95		6	158	4	6	36.7	3.0	6	0.92	0.03	6	13.1	1.2	
5/25/95		7	158	6	7	38.2	5.2	7	0.93	0.02	7	15.6	1.0	
MCN	4/26/95	1	215	0	1	99.2	0.0	1	1.00	0.00	1	14.1	0.0	
	4/28/95	3	281	23	3	207.2	50.2	3	0.89	0.02	3	8.3	0.8	
	5/1/95	2	247	5	2	158.2	38.4	2	1.04	0.20	2	20.7	1.1	
	5/3/95	8	257	9	8	165.1	15.4	8	0.96	0.02	7	12.2	1.2	
	5/5/95	1	195	0	1	98.4	0.0	1	1.33	0.00	1	13.8	0.0	
	5/8/95	7	225	15	7	115.6	25.5	7	0.93	0.02	7	13.9	1.7	
	5/10/95	2	197	17	2	77.8	24.9	2	0.98	0.08	2	17.8	3.2	
	5/12/95	2	240	55	2	135.4	83.0	2	0.84	0.02	2	12.9	1.5	
5/15/95	2	239	12	2	132.9	3.7	2	0.99	0.12	1	12.1	0.0		
5/24/95	3	233	11	3	107.2	16.6	3	0.84	0.01	3	14.1	1.3		

**Appendix 3.17. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity ( $\mu\text{mol Pi} \cdot \text{mg protein}^{-1} \cdot \text{h}^{-1}$ ) for wild steelhead collected from the migration-at-large at the IDFG Snake River Trap (LEW), IDFG Salmon River Trap (SRT), Lower Granite Dam (LGR), and Rock Island Dam (RIS) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	
SRT	4/2/96	1	167	0	1	43.9	0.0	1	0.94	0.00	1	2.9	0.0	
	4/3/96	2	164	3	2	35.3	2.5	2	0.81	0.02	2	3.6	0.3	
	4/8/96	1	186	0	1	56.0	0.0	1	0.87	0.00	1	8.3	0.0	
	4/9/96	18	180	6	18	55.3	6.9	18	0.89	0.01	17	6.2	0.7	
	4/10/96	8	176	9	8	49.7	8.7	8	0.86	0.02	8	4.9	1.1	
	4/11/96	7	173	9	7	50.4	7.1	7	0.96	0.12	7	4.6	0.3	
	4/15/96	5	188	9	5	60.5	9.9	5	0.89	0.02	5	6.0	1.1	
	4/16/96	9	182	7	2	54.0	0.1	2	0.89	0.05	8	4.8	0.5	
	4/17/96	15	172	5	15	46.6	4.3	15	0.89	0.02	15	5.0	0.5	
	4/18/96	8	171	5	8	44.0	4.2	8	0.87	0.02	8	5.4	0.6	
	4/19/96	5	186	8	5	55.3	8.1	5	0.84	0.04	5	6.6	1.1	
	4/22/96	3	174	8	3	46.3	6.0	3	0.87	0.05	3	6.5	0.5	
	4/23/96	7	181	8	7	52.6	7.1	7	0.85	0.02	7	5.6	0.4	
	4/24/96	12	181	7	12	51.2	6.6	12	0.83	0.02	12	4.9	0.6	
	4/25/96	8	172	9	8	45.6	7.8	8	0.85	0.03	8	5.3	0.7	
	4/26/96	7	181	5	7	47.8	5.1	7	0.79	0.05	7	5.0	0.4	
	4/29/96	9	175	5	9	46.7	4.0	9	0.86	0.03	9	5.7	0.7	
	4/30/96	2	182	1	2	49.8	3.0	2	0.83	0.04	2	5.9	0.4	
	5/1/96	15	178	5	15	48.7	4.1	15	0.84	0.01	15	5.2	0.5	
	5/2/96	14	176	6	14	48.2	4.9	14	0.85	0.02	13	5.9	0.5	
	5/3/96	15	179	6	15	51.5	5.0	15	0.86	0.02	15	5.7	0.3	
	5/6/96	13	180	4	13	53.4	4.5	13	0.89	0.02	13	7.6	1.0	
	5/7/96	9	178	6	9	50.7	5.7	9	0.87	0.02	9	8.7	0.8	
	5/8/96	15	172	5	15	46.4	4.1	15	0.88	0.02	15	7.3	0.5	
	5/9/96	15	182	4	15	51.6	3.1	15	0.85	0.02	15	9.0	0.7	
	5/10/96	19	177	3	2	56.4	1.0	2	0.90	0.02	19	8.8	0.6	
	5/13/96	12	182	4	12	55.7	3.1	12	0.93	0.03	12	7.8	0.6	
	5/14/96	16	172	4	16	48.0	2.8	16	0.93	0.03	16	7.6	0.7	
	5/15/96	3	179	4	3	47.7	2.2	3	0.83	0.02	3	5.0	1.2	
	LEW	4/15/96	13	168	6	13	46.7	4.8	13	0.95	0.02	13	7.5	0.6
		4/16/96	17	182	3	17	56.3	3.2	17	0.92	0.01	17	6.8	0.8
		4/17/96	12	173	5	12	47.7	4.5	12	0.90	0.02	12	10.2	1.5
		4/18/96	14	183	7	14	59.4	8.5	14	0.92	0.02	12	9.7	1.3
		4/19/96	19	176	5	19	49.5	3.7	19	0.87	0.01	19	8.7	0.9
		4/22/96	6	173	10	5	51.2	8.5	5	0.88	0.01	6	8.1	1.2
4/23/96		8	185	6	8	56.4	4.6	8	0.89	0.03	8	9.3	1.6	
4/24/96		20	188	6	20	61.3	6.0	20	0.88	0.02	19	6.7	0.4	
4/26/96		20	171	4	20	45.8	2.8	20	0.90	0.01	20	7.3	0.5	
4/29/96		6	185	8	6	55.6	6.3	6	0.87	0.01	6	6.4	0.8	
4/30/96	9	169	6	9	45.0	5.1	9	0.91	0.01	9	6.2	0.8		
5/1/96	6	165	7	6	40.6	4.4	6	0.90	0.04	6	5.8	1.2		
5/2/96	12	171	5	12	44.1	3.5	12	0.86	0.01	12	7.2	0.6		
5/3/96	14	173	4	14	46.0	2.8	14	0.88	0.02	14	7.6	0.8		

**Appendix 3.17. (cont.)**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
LEW	5/6/96	14	168	4	14	43.1	3.2	14	0.89	0.02	14	14.7	1.4
	5/7/96	15	175	5	15	48.2	4.5	15	0.87	0.01	15	12.4	0.7
	5/8/96	15	176	4	15	50.6	3.3	15	0.91	0.02	15	9.9	0.7
	5/9/96	15	173	5	15	47.9	4.4	15	0.90	0.01	14	15.5	0.9
	5/10/96	14	178	8	14	55.3	9.6	14	0.90	0.02	13	12.0	0.8
	5/13/96	15	177	3	15	50.8	3.1	15	0.91	0.01	13	15.1	0.9
	5/14/96	15	181	5	15	57.2	5.5	15	0.92	0.01	15	16.7	1.4
	5/15/96	15	161	4	15	40.2	3.3	15	0.93	0.02	15	13.4	1.2
	5/16/96	12	168	4	12	44.1	3.9	12	0.90	0.02	12	14.7	1.5
LGR	5/2/96	2	190	10	2	59.0	5.6	2	0.87	0.05	2	13.1	0.1
	5/3/96										1	12.5	0.0
	5/5/96	1	142	0	1	28.5	0.0	1	1.00	0.00	1	11.5	0.0
	5/10/96	1	179	0	1	47.1	0.0	1	0.82	0.00	1	7.3	0.0
	5/16/96	1	157	0	1	34.5	0.0	1	0.89	0.00	1	10.3	0.0
	5/17/96	1	146	0	1	32.9	0.0	1	1.06	0.00	1	11.9	0.0
RIS	4/29/96	3	185	13	2	57.7	16.3	2	1.04	0.01	2	14.5	0.5
	4/30/96										3	11.8	3.0
	5/1/96	5	182	7	5	53.7	6.9	5	0.87	0.02	5	14.6	1.4
	5/2/96	7	178	12	7	56.4	9.8	7	0.95	0.07	7	14.2	2.2
	5/3/96	8	163	9	8	40.9	5.7	8	0.91	0.02	8	13.9	2.1
	5/6/96	3	175	8	3	45.0	2.6	3	0.85	0.06	3	16.8	4.8
	5/7/96	3	170	13	3	44.5	11.7	3	0.86	0.03	3	25.6	2.0
	5/8/96	3	186	9	3	62.3	9.7	3	0.95	0.04	3	28.5	7.1
	5/9/96	5	191	13	5	60.3	12.6	5	0.83	0.01	5	17.5	3.1
	5/10/96	6	198	13	6	74.9	14.3	6	0.90	0.01	6	16.3	2.0
	5/13/96	7	185	10	7	62.3	10.4	7	0.92	0.02	7	19.1	1.9
	5/14/96	3	192	6	3	66.4	9.4	3	0.92	0.05			
	5/16/96	4	172	15	4	46.5	11.2	4	0.87	0.02			
	5/17/96	4	204	8									
	5/20/96	7	182	8	6	52.8	7.5	6	0.90	0.01	7	18.2	1.5
	5/21/96	13	173	5	13	47.7	4.1	13	0.90	0.01	13	18.9	3.1
	5/22/96	3	184	22	3	58.9	21.9	3	0.87	0.00	3	26.8	6.7
	5/23/96	8	179	6	8	52.4	4.3	8	0.90	0.02	8	19.8	2.7
	5/24/96	8	170	4	8	45.0	3.4	8	0.91	0.02	8	17.5	2.9
	5/27/96	7	171	2	7	43.2	1.9	7	0.87	0.03	7	17.9	2.4
5/28/96	9	178	8	9	51.5	7.3	9	0.87	0.02	9	21.4	2.4	
5/29/96	6	170	15	6	52.5	11.74	6	0.96	0.07	5	15.2	1.1	
5/30/96	7	173	4	7	45.6	3.0	7	0.88	0.01	7	15.4	1.6	
5/31/96	5	190	5	5	59.3	4.6	5	0.87	0.04	4	22.4	4.5	

**Appendix 3.18. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for hatchery sockeye salmon migration-at-large at Rock Island Dam (RIS) in 1995.**

SITE	DATE	FORK LENGTH		WEIGHT		KFACTOR		ATPASE					
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE			
RIS	4/17/95	3	106	4	3	9.2	1.1	3	0.77	0.01	3	15.6	0.1
	4/18/95	1	102	0	1	8.5	0.0	1	0.80	0.00	1	7.7	0.0
	4/20/95	1	82	0	1	4.5	0.0	1	0.82	0.00	1	12.4	0.0
	4/24/95	8	100	4	7	8.3	1.1	7	0.77	0.02	6	23.5	2.6
	4/26/95	2	89	4	2	5.5	0.7	2	0.79	0.01			
	4/27/95	6	105	3	6	9.8	0.9	6	0.83	0.03	5	28.7	1.5
	5/1/95	2	115	18	2	15.3	7.8	2	0.91	0.09	2	11.0	0.2
	5/2/95	3	108	6	3	10.7	1.7	3	0.83	0.01	3	19.8	2.6
	5/3/95	2	137	32	2	25.4	16.0	2	0.83	0.02	1	16.5	0.0
	5/4/95	3	98	5	3	7.8	1.2	3	0.82	0.01	3	13.2	3.8
	5/8/95	1	100	0	1	9.0	0.0	1	0.90	0.00	1	20.7	0.0
	5/9/95	4	112	2	4	11.9	0.8	4	0.84	0.01	4	19.9	3.2
	5/10/95	6	114	3	6	13.1	1.1	6	0.87	0.02	6	14.2	1.3
	5/11/95	6	107	3	6	10.5	1.0	6	0.85	0.01	6	13.6	1.8
	5/15/95	7	118	2	7	13.7	0.6	7	0.84	0.02	6	16.8	1.4
	5/16/95	9	123	8	9	17.2	4.8	9	0.83	0.03	9	22.8	1.9
	5/17/95	2	120	10	2	15.2	3.3	2	0.88	0.02	2	17.9	0.1
	5/18/95	7	112	2	7	11.5	0.9	7	0.82	0.02	6	19.2	1.5
	5/22/95	4	113	2	4	11.7	0.5	4	0.81	0.02	4	24.3	1.5
	5/23/95	3	117	2	3	13.4	0.3	3	0.83	0.04	3	34.1	12.6
	5/24/95	4	119	3	4	14.3	1.0	4	0.85	0.02	3	37.4	8.6

**Appendix 3.19. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for wild sockeye salmon migration-at-large at Rock Island Dam (RIS) in 1995.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR			ATPASE		
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	4/17/95	8	85	2	7	6.3	1.0	7	1.00	0.14	2	17.1	2.2
	4/18/95	8	89	6	8	6.1	1.5	8	0.80	0.01	6	11.2	1.9
	4/19/95	8	86	1	8	5.1	0.2	8	0.80	0.02	5	15.6	1.9
	4/20/95	8	91	5	8	6.3	1.2	8	0.81	0.02	7	13.5	1.7
	4/24/95	8	99	7							6	21.3	2.5
	4/25/95	9	84	2	9	4.8	0.2	9	0.83	0.03	2	15.8	2.7
	4/26/95	8	101	11	8	10.3	4.5	8	0.74	0.07	7	20.9	3.8
	4/27/95	8	84	2	8	4.8	0.4	8	0.79	0.03	1	17.1	0.0
	5/1/95	8	88	3	8	6.1	0.7	8	0.87	0.03	5	10.0	3.7
	5/2/95	8	81	1	8	4.6	0.2	8	0.85	0.02	6	6.8	1.1
	5/3/95	8	107	4	8	11.9	1.4	8	0.93	0.03	7	16.3	1.9
	5/4/95	8	107	4	8	11.7	1.3	8	0.93	0.02	6	16.9	2.1
	5/8/95	8	95	5	8	8.3	1.2	8	0.91	0.02	5	18.8	1.4
	5/9/95	8	103	4	8	10.4	1.1	8	0.92	0.03	8	17.2	2.8
	5/10/95	7	102	1	7	10.1	0.4	7	0.94	0.01	7	20.7	1.0
	5/11/95	8	102	2	7	9.9	0.4	7	0.91	0.02	7	17.1	1.1
	5/15/95	8	93	2	8	7.6	0.5	8	0.92	0.02	8	18.1	3.0
	5/16/95	6	97	2	6	8.1	0.4	6	0.88	0.01	6	17.4	1.9
	5/17/95	8	91	2	8	7.0	0.6	8	0.91	0.01	7	16.1	1.8
	5/18/95	8	91	3	8	7.1	0.6	8	0.92	0.02	7	16.0	2.1
	5/22/95	8	92	3	8	7.4	0.7	8	0.92	0.02	7	20.4	2.9
	5/23/95	7	97	2	7	8.7	0.5	7	0.95	0.03	6	25.7	4.1
	5/24/95	7	98	1	7	8.8	0.4	7	0.94	0.02	5	19.5	2.8
	5/25/95	6	99	1	6	9.5	0.3	6	0.97	0.01	6	21.6	1.8

**Appendix 3.20. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for hatchery sockeye salmon migration-at-large at Rock Island Dam (RIS) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	4/29/96	1	92	0	1	6.7	0.0	1	0.86	0.00	1	13.6	0.0
	4/30/96										2	17.2	5.8
	5/1/96	2	99	3	2	7.9	0.4	2	0.81	0.03	2	24.7	0.2
	5/2/96	1	101	0	1	9.5	0.0	1	0.92	0.00	1	29.3	0.0
	5/3/96	3	97	1	3	7.5	0.4	3	0.82	0.03	3	20.4	5.2
	5/6/96	6	120	4	6	15.0	1.6	6	0.86	0.03	5	26.4	4.2
	5/7/96	5	116	8	5	14.2	3.1	5	0.87	0.02	4	43.3	4.3
	5/8/96	2	110	11	2	12.0	3.5	2	0.88	0.03			
	5/10/96	4	115	1	4	13.5	0.4	4	0.90	0.02	3	21.5	2.9
	5/13/96	2	100	4	2	8.7	1.2	2	0.87	0.02			
	5/14/96	5	114	4	5	12.9	1.6	5	0.85	0.03			
	5/15/96	1	151	0	1	27.6	0.0	1	0.80	0.00			
	5/16/96	8	117	5	8	13.9	2.0	8	0.83	0.02			
	5/17/96	8	115	4									
	5/20/96	11	125	6	11	18.2	3.0	11	0.86	0.01	8	24.8	4.2
	5/21/96	11	119	3	11	14.7	1.2	11	0.86	0.02	11	30.9	2.6
	5/22/96	13	128	6	13	18.7	2.6	13	0.83	0.01	9	26.9	3.2
	5/23/96	12	131	5	12	19.7	2.1	12	0.84	0.02	9	21.1	2.6
	5/24/96	9	128	7	9	18.8	2.7	9	0.85	0.02	9	21.4	4.4
	5/27/96	13	123	3	13	16.7	1.3	13	0.89	0.05	13	21.1	2.9
	5/28/96	16	124	4	16	16.5	1.6	16	0.83	0.01	16	19.0	2.8
	5/29/96	12	128	4	12	17.6	1.7	12	0.82	0.02	12	20.4	2.8
	5/30/96	8	124	6	8	16.1	2.3	8	0.82	0.02	8	14.7	2.9
	5/31/96	7	132	8	7	19.9	3.7	7	0.83	0.02	7	19.4	3.1

**Appendix 3.21. Sample size (n), mean (MEAN), and standard error (SE) of fork length (mm), wet weight (g), and gill Na<sup>+</sup>-K<sup>+</sup> ATPase activity (̂mol Pi · mg protein<sup>-1</sup> · h<sup>-1</sup>) for wild sockeye salmon migration-at-large at Rock Island Dam (RIS) in 1996.**

SITE	DATE	FORK LENGTH			WEIGHT			KFACTOR		ATPASE			
		n	MEAN	SE	n	MEAN	SE	n	MEAN	SE	n	MEAN	SE
RIS	4/23/96	19	108	6	19	13.1	2.8	19	0.83	0.02	12	13.8	1.3
	4/24/96										17	15.0	1.4
	4/25/96	14	106	7	13	12.6	3.7	13	0.84	0.01	10	14.4	2.3
	4/26/96	12	89	4	12	6.3	0.9	12	0.84	0.02	9	11.7	1.9
	4/29/96	28	97	4	28	8.3	1.5	28	0.78	0.01	26	15.1	1.3
	4/30/96										17	16.6	1.6
	5/1/96	17	110	5	17	13.4	2.7	17	0.87	0.05	17	20.7	1.8
	5/2/96	17	107	7	17	13.1	3.6	17	0.82	0.02	16	19.3	2.6
	5/3/96	26	96	3	26	7.8	0.8	26	0.81	0.01	15	20.5	2.9
	5/6/96	9	99	6	9	8.8	1.9	9	0.81	0.01	8	28.1	5.0
	5/7/96	7	99	9	7	9.8	3.5	7	0.84	0.03	6	21.7	4.1
	5/8/96	1	78	0	1	3.8	0.0	1	0.80	0.00			
	5/9/96	4	111	16	4	14.2	6.8	4	0.84	0.02	3	29.9	3.3
	5/10/96	5	116	12	5	16.2	5.2	5	0.88	0.04	5	25.4	3.7
	5/13/96	5	101	4	5	9.1	1.2	5	0.87	0.02	4	29.5	3.7
	5/14/96	1	95	0	1	6.8	0.0	1	0.79	0.00			
	5/15/96	1	104	0	1	8.5	0.0	1	0.76	0.00			
	5/16/96	2	103	12	2	9.0	3.0	2	0.80	0.01			
	5/17/96	3	123	5									
	5/20/96	6	103	8	6	12.0	2.9	6	1.01	0.04	5	24.0	3.6
	5/21/96	4	118	11	4	16.4	5.5	4	0.90	0.04	4	30.8	3.5
	5/22/96	4	117	8	4	14.0	2.9	4	0.84	0.03	2	24.6	2.6
	5/23/96	3	117	5	3	14.3	3.2	3	0.87	0.08	3	26.6	11.4
	5/24/96	3	127	11	3	19.4	5.3	3	0.89	0.04	3	24.6	1.1
	5/27/96	1	114	0	1	11.8	0.0	1	0.80	0.00	1	21.3	0.0
	5/28/96	1	139	0	1	26.6	0.0	1	0.99	0.00	1	24.1	0.0
	5/29/96	3	117	9	3	15.9	4.1	3	0.94	0.06	3	26.8	0.3
	5/30/96	1	104	0	1	10.0	0.0	1	0.89	0.00	1	14.4	0.0
	5/31/96	4	106	3	4	11.3	1.0	4	0.94	0.01	4	18.4	3.5