Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU

BPA Project # 1991-029-00

Report covers work performed under BPA contract #(s) 56968, 56969

Report was completed under BPA contract #(s) 56968, 56969, 61379

1/1/2012 - 12/31/2013

William P. Connor[1], Kenneth F. Tiffan[2], Frank Mullins[1], Bill Arnsberg[3], Thomas D. Cooney[4], Phillip A. Groves[5], Deborah J. Milks[6], Stuart J. Rosenberger[4], and William Young[6]

[1]U. S. Fish and Wildlife Service, Idaho Fishery Resource Office, 276 Dworshak Complex Drive, Orofino, Idaho 83544, USA

[2]U.S. Geological Survey, Western Fisheries Research Center, 5501 A Cook-Underwood Road, Cook, Washington 98605 USA

[3]Nez Perce Tribe, Department of Fisheries Resources Management, Post Office Box 365, Lapwai, Idaho, 83540, USA

[4]National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division, 525 Northeast Oregon Street, Portland, Oregon 97232-2737, USA

[5]Idaho Power Company, Post Office Box 70, Boise Idaho 83707, USA

[5]Washington Department of Fish and Wildlife, Snake River Laboratory, 401 South Cottonwood Street, Dayton, Washington 99328-1277, USA

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report should be cited as follows: William P. Connor, Kenneth F. Tiffan, Frank Mullins, Bill Arnsberg, Thomas D. Cooney, Phillip A. Groves, Deborah J. Milks, Stuart J. Rosenberger, and William Young. Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU, 1/1/2012 - 12/31/2013 Annual Report, 1991-029-00

Run At 4/10/2014 1:35:42 PM

Table of Contents

Executive Summary 3

Introduction 6

Methods and Protocols 10

Results

- **Adult Escapement** 15
- **Stock Production and Hatchery Supplementation** 18
- **Smolt Abundance and Productivity** 23
- **Redd Counts Upstream of Lower Granite Dam** 27
- **Early Life History Attributes** 30
- **Predation by Smallmouth bass** 39

Synthesis of Findings: Discussion/Conclusions 41

References 44

Appendix A Redd Count Details 46

Appendix B Passage Timing Details 127

Appendix C Predation Details 153

Appendix D List of Metrics and Details 184

1. Executive Summary

a. Fish Population RM&E

This annual report describes the data collected and analyses conducted during calendar year 2013 by staff of project 199102900 and their cooperators from the Idaho Power Company (cost shared), Nez Perce Tribe Department of Fisheries Resources (project 198335003), NOAA Fisheries, and the Washington Department of Fish and Wildlife (USFWS projects F12AC00091 and F13AC00096).

Objective 1: Review estimates of natural and hatchery and adult escapement upstream of Lower Granite Dam during 1976–2013.

Accomplishing Objective 1 helped to inform the F&W Program management question: What are the status and trend of adult abundance of natural and hatchery origin fish populations?

The increase in adult counts at Lower Granite Dam indicates that the Snake River basin fall Chinook salmon ESU is much more abundant than it was at the time of listing under the ESA, and as such, this ESU appears to be responding positively to the implemented actions.

Objective 2: Develop and analyze results from models incorporating a representative range of assumptions regarding stock production relationships and the impacts of supplementation.

Accomplishing Objective 2 was a first step to informing the F&W Program management question: What are the status and trend of adult productivity of fish populations?

Though preliminary, the results reported under this objective on a stock-recruitment model fitted with a module incorporating two alternative assumptions bracketing a range of potential hatchery effects represent the progress being made to establish an understanding of the factors affecting the growth and productivity of the Snake River basin fall Chinook salmon ESU. Additional data collected in upcoming years when the adults return from previous high escapement years will be informative. Adding modules to the model that account for variation in harvest and climatic conditions will also be informative.

Objective 3: Provide a preliminary evaluation of the relation between spawners and smolts produced and how productivity measured as smolts per spawner have changed as escapement to the spawning grounds has increased during 1991–2013.

Accomplishing Objective 3 was a first step to informing the F&W Program management question: What are the status and trend of juvenile abundance and productivity of fish populations?

Acknowledging that the method of estimating passage abundance of juveniles from the Snake River fall Chinook salmon ESU is still under development and will be further refined, adding the 2013 estimate of passage abundance of natural fall Chinook salmon subyearlings from the Snake River basin ESU to the set of results provided further evidence for density-dependent population growth with some linkage to egg to smolt survival. Productivity generally increased after brood year 1993 to a high in brood year 1998 and then declined thereafter. Identifying the mechanisms underlying that decline will more fully inform the BiOp and

other recovery actions. In the upcoming year, work will continue to develop the previously mentioned multistage stock-recruitment model with covariates.

Objective 4: Summarize the 1991 to 2013 redd count data.

Accomplishing Objective 4 informed the F&W Program management question: What are the status and trend of spatial distribution of fish populations?

Basin-wide counts of redds in the Snake River basin upstream of Lower Granite Dam reached a post-listing high in 2013, and the spatial distribution remained balanced among the four major spawning areas with some increase in the proportion of spawning in the lower Clearwater River. These results suggest that the ESU is responding positively to implemented actions. The redd counts produced by our cooperative group in future years will inform the spatial criteria for recovery being established in the draft recovery plan and provide important data for modeling efforts identified in that plan.

Objective 5: Describe some of the early life history attributes of fall Chinook salmon juveniles produced by the three primary spawning aggregates upstream of Lower Granite Dam.

Accomplishing Objective 4 continued to inform the F&W Program management question: What are the status and trend of diversity of natural and hatchery origin fish populations?

Maintenance of the life history characteristics of the natural juveniles that are part of the Snake River fall Chinook salmon ESU is important for assessing the diversity aspect of the draft recovery plan. Adding the 2013 data to the data set collected on timing of parr presence, size, growth, and dispersal timing into the reservoir provided further evidence for density-dependent phenotypic change in Chinook Salmon subyearlings native to an 8th order river that was influenced by the expansion of the recovery program. Natural parr and smolts in a circuitous way have begun to regain the movement timing and size phenotypes expressed by their historical counterparts under similarly high abundances. As such, this report showed that efforts to recover native fishes can have detectable effects in large river landscapes. Past research has shown that survival decreases as growth in riverine habitat and size at dispersal decreases. The outcome of such phenotypic change, which is an important area of future research in the Snake River basin, can only be fully judged by examining the effect of the change on population viability and productivity. Once the multi-stage stock-recruitment model is fitted, phenotypic traits of natural juveniles and abundance of hatchery smolts in the reservoir will be included as covariates in the analyses.

b. Predation and Invasive Species Management RM&E

Objective 6: Describe the seasonal variation in smallmouth bass diets and consumption of subyearlings during the subyearling rearing and outmigration period in Hells Canyon..

We investigated the extent of smallmouth bass predation on juvenile fall Chinook salmon in Hells Canyon as called for in the Fish and Wildlife Program, "The federal action agencies should work cooperatively with NOAA Fisheries, states, tribes, and the council to review, evaluate, develop, and implement strategies to reduce non-native piscivorous predation on salmon and steelhead, especially by smallmouth bass, channel catfish, and walleye" (Page 52). Smallmouth bass stomach contents were

collected and analyzed for the presence of juvenile salmon. Smallmouth bass abundance was estimated with mark-recapture techniques, and salmon consumption by bass was expanded based by bass abundance to determine the annual loss of juvenile fall Chinook salmon for the study period and area. The estimated loss of juvenile fall Chinook salmon to predation in Hells Canyon exceeded 200,000 in 2012 and 940,000 in 2013. This information could be used to adaptively formulate better hatchery release strategies to reduce the effects of predation. Obtaining better estimates of smallmouth bass abundance and distribution in future years would reduce uncertainty of estimates. This study will be completed by 2017.

2. Introduction

For each Fish and Wildlife Program Strategy briefly discuss how your project informs/supports the program sub strategies and associated management questions. The content may be reorganized into any format of your choosing.

a. Fish Population RM&E

F&W Program Strategy: Assess the status and trend of adult natural and hatchery origin abundance of fish populations for various life stages.

F&W Program Management Question: What are the status and trend of adult abundance of natural and hatchery origin fish populations?

Status and Trend Monitoring

Staff of project 199102900 do not directly assess the status and trend in adult abundance of the Snake River fall Chinook salmon ESU, but are working directly with the staff of the Idaho Power Company, Nez Perce Tribe, NOAA Fisheries, and Washington Department of Fish and Wildlife (i.e., the run reconstruction group) that generates estimates of abundance of both natural and hatchery adults. The role of project 199102900 staff is to participate and coordinate the development of models and analyses. The 2008 Biological Opinion was reviewed by the Obama Administration. This review led to the AMIP. A full review of the AMIP is beyond the scope of this introduction, but it builds on the 2008 Biological Opinion and parallels and supports the other regional actions. The AMIP advocates collecting more data and improving analytic tools to better inform future adaptive management decision making. It supports enhanced RM&E actions to fill data gaps including: adult status and trend monitoring, juvenile status and trend monitoring, the development expanded life-cycle and passage models. Objective 1 of this annual report is to review estimates of hatchery and adult escapement measured at Lower Granite Dam made by the run reconstruction group during 1991–2013 to establish the inter-annual trends that are important to modeling and evaluating the status of the population relative to abundance criteria being developed under the recovery plan.

F&W Program Strategy: Assess the status and trend of adult productivity of natural origin fish populations.

F&W Program Management Question: What are the status and trend of adult productivity of fish populations?

Status and Trend Monitoring, Action Effectiveness Research, Uncertainties Research

Natural production of the Snake River Fall Chinook Salmon ESU upstream of Lower Granite Dam is currently and primarily associated with the riverine portion of the lower Snake River (i.e., the Snake River upper and lower reaches), the riverine portion of the lower Clearwater River, and other tributaries where some spawning occurs. Annual returns of natural origin fall chinook to this population have increased substantially in recent years, presumably as a result of a combination of factors including a fortuitous run of annual ocean survivals, improved hydropower related flow and passage regimes, restrictions on harvest impacts and directed supplementation using a locally derived

broodstock. Although there is evidence supporting some contribution for each of these elements, a more quantitative assessment of relative contributions from each to current trends has been elusive. Objective 2 of this report is to develop and analyze results from models incorporating a representative range of assumptions regarding stock production relationships and the impacts of supplementation. The influence of other factors including harvest and ocean conditions will be assessed in future analyses.

F&W Program Strategy: Assess the status and trend of juvenile abundance and productivity of natural origin fish populations.

F&W Program Management Question: What are the status and trend of juvenile abundance and productivity of fish populations?

Status and Trend Monitoring, Action Effectiveness Research, Uncertainties Research

To date, estimates of natural production of the Snake River Fall Chinook Salmon ESU upstream of Lower Granite Dam have been lacking. There is evidence, however, that juvenile production may have been affected in recent years by density-dependent factors (Connor et al. 2013; Groves et al. 2013). The first objective in this report relative to the program strategy given above is to report the results of a method being refined to estimate abundance of natural fall Chinook salmon juveniles at Lower Granite Dam for the years 1992 to present.

Multistage stock recruitment modeling with covariates (e.g., Moussalli and Hilborn 1986; Brooks and Powers 2007; Greene and Beechie 2004; Zabel et al. 2005) will be useful for evaluating the efficacy of management actions as well as other sources of natural (e.g., climate change) and anthropogenic change (e.g., changes in harvest or hatchery release strategies). Objective 3 of this report relative to the program strategy given above is to provide a preliminary evaluation of the relation between spawners and smolts produced and how productivity measured as smolts per spawner have changed as escapement to the spawning grounds has increased during 1991–2013.

F&W Program Strategy: Assess the status and trend of spatial distribution of fish populations.

F&W Program Management Question: What are the status and trend of spatial distribution of fish populations?

Status and Trend Monitoring

One of the objectives of staff of project 199102900 and their Federal, State, and Tribal cooperators is to determine the status of the spatial structure of the Lower Snake River population based on current and historically utilized habitat. This objective focuses on the major and minor spawning areas upstream of Lower Granite Dam at the level of a single population. There are two methods that have proposed to estimate the annual number of natural-origin adults that escaped to the individual spawning areas. The first method takes the run reconstruction estimates of the numbers of hatchery-origin females that returned from releases made into each spawning area (from Monitoring question 1c), and adjusts them

for within-basin dispersal. Assuming that gender ratio, pre-spawning mortality, and redd count accuracy are similar among spawning areas, and that each female constructed one redd; the number of hatchery-origin females estimated to have spawned in each area is subtracted from the observed redd count for that area. That difference represents the numbers of redds constructed by natural-origin females. To estimate the number of full-term (i.e., no jacks) adults that spawned in each area, the number of redds constructed by natural-origin females is multiplied by the by the ratio of full-term (i.e., no jacks) males to females for natural-origin adults from run reconstruction.

The second method is more complicated, but it basically involves fitting a stock-recruitment model for each spawning area using redd counts in year t-4 as stock and redd counts in year t as recruits. Covariates including the number of hatchery juveniles released in year t – 3 are added to the model. Redd counts are predicted with each area-specific model using a value of 0 for the number of hatchery juveniles released. The number of redds predicted in each spawning area is divided by the total number of redds predicted basin-wide. Under the same assumptions of the first analytical method described, those proportions are multiplied by the number of natural-origin females estimated to have passed upstream of Lower Granite Dam in a given year. Adjustments for gender ratios are made as previously described.

Both methods for evaluating the spawning distribution of natural-origin adults are under development and are planned to be applied to data collected during 1991–present. For the present report, Objective 4 is to summarize the 1991 to 2013 redd count data collected by our cooperative group to describe the spawning distribution of the ESU upstream of Lower Granite Dam.

F&W Program Strategy: Assess the status and trend of diversity of natural and hatchery origin fish populations.

F&W Program Management Question: What are the status and trend of diversity of natural and hatchery origin fish populations?

Status and Trend Monitoring

Maintenance of the life history characteristics of the natural juveniles that are part of the Snake River fall Chinook salmon ESU is important for assessing the diversity aspects of the draft recovery plan. Project 199102900 has collected data on the early life history of the Snake River fall Chinook salmon ESU since 1992 primarily in the Snake River upper and lower reaches and at Lower Granite Dam. Collaborative work began in the lower Clearwater River with the Nez Perce Tribe Department of Fisheries Resources during 1993–1995, work was continued thereafter by the Tribe. Life stages studied in the Snake River reaches begin with fry emergence in March, progress through the parr stage as the fish grow and disperse from natal riverine habitat and into Lower Granite Reservoir by July, and end with dam passage. Sampling is logistically difficult in the lower Clearwater River, and the primary information collected is on passage timing at Lower Granite Dam (e.g., Arnsberg and Statler 1995; but see Connor et al. 2002). Objective 5 of this report is to describe some of the early life history attributes of fall Chinook salmon juveniles produced by the three primary spawning aggregates upstream of Lower Granite Dam.

b. Predation and Invasive Species Management RM&E

F&W Program Strategy: Evaluate the effects of the northern pike minnow removal program and investigate strategies to reduce non-indigenous piscivorous (e.g., walleye, bass) predation on salmonids.

F&W Program Management Question: What are the distributions, population sizes, and productivity; and What are the impacts and consumption rates of major piscivorous, avian, and marine mammal predators within the Columbia River Basin?

Predation

Predation by nonnative fishes is one factor that has been implicated in the decline of juvenile salmonids *Oncorhynchus* spp. in the Pacific Northwest. The only evaluation of predation on subyearling Snake River fall Chinook salmon in the Hells Canyon Reach was conducted by Nelle (1999). However, this study in the Snake River was conducted soon after Endangered Species Act (ESA) listing of Snake River fall Chinook salmon (NMFS 1992). During this time, fall Chinook salmon abundance was at an historic low and may explain why consumption rates were relatively low compared to those from studies conducted in the Columbia and Yakima rivers where abundance was higher (Tabor et al. 1993; Fritts and Pearsons 2004). We speculate that predation on subyearlings by smallmouth bass in the Snake River may have increased in recent years for several reasons. Since their ESA listing, recovery measures implemented for Snake River fall Chinook salmon have resulted in a large increase in the juvenile population (Connor et al. 2013). For example, the annual subyearling passage index at Lower Granite Dam, the first dam encountered by fish produced in Hells Canyon, was 18,533 in 1996 but was 749,074 in 2013 (DART 2014). Both Zimmerman (1999) and Naughton et al. (2004) showed that fish can comprise a large portion of smallmouth bass diets. Considering that subyearlings probably now make up a larger portion of the forage fish population, it is plausible they should make up a large portion of smallmouth diets. Here we report on findings from work conducted in 2012 and 2013. Our objective was to describe the seasonal variation in smallmouth bass diets and consumption of subyearlings during the subyearling rearing and outmigration period in Hells Canyon.

Study Area

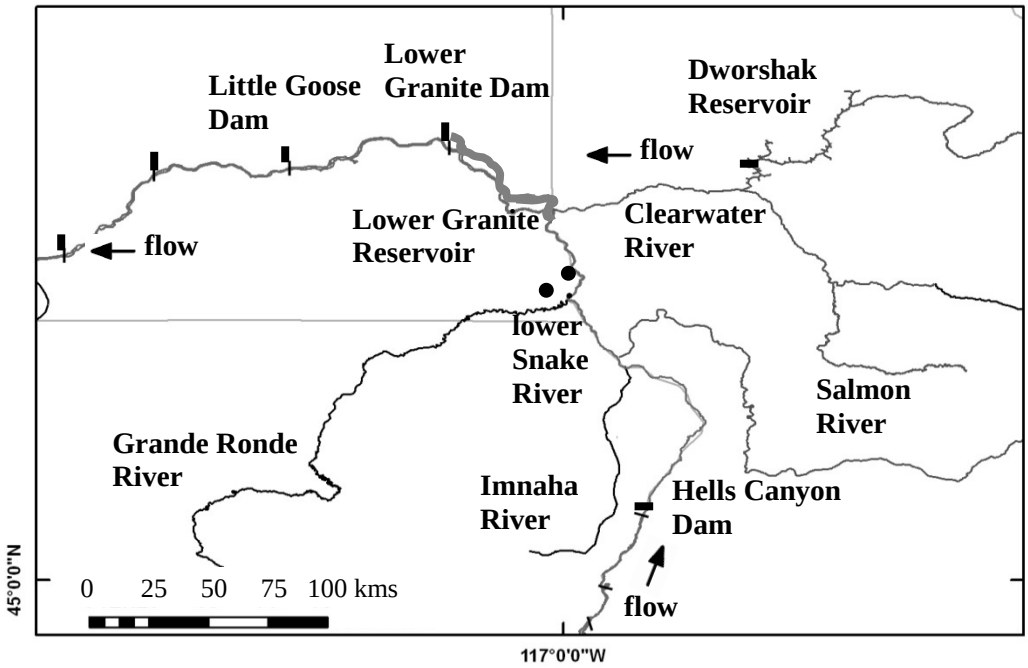

Figure 1. The Snake River basin including the Snake River upper (Hells Canyon Dam to Salmon River mouth) and lower (Salmon River mouth to the upper end Lower Granite Reservoir) reaches, the lower Clearwater River, and other tributary reaches where fall Chinook Salmon spawn and produce natural offspring. All adults spawning and juveniles from those reaches must pass Lower Granite Dam.

3. Methods and Protocols

a. Fish Population RM&E

Objective 1: Review estimates of natural and hatchery and adult escapement upstream of Lower Granite Dam during 1976–2013.

Protocol Title: Protocol will be published when methods and results are finalized.

Protocol Link: NA

Protocol Summary: The run at Lower Granite Dam includes both returns from hatchery releases as well as fish originating from spawning in natural production areas. A systematic trap sampling effort is also carried out at the dam to obtain information on run composition and to generate broodstock for the Snake River fall Chinook salmon programs operated by WDFW (Lyons Ferry Hatchery), the Nez Perce Tribe (Clearwater River releases) and Idaho Power Corporation (releases into the Snake River below Hells Canyon Dam). Estimates of annual returns of Snake River fall Chinook salmon are based on information collected through sampling programs at Lower Granite Dam. Daily ladder counts of returning adults and jacks are compiled in two categories, adults (≥ 53 cm fork length) and jacks (< 53 cm fork length). Each category (jack and adults) is further allocated as hatchery and natural origin by

age based on tag recoveries, lengths and scale samples. The general approach for breaking out natural origin vs. hatchery contributions to the estimated annual returns uses mark recaptures of hatchery released fish of known ages along with the corresponding release group marking rates to estimate hatchery contributions. Natural origin returns are estimated by age through subtraction of the estimated hatchery returns from the total run estimates. The estimation methodology was reviewed and updated in 2011 and applied to return years beginning with 2005. The run reconstruction work group responsible for the updated procedures will be re-analyzing the data for earlier years in the near future. Given the release levels and histories of the hatchery groups contributing to returns, the sampling protocols at the Dam and the ladder counts it is unlikely that substantial changes will result from applying the updated methodology. See Busack (1991), Cooney (1991), LaVoy (1992, 1993, 1994, 1995), LaVoy and Mendel (1996), Mendel and LaVoy (1997), Mendel (1998, 1999, 2000), Young et al. (2012) for additional details.

Objective 2: Develop and analyze results from models incorporating a representative range of assumptions regarding stock production relationships and the impacts of supplementation.

Protocol Title: Protocol will be published when methods and results are finalized. The method is presently under development.

Protocol Link: NA

Protocol Summary: Staff of project 199102900 has been cooperating with the Idaho Power Company, Nez Perce Tribe, NOAA Fisheries, and Washington Department of Fish and Wildlife to increase the understanding of how the Snake River basin Fall Chinook salmon ESU upstream of Lower Granite Dam has been influenced by the straying of hatchery fish, and the directed hatchery supplementation program that began in 1995 with a small experimental release and continues to date. The most recent analysis which is underdevelopment was conducted by NOAA using data generated by the run reconstruction group and reported here under Objective 1. The NOAA analysis is part of a collaborative monograph being written under the lead of project 199102900 staff to retrospectively review Snake River fall Chinook salmon management from the 1800s to present. The analysis tests for density-dependent population growth for brood years 1991 through 2007 (return years 1993 through 2012) and predicts abundance of natural-origin adults with and without supplementation (and will also address harvest and climate). Some of the preliminary results are presented here.

Objective 3: Provide a preliminary evaluation of the relation between spawners and smolts produced and how productivity measured as smolts per spawner have changed as escapement to the spawning grounds has increased during 1991–2013.

Protocol Title: Protocol will be published when methods and results are finalized. The method is presently under development.

Protocol Link: NA

Protocol Summary: Subsamples of subyearling Chinook salmon are collected from the bypass at Lower Granite Dam from late march through October. All of the PIT-tagged fish are detected. Every fish is examined for an adipose fin clip. All fish that do not have an adipose fin clip is scanned for a wire

tag. Using mark-expansion and subtraction methods, the daily number of natural- and hatchery-origin juveniles that are subsampled is estimated. The daily estimates are expanded by sample rate to estimate the daily number of juveniles from each origin passed through the bypass. The estimated daily number of juveniles estimated to have passed through the bypass was expanded by collection probability (Plumb et al. 2012) to estimate daily passage abundance for each origin. The daily passage abundance estimates are summed to provide an estimate of annual passage abundance for the months of March through October. That estimate is adjusted to account spring/summer lineage juveniles. A method to estimate passage abundance of late migrants from November through April is under development. Thus, all analyses presented under this objective are considered to be preliminary.

Objective 4: Summarize the 1991 to 2013 redd count data.

Protocol Title: Protocol will be published when methods and results are finalized. The method is presently under development.

Protocol Link: NA

Protocol Summary: Aerial surveys are scheduled at 7-d to 14-d intervals. Redds are counted from a helicopter flown about 200 m above the river, which allows observing 100% of the river bottom at depths approximately < 3 m (Snake River) to < 5 m (Clearwater). Each survey flight lasts about 3 hr and covers the entire 161 km of the free-flowing portion of the lower Snake River where fall Chinook salmon spawn, between Asotin, WA at river km 237, upstream to the Hells Canyon Dam at river km 398. Redds are counted by the same experienced observer every year, with a secondary observer assisting by maintaining data records and validating counts in areas where questionable redds occurred. Because only fall Chinook salmon spawn in the main stem Snake River during the fall, there was no doubt as to the origin of redds. During each flight shallow redd locations (e.g., those approximately < 3 m deep) are referenced to a tenth of a river mile and general location (left or right bank, or mid-channel) on navigation charts, or with a Global Positioning System (GPS) with mapping software. Specific spawning locations are catalogued, maintained, and updated in a spreadsheet and within a geographic information system. The number of new redds observed at each location, during each flight are recorded. Questionable redds are authenticated as the season progressed by ground-checks. Evaluations on the ground are also performed inconsistently at specific locations to obtain a more accurate total redd count when superimposition (i.e., one redd overlapped with another) is noted during aerial surveys. An example of applying this method is given in Groves et al. (2013).

Potential deep water spawning locations (>3 m) are searched for redds as follows. Deep water searches begin just after peak spawning in mid-November, and are concluded by mid-December. Priority is given to 89 locations we identified during 1991 to 1993 Groves and Chandler 1999). At the onset of each spawning season, the list of locations is divided and assigned to two crews. Priority for searches is given to locations known to be used by spawning Chinook salmon, but the crews attempted to search as many locations as possible that had the potential for use. Deep redds are counted from a boat by passing a remote submersible camera over the river bottom along transects spaced 4–10 m apart at a given site. Distance between transects is maintained by real-time GPS linked to Geographic Information System (GPS/GIS) overlays. Staff attempts to view the entire river bottom at each location by completely covering the area along and between transects, and by continually adjusting camera depth and angle to maximize viewable area. Redds are counted and mapped with shore-based survey

equipment or boat-based GPS/GIS to prevent double counting of redds observed during aerial surveys. During deep water searches, if superimposition is encountered, the river bottom is video-recorded and redd boundary coordinates were obtained with survey equipment, or GPS/GIS when possible. After reviewing the recorded video, while referencing plots of redd boundary coordinates, the number of redds is estimated by dividing the total area (m2) of disturbed bottom substrates by 45.8 m2, and allowing a small buffer for redd spacing. These deeper searches do not provide a 100% census of spawning in deep water because most locations can only be visited once during each spawning season and every potential spawning location is not searched. An example of application of this method is provided by Groves et al. (2013).

Objective 5: Describe some of the early life history attributes of fall Chinook salmon juveniles produced by the three primary spawning aggregates upstream of Lower Granite Dam.

Protocol Title: Protocol will be published when methods and results are finalized. The method is presently under development.

Protocol Link: NA

Protocol Summary: A three-person field crew uses a beach seine to collect subyearlings along three reaches of the lower Snake River at beach seining stations (typically 5 per reach) located from Hells Canyon Dam to the upper end of Lower Granite Reservoir. The lower Clearwater River is seined from a point near the mouth to a point just downstream of the North Fork Clearwater River mouth. The seining stations are selected prior to the field season based on their bathymetry and anticipated flow levels to reduce the effect of flow on seining efficiency within a year. The field crew includes a supervisor who had at least three years of experience seining along the Snake River prior to leading the field crew. Each week, the supervisor randomly selects the sampling order for the seining stations within a reach. The seine will have a weighted multistranded mudline, 0.48 cm mesh, and will be equipped with a 30.5 m x 1.8 m with a 3.9 m3 bag. Each end of the seine is fitted with a weighted brail attached to 15.2 m lead ropes. The seine is set parallel to the shore from a boat and then hauled straight into shore by personnel on the shore. Each seining station in the lower Snake River is sampled once a week from late March to the completion of shoreline rearing in late June or early July, after which time natural subyearlings have dispersed offshore and downstream. Sampling in the cooler lower Clearwater River generally begins in June and extends into August. It is assumed that all subyearlings collected at beach seining stations are of natural origin if they are collected before annual releases of hatchery-origin subyearlings are made locations upstream of the sampling stations. The natural-origin subyearlings collected with the beach seine are PIT tagged according to methods specified by CBFWA. Each anesthetized fish is measured to the nearest mm (fork length), scanned for a PIT tag to determine if it is a recapture, and implanted with a PIT tag if it is untagged. Subyearlings =60 mm fork length are implanted with 11.5-mm tags and subyearlings =50-mm fork length are implanted with 8.5-mm tags. All tagging and recapture data is subsequently be uploaded to the PIT-tag Information system. The data for newly tagged fish includes the unique PIT-tag code, tagging and release date, release location in river kilometers (rkm; Snake River mouth = rkm 0), fork length, and known natural origin. The data for recaptured fish includes the unique PIT-tag code, recapture and re-release date, recapture location (rkm), fork length at recapture, known natural origin, and initial release date. After annual releases of hatchery-origin subyearlings are made upstream of the beach seining stations, the potential exists for hatchery fish to be confused with fish of natural origin. Therefore, every subyearling in the beach seine

catch is examined under the direction of the field supervisor before transferring the catch to a live well. Externally marked hatchery-origin subyearlings are counted and released back to the river unless they have a PIT-tag scar indicative of recapture. Unmarked subyearlings that have relatively large pupils and slender bodies (presumably hatchery origin, 90–100% accurate; are also counted and released back to the river unless they have a PIT-tag scar indicative of recapture. The recaptures and untagged subyearlings with relatively small pupils and robust bodies (presumably natural origin; 90–100% accurate) are then be transferred to the live well and processed as described previously with two exceptions. First, field staff reexamines pupil diameter and body shape a second time when a fish is being measured and this fish is not PIT tagged if the consensus is that it might be a hatchery fish. Second, each recaptured PIT-tagged subyearling that is not externally marked is assigned a "classified" origin of either natural or hatchery. Similar methods are followed in the lower Clearwater River.

b. Predation and Invasive Species Management RM&E

Objective 6: Describe the seasonal variation in smallmouth bass diets and consumption of subyearlings during the subyearling rearing and outmigration period in Hells Canyon.

Protocol Title: Smallmouth bass predation of juvenile fall Chinook salmon in Hells Canyon (199102900) v1.0

Protocol Link: http://www.monitoringmethods.org/Protocol/Details/299

Protocol Summary: This protocol describes the collection and analysis of smallmouth bass population attributes and diet information to estimate the loss of juvenile fall Chinook salmon in Hells Canyon. In brief, smallmouth bass stomach contents are collected and analyzed for the presence of juvenile salmon. Smallmouth bass abundance is estimated with mark-recapture techniques. Salmon consumption by bass is expanded based by bass abundance to determine the annual loss of juvenile fall Chinook salmon for the study period and area.

4. Results

a. Fish Population RM&E

Objective 1: Review estimates of natural and hatchery and adult escapement upstream of Lower Granite Dam during 1976–2013.

Estimated escapement of natural-origin fall Chinook salmon adults upstream of Lower Granite Dam in 2013 reached a record high since 1975 of 20,425 representing an increase of 20,347 fish above the 1990 low of 78 (Table 1; Figure 2, top panel). Estimated escapement of hatchery-origin spawners in 2013 was 30,813 ranking second for the 1976–2013 period of record (Table 1; Figure 2, middle panel). Total estimated escapement of adults reached a record high in 2013 of 51,238 for the 1976–2013 period of record (Table 1; Figure 2, bottom panel).

Table 1.—Estimates of escapement of natural and hatchery-origin adult (≥ 53 cm FL) fall Chinook salmon from the Snake River basin ESU, 1975–2013. Reference the following for the results: Busack (1991), Cooney (1991), LaVoy (1992, 1993, 1994, 1995), LaVoy and Mendel (1996), Mendel and LaVoy (1997), Mendel (1998, 1999, 2000), Young et al. (2012, unpublished).

Year	Natural	Hatchery	Total
1975	1,000	0	1,000
1976	470	0	470
1977	600	0	600
1978	640	0	640
1979	500	0	500
1980	450	0	450
1981	340	0	340
1982	720	0	720
1983	428	104	532
1984	324	294	618
1985	438	235	673
1986	449	312	761
1987	253	649	902
1988	368	241	609
1989	295	382	677
1990	78	239	317
1991	318	253	571
1992	549	111	660
1993	742	195	937
1994	406	186	592
1995	350	267	617
1996	639	260	899
1997	797	195	992
1998	306	610	916
1999	905	890	1,795
2000	1,148	1,410	2,558
2001	5,163	4,382	9,545
2002	2,116	7,231	9,347
2003	3,455	8,974	12,429
2004	2,637	9,773	12,410
2005	4,584	5,340	9,924
2006	3,984	2,501	6,485
2007	2,816	5,538	8,354
2008	2,995	8,930	11,925
2009	4,273	16,412	20,685
2010	7,347	32,417	39,764
2011	8,072	15,508	23,580
2012	11,315	19,048	30,363
2013	20,425	30,813	51,238

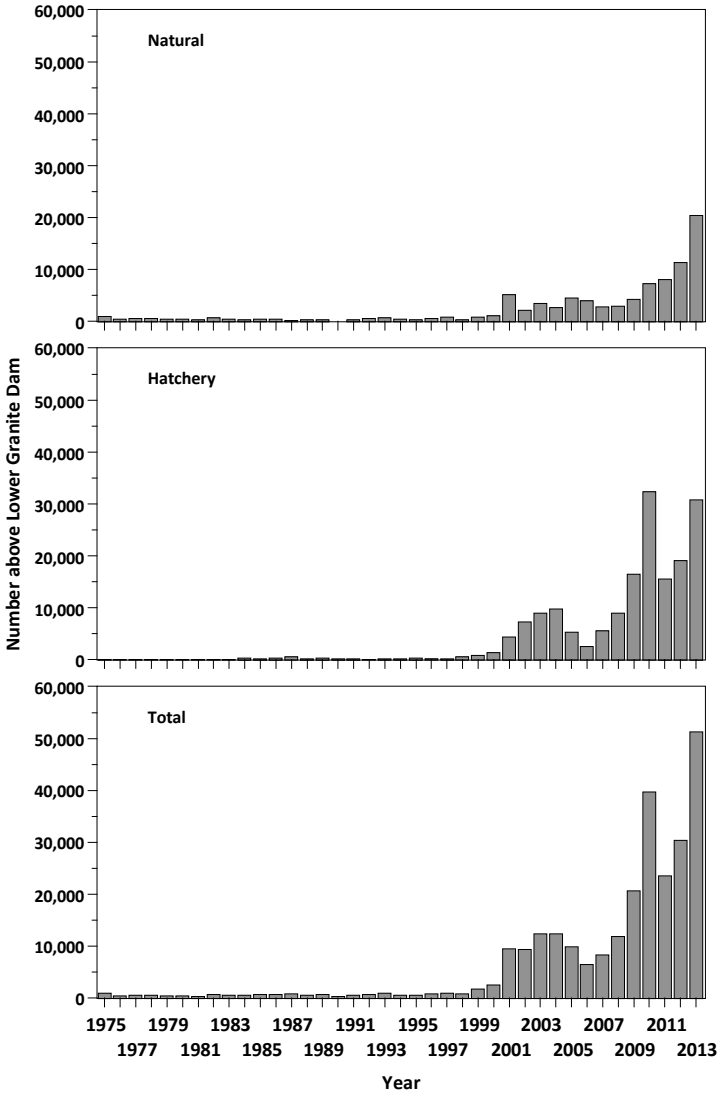

Figure 2.—Estimates of escapement of natural and hatchery-origin adult (≥ 53 cm FL) fall Chinook salmon from the Snake River basin ESU, 1975–2013. Reference the following for the results: Busack (1991), Cooney (1991), LaVoy (1992, 1993, 1994, 1995), LaVoy and Mendel (1996), Mendel and LaVoy (1997), Mendel (1998, 1999, 2000), Young et al. (2012, unpublished)

Objective 2: Develop and analyze results from models incorporating a representative range of assumptions regarding stock production relationships and the impacts of supplementation.

Adult returns of Snake River fall Chinook salmon assessed at Lower Granite Dam have increased substantially since the late 1990s (Figure 3). In more recent years the trend in natural origin returns, while still positive, has lagged behind the continued increases in hatchery returns. Natural origin returns of two other Interior Columbia basin far north migrating fall Chinook salmon stocks (Hanford Reach and Deschutes River) also increased over the same period, but at about half the rate of increase observed for Snake River fall Chinook. That comparison indicates that common factors affecting all three populations (such as year to year variability in ocean conditions) may explain some but not all of the recent increase in Snake Fall Chinook natural abundance.

The results from fitting the three alternative stock recruit functions to the 1991-2007 brood year data for Lower Snake River fall Chinook salmon population are summarized in Table 2 and Figure 4. The analysis focused on recruitment measured as returns to the spawning grounds, an alternative incorporating harvest into recruits (e.g. Figure 3) was fit with both SR functions as well. The two functions incorporating density dependent effects had significantly lower AIC scores than the constant productivity model. The two density dependent models were not significantly different from one another based on the same criteria although the BH form had a slightly lower AIC score.

The Ricker and Beverton-Holt functions that incorporated density-dependent effects were coupled with a function that predicted abundance of natural-origin adults with and without hatchery supplementation. The results of those predictions based on the Ricker function suggest that in the absence of supplementation it would have taken 15 years longer for the natural population to exceed 3,500 adults (Figure 5; bottom panels). Based on the Beverton-Holt function, it would have taken 20 years for the natural population to exceed 3,500 adults had supplementation not been implemented (Figure 5; top panels). The relative impact of hatchery spawners versus natural origin spawners on brood year natural productivity is not known for the Snake River Fall Chinook Salmon population. The analyzes bracketed a potential range in productivity effects by running two sets for each scenario, one which assumed no difference in productivity when hatchery fish were present, the other which assumed a effective reduction of 40% for hatchery spawners. The results assuming a relatively high fitness impact of intermingled hatchery origin spawners indicate that average natural origin return levels could be higher if there was a reduction in hatchery contributions on the spawning grounds under either stock recruitment model (Ricker or Beverton Holt). In the case of the Ricker model, the projected difference would be due to a combination of effects – reduced overall density and increased relative fitness. As noted above, the actual level of relative fitness of hatchery supplementation returns is not known for this population and has proven difficult to directly estimate. Ongoing studies (including possible future adaptations based on learning) should provide additional insights.

This analysis suggests that the Snake River fall Chinook salmon supplementation program has been an example of a properly designed intervention program that accelerated the growth of the natural-origin population in response to improved survivals from a combination of habitat, hydropower and harvest actions. Assuming that for the near term, future natural origin returns remain at or above recent levels, the evaluation of longer term risks associated with hatchery spawners predominating across natural spawning areas within the population will increase in priority. Studies are currently underway to confirm life stage survival improvements and to inform managers about how the program can be adapted to address longer term risks associated with high levels of supplementation. To more fully assess the hatchery effect, it will be

necessary to develop more sophisticated models that can predict abundance of natural-origin adults from the earlier stage of population growth described here through the later stages when density-dependent effects become stronger. The status of such an analysis is summarized next under Objective 3.

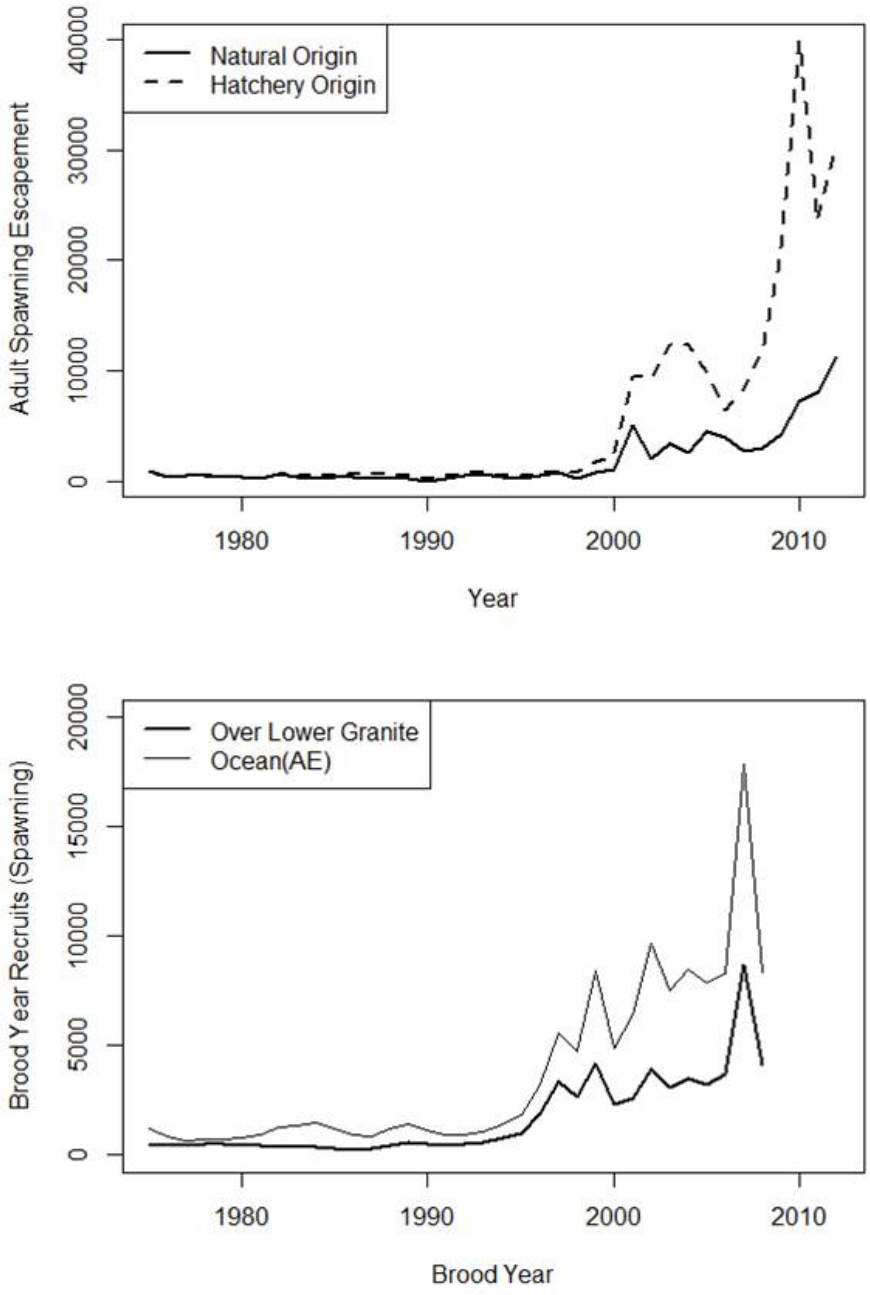

Figure 3.—Escapement of Snake River fall chinook over Lower Granite Dam (top panel) where the solid line represents natural-origin adults, and the dashed line represents total adults (natural origin plus hatchery origin). Brood year recruits are plotted against spawner escapement (bottom panel) without harvest (grey line) and with harvest (black line).

Table 2. Summary of results from fitting alternative stock recruit functions to Snake River basin fall Chinook salmon population data set (1991-2007 brood years). Recruits expressed as spawners and spawners plus harvest.

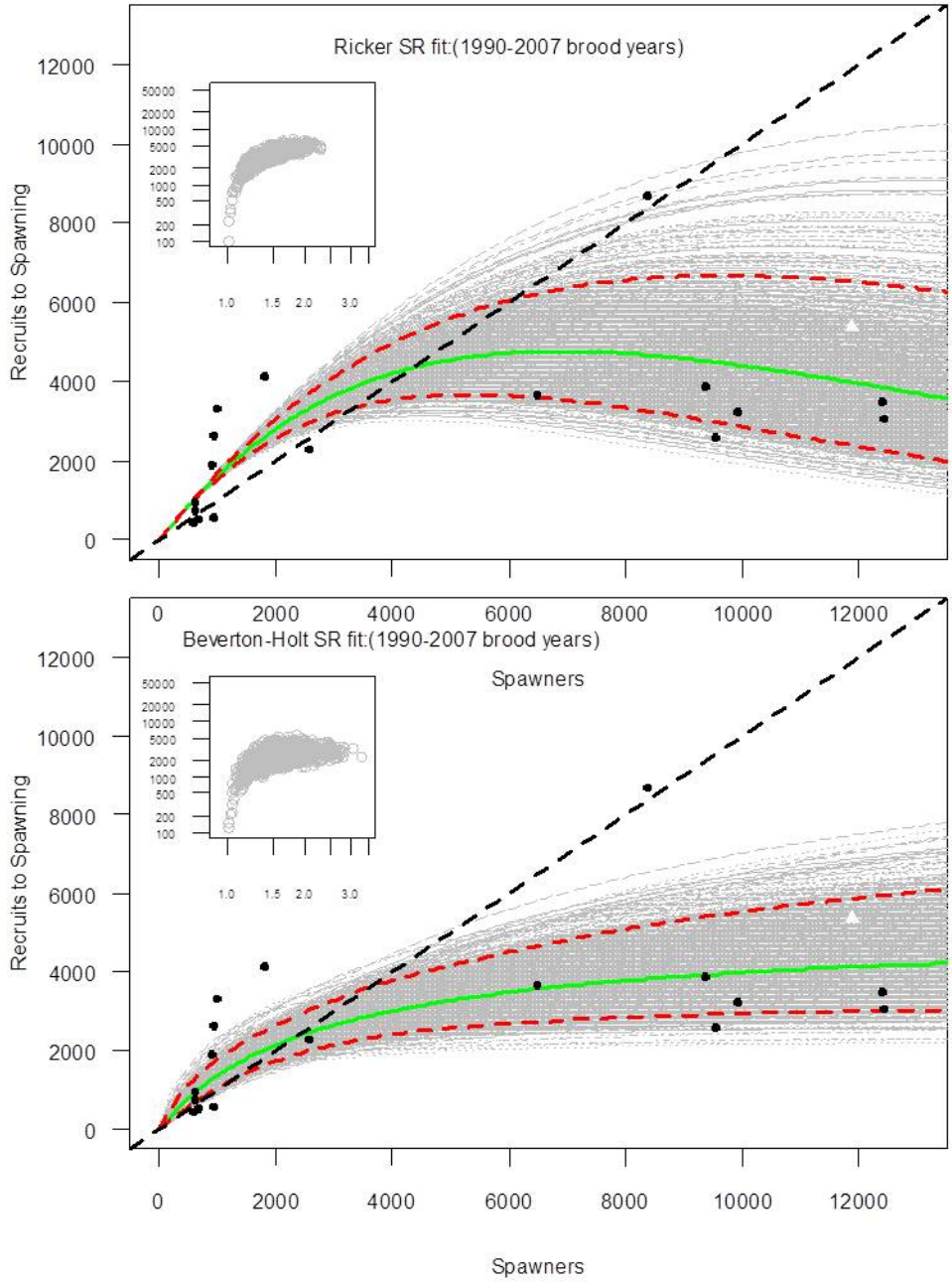

Figure 4.—Fitted Ricker (top panel) and Beverton Holt (bottom panel) functions with 1000 random selections from bootstrap joint probability distributions (insets) of a and b parameters. Points are annual estimates of brood year recruits versus parent spawners. The green lines represent the median functions across iterations, and the red lines represent 90% confidence intervals.

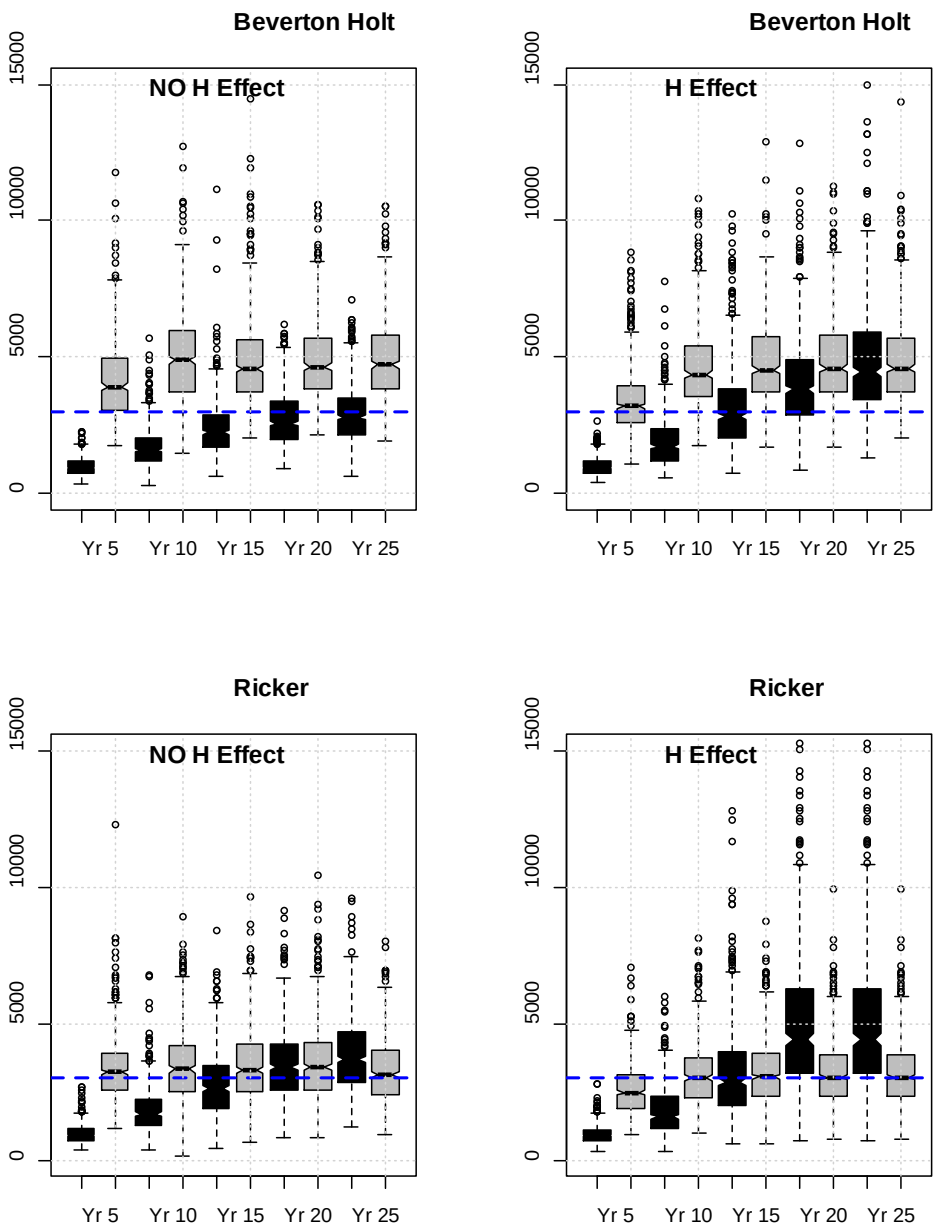

Figure 5. —Projected natural-origin spawner abundance under alternative hatchery supplementation scenarios where the starting escapement was 600. Black boxes represent no supplementation, and the gray boxes represent with supplementation. The blue line marks the abundance goal of 3,500 natural spawners.

Objective 3: Provide a preliminary evaluation of the relation between spawners and smolts produced and how productivity measured as smolts per spawner have changed as escapement to the spawning grounds has increased during 1991–2013.

Estimated passage abundance (99.9% Lower and Upper C.L.s) at Lower Granite Dam for natural fall Chinook salmon subyearlings produced upstream of Lower Granite Reservoir during 2013 was 654,498 (638,684–942,771), which was the fourth highest level of abundance for natural fall Chinook subyearlings since ESA listing in 1992 (Table 3; Figure 6). Estimated passage abundance of natural fall Chinook salmon subyearlings was lowest in 1992 and highest in 2004 when the estimated numbers of fish passing the dam were 13,672 (12,236–21,002) and 1,177,956 (1,118,431–1,514,057).

Acknowledging that the method of estimating passage abundance is still under development and will be further refined, adding the 2013 estimate of passage abundance of natural fall Chinook salmon subyearlings from the Snake River basin ESU to the set of results provided further evidence for density-dependent population growth (Figures 7 and 8).

Table 3.—Estimated annual passage abundance (N^ with 99.9% CLs) of Snake River basin fall Chinook salmon subyearlings at Lower Granite Dam calendar years 1992 to 2013, brood years 1991 to 2012. Passage abundance was not estimated during the months of November through late March when the Smolt Monitoring Program was not in operation or in late March through April during the period of yearling passage.

Year	N^	Lower CL	Upper CL
1992	13,672	12,236	21,002
1993	15,222	14,593	19,387
1994	15,895	15,165	22,403
1995	82,797	81,367	109,757
1996	36,752	35,725	48,805
1997	298,553	274,731	461,608
1998	130,765	124,893	192,413
1999	303,808	280,765	438,467
2000	585,424	471,100	1,172,425
2001	446,497	406,453	633,339
2002	255,237	216,226	405,064
2003	683,169	663,222	873,430
2004	1,177,956	1,118,431	1,514,057
2005	558,317	481,085	910,945
2006	268,364	257,713	394,865
2007	197,907	120,629	370,693
2008	429,650	398,996	644,548
2009	406,498	385,639	552,105
2010	849,839	809,427	1,235,190
2011	423,120	413,022	547,658
2012	584,172	559,331	825,038
2013	654,498	638,684	942,771

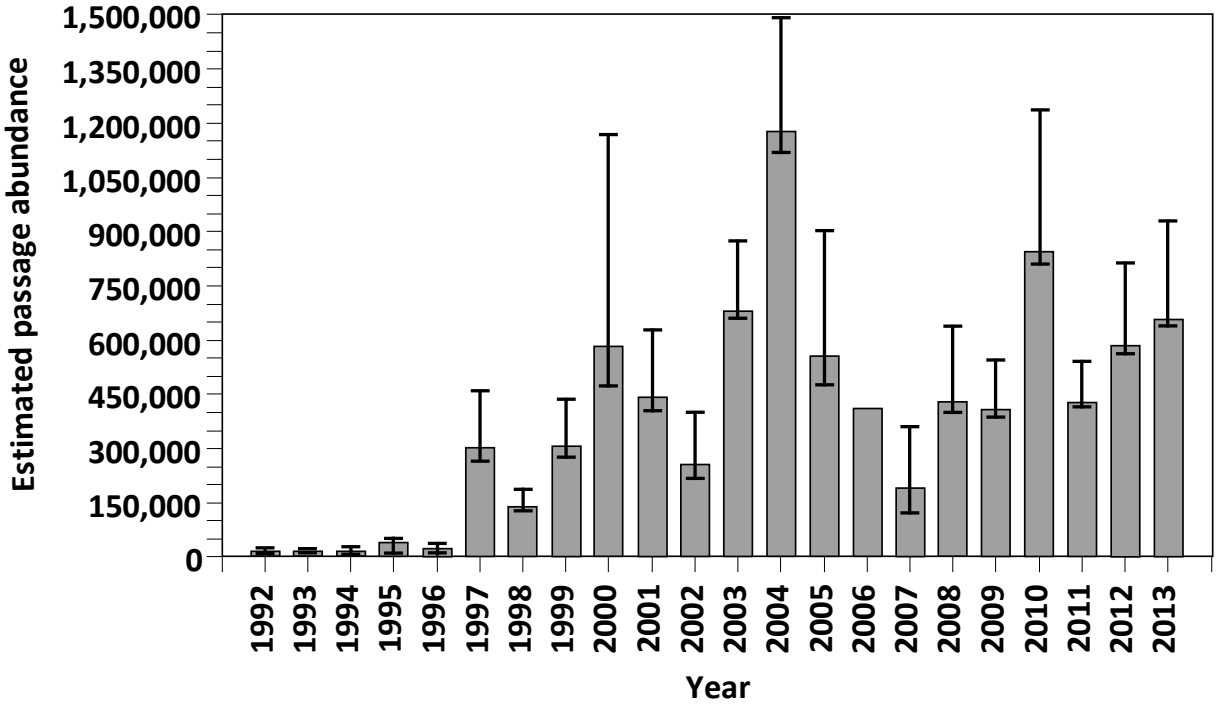

Figure 6.—Estimated annual passage abundance (± 99.9% CI) of Snake River basin fall Chinook salmon subyearlings at Lower Granite Dam calendar years 1992 to 2013, brood years 1991 to 2012. Passage abundance was not estimated during the months of November through late March when the Smolt Monitoring Program was not in operation or in late March through April during the period of yearling passage.

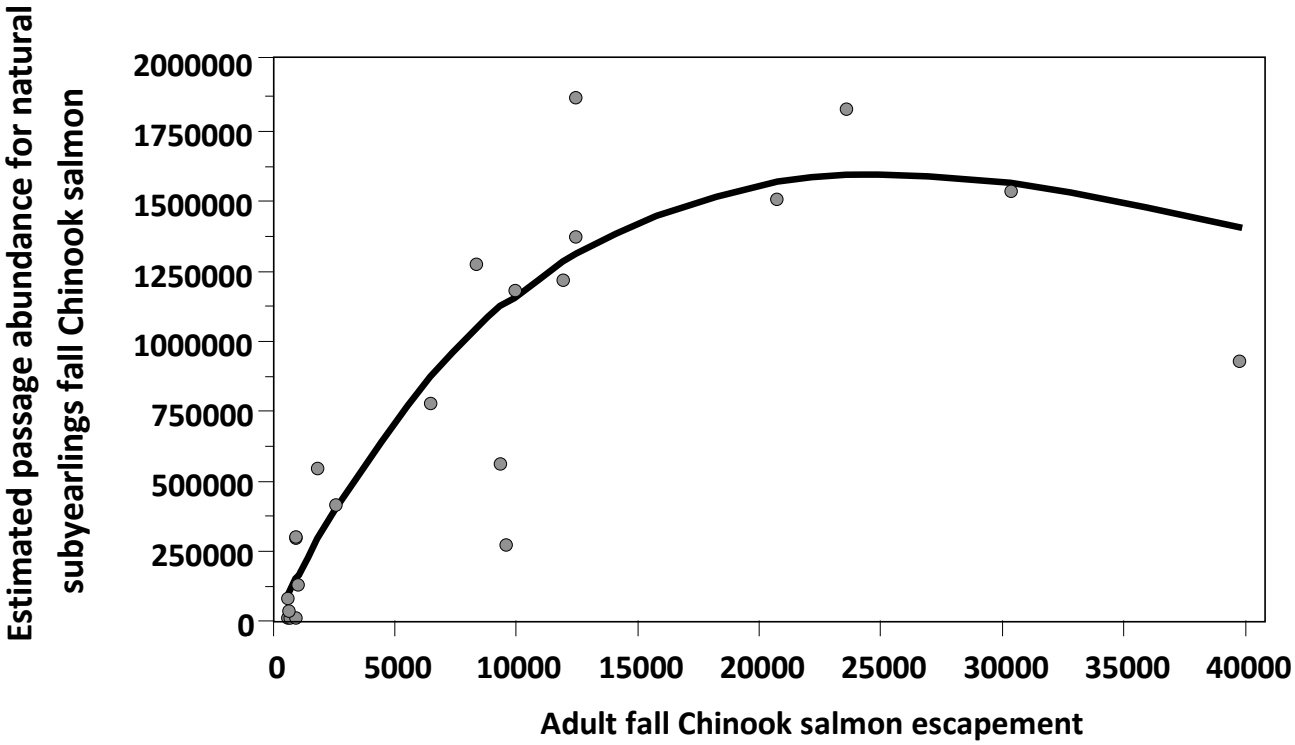

Figure 7.—The preliminary relation between adult stock (Table 1) and natural juvenile recruits (Table 3) for Snake River basin fall Chinook salmon subyearlings at Lower Granite Dam calendar years 1992 to 2013, brood years 1991 to 2012. Passage abundance was not estimated during the months of November through late March when the Smolt Monitoring Program was not in operation or in late March through April during the period of yearling passage.

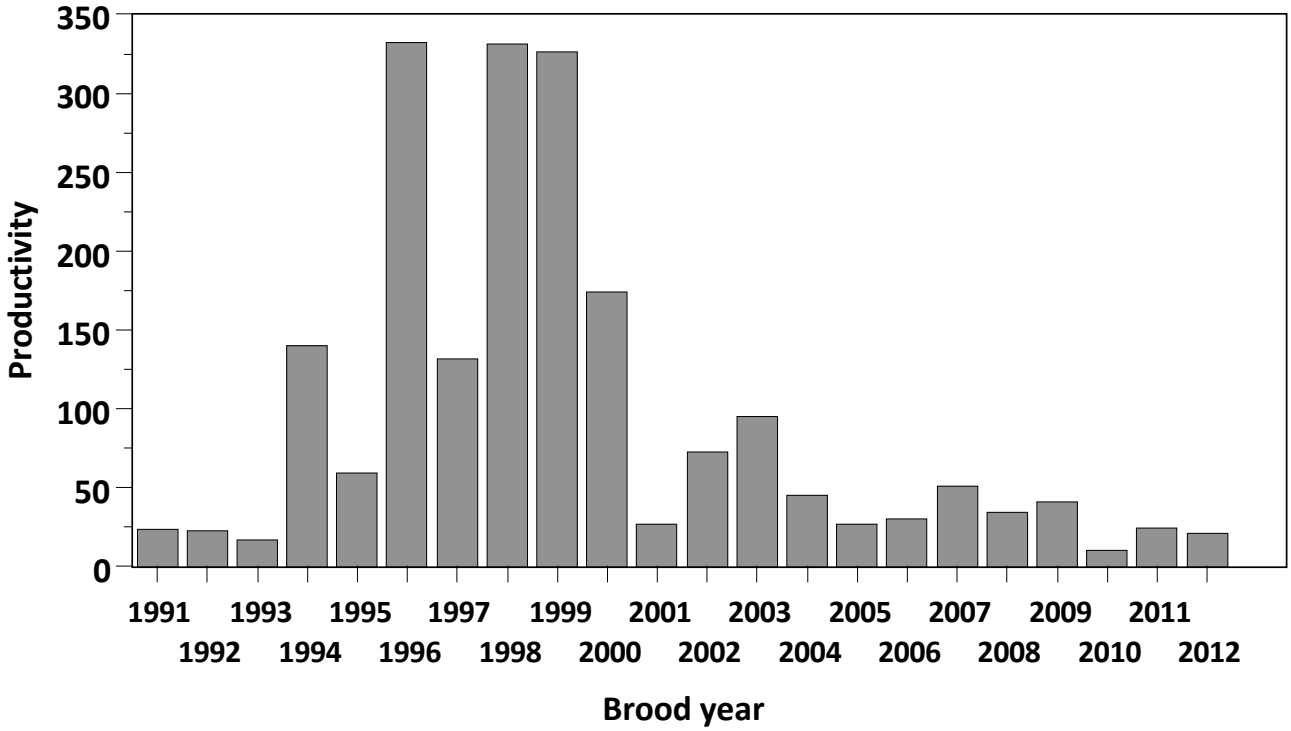

Figure 8.—A preliminary analysis of productivity based on dividing juvenile recruits (Table 3) by parent adult spawners (Table 1) for Snake River basin fall Chinook salmon subyearlings at Lower Granite Dam calendar years 1992 to 2013, brood years 1991 to 2012. Passage abundance was not estimated during the months of November through late March when the Smolt Monitoring Program was not in operation or in late March through April during the period of yearling passage.

Objective 4: Summarize the 1991 to 2013 redd count data.

Annual redd counts for the major spawning areas and other areas upstream of Lower Granite Dam where redds have been counted are given in Table 4. Overall during 1991–2013, 94.1% and 5.9% of the redds counted were counted in the major spawning areas and other areas where redds have been observed.

Using the overall percentages of redds counted in the major spawning areas alone during 1991–2012 as a baseline (Figure 9; top panel), a shift in the spatial distribution of spawning (or redd count accuracy; e.g., Groves et al. 2013) was apparent in 2013 (Figure 9; bottom panel). A higher percentage of the redds counted in the major spawning areas was counted in the lower Clearwater River in 2013 than during the baseline period.

Redd count information for the years 1991–2013 is provided in fine spatial and numerical detail in Appendix A.

Table 4.—The annual number of Snake River basin fall Chinook salmon redds counted in the major spawning areas upstream of Lower Granite Dam including the Snake River upper reach (rkm303–398), Snake River lower reach (rkm 234–302), Grande Ronde River, and lower Clearwater River (rkm 0–66), and in other areas where redds have been observed during 1991–2013. Abbreviation: Clear, Clearwater; MF, Middle Fork; NF, North Fork. The upper Clearwater River extends from rkm 68-119.

	Major spawning areas				Other areas where redds have been observed												
Year	Snake upper	Snake lower	Grande Ronde	lower Clear	Alpowa	Asotin	Imnaha	MF Clear	NF Clear	Potlatch	Salmon	Selway	SF Clear	Upper Clear	Wallowa	Wenaha	Total
1991	22	29	0	4			4	0	0	0	0	0	0	0			59
1992	16	31	5	25			3	0	0	0	1	0	0	1			82
1993	19	108	49	36			4	0	0	0	3	0	0	0			219
1994	37	30	15	30			0	0	7	0	1	0	0	0			120
1995	33	32	18	20			4	0	0	0	2	0	0	0			109
1996	56	48	20	66			3	0	2	0	1	0	1	0			197
1997	24	34	55	58			3	0	14	0	1	0	0	0			189
1998	137	48	24	78			13	0	0	0	3	0	0	0			303
1999	292	81	13	179			9	0	1	7	0	0	2	2			586
2000	228	118	8	164			9	0	0	7	0	0	1	8			543
2001	389	320	197	290			38	0	1	24	22	0	5	16			1,302
2002	648	465	111	520			72	0	0	3	31	0	0	4			1,854
2003	840	672	93	544		3	43	0	8	1	18	0	0	19			2,241
2004	966	743	162	592		4	35	0	2	1	21	0	0	36			2,562
2005	866	575	129	433		6	36	0	0	0	27	0	0	54			2,126
2006	572	453	41	251		1	36	0	0	0	9	0	0	6	0	1	1,370
2007	713	404	80	711		0	17	0	0	0	18	0	0	7	0	1	1,951
2008	1,129	690	185	919		3	68	0	0	16	14	5	3	22	0	1	3,055
2009	1,327	768	104	1,142		0	36	0	1	0	34	1	12	42	0	0	3,467
2010	1,751	1,215	263	1,579	31	4	132	3	8	281	8	1	2	49	0	0	5,296
2011	1,395	1,419	154	1,557	0	2	24	3	3	2	60	8	31	17			4,675
2012	1,290	538	303	1,558	6	30	85	3	0	283	34	20	41	52	1	5	4,249
2013	1,552	1,115	255	2,774		53	38	28	3	10	31	10	47	84			6,000

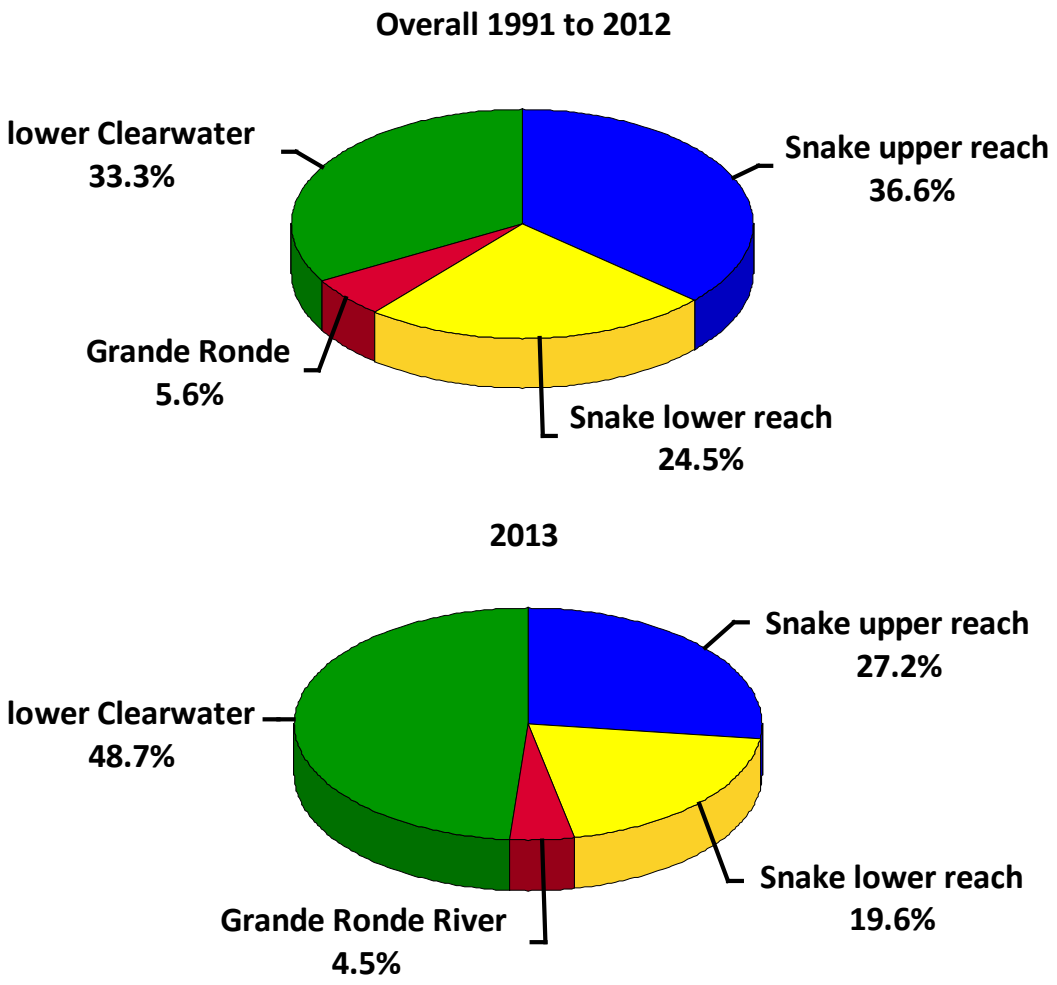

Figure 9.—The overall proportions of the overall number of Snake River basin fall Chinook salmon redds counted in the major spawning area that were counted in each major spawning area during 1991–2012 (top panel) and during 2013 alone (bottom panel).

Objective 5: Describe some of the early life history attributes of fall Chinook salmon juveniles produced by the three primary spawning aggregates upstream of Lower Granite Dam.

Attributes of Rearing in the Snake River reaches

Of the life stages evaluated, timing of fry (< 45 mm fork length; Connor et al. 2002) presence has been the most stable across the years 1992–2013 with emergence timing being earlier in the relatively warmer Snake River upper reach than in the relatively cooler Snake River lower reach (Table 5).

The median date of parr (> 45 mm fork length) presence along the shorelines is an indicator of when the number of parr rearing in riverine habitat became less than the number of parr that had begun downstream dispersal into Lower Granite Reservoir. The median date of parr presence along both Snake River reaches generally became earlier as density along the shorelines increased as can be seen by examining the means of the median dates of parr presence for the periods of low (1992–1999) and high (2000–2013) abundance (Table 6).

Mean fork length of parr in riverine habitat has become smaller as the timing of dispersal into Lower Granite Reservoir has become earlier (Table 7). Growth of parr in fork length of in the Snake River upper reach declined by an average of 0.2 mm between abundance periods, whereas there was no change in growth in fork length of parr in the lower reach (Table 7).

Mean (± SE) wet weight of parr in the Snake River upper reach declined from 4.3±0.4 g during the low abundance period to 1.9±0.2 g during the high abundance period, and a similar decline in wet weight of parr was observed in the Snake River lower reach (Table 7). The decline in wet weight of parr was accompanied by a decline in growth in weight in both reaches, but especially in the upper reach where rearing habitat availability and connectivity are relatively low (Table 7; Figure 10).

Attributes of Migration of Juveniles from Snake River reaches and the lower Clearwater River

Passage timing at Lower Granite Dam for natural fall Chinook salmon subyearlings from the Snake River upper reach was earlier than passage timing of natural fall Chinook salmon subyearlings from the Snake River lower reach, which in turn, was earlier than passage timing of natural fall Chinook salmon subyearlings from the lower Clearwater River (Table 8; Figure 11). Passage timing of fish from the two Snake River spawning aggregates during the low abundance period was later compared to passage timing during the high abundance period (Table 8). Passage timing of fish from the lower Clearwater River spawning aggregate during the low abundance period was earlier compared to passage timing during the high abundance period (Table 8) largely because the bypass and PIT-tag monitoring system were supplied with water for extended periods of time after 2004 and allowed more Clearwater River subyearlings to be detected later at the dam. Extended detection also influenced the values of the rates of downstream movement of Clearwater River fish as it allowed the detection of slower later migrants.

Median rates of downstream movement (km/d) from release in riverine habitat to detection at Lower Granite Dam were fastest for natural fall Chinook salmon subyearlings from the Snake River upper reach and slowest for natural subyearlings from the lower Clearwater River (Table 9). Mean rates of downstream movement of fish from the two Snake River spawning aggregates during the low abundance period were slower compared to mean rates of downstream movement during the high abundance period (Table 9). Mean rate of downstream movement of fish from the lower Clearwater

River spawning aggregate during the low abundance period was faster that mean rate of downstream movement for those fish during the high abundance period (Table 9).

Additional details on passage timing at Lower Granite Dam are given in Appendix B.

Table 5.—Timing of fry presence (day of year; January 1 = 1) along the Snake River upper and lower reaches, 1992–2013. The mean of the annual medians and the mean of the abundance period medians are also given. The low abundance period was during 1992 to 1999 and the high abundance period was during 2000-2013 (after Connor et al. 2013).

	Snake River upper reach				Snake River lower reach			
Year	*N*	Median	Min	Max	*N*	Median	Min	Max
1992					356	117	89	145
1993					199	136	94	171
1994					441	135	93	156
1995	117	113	92	141	257	120	92	155
1996	14	119	105	126	268	126	105	175
1997	1	110	110	110	114	124	110	180
1998	101	109	102	130	322	116	102	165
1999	97	122	94	143	278	122	94	178
2000	683	100	93	135	415	100	93	156
2001	552	119	91	140	1,268	126	91	154
2002	2,289	111	90	153	965	125	90	167
2003	962	103	82	145	1,726	110	82	173
2004	6,123	109	81	144	4,952	123	81	158
2005	5,462	107	86	135	3,786	107	86	156
2006	75	106	85	141	588	134	85	162
2007	4,311	112	84	154	1,771	119	84	154
2008	1,628	118	90	146	1,231	118	83	167
2009	811	109	81	137	1,017	116	81	165
2010	1,572	115	80	157	4,393	115	80	171
2011	1,778	128	86	163	1,408	128	86	191
2012	3,782	120	85	169	2,207	127	85	162
2013	7,874	111	83	146	4,033	118	83	167
Mean (SE)		113(2)				121(2)		
Low abundance		115(3)				125(3)		
High abundance		112(2)				119(2)		

Table 6.—Timing of parr presence (day of year; January 1 = 1) along the Snake River upper and lower reaches, 1992–2013. The mean of the annual medians and the mean of the abundance period medians are also given. The low abundance period was during 1992 to 1999 and the high abundance period was during 2000-2013 (after Connor et al. 2013).

	Snake River upper reach				Snake River lower reach			
Year	*N*	Median	Min	Max	*N*	Median	Min	Max
1992					1765	138	89	159
1993					2166	157	101	199
1994					4348	149	93	191
1995	985	148	99	169	1408	155	92	183
1996	118	133	105	168	756	147	105	196
1997	119	145	110	166	938	159	110	194
1998	1078	137	102	186	2512	151	102	186
1999	1493	143	101	178	1647	157	94	192
2000	1064	114	93	163	1578	135	93	177
2001	794	123	91	161	3076	140	91	175
2002	3013	125	97	181	3620	146	90	188
2003	4523	124	82	173	6821	131	82	180
2004	6310	123	88	172	11225	137	88	179
2005	8119	121	86	170	16803	135	86	184
2006	1344	134	85	176	2658	134	99	176
2007	7226	119	91	182	7500	133	84	182
2008	6610	139	97	195	3357	146	83	195
2009	3876	130	88	165	4706	137	95	186
2010	2502	129	87	199	9193	143	87	199
2011	2237	135	93	184	2759	149	86	191
2012	4769	134	106	176	5791	148	99	190
2013	4503	125	104	174	7171	139	83	174
Mean (SE)		131(2)				144(2)		
Low abundance		141(5)				152(3)		
High abundance		127(2)				140(2)		

Table 7.—Information on size and growth of parr rearing along the Snake River upper and lower reaches, 1992–2013. The mean of the annual medians and the mean of the abundance period medians are also given. The low abundance period was during 1992 to 1999 and the high abundance period was during 2000-2013 (after Connor et al. 2013).

	Fork length (mm)			Growth (mm/d)			Wet weight (g)			Growth (g/d)		
Year	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
1992												
1993												
1994												
1995	1,102	69	16	148	1.2	0.3	723	3.8	3.2	29	0.28	0.13
1996	132	64	13	19	1.1	0.3	122	3.5	2.5	17	0.26	0.13
1997	120	77	12	21	1.3	0.3	115	6.0	2.7	20	0.34	0.10
1998	1,179	68	15	112	1.1	0.3	1,069	4.3	3.1	89	0.25	0.11
1999	1,590	67	14	171	1.3	0.3	1,580	4.1	3.0	169	0.30	0.13
2000	1,747	57	19	97	1.3	0.2	1,452	2.9	3.6	61	0.38	0.11
2001	1,346	50	10	12	1.2	0.1	1,223	1.4	1.2	11	0.22	0.03
2002	5,302	50	11	169	1.1	0.2	5,204	1.5	1.5	169	0.24	0.09
2003	5,485	57	12	359	1.0	0.3	5,333	2.2	1.6	359	0.18	0.10
2004	12,433	48	9	150	1.0	0.3	5,129	1.9	1.4	150	0.18	0.10
2005	13,581	51	10	297	1.1	0.2	13,200	1.5	1.2	218	0.20	0.08
2006	1,419	65	11	80	1.1	0.3	1,205	3.3	1.8	46	0.22	0.12
2007	11,537	49	8	130	1.1	0.3	11,534	1.3	0.9	128	0.21	0.08
2008	8,234	59	14	1,035	1.0	0.3	7,165	2.6	2.3	770	0.17	0.10
2009	4,687	56	10	138	0.8	0.3	4,120	1.9	1.1	121	0.09	0.03
2010	4,073	52	11	324	0.8	0.3	3,124	1.6	1.5	184	0.11	0.07
2011	4,015	50	11	241	0.9	0.4	3,129	1.4	1.3	139	0.15	0.09
2012	8,551	49	10	284	0.9	0.3	7,191	1.3	1.0	133	0.12	0.05
2013	4,020	53	9	283	0.8	0.3	2,685	1.7	1.1	149	0.13	0.09
Mean (SE)		57 (2)			1.1(0.1)			2.5(0.3)			0.21(0.02)	
Low abundance		69(2)			1.2 (0.1)			4.3(0.4)			0.29(0.02)	
High abundance		53(1)			1.0(0.1)			1.9(0.2)			0.19(0.02)	

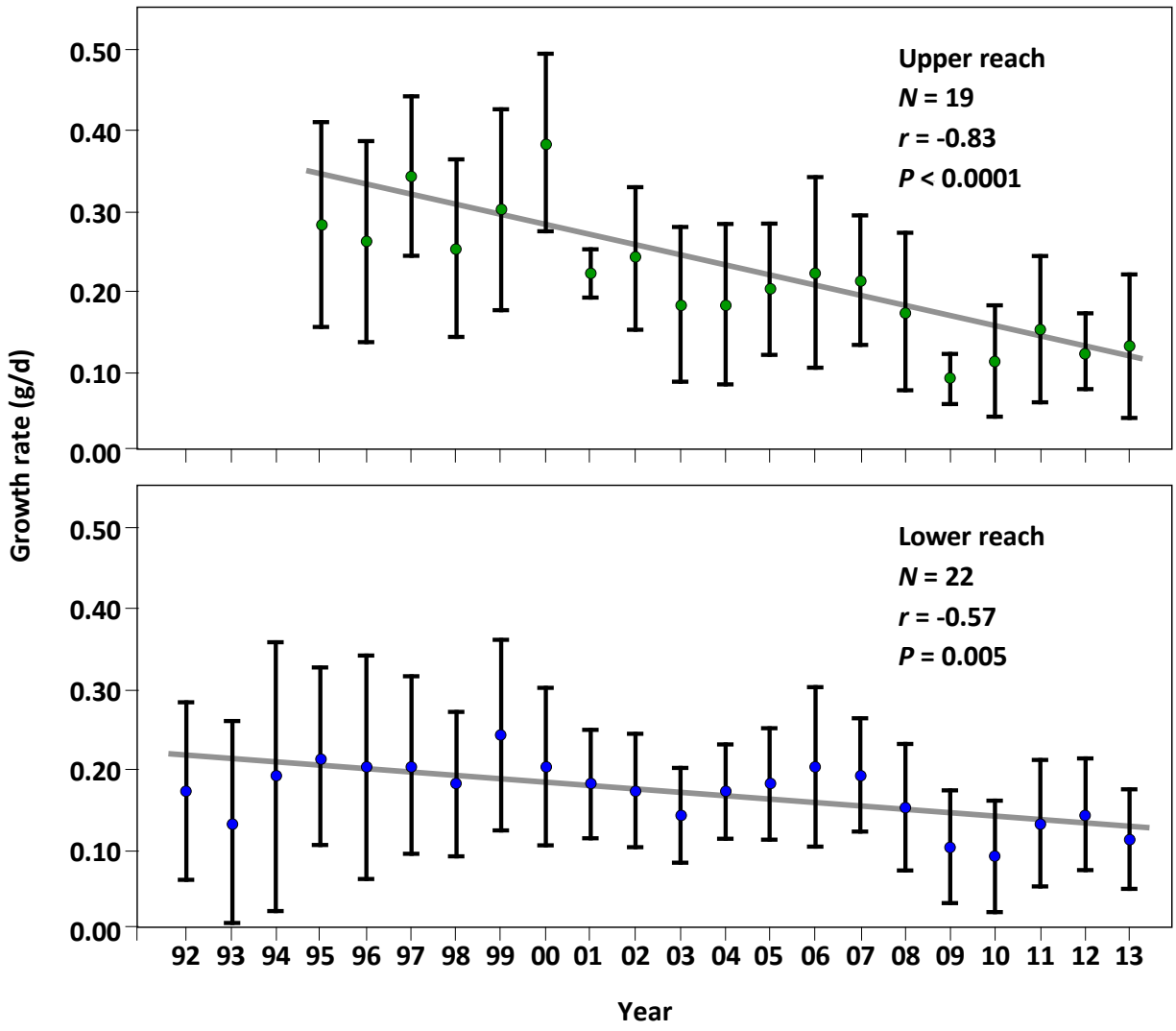

Figure 10.—Growth in wet weight of parr rearing along the Snake River upper and lower reaches, 1992–2013. A Pearson's product-moment correlation coefficient was calculated between year and growth rate within each reach to establish the general trend in growth rate.

Table 8.—Estimated passage timing (Plumb et al. 2013) at Lower Granite Dam of natural-origin subyearling fall Chinook salmon that were PIT tagged along the Snake River upper and lower reaches and lower Clearwater River, 1992–2013. The percentage of total numbers of fish that were last detected as yearlings (Rtype%; except for 2013 because report was written before passage was complete), and the mean of the annual medians and the mean of the abundance period medians are also given. The low abundance period was during 1992 to 1999 and the high abundance period was during 2000-2013 (after Connor et al. 2013).

	Snake River upper reach			Snake River lower reach			lower Clearwater		
Year	*N*^	Median	%Rtype	*N*^	Median	%Rtype	*N*^	Median	%Rtype
1992				85	22-Jun	0.00%			
1993				514	22-Jul	6.00%	66	20-Aug	37.90%
1994				464	17-Jul	3.00%	18	18-Aug	88.90%
1995	401	18-Jul	0.00%	490	02-Aug	0.00%	60	12-Sep	0.00%
1996	47	29-Jun	0.00%	256	18-Jul	0.00%			
1997	55	20-Jun	0.00%	215	16-Jul	10.70%			
1998	356	07-Jul	2.00%	752	11-Jul	1.70%	258	01-Aug	9.70%
1999	712	26-Jun		556	27-Jul				
2000	203	19-Jun	0.00%	544	02-Jul	2.20%			
2001	20	10-Jul	0.00%	374	07-Jul	0.00%			
2002	314	01-Jul	1.30%	1,161	04-Jul	0.40%			
2003	642	24-Jun	0.00%	1,697	27-Jun	0.20%			
2004	337	24-Jun	0.00%	2,911	24-Jun	0.10%	608	25-Aug	6.30%
2005	1,059	20-Jun	0.00%	2,941	24-Jun	0.10%	236	29-Jul	11.90%
2006	335	15-Jun	0.00%	410	27-Jun	0.00%	478	07-Aug	2.50%
2007	238	18-Jun	0.00%	1,260	25-Jun	1.30%	178	21-Oct	13.50%
2008	1,386	01-Jul	0.30%	957	17-Jul	0.00%	318	06-Oct	5.70%
2009	405	22-Jun	0.00%	1,032	03-Jul	0.90%	145	02-Nov	8.30%
2010	263	02-Jul	0.00%	2,014	12-Jul	0.00%	1,025	017-Sep	1.80%
2011	402	17-Jun	0.00%	593	12-Jul	0.70%	143	28-Sep	16.80%
2012	674	25-Jun	0.00%	1,559	09-Jul	0.30%	712	18-Oct	2.20%
2013	177	01-Jul	NA	896	04-Jul	NA	677	13-Sep	NA
Mean		26-Jun	0.20%		7-Jul	1.10%		10-Sep	7.10%
Low abundance		01-Jul	0.50%		16-Jul	3.10%		19-Aug	34.10%
High abundance		24-Jun	0.10%		02-Jul	0.50%		18-Sep	7.60%

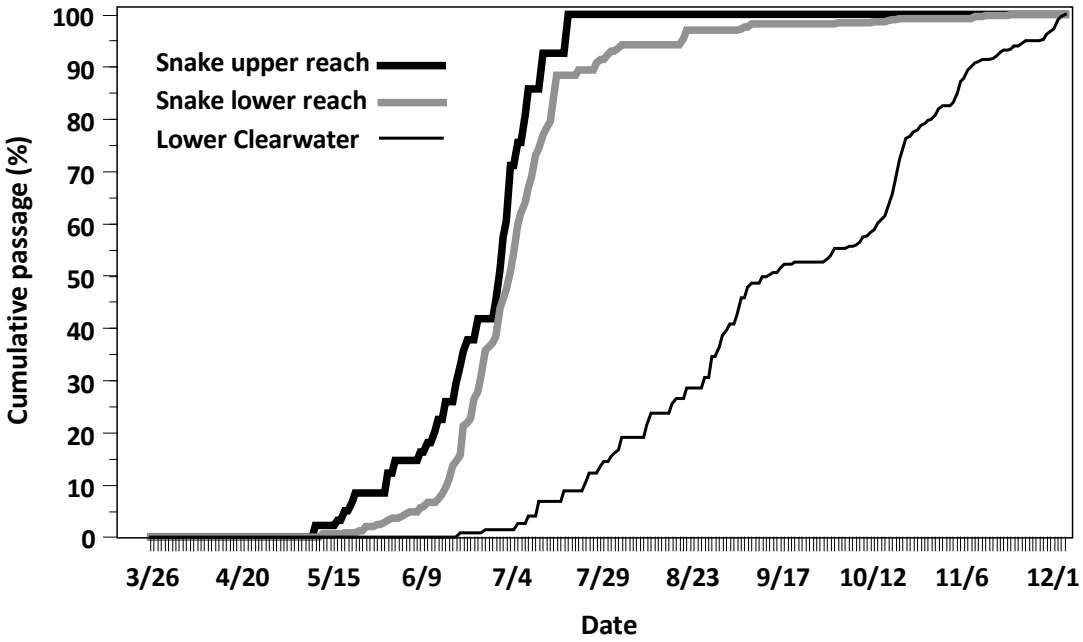

Figure 11.—Estimated cumulative percent passage distributions (Plumb et al. 2013) at Lower Granite Dam for natural-origin subyearling fall Chinook salmon that were PIT tagged along the Snake River upper and lower reaches and lower Clearwater River, 1992–2013.

Table 9.—Rate of downstream movement (km/d) of PIT-tagged natural-origin subyearling fall Chinook salmon from the Snake River upper and lower reaches and lower Clearwater River, 1992–2013. The mean of the annual medians and the mean of the abundance period medians are also given. The low abundance period was during 1992 to 1999 and the high abundance period was during 2000-2013 (after Connor et al. 2013).

	Snake River upper reach				Snake River lower reach				Lower Clearwater			
Year	*N*	Median	Min	Max	*N*	Median	Min	Max	*N*	Median	Min	Max
1992					39	3.3	1.1	18.8				
1993					248	1.5	0.2	19.7	30	1.2	0.2	13.6
1994					201	1.5	0.2	13.8	9	0.4	0.4	1.9
1995	203	3.4	1.1	44.7	239	1.5	0.4	20.3	30	1.3	0.6	13.0
1996	19	3.7	2.1	43.7	126	1.5	0.4	19.3				
1997	24	5.3	1.7	70.5	111	2.0	0.2	21.6				
1998	175	3.4	0.5	20.1	384	2.0	0.2	28.3	126	2.2	0.3	16.0
1999	326	4.7	1.0	35.0	280	2.1	0.4	19.5				
2000	72	5.4	2.6	19.9	263	1.9	0.2	13.6				
2001	10	3.6	1.3	4.5	185	1.8	0.5	15.0				
2002	96	4.6	0.5	25.0	397	2.3	0.2	19.3				
2003	304	5.3	2.3	43.7	815	2.5	0.2	29.5				
2004	186	5.0	2.9	21.9	1599	2.6	0.3	21.3	255	1.3	0.2	9.0
2005	314	6.0	2.9	26.3	673	3.4	0.3	19.7	61	0.6	0.2	10.2
2006	96	8.0	3.5	58.3	103	3.0	0.6	45.0	132	0.6	0.3	34.5
2007	37	5.3	3.8	13.5	182	2.8	0.2	15.6	62	0.6	0.2	7.0
2008	360	5.3	0.6	87.5	211	2.1	0.5	57.0	116	0.7	0.2	12.4
2009	145	4.9	2.2	29.8	320	2.5	0.3	42.5	59	0.6	0.2	8.9
2010	72	6.8	2.8	61.7	475	2.9	0.3	58.0	321	0.6	0.2	20.3
2011	167	7.6	2.4	64.3	233	3.4	0.3	59.0	55	0.6	0.2	7.9
2012	163	5.0	2.2	59.7	305	2.5	0.2	42.5	243	0.6	0.2	9.3
2013	33	4.1	2.6	29.2	143	2.3	0.4	21.8	221	0.6	0.4	9.0
Mean (SE)		5.1(0.3)				2.3(0.1)				0.8(1)		
Low abundance		4.1(4)				1.9(0.2)				1.3(0.4)		
High abundance		5.5(0.3)				2.6(0.1)				0.7(0.1)		

b. Predation and Invasive Species Management RM&E

Objective 6: Describe the seasonal variation in smallmouth bass diets and consumption of subyearlings during the subyearling rearing and outmigration period in Hells Canyon.

In 2012, we collected 610 smallmouth bass by angling in the Hells Canyon Reach of the Snake River and in 2013 we collected 1,672 bass by angling and electrofishing. We estimated a total of 77,940 bass (95% CI: 54,398-101,483) in the upper reach (i.e., above the Salmon River), followed by 12,212 bass (95% CI: 2,959-21,465) in the middle reach (i.e., Grande Ronde River to Salmon River), and 8,577 bass (95% CI: 1,832-15,322) in the lower reach (i.e., Asotin, WA to Grande Ronde River) in 2012. In 2013, we estimated a total of 84,464 bass (95% CI: 41,399-127,560) in the upper reach, followed by 22,058 bass (95% CI: 10,700-45,659) in the middle reach, and 15,431 bass (95% CI: 6,600-52,194) in the lower reach.

Smallmouth bass primarily consumed insects, crayfish, salmonids, and nonsalmonid fishes. Bass consumed more fish in 2013 than in 2012. Salmonids comprised the majority of the diet by weight during the week of 20 May 2013 in the upper reach which was after a large release of hatchery fish (Figure 12). Salmonids also comprised a large portion of the diet by weight at times in the middle and lower reaches in 2013. Typically, the proportion of fish in the diet of smallmouth bass declined seasonally. Based on the lengths of ingested salmonids, most were probably subyearling fall Chinook salmon. Estimated mean size of Chinook salmon consumed in 2012 was 57 mm (SD = 20.1 mm, N = 12, range = 38-92 mm) and the estimated mean size of Chinook salmon consumed in 2013 was 74 mm (SD = 21.1 mm, N = 206, range = 38-132 mm). Newly emerged fry represented most of the consumption in April in both years.

Total estimated loss of salmonids to smallmouth bass predation within our study area was 204,323 individuals (95% CI = 122,300-286,346) in 2012 and 947,772 individuals (95% CI = 415,434-1,794,444) in 2013. Coincident to the abundance estimates, the highest total consumption occurred in the upper reach for both years followed by the middle then the lower reach. In the upper reach alone, 68% of the estimated consumption in 2013 occurred during the 20-May sampling period, when 420,104 salmonids were estimated to be consumed during the 2-week interval. However, this estimate was heavily influenced by a release of hatchery fish that occurred before we sampled. Estimates of zero loss occurred for some sampling weeks in the middle and lower reaches in 2012 due to low catch rates of smallmouth bass and consumption of Chinook salmon.

A complete reporting of 2012 and 2013 results can be found in Appendix C.

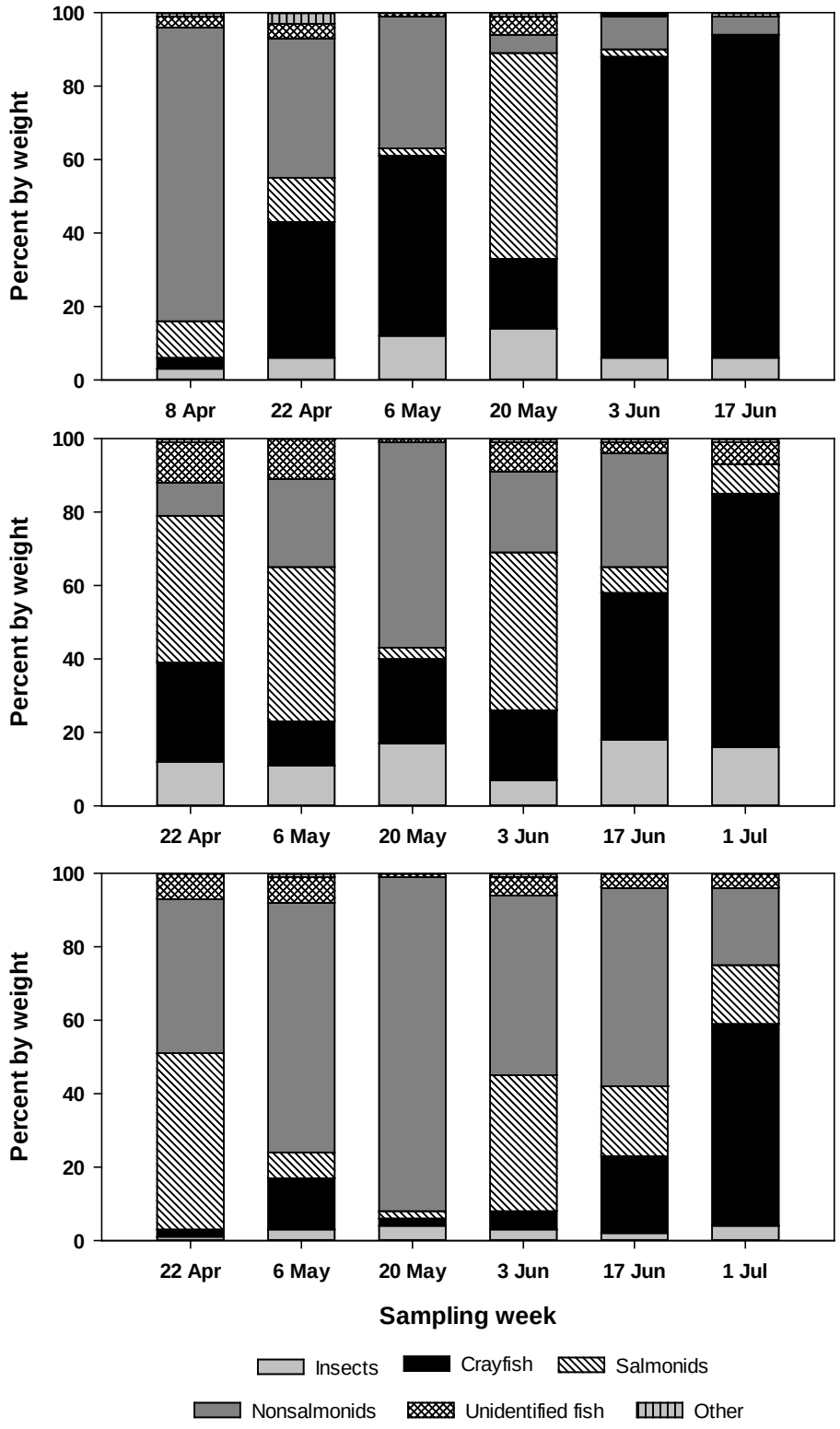

Figure 12. Seasonal variation in diet composition (percent weight based on non-empty stomachs) of smallmouth bass in the upper reach (top panel), middle reach (middle panel), and lower reach (bottom panel) of Hells Canyon in 2013.

5. Synthesis of Findings: Discussion/Conclusions

Lessons Learned: Explain how the results of this project benefit fish and wildlife. Address each applicable sub-strategy and management question(s), provided in the Introduction for higher-level or project/program level adaptive management. If studies are incomplete, discuss preliminary findings. (Refer to the RM&E Annual Technical Reporting guidance document for more information on content to include).

a. Fish Population RM&E

Objective 1: Review estimates of natural and hatchery and adult escapement upstream of Lower Granite Dam during 1976–2013.

Accomplishing Objective 1 helped to inform the F&W Program management question: What are the status and trend of adult abundance of natural and hatchery origin fish populations?

The increase in adult counts at Lower Granite Dam indicates that the Snake River basin fall Chinook salmon ESU is much more abundant than it was at the time of listing under the ESA, and as such, this ESU appears to be responding positively to the implemented actions.

Objective 2: Develop and analyze results from models incorporating a representative range of assumptions regarding stock production relationships and the impacts of supplementation.

Accomplishing Objective 2 was a first step to informing the F&W Program management question: What are the status and trend of adult productivity of fish populations?

Though preliminary, the results reported under this objective on a stock-recruitment model fitted with a module to incorporate alternative assumptions regarding hatchery effects represent the progress being made to establish an understanding of the factors affecting the growth and productivity of the Snake River basin fall Chinook salmon ESU. Additional data collected in upcoming years when the adults return from previous high escapement years will be informative. Adding modules to the model that account for variation in harvest and climatic conditions will also be informative.

Objective 3: Provide a preliminary evaluation of the relation between spawners and smolts produced and how productivity measured as smolts per spawner have changed as escapement to the spawning grounds has increased during 1991–2013.

Accomplishing Objective 3 was a first step to informing the F&W Program management question: What are the status and trend of juvenile abundance and productivity of fish populations?

Acknowledging that the method of estimating passage abundance of juveniles from the Snake River fall Chinook salmon ESU is still under development and will be further refined, adding the 2013 estimate of passage abundance of natural fall Chinook salmon subyearlings from the Snake River basin ESU to the set of results provided further evidence for density-dependent population growth with some linkage to egg to smolt survival. Productivity generally increased after brood year 1993 to a high in brood year 1998 and then declined thereafter. Identifying the mechanisms underlying that decline will more fully inform the BiOp and other recovery actions. In the upcoming year, work will continue to develop the previously mentioned multistage stock-recruitment model with covariates.

Objective 4: Summarize the 1991 to 2013 redd count data.

Accomplishing Objective 4 informed the F&W Program management question: What are the status and trend of spatial distribution of fish populations?

Basin-wide counts of redds in the Snake River basin upstream of Lower Granite Dam reached a post-listing high in 2013, and the spatial distribution remained balanced among the four major spawning areas with some increase in the proportion of spawning in the lower Clearwater River. These results further suggest that the ESU is responding positively to implemented actions. The redd counts produced by our cooperative group in future years will inform the spatial criteria for recovery being established in the draft recovery plan and provide important data for modeling efforts identified in that plan.

Objective 5: Describe some of the early life history attributes of fall Chinook salmon juveniles produced by the three primary spawning aggregates upstream of Lower Granite Dam.

Accomplishing Objective 4 continued to inform the F&W Program management question: What are the status and trend of diversity of natural and hatchery origin fish populations?

Maintenance of the life history characteristics of the natural juveniles that are part of the Snake River fall Chinook salmon ESU is important for assessing the diversity aspect of the draft recovery plan. Adding the 2013 data to the data set collected on timing of parr presence, size, growth, and dispersal timing into the reservoir provided further evidence for density-dependent phenotypic change in Chinook Salmon subyearlings native to an 8th order river that was influenced by the expansion of the recovery program. Natural parr and smolts in a circuitous way have begun to regain the movement timing and size phenotypes expressed by their historical counterparts under similarly high abundances. As such, this report showed that efforts to recover native fishes can have detectable effects in large river landscapes. Past research has shown that survival decreases as growth in riverine habitat and size at dispersal decreases (Connor and Tiffan 2012). The outcome of such phenotypic change, which is an important area of future research in the Snake River basin, can only be fully judged by examining the effect of the change on population viability and productivity. Once the multi-stage stock-recruitment model is fitted, phenotypic traits of natural juveniles and abundance of hatchery smolts in the reservoir will be included as covariates in the analyses.

b. Predation and Invasive Species Management RM&E

Although this study is ongoing, we showed that smallmouth bass predation on subyearling fall Chinook salmon in Hells Canyon has increased substantially since the time the last predation study was conducted in the mid 1990s (Nelle 1999). This is due to a number of factors. First, the abundance of smallmouth bass in the Snake River above the Salmon River may have increased since the 1990s, but results suggest that this may not be the case below. Second, consumption rates of juvenile salmon by smallmouth bass are generally higher today than they were in the 1990s. The latter may be a response to the greater abundance of the subyearling population, which has increased dramatically in recent years through hatchery supplementation. Consequently, the loss of subyearlings is much greater than in the 1990s when the population was at historically low levels following ESA listing. Our results provide managers with insight into the extent of predation on subyearlings by smallmouth bass in Hells Canyon.

6. References

Arnsberg, B. D., and D. P. Statler. 1995. Assessing summer and fall Chinook salmon restoration in the Upper Clearwater River and principal tributaries. Nez Perce Tribe Department of Fisheries Resources Management 1994 Annual Report to the U.S. Department of Energy, Bonneville Power Administration, Project No. 94 034, 67 electronic pages (BPA Report DOE/BP-12873-1).

Brooks, E. N. and J. E. Powers. 2007. Generalized compensation in stock-recruit functions: properties and implications for management. ICES Journal of Marine Science 64: 413–424.

Busack, G. 1991. Genetic evaluation of the Lyons Ferry Hatchery stock and wild Snake River fall Chinook. Washington Department of Fisheries, Genetics Unit, Olympia.

Connor, W.P., H.L. Burge, R. Waitt, and T.C. Bjornn. 2002. Juvenile life history of wild fall Chinook salmon in the Snake and Clearwater rivers. North American Journal of Fisheries 22:703-712.

Connor, W. P., K. F. Tiffan, J., J. M. Plumb, and C. M. Moffitt. 2013. Evidence for density –dependent changes in growth, downstream movement, and size of Chinook salmon subyearlings in a large river landscape. Transactions of the American Fisheries Society 142:1453–1468.

Cooney, T. 1991. Estimation of Snake River fall Chinook returns to Ice Harbor, LF Hatchery, and over Lower Granite, 1990. Washington Department of Fisheries, Resource Planning and Resource Division, Battle Ground.

DART (Data Access in Real Time). 2014. Available at www.cbr.washington.edu/DART.

Fritts, A.L., and T.N. Pearsons. 2004. Smallmouth bass predation on hatchery and wild salmonids in the Yakima River, Washington. Transactions of American Fisheries Society 133:880-895.

Greene, C. M. and T. J. Beechie. 2004. Consequences of potential density-dependent mechanisms on recovery of ocean-type Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 61: 590–602.

Groves, P.A., J.A. Chandler, B. Alcorn, T.J. Richter, W.P. Connor, A.P. Garcia, and S.M. Bradbury. 2013. Evaluating salmon spawning habitat capacity using redd survey data. North American Journal of Fisheries Management 33:707–716.

LaVoy, L. 1992. Age and stock composition of fall Chinook at Lyons Ferry Hatchery, Ice Harbor Dam, and Lower Granite Dam in 1991. Columbia River Laboratory progress report 92-7. Washington Department of Fisheries Planning, Research, and Harvest Management Columbia River Laboratory, Battle Ground.

LaVoy, L. 1993. Stock composition of fall Chinook at Lower Granite Dam in 1992. Columbia River Laboratory progress report 93-5. Washington Department of Fisheries Planning, Research, and Harvest Management Columbia River Laboratory, Battle Ground.

LaVoy, L. 1994. Stock composition of fall Chinook at Lower Granite Dam in 1993. Columbia River Laboratory progress report 94-10. Washington Department of Fish and Wildlife Columbia River Laboratory, Battle Ground.

LaVoy, L. 1995. Stock composition of fall Chinook at Lower Granite Dam in 1994. Columbia River Laboratory progress report 95-6. Washington Department of Fish and Wildlife Anadromous Fish Division-Columbia River, Battle Ground.

LaVoy, L., and G. Mendel. 1996. Stock composition of fall Chinook at Lower Granite Dam in 1995. Columbia River Laboratory progress report 96-13. Washington Department of Fish and Wildlife Anadromous Fish Division-Columbia River, Battle Ground.

Mendel, G., and L. LaVoy. 1997. Stock composition of fall Chinook at Lower Granite Dam in 1996. Columbia River Laboratory progress report 97-10. Washington Department of Fish and Wildlife Anadromous Fish Division-Columbia River, Battle Ground.

Mendel, G. 1998. Stock composition of fall Chinook at Lower Granite Dam in 1997. Columbia River Laboratory progress report 98-15. Washington Department of Fish and Wildlife, Dayton.

Mendel, G. 1999. Stock composition of fall Chinook at Lower Granite Dam in 1998. Unpublished file report. Washington Department of Fish and Wildlife, Dayton.

Mendel, G. 2000. Fall Chinook run reconstruction at LGR for 1999. Unpublished file report. Washington Department of Fish and Wildlife, Dayton.

Moussalli, E. and R. Hilborn. 1986. Optimal stock size and harvest rate in multistage life history models. Canadian Journal of Fisheries and Aquatic Sciences 43: 135–141.

Naughton, G.P., D.H. Bennett, and K.B. Newman. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. North American Journal of Fisheries Management 24:534-544.

Nelle, R.D. 1999. Smallmouth bass predation on juvenile fall Chinook salmon in the Hells Canyon Reach of the Snake River, Idaho. Master's Thesis, University of Idaho, Moscow.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Federal Register 57:78(22 April 1992): 14,653-14,663.

Plumb, J.M., W.P. Connor, K.F. Tiffan, C.M. Moffitt, R.W. Perry, and N. S. Adams. 2012. Estimating and predicting collection probability of fish at dams using multistate modeling, Transactions of the American Fisheries Society 141:1364–1373.

Zabel, R. W., M. D. Scheuerell, M. M. McClure, and J. G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20:190–200.Fisheries Review 39:10–14.

Young, W., S. Rosenberger, D. Milks. 2012. Snake River Fall Chinook Salmon run reconstruction at Lower Granite Dam; Methods for retrospective analysis. MS report. 13 p.

Zimmerman, M.P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.

Appendix A: Redd Count Details

Fall Chinook Salmon Spawning Ground Surveys in the Snake River Basin Upriver of Lower Granite Dam, 1989–2013

by:

F.E. Mullins, A.P. Garcia, and W.P. Connor
U.S. Fish and Wildlife Service
Idaho Fishery Resource Office
Orofino, Idaho 83544

B.D. Arnsberg
Nez Perce Tribe
Department of Fisheries Resources Management
Orofino, Idaho 83544

P.A. Groves
Idaho Power Company
Environmental Affairs Department
Boise, Idaho 83707

Introduction

Redd counts are routinely used to document the spawning distribution of fall Chinook salmon *Oncorhynchus tshawytscha* in the Snake River basin upriver of Lower Granite Dam. The first reported redd counts were from aerial surveys conducted intermittently between 1959 and 1978 (Irving and Bjornn 1981; Witty 1988; Groves and Chandler 1996; Appendix 1). In 1986, the Washington Department of Fish and Wildlife began an annual monitoring program that, in addition to the Snake River, included aerial surveys of the Grande Ronde River the first year (Seidel and Bugert 1987) and the Imnaha River in subsequent years (Seidel et al. 1988; Bugert et al. 1989-1991; Mendel et al. 1992). The U.S. Fish and Wildlife Service and Idaho Power Company began contributing to this effort in 1991 by increasing the number of aerial surveys conducted each year and adding underwater surveys in areas of the Snake River that were too deep to be searched from the air (Connor et al. 1993; Garcia et al. 1994a, 1994b, 1996-2010; Groves 1993; Groves and Chandler 1996). The Nez Perce Tribe added aerial surveys in the Clearwater River basin beginning in 1988 (Arnsberg et. al 1992) and the Salmon River beginning in 1992. Currently surveys are conducted cooperatively by the Nez Perce Tribe, Idaho Power Company, U.S. Fish and Wildlife Service, and the Washington Department of Fish and Wildlife.

Our objective for this report was to consolidate the findings from annual redd surveys upstream of Lower Granite Dam into a single document that contained detailed information about the surveys from the most recent spawning season (Oct-Dec 2013) and summary information from previous years. The work conducted in 2013 was funded by the Bonneville Power Administration and Idaho Power Company.

Study Area

The study area included the unimpounded section of the Snake River between Lower Granite and Hells Canyon dams and portions of the major tributaries that enter therein (Figure 1). We refer to locations using river miles (RM) and river kilometers (RK) based on navigation charts of the Snake River (USACE 1990) and U.S. Geological Survey topographical maps. In 2013, surveys focused on ten river reaches: (1) the Snake River from the head of Lower Granite Reservoir (RM 145; RK 233) to Hells Canyon Dam (RM 247; RK 397), (2) the Clearwater River to the North Fork Clearwater River (RM 41; RK 66), (3) the first half mile of the North Fork Clearwater River (RM .2; RK .3), (4) the Clearwater River to the South Fork (RM 75; RK 120.6), (5) the entire Middle Fork Clearwater river (RM 97; RK 156), (6) the South Fork Clearwater River to Harpster (RM 14; RK 22),(7) the Selway River (RM 116; RK 186.6), (8) the Grande Ronde River to Wildcat Creek (RM 53; RK 85), (9) the Salmon River to the mouth of the South Fork Salmon River (RM 133; RK 213.9), and (10) the Imnaha River to the town of Imnaha (RM 19.5; RK 31.3). The number of surveys per reach varied between reaches and years. There were other areas searched over the years, though less consistently.

Examples include additional portions of the Snake, Grande Ronde, Salmon, Imnaha, and Middle Fork of the Clearwater, rivers, and portions of the Tucannon River, Potlatch River, Asotin Creek, Selway River, Alpowa Creek, Wenaha River, and Wallowa River.

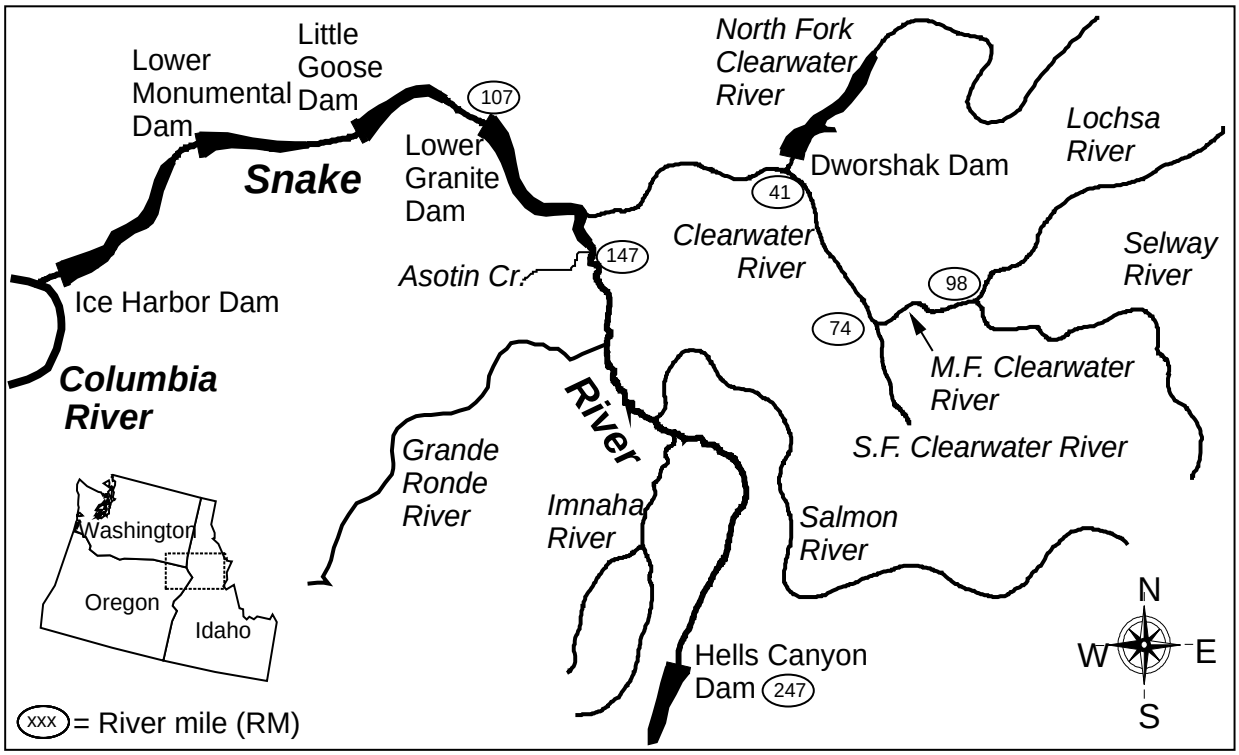

Figure 1. Map of the Snake River drainage in Oregon, Washington, and parts of Idaho.

Methods

From 1991 to 2009, aerial surveys of the Snake, Clearwater, Grande Ronde, and Imnaha rivers were scheduled to be conducted at 7-day intervals from about mid-October to early December. In previous years, and in the other rivers, surveys were generally conducted less frequently. Starting in 2010, surveys of these rivers were reduced to three or four and were distributed evenly within the mid-October-to-early-December period. Scheduled surveys were sometimes canceled, shortened, or conducted over a 3-day period, due to poor visibility or inclement weather. Redd counts from surveys conducted on partial days within the same week were recorded as one survey on the last day of the survey.

Aerial surveys were conducted from a helicopter flown at an altitude of about 700 ft., or less. At a minimum, observations were made by a primary observer and the pilot, though typically at least one additional observer was present. Redd locations were determined by referencing navigation charts of the Snake River (USACE 1990), or U.S. Geological Survey topographical maps, or using the Global Positioning System (GPS) coupled with mapping software. Observers recorded only the numbers of new redds. Redds observed in the Snake River that could not clearly be distinguished from the air were examined from the ground beginning in 1991. This “ground truthing” was also done in the other rivers though less consistently.

Due to the high cost and inherent dangers involved in aerial redd surveys, testing began in 2011 on a new system to estimate shallow water redds. The system, called the unmanned air system (UAS), uses cameras

mounted on small remote controlled drones to sample predetermined "index" sites. Results have been promising, and testing continues.

Redd surveys in the Snake River were also conducted using underwater search methods in areas too deep to be effectively searched from the air. In 1991 and 1992, deep-water redd surveys were conducted using methods developed by Swan (1989) that involved direct observation of bottom substrates by scuba divers (Connor et al. 1993; Garcia et al. 1994a). From 1993 to 2013, deep-water redd surveys were conducted using a submersible video camera connected to a camera cable, and viewing monitor(s). The search camera was either enclosed in an aluminum sheath mounted on a 90-lb lead weight, or attached to an aluminum frame mounted between two 30-lb lead weights, and could be adjusted 45 to 90 degrees down from horizontal (Groves and Garcia, 1998). The camera was suspended from a boat using a wire rope passed through a roller on the bow, and attached to a sounding-reel/depth-indicator mounted in the boat cabin.

Underwater surveys were accomplished by passing the camera over the river bottom in parallel paths spaced roughly 30 ft. apart. Distance between paths was determined by sight estimation or GPS. The distance between the camera and river bottom, and the angle of the camera, was adjusted to maximize the amount of viewable area without losing the ability to observe details of the bottom substrates. If a redd was observed, the distance between passes in the search pattern was reduced, and in some cases, the entire area was searched at least two times in the course of the spawning season.

Camera location was recorded using electronic surveying equipment or GPS. In areas where redds overlapped and could not be identified individually, the perimeter of the redd group (or patch) was surveyed and the overall area divided by 492.5 ft^2/redd (45.8-m^2/redd) based on measurements of fall Chinook salmon redds in the Snake and Columbia rivers (Groves and Chandler 2001). This produced an index count of the total number of redds in the group.

Underwater surveys were limited to areas greater than about 10 ft. deep with a dominant bottom substrate particle size (Bovee 1982) ranging from 1- to 6-in diameter (Raleigh et al. 1986). In 1991 and 1992, a few pilot surveys were conducted at known spawning sites. From 1993 to 2002, search crews attempted to annually search about 90 areas that fit the substrate size and the depth criteria (based on Hells Canyon Dam discharged of about 9,000 cfs). From 2003 to 2013, search crews attempted to search all deep-water sites where redds were observed in previous years, and find new deep water spawning sites when time allowed.

Results and Discussion

Snake River

In 2013, a total of 2,667 redds were counted in the Snake River (Table 1); 2,071 during four aerial surveys (Table 2), and 596 during surveys of 63 deep-water sites (Tables 3 and 4). The deep-water count includes redd estimates based on the measurement of areas where redds overlapped and could not be counted individually (Table 5). Visibility ratings for aerial surveys were mostly "Good" (Table 6). One survey was ended early due to high winds. The last survey was postponed two days due to weather, and covered a reduced area due to turbidity. The locations of all redds counted in the Snake River study area during aerial surveys since 1989 are presented in Appendix 2. The numbers of surveys conducted in the Snake and other rivers are

presented in Table 7. The locations of all redds observed using submersible cameras are presented in Table 8. The locations of all redds counted (aerial, and underwater counts combined) in the Snake River study area since 1989 are presented in Appendix 3.

Redds counted in the Snake River amounted to 44% of all redds observed upriver of Lower Granite Dam in 2013, and 52.8%±8.5% (range, 43-60%) over the past five years (2009-2013). The percentage of redds counted using submersible cameras from 2009 to 2013 averaged 27.6%±5.1% for the Snake River (range, 22-34%), and 14.9%±4.6% (range, 10-19%) for all redds counted above Lower Granite Dam.

Table 1. Number of fall Chinook salmon redds counted in the Snake River and tributaries between Lower Granite and Hells Canyon dams, 1989-2013. An empty cell indicates no surveys were conducted in the corresponding river and year. Some of the data is broken down into method and river mile (RM) sections. Data collected by the Washington Department of Fish and Wildlife, Nez Perce Tribe, Idaho Power Company, and the U.S. Fish and Wildlife Service. Abbreviations: SR=Snake River, LCR=Lower Clearwater River, NFCR=North Fork Clearwater River, UCR=Upper Clearwater River, SFCR=South Fork Clearwater River, MFCR=Middle Fork Clearwater River.

	Redds counted by year																								
Location	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
SR (air+ground)[a]	58	37	46	47	60	53	41	71	49	135	273	255	535	878	1,118	1,218	1,042	696	714	1,233	1,511	1,950	1,949	1,412	2,071
SR (underwater)			5	0	67	14	24	33	9	50	100	91	174	235	394	491	399	329	403	586	584	1,016	865	416	596
Asotin Creek	0	0	0	0											3	4	6	1	0	3	0	4	2	30	53
Grande Ronde	0	1	0	5	49	15	18	20	55	24	13	8	197	111	93	162	129	41	80	185	104	263	154	303	255
Wenaha River																		1	1	1	0	0		5	
Wallowa River																		0	0	0	0	0		1	
Salmon River				1	3	1	2	1	1	3	0	0	22	31	18	21	27	9	18	14	34	8	60	34	31
Imnaha River	1	3	4	3	4	0	4	3	3	13	9	9	38	72	43	35	36	36	17	68	36	132	24	85	38
LCR (RM0-41)[d]	10	4	4	25	36	30	20	66	58	78	179	164	290	520	544	592	433	251	711	919	1,142	1,583	1,557	1,558	2,774
Potlatch River											7	0	24	3	1	1	0	0	0	16	0	281	2	283	10
NFCR [b&c]	0	0	0	0	0	7	0	2	14	0	1	0	1	0	8	2	0	0	0	0	1	8	3	0	3
UCR (RM 42-74)				1	0	0	0	0	0	0	2	8	16	4	19	36	54	6	7	22	42	49	17	52	84
SFCR				0	0	0	0	1	0	0	2	1	5	0	0	0	0	0	0	3	12	2	31	41	47
MFCR (RM 75-98)						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	28
Selway River						0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	1	8	20	10
Totals	69	45	59	82	219	120	109	197	189	303	586	536	1,302	1,854	2,241	2,562	2,126	1,370	1,951	3,055	3,467	5,297	4,675	4,243	6,000

[a] The targeted search area was the entire reach from the head of Lower Granite Reservoir to Hells Canyon Dam.
[b] Surveys covered from the mouth to the Ahsahka boat ramp in 2002. Surveys covered from the mouth to Dworshak Dam in previous years.
[c] It was estimated that 50% of the redds were missed because of turbid water and not conducting a survey after October 30 (Arnsberg and Kellar, 2006)
[d] Due to hight turbidity redds were estimated for the lower Clearwater River during 2012..

Table 2. New fall Chinook salmon redds counted during aerial and ground surveys of the Snake River in 2013 (Data collected by Idaho Power Company and the U.S. Fish and Wildlife Service). Counts are presented by river mile (RM), river kilometer (RK), and date. An empty cell indicates no redds were observed at the corresponding location and date. A dash (-) indicates no search was conducted at the corresponding river mile.

		New Redds Counted by Flight Date				Ground	
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
145.3	233.8						
147.1	236.7						
148.0	238.1						109
148.5	238.9	1	74	34			
148.9	239.6						
149.0	239.7			1			1
149.1	239.9		12	9			21
149.2	240.1						
149.6	240.7		1	1			2
149.8	241.0						
150.9	242.8						
151.7	244.1						
151.9	244.4		49	40			89
152.1	244.7						
152.3	245.1	4	32	23			59
152.8	245.8	1	1				2
154.3	248.3		2				2
154.7	248.9						
155.2	249.7						
155.6	250.4			4			4
155.8	250.7		3	2			5
157.6	253.6		6	8			14
159.3	256.3		6	9			15
159.7	257.0		2	1			3
159.8	257.1			1			
161.0	259.0	2	8				11
162.4	261.3	3	34	22			59
163.4	262.9		5	4			9
163.7	263.4		4	4			8
164.7	265.0	3	36	9			48
165.3	266.0	5	42	10			57
165.8	266.8	8	43	10			61
166.2	267.4	2	14				16

Table 2 Continued.

		New Redds Counted by Flight Date				Ground	
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
166.6	268.1						
167.7	269.8		1				1
167.9	270.2		9				9
168.6	271.0		5	2			7
168.7	271.4	5	7	11			23
169.7	273.0		15	6			21
171.9	276.6						
172.5	277.6		18	6			24
173.9	279.8		9	7			16
175.1	281.7						
175.2	281.9		8				8
175.9	283.0		3				3
176.5	284.0		1	1			2
176.7	284.3		8				8
177.9	286.2		1				1
178.3	286.9		4				4
178.4	287.0						
178.5	287.2						
178.9	287.9	2	16	11			29
179.5	288.8		4	7			11
179.6	289.0		11	13			24
181.7	292.4	1	9	1			11
182.3	293.3						
183.2	294.8						
183.5	295.3		21	6			27
187.4	301.5	1	3	11			15
187.5	301.7						
187.7	302.0						
187.8	302.2		2				2
188.0	302.5						10
188.2	302.8	2		8			

Table 2 Continued.

		New Redds Counted by Flight Date				Ground	
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
189.9	305.5						
190.1	305.9						
190.2	306.0	2	2	5			9
190.6	306.7		5	1			6
190.8	307.0	1	24	20			45
191.0	307.3						
191.7	308.4	4	3	4			11
193.4	311.2						
193.6	311.5		11				11
193.7	311.6	3	20				23
193.9	312.0	3	29				32
194.1	312.3		1				1
195.3	314.2						
195.7	314.9	1	8				9
196.0	315.4	3	36				39
198.2	318.9		14	2			16
198.8	319.9	4	44		1		49
199.2	320.5						
199.4	320.8						
199.7	321.3						
201.0	323.4		3				3
203.1	326.8		11				11
205.3	330.3	2	29				31
205.4	330.5	3	18				21
206.5	332.3	4	34	8	1		47
206.6	332.4	2	2	1			5
207.5	334.2		5				5
207.8	334.4		8				8
208.0	334.7	1	63	5			69
208.3	336.0		4				4
209.6	337.2						
210.5	338.7						
211.9	340.9		35	4			39

Table 2 Continued.

		New Redds Counted by Flight Date				Ground	
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
212.3	341.6		1				1
213.3	343.2	1					1
213.6	343.7						
213.7	343.8	1	7				8
213.9	344.2		8				8
214.5	345.1		4				4
215.4	346.6	2	4	1			7
216.1	347.7		12	4			16
216.5	348.3						
216.9	349.0	1	10	1			12
217.3	349.6		42	18			60
217.8	350.4		1				1
218.5	351.6		10				10
218.7	351.9	1	46		1		48
219.0	352.4	1	17	8	1		27
219.3	352.9	1	18	4			23
220.7	355.1						
220.8	355.3		11	7			18
221.0	355.6		2				2
221.3	356.1						
221.8	356.9			3			3
222.3	357.7		8	4			12
222.7	358.3		3				3
222.9	358.6		33	24			57
223.2	359.1						
223.3	359.3		25	4			29
224.7	361.5						
224.8	361.7						

Table 2 Continued.

		New Redds Counted by Flight Date				Ground	
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
225.0	362.0						
225.1	362.2		12				12
226.6	364.6			4			4
226.7	364.8	2	2	3			7
227.2	365.6						
227.9	366.7		1				1
229.8	369.7		3				3
231.3	372.2						
235.0	378.1	1	11				12
235.6	379.1	4	23		2		29
235.7	379.2						
236.0	379.7						
236.1	379.9		7				7
237.0	381.3	3	22		3		28
238.4	367.5		7				7
238.6	383.9	2	21				23
239.8	385.8	3	2				5
240.4	386.8		14				14
240.6	387.1	1	46		5		52
240.7	387.3		1				1
241.0	387.8		14				14
241.7	388.9		10				10
242.8	390.7		29		2		31
243.2	391.3		18				18
244.0	392.6		3				3
244.5	393.4		37				37
244.7	393.7						
245.0	394.2						
245.3	394.7		30				30
245.7	395.3	3	21				24

Table 2 Continued.

		New Redds Counted by Flight Date					
RM	RK	21-Oct	4-Nov	18-Nov	4-Dec	Counts	Totals
246.0	395.8						
247.5	398.2		4				4
Totals		100	1,538	417	16		2,071

Table 3. Record of fall Chinook salmon redds counted in the Snake River using submersible cameras in 2013 (Data collected by the Idaho Power Company and U.S. Fish and Wildlife Service). Counts are presented by river mile (RM) and river kilometer (RK). At RM 212.2, 1,207 m^2 of disturbed bottom substrates. We estimated the disturbed bottom substrates amounted to roughly 26 redds using a conversion factor of 45.8 m^2/redd.

RM	RK	Totals
160.6	258.4	2
163.6	263.2	4
165.7	266.6	2
166.2	267.4	4
166.6	268.1	10
168.7	271.4	30
169.6	272.9	34
179.6	289.0	125
183.2	294.8	31
183.6	295.4	10
184.6	297.0	8
185.9	299.1	4
188.9	303.9	8
189.1	304.3	17
190.0	305.7	39
192.9	310.4	31
194.1	312.3	13
194.2	312.5	7
195.2	314.1	4
195.6	314.7	47
198.2	318.9	7
198.8	319.9	5
199.4	320.8	6
203.1	326.8	10
205.7	331.0	10
208.0	334.7	1
208.3	335.2	6
212.2	341.4	26
212.3	341.6	4
213.3	343.2	3
216.9	349.0	2
218.4	351.4	15
218.8	352.0	7
219.3	352.9	4
220.6	354.9	9
228.0	366.9	1

235.0	378.1	40

Table 3. Continued.

RM	RK	Totals
236.3	380.2	2
242.7	390.5	8
Total		596

Table 4. List of the 63 sites searched for fall Chinook salmon redds in the Snake River by river mile (RM), 2013.

RM Searched	RM Searched
149.1	192.9
153.2	193.4
154.1	193.6
155.0	194.1
155.2	194.2
155.6	195.2
158.0	195.6
160.6	198.2
162.4	198.8
163.6	199.4
165.3	203.1
165.7	205.7
166.2	208.0
166.6	208.3
168.7	212.2
169.6	212.3
171.3	213.3
171.9	216.9
177.6	218.4
178.3	218.8
178.5	219.3
179.6	220.6
181.7	221.0
183.2	222.3
183.6	223.2
184.6	224.7
185.7	228.0
185.9	228.4
188.9	235.0
189.1	236.3
190.0*	242.7
190.0	

*IPC and the USFWS did two coordinated, non-overlapping searches within the same tenth of a mile.

Table 5. Area (m^2) containing overlapping redds in the Snake River, by river mile, 1995-2013.

	Area (m^2) by river mile							
Year	158.0	179.6	188.9	190.0	193.0	208.0	212.2	221.0
1995		170						
1996		238						
2001		1,226						
2002		1,282						
2003		1,122					1,184	
2004	1,259	1,479			981		1,257	
2005		990			900	620	1,270	
2006		918					613	
2007		1,275					1,293	392
2008		1,309					1,758	
2009		1,082					1,449	
2010			1,187	2,001			1,754	
2011				1,433			1,691	
2012							1,964	
2013							1,207	

Table 6. Flight information for aerial surveys of the Snake River in 2013. For all flights, aircraft vendor was Hillcrest (Lewiston, ID), aircraft type was Bell-Jet Ranger, and observers were P. Groves, and Ken Bugler.

	Flight information by flight date			
Category	21-Oct	4-Nov	*18-Nov	**4-Dec
Start Time (Hangar)	9:16	10:01	10:29	8:30
End Time (Hangar)	12:20	1:42	1:35	10:30
River Mile Start	144.1	144.1	144.1	168.9
River Mile End	247.5	247.5	*233	247.5
Pilot	K. White	P. Fenter	P. Fenter	P. Fenter
Weather	Mostly Clear	Mostly Cloudy	Cloudy	Clear
Flow at Anatone (cfs)	15,500	15,100	15,300	21,300
Flow at Hells Canyon Dam (cfs)	9,110	8,910	8,930	9,110
Obs Rating: Asotin to Grande Ronde River	Fair	Good	Good	Poor
Obs Rating: G.R. River to Salmon River	Good	Good	Good	Good
Obs Rating: Salmon River to H.C. Dam	Good	Good	Good	Good

Notes:

* On November 18, the survey was terminated due to high winds at RM 233.
** On December 4, we flew directly to RM 168.9 and began surveying upstream to HCD.

Table 7. Number of redd surveys conducted in the Snake River and tributaries between Lower Granite and Hells Canyon dams, 1989-2013. Data for underwater surveys indicates the number of discrete patches of gravels searched, whereas all other data indicates the number of helicopter flights over portions of the corresponding river.

	Redd surveys by year																								
Location	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
Snake (helicopter)	2	3	9	8	8	8	7	7	8	8	9	9	10	7	7	8	9	6	8	8	8	4	4	4	4
Snake (camera)			1	3	50	73	42	32	63	48	73	60	67	60	47	67	41	56	57	71	65	86	67	63	63
Lower Clearwater (RM 0-41)	2	2	2	2	5	5	3	4	9	5	10	11	8	9	9	10	10	6	8	8	9	4	4	2	4
Potlatch River											1	5	3	3	2	3	0	0	2	2	2	2	4	2	4
N.F. Clearwater				2	4	5	3	5	9	5	7	11	4	9	9	10	10	6	8	8	9	4	2	2	4
Clearwater River (RM 45-74)				2	4	5	2	1	7	5	8	11	4	3	9	2	3	2	2	3	11	3	3	2	3
S.F. Clearwater				2	4	4	1	3	7	5	8	6	7	3	3	2	1	1	1	4	3	2	3	2	3
M.F. Clearwater (RM 75-98)						1	2	2	2	5	3	4	5	1	1	0	1	1	1	4	3	2	3	2	3
Selway River						1	2	2	2	5	3	5	6	1	1	0	2	1	1	5	3	2	3	2	3
Asotin Creek	1	2	1												2	2	3	2	1	2	2	1	1	0	0
Grande Ronde	1	1	3	6	8	7	3	4	8	6	7	7	9	7	8	8	9	6	8	7	10	3	3	4	3
Wenaha River																		2	1	2	1	1	N/S	1	N/S
Wallowa River																		1	1	1	1	1	N/S	1	N/S
Salmon River				2	3	3	1	4	3	3	3	2	1	2	3	3	3	3	5	3	4	2	2	1	1
Imnaha River	2	1	9	6	8	8	6	5	7	6	9	9	9	7	8	8	8	6	6	7	8	3	2	3	3

Table 8. Numbers of fall Chinook salmon redds counted using submersible cameras in the Snake River, 1994-2013. Counts are presented by river mile (RM) and river kilometer (RK). A zero indicates the site was searched but no redds were observed. An empty cell indicates the site was not searched in the corresponding year.

		Year																			
RM	RK	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
149.1	239.9																	6	0	0	0
148.5	238.9	0		0	0		0	0	1	3		8	0			0		0			
149.1	239.9															1	0	1			
151.7	244.1				0		0	0	0	0		0						15			
153.2	246.5																		0	0	0
154.1	247.9																		0	0	0
155.0	249.4											2		0	0	5	0	0	0	0	0
155.2	249.7																0	1	0	0	0
155.6	250.4	0		0	0	0	0	0	0	0				0	0	0	0	1	0	0	0
156.4	251.6									18	0		0	0	0	0	0	0	0		
158.0	254.2	0		0	0	0	0	0	0	1	4	30	6	0	0	0	0	0	0	0	0
160.6	258.4																				2
162.4	261.3	0		2	0	0	0	0	6	1	0		1	5	12	3	0	4	0	0	0
163.6	263.2																				4
163.7	263.4	0		0	0		0	0	0	0	10	9	5	3	14	5	0	20	0		
165.1	265.6																0		0		
165.3	266.0	0							4	0						11	1	13	25	0	0
165.7	266.6	0		0	0	0	0	0	6	8	48	13	12	13	11	15	15	35	45	5	2
166.2	267.4	0		0	0	0	0	0	0	1	0		3	5	9	9	2	13	5	0	4
166.6	268.1	0		0	0	6	0	1	0	9	1	8	21	11	10	30	18	27	27	0	10
168.7	271.4										28	24	21	28	16	18	3	6	35	16	30
169.6	272.8																				34
169.7	273.0	0		0	0						10	17	15	12	5	10	5	5	31	10	
171.3	275.6																		0	0	0
171.9	276.6																		0	0	0
177.6	285.8																		0	0	0
178.3	286.9																		0	0	0
178.5	287.2										25					0	0	14	4	0	0
179.6	289.0	8	19	24	5	16	30	48	67	75	94	82	100	83	82	97	115	155	141	85	125
181.7	292.4																		4	0	0
181.8	292.5	0			0		1		0	0		5	0	1	0	1	6				
183.1	294.6	0			0	0	2	0	0	4		1	6		6	0	1	13			
183.2	294.8																		12	6	31
183.5	295.3											9		4	1	3	7	5	13	4	
183.6	295.4																				10
184.6	297.0																				8
184.7	297.2	0			0		0	0	0	0	6	1	9	5	1	1	3	0			
185.7	298.8											0			0	0	8	0	0	0	0
185.9	299.1													6		2	12	8	2	14	4
188.2	302.8						0	0	2	0	3	1	2			1	3	17	0	2	
188.9	303.9													4	8	9	29	35	27	9	8
189.1	304.3													17	0	27	12	24	26	13	17

Table 8 Continued.

		Year																			
RM	RK	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	‘11	‘12	‘13
189.9	305.5																		9		
190.0	305.7													10		14	17	44	35	15	39
190.1	305.9																		9	9	
190.2	306.0			0	0	0								0				6			
190.8	307.0													2			5	0			
192.9	310.4																				31
193.0	310.5									21	16	22	21	10	13	9	35	45	4	33	
193.4	311.2											1	0	0	4	2	0	8	0	0	0
193.6	311.5	0	0	0	0	0	0	0	4	2		3	0	2	5	0	0	0	9	0	0
193.7	311.7	0	0	0	0	0	0	0	1	1		2	2	1	0	0	0	0			
193.8	311.8	0	0	0	0	0	0	0	0	1		2	0	0	4	1	0	7	3	0	
194.1	312.3	5	0	0	0	0			0	0		5	0	4	4	2	10	8	9	6	13
194.2	312.5																				7
194.4	312.8	0	0		0		0	0	0	1	5	23	13	2	1	9		12	3	4	
195.2	314.1																	3	5	0	4
195.7	314.9												10	15	19	28	31	35	84	30	47
198.2	318.9	0	0	2	0	0	6	5	19	11	13	18	7	4	6	9	13	9	14	9	7
198.8	319.9	0	0	0	0	0	4	4	2	2	4	12	2	3	7	12	4	19	16	5	5
199.4	320.8	0	0	5	0	0	2	1	2	0	0	1	0	7	6	13	7	9	14	4	6
203.1	326.8	0	0	0	0	10	0	0	0	0	2			4	5	9	3	3	10	8	10
205.7	331.0																0	5	8	8	10
206.6	332.4	0	0	0			0					0						3			
208.0	334.7	0	0	0	4	0	11	0	0	1	14	5	15	4	2	4	4	4	4	0	1
208.3	335.2	0	0	0	0	0	4	0	4	0	0		0	5	3	8	5	5	5	2	6
211.9	340.9						1				0										
212.2	341.4	0	2	0	0	17	24	28	37	37	33	27	29	13	34	38	39	43	40	43	26
212.3	341.6		0			0	2	3	8	5	2	8	4	3	4	7	4	5	8	2	4
213.3	343.2	0	0		0	0	0	0	4	8	8	6	2	1	7	11	7	2	0	0	3
214.5	345.1																	3			
216.9	349.0						4	0	1		2	23	8	1	12	15	8	23	12	4	2
218.2	351.1					0	0		0							4		3			
218.4	351.4																				15
218.5	351.6						0	1	0	11	1	37	48	0	12	45	76	89	75	8	
218.7	351.9		3		0	0	1		4	2	0	3	7		9	8	12	35	3		
218.8	352.0																				7
219.0	352.4						1			0											
219.3	352.9											4				3	6	8	5	6	4
220.6	354.9														6	15	1	9	0	8	9
221.0	355.6						0	0	0	1	0		0	5	22	5	0	0	6	0	0
222.3	357.7	0	0		0	0	0	0	0	0	0	6			0	0	0	0	3	0	0
222.8	358.5	0	0				0	0			0	2					0	1			
223.1	359.1						3	0	0				0	0	5	1	0	0			

Table 8 Continued

		Year																			
RM	RK	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
223.2	361.5																		6	0	0
224.7	361.5											3			0	0		0	7	0	0
228.0	366.9	0	0	0	0	0	2	0	0	0	1					2	0	3	8	0	1
228.4	367.5																0	7	2	3	0
228.7	368.0	0	0		0		0					3			0	0		1			
235.0	378.1	0	0			0		0		9	56	48	28	31	31	42	48	68	0	30	40
235.7	379.2		0	0	0	0					0	2			4	9					
236.0	379.7	0										1									
236.3	380.2	0										1	1		2	3	3	12	11	2	2
236.9	381.2	1	0	0	0	0				0			0								
237.0	381.3	0	0	0	0	0			0		2			1	0						
239.4	385.2										6							13	9	4	
242.8	390.7																		35	9	
242.7	390.5																				8
242.9	390.8					1	2		1	2	2	11	8		5	4		32			
Totals		14	24	33	9	50	100	91	174	235	394	491	400	329	403	586	584	994	865	416	596

Clearwater River basin

A total of 2,956 redds were counted in the Clearwater River basin in 2013 (Table 1). Redds were observed in six rivers: (1) 2,886 redds in the Clearwater River, with 2,774 between RM 0-41 during four surveys (observation ratings “good” to “excellent”), and 84 between RM 42-74 during three surveys (observation conditions rated “good” to “excellent”); Tables 7, 9, and 10); (2) 47 redds in the South Fork Clearwater River during three surveys with “good” to “excellent” conditions (Tables 7 and 11); (3) 10 redds in the Selway River during three surveys with “good” to “excellent” conditions (Tables 7 and 12); (4) and 10 redds in the Potlatch River during four surveys from the mouth upstream to RM 4. (5) The Middle Fork Clearwater River was surveyed three times in 2013 (Table 7), with 28 redds observed; (6) and the North Fork of the Clearwater was survey four times with 3 redds observed. The locations of all redds counted in the Clearwater River from 1990 to 2013 are given in Appendix 4.

Redds counted in the Clearwater River basin amounted to 49% of all redds observed upriver of Lower Granite Dam in 2013, and 40.2%±7.0% (range, 35-49%) over the past five years (2009-2013).

Table 9. New fall Chinook salmon redds counted in the Clearwater River in 2013. Counts are presented by river mile (RM), river kilometer (RK), and flight date. An empty cell indicates no redds were observed at the corresponding location and date. A dash (-) indicates no search was conducted at the corresponding river mile. (Data collected by the Nez Perce Tribe).

		New Redds Counted by Flight Date						
RM	RK	14-Oct	16-Oct	30-Oct	15-Nov	18-Nov	25-Nov	Totals
5.2	8.4				2			2
6.8	12.5			2	3		5	10
8.0	12.9							
8.5	13.6			14				14
9.0	14.5							
9.5	15.3				10			10
11.0	17.7				7			7
11.1	17.8							
11.9	19.2							
12.4	20.0				3		1	4
13.8	22.2			4	2			6
14.0	22.5							
15.2	24.5				1			1
16.4	26.4	17		30	8			55
17.0	27.4				10			10
17.3	27.9	2		4				6
17.8	28.6				12			12
18.0	29.0	66		29				95
19.1	30.7	40		39	4		16	99
19.3	31.1	5		10	13			28
20.0	32.2			24	39		5	68
21.0	33.8	19		60	3		8	90
21.5	34.6	1		5	2		7	15
21.7	35.0							
22.0	35.4	72		156	142		128	498
22.2	35.7	16		203	51		60	330
22.6	36.4			17	73			90
23.3	37.5	3		24	28			55
23.9	38.5			8			3	11
25.1	40.4	1		2	19			22
26.0	41.8				6			6
26.5	42.7	23		52				75
27.4	44.1						55	55
27.5	44.3	20		57				77
28.4	45.7	19		39	12			70
29.2	47.0			1			1	2
29.8	47.9				5			5
30.1	48.4	6		25				31
31.5	50.7	13		20				33
32.5	52.3	26		56			40	122
32.8	52.8	5		46	9			60

Table 9 Continued.

		New Redds Counted by Flight Date						
RM	RK	14-Oct	16-Oct	30-Oct	15-Nov	18-Nov	25-Nov	Totals
34.0	54.7	11		63	11			85
35.4	60.0	33		20	5			58
35.7	57.5			19	30			49
36.2	58.3	14		70	31			115
37.9	61.0			10			1	11
39.1	62.9	21		77				98
39.6	63.7	5		7	13			25
40.3	64.9	35		175	24		25	259
0.2	0.3						3	3
43.2	69.5	1						1
43.7	70.3				1		2	3
44.5	73.3			1				1
45.0	72.4							
45.5	73.8							
46.1	74.2			1				1
49.8	80.2							
51.4	82.7							
51.6	83.0		1	1				2
52.4	84.4							
52.7	84.8		1	2		2		5
53.6	86.2		2			2		4
54.9	88.4					2		2
58.1	93.5							
60.8	97.8			1				1
63.1	101.6			1				1
63.8	102.8		1			1		2
65.5	105.4			5				5
65.7	105.8							
66.0	106.2		2	13		8		23
66.4	106.8							
67.3	108.3			3				3
67.9	109.3			1				1
68.7	110.5		2	2				4
72.5	116.8					12		12
73.9	119.0		2	7		2		11
74.4	119.7			2				2
Totals		474	11	1,408	579	29	360	2,861

Table 10. Flight information, river flow, and visibility rating for aerial redd surveys of the Clearwater River in 2013. (Data provided by the Nez Perce Tribe).

	Flight Information by Flight Date					
Landmark	14-Oct	16-Oct	30-Oct	15-Nov	18-Nov	25-Nov
River Mile Start	4	45	4	4	45	4
River Mile End	45	75	75	75	75	75
Flow (cfs) at Spalding Gauge	3,560		3,220	4,230		3,540
Flow (cfs) from Dworshak Dam	1,600		1,600	1,600		1,700
Flow (cfs) at Orofino Gauge	2,060	1,920	1,560	2,360	2,360	2,830
Observation rating	Excel	Excel	Excel	Good	Good	Excel

Table 11. New fall Chinook salmon redds counted in the South Fork Clearwater River in 2013. Counts are presented by river mile (RM), river kilometer (RK), and flight date. An empty cell indicates no redds were observed at the corresponding location and date. (Data collected by the Nez Perce Tribe).

			New Redds Counted by Flight Date			
RM	RK	Landmark	16-Oct	30-Oct	18-Nov	Total
0.1	0.2	Just above mouth	1			1
0.2	0.3	Island above mouth	2			2
0.9	1.4	Eater treatment pond			1	1
1.1	1.8	Upper end of Kooskia			2	2
2.1	3.4	Kooskia school track		1		1
2.8	4.5	Below Stites			4	4
5.4	8.7	Upper end of Stites			3	3
5.6	9.0	At Y in the road	1		2	3
6.2	9.9	Where Lukes Gulch road hits the river	2	10	4	16
6.7	10.8	About 400 m. below cliff on bank			3	3
6.8	11.0	By bend and cliff on west bank	2			2
7.3	11.7	Just above big bend	1	1		2
7.5	12.1	Below Lukes Gulch		2		2
7.8	12.6	Below Lukes Gulch		1		1
11.9	19.1	Just above Lukes Gulch	2		2	4
Totals			11	15	21	47
River Mile Start			0	0	0	
River Mile End			14	14	14	
River Flow (cfs) at S. Fork Gauge			238	176	240	
Observation Rating			Excellent	Excellent	Good	

Table 12. New fall Chinook salmon redds counted in the Selway River in 2013. Counts are presented by river mile (RM), river kilometer (RK), and flight date. An empty cell indicates no redds were observed at the corresponding location and date. (Data collected by the Nez Perce Tribe).

			New Redds Counted by Flight Date			
RM	RK	Landmark	16-Oct	30-Oct	18-Nov	Total
0.06	0.1	At mouth east shore	1	4		5
2.6	4.2	Just below first bridge	1		2	3
4.5	7.2	Ranger Station		1		1
15.9	25.7	Below Gedney Cr.			1	1
Totals			2	5	3	10
River Mile Start			0	0	0	
River Mile End			31	31	31	
River Flow (cfs) near Lowell			880	1,140	1,010	
Observation Rating			Excellent	Excellent	Good	

Table 13. New fall Chinook salmon redds counted during aerial surveys of the North Fork Clearwater River, and river flows, 2013. Counts are presented by river mile (RM), river kilometer (RK), and date. An empty cell indicates no redds were observed at the corresponding location and date. A dash (-) indicates no search was conducted at the corresponding river mile. (Data collected by the Nez Perce Tribe).

			New Redds Counted by Flight Date				
RM	RK	Landmark	14-Oct	30-Oct	15-Nov	25-Nov	Totals
0.2	0.3	N.F. Clearwater				3	3
Totals							3
Flow (cfs) from Dworshak Dam			1,600	1,600		1,700	

Asotin Creek

Fifty-three redds were observed during ground surveys of Asotin Creek during 2013. The surveys were conducted by staff of the WDFW, and covered the lower 3.1 miles of the creek. Redds counted in 2013 mark the highest number of redds ever counted on Asotin Creek. Undoubtably the dense canopy covering Asotin Creek made aerial surveys difficult. No aerial surveys were conducted in 2013.

Grande Ronde River basin

In 2013, a total of 255 redds were counted in the Grand Ronde River during three aerial searches with “poor” to “excellent” observation conditions (Tables 1, 7, and 15).

Redds counted in the Grande Ronde River amounted to roughly 4.3% of all redds observed upriver of Lower Granite Dam in 2013, and 4.5%±1.7% (range, 3-7.1%) over the past five years (2009-2013). Locations of all redds counted in the Grande Ronde River from 1994 to 2013 are presented in Appendix 6.

Table 15. New fall Chinook salmon redds counted during aerial surveys of the Grande Ronde River, and flight information, 2013. Counts are presented by river mile (RM), river kilometer (RK), and date. An empty cell indicates no redds were observed at the corresponding location and date. A dash (-) indicates no search was conducted at the corresponding river mile. (Data collected by the Nez Perce Tribe).

		New Redds Counted by Flight Date			
RM	RK	23-Oct	6-Nov	20-Nov	Totals
0.1	0.2				
0.2	0.3				
0.4	0.6	8	6		14
0.6	1.0	1	7		8
0.7	1.1				
1.0	1.6	10	15		25
2.0	3.2	1	30		31
2.3	3.7	1	3		4
3.4	5.5				
3.7	6.0	4	1	5	10
4.0	6.4	1	10		11
5.0	8.0	2	1		3
5.2	8.4	2	1		3
6.8	10.9				
7.0	11.3	3	1		4
7.4	11.9	1	1		2
7.5	12.1	9	23		32
9.6	15.4				
10.2	16.4	2	2		4
10.4	16.7				
10.5	16.9	4	5		9
10.6	17.1	1	1		2
11.3	18.2	3	5		8
11.4	18.3				
12	19.3				
12.2	19.6				
12.4	20.0	4	5		9
12.5	20.1	1	1		2
13.4	21.6	1	1		2
13.5	21.7				
13.6	21.9		2		2
15.0	24.1		3		3

Table 15 continued.

RM	RK	New Redds Counted by Flight Date			
		23-Oct	6-Nov	20-Nov	Totals
16.2	26.1				
16.4	26.4		7		7
16.5	26.5		2		2
17.7	28.5		5		5
18.2	29.3		4		4
18.6	29.9				
19.3	31.1		4		4
19.6	31.5		2		2
22.0	35.4		2		2
22.2	35.7		2		2
22.7	36.5		4		4
25.5	41.0		3		3
26.2	42.2				
26.5	42.6		1		1
28.0	45.1		5		5
32.8	52.8		2		2
33.5	53.9		2		2
37.4	60.2		10		10
37.5	60.3		2		2
38.5	61.9		2		2
43.0	69.2		6		6
44.0	70.8		2		2
Totals		59	191	5	255
River Mile Start		52.7	52.7	52.7	
River Mile End		0	0	0	
Flow (cfs) at Troy		820		1,400	
Observation Rating		Excellent	Fair	Poor	

Salmon River

A total of 31 redds were observed during one surveys of the Salmon River in 2013 (Table 1, 7, and 16). Observation conditions were reported as "good". Redds counted in the Salmon River amounted to less than 1% of all redds counted upstream of Lower Granite Dam in 2013, and .7%± .4% (range, .2-1.3%) of all redds counted upriver of Lower Granite Dam over the past five years (2009-2013). The locations of all redds counted in the Salmon River are given in Appendix 7.

Imnaha River

A total of 38 redds were observed during three surveys of the Imnaha River in 2013 (Tables 1, 7, and 17). Observation conditions were reported as "good" to "excellent". Redds counted in the Imnaha River amounted to 0.6% of all redds observed upriver of Lower Granite Dam in 2013, and 1.3%±.9% (range, .5-2.5%) of all redds counted upriver of Lower Granite Dam over the past five years (2009-2013). The locations of all redds counted in the Imnaha River are given in Appendix 8.

Table 16. Fall Chinook aerial spawning ground surveys conducted in the Salmon River, and flight information, 2013. Counts are presented by river mile (RM), river kilometer (RK), and date. An empty cell indicates no redds were observed at the corresponding location and date. A dash (-) indicates no search was conducted at the corresponding river mile. (Data collected by the Nez Perce Tribe).

		New Redds Counted by Flight Date	
RM	RK	21-Nov	Totals
14.4	23.1	18	18
16.4	26.4	12	12
103.5	166.5	1	1
Totals		31	31

River Mile Start	0
River Mile End	133.0
River Flows (cfs) at Whitebird	5,200
Observation rating	Good

Table 17. New fall Chinook salmon redds counted during aerial surveys of the Imnaha River, and flight information, 2013. Counts are presented by river mile (RM), river kilometer (RK), and date. An empty cell indicates no redds were observed at the corresponding location and date (Data collected by the Nez Perce Tribe).

		New Redds Counted by Flight Date			
RM	RK	18-Oct	6-Nov	20-Nov	Totals
0.2	0.3	1	1		2
0.4	0.6			1	1
0.5	0.8	4	2	1	7
0.8	1.3	1	1		2
1.2	1.9	1	1		2
1.5	2.4	1	1		2
2.5	4.0	2	3		5
2.7	4.3			1	1
2.8	4.5			1	1
2.9	4.7	2	1		3
3.2	5.1		3		3
3.4	5.5		1		1
3.5	5.6		2		2
4.1	6.6		2	1	3
4.3	6.9			2	2
11.5	18.5			1	1
Totals		12	18	8	38
River Mile Start		19.2	19.2	19.2	
River Mile End		0	0	0	
River Flow (cfs) at Imnaha		133	N/A	N/A	
Observation rating		Excellent	Fair	Fair	

Escapement of adults versus redds counted

The numbers of adult fall Chinook salmon escaping to the spawning grounds, per redds counted within (adults/redds) is used as a rough indicator of redd count consistency. In 2013 an estimated 27,643 adults escaped (Table 18 and Figure 2) to the spawning grounds upstream of Lower Granite Dam, and we counted a total of 6,000 redds. This equated to 4.7 adults/redd in 2013. This compares to an average of 4.7±1.4 adults/redd (range 3.3-7.0) over the past five years (2009-2013).

Table 18. Annual count of adult fall Chinook salmon in the Lower Granite Dam fish ladder (Raw count), the number removed from the river (Adult take*), the number estimated to have passed the dam (Adults passed), the number of redds counted upstream of the dam, and number of adult fall Chinook salmon counted per redd counted upstream (adults/redd), 1986-2013. Raw adult fish counts are from USACE (e.g., USACE 1986-2012), and values for adult take are from WDFW, IDFG and NPT (unpublished data).

Year	Raw adult fish counts	Adult take	Adults passed	Redds counted upstream	Number of adults/redds
1986	784	13	771	7	110.1
1987	951	3	948	73	13.0
1988	627	2	625	87	7.2
1989	706	0	706	69	10.2
1990	385	50	335	45	7.4
1991	630	40	590	54	10.9
1992	855	187	668	82	8.1
1993	1,170	218	952	219	4.3
1994	791	185	606	120	5.1
1995	1,067	432	635	109	5.8
1996	1,308	389	919	197	4.7
1997	1,451	444	1,007	189	5.3
1998	1,909	947	962	303	3.2
1999	3,381	1,519	1,862	586	3.2
2000	3,696	1,470	2,226	536	4.2
2001	8,915	2,286	6,629	1,302	5.1
2002	12,351	2,404	9,947	1,854	5.4
2003	11,732	489	11,243	2,241	5.0
2004	14,960	466	14,494	2,562	5.7
2005	11,194	1,340	9,854	2,127	4.6
2006	8,048	1,080	6,968	1,370	5.1
2007	10,197	2,264	7,933	1,951	4.1
2008	16,628	3,602	13,026	3,055	4.3
2009	15,167	3,652	11,515	3,467	3.3
2010	41,815	4,704	37,111	5,275	7.0
2011*	25,249	3,345	21,904	4,675	4.7
2012	34,688	7,045	27,643	4,243	6.5
2013	56,573	Not available at time of report submission			

*Starting in 2011 Adult take includes; adults collected at LGR, harvest, and fish collected at the N.P.T.H.

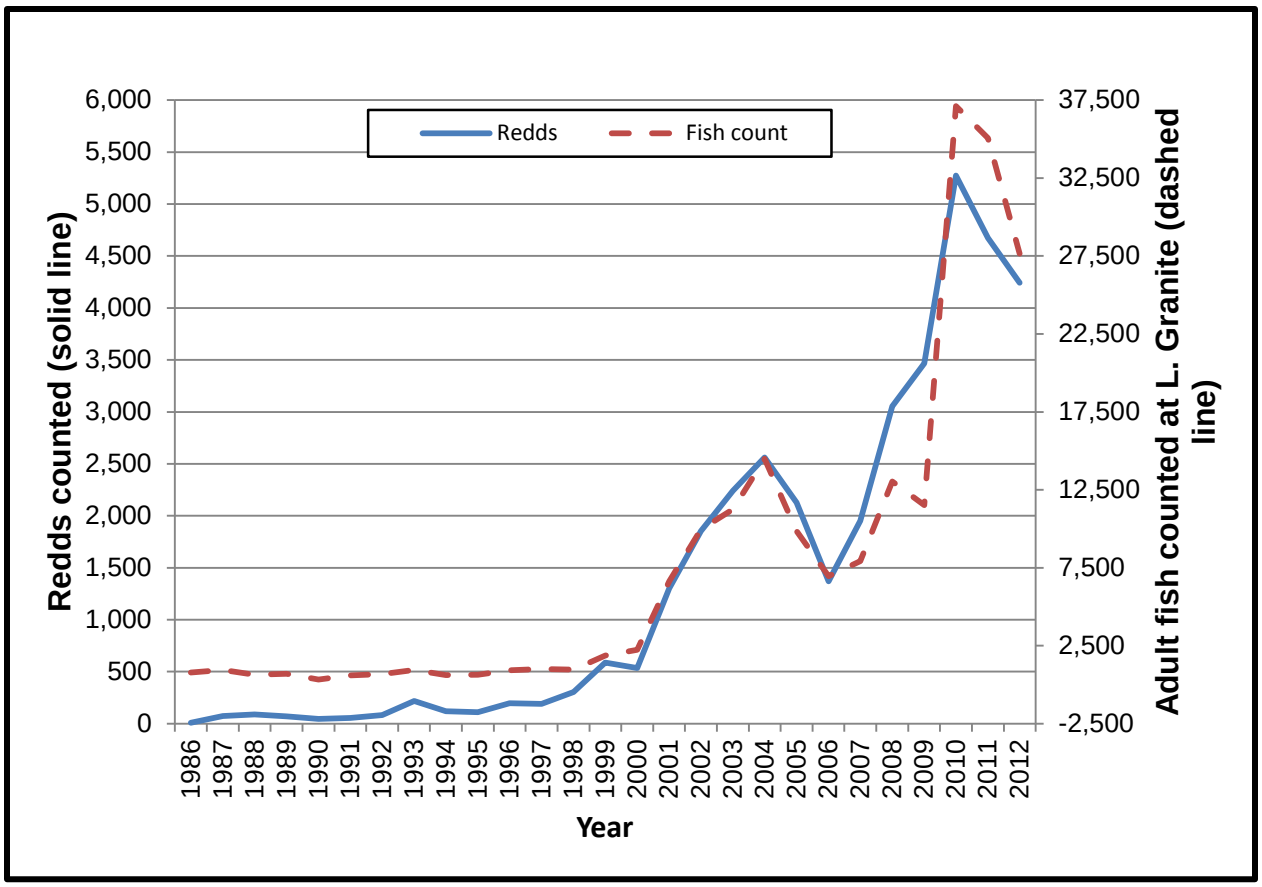

Figure 2. Number of adult fall Chinook salmon counted at Lower Granite Dam, and number of redds counted above the dam, 1986-2012 (Fish counts from USACE 1986-2012, and unpublished data from WDFW and NPT).

References

Arnsberg, B.D., W.P. Connor, and E. Connor. 1992. Mainstem Clearwater River study: Assessment for salmonid spawning, incubation, and rearing. Final Report by the Nez Perce Tribe, Contract DE-AI79-87-BP37474 to Bonneville Power Administration, Portland, Oregon.

Arnsberg, B.D. and D.S. Kellar. 2007. Nez Perce Tribal Hatchery monitoring and evaluation project; Fall Chinook salmon (Oncorhynchus tshawytscha) supplementation in the Clearwater River Subbasin. 2006 Annual Report to the U.S. Department of Energy, Bonneville Power Administration, Project No. 1983-350-003.

Arnsberg, B.D., P.A. Groves, D. Milks, and F. Mullins. 2012. Cooperative Snake River fall Chinook Spawning Summary.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12, FWS/OBS-82/26, U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Bugert, R., P. Seidel, P. LaRiviere, D. Marbach, S. Martin, and L. Ross. 1989. Lower Snake Compensation Plan, Lyons Ferry Hatchery Evaluation Program, 1988 Annual Report. Cooperative Agreement 14-16-001-88519, U.S. Fish and Wildlife Service, Boise, Idaho.

Bugert, R., P. LaRiviere, D. Marbach, S. Martin, L. Ross, and D. Geist. 1990. Lower Snake Compensation Plan, Lyons Ferry Hatchery Evaluation Program, 1989 Annual Report. Cooperative Agreement 14-16-0001-89525, U.S. Fish and Wildlife Service, Boise, Idaho.

Bugert, R., and six coauthors. 1991. Lyons Ferry Hatchery Evaluation Program, 1990 annual report. Cooperative Agreement 14-16-001-90525 to Lower Snake River Compensation Plan, U.S. Fish and Wildlife Service, Boise, Idaho.

Chapman, D.W., D.E. Weitkamp, T.L. Welsh, M.B. Dell, and T.H. Schadt. 1986. Effects of river flow on the distribution of Chinook salmon redds. Transactions of the American Fisheries Society 115:537-547.

Connor, W.P., A.P. Garcia, H.L. Burge, and R.H. Taylor. 1993. Fall Chinook salmon spawning in free-flowing reaches of the Snake River. Pages 1-29 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall Chinook salmon in the Columbia River basin. 1991 Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P., W.P. Connor, and R.H. Taylor. 1994a. Fall Chinook spawning ground surveys in the Snake River. Pages 1-19 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall Chinook salmon in the Columbia River basin. 1992 Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P., W.P. Connor, and R.H. Taylor. 1994b. Fall Chinook spawning ground surveys in the Snake River. Pages 1-21 *in* D.W. Rondorf and K.F. Tiffan, editors. Identification of the spawning, rearing, and migratory requirements of fall Chinook salmon in the Columbia River basin. 1993 Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P., and six coauthors. 1996. Fall Chinook spawning ground surveys in the Snake River, 1994. Pages 1-18 *in* D.W. Rondorf and K.F. Tiffan, editors. Identification of the spawning, rearing, and migratory requirements of fall Chinook salmon in the Columbia River basin. 1994 Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P., W.P Connor, R.D. Nelle, R.D. Waitt, E.A. Rockhold, and R.S. Bowen. 1997. Fall Chinook spawning ground surveys in the Snake River, 1995. Pages 1-17 *in* D.W. Rondorf and K.F. Tiffan, editors. Identification of the spawning, rearing, and migratory requirements of fall Chinook salmon in the Columbia River basin. 1995 Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P., R.D. Waitt, C.A. Larsen, S.M. Bradbury, B.D. Arnsberg, M. Key, P.A. Groves. 1999. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 1998. Pages 7-19 *in* A.P. Garcia editor. Spawning distribution of fall Chinook salmon in the Snake River. 1998 Annual Report to Bonneville Power Administration, Project number 9801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., R.D. Waitt, C.A. Larsen, D. Burum, B.D. Arnsberg, M. Key, P.A. Groves. 2000. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 1999. Pages 10-28 *in* A.P. Garcia editor. Spawning distribution of fall Chinook salmon in the Snake River. 1999 Annual Report to Bonneville Power Administration, Project number 9801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., R.D. Waitt, C.A. Larsen, D. Burum, B.D. Arnsberg, M. Key, P.A. Groves. 2001. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2000. Pages 13-31 *in* A.P. Garcia editor. Spawning distribution of fall Chinook salmon in the Snake River. 2000 Annual Report to Bonneville Power Administration, Project number 199801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., and six coauthors. 2003. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam. Pages 14-22 *in* A.P. Garcia editor. Spawning distribution of fall Chinook salmon in the Snake River. 2001 Annual Report to Bonneville Power Administration, Project number 199801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, S.J. Rocklage, and P.A. Groves. 2003. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2002. 2002 Annual Report to Bonneville Power Administration, Project number 199801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, S.J. Rocklage, and P.A. Groves. 2004. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2003. 2003 Annual Report to Bonneville Power Administration, Project number 199801003, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, S.J. Rocklage, and P.A. Groves. 2005. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2004. 2004 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, S.J. Rocklage, and P.A. Groves. 2006. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2005. 2005 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, S.J. Rocklage, and P.A. Groves. 2007. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2006. 2006 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 98-AI-37776, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, and P.A. Groves. 2008. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2007. 2007 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 35778, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, and P.A. Groves. 2009. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2008. 2008 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 40522, Portland, Oregon.

Garcia, A.P., S. Bradbury, B.D. Arnsberg, and P.A. Groves. 2010. Fall Chinook salmon spawning ground surveys in the Snake River basin upriver of Lower Granite Dam, 2009. 2009 Annual Report to Bonneville Power Administration, Project number 1998-010-03, Contract 45097, Portland, Oregon.

Groves, P.A. 1993. Habitat available for, and used by, fall Chinook salmon within the Hells Canyon Reach of the Snake River. Idaho Power Company, Boise, Idaho.

Groves, P.A, and J.A. Chandler. 1996. A summary of fall Chinook salmon *(Oncorhynchus tshawytscha)* redd surveys within the Hells Canyon reach of the Snake River, Idaho: 1991-1995. Report to the National Marine Fisheries Service, Silver Springs, Maryland.

Groves, P.A., and J.A. Chandler. 2001. Chapter 3: The quality and availability of fall Chinook salmon spawning and incubation habitat downstream of the Hells Canyon Complex. In: P.A. Groves, editor. Evaluation of anadromous fish potential within the mainstem Snake River, downstream of the Hells Canyon Complex of reservoirs. Technical Appendices for Hells Canyon Complex Hydroelectric Project. Technical Report E.3.1-3. Idaho Power Company, Boise, Idaho.

Groves, P.A., and A.P. Garcia. 1998. Two carriers used to suspend an underwater video camera from a boat. North American Journal of Fisheries Management18:1004-1007.

Irving, J.S. and T.C. Bjornn. 1981. Status of Snake River fall Chinook salmon in relation to the Endangered Species Act. Prepared for the U.S. Fish and Wildlife Service, Portland, Oregon.

Mendel, G.K., and six coauthors. 1992. Lower Snake River Compensation Plan Lyons Ferry fall Chinook salmon hatchery program. 1991 Evaluation Report. Cooperative Agreement 14-16-0001-91534, Washington Department of Fisheries report to the U.S. Fish and Wildlife Service, Lower Snake River Compensation Plan Office, Boise, Idaho.

Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitablility curves: Chinook salmon. U.S. Fish and Wildlife Service, Biological Report 82(10.122).

Seidel, P., and R. Bugert. 1987. Lower Snake River Compensation Plan, Lyons Ferry Salmon Evaluation Program, 1986 Annual Report. Cooperative Agreement 14-16-0001-86521. U.S. Fish and Wildlife Service, Boise, Idaho.

Seidel, P., R. Bugert, and P. LaRiviere, D. Marbach, S. Martin, and L. Ross. 1988. Lower Snake River Compensation Plan, Lyons Ferry Evaluation Program, 1987 Annual Report. Cooperative Agreement 14-16-0001-87512. U.S. Fish and Wildlife Service, Boise, Idaho.

Swan, G.A. 1989. Chinook salmon spawning surveys in deep waters of a large, regulated river. Regulated Rivers: Research and Management 4:355-370.

USACE (U.S. Army Corp of Engineers). 1986-2007. Annual fish passage reports, Columbia and Snake Rivers. North Pacific Division, U.S. Army Corps of Engineers, Portland and Walla Walla Districts.

USACE (U.S. Army Corp of Engineers). 1990. Navigation charts of the Snake River, Oregon, Washington, and Idaho. Lewiston to Johnson Bar. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Witty, K. L. 1988. Annual Fish Report. Wallowa Fish District. Oregon Department of Fish and Wildlife, Enterprise, Oregon.

Appendices

Appendix 1. Redd counts recorded from 1959 to 1978 in the Snake River between Lewiston, Idaho, and the Hells Canyon Dam site.

		Year											
River section	**Citation**	**1959**	**1960**	**-**	**1967**	**-**	**1969**	**-**	**1974**	**1975**	**1976**	**-**	**1978**
Hells Canyon Dam to Pleasant Valley Dam Site	Irving and Bjornn 1981	19	2		144		294						
Pleasant Valley Dam Site to Imnaha River	Irving and Bjornn 1981	7	2		11		94						
Imnaha River to Lewiston, ID	Irving and Bjornn 1981	2	0		33		180						
		28	**4**		**188**		**568**						
Hells Canyon Dam to Johnson Bar	Witty 1988						170		1	N.D.	8		
Johnson Bar to Pleasant Valley	Witty 1988						124		10	N.D.	1		
Pleasant Valley to Appaloosa	Witty 1988						61		3	N.D.	0		
Appaloosa to Mountain Sheep	Witty 1988						33		2	N.D.	4		
Mountain Sheep to State Line	Witty 1988						0		0	N.D.	0		
							388		**16**	**10**	**13**		
Hells Canyon Dam to Asotin, WA	Groves and Chandler 1996												**132**
Maximum annual count		**28**	**4**	**-**	**188**	**-**	**568**	**-**	**16**	**10**	**13**	**-**	**132**

Appendix 2. Fall Chinook salmon redds counted in the Snake River during aerial and ground surveys, by river mile (RM), river kilometer (RK), and year (1989-2013). An empty cell indicates no redds were observed at the corresponding site and year.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
145.3	233.8																						1	2		
147.1	236.7																							5		
148.0	238.1														5						1	4		8		
148.3	238.6		1													1			5		1	1				
148.5	238.9												5	3	34	22	59	15			34	23	87	2	76	109
148.8	239.4	1													2	4				2						
148.9	239.6																							115		
149.0	239.7																							2		1
149.1	239.9	1		2		1					2	1		2	13			3			7	1	37		23	21
149.2	240.1													4		15		15	1		36	4	10	48		
149.4	240.4															1	9									
149.6	240.7																2				6	1	13		1	2
149.8	241.0																							4	1	
150.0	241.4														1							2	1			
150.9	242.8																								1	
151.5	243.8					2						1		5		4	3		6		5	2	39			
151.7	244.1																					47	66	145		
151.9	244.4							3	4	8					7	31	26	2	23		42	15	64	13	4	89
152.1	244.7													1		6		9		7					21	
152.3	245.1	23	16		7	3	5		3	12	3	20	21	52	23	19	46	45	28	27	59	65	79	51	73	59
152.4	245.2																2									
152.8	245.9																1				1	1	1			2
153.2	246.5														4	1	5		1		5	7				
154.0	247.8																		1							
154.3	248.3																		1			3	1	1	8	2
154.7	248.9																					3		13		
155.0	249.4																13									
155.2	249.7														1						15			1		
155.6	250.4																		6		3		1			4

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
155.8	250.7																					2				5
155.9	250.8																11	1			14					
156.1	251.2																				1					
156.4	251.6																10									
156.6	252.0														28							1				
156.8	252.3												1	3					1		3		3		2	
156.9	252.5	1																								
157.2	252.9		1																							
157.4	253.3																									
157.6	253.6									1	3				1	2	1				7	2	9	61	10	14
157.7	253.7																					1				
158.0	254.2													1	1	9	25	13			1					
159.3	256.3													1		1						3	4	10	2	15
159.6	256.8													1		2		1								
159.7	257.0				3										3	1	1			1	2			2		3
159.8	257.1																					3			3	
160.2	257.8																						3			
160.5	258.2													1		2		2								
160.8	258.7												1									1				
161.0	259.0				7	11		3		7	9	1	7	12	11	20	16	19	11	16	16	9	21	19	7	11
161.8	260.3													1												
162.4	261.3	1	2	15	11	1						1	4	50	32	2	27	15	4	27	5	28	68	60	14	59
163.0	262.3																									
163.3	262.7		2																							
163.4	262.9																					1				9
163.7	263.4															14	5				1	2				8
164.4	264.5																									
164.7	265.0	2	1				1			1				19	12	25	28	9		11	3	26	45	13	9	48
165.2	265.8					2	3							1												
165.3	266.0					2					1				7	19	27	14	32	40	28	14	40	28	28	57

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
165.5	266.3																									
165.8	266.8											5			44	69	60	95	41	51	64	74	70	57	31	61
165.9	266.9			1	3	9			3		2			32												
166.2	267.4					6											1	5				13	7	16	3	16
166.5	267.9			6																						
166.6	268.1																							1		
167.7	269.8																					2				1
167.9	270.2														1			2	1							9
168.1	270.5														1											
168.4	271.0																						2	3		
168.6	271.3														1	8		1					5			7
168.7	271.4					5	6	3						7	47	62	48	46	18	13	24	34	22	72	1	23
168.9	271.8																						6			
169.7	273.0	1						1	1						11	21	6	7	3	1	1	3	14	3		21
169.9	273.4															1										
171.9	276.6																1							1		
172.5	277.6								3		4	1	1	18	11	1	11	2	11	6	13	20	20	38	18	24
173.9	279.8												1	1		2	9			5		19	10	50		16
175.1	281.7																							7		
175.2	281.9													2						1	3	2	5	26	8	8
175.7	282.7														1	1										
175.9	283.0																4	2			2		5			3
176.5	284.0							1					2	1		2			1					1		2
176.7	284.3																7	1		3	9	5	4	13	5	8
177.3	285.3																						1			
177.9	286.2																1						1			1
178.3	286.9						1										10				3		6	5	1	4
178.4	287.0																							3		
178.5	287.2												2			13	1						3		1	
178.9	287.9	1					1				2	7	13	3	18	10	11	7	10	2	7	18	8	18	5	29

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
179.5	288.8																6					5	1	5		11
179.6	289.0					4	5	2	8			10	8	5	17	16	17	28	12	9	19	32	11	39	5	24
181.7	292.4												1	1	3	9	10	6	10		4	5	4	20	9	11
182.3	293.3															8		10				6	2	16		
183.1	294.6																1					11				
183.2	294.8																							8		
183.4	295.1															1	8		1							
183.5	295.3															11		2	4	2	6	18	20	36	7	27
186.7	300.4														3											
187.4	301.5																				10		13	23	5	15
187.5	301.7													1	1				8		9	2	3	6	4	
187.7	302.0													1		7	3		1	1		14		2	4	
187.8	302.2																			4	1	1		3		2
188.0	302.5																								3	
188.1	302.7																				1					
188.2	302.8											1	2	5	1		1	3	3	3		7	4		3	10
188.5	303.3																					3				
189.9	305.5																	1	7	10	14	16	28	2		
190.0	305.7							1								1	1				2	4	4			
190.1	305.9																								6	
190.2	306.0						1							2	5	3	2	2	5	1	3	4	5	8	5	9
190.6	306.7																					3	1		5	6
190.7	306.8																3									
190.8	307.0		2	4	1				1		4	2	5	18	28	6	17	4	7	9	16	20	40	45	22	45
191.0	307.3															2	2								2	
191.1	307.5																1	1								
191.6	308.3																	2								
191.7	308.4											1		3	10	11	6	1	2		4		1	18	5	11
193.0	310.5														7	2										
193.2	310.9															1										

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
193.4	311.2	5	2				2		2	1	4			2	3	3				7	11	7	7	13	6	
193.6	311.5														1	9	3	3	9	8	14	9	16	27	12	11
193.7	311.7				6	1	2	1		2	3	1	5	7	7		9	2	6							23
193.8	311.8						1	1					2	1			1				1					
193.9	312.0																				25	21	30	28	28	32
194.0	312.1		3			1	2	4	2	6	14	11	11	22	26	20	21	21	24	19						
194.1	312.3		2											1		1	1	4		1		2	3	6	1	1
195.3	314.2																					1	1	3	1	
195.7	314.9																	7	6		1	20	10		10	9
196.0	315.4						2				1	6	10	20	23	34	29	26	11	16	28	22	34	37	43	39
196.2	315.7																									
198.2	318.9										1	11	9	17	22	25	17	26	12	11	21	34	21	23	41	16
198.8	319.9	3	2	5	3		6	1	6		4	11	13	19	23	35	31	27	30	23	51	36	46	25	41	49
199.2	320.5																				8	2	1		1	
199.4	320.8																					1			1	
199.7	321.3																		4					3		
201.0	323.4																							4	2	3
201.1	323.6											1	1	2	3	6	4					1	2			
203.1	326.8														1	8					5	9	3	10	3	11
204.1	328.4																									
205.3	330.3			3				1			3	6	2		11	17	12	16	3		7	19	23	26	26	31
205.4	330.5								2				4		2	4	5	2	2	4	11	15	22	15	12	21
205.7	331.0															2		1				6				
206.5	332.3			1	2	1		2			2	4		2	2	10	15	8	15	13	31	27	41	20	29	47
206.6	332.4											2			1	5	2	2				3			6	5
207.5	333.9														3	3	1	1			1		7			5
207.7	334.2											2	1							1		4		4	6	
207.8	334.4								3	2		5			1	3	4	5	4	3	5	12	20	30	8	8
207.9	334.5																									
208.0	334.7	1						2	9	1	13	25	17	22	36	48	46	37	32	37	50	47	47	17	37	69

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
208.1	334.8														1				2							
208.3	335.2																	1	1	2	5	2	1			4
208.8	336.0																							1		
209.1	336.4											1			1											
209.6	337.2																								1	
209.7	337.4											1			2											
210.5	338.7																					2	1	3	3	
210.8	339.2															1										
211.0	339.5																					1				
211.9	340.9					2					11	9	6	14	25	30	28	20	18	22	36	23	37	20	31	39
212.2	341.4															1							1		4	
212.3	341.6													1	4	2	4	3	4	2	3	1	3			1
213.3	343.2	2							1				1	2	1	4		7	3	2	3	9	8		9	1
213.6	343.7								1			2	1	2	4	6	5	5	1	5	3	6	6		9	
213.7	343.8		1		2						4	1	1	6	7	1	13	3	15	23	19	18	8	9	3	8
213.9	344.2																2								1	8
214.5	345.1					1								1	4	3	7	6			1	3	2	5	3	4
214.7	345.5															3										
215.4	346.6										1	2				6	3	6	2	10	4	8	8	5	3	7
216.1	347.7						1				3	1	2	6	4		9	9	10	10	15	12	18	6	8	16
216.5	348.3																					1	1	1		
216.9	349.0												5	6	21	21	30	28	7	8	15	33	23		5	12
217.3	349.6				1	3		1			4	24	6	13	22	42	36	35	19	16	44	46	63	61	61	60
217.8	350.4	1														2					3		3	4		1
218.1	350.9																	1				4				
218.2	351.1																									
218.5	351.6											3	2		5	10	10	18	2	12	10	25	16	9	25	10
218.7	351.9							1	7		4	12	5	11	15	20	13	11	14	19	16	33	48	26	55	48
219.0	352.4							3	2		4	4	6	3	11	7	12	7	5	11	11	16	13	18	11	27
219.3	352.9				1		3		2	3	6	8	5	7	13	12	13	13	10	19	21	16	20	15	19	23

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
220.6	354.9																			6	1					
220.7	355.1															4	1				7	3	23		1	
220.8	355.3																								14	18
221.0	355.6																						2	2	2	2
221.3	356.1																								1	
221.5	356.4													1								1				
221.8	356.8																									3
222.3	357.7														2				4		8	4	7		2	12
222.7	358.3	1										6		1		8	14	3				3	11			3
222.8	358.5												5													
222.9	358.6	3					1					9		4	20	19	21	17	9	6	26	23	69	33	48	57
223.2	359.1						3	3							1					2	9	12	9		8	
223.3	359.3																	1			3	1	11	13	16	29
223.7	359.9																									
224.7	361.5										3					12	12	7			8	31		1		
224.8	361.7																							1		
225.0	362.0											2		8	2		1	1	1	1	2		3	17	5	
225.1	362.2											2				3		1			4	8	5	17	6	12
226.4	364.3																				3		1			
226.6	364.6																		3						1	4
226.7	364.8											3			1									7	4	7
227.2	365.6																						2		3	
227.5	366.0																	3								
227.9	366.7																						2			1
228.4	367.5																				3		6	1		
229.8	369.7																						1			3
231.3	372.2														1	1	2	2						2		
231.8	373.0																						1			
235.0	378.1							1			1	2	3		12	10	9	12	4	3	7	11	17		8	12
235.3	378.6																					1				

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
235.5	378.9																					4				
235.6	379.1																	2	7	8		29	5			29
235.7	379.2	3					5	2	7	1	4	11	16	16	22	16	23	33	12	14	18		25	25	20	
236.0	379.7												1		1	2	2	6		4	5	7	4	1		
236.1	379.9	1										2	1	1			2	2	4	8	10	9	10	6	6	7
237.0	381.3					5	2	1		2	8	6	13	14	26	20	24	23	24	18	23	31	23	28	34	28
238.1	383.1																1		2		3	2	4			
238.4	383.6											1	1		2	1		1		3					16	7
238.6	383.9	2						1				4	4	8	13	23	16	21	9	11	16	15	26	17	25	23
239.4	385.2																		7							
239.8	385.8																			5	2	16			3	5
240.4	386.8														11	11	15	16	6	4	12	9	13	18	12	14
240.6	387.1								1		2	8	1	3			36	32	14	16	24	26	46	48	42	52
240.7	387.3	3		4					1	1	4	7	11	13	21	24		1								1
241.0	387.8									1				4	5	8	8	6		1	5	6	10	18	11	14
241.6	388.7																					1		1		
241.7	388.9																				4	3				10
242.3	389.9																	4	5							
242.8	390.7												4	3	7	11	10	17		8	8	21	4		8	31
243.0	391.0																		12							
243.2	391.3																	14	7				6			18
243.3	391.5	1											4													
243.5	391.8								2			1		5		13	12			9	7	8		9	15	
243.8	392.3															2	2	1								
244.0	392.6											2			12		8	9		1		4	5		3	3
244.2	392.9																					7				
244.3	393.1														2							3				
244.5	393.4	1	2									1	2	9	13	31	25	29	13	18	20	24	35	29		37

Appendix 2. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
244.7	393.7															2	1	2					1		37	
245.0	394.2																						1	1		
245.2	394.5																1		13							
245.3	394.7											1		1		9	7			5	5	9	15	6	28	30
245.5	395.0																	10								
245.7	395.3							2								2	6	2	3				13	19	25	24
245.8	395.5											2			4	6	9	9		4		9				
246.0	395.8																	1						1		
246.5	396.6																									
247.5	398.2															4	2	2	1	3			1	6	2	4
	Totals	58	37	41	47	60	53	41	71	49	135	273	255	535	878	1,118	1,218	1,042	696	714	1,233	1,511	1,950	1,949	1,412	2,071

Appendix 3. Fall Chinook salmon redds counted in the Snake River during aerial, ground, and underwater surveys, by river mile (RM), river kilometer (RK), and year (1989-2013). An empty cell indicates no redds were observed at the corresponding site and year.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
145.3	233.8																						1	2		
147.1	236.7																							5		
148.0	238.1														5						1	4	6	8		
148.3	238.6		1													1			5		1	1				
148.5	238.9												5	4	37	22	67	15			34	23	87	2	76	109
148.8	239.4	1																								
148.9	239.6														2	4				2				115		
149.0	239.7																							2		1
149.1	239.9	1		2		1					2	1		2				3			8	1	38		23	21
149.2	240.1													4	13	15		15	1		36	4	10	48		
149.4	240.4															1	9									
149.6	240.7																2				6	1	13		1	2
149.8	241.0																							4	1	
150.0	241.4														1							2	1			
150.9	242.8																								1	
151.5	243.8					2								5		4	3		6		5	2	39			
151.7	244.1																					47	81	145		
151.9	244.4							3	4	8		1			7	31	26	2	23		42	15	64	13	4	89
152.1	244.7													1		6		9		7					21	
152.3	245.1	23	16		7	3	5		3	12	3	20	21	52	23	19	46	45	28	27	59	65	79	51	73	59
152.4	245.2																2									
152.8	245.9																1				1	1	1			2
153.2	246.5														4	1	5		1		5	7				
154.0	247.8																		1							
154.3	248.3																		1			3	1	1	8	2

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
154.7	248.9																					3		13		
155.0	249.4																15				5					
155.2	249.7														1						15		1	1		
155.6	250.4																		6		3		2			4
155.8	250.7																					2				5
155.9	250.8																11	1			14					
156.1	251.2																				1					
156.4	251.6														18		10									
156.6	252.0														28							1				
156.8	252.3												1	3					1		3		3		2	
156.9	252.5	1																								
157.2	252.9		1																							
157.4	253.3																									
157.6	253.6									1	3				1	2	1				7	2	9	61	10	14
157.7	253.7																					1				
158.0	254.2													1	2	13	55	19			1					
159.3	256.3													1		1						3	4	10	2	15
159.5	256.6													1		2										
159.7	257.0				3										3	1	1	1		1	2			2		3
159.8	257.1																					3			3	
160.2	257.8																						3			
160.5	258.2													1		2		2								2
160.8	258.7												1									1				
161.0	259.0				7	11		3		7	9	1	7	12	11	20	16	19	11	16	16	9	21	19	7	11
161.8	260.3													1												
162.4	261.3	1	2	20	11	1			2			1	4	56	33	2	27	16	9	39	8	28	72	60	14	59
163.0	262.3																									
163.3	262.7		2																							
163.4	262.9																					1				13

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
163.7	263.4															24	14	5	3	14	6	2	20			8
164.4	264.5																									
164.7	265.0	2	1				1			1				19	12	25	28	9		11	3	26	45	13	9	48
165.2	265.8					2	3							5												
165.3	266.0					2					1				7	19	27	14	32	40	39	15	53	53	28	57
165.5	266.3																									
165.7	266.6					28								38	52	117	73	107	13	11	15	15	35	45		2
165.8	266.8																		41	51	64	74	70	57	36	61
165.9	266.9			1	3	9			3		2	5														
166.2	267.4					17									1		1	8	5	9	9	15	20	21	3	20
166.4	267.7														9											
166.6	268.1			6		21					6		1			1	8	21	11	10	30	18	27	28		10
167.7	269.8																					2				1
167.9	270.2														1			2	1							9
168.1	270.5														1											
168.4	271.0																						2	3		
168.6	271.3														1	8		1					5			7
168.7	271.4					5	6	3						7	47	90	72	67	46	29	42	37	28	107	17	53
168.9	271.8																						6			34
169.7	273.0	1						1	1						11	31	23	22	15	6	11	8	19	34	10	21
169.9	273.4															1										
171.9	276.6																1							1		
172.5	277.6								3		4	1	1	18	11	1	11	2	11	6	13	20	20	38	18	24
173.9	279.8												1	1		2	9			5		19	10	50		16
175.1	281.7																							7		
175.2	281.9													2						1	3	2	5	26	8	8

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
175.7	282.7														1	1										
175.9	283.0																4	2			2		5			3
176.5	284.0							1					2	1		2			1					1		2
176.7	284.3																7	1		3	9	5	4	13	5	8
177.3	285.3																						1			
177.9	286.2																1						1			1
178.3	286.9						1							3			10				3		6	5	1	4
178.4	287.0																							3		
178.5	287.2												2			38	1						17	4	1	
178.9	287.9	1					1				2	7	13		18	10	11	7	10	2	7	18	8	18	5	29
179.5	288.8																6					5	1	5		11
179.6	289.0					6	13	21	32	5	16	40	56	72	92	110	99	128	95	91	116	147	166	180	90	149
181.7	292.4											1	1	1	3	9	15	6	10	1	10	5	10	24	9	11
181.8	292.5																						6			
182.3	293.3															8		10				6		16		
183.1	294.6																						1			
183.2	294.8											2			4		2		6		1	24	2	20	6	31
183.4	295.1															1	8		1							
183.5	295.3															11	9	2	8	3	9	25	25	49	11	37
184.7	297.2															6	1	9	5	1	1	3				8
185.7	298.8																					8				
185.9	299.1																		6		2	12	8	2	14	4
186.7	300.4														3											
187.4	301.5																						13	23	5	15
187.5	301.7													1	1				8		19	2	3	6	4	
187.7	302.0													1		7	3		1	1		14		2	4	
187.8	302.2																			4	1	1		3		2
188.0	302.5																								3	

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
188.2	302.8											1	2	7	1	3	2	5	3	3	2	10	21		5	10
188.5	303.3																					3				
188.9	303.9																		4	8	9	29	35	27	9	8
189.1	304.3																		17		27	12	24	26	13	17
189.9	305.5																		7	10	14	16	28	11		
190.0	305.7							1								1	1	1			2	4	48	35	15	39
190.1	305.9						1							2	5	3			15		17	17		6	6	
190.2	306.0																2	2		1		4	11	8	14	9
190.6	306.7																					3	1		5	6
190.7	306.8															3										
190.8	307.0		2	4	1				1		4	2	5	18	28	6	17	4	9	9	16	25	40	45	22	45
191.0	307.3															2	2								2	
191.1	307.5																1	1								
191.6	308.3																	2								
191.7	308.4											1		3	10	11	6	1	2		4		1	18	5	11
193.0	310.5														28	18	22	21	10	13	9	35	45	4	33	31
193.2	310.9															1										
193.4	311.2	5	2				2		2	1	4				5	3	1			11	13	7	15	13	6	
193.6	311.5													6	1	9	6	3	11	13	14	9	16	36	12	11
193.7	311.7				6	1	2	1		2	3		5	8	8		11	4	7							23
193.8	311.8					1	1	1				1	2	1	1		3			4	2		7	3		
193.9	312.0																							28	28	32
194.0	312.1		3			1	2	4	2	6	14	11	11	22	26	20	21	21	24	19	25	21	30			
194.1	312.3		2				5							1		1	6	4	4	5	2	12	11	15	7	14
194.4	312.8														1	5	23	13	2	1	9		12	3	4	7
195.2	314.1																						3	5		4
195.3	314.2																					1	1	3	1	
195.7	314.9																	17	21	19	29	51	45	84	40	56

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
196.0	315.4						2				1	6	10	20	23	34	29	26	11	16	28	22	34	37	43	39
196.2	315.7															25										
198.2	318.9								2		1	17	14	36	33	13	35	33	16	17	30	47	30	37	50	23
198.8	319.9	3	2	5	3		6	1	6		4	15	17	21	25	39	43	29	33	30	63	40	65	41	46	54
199.2	320.5																				8	2	1		1	
199.4	320.8					1			5			2	1	2			1		7	6	13	8	9	14	5	6
199.7	321.3																		4					3		
201.0	323.4																4					1	2	4	2	3
201.1	323.6											1	1	2	3	6										
203.1	326.8										10				1	10			4	5	14	12	6	20	11	21
204.1	328.4																									
205.3	330.3			3				1			3	6	2		11	17	12	16	3		7	19	23	26	26	31
205.4	330.5								2				4		2	4	5	2	2	4	11	15	22	15	12	21
205.7	331.0															2		1				6	5	8	8	10
206.4	332.1			1	2	1		2			2	4		2	2	10	15	8	15	13	31	27	41			
206.5	332.3																							20	29	47
206.6	332.4											2	1		1	5	2	2				3	3		6	5
207.5	333.9																1	1			1		7			5
207.7	334.2											2			3	3				1	5	4		4	6	
207.8	334.4								3	2		5			1	3	4	5	4	3		12	20	30	8	8
207.9	334.5																									
208.0	334.7	1						2	9	5	13	36	17	26	37	62	51	52	36	39	54	51	51	21	37	70
208.1	334.8														1				2							
208.3	335.2											4						1	6	5	13	7	6	5	2	10
208.8	336.0																							1		
209.1	336.4											1			1											
209.6	337.2																								1	

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
209.7	337.4											1			2											
210.5	338.7																					2	1	3	3	
210.8	339.2															1										
211.0	339.5																					1				
211.9	340.9					2					11	10	6	14	25	30	28	20	18	22	36	23	37	20	31	39
212.2	341.4							2			17	24	28	37	37	34	27	29	13	34	38	39	44	40	47	26
212.3	341.6											2	3	9	9	4	12	7	7	6	10	5	8	8	2	5
213.3	343.2	2							1				1	6	9	12	6	9	4	9	14	16	10		9	4
213.5	343.5								1			2	1	2	4	6	5	5	1	5	3	6	6			
213.6	343.7																								9	
213.7	343.8		1		2						4	1	1	6	7	1	13	3	15	23	19	18	8	9	3	8
213.9	344.2																2								1	8
214.5	345.1					1								1	4	3	7	6			1	3	5	5	3	4
214.7	345.5																									
215.4	346.6										1	2				3	3	6	2	10	4	8	8	5	3	7
216.1	347.7						1				3	1	2	6	4	6	9	9	10	10	15	12	18	6	8	16
216.5	348.3																					1	1	1		
216.9	349.0											4	5	7	21	23	53	36	8	20	30	41	46	12	9	14
217.3	349.6				1	3		1			4	24	6	13	22	42	36	35	19	16	44	46	63	61	61	60
217.8	350.4	1														2					3		3	4		1
218.2	351.1																	1			4	4	3			
218.5	351.6											3	3		16	11	47	66	2	24	55	101	105	84	33	25
218.6	351.7											1														
218.7	351.9							4	7		4	12	5	15	17	20	16	18	14	28	24	45	83	29	55	55
219.0	352.4							3	2		4	5	6	3	11	7	12	7	5	11	11	16	13	18	11	27
219.3	352.9				1		3		2	3	6	8	5	7	13	12	17	13	10	19	24	22	28	20	25	27
220.6	354.9																			6	16	1	9		8	9
220.7	355.1															4	1			6	7	3	23		1	
220.8	355.3																								14	18

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
221.0	355.6														1				5	22	5		2	8	2	2
221.3	356.1																								1	
221.5	356.4													1								1				
221.8	356.8																									3
222.3	357.7														2		6		4		8	4	7	3	2	12
222.7	358.3	1										6		1		8	14	3				3	11			3
222.8	358.5												5				2						1			
222.9	358.6	3				3	1					9		4	20	19	21	17	9	6	26	23	69	33	48	57
223.2	359.1						3	3				3			1			1		7	10	12	9	6	8	
223.3	359.3																				3	1	11	13	16	29
223.7	359.9																									
224.7	361.5										3					12	15	7			8	31		8		
224.8	361.7																							1		
225.0	362.0											2			2		1	1	1	1	2		3	17	5	
225.1	362.2											3			1	3		1			4	8	5	17	6	12
226.4	364.3																				3					
226.6	364.6																		3				1		1	4
226.7	364.8											2												7	4	7
227.2	365.6																						2		3	
227.5	366.0																	3								
227.9	366.7																						2			1
228.0	366.9											2				1					2		3	8		1
228.4	367.5																				3		13	3	3	
228.7	368.0																3						1			
229.8	369.7																						1			3
231.3	372.2														1	1	2	2						2		
231.8	373.0																						1			
235.0	378.1																57	40	31	34	49	59	85		38	52
235.1	378.3							1			1	2	3	8	21	66			4							
235.3	378.6																					1				

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
235.5	378.9																					4				
235.6	379.1																	2	7	8		29	5			29
235.7	379.2	3					5	2	7	1	4	11	16	16	22	16	25	33	12	18	27		25	25	20	
236.0	379.7	1										2	1			2	3	6		4	5	7	4	1		
236.1	379.9												1	1	1		2	2	4	8	10	9	10	6	6	7
236.3	380.2																1	1		2	3	3	12	11	2	2
236.7	380.9																									
237.0	381.3					5	3	1		2	8	6	13	14	26	20	26	23	24	19	23	31	23	28	34	28
238.1	383.1																1		2		3	2	4			
238.3	383.4											1	1		2	1		1		3						
238.4	383.6																								16	7
238.6	383.9	2						1				4	4	8	13	23	16	21	9	11	16	15	26	17	25	23
239.4	385.2															6			7				13	9	4	
239.8	385.8																			5	2	16			3	5
240.4	386.8																15	16	6	4	12	9	13	18	12	14
240.5	387.0								1		2	8	1	3	11	11	36	32	14	16	24	26	46			
240.6	387.1																							48	42	52
240.7	387.3	3		4					1	1	4	7	11	13	21	24		1								1
241.0	387.8									1				4	5	8	8	6		1	5	6	10	18	11	14
241.6	388.7																					1		1		
241.7	388.9																				4	3				10
242.3	389.9																	4	5							
242.8	390.7										1		4	4	9	13	21	25		13	12	21	4	35	17	39
242.9	390.8																						32			
243.0	391.0											2							12							
243.2	391.3																									18
243.3	391.5	1											4					14	7				6			
243.5	391.8								2		1			5		13	12			9	7	8		9	15	

Appendix 3. Continued.

		Year																								
RM	RK	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
243.8	392.3															2	2	1								
244.0	392.6											2			12		8	9		1		4	5		3	3
244.2	392.9																					7				
244.3	393.1														2							3				
244.5	393.4																25	29	13	18	20	24	35	29		37
244.6	393.6	1	2									1	2	9	13	31										
244.7	393.7															2	1	2					1		37	
245.0	394.2																						1	1		
245.2	394.5																1		13							
245.3	394.7											1		1		9	7			5	5	9	15	6	28	30
245.5	395.0																	10								
245.7	395.3							2								2	6	2	3				13	19	25	24
245.8	395.5											2		1	4	6	9	9		4		9				
246.0	395.8																	1						1		
246.5	396.6																									
247.5	398.2															4	2	2	1	3			1	6	2	4
	Totals	58	37	46	47	127	67	65	104	58	185	373	346	709	1,113	1,512	1,709	1,442	1,025	1,117	1,819	2,095	2,950	2,814	1,828	2,667

Appendix 4. Fall Chinook salmon redds counted in the Clearwater River during aerial surveys, by river mile (RM), river kilometer (RK), and year (1990-2013). An empty cell indicates no redds were observed at the corresponding site and year. The maximum upstream RM searched was 41 (North Fork Clearwater River) from 1988 to 1990, 67 (Kamiah, Idaho) in 1991, and 74 (beginning of Middle Fork Clearwater River) from 1992 to 2013. *Due to high water and turbidity no surveys of the Clearwater River could be conducted after 8 November 2012. Biologists from the Nez Perce Tribe estimated the total number of redds present in the Clearwater River during 2012.

		Year																							
RM	RK	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12*	‘13
4.0	6.4						1																		
4.5	7.2																				1				
5.2	8.4																								2
6.2	10.0							5																	
6.7	10.8												2												
6.8	10.9																				5	11	2	4	10
7.2	11.6												2												
7.8	12.6												7	6											
8.0	12.8										1													9	
8.1	13.0			1	2	6	6			1															
8.5	13.6																								14
8.8	14.2												1	5											
9.0	14.5																						2		
9.5	15.3																								10
10.6	17.1	1																							
11.0	17.7																						14		7
11.1	17.8																							3	
11.8	19.0				1																				
11.9	19.2																						4		
12.4	20.0																								4
13.8	22.2																								6
13.9	22.4	3							1		2	8	12			7									
14.0	22.5																			8		2	23	20	
15.2	24.5																								1
16.2	26.1													1											
16.4	26.4																							6	55
17.0	27.4																								10
17.3	27.8								1	2	1			2			3			4	2		11	3	6

Appendix 4. Continued.

		Year																							
RM	RK	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12*	‘13
17.8	28.6																								12
18.0	29.0		1						1	2	15	2	18	22	36	45	38	22	35	62	78	80	94	134	95
18.6	29.9								1						6										
18.9	30.4										1														
19.0	30.6			2																					
19.1	30.7										3		6	17	8	7	9	12	15	27	22	36	28	49	99
19.3	31.1								1	4	5					31	7		4	18		43	23	36	28
19.5	31.4											7	14	1	11	1					21				
20.0	32.2						4	6	1														3		68
21.0	33.8																3		1		2	35	74	109	90
21.4	34.5																								15
21.5	34.6																						4		
21.7	34.9												2	1	7	3	6	1	5	8	5	9	18	3	
21.8	35.0										1														
22.0	35.4			21	9	18	5	24	16	25	62	77	60	110	107	119	139	45	117	223	207	335	263	364	498
22.2	35.7														49	22	31	7	22	109	121	191	191	209	330
22.6	36.4																								90
23.0	37.0		3										29								1				
23.3	37.5													9	3	18	36	2	49			10	47	96	55
23.4	37.7								1																
23.9	38.5																						6	1	11
24.0	38.6												1			7		1		2	3	47			
25.1	40.4																			4	6				22
25.5	41.0													1	5										
26.0	41.5																								6
26.3	42.3														2										
26.5	42.6											3	2	20	4	18	9	1	9	21	27	37	112	8	75
26.8	43.1									1															
27.4	44.1																								55
27.5	44.2									2				15	7	6	6	3	8	6	19	12	47	78	77
28.0	45.1					1								48	20										
28.4	45.7								11	1	26	1				20	20	19	38	60	37	68	89	46	70
29.2	47.0																			3	1				2

Appendix 4. Continued.

		Year																							
RM	RK	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12*	‘13
29.8	47.9																								5
30.1	48.4													3	5	35		30	19	6	44		37	46	31
31.5	50.7												3	28	3	37		4	4	13	37	38	14	1	33
31.7	51.0							4		6					37										
32.5	52.3										23	13	19	11		20	10	21	53	12	124	159	18	1	122
32.8	52.8													4				1	7	6	4	13	7		60
33.6	54.0				13																				
33.8	54.4											6													
34.0	54.7								9	4	9	2	13	42	20	15	26	22	30	81	20	27	33		85
34.2	55.0							10																	
35.0	56.3						3	6	7																
35.4	56.9										2	9	47	41	53	50	25		133	78	89	114	39		58
35.7	57.5										3		1	7	7			31	5	9	51	16	31	99	49
36.2	58.2								6	11	3	11		7	4	10	16		2	11	8	8	7	37	115
36.7	59.0					1																			
37.9	61.0												1	8	1	1			2	16	8	1	31		11
39.1	62.9														1	9		1	24		10	42	15	6	98
39.6	63.7								1	9	1		4	2	1		1	4	11	2	4	19	25	19	25
40.3	64.8			1	11	4	1	11	1	10	21	22	46	109	147	111	48	24	118	130	185	226	245	171	259
40.6	65.3											3													
43.2	69.5													1	1		6				1	4			1
43.7	70.3																								3
44.5	73.3																								1
45.0	72.4											3	9	2	2	10	8				1			3	
45.5	73.2																					2	3		
46.1	74.2																								1
49.2	79.2											1				3				1					
49.4	79.5														1			4							
49.8	80.1															1								7	
50.5	81.3																			3					
51.0	82.1																			1					
51.2	82.4															3						4	2		

Appendix 4. Continued.

		Year																							
RM	RK	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12*	‘13
51.3	82.5																			4					
51.4	82.7																							7	
51.5	82.9															5	3								
51.6	83.0																								2
51.7	83.2											3					1								
52.0	83.7			1									3												
52.2	84.0																5								
52.3	84.2																			1	1				
52.4	84.4																							3	
52.5	84.5																3			1		5			
52.7	84.8																								5
52.8	85.0														3	2	4					5			
53.4	85.9										2														
53.6	86.2																							4	4
53.8	86.6															12	10	2	3		5	2	9		
54.9	88.4																								2
57.2	92.0														9										
58.1	93.5																							14	
58.2	93.6																2				23	4			
60.8	97.8																								1
61.0	98.1											1													
62.4	100.4														1					1		5			
63.0	101.4																					13			
63.1	101.6																								1
63.4	102.0																						2		
63.8	102.8																								2
64.5	103.8																		1						
65.5	105.4																								5
65.7	105.8																							6	
66.0	106.2												4	1			8		3	1		1	1	4	23
66.4	106.8																							1	
66.6	107.2																				6				
67.1	108.0																			3					

Appendix 4 Continued.

		Year																							
RM	RK	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12*	‘13
67.3	108.3																								3
67.9	109.3																								1
68.0	109.4																4								
68.7	110.5																								4
69.6	112.0																			4	4				
69.9	112.5																			2					
70.2	113.0														2										
72.1	116.0																				1				
72.5	116.8																								12
72.9	117.3																							3	
73.0	117.5																					8			
73.9	119.0																								11
74.4	119.7																								2
	Total	4	4	26	36	30	20	66	58	78	181	172	306	524	563	628	487	257	718	941	1,184	1,632	1,577	1,610*	2,858

Appendix 5. Fall Chinook salmon redds counted in Asotin Creek during aerial surveys, by latitude/longitude, and year (2005-2013). An empty cell indicates no redds were observed at the corresponding location and year. No redds were observed during surveys performed in 2007 and 2009.

			Redds counted by year								
RM	RK	Latitude / Longitude	2005	2006	2007	2008	2009	2010	2011	2012	2013
0.1	0.2	N 46° 20' 35.734", W 117° 3' 19.243"				1					
0.2	0.3	N 46° 20' 24.814", W 117° 3' 17.806"									
0.2	0.3	N 46° 20' 26.014", W 117° 3' 18.044"	1								
0.2	0.3	N 46° 20' 29.554", W 117° 3' 20.143"				1					
0.5	0.8	N 46° 20' 16.062", W 117 3' 30.532"									
0.6	1.0	N 46° 20' 16.115", W 117° 3' 32.084"				1					
1.0	1.6	N 46° 20' 2.098", W 117° 3' 59.566"									
1.0	1.6	N 46° 20' 3.703", W 117° 3' 53.687"									
1.0	1.6	N 46° 20' 2.947", W 117° 3' 55.947"	1								
1.1	1.8	Data not recorded						1			
1.3	2.1	N 46° 19' 59.376", W 117° 4' 10.182"	1								
1.5	2.4	Data not recorded			No		No	2		No	No
1.7	2.7	N 46° 19' 50.675", W 117° 4' 41.981"	2		Redd		Redd			Aerial	Aerial
1.8	2.9	N 46° 19' 51.035", W 117° 4' 44.562"	1							Survey	Survey
2.6	4.2	Data not recorded						1			
3.1	5.0	N 46° 19' 37.236", W 117° 6' 13.239"		1							
3.8	6.1	Data not recorded							2		
12.5	20.1	N 46° 17' 35.448", W 117° 16' 24.622"									
		Totals	6	1	0	3	0	4	2		

Appendix 6. Fall Chinook salmon redds counted in the Grande Ronde River during aerial surveys, by river mile (RM), river kilometer (RK), and year (1994-2013). An empty cell indicates no redds were observed at the corresponding site and year. Redd surveys were also conducted from 1986 to 1991; however, no ground locations were recorded. Redd counts totaled 0 in 1986, 7 in 1987, 1 in 1988, 0 in 1989, 1 in 1990, and 1991. The maximum upstream RM searched was 4.5 in 1986, 36 in 1987, and 45.5 from 1988 to 1991, 45.3 in 1992. From 1993 to 2005 and 2011 and 2013, the maximum RM searched was RM 53. From 2006 to 2010, and in 2012 the maximum RM searched was RM 81.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
0.0	0.0																7				
0.1	0.2								12		2	1					3			6	
0.2	0.3																			4	
0.3	0.5																	8			
0.4	0.6																				14
0.5	0.8										2						1				
0.6	1.0														5	8		2	3		8
0.7	1.1								22				18	11			2	3		13	
0.8	1.3									2											
1.0	1.6								2		4	2					4	2			25
1.1	1.8																		13		
1.2	1.9								2												
1.3	2.1																5				
1.5	2.4																	4			
1.7	2.7												11		10	5	3				
1.9	3.1								3	8											
2.0	3.2								2			30	33		4	10		25	6	4	31
2.1	3.4										2										
2.2	3.5								4								7				
2.3	3.7																				4
2.4	3.9											2							2		
3.0	4.8					1			1	1											
3.1	5.0																	1	1		
3.2	5.1				1	1			7	5	2	3									
3.3	5.3											1	1		4	26		8			
3.4	5.5																2	19		4	
3.5	5.6										1						5		3		
3.6	5.8		2	2				1	14	3	4	31	3			7		6			
3.7	6.0												16		1	4		39	16	32	10

Appendix 6. Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
4.0	6.4													16			4	4			11
4.2	6.8																7				
4.3	6.9											4	3		3	15					
4.4	7.1				1	3	1	1	1	9	6	2	3		1	10					
4.5	7.2								2	1	3							4	8		
4.6	7.4			1					7		1	1	4		5	2					
5.0	8.0																				3
5.2	8.4																				3
5.5	8.8								8			1									
6.2	10.0								4												
6.5	10.5										1										
6.8	10.9								1											11	
7.0	11.3																				4
7.4	11.9																		2		2
7.5	12.1																	3			32
7.6	12.2																		1		
7.9	12.7								1												
8.2	13.2									1	1		1		3	5					
8.5	13.7								7												
8.9	14.3										1										
9.2	14.8								6			1									
9.5	15.3																		4		
9.6	15.4				1															1	
10.0	16.1									2		3	3		2			5	1		
10.2	16.4																				4
10.4	16.7									6								2	6	3	
10.5	16.9	1		6	7	2			9	6		13	7		4	12	3	3		2	9
10.6	17.1																	12	8		2
11.0	17.7										1							3			
11.2	18.0															5					
11.3	18.2																				8
11.4	18.3											1								1	
11.5	18.5																2		1		

Appendix 6. Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
11.6	18.7									1											
11.7	18.8								3		2	2									
12.0	19.3								2											8	
12.2	19.6																			2	
12.3	19.8																	3			
12.4	20.0																2			4	9
12.5	20.1								12	4	4	3						1	12	13	2
12.6	20.3				6	5			6			2		6		5	7				
12.7	20.4								3				1		1						
13.2	21.2			1														1			
13.4	21.6											3						12			2
13.5	21.7																			12	
13.6	21.9																				2
13.8	22.2		4						1	2	3	8	4		1	3		9			
13.9	22.4									2											
14.2	22.8											2		5							
14.3	23.0											4									
15.0	24.1										1										3
15.2	24.5												1		7	2					
15.5	24.9																			7	
15.7	25.3													2					2		
16.0	25.7																	3	4	10	
16.2	26.1																			2	
16.3	26.2										1	2									
16.4	26.4																				7
16.5	26.5																				2
16.8	27.0									1											
17.0	27.4	1														7	2				
17.4	28.0																			6	
17.6	28.3	3	5		9				10	13	5	6	4								
17.7	28.5														1	8		16	1		5

Appendix 6 Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
17.8	28.6																		12		
18.0	29.0				4						6						7	2		1	
18.2	29.3																	2			4
18.5	29.8																			2	
18.6	29.9																			1	
19.1	30.7								1	3						6		2			
19.2	30.9				3					2	2										
19.3	31.1																			2	4
19.4	31.2																	1			
19.5	31.4					2															
19.6	31.5																				2
20.0	32.2				4	5			2		1		1								
20.1	32.3														1	7					
20.3	32.7															3					
21.0	33.8								3		1		1		3					3	
21.5	34.6										2										
22.0	35.4								1										6		2
22.1	35.6											1	1		4			2			
22.2	35.7											1									2
22.3	35.9																	3			
22.7	36.5																				4
23.0	37.0																			6	
23.1	37.2																			2	
24.0	38.6											2					5				
24.4	39.3											1				2					
24.7	39.7																			2	
25.5	41.0																				3
25.6	41.2																			2	
26.0	41.8																1				
26.2	42.2																			3	
26.4	42.5	7							1		1					9					
26.5	42.6																			9	1
26.7	43.0											1									
26.9	43.3										5										

Appendix 6 Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
27.0	43.4																	1			
27.1	43.6								2												
27.3	43.9								2		2										
27.4	44.1																			4	
27.6	44.4																	2			
27.8	44.7																		4		
27.9	44.9			3			6					1								3	
28.0	45.1																	1			5
28.2	45.4																			1	
28.3	45.5																5			6	
28.4	45.7																	4	4	4	
29.1	46.8									2	1	5									
29.2	47.0																		1		
29.3	47.1									1											
29.5	47.5																			2	
29.7	47.8									3								1			
29.8	47.9									1											
30.0	48.3																1		2	4	
30.1	48.4																			4	
30.2	48.6																		1		
30.4	48.9																			8	
30.5	49.1																		2		
30.8	49.6																			2	
31.1	50.0									3		1									
32.0	51.5																	2			
32.2	51.8	1			1																
32.4	52.1																		3		
32.5	52.3																			10	
32.6	52.5																	4			
32.7	52.6				4																
32.8	52.8																				2
33.0	53.1																	4		2	
33.1	53.3									1											
33.3	53.6	1		1	2	3			10	7	3		2			9			2		

Appendix 6. Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
33.4	53.7														2						
33.5	53.9																	13	2	11	2
34.0	54.7																				
35.5	57.1																			2	
35.6	57.3																			1	
36.4	58.6				1												5				
36.5	58.7																				
36.7	59.1																			1	
36.8	59.2															4				7	
37.2	59.9																		2		
37.4	60.2															3	2		1		10
37.5	60.3								2							2					2
37.6	60.5		1			2		2	2	4	4	4	3		2			1	2		
37.7	60.7												1		2						
37.8	60.8	1			3						2		1					1			
37.9	61.0														3		1				
38.0	61.1																				
38.3	61.6																		1		
38.4	61.8												1		2	2	1				
38.5	61.9																				2
39.0	62.8								3											10	
39.1	62.9				1															4	
39.4	63.4																			4	
39.5	63.6																			5	
41.2	66.3																	2			
41.3	66.5				2																
41.5	66.8																			1	
41.7	67.1																				
41.8	67.3			1													2				
42.0	67.6																				
42.5	68.4										1						6				
43.0	69.2																				6

Appendix 6. Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
43.2	69.5		3				2		11	8	1	1									
43.5	70.0																		6		
44.0	70.8																				2
44.2	71.1												1		2			3			
44.3	71.3																		2		
44.5	71.6									2		4	1		3	2		6	2		
44.6	71.8																	2			
44.9	72.2							4		2	4	5	1			2					
45.5	73.2												1		2					3	
45.7	73.5									4		4							2		
45.9	73.9			4																	
46.3	74.5																	2			
46.4	74.7																	2	4	3	
46.5	74.8		2																	1	
47.5	76.4				1		4														
47.7	76.7														1						
47.8	76.9								2		10		1		1						
48.7	78.4											2									
49.3	79.3								3	1		1									
50.5	81.3				4																
51.4	82.7																		1		
51.5	82.9		1	1															1	3	
52.6	84.6																		1		
53.3	85.8																			2	
53.4	85.9																			2	
53.5	86.1																			3	
54.3	87.4																			2	
55.0	88.5																1				
56.0	90.1																1				
58.3	93.8																			1	
58.5	94.1																	2			
60.6	97.5																			3	
63.2	101.7																			1	

Appendix 6 Continued.

		Year																			
RM	RK	‘94	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
63.5	102.2																			3	
63.7	102.5																			1	
67.6	108.8																			1	
72.0	115.8													1							
	Totals	15	18	20	55	24	13	8	197	111	93	162	129	41	80	185	104	263	154	303	255

Appendix 7. Fall Chinook salmon redds counted in the Salmon River during aerial surveys, by river mile (RM), river kilometer (RK), and year (1995-2013). An empty cell indicates no redds were observed at the corresponding site and year. The maximum upstream RM searched was 87 in 1992, 97 in 1993, 134 in 1994, 105 in 1995, 87 in 1996, 134 in 1997, 105 in 1998, 96 in 1999 and 2000, and 105 from 2001 to 2012. In 2013 the survey was extended to RM 133.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
0.0	0.0													4						
0.1	0.2												5						3	
2.0	3.2															3				
2.3	3.7												1							
2.8	4.5																		2	
3.9	6.3													4						
4.0	6.4									1	6	4	2							
4.1	6.6																	6		
4.6	7.4														3			2	2	
4.8	7.7							1			1							2		
4.9	7.9														1					
5.0	8.0															1				
5.3	8.5											2		4				6		
5.5	8.8									1										
5.6	9.0									1										
6.0	9.7																		1	
11.5	18.5															8				
12.0	19.3																2			
12.1	19.5											1		1						
14.0	22.5																		10	
14.2	22.8							1				5								
14.3	23.0																	4		
14.4	23.1																			18
15.0	24.1				1														6	
15.2	24.5														4					
15.3	24.6							2				2								
15.5	24.9																2		2	
15.7	25.3							1										11		
16.0	25.7	1	1												4					
16.2	26.1																	1		
16.4	26.4																			12
16.6	26.7																	3		
16.8	27.0																	2		
17.0	27.4																	1		
18.5	29.8															2				
19.9	32.0																	1		

Appendix 7. Continued.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
20.3	32.7									1										
20.6	33.1									2										
20.8	33.5															4				
22.2	35.7																	5		
24.0	38.6																		2	
24.4	39.3										1									
26.1	42.0	1																		
26.5	42.6							1												
27.0	43.4																	3		
30.0	48.3												1						3	
30.9	49.7									5	8	10		1						
31.1	50.0				1					1	1	3		2						
31.4	50.5							1												
31.6	50.8															11				
32.0	51.5																	2		
33.3	53.6														2					
34.2	55.0																	1		
35.0	56.3			1																
35.7	57.4								11		1									
38.0	61.1													1						
40.8	65.6																	2		
44.3	71.3																		3	
45.2	72.7								3											
48.6	78.2																2			
48.8	78.5							3												
54.6	87.9															2				
55.7	89.6																	5		
56.7	91.2							1												
62.0	99.8							3	8											
63.3	101.8																	2		
63.9	102.8								2	2										
64.5	103.8													1						
65.0	104.6							2												
65.4	105.2				1				2											
65.5	105.4																2			
65.7	105.7							2	3											
65.8	105.9							1										1		
68.5	110.2									2										

Appendix 7. Continued.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
70.5	113.4							1												
70.6	113.6							1												
82.2	132.3										1									
85.0	136.8							1												
87.0	140.0																			
88.0	141.6								2											
90.7	146.0																			
91.0	146.4									1										
100.7	162.0									1										
103.5	166.5																			1
104.0	167.3															3				
110.0	177.0										2									
	Total	2	1	1	3	0	0	22	31	18	21	27	9	18	14	34	8	60	34	31

Appendix 8. Fall Chinook salmon redds counted in the Imnaha River during aerial surveys, by river mile (RM), river kilometer (RK), and year (1995-2013). An empty cell indicates no redds were observed at the corresponding site and year. A dash indicates no surveys were conducted in the corresponding site and year. Redd surveys were conducted from 1987 to 1991, and in 1999, 2001, 2003, and 2006; however, no ground locations were recorded in those years. Redd counts totaled 0 in 1987, one in 1988 and 1989, three in 1990, four in 1991, and three in 1992. The maximum upstream RM searched was 4.1, 19, 9.8, 3.8, 3.8, 14, respectively, then 35 in 1999 and 2001, 19.5 in 2003 and 2006, and 19.2 in 2007 and 2011-13. N.D. stands for No Data.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
0.0	0.0					N.D		N.D		N.D			2							
0.1	0.2					"		"		"						5			2	
0.2	0.3					"		"	3	"						4			3	2
0.3	0.5					"		"	7	"								1		
0.4	0.6					"		"	3	"	3	4			2	1	2			1
0.5	0.8	1	2	1	1	"	1	"		"	4	4			7		3		3	7
0.6	1.0		1		2	"	2	"	2	"						1		2		
0.7	1.1					"		"		"							3	1		
0.8	1.3					"		"		"			9			2				2
0.9	1.4					"		"	2	"		1				2				
1.0	1.6			2	1	"		"		"	2	1				1	1			
1.1	1.8					"		"		"						1				
1.2	1.9				1	"		"		"	1					1		2		2
1.3	2.1					"		"	1	"	1						2			
1.4	2.3				1	"		"		"										
1.5	2.4					"		"	3	"				5						2
1.6	2.6					"		"	3	"				3						
1.7	2.7					"		"	2	"		2	7		7					
1.8	2.9	2				"		"	1	"									2	
1.9	3.1					"		"		"			8						2	
2.0	3.2					"		"	2	"					4					
2.1	3.4					"		"		"							3		2	
2.2	3.5					"		"		"						3				
2.3	3.7					"		"	1	"							2			
2.4	3.9				2	"	2	"	7	"	2	3		1						
2.5	4.0					"		"	9	"						1	4	5		5
2.6	4.2					"		"		"									3	
2.7	4.3					"		"	2	"	2									1
2.8	4.5					"		"		"	1									1
2.9	4.7					"		"	1	"										3
3.0	4.8					"	2	"		"							2			
3.2	5.1					"		"		"		2								3
3.3	5.3					"		"		"					4					
3.4	5.5				1	"		"	2	"		1							2	1
3.5	5.6					"		"		"		2							2	2

Appendix 8. Continued.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
3.6	5.8					"		"		"					3				7	
3.7	6.0					N.D		N.D	1	N.D							1	1	3	
3.8	6.1					"		"		"	1	2		1		1	2	1		
3.9	6.3					"		"		"					5		5		2	
4.0	6.4					"		"		"		2				1		1		
4.1	6.6	1				"		"	1	"		2		2					1	3
4.2	6.8					"		"		"							2	2	5	
4.3	6.9					"		"		"							4		3	2
4.4	7.1					"		"		"	1				4					
4.5	7.2					"		"		"						1				
4.6	7.4					"		"		"									2	
4.7	7.6					"		"		"			6							
4.8	7.7					"		"		"					1					
5.0	8.0					"		"		"					11	1				
5.2	8.4					"		"		"							3			
5.3	8.5					"		"		"							3	2		
5.4	8.7					"		"	1	"		1				1	6		10	
5.5	8.8					"		"		"							17			
5.6	9.0					"		"		"									1	
5.7	9.2					"		"		"									2	
6.0	9.7					"		"		"	1									
6.2	10.0					"		"		"							2			
6.3	10.1					"		"		"							5			
6.5	10.5					"	1	"		"	2						3		3	
6.6	10.6					"		"		"			4				2			
6.7	10.8					"		"		"							20		2	
6.8	10.9					"		"		"							5			
6.9	11.1					"		"		"							4		2	
7.0	11.3					"		"		"	1	1		2			3		2	
7.1	11.4					"		"	10	"										
7.7	12.4					"		"		"		1							1	
7.8	12.6					"		"		"	9	2							2	
7.9	12.7					"		"		"		1							2	
8.2	13.2					"		"		"	1				7					
8.4	13.5					"		"		"							4		2	
8.5	13.7					"		"		"							4		1	
8.6	13.8					"		"		"							4		3	
8.7	14.0					"		"		"						2	2			

Appendix 8. Continued.

		Year																		
RM	RK	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13
8.8	14.2					"		"		"							1			
8.9	14.3					N.D		N.D		N.D	1	1		2	5	1				
9.0	14.5					"		"		"							1			
9.2	14.8					"		"		"							1			
9.3	15.0					"		"		"	1							2	3	
9.4	15.1					"		"		"							2	1		
9.5	15.3					"		"		"							1		1	
9.6	15.4					"		"		"							2			
9.7	15.6					"		"		"									1	
9.8	15.8					"		"		"		1				1				
9.9	15.9					"		"	1	"		1								
10.0	16.1				2	"	1	"		"						1				
10.3	16.6					"		"		"					4					
10.4	16.7					"		"		"							1			
11.0	17.7					"		"		"						1				
11.2	18.0					"		"		"									1	
11.5	18.5																			1
12.0	19.3				1	"		"		"										
12.3	19.8					"		"		"								1		
12.7	20.4					"		"		"						1				
12.8	20.6					"		"	1	"										
12.9	20.8					"		"		"						1		2		
13.0	20.9				1	"		"	1	"										
13.1	21.1					"		"		"					2					
13.3	21.4					"		"		"						1				
13.4	21.6					"		"	2	"		1			2				1	
13.5	21.7					"		"	1	"										
13.7	22.0					"		"		"									1	
14.3	23.0					"		"		"	1									
18.2	29.3					"		"	1	"										
19.2	30.9					"		"		"										
20.7	33.3					"		"	1	"				1						
Totals		4	3	3	13	9	9	38	72	43	35	36	36	17	68	36	132	24	85	38

Appendix B: Passage Timing Details

Passage Timing of PIT-tagged Natural Fall Chinook Salmon at Lower Granite Dam

1992–2013

William P. Connor

U.S. Fish and Wildlife Service, Idaho Fishery Resource Office,

276 Dworshak Complex Drive, Orofino, Idaho 83544, USA

04/16/2014

Table 1. Genetic lineage composition (%) for random samples of natural-origin Chinook salmon subyearlings collected along the riverine shorelines of the Snake River, 1992–2013.

Year	Number sampled	Percentage	
		Fall	Spring/summer
1992	17	88.2	11.8
1993	116	42.2	57.8
1994	124	98.4	1.6
1995	145	97.2	2.8
1996	62	85.5	14.5
1997	93	63.4	36.6
1998	245	54.7	45.3
1999	143	93.0	7.0
2000	91	100.0	0.0
2001	46	95.7	4.3
2002	207	76.3	23.7
2003	116	85.3	14.7
2004	231	97.0	3.0
2005	273	96.7	3.3
2006	259	83.8	16.2
2007	233	95.7	4.3
2008	274	92.0	8.0
2009	249	Not processed	
2010	283	"	"
2011	265	"	"
2012	246	"	"
2013	233	"	"

Note: Connor et al. (2001) found that natural spring Chinook salmon subyearlings migrated downstream earlier than natural fall Chinook salmon subyearlings, but there was considerable overlap in passage timing of the two runs (Connor et al. 2001). For the sake of simplicity, and as suggested by peer-review, we have made it standard practice to group all the fish tagged under the category of fall-run fish.

Connor, W.P., T. C. Bjronn, H. L. Burge, A. R. Marshall, H. L. Blankenship, R. K. Steinhorst, and K. F. Tiffan. 2001. Early life history attributes and run composition and of wild subyearling Chinook salmon recaptured after migrating downstream past Lower Granite Dam. Northwest Science 75:254-261.

Table 2. The medians of annual passage date distributions estimated at Lower Granite Dam (Plumb et al. 2012) for natural fall Chinook salmon subyearlings PIT tagged in the Snake River upper reach, Snake River lower reach, and lower Clearwater River that migrated as subyearlings, and the percentage of the estimated total number of fish that passed the dam (*N*^) when the PIT-tag detection system was supplied with water after the fish wintered in Lower Granite Reservoirs (overwintered [%]). Inter-annual means of the median passage dates, and percent overwintered (%) are also given for the period of record (1992–2013), and by abundance period (low abundance period, 1992–1999; high abundance period, 2000–2013). FC = frequency change prevented detections of fish tagged in 1999 in 2000.

	Snake upper reach			Snake lower reach			lower Clearwater		
Tagging year	*N*^	Date	Over-wintered(%)	*N*^	Date	Over-wintered(%)	*N*^	Date	Over-wintered(%)
1992				85	06/22	0.0			
1993				514	07/22	6.0	66	08/20	37.9
1994				464	07/17	3.0	18	08/18	88.9
1995	401	07/18	0.0	490	08/02	0.0	60	09/12	0.0
1996	47	06/29	0.0	256	07/18	0.0	0		
1997	55	06/20	0.0	215	07/16	10.7	7		71.4
1998	356	07/07	2.0	752	07/11	1.7	258	08/01	9.7
1999	712	06/26	FC	556	07/27	FC	34	08/12	FC
2000	203	06/19	0.0	544	07/02	2.2	12	09/18	16.7
2001	20	07/10	0.0	374	07/07	0.0	94	08/14	2.1
2002	314	07/01	1.3	1161	07/04	0.4	40	10/06	55.0
2003	642	06/24	0.0	1697	06/27	0.2	127	08/27	11.0
2004	337	06/24	0.0	2911	06/24	0.1	608	08/25	6.3
2005	1059	06/20	0.0	2941	06/24	0.1	236	07/29	11.9
2006	335	06/15	0.0	410	06/27	0.0	478	08/07	2.5
2007	238	06/18	0.0	1260	06/25	1.3	178	10/21	13.5
2008	1386	07/01	0.3	957	07/17	0.0	318	10/06	5.7

Table 2. (Extended)

Tagging year	Snake upper reach *N*^	Date	Over-wintered(%)	Snake lower reach *N*^	Date	Over-wintered(%)	lower Clearwater *N*^	Date	Over-wintered(%)
2009	405	06/22	0.0	1032	07/03	0.9	145	11/02	8.3
2010	263	07/02	0.0	2014	07/12	0.0	1025	09/17	1.8
2011	402	06/17	0.0	593	07/12	0.7	143	09/28	16.8
2012	674	06/25	0.0	1559	07/09	0.3	712	10/18	2.2
2013	177	07/01	NA	896	07/04	NA	677	09/13	NA
Period of record means (*N* = years)									
	N = 19	06/26	0.2	22	07/07	1.1	21	09/07	14.7
Abundance period means (*N* = years)									
Low	*N* = 5	07/02	0.5	8	07/17	3.1	7	08/17	41.6
High	*N* = 14	06/24	0.1	14	07/02	0.5	14	09/15	11.8

Plumb, J.P., W.P. Connor, K.F. Tiffan, C.M. Moffitt, R.W. Perry, and N.S. Adams. 2012. Estimating and predicting collection probability of fish at dams using multistate modeling. Transactions of the American Fisheries Society141:1364–1373.

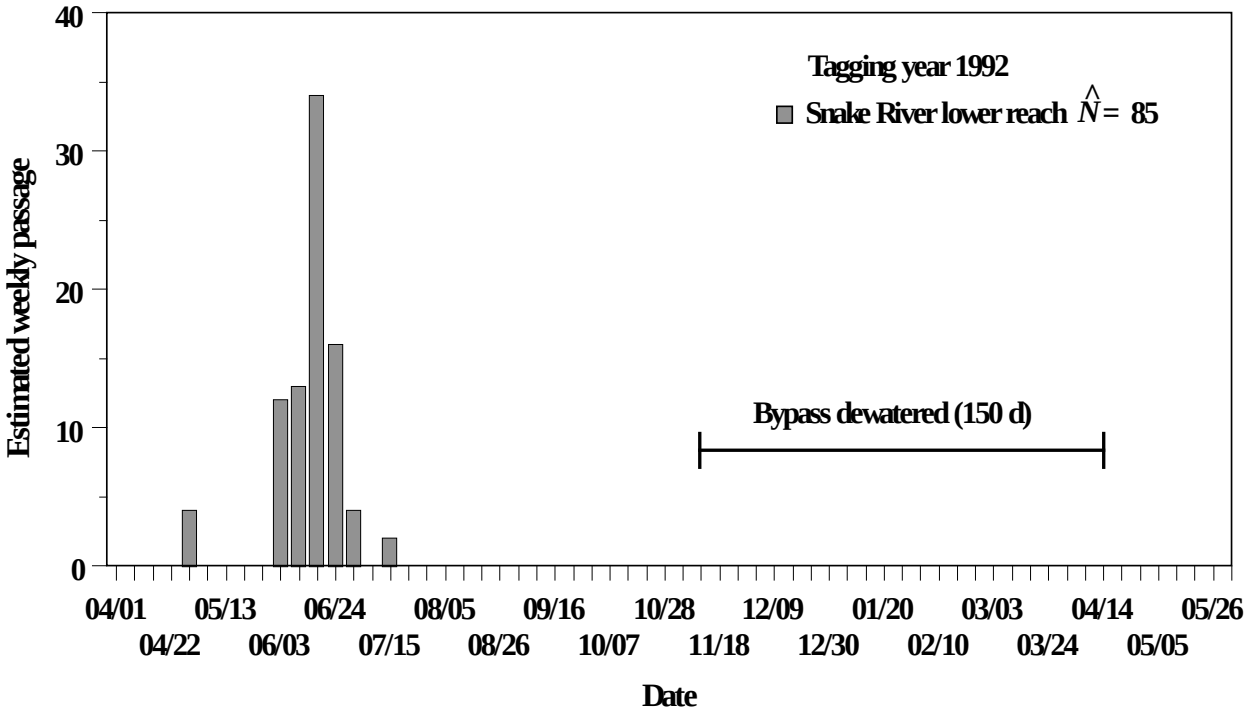

Figure 1. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River lower reach in 1992.

Note: The Snake River upper reach and lower Clearwater River were not seined. This was a very low flow year with limited flow augmentation. Hence, the compressed passage date distribution.

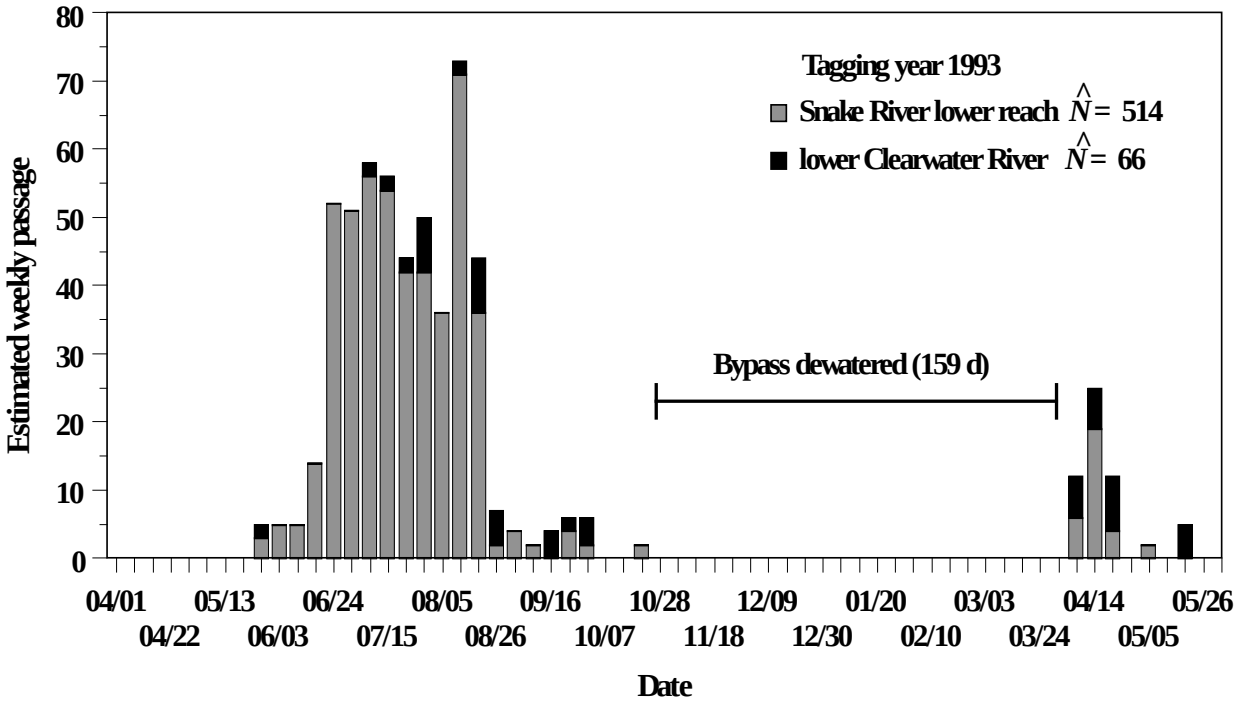

Figure 2. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River lower reach and lower Clearwater River in 1993.

Note: This was the first year the lower Clearwater River was sampled. It was sampled thereafter in 1994 and 1995, and then in 1998. It was not sampled again until 2004.

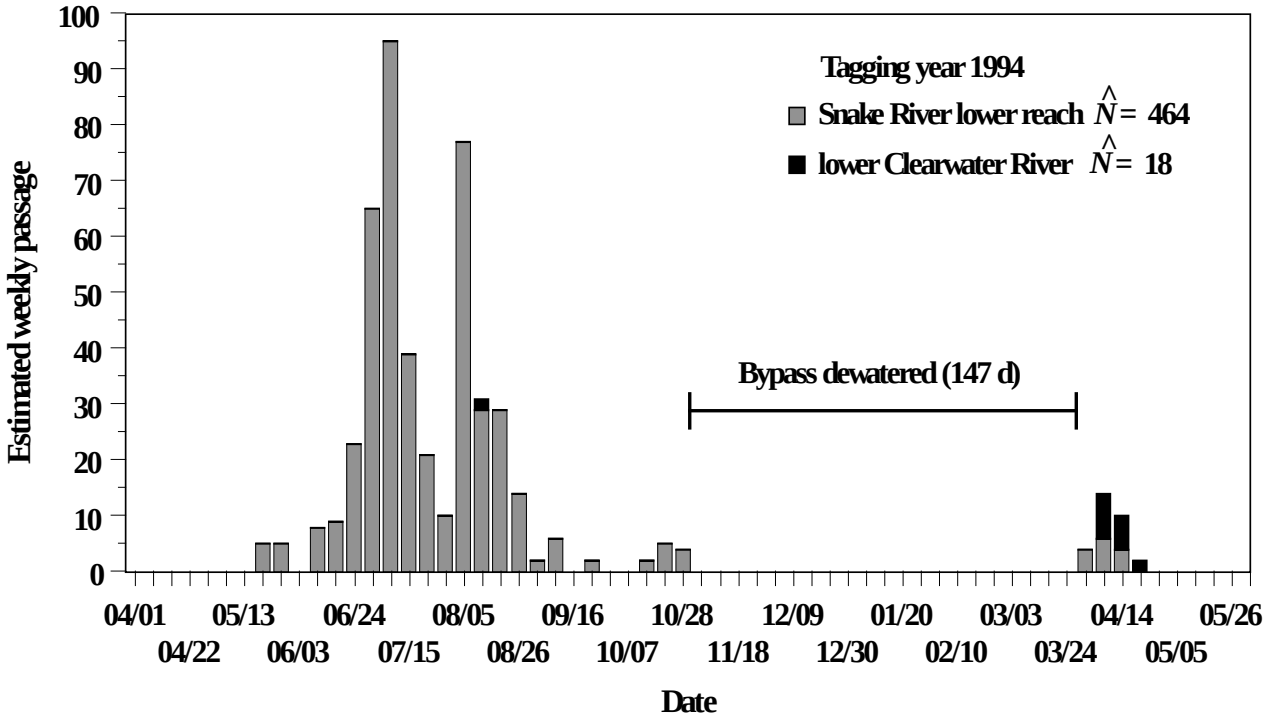

Figure 3. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River lower reach and lower Clearwater River in 1994.

Note: The Snake River fall Chinook salmon ESU was emergency upgraded to endangered status in 1994. A very large volume of very cold water was released during the rearing period of fall Chinook salmon in the lower Clearwater River. Hence, the large majority of the lower Clearwater River fish that passed the dam, passed as yearlings (Table 2). In subsequent years, more attention was given to the preventing such a growth effect in lower Clearwater River fish, and eventually, the State of Idaho discontinued granting a waiver on the gas cap. This limited the maximum volume that could be released from Dworshak Dam to 14 KCFS.

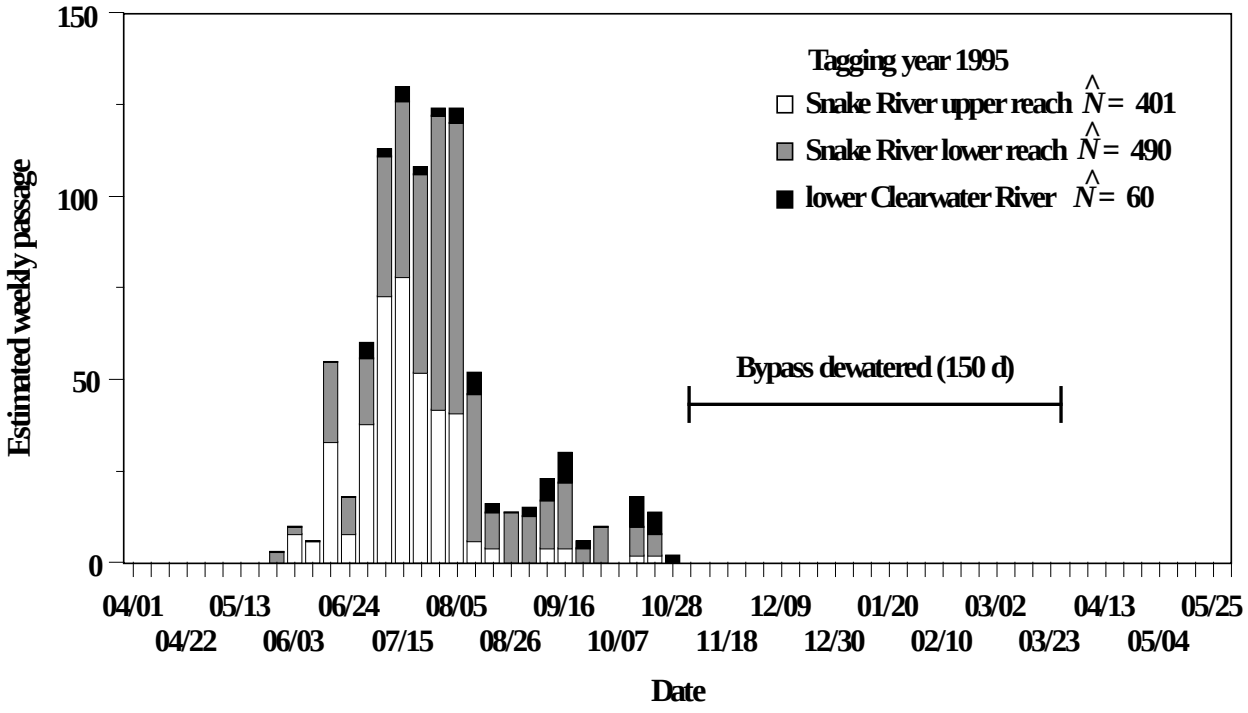

Figure 4. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches and lower Clearwater River in 1995.

Note: This is the first year the Snake River upper reach was sampled.

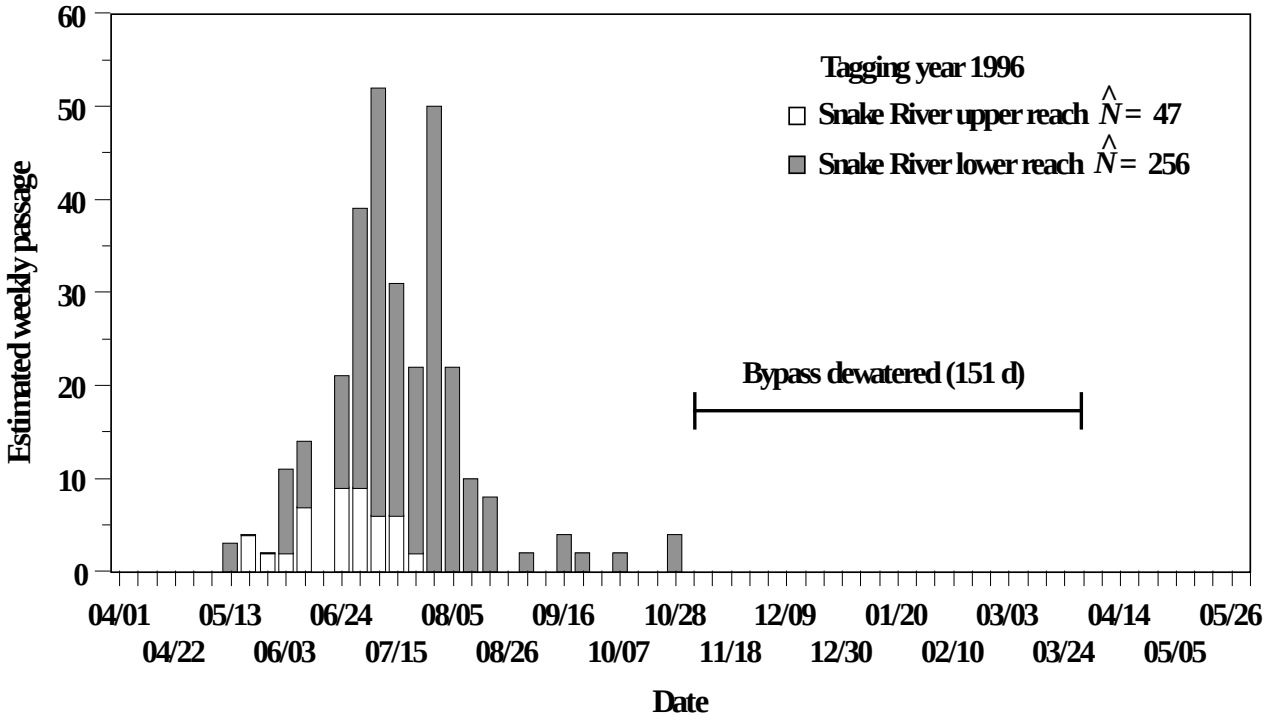

Figure 5. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 1996. No fish tagged in the lower Clearwater River were detected.

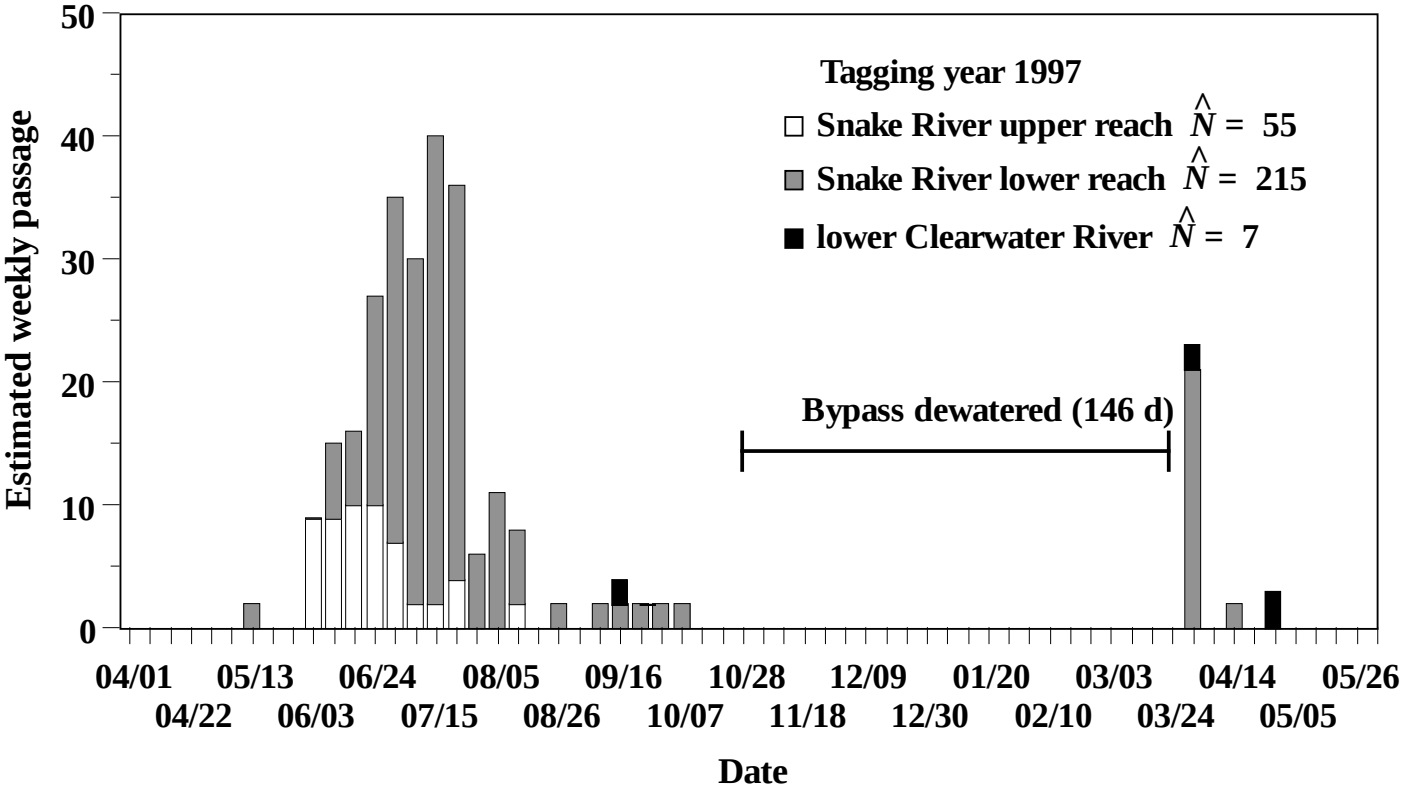

Figure 6. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 1997.

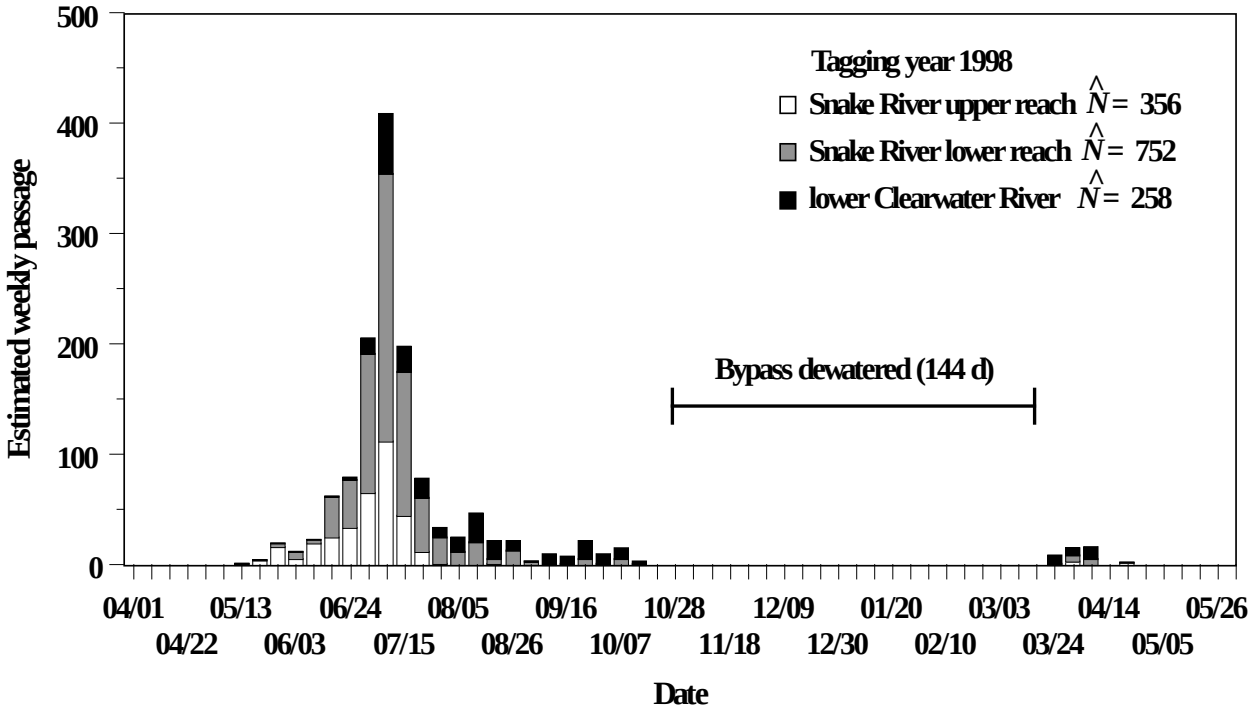

Figure 7. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches and lower Clearwater River in 1998.

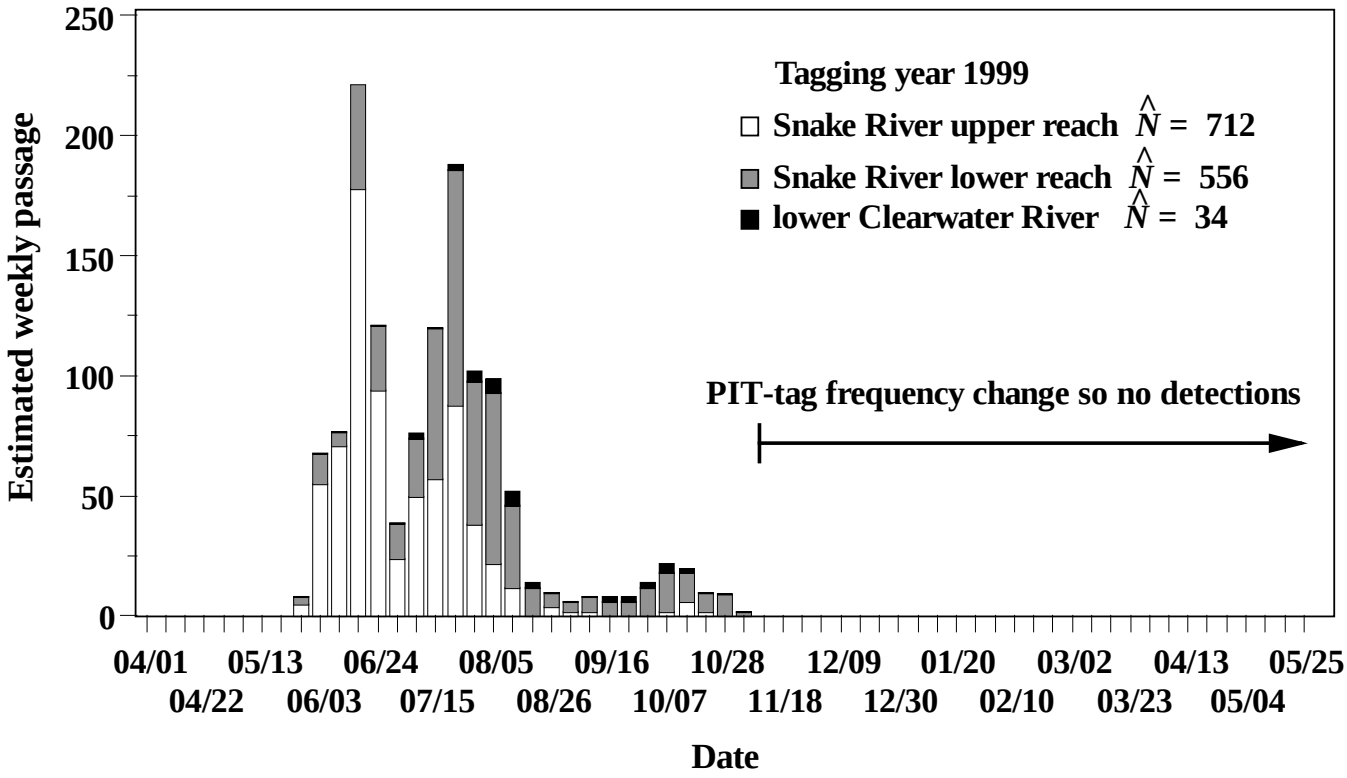

Figure 8. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 1999.

Note: The frequency of the PIT tags switched between 1999 and 2000. On 09/01/1999, the PIT-tag monitors at Lower Granite Dam (and downstream dams) were converted over. The sampler rate at the dam was 100% from 09/01 and every fish that was bypassed was hand scanned until early November. The bypass was dewatered during late fall through early spring. However, no detection data could be collected on fish tagged in 1999 that passed after operation of the bypass was re-initiated in 2000 because the monitors had been changed, the sample rate was low, and too many fish were sampled to hand scan.

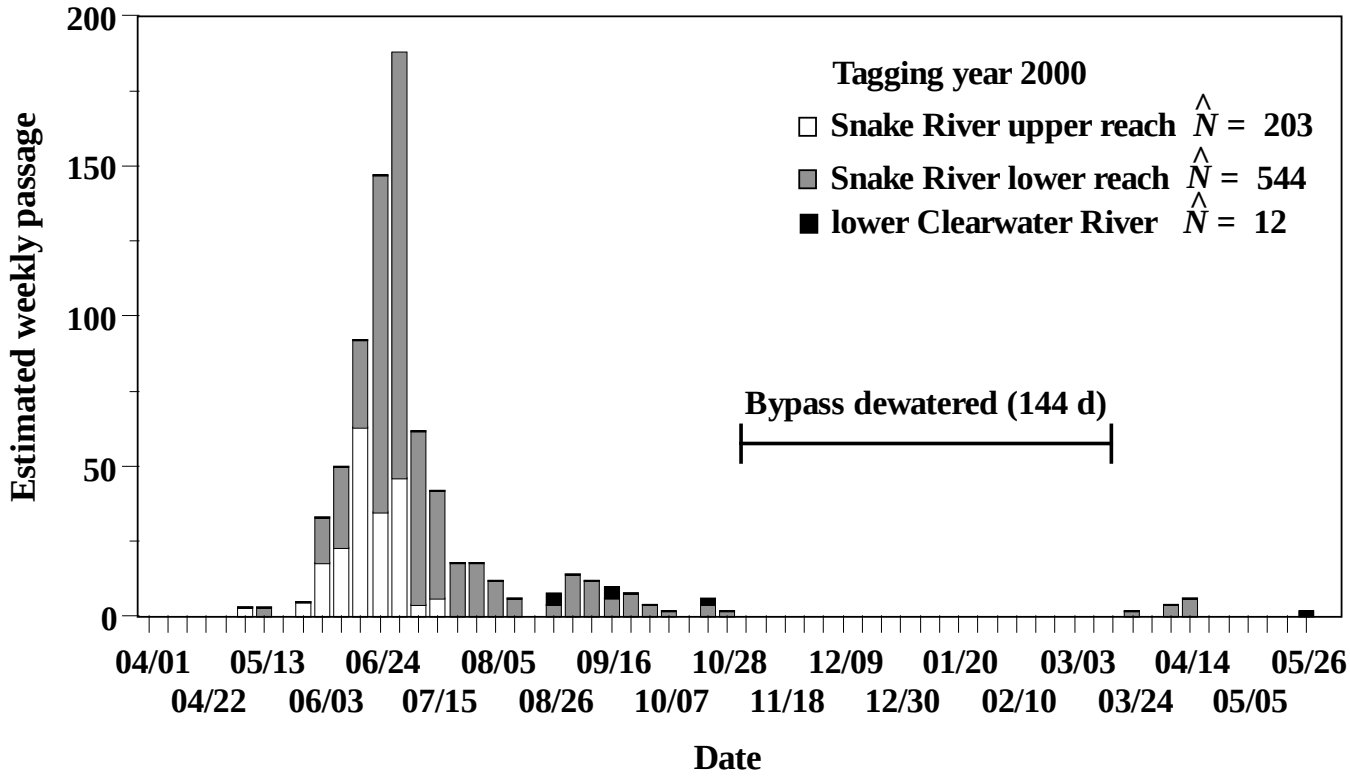

Figure 9. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 2000.

Note: This is the first year of the high abundance period. There are two trends to follow. First, watch how the number of Snake River fish passing after July diminishes. Second, see how passage of the Snake River upper and lower reach fish become more similar as the largest change in passage timing between abundance periods is observed for the lower reach fish (Table 2).

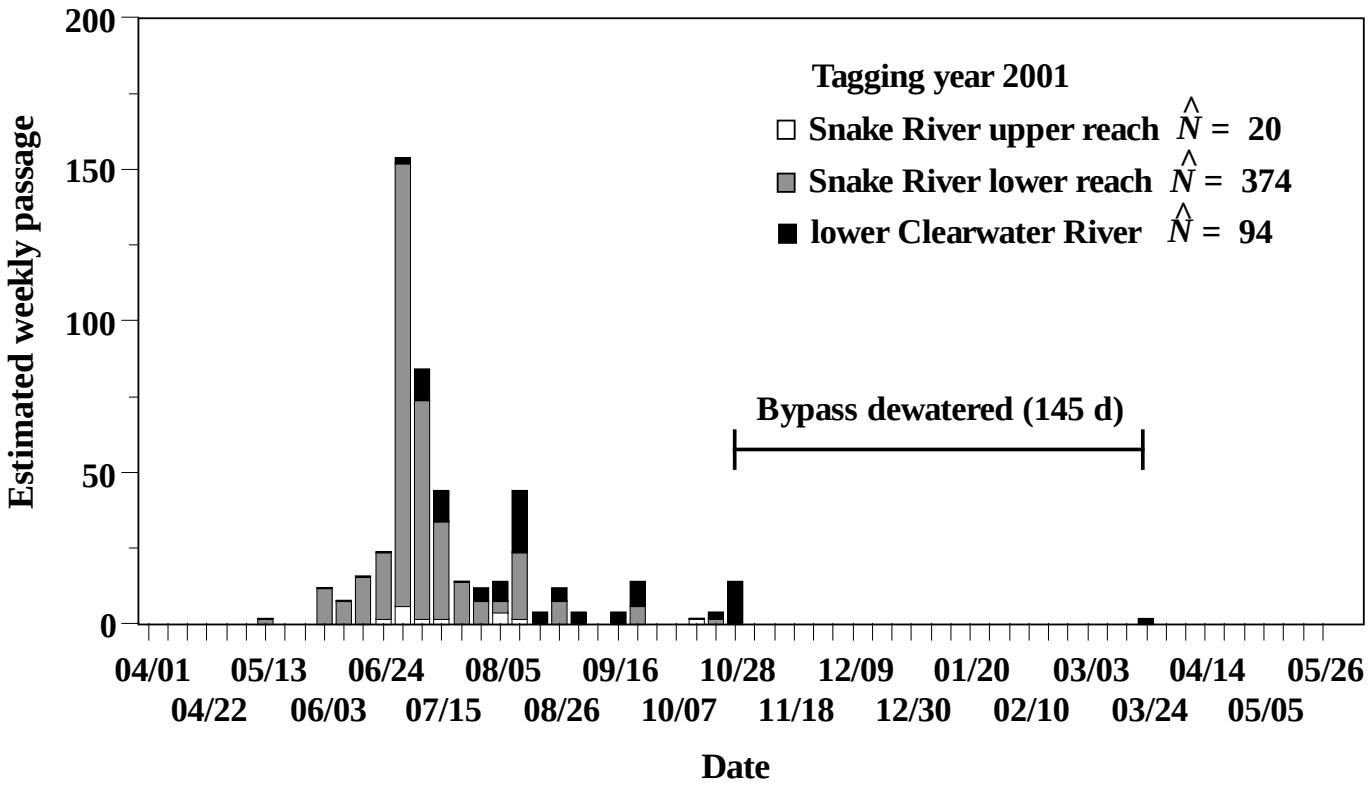

Figure 10. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 2001.

Note: Flow was low and temperature was high. Survival this year was very low (e.g., Snake River upper reach, 9 to 10% from release to tailrace of Lower Granite Dam; Connor and Tiffan 2012). However, summer flow augmentation was fully implemented and likely prevented the type of truncated passage observed in 1992.

Connor, W.P., and K.F. Tiffan. 2012. Evidence for parr growth as a factor affecting parr-to-smolt survival. Transactions of the American Fisheries Society 141:1207-1218.

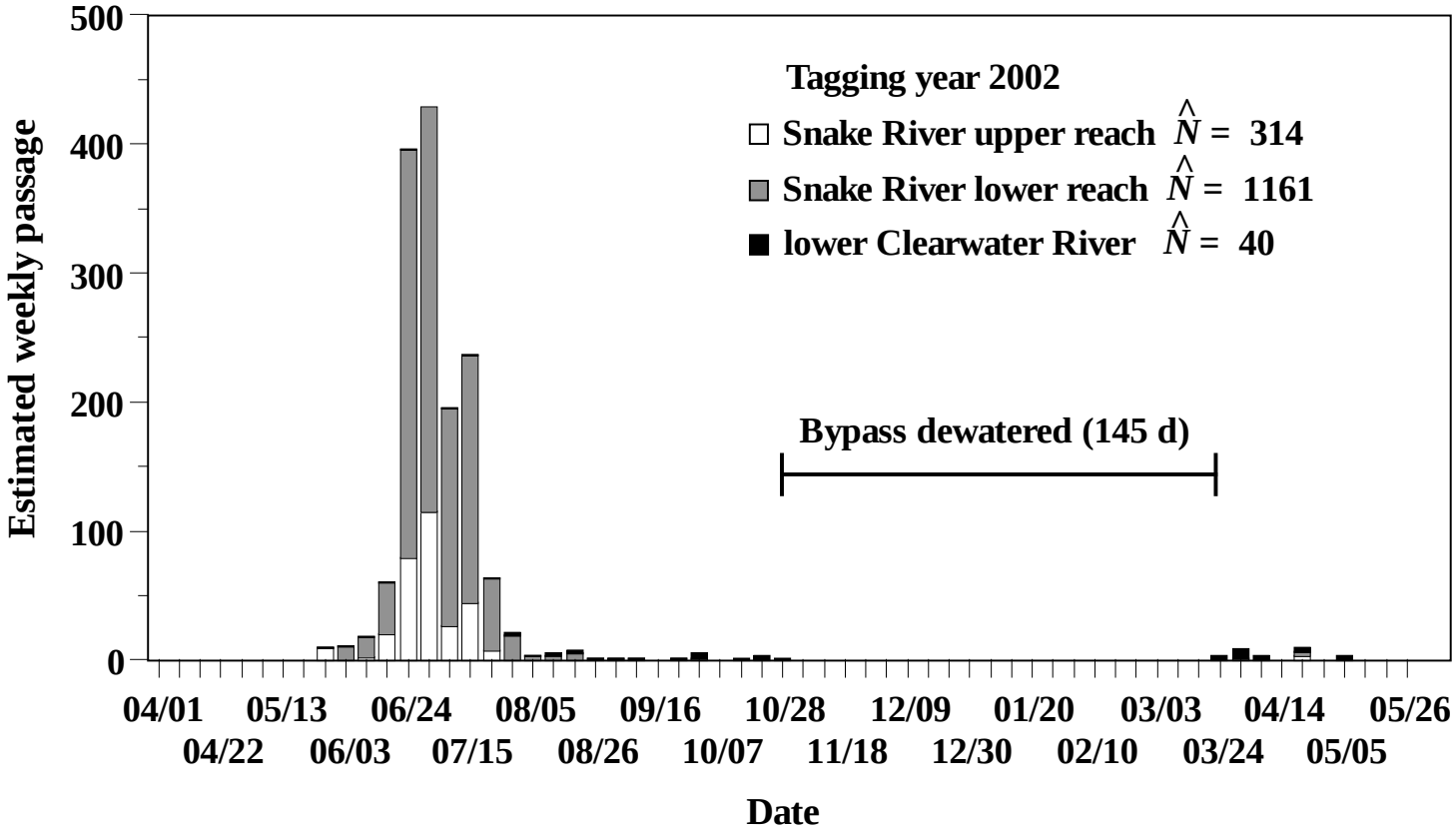

Figure 11. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 2002

Note: Number of fish passing after July has declined.

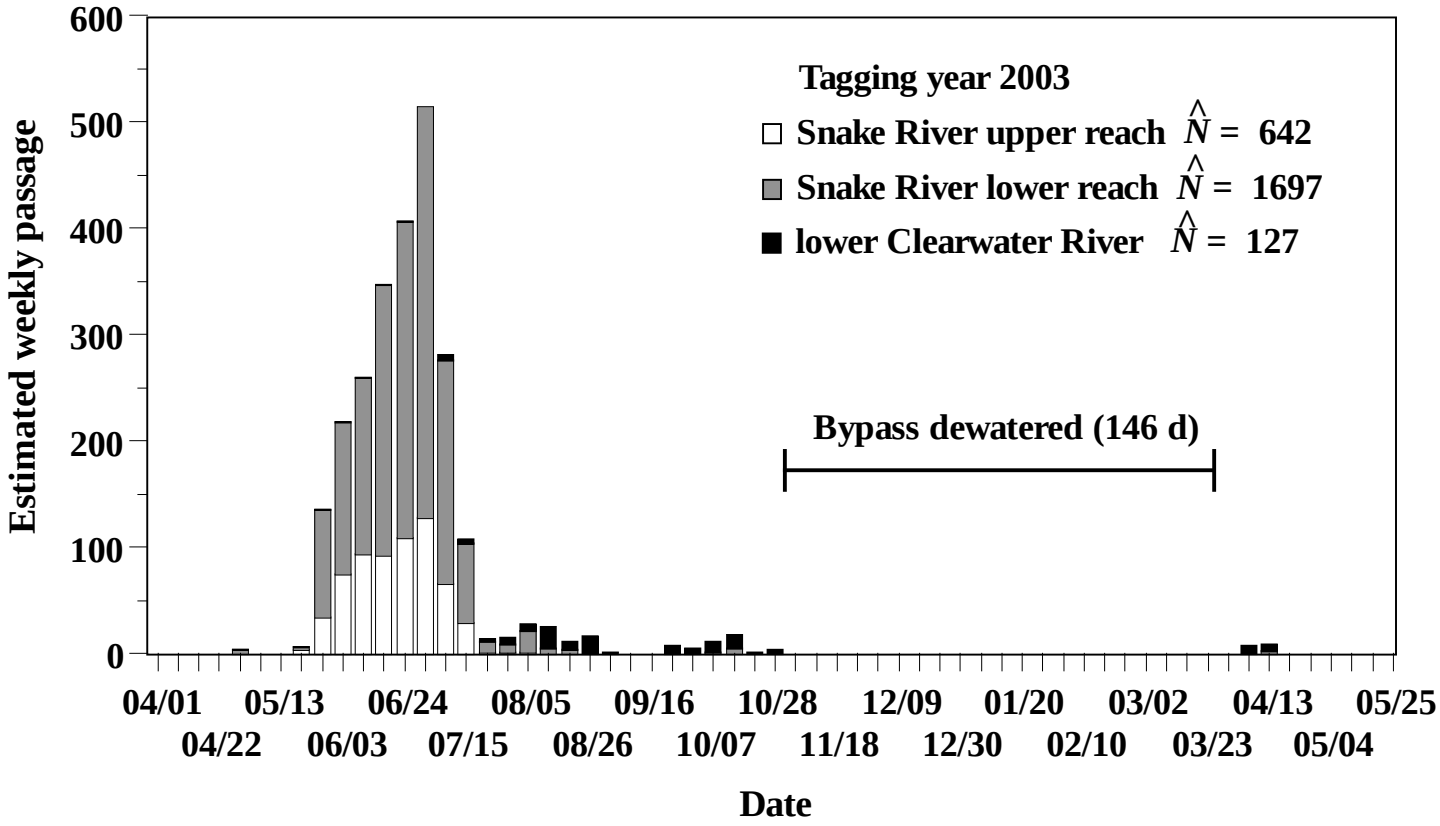

Figure 12. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches in 2003.

Note: Number of fish passing after July has declined.

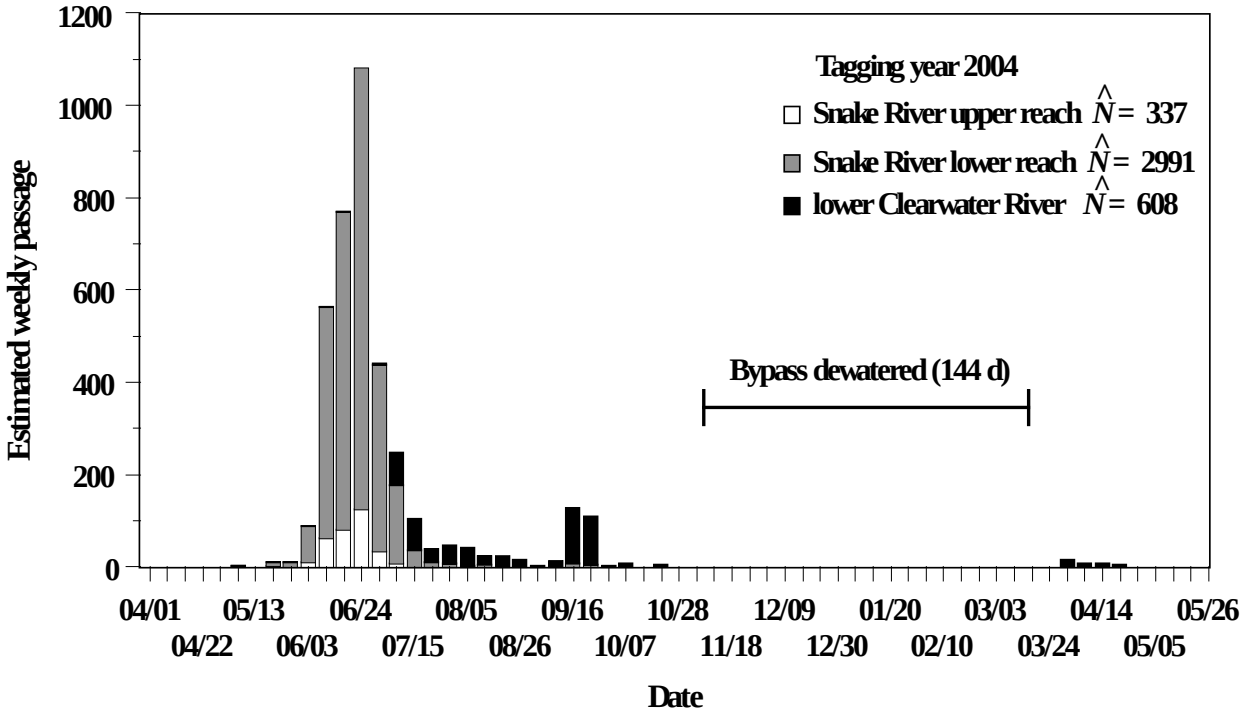

Figure 13. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2004.

Note: The spike in passage in late September.

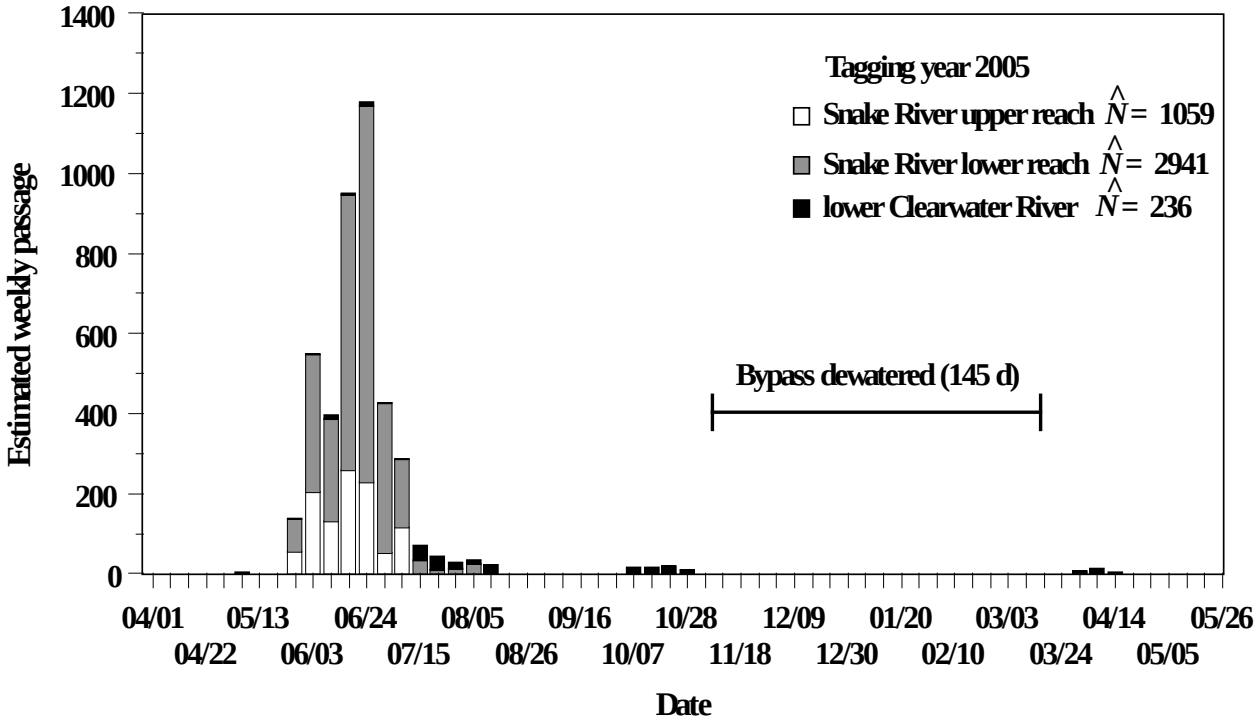

Figure 14. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2005.

Note: This was the first year of the new transportation study. We were working with the Corps to extend the operation of the bypass into winter. It didn't happen in 2005, but focus on the date 10/28 and then page down to Figure 15.

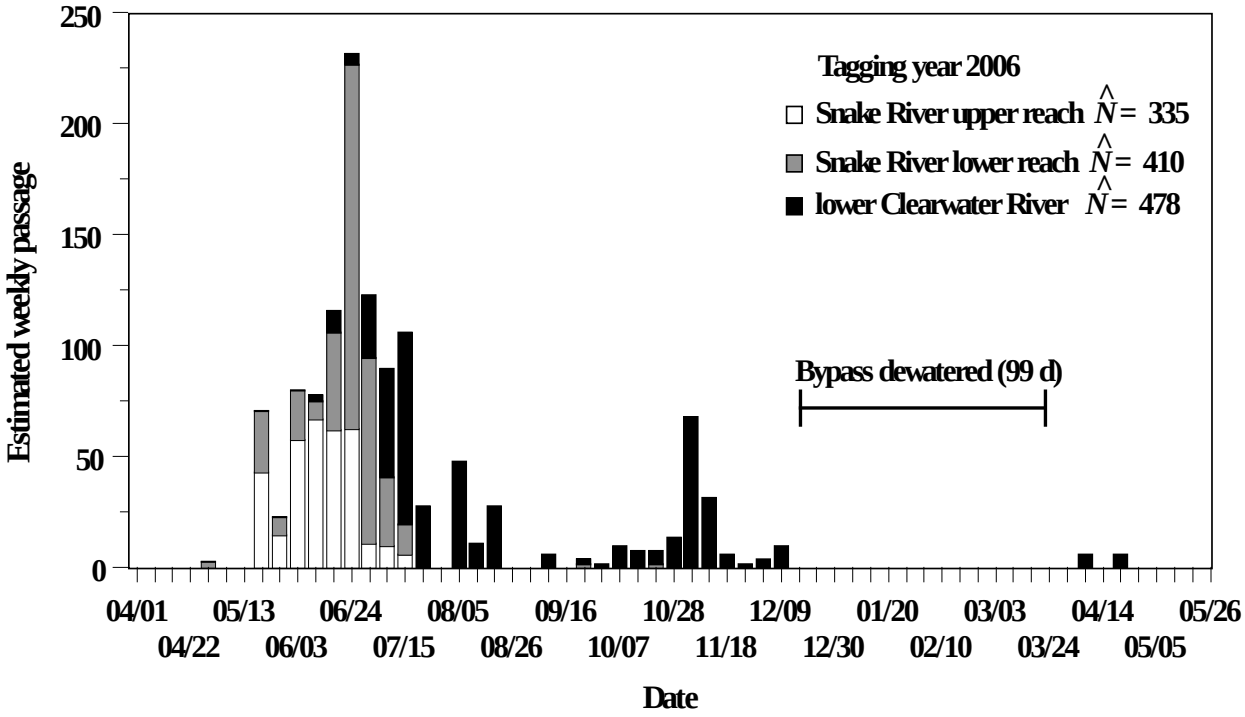

Figure 15. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2006.

Note: It is likely that prior to 2005, many natural fall Chinook salmon juveniles from the lower Clearwater River passed Lower Granite Dam through the turbine intakes during winter when the bypass systems were not operated. This was further confirmed for Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams by (Tiffan et al. 2012).

Tiffan, K.F., T.J. Kock, W.P. Connor, F. Mullins, and R.K. Steinhorst. 2012. Downstream movement of fall Chinook salmon juveniles in the lower Snake River reservoirs during winter and early spring. Transaction of the American Fisheries Society 141:285-293.

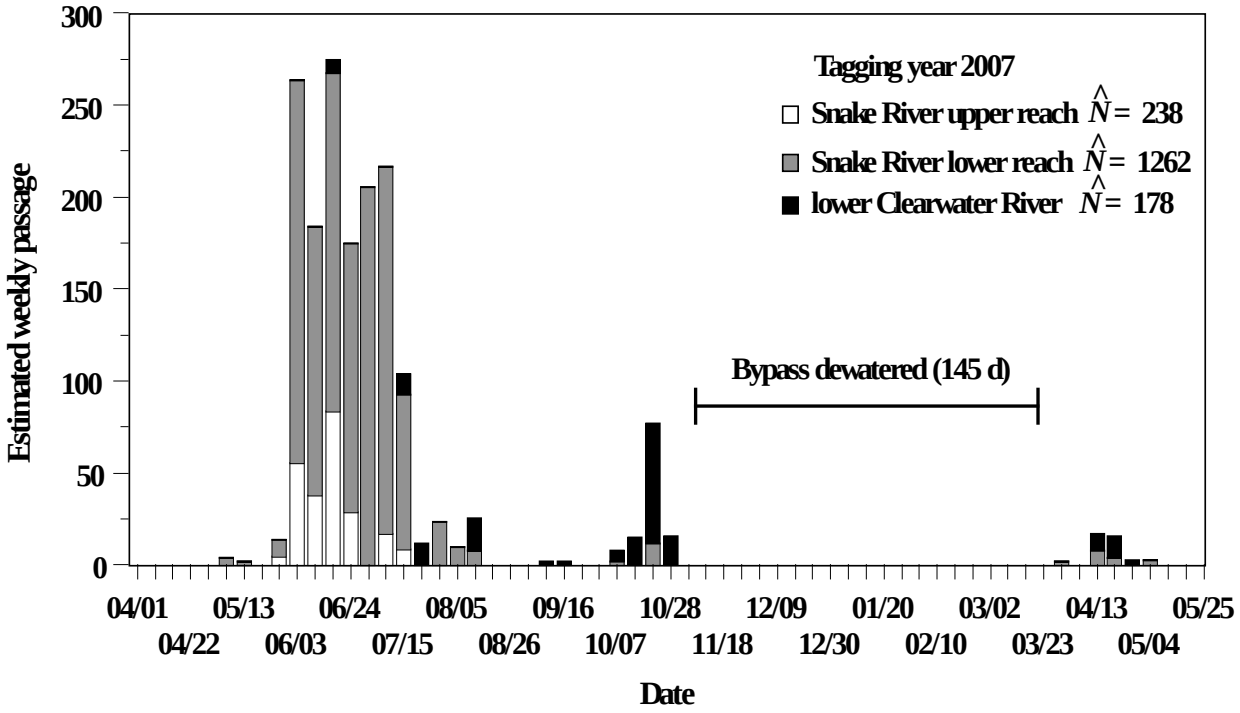

Figure 16. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2007.

Note: Fish were not provided for the transport study, so the Corps did not extend operation of the bypass. NPT begin seining the east arm of Lower Granite Reservoir formed by the lower Clearwater River. This allowed the inclusion of fish that were delayed in this transitional habitat.

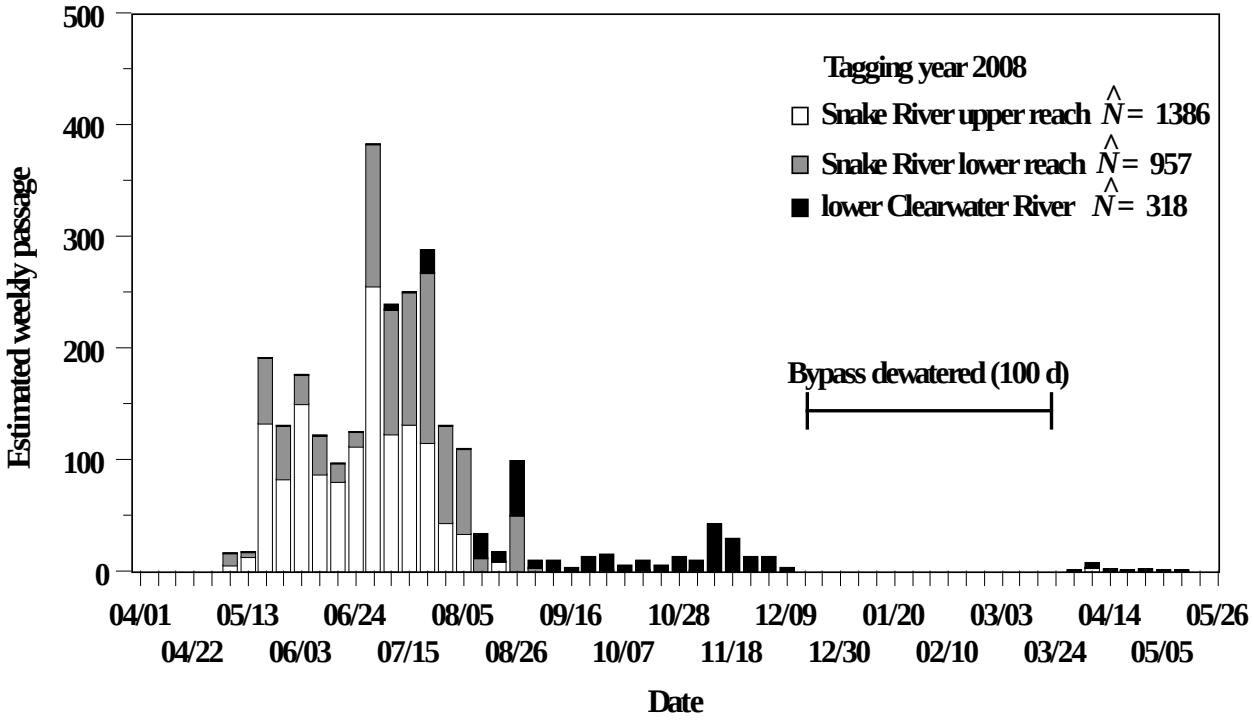

Figure 17. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2008.

Note: Fish were provided for the transport study, so the Corps extended operation of the bypass. We started tagging 50–60 mm fish with 8.5 mm tags in addition to fish ≥ 59 mm with 11.5 mm tags. Connor et al. (in press) conducted preliminary analyses prior to pooling the data across Snake River reaches and tag size. They found that the maximum difference (Dmax) between the cumulative passage date distributions calculated using both tag sizes together and the 11.5 mm tags alone, was 8% ($P < 0.001$) in 2008, 6% in ($P = 0.04$) in 2009, 3% ($P = 0.5$) in 2010, and frequency distributions of both evaluated the effect of adding , and 11% ($P = 0.003$) in 2011. The differences in the median dates of passage for the two tag groups was 0 d in 2008, 2 d in 2009, 1 d in 2009, and 3 d in 2011. The bottom line was that use of the smaller tags better represented the run because fish size during tagging declined during the high abundance period, and that fish tagged fork lengths ≤ 59 passed Lower Granite Dam a little earlier than fish tagged at fork lengths ≥ 59 mm. Operation of the bypass system was extended and this operation continued through 2012. Not sure if it will be continued in 2013.

Connor, W. P., K. F. Tiffan, J., J. M. Plumb, and C. M. Moffitt. 2013. Evidence for density –dependent changes in growth, downstream movement, and size of Chinook salmon subyearlings in a large river landscape. Transactions of the American Fisheries Society 142:1453–1468.

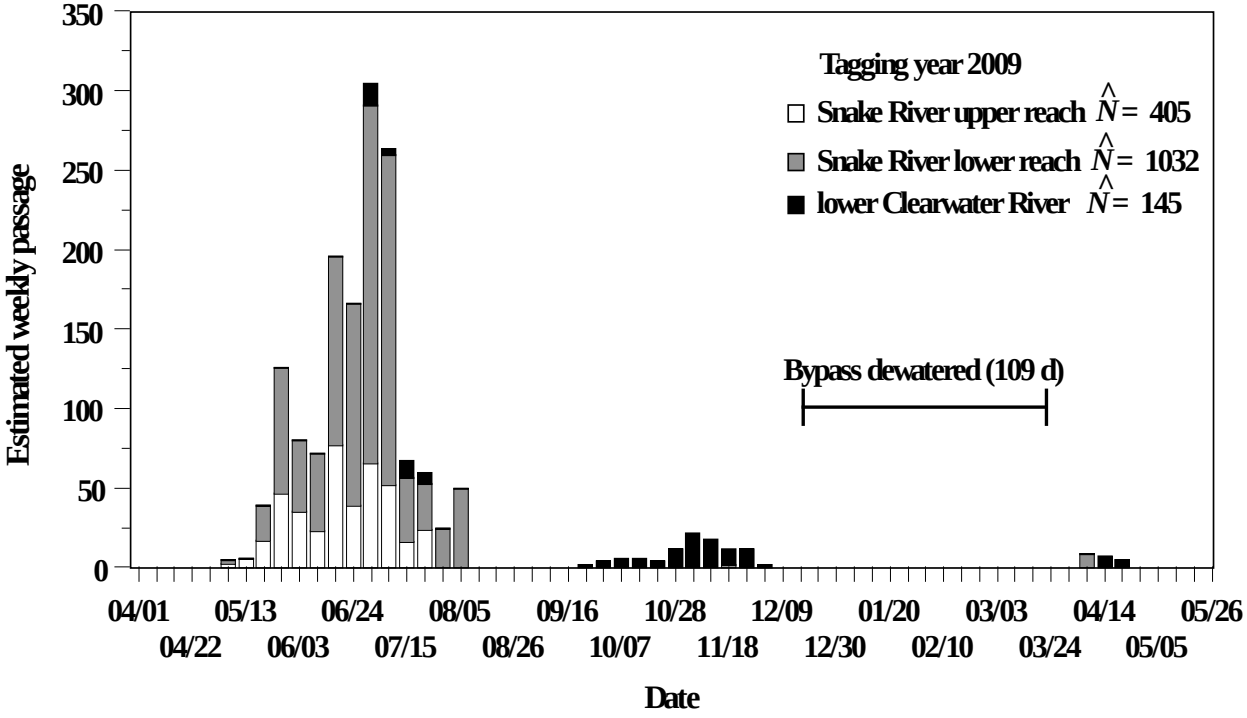

Figure 18. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2009.

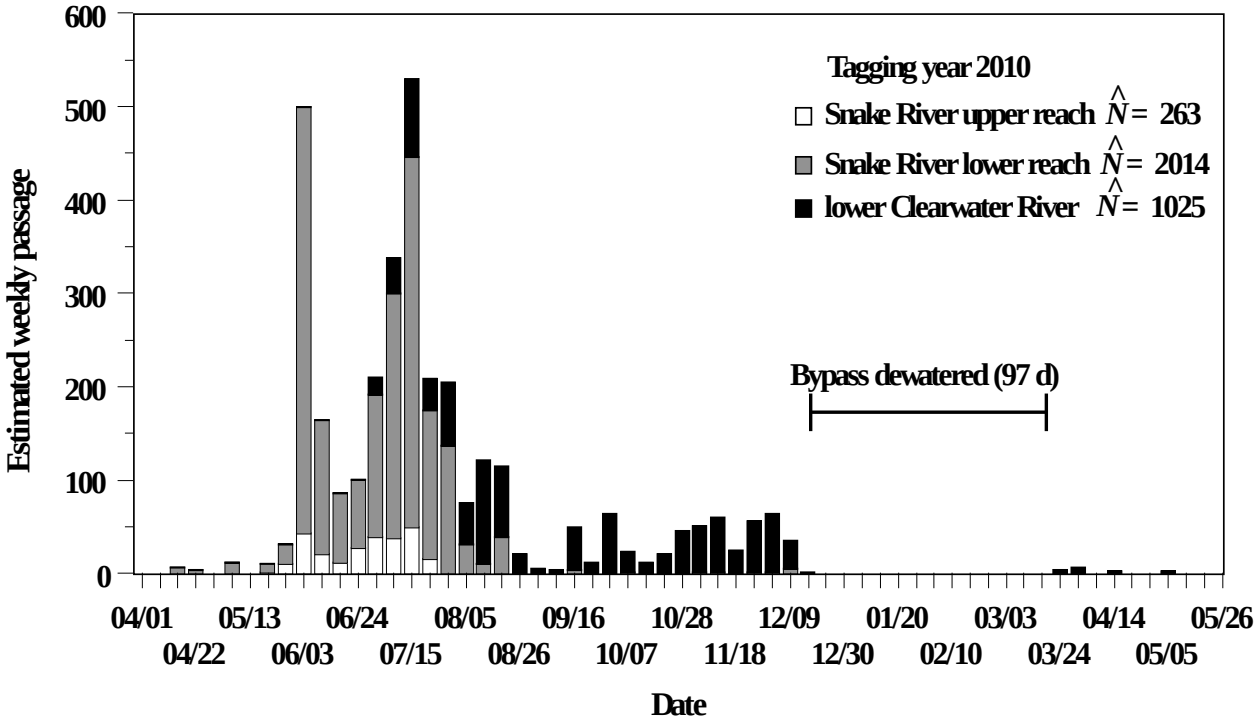

Figure 19. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2010.

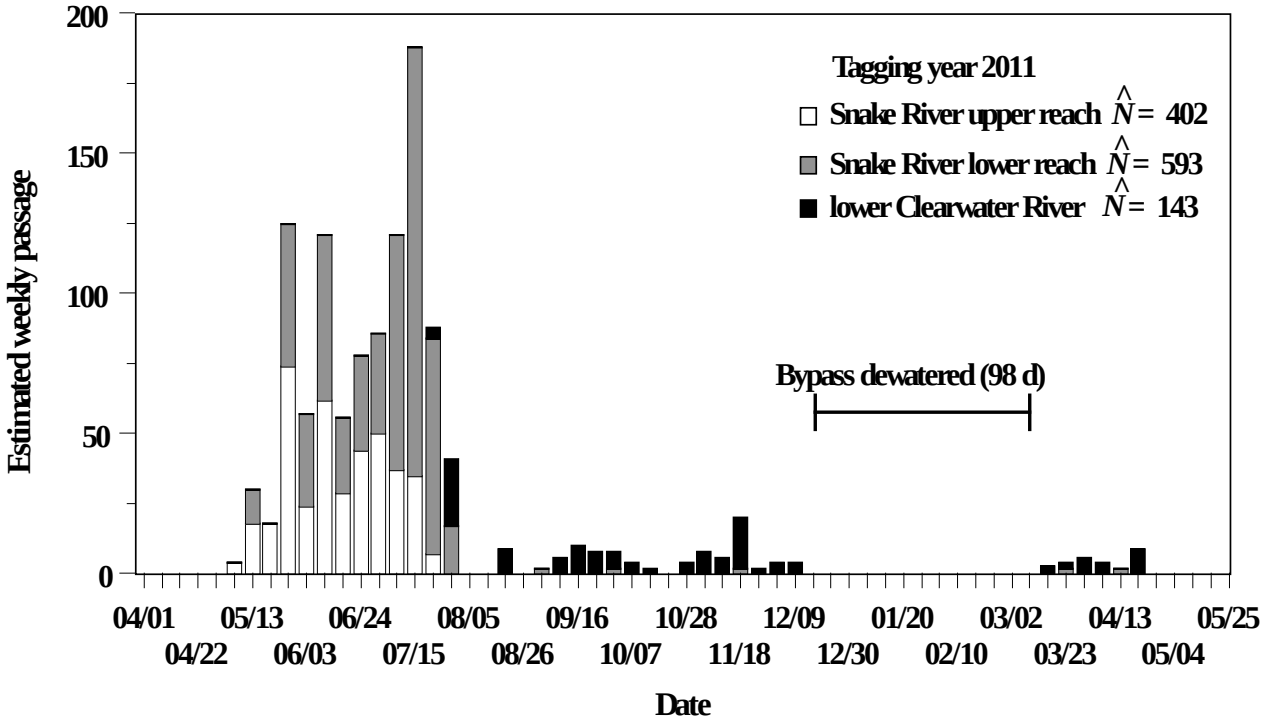

Figure 20. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2011.

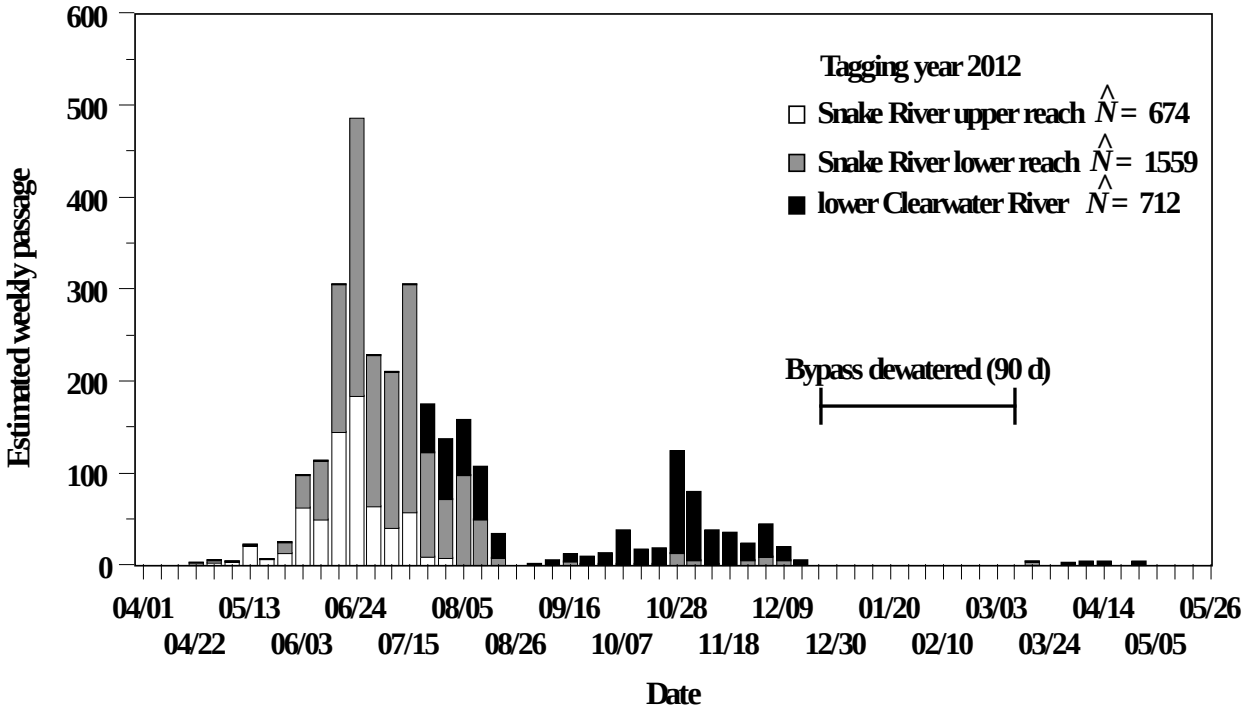

Figure 21. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2012.

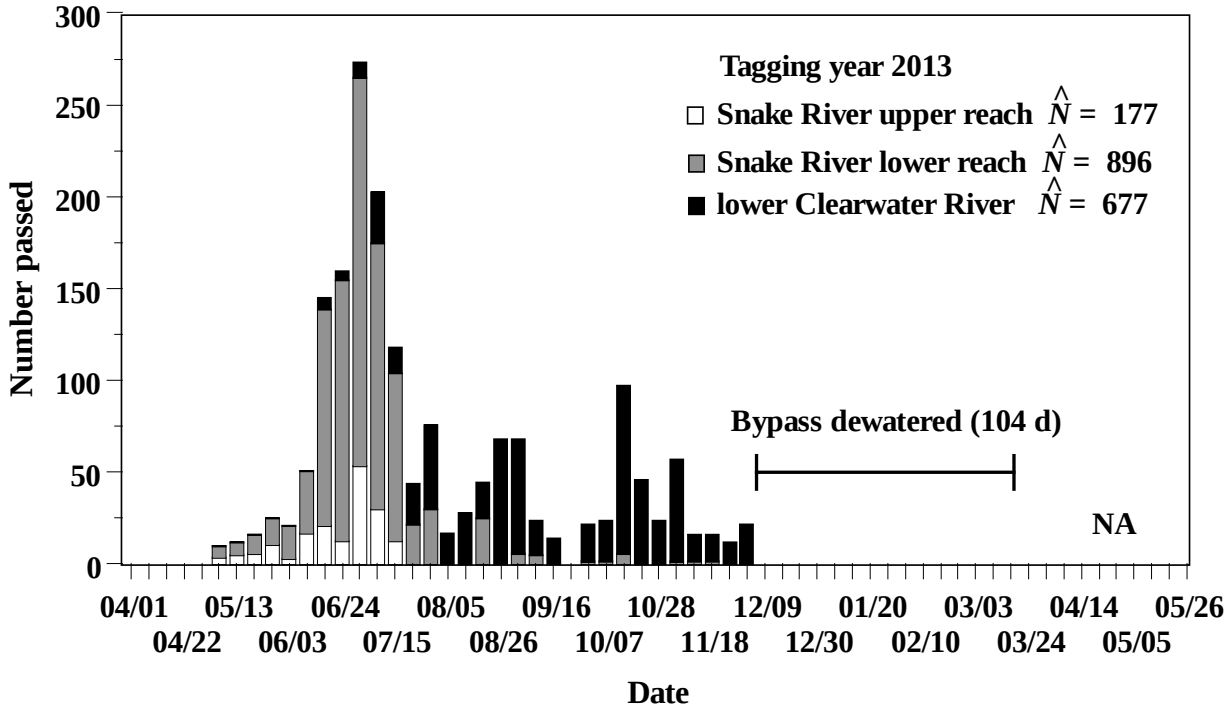

Figure 22. Estimated weekly passage at Lower Granite Dam for natural fall Chinook salmon subyearlings PIT-tagged in the Snake River upper and lower reaches, and the lower Clearwater River in 2013.

Note: NA = The annual report was due before detection data were available in 2014. Data will be provided in the next annual report.

Appendix C: Predation Details

Smallmouth bass predation on juvenile fall Chinook salmon in the Hells Canyon Reach of the Snake River, 2012-2013

Scott J. St. John, John M. Erhardt, Brad K. Bickford, Tobyn N. Rhodes, and Kenneth F. Tiffan
U.S. Geological Survey
Western Fisheries Research Center
5501A Cook-Underwood Rd.
Cook, WA 98605

Introduction

Predation by nonnative fishes is one factor that has been implicated in the decline of juvenile salmonids *Oncorhynchus* spp. in the Pacific Northwest. Smallmouth bass *Micropterus dolomieu* were thought to have first been stocked into the Snake River basin in the late 1800s to provide angling opportunities (Munther 1970). Smallmouth bass were actively stocked in the Snake River by the Idaho Department of Fish and Game in 1941, and have become the most abundant predator in the unimpounded Hells Canyon Reach of the Snake River (Nelle 1999) and its lower reservoirs (Zimmerman and Parker 1995). This is a particular concern for Snake River fall Chinook salmon *O. tshawytscha* subyearlings because their relatively small size and the overlap of their main-stem rearing habitats with that of smallmouth bass may make them particularly vulnerable to predation (Curet 1993; Tabor et al. 1993).

Concern over juvenile salmon predation spawned a number of large-scale studies to quantify its effect in the late 1980s, 1990s, and early 2000s (Poe et al. 1991; Rieman et al. 1991; Vigg et al. 1991; Fritts and Pearsons 2004; Naughton et al. 2004). In transitional habitat between the Hanford Reach of the Columbia River and McNary Reservoir, juvenile salmon (presumably subyearlings) were found in 65% of smallmouth bass (>200 mm) stomachs and composed 59% of the diet by weight (Tabor et al. 1993). Within the upper portion of the Hells Canyon Reach of the Snake River, Nelle (1999) reported that subyearlings only made up 1.9% and 0.8% of smallmouth bass diets by weight in 1996 and 1997, respectively. However, this study in the Snake River was conducted soon after Endangered Species Act (ESA) listing of Snake River fall Chinook salmon (NMFS 1992). During this time, fall Chinook salmon abundance was at an historic low and may explain why consumption rates were relatively low compared to those from studies conducted in the Columbia and Yakima rivers where abundance was higher (Tabor et al. 1993; Fritts and Pearsons 2004).

We speculate that predation on subyearlings by smallmouth bass in the Snake River may have increased in recent years for several reasons. Since their ESA listing, recovery measures implemented for Snake River fall Chinook salmon have resulted in a large increase in the juvenile population (Connor et al. 2013). For example, the annual subyearling passage index at Lower Granite Dam, the first dam encountered by fish produced in Hells Canyon, was 18,533 in 1996 but was 749,074 in 2013 (DART 2014). Both Zimmerman (1999) and Naughton et al. (2004) showed that fish can comprise a large portion of smallmouth bass diets. Considering that subyearlings probably now make up a larger portion of the forage fish population, it is plausible they should make up a large portion of smallmouth diets. We initiated a study in 2012 to re-examine smallmouth predation on subyearlings in Lower Granite Reservoir. Our objectives were to 1) describe the seasonal variation in smallmouth bass diets during the subyearling rearing and outmigration period, and 2) estimate the abundance of smallmouth and quantify their consumption of subyearlings.

Study Area

We conducted our study within Hells Canyon between Asotin, Washington (river kilometer [rkm] 234) and Sheep Creek Rapids (rkm 369). The Snake River flows through Hells Canyon in a northwesterly direction through a semi-arid environment of steep canyon walls of basalt. The overall mean gradient in this reach is 1.1

m/km and mean width is 142 m (Nelle 1999). Shoreline substrates consist mainly of bedrock, large boulders, and cobble interspersed with occasional small sandy beaches.

We divided the study area into three reaches for sampling. The lower reach extended from Asotin, Washington upstream to the mouth of the Grande Ronde River (rkm 272). The middle reach extended from the mouth of the Grande Ronde River upstream to the mouth of the Salmon River (rkm 303). The upper reach extended from the mouth of the Salmon River upstream to Sheep Creek Rapids, and has slightly warmer water temperatures than the downstream reaches. The upper reach encompasses the "upper section" sampled by Nelle (1999), whereas the lower and middle reaches combined correspond to the "lower or downstream section" sampled by Nelle (1999).

Methods

Smallmouth bass collections

We collected smallmouth bass in each reach using angling or boat electrofishing depending on the year. In 2012, we only used angling to minimize encounters with ESA-listed salmonids. In 2013, we used angling and some electrofishing to increase our catch of smallmouth bass, which was more effective during periods of high flows and turbid water. ESA permit restrictions forced us to use angling once water temperatures exceeded 18°C.

In 2012, we divided each reach into 0.1-km sites that served as the basis for sampling. We randomly selected 8 to 17 sites to sample without replacement within a given reach and week. Angling was conducted biweekly from 23 April to 2 July by 2-5 people fishing out of 1-2 boats. Each site was fished by the crew of one boat for 20 min. Boats either remained stationary during sampling or drifted (no more than 100 m) along the shoreline when river velocities were high. The number of anglers and time angled were recorded for each site. In 2013, we randomly selected four 0.1-km locations and used these as starting points for sites that remained fixed for the remainder of the study. We refer to these as fixed sites. Each fixed site included both banks of the river and each bank was sampled for about 200-800 m in length for 75 minutes by one boat with 2-3 people. We supplemented the fixed sampling sites with randomly chosen sites (without replacement) in the same manner as 2012. In 2013, sampling was conducted from 8 April to 1 July.

In 2013, daytime electrofishing was conducted in the lower reach until 17 June, in the middle reach on 20 May and 13 June, and in the upper reach on 6 May. The shorelines of each site were sampled in a downstream direction from the starting point. The time and distance sampled was recorded for each site. Electrofishing output was 400 V DC with 60 pulses per second at 2-4amps. Smallmouth bass were collected by two dipnetters.

All captured smallmouth bass were placed in an aerated live well supplied with recirculating water and held no longer than 80 minutes for electrofishing events and 25-80 minutes for angling events before being processed and released. All fish over 150 mm total length (TL) were measured then tagged with a unique Floy

tag. Weights were estimated from a regression we developed from length and weight data collected from all fish in 2012 and 20 fish in each reach and each sampling week in 2013. The regression was:

$$Wt = 0.00002TL^{2.94} \quad (1)$$

where Wt is the weight (g) and TL is the total length (mm; N=2,417, R^2=0.87).

At each sampling site, we collected the stomach contents from all smallmouth bass using modified non-lethal lavage (Seaburg 1957). The lavage instrument consisted of a ¼" tube connected to a common garden spray nozzle that supplied filtered river water via a wash-down pump installed on the boat. Stomach contents were collected in a 425µm sieve and preserved in 90% ethanol.

Smallmouth bass abundance

We calculated catch-per-unit-effort (CPUE) for both angling and electrofishing to compare the efficiency of each method. CPUE for each reach and sampling week was calculated as the total number of smallmouth bass collected divided by the total sampling time (min).

In 2012, we estimated the absolute abundance of smallmouth bass ≥150 mm TL during a mark-recapture sampling effort in the fall using electrofishing. We sampled 39 randomly selected sites from 9 to 12 October (marking event) and re-sampled the same sites from 22 to 24 October (recapture event). Fish collected during the marking event were tagged with unique Floy tags. Data for each reach were pooled due to low numbers of recaptured fish. Abundance $(\widehat{N})$ in the sampling sites (s) for each reach (r) was estimated with the Chapman estimator of the Petersen index (Seber 1982):

$$\widehat{N}_{s,r} = \frac{(n_1+1)(n_2+1)}{(R+1)} - 1\,, \quad (2)$$

where n_1 = number of bass caught and marked in the first sampling period, n_2 = number of bass caught in the second sampling period, and R = the number of recaptured bass in the second sampling period. We calculated variances of the estimates and 95% confidence intervals (CI) using a normal approximation (Seber 1982). The abundance estimates (and CIs) for the sites in each reach were then divided by the number of meters sampled (MS_r) to determine the number of fish per meter of shoreline. These estimates were then extrapolated to the number of total meters of shoreline in each reach to derive a total population estimate ($\widehat{N}_r$).

In 2013, we used an open population mark-recapture model in program MARK (White and Burnham 1999) to estimate weekly abundances of smallmouth bass in each reach because we sampled four fixed sites/reach (fs/r) throughout the study (described above). Data for all sites were pooled by reach. The POPAN parameterization of the Jolly-Seber model (Schwarz and Arnason 1996) was used to derive estimates of abundance for each sampling occasion. A fully time-dependent model and models with constant survival and catchability (p) were fit and AIC was used to determine the best overall model. Due to confounding constraints on the first and last sampling occasion, the mean abundance estimate from the second through fifth sampling

occasion was used. The abundance estimates (and CIs) for the fixed sites in each reach were then divided by the number of meters sampled (MS_r) to determine the number of fish per meter of shoreline. These estimates were then extrapolated to the number of total meters of shoreline in each reach and summed to derive a total population estimate for each reach/sampling occasion.

Diet analysis

Smallmouth bass dietary items were identified to the lowest practical taxon in the laboratory, and were placed into four groups: insects, crayfish, fish, and other. All diet items were then enumerated, blotted for 30 s, and weighed (± 0.001 g). All insects were identified to Order and unidentifiable insect parts were not enumerated, but were weighed together as a group. Crustaceans were identified to order, and where possible to genus and species. All other prey that could not be assigned to a group were classified as "other" and often consisted of vegetation, rocks, and worms. Ingested fish were identified to lowest possible taxon (usually species) using diagnostic bones (i.e., dentary, cleithrum, opercle; Parrish et al. 2006). Fish remains were soaked in warm water to soften muscle tissue which was then scraped from the bones. Bones were measured with an ocular micrometer mounted in a dissecting scope. We back-calculated FL at ingestion of each individual salmonid, and other prey fish, consumed using bone-length regressions from literature (Hansel et al. 1988) or to standard length (SL) with regressions developed by this study (Table 1). We used additional regressions to calculate FL from SL, nape to tail lengths, or dorsal standard lengths when necessary (Vigg et al. 1991, Parris et al. 2006). Fish remains that did not contain diagnostic bones were classified as "unidentified" and were weighed. When only unidentifiable fish parts where present with a diagnostic bone in a sample, we associated all weight to the species identified. We calculated the maximum relative length of prey fish consumed by smallmouth bass (prey fish FL/bass TL * 100) to determine size of prey vulnerability.

Table 1. Linear regressions for predicting various measures of fish length based on measurements of diagnostic bones. Regression model take the form of $y=a+bx$, where y is the fish length (mm) to be estimated, a is the intercept, b is the slope, and x is the measure of the diagnostic bone (mm).

Fish length measure	*N*	*a*	*b*	r^2
		Cleithrum		
Fork length	31	1.983	7.347	0.96
Standard length	114	-0.408	6.984	0.95
		Dentary		
Fork length	30	14.823	7.819	0.83
Standard length	96	13.291	7.499	0.80
		Opercle		
Fork length	12	9.844	10.888	0.89
Standard length	29	10.485	9.884	0.80

Consumption

Preliminary analyses of two different size classes of smallmouth bass (150-200 mm, >200 mm) did not show any differences in diet or consumption, therefore we pooled all fish for final analyses. We estimated the daily consumption of juvenile salmonids and other prey fish by smallmouth bass (≥150 mm) in each reach. First, we calculated the weight at ingestion (*WI*) of each fish species consumed from their predicted or actual fork length measurement and regressions from Vigg et al. (1991). Next, we calculated meal weight (*MW*) using an equation similar to Vigg et al. (1991) for each individual bass that had a prey fish in their stomach where the digested weight was within 90% of *WI* (WI_{90}):

$$MW = \sum_{i=1}^{n} WI_{90} + D \ , \qquad (3)$$

where $n =$ the number of prey fish in the stomach contents of an individual bass (that were <90% digested) and *D* is the digested weight of all other prey items (mainly insects and crustaceans) in the sample. We also included all digested weights of prey fish that were not within 90% of original weight in the calculation of *D* because meal weight has an impact on evacuation rates (Rogers and Burley 1991). We used 90% digestion (after Rogers and Burley 1991) because indigestible parts could remain in the gut of fish for long periods of time. We calculated the evacuation time (hours) to 90% digestion (ET_{90}) for each bass using a model developed for smallmouth bass by Rogers and Burley (1991) and re-solved for by Fritts and Pearsons (2004):

$$ET_{90} = (24.542)(MW^{0.29} e^{-0.15T} W^{-0.23})(24), \qquad (4)$$

where *T* is temperature (°C; measured at time of sample collection) and *W* is bass weight (g; also taken at time of sample collection). The consumption rate (*C*; the number of salmonids per bass per day) was then calculated following Ward et al. (1995):

$$C = n_{90}(24/ET_{90}), \qquad (5)$$

where n_{90} is the number of salmonids within 90% digestion found in the individual bass. The mean *C* per reach per sampling occasion (*CM*) was calculated and input into the Fritts and Pearsons (2004) equation (6) to estimate the daily number of salmonids consumed (*SC*) within each reach (*r*) for each sampling occasion (*o*):

$$SC_{ro} = \widehat{N}_r \cdot BS \cdot \ CM_{ro}, \qquad (6)$$

where *BS* is the number of bass stomachs (per reach per sampling occasion) that contained at least one salmonid within 90% digestion divided by the total number of stomachs examined (per reach per sampling occasion), including bass that had empty stomachs. The single abundance estimate (closed model) for each reach from 2012 ($\widehat{N}_r$) and estimates/occasion in 2013 (open model) were used (calculated above). We also calculated 95%

CIs for SC_{ro} by multiplying the 95% CIs of each corresponding abundance estimate by SC_{ro}. Finally, the total loss of salmonids (S_{tot}) per reach was calculated as:

$$S_{tot} = \sum_{i=1}^{n} SC_{ro} \times I \,, \qquad (7)$$

where I is the interval between sampling occasions (i.e., 14 d).

Results

Abundance

Relative abundance.—In 2012, we sampled a total of 181 randomly selected sites by angling (Table 2). A total of 3,473 minutes were expended angling resulting in the collection of 610 bass, most of which were collected in the upper reach. In 2013, we sampled a total of 127 random and fixed sites by angling and 26 sites by electrofishing (Table 2). A total of 10,323 minutes were expended angling resulting in the collection of 1,672 bass, most of which were collected in the upper reach. In 2013, 547 minutes of electrofishing effort was recorded and used to calculate CPUE. Additional electrofishing was conducted but times were not recorded due to mechanical failure of the electroshocker timer. In 2013, 0.71 smallmouth bass were collected per minute of electrofishing whereas only 0.08 bass per minute were caught by angling (Table 2).

Absolute abundance.—The abundance of smallmouth bass ≥150 mm was highest in the upper reach for both years and all biweekly sampling occasions (Table 3). For the 2012 fall mark-recapture event, we estimated 77,940 bass (95% CI: 54,398-101,483) in the upper reach, followed by 12,212 bass (95% CI: 2,959-21,465) in the middle reach, and 8,577 bass (95% CI: 1,832-15,322) in the lower reach (Table 3). This equates to 0.85, 0.19, and 0.12 fish/m of shoreline in each reach, respectively. Similar abundance estimates were calculated for the 2013 data using the open population model. The fully time-dependent model fit the mark-recapture data the best for 2013. Abundance estimates varied by sampling week but were generally similar within a reach when very high and low estimates are excluded. The highest abundance estimate was in the upper reach (102,875 bass; 1.12 bass/m of shoreline). The highest estimate in the middle reach was 31,629 bass (0.50 bass/m of shoreline) while the highest estimate in the lower reach was 27,144bass (0.37 bass/m of shoreline).

Table 2. Seasonal catch-per-unit-effort of smallmouth bass collected by angling and boat electrofishing in three reaches in Hells Canyon of the Snake River, 2012-2013. Effort was calculated from total minutes angled by individual boat or total time the electroshocking unit was on.

Week beginning	Method	Site Type	Number of sites	Effort (minutes)	Number captured	Number per site	Number per minute
				Upper			
4/23/12	Angling	Random	8	160	23	2.88	0.14
5/7/12	Angling	Random	15	300	83	5.53	0.28
5/21/12	Angling	Random	6	120	16	2.67	0.13
6/4/12	Angling	Random	16	320	148	9.25	0.46
6/18/12	Angling	Random	9	175	82	9.11	0.47
7/2/12	Angling	Random	9	180	80	8.89	0.44
All 2012	Angling	Random	63	1,255	432	6.86	0.34
4/8/13	Angling	Random	17	377	42	2.47	0.11
	Angling	Fixed	4	602	82	20.50	0.14
4/22/13	Angling	Random	16	320	111	6.94	0.35
	Angling	Fixed	4	610	160	40.00	0.26
5/6/13	Angling	Random	10	200	68	6.80	0.34
	Angling	Fixed	4	600	208	52.00	0.35
	Electrofishing	Fixed	1	37	66	66.00	1.78
5/20/13	Angling	Fixed	3	460	87	29.00	0.19
6/3/13	Angling	Random	1	20	17	17.00	0.85
	Angling	Fixed	4	600	183	45.75	0.31
6/17/13	Angling	Fixed	4	595	185	46.25	0.31
All 2013	Angling	Both	67	4,384	1,143	17.06	0.26
				Middle			
4/23/12	Angling	Random	15	300	15	1.00	0.05
5/7/12	Angling	Random	9	180	9	1.00	0.05
5/21/12	Angling	Random	8	160	5	0.63	0.31
6/4/12	Angling	Random	9	180	13	1.44	0.07
6/18/12	Angling	Random	7	140	21	3.00	0.15
7/2/12	Angling	Random	9	180	15	1.67	0.08
All 2012	Angling	Random	57	996	78	1.37	0.08
4/22/13	Angling	Fixed	4	600	60	15.00	0.10

Table 2. Continued

Week beginning	Method	Site Type	Number of sites	Effort (minutes)	Number captured	Number per site	Number per minute
5/6/13	Angling	Fixed	4	600	78	19.50	0.13
5/20/13	Angling	Random	7	184	20	2.86	0.11
	Angling	Fixed	4	450	39	9.75	0.09
	Electrofishing	Fixed	1	49	19	19.00	0.39
6/3/13	Angling	Random	6	90	9	1.50	0.10
	Angling	Fixed	4	600	47	11.75	0.08
	Electrofishing	Random	2	81	56	28.00	0.69
	Electrofishing	Fixed	1	29	57	57.00	1.97
6/17/13	Angling	Fixed	4	600	48	12.00	0.08
7/1/13	Angling	Random	1	17	2	2.00	0.12
	Angling	Fixed	3	450	28	9.33	0.06
All 2013	Angling	Both	37	3,591	331	8.95	0.09
	Electrofishing	Both	4	159	132	33.00	0.83
				Lower			
5/7/12	Angling	Random	11	220	9	0.82	0.04
5/21/12	Angling	Random	15	300	2	0.13	0.01
6/4/12	Angling	Random	10	202	12	1.2	0.06
6/18/12	Angling	Random	8	160	33	4.13	0.21
7/2/12	Angling	Random	17	340	44	2.59	0.13
All 2012	Angling	Random	61	1,222	100	1.64	0.08
4/22/13	Angling	Fixed	4	600	9	2.25	0.02
	Electrofishing	Fixed	4	---	31	7.75	
	Electrofishing	Random	1	8	2	2.00	0.25
5/6/13	Angling	Fixed	4	417	19	4.75	0.05
	Electrofishing	Fixed	3	95	70	23.33	0.74
5/20/13	Angling	Fixed	2	29	0	0.00	0.00
	Angling	Random	1	22	0	0.00	0.00
	Electrofishing	Fixed	4	110	54	13.50	0.49
	Electrofishing	Random	4	89	106	26.50	1.19
6/3/13	Angling	Random	3	60	11	3.67	0.18
	Electrofishing	Fixed	4	245	154	38.50	0.63
6/17/13	Angling	Random	1	20	3	3.00	0.15

Table 2. Continued

Week beginning	Method	Site Type	Number of sites	Effort (minutes)	Number captured	Number per site	Number per minute
	Electrofishing	Fixed	1	---	52	52.00	
7/1/13	Angling	Fixed	4	600	78	19.50	0.13
All 2013	Angling	Both	23	2,348	198	8.61	0.08
	Electrofishing	Both	21	547[a]	386[a]	22.33	0.71[a]

[a]Calculated from available data.

Table 3. Estimates of population abundance of smallmouth bass >150 mm TL in study reaches in Hells Canyon in 2012-13. Also shown are the population estimates for fish ≥175 mm made by Nelle (1999) for the upper and lower sections in 1997. The lower section of Nelle encompassed our middle and lower reaches.

Reach	Week	Estimated abundance	95% confidence interval	Fish/m of shoreline
		2012		
Upper	na	77,940	54,398-101,483	0.85
Middle	na	12,212	2,959-21,465	0.19
Lower	na	8,577	1,832-15,322	0.12
		2013		
Upper	8 Apr	84,379[a]	41,364-127,485[a]	0.92[a]
Upper	22 Apr	102,875	63,501-142,248	1.12
Upper	6 May	67,927	36,658-99,195	0.74
Upper	20 May	86,083	30,737-141,429	0.94
Upper	3 Jun	81,141	34,767-127,515	0.88
Upper	17 Jun	84,379[a]	41,364-127,485[a]	0.92[a]
Upper (Average)		84,464		0.92
Middle	22 Apr	22,051[b]	10,711-45,677[b]	0.35[b]
Middle	6 May	31,629	16,303-61,362	0.50
Middle	20 May	16,221	7,159-36,752	0.26
Middle	3 Jun	19,355	9,248-40,509	0.31
Middle	17 Jun	21,040	10,067-43,974	0.33
Middle	2 Jul	22,051[b]	10,711-45,677[b]	0.35[b]
Lower	22 Apr	15,427[b]	6,612-52,158[b]	0.21[b]
Lower	6 May	18,200	2,582-128,280	0.25
Lower	20 May	27,144	14,656-50,271	0.37
Lower	3 Jun	4,169	1,702-10,212	0.06
Lower	17 Jun	12,220	7,435-20,085	0.17
Lower	2 Jul	15,427[b]	6,612-52,158[b]	0.21[b]
Middle and Lower (Average)		18,744		0.28
		1997		
Upper	October	16,254	266-32,912	0.19
Lower	October	26,994	412-55,007	0.20

[a] Mean of 22 April-3 June estimates
[b] Mean of 6 May-17 June estimates

Diet

We captured 611 smallmouth bass for dietary analysis from 23 April through 2 July 2012 and 2,068 bass from 22 April through 1 July 2013. Smallmouth bass were of similar size between the three study reaches and weekly mean sizes were typically between 209 and 315 mm TL (Tables 4 and 5). Prey items were present in the majority of smallmouth bass stomachs sampled in 2012 and 2013 (Tables 6 and 7). The most common prey in smallmouth bass stomachs (based on frequency of occurrence) were insects, crayfish, salmonids, and non-salmonid fishes (Tables 6 and 7). Few salmonids were found in stomachs in 2012 making it difficult to identify trends in the diet for this prey. However in 2013, salmonids and other fish were prevalent in bass diets throughout the season (Table 7). The frequency of occurrence of fish in smallmouth bass diets declined by late June and early July.

Smallmouth bass diets varied both between reaches and between years when examined on a percent weight basis (Figures 1 and 2; Tables 8 and 9). In 2012, crayfish were more prominent in the diet in all reaches compared to 2013. In both years the percentage of crayfish in the diet tended to increase seasonally. Smallmouth bass consumed more fish, both salmonids and nonsalmonids, in 2013 than in 2012 (Figures 1 and 2; Tables 8 and 9). Salmonids comprised the majority of the diet by weight during the week of 20 May 2013 in the upper reach which was after a large release of hatchery fish. Salmonids also comprised a large portion of the diet by weight at times in the middle and lower reaches in 2013. Typically, the proportion of fish in the diet of smallmouth bass declined seasonally.

Based on the lengths of ingested salmonids, most were probably subyearling fall Chinook salmon (Figure 3). Estimated mean size of Chinook salmon consumed in 2012 was 57 mm (SD = 20.1 mm, N = 12, range = 38-92 mm) and the estimated mean size of Chinook salmon consumed in 2013 was 74 mm (SD = 21.1 mm, N = 206, range = 38-132 mm). Newly emerged fry represented most of the consumption in April in both years. The maximum relative length of salmonids consumed by bass (prey FL/bass TL*100) was 47.2% (mean= 27.8%) and for all prey fish was 63.4% (mean= 27.5%).

Sculpins and sand rollers *Percopsis transmontana* were the main nonsalmonid fishes consumed in both years (Tables 10 and 11). Scuplins were consumed throughout Hells Canyon whereas sand rollers were primarily consumed in the lower reach.

Table 4. Seasonal lengths and weights of smallmouth bass collected for diet analysis from study reaches on the Snake River in Hells Canyon in 2012.

Week Beginning	*N*	Total Length (mm)			Weight (g)		
		Mean	SD	Range	Mean	SD	Range
				Lower			
7 May	9	271	20	250-305	246	59	190-370
21 May	2	297	26	278-315	300	71	250-350
4 Jun	12	304	97	189-538	468	534	80-1860
18 Jun	33	225	35	172-295	152	81	50-320
2 Jul	44	223	34	151-310	145	75	40-420
All	100	239	53	151-538	199	219	40-1860
				Middle			
23 Apr	15	299	61	208-430	332	236	40-910
7 May	9	291	41	231-364	326	125	160-570
21 May	5	261	25	245-305	208	59	160-310
4 Jun	13	276	23	243-325	268	84	180-490
18 Jun	21	248	43	174-338	196	96	60-450
2 Jul	15	253	54	199-360	197	110	90-430
All	78	269	49	174-430	250	145	40-910
				Upper			
23 Apr	23	273	31	218-355	258	158	120-880
7 May	83	267	33	208-350	249	99	110-540
21 May	17	277	41	208-332	288	123	140-480
4 Jun	148	255	30	202-350	224	72	100-470
18 Jun	82	259	38	201-357	228	87	110-490
2 Jul	80	257	35	179-360	224	86	70-530
All	433	260	34	179-360	234	92	70-880

Table 5. Seasonal lengths and weights of smallmouth bass collected for diet analysis from study reaches on the Snake River in Hells Canyon in 2013.

Week Beginning	*N*	Total Length (mm)			Weight (g)		
		Mean	SD	Range	Mean	SD	Range
				Lower			
22 Apr	44	312	55	205-450	469	318	100-1560
6 May	86	234	46	150-354	225	140	50-750
20 May	151	209	51	150-463	259	354	30-1490
3 Jun	157	238	62	150-485	324	328	30-1510
17 Jun	111	233	47	150-371	224	136	30-700
1 Jul	68	212	44	150-342	160	108	40-420
All	617	232	58	150-485	290	268	30-1560
				Middle			
22 Apr	60	291	31	224-385	334	127	140-810
6 May	75	263	31	199-346	252	109	60-550
20 May	71	245	38	151-349	204	94	40-430
3 Jun	133	230	45	150-341	204	86	30-430
17 Jun	45	244	40	159-329	185	96	30-440
1 Jul	26	248	34	172-322	209	79	90-450
All	410	250	43	150-385	245	119	30-810
				Upper			
8 Apr	102	315	33	213-444	413	143	220-1120
22 Apr	255	294	26	236-385	319	101	140-770
6 May	300	271	32	151-354	270	92	80-540
20 May	72	277	27	230-346	278	82	160-430
3 Jun	173	270	29	171-366	270	108	110-650
17 Jun	139	268	35	180-386	327	173	150-620
All	1041	281	34	151-444	325	121	80-1120

Table 6. Seasonal variation in diet composition (percent frequency of occurrence of non-empty stomachs) of smallmouth bass in three reaches of Hells Canyon on the Snake River in 2012. *N*s indicate the number of smallmouth bass with empty and non-empty stomachs.

			Prey			
Week beginning	*N* (empty)	*N* (non-empty)	Insects	Crayfish	Salmonid	Other fish
			Upper			
23 Apr	5	18	72	11	0	11
7 May	0	83	100	34	5	10
21 May	1	16	100	31	0	6
4 Jun	3	145	97	54	1	6
18 Jun	5	77	94	39	0	3
2 Jul	9	71	66	70	0	3
			Middle			
23 Apr	1	14	79	21	0	0
7 May	3	6	100	33	0	33
21 May	1	4	75	0	0	75
4 Jun	1	12	92	25	8	8
18 Jun	4	17	94	29	0	18
2 Jul	2	13	100	54	0	0
			Lower			
7 May	5	4	50	50	25	25
21 May	0	2	50	0	0	50
4 Jun	7	5	20	20	0	0
18 Jun	6	27	70	37	0	19
2 Jul	1	43	88	28	0	9

Table 7. Seasonal variation in diet composition (percent frequency of occurrence of non-empty stomachs) of smallmouth bass in three reaches of Hells Canyon on the Snake River in 2013. *N*s indicate the number of smallmouth bass with empty and non-empty stomachs.

			Prey			
Week beginning	*N* (empty)	*N* (non-empty)	Insects	Crayfish	Salmonid	Other fish
			Upper			
8 Apr	19	91	66	10	9	45
22 Apr	37	233	76	18	10	20
6 May	32	302	90	37	5	16
20 May	1	86	93	42	35	2
3 Jun	9	170	88	54	1	9
17 Jun	4	165	83	77	0	4
			Middle			
22 Apr	12	48	60	19	19	10
6 May	10	68	56	12	21	13
20 May	21	57	84	25	2	37
3 Jun	24	117	78	16	27	20
17 Jun	7	41	85	29	5	7
1 Jul	2	28	86	21	4	4
			Lower			
22 Apr	13	32	28	13	28	38
6 May	21	66	50	12	5	38
20 May	32	127	71	11	1	37
3 Jun	36	127	57	10	18	29
17 Jun	14	114	69	29	10	21
1 Jul	14	64	70	41	6	14

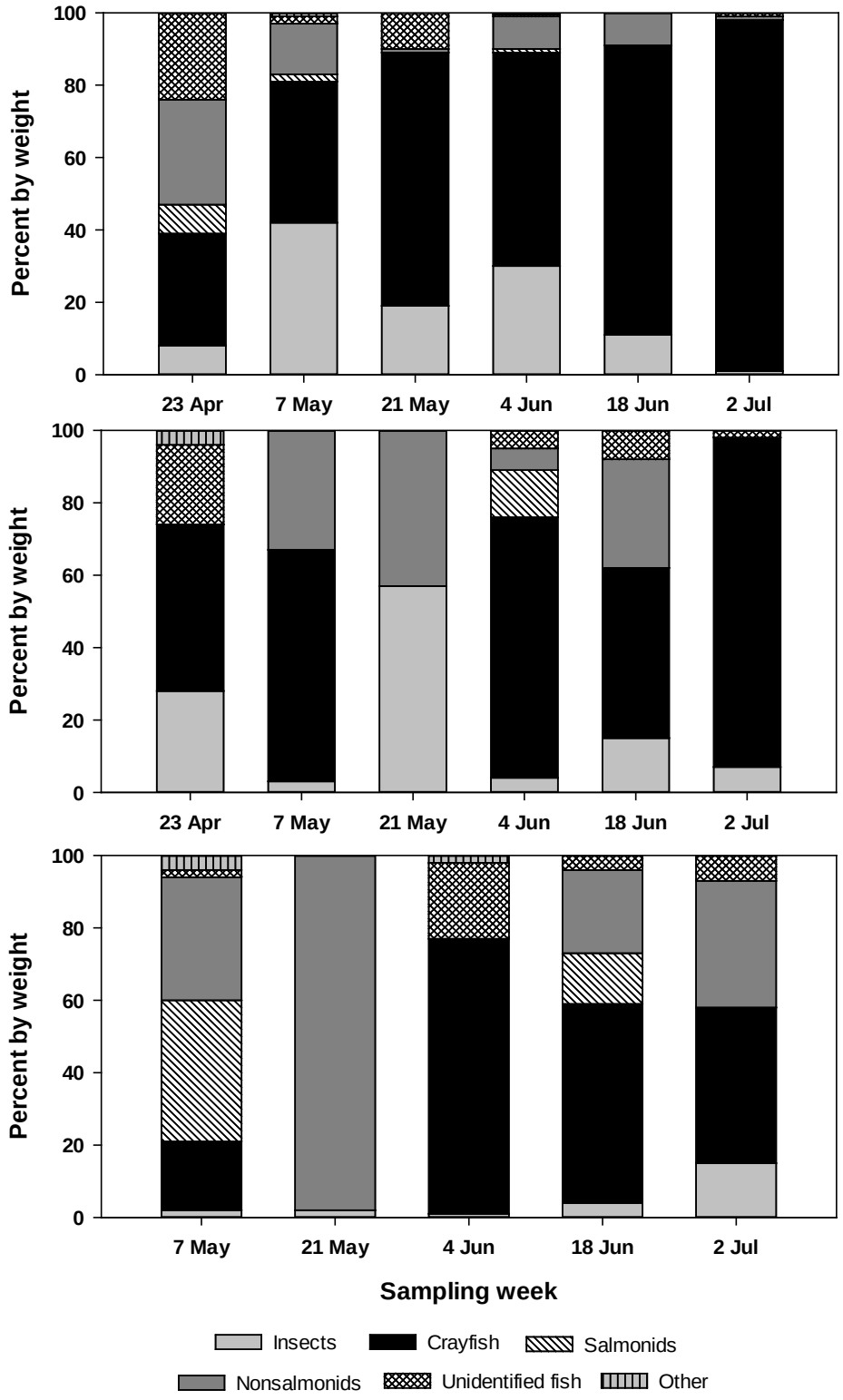

Figure 1. Seasonal variation in diet composition (percent weight based on non-empty stomachs) of smallmouth bass in the upper reach (top panel), middle reach (middle panel), and lower reach (bottom panel) of Hells Canyon in 2012.

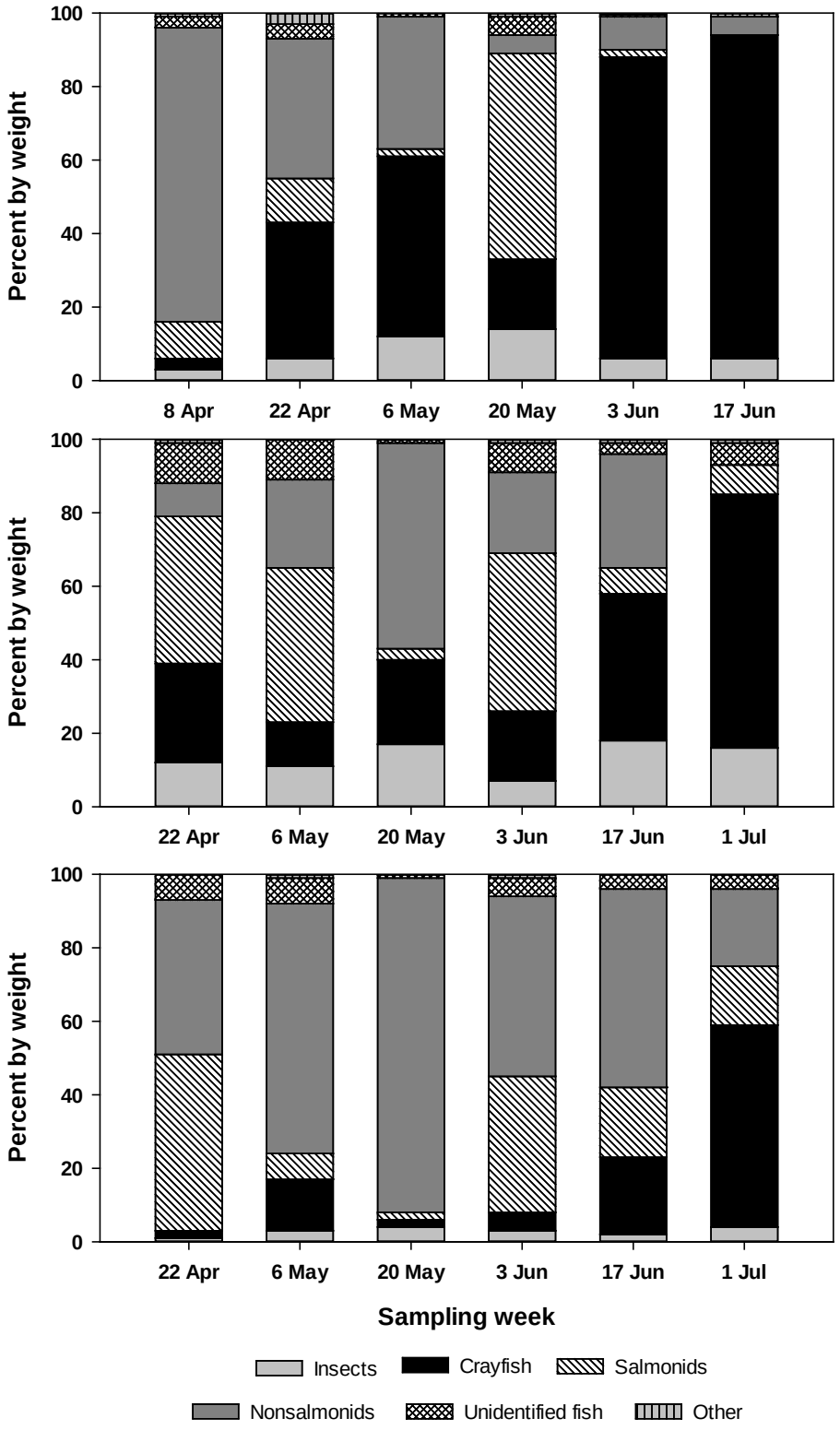

Figure 2. Seasonal variation in diet composition (percent weight based on non-empty stomachs) of smallmouth bass in the upper reach (top panel), middle reach (middle panel), and lower reach (bottom panel) of Hells Canyon in 2013.

Table 8. Seasonal variation in diet composition (percent weight based on non-empty stomachs) of smallmouth bass in three reaches of the Snake River in Hells Canyon in 2012. *N*s indicate the number of smallmouth bass with empty and non-empty stomachs.

			Prey					
Week beginning	*N* (empty)	*N* (non-empty)	Insects	Crayfish	Salmonid	Other fish	Unidentified fish	Other
				Upper				
23 Apr	5	18	8	31	8	29	24	0
7 May	0	83	42	39	2	14	2	1
21 May	1	16	19	70	0	1	10	0
4 Jun	3	145	30	59	1	9	<1	<1
18 Jun	5	77	11	80	0	9	0	0
2 Jul	9	71	1	97	0	1	1	0
				Middle				
23 Apr	1	14	28	46	0	0	22	4
7 May	3	6	3	64	0	33	0	0
21 May	1	4	57	0	0	43	0	0
4 Jun	1	12	4	72	13	6	5	0
18 Jun	4	17	15	47	0	30	8	0
2 Jul	2	13	7	91	0	0	2	0
				Lower				
7 May	5	4	2	19	39	34	2	4
21 May	0	2	2	0	0	98	0	0
4 Jun	7	5	1	76	0	0	21	2
18 Jun	6	27	4	55	14	23	4	0
2 Jul	1	43	15	43	0	35	7	0

Table 9. Seasonal variation in diet composition (percent weight based on non-empty stomachs) of smallmouth bass in three reaches of the Snake River in Hells Canyon in 2013. *N*s indicate the number of smallmouth bass with empty and non-empty stomachs.

			Prey					
Week beginning	*N* (empty)	*N* (non-empty	Insects	Crayfish	Salmonid	Other fish	Unidentified fish	Other
				Upper				
8 Apr	19	91	3	3	10	80	3	1
22 Apr	37	233	6	37	12	38	4	3
6 May	32	302	12	49	2	36	1	0
20 May	1	86	14	19	56	5	5	1
3 Jun	9	170	6	82	2	9	<1	<1
17 Jun	4	165	6	88	0	5	0	1
				Middle				
22 Apr	12	48	12	27	40	9	11	1
6 May	10	68	11	12	42	24	11	0
20 May	21	57	17	23	3	56	1	0
3 Jun	24	117	7	19	43	22	8	1
17 Jun	7	41	18	40	7	31	3	1
1 Jul	2	28	16	69	8	0	6	1
				Lower				
22 Apr	13	32	1	2	48	42	7	0
6 May	21	66	3	14	7	68	7	1
20 May	32	127	4	2	2	91	1	0
3 Jun	36	127	3	5	37	49	5	1
17 Jun	14	114	2	21	19	54	4	0
1 Jul	14	64	4	55	16	21	4	0

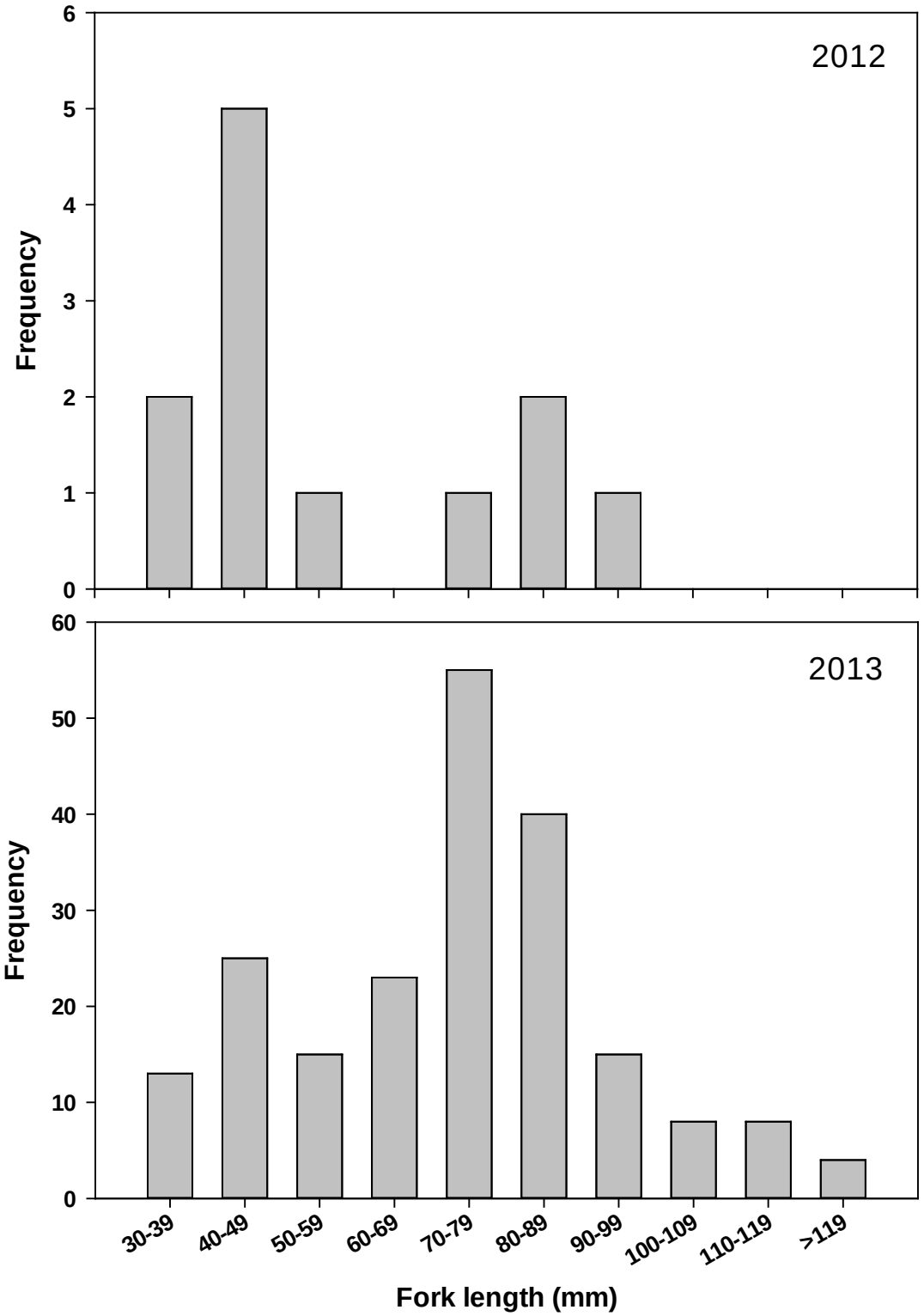

Figure 3. Size distribution of Chinook salmon consumed by smallmouth bass in the Hells Canyon Reach of the Snake River in 2012 (top panel) and 2013 (bottom panel).

Table 10. Summary of prey items obtained from all smallmouth bass stomachs sampled on the Snake River in Hells Canyon in 2012.

Category	Taxon	Total mass (g)	Percent
Insects	Trichoptera	67.5	47
	Unidentifiable insect parts	47.1	33
	Ephemeroptera	18.7	13
	Plecoptera	3.1	2
	Odonata	2.9	2
	Lepidoptera	1.2	1
	Diptera	1.0	1
	Coleoptera	0.4	<1
	Dermaptera	0.3	<1
	Hymneoptera	0.3	<1
Crustaceans	Crayfish	511.6	100
	Amphipoda	0.1	--
	Isopoda	0.1	--
Salmonids	Chinook	14.2	100
Other fish	Sculpin spp.	65.8	84
	Northern Pikeminnow	4.7	6
	Smallmouth bass	3.0	4
	Sucker spp.	2.5	3
	Black crappie	0.9	1
	Sand roller	0.6	1
	Peamouth	0.5	1
	Chiselmouth	0.3	<1
Unidentifiable fish	Parts	17	96
	Fry	0.7	4
Other	Unknown	1.4	48
	Rock	0.6	22
	Eggs	0.6	20
	Arachnida	0.2	6
	Vegetation	0.1	3
	Oligochaeta	<0.1	1

Table 11. Summary of prey items obtained from all smallmouth bass stomachs sampled on the Snake river in Hells Canyon in 2013.

Category	Taxon	Total mass(g)	Percent
Insects	Trichoptera	56.9	26
	Unidentifiable insect parts	46.7	21
	Diptera	30.1	14
	Ephemeroptera	28.8	13
	Odonata	26.5	12
	Plecoptera	26.1	12
	Hymneoptera	1.2	1
	Coleoptera	1.1	1
	Lepidoptera	0.5	<1
	Dermaptera	0.1	<1
	Orthoptera	0.1	<1
	Raphidoptera	<0.1	<1
	Hemiptera	<0.1	<1
	Homoptera	<0.1	<1
Crustaceans	Crayfish	1091.0	100
	Isopoda	0.2	<1
	Amphipoda	0.1	<1
	Neomysis	<0.1	<1
Salmonids	Chinook	596.0	99
	Mountain Whitefish	4.2	1
	Unknown	2.6	<1
	Steelhead	1.4	<1
Other fish	Sculpin spp.	644.0	56
	Sandroller	294.0	26
	Smallmouth bass	60.6	5
	Chiselmouth	53.7	5
	Sucker spp.	53.3	5
	Northern Pikeminnow	25.2	2
	Peamouth	13.6	1
	Catfish spp.	2.2	<1
Unidentifiable fish	Parts	103.3	92
	Fry	9.6	8
Other	Rock	11.4	50
	Egg	4.4	20
	Unknown	3.5	15
	Vegetation	2.5	11
	Earthworm	0.3	1
	Nematoda	0.2	1
	Bivalva	0.2	1
	Arachnida	0.1	1
	Centipede	0.1	<1
	Hirudinea	<0.1	<1
	Oligochaeta	<0.1	<1

Consumption and loss

Total estimated loss of salmonids to smallmouth bass predation within our study area was 204,323 individuals (95% CI = 122,300-286,346; Table 12) in 2012 and 947,772 individuals (95% CI = 415,434-1,794,444) in 2013. Coincident to the abundance estimates, the highest total consumption occurred in the upper reach for both years followed by the middle then the lower reach. In the upper reach alone, 68% of the estimated consumption in 2013 occurred during the 20-May sampling period, when 420,104 salmonids were estimated to be consumed during the 2-week interval. However, this estimate was heavily influenced by a release of hatchery fish that occurred before we sampled. Estimates of zero loss occurred for some sampling weeks in the middle and lower reaches in 2012 due to low catch rates of smallmouth bass and consumption of Chinook salmon.

Consumption of fall Chinook salmon was documented in the upper reach during the first sampling occasion in 2012 (23 April; 0.09 salmonids/bass/day) and 2013 (8 April; 0.05 salmonids/bass/day; Table 13). The last documented consumption of Chinook salmon in the upper reach in 2012 occurred during the week of 4 June (0.01 salmonids/bass/day) and during the week of 3 June (0.01 salmonids/bass/day) in 2013. Consumption in the middle reach was only documented during the week of 4 June in 2012, however sample sizes for the middle reach were very low during 2012 (Table 13). In 2013, however, consumption of Chinook salmon was first documented during the 22 April sampling week and had the highest consumption rate for all middle reach samplings (0.22 salmonids/bass/day). The last documented consumption of Chinook salmon occurred during the week of 1 July (0.08 salmonids/bass/day). Consumption in the lower reach was only documented during the 7-May and 18-June sampling weeks in 2012 but sample sizes were also low (Table 13). In 2013, consumption of Chinook salmon in the lower reach was documented during all sampling occasions and was highest during the weeks of 22 April (0.14 salmonids/bass/day) and 1 July (0.14 salmonids/bass/day). By comparison, consumption rates derived by Nelle (1999) were generally much lower than our estimates except for areas immediately downstream of hatchery release sites and just following releases (Table 14).

Table 12. Estimated losses (95% CI) of juvenile salmonids in the upper, middle, and lower reaches of Hells Canyon on the Snake River in 2012 and 2013.

Week	Upper reach	Middle reach	Lower reach
		2012	
23 Apr	93,935 (65,561-122,309)	0	No sampling
7 May	61,789 (43,125-80453)	0	21,080 (4,503-37,658)
21 May	0	0	0
4 Jun	5,530 (3,859-7,200)	19,333 (4,684-33,981)	0
18 Jun	0	0	2,656 (567-4,745)
2 Jul	0	0	0
Total	161,253 (112,546-209,962)	19,333 (4,684-33,981)	23,737 (5,070-42,403)
		2013	
8 Apr	53,749 (26,349-81,208)	No sampling	No sampling
22 Apr	95,883 (59,186-132,580)	68,998 (33,513-142,925)	29,181 (12,506-98,659)
6 May	40,061 (21,620-58,501)	69,489 (36,004-135,512)	14,834 (2,105-104,555)
20 May	420,104 (150,004-690,204)	1,342 (592-3,041)	1,888 (1,019-3,497)
3 Jun	12,261 (5,254-19,268)	43,972 (21,010-92,031)	6,720 (2,743-16,462)
17 Jun	0	17,391 (8,321-36,348)	17,643 (10,734-28,998)
1 Jul	No sampling	24,100 (11,706-49,922)	29,794 (12,769-100,731)
Total	622,058 (262,411-981,762)	225,654 (111,146-459,779)	100,060 (41,877-352,903)

Table 13. Estimated consumption rates of subyearling fall Chinook salmon by smallmouth bass ≥150 mm (fish/smallmouth bass/day) in the Hells Canyon Reach of the Snake River in 2012 and 2013. No distinction was made between hatchery and natural subyearling prey.

Week	Upper reach	Middle reach	Lower reach
	2012		
23 Apr	0.086	0	No sampling
7 May	0.057	0	0.176
21 May	0	0	0
4 Jun	0.005	0.113	0
18 Jun	0	0	0.022
2 Jul	0	0	0
	2013		
8 Apr	0.046	No sampling	No sampling
22 Apr	0.067	0.224	0.135
6 May	0.042	0.158	0.058
20 May	0.349	0.006	0.005
3 Jun	0.011	0.162	0.115
17 Jun	0	0.059	0.103
1 Jul	No sampling	0.078	0.138

Table 14. Estimated consumption rates of subyearling fall Chinook salmon by smallmouth bass ≥150 mm (fish/smallmouth bass/day) in the Hells Canyon Reach of the Snake River in 1996 and 1997. Table reprinted from Nelle (1999). The Adams et al. (1982) model of consumption was used to derive estimates. Nelle's upstream reach is analogous to our upper reach and his downstream reach is analogous to our middle and lower reaches combined.

Month	Subyearling origin	Smallmouth bass length (mm)	Hatchery release site	Upstream reach	Downstream reach
			1996		
June	Hatchery	150-249	0.250	0	0
		≥250	0.933	0.009	0
	Wild	150-249	---	0	0.009
		≥250	---	0.008	0
July	Hatchery	150-249	0.615	0	0
		≥250	0.333	0.027	0.009
	Wild	150-249	---	0	0.006
		≥250	---	0	0
			1997		
June	Hatchery	150-249	0	0.008	0
		≥250	0	0	0
	Wild	150-249	---	0	0
		≥250	---	0	0
July	Hatchery	150-249	1.143	0	0
		≥250	0	0	0
	Wild	150-249	---	0	0
		≥250	---	0	0

Discussion

Juvenile salmonids were not a major component of smallmouth bass diets in 2012 but were preyed upon to a greater extent in 2013. However, in both years salmonid and nonsalmonid fishes composed a large portion of smallmouth bass diets at times, particularly early in the season. The greater occurrence of nonsalmonids fishes such as sculpins in the diet may be due to greater habitat overlap between sculpins and bass than between juvenile salmon and bass. However, smallmouth bass may key in on juvenile salmon when they are more vulnerable such as following emergence and after a hatchery release. Indeed, over 40% of the diet (based on weight) was composed of juvenile salmon in the lower and middle reaches in early spring 2013. In addition, we observed the highest salmonid consumption in late May, 2013 in the upper reach following a release of hatchery fish from Hells Canyon Dam and Pittsburg Landing.

We believe that most of the salmonids consumed by smallmouth bass were probably subyearlings based on their lengths at time of ingestion. Subyearlings may be more vulnerable to predation than larger yearling spring Chinook and steelhead because of their small size. We found that smallmouth bass as small as 161 mm contained subyearlings as large as 62 mm FL, which suggests that even small bass may pose a predation threat. Fritts and Pearsons (2006) found that 150-199 mm smallmouth bass accounted for 42.9% of the salmonid consumption in the Yakima River, and that decreasing relative length of salmonid prey increased with bass size. In our study, the maximum relative length of salmonids (salmonid FL/bass TL * 100) consumed by 150-199 mm smallmouth bass was 47.2%, suggesting that subyearling susceptibility to predation based on size alone is very high because of the high abundance of small-sized (<200 mm) bass in the Hells Canyon Reach. Conversely, Anglea (1997) found that smallmouth bass ranging in size from 250-389 mm had the highest salmonid consumption in Lower Granite Reservoir in 1994-1995. It is clear that smallmouth bass over 150 mm pose a predation risk to subyearling fall Chinook salmon in Hells Canyon.

Our estimates of smallmouth bass consumption rates of juvenile salmonids are generally much higher than those reported by Nelle (1999), who studied smallmouth predation of subyearlings in the mid to late 1990s. Nelle (1999) observed the highest consumption rates of subyearlings directly below hatchery release sites and immediately following releases. However, at sites located away from these sites, Nelle (1999) found consumption rate to generally be zero or <0.009 subyearling/smallmouth bass/day. By comparison, most consumption rates in the middle and lower reaches exceeded 0.1 subyearling/smallmouth bass/day.

There are several reasons for the increase in daily consumption rates of subyearlings by smallmouth bass that we observed. First, the run size of subyearlings has increased dramatically since 1996. Hatchery supplementation has directly increased the population via annual releases of juvenile and indirectly as a result of increased production from natural spawners (Connor et al. 2013). Nelle (1999) conducted his study in 1996 and 1997 when the subyearling population was at a low level and hatchery supplementation was just beginning in the Snake River. To illustrate, the number of subyearlings that passed Lower Granite Dam during the 1 April to 1 October outmigration was 18,066 fish in 1996 and 97,985 fish in 1997. In 2012, there were 1,069,525 subyearlings estimated to have passed the dam during this time (DART 2014). The large increase in the

subyearling population may have made more fish accessible to smallmouth bass predators. Nonetheless, despite their high abundance, subyearlings never did make up a significant portion of the smallmouth bass diets in 2012, but did so in 2013. This suggests that predation on subyearlings can vary substantially from year to year. It appears that the increase in consumption rate by smallmouth bass may be a response to the increase in the subyearling population.

Our loss estimates of subyearling fall Chinook salmon to smallmouth bass predation were also significantly higher than those reported by Nelle (1999). One reason for this is that our abundance estimates of smallmouth bass were much higher than those estimated by Nelle (1999) in 1997 in the upper reach. However, abundance estimates were more similar between our lower and middle reaches and Nelle's downstream reach. Loss estimates are most sensitive to smallmouth bass abundance and admittedly the confidence intervals on our estimates are wide. Nonetheless, we believe our multiple mark-recapture approach using an open population model on data collected when consumption data were collected was a more robust approach than the single mark-recapture event that Nelle used in October, 1997. Additional electrofishing effort in 2014 should improve our recapture rate of marked fish and our abundance estimates.

We recognize that certain sampling limitations and assumptions may have influenced our results. We primarily used angling in 2012 to minimize capture of ESA-listed salmonids and because electrofishing is not permitted when temperatures exceed 18°C. In addition, we did not have an electrofishing boat that was safe to use in Hells Canyon. Consequently, catch rates were often low, particularly during high-water events when the water was turbid. Adding limited electrofishing in 2013 greatly increased our catch rates. However, bias associated with both angling and electrofishing may have affected our results. Also, expansion of consumption estimates to estimate subyearling loss over the entire study area assumes that our sampling sites were representative of the larger study area and that smallmouth bass are distributed evenly throughout each reach. We believe the mix of fixed and random sampling sites that we used in 2013 represented the best approach for minimizing the effects if the assumption did not hold. Finally, we recognize that large hatchery releases of subyearlings could produce a short-term increase in apparent smallmouth bass predation that might artificially increase consumption and loss estimates. We believe this was the case during the week of 20 May 2013 when we observed our highest subyearling consumption and loss. The elevation of predation following a hatchery release probably does not last for the two-week interval over which loss was estimated.

References

Adams, S.M, R.B. McLean, and M.M. Huffamn. 1982. Structuring of a predator community through temperature-mediated effects on prey availability. Canadian Journal of Fisheries and Aquatic Sciences 39:1175-1184.

Connor, W.P., K.F. Tiffan, J.M. Plumb, and C.M. Moffitt. 2013. Evidence for density-dependent changes in growth, downstream movement, and size of Chinook salmon subyearlings in a large-river landscape. Transactions of the American Fisheries Society 142:1453-1468.

Curet, T.S. 1993. Habitat use, food habits, and the influence of predation on subyearling Chinook salmon in Lower Granite and Little Goose reservoirs, Washington. Master's Thesis. University of Idaho, Moscow.

Fritts, A.L., and T.N. Pearsons. 2004. Smallmouth bass predation on hatchery and wild salmonids in the Yakima River, Washington. Transactions of American Fisheries Society 133:880-895.

Gulland, J.A. 1983. Fish Stock Assessment. Wiley, Chichester, UK.

Hansel, H.C., S.D. Duke, P.T. Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of American Fisheries Society 117:55-62.

Munther, G.L. 1970. Movement and distribution of smallmouth bass in the middle Snake River. Transactions of the American Fisheries Society 99:44-53.

Naughton, G.P., D.H. Bennett, and K.B. Newman. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. North American Journal of Fisheries Management 24:534-544.

Nelle, R.D. 1999. Smallmouth bass predation on juvenile fall Chinook salmon in the Hells Canyon Reach of the Snake River, Idaho. Master's Thesis, University of Idaho, Moscow.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Federal Register 57:78(22 April 1992):14,653-14,663.

Parris, J.K., K. Haapa-aho, W. Walker, M. Stratton, J. Walsh, and H. Ziel. 2006. Small-bodied and juvenile fishes of the Mid-Columbia Region including keys to diagnostic otoliths and cranial bones. Draft Version, March 2006. University of Washington, Seattle WA. 137 p.

Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L.A. Predergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Rogers, J.B., and C.C. Burley . 1991. A sigmoid model to predict gastric evacuation rates of smallmouth bass (*Micropterus dolomieu*) fed juvenile salmon. Canadian Journal of Fisheries and Aquatic Sciences 48:933-937.

Rieman, B.E., R.C. Beamsderfer, S. Vigg, and T.P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Schwarz, C. J. and A.N. Arnason. 1996. A general methodology for the analysis of open model capture recapture experiments. *Biometrics* **52**, 860-873

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Edward Arnold, London.

Seaburg, K.G. 1957. A stomach sampler for live fish. The Progressive Fish Culturist 19:137-139.

Tabor, R.A., R.S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

Vigg, S., T.P. Poe, L.A. Prendergast, and H.C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternate prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Ward, D.L., J.H. Petersen, and J.J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 124:321-334.

White, G. C., and K. P. Burnham. 1999. Program MARK-survival estimation from populations of marked animals. Bird Study 46:120-138.

Zimmerman, M.P., and R.M Parker. 1995. Relative density and distribution of smallmouth bass, channel catfish and walleye in the lower Columbia and Snake rivers. Northwest Science 69:19-28.

Zimmerman, M.P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.

Appendix D: List of Metrics and Indicators

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Fish	Abundance of Fish	Fish Life Stage: Adult - Returner	Fish Origin: Both	Adult counts at dams
Fish	Abundance of Fish	Fish Life Stage: Adult - Spawner	Fish Origin: Both	Redd counts in the river
Fish	Abundance of Fish	Fish Life Stage: Adult - Returner	Fish Origin: Both	Adult counts at dams
Fish	Abundance of Fish	Fish Life Stage: Adult - Spawner	Fish Origin: Both	Redd counts in the river
Fish	Abundance of Fish	Fish Life Stage: Juvenile - Migrant	Fish Origin: Natural	Juvenile passage abundance
Fish	Distribution of Fish Species	Fish Life Stage: Juvenile - Migrant		Geographic distribution of juveniles
Fish	Diversity of Fish: Change	Fish Life Stage: Juvenile - Migrant		Juvenile life history diversity
Fish	Mark/Tag Application			PIT-tag tagging data
Fish	Mark/Tag Recovery or Detection			PIT-tag detection data
Fish	Abundance of Fish	Fish Life Stage: Adult - Returner	Fish Origin: Natural	Natural adult abundance
Fish	Abundance of Fish	Fish Life Stage: Adult - Spawner	Fish Origin: Both	Geographic spawning distribution
Fish	Abundance of Fish	Fish Life Stage: Adult - Returner	Fish Origin: Both	Adult counts at dams
Fish	Abundance of Fish	Fish Life Stage: Adult - Spawner	Fish Origin: Both	Redd counts in the river
Fish	Abundance of Fish	Fish Life Stage: Adult - Returner	Fish Origin: Natural	Natural adult abundance
Fish	Abundance of Fish	Fish Life Stage: Adult - Spawner	Fish Origin: Both	Geographic spawning distribution
Fish	Abundance of Fish	Fish Life Stage: Juvenile - Migrant	Fish Origin: Natural	Juvenile passage abundance

Fish	Distribution of Fish Species	Fish Life Stage: Juvenile - Migrant		Geographic distribution of juveniles
Fish	Diversity of Fish: Change	Fish Life Stage: Juvenile - Migrant		Juvenile life history diversity
Fish	Mark/Tag Application			PIT-tag tagging data
Fish	Mark/Tag Recovery or Detection			PIT-tag detection data
Fish	Abundance of Fish	Fish Life Stage: Juvenile - Migrant	Fish Origin: Natural	Juvenile passage abundance
Fish	Distribution of Fish Species	Fish Life Stage: Juvenile - Migrant		Geographic distribution of juveniles
Fish	Diversity of Fish: Change	Fish Life Stage: Juvenile - Migrant		Juvenile life history diversity
Fish	Mark/Tag Application			PIT-tag tagging data
Fish	Mark/Tag Recovery or Detection			PIT-tag detection data
Fish	Abundance of Fish Predators	Fish Life Stage: Adult Fish		Abundance of smallmouth bass in Hells Canyon
Fish	Predation Rate: Fish	Fish Life Stage: Juvenile - Parr		Loss of juvenile fall Chinook to smallmouth bass predation
Fish	Prey Indices: Fish			Diet composition of smallmouth bass
Fish	Abundance of Fish Predators	Fish Life Stage: Adult Fish		Abundance of smallmouth bass in Hells Canyon
Fish	Predation Rate: Fish	Fish Life Stage: Juvenile - Parr		Loss of juvenile fall Chinook to smallmouth bass predation
Fish	Prey Indices: Fish			Diet composition of smallmouth bass
Fish	Abundance of Fish	Fish Life Stage: Adult		Abundance of smallmouth bass in

	Predators	Fish		Hells Canyon
Fish	Predation Rate: Fish	Fish Life Stage: Juvenile - Parr		Loss of juvenile fall Chinook to smallmouth bass predation
Fish	Prey Indices: Fish			Diet composition of smallmouth bass
Fish	Abundance of Fish Predators	Fish Life Stage: Adult Fish		Abundance of smallmouth bass in Hells Canyon
Fish	Predation Rate: Fish	Fish Life Stage: Juvenile - Parr		Loss of juvenile fall Chinook to smallmouth bass predation
Fish	Prey Indices: Fish			Diet composition of smallmouth bass
Fish	Abundance of Fish Predators	Fish Life Stage: Adult Fish		Abundance of smallmouth bass in Hells Canyon
Fish	Predation Rate: Fish	Fish Life Stage: Juvenile - Parr		Loss of juvenile fall Chinook to smallmouth bass predation
Fish	Prey Indices: Fish			Diet composition of smallmouth bass