FISHERY RESEARCH

IDAHO ADULT CHINOOK SALMON MONITORING

2020 ANNUAL REPORT

Photo: Eric Stark

Prepared by:

Cynthia I. Nau, Fisheries Biologist
Eli A. Felts, Fisheries Biologist
Bruce Barnett, Fisheries Data Coordinator
Micah Davison, Supervisory Fisheries Biologist
Conor McClure, Fisheries Biologist
Joshua R. Poole, Fisheries Biologist
Robert Hand, Fisheries Biologist
Evan Brown, Sr. Fisheries Data Coordinator

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Cynthia I. Nau
Eli A. Felts
Bruce Barnett
Micah Davison
Conor McClure
Joshua R. Poole
Robert Hand
Evan Brown

Idaho Department of Fish and Game
600 South Walnut Street
P.O. Box 25
Boise, ID 83707

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Report Authors:

Cynthia I. Nau

Eli A. Felts

Bruce Barnett

Micah Davison

Conor McClure

Joshua R. Poole

Robert Hand

Evan Brown

Report Contributors: Data and Field Work (*alphabetical*)

IDFG Southwest Region (Nampa)

- Timothy D'Amico
- Jordan Everson
- Cory Kerr
- Milan Sengthep

IDFG Southwest Region (McCall)

- Luke Brooks
- Trent Foky
- Isaac Fournier
- Steven Hughes
- Laurie Janssen
- Lauren Ralbovsky
- Mike Thomas
- Caitlyn Uhlenbrauck
- Kaitlyn Wauhkonen

IDFG Salmon Region

- J. Beers
- Brent Beller
- D. Bertram
- Jessica Buelow
- K. Estep
- Stacey Feeken
- C. Gaughan
- Eric Geisthardt
- Courtnie Ghere
- Kat Gillies-Rector
- Breanna Graves
- Jonah Keith
- Vasili Luzanau
- T. Mackey
- T. L. Morlan
- T. W. Morlan
- Quinn Richard
- J. Ruterbusch
- J. Saydell
- Greg Schoby
- Windy Schoby
- S. Zabronsky

IDFG Clearwater Region

- Hunter Distad
- Marika Dobos
- Jason Fortier
- Beth Kennedy
- Brian Knoth
- Kristina Morben
- Dave Overy
- Scott Putnam
- Devan Reid
- Nolan Smith
- CeCe Spangler
- Patrick Vrablik

IDFG Nampa Research

- Corey Dondero
- Jared Jones
- Joseph Hirsch
- Katherine Lawry
- Z. Nemeth
- Ron Roberts
- Eric Stark
- Dave Venditti
- Mack Woodruff

IDFG Headquarters

- Sara Cassinelli
- Tim Copeland
- Jonathan Ebel
- Chris Harrington
- Sharon Kiefer
- Brock Lipple

IDFG Eagle Fish Genetics Lab

- Brian Ayers
- John Powell

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Report Contributors: Data and Field Work (*alphabetical, continued*)

Nez Perce Tribe

- Brent Broncheau
- Dale Brown
- John Byrne
- Anthony Capetillo
- Chris Eaton
- Leander Goodteacher
- Frederick Haberman
- Travis Hodsdon
- Mike Kosinski
- Mark Maze
- Neal Meshell
- Doug Nelson
- Jay Oatman
- Bailey Peters
- Craig Rabe
- Jon Rombach
- Brian Simmons
- Sherman Sprague
- Tyler Stright
- M. Sublett
- Nickles Two-Moons
- Eric Wilcox

Shoshone-Bannock Tribe

- Kermit Bacon
- Scott Cazier
- Rebecca Croy
- Lytle Denny
- Ron Diaz
- Kameryn Farmer
- Josh Gable
- Cerissa Honena
- Josh Jackson
- Peyton Sequints
- Joseph Snapp
- Kurt Tardy
- Joshua Taryole
- Ethen Tendor
- Rob Trahant

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- Scott Brandt
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- Christine Stewart
- Russ Thurow

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ABBREVIATIONS AND ACRONYMS

BIG	Big Creek
BPA	Bonneville Power Administration
BVC	Bear Valley Creek
BY	Brood Year
CAM	Camas Creek
CHC	Chamberlain Creek
CWT	Coded Wire Tag
DPS	Distinct Population Segment
EFSR	East Fork Salmon River
EFSFSR	East Fork South Fork Salmon River
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
FINS	Fish Inventory System Hatchery Database
GPS	Global Positioning System
ICBTRT	Interior Columbia Basin Technical Recovery Team
IFWIS	Idaho Fish and Wildlife Information System
IDFG	Idaho Department of Fish and Game
LAP	Lapwai/Big Canyon creeks
LEM	Lemhi River
LSR	Little Salmon River
LOC	Lochsa River
LOLO	Lolo Creek
LOON	Loon Creek
LNFC	Lower North Fork Clearwater River
MAR	Marsh Creek
MED	Meadow Creek
MPG	Major Population Group
MFSRU	Middle Fork Salmon River above and including Indian Creek
MFSRL	Middle Fork Salmon River below Indian Creek
MOO	Moose Creek
NFSR	North Fork Salmon River
NMFS	U.S. Department of Commerce, National Marine Fisheries Service

NPCC	Northwest Power and Conservation Council
NPT	Nez Perce Tribe
NRAAL	Nampa Research Anadromous Ageing Laboratory
NWFSC	Northwest Fisheries Science Center
PA	Percent Agreement
PAH	Pahsimeroi River
PAN	Panther Creek
PCSRF	Pacific Coast Salmon Recovery Funds
PDO	Pacific Decadal Oscillation
PIT	Passive Integrated Transponder
POT	Potlatch River
PSMFC	Pacific States Marine Fisheries Commission
PTAGIS	PIT Tag Information System
RMSE	Root Mean Squared Error
SAR	Smolt-to-adult Return Rate
SBT	Shoshone-Bannock Tribes
SEC	Secesh River
SEL	Upper Selway River
SFSR	South Fork Salmon River mainstem
SGS	Spawning Ground Survey
SGSA	Spawning Ground Survey Application
SUL	Sulphur Creek
UAS	Unmanned Aircraft System
USFS	U.S. Forest Service
UNFC	Upper North Fork Clearwater River
USFC	Upper South Fork Clearwater River
USRL	Salmon River Upper Mainstem below Redfish Lake Creek
USRU	Salmon River Upper Mainstem above Redfish Lake Creek
VAL	Valley Creek
YFK	Yankee Fork Salmon River

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS i
ABBREVIATIONS AND ACRONYMS iv
FOREWORD 12
INTRODUCTION 12
REPORT CHAPTERS AND TOPICS 13
DATA MANAGEMENT AND ACCESS 14
FIGURES 15
LITERATURE CITED 2
CHAPTER 1. RELATIVE ABUNDANCE AND PRODUCTIVITY IN IDAHO POPULATIONS OF SPRING-SUMMER CHINOOK SALMON 3
ABSTRACT 3
INTRODUCTION 4
METHODS 4
Study Design 4
Data Collection 5
Data Analysis 6
RESULTS 7
DISCUSSION 9
RECOMMENDATIONS 11
LITERATURE CITED 12
TABLES 14
FIGURES 26
CHAPTER 2. DISTRIBUTION OF CHINOOK SALMON REDDS IN THE MIDDLE FORK SALMON RIVER BASIN, IDAHO 38
ABSTRACT 38
INTRODUCTION 39
METHODS 39
Study Design 39
Data Collection 40
RESULTS 40
DISCUSSION 41
LITERATURE CITED 42
TABLES 44
FIGURES 46
APPENDICES 50

LIST OF TABLES

Page

Table 1-1. List of Idaho spring-summer Chinook Salmon redd count index transects and 2019 sampling information. NS = Not Surveyed, NA = Not Applicable, NT= No index transects identified, NPT = Nez-Perce Tribe, SBT = Shoshone-Bannock Tribe, UAS = Unmanned Aircraft System. See Abbreviations and Acronyms pages for population abbreviations. 15

Table 1-2. List of PTAGIS sites queried for PIT-tagged spring-summer Chinook Salmon adults to obtain scale age assignments in 2020. 19

Table 1-3. Spring-summer Chinook Salmon redds counted in Idaho index transects in 2020. Hatchery fraction based on carcass information in Table 1-4 is also indicated. See Abbreviations and Acronyms pages for population abbreviations. NT= No index transects identified, NA = Not Applicable. Asterisks denote assumed values where no carcasses were recovered. 20

Table 1-4. Spring/summer Chinook Salmon carcasses collected during spawning ground surveys in Idaho during 2020. Surveys are organized by major population group (MPG). F = female; M = male; U = unknown sex. Hatchery fraction is the number of hatchery-origin carcasses divided by the number of known-origin carcasses. Downloaded from SGS database 18 Feb 2021. 22

Table 1-5. Age composition of natural-origin spring-summer Chinook Salmon estimated from carcasses collected during spawning ground surveys, natural origin brood stock removed at weirs, and from PIT array detections in Idaho during 2020. See Abbreviations and Acronyms pages for population abbreviations. NA = Not Applicable. 24

Table 2-1. Stream length surveyed and Chinook Salmon total redd counts in the Middle Fork Salmon River, Idaho, 2020. 45

LIST OF FIGURES

Page

Figure 1. Spring-summer Chinook Salmon independent populations and major population groups (MPGs) in the Snake River evolutionary significant unit (ESU). Red dots represent impassable dams. 1

Figure 1-1. Number of spring-summer Chinook Salmon redds counted in index transects of the Clearwater River and Salmon River basins from 2015 through 2020....27

Figure 1-2. Number of spring-summer Chinook Salmon redds counted in index transects of the South Fork Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales. 28

Figure 1-3. Number of spring-summer Chinook Salmon redds counted in index transects of the Middle Fork Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales. 29

Figure 1-4. Number of spring-summer Chinook Salmon redds counted in index transects of the Upper Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales. 30

Figure 1-5. Number of spring-summer Chinook Salmon redds counted in index transects of the Clearwater River basin populations during the recent era, 2015-2020....31

Figure 1-6. Age bias plot depicting the relationship between ages assigned to spring-summer Chinook Salmon using fin rays and their corresponding known ages as determined by PIT tags and CWTs. All samples were collected in 2020. RMSE = root mean squared error, PA = percent agreement, and n = the number of known-age fish. 32

Figure 1-7. Length frequency distribution stacked by age class for natural-origin spring-summer Chinook Salmon carcasses collected in Idaho during 2020 (n = 765). 33

Figure 1-8. Box and whisker plot of productivity (natural-origin returned redds per spawned redd) estimates for 19 spring-summer Chinook Salmon populations sampled in Idaho over brood years 2001-2015. Select populations in some years were omitted due to incomplete data (see Figures 1-11 to 1-13). Dashed line represents 1:1 replacement. 34

Figure 1-9. Productivity (natural-origin returned redds per spawned redd) of all South Fork Salmon River spring-summer Chinook Salmon populations, except Little Salmon River and East Fork South Fork Salmon River, over brood years 2001-2015. Dashed line represents 1:1 replacement. 35

Figure 1-10. Productivity (natural-origin returned redds per spawned redd) of all Middle Fork Salmon River spring-summer Chinook Salmon populations over brood years 2001-2015. Select brood years were omitted due to incomplete data. Dashed line represents 1:1 replacement. 36
Figure 1-11. Productivity (natural-origin returned redds per spawned redd) of all Upper Salmon River spring-summer Chinook Salmon populations over brood years 2001-2015. Select brood years were omitted due to incomplete data. Dashed line represents 1:1 replacement. 37
Figure 2-1. Chinook Salmon redds (white circles; N = 467) observed in independent populations of the Middle Fork Salmon River basin, Idaho, 2020. Bold line indicates main stem Middle Fork Salmon River. 47
Figure 2-2. Total redd counts in the Middle Fork Salmon River basin, Idaho, 1995-2020. Dashed line represents the average redd abundance for 1995-2019. 48
Figure 2-3. Total redd counts in independent populations of the Middle Fork Salmon River basin, Idaho, 1995-2020. Dashed line represents the average for 1995-2019. Note differing scales on y-axes. 49

LIST OF APPENDICES

Page

Appendix A. Comparison of GPS units used to georeferenced Chinook redds observed on aerial surveys....51

Appendix Figure A-1. Example of a comparison between a redd waypoint taken from the ground with the Garmin unit (blue point) and from a moving helicopter with the Trimble unit (red point) on Pistol Creek in 2018....55

Appendix Figure A-2. Example of redd waypoint locations from a moving helicopter with a Trimble unit (red points) on Loon Creek, 1995-2018. 56

Appendix Figure A-3. Example of red waypoint locations from a moving helicopter with a Trimble unit (red points) on Rapid River, 1995-2018. 57

Appendix Figure A-4. Example of redd waypoint locations from the ground with a Garmin unit (blue points) on Marsh Creek, 2020. 58

Appendix B. Additional information collected on spawning ground surveys and at hatchery weirs in 2020. 59

Appendix Table B-1. Multiple-pass redd count census surveys that were conducted for spring-summer Chinook Salmon in Idaho during 2020. Surveys are organized by major population group (MPG)....62

Appendix Table B-2. Additional redd count surveys that were conducted in the Dry Clearwater MPG for spring-summer Chinook Salmon in Idaho during 2020....63

Appendix Table B-3. Data collected for estimating Chinook Salmon abundance above IDFG weirs in 2020. No prespawn mortalities were observed in 2020 at any of the weirs. No estimate was generated for hatchery-origin fish above the South Fork Salmon weir as no hatchery-origin fish were passed over the weir in 2020. 64

Appendix Table B-4. Number of genetic samples collected from adult Chinook Salmon released at IDFG hatchery and research weirs, 2015-2020. NA = not applicable, weir not operated for Chinook Salmon during these years. 65

Appendix C. Evaluation of probabilistic sampling designs for Chinook Salmon redd counts in the lower mainstem Salmon River....66

Appendix Table C-1. Recommendations for adjusted segment lengths within transects and optimal sample size for 80 km total effort. 72

Appendix Figure C-1. Number of 2 km segments allotted to transects within the USRL population based on Neyman allocation. Dashed lines represent the total number of sections present within transects....73

Appendix Figure C-2. Number of redds observed in USRL population from Redfish Lake Creek downstream to the Pahsimeroi River, 1999-2019. Dashed line represents the mean over those years. 74

Appendix Figure C-3. Plot of percent occupancy (top panel), mean redd count (middle panel), and weighted IP length (bottom panel) for 1 km river segments in USRL population from Redfish Lake Creek downstream to the Pahsimeroi River, 1999-2019. 75

Appendix Figure C-4. Map of IP habitat ratings in the USRL population. 76

Appendix Figure C-5. Measures of accuracy (RMSE) for simulated sampling designs across a range of true redd counts. Horizontal panels represent different variables used to determine strata, and vertical panels represent differing

sample unit sizes. Different color lines within plots represent variation in total sampling effort. 77

Appendix Figure C-6. Measures of precision (CV) for simulated sampling designs across a range of true redd counts. Horizontal panels represent different variables used to determine strata, and vertical panels represent differing sample unit sizes. Different color lines within plots represent variation in total sampling effort. 78

Appendix Figure C-7. Measures of accuracy (RMSE) for simulated sampling designs across a range of true redd counts for three different stratifying variables using 2 km sampling units. 79

Appendix Figure C-8. Comparison of estimated redd abundance to true redd abundance in simulations using 2 km sections stratified by mean redd count at various amounts of total sampling effort. Error bars represent the 2.5th and 97.5th percentile of the 1,000 simulated estimates. Line represents a 1:1 unbiased relationship. 80

Appendix Figure C-9. Comparison of estimated redd abundance to true redd abundance in simulations using 2 km sections stratified by IDFG transects at various amounts of total sampling effort. Error bars represent the 2.5th and 97.5th percentile of the 1,000 simulated estimates. Line represents a 1:1 unbiased relationship. 81

FOREWORD

INTRODUCTION

Historically, Idaho waters supported abundant, naturally reproducing Chinook Salmon *Oncorhynchus tshawytscha* runs, which represented an important cultural, economic, and recreational resource within the state (Fulton 1968; Chapman 1986). Adult spring-run, summer-run, and fall-run Chinook Salmon migrate through the Columbia River and enter Idaho via the Snake River. Fall-run Chinook Salmon are monitored in Idaho by Idaho Power Company and the Nez Perce Tribe. As such, this report is exclusively focused on spring-summer Chinook Salmon.

Snake River spring-summer Chinook Salmon runs were historically supported by populations that spawned in the Salmon River and Clearwater River basins of Idaho. The Salmon River basin has long been recognized as the most productive spawning area for spring-summer Chinook Salmon in the entire Columbia River basin (Fulton 1968). During the late 1950s, an estimated 44 percent of the spring and summer runs in the Columbia River, and 83 percent in the Snake River, were destined for the Salmon River basin (Fulton 1968). The Clearwater River basin represented an important spawning area for Snake River spring-summer Chinook Salmon until 1927, when the construction of Lewiston Dam prevented passage and functionally extirpated all populations in this basin (Fulton 1968). Lewiston Dam was removed in 1973 to accommodate other projects taking place as part of the Federal Columbia River Power System (FCRPS). Dworshak Dam, located on the North Fork Clearwater River 5 km upstream of the confluence with the Clearwater River, was completed in 1973 and currently prevents Chinook Salmon passage into previously productive spawning grounds (Fulton 1968). Hence, population abundance in the Salmon and Clearwater basins has declined from historic levels but their history and current status are quite different.

Populations of spring-summer Chinook Salmon in the Snake River basin declined substantially following the construction of hydroelectric dams in the Snake and Columbia rivers in the late 1960s and early 1970s. Survival of Chinook Salmon emigrating from the Snake River basin decreased following the construction of these dams (Raymond 1988). Shifts in ocean climatic regime also contributed to an unfavorable state for all Columbia River salmonid stocks in the 1980s and early 1990s (Mantua et al. 1997). Declines in abundance from the late 1960s until the early 1990s resulted in listing of Snake River spring-summer Chinook Salmon as threatened under the Endangered Species Act (ESA) in 1992 (Federal Register notice 57FR14653). Abundance has been variable since the initial 1992 listing but observed increases have not been sufficient for delisting (NMFS 2016).

Current monitoring of Chinook Salmon recovery is framed by population boundaries established by the Interior Columbia Basin Technical Recovery Team (ICBTRT 2003, 2005) following ESA guidance. The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. Policy guiding identification of DPS for salmon species directs the National Marine Fisheries Service (NMFS) to identify population groups that are evolutionarily significant units (ESU) within their species (NMFS 2016). NMFS considers a group of populations an ESU “if it is substantially reproductively isolated from other populations, and represents an important component in the evolutionary legacy of the biological species” (NMFS 2016). Evolutionarily Significant Units are divided into hierarchical levels including Major Population Groups (MPGs), which are further divided into independent populations (McElhany et al. 2000; ICBTRT 2005). The 1992 ESA listing organized the Snake River spring-summer Chinook Salmon ESU into seven MPGs, five of which are in Idaho (ICBTRT 2005). A total of 33 independent populations have been identified in Idaho, of which 12 have been extirpated.

However, 6 previously extirpated populations have been re-established with stocks from extant Snake River populations. Currently there are 27 extant or re-established populations across all 5 Idaho MPGs.

Anadromous fish management programs in the Snake River basin include large-scale hatchery programs – intended to mitigate for the impacts of hydroelectric dam construction and operation in the basin – and recovery planning and implementation efforts aimed at recovering ESA-listed wild salmon and steelhead stocks. The Idaho Department of Fish and Game's anadromous fish program long-range goals, consistent with basinwide mitigation recovery programs, are to preserve Idaho's salmon and steelhead runs and recover them to provide benefit to all users (IDFG 2019). Management to achieve these goals requires an understanding of how salmon populations function (McElhany et al. 2000) as well as regular status assessments.

The Idaho Salmon and Steelhead Monitoring and Evaluation Studies project is designed to collect information necessary to assess the status of Idaho's spring/summer Chinook Salmon populations relative to IDFG and ESA goals. These data are used in fishery planning and management in accordance with goals for wild- and natural-origin spring-summer Chinook Salmon stated in the current IDFG fisheries management plan (IDFG 2019). Additionally, status of Pacific salmonids listed under the ESA is assessed by NMFS using viability criteria which are related to trends and status in abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). Data collected from this project are provided to NMFS for status review of extant MPGs of the Snake River spring-summer Chinook Salmon ESU (hereafter Chinook Salmon).

REPORT CHAPTERS AND TOPICS

This report documents status and trends in spawner abundance and productivity of Chinook Salmon using data collected on Idaho's spawning grounds. Abundance of spawning salmon can fluctuate greatly and should be related to historic observations for proper interpretation. Chapter 1 reports annual redd counts at index transects surveyed during the historical peak spawning period, and compares current observations to select long-term data collected since the 1950s. In addition to a metric of relative spawner abundance such as redd counts, the adult-to-adult productivity of the population is essential to evaluate population status. Chapter 1 also reports spawner composition metrics necessary to quantify productivity (i.e. age composition, hatchery fraction), and uses that information to quantify adult-to-adult productivity through the most recently completed brood year.

Chapter 2 focuses on a unique MPG by analyzing the persistence and spatial dynamics of Chinook Salmon in Idaho's pristine Middle Fork Salmon River basin. A long-term plan for annual spawning ground surveys in the Middle Fork Salmon River wilderness was developed for this basin in 2018 and was provided in a previous version of this report (Felts et al. 2019, Appendix A).

Additional data not related to specific chapter objectives are often collected during spawning ground surveys and hatchery weir operations. This annual report also serves to document those collection efforts or any changes to our standard efforts. Appendix A provides a comparison of GPS units used to georeference Chinook Salmon redds during aerial surveys. Appendix B documents data collected at hatchery weirs and during multiple pass redd counts. Appendix C evaluates sampling designs used for redd count index transects in the lower mainstem Salmon River.

DATA MANAGEMENT AND ACCESS

Throughout this report we refer to populations designated by the Interior Columbia Basin Technical Recovery Team (ICBTRT 2003, 2005). Because some of these names are quite long, we use our own abbreviations (see Abbreviations and Acronyms page) to describe populations in tables and figures.

Data management follows protocols detailed in Copeland et al. (2019). Spawning ground survey (SGS) data, including redd count and carcass survey data, are recorded in the field on standardized paper data sheets and with global positioning systems (GPS) devices. Waypoints are captured for new redds, carcasses, and survey boundaries using standardized naming conventions. Personnel from IDFG and the Shoshone-Bannock Tribes enter index and non-index survey data into a local Spawning Ground Survey application (SGSA), and the GPS data are imported into their respective surveys in the SGSA. The data are quality checked by the compilers against the paper survey forms. The waypoint data are visually inspected by the compilers to ensure accuracy in the SGSA. Upon verification of complete and correct surveys, the data are uploaded to the centralized, Microsoft Sequel Server SGS database. Other organizations such as the Nez Perce Tribe send index count data to IDFG biologists who then enter it into a local SGSA. The transferred index data are checked for completeness and correctness by data managers, and corrections are uploaded from their SGSA to the SGS database if necessary. Non-index data collected by other organizations are housed and maintained in their separate databases. The data from all compilers are accessible with permission from Idaho Department of Fish and Game (IDFG) in read-only views from the Idaho Fish and Wildlife Information System (IFWIS) web reports, which query the SGS database: https://fishandgame.idaho.gov/ifwis/portal.

Carcass sample data - such as fin ray, genetic, and otolith data - that are recorded on the spawning grounds are entered into SGSA, uploaded to the SGS database, and then transferred from the SGS database to the BioSamples database, which is located on a Microsoft Sequel Server. The transfer is performed by the ageing laboratory coordinator who uses a data template in Microsoft Excel to reformat data from the SGS database for entry into the BioSamples database. A unique fish identification code from the SGS database is entered into the BioSamples database to assist in joining the two databases. Carcass records in the SGS database with fin ray samples are joined to the ageing data in the BioSamples database using the unique fish identification code and the sample number. When the fin rays are analyzed, the estimated age from the BioSamples database populates the Estimate Total Age field in the SGS database.

For the purposes of this report, all index and census redd survey data were entered into preformatted tables by biologists responsible for their collection. Length and fin ray age data were downloaded from the BioSamples database on 23 March 2021. Adult weir and trap data are stored in and accessed from the Fish Inventory System Hatchery Database https://www.finsnet.org/#. These data include all adult Chinook Salmon that are trapped, spawned, or released to spawn naturally. Weir and trap genetics sample data were downloaded from the IDFG Eagle Fish Genetics Laboratory Progeny database on 18 March 2021.

Authors:

Eli A. Felts
Fisheries Biologist

Evan Brown
Sr. Fisheries Data Coordinator

FIGURES

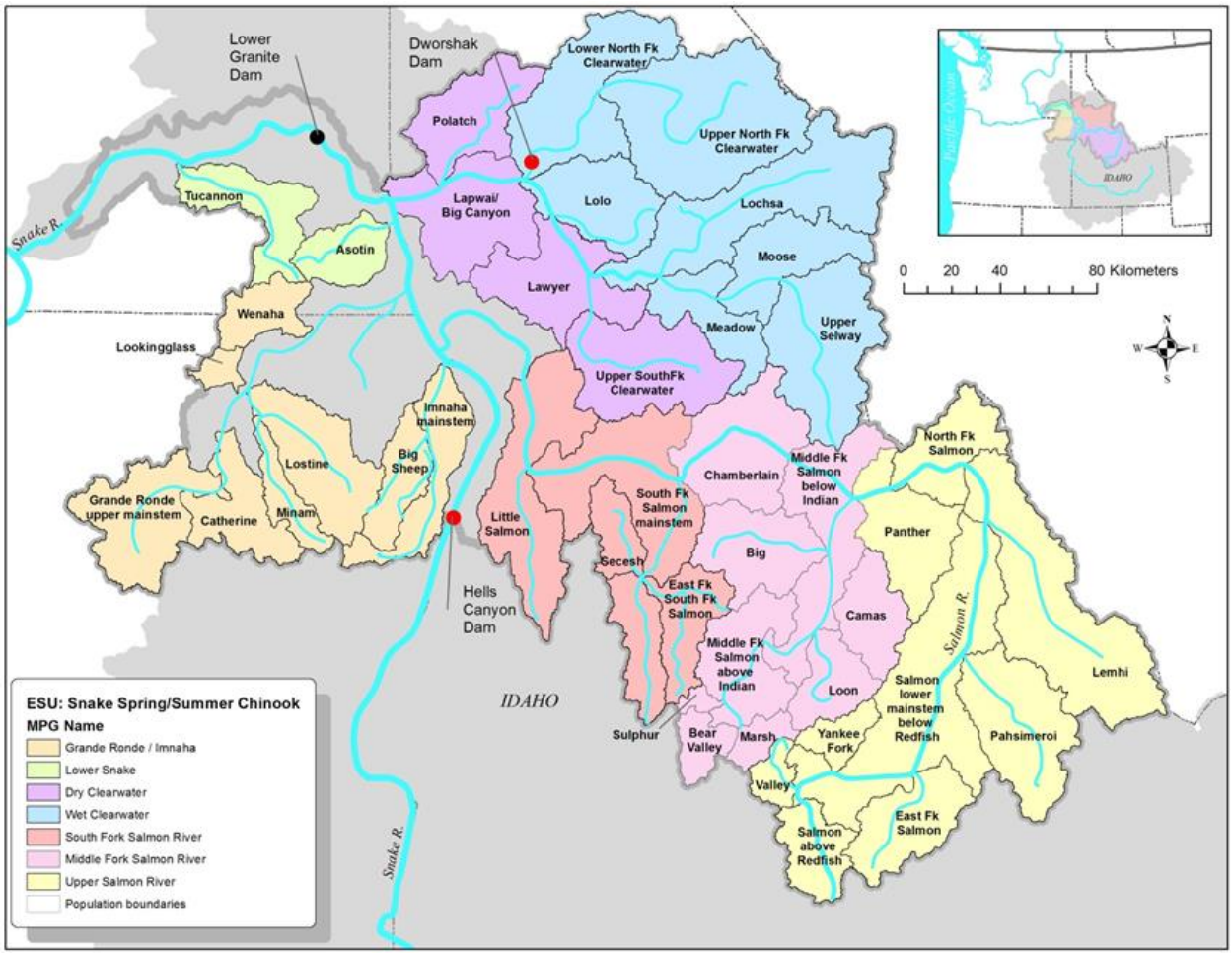

Figure 1. Spring-summer Chinook Salmon independent populations and major population groups (MPGs) in the Snake River evolutionary significant unit (ESU). Red dots represent impassable dams.

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CHAPTER 1. RELATIVE ABUNDANCE AND PRODUCTIVITY IN IDAHO POPULATIONS OF SPRING-SUMMER CHINOOK SALMON

ABSTRACT

The Idaho Natural Production Monitoring and Evaluation Project monitors the status of Snake River spring-summer Chinook Salmon *Oncorhynchus tshawytscha* populations in the Salmon River and Clearwater River basins. Annual single-pass redd counts and carcass surveys are conducted at index transects and provide estimates of relative abundance and productivity of Chinook Salmon. These surveys are conducted annually to document temporal trends in relative abundance and productivity. In 2020, a total of 1,208 redds were counted at 110 transects covering 1,236.8 km, 27 populations, and five major population groups. With few exceptions, relative abundance in 2020 was higher than in 2019. However, in most populations, relative abundance has decreased in many Idaho populations since 2014 and remain well below the pre-dam era range for all populations. The brood year 2016 cohort, represented by age-4 fish on the spawning grounds in 2020, was the most common among all age classes observed. Adult-to-adult productivity estimates for the brood year 2015 cohort are now complete, and were less than one recruit per spawner for every population.

Authors:

Cynthia I. Nau
Fisheries Biologist

Eli A. Felts
Fisheries Biologist

Bruce Barnett
Fisheries Data Coordinator

Micah Davison
Supervisory Fisheries Biologist

Conor McClure
Fisheries Biologist

Joshua R. Poole
Fisheries Biologist

Robert Hand
Fisheries Biologist

Evan Brown
Sr. Fisheries Data Coordinator

INTRODUCTION

Abundance is an essential metric in monitoring fish populations as it represents the end product of the interplay between three processes (recruitment, growth, and mortality) considered to be the pillars of fisheries management (Ricker 1975; Allen and Hightower 2010). Population status is often assessed by using current abundance estimates to predict extinction risk and future trends (McElhany et al. 2000). The direct link between population processes and abundance have led to the latter being designated as a critical metric in assessing viability of salmonid populations (ICBTRT 2005).

Understanding the relationship between spawner abundance and recruitment of a new generation of spawners is important when managing fish populations. In semelparous fishes such as Chinook Salmon *Oncorhynchus tshawytscha*, estimation of adult-to-adult productivity is straightforward if abundance and age composition of spawners is quantified annually (Myers et al. 1999). This metric represents the integrated effects of factors such as population density, environmental conditions, and ecological conditions throughout the entire life cycle (McElhany et al. 2000). Adult-to-adult productivity offers an indication of population trends that is robust to annual fluctuations in spawner abundance. If population abundance is below a desired threshold, as is the case for all spring-summer Chinook Salmon populations in Idaho (NMFS 2016), productivity must, on average, exceed replacement for abundance to increase. As such, adult-to-adult productivity and abundance are given the highest priority in assessing viability of salmonid populations (McElhany et al. 2000, ICBTRT 2005).

In this chapter, relative abundance of Snake River spring-summer Chinook Salmon (hereafter Chinook Salmon) escaping to Idaho in 2020 is summarized using single-pass redd counts. Redd counts are commonly used as a *relative* index of population abundance across space and time. Hence, continuous standardized redd count data were used to compare 2020 relative abundance to the most recent 5-year era, to the 1957-1969 pre-dam era, and across the Idaho landscape. Specific objectives were to:

1) Quantify spawner relative abundance for 27 Idaho populations of Chinook Salmon that were surveyed in 2020.

2) Quantify adult-to-adult productivity using completed brood years for 19 Idaho populations of Chinook Salmon where sufficient data were available.

METHODS

Study Design

Stream transects targeted for redd counts in 2020 were selected based on long-term monitoring conducted by Idaho Department of Fish and Game (IDFG) and collaborators (Table 1-1). Standardized sampling of trend transects began as early as 1957 (Hassemer 1993; Copeland et al. 2019). Trend transects were selected to represent important production areas containing a large portion of available spawning habitat (Copeland et al. 2019). Transects have been added or dropped periodically over the course of the program's history, so the amount of habitat surveyed has changed over time (Copeland et al. 2019). Transect distances have also been refined in 2020, reflecting the use of updated GIS layers. Trend surveys were timed to coincide with the period of peak spawning activity on a particular stream as estimated from

historical observations (Copeland et al. 2019). The timing of trend surveys ranges from mid-August to late September (Table 1-1)

Data Collection

Observers conducting surveys in Idaho were trained annually to accurately determine and record redds and sample carcasses during surveys in a standardized manner. Due to the COVID-19 pandemic, the typical multi-agency training for was canceled in 2020. Instead training was conducted for IDFG staff through experienced surveyors at several smaller regional gatherings. The Salmon region and Nampa subregion redd training occurred outside Stanley, Idaho on August 17, 2020. The McCall subregion completed their own training on August 20, 2020 and the Lewiston office completed theirs on August 25, 2020.

Surveys were conducted by walking or flying a single pass along the designated transect and examining the streambed for redds. Redds were identified by the presence of two features: 1) a “pit” resulting from excavation of the redd and covering of the eggs, and 2) tailspill, which is defined by the presence of loose substrate immediately downstream of the excavated pit (Burner 1951; Copeland et al. 2019). Training emphasized the “four D’s” (disturbance, digging, definition, and deposition) as a standard criteria indicating a completed redd (Copeland et al. 2019). Aerial surveys were conducted with either low-flying helicopter or unmanned aircraft systems (UAS; Table 1). All redds were enumerated and georeferenced using GPS units.

Chinook Salmon carcasses encountered during ground surveys were sampled to determine origin, estimate age composition, and to collect tissue for genetic analysis. Supplemental surveys were also conducted for the sole purpose of collecting biological information from carcasses. Carcasses were first identified as either natural- or hatchery-origin based on where they were produced and as indicated by marks and tags. All carcasses encountered were visually inspected for an adipose or other fin clip and scanned for a coded wire tag (CWT) and passive integrated transponder (PIT) tag. Carcasses which were too decomposed to inspect for fin clips and tags were considered unknown origin fish.

Natural-origin fish were those produced outside of a hatchery, whereas hatchery-origin fish were those produced in a hatchery. For the purposes of this chapter, wild-origin fish, as determined by genetic lineage (IDFG 2019), were considered to be a subset of natural-origin fish. Hatchery fish were further distinguished by either segregated or integrated production type. Segregated hatchery-origin Chinook Salmon were those produced from crosses of hatchery fish only, whereas integrated hatchery-origin fish were produced from crosses of either two natural-origin parents or crosses of one natural- and one hatchery-origin parent. Carcasses with an adipose fin clip were considered segregated hatchery-origin. Carcasses with a CWT and an intact adipose fin were considered integrated hatchery-origin. All other carcasses with an intact adipose fin were considered natural. Some hatchery release groups from the Clearwater basin did not receive an adipose fin clip or a CWT. Carcasses which were too decomposed to inspect for fin clips and tags were considered unknown origin.

Each carcass was inspected for any other marks and tags, measured for fork length (mm), and examined internally to determine sex. Dorsal fin ray and tissue samples were taken from all carcasses. Four to five fin rays were collected, placed in a coin envelope, and frozen. Tissue samples were collected from the least decayed fin and stored on a piece of paper inside separate coin envelopes. Fin ray and tissue samples were delivered to the IDFG Nampa Research Anadromous Ageing Laboratory (NRAAL) located in Nampa, Idaho.

Once delivered to NRAAL, dorsal fin rays were processed and assigned a saltwater age. Fin rays were dried, set in epoxy resin, cut into cross sections with a TechCut 5™ Precision High Speed Saw, and mounted on microscope slides using Shandon-Mount™. Mounted fin rays were digitally imaged using a Leica DFC 450 microscope camera attached to a Leica DM1000 LED microscope. Imaged fin rays were read independently by two trained readers and discrepancies were re-examined in a referee session until both readers and a third party came to a consensus. If a consensus could not be reached, the sample was removed from analysis. Total age (hereafter age unless otherwise denoted) was assigned by adding assumed freshwater age to assigned saltwater age. All freshwater ages were assumed to be 2 years old. This step allows us to assign fish to the correct brood year. To assess the accuracy of our age assignments, fin ray samples from known-age fish were mixed into the overall sample. Smolts marked with PIT tags and CWTs and recovered during hatchery spawning or carcass surveys were considered known-age.

In addition to ages obtained from fin ray samples, age composition data is also obtained from in-stream array detections of know age individuals. These additional samples bolster sample size, particularly in remote populations where few carcasses are encountered during spawning ground surveys. Final detections of PIT-tagged adults at sites with in-stream arrays, weirs, or hatchery traps which could be assigned to independent populations were queried to obtain age composition data from the IDFG BioSample database, these data are accessible to collaborators upon request (Table 1-2). Scale samples are taken from adipose-intact adults sampled at Lower Granite Dam (Camacho et al. 2018). Technicians at NRAAL process scale samples and assign ages according to protocols detailed in Wright et al. (2015). When PIT-tagged fish were also recovered from carcass surveys and assigned an age from a fin ray sample, the fin ray age assignment was used in further analysis. Due to the COVID-19 pandemic, trapping was suspended at Lower Granite Dam from 24 March through 30 June in 2020. Because the majority of the spring-summer Chinook Salmon run was not sampled, once the trap reopened on 1 July, no additional fish were sampled for scales, tissue, or PIT tagged.

Data Analysis

The number of redds counted in index transects in 2020 was summed by population and plotted alongside observations from the recent era (previous five years, 2015-2019) and from the pre-dam era (13 years, 1957-1969). Geometric mean, minimum, and maximum number of redds were calculated for the pre-dam era comparison. This period also corresponds to the “pre-dam era” described in the Comparative Survival Studies (McCann et al. 2018).

Hatchery fraction was estimated as the proportion of carcasses which were hatchery-origin within populations. For populations with hatchery weirs, hatchery fraction was estimated at the population level, and separately above and below the weir. In populations where no carcasses were recovered, hatchery fraction was assumed to be 0 if there were no hatchery releases within the population. Carcasses were recovered in all populations with intended hatchery releases in 2020 so no assumptions were necessary for these populations.

Performance of NRAAL age assignment from fin rays was evaluated using a combination of metrics and graphical assessment. Accuracy was assessed using root mean squared error (RMSE), percent agreement (PA) between assigned and known age, and age bias plots. RMSE was calculated as the square root of the mean squared difference between the assigned age (A_e) and the known age (A_k):

$$RMSE = \sqrt{(A_e - A_k)^2}$$

Percent agreement was calculated as the number of samples for which assigned age was equal to known age divided by the total number of known-age samples, then multiplied by 100. An age bias plot was constructed to depict the relationship between known age and assigned age for a group of samples. Accuracy metrics and age bias plots were computed using the base and ggplot2 (Wickham 2009) packages in Program R (R Core Team 2017).

Population-specific age composition for 2020 was estimated directly using the age class proportions of sampled fish observed in each population, or from age class proportions in the MPG aggregate, depending on sample size. If at least 20 samples in a population were assigned an age from fin rays or scales, then age composition was estimated directly (Felts et al. 2019). If at least 20 samples in a population were assigned an age, but additional carcasses were measured for fork length and not assigned an age, then an age-length key was constructed for natural origin fish using methods described by Isley and Grabowski (2007). In this scenario, the combined sample of assigned ages and indirect ages from the age-length key was used to estimate population-specific age composition. If less than 20 samples in a population were assigned an age, then the aggregate age composition for the MPG was taken to represent population-specific age composition. Age composition at the MPG level was calculated using the same methods described for populations. If less than 20 samples in an MPG were assigned an age, then the aggregate age composition for the ESU was taken to represent population-specific age composition within that MPG. In addition to overall age composition, adult age composition was estimated by excluding age-3 fish. This metric was calculated because age-3 fish are almost exclusively males, whereas our index of abundance is derived from redds which are constructed by the female population.

Adult-to-adult productivity was updated through brood year 2015 for this report. The number of redds counted during a given brood year was taken as a measure of “stock.” Adult returns (“recruits”), which excluded jacks, were calculated by estimating the number of natural-origin redds produced from a brood year at age 4, 5, and 6:

$$R_j = \left(age4prop_{j+4} * wr_{j+4}\right) + \left(age5prop_{j+5} * wr_{j+5}\right) + \left(age6prop_{j+6} * wr_{j+6}\right)$$

where R_j is recruits (natural-origin redds) from brood year j, *ageXprop* is the proportion of adults which were age *X*, and *wr* is the estimated number of natural-origin redds. Natural-origin redds was estimated by multiplying wild fraction (1 minus hatchery fraction) by the total number of redds counted in index transects within populations. Adult age composition was applied because age-3 fish, which were primarily males, were assumed to have no effect on redd abundance (Quinn 2018). Age composition dating back to brood year 2001 was calculated using the methods described above for the current year’s age composition. This time series was selected to characterize productivity over the three most recent brood cycles. The estimated number of natural-origin redds was used for returning redds because we were primarily interested in how many returning redds were produced by natural-origin Chinook Salmon. Clearwater River basin populations were omitted from productivity analysis because of inconsistency in transect boundaries and uncertainty associated with estimates of hatchery fraction. Panther Creek and Yankee Fork Salmon River were omitted for the same reasons, and the Little Salmon River did not have sufficient data because index transects were not established until 2017.

RESULTS

During August and September 2020, 109 transects covering 1,236.8 km of streams in Idaho were surveyed for Chinook Salmon redds (Table 1-3). A total of 1,208 redds were counted

in index transects across five MPGs and 27 populations in the Salmon River and Clearwater River basins. Ninety percent of redds were counted in the Salmon River basin (Table 1-3; Figure 1-1; Figure 1-2). Number of redds were highest in the Upper Salmon River above Redfish Lake Creek, Bear Valley Creek, Marsh Creek, and the Secesh River populations (Table 1-3). Hatchery fraction was 27% in the Upper Salmon River above Redfish Lake Creek and 1% in the Secesh River population. Only natural-origin fish returned to the Bear Valley Creek and Marsh Creek populations.

All index transects in the South Fork Salmon River MPG were surveyed, which included 112.3 km of current spawning habitat. The total number of redds counted ranged from no redds in the Little Salmon River to 112 redds in the Secesh River (Table 1-3; Figure 1-2). Redd abundance within this MPG in 2020 was below the pre-dam era range for all populations except the Secesh River. Hatchery-origin fish composed 19% of carcasses in the East Fork South Fork Salmon River mainstem, 18% in the South Fork Salmon River upstream of the weir, and 1% in the Secesh River (Table 1-4).

All index transects in the Middle Fork Salmon River MPG were surveyed, which included 491.3 km of current spawning habitat. The total number of redds counted ranged from two redds in Camas Creek to 127 redds in the Bear Valley Creek population (Table 1-3; Figure 1-3). Redd abundance within this MPG in 2020 was below the pre-dam era range for all populations except Chamberlain Creek, Marsh Creek and the Middle Fork Salmon River below Indian Creek. All carcasses collected during 2020 in the Middle Fork Salmon River MPG were natural-origin (Table 1-4).

All index transects in the Upper Salmon River MPG were surveyed, which totaled 510.3 km of current spawning habitat. The total number of redds counted ranged from three in Panther Creek to 191 in the Upper Salmon River mainstem above Redfish Lake (Table 1-3; Figure 1-4). Redd abundance within this MPG in 2020 was below the pre-dam era range for all populations except Panther Creek, the Pahsimeroi River, the North Fork Salmon River and Valley Creek. Hatchery-origin fish composed 4% of carcasses collected in Valley Creek, Panther Creek, and the Upper Salmon River mainstem upstream of the weir. The highest hatchery proportion in this MPG was 39% in the Upper Salmon River downstream of the weir (Table 1-4). No hatchery carcasses were encountered in the North Fork Salmon River, the Salmon River Upper Mainstem below Redfish Lake Creek, the East Fork Salmon River, the Pahsimeroi River downstream of the weir, the Yankee Fork, or the Lemhi River.

All index transects in the Dry Clearwater MPG were surveyed, which included 88.0 km of current spawning habitat (Table 1-3). Only one population in the Dry Clearwater MPG was sampled, the Upper South Fork Clearwater River because there is no evidence of substantial spawning by spring Chinook in other populations. In 2020, 80 redds were counted for this population. The 2020 count was an increase from the 44 redds observed in 2019 (Figure 1-5). Eighty-five percent of the carcasses collected in the Upper South Fork Clearwater population were hatchery-origin (Table 1-4). Some hatchery release groups from the Dry Clearwater MPG did not receive an adipose fin clip or a CWT, so hatchery-origin fish was likely underestimated for this population.

Four index transects in the Wet Clearwater MPG were surveyed, which comprised 34.9 km of current spawning habitat. The reduction in area surveyed in this MPG in 2020 is outlined in Felts et al. 2020. Total number of index redds counted ranged from 0 redds in Lolo Creek to 18 redds in the Lochsa River (Table 1-3; Figure 1-5). The Lower North Fork Clearwater River and Upper North Fork Clearwater River populations are inaccessible to Chinook because Dworshak

Dam prevents passage so no index transects exist. In the Meadow Creek population there is no evidence of substantial spawning by Chinook Salmon. Nine carcasses were recovered in the Wet Clearwater MPG, and 2 of those were hatchery-origin (Table 1-4). Some hatchery release groups from the Wet Clearwater MPG did not receive an adipose fin clip or a CWT, so hatchery-origin fish was likely underestimated for this population.

In total, 866 natural-origin samples were assigned an age using fin rays or scales in 2020 (Table 1-5). Fin ray samples from carcasses accounted for 771, or about 89%, of the age assignments. Age assignments matched their known ages for 94.5% of the known-age fin ray samples (n =103), and the most common error was for known age-4 fish to be under-estimated by one year (n=3; Figure 1-6). The brood year 2016 cohort, represented by age-4 fish on the spawning grounds in 2020, was the most common among all age classes observed within MPGs (Table 1-5) and across all samples (Figure 1-7). Age-3 and age-5 fish were also observed.

Adult-to-adult productivity over brood years 2001-2015 was estimated for 19 populations within the South Fork Salmon River, Middle Fork Salmon River, and Upper Salmon River MPGs. Temporal trends in productivity (returned redds per spawned redd) tracked similarly among populations over brood years 2001-2015 (Figure 1-8). Productivity in nearly all populations was below replacement for brood years 2001-2003, and above replacement for brood years 2006 and 2007. Productivity has been below replacement in nearly all populations for the last four completed brood years, 2012-2015. Time series of productivity by population for brood years 2001-2015 were provided (Figures 1-9 – 1-11).

DISCUSSION

Idaho spring-summer Chinook Salmon redd abundance in 2020, measured by our standard index redd counts, was low compared to the past five years across all Idaho populations. Many populations experienced higher counts in the 2015 and 2016 surveys but have been declining since. The five-year range of recent observations has been below or near the low end of the pre-dam era range, indicating that even “good” runs in recent years were well below their potential. In a broader context, index redd counts within many populations were among the lowest observed in the 64-year history of this data set. We presume that low relative redd abundance indicates low absolute spawner abundance. Relative abundance within supplemented populations, including the East Fork South Fork Salmon River, Pahsimeroi River, and Salmon River mainstem above Redfish Lake, has been within the pre-dam era range and near the geometric mean over recent years, but hatchery-origin fish constructed most of the redds in these populations. Thus, relative abundance in these populations as indicated by redd counts is augmented by hatchery production and should not be taken as an indication of better performance.

While the abundance of Chinook Salmon redds in 2020 increased in both the Salmon and Clearwater River basins from the all-time low values recorded in 2019, the Salmon River basin exhibited a more dramatic increase. The abundance of redds within these two basins was highly variable between the individual populations. For example, within the South Fork Salmon River MPG, the Secesh River and the East Fork South Fork Salmon River recorded an increase in redds compared to 2019 values; whereas the Lower Salmon River and the South Fork Salmon River recorded declines in redd abundance. This same trend can be seen in the Middle Fork Salmon River MPG where in 2020 Bear Valley Creek, Marsh Creek, Chamberlain Creek, and Middle Fork Salmon River (both the upper and lower sections) exhibited an increase in the number of redds observed compared to 2019. In contrast, Big Creek, Loon Creek, and Sulphur Creek

recorded a similar number of redds as 2019, and Camas Creek redd numbers declined from 2019. Historically, Idaho Chinook Salmon populations tend to have a high degree of synchrony in return rates and redd observations among and within MPGs but variation has been shown to increase in periods of low abundance (Isaak et al. 2003).

In addition to the index redd counts, samples from carcasses collected during surveys are used to produce productivity estimates which are used to assess population status and viability. The accuracy of these estimates relies on accurate aging of the samples. The Nampa Research Anadromous Ageing Lab (NRAAL) has an accuracy goal of >90% for total and saltwater age determination using fin rays. This standard is based on historical accuracy assessments of NRAAL age determination, and is met or exceeded in the vast majority of years in which accuracy has been assessed. In spawn year 2020, the accuracy of total age assignments exceeded this standard at 94.5%, and represents the percent agreement (PA) between known age samples and a multiple reader consensus read. Overall inaccuracies were biased toward under-aging, which accounted for 4/6 disagreements between known total age and consensus age.

Productivity of brood year 2015 was below replacement in all populations, and has been below replacement for each of the last three completed brood years (2012-2014) across nearly all populations. Density-independent factors affecting survival through the hydrosystem and ocean have driven recent productivity trends for Snake River spring-summer Chinook Salmon (McCann et al. 2018). Ocean climatic conditions since 2013 have been especially abnormal and are suspected to have had a large negative impact on productivity of Pacific Northwest salmon (Peterson et al. 2018). A large area of abnormally warm water nicknamed the “Blob” stretched from the coast of Alaska to Baja California in the northeastern Pacific from late 2013 until late 2015 (Cavole et al. 2016). The elevated sea surface temperatures associated with the “Blob” reduced phytoplankton availability and caused several food web changes thought to reduce prey quality for Chinook Salmon (Cavole et al. 2016). Changes in forage fish abundance, distribution and spawning time have also been observed due to increased surface temperatures (Auth et al. 2017, Brodeur et al. 2019), contributing to changes in Chinook Salmon distribution in the Pacific Ocean as well (Shelton et al. 2020). Observations indicate the Blob has since dissipated (Peterson et al. 2018), but high temperature events have since reoccurred in 2019 and will likely continue to occur periodically in the future (Scannell et al. 2020). The low productivity of recent brood years is likely due to those conditions because those brood years would have been exposed to the Blob or the 2019 high temperature event for part or all of their ocean phase.

Results from 2020 indicate Idaho populations of spring-summer Chinook Salmon are at low spawner abundance relative to recent era and pre-dam era observations and NMFS recovery goals. The most recent status review for the Snake River spring-summer Chinook Salmon ESU concluded the majority of populations in the ESU were at high overall risk and recommended no change in status (NMFS 2016). A current status review is in progress (see Chapter 3), and overall status has not improved since the previous status review. Low productivity has been observed since the 2015 status assessment, resulting in decreased abundance throughout the ESU. Poor ocean conditions have likely been a major driver of recent trends, and abundance is unlikely to increase to desired levels without favorable ocean conditions. Chinook Salmon have a high maximum annual reproductive rate (Myers et al. 1999), meaning populations can quickly increase in abundance when exposed to favorable conditions. If poor ocean conditions continue, Idaho populations of spring-summer Chinook Salmon will remain at low abundance, and ESA-listed populations will continue to be considered at high overall risk. However, changes in density independent factors which affect productivity could quickly reverse recent trends.

RECOMMENDATIONS

1. Maintain the IDFG redd count index surveys.

2. Continue to evaluate potential spatial or temporal changes to index surveys relative to maintaining our ability to track long and short-term abundance trends in Chinook Salmon spawning in the Idaho.

3. Continue to refine spawning ground survey data management, from quality assurance in the field to quality control of the Spawning Ground Survey database and its output to ensure timely and accurate summaries.

4. Investigate factors affecting redd detection probability by UAS.

5. Continue to evaluate and compare accuracy between ground, helicopter, and UAS red survey methods.

6. Analyze the sensitivity of age estimation errors on productivity metrics such as adult-to-adult productivity and smolt-to-adult return ratios.

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TABLES

Table 1-1. List of Idaho spring-summer Chinook Salmon redd count index transects and 2019 sampling information. NS = Not Surveyed, NA = Not Applicable, NT= No index transects identified, NPT = Nez-Perce Tribe, SBT = Shoshone-Bannock Tribe, UAS = Unmanned Aircraft System. See Abbreviations and Acronyms pages for population abbreviations.

Population	Transect ID	Target survey date	2020 survey date	Method	Agencies
		South Fork Salmon River MPG			
LSR	NS-34	9/5-9/10	9/11	Ground	IDFG
SFSR	NS-26	9/5	9/1-9/2	Ground	IDFG
	NS-27	9/5	9/1-9/9	Ground	NPT, IDFG
	NS-28	9/5	9/3-9/9	Ground	NPT, IDFG
	NS-29	9/6	9/3	Ground	IDFG
SEC	WS-16	8/25-9/1	8/24	Ground	IDFG
	WS-17	8/25-9/1	8/24	Ground	IDFG
	WS-18	8/25	8/25	Ground	IDFG
	WS-19	8/25	8/20	Ground	IDFG
	WS-20	8/25	8/27	Ground	IDFG
EFSFSR	NS-30	9/1-9/5	8/27	Ground	NPT
	NS-31	9/1-9/5	9/14	Ground	NPT
		Middle Fork Salmon River MPG			
CHC	WS-1	8/25	8/27	Ground	IDFG
	WS-1a	8/25	8/26	Ground	IDFG
MFSRL	WS-15c	9/5-9/12	9/21	Raft	USFS,IDFG
	WS-15d	9/5-9/12	9/21	Raft	USFS,IDFG
	WS-15e	9/5-9/12	9/21	Raft	USFS,IDFG
BIG	WS-13	9/5	8/31	Ground	IDFG
	WS-14a	9/5	8/31	Ground	NPT, IDFG
	WS-14b	9/5	9/10	Helicopter	IDFG
	WS-14c	9/5	9/10	Helicopter	IDFG
	WS-14d	9/5	9/10	Helicopter	IDFG
CAM	WS-8	8/25-9/5	9/10	Helicopter	IDFG
LOON	WS-6	8/25-9/5	9/9	Helicopter	IDFG
	WS-7	8/25-9/5	9/9	Helicopter	IDFG
MFSRU	WS-15a	9/5-9/12	9/7	Helicopter	IDFG
	WS-15b	9/5-9/12	9/21	Raft	USFS,IDFG
	WS-21	9/5-9/12	9/8	Helicopter	IDFG
	WS-22a	9/5-9/12	9/8	Helicopter	IDFG
	WS-22b	9/5-9/12	9/8	Helicopter	IDFG
	WS-23	9/5-9/12	9/8	Helicopter	IDFG
	WS-24	9/5-9/12	9/8	Helicopter	IDFG
SUL	OS-4	8/21	8/27	Ground	IDFG
	WS-12	8/21	8/27	Ground	IDFG
BVC	WS-9a	8/27	8/24	Ground	IDFG

Table 1-1. Continued.

Population	Transect ID	Target survey date	2020 survey date	Method	Agencies
		Middle Fork Salmon River MPG (continued)			
BVC, continued	WS-9b	8/27	8/24	Ground	IDFG
	WS-9c	8/27	8/26	Ground	IDFG
	WS-9d	8/27	8/26	Ground	IDFG
	WS-10a	8/27	8/25	Ground	IDFG
	WS-10b	8/27	8/25	Ground	IDFG
	WS-11a	8/27	8/25	Ground	IDFG
	WS-11b	8/27	8/25	Ground	IDFG
	WS-11c	8/27	8/25	Ground	IDFG
MAR	WS-2a	8/18	8/22	Ground	IDFG
	WS-2b	8/18	8/22	Ground	IDFG
	WS-3	8/17	8/21	Ground	IDFG
	WS-4	8/19	8/24	Ground	IDFG
	WS-5	8/16	8/23	Ground	IDFG
		Upper Salmon River MPG			
PAN	NS-11a	9/8	9/4	UAS	IDFG
	NS-11b	9/8	9/4	UAS	IDFG
	NS-11c	9/8	9/4	UAS	IDFG
	NS-11d	9/8	9/4	UAS	IDFG
NFSR	NS-25a	9/8	9/7	Ground	IDFG
	NS-25b	9/8	9/8	Ground	IDFG
	NS-25c	9/8	9/8	Ground	IDFG
LEM	NS-9	9/8	9/9	Ground	IDFG
	NS-10	9/8	9/28	UAS	IDFG
	NS-35a	9/8	9/8	Ground	IDFG
	NS-35b	9/8	9/8	Ground	IDFG
USRL	NS-17	9/8	9/8	UAS	IDFG
	NS-18	9/8	9/9	UAS	IDFG
	NS-19	9/8	9/10	UAS	IDFG
	NS-20	9/8	9/14	UAS	IDFG
	NS-21	9/8	9/21	UAS	IDFG
	NS-22	9/8	9/18	UAS	IDFG
	NS-23	9/8	9/16	UAS	IDFG
PAH	NS-33a	9/20	9/28 & 10/1	Ground/UAS	IDFG
	NS-33b[a]	9/20	9/21-9/22	Ground	IDFG
EFSR	NS-1a	9/8	9/16	Ground	IDFG
	NS-1b	9/8	9/14	Ground	IDFG
	NS-2a	9/8	9/14	UAS	IDFG
	NS-2b	9/8	9/15	Ground	IDFG
	NS-2c	9/8	9/14	UAS	IDFG

Table 1-1. Continued.

Population	Transect ID	Target survey date	2020 survey date	Method	Agencies
		Upper Salmon River MPG (Continued)			
YFK, continued	NS-5	9/8	9/9	UAS	IDFG
	NS-6	9/8	9/9	UAS	IDFG
	NS-7	9/8	9/11	Ground	IDFG
	NS-8	9/8	9/11	Ground	IDFG
VAL	NS-3a	9/8	9/8	Ground	IDFG
	NS-3b	9/8	9/8	Ground	IDFG
	NS-4	9/8	9/8	Ground	IDFG
USRU	NS-12	8/31-9/5	9/12	Ground	IDFG
	NS-13a	9/8	9/8	UAS	IDFG
	NS-13b	9/8	9/7	UAS	IDFG
	NS-15a	9/8	9/9	Boat	IDFG
	NS-15b	9/8	9/9	Boat	IDFG
	NS-15c	9/8	9/8	UAS	IDFG
	NS-16	9/8	9/9	Ground	IDFG
	OS-1	8/31-9/5	9/2	Ground	IDFG
	OS-2	8/31-9/5	9/2	Ground	IDFG
	OS-3	8/31-9/5	9/2	Ground	IDFG
	OS-5	9/8	9/8	UAS	IDFG
	OS-6	9/8	9/9	Ground	IDFG
		Dry Clearwater MPG			
LAP	NT	NA	NA	NA	NA
LAW	NT	NA	NA	NA	NA
POT	NT	NA	NA	NA	NA
USFC	NC-1	9/3	9/6-9/8	Ground	IDFG
	NC-2a	9/3	9/8	Ground	IDFG
	NC-2b	9/3	9/8	Ground	IDFG
	NC-3	9/3	9/8	Ground	IDFG
	NC-4	9/1-9/5	9/9	Ground	IDFG
	NC-6[a]	9/3	9/20-9/23	Ground	IDFG
	NC-8	9/3	9/10	Ground	NPT, IDFG
		Wet Clearwater MPG			
LNFC	NT	NA	NA	NA	NA
LOLO	NC-14	9/3	9/8	Ground	NPT, IDFG
LOC	NC-10	9/3	9/8	Ground	IDFG
	NC-11	9/3	9/8	Ground	IDFG
MED	NT	NA	NA	NA	NA
MOO	WC-3c	9/8	9/16	Ground	IDFG
	WC-3d	9/8	9/14	Ground	IDFG
SEL	WC-2	9/8	9/22	Ground	IDFG

Table 1-1. Continued.

Population	Transect ID	Target survey date	2020 survey date	Method	Agencies
	WC-5	9/8	NS	NA	NA
	WC-7	9/8	9/15	Ground	IDFG
UNFC	NT	NA	NA	NA	NA

[a] Partial survey.

Table 1-2. List of PTAGIS sites queried for PIT-tagged spring-summer Chinook Salmon adults to obtain scale age assignments in 2020.

Population	PTAGIS site code	Type
South Fork Salmon River MPG		
LSR	RAPH	Hatchery Trap
SFSR	KRS	In-stream Array
	SALSFW	Hatchery Trap
	SFG	In-stream Array
SEC	ZEN	In-stream Array
EFSFSR	ESS	In-stream Array
	JOHNSC	Carcass Recovery
Middle Fork Salmon River MPG		
BIG	TAY	In-stream Array
BVC	BRC	Weir
Upper Salmon River MPG		
NFSR	NFS	In-stream Array
LEM	HYC	In-stream Array
	LLR	In-stream Array
	LRW	In-stream Array
PAH	PAHH	Hatchery Trap
YFK	YFK	In-stream Array
VAL	VC1	In-stream Array
USRU	SAWT	Hatchery Trap
Dry Clearwater MPG		
USFC	CROOKR	Carcass Recovery
	SC1	In-stream Array
	SC2	In-stream Array
Wet Clearwater MPG		
LOLO	LC1	In-stream Array
	LC2	In-stream Array
LOC	LRL	In-stream Array
	LRU	In-stream Array
MOO/SEL	SW1	In-stream Array
	SW2	In-stream Array

Table 1-3. Spring-summer Chinook Salmon redds counted in Idaho index transects in 2020. Hatchery fraction based on carcass information in Table 1-4 is also indicated. See Abbreviations and Acronyms pages for population abbreviations. NT= No index transects identified, NA = Not Applicable. Asterisks denote assumed values where no carcasses were recovered.

Population	Distance surveyed (km)	Redds	Hatchery fraction
	South Fork Salmon River MPG		
LSR	3.8	0	0.00
SFSR	70.0	68	0.13
SEC	28.0	112	0.01
EFSFSR	10.5	65	0.19
MPG Total	**112.3**	**245**	**0.11**
	Middle Fork Salmon River MPG		
CHC	7.8	18	0.00
MFSRL	107.5	4	0.00
BIG	63.6	29	0.00
CAM	9.9	2	0.00
LOON	24.4	13	0.00
MFSRU	179.1	14	0.00
SUL	9.5	9	0.00
BVC	62.9	127	0.00
MAR	26.6	125	0.00
MPG Total	**491.3**	**341**	**0.00**
	Upper Salmon River MPG		
PAN	46.9	3	0.04
NFSR	29.3	19	0.00
LEM	48.8	101	0.00
USRL	138.3	23	0.00
PAH	45.8	37	0.35
EFSR	62.5	47	0.00
YFK	41.4	4	0.00
VAL	28.3	75	0.04
USRU	69.0	191	0.27
MPG Total	**510.3**	**500**	**0.21**
Salmon River Basin Total	**1,113.9**	**1,086**	**0.15**
	Dry Clearwater MPG		
LAP	NT	NA	NA
LAW	NT	NA	NA
POT	NT	NA	NA
USFC	88.0	80	0.85

Table 1-3. Continued.

Population	Distance surveyed (km)	Redds	Hatchery fraction
	Dry Clearwater MPG (Continued)		
MPG Total	**88.0**	**80**	**0.85**
	Wet Clearwater MPG		
LNFC	NT	NA	NA
LOLO	7.9	0	0.17
LOC	6.3	18	0.00
MED	NT	NA	NA
MOO	9.6	13	0.00
SEL	11.1	11	0.50
UNFC	NT	NA	NA
MPG Total	**34.9**	**42**	**0.22**
Clearwater River Basin Total	**122.9**	**122**	**0.82**
Idaho Total	**1236.8**	**1,208**	**0.26**

Table 1-4. Spring/summer Chinook Salmon carcasses collected during spawning ground surveys in Idaho during 2020. Surveys are organized by major population group (MPG). F = female; M = male; U = unknown sex. Hatchery fraction is the number of hatchery-origin carcasses divided by the number of known-origin carcasses. Downloaded from SGS database 18 Feb 2021.

	Segregated hatchery			Integrated hatchery			Natural			Unknown			Totals			
Population	**F**	**M**	**U**	**F**	**M**	**U**	**F**	**M**	**U**	**F**	**M**	**U**	**All**	**Known-origin**	**Hatchery**	**Hatchery fraction**
South Fork Salmon River MPG																
LSR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
SFSR downstream of weir[e]	3	0	0	0	0	0	10	14	0	0	0	1	28	27	3	0.11
SFSR upstream of weir	0	0	0	0	2	0	1	8	0	0	0	0	11	11	2	0.18
SEC[a]	0	1	0	0	0	0	48	51	8	2	1	4	115	103	1	0.01
EFSFS [e]	1	1	0	1	18	0	39	48	0	0	1	0	109	109	21	0.19
MPG Total	**4**	**2**	**0**	**1**	**20**	**0**	**98**	**121**	**8**	**2**	**2**	**5**	**263**	**250**	**27**	**0.11**
Middle Fork Salmon River MPG																
CHC	0	0	0	0	0	0	4	0	0	0	0	0	4	4	0	0.00
MFSRU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
MFSRL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
BIG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
CAM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
LOON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
SUL	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0.00
BVC[c]	0	0	0	0	0	0	14	8	1	0	0	0	23	23	0	0.00
MAR	0	0	0	0	0	0	56	43	1	0	0	0	100	100	0	0.00
MPG Total	**0**	**0**	**0**	**0**	**0**	**0**	**75**	**51**	**2**	**0**	**0**	**0**	**128**	**128**	**0**	0.00
Upper Salmon River MPG																
PAN[c]	0	1	0	0	1	0	19	29	2	0	0	0	52	52	2	0.04
NFSR	0	0	0	0	0	0	3	0	0	0	0	0	3	3	0	0.00
LEM	0	0	0	0	0	0	20	6	2	0	0	1	29	28	0	0.00
USRL	0	0	0	0	0	0	2	1	0	0	0	0	3	3	0	0.00

Table 1-4. Continued.

Population	Segregated hatchery			Integrated hatchery			Natural			Unknown			Totals			Hatchery fraction
	F	M	U	F	M	U	F	M	U	F	M	U	All	Known-origin	Hatchery	
Upper Salmon River MPG (continued)																
PAH downstream of weir	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0.00
PAH upstream of weir	0	0	0	0	6	0	4	6	0	0	0	0	16	16	6	0.37
EFSR[c]	0	0	0	0	0	0	11	10	1	0	0	0	22	22	0	0.00
YFK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
VAL	0	0	1	0	0	0	17	9	0	0	0	0	27	27	1	0.04
USRU downstream of weir	55	28	1	4	4	0	79	65	0	0	0	0	236	236	92	0.39
USRU upstream of weir	0	2	0	1	2	0	17	95	1	0	0	0	118	118	5	0.04
MPG Total	**55**	**31**	**2**	**5**	**13**	**0**	**173**	**221**	**6**	**0**	**0**	**1**	**507**	**506**	**106**	**0.21**
Dry Clearwater MPG																
USFC	73	64	5	0	0	0	12	12	1	5	3	4	179	167	142	0.85
MPG Total	73	64	5	0	0	0	12	12	1	5	3	4	179	167	142	0.85
Wet Clearwater MPG																
LOC	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0.00
LOLO[e]	1	0	0	0	0	0	3	2	0	0	0	0	6	6	1	0.17
MOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
SEL	1	0	0	0	0	0	0	1	0	0	0	0	2	2	1	0.50
MPG Total	**2**	**0**	**0**	**0**	**0**	**0**	**4**	**3**	**0**	**0**	**0**	**0**	**9**	**9**	**2**	**0.22**

[a] Staff from the Nez Perce Tribe and Idaho Department of Fish and Game collected and provided information.
[b] Staff from U.S. Forest Service collected and provided information.
[c] Staff from the Shoshone-Bannock Tribes and Idaho Department of Fish and Game collected and provided information.
[d] Staff from the Shoshone-Bannock Tribes collected and provided information.
[e] Staff from the Nez Perce Tribe collected and provided information.

Table 1-5. Age composition of natural-origin spring-summer Chinook Salmon estimated from carcasses collected during spawning ground surveys, natural origin brood stock removed at weirs, and from PIT array detections in Idaho during 2020. See Abbreviations and Acronyms pages for population abbreviations. NA = Not Applicable.

Population	# Carcass fin ray samples	# PIT array scale samples	Length Samples	# Total age samples	Freshwater.Saltwater Age (Total Age)			
					2.1 (3)	2.2 (4)	2.3 (5)	2.4 (6)
South Fork Salmon River MPG								
LSR	0	0	0	0	0	0	0	0
SFSR[a]	28	0	9	37	2	35	0	0
SEC	101	0	1	102	13	84	5	0
EFSFSR	83	0	0	83	11	69	3	0
MPG Total	**212**	**0**	**10**	**222**	**26**	**188**	**8**	**0**
Middle Fork Salmon River MPG								
CHC	4	0	0	4	0	4	0	0
MFSRL	0	0	0	0	0	0	0	0
BIG	7	0	0	7	0	6	1	0
CAM	0	0	0	0	0	0	0	0
LOON	0	0	0	0	0	0	0	0
MFSRU	0	0	0	0	0	0	0	0
SUL	1	0	0	1	0	0	1	0
BVC[b]	21	0	2	23	2	17	4	0
MAR	64	0	36	100	4	92	4	0
MPG Total	**97**	**0**	**38**	**135**	**6**	**119**	**10**	**0**
Upper Salmon River MPG								
PAN	48	0	2	50	5	37	8	0
NFSR	2	0	1	3	0	3	0	0
LEM	25	0	3	28	2	23	3	0
USRL	3	0	0	3	0	3	0	0
PAH	41	0	4	45	0	39	6	0
EFSR	18	0	3	21	1	15	5	0
YFK	7	0	0	7	1	5	1	0
VAL	25	0	1	26	0	24	2	0

Table 1-5. Continued.

Population	# Carcass fin ray samples	# PIT array scale samples	Length Samples	# Total age samples	Freshwater.Saltwater Age (Total Age)			
					2.1 (3)	2.2 (4)	2.3 (5)	2.4 (6)
Upper Salmon River MPG (Continued.)								
USRU	293	0	2	295	12	263	20	0
MPG Total	**462**	**0**	**16**	**478**	**21**	**412**	**45**	**0**
Salmon River Basin Total	**771**	**0**	**64**	**835**	**53**	**719**	**63**	**0**
Dry Clearwater MPG								
LAP	NA	0	0	0	0	0	0	0
LAW	NA	0	0	0	0	0	0	0
POT	NA	0	0	0	0	0	0	0
USFC	0	0	24	24	2	18	4	0
MPG Total	**0**	**0**	**24**	**24**	**2**	**18**	**4**	**0**
Wet Clearwater MPG								
LNFC	0	0	0	0	0	0	0	0
LOLO	0	0	5	5	1	4	0	0
LOC	0	0	1	1	0	1	0	0
MED	0	0	0	0	0	0	0	0
MOO	0	0	0	0	0	0	0	0
SEL	0	0	1	1	0	1	0	0
UNFC	0	0	0	0	0	0	0	0
MPG Total	**0**	**0**	**7**	**7**	**1**	**6**	**0**	**0**
Clearwater River Basin Total	**0**	**0**	**31**	**31**	**3**	**24**	**4**	**0**
Idaho Total	**771**	**0**	**95**	**866**	**56**	**743**	**67**	**0**

[a] Staff from the Nez Perce Tribe and Idaho Department of Fish and Game collected and provided information.
[b] Staff from the Shoshone-Bannock Tribes and Idaho Department of Fish and Game collected and provided information.
[c] PIT array scale samples detected in the Selway River could potentially spawn in the SEL or MOO populations.

FIGURES

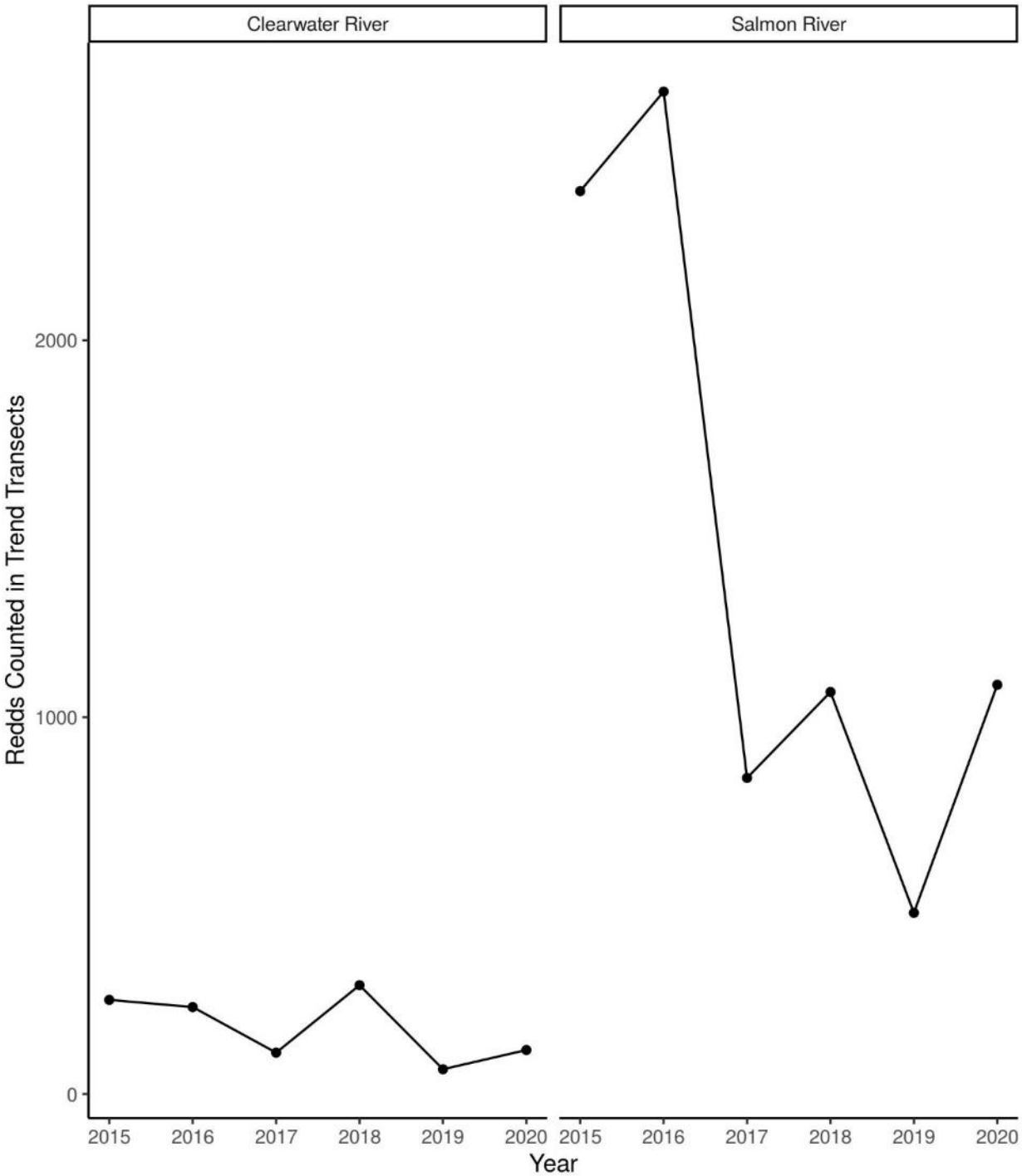

Figure 1-1. Number of spring-summer Chinook Salmon redds counted in index transects of the Clearwater River and Salmon River basins from 2015 through 2020.

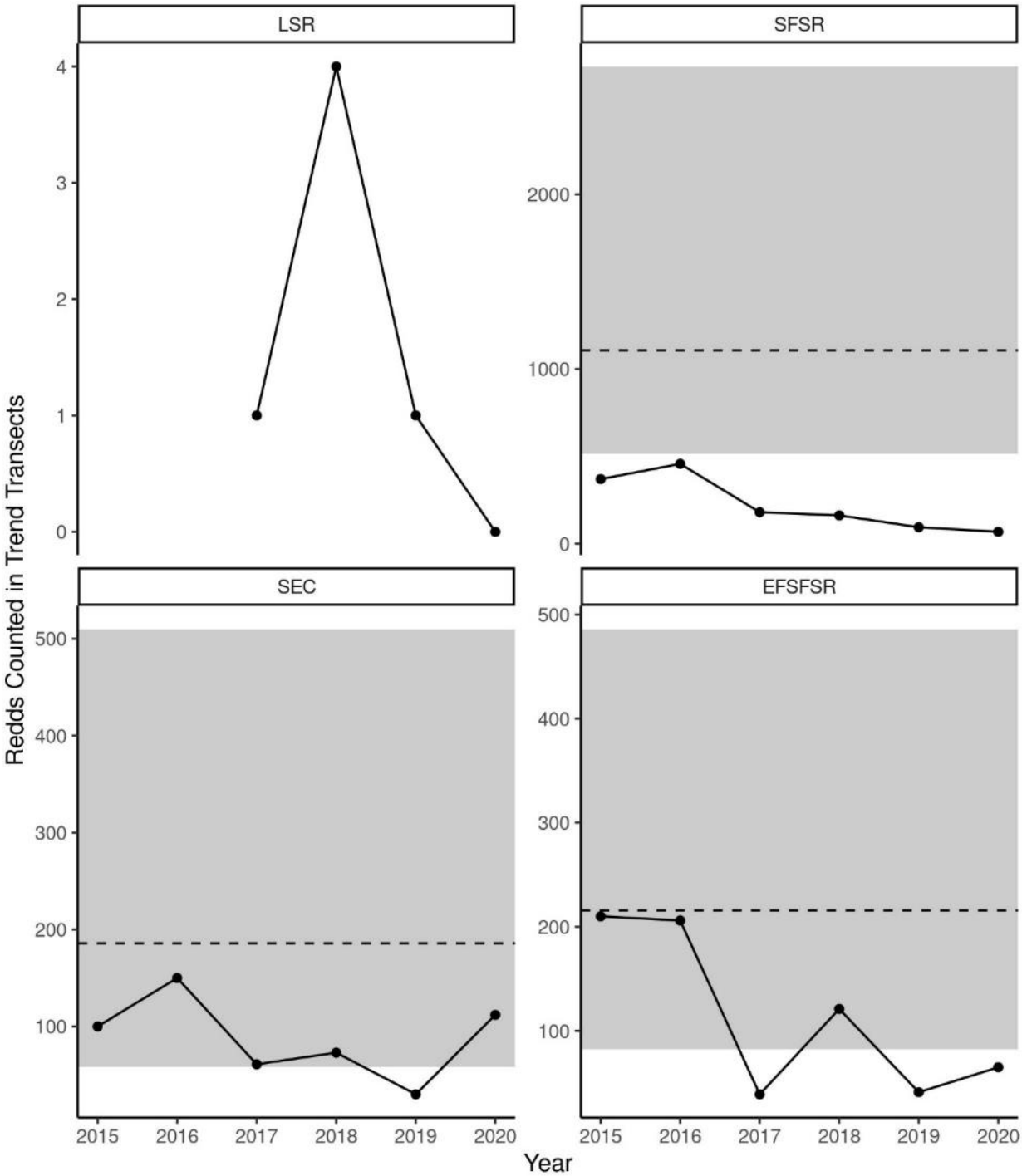

Figure 1-2. Number of spring-summer Chinook Salmon redds counted in index transects of the South Fork Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales.

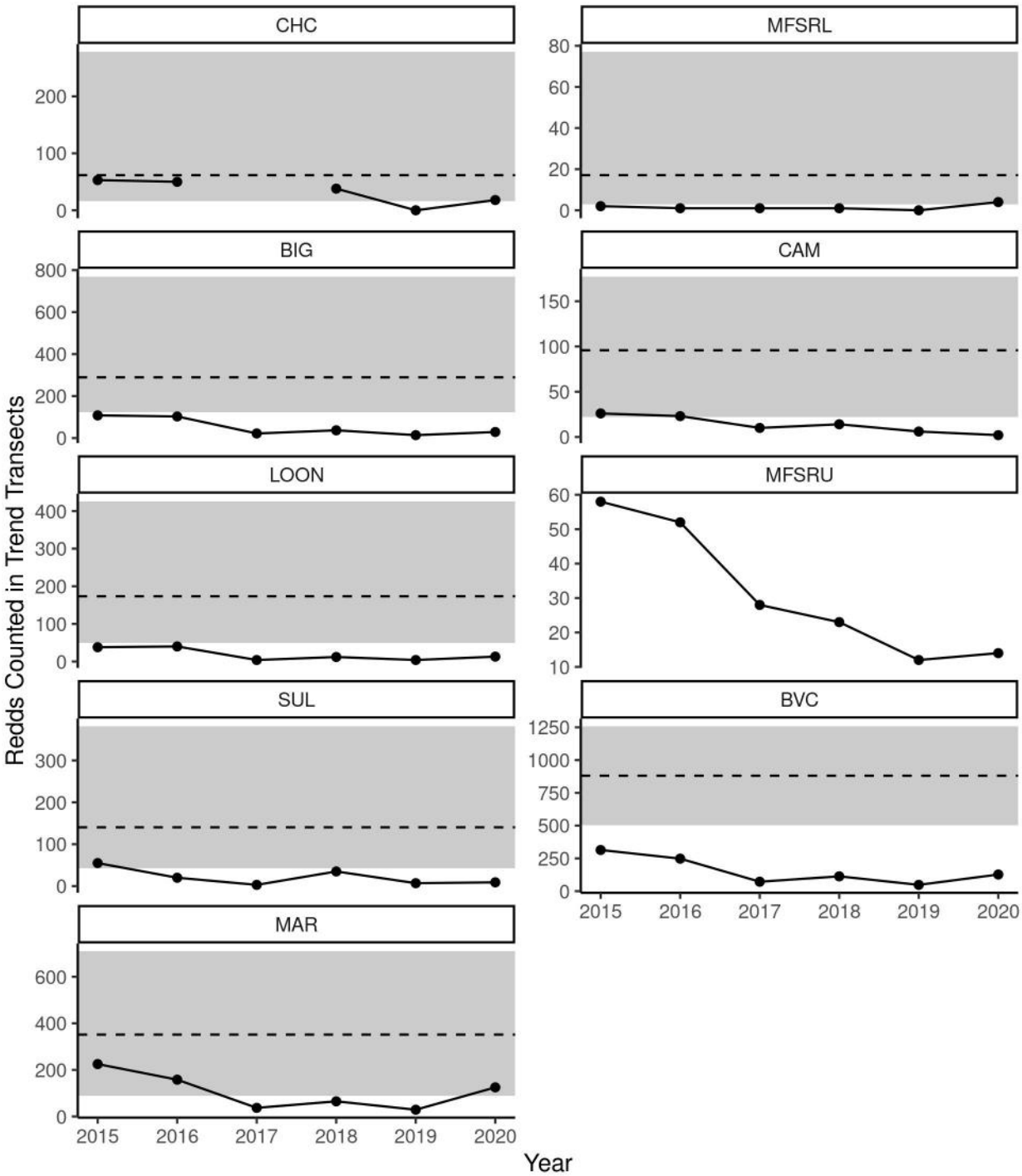

Figure 1-3. Number of spring-summer Chinook Salmon redds counted in index transects of the Middle Fork Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales.

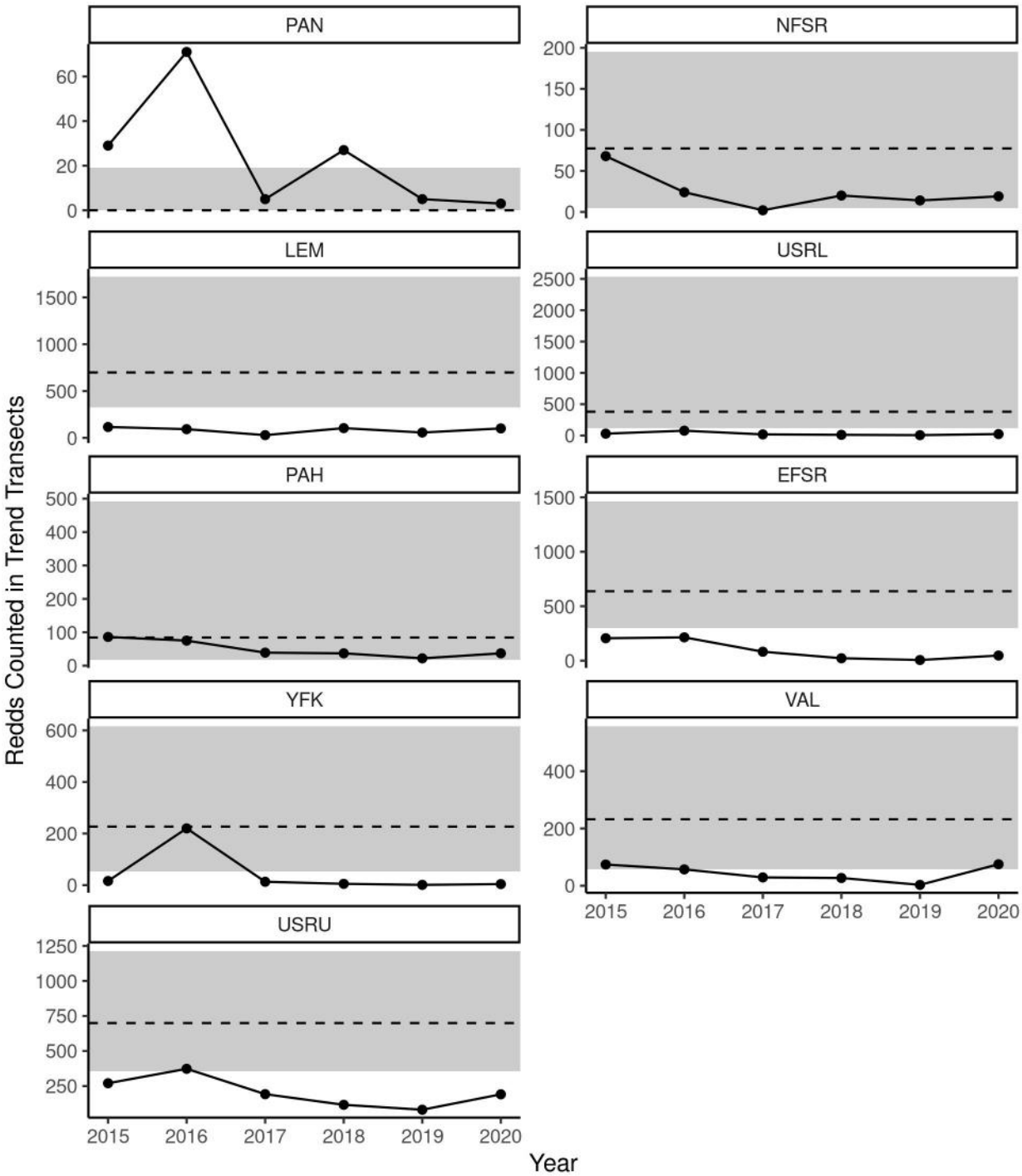

Figure 1-4. Number of spring-summer Chinook Salmon redds counted in index transects of the Upper Salmon River populations during the recent era, 2015-2020. Shaded area represents the pre-dam era range, and dashed reference line represents the pre-dam era geometric mean. No shading or dashed line represents lack of pre-dam era data. Note different y-axis scales.

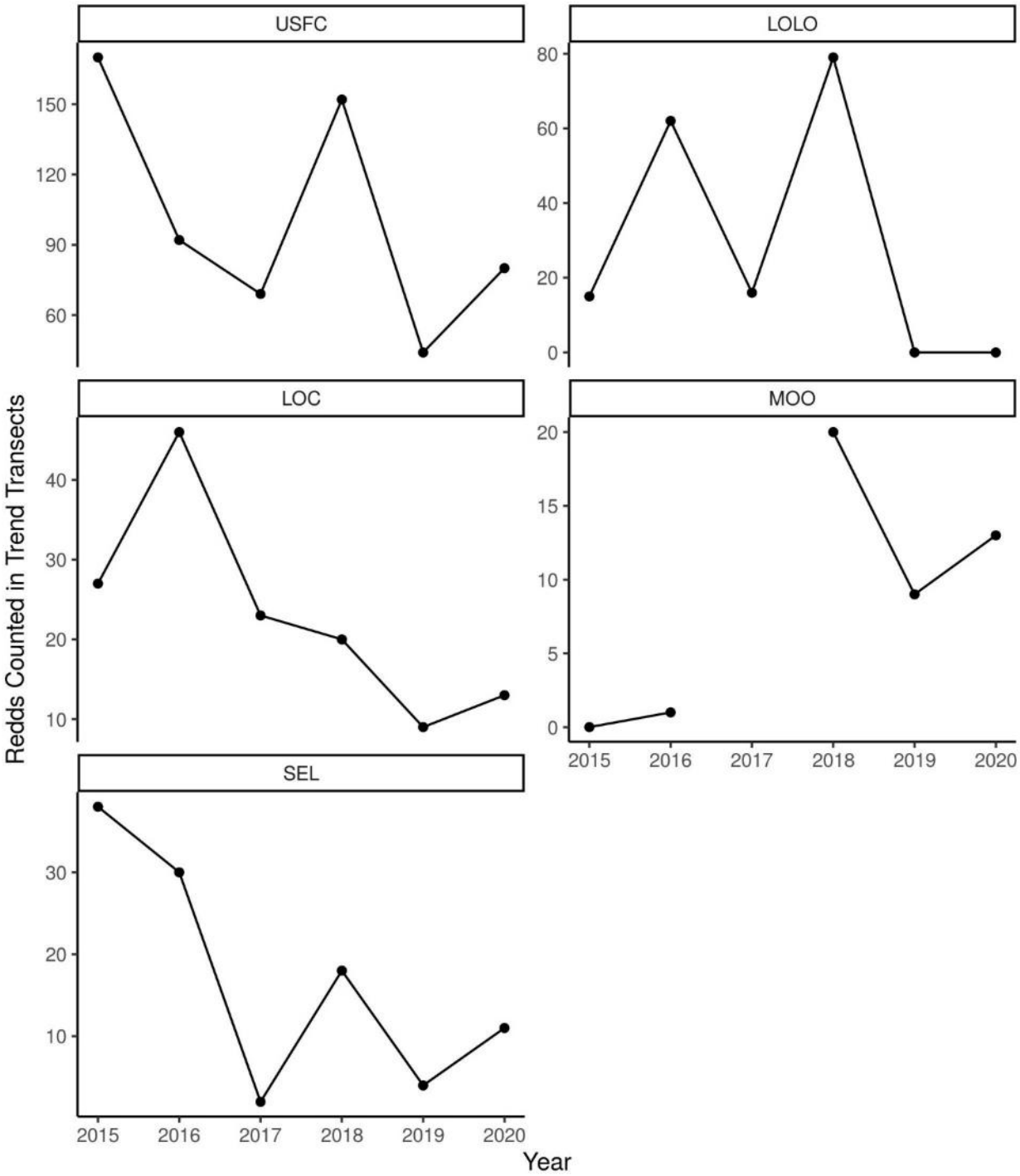

Figure 1-5. Number of spring-summer Chinook Salmon redds counted in index transects of the Clearwater River basin populations during the recent era, 2015-2020.

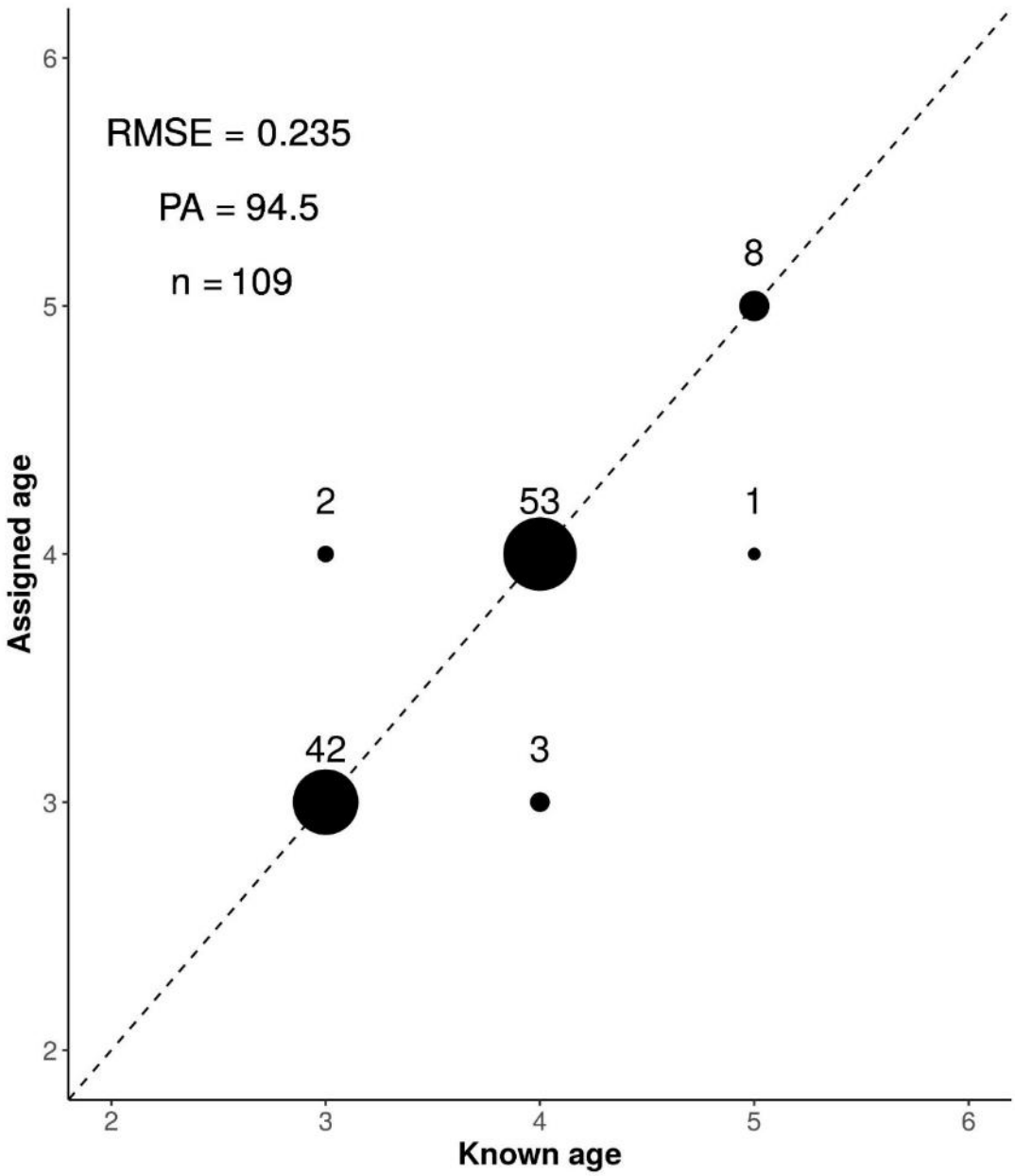

Figure 1-6. Age bias plot depicting the relationship between ages assigned to spring-summer Chinook Salmon using fin rays and their corresponding known ages as determined by PIT tags and CWTs. All samples were collected in 2020. RMSE = root mean squared error, PA = percent agreement, and n = the number of known-age fish.

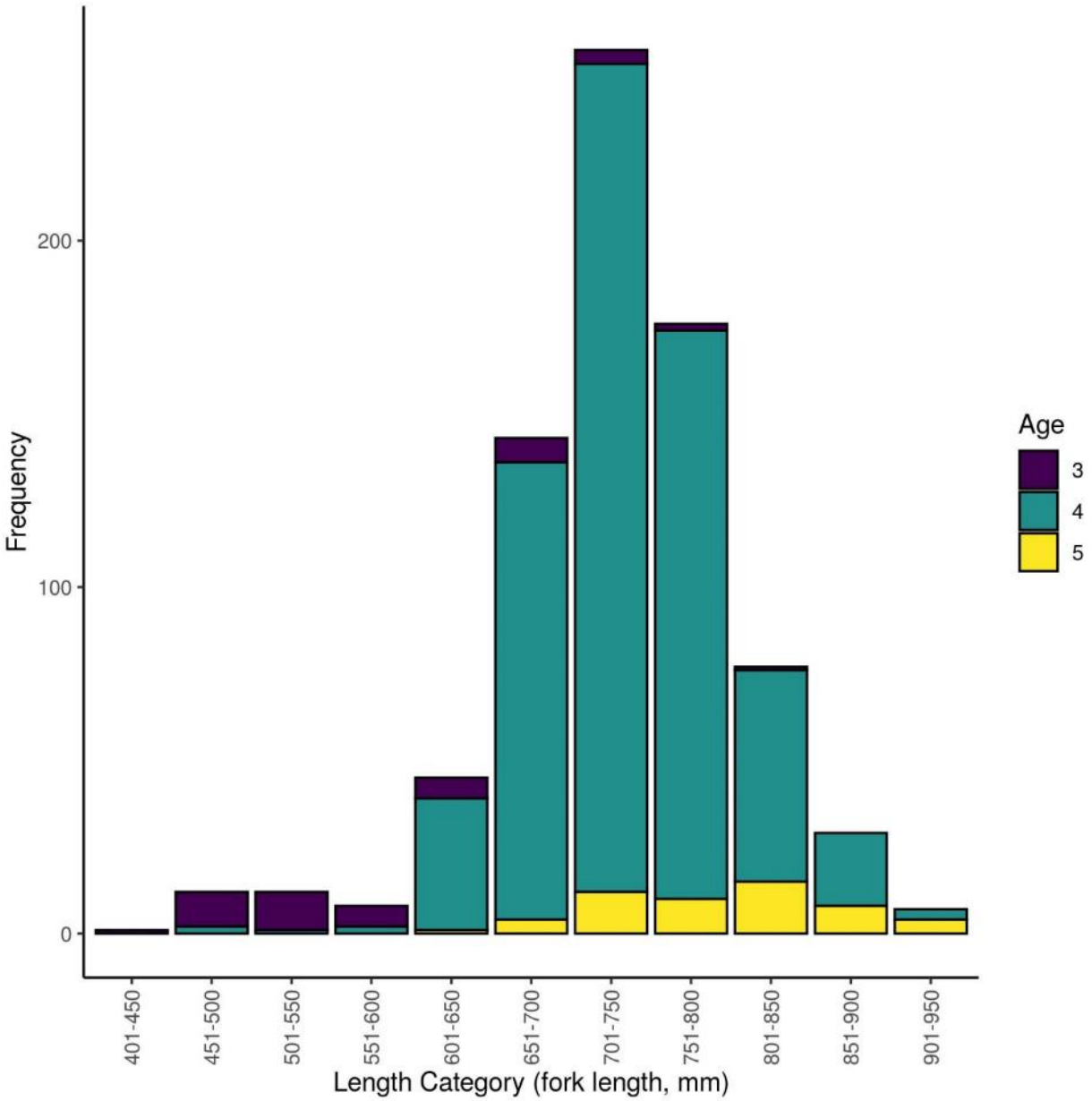

Figure 1-7. Length frequency distribution stacked by age class for natural-origin spring-summer Chinook Salmon carcasses collected in Idaho during 2020 (n = 765).

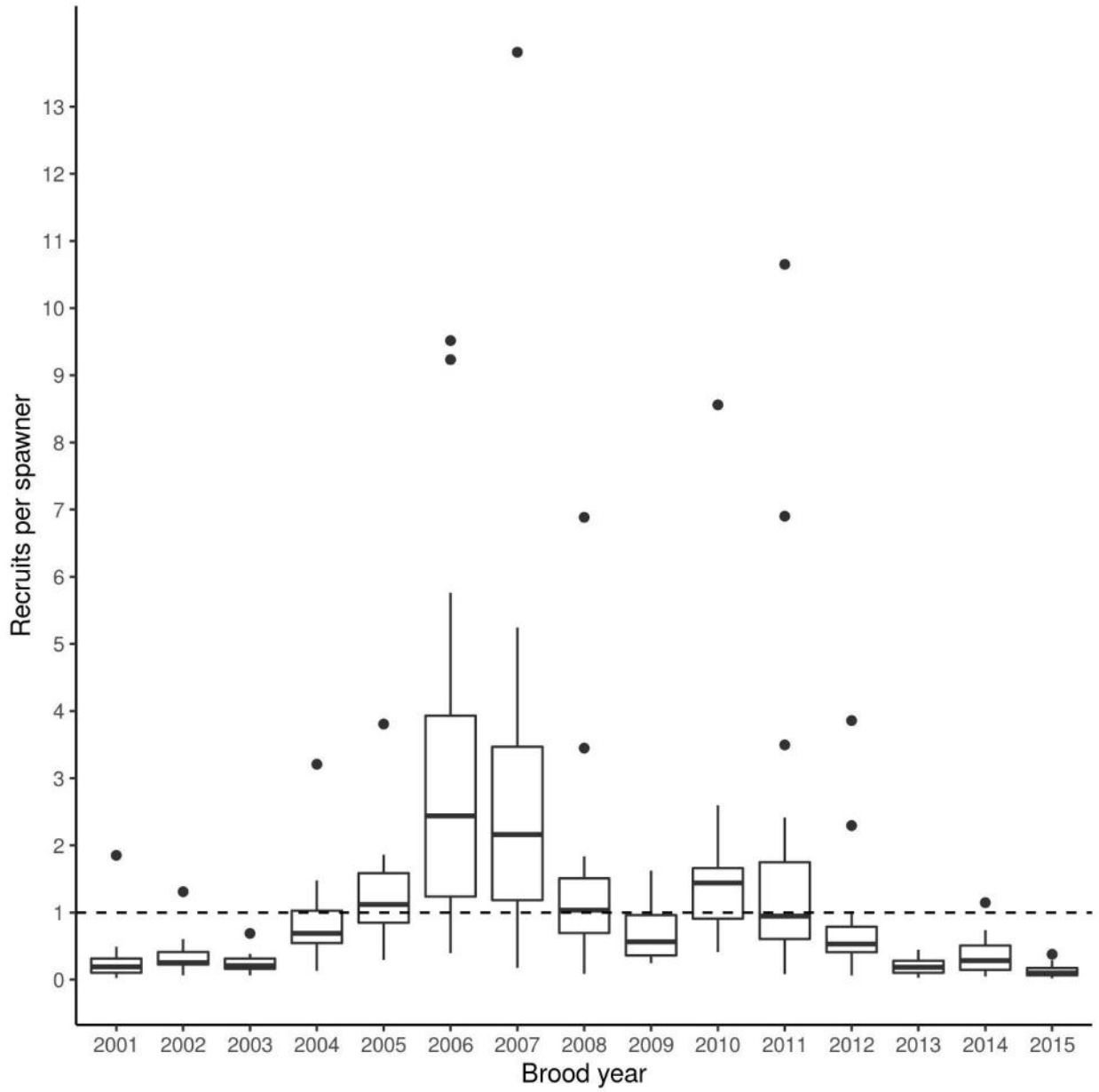

Figure 1-8. Box and whisker plot of productivity (natural-origin returned redds per spawned redd) estimates for 19 spring-summer Chinook Salmon populations sampled in Idaho over brood years 2001-2015. Select populations in some years were omitted due to incomplete data (see Figures 1-11 to 1-13). Dashed line represents 1:1 replacement.

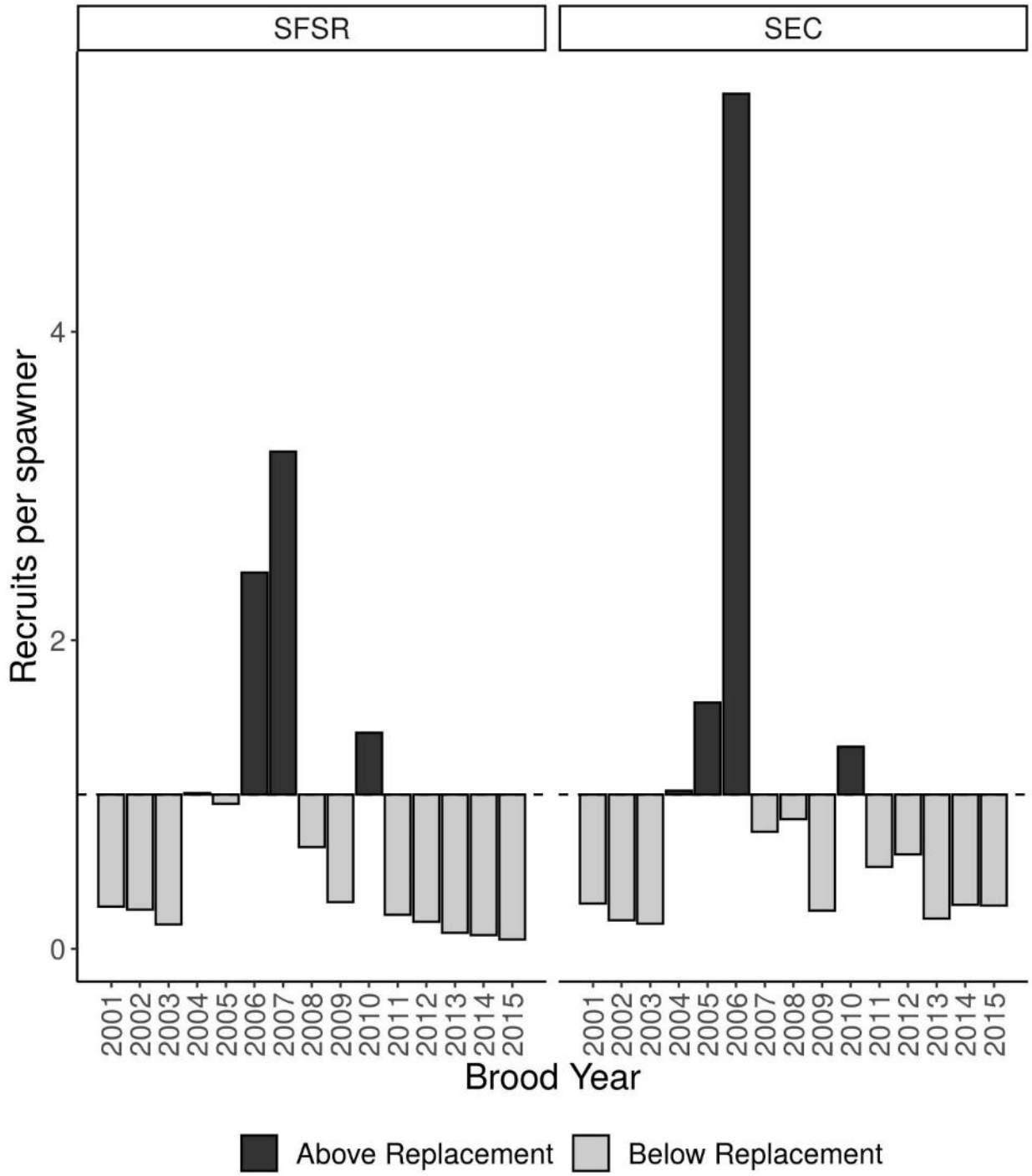

Figure 1-9. Productivity (natural-origin returned redds per spawned redd) of all South Fork Salmon River spring-summer Chinook Salmon populations, except Little Salmon River and East Fork South Fork Salmon River, over brood years 2001-2015. Dashed line represents 1:1 replacement.

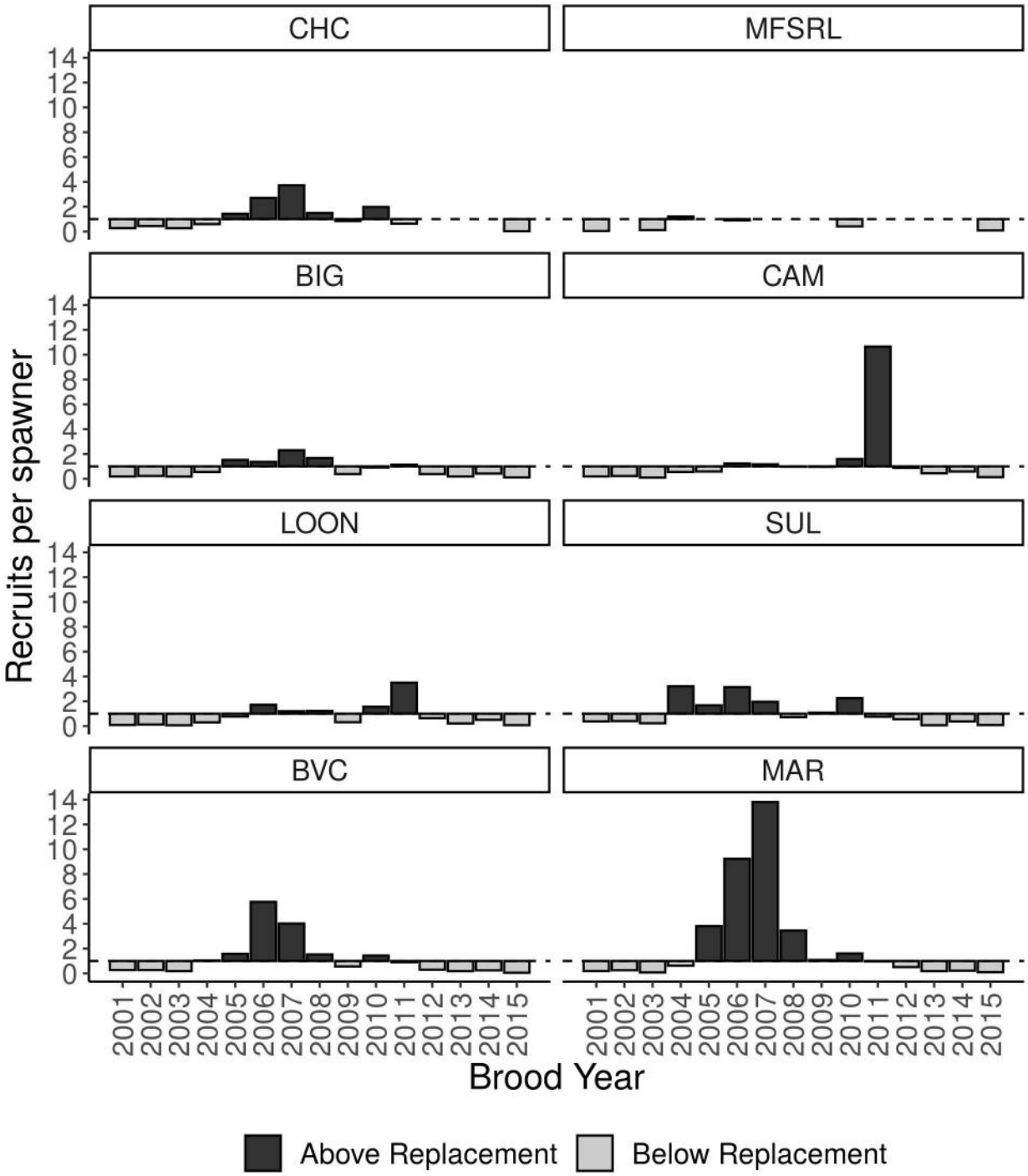

Figure 1-10. Productivity (natural-origin returned redds per spawned redd) of all Middle Fork Salmon River spring-summer Chinook Salmon populations over brood years 2001-2015. Select brood years were omitted due to incomplete data. Dashed line represents 1:1 replacement.

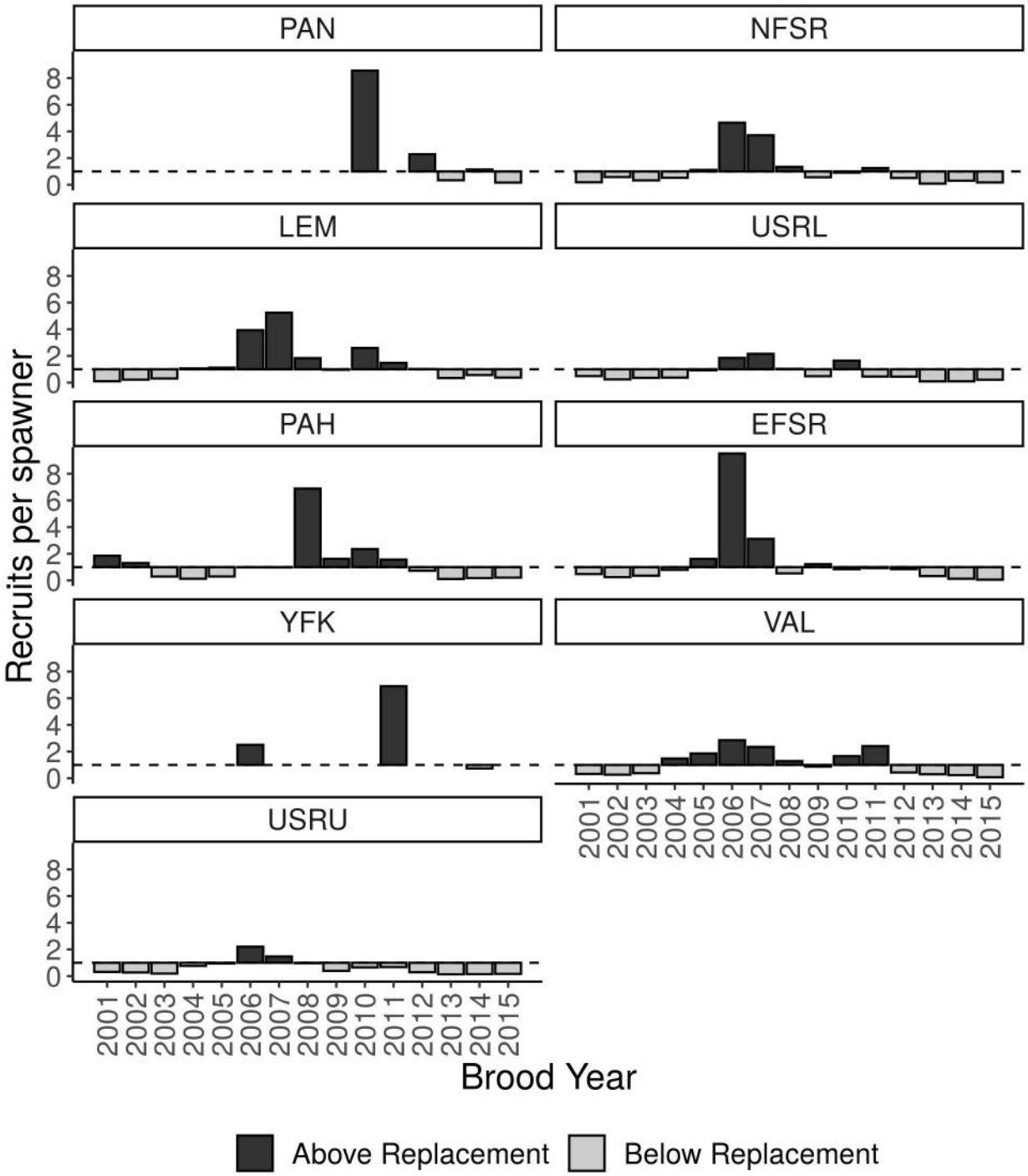

Figure 1-11. Productivity (natural-origin returned redds per spawned redd) of all Upper Salmon River spring-summer Chinook Salmon populations over brood years 2001-2015. Select brood years were omitted due to incomplete data. Dashed line represents 1:1 replacement.

CHAPTER 2. DISTRIBUTION OF CHINOOK SALMON REDDS IN THE MIDDLE FORK SALMON RIVER BASIN, IDAHO

ABSTRACT

Intensive monitoring of redd distribution has been conducted in the Middle Fork Salmon River basin since 1995 to better understand spawning distribution of Chinook Salmon *Oncorhynchus tshawytscha*. In 2020, approximately 752 km of Chinook Salmon spawning habitat was surveyed for redds by air and ground, and a total of 467 redds were identified. These surveys cover approximately 260 km of Chinook Salmon Spawning that is not included in IDFG index transects. Basinwide redd counts increased from 2019 but were still well below the 1995-2019 average.

Authors:

Cynthia I. Nau
Fisheries Biologist

Eli A. Felts
Fisheries Biologist

Bruce Barnett
Fisheries Data Coordinator

Conor McClure
Fisheries Biologist

INTRODUCTION

Snake River spring-summer Chinook Salmon *Oncorhynchus tshawytscha* have been listed as threatened under the Endangered Species Act (ESA) since 1992 (Federal Register notice 57FR14653). Monitoring strategies have been designed to document trends in abundance, productivity, spatial structure, and diversity, and relating those metrics to viability criteria (ICBTRT 2007). Viability is assessed at the population scale but must also be considered at a broader spatial scale. The long-term viability of Chinook Salmon on a broad scale such as an ESU is thought to be dependent on large-scale interactions among individual populations.

The Middle Fork Salmon River (MFSR) basin is an ideal area to study the persistence and spatial dynamics of Chinook Salmon for several reasons. No hatchery releases have occurred in the MFSR, meaning Chinook Salmon stocks are wild and indigenous (IDFG 2019). Most of the basin is located within the Frank Church River of No Return Wilderness, which has limited anthropogenic habitat degradation (Thurow 2017). Finally, the MFSR basin consists of approximately 800 km of Chinook Salmon spawning habitat spread across the main stem and ten tributary basins which have consistently supported spawning in recent decades (Thurow 2017). Thus, the MFSR basin represents a large, complex network of relatively unaltered Chinook Salmon spawning habitat occupied by wild, indigenous stocks.

Intensive monitoring in the MFSR has been conducted since 1995 to better understand persistence and spatial dynamics of Chinook Salmon (Thurow 2017). This monitoring effort was designed to investigate the influence of habitat area, quality, and configuration on the distribution, pattern, and persistence of Chinook Salmon (Thurow 2017). In the late 1990s and early 2000s Chinook Salmon abundance in the MFSR increased and spawners expanded into previously unoccupied portions of the basin, but the majority of redds remained clustered in a limited area of the basin (Isaak and Thurow 2006).

The objective of this chapter is to summarize 2020 surveys in the MFSR designed to describe factors influencing the spatial distribution and persistence of wild-origin Chinook Salmon. Survey methods and study sites were consistent with those first implemented by the Rocky Mountain Research Station in 1995. The specific objectives of this study are to: 1) monitor Chinook Salmon distribution and abundance by mapping the annual distribution of Chinook Salmon redds across the entire Middle Fork Salmon River basin, 2) assess spatial and temporal colonization dynamics of Chinook Salmon, 3) describe both individual and population level Chinook Salmon genetic variation, and 4) evaluate methods for measuring Chinook Salmon dispersal for describing salmon life history patterns. This work includes 260 km of Chinook Salmon spawning habitat beyond what is sampled for index surveys.

METHODS

Study Design

All tributaries that were known to historically support Chinook Salmon spawning were selected to be surveyed. Determination of historical and current occurrence was made by reviewing past redd surveys, anecdotal accounts of spawning activities, interviewing biologists familiar with the MFSR, and reviewing records of juvenile Chinook Salmon occurrence (Isaak and Thurow 2006). Three tributaries (Sheep Creek, Wilson Creek, and Little Loon Creek) that had previously been surveyed as part of basinwide redd counts in the MFSR, were not surveyed in 2020. Zero redds have been observed in Sheep and Wilson creeks since basinwide redd counts

began in 1995 (Thurow 2018). Little Loon Creek was added to basinwide redd counts in 2016, and zero redds have been observed in 2 years of surveys (Thurow 2017). We are unaware of any historical records of Chinook Salmon redds in Little Loon Creek. These three streams are assumed to not currently support Chinook Salmon spawning but will be surveyed when adult escapements above Lower Granite Dam exceed 30,000 natural-origin fish to monitor for recolonization. Surveys were targeted to occur between September 5-12, which coincides with the end of the spawning period while redds are still visible (Thurow 2010).

Data Collection

Surveys were conducted by walking, flying, or rafting along designated stream sections and examining the streambed for redds. Aerial surveys were conducted from a helicopter between 0930 and 1800 hours to increase the likelihood of direct overhead sunlight (Copeland et al. 2019). Airspeeds ranged approximately 10-20 knots and surveys were suspended if the pilot was unable to maintain these airspeeds. Altitude ranged 15-50 m above ground level. Two trained observers examined the streambed for redds. All redds were georeferenced using GPS. The primary observer, located in the front seat, marked locations using a Garmin Rino 750 handheld GPS unit, and the secondary observer, located in the back seat, marked locations using the same model of GPS as a backup. In 2020 flights occurred from September 7-11.

Raft surveys were conducted by USFS personnel on the main stem Middle Fork Salmon River from Boundary Creek to the confluence with the Salmon River every other week from early August until late September. Because of the COVID-19 pandemic, no IDFG staff accompanied USFS personnel during the raft surveys. Two rafts floated the river in tandem, one on river right and one on river left. The bow of each raft was outfitted with an elevated observation platform, and the platform on each raft was occupied by a trained observer for the duration of the float. Whenever observers spotted likely spawning habitat they instructed the oarsman to approach it and float by as slowly as possible so it could be examined for redds. When a redd was spotted, the oarsman landed the raft at the nearest safe point. Once landed, the observer waded back to the redd and marked it using handheld GPS (Garmin Rino 750 or Garmin Rino 650). Signs and flagging were then installed to protect the redd from disturbance by other rafters. When side channels or other river morphology features made the raft survey method impractical both trained observers got off the rafts and walked those areas. The number of redds reported is the sum of all raft survey passes.

Ground surveys consisted of either multiple pass surveys or single pass surveys targeted to occur from September 5-12, which coincides with the end of the spawning period while redds are still visible (Thurow 2010). Multiple pass surveys were used for reaches where IDFG index counts occur during the peak of spawning and in populations that are intensively surveyed for fish-in, fish-out monitoring. For these reaches, additional passes were made after the peak count such that a final pass occurred at the end of the spawning period (Copeland et al. 2019). During ground and raft surveys, observers examined the streambed and marked redds using handheld GPS (Garmin Rino 750 or Garmin Rino 650). On each pass of multiple pass surveys, newly observed redds were flagged and assigned a unique number to avoid double counting. Flagging was removed on the final pass.

RESULTS

In 2020 a total of 467 Chinook Salmon redds were identified across 751.7 km of stream surveyed in the MFSR basin (Table 2-1, Figure 2-1). Aerial surveys encompassed 50% of the

surveyed area. Multiple pass ground counts occurred at all IDFG index transects in the Bear Valley Creek and Sulphur Creek, and covered all potential spawning habitat upstream of the rotary screw trap in Marsh Creek. All other aerial, raft, and ground counts consisted of a single pass at the end of the spawning period.

Redds were observed for all surveyed streams within the Middle Fork Salmon River basin. Redd counts were highly variable among streams surveys ranging from a low of four observed in the Middle Fork Salmon River below Indian Creek population to a high of 183 in Marsh Creek. The 2020 basinwide redd count was below the 1995-2019 average (Figure 2-2) with the majority of streams surveyed being below the 1995-2019 average. Only Marsh Creek and the Middle Fork Salmon River below Indian Creek were above that average in redds observed (Figure 2-3). The majority of redds (83.7%) were in three high elevation streams (Bear Valley, Marsh, and Sulphur creeks) at the upper extent of the MFSR drainage (Figure 2-1).

DISCUSSION

The number of redds counted in 2020 across the MFSR basin increased from 2019 but was still well below the 1995-2019 average of 746 redds. Spawner abundance, along with patch size and connectivity of spawning habitat, influence distribution of Chinook Salmon redds in the MFSR (Isaak and Thurow 2006; Isaak et al. 2007). When spawner abundance is low, most redds are found in areas with large patches of spawning habitat and high connectivity among those patches (Isaak and Thurow 2006). The distribution of redds in 2020 was consistent with this observation, as 83.7% of redds were found in the upper Middle Fork basin, where large connected patches of spawning habitat occur within Bear Valley Creek, Marsh Creek, and Sulphur Creek drainages.

The data collected in this study add another year to a rich data set which has been used in studies of temporal change in population synchrony (Isaak et al. 2003), sampling design for monitoring Chinook Salmon populations (Courbois et al. 2008), temporal variation in redd distribution (Isaak and Thurow 2006), factors affecting natal homing (Neville et al. 2006), genetic structure of Chinook Salmon (Neville et al. 2006), factors affecting use of spawning patches (Isaak et al. 2007), and effects of climate change and fire regime on redd distribution (Jacobs et al. 2021). Analysis of the spatial and temporal variability of Chinook Salmon in the MFSR basin will continue as this data set continues to grow.

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TABLES

Table 2-1. Stream length surveyed and Chinook Salmon total redd counts in the Middle Fork Salmon River, Idaho, 2020.

Population	Distance surveyed (km)	Redds
MFSRL	107.5	4
BIG[a]	120.8	32
CAM	74.7	9
LOON	85.6	22
MFSRU	180.8	14
SUL	23.5	24
BVC[b]	89.7	179
MAR	61.3	183
Total	**751.7**	**467**

[a] Staff from Nez Perce Tribe, U.S. Forest Service, and Idaho Department of Fish and Game collected and provided information.

[b] Staff from the Shoshone-Bannock Tribes, U.S. Forest Service, and Idaho Department of Fish and Game collected and provided information.

FIGURES

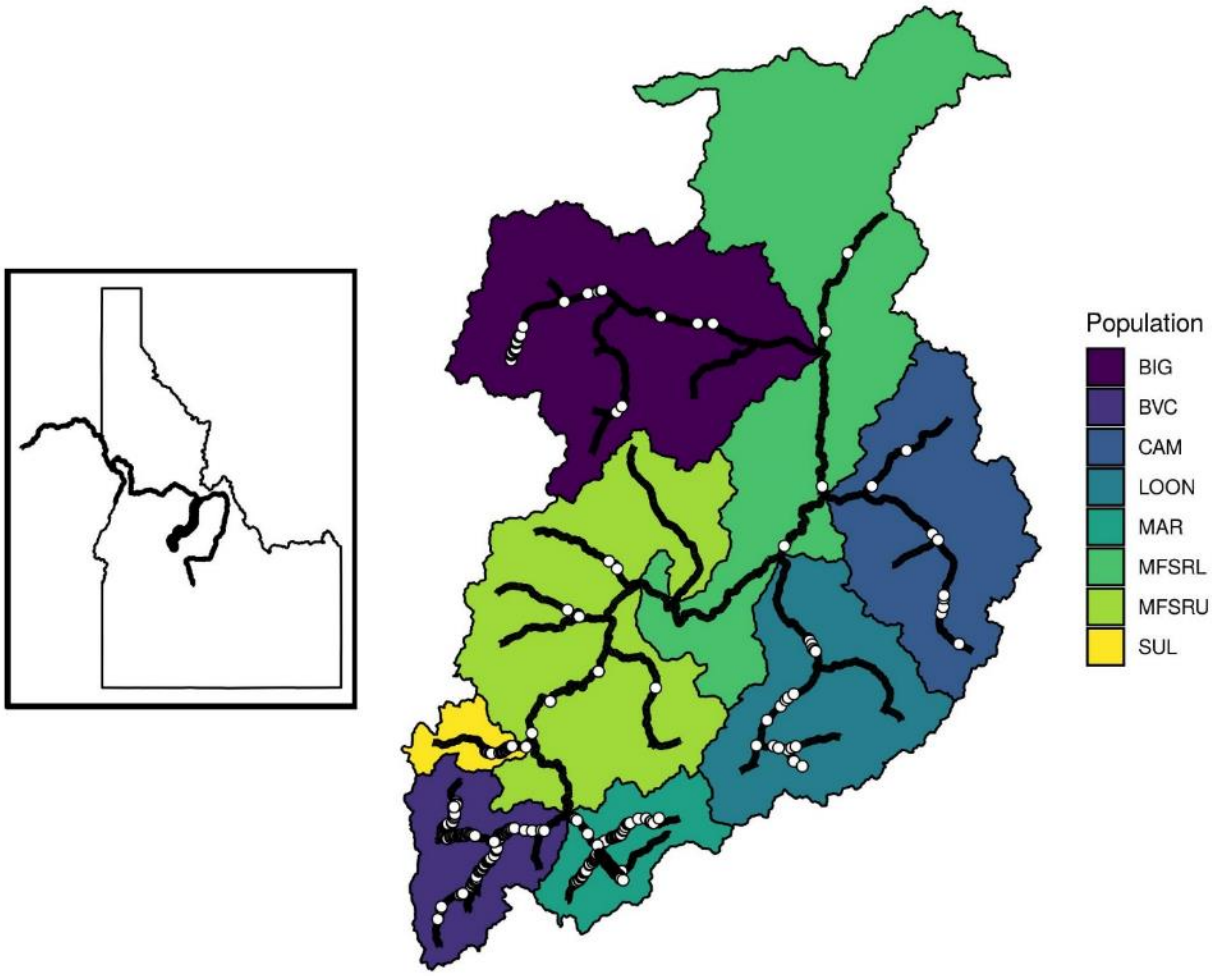

Figure 2-1. Chinook Salmon redds (white circles; N = 467) observed in independent populations of the Middle Fork Salmon River basin, Idaho, 2020. Bold line indicates main stem Middle Fork Salmon River.

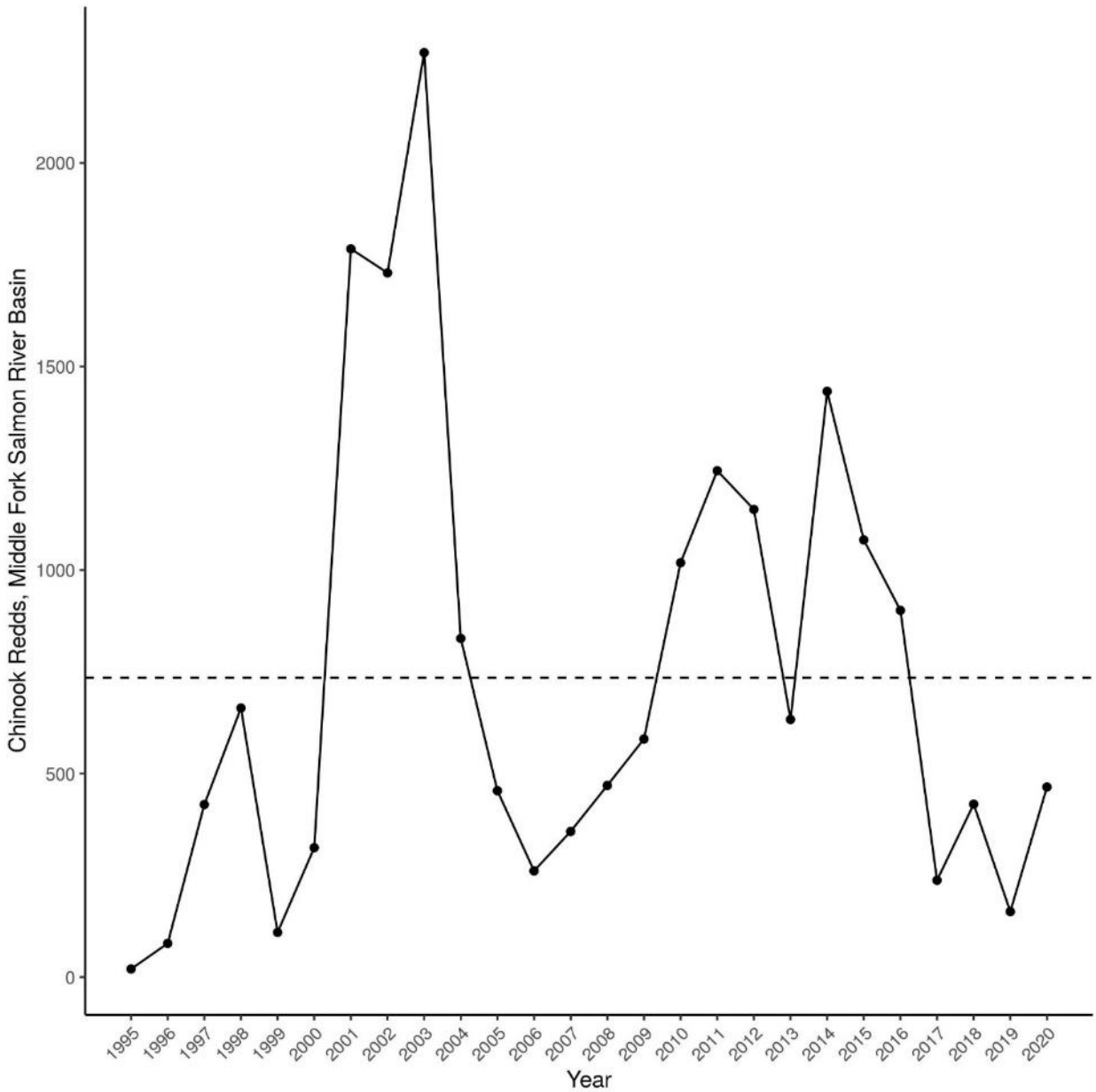

Figure 2-2. Total redd counts in the Middle Fork Salmon River basin, Idaho, 1995-2020. Dashed line represents the average redd abundance for 1995-2019.

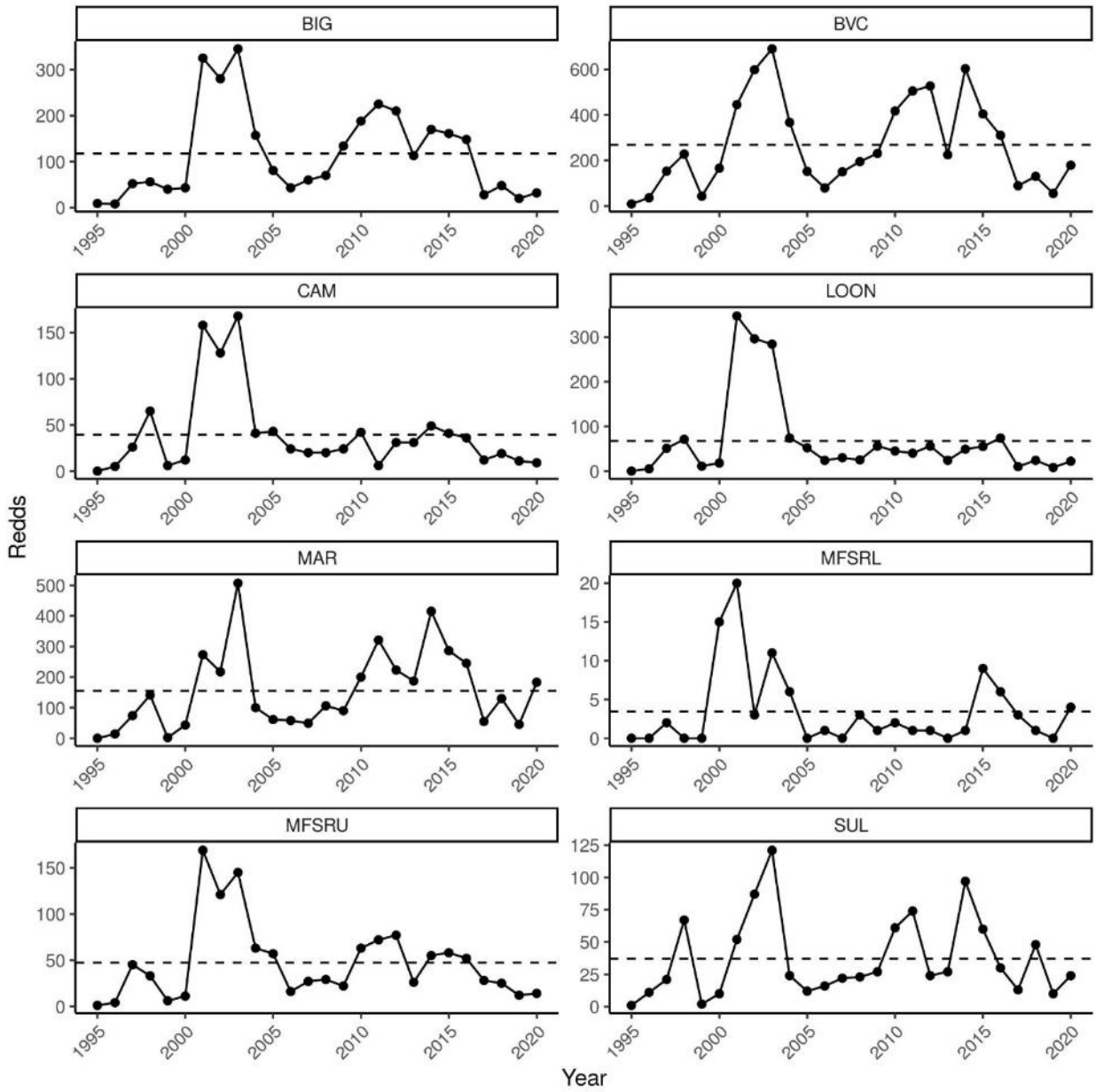

Figure 2-3. Total redd counts in independent populations of the Middle Fork Salmon River basin, Idaho, 1995-2020. Dashed line represents the average for 1995-2019. Note differing scales on y-axes.

APPENDICES

Appendix A. Comparison of GPS units used to georeferenced Chinook redds observed on aerial surveys

Eli A. Felts, IDFG, Nampa Fisheries Research

FINAL January 25, 2021

INTRODUCTION

Intensive Chinook redd counts have been conducted annually in the Middle Fork Salmon River basin since 1995 by staff from the Rocky Mountain Research Station (RMRS). A large portion of the survey is conducted from low-flying helicopter. The purpose of these surveys is to quantify basinwide redd abundance and to investigate the spatial and temporal patterns of redd distribution. Because of the interest in spatial patterns, the previous project leader used a highly accurate global positioning systems for georeferencing redds.

At the time when the project was transferred to IDFG, waypoints were recorded using a Trimble Zephyr Rover GNSS (Global Navigation Satellite System) antenna that relayed a signal to a Trimble Pathfinder ProXH receiver. The data and surveys were managed from a Juniper Systems TK6000 handheld computer using a program called TerraSync. Upon completion of surveys data were downloaded from the handheld computer using Trimble PathFinder software, where waypoints underwent differential corrections using base stations to further increase the accuracy of waypoints. The expected accuracy of waypoints captured using these tools is difficult to determine because a variety of conditions influence accuracy, but under ideal conditions it should be on the order of centimeters. Throughout this document I will refer to this system as the Trimble unit.

IDFG uses handheld GPS to georeference redds observed during redd counts. Currently, we use Garmin Rino 755t handheld units which uses GPS and GLONASS (Global Navigation Satellite System). Garmin GPS receivers are accurate to within 15 meters 95% of the time, and our units which incorporate GLONASS satellites improve accuracy. I expect that accuracy under ideal conditions should be on the order of meters. As with any GPS technology, including survey-grade units like the Trimble, accuracy is variable and depends on factors such as satellite reception and atmospheric conditions. Throughout this document I will refer to this system as the Garmin unit.

The question has been raised: are waypoints collected with the Garmin unit comparable to those collected with the Trimble? The simple answer prior to any analysis is “yes”. The only context in which these waypoints may not be considered comparable would be for spatial analysis that is conducted on a very fine scale. The error introduced by using the Garmin unit would have to exceed the desired scale of analysis. However, in every current application, and in the many peer-reviewed publications that have come from this project, there would be no issue with using waypoints from the two interchangeably. Spatial analysis of redd distributions is often looked at on broad scales such as populations, streams, or large patches (200 m to 400 m) within streams. The finest scale I’m aware of these data being used on is 200 m.

Likely the biggest limitation in recording accurate waypoint locations from a helicopter is that the GPS receiver is not located at the point of interest. No matter how good the receiver and correction techniques, the point being recorded is always going to be where the helicopter is at that moment, and not where the redd is. In aerial surveys, observers are always a considerable

distance away from their point of interest. For example, during redd counts the helicopter is typically offset slightly from the stream to allow observers a better view, and the helicopter is moving. By contrast, during ground counts observers stop at redds and stand in the stream as close to the redd as possible without disturbing the structure. Post-processing techniques like differential corrections give a more accurate picture of where the helicopter was when the waypoint was recorded, not where the redd actually was.

Data collected during 2018 and 2020 afforded the opportunity to compare results generated by the Trimble and Garmin units. Two types of comparisons were made with the objectives of quantifying the accuracy of the Garmin unit in relation to the Trimble, and to quantify the impact of aerial survey methodology on accuracy of both units.

METHODS

Accuracy of the Garmin unit was assessed by recording waypoints with both units while in a stationary position on the ground. The differentially corrected waypoints from the Trimble unit were assumed to be more accurate so these outputs were treated as “truth” against which to compare positions taken with the Garmin unit. In practice, it may not be true that the Trimble unit is more accurate, but it is an acceptable way to frame this analysis. These comparisons occurred at redds recorded on Marsh Creek during 2020. Accuracy of waypoints taken with the Garmin unit was quantified as the distance from the Garmin point to the Trimble point representing the same redd.

The impact of aerial survey methodology on accuracy was assessed by recording waypoints from both the ground and the air. The ground positions were treated as “truth” against which to compare positions taken from the air. These comparisons occurred at redds recorded on Pistol Creek in 2018, and at Marsh Creek in 2020. Aerial positions used the Trimble unit in 2018 and the Garmin unit in 2020. Accuracy of waypoints taken from the air was quantified as the distance from the aerial point to the ground point representing the same redd.

Two-dimensional Euclidean distances between points were measured using the sf package (Pebesma 2018) in program R (R Core Team 2020).

RESULTS

The distance between ground-based waypoints recorded by both the Garmin unit and the Trimble unit on Marsh creek in 2020 (n = 57) ranged from 0.02 m to 3.0 m and averaged 1.05 meters.

The distance between aerial waypoints and ground waypoints on Pistol Creek in 2018 and Marsh Creek in 2020 (n = 9), ranged from 23 m to 93 m and averaged 54.8 m. The distances for the 2018 aerial survey, which used the Trimble unit, ranged from 25 m to 93 m. The distances for the 2020 aerial survey, which used the Garmin unit, ranged from 23 m to 64 m.

DISCUSSION

Waypoints taken on the ground with the Garmin unit were very close to those taken with the Trimble. As such, either the Garmin or Trimble could be used to generate waypoints for fine-

scale analysis. The length of spring-summer Chinook Salmon redds in Idaho ranges from 1.8 m to 5.3 m, so the average accuracy of the Garmin unit (1.05 m) was smaller than the average redd. This means that more variability would be introduced by an observer taking a waypoint from one end of a redd versus the other end than would be introduced by using the Garmin unit instead of the Trimble.

The error introduced by aerial methodology was an order of magnitude greater than that introduced by using the Garmin unit. Although sample sizes were small, there is no evidence that error caused by aerial methodology is any different between the Garmin and Trimble units, and there's no reason to think there would be. This error occurs because observers are in a different physical location than the redd when they record the waypoint. This is certainly true at the exact moment when an observer recognizes a redd, but by the time they press the button to record a waypoint they will be even further away. An examination of aerial waypoint locations in relation ground waypoint locations makes this clear. In Appendix Figure A-1, the helicopter was traveling downstream, which is from left to right in this image. The observer correctly identified the redd, but by the time it was entered into the Trimble unit the helicopter was some distance downstream. This particular waypoint was 93 m away from the actual redd location. The waypoint is also offset from the stream, as is typical to give the observer a good view looking out the side.

An examination of waypoints collected using aerial methods in the Middle Fork basin since 1995 confirms that this type of error is quite common throughout the data set. Appendix Figure A-2 shows an example in Loon Creek. This area of Loon Creek represents a best-case scenario for getting waypoints from a helicopter. The valley is wide and there are no tall trees, and the area is known to commonly have redds. As such, the pilot typically flies relatively low and slow and has the ability to slow almost to a hover when a redd is observed. This means that the observer is close to the actual redd location and often barely moving when trying to record a waypoint. Even under those conditions we can see that 14 of the 21 redds shown in this photo are not even in the stream, likely because the helicopter was still slightly offset to give a better view.

Other areas present a more challenging scenario for collecting accurate redd waypoints. Appendix Figure A-3 shows an example in Rapid River. This area of Rapid River is narrow and has many tall trees, so the pilot has little ability to slow down or change altitude even when observers have identified a redd. As such, the observer is typically moving at a relatively high rate of speed and is a fair distance from the redd by the time it is recorded in the GPS. In this image only 3 of the 23 redds appear to be in the stream.

There are potential alternative explanations for redds not aligning with the stream location in aerial photographs. The stream channel can wander, and one could argue that the various spatial projections may cause some error. However, the above examples were selected specifically because they are in areas where the stream channel hasn't moved recently. Additionally, when ground-based waypoints are plotted on top of aerial imagery there appears to be no error in the projection of the imagery as the vast majority of waypoints appear in the stream (Appendix Figure A-4).

The error demonstrated here does not invalidate the data collected from aerial surveys, but it does call attention to limitations regarding fine-scale spatial analysis. The factors that influence the error in aerial waypoints are not consistent so it is difficult to make a quantitative recommendation for the finest scale at which to conduct spatial analysis using these data. A conservative approach would be to use the maximum known error as a guideline. In any event, researchers should give careful thought to the potential impacts of this error in spatial analysis.

Although accuracy is important, there are other features of GPS units which affect data quality. Technical features include how quickly the unit gets a position fix, and how often the position is lost. The Garmin units are much quicker to get a fix and rarely lose a position fix once it's acquired. The Trimble unit is very slow to get a fix, and often loses its position. These issues were so bad that the previous project lead recorded audio files of flights and called out landmarks as he passed them so that missed waypoints could be interpolated. We have used the Garmin units on these flights since 2017, either as a backup to the Trimble or as the primary unit, and we have not missed a single waypoint because of lost satellites.

In addition to technical aspects of the GPS unit, the user interface also affects data quality. I have observed several aspects of the Trimble computer (TK6000) user interface that have a negative effect on data quality. This unit uses a program within the Windows operating system to record tracks and waypoints from the GPS receiver. There is no display of the user's position or any sort of map similar to the standard view on a handheld GPS. When a user records a waypoint, or thinks that they did, there's no quick way to check that the point was actually recorded and saved. This is in contrast to the Garmin unit which displays a map with the current position and any waypoints stored on the unit. There have been a few instances where I thought I recorded a waypoint on the Garmin, then checked the map and noticed that it wasn't saved. In those situations it was easy to have the pilot circle back to the redd so I could get the waypoint. This scenario also happens with the Trimble but there is no way to know in real time so missed waypoints have to be interpolated later based on the tape recorder files.

The difference in accuracy between the Garmin and Trimble units is trivial when compared to the error associated with aerial surveys in general. The error from aerial surveys is always going to be present, so the choice of which GPS unit to use comes down to differences in other factors such as time to first fix, maintenance of position fix, and user interface. As discussed, these factors can also influence overall accuracy because they affect the incidence of missed waypoints that have to be interpolated from audio recordings. The Garmin unit is far superior to the Trimble when considering these factors. I recommend that IDFG uses the Garmin unit for aerial surveys moving forward. I also recommend that both observers record waypoints on a Garmin unit. In 2019 and 2020 the majority of our flights had 2 observers who each recorded waypoints on a Garmin unit, and we did not have to interpolate a single waypoint from those flights.

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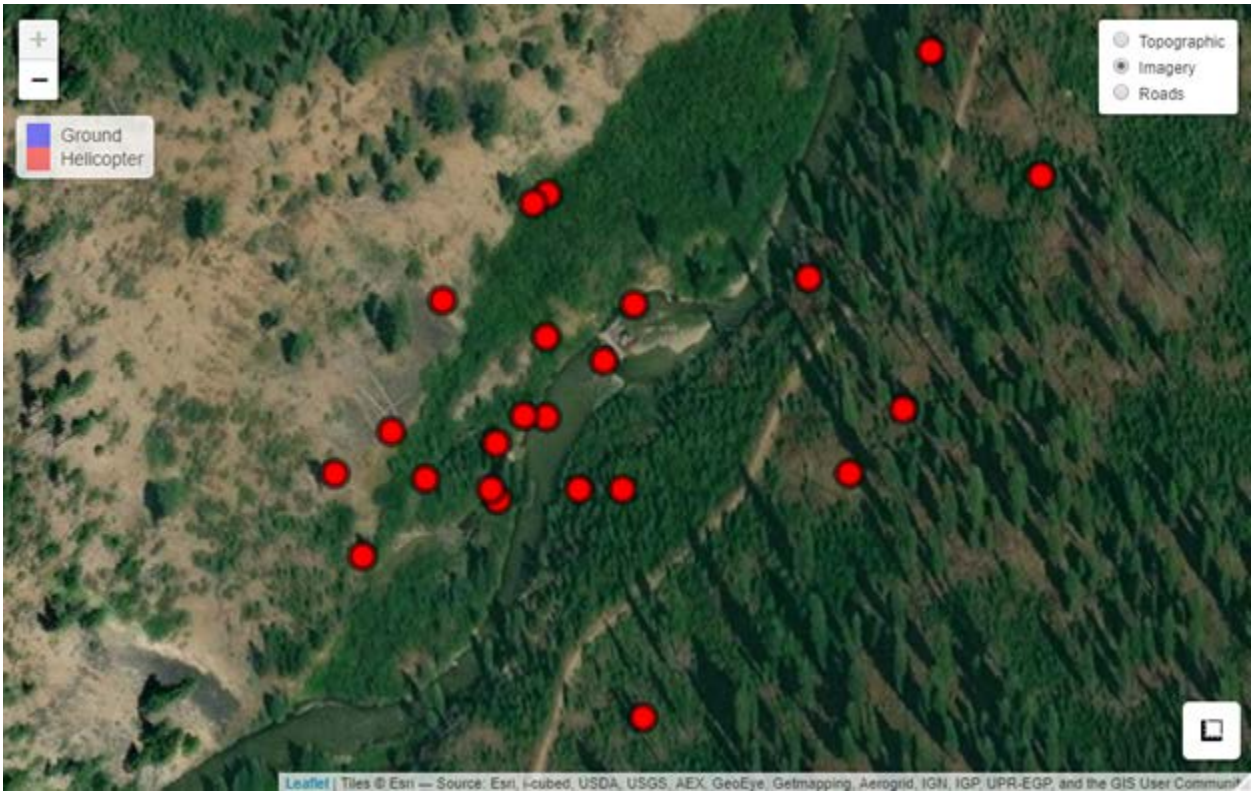
Appendix Figure A-1. Example of a comparison between a redd waypoint taken from the ground with the Garmin unit (blue point) and from a moving helicopter with the Trimble unit (red point) on Pistol Creek in 2018.

Appendix Figure A-2. Example of redd waypoint locations from a moving helicopter with a Trimble unit (red points) on Loon Creek, 1995-2018.



Appendix Figure A-3. Example of red waypoint locations from a moving helicopter with a Trimble unit (red points) on Rapid River, 1995-2018.

Appendix Figure A-4. Example of redd waypoint locations from the ground with a Garmin unit (blue points) on Marsh Creek, 2020.

Appendix B. Additional information collected on spawning ground surveys and at hatchery weirs in 2020.

Eli A. Felts, Nampa Fisheries Research

INTRODUCTION

Chinook Salmon spawning ground surveys are primarily designed to monitor status and trends in abundance and productivity within and among Idaho populations. However, some additional data are collected in order to monitor more intensively at smaller scales and to address ancillary objectives. These data are not comparable on the broad scale that is the focus of this report. In most cases, these data will eventually be used in completion reports on projects such as habitat effectiveness monitoring and genetic diversity monitoring, or help to improve monitoring methods. The purpose of this appendix is to report the annual collection methods for these data.

METHODS

Multiple Pass Surveys

Multiple pass redd counts were used to estimate total redds within two populations, Marsh Creek and Lemhi River, and one specific transect, NS-16, in the Salmon River upper mainstem above Redfish Lake population. Multiple pass surveys were designed to begin with the start of spawning activity, with subsequent surveys conducted weekly until the end of spawning activity. Each survey followed data collection methods described in Chapter 2 of this report. On each pass, newly observed redds were flagged, assigned a unique number, and georeferenced using GPS units. Flags were removed on the last pass.

Additional Redd Count Surveys

Additional redd surveys were conducted in various streams of the Clearwater River basin to address specific questions regarding spawner abundance, spatial distribution, and spawn timing. Two passes, separated by one to two weeks, were made at each transect. One of the passes corresponded with the target date for a peak count and was considered to be the index count for trend-monitoring purposes.

Weir Passage

Adult Chinook Salmon passage is recorded at IDFG weirs at the Pahsimeroi, Sawtooth, and South Fork Salmon River hatcheries. All fish released above weirs were marked with an opercle punch. Carcass surveys were conducted above weirs. Abundance above the Sawtooth and South Fork Salmon river weirs was estimated using the Chapman modification of the Lincoln-Petersen method (Chapman 1951, Seber 1982):

$$\widehat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1$$

Where M was the number of fish marked at the weir, C was the number of carcasses recovered above the weir, and R was the number of marked carcasses recovered above the weir. Prespawn survival was assessed by examining the spawning stage of carcasses collected on spawning

grounds, and escapement was estimated by directly subtracting observed prespawn mortalities from estimated abundance.

Genetics Samples at Weirs and Traps

All adult Chinook Salmon captured at IDFG weirs or traps had the following data recorded: origin (natural or hatchery), any marks or tags, fork length (mm), and sex. We refer the reader to hatchery reports and to the Fish Inventory System Hatchery Database (FINS; http://www.fishnet.org/) to obtain more specific information. Tissue samples for genetics analysis were collected from all fish released upstream of the weir for natural spawning. Tissue samples were stored on Whatman sheets and delivered to the IDFG Eagle Fish Genetics Laboratory located in Eagle, Idaho.

RESULTS

Multiple Pass Surveys

Surveys in the Marsh Creek population went from the first week of August until the first or second week of September and documented 177 redds (Appendix Table B-1). Surveys in the Lemhi River population went from the last week of August until the last week of September and documented 118 redds. Valley Creek was also surveyed three times from third week of August to the first week of September, 75 redds were observed (Appendix Table B-1). Surveys in transect NS-16 went from the last week of August until the last week of September and documented 75 redds.

Additional Redd Count Surveys

In 2020, additional redd count surveys were conducted in American River and Red River of the Upper South Fork Clearwater River Population. Two passes were conducted at each transect. Staff counted a total of 16 redds in American River and 102 redds in Red River (Appendix Table B-2).

Weir Passage

A total of 157 Chinook Salmon were marked and passed above the Pahsimeroi weir, 37 of which were natural origin (Appendix Table B-3). At the Sawtooth weir, 191 Chinook Salmon were marked and passed, only four of which were of natural origin. At the South Fork Salmon weir, 79 individuals were marked and pass with no fish identified as natural origin. All weirs were found to have an efficiency value of 1.00 for both hatchery and natural origin fish except the Sawtooth weir that had an efficiency value 0.96 for natural origin individuals, resulting in an abundance estimate of 196 instead of the observed count of 187 natural origin Chinook Salmon.

Genetics Samples at Weirs and Traps

A total of 502 tissue samples were collected from Chinook Salmon released at IDFG hatchery and research weirs during 2020 (Appendix Table B-4). Most samples (n = 191) were collected at the Sawtooth weir in the Salmon River. The East Fork Salmon River weir was not operated for Chinook Salmon in 2020 and no samples were collected. Chinook Salmon are incidental catch at the Fish Creek research weir, which is operated for steelhead *Oncorhynchus mykiss*.

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Appendix Table B-1. Multiple-pass redd count census surveys that were conducted for spring-summer Chinook Salmon in Idaho during 2020. Surveys are organized by major population group (MPG).

Population	Waterbody	Date	New redds[a]	Date	New redds[a]	Date	New redds[a]	Date	New redds[a]	Date	New redds[a]	Date	New Redds[a]	Total
					Middle Fork Salmon River MPG									
MAR	Beaver Creek	8/9	9	8/15	10	8/23	10	8/29	6	9/7	2	9/11	0	37
	Banner Creek	8/7	1	8/13	1	8/21	1	-	-	9/6	0	-	-	3
	Cape Horn Creek	8/7	1	8/13	11	8/21	14	8/28	1	9/6	3	9/12	0	30
	Knapp Creek	8/10	0	8/16	2	8/24	3	-	-	9/4	0	-	-	5
	Marsh Creek	8/8	4	8/14	19	8/22	53	8/30	20	9/5	6	9/10	0	102
Total New Redds			**15**		**43**		**81**		**27**		**11**		**0**	**177**
					Upper Salmon River MPG									
LEM	Bear Valley Creek	-	-	8/20	0	8/27	0	-	-	-	-	-	-	0
	Big Springs Creek	-	-	-	-	-	-	-	-	9/10	2	-	-	2
	Big Timber Creek	-	-	-	-	8/28	0	-	-	9/11	0	-	-	0
	Hayden Creek	8/15	3	8/21	1	8/27	16	9/2	10	9/8	3	-	-	33
	Lemhi River	-	-	-	-	-	-	-	-	9/9	71	9/23	12	83
	Little Springs Creek	-	-	-	-	8/24	0	9/3	0	-	-	-	-	0
Total New Redds			**3**		**1**		**16**		**10**		**76**		**12**	**118**
VAL	Valley Creek	8/22	19	-	-	8/29	33	-	-	9/8	23	-	-	75
Total New Redds			**19**				**33**				**23**			**75**
USRU	Redfish Lake Creek upstream to Sawtooth Weir	-	-	8/27	15	9/3	91	9/9	47	9/16	30	9/23	3	186
Total New Redds					**15**		**91**		**47**		**30**		**3**	**186**

[a] Downloaded from the SGS database on 2/26/20.

Appendix Table B-2. Additional redd count surveys that were conducted in the Dry Clearwater MPG for spring-summer Chinook Salmon in Idaho during 2020.

Population	Waterbody	Transect	Date	New redds	Date	New redds	Total redds
USFC	American River	Mouth upstream to Limber Luke Creek	9/9	14	9/22	2	16
	Red River	Mouth upstream to Shissler Bridge	9/5-9/8	74	9/19-9/21	28	102
Total redds				**88**		**30**	**118**

a) Redd counts downloaded from SGS database on 2/26/21

Appendix Table B-3. Data collected for estimating Chinook Salmon abundance above IDFG weirs in 2020. No prespawn mortalities were observed in 2020 at any of the weirs. No estimate was generated for hatchery-origin fish above the South Fork Salmon weir as no hatchery-origin fish were passed over the weir in 2020.

Weir name	Fish marked & passed	Total carcasses recovered	Marked carcasses recovered	Weir efficiency	Abundance estimate
		Natural-origin			
Pahsimeroi	120	7	7	1.00	120
Sawtooth	187	85	82	0.96	196
South Fork Salmon	79	11	11	1.00	79
		Hatchery-origin			
Pahsimeroi	37	6	6	1.00	37
Sawtooth	4	2	2	1.00	4
South Fork Salmon	0	0	0	-	-

Appendix Table B-4. Number of genetic samples collected from adult Chinook Salmon released at IDFG hatchery and research weirs, 2015-2020. NA = not applicable, weir not operated for Chinook Salmon during these years.

Weir name	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Salmon River (Sawtooth)	447	421	305	152	78	191
E. F. Salmon River	NA	NA	NA	NA	NA	NA
Pahsimeroi River	455	399	277	320	92	161
S. F. Salmon River	696	709	389	455	291	110
Rapid River	34	23	30	30	19	22
Hells Canyon Dam	114	29	0	3	1	17
Lochsa River (Powell)	10	23	24	27	0	0
Fish Creek	3	3	3	0	0	1
Red River	36	31	22	15	0	0
Crooked River	70	30	8	13	0	0
Total	**1,865**	**1,668**	**1,058**	**1,015**	**462**	**502**

Appendix C. Evaluation of probabilistic sampling designs for Chinook Salmon redd counts in the lower mainstem Salmon River

Eli A. Felts, Nampa Fisheries Research

May 5, 2021

INTRODUCTION

Adult Chinook Salmon (hereafter Chinook) spawning escapement to the Lower Mainstem Salmon River population (USRL) has been monitored by the Idaho Department of Fish and Game (IDFG) since the early 1950s and standardized transects were established in 1957. These transects are all on the main stem Salmon River and extend from the confluence with Redfish Lake Creek downstream to the confluence with the Lemhi River. These areas are assumed to encompass all currently occupied Chinook spawning habitat in this population (Felts et al. 2019). Surveys of the USRL were conducted from fixed-wing aircraft or helicopter from 1957-2017 with the exception of ground surveys in transects NS-18, NS-19, and NS-20 in 2010. In 2018 and 2019 unmanned aircraft systems (UAS) were used for all index counts of the USRL.

In 2019 IDFG biologists agreed to drop transect NS-24 which extends from the Pahsimeroi River downstream to the Lemhi River from annual monitoring due to lack of spawning activity over the last several decades (Felts et al. 2020). The remaining transects will continue to be monitored using UAS. Biologists have noted a patchy distribution of redds in the USRL population and have expressed interest in using a probabilistic sampling design. Probabilistic sampling designs involve surveying a subsample of the available habitat in a manner that allows for unbiased estimates of redd abundance, and estimates of precision (Liermann et al. 2015).

Stratified designs can increase monitoring efficiency for salmonids such as Chinook and steelhead by focusing effort in areas with higher spawner density (Liermann et al. 2015; Groves et al. 2016). Stratification can produce more precise estimates than simple random samples when variability within strata is smaller than the variability between strata (Liermann et al. 2015). Chinook populations are more likely to meet this criteria when the distribution of spawning habitat is patchy, which seems to be the case in the USRL population.

METHODS

Study Area

The portion of the USRL population considered extant was used in this analysis. This includes 139 km of the main Salmon River from Redfish Lake Creek downstream to the Pahsimeroi River. This area has been surveyed annually since 1957.

Data

Redd counts were conducted by trained observers and were timed to coincide with the period of peak spawning activity based on historical observations (Copeland et al. 2019). Redd location data were collected using global positioning systems (GPS) from 1999-2019. Transects were surveyed with low-flying helicopter from 1999-2017 and UAS from 2018-2019. Although these were peak counts and thus incomplete, they were treated as the underlying “truth” for the purposes of simulations.

Probabilistic sampling strategies

Different approaches to implementing a stratified random sampling design for estimating annual total redd abundance were evaluated. The effect of input parameters, including size of sample units, stratification variable, and effort were evaluated using simulations. The observed data from 1999-2019 were treated as “true” for the purposes of simulations. Sampling units were stream segments which varied between 1, 2, and 5 km. The size of sampling units was constrained to be within the capability of UAS batteries which last long enough to survey approximately 5 km when using a linear flight plan.

Each redd waypoint was joined spatially to the closest 200-m segment of stream within the Intrinsic Potential (IP) habitat GIS layer. Attributes from the 200-m scale were summed to quantify attributes at the 1, 2, and 5 km scales. Variables used in stratification included weighted IP length, percent occupancy, and mean redd count.

Within the IP layer each 200-m stream section was assigned a rating of “High,” “Medium,” “Low,” or “None.” These ratings are given weights of 1.0, 0.5, 0.25, and 0, respectively. The weighted length of each 200-m section is based on these weights so, for example, a “High” rated 200-m section has a weighted length of 200 m, whereas a “Medium” rated 200-m section has a weighted length of 100 m.

Percent occupancy within sections was calculated as the number of years at least 1 redd was observed divided by the total number of years (N = 21), multiplied by 100. The mean redd count within sections was calculated as the arithmetic mean over the 21 year time series.

The number of strata was fixed at 3 for all designs considered. Optimum Strata Boundaries (OSB) for the various stratification variables were determined using Dynamic Programming (Bühler and Deutler 1975) within the stratifyR package (Reddy and Khan 2019) within program R (R Core Team 2019). Once the OSB were determined, the Optimum Sample Sizes (OSS) within strata were calculated using Neyman allocation (Neyman 1934). The OSB were calculated for each combination of stratification variables and sample unit size and within those units OSS was calculated for varying levels of total effort. Total effort was allowed to vary from 30 to 100 km at increments of 10 km, which represented approximately 22 – 72 % of total available habitat.

Once the OSB and OSS were determined, samples were drawn from the simulation data set 1,000 times. These 1,000 iterations were conducted at each combination of stratification variable (weighted IP length, percent occupancy, mean redds) and sample unit size (1, 2, and 5 km) across the range of total effort (30-100 km). This resulted in 21,000 estimates which included 1,000 estimates for each of the 21 years contained in the known data set. Accuracy of simulated data was evaluated using root mean square error (RMSE) which quantifies the average error from the observed data in terms of the units of interest. For example, in this evaluation an RMSE of 5 would mean that a given sampling design, on average, yielded an estimate of redd abundance that was 5 redds different than the truth. Precision of simulated data was evaluated using the coefficient of variation (CV). The simulation CV was calculated as the standard error of the 1,000 simulated redd abundance estimates divided by the true redd abundance estimates. Accuracy and precision were both summarized annually and evaluated across the 21 years to explore the performance of sampling designs across the observed range of abundances. Estimates were expected to be unbiased because a probabilistic design was implemented. However, bias was quantified for the sampling design which was ultimately recommended to demonstrate that it is unbiased in simulations. Bias for individual simulations was calculated as the simulated estimates minus the true estimates, and was averaged across the 1,000 simulations for each year.

A follow up to the initial analysis was done to include the potential for using IDFG standardized transects as strata. All USRL transects except for NS-24 (N = 7) were used as strata, and Neyman allocation based on mean redds as a stratifying variable was used to determine OSS within those transects for given levels of total effort ranging from 30-100 km. For this analysis, segment size was fixed at 2 km based on previous results. Because of differences in length and redd density within transects, the allocation of overall sampling effort was quite variable among the 7 transects. Neyman allocation does not account for a finite amount of sampling area, so at given levels of overall effort in the population some transects were allocated more 2 km sections than they actually possessed (Appendix figure C-1).

For example, transect NS-19 has only six 2-km stream segments, and as total sampling effort increased above 50 km, the OSS equation allocated more than 3 segments to this transect. To redistribute this “surplus” effort transects were manually removed from the Neyman allocation process at levels of total effort beyond which they were completely sampled and the difference resulted in at least 1 extra 2-km segment, and ran the OSS procedure for the total level of effort subtracting the amount that represented complete sampling of those transects. For example, at a total effort of 50 km, OSS allocated 3.12 sampling units to transect NS-19, which only contains 3 sampling units; because the remainder was only 0.12 sampling units I did not distribute the surplus to other transects. However, at 60 km, OSS allocated 4.88 sampling units so I distributed the surplus by removing NS-19 from the Neyman allocation process and rerunning the procedure with 54 km (i.e., 60 - 6) distributed across the remaining 6 transects. This procedure was expanded as necessary to remove NS-17 and NS-20 from the Neyman allocation process, depending on the overall effort. Once the OSS was determined for transects at various levels of total effort, a set of 1,000 simulated data sets for the 1999-2019 data set was generated using the same procedures as used for other stratifying variables. Likewise, accuracy and precision were quantified using RMSE and CV.

RESULTS AND DISCUSSION

An average of 66 redds were observed in the USRL population from 1999-2019 and ranged from a low of 6 in 2019 to a high of 202 in 2002 (Appendix Figure C-2).

At the 1-km scale, at least one redd was observed at 89 of 139 river kilometers, or 64% of the sampling universe. In general, occupancy was lower at further downstream locations (Appendix Figure C-3). A continuous 17 km section from river kilometer 62-78 was unoccupied over the entire 21 year data set Appendix Figure C-3). This is the section of the Salmon River from just upstream of the town of Clayton to 6 km downstream of the confluence with the East Fork Salmon River. Within the 89 1-km segments where redds had been observed, mean redd count ranged from .05 to 8.6 redds per year (Appendix Figure C-3).

The highest rated habitat occurs at the furthest upstream sections of the USRL population (Appendix Figure C-3; Appendix Figure C-4) but the IP model predicts suitable habitat throughout the population (Appendix Figure C-4). The 1-km section with the highest mean redd count had a weighted IP length of 0 which illustrates some of the shortcomings of using that model to design surveys Appendix Figure C-3).

Stratification using mean redd count had the lowest RMSE (Appendix Figure C-5) and CV Appendix Figure C-6) when comparing equivalent sample unit sizes and total effort, although the differences between mean redd count and percent occupancy were minor.

Stratification using weighted IP length yielded less accurate estimates especially when true abundance was high. The IP model does not predict spawning aggregate location or abundance well in the USRL population. As a result, stratifying based on this variable does not effectively partition variance in the metric of interest, which is redd abundance. Because the stratification of the sampling universe does not align with redd abundance, the sample often misses stream sections with relatively high abundance, which is especially problematic due to the patchy distributions of redds in this population. Due to the poor performance of the IP attribute for stratification, further analysis was limited to mean redd count and percent occupancy.

Within those 2 stratifying variables it is clear that accuracy is much improved by surveying 1 or 2 km units as opposed to 5 km units (Appendix Figure C-5). The tradeoff between 1 and 2 km units is in sampling efficiency; the battery life of UAS ensures that a survey of either one of these lengths can easily be completed within the life span of a single battery. Thus, 2 km units would be more time efficient because it would reduce the amount of time spent relocating among units. The improvements to accuracy in using 1 km units are more pronounced at lower total sample effort, especially when total effort is less than 50 km. Assuming total effort will likely remain greater than 50 km I recommend defining sample units at the 2-km scale rather than 1-km.

Closer inspection of simulated accuracy when using mean redds and percent occupancy as the stratifying variable and 2 km sample units is presented in figure 7; this figure also includes results from analysis using transects as strata boundaries rather than OSB based on observed data. In general, RMSE increases with the true number of redds with some exceptions. Because these designs select sites based on previous distribution and abundance, accuracy will decrease when redd abundance is relatively high in areas which have not previously exhibited high abundance and/or occupancy. Spawning distribution expanding to less suitable habitat is expected as escapement increases (Isaak et al. 2007). However, overall accuracy was still high; RMSE when using mean redds as a stratifying variable never exceeded 41 redds even when total effort was as low as 30 km (Appendix Figure C-7). Accuracy when using transects to define strata was comparable to results when using percent occupancy as a stratifying variable, and RMSE was similar to both other stratifying variables when total effort was at least 80 km (Appendix Figure C-7).

A comparison of true abundance and mean estimates when using 2 km sections stratified by mean redd count demonstrates that this design produced unbiased estimates (Appendix Figure C-8). Variance of estimates decreases with increasing sample effort but the decrease is minimal when sampling effort exceeds 80 km (Appendix Figure C-9). Stratification using transects as strata also produced unbiased estimates and variance was also low when sampling effort increased, particularly above 70 km (Appendix Figure C-9).

CONCLUSIONS AND RECOMMENDATIONS

Overall, the results of these simulations suggest that total effort in the USRL population could be reduced substantially with little loss in accuracy and precision. I recommend using 2-km sections in a probabilistic design. This will ensure that a UAS will be able to complete an entire section on a single battery while realizing marked improvements in accuracy when compared to using 5-km sections. Using the mean redd count within 2-km sections from 1999-2019 to separate the sampling universe into 3 strata would produce the most accurate counts at the population scale. However, if sampling effort is greater than approximately 70 km then using IDFG transects as strata produced similar levels of accuracy. This option may be preferable because it would allow for estimates of redd abundance and variance at both the population scale and the transect

scale. The location of redds counted prior to 1999 was not documented using GPS, so the only information on spatial distribution available during that period of time is the distribution among transects. Using transects as strata boundaries within a stratified random sampling design would allow for direct comparison at that scale to continue.

The improvements in accuracy were relatively uniform over the range of sampling effort included in the simulations. However, I would recommend surveying a maximum of 80 km total because the improvements in accuracy past that mark are very small (Figure 8). It is also worth noting that when total abundance is less than approximately 75 redds there was very little difference in precision among all levels of sampling effort considered. Again, this is likely due to Chinook spawning distribution contracting to core spawning areas which are always selected for sampling using this stratified design. Thus, if forecasted runs are very small then a lower amount of total effort may be sufficient.

Initial recommendations from this appendix were implemented in 2020. Specifically, total effort was set at 80 km and transects were used as strata. With those specifications, a total of 40 2 km segments allocated across the transects based on OSS calculations were selected for sampling. One issue that became apparent was that the available sampling universe does not divide into an even number of 2 km segments. For 2020 site selection, I divided transects into exactly 2 km segments starting at the upstream end, but this resulted in the furthest downstream segment being less than 2 km. For example, NS-20 is 36.3 km, so there were 18 2 km segments and one that was 0.3 km. None of the short segments were selected in 2020, but this procedure should be adjusted for future years so that the segments within strata are of equal size. My recommendation is to calculate the segment length closest to 2 km that will result in equally sized segments throughout a transect. To do so, the total length of the transect can be divided by 2 to calculate the exact number of 2 km segments; this number will not be an integer because none of the transect lengths are even integers that are exactly divisible by 2. Next, this exact number should be rounded to the nearest integer, and then the total length for the transect can be divided by this rounded number to find the correct length into which segments should be divided.

For the near future, we have agreed to survey a total of 80 km and use transects as strata. Based on OSS calculations transects NS-17 and NS-19 will be completely sampled under these specifications. For the remaining transects that will be subsampled, I have calculated the adjusted segment length to be used in future segment selection following the methods described in the previous paragraph. These numbers and the optimal sample size for a total effort of 80 km are listed in Appendix Table C-1.

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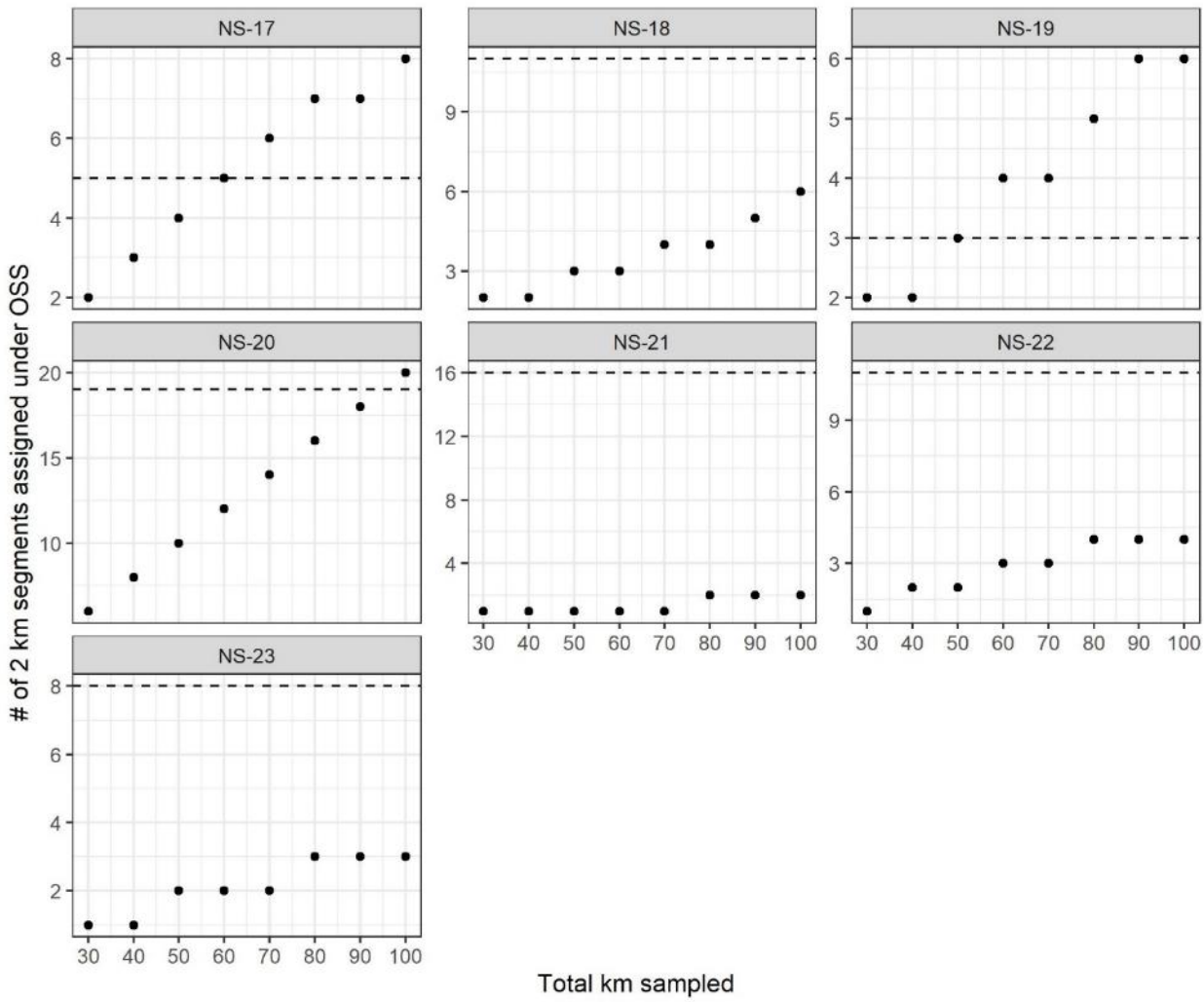
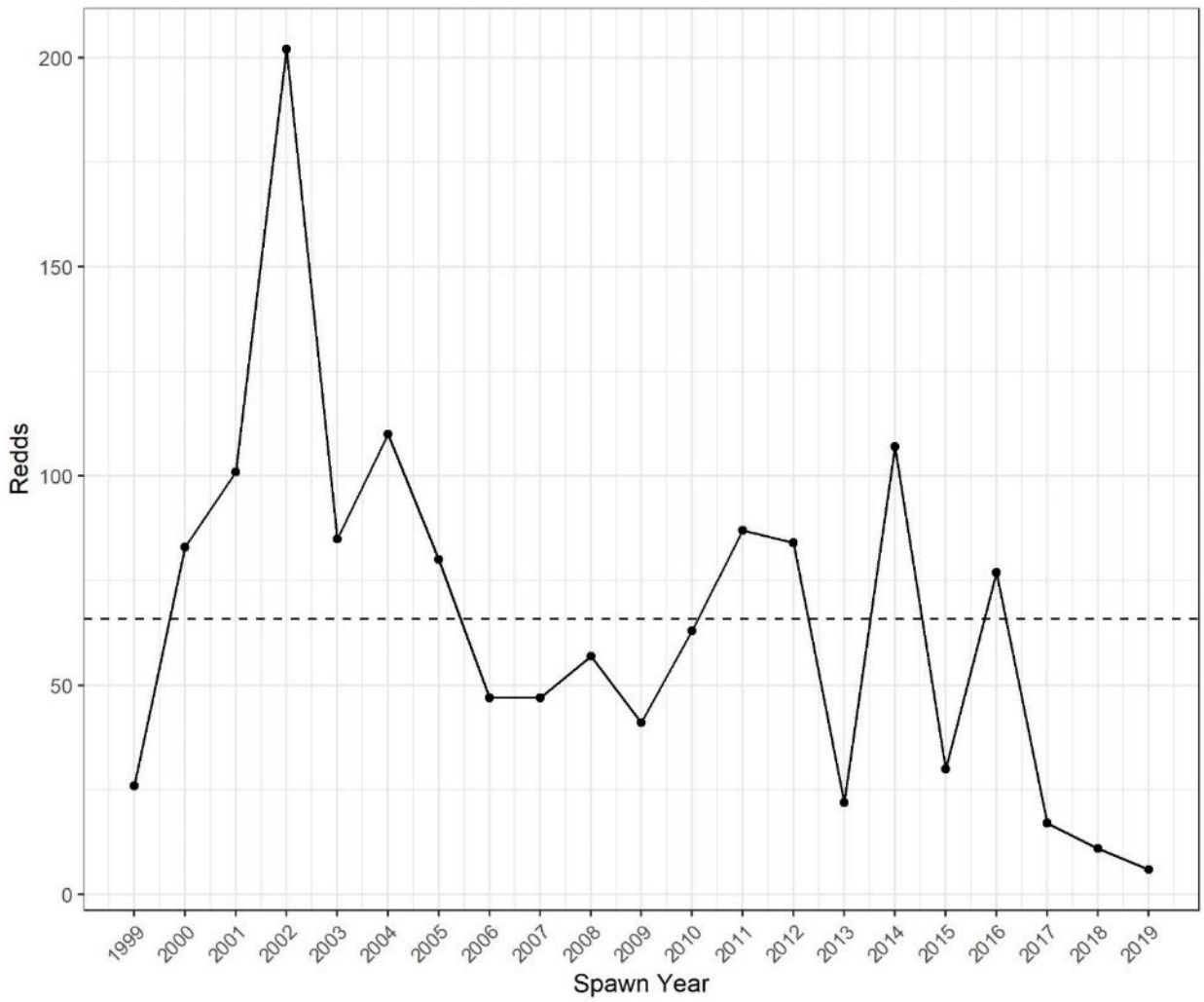
Appendix Table C-1. Recommendations for adjusted segment lengths within transects and optimal sample size for 80 km total effort.

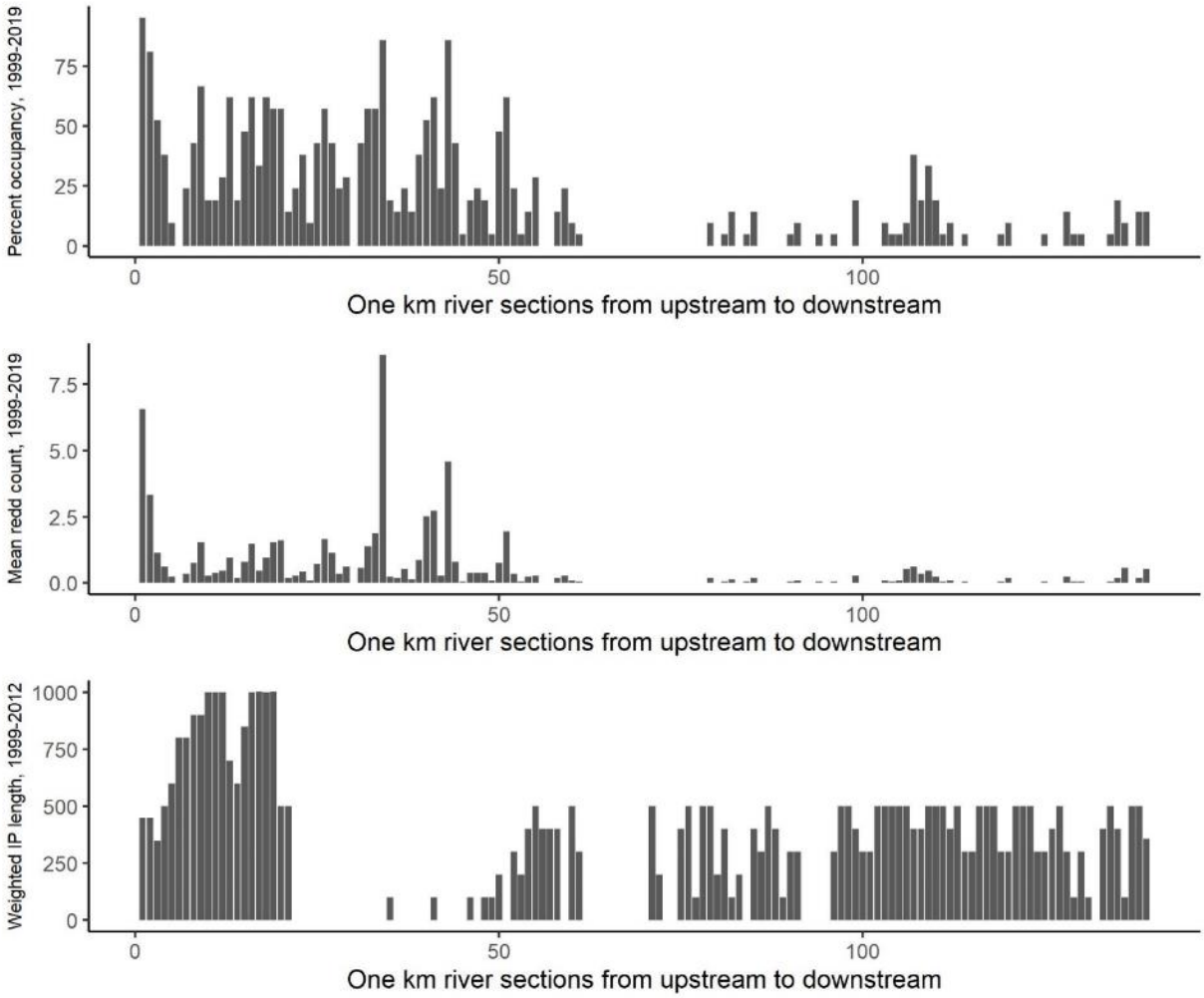
Transect	Length (km)	2 km segments (exact)	2 km segments (rounded)	Recommended Segment Length	OSS, 80 km total effort
NS-17	8.7	4.34	4	2.17	4
NS-18	20.3	10.16	10	2.03	5
NS-19	6.1	3.06	3	2.04	3
NS-20	36.3	18.17	18	2.02	18
NS-21	31.0	15.48	15	2.06	2
NS-22	20.0	10.02	10	2.00	4
NS-23	15.8	7.92	8	1.98	3



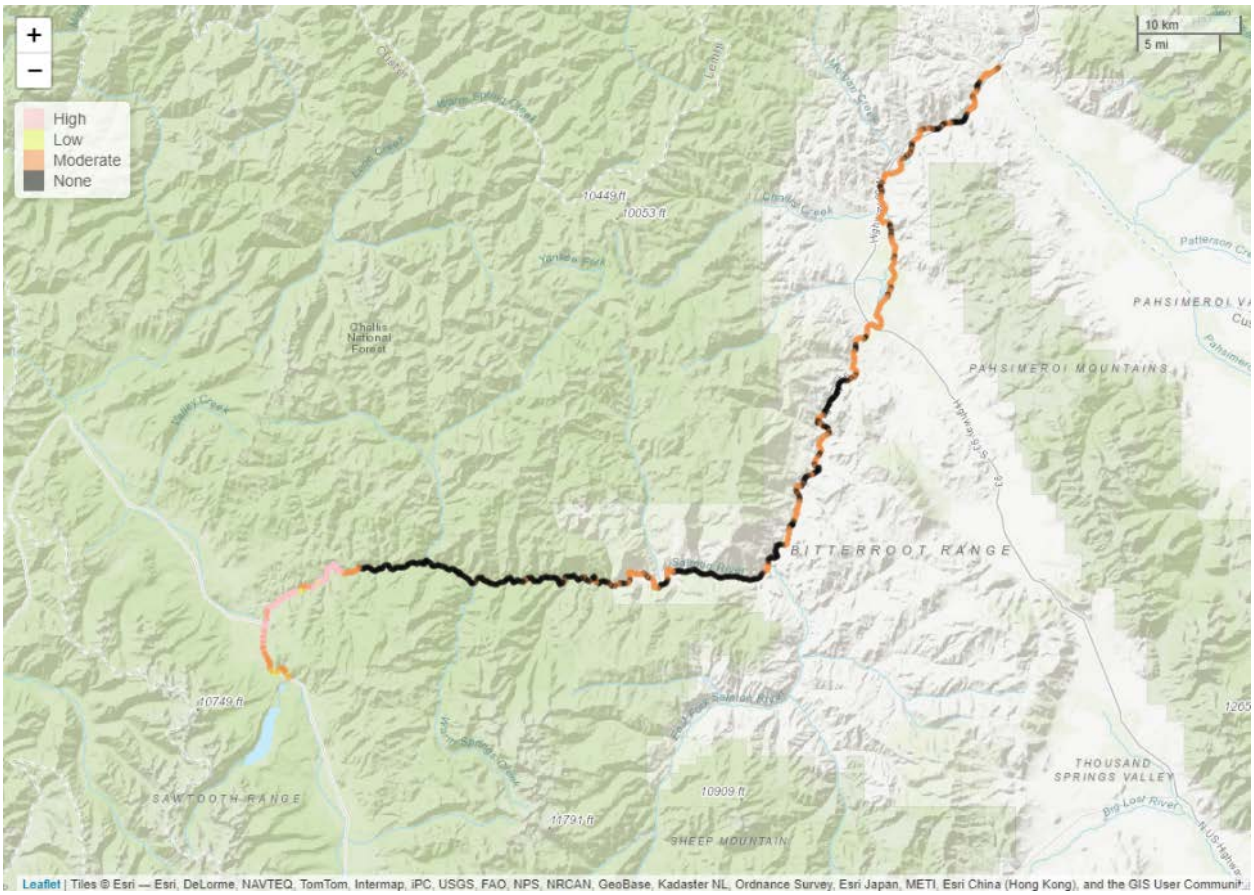
Appendix Figure C-1. Number of 2 km segments allotted to transects within the USRL population based on Neyman allocation. Dashed lines represent the total number of sections present within transects.



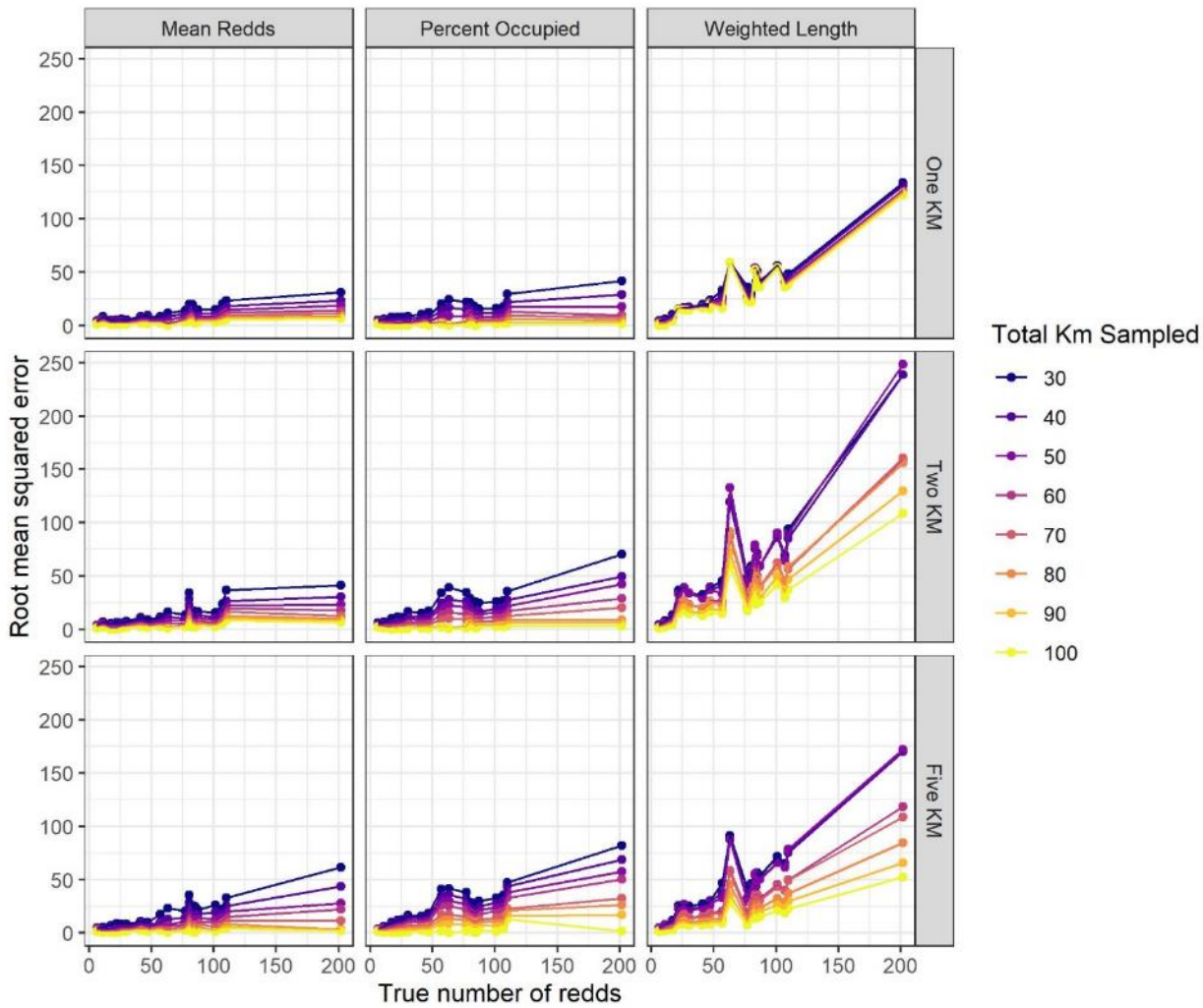
Appendix Figure C-2. Number of redds observed in USRL population from Redfish Lake Creek downstream to the Pahsimeroi River, 1999-2019. Dashed line represents the mean over those years.



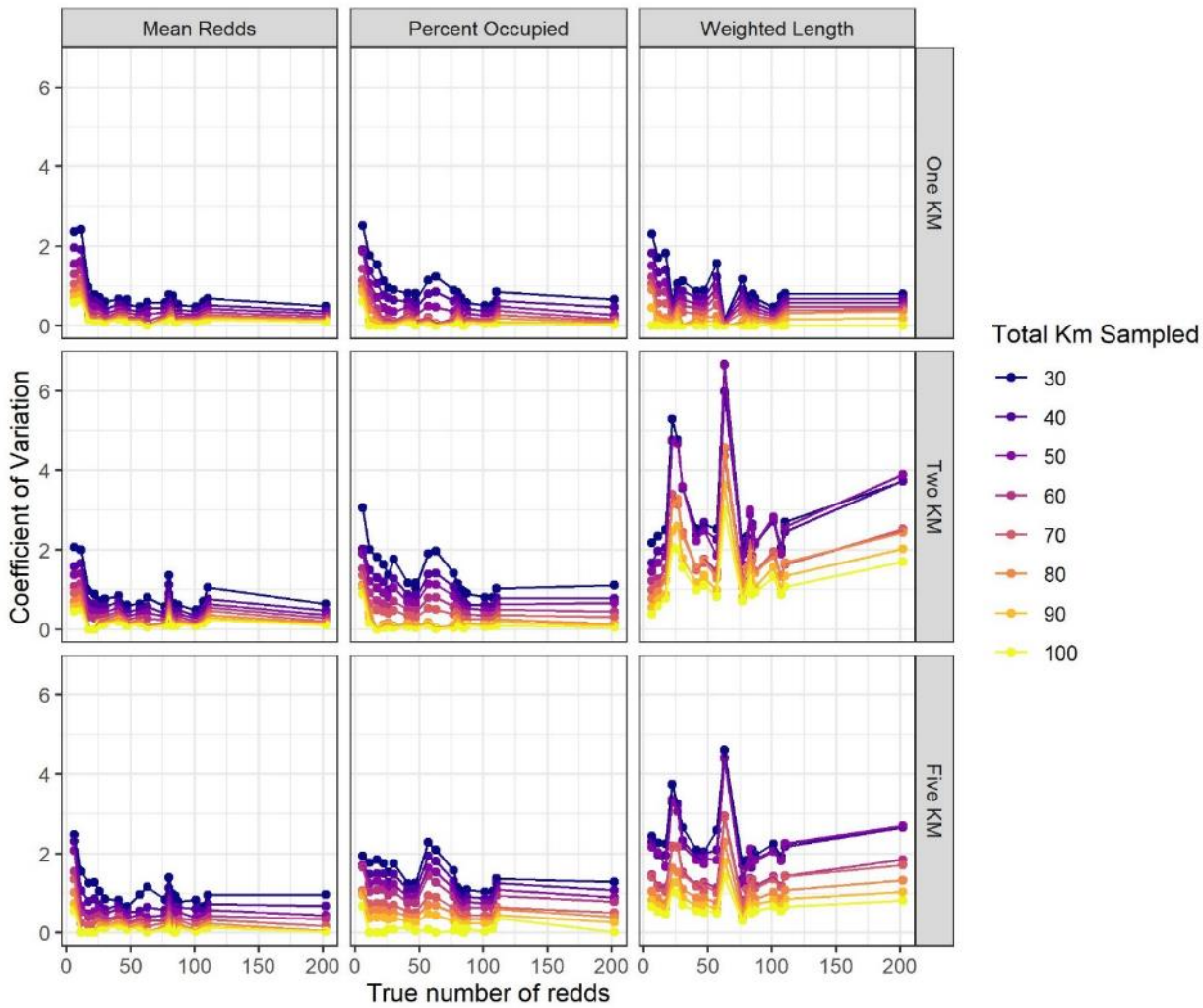
Appendix Figure C-3. Plot of percent occupancy (top panel), mean redd count (middle panel), and weighted IP length (bottom panel) for 1 km river segments in USRL population from Redfish Lake Creek downstream to the Pahsimeroi River, 1999-2019.



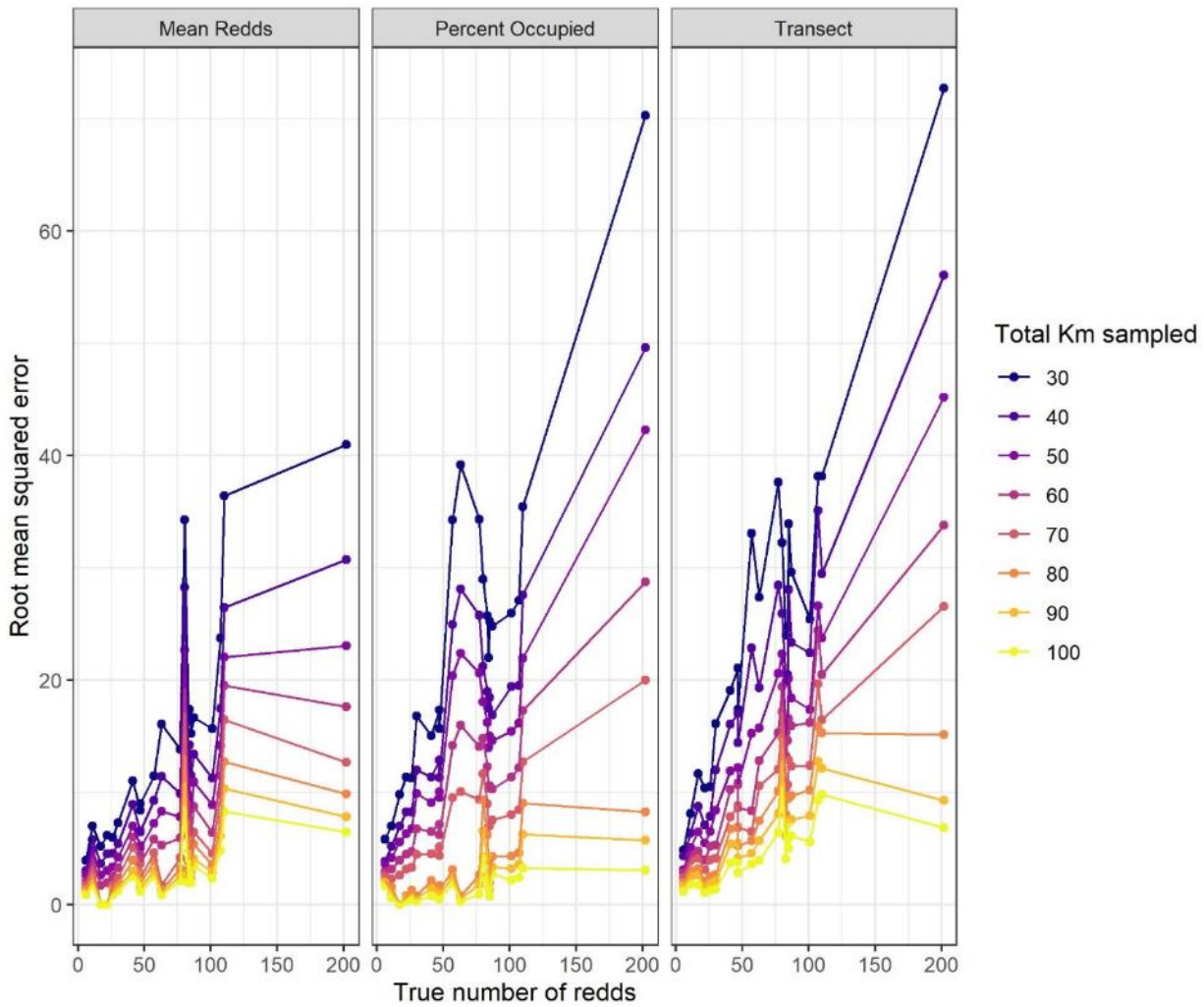
Appendix Figure C-4. Map of IP habitat ratings in the USRL population.



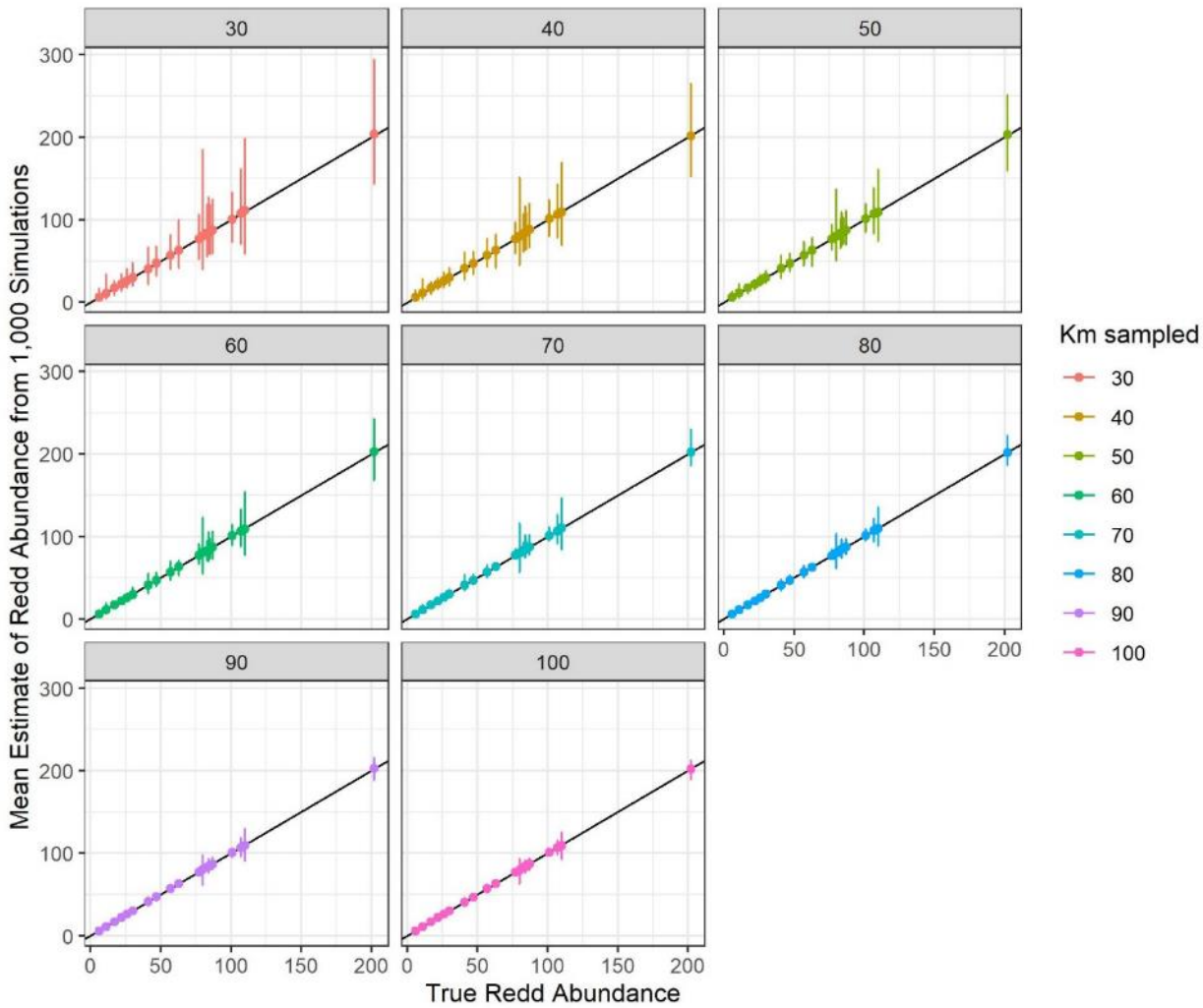
Appendix Figure C-5. Measures of accuracy (RMSE) for simulated sampling designs across a range of true redd counts. Horizontal panels represent different variables used to determine strata, and vertical panels represent differing sample unit sizes. Different color lines within plots represent variation in total sampling effort.



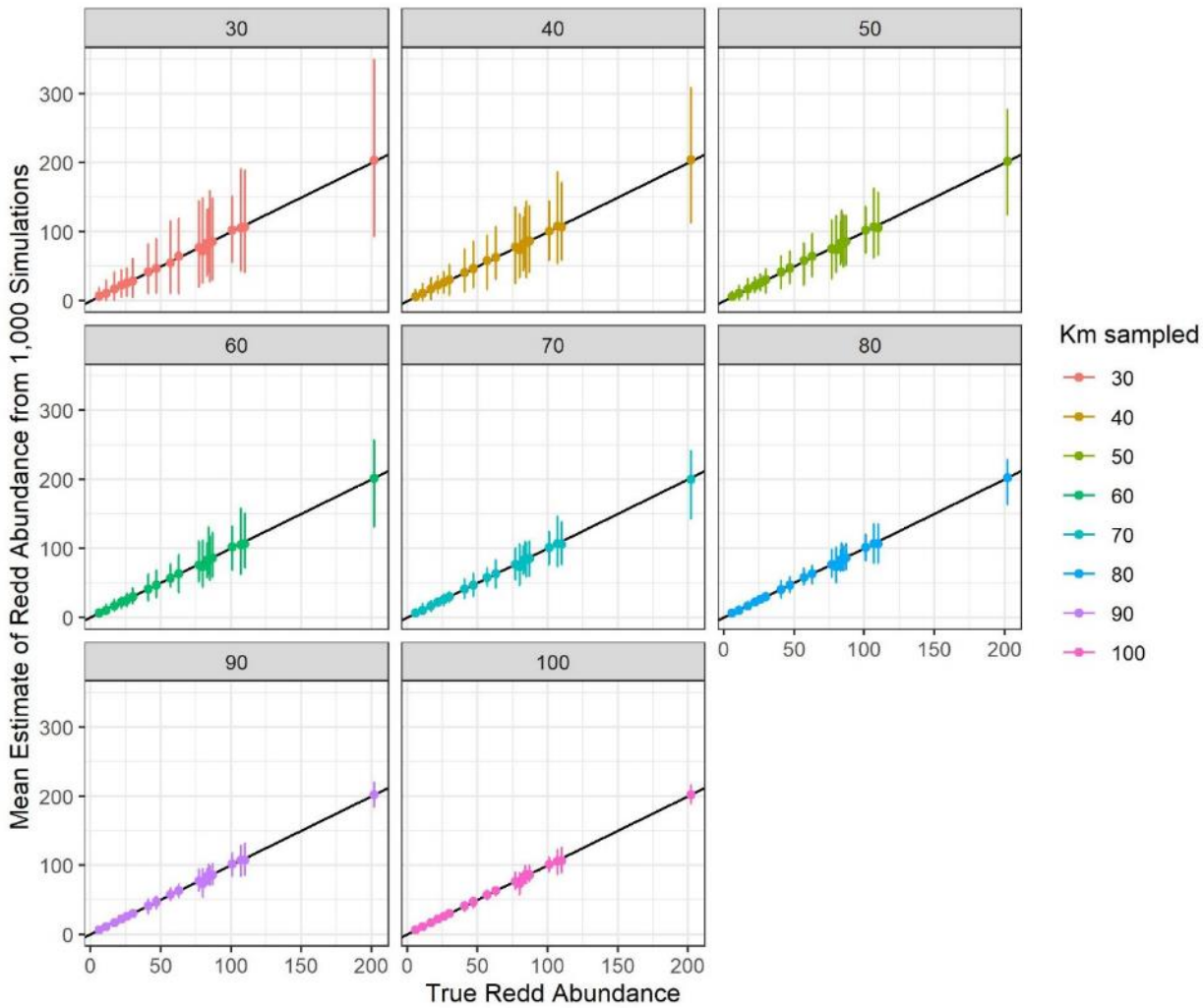
Appendix Figure C-6. Measures of precision (CV) for simulated sampling designs across a range of true redd counts. Horizontal panels represent different variables used to determine strata, and vertical panels represent differing sample unit sizes. Different color lines within plots represent variation in total sampling effort.



Appendix Figure C-7. Measures of accuracy (RMSE) for simulated sampling designs across a range of true redd counts for three different stratifying variables using 2 km sampling units.



Appendix Figure C-8. Comparison of estimated redd abundance to true redd abundance in simulations using 2 km sections stratified by mean redd count at various amounts of total sampling effort. Error bars represent the 2.5th and 97.5th percentile of the 1,000 simulated estimates. Line represents a 1:1 unbiased relationship.



Appendix Figure C-9. Comparison of estimated redd abundance to true redd abundance in simulations using 2 km sections stratified by IDFG transects at various amounts of total sampling effort. Error bars represent the 2.5th and 97.5th percentile of the 1,000 simulated estimates. Line represents a 1:1 unbiased relationship.

Prepared by:

Cynthia I. Nau
Fisheries Biologist

Eli A. Felts
Fisheries Biologist

Bruce Barnett
Fisheries Data Coordinator

Micah Davison
Supervisory Fisheries Biologist

Conor McClure
Fisheries Biologist

Joshua R. Poole
Fisheries Biologist

Robert Hand
Fisheries Biologist

Evan Brown
Sr. Fisheries Data Coordinator

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

John D. Cassinelli
Anadromous Fisheries Manager

J. Lance Hebdon, Chief
Bureau of Fisheries