



**WILD ADULT STEELHEAD AND CHINOOK SALMON
ABUNDANCE AND COMPOSITION AT
LOWER GRANITE DAM,
SPAWN YEAR 2021**

ANNUAL PROGRESS REPORT



Photo: IDFG

Prepared by:

**Carli M. Baum, Fisheries Biologist
John S. Hargrove, Fishery Biologist 2
Thomas Delomas, Fishery Biologist 2
Micah Davison, Supervisory Fisheries Biologist
Marika E. Dobos, Staff Biologist
Nolan R. Smith, Fishery Biologist 1
William C. Schrader, Principal Fisheries Research Biologist
Timothy Copeland, Fisheries Program Coordinator
Matthew R. Campbell, Fisheries Program Coordinator**

**IDFG Report Number 22-14
July 2022**

**Wild Adult Steelhead and Chinook Salmon Abundance and
Composition at Lower Granite Dam, Spawn Year 2021**

2021 Annual Report

By

**Carli M. Baum
John S. Hargrove
Thomas Delomas
Micah Davison
Marika E. Dobos
Nolan R. Smith
William C. Schrader
Timothy Copeland
Matthew R. Campbell**

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

**IDFG Report Number 22-14
July 2022**

ACKNOWLEDGEMENTS

Report Authors:

Carli M. Baum (IDFG)

John S. Hargrove (IDFG / PSMFC)

Thomas Delomas (IDFG/PSMFC)

Micah Davison (IDFG / PSMFC)

Marika E. Dobos (IDFG)

Nolan R. Smith (IDFG / PSMFC)

William C. Schrader (IDFG)

Timothy Copeland (IDFG)

Matthew R. Campbell (IDFG)

Report Contributors: Data, reviews, and other assistance (*alphabetical*)

IDFG

- Matt Belnap
- Alan Byrne
- Lance Hebdon
- Alex LeCheminant
- Brian Leth
- Chris Sullivan

IDFG / PSMFC

- Lara Breikreutz
- Paul Bunn
- Andrea Butterfield
- Angie Chia
- Corey Dondero
- Dan Eardley
- Karen Gregory
- Kelly Heindel
- Lillian Legg
- Jesse McCane
- Eduard Mixich
- Leslie Reinhardt
- Lynn Schrader
- Craig Steele
- Patrick Vrablik

Northwest Fisheries Science Center

- Amber Barenberg
- Allen Bartels
- Ross Gleason
- Tiffani Marsh
- Darren Ogden

Columbia River Inter-Tribal Fish Commission

- Stephanie Harmon
- Rebekah Horn
- Shawn Narum
- Jeff Stephenson

Ocean Associates Inc. / Stillwater Inc.

- Colby Bunce
- Randy Bunce
- Kyle King
- Kriston Snyder
- Lela Work

PSMFC

- Elizabeth Kennedy
- Allan Martin

WDFW

- Afton Oakerman

ACKNOWLEDGEMENTS (continued)

Project Administration: Funding and other assistance (*alphabetical*)

- Biomark, Applied Biological Services
- Bonneville Power Administration (BPA); projects:
 - 1990-055-00 Idaho Salmon and Steelhead Monitoring and Evaluation Studies
 - 2010-026-00 Chinook and Steelhead Genotyping for Genetic Stock Identification (GSI) at Lower Granite Dam
 - 2010-031-00 Parentage-Based Tagging (PBT) of Snake River Hatchery Steelhead and Chinook Salmon
- Idaho Office of Species Conservation (IOSC)
- Idaho Power Company (IPC)
- National Marine Fisheries Service (NMFS)
- Northwest Power and Conservation Council (NPCC)
- Pacific States Marine Fisheries Commission (PSMFC)
- U. S. Fish and Wildlife Service, Lower Snake River Compensation Program (LSRCP)

Suggested citation:

Baum, C. M., J. S. Hargrove, T. Delomas, M. Davison, M. E. Dobos, N. R. Smith, W. C. Schrader, T. Copeland, and M. R. Campbell. 2022. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn year 2021. Annual report 2021. Idaho Department of Fish and Game Report 22-14.

ABBREVIATIONS AND ACRONYMS

BPA	Bonneville Power Administration
BY	Brood Year
CI	Confidence Interval
CHMBLN	Chamberlain Creek Genetic Stock
CLRWTR	Clearwater River Genetic Stock
CWT	Coded Wire Tag
DPS	Distinct Population Segment
EFGL	Eagle Fish Genetics Laboratory
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FALL	Snake River Fall Chinook Salmon
FL	Fork Length
FPC	Fish Passage Center
GRROND	Grande Ronde River Genetic Stock
GSI	Genetic Stock Identification
GT-seq	Genotyping-in-Thousands by Sequencing
H	Adipose Fin Clipped Hatchery
HELLSC	Hells Canyon Genetic Stock
HNC	Adipose Fin Intact Hatchery
ICBTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IMNAHA	Imnaha River Genetic Stock
IOSC	Idaho Office of Species Conservation
IPC	Idaho Power Company
LGR	Lower Granite Dam
LOCLWR	Lower Clearwater River Genetic Stock
LOSALM	Lower Salmon River Genetic Stock
LSNAKE	Lower Snake River Genetic Stock
LSRCP	Lower Snake River Compensation Plan
MFSALM	Middle Fork Salmon River Genetic Stock
MPG	Major Population Group
MY	Smolt Migration Year
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRAAL	Nampa Research Anadromous Ageing Laboratory
NWFSC	Northwest Fisheries Science Center
PBT	Parentage Based Tag
PIT	Passive Integrated Transponder
PSMFC	Pacific States Marine Fisheries Commission
SALMON	Salmon River Major Population Group
SAR	Smolt-to-adult return rate
SCOBI	Salmonid Compositional Bootstrap Intervals

SFCLWR	South Fork Clearwater River Genetic Stock
SFSALM	South Fork Salmon River Genetic Stock
SNP	Single Nucleotide Polymorphism
SY	Spawn Year
TUCANO	Tucannon River Genetic Stock
UPCLWR	Upper Clearwater River Genetic Stock
UPSALM	Upper Salmon River Genetic Stock
USACE	U. S. Army Corps of Engineers
W	Wild
WDFW	Washington Department of Fish and Wildlife

TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS	i
ABBREVIATIONS AND ACRONYMS	iii
ABSTRACT	1
INTRODUCTION	3
METHODS.....	4
Adult Trap Operations at Lower Granite Dam	4
Trap Data Management	6
Valid Sample Selection	6
Scale Processing, Analysis, and Age Validation.....	6
Genetics Tissue Processing and Analysis.....	7
Wild Escapement by Origin, Genetic Stock, Size, Sex, and Age	8
Smolt-to-Adult Return Rate	11
RESULTS	12
Steelhead Escapement	12
Steelhead by Genetic Stock, Size, Sex, and Age	12
Steelhead Adult-to-Adult Productivity	13
Steelhead Smolt-to-Adult Return Rate	14
Chinook Salmon Escapement	14
Chinook Salmon by Genetic Stock, Size, Sex, and Age	14
Chinook Salmon Adult-to-Adult Productivity	15
Chinook Salmon Smolt-to-Adult Return Rate	15
DISCUSSION.....	16
TABLES	19
FIGURES.....	26
APPENDICES.....	38
LITERATURE CITED	71

LIST OF TABLES

	<u>Page</u>
Table 1.	Major population groups and independent populations within the Snake River steelhead distinct population segment (DPS) and spring-summer Chinook Salmon evolutionary significant unit (ESU; ICBTRT 2003, 2005, 2009; Ford 2011, 2015; NMFS 2016). Extirpated populations are shaded.20
Table 2.	Estimated annual escapement, by fish size and origin, of steelhead, spawn years 1998–2021. Large fish were greater than or equal to 78 cm fork length (FL) and small fish were less than 78 cm FL. Ad-clipped and ad-intact refer to the adipose fin. Estimates from 1998–2020 were generated by IDFG and are the USACE window counts decomposed using adult trap data (Alan Byrne, IDFG, personal communication; Camacho et al. 2017, 2018a, 2019a; Lawry et al. 2020; Baum et al. 2022). Spawn year 2021 estimates were generated by IDFG using the USACE window counts and adult trap data in EASE (present study).22
Table 3.	Estimated number of wild steelhead smolts, number of returning adults by saltwater age, and percent smolt-to-adult return (% SAR) rate at Lower Granite Dam. Scale samples were used for all smolt migration years. Repeat spawners (shaded) were not used to estimate SARs. Included in parentheses are 95% confidence intervals for SARs.....23
Table 4.	Estimated annual escapement, by origin and saltwater age, of Chinook Salmon, spawn years 1998–2021. Jacks were one-saltwater age and include zero-saltwater age mini-jacks; adults were two-saltwater age and older. Estimates from 1998–2020 were generated by IDFG and are the USACE window counts decomposed using adult trap data (Alan Byrne, IDFG, personal communication; Camacho et al. 2017, 2018a, 2019a; Lawry et al. 2020; Baum et al. 2022). Spawn year 2021 estimates were generated by IDFG using adult trap data in EASE (present study).24
Table 5.	Estimated number of wild Chinook Salmon smolts, number of returning adults by saltwater age, and percent smolt-to-adult return (% SAR) rate at Lower Granite Dam. Fin ray samples were used to estimate age composition for adults returning from smolt migration years 1996–2004 (above the dashed line) whereas scale samples were used in smolt migration year 2005 and after (below the dashed line). SAR 95% confidence intervals are in parentheses.25

LIST OF FIGURES

		<u>Page</u>
Figure 1.	Map of steelhead genetic stocks and sample collections included in the Snake River basin SNP baseline version 3.1 (Powell et al. 2018) used for genetic stock identification at Lower Granite Dam. A detailed description of collections can be found in Hargrove et al. (2021). The Hells Canyon Tributaries major population group does not support independent populations and is considered extirpated (NMFS 2016). See Genetic Tissue Processing and Analysis section for genetic stock abbreviations.....	27
Figure 2.	Map of Chinook Salmon genetic stocks and sample collections included in the Snake River basin SNP baseline version 3.1 (Powell et al. 2018) used for genetic stock identification at Lower Granite Dam. A detailed description of collections can be found in Hargrove et al. (2022). Reintroduced fish exist in functionally extirpated TRT populations as mapped. See Genetic Tissue Processing and Analysis section for genetic stock abbreviations.....	28
Figure 3.	Schematic of the Lower Granite Dam Estimating Adult Salmonid Escapement (EASE) decomposition model. Total adjusted escapement refers to the LGR window counts with nighttime passage and fallback-reascension rates incorporated. Large/Small refer the fork length (FL) designations for Chinook Salmon large (≥ 57 cm FL) and small (< 57 cm FL) and steelhead large (≥ 78 cm FL) and small (< 78 cm FL). Fish less than 30 cm FL are not designated to species and are ignored.....	29
Figure 4.	Estimated escapement by genetic stock of wild steelhead at Lower Granite Dam for spawn years 2009–2021. Confidence intervals are at 90%.	30
Figure 5.	Adult-to-adult productivity (returning recruits per parent spawner) of wild steelhead at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2013. Note brood year 2014 was shown for reference, but represents a preliminary result that will be completed in SY2022.	31
Figure 6.	Adult-to-adult productivity (returning recruits per parent spawner) for each genetic stock of wild steelhead at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2013. Note brood year 2014 was shown for reference, but represents a preliminary result that will be completed in SY2022.....	32
Figure 7.	Estimated wild steelhead smolt-to-adult return (% SAR) rate of emigrant smolts and adult returns to Lower Granite Dam for smolt migration years 2010–2017. Confidence intervals are at 95%. The dashed lines represent the lower and upper range SAR objectives for wild steelhead established by the Northwest Power and Conservation Council (NPCC 2014, 2020). See Table 3 for numbers.....	33
Figure 8.	Estimated escapement by genetic stock of wild Chinook Salmon at Lower Granite Dam during March 1 to August 17 of spawn years 2009–2021. Confidence intervals are at 90%. Spawn year 2020 stock-specific estimates were generated using run reconstruction and do not include jacks or have confidence intervals. Hells Canyon stock is an aggregate genetic stock that includes the Clearwater, Little Salmon, Lower Salmon, Grande Ronde, Imnaha, and Lower Snake rivers.....	34

Figure 9. Adult-to-adult productivity (returning recruits per parent spawner) of wild Chinook Salmon at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2015. Note brood year 2016 was shown for reference, but represents a preliminary result that will be completed in SY2022.35

Figure 10. Adult-to-adult productivity (returning recruits per parent spawner) for each genetic stock of wild Chinook Salmon at Lower Granite Dam. The dashed line at 1.0 recruits per spawner replacement. Spawn year 2021 completed brood year 2015. Note brood year 2016 was shown for reference, but represents a preliminary result that will be completed in SY2022.....36

Figure 11. Estimated wild Chinook Salmon smolt-to-adult return (% SAR) rate of emigrant smolts and adult returns to Lower Granite Dam. Confidence intervals are at 95%. The dashed lines represent the lower and upper range SAR objectives for wild Chinook Salmon established by the Northwest Power and Conservation Council (NPCC 2014, 2020). See Table 5 for numbers.....37

LIST OF APPENDICES

	<u>Page</u>
Appendix A: Annual Lower Granite Dam trapping operations, 2020–2021.	39
Appendix A-1. Annual Lower Granite Dam trapping operations, 2020–2021. Shaded areas were outside the 2021 spawn year (July 1, 2020 to June 30, 2021 for steelhead and March 1 to August 17, 2021 for Chinook Salmon).....	40
Appendix A-2. Daily number of steelhead counted at the Lower Granite Dam window, spawn year 2021. Vertical gray bars indicate when the trap was open and daily trapping rate. 93.4% of the steelhead passed LGR when the trap was open. See Appendix A-1 and text for explanation of various trap closures.	41
Appendix A-3. Daily number of Chinook Salmon counted at the Lower Granite Dam window, spawn year 2021. Vertical gray bars indicate when the trap was open and daily trapping rate. 71.6% of the Chinook Salmon passed LGR when the trap was open. See Appendix A-1 and text for explanation of various trap closures.	42
Appendix A-4. A hierarchical (top to bottom) key of external marks and internal tags used to determine hatchery origin steelhead and Chinook Salmon at Lower Granite Dam (LGR), spawn years 2009–2021. Only fish failing to meet criteria were considered wild.	43
Appendix A-5. Weekly window counts and valid adult trap samples of steelhead at Lower Granite Dam, spawn year 2021. Data were summarized by weekly strata for analysis using the Estimating Adult Salmonid Escapement (EASE) model.	44
Appendix A-6. Weekly window counts and valid adult trap samples of Chinook Salmon at Lower Granite Dam, spawn year 2021. Data were summarized by weekly strata for analysis using the Estimating Adult Salmonid Escapement (EASE) model.	45
Appendix B. Methods description of Estimating Adult Salmonid Escapement (EASE) model used for all steelhead and spring-summer Chinook Salmon estimates, spawn year 2021.....	46
Appendix B-1. Methods description of Estimating Adult Salmonid Escapement (EASE) model used for all steelhead and spring-summer Chinook Salmon estimates, spawn year 2021.....	47
Appendix C: Steelhead and Chinook Salmon age validation.	52
Appendix C-1. Age bias plot illustrating pairwise comparisons of scale assigned saltwater age with known age for steelhead at Lower Granite Dam, spawn year 2021 (Micah Davison, IDFG, scale data; PTAGIS, PIT-tag data). Dashed line represents the 1:1 relationship. PA = percent agreement.....	53
Appendix C-2. Age bias plot illustrating pairwise comparisons of scale assigned saltwater age with known age for Chinook Salmon at Lower Granite Dam, spawn year 2021 (Micah Davison, IDFG, scale data; PTAGIS, PIT-tag data). Dashed line represents the 1:1 relationship. PA = percent agreement.	54
Appendix D: Wild steelhead at Lower Granite Dam, spawn year 2021.	55
Appendix D-1. Percentage of the estimated escapement of wild steelhead by genetic stock to the overall estimated wild escapement at Lower Granite Dam, spawn years 2010–2021. See Genetic Tissue Processing and Analysis section for stock abbreviations.	56

Appendix D-2. Estimated escapement of wild steelhead at Lower Granite Dam by sex and by size for each genetic stock, spawn year 2021. L = lower bound and U = upper bound of 90% confidence intervals. See Genetic Tissue Processing and Analysis section for stock abbreviations.	57
Appendix D-3. Estimated escapement by sex of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%.	58
Appendix D-4. Estimated escapement of wild steelhead at Lower Granite Dam by smolt migration year, brood year, and age class for each genetic stock, spawn year 2021. Only individual fish that had both a total age and an assigned stock were used (n = 2,085). Age class format is European: freshwater age.saltwater age. R represents consecutive year repeat spawners who spawned two years in a row, and R1 represents skip spawners who spent one year in saltwater between spawning years. See Genetic Tissue Processing and Analysis section for stock abbreviations.....	59
Appendix D-5. Estimated escapement by saltwater age of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Repeat refers to steelhead showing evidence of previous spawning events.....	60
Appendix D-6. Estimated escapement by genetic stock and saltwater age of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Repeat refers to steelhead showing evidence of previous spawning events.	61
Appendix D-7. Length frequency distribution by saltwater age of wild steelhead trapped at Lower Granite Dam, spawn year 2021. Solid black vertical line represents the mean fork length (FL) for each saltwater age. Dashed vertical red line represents the 780 mm FL cutoff for determining large-sized steelhead.	62
Appendix E: Wild Chinook Salmon at Lower Granite Dam, spawn year 2021.	63
Appendix E-1. Percentage of the estimated escapement of wild Chinook Salmon by genetic stock to the overall estimated wild escapement at Lower Granite Dam, spawn years 2010–2021. Spawn year 2020 stock-specific estimates were generated using run reconstruction methods and do not include jacks in the total wild count. See Genetic Tissue Processing and Analysis section for stock abbreviations.	64
Appendix E-2. Estimated escapement of wild Chinook Salmon at Lower Granite Dam by sex and by size for each genetic stock, spawn year 2021. L = lower bound and U = upper bound of 90% confidence intervals. See Genetic Tissue Processing and Analysis section for stock abbreviations.....	65
Appendix E-3. Estimated escapement by sex of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Spawn year 2020 sex estimates are not available because the trap was closed due to COVID-19 restrictions.....	66
Appendix E-4. Estimated escapement of wild Chinook Salmon at Lower Granite Dam by smolt migration year, brood year, and age class for each genetic stock, spawn year 2021. Only individual fish that had both a total age and an assigned stock were used (n = 1,832). See Genetic Tissue Processing and Analysis section for stock abbreviations.....	67
Appendix E-5. Estimated escapement by saltwater age of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Spawn year 2020 saltwater age estimates were generated using run	

reconstruction and do not have confidence intervals. Saltwater age-0 refers to mini-jacks.....	68
Appendix E-6. Estimated escapement by genetic stock and saltwater age of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Spawn year 2020 saltwater age estimates were not available at the stock level because the trap was closed due to COVID-19 restrictions. Confidence intervals are at 90%. Saltwater age-0 refers to mini-jacks.	69
Appendix E-7. Length frequency distribution by saltwater age of wild Chinook Salmon trapped at Lower Granite Dam, spawn year 2021. Solid black vertical line represents the mean length for each saltwater age. Dashed vertical red line represents the 570 mm FL cutoff for determining large-sized Chinook Salmon.	70

ABSTRACT

This report summarizes the abundance and composition of wild adult steelhead *Oncorhynchus mykiss* and spring-summer Chinook Salmon *O. tshawytscha* returning to Lower Granite Dam in spawn year 2021. We used a combination of window counts, nighttime passage rates, fallback-reascension rates, and biological samples collected using a systematic random sample design from the fish trap at Lower Granite Dam to decompose each species by origin, body size, sex, age, and stock. The time series of abundance and composition was then used to calculate adult-to-adult productivity, expressed as recruits per spawner, and smolt-to-adult return rate for each species. The estimated total escapement for hatchery and wild steelhead was 61,315 (60,515–62,214 90% CI). The estimated wild steelhead escapement was 15,478 fish (15,001–15,973 90% CI), comprising 25% of the total estimate. The Grande Ronde River genetic stock was the most abundant followed by the Upper Salmon River. Small steelhead (<78 cm fork length [FL]) dominated the ad-clipped hatchery run and the total wild run; however, large steelhead (≥ 78 cm FL) were most abundant in the ad-intact hatchery run. The wild steelhead aggregate at Lower Granite Dam was female biased (78%) with female percentages of genetic stocks that ranged from 71% for the South Fork Clearwater River to 82% for the Middle Fork Salmon River. We observed 20 different steelhead age classes. Total age for adults at Lower Granite Dam ranged from three to seven years, with freshwater ages that ranged from one to four years, and saltwater ages that ranged from zero to three years, and additional fish returning as repeat spawners. Adult-to-adult productivity was completed for brood year 2013 and was 0.34 returning recruits per spawner. Productivities for all genetic stocks were below replacement. The smolt-to-adult return rate for the aggregate wild steelhead run was 0.86% for smolts crossing Lower Granite Dam in migration year 2017. We noted overall declining trends in wild steelhead escapement, productivity, and smolt-to-adult return rates over the past five years. The estimated total escapement for hatchery and wild spring-summer Chinook Salmon was 46,429 (45,967–46,903 90% CI). The estimated wild Chinook Salmon escapement was 8,604 (8,318–8,929 90% CI) fish, comprising 19% of the total estimate. The Hells Canyon genetic stock was the most abundant followed by the South Fork Salmon River. Large Chinook Salmon (≥ 57 cm FL) dominated the ad-clipped hatchery run, ad-intact hatchery run, and the wild run. Wild Chinook Salmon were male biased at 61%. Sex ratios for each genetic stock mirrored the aggregate wild run and ranged from 58% male for Hells Canyon to 77% male for Chamberlain Creek, with the exception of the Tucannon River stock, which was female biased. We observed nine different Chinook Salmon age classes. Total age for adults at Lower Granite Dam ranged from two to six years, with freshwater ages ranged from one to two years, and saltwater ages that ranged from zero (mini-jacks) to four years. Adult-to-adult productivity was completed for brood year 2015 and was 0.18 returning recruits per spawner. Productivities for all genetic stocks were below replacement. The smolt-to-adult return rate for the aggregate wild Chinook Salmon run was 0.35% for smolts crossing Lower Granite Dam in migration year 2017. Although we noted a slight overall increasing 5-year trend in wild Chinook Salmon escapement, abundance is still relatively low compared to previous years' data and we noted overall declining trends in overall Chinook Salmon abundance (hatchery included), productivity, and smolt-to-adult return rates over the past five years.

Authors:

Carli M. Baum
Fisheries Biologist

Micah Davison
Supervisory Fisheries Biologist

William C. Schrader
Principal Fisheries Research Biologist

John S. Hargrove
Fishery Biologist 2

Marika E. Dobos
Staff Biologist

Timothy Copeland
Fisheries Program Coordinator

Thomas Delomas
Fishery Biologist 2

Nolan R. Smith
Fishery Biologist 1

Matthew R. Campbell
Fisheries Program Coordinator

INTRODUCTION

Populations of steelhead trout *Oncorhynchus mykiss* and Chinook Salmon *O. tshawytscha* in the Snake River basin declined substantially following the construction of hydroelectric dams in the Snake and Columbia rivers. Raymond (1988) documented a decrease in survival of emigrating steelhead trout and Chinook Salmon from the Snake River following the construction of dams on the lower Snake River during the late 1960s and early 1970s. Abundance rebounded slightly in the early 1980s, but escapements over Lower Granite Dam (LGR) into the Snake River basin declined again (Busby et al. 1996). In recent years, abundances in the Snake River basin have slightly increased. However, the increase has been dominated by hatchery fish, while the returns of naturally produced steelhead trout and Chinook Salmon remain critically low. As a result, Snake River spring-summer Chinook Salmon (hereafter Chinook Salmon) were classified as threatened under the Endangered Species Act (ESA) in 1992 and Snake River steelhead trout (hereafter steelhead) were classified as threatened under the ESA in 1997.

Within the Snake River steelhead distinct population segment (DPS), there are six major population groups (MPGs): Lower Snake River, Grande Ronde River, Imnaha River, Clearwater River, Salmon River, and Hells Canyon Tributaries (Table 1; ICBTRT 2003, 2005, 2009; Ford 2011, 2015; NMFS 2016). The Hells Canyon MPG is considered to have been functionally extirpated. In total, 24 extant populations have been identified in the DPS.

Within the Snake River spring-summer Chinook Salmon evolutionarily significant unit (ESU), there are seven MPGs: Lower Snake River, Grande Ronde/Imnaha Rivers, South Fork Salmon River, Middle Fork Salmon River, Upper Salmon River, Dry Clearwater River, and Wet Clearwater River (Table 1; ICBTRT 2003, 2005, 2009; Ford 2011, 2015; NMFS 2016). The Dry Clearwater River and Wet Clearwater River MPGs are considered to have been extirpated but have been refounded with stocks from other Snake River MPGs. In total, 28 extant populations have been identified in the ESU.

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 steelhead and salmon stocks. The Idaho Department of Fish and Game's anadromous fish program long-range goals, consistent with basinwide mitigation and 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 salmonid populations function (McElhany et al. 2000) as well as regular status assessments. The key metrics to assessing viability of salmonid populations are abundance, productivity, spatial structure, and diversity (McElhany et al. 2000).

The aggregate escapement of Snake River steelhead and Chinook Salmon is measured at LGR, with the exception of the Tucannon River population in Washington, which is downstream of LGR. Some of the wild fish migrate to Washington or Oregon tributaries to spawn, but the majority are destined for Idaho. Age, sex, and stock composition data are important for monitoring recovery of wild fish for both species. Age data collected at LGR are used to assign returning adults to specific brood years, for cohort analysis, and to estimate productivity and survival rates (Camacho et al. 2017; 2018a; 2018b; 2019a; 2019b; Lawry et al. 2020; Baum et al. 2022). In addition, escapement estimates by cohort are used to forecast run sizes in subsequent years, and these forecasts are the basis for preliminary fisheries management plans in the Columbia River basin.

At Columbia River dams, U.S. Army Corps of Engineers (USACE) counts fish at viewing windows and designates jack Chinook Salmon as fish between 30 and 56 cm (12 and 22 inches) in total length. Salmonids under 30 cm (12 inches) in length are not identified to species. Mini-jacks are precocious salmon generally under 30 cm in length and thus are not counted (Steve Richards, WDFW, personal communication). Throughout this report, unless otherwise stated, adult Chinook Salmon refers to reproductively mature fish returning to spawn, including jacks but excluding mini-jacks less than 30 cm.

Additionally, the USACE defines the Chinook Salmon run type by calendar date. Any Chinook Salmon counted at the LGR window from March 1 to June 17 is considered spring run, June 18 to August 17 is considered summer run, and August 18 to December 31 is considered fall run. Fall-run Chinook Salmon passing LGR during the March 1 to August 17 time period are presented in this report for accounting purposes only and do not represent the entirety of the fall-run Chinook Salmon. For steelhead, the run year at LGR is defined to be from July 1 of the previous year to June 30 of the current year. The steelhead run year dates were chosen to be consistent with the upriver steelhead run year at Bonneville Dam as defined in the *U.S. v. Oregon* management agreement (Joint Columbia River Management Staff 2021). Most steelhead pass LGR in the fall but are assigned to their spawn year the following spring.

The goal of this report is to summarize the abundance and composition of wild adult steelhead and spring-summer Chinook Salmon returning to LGR during spawn year (SY) 2021. We also update the abundance trends for adult-to-adult productivity series for both species and the smolt-to-adult return (SAR) rate series for Chinook Salmon and steelhead last described by Baum et al. (2022). The objectives of this report are to:

1. Describe LGR adult trap operations and data collection during 2020–2021, which is the timeframe encompassing all steelhead and Chinook Salmon passing LGR for SY2021.
2. Estimate wild steelhead and Chinook Salmon escapement and age, sex, and size composition in aggregate and by genetic stock.
3. Evaluate wild steelhead and Chinook Salmon status using adult-to-adult productivity and replacement rates in aggregate and by genetic stock.
4. Estimate survival using SAR rate for the aggregate return of wild steelhead and Chinook Salmon.

METHODS

Adult Trap Operations at Lower Granite Dam

Systematic samples of adult steelhead and Chinook Salmon ascending LGR were collected during daily operation of the adult fish trap by National Marine Fisheries Service (NMFS). The trap is located in the LGR fish ladder upstream from the fish-counting window. The trap captured a systematic random sample of fish by operating a computerized trap gate according to a predetermined sample rate. The trap gate was opened four times per hour for a length of time directed by the programmed sample rate; the trap was operational 24 hours per day. The sample rate is determined based on sample size goals of the various projects using the adult trapping data combined with forecasted abundance of the targeted species, run, and rear type. Ideally, the

sample rate is apportioned equally across the entire sampling season. However, the trap did not operate during weekends from March 1 to August 17, and the trap rate was adjusted to continue achieving the sample rate goal by compensating for the two non-trapping weekend days. In-season adjustments to the sample rate were sometimes needed to accommodate limitations at the trapping facility, changes to the forecast, or sample size goal modifications. Additionally, high ($\geq 21^{\circ}\text{C}$ or $\geq 70^{\circ}\text{F}$) and low ($\leq 0^{\circ}\text{C}$ or $\leq 32^{\circ}\text{F}$) water temperatures require the trapping facility to temporarily modify or cease operations.

During SY2021, the trap was closed November 13, 2020 through March 1, 2021 for the winter (Appendix A-1). Outside the winter and weekend closures, daily trapping rates varied from 18 to 80%. For steelhead, 93.4% of the fish passed the window while the trap was open (Appendix A-2). The majority of the steelhead run crossed LGR in the fall of 2020, but a second small pulse occurred in mid-March and April 2021. For Chinook Salmon, 71.6% of the fish passed the window while the trap was open (Appendix A-3). More information about the trap logistics can be found in Harmon (2003), Steinhorst et al. (2010), and USACE (2020, 2021).

Standard methods were used by NMFS and IDFG staff to process and biologically sample fish at the trap. All fish captured were anesthetized; examined for external marks, tags, and injuries; scanned for a coded wire tag (CWT) or passive integrated transponder (PIT) tag; and measured for fork length (FL, nearest cm). Number of fish processed each day at the LGR trap in SY2021 ranged from two fish to 726 fish. Each fish was directly handled for a minimum of 15 seconds to a maximum of 1 minute and 15 seconds.

All fish were classified by origin (hatchery or wild) based on a hierarchical key of external marks and internal tags identified at LGR and after post hoc genetic analysis conducted in the laboratory (Appendix A-4). At the LGR trap, the presence or absence of an adipose fin was examined first. All fish considered to have a clipped adipose fin (absent or partial clip evident by a healed scar) were classified as ad-clipped hatchery fish. Although most hatchery steelhead and Chinook Salmon have a clipped adipose fin (hereafter ad-clipped), some were released with an unclipped adipose fin (hereafter ad-intact) for supplementation or broodstock management purposes. All ad-intact fish were subsequently scanned for CWT and examined for ventral fin clips or other external marks and tags. Any ad-intact fish with the presence of a CWT, ventral fin clip, or (for steelhead only) dorsal fin erosion were classified as ad-intact hatchery fish. The trap crew sampled fin tissue from all ad-intact fish; genotyping for parentage-based tagging (PBT) analysis was conducted post hoc to further classify ad-intact hatchery fish (Hargrove et al. 2020). In summary, final classification of hatchery fish was made using any of five marks or tags: adipose fin clip (complete removal or partial clip), CWT, ventral fin clip, dorsal or ventral fin erosion (steelhead only), or PBT. Information associated with previous PIT tagging events was not used to determine origin.

For all ad-intact fish, scale samples were taken from above the lateral line and posterior to the dorsal fin. Samples were stored in coin envelopes for transport to the IDFG Nampa Research Anadromous Ageing Laboratory (NRAAL). For all ad-intact fish, tissue samples for genetic analysis were taken from a small clip of the anal fin. Tissues were stored on a dry Whatman paper medium (LaHood et al. 2008) for transport to the IDFG Eagle Fish Genetics Laboratory (EFGL). All ad-intact fish captured were also PIT tagged (if not previously tagged) for abundance estimation at instream PIT detectors upstream of LGR (IPTDSW 2020; See et al. 2021). After processing, all fish were returned to the adult fish ladder to resume their upstream migration.

Trap Data Management

All data were entered into a NMFS cloud-based database via touch-screen computer systems located in the trap work area. Initiated in 2012, this system allowed interested parties to access the data they needed at the end of each day and eliminated transcription errors from paper data sheets to electronic form. The IDFG LGR SQL server database automatically queries the NMFS database daily to populate tables used by IDFG for reporting purposes. The IDFG LGR SQL server database also queries and combines all genetic data from the EFGL Progeny database and the ageing data from the NRAAL BioSamples database to the associated trap records.

Valid Sample Selection

Not all trapped fish were deemed valid by IDFG for sample selection or analysis. Trapped fish that were missing data for any of the following five fields were considered invalid: date of collection, species, FL, origin (hatchery or wild), or adipose fin status (ad-clipped or ad-intact). Trapped fish less than 30 cm FL were considered invalid as they are not identified to species at the USACE fish-counting window. Further, the trap was not designed to efficiently trap these smaller fish (Darren Ogden, NMFS, personal communication); for Chinook Salmon, this includes all mini-jacks less than 30 cm FL.

Our objective was to age and genotype approximately 2,000 wild steelhead and 2,000 wild Chinook Salmon. In collaboration with our work, a second objective was to PIT tag, age, and genotype approximately 4,000 wild steelhead and 4,000 wild Chinook Salmon to estimate abundance at instream PIT detectors. We emphasize that both objectives were complimentary and not mutually exclusive. Every ad-intact steelhead and Chinook Salmon trapped at LGR was genotyped to simplify collaborative logistics and to increase accuracy and precision of abundance estimates using genetic stock identification (GSI) and PBT. All valid samples from wild fish were systematically subsampled if more than approximately 2,000 samples were available for each species. The result was a pool of samples collected systematically across the spawning run of each species and generally in constant proportion to their abundance. Hence, for either species, the sample pool can be considered a daily systematic sample (Steinhorst et al. 2017).

Scale Processing, Analysis, and Age Validation

Technicians processed scale samples in the NRAAL according to protocols detailed in Wright et al. (2015). Ages were formatted using the European system where freshwater age was separated from saltwater age by a decimal. For steelhead repeat spawners, an 'R' is added to the saltwater age to designate the winter spent in freshwater while on the first spawning run (see Copeland et al. 2018 for ageing repeat spawners). Age classes are defined as the unique combinations of freshwater, saltwater, and repeat spawning ages. Brood year (BY) is the spawn year minus the total age at spawning (total age = freshwater age + saltwater age + 1). One year is added to scale age determinations for steelhead and Chinook Salmon where a visible annulus is not formed during growth but is assumed to have occurred. For steelhead, no visible annulus forms during the adult period of the lifecycle spent in freshwater over winter, when mineral deposits that form on scales are metabolized for gonadal and gamete growth (Persson et al. 1998; Witten and Huysseune 2009). For Chinook Salmon, no annulus forms during the first winter of juvenile development because they are still in the redd. Fish lacking either a freshwater or saltwater age were not used for analysis.

We validated wild fish saltwater age assignments with known saltwater ages from hatchery and wild fish PIT tagged as juveniles and hatchery fish with CWT. Accuracy of age assignments was estimated by percent agreement between saltwater age and known emigration date determined from juvenile PIT-tag detection in the hydrosystem. Known saltwater age fish were used to compute accuracy rates for steelhead and Chinook Salmon ages. Analysis of scales is sufficiently accurate to produce unbiased age compositions (Copeland et al. 2018; Reinhardt et al. 2022).

Genetics Tissue Processing and Analysis

Detailed methods for extraction of genomic DNA from tissue samples, DNA amplification, and single nucleotide polymorphism (SNP) genotyping are described in Vu et al. (2015) and Campbell et al. (2015). Briefly, samples were processed using “Genotyping-in-Thousands by sequencing” (GT-seq) protocols at either the EFGL in Eagle, Idaho, or the Columbia River Inter-Tribal Fish Commission’s genetics laboratory in Hagerman, Idaho. Steelhead were examined at a 368 SNP marker panel and Chinook Salmon were examined at a 343 SNP marker panel. Each panel contains SNPs for PBT, GSI, and sex-determination analysis.

Parentage-based tagging involves annual sampling and genotyping of hatchery broodstock that are used to create a database of parental genotypes. Subsequently, progeny of these genotyped parents (collected either as juveniles or adults) can be assigned back to their parents via parentage analysis. Parentage assignments were performed on all ad-intact adults returning to LGR to identify hatchery fish that were phenotypically wild (unclipped/unmarked) using the program SNPPIT (Anderson 2010, available at: <https://github.com/eriqande/snppit>). Since 2008, fin tissue has been sampled from nearly all adult steelhead and spring-summer Chinook Salmon broodstock spawned at Snake River hatcheries in Idaho, Oregon, and Washington (Delomas et al. 2020). The PBT project essentially “tags” all hatchery steelhead and spring-summer Chinook Salmon smolts released in the Snake River basin. This allows researchers to identify the exact parents of an individual, and thus its hatchery of origin and total age (Steele et al. 2013). Parentage Based Tagging is a critical tool to differentiate hatchery fish when no other physical tags (e.g., CWT and fin clips) are present and can significantly improve escapement estimates for wild Chinook Salmon and steelhead (Hargrove et al. 2021).

Genetic stock identification is a complimentary genetic technique to PBT that seeks to identify the source of origin of wild fish. Briefly, this technique involves genotyping wild fish sampled on the landscape and using these population-level allele frequencies to assign individual fish of unknown origin (adults sampled at LGR) to unique groups (referred henceforth as genetic stocks). Genotypes were analyzed against genetic baseline populations to assign each individual to the genetic stock in which the probability of its genotype occurring is the greatest. Vu et al. (2015) and Powell et al. (2018) provide a detailed description of the Snake River genetic baselines used for both steelhead and Chinook Salmon GSI analyses (Figure 1; Figure 2). Genetic stocks were assemblages of baseline populations grouped primarily by genetic and geographic similarities and secondarily by political boundaries and management units (Ackerman et al. 2012). Individuals were assigned to genetic stocks using the algorithms implemented in the Program R package rubias (Moran and Anderson 2019). An individual’s genetic stock was assigned as the stock with the maximum probability of membership.

Ten wild steelhead genetic stocks were used. The genetic stocks include: 1) UPSALM: upper Salmon River (including North Fork Salmon River and upstream); 2) MFSALM: Middle Fork Salmon River (including Chamberlain and Bargamin creeks); 3) SFSALM: South Fork Salmon River; 4) LOSALM: Little Salmon River and tributaries of the lower Salmon River; 5) UPCLWR:

upper Clearwater River (Lochsa and Selway rivers); 6) SFCLWR: South Fork Clearwater River (including Clear Creek); 7) LOCLWR: lower Clearwater River; 8) IMNAHA: Imnaha River; 9) GRROND: Grande Ronde River; and 10) LSSNAKE: tributaries of the lower Snake River both upstream (e.g., Alpowa and Asotin creeks) and downstream (primarily Tucannon River) of LGR. Some Tucannon River steelhead ascend the dam and either stay upriver to spawn or fall back and spawn downriver. Results from some genetic stocks are aggregated to report by Snake River steelhead MPGs (Table 1).

Seven wild Chinook Salmon genetic stocks were used. The genetic stocks include: 1) UPSALM: upper Salmon River (including North Fork Salmon River and upstream); 2) MFSALM: Middle Fork Salmon River; 3) CHMBLN: Chamberlain Creek; 4) SFSALM: South Fork Salmon River; 5) HELLSC: Hells Canyon stock, an aggregate genetic stock that includes the Clearwater, Little Salmon, lower Salmon, Grande Ronde, Imnaha, and lower Snake rivers; 6) TUCANO: Tucannon River; and 7) FALL: Snake River fall Chinook Salmon. Chinook Salmon populations in TUCANO can be distinguished from HELLSC in GSI analyses because they exhibit low levels of introgression with fall Chinook Salmon (Narum et al. 2010). The TUCANO genetic stock was included in the baseline to account for returning adults that originated from populations below LGR, but ascend the dam and either stay upriver to spawn or fall back and spawn downriver. Except for fall Chinook Salmon, these genetic stocks largely correspond to Snake River spring-summer Chinook Salmon MPGs (Table 1). The MFSALM and CHMBLN genetic stock results were aggregated to report the Middle Fork Salmon River MPG. Three collections of Snake River fall Chinook Salmon (Clearwater River, Nez Perce Tribal Hatchery, and Lyons Ferry Hatchery) were included in the baseline to distinguish fall Chinook Salmon trapped prior to August 18 from spring-summer Chinook Salmon using genetic data (Ackerman et al. 2014).

The resolution of the Snake River genetic baselines was evaluated in Vu et al. (2015). The GSI project continues to update the genetic baselines periodically in an effort to improve resolution. Further, the GSI project continues to develop methods and evaluate available tools to assess and improve the accuracy and precision of genetic stock proportion and abundance estimates. These efforts are reported separately in the annual progress reports for the GSI project (Hargrove et al. 2020).

Phenotypic sex was not, and generally cannot be, reliably determined by personnel at the LGR trap, as most adult anadromous fish typically do not exhibit sexually dimorphic characteristics at LGR. A sex-determination assay developed by Campbell et al. (2012) was used and included in the genotyping process. The accuracy of the sex-determination assays was evaluated in Steele et al. (2016). Further details can be found in Campbell et al. (2012).

Wild Escapement by Origin, Genetic Stock, Size, Sex, and Age

Total aggregate escapement of steelhead and Chinook Salmon in SY2021 were estimated using a new statistical model EASE (Estimating Adult Salmonid Escapement) developed by Thomas Delomas ([GitHub - delomast/escapeLGD: Escapement Estimation at Lower Granite Dam](https://github.com/delomast/escapeLGD); R Development Core Team 2021). The general process of EASE involves obtaining the total number of ascensions (nighttime and daytime ascensions combined), estimating the composition of ascensions (relative to stock groups; Figure 3), defining strata sets, then applying the stock-specific (upper or lower) fallback-reascension rates to the composition of ascensions to obtain the adjusted escapement estimates (hereafter referred to as total adjusted escapement). Uncertainty surrounding GSI is quantified between steps by bootstrapping. A more detailed description of EASE methods can be found in Appendix B-1.

To obtain total number of ascensions, EASE began with the USACE daily window counts, or counts of salmonids over 30 cm in length identified to species as they swim past the viewing window during counting hours. Before SY2021, the window counts, which occur in the fish ladder downstream of the trap, were assumed to be the daily aggregate escapement to LGR for each species. However, for EASE, the window counts were treated as a measure of the number of daytime ascensions (Appendix B-1, Daytime Ascensions, Nighttime Passage, and Total Number of Ascensions section). Window count data were downloaded from the Fish Passage Center (FPC) website: [Adult Daily Dam Counts - Data Query \(fpc.org\)](https://www.fpc.org/data/adult-daily-dam-counts). The total number of daytime ascensions was estimated by expanding the window counts for the sampling rate (historically $\frac{5}{6}$, or 50 minutes out of every hour). The counts were only performed during the daytime, therefore the frequency of nighttime ascensions (nighttime passage) also needed to be estimated (Appendix B-1, Daytime Ascensions, Nighttime Passage, and Total Number of Ascensions section). The proportion of ascensions occurring at night was estimated using PIT tag detections in the ladder and was used to estimate the total number of ascensions (Columbia River Data Access in Real Time [DART]; [DART PIT Tag Adult Lower Granite Ladder Window Count Hour Summary and Detection Details | Columbia Basin Research \[washington.edu\]](https://www.washington.edu/research/cbrd/dart/pit-tag-adult-lower-granite-ladder-window-count-hour-summary-and-detection-details)). After incorporating sampling rate and nighttime passage, the resulting estimate represents the total number of ascensions.

To estimate the composition of ascensions, the total number of ascensions were then decomposed into escapement estimates for reporting groups of interest with 90% confidence intervals (CI) so the fallback-reascension rates (proportion of fish that fell back below the dam and later reascended) can be proportionally applied (Appendix B-1, Fallback Rates and Composition of Ascensions sections). The total number of ascensions initially includes repeat ascensions, so the fallback-reascension rates were applied to the total number of ascensions after decomposition, assuming every fish that fell back reascended. Fallback-reascension rate was calculated separately for upper (upstream of LGR) and lower (downstream of LGR) stocks to account for differences in rates between the stocks. Fallback-reascension rates were also calculated using PIT tag detections from DART (excluding fish tagged as adults at LGR). The basic methods for estimating the composition of ascensions were developed by Delomas and Hess (2021) and implemented in the EASE R package ([GitHub - delomast/escapeLGD: Escapement Estimation at Lower Granite Dam](https://github.com/delomast/escapeLGD); R Development Core Team 2021). The EASE model combined the number of ascensions with the adult trap sample data on a temporally stratified basis to account for changes in the trapping rate and run characteristics through time. The spawn year for each species was divided into “statistical week” strata with each stratum defined as a week (starts on Monday and ends on Sunday) or a series of adjacent weeks with sufficient trap numbers ($n \geq 100$) to adequately estimate all proportions. In addition to the defined strata for composition estimates, two other sets of strata were defined for fallback-reascension and nighttime passage estimates through time. Criteria for these strata sets can be found in the Stratification section of Appendix B-1. Escapement by stratum was estimated by applying the strata-specific nighttime passage and fallback-reascension rates to the ascensions and then multiplying the ascensions by the trap proportions. The total adjusted escapement to LGR for the spawn year was the sum of escapement estimates from each stratum. In essence, the stratum proportions were weighted by stratum run size of all fish from each species. We assumed 1) the total number of ascensions represents true abundance; 2) fish pass LGR only by the ladder; 3) counts by species are accurate; 4) PIT-tagged fish represent the behavior of untagged fish in regards to fallback-reascension and nighttime passage; and 5) proportions are constant within each stratum.

The composition of ascensions decomposes total adjusted escapement into rearing type, primary, and secondary categories (Figure 3; Appendix B-1, Composition of Ascensions section). These are hierarchical and each category is nested within the previous category, thus point estimates of nested categories must sum to equal the parent category. First, the total adjusted escapement is decomposed into rearing type (ad-intact hatchery, ad-clipped hatchery, and wild). Fish from each rearing type are then divided into primary categories. Hatchery-reared fish (ad-clipped and ad-intact) are divided into primary size categories (large and small). Wild-reared fish are divided into primary categories by genetic stock and Major Population Group. Wild fish genetic stocks are then further decomposed into secondary categories (size, sex, brood year, saltwater age, and age class).

To obtain abundance estimates for each category of interest, the composition proportions were multiplied by the total number of ascensions. Escapement in each category was then calculated by multiplying the ascension estimates by $1 - p_f$, where p_f is the corresponding fallback rate for that category of interest. A small minority of hatchery steelhead groups are split between release sites and have ambiguous PBT groups, so PIT tag detections were used to split the composition estimate into separate release groups and assign the appropriate fallback-reascension rate (Appendix B-1, Non-specific PBT Groups section). To obtain estimates at higher levels (e.g., total number of wild fish), the estimates for the relevant categories are summed. A parametric bootstrap is used to find 90% CIs on the estimated abundance of wild (W), ad-clipped hatchery (H), and ad-intact hatchery (HNC). The parametric bootstrap uses the number of adults trapped in each stratum along with the three estimated multinomial proportions for W, H, and HNC in that stratum to produce bootstrap pseudo values for numbers of fish by rearing category. These are converted to pseudo proportions by stratum and multiplied by weekly ascensions to produce bootstrap estimates of totals by W, H, and HNC. The three bootstrap series of estimates are ordered and the fifth and ninety-fifth ordered values give the three one-at-a-time confidence intervals. All CIs are generated for the spawn year total rather than for individual strata.

Finally, for each stratum a two-way table of proportions was calculated for combinations of the primary and secondary variable categories. For each stratum these proportions are applied to estimated numbers of fish of the given rearing type and primary category to get estimates of numbers of fish for each level of the secondary category. That is, if one fixes a primary category, then the estimated number of fish of that primary category is decomposed into estimates for each of the secondary categories. Summing over primary categories, the resulting estimate of fish in each secondary category is constrained to sum to the total fish found in the primary categories. Each row of a table of proportions for fixed stratum and primary category was used to produce multinomial parametric bootstrap pseudo values for numbers of fish in each secondary category leading to confidence intervals for the corresponding estimates.

Additional steps were developed to adjust point estimates due to rounding error in the final output of data. First, all rear types must sum to the total adjusted escapement (Figure 3). If rear types do not sum to the total adjusted escapement, fish were added or subtracted from the rear type with the largest number of fish. Second, genetic stock estimates must sum to the wild fish estimate. If not, fish were added or subtracted from the genetic stock with the largest number of fish. The adjusted estimates for the genetic stocks were used to further adjust the MPG and composition estimates. Estimates for MPGs were adjusted to match the summation of corresponding genetic stocks (e.g., all CLWR genetic stocks combine to CLRWTR, all SALM genetic stocks combine to SALMON). For composition estimates (size, sex, age class), fish were added or subtracted from the group with the largest number of fish (e.g., male and female CHMBLN need to add up to the total genetic stock estimate for CHMBLN). For total age and saltwater age composition estimates within each genetic stock, estimates must sum to the

corresponding aggregation of age class composition estimates within each genetic stock. Fish were added or subtracted from each total age and saltwater age group to match the corresponding aggregation of age classes, (e.g., two-saltwater age CHMBLN must sum to the aggregated total estimate from age classes F1S2 and F2S2 for CHMBLN). After adjusting composition groups within each genetic stock, individual composition group estimates over all genetic stocks were summed to obtain aggregate estimates (e.g., male aggregate estimate is the sum of all male estimates from each genetic stock). All aggregate composition estimates must add up to the rear type estimate. In general, adjustments involved adding or subtracting fewer than five fish.

Reporting groups for each of the primary and secondary categories were defined based on criteria important for fishery management and monitoring and evaluation. Genetic stock encompassed the species-specific reporting groups (ten for steelhead and seven for Chinook Salmon) described in the Genetics Tissue Processing and Analysis section above. Sex included a male and a female reporting group. Age class, brood year, and saltwater age reporting groups vary in number based on the freshwater and saltwater age structure observed from scale samples of trapped fish during the spawn year. Lastly, size included two length-reporting groups (large, small); however, length cutoffs differ for each species. Large steelhead are greater than or equal to 78 cm FL (B-Index), whereas small steelhead are less than 78 cm FL (A-Index), for fisheries managed under the U.S. v. Oregon Management Agreement (Joint Columbia River Management Staff 2021). For Chinook Salmon, large fish are greater than or equal to 57 cm FL (24 inches total length) corresponding to adult-sized fish, whereas small fish are less than 57 cm FL corresponding to jack-sized fish. A linear regression equation for saltwater-caught Chinook Salmon in Southeast Alaska was used to convert the 24-inch (61 cm) total length cutoff to a FL equivalent of 57 cm (Conrad and Gutmann 1996).

Smolt-to-Adult Return Rate

To estimate the aggregate SAR rate for wild steelhead and Chinook Salmon, the age composition of adults at LGR was combined with estimates of emigrating wild smolt cohorts at LGR. Smolt production estimates for both species were acquired from Ebel et al. (2022). For steelhead, we continue the SAR series that began with smolt migration year (MY) 2010. Repeat spawning steelhead were not included in the SAR estimates because they were already accounted for on their maiden spawning migration. Furthermore, repeat spawners likely have different downstream survival rates than smolts. For Chinook Salmon, we continue the SAR series that began with MY1996. No smolt estimates were available for MY2020 due to COVID-19 closures; however, IDFG and FPC personnel are currently collaborating to develop the best approach to address the data gap implications.

To calculate a SAR for a particular smolt migration year, the sum of ocean returns from that cohort was divided by the estimate of wild smolts arriving at LGR, given by the equation

$$SAR_k = \frac{\sum_{l=1}^4 r_{k+l}}{S_k},$$

where SAR_k is the smolt-to-adult return rate of smolt migration year k ; r_{k+l} is the return from that cohort in year $k + l$; l is saltwater age; and S_k is the estimate of smolts migrating in year k . The maximum value of l was four because that was the maximum saltwater age observed for steelhead and spring-summer Chinook Salmon at LGR (Copeland et al. 2004). Formulas from Fleiss (1981) were used to estimate the 95% confidence limits on SAR values. The lower limit is given by

$$\frac{(2np + t_{\alpha/2}^2 - 1) - t_{\alpha/2} \sqrt{t_{\alpha/2}^2 - (2 + 1/n) + 4p(nq + 1)}}{2(n + t_{\alpha/2}^2)},$$

and the upper limit by

$$\frac{(2np + t_{\alpha/2}^2 + 1) + t_{\alpha/2} \sqrt{t_{\alpha/2}^2 + (2 + 1/n) + 4p(nq + 1)}}{2(n + t_{\alpha/2}^2)},$$

where n is the number of smolts, p is the SAR value as a proportion, q is 1-SAR, and $t_{\alpha/2}$ is 1.96.

RESULTS

Steelhead Escapement

The total escapement estimate of steelhead for SY2021 was 61,315 fish (60,515–62,214 90% CI) based on a window count of 59,126 fish (Table 2). The fallback-reascension rate for upper stock groups (upstream of LGR) was 3.89% (3.31–4.52 90% CI) and was 21.60% (15.95–27.48 90% CI) for lower stock groups (downstream of LGR). The overall nighttime passage rate for the entire run was 8.74% (7.79–9.77 90% CI). Of the 61,315 fish, the LGR trap captured 11,996 of them, of which 3,195 were valid wild fish (Appendix A-5). Our estimate of wild escapement was 15,478 fish (15,001–15,973 90% CI), which comprised approximately 25% of the total estimate (Table 2). The remaining 45,837 fish were of hatchery origin. We estimate ad-clipped hatchery escapement was 40,429 fish (39,754–41,154 90% CI) and ad-intact hatchery escapement was 5,408 fish (5,117–5,720 90% CI). External marks, internal tags, and genetics were used to determine that 12% of the total hatchery fish and 9% of the total steelhead run were ad-intact hatchery fish. Hatchery fish comprised 26% of the ad-intact steelhead.

Steelhead by Genetic Stock, Size, Sex, and Age

Relative abundance of wild steelhead by genetic stock varied greatly in SY2021 with the Grande Ronde highest at 30% and the Lower Salmon stock lowest at <3% (Appendix D-1). Escapement estimates for each genetic stock were as follows (Appendix D-2): UPSALM 1,911 (1,675–2,122 90% CI); MFSALM 950 (819–1,077 90% CI); SFSALM 457 (365–546 90% CI); LOSALM 401 (292–535 90% CI); UPCLWR 1,665 (1,509–1,837 90% CI); SFCLWR 1,526 (1,354–1,706 90% CI); LOCLWR 1,138 (946–1,356 90% CI); IMNAHA 988 (825–1,151 90% CI); GRROND 4,622 (4,281–4,982 90% CI); and LSNAKE 1,820 (1,518–2,153 90% CI).

Small steelhead dominated ad-clipped hatchery and wild runs for SY2021. Small wild steelhead escapement was 12,213 fish (11,744–12,620 90% CI), small ad-clipped hatchery steelhead at 26,248 fish (25,483–27,123 90% CI), and small ad-intact hatchery steelhead at 1,528 fish (1,366–1,691 90% CI). However, large steelhead (≥ 78 cm FL) were most abundant among the ad-intact hatchery fish. Large wild steelhead escapement was 3,265 fish (3,052–3,548 90% CI), large ad-clipped hatchery steelhead at 14,181 fish (13,467–14,850 90% CI), and large ad-intact hatchery steelhead at 3,880 fish (3,657–4,161 90% CI). Stock-specific estimates for wild fish by size are reported in Appendix D-2.

Wild steelhead were female-biased, and females accounted for 78% of the overall wild aggregate return to LGR (Appendix D-3). Female escapement was estimated at 12,031 fish (11,609–12,447 90% CI) and males at 3,447 fish (3,200–3,701 90% CI). Sex ratios for each genetic stock mirrored the aggregate wild run and ranged from 71% female for South Fork Clearwater River to 82% female for Middle Fork Salmon River (Appendix D-2).

Twenty different age classes were observed from the 2,085 wild fish that were assigned a genetic stock and a total age (Appendix D-4). Total age at spawning ranged from three to seven years with freshwater age ranging from one to four years and saltwater age ranging from zero to three years. Some steelhead returned as repeat spawners. Repeat spawning fish made up 0.6% of all wild steelhead crossing LGR. Repeat spawners were observed in most genetic stocks except for LOSALM, UPCLWR, and SFCLWR. The proportions of repeat spawners slightly varied across the other genetic stocks. Repeat spawners as a proportion of the run for each genetic stock ranged from 0.4% (SFSALM) to up to 1.2% (MFSALM).

For most genetic stocks of steelhead, age-5 fish (hatched in BY2016) was the dominant total age cohort, with the exception of Middle Fork Salmon and South Fork Salmon where age-6 fish (BY2015) were the dominant total age cohort (Appendix D-4). We estimated that 53 (23–88 90% CI) of the returning adults were age-3 fish (BY2018); 1,582 (1,411–1,769 90% CI) were age-4 fish (BY2017); 9,631 (9,215–10,049 90% CI) were age-5 fish (BY2016); 4,096 (3,822–4,387 90% CI) were age-6 fish (BY2015); and 116 (69–179 90% CI) were age-7 fish (BY2014).

The majority of the wild return (62%) emigrated to the ocean as two-freshwater fish and excluding repeat spawners, 90% returned as two-saltwater fish (Appendix D-5). Saltwater age estimates were 15 (0–35 90% CI) zero-saltwater fish (MY2020); 1,354 (1,201–1,528 90% CI) one-saltwater fish (MY2019); 13,988 (13,540–14,460 90% CI) two-saltwater fish (MY2018); 25 (0–53 90% CI) three-saltwater fish (MY2017); and 96 (51–151 90% CI) repeat spawning steelhead regardless of migratory year. Furthermore, two-saltwater fish made up the majority of returning steelhead in all ten genetic stocks (Appendix D-6). The mean fork lengths of one-saltwater and two-saltwater fish were less than the 78 cm FL threshold for large steelhead (Appendix D-7).

Readers accurately determined the saltwater age of 100% of the scale samples (n = 69) from known saltwater age steelhead collected during SY2021 (Appendix C-1). The known saltwater age sample was 12% one-saltwater and 88% two-saltwater. There were no three-saltwater fish, four-saltwater fish, or repeat spawners in the known saltwater age sample.

Steelhead Adult-to-Adult Productivity

Wild steelhead returning to LGR in SY2021 completed the BY2013 cohort necessary for an adult-to-adult productivity estimate. Brood year 2013 returned 7,889 adults from 23,143 parents resulting in an adult-to-adult productivity estimate of 0.34 recruits per spawner, which is well below the 1.0 recruits per spawner necessary for replacement (Figure 5). A preliminary estimate of adult-to-adult productivity for the BY2014 cohort also placed it below replacement. Although unlikely to change significantly, the estimate for BY2014 is preliminary and will be completed with the SY2022 return.

None of the genetic stocks had adult-to-adult productivity estimates that were above replacement (Figure 6). The recruits per spawner estimates for each stock were as follows: UPSALM 0.20, MFSALM 0.28, SFSALM 0.35, LOSALM 0.21, UPCLWR 0.62, SFCLWR 0.21, LOCLWR 0.18, IMNAHA 0.30, and GRROND 0.48. Estimates for LSNAKE were not included, because the fish from this stock recorded at LGR were only a proportion of the total returning

adults; therefore, productivity estimates for LSNAKE were not representative of the entire stock. Preliminary estimates of adult-to-adult productivity by genetic stock for BY2014 placed all genetic stocks below replacement. The estimates for BY2014 are preliminary and will be completed with the SY2022 return.

Steelhead Smolt-to-Adult Return Rate

This report continued the SAR series that began with smolt MY2010 (Table 3; Figure 7). With adult returns from SY2021, the SAR time series was completed for MY2010–2017. The most recently completed cohort, MY2017, returned 7,822 fish from 908,556 emigrants for a SAR estimate of 0.86% (0.84–0.86 95% CI). The 5-year geometric mean SAR was 1.62%.

Chinook Salmon Escapement

The total escapement estimate of Chinook Salmon for SY2021 was 46,429 fish (45,967–46,903 90% CI) based on a window count of 47,251 fish (Table 4). The overall fallback-reascension rate for the entire run was 3.49% (2.77–4.28 90% CI) and the overall nighttime passage rate was 1.79% (1.32–2.36 90% CI). Of the 46,429 fish, the LGR trap captured 10,104 of them, of which 1,995 were valid wild fish (Appendix A-6). Our estimate of wild escapement was 8,604 fish (8,318–8,929 90% CI), which comprised approximately 19% of the total estimate (Table 4). The remaining 37,825 fish were of hatchery origin. We estimate ad-clipped hatchery escapement was 34,655 fish (34,175–35,171 90% CI) and ad-intact hatchery escapement was 3,170 fish (2,958–3,361 90% CI). External marks, internal tags, and genetics were used to determine that 8% of the total hatchery fish and 7% of the total Chinook Salmon run were ad-intact hatchery fish. Hatchery fish comprised 27% of the ad-intact Chinook Salmon.

Chinook Salmon by Genetic Stock, Size, Sex, and Age

Relative abundance of wild Chinook Salmon by genetic stock varied greatly in SY2021 with the Hells Canyon stock highest at 35% and the Tucannon River stock lowest at approximately 0.2% (Figure 8; Appendix E-1). Escapement estimates for each genetic stock were as follows (Appendix E-2): UPSALM 1,655 (1,490–1,825 90% CI); CHMBLN 149 (100–198 90% CI); MFSALM 1,060 (927–1,205 90% CI); SFSALM 2,218 (2,014–2,427 90% CI); HELLSC 3,008 (2,797–3,238 90% CI); TUCANO 15 (0–39 90% CI); and FALL 499 (432–575 90% CI).

Large fish (≥ 57 cm FL) dominated wild, ad-clipped hatchery, and ad-intact hatchery Chinook Salmon returns. Large wild Chinook Salmon were estimated at 7,025 fish (6,730–7,329 90% CI), large ad-clipped hatchery Chinook Salmon at 26,721 fish (26,284–27,182 90% CI), and large ad-intact hatchery Chinook Salmon at 2,430 fish (2,233–2,588 90% CI). Small wild Chinook Salmon were estimated at 1,579 fish (1,436–1,740 90% CI), small ad-clipped hatchery Chinook Salmon at 7,934 fish (7,634–8,231 90% CI), and small ad-intact hatchery Chinook Salmon at 740 fish (647–842 90% CI). Stock-specific estimates for wild fish by size are reported in Appendix E-2.

Wild Chinook Salmon were male-biased, and males accounted for 61% of the overall wild aggregate return at LGR (Appendix E-3). Male escapement was estimated at 5,220 fish (4,975–5,456 90% CI) and females at 3,384 fish (3,190–3,588 90% CI). Sex ratios for all but one genetic stock mirrored the aggregate wild run and ranged from 58% male for Hells Canyon to 77% male for Chamberlain Creek (Appendix E-2). The exception was the Tucannon River stock, located downstream of LGR, with a sex ratio of 7% male to 93% female, based on a low sample size of four trapped Tucannon fish.

Nine different age classes were observed from the 1,832 wild fish that we assigned a genetic stock and a total age (Appendix E-4). Age at spawning ranged from two to six years with freshwater age ranging from one to two years and saltwater age ranging from zero (mini-jacks) to four years.

For all genetic stocks, age-4 fish (hatched in BY2017) was the dominant total age cohort (Appendix E-4). We estimated that 9 (0–21 90% CI) of the returning adults were age-2 fish (BY2019); 1,958 (1,807–2,103 90% CI) were age-3 fish (BY2018); 5,568 (5,324–5,825 90% CI) were age-4 fish (BY2017); 1,056 (941–1,172 90% CI) were age-5 fish (BY2016); and 13 (0–26 90% CI) were age-6 fish (BY2015).

The majority of the wild return (97%) emigrated to the ocean as one-freshwater fish and 65% returned as two-saltwater fish (Appendix E-5). Saltwater age estimates were 32 (14–54 90% CI) zero-saltwater mini-jacks (MY2021); 2,009 (1,847–2,157 90% CI) one-saltwater jacks (MY2020); 5,629 (5,369–5,879 90% CI) two-saltwater fish (MY2019); 929 (825–1,046 90% CI) three-saltwater fish (MY2018); and 5 (0–14 90% CI) four-saltwater fish (MY2017). Furthermore, two-saltwater fish made up the majority of returning Chinook Salmon in all seven genetic stocks (Appendix E-6). The mean FL of two-saltwater fish was greater than the 57-cm FL threshold for large Chinook Salmon (Appendix E-7).

Readers accurately determined the saltwater age of 94.6% of the scale samples (n = 56) from known saltwater age Chinook Salmon collected during SY2021 (Appendix C-2). The known saltwater age sample was 32% one-saltwater, 61% two-saltwater, and 7% three-saltwater. There were no four-saltwater fish in the known saltwater age sample.

Chinook Salmon Adult-to-Adult Productivity

Wild Chinook Salmon returning to LGR in SY2021 completed the BY2015 cohort necessary for an adult-to-adult productivity estimate. Brood year 2015 returned 4,134 adults from 23,409 parents resulting in an adult-to-adult productivity estimate of 0.18 recruits per spawner, which is well below the 1.0 recruits per spawner necessary for replacement (Figure 9). A preliminary estimate of adult-to-adult productivity for the BY2016 cohort also placed it below replacement. Although unlikely to change significantly, the estimate for BY2016 is preliminary and will be completed with the SY2022 return.

Adult-to-adult productivity estimates were below replacement for all genetic stocks. Recruits per spawner of each genetic stock were as follows: UPSALM 0.12; CHMBLN 0.10; MFSALM 0.09; SFSALM 0.27; and HELLSC 0.18 (Figure 10). Estimates for TUCANO and FALL stocks were not included, because the fish from these stocks recorded at LGR were only a proportion of the total returning adults; therefore, productivity estimates for these two stocks were not representative of the entire stock. Preliminary estimates of adult-to-adult productivity by genetic stock for BY2016 also placed all genetic stocks below replacement. The estimates for BY2016 are preliminary and will be completed with the SY2022 return.

Chinook Salmon Smolt-to-Adult Return Rate

This report continued the SAR series that began with smolt migration year 1996 (Table 5; Figure 11). With adult returns from SY2021, the SAR time series was completed for MY1996–2017. The most recently completed cohort, MY2017, returned 4,113 fish from 1,171,926 yearling emigrants for a SAR estimate of 0.35 (0.34–0.66 95% CI). The 10-year geometric mean SAR was 1.32% and the 5-year geometric mean SAR was 0.85%.

DISCUSSION

Abundance of returning SY2021 summer steelhead and Chinook Salmon estimated at Lower Granite Dam were relatively low compared to previous years' estimates. For steelhead, overall escapement (all rear types combined) in SY2021 was the third lowest on record going back to at least SY1998 and shows a declining 5-year trend (Table 2). Hatchery steelhead escapement was also the third lowest on record, and wild steelhead escapement was below 20,000 fish. Abundance of wild steelhead was below IDFG's "healthy and harvestable" escapement goals and NMFS' minimum abundance thresholds (NMFS 2017; IDFG 2019; Columbia Basin Partnership Task Force 2020). Wild steelhead escapement was less than 17% of the proposed escapement goal of 104,500 fish, and about 75% of NMFS' minimum abundance threshold of 21,000 fish, to the Snake River basin (NMFS 2017; IDFG 2019; Columbia Basin Partnership Task Force 2020). Fortunately, overall steelhead abundance increased compared to SY2020, and for eight of the ten of wild stocks, escapement estimates increased significantly, as evidenced by non-overlapping 90% CIs (Figure 4). The remaining two genetic stocks, Upper Salmon and Lower Snake, did not change statistically from last year. Despite recent increases in abundance, the 5-year trend in point estimates still shows a continued decline for the majority of wild steelhead stocks. For Chinook Salmon, overall escapement (all rear types combined) in SY2021 was the ninth lowest on record going back to at least SY1998 and shows a declining 5-year trend (4). Hatchery Chinook Salmon escapement was also the ninth lowest on record, and wild Chinook Salmon escapement was below 10,000 fish. Abundance of wild Chinook Salmon was below IDFG's "healthy and harvestable" escapement goals and NMFS' minimum abundance thresholds (NMFS 2017; IDFG 2019; Columbia Basin Partnership Task Force 2020). Wild Chinook Salmon escapement was less than 8% of the proposed escapement goal of 127,000 fish, and less than 33% of NMFS' minimum abundance threshold of 31,500 fish, to the Snake River basin (NMFS 2017; IDFG 2019; Columbia Basin Partnership Task Force 2020). Fortunately, overall Chinook Salmon abundance increased compared to SY2020; however, this trend was mostly attributed to an increase in hatchery fish because wild escapement estimates decreased for five of the seven stocks (Figure 8). Despite recent decreases in wild abundance, the 5-year trend in point estimates actually showed a slight increase for the majority of wild Chinook Salmon stocks.

Regardless of abundance, low adult-to-adult productivity estimates are a major cause for concern because steelhead and Chinook Salmon populations with productivities far below one recruit per spawner (replacement) are at risk of severe population declines or extirpation. In both species, overall adult-to-adult productivities have shown a steady declining trend below replacement in the recently completed brood year cohorts (Figure 5; Figure 9). Additionally, stock-specific adult-to-adult productivities have been declining below replacement since BY2011 (Figure 6; Figure 10). In the most recently completed brood year cohorts, all genetic stocks of both species (except Upper Clearwater steelhead) showed productivities below 0.5 recruits per spawner. Small stocks with dwindling productivities are particularly the most vulnerable to extirpation, and their extinction would be a big loss for the overall genetic diversity of both species in the Snake River basin.

Adult-to-adult productivity is directly linked to smolt-to-adult return rates, which have also remained below recovery goals. For both steelhead and Chinook Salmon, SARs of the most recently completed brood year cohorts as well as the 5- and 10- year geometric means were all below the NPCC fish and wildlife program objective to achieve a range of 2–6% (minimum of 2%; mean of 4%; NPCC 2014, 2020; Figure 7; Figure 11). Estimated Chinook Salmon SARs in the

past using our analysis have been slightly higher but closely track the estimates provided by the Comparative Survival Study (CSS; McCann et al. 2015). Smolt-to-adult returns rates are affected by environmental conditions, predation, and other factors that vary across years, but are also directly influenced by the marine environment and passage conditions at hydropower dams during smolt outmigration (Petrosky et al. 2020). Although ocean conditions are becoming increasingly variable and unfeasible to regulate, managers may be able to improve SARs by altering passage conditions at hydropower dams. For example, managers have designed flex-spill operations at LGR that may prove beneficial for outmigrating smolts.

Continuous monitoring of population metrics, such as size and age, is essential for adaptive management and tracking trends over time. Steelhead fisheries in the Columbia and Snake rivers are partially constrained by the abundance of large steelhead, often called B-run steelhead in fisheries regulations, counted at Bonneville and Lower Granite dams. B-run steelhead are defined as fish ≥ 78 cm FL and are often associated with a two-saltwater age. A-run steelhead (< 78 cm FL) can also have two-saltwater fish returning, but are typically smaller in size than the B-run dominated stocks. Large steelhead (≥ 78 cm FL) abundance increased significantly from SY2020 to SY2021 for hatchery, hatchery ad-clipped, and wild runs (Table 2). Interestingly, total two-saltwater wild steelhead returns in SY2021 were also the highest they have been in the past five years (Appendix D-5). However, the mean length-at-age for two-saltwater steelhead was below the length cutoff for the B-run size classification. In SY2021, two-saltwater returns were on average 1.5 cm larger than SY2020 two-saltwater fish, but still 6 cm smaller than the 78 cm length requirement for large fish (Appendix D-7). The reduced FL-at-age is not novel or restricted to this spawn year, but a continuation of a developing trend, and poor growth and survival in the ocean may be a contributing factor (Bowersox et al. 2019). The depressed returns of populations that typically produce larger two- and three-saltwater fish, particularly, the Upper Clearwater, South Fork Clearwater, Middle Fork Salmon, and South Fork Salmon river wild populations and the Dworshak hatchery stock, may have contributed to the apparent return of smaller steelhead. The declining average FL of two-saltwater steelhead poses a challenge to fisheries managers because it has impacted fishing regulations and public perception of fewer returning B-run steelhead (Copeland et al. 2017; Bowersox et al. 2019). It is also important to recognize that size and age trends likely behave differently between A-run dominant and B-run dominant stocks; therefore, fisheries managers must be cautious in their data interpretation and instead look at stock-specific trends to better inform their conclusions.

We observed some changes in Chinook Salmon age composition in SY2021 compared to previous years. The number of returning wild jacks and hatchery jacks in SY2021 increased compared to last year. This is encouraging, as it suggests an improvement in two-saltwater returns is on the horizon for next year. We also observed a slight increasing trend in wild jacks over the past five years (Table 4).

In this report, we omitted the productivity estimates for three genetic stocks that are not complete for the entirety of that stock. In other words, the estimates represented only a portion of the stock population that could be accounted for at LGR. A genetic stock can have an incomplete estimate in two ways. The first way is that the genetic stock, wholly or partially, contains populations that originate downstream of LGR. The LSNKE (steelhead) and TUCANO (Chinook Salmon) stocks contain the Tucannon River population which are downstream of LGR. Some returning adults that are born in the Tucannon River overshoot their natal stream and stray upstream of LGR (Boggs et al. 2004; Richins and Skalski 2018). Without abundance information from the Tucannon River for each species, estimates for the LSNKE and TUCANO should be considered minimum returns to the Snake River basin. The second way is that a genetic stock overlaps run designations defined by USACE calendar dates. The FALL (Chinook Salmon)

genetic stock reported here only includes fall-run Chinook Salmon that cross LGR during the spring-summer Chinook Salmon run timing (March 1–August 17). The vast majority of the FALL genetic stock cross LGR after August 17. However, by accounting for FALL Chinook Salmon trapped on August 17 and earlier, we get a better estimate of the true spring-summer stocks returning to the Snake River. Additionally, preliminary evidence from PIT tags suggests a small amount (<30 PIT-tagged fish in any given year) of spring-summer Chinook Salmon cross LGR after August 17. However, quantifying abundances of spring-summer Chinook Salmon during the USACE fall-run timing designation is not within the scope of this report. Reporting estimates from the incomplete genetic stocks is mainly for accounting purposes and inferences should not be made using the associated results. The inclusion of these stocks provides critical information for a more refined decomposition of the aggregate run at LGR into desired reporting groups.

The newly developed EASE model estimated escapement of steelhead and Chinook Salmon at LGR by utilizing the same basic principles of previous methods, but combining their strengths and addressing biases (steelhead run reconstruction [Stark et al. 2021], fall Chinook run reconstruction [Steinhorst et al. 2010], SCOBIR [Steinhorst et al. 2017], STADEM [See et al. 2021]). Prior to this report, wild (and hatchery) escapement estimates were previously based on unadjusted window counts (i.e. the counts were treated as a complete census). However, there were a couple of potential biases when estimating total adult escapement at LGR using unadjusted window counts. First, some returning fish were known to fallback downstream of LGR after successfully crossing to the upstream side. The fallback fish that re-ascend the LGR ladder were essentially counted twice at the window. Second, the window was not counted 24 hours a day throughout the season; therefore, the daily counts did not include nighttime passage (USACE 2020, 2021). The EASE model is fundamentally similar to the previously implemented SCOBIR package; however, it incorporates fallback/reascension with group-specific rates and estimates nighttime passage rates to inform the total daily counts. Window counts are a critical component of the ESA listing and have been used for decades to evaluate population performance in the hydrosystem; therefore, the adjusted EASE escapement estimates are still directly related to and maintain a transparent relationship with window count data. Window counts at LGR are still reported in Table 2. EASE also provides a measure of GSI uncertainty when assigning stocks and does not utilize the number of trapped fish to inform the total number of fish that ascended the ladder. Accounting for all the aforementioned issues increases the value of the series to address multiple management and assessment needs.

This report provides valuable basin-wide escapement information for assessing the status of Snake River summer steelhead and spring-summer Chinook Salmon. We summarized the abundance and composition of wild adult steelhead and Chinook Salmon returning to LGR during SY2021. We estimated wild steelhead and Chinook Salmon escapement and age, sex, and size composition in aggregate and by genetic stock. We also updated the adult-to-adult productivity series and the SAR series for both species. We noted an overall declining trend in wild steelhead abundance and a slight increasing trend in wild Chinook Salmon abundance over the past five years. We also observed overall declining trends in productivity and smolt-to-adult return rates for both species over the past five years.

TABLES

Table 1. Major population groups and independent populations within the Snake River steelhead distinct population segment (DPS) and spring-summer Chinook Salmon evolutionary significant unit (ESU; ICBTRT 2003, 2005, 2009; Ford 2011, 2015; NMFS 2016). Extirpated populations are shaded.

Snake River steelhead DPS	
Major population group	Population name
Lower Snake River	1. Tucannon River 2. Asotin Creek
Grande Ronde River	3. Lower Grande Ronde River 4. Joseph Creek 5. Wallowa River 6. Upper Grande Ronde River
Imnaha River	7. Imnaha River
Clearwater River	8. Lower Clearwater River
	9. North Fork Clearwater River (extirpated)
	10. Lolo Creek
	11. Lochsa River
	12. Selway River
Salmon River	13. South Fork Clearwater River
	14. Little Salmon River
	15. Chamberlain Creek
	16. South Fork Salmon River
	17. Secesh River
	18. Panther Creek
	19. Lower Middle Fork Salmon River
	20. Upper Middle Fork Salmon River
	21. North Fork Salmon River
	22. Lemhi River
	23. Pahsimeroi River
	24. East Fork Salmon River
25. Upper Salmon River	
Hells Canyon Tributaries (extirpated)	

Table 1. Continued.

Snake River spring-summer Chinook Salmon ESU	
Major population group	Population name
Lower Snake River	1. Tucannon River
	2. Asotin Creek (extirpated) ^a
Grande Ronde/Imnaha Rivers	3. Wenaha River
	4. Lostine River
	5. Minam River
	6. Catherine Creek
	7. Upper Grande Ronde River
	8. Imnaha River
	9. Big Sheep Creek (extirpated) ^a
	10. Lookingglass Creek (extirpated) ^a
South Fork Salmon River	11. Little Salmon River
	12. South Fork Salmon River
	13. Secesh River
	14. East Fork South Fork Salmon River
Middle Fork Salmon River	15. Chamberlain Creek
	16. Lower Middle Fork Salmon River
	17. Big Creek
	18. Camas Creek
	19. Loon Creek
	20. Upper Middle Fork Salmon River
	21. Sulphur Creek
	22. Bear Valley Creek
	23. Marsh Creek
Upper Salmon River	24. North Fork Salmon River
	25. Lemhi River
	26. Upper Salmon River Lower Mainstem
	27. Pahsimeroi River
	28. East Fork Salmon River
	29. Yankee Fork Salmon River
	30. Valley Creek
	31. Upper Salmon River Upper Mainstem
	32. Panther Creek (extirpated) ^a
	Dry Clearwater River (extirpated) ^a
34. Lapwai Creek (extirpated) ^a	
35. Lawyer Creek (extirpated) ^a	
36. Upper South Fork Clearwater River (extirpated) ^a	
Wet Clearwater River (extirpated) ^a	37. Lower North Fork Clearwater River (extirpated)
	38. Upper North Fork Clearwater River (extirpated)
	39. Lolo Creek (extirpated) ^a
	40. Lochsa River (extirpated) ^a
	41. Meadow Creek (extirpated) ^a
	42. Moose Creek (extirpated) ^a
	43. Upper Selway River (extirpated) ^a

^a Reintroduced fish exist in extirpated areas except the North Fork Clearwater River basin upstream of Dworshak Dam.

Table 2. Estimated annual escapement, by fish size and origin, of steelhead, spawn years 1998–2021. Large fish were greater than or equal to 78 cm fork length (FL) and small fish were less than 78 cm FL. Ad-clipped and ad-intact refer to the adipose fin. Estimates from 1998–2020 were generated by IDFG and are the USACE window counts decomposed using adult trap data (Alan Byrne, IDFG, personal communication; Camacho et al. 2017, 2018a, 2019a; Lawry et al. 2020; Baum et al. 2022). Spawn year 2021 estimates were generated by IDFG using the USACE window counts and adult trap data in EASE (present study).

Spawn year ^(a)	EASE escapement estimate	LGR window count	Estimated number of steelhead at LGR that were:							
			Large wild	Large hatchery ad-clipped	Large hatchery ad-intact	Small wild	Small hatchery ad-clipped	Small hatchery ad-intact	Total hatchery	Total wild
1998	-	86,646	1,325	10,878	0	7,424	67,019	0	77,897	8,749
1999	-	70,662	2,301	17,455	0	7,074	43,832	0	61,287	9,375
2000	-	74,051	914	8,834	0	10,184	54,119	0	62,953	11,098
2001	-	117,302	2,886	17,128	0	17,689	79,589	10	96,727	20,575
2002	-	268,466	3,174	30,677	0	37,545	191,091	5,979	227,747	40,719
2003	-	222,176	13,623	51,358	6,618	28,308	110,535	11,734	180,245	41,931
2004	-	172,510	7,254	23,058	2,132	21,892	106,334	11,840	143,364	29,146
2005	-	151,646	4,774	23,179	2,005	18,297	94,225	9,166	128,575	23,071
2006	-	158,165	3,544	26,143	3,345	14,586	96,644	13,903	140,035	18,130
2007	-	149,166	1,633	33,332	5,880	7,877	85,210	15,234	139,656	9,510
2008	-	155,142	2,924	20,513	3,446	11,242	102,374	14,643	140,976	14,166
2009	-	178,870	5,659	40,713	6,998	18,216	94,205	13,079	154,995	23,875
2010	-	323,382	4,529	16,555	2,700	38,210	231,003	30,385	280,643	42,739
2011	-	208,296	9,584 ^(b)	31,574	4,118 ^(b)	34,549 ^(b)	110,750	17,721 ^(b)	164,163	44,133
2012	-	180,320	4,198	17,801	2,113	35,240	113,038	7,930	140,882	39,438
2013	-	109,186	3,337	13,695	3,970	19,806	63,611	4,767	86,043	23,143
2014	-	108,154	1,885	5,546	1,593	23,470	70,332	5,328	82,799	25,355
2015	-	165,591	6,928	21,067	3,639	38,861	89,341	5,755	119,802	45,789
2016	-	136,150	3,130	8,465	1,408	30,806	88,296	4,045	102,214	33,936
2017	-	101,826	3,001	25,724	4,145	12,575	52,825	3,556	86,250	15,576
2018	-	74,097	263	3,845	539	10,454	56,738	2,258	63,380	10,717
2019	-	51,818	1,232	13,119	2,223	7,055	26,776	1,413	43,531	8,287
2020	-	34,410	400	2,194	871	9,234	20,259	1,452	24,776	9,634
2021 ^(c)	61,315	59,126	3,265	14,181	3,880	12,213	26,248	1,528	45,837	15,478

^a Steelhead at Lower Granite Dam are considered fish passing July 1 through June 30; most steelhead pass the dam in the fall but are assigned to their spawn year the following spring.

^b Spawn year 2011 was the first year of adult Parentage Based Tagging returns used to adjust wild and hatchery ad-intact fish estimates.

^c Escapement estimates using EASE model began in SY2021. EASE estimate does not exactly match the LGR window counts. Decomposition estimates add up to EASE escapement estimate, not the LGR window count.

Table 3. Estimated number of wild steelhead smolts, number of returning adults by saltwater age, and percent smolt-to-adult return (% SAR) rate at Lower Granite Dam. Scale samples were used for all smolt migration years. Repeat spawners (shaded) were not used to estimate SARs. Included in parentheses are 95% confidence intervals for SARs.

Smolt migration year	Estimated number of smolts ^(a)	Adults returning to Lower Granite Dam by saltwater age			Repeat spawners	% SAR (95% CI)
		1	2	3		
2005	n/a	n/a	n/a	902	n/a	n/a
2006	n/a	n/a	12,129	869	270	n/a
2007	n/a	10,844	16,404	252	441	n/a
2008	n/a	25,175	32,096	345	643	n/a
2009	n/a	11,360	24,538	157	555	n/a
2010	851,481	14,051	14,596	317	386	3.40 (3.36–3.44)
2011	911,602	7,785	7,750	364	278	1.74 (1.72–1.77)
2012	890,665	16,936	30,450	124	484	5.33 (5.29–5.38)
2013	792,037	14,482	21,839	121	222	4.60 (4.56–4.65)
2014	816,219	11,598	13,499	71	124	3.08 (3.05–3.12)
2015	669,442	1,706	2,040	30	257	0.56 (0.54–0.58)
2016	805,433	8,498	4,169	53	48	1.58 (1.55–1.61)
2017	908,556	3,804	3,993	25	96	0.86 (0.84–0.88)
2018 ^(b)	949,098	5,511	13,988	-	-	2.05 (2.03–2.08)
2019 ^(c)	845,815	1,354	-	-	-	0.16 (0.15–0.17)

^a Smolt abundance for 2010–2019 derived from SCRAPI program (Camacho et al. 2018b, 2019b; Ebel et al. 2022).

^b Preliminary SAR until saltwater age-3 is added (SY2022).

^c Preliminary SAR until saltwater age-2 and age-3 are added (SY2023).

Table 4. Estimated annual escapement, by origin and saltwater age, of Chinook Salmon, spawn years 1998–2021. Jacks were one-saltwater age and include zero-saltwater age mini-jacks; adults were two-saltwater age and older. Estimates from 1998–2020 were generated by IDFG and are the USACE window counts decomposed using adult trap data (Alan Byrne, IDFG, personal communication; Camacho et al. 2017, 2018a, 2019a; Lawry et al. 2020; Baum et al. 2022). Spawn year 2021 estimates were generated by IDFG using adult trap data in EASE (present study).

Spawn year ^(a)	EASE escapement estimate	LGR window count	Estimated number of Chinook Salmon at Lower Granite Dam that were:								
			Wild adults ^(b)	Wild jacks ^(b)	Total wild	Hatchery adults ^(b)	Hatchery jacks ^(b)	Total hatchery	Total adults ^(b)	Total jacks ^(b)	
1998	-	14,646	5,378	122	5,500	8,831	315	9,146	14,209	437	
1999	-	10,647	2,695	236	2,931	3,861	3,855	7,716	6,556	4,091	
2000	-	51,835	7,347	1,500	8,847	30,414	12,574	42,988	37,761	14,074	
2001	-	192,632	37,063	1,621	38,684	148,630	5,318	153,948	185,693	6,939	
2002	-	101,226	27,743	340	28,083	69,441	3,702	73,143	97,184	4,042	
2003	-	99,463	29,270	2,349	31,619	57,761	10,083	67,844	87,031	12,432	
2004	-	86,501	16,808	982	17,790	62,701	6,010	68,711	79,509	6,992	
2005	-	35,100	8,691	386	9,077	25,118	905	26,023	33,809	1,291	
2006	-	31,223	8,775	292	9,067	21,312	844	22,156	30,087	1,136	
2007	-	42,551	7,694	1,114	8,808	21,034	12,709	33,743	28,728	13,823	
2008	-	88,776	14,046	2,333	16,379	53,027	19,370	72,397	67,073	21,703	
2009	-	111,580	12,963	3,454	16,417	45,477	49,686	95,163	58,440	53,140	
2010	-	134,684	26,281	1,368	27,649	97,273	9,762	107,035	123,554	11,130	
2011	-	134,594	22,407	4,176	26,583	69,636	38,375	108,011	92,043	42,551	
2012	-	84,771	20,298	1,242	21,540	59,221	4,010	63,231	79,519	5,252	
2013	-	70,966	12,407	6,856	19,263	30,556	21,147	51,703	42,963	28,003	
2014	-	114,673	26,351	3,987	30,338	65,415	18,920	84,335	91,766	22,907	
2015	-	132,432	21,499	1,910	23,409	96,163	12,860	109,023	117,662	14,770	
2016	-	81,753	15,939	813	16,752	58,187	6,814	65,001	74,126	7,627	
2017	-	48,192	4,108	1,685	5,793	30,180	12,219	42,399	34,288	13,904	
2018	-	42,232	6,863	519	7,382	31,820	3,030	34,850	38,683	3,549	
2019	-	29,617	4,152	1,010	5,162	19,528	4,927	24,455	23,680	5,937	
2020 ^(c)	-	34,786	8,565	1,209	9,774	21,564	3,448	25,012	30,129	4,657	
2021 ^(d)	46,429	47,251	6,563	2,041	8,604	29,252	8,573	37,825	35,815	10,614	

^a Spring-summer Chinook Salmon at Lower Granite Dam are considered fish passing March 1 through August 17.

^b For spawn years 2005–2019 (unshaded), the wild vs. hatchery and adults vs. jacks splits were estimated using scale samples, other biological data, and starting in 2011 parentage based tagging (PBT) samples collected at the LGR adult trap. Due to COVID-19 trap closures in SY2020, few scale samples were taken, so adults and jacks were estimated using length at the LGR counting window (adult ≥57 cm FL; jack <57 cm FL). For spawn years 1998–2004 (shaded gray), the splits were estimated using fin ray samples collected on the spawning grounds and biological samples collected at the adult trap.

^c Window count, total adult, and total jack numbers for SY2020 are from actual LGR window count data. All other SY2020 estimates were calculated using run reconstruction methods described in Baum et al. (2022).

^d Escapement estimates using EASE model began in SY2021. EASE estimate does not exactly match the LGR window counts. Decomposition estimates add up to EASE escapement estimate, not the LGR window count.

Table 5. Estimated number of wild Chinook Salmon smolts, number of returning adults by saltwater age, and percent smolt-to-adult return (% SAR) rate at Lower Granite Dam. Fin ray samples were used to estimate age composition for adults returning from smolt migration years 1996–2004 (above the dashed line) whereas scale samples were used in smolt migration year 2005 and after (below the dashed line). SAR 95% confidence intervals are in parentheses.

Smolt migration year	Estimated number of smolts ^(a)	Adults returning to Lower Granite Dam by saltwater age					% SAR (95% CI)
		0 ^(b)	1	2	3	4	
1996	419,826	n/a	n/a ^(c)	628	451	0	0.26 (0.24–0.27)
1997	161,157	n/a	122	2,162	409	23	1.69 (1.62–1.75)
1998	599,159	n/a	236	6,938	1,056	281	1.42 (1.39–1.45)
1999	1,560,298	n/a	1,500	35,984	12,455	481	3.23 (3.20–3.26)
2000	1,344,382	n/a	1,621	15,007	22,724	43	2.93 (2.90–2.96)
2001	490,534	n/a	340	6,065	1,799	53	1.68 (1.65–1.72)
2002	1,128,582	n/a	2,349	14,966	2,739	24	1.78 (1.75–1.80)
2003	1,455,786	n/a	982	5,899	1,886	10	0.60 (0.59–0.62)
2004	1,517,951	n/a	351	6,865	3,903	27	0.73 (0.72–0.75)
2005	1,734,464	35	280	3,781	2,703	22	0.39 (0.38–0.40)
2006	1,227,474	12	1,104	11,316	2,937	0	1.25 (1.23–1.27)
2007	787,150	10	2,306	10,004	1,368	0	1.74 (1.71–1.77)
2008	856,556	27	3,431	24,914	7,658	59	4.21 (4.17–4.26)
2009	894,629	23	1,344	14,751	6,258	14	2.50 (2.47–2.54)
2010	1,268,659	23	3,985	13,980	4,523	0	1.77 (1.75–1.80)
2011	1,184,839	189	1,194	7,870	1,408	0	0.90 (0.88–0.92)
2012	1,674,268	49	6,780	24,942	2,866	27	2.07 (2.05–2.09)
2013	1,006,960	76	3,921	18,633	5,709	33	2.82 (2.79–2.85)
2014	1,406,596	67	1,894	10,203	1,258	0	0.95 (0.94–0.97)
2015	525,743	16	766	2,817	333	5	0.75 (0.73–0.77)
2016	1,424,036	47	1,651	6,530	956	0	0.64 (0.63–0.66)
2017	1,171,926	34	490	3,191	393	5	0.35 (0.34–0.36)
2018 ^(d)	1,437,312	29	992	8,172	929	-	0.70 (0.68–0.73)
2019 ^(e)	794,695	18	1,209	5,629	-	-	0.86 (0.83–0.89)
2020	n/a ^(f)	0	2,009	-	-	-	-
2021	n/a ^(g)	32	-	-	-	-	-

^a Smolt abundance for 2010–2019 derived from SCRAPI program (Camacho et al. 2018b, 2019b; Ebel et al. 2022).

^b Mini-jack (zero-saltwater age) samples were not sampled on the spawning grounds, thus mini-jack fin rays are not available for smolt migration years 1996–2004; only mini-jacks ≥ 30 cm FL, were sampled for scales at Lower Granite Dam for smolt migration years 2005–2019.

^c Jack (saltwater age-1) fin ray samples were not collected on the spawning grounds and are not available (n/a) for smolt migration year 1996.

^d Preliminary SAR until saltwater age-4 is added (SY2022).

^e Preliminary SAR until saltwater age-3 and age-4 are added (SY2023).

^f MY2020 smolt estimate not available due to COVID-19 closures.

^g MY2021 smolt estimate not yet analyzed.

FIGURES

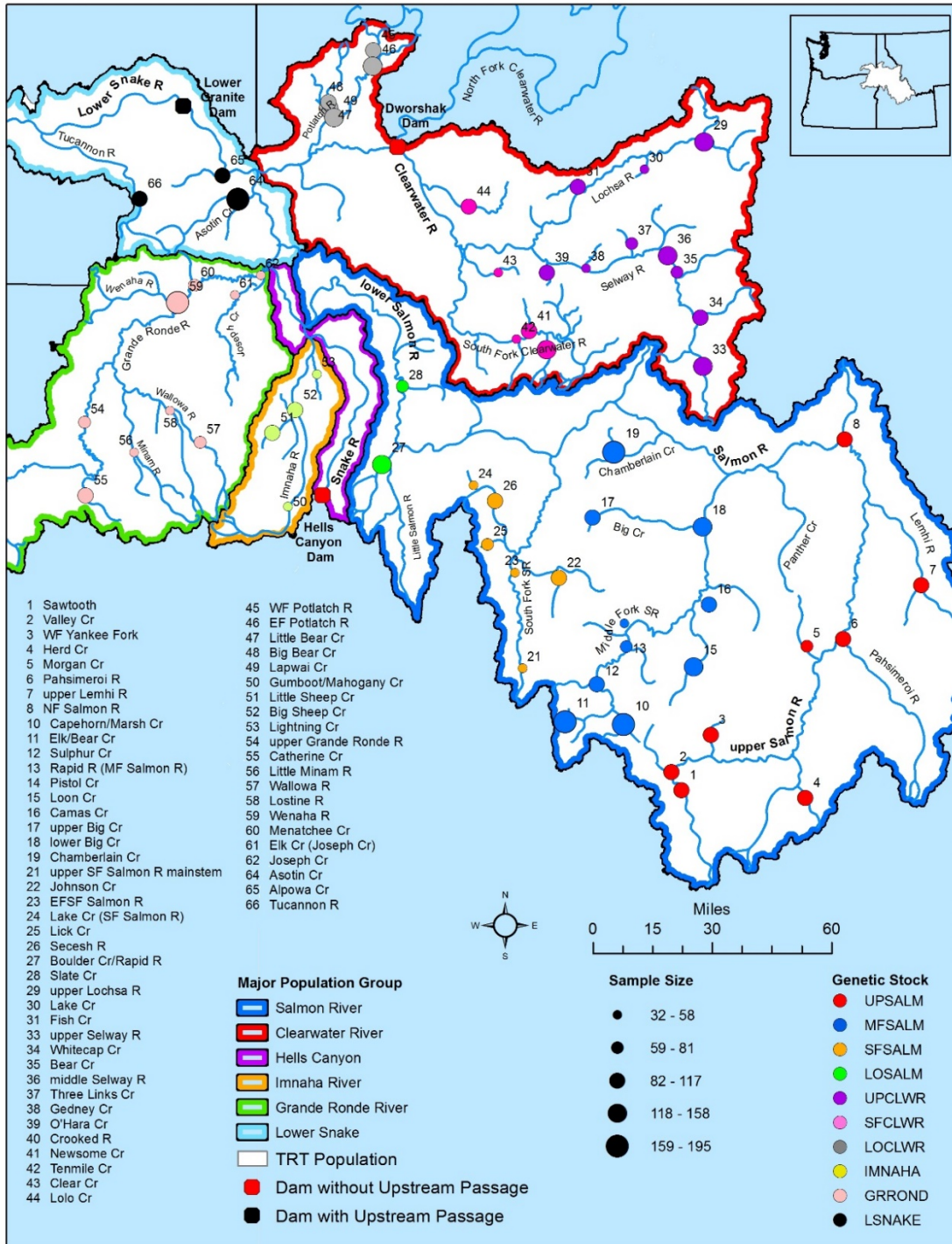


Figure 1. Map of steelhead genetic stocks and sample collections included in the Snake River basin SNP baseline version 3.1 (Powell et al. 2018) used for genetic stock identification at Lower Granite Dam. A detailed description of collections can be found in Hargrove et al. (2021). The Hells Canyon Tributaries major population group does not support independent populations and is considered extirpated (NMFS 2016). See Genetic Tissue Processing and Analysis section for genetic stock abbreviations.

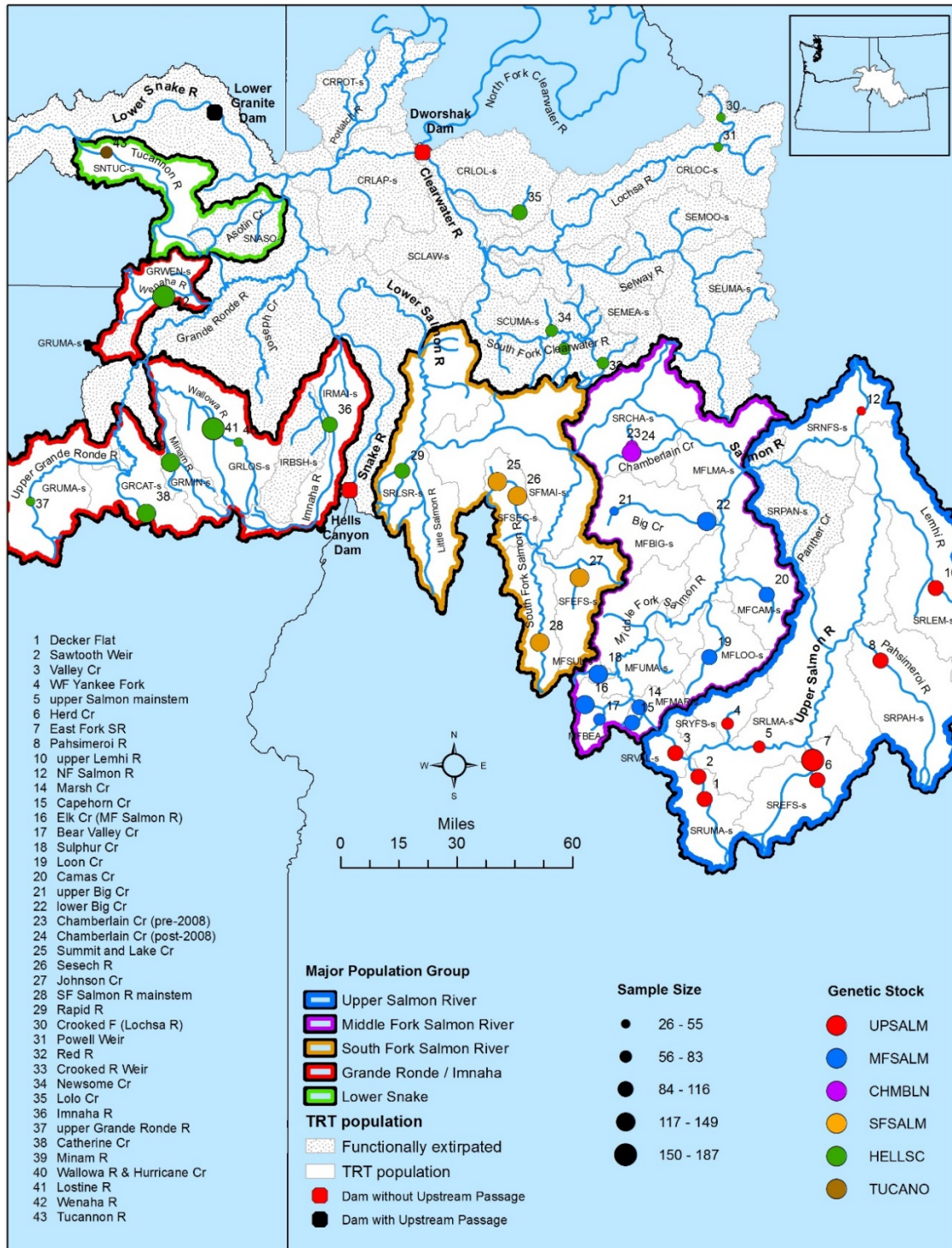


Figure 2. Map of Chinook Salmon genetic stocks and sample collections included in the Snake River basin SNP baseline version 3.1 (Powell et al. 2018) used for genetic stock identification at Lower Granite Dam. A detailed description of collections can be found in Hargrove et al. (2022). Reintroduced fish exist in functionally extirpated TRT populations as mapped. See Genetic Tissue Processing and Analysis section for genetic stock abbreviations.

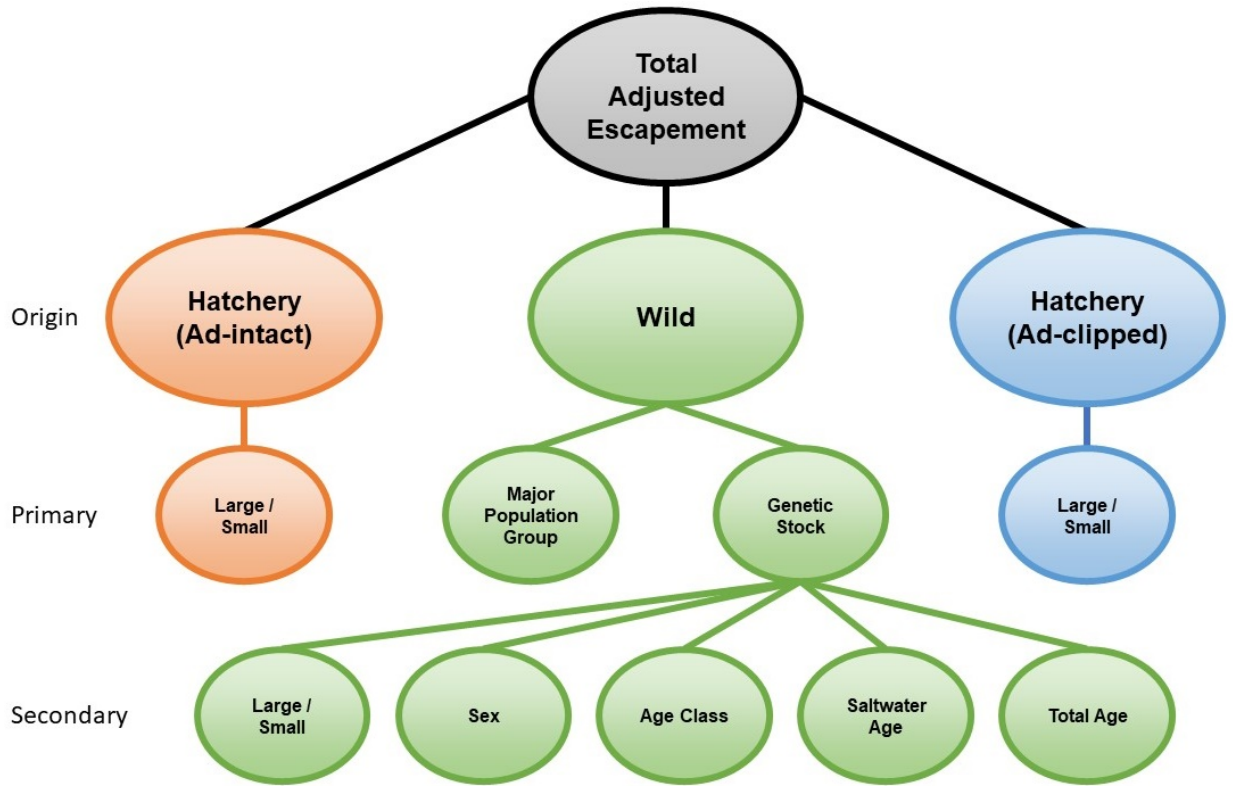


Figure 3. Schematic of the Lower Granite Dam Estimating Adult Salmonid Escapement (EASE) decomposition model. Total adjusted escapement refers to the LGR window counts with nighttime passage and fallback-reascension rates incorporated. Large/Small refer the fork length (FL) designations for Chinook Salmon large (≥ 57 cm FL) and small (< 57 cm FL) and steelhead large (≥ 78 cm FL) and small (< 78 cm FL). Fish less than 30 cm FL are not designated to species and are ignored.

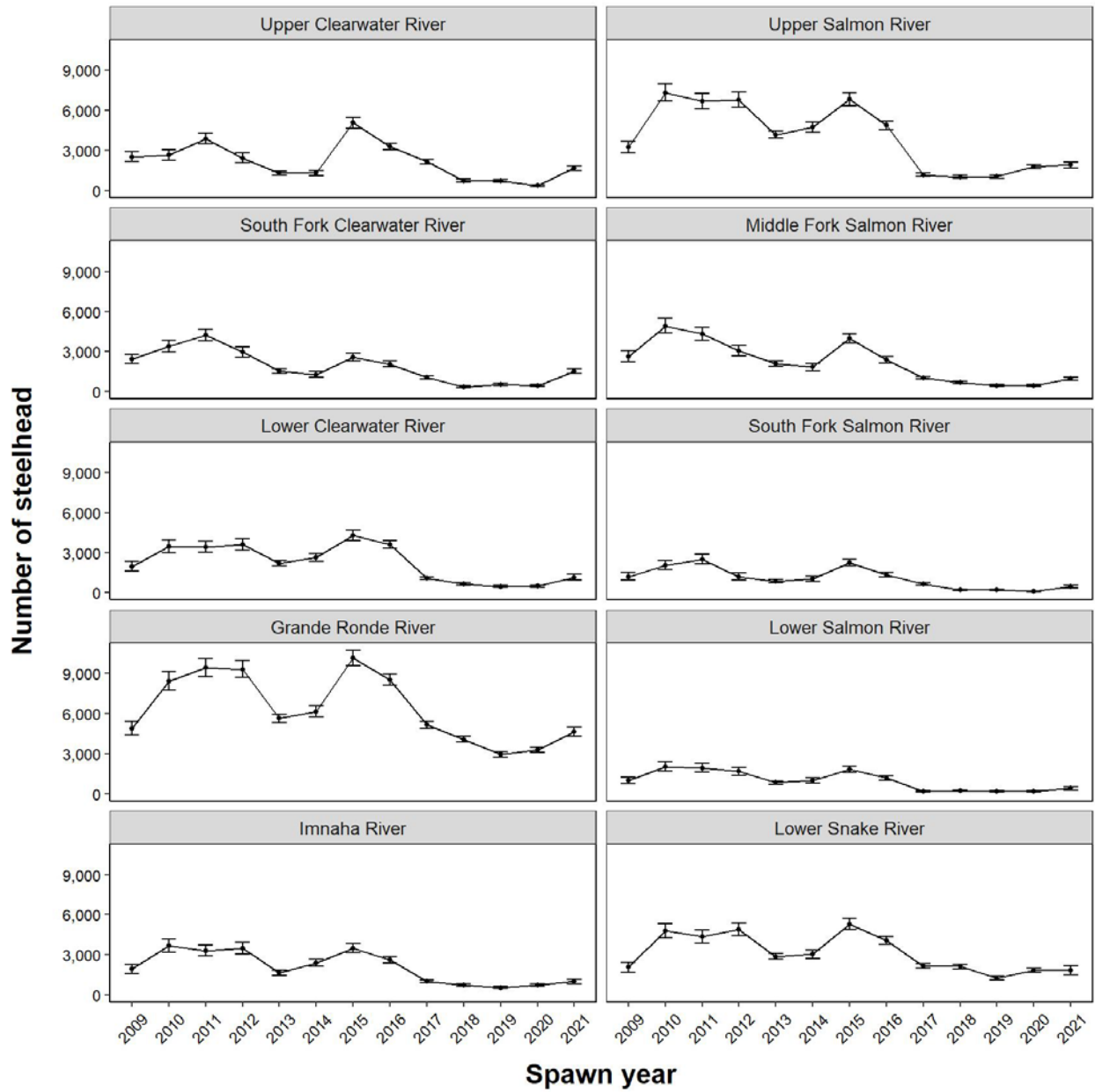


Figure 4. Estimated escapement by genetic stock of wild steelhead at Lower Granite Dam for spawn years 2009–2021. Confidence intervals are at 90%.

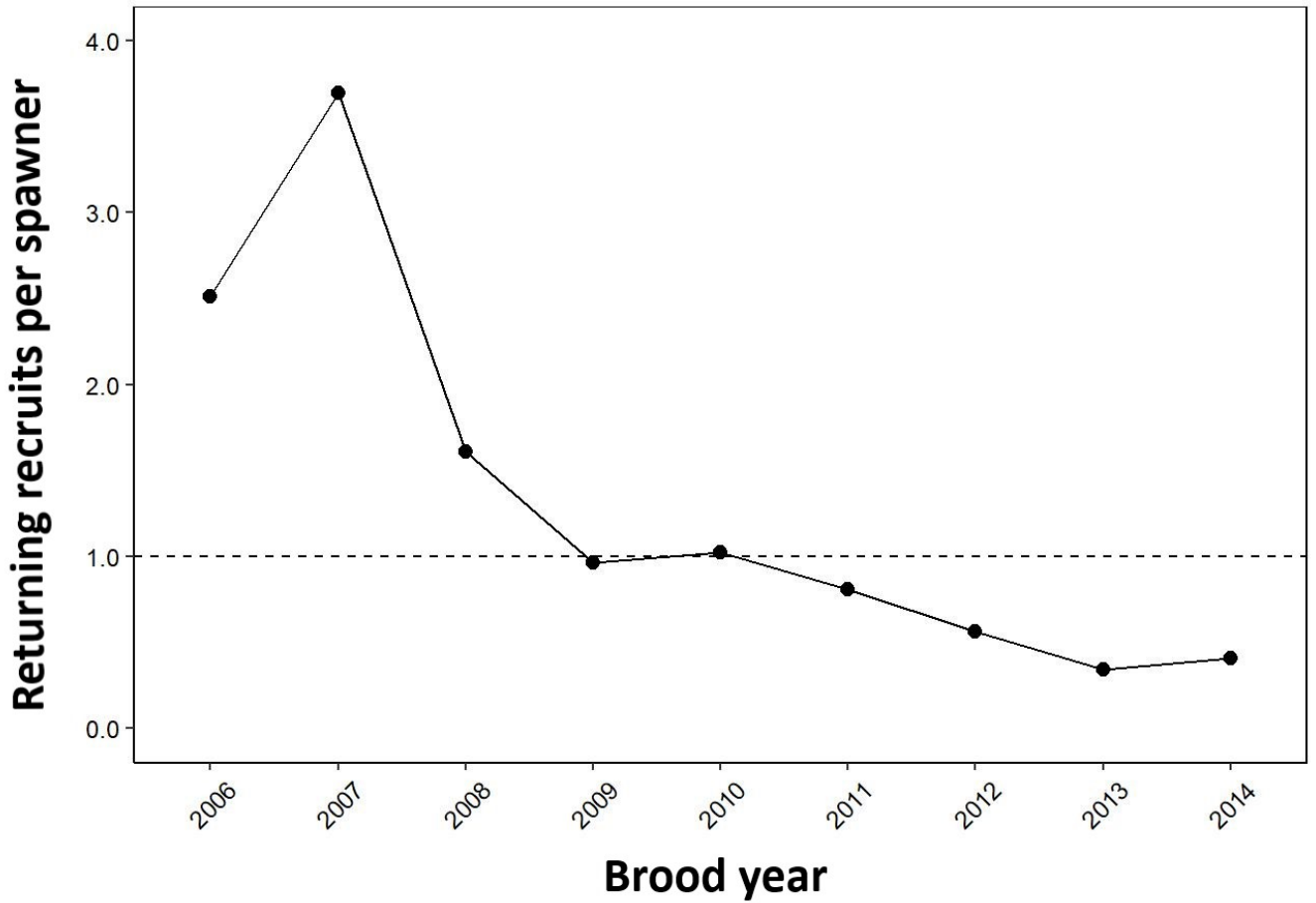


Figure 5. Adult-to-adult productivity (returning recruits per parent spawner) of wild steelhead at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2013. Note brood year 2014 was shown for reference, but represents a preliminary result that will be completed in SY2022.

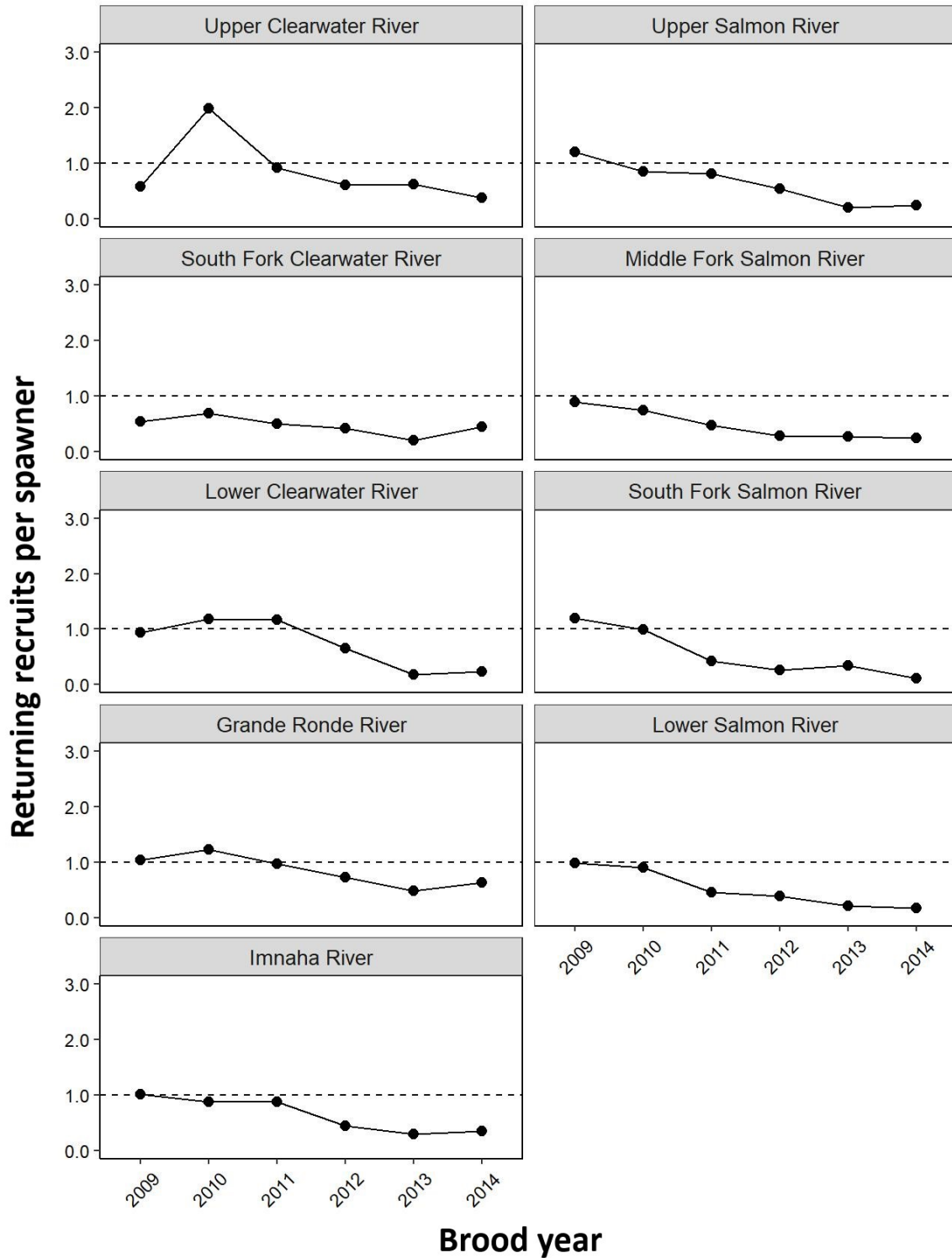


Figure 6. Adult-to-adult productivity (returning recruits per parent spawner) for each genetic stock of wild steelhead at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2013. Note brood year 2014 was shown for reference, but represents a preliminary result that will be completed in SY2022.

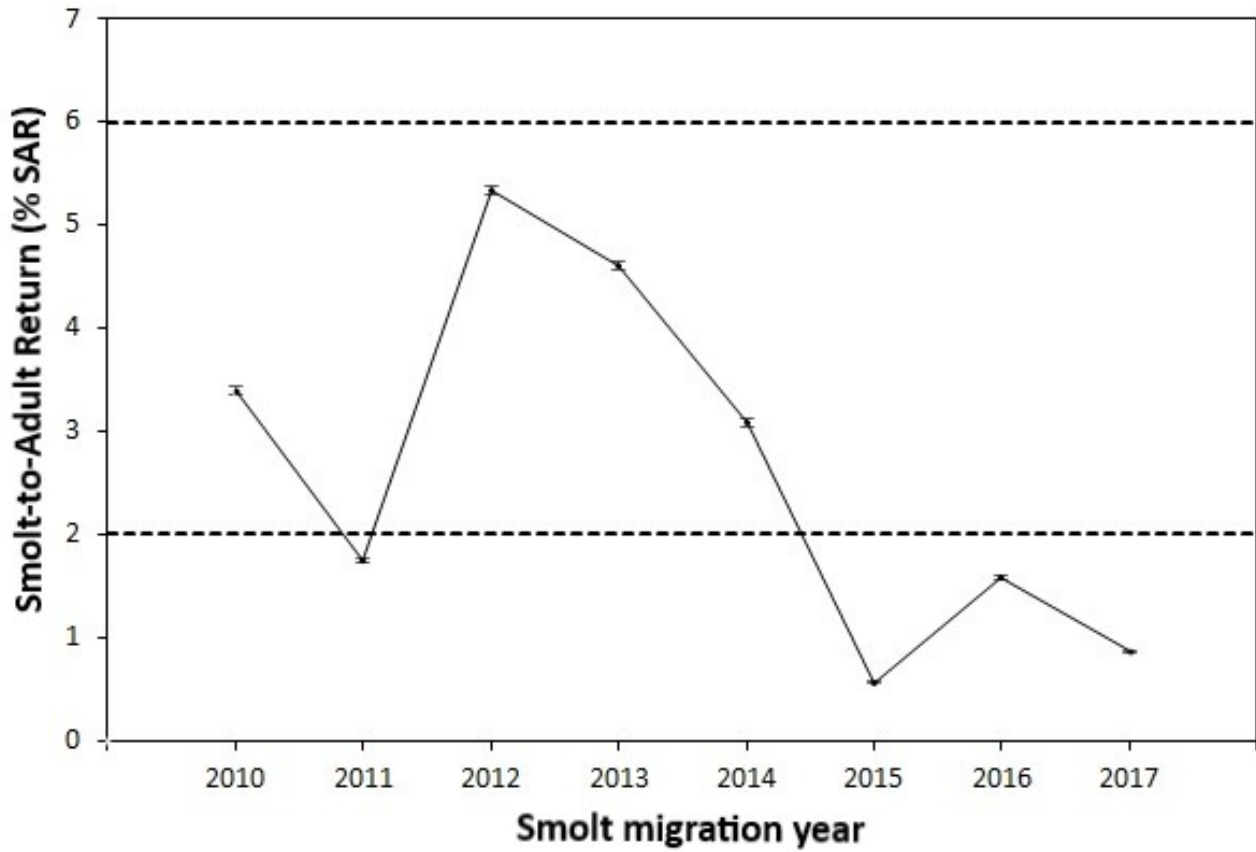


Figure 7. Estimated wild steelhead smolt-to-adult return (% SAR) rate of emigrant smolts and adult returns to Lower Granite Dam for smolt migration years 2010–2017. Confidence intervals are at 95%. The dashed lines represent the lower and upper range SAR objectives for wild steelhead established by the Northwest Power and Conservation Council (NPCC 2014, 2020). See Table 3 for numbers.

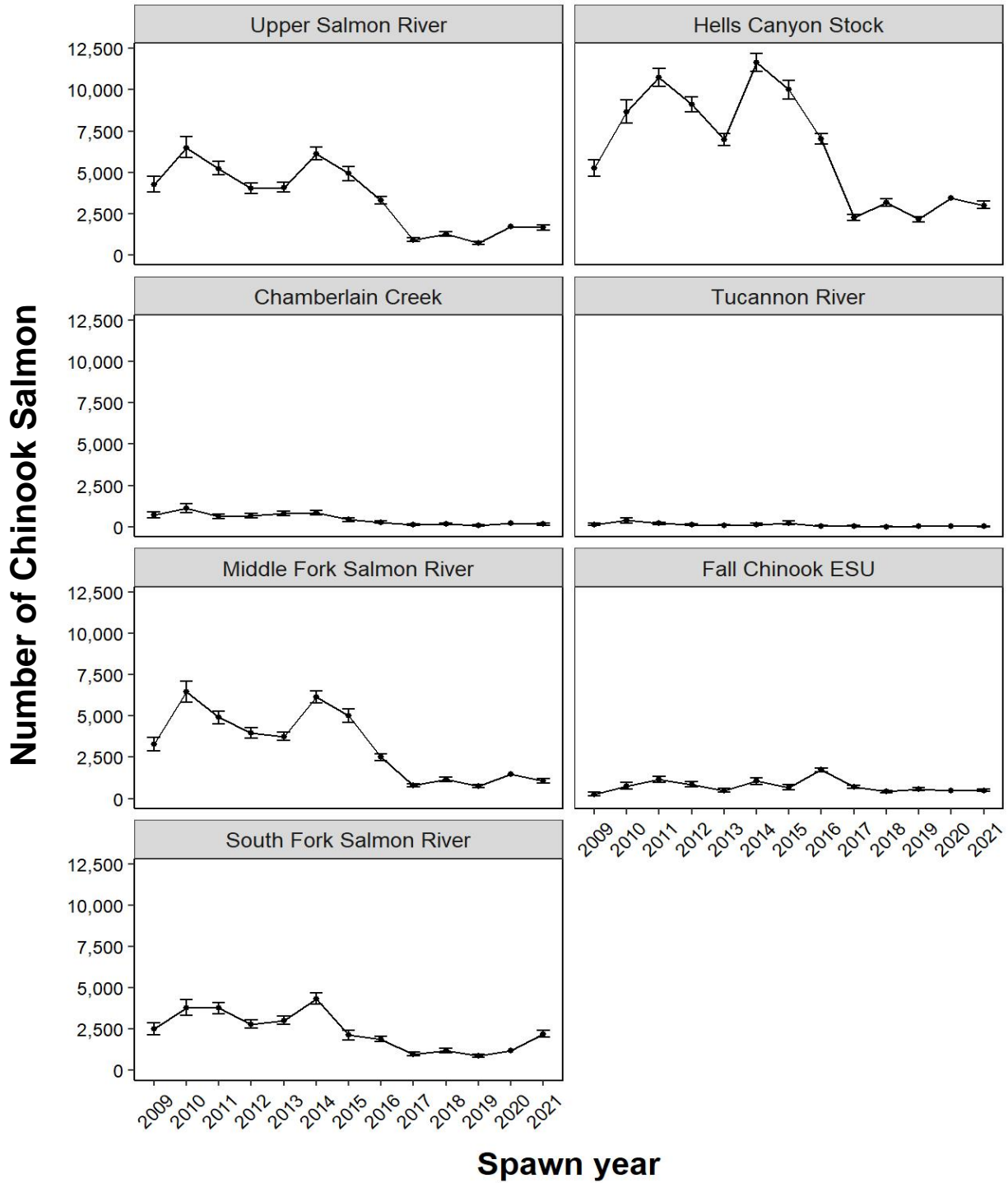


Figure 8. Estimated escapement by genetic stock of wild Chinook Salmon at Lower Granite Dam during March 1 to August 17 of spawn years 2009–2021. Confidence intervals are at 90%. Spawn year 2020 stock-specific estimates were generated using run reconstruction and do not include jacks or have confidence intervals. Hells Canyon stock is an aggregate genetic stock that includes the Clearwater, Little Salmon, Lower Salmon, Grande Ronde, Imnaha, and Lower Snake rivers.

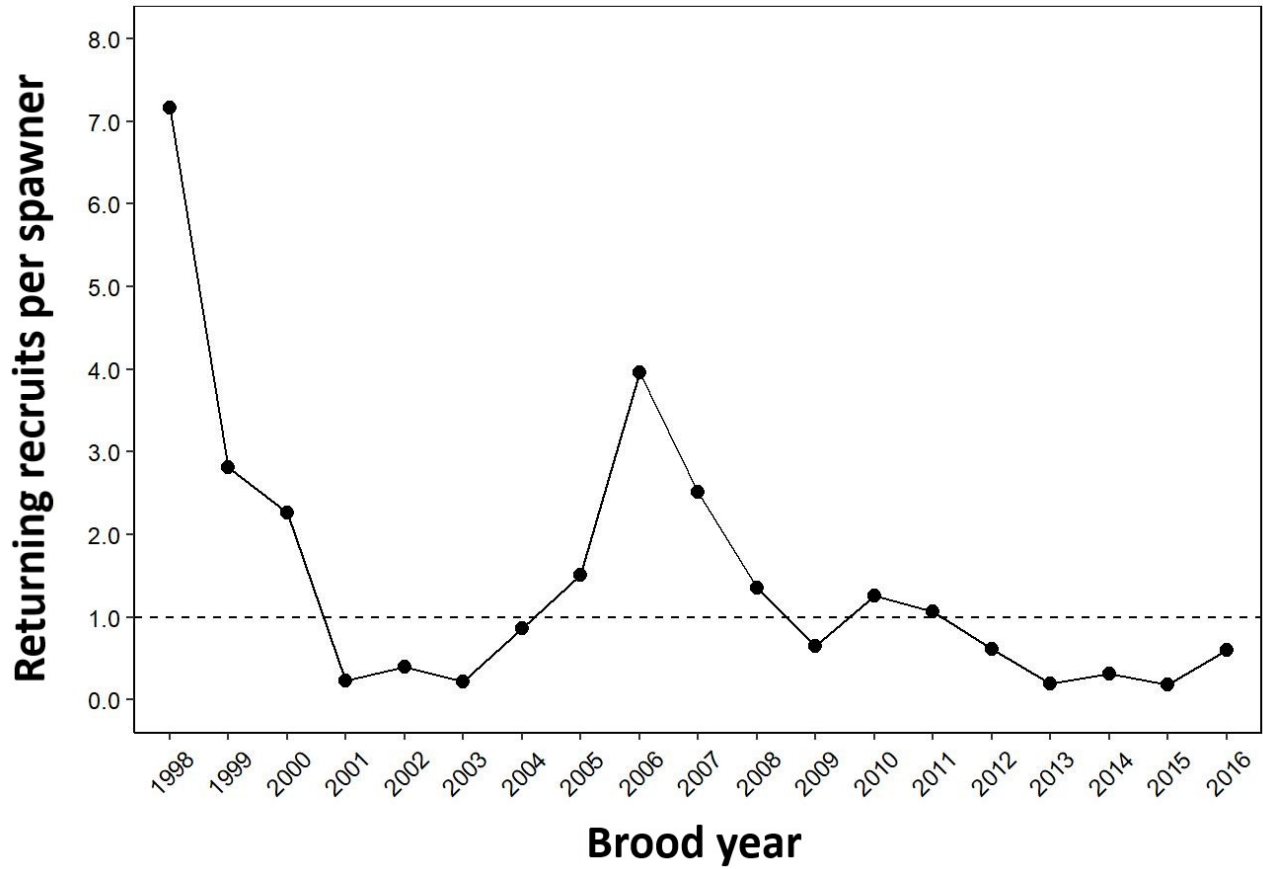


Figure 9. Adult-to-adult productivity (returning recruits per parent spawner) of wild Chinook Salmon at Lower Granite Dam. The dashed line at 1.0 recruits per spawner represents replacement. Spawn year 2021 completed brood year 2015. Note brood year 2016 was shown for reference, but represents a preliminary result that will be completed in SY2022.

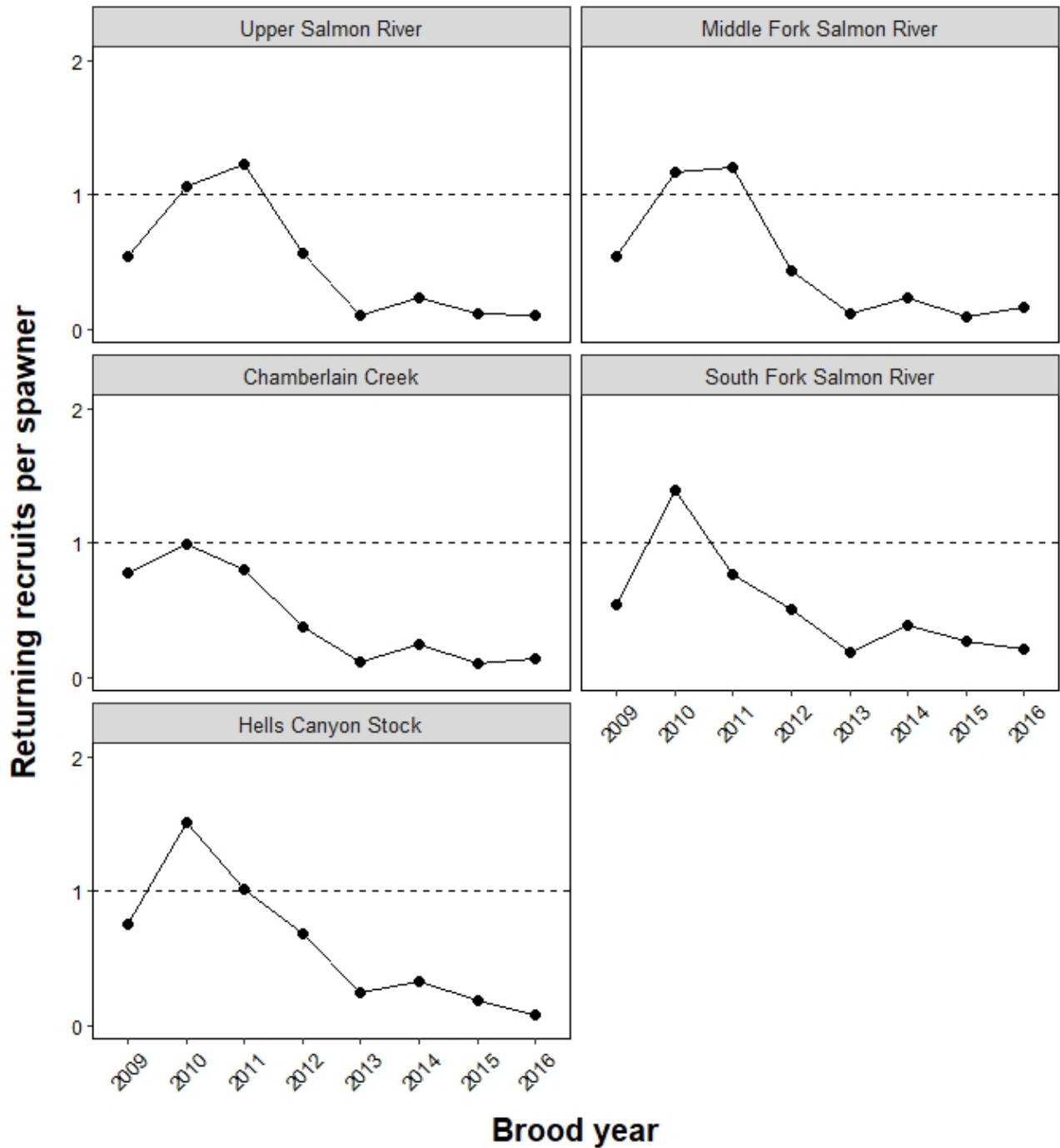


Figure 10. Adult-to-adult productivity (returning recruits per parent spawner) for each genetic stock of wild Chinook Salmon at Lower Granite Dam. The dashed line at 1.0 recruits per spawner replacement. Spawn year 2021 completed brood year 2015. Note brood year 2016 was shown for reference, but represents a preliminary result that will be completed in SY2022.

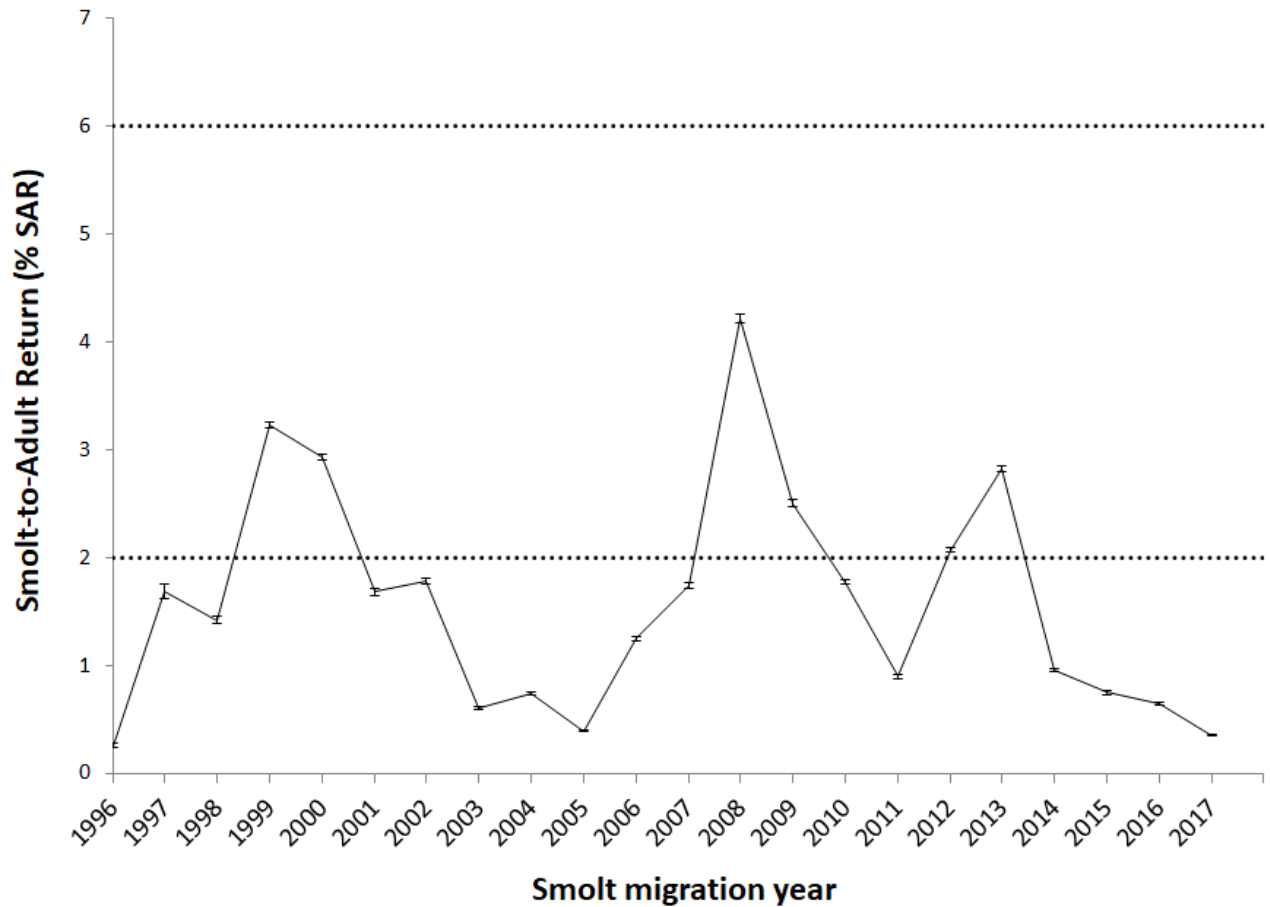


Figure 11. Estimated wild Chinook Salmon smolt-to-adult return (% SAR) rate of emigrant smolts and adult returns to Lower Granite Dam. Confidence intervals are at 95%. The dashed lines represent the lower and upper range SAR objectives for wild Chinook Salmon established by the Northwest Power and Conservation Council (NPCC 2014, 2020). See Table 5 for numbers.

APPENDICES

Appendix A: Annual Lower Granite Dam trapping operations, 2020–2021.

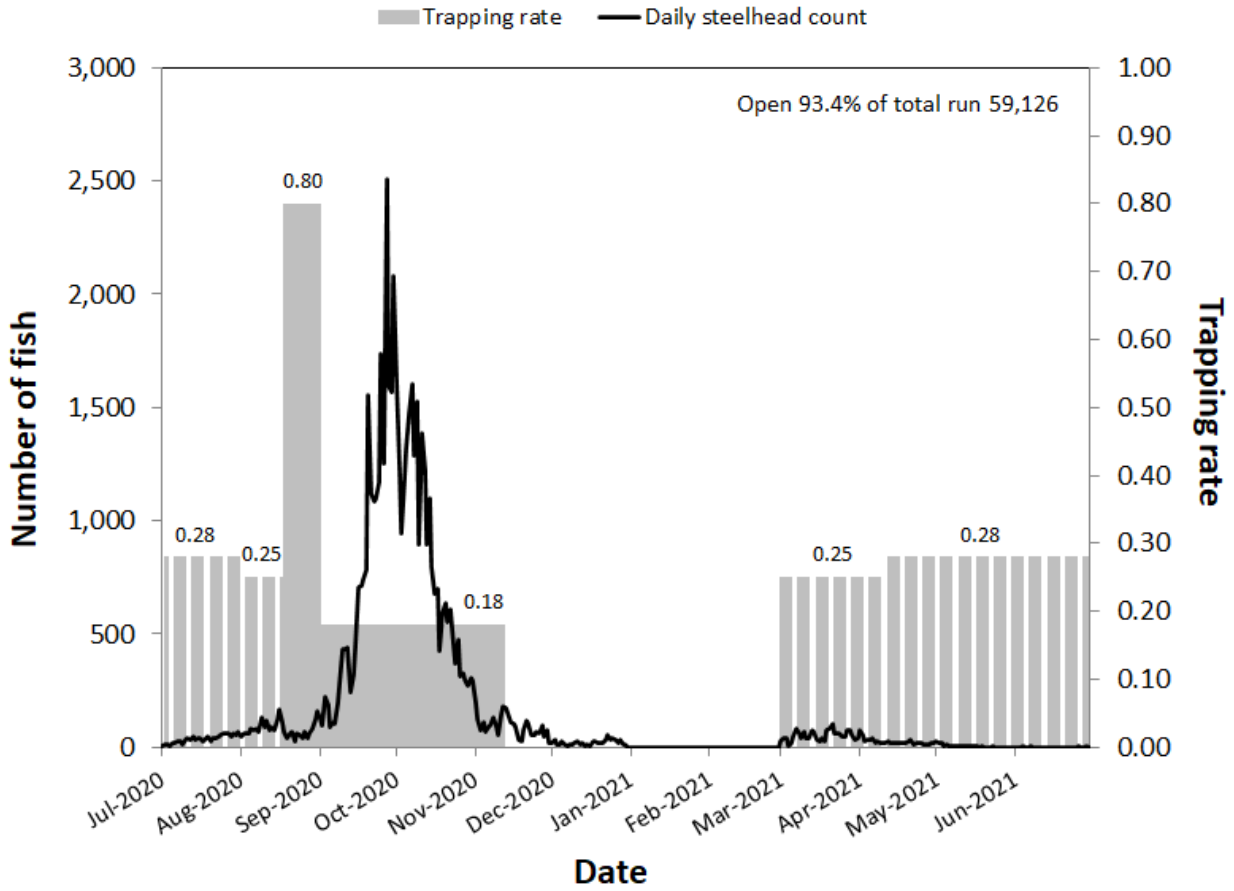
Appendix A-1. Annual Lower Granite Dam trapping operations, 2020–2021. Shaded areas were outside the 2021 spawn year (July 1, 2020 to June 30, 2021 for steelhead and March 1 to August 17, 2021 for Chinook Salmon).

Calendar date	Trap operation	Comments
<i>Calendar year 2020</i>		
January 1–March 1	Closed	Winter closure
March 2–24	5 days/week, 28% Daily Rate	
March 25–July 1	Closed ^(a)	COVID-19 closure
July 2–August 2	5 days/week, 28% Daily Rate	
August 3–17	5 days/week, 25% Daily Rate	
August 18–September 1	7 days/week, 80% Daily Rate ^(b)	
September 2–November 12	7 days/week, 18% Daily Rate	
November 13–December 31	Closed	Winter closure
<i>Calendar year 2021</i>		
January 1–March 1	Closed	Winter closure
March 2–April 9	5 days/week, 25% Daily Rate	
April 10–August 17	5 days/week, 28% Daily Rate	
August 18–September 1	7 days/week, 70% Daily Rate ^(b)	
September 2–November 18	7 days/week, 18% Daily Rate	
November 19–December 31	Closed	Winter closure

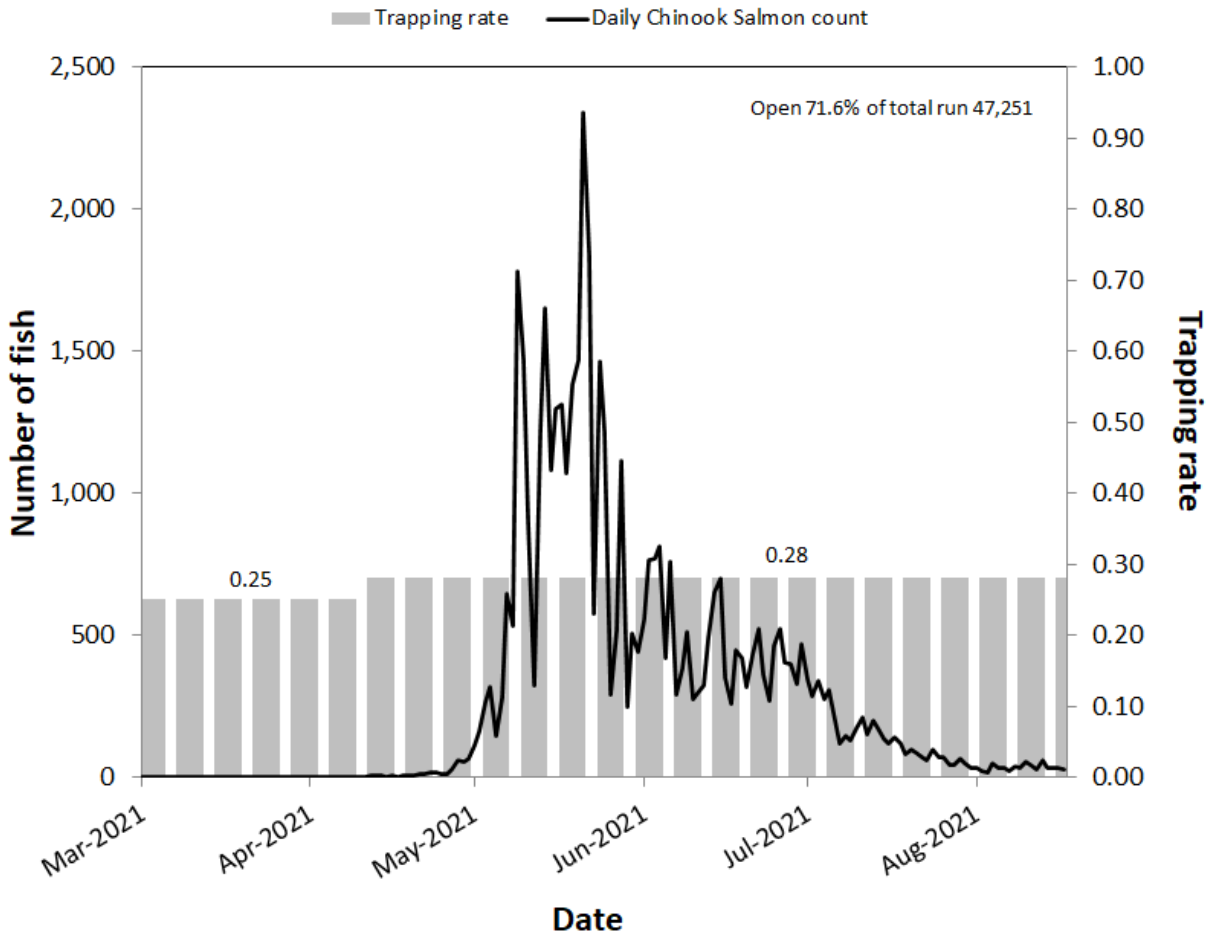
^a Trap operations were shut down due to COVID-19 safety policies.

^b Trap rate exceeded co-manager agreement for a trap rate maximum of 20% (7 days/week) to accommodate fall-run Chinook Salmon broodstock collection at the LGR trap.

Appendix A-2. Daily number of steelhead counted at the Lower Granite Dam window, spawn year 2021. Vertical gray bars indicate when the trap was open and daily trapping rate. 93.4% of the steelhead passed LGR when the trap was open. See Appendix A-1 and text for explanation of various trap closures.



Appendix A-3. Daily number of Chinook Salmon counted at the Lower Granite Dam window, spawn year 2021. Vertical gray bars indicate when the trap was open and daily trapping rate. 71.6% of the Chinook Salmon passed LGR when the trap was open. See Appendix A-1 and text for explanation of various trap closures.



Appendix A-4. A hierarchical (top to bottom) key of external marks and internal tags used to determine hatchery origin steelhead and Chinook Salmon at Lower Granite Dam (LGR), spawn years 2009–2021. Only fish failing to meet criteria were considered wild.

If the LGR mark or tag is:	Then the origin at window is:	Then the origin at trap is:	And the final origin is:
Adipose fin clip	Hatchery	Hatchery	Hatchery
Coded wire tag (CWT)	N/A ^(a)	Hatchery	Hatchery
Ventral fin clip	N/A	Hatchery	Hatchery
Parentage based tag (PBT)	N/A	N/A	Hatchery ^(a)
Passive integrated transponder (PIT)	N/A	N/A	N/A ^(b)

^a Started in SY2011 with complete coverage by SY2013.

^b Minor discrepancies occurred between the PIT-tag database (PTAGIS) and LGR trap databases (LGTrappingDB, BioSamples, and Progeny) that prevent the use of PIT-tags to determine origin at this time.

Appendix A-5. Weekly window counts and valid adult trap samples of steelhead at Lower Granite Dam, spawn year 2021. Data were summarized by weekly strata for analysis using the Estimating Adult Salmonid Escapement (EASE) model.

Time strata	Statistical week ^(a)	Sampling period	Number of days	Days trap open ^(b)	Window count	Total valid fish trapped	Valid wild fish trapped	Number of valid wild fish samples used in EASE analysis			
								Genetic stock	Size	Sex	Age
<i>Fall 2020</i>											
1	27A - 33 ^(c)	7/1 - 8/16	47	32	2,610	462	291	285	285	285	185
2	34-36	8/17 - 9/6	21	21	1,926	1,107	473	444	444	444	277
3	37	9/7 - 9/13	7	7	2,211	426	162	161	161	161	106
4	38	9/14 - 9/20	7	7	5,261	881	229	218	218	218	149
5	39	9/21 - 9/27	7	7	9,961	1,901	458	446	446	446	294
6	40	9/28 - 10/4	7	7	10,205	2,101	361	359	359	358	252
7	41	10/5 - 10/11	7	7	9,490	1,852	345	345	345	345	242
8	42	10/12 - 10/18	7	7	5,820	1,235	216	214	214	214	161
9	43	10/19 - 10/25	7	7	3,758	787	193	187	187	187	143
10	44 – 53 ^(c)	10/26 – 12/31	67	18	5,301	640	163	161	161	161	130
<i>Spring 2021</i>											
11	10 - 27B ^(c)	3/1 - 6/30	122	122	2,583	604	304	285	285	285	146
Total:			306	242	59,126	11,996	3,195	3,105 ^(d)	3,105 ^(d)	3,104 ^(d)	2,085

^a Statistical weeks are grouped to try to provide a minimum sample size of 100 valid fish with a genotype and age.

^b See Appendix A-1 for trapping operation details.

^c Includes a partial week.

^d One hundred-six additional fish without ages were removed from the genetic stock, size, and sex sample due to analytical complications in EASE, reducing the sample size to 2,999, 2,999, and 2998 fish, respectively.

Appendix A-6. Weekly window counts and valid adult trap samples of Chinook Salmon at Lower Granite Dam, spawn year 2021. Data were summarized by weekly strata for analysis using the Estimating Adult Salmonid Escapement (EASE) model.

Time strata	Statistical week ^(a)	Sampling period	Number of days	Days trap open ^(b)	Window count	Total valid fish trapped	Valid wild fish trapped	Number of valid wild fish samples used in EASE analysis			
								Genetic stock	Size	Sex	Age
1	10 - 20	3/1 - 5/16	77	77	12,510	2,043	163	161	161	161	148
2	21	5/17 - 5/23	7	7	9,987	2,168	243	241	241	241	227
3	22	5/24 - 5/30	7	7	5,359	1,376	217	216	216	216	202
4	23	5/31 - 6/6	7	7	4,514	913	171	171	171	171	159
5	24	6/7 - 6/13	7	7	2,568	579	132	132	132	132	123
6	25	6/14 - 6/20	7	7	3,146	773	217	217	217	217	199
7	26	6/21 - 6/27	7	7	2,971	575	188	188	188	188	175
8	27	6/28 - 7/4	7	7	2,441	551	213	211	211	211	199
9	28-29	7/5 - 7/18	14	14	2,319	742	290	287	287	287	262
10	30-34 ^(c)	7/19 - 8/17	30	30	1,436	384	161	158	158	158	138
Total:			170	170	47,251	10,104	1,995	1,982 ^(d)	1,982 ^(d)	1,982 ^(d)	1,832

^a Statistical weeks are grouped to try to provide a minimum sample size of 100 valid fish with a genotype and age.

^b See Appendix A-1 for trapping operation details.

^c Includes a partial week.

^d Seven additional fish without ages were removed from the genetic stock, size, and sex sample due to analytical complications in EASE, reducing the sample size to 1,975 fish for all three categories.

Appendix B. Methods description of Estimating Adult Salmonid Escapement (EASE) model used for all steelhead and spring-summer Chinook Salmon estimates, spawn year 2021.

Appendix B-1. Methods description of Estimating Adult Salmonid Escapement (EASE) model used for all steelhead and spring-summer Chinook Salmon estimates, spawn year 2021.

The following methods provide detailed information about the newly developed Estimating Adult Salmonid Escapement model (EASE) used for all escapement estimates of steelhead and spring-summer Chinook Salmon at Lower Granite Dam in SY2021.

Daytime Ascensions, Nighttime Passage, and Total Number of Ascensions

For daytime ascensions, the window count, w , is considered a binomial random variable

$$w \sim \text{bin}(r, a_d), \quad (1)$$

where r is the proportion of time counting was performed and a_d is the number of daytime ascensions. The point estimate of a_d is therefore $\frac{w}{r}$. Bootstrap estimates are generated by parametric bootstrapping. Random binomials are generated using a probability of success of r and number of trials of a_d . These random binomials are then divided by r to yield bootstrap estimates of a_d .

For nighttime passage, the probability a given ascension occurs at night is estimated using PIT tag detections in the ladder. The number of PIT ascensions at night, d_n , is treated as a binomial random variable

$$d_n \sim \text{bin}(p_n, d_a), \quad (2)$$

where p_n is the probability a given ascension occurs at night and d_a is the total number of PIT ascensions. The maximum likelihood estimate of p_n is therefore $\frac{d_n}{d_a}$. Bootstrap estimates are generated by parametric bootstrapping. Random binomials are generated using a probability of success of the maximum likelihood estimate of p_n and number of trials of d_a . These random binomials are then divided by d_a to yield bootstrap estimates of p_n .

Using the estimates of a_d and p_n , the total number of ascensions, a_t , is calculated as

$$a_t = a_d / (1 - p_n). \quad (3)$$

To generate d_n for input to the model, a user must categorize PIT ascensions as occurring during the day or night. This is currently performed by Columbia River DART. Detection histories are broken into ascensions with each ascension beginning with a detection at the viewing window array and ending with a detection at the ladder exit array. We then exclude any fish that were PIT tagged as adults in the Lower Granite trap. Ascensions whose first detection at the viewing window is outside of counting hours are assigned to the night. Detection efficiency of PIT tags in the ladder is assumed to be 100%, and if any fish are not detected at the viewing window and subsequently at the ladder exit, they are excluded.

Fallback Rates

Fallback rates have previously been observed to vary between groups of steelhead stocks, specifically between stocks upstream and downstream of LGR. To estimate escapement

to the level of these stocks, fallback rates must be estimated separately for each group. The method described here is applied separately to each group to yield group-specific estimates of fallback rates.

The probability that a given ascension results in fallback (e.g., the fish that ascended later fell back below the dam) is estimated using PIT tag detections. The number of PIT ascensions that later reascended, d_f , is treated as a binomial random variable

$$d_f \sim \text{bin}(p_f, d_{as}), \quad (4)$$

where p_f is the probability that a given ascension results in fallback and d_{as} is the total number of ascensions from the given stock group. The maximum likelihood estimate of p_f is therefore $\frac{d_f}{d_{as}}$. Bootstrap estimates are generated by parametric bootstrapping. Random binomials are generated using a probability of success of the maximum likelihood estimate of p_f and number of trials of d_{as} . These random binomials are then divided by d_{as} to yield bootstrap estimates of p_f .

It is important to realize that because fish are only detected as having fallen back if they later reascend, this assumes that the rate of fallback without reascension is 0.

To generate d_f for input to the model, a user must categorize PIT ascensions as being first ascensions or reascensions. This is currently performed by Columbia River DART by breaking detection histories into unique ascensions as described in the previous section. We then exclude any fish that were PIT tagged as adults in the Lower Granite trap. By only using fish PIT tagged prior to arrival at the dam, we ensure that sampling is not biased with respect to whether a fish is trapped or not.

Composition of Ascensions

The trap provides a sample of all fish ascending the ladder as it traps fish 24 hours a day during the days it is operational. We used this sample to estimate the composition of fish ascending the ladder by adipose fin status (ad-clipped or ad-intact), origin (hatchery or wild), and one or two additional categorical variables (e.g. PBT, GSI, genetic sex). Composition is estimated using the methods developed by Delomas and Hess (2021) and implementing the approach discussed therein for integrating GSI uncertainty into the estimates. Inputs required for this step are the attributes recorded for trapped fish and parentage-based tagging (PBT) tag rates.

Composition is estimated in a hierarchical, step-wise manner (Steinhorst et al. 2017) to accommodate the desire for marginal totals for some variables to be the same regardless of the other variables being estimated in a given run of the model. For example, the number of ad-intact hatchery fish estimated should be the same regardless of whether the wild component is being estimated by genetic stock and sex or by genetic stock and size. The proportions of ad-clipped and ad-intact fish are first estimated using clip information recorded at the trap. The proportion of fish that are ad-clipped, p_{AD} , is estimated as $\frac{\text{Number of ad-clipped fish}}{\text{Total number of fish}}$. The ad-intact portion is then split further into fish with physical tags denoting them of hatchery origin (e.g. CWT, ventral fin clips) and fish without such physical tags. The proportion of ad-intact fish with physical tags, p_{phys} , is estimated as $\frac{\text{Number of physically tagged ad-intact fish}}{\text{Total number of ad-intact fish}}$. The unmarked (ad-intact, no physical tags), genotyped fish are then used to estimate the proportion of unmarked fish that are hatchery origin, p_{PBT} , and wild using PBT assignments and tag rates. This is done using a maximum

likelihood method (Delomas and Hess 2021). The proportions of fish that are ad-clipped hatchery-origin (H), ad-intact hatchery-origin (HNC), and wild-origin (W) can then be calculated as

$$H = p_{AD}, \quad (5)$$

$$HNC = (1 - p_{AD})(p_{phys} + (1 - p_{phys})p_{PBT}), \quad (6)$$

$$W = (1 - p_{AD})(1 - p_{phys})(1 - p_{PBT}). \quad (7)$$

Composition within each group (H , HNC , W) is then estimated for one or two additional variables.

For the H group, composition of the first variable is estimated using all ad-clipped fish with data for the first variable. Composition of a second variable (if included) within the categories of the first variable is then estimated using all ad-clipped fish with data for both the first and second variables and with marginal proportions for the first variable constrained to their estimated values. The composition of the PBT grouping variable (groups for which PBT tag rates are defined) and the composition of the second variable if the first variable is the PBT grouping variable are estimated using the maximum likelihood method described by Delomas and Hess (2021). Other variables are treated as multinomial random variables and maximum likelihood estimates (observed proportions in the sample) are calculated (ex: size category).

For the HNC group, composition is estimated using the maximum likelihood method described by Delomas and Hess (2021) applied separately to the ad-intact, physically tagged fish and the unmarked fish and then summed together. If the variable of interest is not the PBT grouping variable, the estimates for the ad-intact, physically tagged fish are simply the observed proportions in the sample. For the unmarked fish, the proportions of the PBT grouping variable are constrained to the values estimated during the previous estimation of p_{PBT} .

For the W group, composition for the first variable is estimated using the maximum likelihood method described by Delomas and Hess (2021) and using data from all ad-intact, genotyped samples with data for the first variable. The W group is a mixture of different genetic stocks and so the first variable should always be genetic stock. Composition of a second variable (if included) within the categories of the first variable is then estimated using all ad-intact, genotyped fish with data for both the first and second variables and with marginal proportions for the first variable constrained to their estimated values. Secondary variables for this analysis include size, sex, age class, saltwater age, and brood year (Figure 3). The proportions of the PBT grouping variable within the ad-intact, unmarked fish are constrained to the values estimated during the previous estimation of p_{PBT} . It is important that the variables of interest for the W group (e.g. GSI) are recorded for ad-intact, unmarked samples regardless of PBT assignment. This is because the composition of the ad-intact, unmarked, PBT assigned samples contributes to the likelihood used to calculate composition of the W group. For estimating composition of the second variable, it is assumed that within the PBT groups of the unmarked HNC fish, the first and second variables are independent. This is expected to be the case as one variable is typically GSI assignment, and within an HNC PBT group, variation in GSI assignment is not expected to reflect meaningful genetic structure.

The uncertainty in GSI assignments is incorporated into the composition point estimates by estimating composition iteratively while replacing GSI assignments with draws from the joint posterior distribution of all GSI assignments in the dataset (Delomas and Hess 2021). Point estimates are then calculated as the means across iterations. Bootstrap estimates are obtained

by non-parametric bootstrapping and simultaneously replacing GSI assignments with draws from the posterior of GSI assignments.

Stratification

When estimating escapement over an extended time period, a stratified approach has been previously demonstrated to be superior to a pooled approach as many parameters change over time and the trap (sampling) rate can also change during the run (Steinhorst et al. 2017). As such, this model is implemented using a stratified approach and estimates are obtained by summing results across strata. Confidence intervals are then calculated as the quantiles $(\frac{\alpha}{2}$ and $1 - \frac{\alpha}{2})$ of the bootstrap estimates.

As multiple datasets are used to estimate different parameters, several sets of strata are defined. One set is defined for nighttime passage estimates. Separate sets of strata are defined for fallback rates for each stock group. This allows strata to be shorter in duration for stock groups with more PIT tag detections. Finally, a set of strata is defined for the composition estimates. The one interdependency between strata is that every composition estimate stratum must correspond to one and only one fallback stratum for each stock group. When defining strata, several criteria are kept in mind. The model must be able to estimate parameters in each time step, so there must be at least one sample informing each parameter. The parameters being estimated should be approximately constant in each stratum, so strata should not span changes in environmental conditions that could affect the underlying parameters (e.g., for estimating steelhead escapement, fall and spring time periods should not be combined). Additionally, while a minimum of one sample is required for each stratum, it is recommended that there be sufficient samples to provide a reasonable estimate of the underlying parameters. For example, if composition of the W portion of the run is being estimated by genetic stock, approximately 45 genotyped, unmarked, untagged samples per stratum (Given more than three possible categories, a sample size of 45 indicates a maximum error of any estimated multinomial proportion within that stratum of 0.15 with $\alpha = 0.10$) for the composition estimates can be recommended (Thompson 1987).

Based on data for previous years, for the bulk of the run, a stratum corresponds to a week, but for the tails of the run several weeks may be combined into one stratum. The exception to this may be the fallback estimates for steelhead released below Lower Granite Dam. Since there are fewer PIT tagged fish in this group, combining weeks into a single stratum may be a more frequent occurrence.

Non-specific PBT Groups

For a small minority of hatchery releases, PBT assignments do not definitively indicate which stock group (upper or lower) a fish belongs to for application of fallback rates. This occurs when fish from the same family are split (and not differentially marked) between two release groups. In these scenarios, the release groups are typically PIT tagged separately, and so PIT tag detections can be used to split the composition estimate for the PBT group into separate release groups. Consider a PBT group that is composed of two release groups (release A and B), and the PIT tagging rates at release are t_A and t_B . The number of detections of PIT tags from each group, d_A and d_B , can be considered binomial random variables

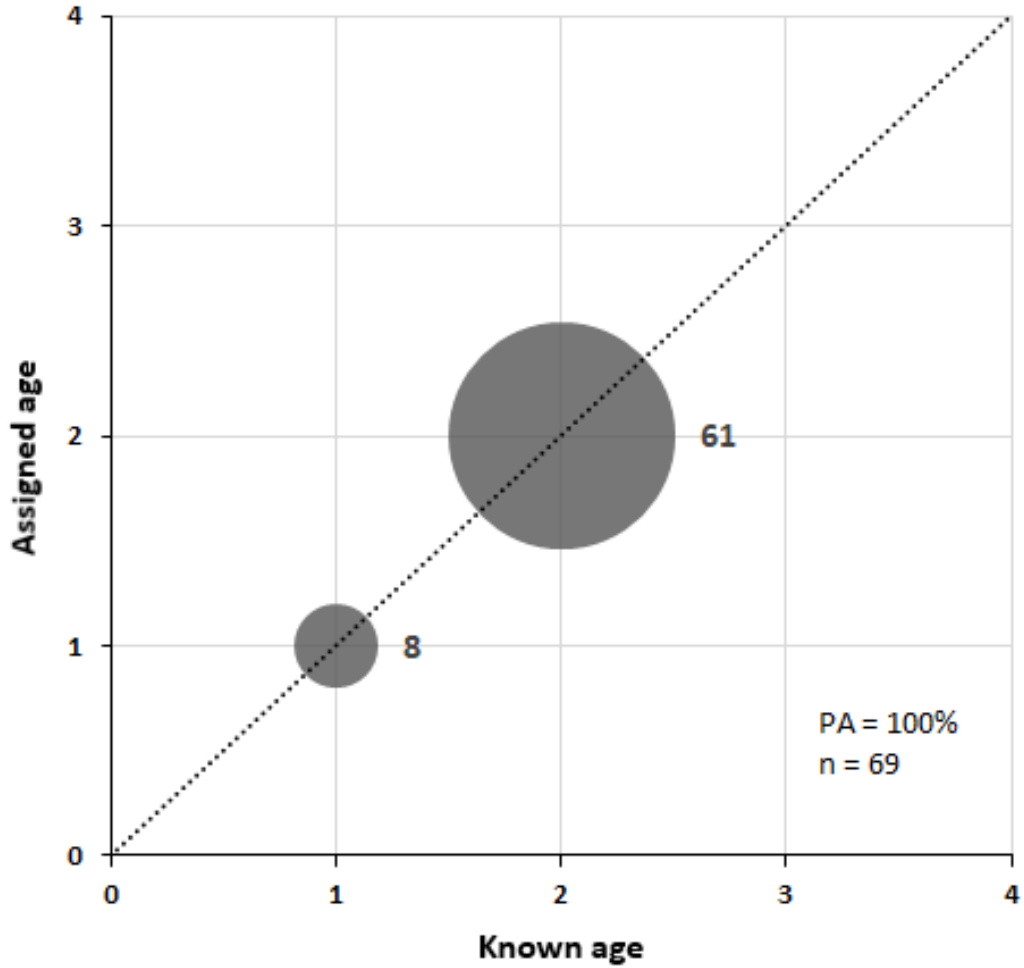
$$d_A \sim \text{bin}(t_A, N_A), \tag{8}$$

$$d_B \sim \text{bin}(t_B, N_B), \tag{9}$$

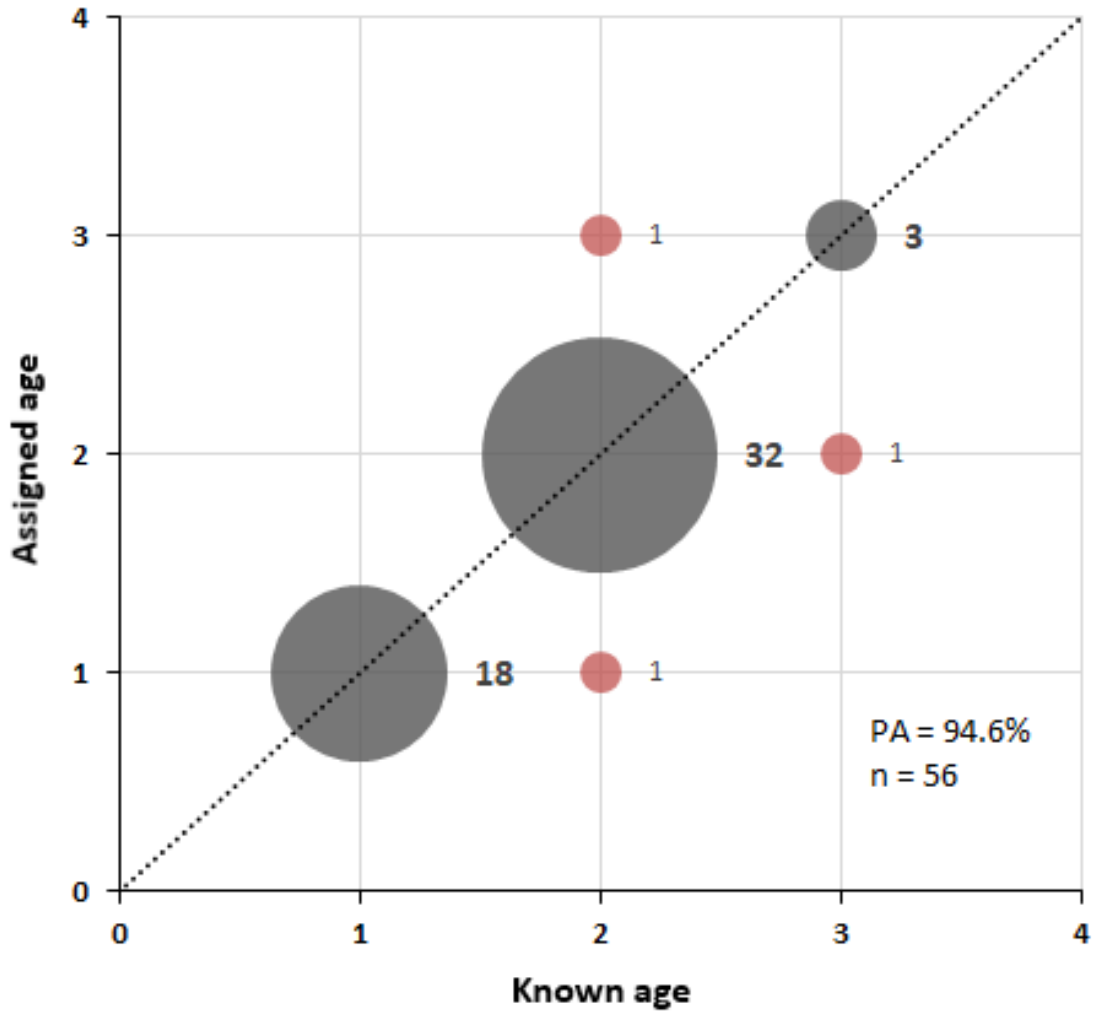
where N_A and N_B are the total numbers of fish in each release. An estimate of N_A is simply $\frac{d_A}{t_A}$, and similarly for N_B . The proportion of fish in the PBT group that belong to each release group is then calculated and used to split the PBT group composition estimate. Bootstrap estimates of N_A and N_B are obtained by parametric bootstrapping. Random binomials are generated using a probability of success of t_A and t_B and number of trials of N_A and N_B . These random binomials are then divided by the tag rates to yield bootstrap estimates of N_A and N_B . This procedure is extendable to PBT groups containing more than two separately PIT tagged release groups.

Appendix C: Steelhead and Chinook Salmon age validation.

Appendix C-1. Age bias plot illustrating pairwise comparisons of scale assigned saltwater age with known age for steelhead at Lower Granite Dam, spawn year 2021 (Micah Davison, IDFG, scale data; PTAGIS, PIT-tag data). Dashed line represents the 1:1 relationship. PA = percent agreement.

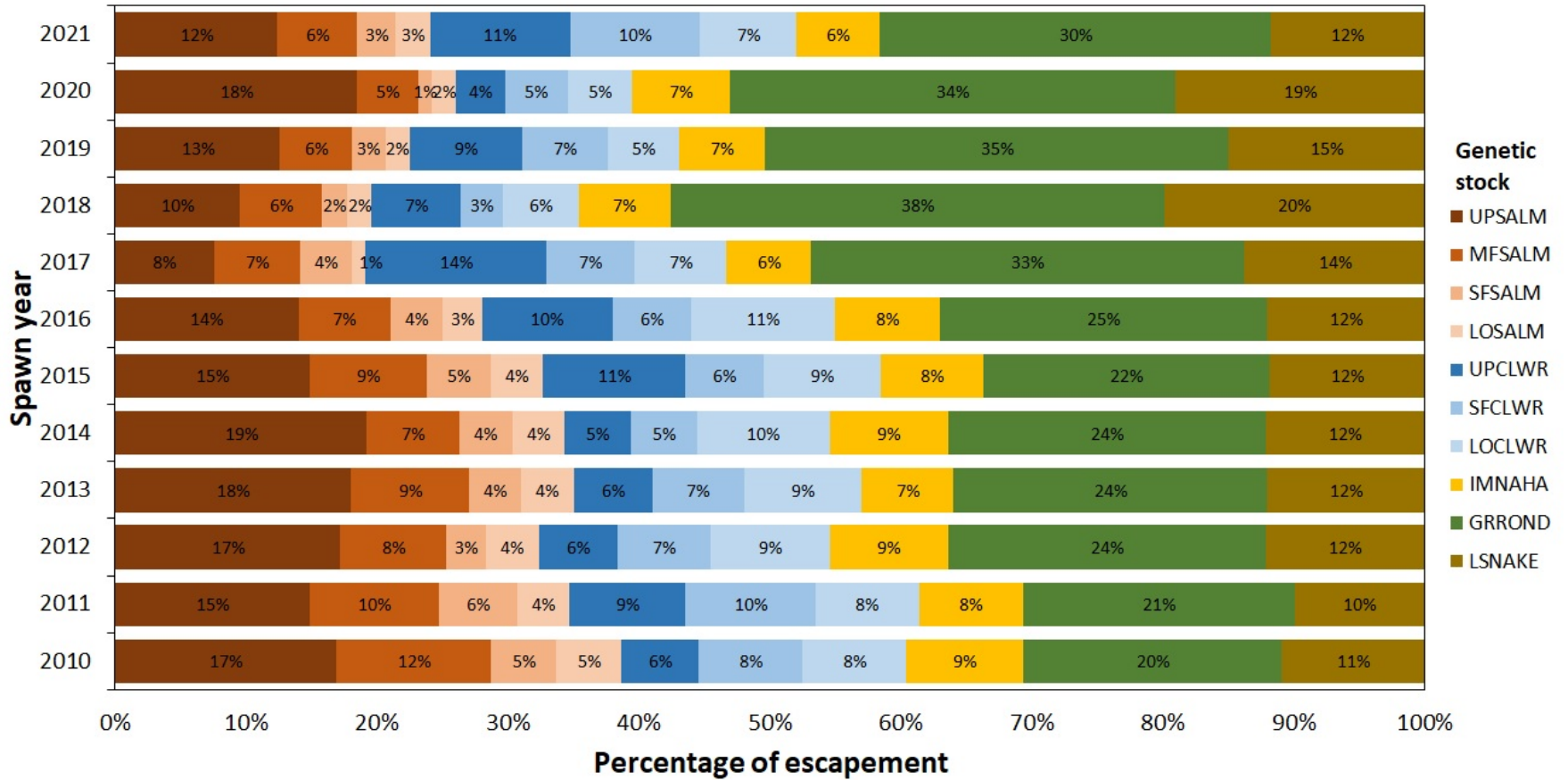


Appendix C-2. Age bias plot illustrating pairwise comparisons of scale assigned saltwater age with known age for Chinook Salmon at Lower Granite Dam, spawn year 2021 (Micah Davison, IDFG, scale data; PTAGIS, PIT-tag data). Dashed line represents the 1:1 relationship. PA = percent agreement.



Appendix D: Wild steelhead at Lower Granite Dam, spawn year 2021.

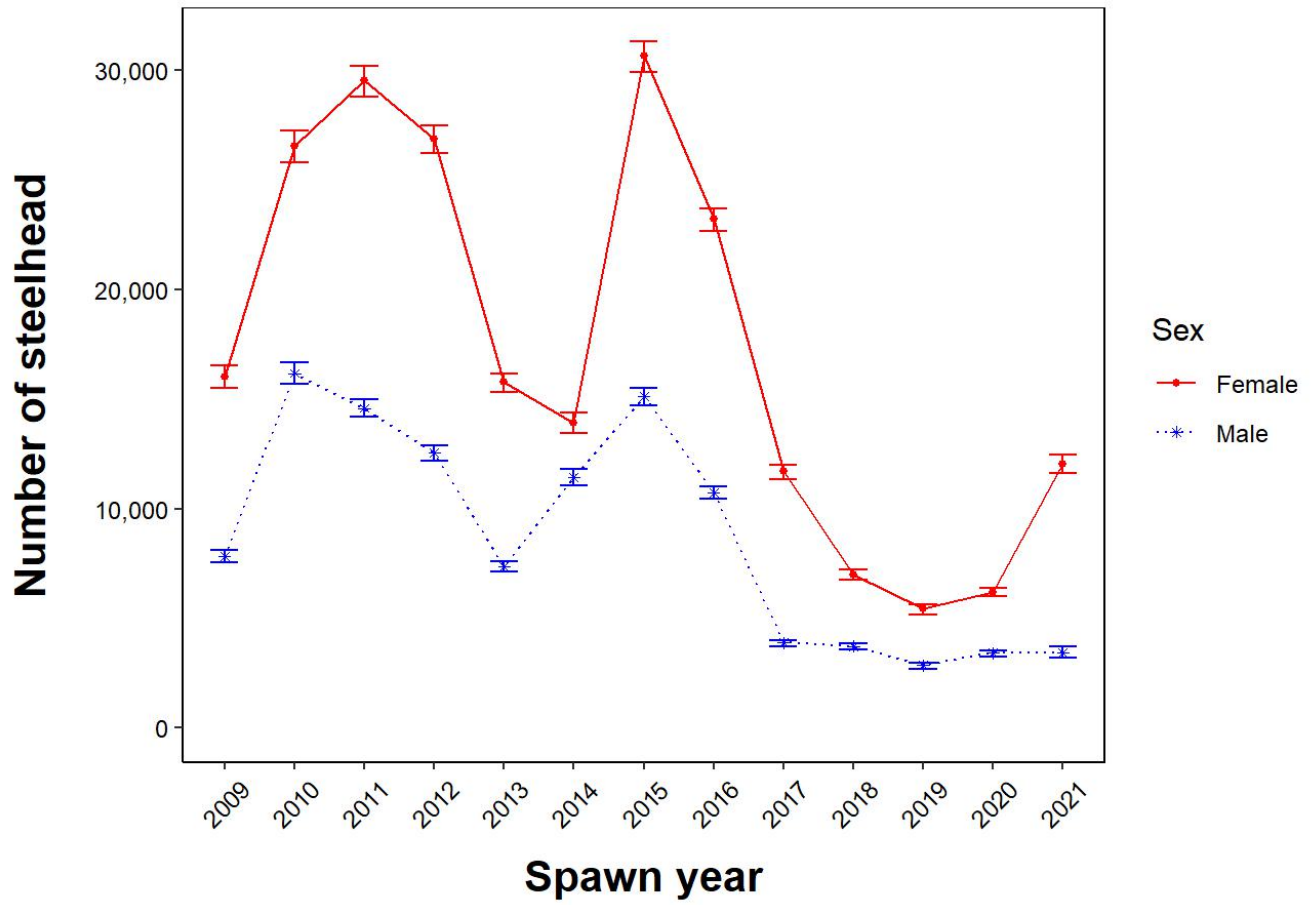
Appendix D-1. Percentage of the estimated escapement of wild steelhead by genetic stock to the overall estimated wild escapement at Lower Granite Dam, spawn years 2010–2021. See Genetic Tissue Processing and Analysis section for stock abbreviations.



Appendix D-2. Estimated escapement of wild steelhead at Lower Granite Dam by sex and by size for each genetic stock, spawn year 2021. L = lower bound and U = upper bound of 90% confidence intervals. See Genetic Tissue Processing and Analysis section for stock abbreviations.

Genetic stock	Estimated number of steelhead at Lower Granite Dam that were:														
	Female			Male			Large			Small			Total wild		
	Estimate	L	U	Estimate	L	U	Estimate	L	U	Estimate	L	U	Estimate	L	U
UPSALM	1,477	1,280	1,668	434	333	534	90	43	144	1,821	1,590	2,021	1,911	1,675	2,122
MFSALM	783	662	895	167	116	221	255	196	322	695	579	797	950	819	1,077
SFSALM	361	278	438	96	56	135	266	207	333	191	127	253	457	365	546
LOSALM	325	233	446	76	40	131	22	2	51	379	276	508	401	292	535
UPCLWR	1,336	1,194	1,495	329	257	417	1,120	988	1,257	545	449	645	1,665	1,509	1,837
SFCLWR	1,080	938	1,225	446	360	547	1,033	892	1,176	493	394	597	1,526	1,354	1,706
LOCLWR	888	720	1,064	250	167	336	162	103	231	976	792	1,179	1,138	946	1,356
IMNAHA	804	656	944	184	119	257	30	7	59	958	793	1,114	988	825	1,151
GRROND	3,584	3,282	3,907	1,038	884	1,192	179	130	298	4,443	4,084	4,768	4,622	4,281	4,982
LSNAKE	1,393	1,148	1,642	427	318	550	108	60	170	1,712	1,414	2,026	1,820	1,518	2,153
Total	12,031	11,609	12,447	3,447	3,200	3,701	3,265	3,052	3,548	12,213	11,744	12,620	15,478	15,001	15,973

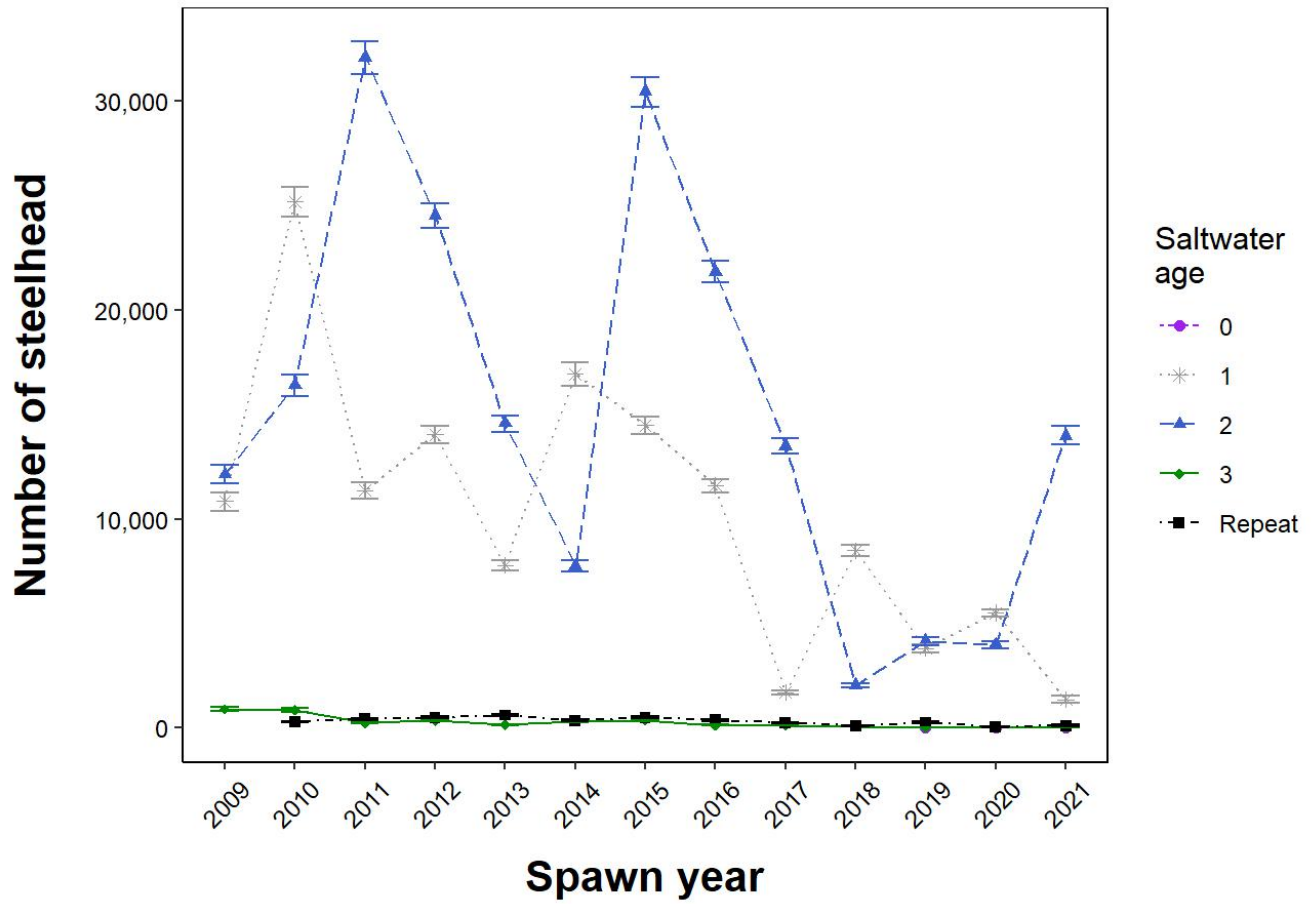
Appendix D-3. Estimated escapement by sex of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%.



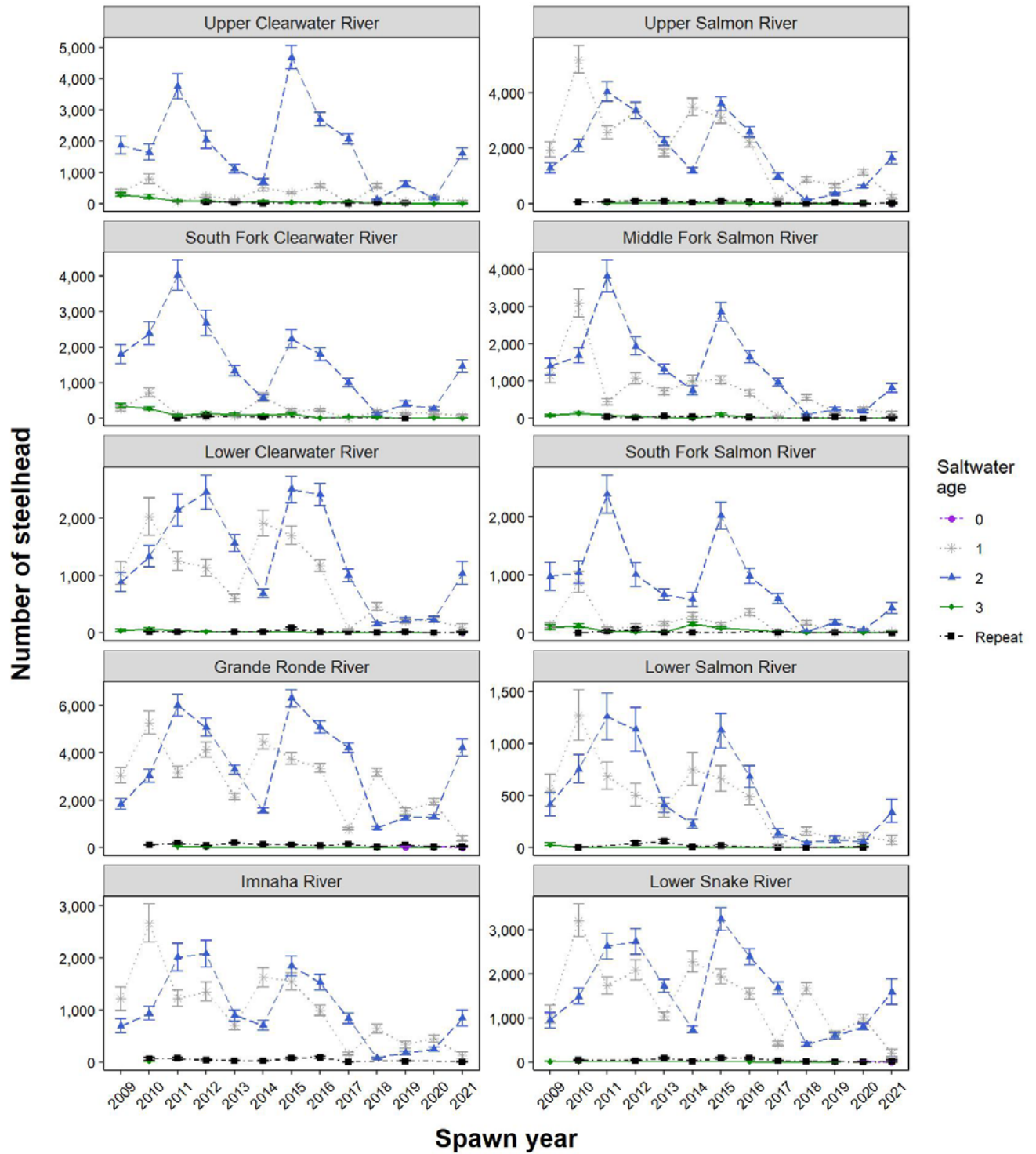
Appendix D-4. Estimated escapement of wild steelhead at Lower Granite Dam by smolt migration year, brood year, and age class for each genetic stock, spawn year 2021. Only individual fish that had both a total age and an assigned stock were used (n = 2,085). Age class format is European: freshwater age.saltwater age. R represents consecutive year repeat spawners who spawned two years in a row, and R1 represents skip spawners who spent one year in saltwater between spawning years. See Genetic Tissue Processing and Analysis section for stock abbreviations.

Genetic stock	Smolt migration year (MY), brood year (BY), and age class																				Total wild
	MY16		MY17					MY18					MY19				MY20				
	BY14	BY14	BY14	BY15	BY15	BY15	BY16	BY14	BY14	BY15	BY15	BY16	BY16	BY17	BY15	BY16	BY17	BY18	BY17	BY18	
	2.2R1	3.1R1	3.3	2.1R1	2.2.R	2.3	1.1R1	4.1R	4.2	3.1R	3.2	2.1R	2.2	1.2	4.1	3.1	2.1	1.1	3.0	2.0	
UPSALM	0	7	0	0	0	0	4	0	8	0	374	0	1,137	136	24	80	121	17	0	3	1,911
MFSALM	0	0	0	0	0	1	0	0	9	10	562	1	240	3	12	95	16	1	0	0	950
SFSALM	2	0	0	0	0	8	0	0	14	0	295	0	119	0	2	10	7	0	0	0	457
LOSALM	0	0	0	0	0	0	0	0	4	0	114	0	212	7	2	28	32	2	0	0	401
UPCLWR	0	0	3	0	0	7	0	0	8	0	717	0	822	55	11	39	3	0	0	0	1,665
SFCLWR	0	0	6	0	0	0	0	0	4	0	273	0	1,009	178	0	33	23	0	0	0	1,526
LOCLWR	1	0	0	0	0	0	2	6	3	0	165	0	764	101	2	29	58	4	0	3	1,138
IMNAHA	0	0	0	0	6	0	4	0	2	0	174	0	633	37	1	55	67	3	6	0	988
GRROND	11	1	0	5	7	0	6	0	12	0	990	5	2,938	280	7	160	190	8	2	0	4,622
LSNAKE	6	4	0	3	0	0	2	2	3	0	321	1	1,100	165	3	103	95	11	0	1	1,820
Total	20	12	9	8	13	16	18	8	67	10	3,985	7	8,974	962	64	632	612	46	8	7	15,478

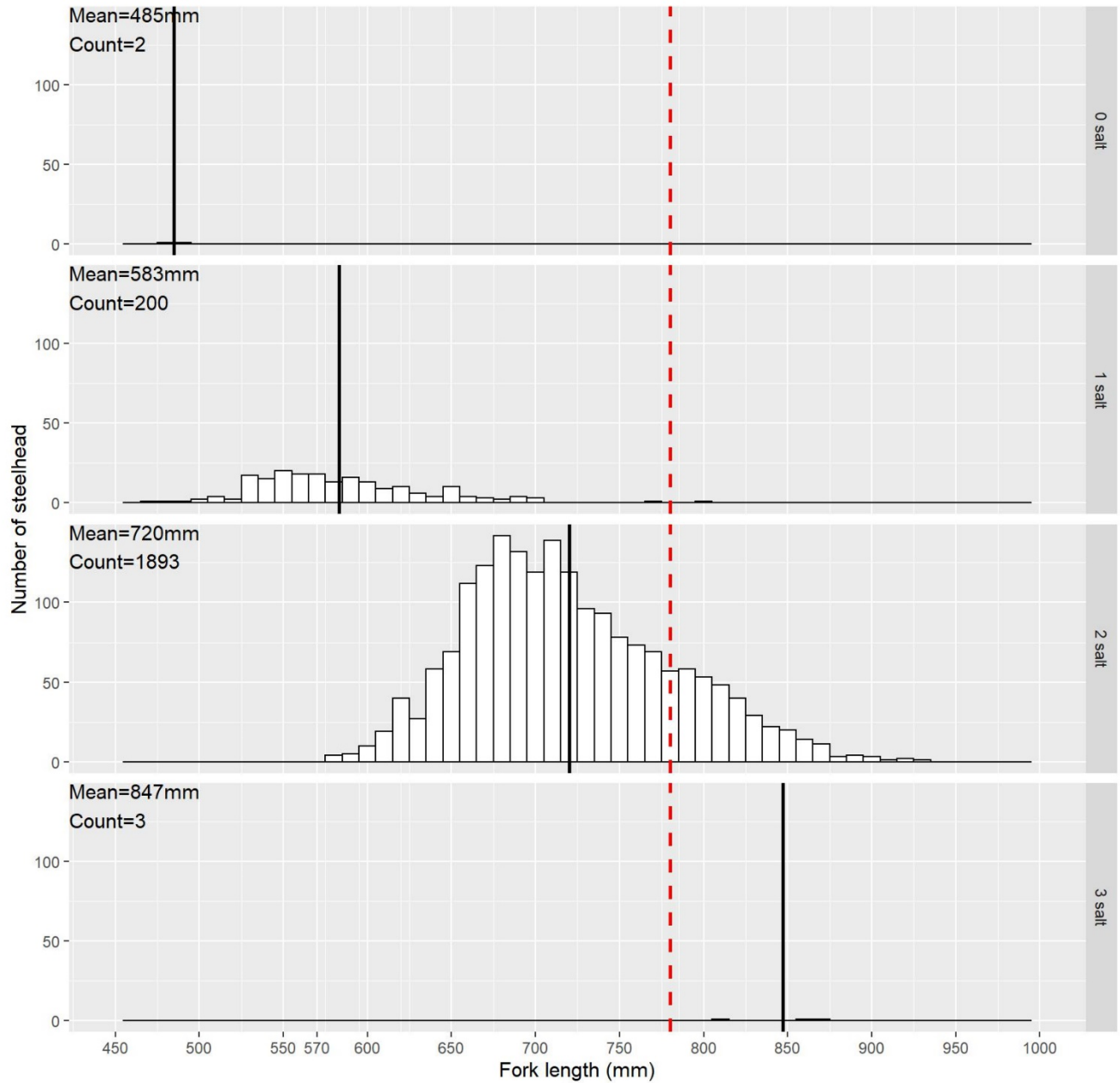
Appendix D-5. Estimated escapement by saltwater age of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Repeat refers to steelhead showing evidence of previous spawning events.



Appendix D-6. Estimated escapement by genetic stock and saltwater age of wild steelhead at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Repeat refers to steelhead showing evidence of previous spawning events.

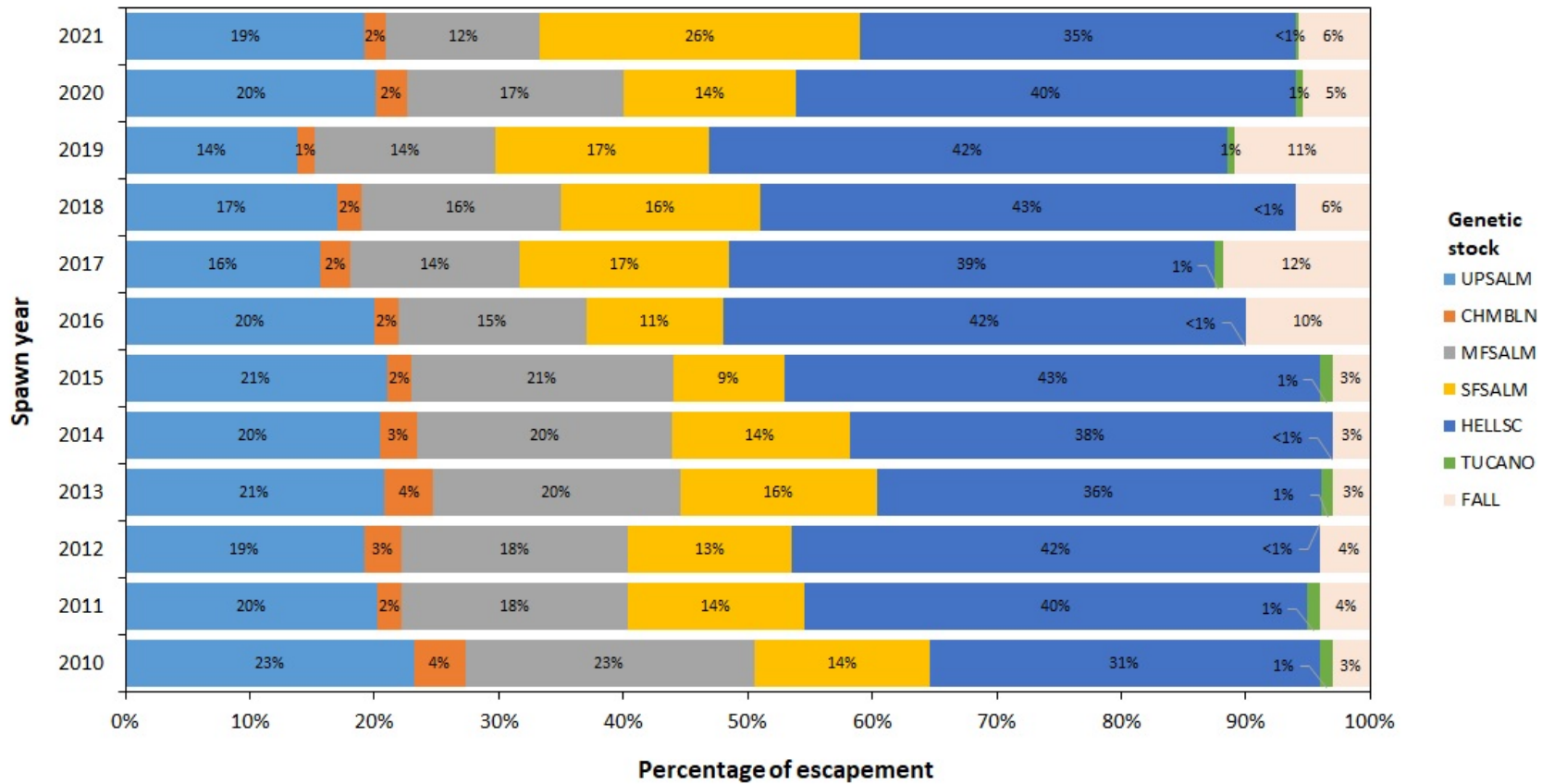


Appendix D-7. Length frequency distribution by saltwater age of wild steelhead trapped at Lower Granite Dam, spawn year 2021. Solid black vertical line represents the mean fork length (FL) for each saltwater age. Dashed vertical red line represents the 780 mm FL cutoff for determining large-sized steelhead.



Appendix E: Wild Chinook Salmon at Lower Granite Dam, spawn year 2021.

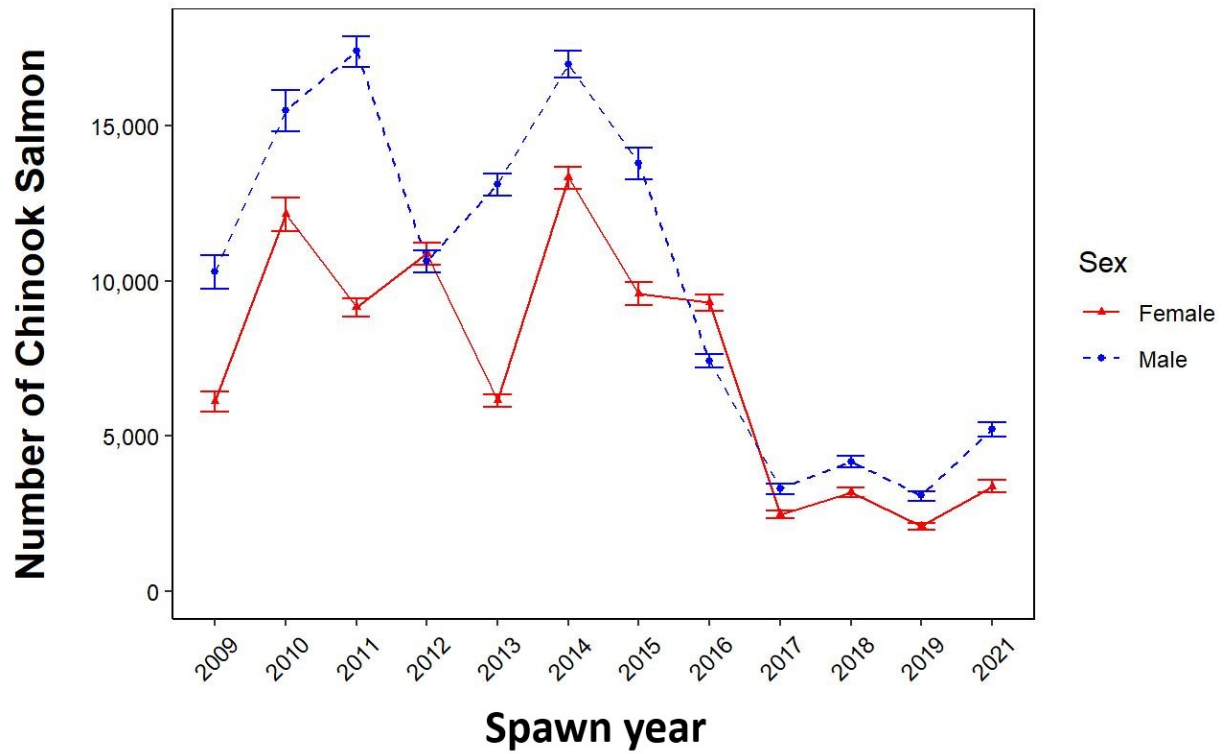
Appendix E-1. Percentage of the estimated escapement of wild Chinook Salmon by genetic stock to the overall estimated wild escapement at Lower Granite Dam, spawn years 2010–2021. Spawn year 2020 stock-specific estimates were generated using run reconstruction methods and do not include jacks in the total wild count. See Genetic Tissue Processing and Analysis section for stock abbreviations.



Appendix E-2. Estimated escapement of wild Chinook Salmon at Lower Granite Dam by sex and by size for each genetic stock, spawn year 2021. L = lower bound and U = upper bound of 90% confidence intervals. See Genetic Tissue Processing and Analysis section for stock abbreviations.

Genetic stock	Estimated number of Chinook Salmon at Lower Granite Dam that were:														
	Female			Male			Large			Small			Total wild		
	Estimate	L	U	Estimate	L	U	Estimate	L	U	Estimate	L	U	Estimate	L	U
UPSALM	652	556	753	1,003	873	1,121	1,405	1,245	1,552	250	191	329	1,655	1,490	1,825
CHMBLN	35	14	59	114	72	158	95	60	137	54	26	83	149	100	198
MFSALM	385	303	466	675	567	785	850	718	977	210	154	283	1,060	927	1,205
SFSALM	821	706	931	1,397	1,247	1,552	1,764	1,581	1,941	454	381	541	2,218	2,014	2,427
HELLSC	1,271	1,143	1,418	1,737	1,587	1,904	2,487	2,306	2,715	521	419	604	3,008	2,797	3,238
TUCANO	14	0	35	1	0	8	15	0	38	0	0	4	15	0	39
FALL	206	160	254	293	239	350	409	348	477	90	61	122	499	432	575
Total	3,384	3,190	3,588	5,220	4,975	5,456	7,025	6,730	7,329	1,579	1,436	1,740	8,604	8,318	8,929

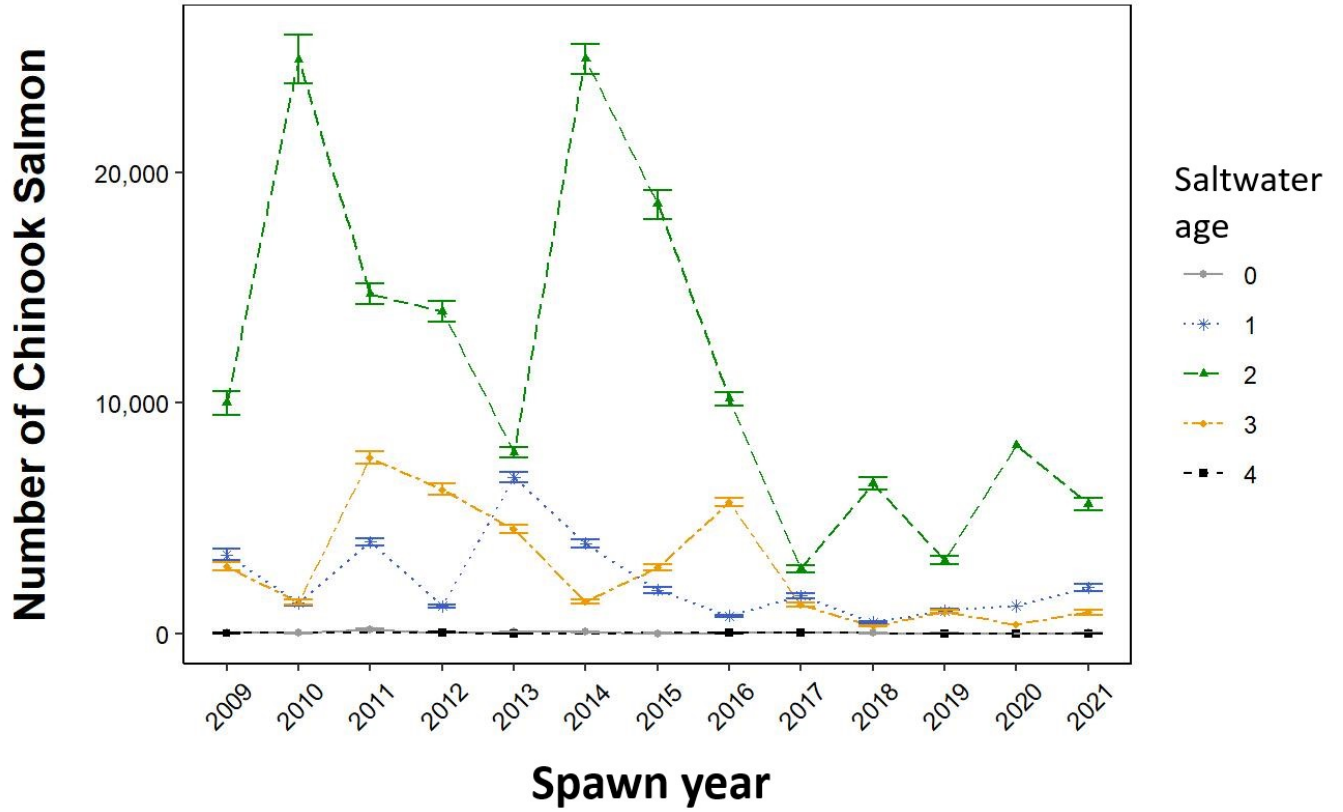
Appendix E-3. Estimated escapement by sex of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Spawn year 2020 sex estimates are not available because the trap was closed due to COVID-19 restrictions.



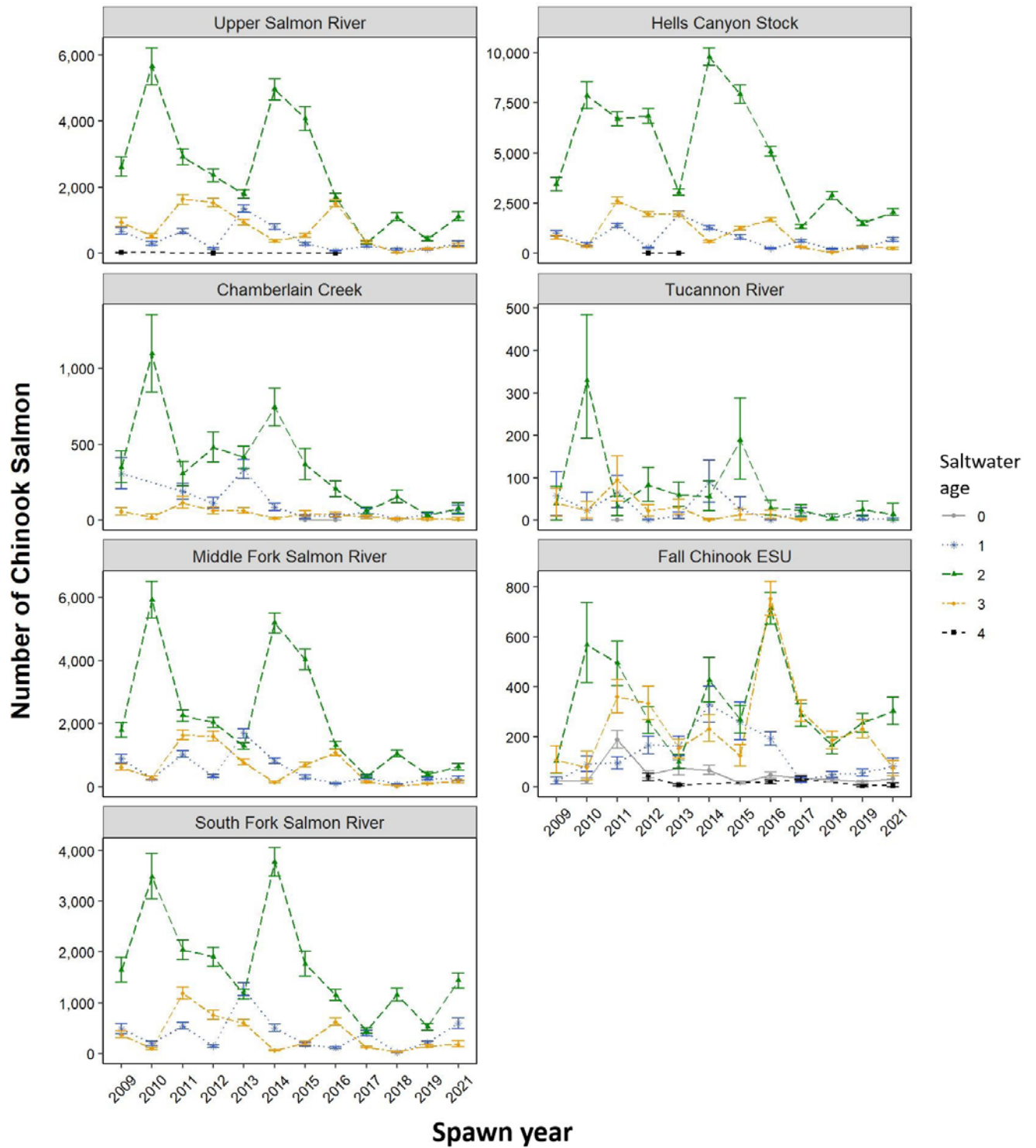
Appendix E-4. Estimated escapement of wild Chinook Salmon at Lower Granite Dam by smolt migration year, brood year, and age class for each genetic stock, spawn year 2021. Only individual fish that had both a total age and an assigned stock were used (n = 1,832). See Genetic Tissue Processing and Analysis section for stock abbreviations.

Genetic stock	Smolt migration year (MY), brood year (BY), and age class									Total wild
	MY2017	MY2018		MY2019		MY2020		MY2021		
	BY15 1.4	BY15 2.3	BY16 1.3	BY16 2.2	BY17 1.2	BY17 2.1	BY18 1.1	BY18 2.0	BY19 1.0	
UPSALM	0	0	236	8	1,108	8	295	0	0	1,655
CHMBLN	0	0	5	0	78	0	66	0	0	149
MFSALM	0	3	166	4	632	2	253	0	0	1,060
SFSALM	0	0	184	9	1,430	9	586	0	0	2,218
HELLSC	0	1	259	12	2,030	21	685	0	0	3,008
TUCANO	0	0	0	0	14	0	1	0	0	15
FALL	5	4	71	102	202	34	49	23	9	499
Total	5	8	921	135	5,494	74	1,935	23	9	8,604

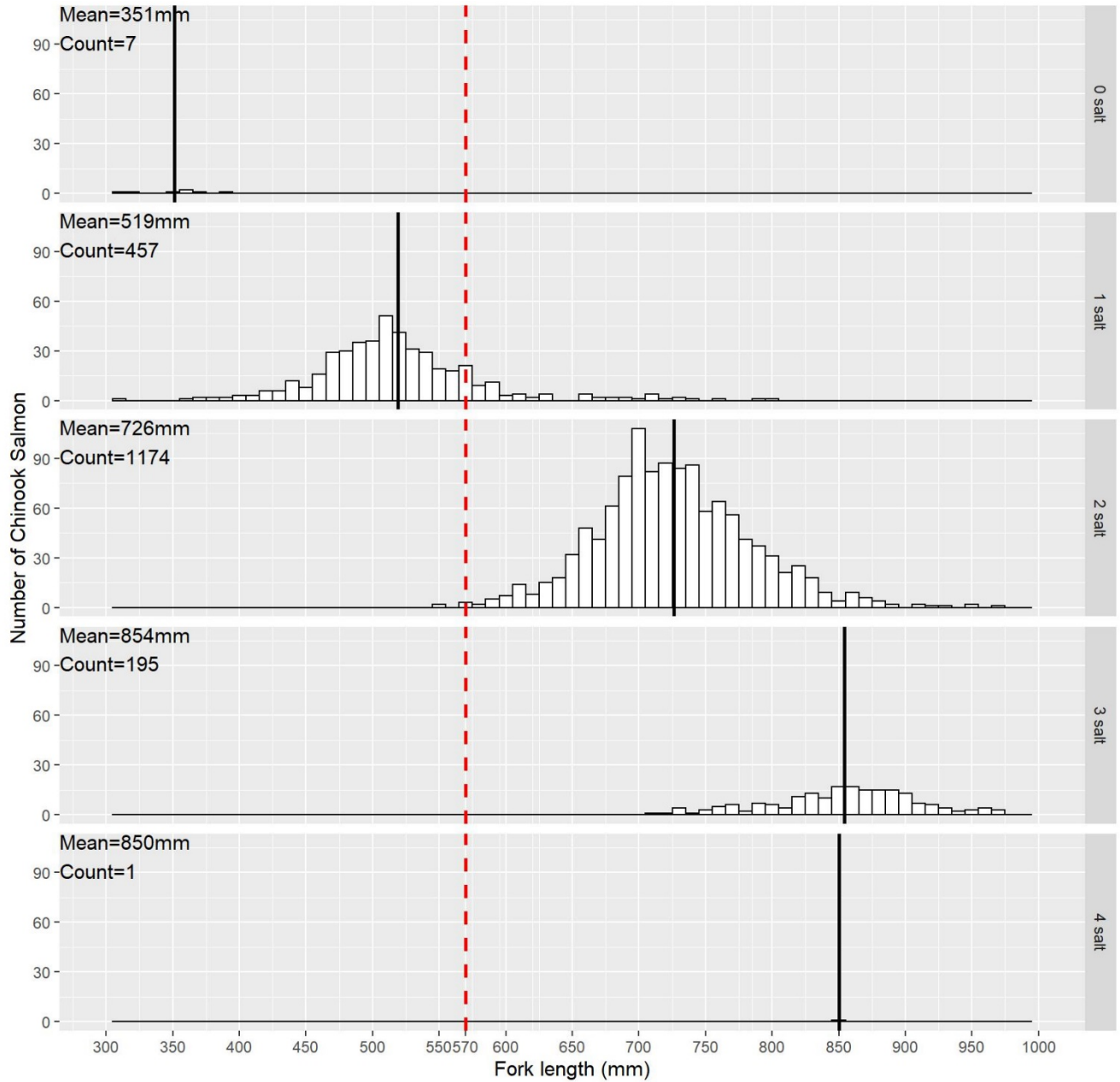
Appendix E-5. Estimated escapement by saltwater age of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Confidence intervals are at 90%. Spawn year 2020 saltwater age estimates were generated using run reconstruction and do not have confidence intervals. Saltwater age-0 refers to mini-jacks.



Appendix E-6. Estimated escapement by genetic stock and saltwater age of wild Chinook Salmon at Lower Granite Dam, spawn years 2009–2021. Spawn year 2020 saltwater age estimates were not available at the stock level because the trap was closed due to COVID-19 restrictions. Confidence intervals are at 90%. Saltwater age-0 refers to mini-jacks.



Appendix E-7. Length frequency distribution by saltwater age of wild Chinook Salmon trapped at Lower Granite Dam, spawn year 2021. Solid black vertical line represents the mean length for each saltwater age. Dashed vertical red line represents the 570 mm FL cutoff for determining large-sized Chinook Salmon.



LITERATURE CITED

- Ackerman, M. W., J. McCane, C. A. Steele, M. R. Campbell, A. P. Matala, J. E. Hess, and S. R. Narum. 2012. Chinook and steelhead genotyping for genetic stock identification at Lower Granite Dam. Idaho Department of Fish and Game Report 12-15. Annual Report 2011, BPA Project 2010-026-00. <https://collaboration.idfg.idaho.gov/Fisheries/TechnicalReports/Forms/AllItems.aspx>.
- Ackerman, M. W., N. V. Vu, J. McCane, C. A. Steele, M. R. Campbell, A. P. Matala, J. E. Hess, and S. R. Narum. 2014. Chinook and steelhead genotyping for genetic stock identification at Lower Granite Dam. Idaho Department of Fish and Game Report 14-01. Annual Report 2013, BPA Project 2010-026-00. <https://collaboration.idfg.idaho.gov/Fisheries/TechnicalReports/Forms/AllItems.aspx>.
- Anderson, E. C. 2010. Computational algorithms and user-friendly software for parentage-based tagging of Pacific salmonids. Final report submitted to the Pacific Salmon Commission's Chinook Technical Committee.
- Baum, C. M., K. M. Lawry, C. L. Sullivan, J. S. Hargrove, T. Delomas, M. Davison, M. E. Dobos, N. R. Smith, W. C. Schrader, T. Copeland, and M. R. Campbell. 2022. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn year 2020. Annual Report 2020. Idaho Department of Fish and Game Report 22-11.
- Boggs, C. T., M. L. Keefer, C. A. Peery, and T. C. Bjornn. 2004. Fallbacks, reascension, and adjusted fishway escapement estimates for adult CHS and STHD at Columbia and Snake river dams. Transactions of the American Fisheries Society 133:932-949.
- Bowersox, B. J., M. P. Corsi, J. L. McCormick, T. Copeland, and M. R. Campbell. 2019. Examining life history shifts and genetic composition in a hatchery steelhead population, with implications for fishery and ocean selection. Transactions of the American Fisheries Society 148:1056-1068. DOI:10.1002/tafs.10199
- Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Wauneta, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27.
- Camacho, C. A., K. K. Wright, J. Powell, W. C. Schrader, T. Copeland, M. W. Ackerman, M. Dobos, M. P. Corsi, and M. R. Campbell. 2017. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn years 2009-2016. Cumulative Report 2009 through 2016. Idaho Department of Fish and Game Report 17-06.
- Camacho, C. A., J. Powell, M. Davison, M. E. Dobos, W. C. Schrader, T. Copeland, and M. R. Campbell. 2018a. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn year 2017. Annual Report 2017. Idaho Department of Fish and Game Report 18-06.
- Camacho, C. A., K. K. Wright, J. Powell, W. C. Schrader, T. Copeland, M. W. Ackerman, M. Dobos, M. P. Corsi, and M. R. Campbell. 2018b. Wild juvenile steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, migration years 2010–2017. Cumulative Report 2010 through 2017. Idaho Department of Fish and Game Report 18-05.

- Camacho, C. A., T. Delomas, M. Davison, M. E. Dobos, W. C. Schrader, T. Copeland, and M. R. Campbell. 2019a. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn year 2018. Annual Report 2018. Idaho Department of Fish and Game Report 19-09.
- Camacho, C. A., T. Delomas, M. Davison, M. E. Dobos, W. C. Schrader, T. Copeland, and M. R. Campbell. 2019b. Wild juvenile steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, migration year 2018. Annual Report 2018. Idaho Department of Fish and Game Report 19-12.
- Campbell, M. R., C. C. Kozfkay, T. Copeland, W. C. Schrader, M. W. Ackerman, and S. R. Narum. 2012. Estimating abundance and life history characteristics of threatened wild Snake River steelhead stocks by using genetic stock identification. *Transactions of the American Fisheries Society* 141:1310-1327.
- Campbell, M. R., S. A. Harmon, and S. R. Narum. 2015. Genotyping-in-Thousands by sequencing (GT-seq): A cost effective SNP genotyping method based on custom amplicon sequencing. *Molecular Ecology Resources* 15(4):855–867.
- Columbia Basin Partnership Task Force. 2020. A vision for salmon and steelhead: goals to restore thriving salmon and steelhead to the Columbia River Basin. Phase 2 Report of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee. [A Vision for Salmon and Steelhead](#).
- Conrad, R. H., and J. L. Gutmann. 1996. Conversion equations between fork length and total length for Chinook Salmon (*Oncorhynchus tshawytscha*). Northwest Indian Fisheries Commission. Northwest Fishery Resource Bulletin Project Report Series No. 5. Olympia, WA.
- Copeland, T., J. Johnson, and P. R. Bunn. 2004. Idaho natural production monitoring and evaluation. Idaho Department of Fish and Game Report 04-07. BPA Project 1991-073-00. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.
- Copeland, T., M. W. Ackerman, K. K. Wright, and A. Byrne. 2017. Life history diversity of Snake River steelhead populations between and within management categories. *North American Journal of Fisheries Management* 37:395-404.
- Copeland, T., K. Hernandez, M. T. Davison, and K. Wright. 2018. Validation of spawn checks and saltwater age assignments based on scales from known repeat-spawning steelhead. *North American Journal of Fisheries Management*, 38: 1050-1058. <https://doi.org/10.1002/nafm.10210>.
- Delomas, T., J. McCane, J. Hargrove, M. Campbell, R. Horn, and S. Narum. 2020. Parentage-based tagging of Snake River hatchery steelhead and Chinook Salmon. Idaho Department of Fish and Game Report 20-02. Annual Report 2019. BPA Project 2010-031-00. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.
- Delomas, T. A., and J. E. Hess. 2021. A new estimator to correct for bias from tag rate expansion on natural-origin fish attributes in mixed-stock analysis using parentage-based tagging. *North American Journal of Fisheries Management*. <https://doi.org/10.1002/nafm.10537>

- Ebel, J. D., T. Copeland, J. S. Hargrove, M. Davison, M. E. Dobos, W. C. Schrader, and M. R. Campbell. 2022. Wild juvenile steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, migratory year 2019. Annual Report 2019. Idaho Department of Fish and Game Report 22-08.
- Fleiss, J. L. 1981. Statistical Methods for Rates and Proportions. 2nd ed. Wiley, New York.
- Ford, M. J. (ed.). 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. US Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-113.
- Ford, M. J. (ed.). 2015. Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest. National Marine Fisheries Service, Northwest Fisheries Science Center.
- Hargrove, J. S., T. A. Delomas, J. McCane, M. Davison, M. R. Campbell, R. L. Horn, and S. R. Narum. 2020. Chinook Salmon and steelhead genotyping for genetic stock identification at Lower Granite Dam. Idaho Department of Fish and Game Report 20-05. Annual Report 2019. BPA Project 2010-026-00. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.
- Hargrove, J. S., C. A. Camacho, W. C. Schrader, J. H. Powell, T. A. Delomas, J. E. Hess, S. R. Narum, and M. R. Campbell. 2021. Parentage-based tagging improves escapement estimates for ESA-listed adult Chinook salmon and steelhead in the Snake River basin. Canadian Journal of Fisheries and Aquatic Sciences 78(4): 349-360.
- Hargrove, J. S., A. C. Harris, J. McCane, M. Davison, M. R. Campbell, R. L. Horn, and S. R. Narum. 2022. Genetic Monitoring of Snake River Salmonids. Idaho Department of Fish and Game Report 22-06. Annual Report, BPA Project 2010-031-00.
- Harmon, J. R. 2003. A trap for handling adult anadromous salmonids at Lower Granite Dam on the Snake River, Washington. North American Journal of Fisheries Management 23:989-992.
- ICBTRT (Interior Columbia Basin Technical Recovery Team). 2003. Independent populations of Chinook, steelhead, and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Working Draft, July 2003.
- ICBTRT (Interior Columbia Basin Technical Recovery Team). 2005. Updated population delineation in the interior Columbia basin. Memo to NMFS Northwest Regional Office May 11, 2005.
- ICBTRT (Interior Columbia Basin Technical Recovery Team). 2009. Updated population delineation in the interior Columbia basin. Memo to NMFS Northwest Regional Office May 2009.
- IDFG (Idaho Department of Fish and Game). 2019. Fisheries management plan 2019–2024. IDFG, Boise. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.
- IPTDSW (In-stream PIT-tag detection systems workgroup). 2020. Report to NOAA Fisheries for 5-Year ESA Status Review: Snake River Basin Steelhead and Chinook Salmon

Population Abundance, Life History, and Diversity Metrics Calculated from In-stream PIT Tag Observations (SY2010–SY2019). January 2020.

- Joint Columbia River Management Staff. 2021. Stock status and fisheries for fall Chinook Salmon, Coho Salmon, Chum Salmon, summer steelhead, and White Sturgeon. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife Joint Staff Report 2021. [2007 JOINT STAFF REPORT: \(wa.gov\)](#)
- LaHood, E. S., J. J. Miller, C. Apland, and M. J. Ford. 2008. A rapid, ethanol-free fish tissue collection method for molecular genetic analyses. *Transactions of the American Fisheries Society* 137(4):1104-1107.
- Lawry, K. M., C. A. Camacho., J. S. Hargrove, T. Delomas, M. Davison, M. E. Dobos, W. C. Schrader, T. Copeland, and M. R. Campbell. 2020. Wild adult steelhead and Chinook Salmon abundance and composition at Lower Granite Dam, spawn year 2019. Annual Report. Idaho Department of Fish and Game Report 20-12.
- McCann, J., B. Chockley, E., Cooper, H. Schaller, S. Haesecker, R. Lessard, C. Petrosky, E. Tinus, E. Van Dyke, and R. Ehlke. 2015. Comparative survival study of PIT-tagged spring/summer/fall Chinook, summer steelhead, and sockeye, 2015 annual report. Report to Bonneville Power Administration, project 1996-02-00, Portland, Oregon.
- McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonids populations and the recovery of evolutionarily significant units. National Oceanic and Atmospheric Administration Technical Memorandum NMFS-NWFSC-42.
- Moran, B. M., and E. C. Anderson. 2019. Bayesian inference from the conditional genetic stock identification model. *Canadian Journal of Fisheries and Aquatic Sciences* 76(4):551-560.
- Narum, S. R., J. E. Hess, and A. P. Matala. 2010. Examining genetic lineages of Chinook Salmon in the Columbia River basin. *Transactions of the American Fisheries Society* 139(5):1465-1477. <https://doi.org/10.1577/T09-150.1>.
- NMFS (National Marine Fisheries Service). 2016. Five-year review: summary and evaluation of Snake River sockeye, Snake River spring-summer Chinook, Snake River fall-run Chinook, Snake River basin steelhead. NMFS, Northwest Region.
- NMFS (National Marine Fisheries Service). 2017. ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (*Oncorhynchus tshawytscha*) and Snake River Basin Steelhead (*Oncorhynchus mykiss*). www.fisheries.noaa.gov/resource/document/recovery-plan-snake-river-spring-summer-chinook-salmon-and-snake-river-basin
- NPCC (Northwest Power and Conservation Council). 2014. Columbia River Basin Fish and Wildlife Program 2014: 2014 Amendments. Northwest Power and Conservation Council document 2014-12. [2014-12_1.pdf \(nwcouncil.org\)](#)
- NPCC (Northwest Power and Conservation Council). 2020. Columbia River Basin Fish and Wildlife Program 2014: 2020 Addendum. Northwest Power and Conservation Council document 2020-9. [2020-9.pdf \(nwcouncil.org\)](#)

- Persson, P., K. Sundell, B. T. Björnsson, and H. Lundqvist. 1998. Calcium metabolism and osmoregulation during sexual maturation of river running Atlantic Salmon. *Journal of Fish Biology* 52:334–349.
- Petrosky, C. E., H. A. Schaller, E. S. Tinus, T. Copeland, and A. J. Storch. 2020. Achieving Productivity to Recover and Restore Columbia River Stream-Type Chinook Salmon Relies on Increasing Smolt-To-Adult Survival. *North American Journal of Fisheries Management* 40:789-803. <https://doi.org/10.1002/nafm.10449>
- Powell, J. H., N. Vu, J. McCane, M. Davison, M. R. Campbell, D. J. Hasselman, and S. R. Narum. 2018. Chinook and Steelhead Genotyping for Genetic Stock Identification at Lower Granite Dam. Idaho Department of Fish and Game Report 18-03. Annual Report, BPA Project 2010-026-00.
- R Development Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>.
- Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer Chinook Salmon and steelhead in the Columbia River basin. *North American Journal of Fisheries Management* 8:1-24.
- Reinhardt, L., T. Copeland, and M. Davison. 2022. Validation of Scale-Derived Ages in Wild Juvenile and Adult Steelhead Using Parental-Based Tagging. *North American Journal of Fisheries Management* 42:260-269. <https://doi.org/10.1002/nafm.10737>
- Richins, S. M, and J. R. Skalski. 2018. Steelhead overshoot and fallback rates in the Columbia-Snake River basin and the influence of hatchery and hydrosystem operations. *North American Journal of Fisheries Management* 38:1122-1137.
- See, K. E., R. N. Kinzer, and M. W. Ackerman. 2021. State-space model to estimate salmon escapement using multiple data sources. *North American Journal of Fisheries Management*. <https://doi.org/10.1002/nafm.10649>
- Stark, E. J., P. J. Cleary, J. M. Erhardt, T. Miller, and J. W. Feldhaus. 2021. Snake River basin 2018–2019 steelhead run reconstruction. BPA Project 1990-055-00, Report to Bonneville Power Administration, Portland, Oregon.
- Steele, C. A., E. C. Anderson, M. W. Ackerman, M. A. Hess, N. R. Campbell, S. R. Narum, and M. R. Campbell. 2013. A validation of parentage-based tagging using hatchery steelhead in the Snake River basin. *Canadian Journal of Fisheries and Aquatic Sciences* 70:1-9. <https://cdnsciencepub.com/doi/10.1139/cjfas-2012-0451> .
- Steele, C. A., J. McCane, M. Ackerman, N. Vu, M. Campbell, M. Hess, and S. Narum. 2016. Parentage Based Tagging of Snake River hatchery steelhead and Chinook Salmon. SY2014. Idaho Department of Fish and Game Report 16-02. Annual report 2015, BPA Project 2010-031-00. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.
- Steinhorst, K., D. Milks, G. P. Naughton, M. Schuck, and B. Arnsberg. 2010. Use of statistical bootstrapping to calculate confidence intervals for the fall Chinook Salmon run

- reconstruction to Lower Granite Dam. Transactions of the American Fisheries Society 139:1792-1801.
- Steinhorst, K. T. Copeland, M. W. Ackerman, W. C. Schrader, and E. C. Anderson. 2017. Abundance estimates and Confidence Intervals for Run Composition of Returning Salmonids. Fishery Bulletin 115:1-12. <https://doi.org/10.7755/FB.115.1.1>
- Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41:42-46.
- USACE (U.S. Army Corps of Engineers). 2020. Annual fish passage report. U.S. Army Engineer Districts, Portland and Walla Walla.
- USACE (U.S. Army Corps of Engineers). 2021. Annual fish passage report. U.S. Army Engineer Districts, Portland and Walla Walla.
- Vu, N., M. W. Ackerman, K. K. Wright, J. McCane, M. R. Campbell, J. E. Hess, and S. R. Narum. 2015. Chinook and steelhead genotyping for genetic stock identification at Lower Granite Dam. Idaho Department of Fish and Game Report 15-02. Annual Report, BPA Project 2010-026-00.
- Witten, P. E., and A. Huysseune. 2009. A comparative view on mechanisms and functions of skeletal remodeling in teleost fish, with special emphasis on osteoclasts and their function. Biological Reviews 84:315–346.
- Wright, K., W. Schrader, L. Reinhardt, K. Hernandez, C. Hohman, and T. Copeland. 2015. Process and methods for assigning ages to anadromous salmonids from scale samples. Idaho Department of Fish and Game Report 15-03. <https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Forms/AllItems.aspx>.

Prepared by:

Carli M. Baum
Fisheries Biologist

John S. Hargrove
Fishery Biologist 2

Thomas Delomas
Fishery Biologist 2

Micah Davison
Supervisory Fisheries Biologist

Marika E. Dobos
Staff Biologist

Nolan R. Smith
Fishery Biologist 1

William C. Schrader
Principal Fisheries Research Biologist

Timothy Copeland
Fisheries Program Coordinator

Matthew R. Campbell
Fisheries Program Coordinator

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

John D. Cassinelli
Anadromous Fisheries Manager

J. Lance Hebdon, Chief
Bureau of Fisheries