NOAA Contract Report NMFS-NWFSC-CR-2021-03

https://doi.org/10.25923/7nf5-8f16

Monitoring the Migrations of Wild Snake River Spring/Summer Chinook Salmon Juveniles:

Survival and Timing, 2020

Project **1991-028-00**, Contract **83639 REL 7**
covering the period from **January 2019 to December 2020**

May 2021

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

NOAA Contract Report Series NMFS-NWFSC-CR

Recommended citation:

(Lamb et al. 2021)[1]

[1] Lamb, J. J., B. P. Sandford, G. A. Axel, S. G. Smith, M. G. Nesbit, and B. L. Sanderson. 2021. Monitoring the Migrations of Wild Snake River Spring/Summer Chinook Salmon Juveniles: Survival and Timing, 2020. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC-CR-2021-03.

https://doi.org/10.25923/7nf5-8f16

NOAA FISHERIES

Monitoring the Migrations of Wild Snake River Spring/Summer Chinook Salmon Juveniles: Survival and Timing, 2020

Jesse J. Lamb, Benjamin P. Sandford, Gordon A. Axel, Steven G. Smith, Matthew G. Nesbit, and Beth L. Sanderson

https://doi.org/10.25923/7nf5-8f16

May 2021

Fish Ecology Division
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

Report prepared for:
Division of Fish and Wildlife
Bonneville Power Administration
U.S. Department of Energy
P.O. Box 3621
Portland, Oregon 97208

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

Contents

Acknowledgments

We thank the Bonneville Power Administration for funding this project. Thanks also to Louis Tullos, Ron Marr, Amber Barenberg, Lela Work, Jared Siegel, Steve Corbett, Kris Snyder, Sarah Fesenmeyer, Aurele LaMontagne, Karl Veggerby, and Ross Gleason of the National Marine Fisheries Service for their excellent assistance in collecting and PIT tagging fish for this study.

We are grateful to staff of the University of Idaho who provided lodging at Taylor Ranch during our sample efforts at Big Creek. Special thanks to Pete and Meg Gag and University of Idaho for hosting us during our stay. We thank Brian Kennedy of the University of Idaho for data collection and management of the "Edwardsburg" instream detection site on Upper Big Creek.

Finally, we are grateful to personnel from Nez Perce Tribe, Quantitative Consultants Inc., and Gabriel Brooks of NOAA for troubleshooting and maintaining PIT tag arrays associated with the project.

Executive Summary

From late summer 2019 to mid-2020, we continued a multiyear research project to monitor the migration behavior and survival of wild juvenile spring/summer Chinook salmon *Oncorhynchus tshawytscha* in the Snake River Basin of Idaho. Wild parr were collected in natal tributaries, implanted with passive integrated transponder (PIT) tags, and released near their respective collection sites. In this report, we present data and analyses from detections of fish tagged in summer 2019 and monitored through spring 2020. Complete detail on fish collection and tagging is described in our report of April 2020, *Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: Fish collection and tagging, 2019*.

Our analyses included estimates of survival from release to instream monitoring systems and from monitoring systems to Lower Granite Dam. These estimates are summarized in Table 1 for populations from the seven Idaho streams with PIT-tag monitoring systems. For the remaining populations and for all stream populations combined, we estimated detection and survival estimates from release to Lower Granite Dam, median date of arrival at the dam. We also recorded growth rate and fish condition factor for recaptured subsamples of these fish. Results from all work in 2019-2020 are summarized below:

- During July-August 2019, we PIT tagged and 8,421 wild Chinook salmon parr and released them to 16 streams or sample reaches.

- For fish from all streams combined, the average estimated rate of survival to Lower Granite Dam (parr-to-smolt survival) was 18.0% (range 11.0-41.8%).

- For tagged parr from all 16 stream populations combined, peak detections at Lower Granite Dam occurred during 25-27 April 2020. Respective dates of the 10th, 50th, and 90th passage percentiles at the dam were 25 April, 5 May, and 26 May 2020.

- During 2020, we were unable to recaptured fish using the separation-by-code system at Lower Granite Dam due to the coronavirus disease 2019 (COVID-19) pandemic.

Table 1. Numbers and proportions of wild spring/summer Chinook salmon released during 2019 and detected during 2019-2020 with associated estimates of survival to monitoring systems and to Lower Granite Dam. Results shown are for eight Idaho streams with instream PIT-tag monitoring systems. Fish from Marsh and Cape Horn Creeks were tagged with either 12- or 9-mm PIT tags.

		Instream monitoring systems						Estimated survival (%)		
		Detected		Detection period (%)			Instream		To Lower Granite Dam	
Collection site	Released (n)	(n)	(%)	Late summer/ fall	Winter	Spring	detection efficiency (%)	To instream monitor	From instream monitor	From release site
Valley Creek	1,144	445	38.9	55.0	34.4	10.6	96.4	40.4	27.4	11.1
Lower Big Creek	193	59	30.6	69.5	28.8	0.7	29.2	104.8	35.8	41.8
Upper Big Creek										
Edwardsburg[a]	565	312	55.2	100.0	--	--	65.5	84.0	25.5	21.9
Taylor Ranch	565	58	10.3	32.7	32.7	34.5	25.6	39.9	63.9	21.9
Lake Creek	327	66	20.2	80.3	16.7	3.0	57.1	35.3	50.9	18.7
Secesh River	450	143	31.8	81.8	15.4	2.8	70.0	45.4	44.2	18.0
S Fork Salmon R	1,241	244	19.7	76.2	7.0	16.8	48.4	40.6	26.8	12.6
Marsh Creek[b]	515	62	12.0	--	--	--	--	--	--	25.2
Cape Horn Creek[b]	128	19	14.8	--	--	--	--	--	--	11.0

[a] The Edwardsburg monitoring system does not run during December-April due to its remote location and limited access to off-grid power.
[b] The new instream monitoring system on Marsh Creek was installed and became operational during October 2019 (an unknown number of fish migrated downstream prior to October).

Introduction

Snake River spring/summer-run Chinook salmon *Oncorhynchus tshawytscha* was listed as threatened under the U.S. Endangered Species Act in 1992 (Matthews and Waples 1991; NMFS 1992). Since that time, this ecologically significant unit (ESU) has been the focus of a recovery plan to restore its populations to self-sustaining levels. Tagging and recapture studies are a vital component of these recovery efforts.

For recovery of Pacific salmon *Oncorhynchus* spp., tagging and recapture studies focus on the juvenile stage because first-year survival is thought to be the greatest contributor to increased population abundance (Kareiva et al. 2000). Advances in telemetry have allowed tagging of smaller juveniles with improved detection data quality. In the late 1980s, the passive integrated transponder (PIT) tag was developed to provide inexpensive, large-scale tagging of juvenile salmonids (Prentice et al. 1990a,b,c).

Each PIT tag contains a unique code, which allows researchers to track and record the movements of individual fish. These small and biologically inert tags can be retained throughout the fish's life cycle, allowing multiple detections of an individual fish without physical recapture. Since its introduction, use of the PIT tag has expanded from about 50,000 to more than 2 million fish tagged annually. These annual tagging efforts, along with automated data collection methods, have created large data sets for wild/natural and hatchery stocks. The Columbia Basin PIT Tag Information System (PTAGIS) was established as a shared repository for these data (PSMFC 1996).

Data from PIT tag detections has provided insight for decisions on programs to enhance juvenile passage at dams, such as spill and transportation (NMFS 2000). However, there is a continuing need for data upon which to base decisions for these and other restoration and recovery efforts. Major gaps remain in our understanding of Columbia Basin stocks, including life history strategies and survival at different stages of the life cycle.

Our multiyear research to tag wild parr directly addresses these data gaps for wild Snake River spring/summer Chinook salmon during the parr-to-smolt stage. In addition to acquiring data for the Northwest Power Planning Council and several other fish and wildlife programs, our research addresses "Reasonable and Prudent Alternatives" in the 2000 NMFS Biological Opinion (NMFS 2000).

For example, section 9.6.5.2, action 180 calls for regional monitoring of population and environmental status of natal streams and tributaries for wild fish stocks. The same biological opinion calls for "research to produce information on the migrational characteristics of Columbia and Snake River Basin salmon and steelhead" (NMFS 2000).

More recently, in response to the remanded biological opinion, the *Final Updated Proposed Action for the FCRPS Biological Remand* proposed that "development and implementation of new fish detection and tagging techniques" be continued (Action Agencies 2004). Marking wild parr in natal streams during their first summer provides the opportunity to precisely track these stocks as they migrate downstream, passing instream PIT-tag monitors, traps, and hydroelectric dams of the Federal Columbia River Power System.

This report includes information on wild Chinook salmon monitored from fall 2019 to spring and early summer 2020 as they moved downstream and began migration towards the Pacific Ocean. Estimates of survival and timing to Lower Granite Dam are reported, as well as interrogation data at several other sites throughout the Snake and Columbia River hydropower system (Appendix Table 18). Results from previous study years were reported by Achord et al. (1994, 1995a,b, 1996a, 1997, 1998, 2000, 2001a,b, 2002,-2012; Lamb et al. 2013-2019a,b). The goals of this ongoing study are to:

1. Characterize migration timing and growth and estimate parr-to-smolt survival to Lower Granite Dam for individual stream populations of wild Snake River spring/summer Chinook salmon
2. Determine whether consistent patterns in migration timing and survival are apparent
3. Determine which environmental factors may influence patterns in migration/survival
4. Characterize the migrational behavior and estimated survival of different wild juvenile Chinook populations as they migrate from natal rearing areas.

This study provides critical information for recovery planning and restoration efforts for these wild Chinook salmon populations, all of which remain listed as threatened under the U.S. Endangered Species Act of 1973 (NMFS 2008).

During 2019, we recorded water temperature and depth measured at 15 locations in the Salmon River Basin, Idaho, for the *Baseline Environmental Monitoring Program*. These environmental data can be compared with parr/smolt migration, survival, and timing data to discern patterns or characteristic relationships that may exist. Understanding these relationships will provide additional insight for recovery planning of threatened salmon populations.

Fish Collection, Tagging, and Release

This section provides a brief summary of tagging and collection effort in summer 2019. Complete details of this work are reported by Lamb et al. (2019b). Briefly, National Marine Fisheries Service (NMFS) personnel tagged fish in 16 Idaho streams or sample reaches (Figure 1). Fish collection followed the safe handling methods developed for this study by Matthews et al. (1990, 1997). Anesthetized fish were haphazardly selected for tagging, provided they met the minimum fork length (FL) requirement of 55 mm.

In 2019, fish were tagged using either 9- or 12-mm PIT tags, with the smaller tags used for fish measuring less than 60 mm fork length. Fish from monitored streams were tagged only with 12-mm advanced performance tags (ATP12, Biomark, Inc. Boise, Idaho).[1] All fish were implanted with tags using pre-loaded, individual single-use hypodermic needles. This method ensured that each fish was tagged with a sterile, sharp needle, thus minimizing stress and injury during the tagging process. After recovery from the anesthetic, fish were released back to the streams where they had been originally captured.

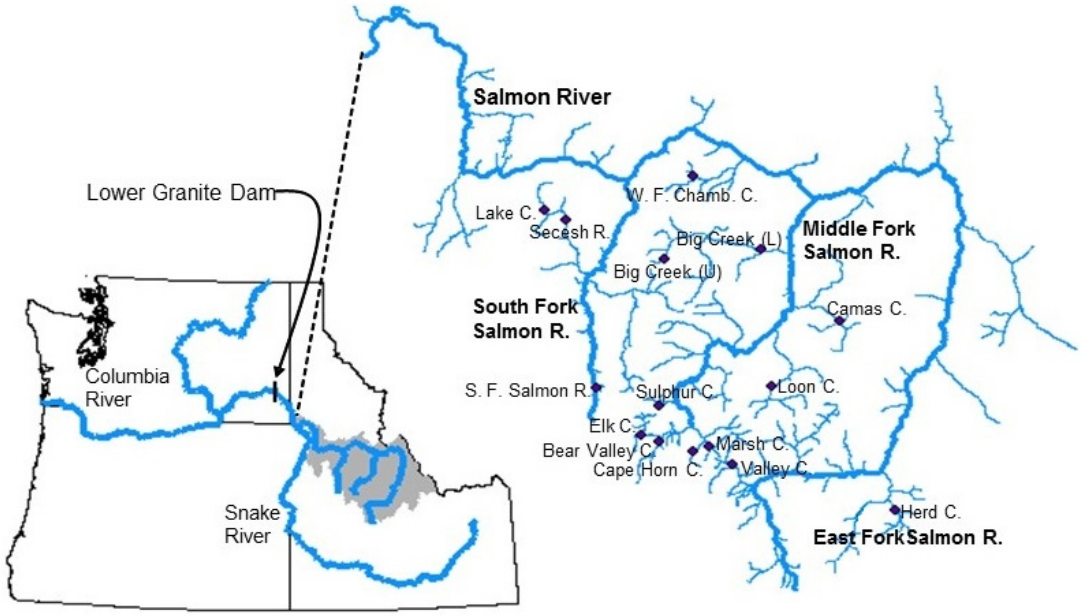

Figure 1. Map showing the streams and sample reaches where wild spring/summer Chinook salmon parr were PIT tagged during 2019.

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 2. Summary of collection, PIT tagging, and release of wild Chinook salmon parr with average fork length and weight (includes recaptured fish), approximate distances, and estimated areas sampled in Idaho streams from July through August 2019.

Tagging location	Number of fish		Average fork length (mm)		Average weight (g)		Collection area to stream mouth (km)	Estimated stream area sampled (m^2)
	Collected	Tagged & released	Collected	Tagged	Collected	Tagged		
Herd Creek	37	35	66.2	64.6	4.0	3.2	2.0-3.3	8,531
Camas Creek	308	177	57.2	61.1	2.7	2.9	21-23	11,684
Loon Creek	596	255	54.3	60.7	2.5	2.7	28-30	13,271
Marsh Creek	824	515	59.8	62.8	2.8	3.1	11-12.8	22,559
Cape Horn Creek	546	128	55.9	58.7	3.3	2.4	0.5-1.6	13,364
Valley Creek	1,219	1,144	64	64.0	3.2	3.1	3.5-5.0 & 7.0-8.3	35,262
Big Creek (upper)	995	565	59.8	62.4	3	3.1	56.5-59	28,520
Bear Valley Creek	1,041	1,000	68.4	68.4	4.2	4.2	8-9.75 & 12.3-13.3	34,147
Elk Creek	634	619	71.2	71.2	4.5	4.6	0.2-1.8	14,888
Sulphur Creek	564	535	64.4	64.5	3.2	3.1	5-6.4	15,861
S Fork Salmon R	1,875	1,241	62.1	64.8	2.9	3.1	117-119	28,595
Secesh River	527	450	61.8	63.1	2.9	2.8	24.2-26	16,662
Lake Creek	566	327	62.1	64.8	3.2	3.2	2-3	20,254
West Fork Chamberlain Cr	534	500	70.2	70.4	3.9	3.9	1-2	14,554
Chamberlain Creek	764	737	67.1	66.9	3.5	3.4	23.6-25	18,394
Big Creek (lower)	201	193	80.2	80.2	6.2	6.2	9-11	17,741
Totals/averages	**11,231**	**8,421**	**64.0**	**65.5**	**3.5**	**3.4**	**28.5**	**314,287**

Downstream Detection and Recapture

Detection of Tagged Fish

Instream monitoring systems

In 2002, the first instream PIT-tag monitoring systems were installed by NOAA at two sites in Valley Creek. These systems were designed to detect fish closer to their natal rearing sites. Expansion and improvement of these systems since 2002 has been detailed in previous annual reports (Achord et al. 2004-2005, 2009-2012; Lamb et al 2013-2019a). Details on systems developed to date are shown in Table 3.

Instream monitoring systems automatically interrogate, store, and transmit data from passing tagged fish that are detected. Detection data are uploaded to the Columbia River PIT-Tag Information System (PTAGIS), a regional shared database operated by the Pacific States Marine Fisheries Commission (PSMFC 1996).

From late July 2019 through June 2020, we collected detection data from wild PIT-tagged Chinook salmon juveniles passing NOAA instream monitoring sites (Table 3).

In October 2019, an instream monitoring system was installed on Marsh Creek near Lola Creek Campground below the confluence of Cape Horn and Marsh Creek. This site was installed by Biomark, Inc. (Boise, Idaho) in collaboration with the Idaho Department of Fish and Game in an effort to expand instream monitoring. The site became operational on 17 October 2019.

Table 3. Details of collection, tagging, and release areas and instream monitoring sites used in studies of wild spring/summer Chinook salmon parr implanted with 12-mm passive integrated transponder (PIT) tags, 2019-2020.

Fish collection, tagging, and release areas	Instream monitoring site		
	Description	River or creek (rkm)	Site code
Valley Creek	Valley Creek upstream array	Valley Creek (rkm 2)	VC1
Valley Creek	Valley Creek downstream array	Valley Creek (rkm 1)	VC2
Valley and Herd Creek	Upper Salmon River upstream array	Salmon River (rkm 460)	USE
Valley and Herd Creek	Upper Salmon River downstream array	Salmon River (rkm 437)	USI
Upper Big Creek	Edwardsburg, Idaho	Big Creek (rkm 57)	---
Upper and Lower Big Creek	Taylor Ranch upstream array	Big Creek (rkm 12)	TAY-a
Upper and Lower Big Creek	Taylor Ranch downstream array	Big Creek (rkm 11)	TAY-b
Secesh R and Lake Cr	Zena Creek Ranch	Lower Secesh R (rkm 5)	ZEN
South Fork Salmon River	Krassel Creek	S Fork Salmon R (rkm 65)	KRS
South Fork Salmon River	Guard Station Road Bridge	S Fork Salmon R (rkm 30)	SFG
Marsh Creek	Lola Creek Campground	Marsh Creek (rkm 8)	MAR
Cape Horn Creek	Lola Creek Campground	Marsh Creek (rkm 8)	MAR

Monitoring systems at dams and in the estuary

During spring and summer 2020, wild Chinook smolts that had been PIT-tagged as parr in 2019 began a directed migration downstream. Of the eight dams encountered by these smolts on the lower Snake and Columbia Rivers, seven had PIT-tag interrogation systems in their juvenile bypass systems. These were Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dam on the Snake River and McNary, John Day, and Bonneville Dam on the Columbia River.

At these seven dams, smolts guided into juvenile bypass systems were monitored for PIT tags by interrogation systems similar to those described by Prentice et al. (1990). At Lower Granite dam, a new ogee detection system began operation in 2020 (Axel et al. 2021). Of the 499 wild fish from our study detected at Lower Granite, 357 (72%) were detected on the ogee system, providing a substantial increase in detection capability.

Tagged fish encountered a final opportunity for detection in the upper Columbia River estuary. A pair-trawl fitted with a PIT-tag detection antenna is operated ~150 km downstream from Bonneville Dam from Columbia River rkm 66 to 84 (Ledgerwood et al. 2004; Magie et al. 2010; Morris et al. 2015). In 2020, a prototype autonomous barge detection system was also deployed approximately 3.5 km downstream from Bonneville Dam (Axel et al. 2021).

For all of these monitoring systems, date and time to the nearest second were automatically recorded for each detected fish. Detection data were then transferred to the PTAGIS database at designated intervals, depending on the respective communications procedure of each monitoring system.

Recapture of Tagged Fish

Juvenile migrant traps

Some fish PIT tagged as parr in natal rearing areas were subsequently collected at migrant traps. During summer/fall 2019 and spring 2020, juvenile migrant traps were operated at the following locations:

- South Fork Salmon River at Krassel Creek
- Secesh River near Calf Creek confluence
- Bear Valley Creek near Fir Creek Campground
- Marsh Creek below its confluence with Cape Horn Creek, near Lola Campground
- Lower Big Creek at Taylor Ranch
- Salmon River at rkm 103 near Whitebird
- Snake River at Lewiston, Idaho

Traps were operated by the Nez Perce Tribe, Shoshone-Bannock Tribes, and Idaho Department of Fish and Game. Generally, study fish recaptured at these traps were anesthetized, scanned for PIT tags, measured, and weighed. Upon recovery from the anesthetic, fish were released back to the stream or river.

Separation-by-code at Lower Granite Dam

At Lower Granite Dam, sampling is typically conducted from April through June in an effort to recapture subsamples of our study fish tagged as parr the previous summer. Recaptures are obtained by programming the PIT-tag separation-by-code system (SbyC) to divert tagged study fish from the population passing the dam (Downing et al. 2001). Unfortunately, during 2020 we were unable to collect any study fish due to limitations in staffing during the coronavirus disease 2019 (COVID-19) pandemic.

Results and Discussion

A total of 160 wild spring/summer Chinook salmon tagged in summer 2019 were recaptured at traps above Lower Granite Dam from summer/fall 2019 to spring 2020 (Table 4).

The number of fish recaptured at traps was much lower in 2019-2020 than in than previous years (Achord et al. 2009-2012; Lamb et al 2013-2019). This lower number of recaptures was partially a result of some traps not operating in spring 2020 due to the COVID-19 pandemic. The Snake River Trap (SNJ; rkm 225) and Salmon River Trap (SAJ; rkm 103) were both operational during spring 2020, but did not produce many recaptures, most likely due to juvenile migration timing.

Table 4. Fork length, weight, and condition factor of wild spring/summer Chinook salmon PIT-tagged in Idaho during summer 2019 and recaptured at traps during summer/fall 2019 and spring/summer 2020. Precocious males were not included in the analysis.

	Recaptured fish						Weight and condition factor (CF)				
		Days to recapture		Length gain (mm)				Weight gain (g)		Mean CF	
Origin	n	range	mean	n	range	mean	n	range	Mean	release	recapture
	Wild spring/summer Chinook salmon recaptured at traps										
Big Creek (Taylor)											
Upper Big Cr-fall	9	24-86	58	9	11-32	20	7	1.4-4.6	2.8	1.29	1.10
Lower Big Cr-fall	13	0-32	5	13	-5-5	-1	8	-0.6-1.2	0.0	1.10	1.17
S Fork Salmon R (Krassel)											
Fall	24	48-77	64	21	5-21	11	21	-0.2-3.4	1.3	1.11	0.96
Spring	5	228-253	235	5	17-28	21	5	3.1-4.8	3.6	1.11	1.01
Marsh Cr											
Cape Horn Cr-fall	5	5-95	70	5	5-22	15	5	-0.5-3.2	2.0	1.20	1.03
Marsh Cr-fall	9	3-94	62	9	2-25	15	5	0.1-4.2	2.0	1.24	1.04
Marsh Cr-spring	1	---	248	1	---	28	1	---	4.4	1.38	1.06
Secesh River											
Lake Creek-fall	21	10-73	35	21	-5-32	7	14	-0.5-1.3	0.5	1.11	1.02
Secesh River-fall	39	8-71	33	39	-1-24	10	34	-0.4-4.5	1.1	1.20	1.07
Bear Valley Creek											
Bear Valley Cr.	14	1-80	39	0	---	---	0	---	---	1.26	---
Elk Creek	11	2-72	25	1	---	7	1	---	1.3	1.24	1.17
Salmon River-spring	8	211-264	244	8	19-47	31	0	---	---	1.16	---
Snake River-spring	1	---	278	1	---	24	0	---	---	1.31	---
Total or average	160	0-278	60	134	-5-47	11	101	-0.6-4.8	1.3	1.16	1.04

Detection and Survival in Monitored Streams

Methods

For each release group from each stream population, we estimated detection probability at Lower Granite Dam. Estimates of survival from release as parr to arrival at the dam as smolts were based on these detection probability estimates. However, for fish from monitored streams, the reach was divided into two smaller segments: 1) a stream segment, which spanned from the point of release to the lower instream monitor, and 2) a river segment, which spanned from the lower instream monitor to the dam.

For estimates of parr-to-smolt survival in stream segments, we constructed a detection history for each fish that included detection or non-detection at 1) either the upper or lower instream monitor and 2) any downstream dam. This produced four possible detection histories, with detection or non-detection at a stream monitor and detection or non-detection at a dam. Counts of fish with each detection history were fitted to a multinomial model, with cell probabilities parameterized as functions of detection and survival probability.

To estimate survival, we used the Cormack-Jolly-Seber (CJS) single-release model with multiple recapture (Cormack 1964; Jolly 1965; Seber 1965). This model is used extensively to estimate survival for PIT-tagged fish in the Columbia River Basin.

Because there were two monitoring sites at Valley Creek, Lower Big Creek, and the upper Salmon River, we explored a method to estimate detection and survival in these reaches based only on detection data from instream monitors (Connolly et al. 2008). However, detection data from sites with two antenna arrays have shown that detection probability at an upstream monitoring system was not independent of detection probability at a downstream system.

This pattern of detection violated a critical assumption required by the CJS model—that probabilities of detection (recapture) at each location are independent of one another. Assuming a survival rate of 100% between upper and lower instream monitors, we could have modeled dependency between these detection probabilities.

However, it was not possible to test the assumption of 100% survival, and sample size in many cases was not sufficient to obtain useful estimates of dependency. Therefore, we used the CJS model to estimate survival from release to the pooled instream monitors and from the pooled instream monitors to Lower Granite Dam.

Results

Valley Creek

We released 1,144 tagged wild Chinook salmon parr to Valley Creek during 23-24 July 2019 (Table 2). All fish were tagged with 12-mm PIT tags and released in natal rearing areas 3-8 km above the upper instream monitor, VC1. Of these fish, 445 were detected on one or both Valley Creek monitors between 23 July 2018 and 21 May 2020 (Table 1; Figure 2).

For the 101 fish detected on both Valley Creek monitors, median downstream travel time between the upstream and downstream monitors (VC1 to VC2) was 11.19 h (range -24.84 h-153.7 d). Negative values for travel time resulted from 10 fish that exhibited upstream "wandering" movement, which caused them to be detected at the upper monitor after detection at the lower monitor. Of the 445 detections in Valley Creek, 245 (55.0%) occurred in late summer/fall, 153 (34.4%) in winter, and 47 (10.6%) in spring (Figure 2).

Based on detections at downstream dams, overall detection efficiency for Valley Creek monitors was 96.4%. Based on this efficiency, we estimated that 40.4% of the tagged parr released to Valley Creek had survived to pass the Valley Creek instream monitors (Table 1). We found no significant difference in timing on these monitors for fish of varying fork length (R^2 = 0.53%, P = 0.127; Figure 3).

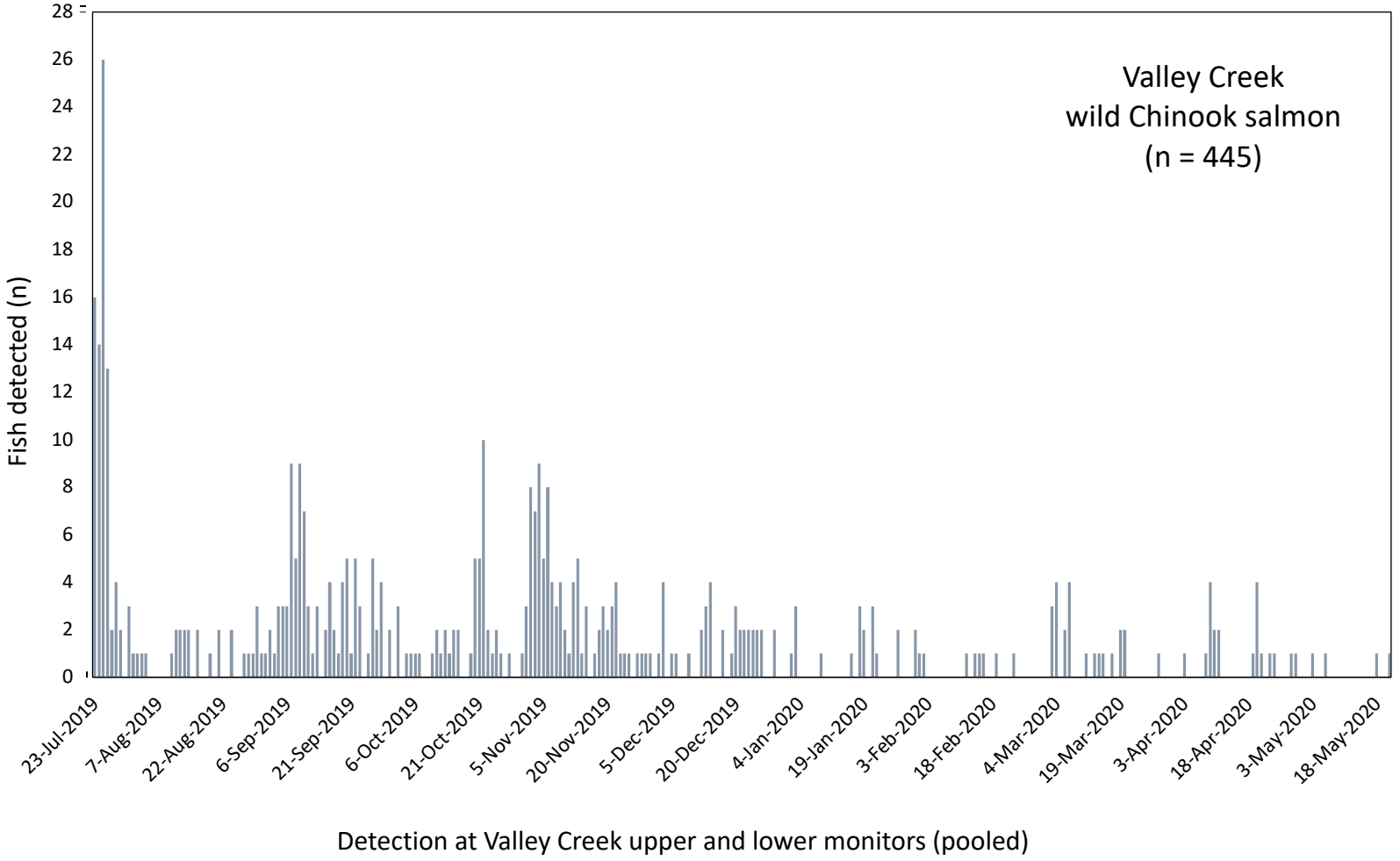

Figure 2. Detections of 445 PIT-tagged wild spring/summer Chinook salmon parr, pre-smolts, and smolts at the upper and lower instream monitoring systems at lower Valley Creek (VC1 and VC2), July 2019-May 2020. A total of 1,144 parr were tagged and released 3-10 km upstream from these antennas during 23-24 July 2019.

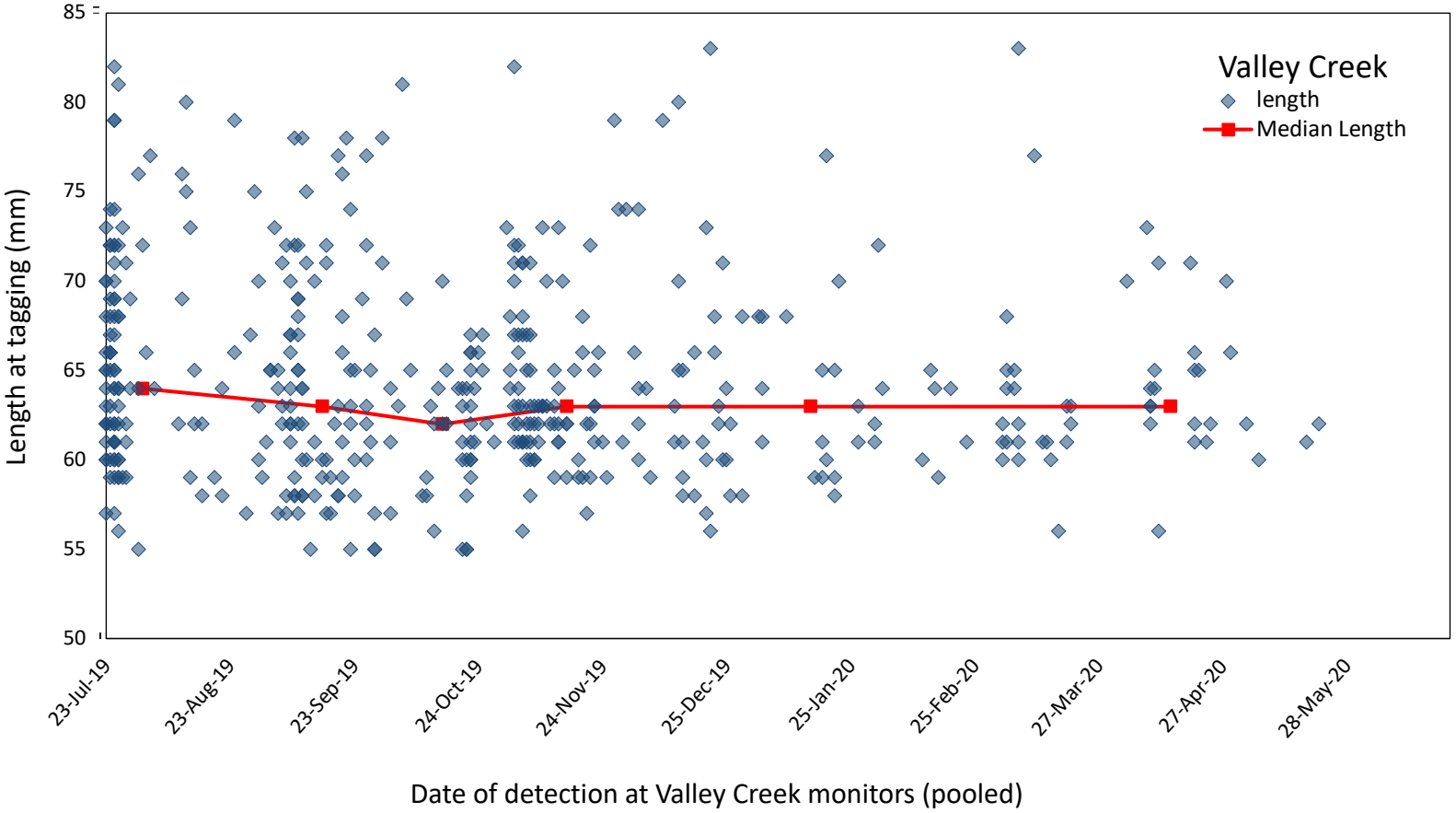

Figure 3. Fork length at tagging vs. date of detection for 445 wild Chinook tagged as parr in Valley Creek. Fish were detected on the upstream and downstream PIT-tag monitoring antennas at Valley Creek rkm 2 and 1 (VC1 and VC2 pooled).

Upper Big Creek

We released 565 tagged wild Chinook salmon parr to Upper Big Creek during 31 July-1August 2019 (Table 2). All fish were released in natal rearing areas 1.5-2 km upstream from the instream monitoring system on Upper Big Creek near Edwardsburg, Idaho (rkm 57), and 48 km upstream from the monitoring systems in Lower Big Creek at Taylor Ranch (TAY; rkm 11).

Of the 565 fish released, 312 were detected on the instream monitor near Edwardsburg between August and November 2019 (Table 1; Figure 4). Based on detections at downstream dams, overall detection efficiency was estimated at 65.5% for the Edwardsburg detection site. Based on this detection efficiency, survival to the instream monitor at Edwardsburg was estimated at 84.0% for fish tagged and released in Upper Big Creek. Detection data did not indicate a significant relationship between fork length at tagging and date of detection at the Edwardsburg site for these fish (R^2 = 0.13%, P = 0.529; Figure 5).

Of the 565 fish released to Upper Big Creek, 58 were detected on one or both instream monitors at Taylor Ranch between August 2019 and May 2020 (Table 1). Based on detections at downstream dams, overall detection efficiency at the Taylor Ranch monitors was 25.6% for Upper Big Creek fish. Based on this detection efficiency, survival to the Taylor Ranch monitors was 39.9%. Detection data did not indicate a significant relationship between fork length at tagging and date of detection at Taylor Ranch for these fish (R^2 = 1.98%, P = 0.292; Figure 5).

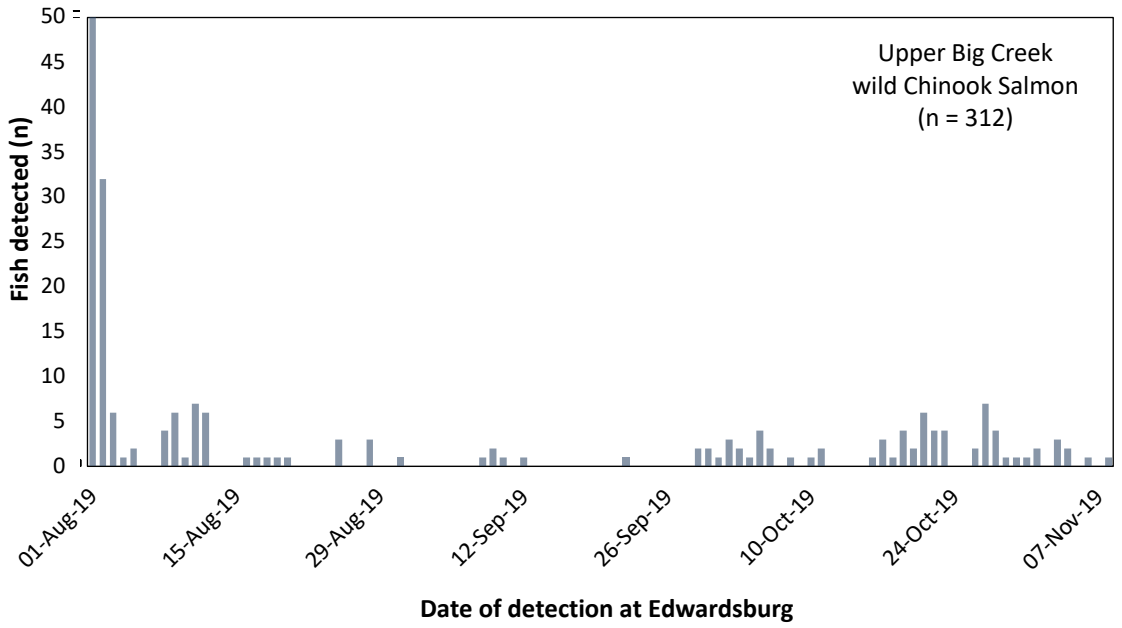

Figure 4. Detections by date of 312 wild spring/summer Chinook parr, pre-smolts, and smolts from Upper Big Creek. A total of 565 parr were tagged and released 1.5-2 km upstream from this monitoring system during 31 July-1 August 2019.

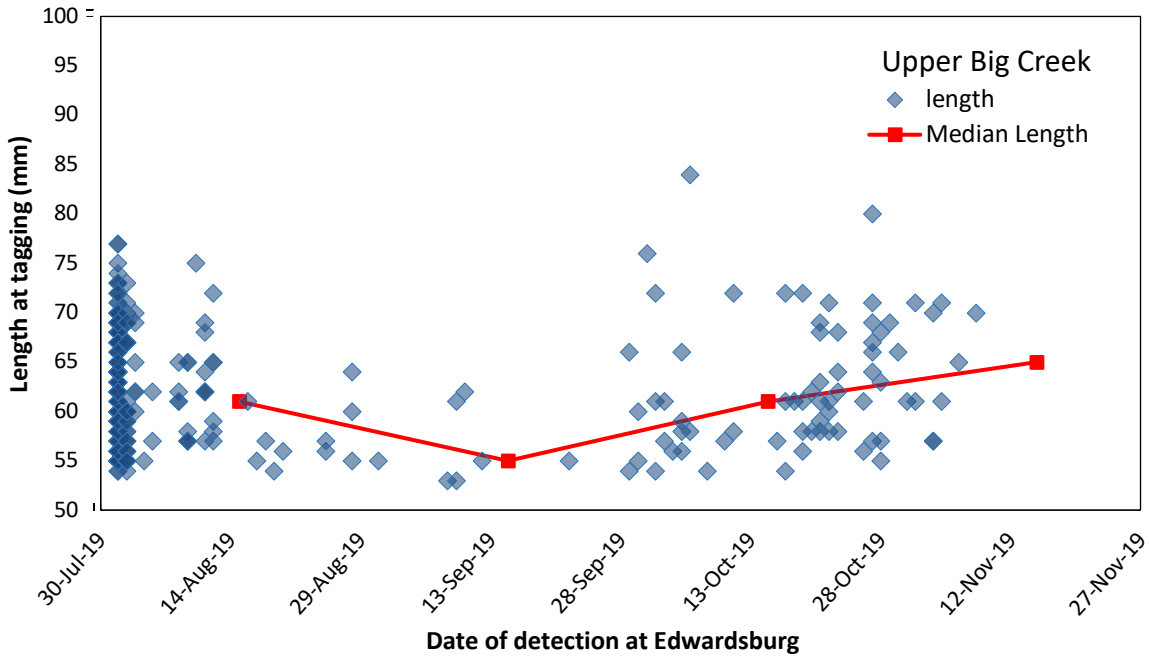

Figure 5. Fork length at tagging vs. date of detection for 311 wild spring/summer Chinook tagged at Upper Big Creek and detected at the instream PIT-tag monitoring system near Edwardsburg, Idaho.

Lower Big Creek

We released 193 tagged wild Chinook salmon parr to Lower Big Creek on 25 August 2019 (Table 2). All fish were tagged and released in natal rearing areas 0-3 km above the instream monitors at Taylor Ranch in Lower Big Creek. Of these fish, 59 were detected between August 2019 and April 2020.

Based on detections at downstream dams, overall detection efficiency was 29.2% for the instream monitors at Taylor Ranch. Using this detection efficiency rate, we estimated that 104.8% (SE 20.5%) of the tagged parr from Lower Big Creek survived to the Taylor Ranch monitors (Table 1). Detection data did not indicate a significant relationship between fork length at tagging and date of detection for these fish (R^2 = 0.24%, P = 0.624; Figure 5).

Secesh River and Lake Creek

We collected and tagged 450 wild Chinook salmon parr from the Secesh River on 14 August 2019. We then collected and tagged 327 fish from Lake Creek on 15 August. Release sites for these fish were 21-42 km upstream from the instream monitoring array near Zena Creek Ranch in the lower Secesh River.

From August 2019 to April 2020, 143 Secesh River fish and 66 Lake Creek fish were detected near Zena Creek Ranch (Figure 6). Of the 143 detections of Secesh River fish, 117 (81.8%) occurred in late summer/fall, 22 (15.4%) in winter, and four (2.8%) in spring. Of the 66 detections of fish from Lake Creek, 53 (80.3%) occurred in late summer/fall, 11 (16.7%) in winter, and two in spring (3.0%; Table 1).

Based on detections at downstream dams, overall detection efficiency of the instream monitoring system at Zena Creek was 70.0% for parr from the Secesh River (n = 143) and 57.1% for those from Lake Creek (n = 66; Table 1). Based on these detection efficiencies, we estimated survival to the Zena Creek instream monitoring system at 45.4% for parr from the Secesh River and 35.3% for those from Lake Creek (Table 1).

Data from the Zena Creek monitoring system showed that Lake Creek fish that had been larger at the time of tagging were detected significantly later than their smaller cohorts (R^2 = 6.5%, P = 0.039). However, for Secesh River fish, detection data from Zena Creek indicated no significant relationship between fork length at tagging and date of detection (R^2 = 1.99%, P = 0.093; Figure 7).

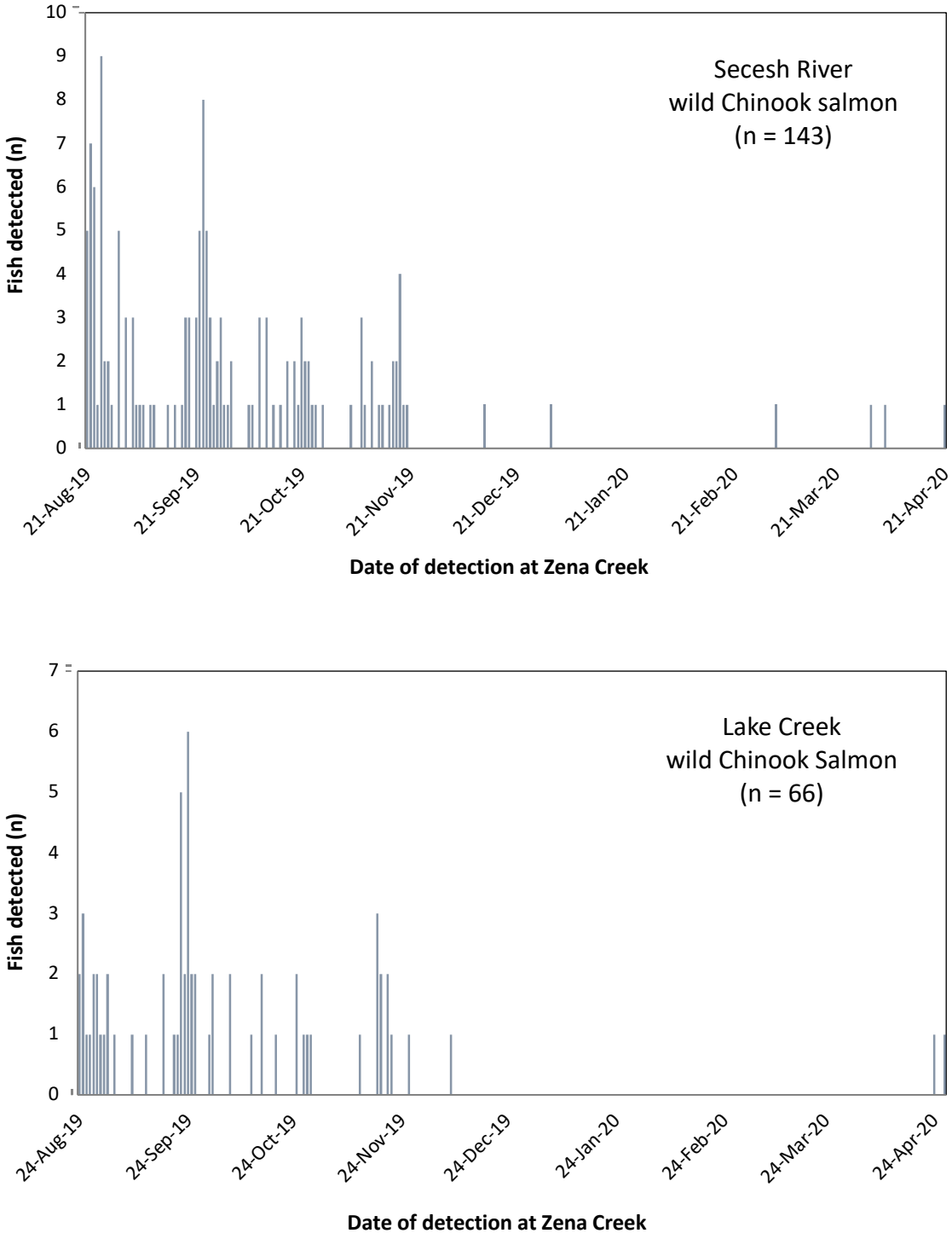

Figure 6. Detections on instream monitors at Zena Creek Ranch from wild spring/summer Chinook salmon from the Secesh River and Lake Creek. We tagged and released 450 fish from the Secesh River and an additional 327 fish from Lake Creek. All fish were released in areas ~21-42 km above the Zena Creek monitors

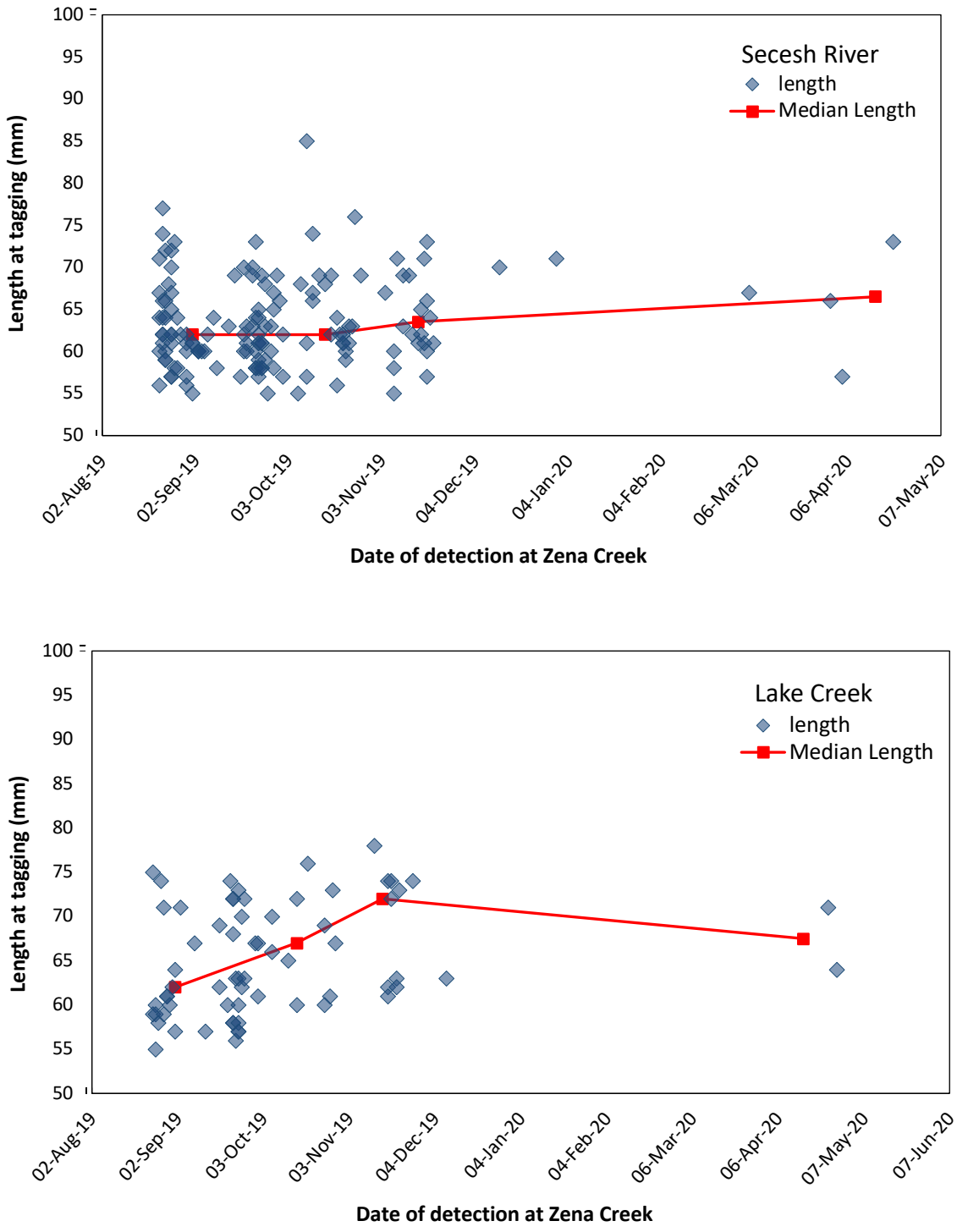

Figure 7. Length at tagging vs. date of detection for fish collected and tagged at the Secesh River and Lake Creek. A total of 143 fish from the Secesh River and 66 from Lake Creek were detected at the instream monitoring site in the lower Secesh River near Zena Creek Ranch.

South Fork Salmon River

We released 1,241 tagged wild Chinook salmon parr to the South Fork Salmon River during 12-13 August 2019 (Table 2). All fish were released to natal rearing areas 52-53 km upstream from the monitoring system near Krassel Creek at rkm 65. Of fish tagged and released to the South Fork Salmon River, 244 were detected near Krassel Creek from August 2019 through April 2020. Of these 244 detections, 103 (42.2%) occurred during late summer/fall, 100 (41.0%) during winter, and 41 (16.8%) during the following spring (Figure 8).

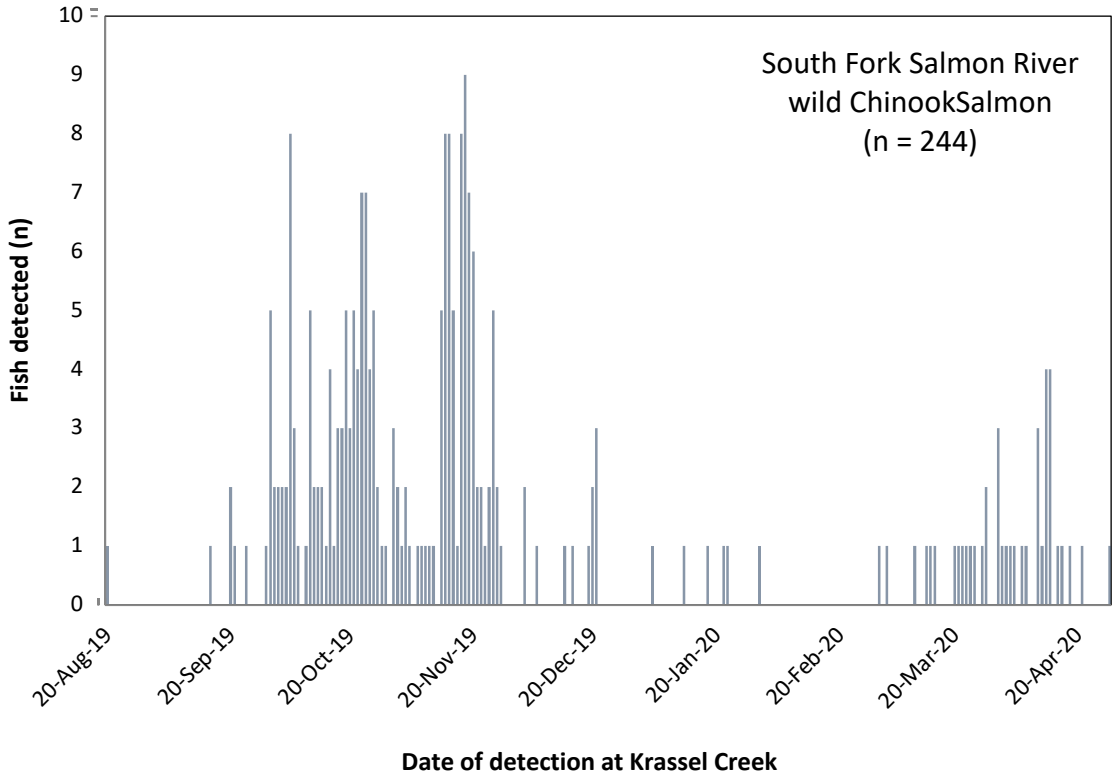

Figure 8. Detections by date of 244 wild spring/summer Chinook salmon parr, pre-smolts, and smolts at instream monitors in the South Fork Salmon River near Krassel Creek. A total of 1,241 Chinook parr were PIT tagged and released approximately 52-53 km upstream from the Krassel Creek monitors.

Based on detections at downstream dams, overall detection efficiency of the instream monitoring system at Krassel Creek was 48.4%. Using this detection efficiency rate, we estimated survival to the Krassel Creek monitoring system at 40.6% for all tagged parr from the South Fork Salmon River. We found no significant relationship between fork length at tagging and timing of detection for these fish (R^2 = 0.73%, P = 0.182; Figure 9).

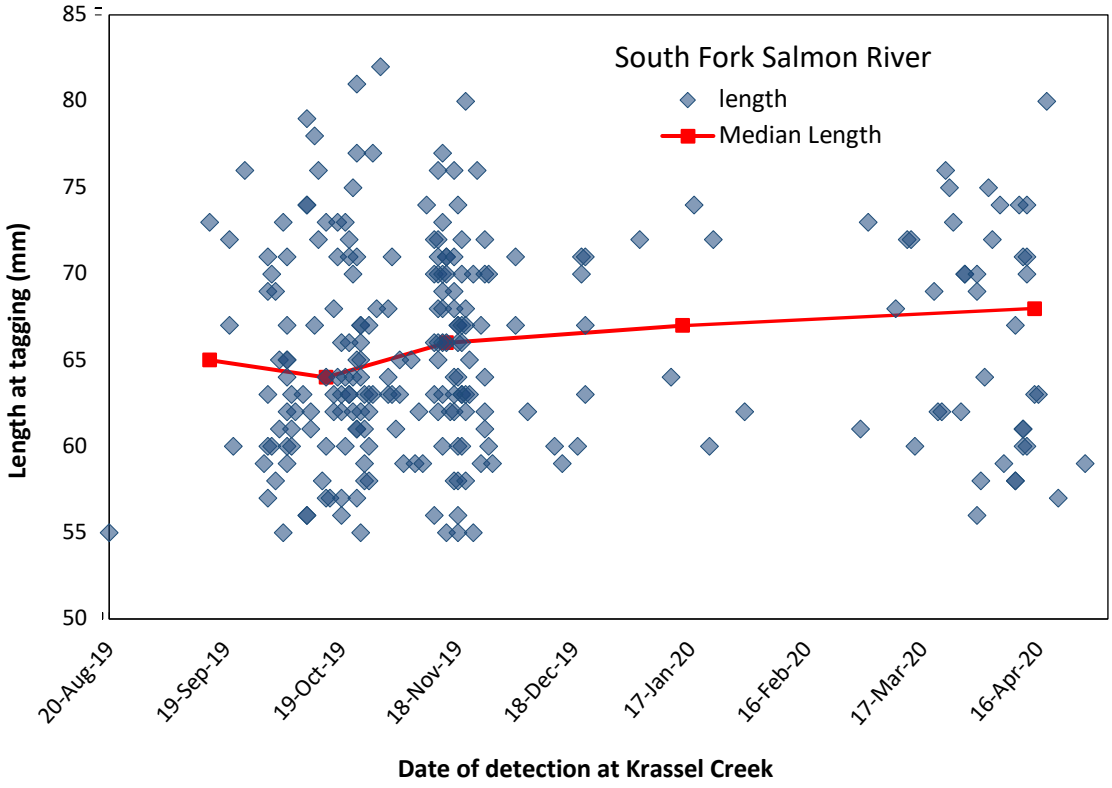

Figure 9. Fork length at tagging vs. date of detection for 244 wild spring/summer Chinook salmon tagged in the South Fork Salmon River and detected at the instream PIT-tag monitoring site at Krassel Creek in the South Fork Salmon River.

Discussion

In Valley Creek, the PIT-tag monitoring system has been operating for 17 years, from 2003 to 2020. Data from this system has been used to produce accurate estimates of annual survival and migration timing for tagged wild Chinook juveniles leaving this stream from late summer/fall to the following spring.

During 2020, the estimated detection efficiency at Valley Creek was 96.4%, based on detections of tagged fish at Lower Granite Dam. This is the highest detection efficiency estimate on record (Appendix Table 25). This increased detection efficiency was likely attributable to three factors: First, low flows kept fish physically closer to antenna arrays, which increased detection efficiency.

Second, instream monitor operations were relatively stable over the study period, with few interruptions from technical issues or mechanical failures. Third, the use of advanced performance tags (APT12, Biomark, Inc., Boise, Idaho) produced a noticeable increase in detection efficiency. These new 12-mm PIT tags had a greater detection range than any of the 12-mm tags used in previous study years.

The Valley Creek instream system had been slated to undergo a major change in configuration during 2020. These changes were not completed in 2020 due to restrictions related to the COVID-19 pandemic, but were rescheduled for 2021. The VC1 and VC2 sites will be condensed to a single site at the VC2 location, which will have dual arrays spaced less than 100 m apart. These changes will affect analyses of the juvenile migration in future years. The new configuration should provide higher and more consistent detection efficiency.

During fall 2019, the interrogation site near Edwardsburg, Idaho (rkm 57) on Upper Big Creek continued to provide quality data. We estimated a detection efficiency of 65.5% at the Edwardsburg site based on the relatively high percentage of fish detected (55.2%) of the total number released (Table 1). Due to its remote location and off-grid power source, the Edwardsburg site is only operational from March to November. Operational periods may vary from year to year due to a lack of year-round power. Lack of power and network capabilities also restrict this site from producing “real time” detection data, and data must be physically retrieved by researchers from the University of Idaho.

During 2020, detection efficiencies at Taylor Ranch were low, but still increased relative to the very poor performance at this site during 2019. At Taylor Ranch, tagged fished from Upper and Lower Big Creek had detection efficiencies of 25.6 and 29.2% (Table 1), respectively. Increased detection efficiencies were likely due to optimal environmental conditions and the use of APT12 tags.

For fish from Lake Creek and the South Fork Salmon and Secesh Rivers, detection efficiencies were higher in 2020 than in any prior year. At Zena Creek Ranch, detection efficiencies were 57.1% for fish from Lake Creek and 70.0% for fish from the Secesh River. At Krassel Creek (rkm 65), detection efficiency was 48.4% for South Fork Salmon fish. These increased detection efficiencies are most likely attributable to the same combination of environmental conditions and use of APT12 tags that contributed to the increases seen at other instream detection sites.

During fall 2019, a new instream PIT-tag monitoring system was installed by Biomark Inc. on Marsh Creek below its confluence with Capehorn Creek near Lola Campground (Marsh Creek rkm 8; site code MAR). This system became active on 17 October 2019 and detected a fish tagged in Marsh Creek on the first day of operation. By spring 2020, 62 tagged fish from Marsh Creek and 19 fish from Cape Horn Creek were detected at the new monitoring system.

Based on numbers of fish detected at Marsh Creek and subsequently detected at downstream dams, we estimated detection efficiency of the new system at 27.8%. However, this estimate was biased low based on the late date of system installation. By October, large numbers of fish that typically migrate downstream earlier in the year would have been missed. We look forward to the availability of new data from this system to support more accurate estimates of survival for fish from Marsh and Cape Horn Creek.

Survival to Lower Granite Dam and Overall Parr-to-Smolt Survival

Methods

In this section, we present methods for estimating detection probability and parr-to-smolt survival at Lower Granite Dam. For fish from the six streams with monitoring systems, we also estimated survival from instream monitors to Lower Granite Dam. For fish from streams without monitoring systems, we estimated detection and survival probability from respective release points to the dam, pooling detection data from 9- and 12-mm PIT tags.

Estimated survival from streams to Lower Granite Dam

We estimated separate probabilities of survival to Lower Granite Dam for fish from each stream overall and for each of three detection periods: late summer/fall (August-October), winter (November-February), and spring (March-June). For fish from monitored streams with two arrays, we estimated survival from the lowermost array to the dam.

First, we grouped detected fish by seasonal period of detection on instream monitors. For each seasonal group, we then compiled a temporal distribution of daily detections at Lower Granite Dam by stream cohort.

For fish from each stream, each daily count at the dam was divided by the *expanded* estimate of detection probability for Lower Granite Dam on that day (methods for expanded estimates are explained below in *Estimates of parr to smolt survival*). Daily passage estimates for each stream population were then derived using the ratios of observed daily counts vs. expanded daily detection probabilities at the dam.

Daily passage estimates were then summed to estimate the total number of fish from each stream that survived to Lower Granite Dam. This total was then divided by the total number of fish released from that stream to derive the estimate of survival to Lower Granite Dam.

For the six sampling sites with monitoring systems, we summed the number of fish that survived to Lower Granite Dam *and* had previously been detected on an instream monitoring system during each seasonal period. To derive estimates of survival to the dam by season, this total was divided by the total number of fish detected on instream monitors during each seasonal period, regardless of whether they were detected at Lower Granite Dam.

Estimates of parr-to-smolt survival

To estimate parr-to-smolt survival, we used *expanded* detection probabilities at Lower Granite Dam. Expanded detection probability estimates were based on detections of our tagged study fish pooled with detections of fish tagged for other studies, or "auxiliary" detection data. These auxiliary data included any wild Snake River Chinook salmon PIT tagged and released upstream from the dam, regardless of source. Pooled detections of study and auxiliary fish at Lower Granite Dam were used for all estimates of parr-to-smolt survival and travel time.

For fish from monitored streams, we estimated overall parr-to-smolt survival by calculating the weighted mean of the three seasonal survival estimates. Means for each season were weighted according to the proportion of total detections from that season.

To estimate expanded detection probabilities from pooled detections, we followed the methods of Schaefer (1951) as modified by Sandford and Smith (2002). For each day of the migration season, we estimated numbers of tagged fish detected at Lower Granite Dam, as well as numbers of tagged fish *not* detected that day, but known to have passed because they were subsequently detected downstream. We developed a series of daily detection probabilities as follows:

1) Fish detected on day *i* at Little Goose Dam that had previously been detected at Lower Granite were tabulated according to day of passage at Lower Granite Dam.
2) Fish detected on day *i* at Little Goose but ***not*** previously detected at Lower Granite were assigned an estimated day of passage at Lower Granite, assuming that passage distribution for these fish was proportionate to passage distribution of fish detected at Lower Granite.
3) This process was repeated for all days with detections at Little Goose Dam.
4) Detected and non-detected fish known to have passed Lower Granite Dam on day *i* were summed.
5) Detection probability on day *i* was estimated by dividing the number of fish detected at Lower Granite on day *i* by the sum of fish both detected and not detected, but known to have passed Lower Granite (because of detection at Little Goose) and estimated to have passed on day *i*.

We slightly modified the method of Sandford and Smith (2002) for parr-to-smolt survival estimates of fish that passed Lower Granite during the early and late periods of each season, or "tails" of the passage distribution curve. This modification was necessary because for fish passing during these periods, there were often no detections at Little Goose Dam; thus, no passage date at Lower Granite could be inferred. For this modification, bootstrap methods were used to derive standard errors for the estimated probability of survival to Lower Granite Dam.

Auxiliary data were used to derive bootstrap distributions of estimated daily detection probability at the dam. Standard errors were derived for estimates of survival to the dam from both release sites and instream monitors (Achord et al. 2007b). For fish from each stream release or instream monitor detection group, we used detections at Lower Granite for bootstrap distributions of dam passage.

Results

Survival of fish from all Idaho streams

For fish from all Idaho streams combined, we estimated average parr-to-smolt survival probability at 18.0% (SE 1.1%; Table 5). This estimate was based on expanded detections at Lower Granite Dam from 4 April to 5 July 2020 (n = 1,513). An additional 311 first-time detections were recorded at Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dam (Appendix Tables 3-17).

Table 5. Summary of observed vs. expanded detections of wild spring/summer Chinook smolts at Lower Granite Dam in 2020. Proportions of detected fish from the expanded numbers were used for parr-to-smolt survival estimates and are shown with the SE of each estimate.

	Tagged and released (n)	Lower Granite Dam detections, 2020				
		Observed		Expanded (parr-to-smolt survival)		
Stream		(n)	(%)	(n)*	(%)	SE (%)
Herd Creek	35	0	---	---	---	--
Camas Creek	177	10	5.6	28	16.0	5.7
Loon Creek	255	18	7.1	55	21.7	5.4
Marsh Creek	515	44	8.5	130	25.2	4.0
Cape Horn Creek	128	4	3.1	14	11.0	6.0
Valley Creek	1,144	39	3.4	127	11.1	2.0
Big Creek (upper)	565	39	6.9	124	21.9	3.9
Bear Valley Creek	1,000	62	6.2	184	18.4	2.7
Elk Creek	619	44	7.1	128	20.7	3.5
Sulphur Creek	535	32	6.0	98	18.3	3.4
S Fork Salmon River	1,241	54	4.4	157	12.6	1.8
Secesh River	450	30	6.7	81	18.0	3.3
Lake Creek	327	18	5.5	61	18.7	5.1
W Fork Chamberlain Cr	500	31	6.2	94	18.8	3.6
Chamberlain Creek	737	47	6.4	151	20.5	3.0
Big Creek (lower)	193	27	14.0	81	41.8	3.9
Totals or averages	8,421	499	5.9	1,513	18.0	1.1

* Due to rounding, expanded detection numbers may vary slightly from those in Appendix Tables 3-17.

Survival of Fish from Monitored Streams

Valley Creek—For wild juvenile Chinook from Valley Creek detected on Valley Creek monitors, we estimated overall survival to Lower Granite Dam at 27.4% and overall parr-to-smolt survival at 11.1% (Table 6).

Upper and Lower Big Creek—For wild juvenile Chinook from Upper Big Creek detected on the instream arrays at Edwardsburg, overall survival to Lower Granite Dam was estimated at 25.5% and overall parr-to-smolt survival at 21.9% (Table 6).

For wild juvenile Chinook released to Lower Big Creek and detected on instream arrays near Taylor Ranch, overall estimated survival to Lower Granite Dam was 35.8%, and overall parr-to-smolt survival was 41.8% (Table 6).

Table 6. Estimated survival to Lower Granite Dam using instream detections with overall estimated parr-to-smolt survival for study populations passing instream PIT-tag monitoring arrays, 2019-2020.

		Estimated survival to Lower Granite Dam (%)			Estimated parr-to-smolt survival (%)		
Stream population	Instream monitor	Overall mean	SE	95% CI	Overall mean	SE	95% CI
Valley Creek	Valley Creek	27.4	4.5	19.0-36.8	11.1	2.0	4.7-12.1
Upper Big Creek	Edwardsburg	25.5	5.2	16.8-37.4	21.9	3.9	15.4-30.7
Upper Big Creek	Taylor Ranch	63.9	17.7	33.9-102.6	21.9	3.9	15.4-30.7
Lower Big Creek	Taylor Ranch	35.8	11.9	14.7-60.2	41.8	7.7	27.6-58.1
Secesh River	Zena Creek	44.2	9.0	28.2-63.2	18.0	3.3	12.2-25.0
Lake Creek	Zena Creek	50.9	15.5	22.3-85.2	18.7	5.1	8.7-29.6
S Fork Salmon R	Krassel Creek	26.8	5.8	17.0-39.6	12.6	1.8	9.4-16.4

Secesh River and Lake Creek—For wild juvenile Chinook from the Secesh River detected at the Zena Creek monitoring system in the South Fork Salmon River, overall survival to Lower Granite Dam was estimated at 44.2%, and overall estimated parr-to-smolt survival at 18.0% (Table 6). For fish from Lake Creek detected on the Zena Creek array, survival to Lower Granite Dam was estimated at 50.9%, and overall parr-to-smolt survival was estimated at 18.7%.

South Fork Salmon River—For wild juvenile Chinook from the South Fork Salmon River detected on the instream array near Krassel Creek, overall survival to Lower Granite Dam was estimated at 26.8% and overall parr-to-smolt survival at 12.6% (Table 6).

Relationship between Length at Tagging and Detection at Dams

For tagged fish from all streams combined, average fork length at release was 65.5 mm (Table 2; Appendix Table 1). Among these fish, average fork length at release was significantly longer for fish detected the following spring at dams than for those not detected at dams (67.4 vs. 65.6 mm; $Z = 7.29$; $P < 0.001$). Also, larger fish were detected at Lower Granite Dam significantly earlier than their smaller cohorts (regression slope = -0.31; $R^2 = 2.8\%$; $P < 0.05$; Figure 14).

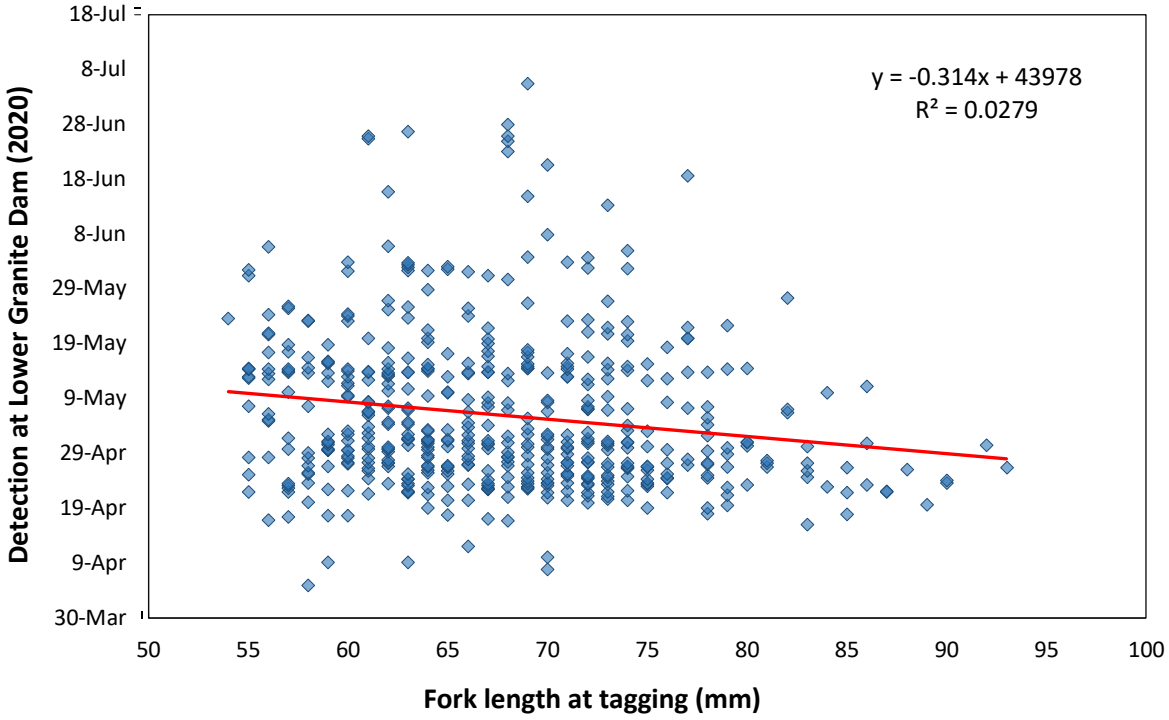

Figure 10. Relationship between fork length of wild Chinook salmon parr at tagging (2019) and detection date at Lower Granite Dam in 2020 (n = 810).

To examine this relationship further, we grouped all released fish into 5-mm length bins and compared length distributions at release vs. detection using a series of *Z*- tests. Length distribution of non-detected fish was compared to that of fish detected at dams in spring by comparing the two percentages in each bin. Percentages were relative to the total released for each bin (detected or not). For fish ranging 60-64 mm fork length (FL), relatively fewer detected than non-detected fish were observed, and the difference was significant ($P < 0.001$). For larger-than-average fish (<70 mm FL), the opposite trend was seen ($P < 0.05$; Figure 11).

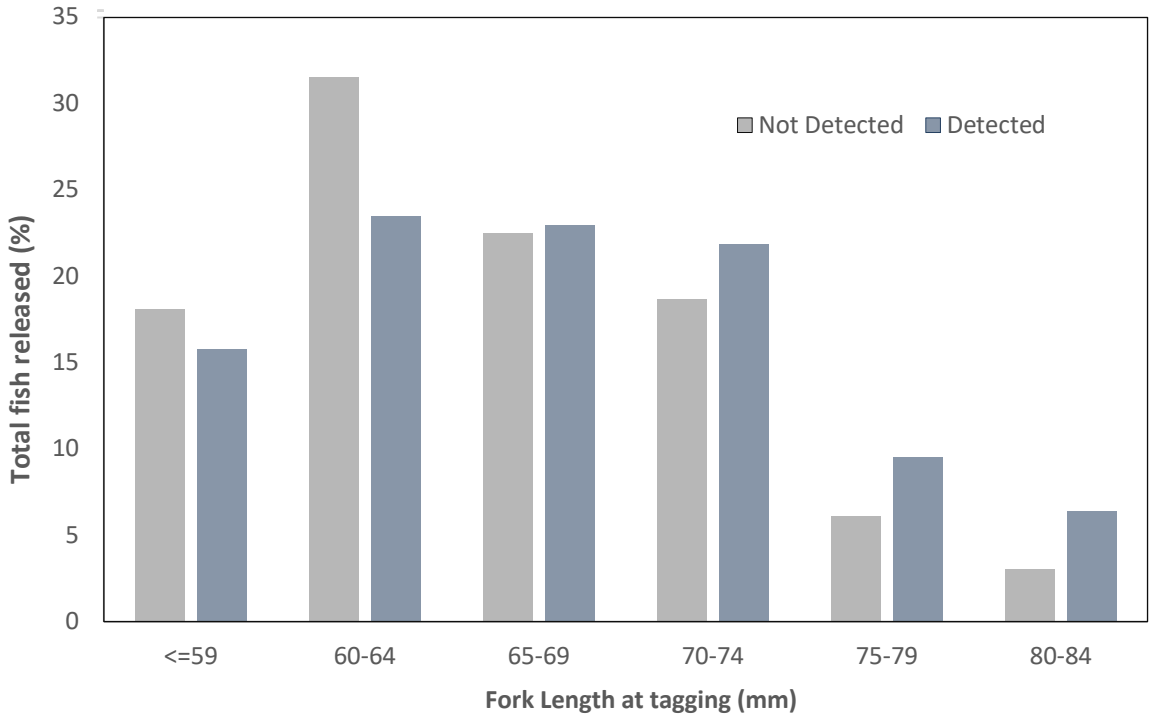

Figure 11. Distributions of fork length by 5-mm length bin for wild spring/summer Chinook salmon parr PIT-tagged and released in Idaho streams, 2019. Gray bars represent percentages not detected (n = 7,602) and blue bars represent percentages detected at dams in spring/summer 2020 (n = 810).

Discussion

Annual parr-to-smolt survival estimates have ranged 7.9-25.4% for Idaho stream populations studied over the past 29 years. Fish from all streams combined had an overall parr-to-smolt survival rate of 15.0% averaged over all years (Figure 12). During 2020, we estimated an overall survival of 18.0%, which was among the highest survival rates recorded during all 29 years of study.

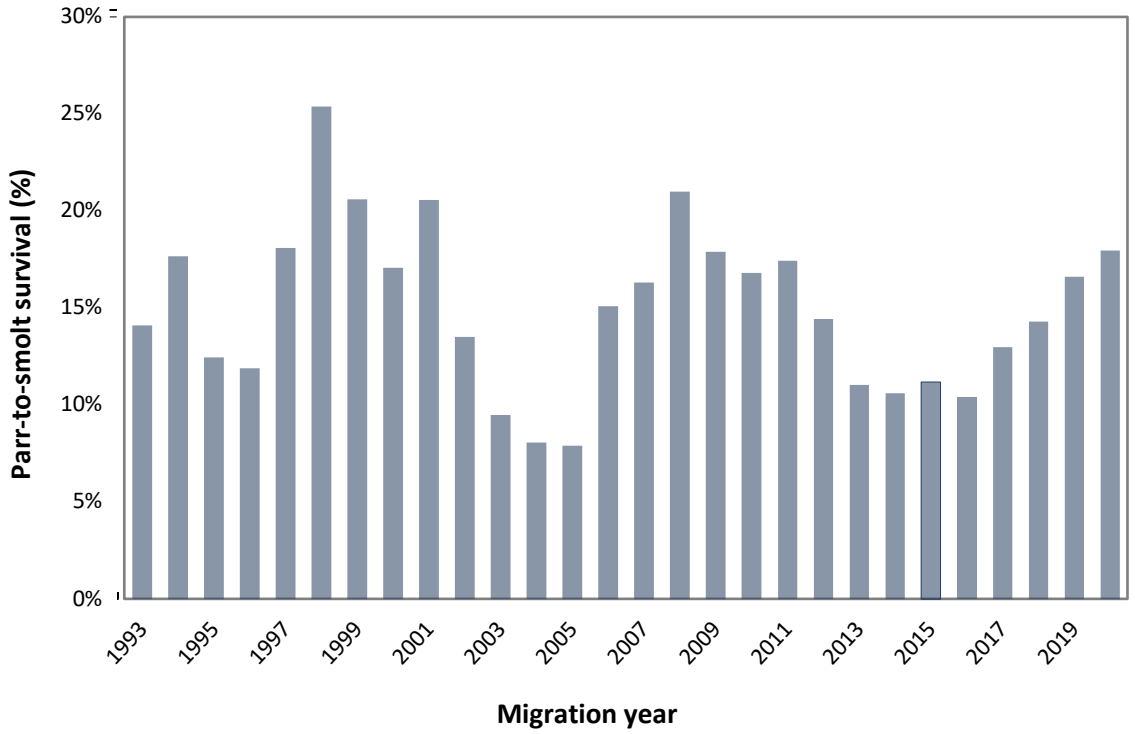

Figure 12. Overall estimated rates of parr-to-smolt survival for wild spring/summer Chinook salmon from all streams combined, 1993-2020. Standard errors ranged 0.3-2.5% over all years and averaged 0.8%.

Annual average data has indicated a potential inverse relationship between parr-to-smolt survival and parr density (Figure 13). This relationship is also supported by data from adult returns of wild Chinook to the Snake River Basin. Adult returns from fish that migrated as juveniles during 2001-2003 were more than one order of magnitude greater than those of fish that migrated as juveniles during 1997-1999, when estimates of parr-to-smolt survival were higher than the overall average (18.1-25.4%).

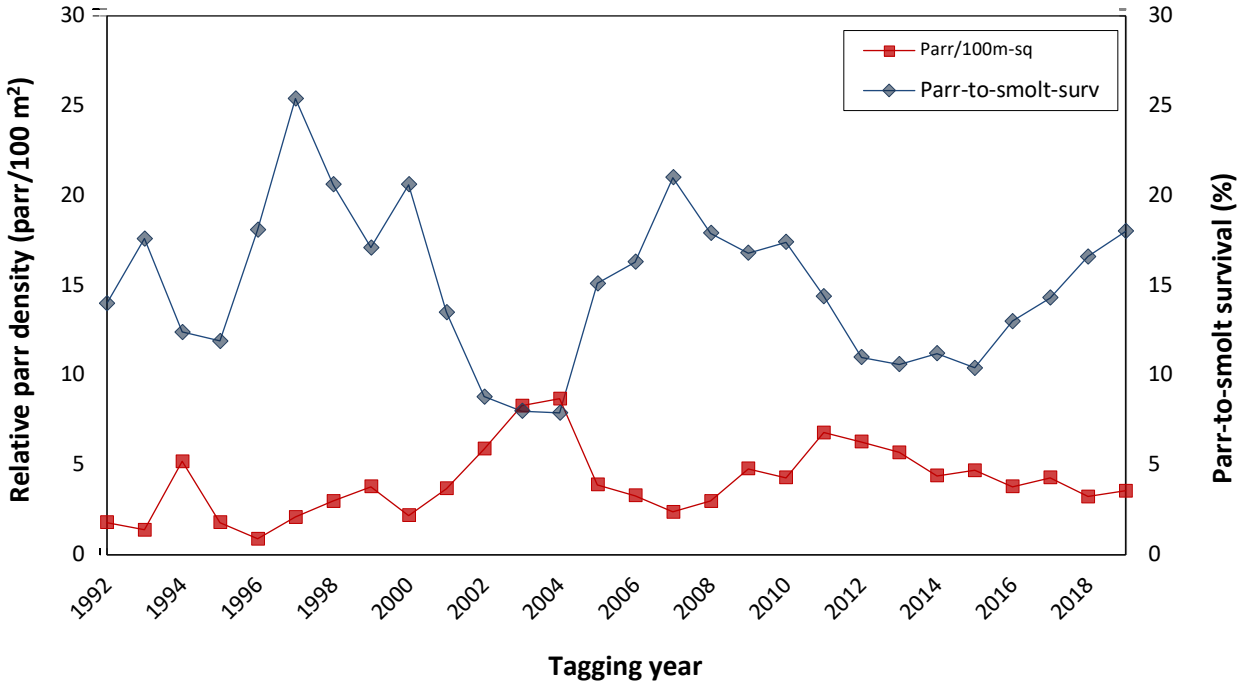

Figure 13. Annual average relative Chinook salmon parr densities (parr/100 m^2) in areas sampled in all streams from 1992 to 2019 vs. annual smolt survival estimate to Lower Granite Dam the following year.

Arrival Timing at Lower Granite Dam

Methods

For each stream population, we estimated arrival timing at Lower Granite Dam based on detections of tagged study fish at the dam. Variation in arrival timing was expected because stream populations vary in size and streams vary in temperature, elevation, and mean flow.

To estimate arrival time, we used expanded detection data as described in the methods section, *Estimates of parr-to-smolt survival*. We pooled daily detections at Lower Granite Dam and divided each daily detection total by its corresponding daily detection probability estimate. Arrival timing at the dam was then calculated based on dates from the expanded detections, with passage dates of the 10th, median, and 90th percentile calculated for each stream population.

We compared arrival timing at Lower Granite Dam among individual populations and among years to determine trends and similarities or differences between years and populations. Comparisons of the 10th, 50th, and 90th percentile passage dates were made among streams using a two-factor analysis of variance (ANOVA), where year was considered a random factor and stream a fixed factor. Residuals were visually examined to assess normality. Treatment means were compared using Fisher's least significant difference procedure (Peterson 1985) with $\alpha = 0.05$.

Results

Dates of arrival at Lower Granite Dam

In 2020, arrival timing of tagged fish at Lower Granite Dam varied among Idaho stream populations (Figure 14). Fish from the Secesh River and Lake Creek were the first to arrive, while fish from Cape Horn Creek arrived later than fish from all other streams. For populations from all streams combined, the median passage date at Lower Granite was similar to those of past median dates, occurring from mid-April to mid-May (Figure 14; Table 7).

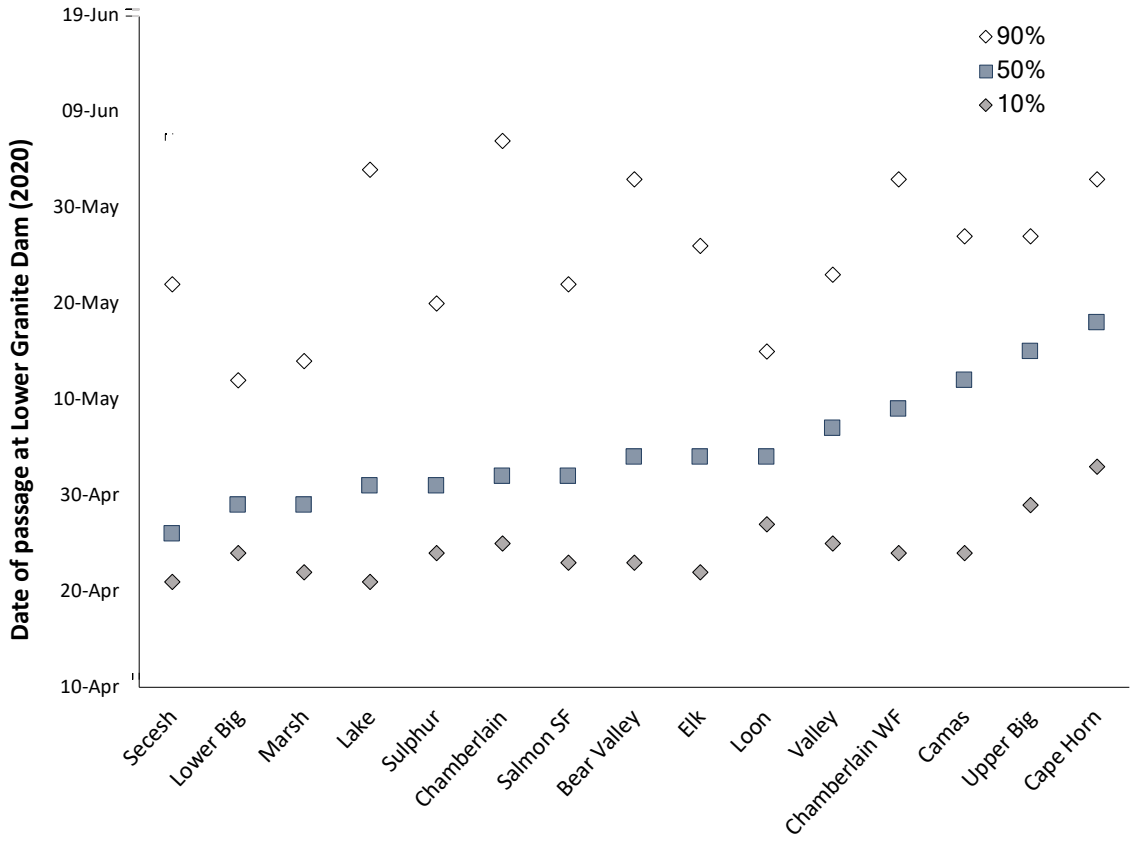

Figure 14. Estimated passage distribution dates at Lower Granite Dam from earliest to latest in 2020 for wild spring/summer Chinook salmon smolts tagged in Idaho streams. See Appendix Tables 3-17 for daily estimated passage numbers.

For fish from the 16 sample sites studied for 15 years or more, detection data at Lower Granite Dam has shown clear patterns among stream populations in timing of the 10th, 50th, and 90th passage percentiles (Table 7). In 2020, as seen over all study years, timing of the 10th passage percentile at Lower Granite Dam was significantly earlier for fish from the Secesh River than for fish from all other streams with the exception of Lake Creek.

Dates of the 50th passage percentile at Lower Granite Dam have been significantly later for fish from Upper Big Creek than for fish from all other streams. Over all study years, the Upper Big Creek population has also been one of the latest arriving groups in comparisons of the 90th passage percentile; only Valley Creek and South Fork Salmon River have been comparable.

Table 7. Percentile passage dates at Lower Granite Dam by stream population of wild spring/summer Chinook salmon smolts tagged as parr in Idaho streams the previous summer. Statistics for each stream are constructed using only migration years that stream was sampled from 1989 to 2020. For each stream population, 95% confidence intervals (CIs) for each passage percentile are included with standard errors (SEs).

	Dates of passage at Lower Granite Dam by population percentile, 2020									
	10th			50th			90th			Study
Stream	Mean date	95% CI	SE (d)	Mean date	95% CI	SE (d)	Mean date	95% CI	SE (d)	years
Secesh River	14 Apr	11-16 Apr	1	25 Apr	23-28 Apr	1	24 May	18-30 May	3	31
S Fork Salmon River	18 Apr	15-21 Apr	1	5 May	2-9 May	2	29 May	24 May-3 Jun	3	29
Bear Valley Creek	20 Apr	18-22 Apr	1	5 May	3-8 May	1	28 May	24 May-1 Jun	2	29
Valley Creek	22 Apr	19-25 Apr	2	9 May	5-12 May	2	31 May	26 May-4 Jun	2	29
Elk Creek	19 Apr	16-22 Apr	1	3 May	30 Apr-6 May	1	25 May	21-29 May	2	28
Lake Creek	15 Apr	13-17 Apr	1	28 Apr	25 Apr-1 May	1	26 May	20 May-1 Jun	3	27
Big Creek (upper)	27 Apr	24 Apr-1 May	1	15 May	12-19 May	2	2 Jun	27 May-7 Jun	3	26
Big Creek (lower)	17 Apr	15-20 Apr	1	27 Apr	24-29 Apr	1	10 May	8-12 May	1	24
Marsh Creek	19 Apr	17-21 Apr	1	2 May	30 Apr-5 May	1	20 May	17-24 May	2	24
Loon Creek	24 Apr	21-28 Apr	2	6 May	2-9 May	2	18 May	14-21 May	2	21
WF Chamberlain Creek	21 Apr	18-23 Apr	1	2 May	28 Apr-5 May	2	23 May	15-31 May	4	20
Cape Horn Creek	22 Apr	18-26 Apr	2	8 May	3-12 May	2	25 May	20-31 May	3	20
Sulphur Creek	21 Apr	18-24 Apr	2	6 May	2-10 May	2	24 May	19-28 May	2	19
Camas Creek	26 Apr	23-29 Apr	1	9 May	5-13 May	2	23 May	20-26 May	2	19
Chamberlain Creek	20 Apr	16-23 Apr	2	29 Apr	26 Apr-3 May	2	20 May	13-27 May	3	15

Table 7. Mean annual passage dates at Lower Granite Dam for the past 10 years (2011-2020) for combined stream populations of wild spring/summer Chinook salmon smolts PIT tagged the previous summers as parr. For all study years (1989-2020), average dates for the 10th, 50th, and 90th passage percentiles were 20 April, 4 May, and 25 May, respectively.

	Timing of passage percentiles at Lower Granite Dam			
Year	10th	50th	90th	Range
2011	17 Apr	8 May	22 May	1 Apr–27 Jun
2012	17 Apr	27 Apr	20 May	25 Mar-2 Jul
2013	22 Apr	6 May	15 May	27 Mar-9 Jun
2014	17 Apr	28 Apr	19 May	25 Mar-15 Jun
2015	20 Apr	30 Apr	14 May	25 Mar-12 Jun
2016	13 Apr	24 Apr	12 May	24 Mar-9 Jun
2017	12 Apr	23 Apr	15 May	23 Mar-6 Jun
2018	14 Apr	29 Apr	14 May	1 Apr-8 Jun
2019	13 Apr	29 Apr	17 May	28 Mar-24 Jun
2020	25 Apr	5 May	26 May	4 Apr-5 Jul
10-year average	**17 Apr**	**29 Apr**	**17 May**	**27 Mar-17 Jun**
All-year average	**20 April**	**4 May**	**25 May**	**23 Mar-22 Sept**

Flow Volume vs. Arrival Timing at Lower Granite Dam

To examine potential relationships between flow levels and arrival timing at Lower Granite Dam, we used first-time detections at Lower Granite Dam for tagged fish from all streams combined. First detections at Lower Granite were expanded using the same methods described previously in *Estimates of parr-to-smolt survival*.

We then compared the temporal distribution of expanded detections with river flows during the same period (Figure 15; Appendix Table 18). Overall, the passage distribution of first detections ranged from early April to early July 2020, with the middle 80th percentile occurring during the 31-d period from 25 April to 26 May (Table 7). Peak passage dates were also estimated using expanded detections, and these occurred from 25 to 27 April during a period of rising flows at the dam (Figure 15; Appendix Table 18).

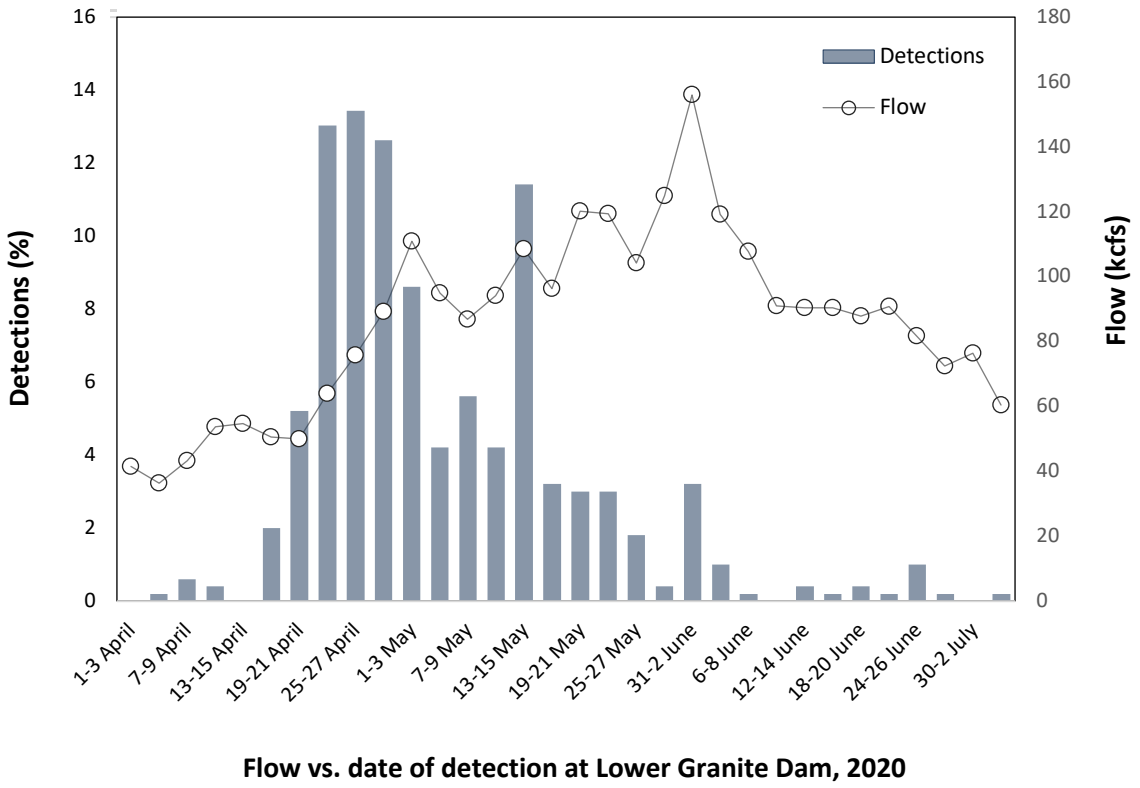

Figure 15. Overall migration timing of PIT-tagged wild spring/summer Chinook salmon smolts with associated river flows at Lower Granite Dam, 2020. Daily detections from all streams were expanded based on daily detection probability and pooled in 3-d intervals. Daily river flows at the dam were averaged over the same intervals.

Discussion

For fish detected on instream monitoring systems, the relationship between length at tagging and movement downstream has varied widely (Achord et al. 2010-2012; Lamb et al. 2013-2019). Results over all study years have shown that initiation of movement from natal rearing streams to larger rivers by parr, pre-smolts, and smolts is probably not related to parr size at tagging. However, larger tagged fish probably transition to the smolt stage earlier in spring than their smaller tagged cohorts; thus, they begin moving downstream sooner and arrive at Lower Granite Dam earlier.

Arrival timing of wild juvenile Chinook at Lower Granite Dam has continued to vary among populations from streams with and without monitoring systems, but individual populations have shown similar trends over time. In all study years, fish from Lake Creek and the Secesh River have arrived significantly earlier at the dam than fish from all other streams, and fish from upper Big Creek have been the latest arriving group. Dates encompassing the middle 80th percentile passage period have varied from year to year and between all streams.

During 2020, passage of the middle 80th percentile occurred over 31 d on average for the combined Idaho stream populations. This period began in late April and ended in late May 2020 (Figure 15).

Environmental Information

In 2007, the Northwest Fisheries Science Center personnel completed the *Water Quality Baseline Environmental Monitoring* website for storage and dissemination of water quality data collected during this study since 1993 (NWFSC 2007). This website was updated in January 2020 and converted to a web application.

In 2020, we were unable to collect hourly water quality measurements from all stream locations due to the COVID-19 pandemic. However, we are confident that the data loggers in these streams had sufficient battery life to maintain hourly data collection (Level Troll 300, In-Situ Inc., Fort Collins, Colorado). We look forward to retrieving these data during 2021.

Mapped over time, this information, along with weather and climate data, can provides tools to predict movement of individual wild fish populations. Such tools and information are vital to recovery planning for threatened and endangered populations of Pacific salmon.

Conclusions and Recommendations

1. During 2020, for the first time ever, we had detection capability for PIT-tagged fish passing via the spill bay below the removable spillway weir at Lower Granite Dam. The new ogee detection system is designated GRS in the PTAGIS database. The new system performed better than expected, detecting 357 of the 499 wild fish from our study detected at Lower Granite during 2020.

   At this time we do not have an estimate of detection efficiency for the new site; however, during 2021 we hope to resume the testing needed for estimates of GRS efficiency. This new interrogation site provides us with sufficient data for more accurate estimates and a better understanding of relationships between environmental conditions and movement of fry, parr, and smolts from natal rearing areas.

2. During 2020, we observed increased detection efficiency at nearly all of our instream interrogation sites, with most sites recording the best detection efficiencies ever. These increases were attributable to three main factors. First, a considerable improvement in tag reading range was achieved using the advanced performance tag (APT12, Biomark, Inc., Boise, Idaho). Second, low water levels directed fish closer to instream detection antennas and thus produced a mechanical increase in detection efficiency. Third, we experienced a relatively stable period of instream monitor operation, with few interruptions from technological or logistical issues such as power outages, broken equipment, etc.

3. Complex interrelationships between climate conditions and stream flow play an important role in yearly migration timing. Other abiotic factors that influence migration include water temperature, turbidity, and photoperiod. Biotic factors also contribute to the migration timing and survival of wild salmon and include physiological development, variability in stock behavior, and fish size. These complexities continue to drive a high and continual need for monitoring of threatened stocks.

4. During 2020, the COVID-19 pandemic created many challenges, both for research and for researchers. Due to local and national restrictions, we were not able to conduct field operations during summer 2020. As a result, no fish were tagged and no environmental data were collected for our project. This will create an irreparable gap in our long-term data set of survival and timing for juvenile Snake River wild spring/summer Chinook salmon. However, the environmental data is salvageable and will be collected during 2021 operations.

References

Achord, S., G. A. Axel, E. E. Hockersmith, B. P. Sandford, M. B. Eppard, and G. M. Matthews. 2001a. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1999. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Achord, S., G. A. Axel, E. E. Hockersmith, B. P. Sandford, M. B. Eppard, and G. M. Matthews. 2001b. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 2000. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., G. A. Axel, E. E. Hockersmith, B. P. Sandford, M. B. Eppard, and G. M. Matthews. 2002. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 2001. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., M. B. Eppard, E. E. Hockersmith, B. P. Sandford, G. A. Axel, and G. M. Matthews. 2000. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1998. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., M. B. Eppard, E. E. Hockersmith, B. P. Sandford, and G. M. Matthews. 1997. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1996. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., M. B. Eppard, E. E. Hockersmith, B. P. Sandford, and G. M. Matthews. 1998. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1997. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., M. B. Eppard, B. P. Sandford, and G. M. Matthews. 1996a. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1995. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., J. R. Harmon, D. M. Marsh, B. P. Sandford, K. W. McIntyre, K. L. Thomas, N. N. Paasch, and G. M. Matthews. 1992. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1991. Report to U.S. Army Corps of Engineers, Portland, OR. Available https://www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., E. E. Hockersmith, B. P. Sandford, R. A. McNatt, B. E. Feist, and G. M. Matthews. 2003. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 2002. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., J. M. Hodge, B. P. Sandford, E. E. Hockersmith, K. W. McIntyre, N. N. Paasch, and J. G. Williams. 2005. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 2004. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., D. J. Kamikawa, B. P. Sandford, and G. M. Matthews. 1995a. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1993. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., D. J. Kamikawa, B. P. Sandford, and G. M. Matthews. 1995b. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 1994. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., G. M. Matthews, O. W. Johnson, and D. M. Marsh. 1996b. Use of Passive Integrated Transponder (PIT) tags to monitor migration timing of Snake River Chinook salmon smolts. North American Journal of Fisheries Management 16:302-313.

Achord, S., G. M. Matthews, D. M. Marsh, B. P. Sandford, and D. J. Kamikawa. 1994. Monitoring the migrations of wild Snake River spring and summer Chinook salmon smolts, 1992. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., R. A. McNatt, E. E. Hockersmith, B. P. Sandford, K. W. McIntyre, N. N. Paasch, J. G. Williams, and G. M. Matthews. 2004. Monitoring the migrations of wild Snake River spring/summer Chinook salmon smolts, 2003. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, J. M. Hodge, K. W. McIntyre, N. N. Paasch, L. G. Crozier, and J. G. Williams. 2006. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2004-2005. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, J. J. Lamb, K. W. McIntyre, N. N. Paasch, and R. W. Zabel. 2012. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2010-2011. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, K. W. McIntyre, N. N. Paasch, and J. G. Williams. 2007a. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2005-2006. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, M. G. Nesbit, N. D. Dumdei, J. J. Lamb, K. W. McIntyre, N. N. Paasch, and J. G. Williams. 2008. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2006-2007. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, M. G. Nesbit, N. D. Dumdei, J. J. Lamb, K. W. McIntyre, N. N. Paasch, and J. G. Williams. 2009. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2007-2008. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, M. G. Nesbit, N. D. Dumdei, J. J. Lamb, K. W. McIntyre, N. N. Paasch, and J. G. Williams. 2010. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2008-2009. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., B. P. Sandford, E. E. Hockersmith, M. G. Nesbit, N. D. Dumdei, J. J. Lamb, K. W. McIntyre, N. N. Paasch, S. G. Smith, and R. W. Zabel. 2011. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2009-2010. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Achord, S., R. W. Zabel, and B. P. Sandford. 2007b. Migration timing, growth, and estimated parr-to-smolt survival rates of wild Snake River spring/summer Chinook salmon from the Salmon River basin, Idaho, to the lower Snake River. Transactions of the American Fisheries Society 136:142-154.

Action Agencies. 2004. Final Updated Proposed Action for the FCRPS Biological Remand. Report of the Action Agencies (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and Bonneville Power Administration). Available at www.salmonrecovery.gov/Files/BiologicalOpinions/2004/FinalUPANov242004.pdf.

Axel, G. A., G. T. Brooks, and B. P. Sandford. 2021. New marking and monitoring technologies for the passive integrated transponder, 2020. Report of the National Marine Fisheries Service to the Bonneville Power Administration, Portland, Oregon.

Connolly, P. J., I. G. Jezorek, and K. D. Martens. 2008. Measuring the performance of two stationary interrogation systems for detecting downstream and upstream movement of PIT-tagged salmonids. North American Journal of Fisheries Management 28:402-417.

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429-438.

Downing, S. L., E. F. Prentice, B. W. Peterson, E. P. Nunnallee, and B. F. Jonasson. 2001. Development and evaluation of passive integrated transponder tag technology, annual report: 1999 to 2000. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, Norwell, MA, 436 p.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration—stochastic model. Biometrika 52:225-247.

Kareiva, P., M. Marvier, and M. McClure. 2000. Recovery and management options for spring/summer Chinook salmon in the Columbia River Basin. Science 290:290:977-979.

Lady, J. M., P. Westhagen, and J. R. Skalski. 2003. USER 2.1 User Specified Estimation Routine. Columbia Basin Research, University of Washington, Seattle, WA. Available at http://www.cbr.washington.edu/analysis/apps/user.

Lamb, J. J., S. Achord, B. P. Sandford, G. A. Axel, M. G. Nesbit, K. W. McIntyre, and B. L. Sanderson. 2013. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2011-2012. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Lamb, J. J., B. P. Sandford, G. A. Axel, S.G. Smith, M. G. Nesbit, and B. L. Sanderson. 2014. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2012-2013. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Lamb, J. J., B. P. Sandford, G. A. Axel, S.G. Smith, M. G. Nesbit, and B. L. Sanderson. 2015. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2013-2014. Report to the Bonneville Power Administration, Portland, OR. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Lamb, J. J., B. P. Sandford, G. A. Axel, S. G. Smith, M. G. Nesbit, and B. L. Sanderson. 2016. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2014-2015. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Lamb, J. J., B. P. Sandford, G. A. Axel, S. G. Smith, M. G. Nesbit, and B. L. Sanderson. 2017. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles, 2015-2016. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm

Lamb, J. J., B. P. Sandford, G. A. Axel, M. G. Nesbit, and B. L. Sanderson. 2018. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: fish collection and tagging, 2017. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Lamb, J. J., B. P. Sandford, G. A. Axel, S. G. Smith, M. G. Nesbit, and B. L. Sanderson. 2018. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: survival and timing, 2017. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Lamb, J. J., B. P. Sandford, G. A. Axel, M. G. Nesbit, and B. L. Sanderson. 2018. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: fish collection and tagging, 2018. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Lamb, J. J., B. P. Sandford, G. A. Axel, S. G. Smith, M. G. Nesbit, and B. L. Sanderson. 2019a. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: survival and timing, 2018. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Lamb, J. J., B. P. Sandford, G. A. Axel, M. G. Nesbit, and B. L. Sanderson. 2019b. Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: fish collection and tagging, 2019. Report to Bonneville Power Administration, Portland, OR Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Ledgerwood, R. D., B. A. Ryan, E. M. Dawley, E. P. Nunnallee, and J. W. Ferguson. 2004. A Surface Trawl to Detect Migrating Juvenile Salmonids Tagged with Passive Integrated Transponder tags. North American Journal of Fisheries Management 24:440-451.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Pages 317-322 in Parker, N. C., A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, G. A. Winans. (Eds.) Fish-Marking Techniques. American Fisheries Society Symposium 7. Bethesda, Maryland.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon. 1990b. PIT tag monitoring systems for hydroelectric dams and fish hatcheries. Pages 323-334 in Parker, N. C., A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, G. A. Winans. (Eds.) Fish marking techniques. American Fisheries Society Symposium 7. Bethesda, Maryland. Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, D. C. Cross. 1990c. Equipment, methods, and an automated data-entry station for PIT tagging. Pages 335-340 in Parker, N. C., A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, G. A. Winans. (Eds.) Fish-Marking Techniques. American Fisheries Society Symposium 7. Bethesda, Maryland.

Magie, R. J., M. S. Morris, R. D. Ledgerwood, A. Cook, B. P. Sandford, and G. M. Matthews. 2010. Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary using Pair-Trawls, 2008. Report of the National Marine Fisheries Service to the , U.S. Army Corps of Engineers. Walla Walla, Washington. Available www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Matthews, G. M., and R. S. Waples. 1991. Status review for Snake River spring and summer Chinook salmon. NOAA Tech. Memo. NMFS F/NWC-200. Available www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Matthews, G. M., N. N. Paasch, S. Achord, K. W. McIntyre, and J. R. Harmon. 1997. A technique to minimize the adverse effects associated with handling and marking salmonid smolts. The Progressive Fish-Culturist 59:307-309.

Matthews, G. M., J. R. Harmon, S. Achord, O. W. Johnson, and L. A. Kubin. 1990. Evaluation of transportation of juvenile salmonids and related research on the Snake and Columbia Rivers, 1989. Report to the U.S. Army Corp of Engineers. Available www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

Morris, M. S., L. N. Webb, P. J. Bentley, A. J. Borsky, B. P. Sandford, and R. D. Ledgerwood. 2015. Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary using Pair-Trawls, 2015. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers. Walla Walla, Washington. Available at www.nwfsc.noaa.gov/publications/scipubs/index.cfm.

NMFS (National Marine Fisheries Service). 1992. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Federal Register FR-1992-04-22. Endangered and Threatened Species; Threatened Status for Snake River Spring/Summer Chinook Salmon, Threatened Status for Snake River Fall Chinook Salmon. Final rule. 50 CFR Part 227 [Docket No. 910647-2043].

NMFS (National Marine Fisheries Service). 2000. Biological opinion: reinitiation of consultation on the Federal Columbia River Power System, including the juvenile fish transportation system, and 19 Bureau of Reclamation projects in the Columbia Basin. (Available from NOAA Fisheries Northwest Region, Hydro Program, 525 NE Oregon Street, Suite 500, Portland OR 97232).

NMFS (National Marine Fisheries Service). 2008. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: NOAA, Log number F/NWR/2005/05883.

NWFSC (Northwest Fisheries Science Center). 2007. The baseline water quality environmental monitoring program. Online database available at https://www.webapps.nwfsc.noaa.gov/WaterQuality/.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. American Fisheries Society Symposium 7:323-334.

PSMFC (Pacific States Marine Fisheries Commission). 1996. The Columbia Basin PIT Tag Information System. Interactive database available at www.ptagis.org.

Sandford, B. P., and S. G. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agricultural, Biological, and Environmental Statistics 7(2):243-263.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. U.S. Fish and Wildlife Service Fishery Bulletin 52:191-203.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Appendix

Appendix Table 1. Summary of numbers collected, tagged, released (with tags), and minimum, maximum, and mean lengths and weights of wild Chinook salmon parr, collected and PIT tagged in various Idaho streams, 2019. Some length-weight data includes recaptured tagged fish.

				Collection				Tagging and release			
	Fish (n)			Length (mm)		Weight (g)		Length (mm)		Weight (g)	
	Collected	Tagged	Released	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Herd Creek	37	35	35	54-133	66.2	1.5-33.8	4.0	56-76	64.6	2.0-5.1	3.2
Camas Creek	308	177	177	45-73	57.2	1.2-4.7	2.7	55-73	61.1	1.7-4.7	2.9
Loon Creek	596	255	255	40-103	54.3	0.8-13.3	2.5	55-72	60.7	1.1-4.3	2.7
Marsh Creek	824	515	515	44-135	59.8	0.7-33.3	2.8	55-84	62.8	1.2-6.9	3.1
Cape Horn Creek	546	128	128	41-118	55.9	1.1-22.8	3.3	55-76	58.7	1.5-5.7	2.4
Valley Creek	1,219	1,144	1,144	48-133	64	0.9-34.4	3.2	55-87	64.0	1.4-8.1	3.1
Big Creek (upper)	995	565	565	44-116	59.8	0.9-22.1	3	53-84	62.4	1.2-6.9	3.1
Bear Valley Creek	1,041	1,000	1,000	54-91	68.4	2.0-9.0	4.2	54-91	68.4	2.0-9.0	4.2
Elk Creek	634	619	619	54-87	71.2	2.1-8.5	4.5	56-87	71.2	2.2-8.5	4.6
Sulphur Creek	564	535	535	50-125	64.4	1.1-24.8	3.2	55-83	64.5	1.5-6.1	3.1
S.F.Salmon River	1,875	1,244	1,241	41-120	62.1	0.5-21.5	2.9	55-85	64.8	1.5-7.3	3.1
Secesh River	527	450	450	47-115	61.8	0.9-19.2	2.9	55-85	63.1	1.7-7.8	2.8
Lake Creek	566	327	327	49-114	62.1	1.0-18.3	3.2	55-83	64.8	1.6-8.2	3.2
W. Fork Chamberlain Creek	534	500	500	52-93	70.2	1.3-8.5	3.9	55-93	70.4	1.6-8.5	3.9
Chamberlain Creek	764	737	737	48-120	67.1	0.8-19.4	3.5	55-90	66.9	1.5-8.6	3.4
Big Creek (lower)	201	193	193	60-93	80.2	2.2-9.7	6.2	60-93	80.2	2.2-9.7	6.2
Total or mean	**11,231**	**8,424**	**8,421**	**40-133**	**64.0**	**0.5-34.4**	**3.5**	**53-93**	**65.5**	**1.1-9.7**	**3.4**

Appendix Table 2. Cumulative passage dates at Lower Granite Dam for tagged wild spring/summer Chinook salmon smolts from streams over the past ten years.

	Percentile passage dates at Lower Granite Dam			
Year	10th	50th	90th	Range
Bear Valley Creek				
2011	17 April	9 May	30 May	4 April-9 June
2012	17 April	25 April	21 May	29 March-10 June
2013	22 April	2 May	13 May	20 April-20 May
2014	17 April	11 May	12 June	13 April-15 June
2015	20 April	27 April	2 June	13 April-2 June
2016	13 April	26 April	12 May	12 April-31 May
2017	13 April	25 April	24 May	9 April-5 June
2018	17 April	30 April	12 May	12 April-30 May
2019	14 April	30 April	17 May	1 April-6 June
2020	**24 April**	**5 May**	**3 June**	**16 April -26 June**
Elk Creek				
2011	13 April	4 May	27 May	5 April-21 June
2012	21 April	25 April	22 May	1 April-12 June
2013	22 April	7 May	14 May	22 April-20 May
2014	17 April	25 April	22 May	14 April-9 June
2015	18 April	27 April	11 May	2 April-19 May
2016	14 April	27 April	13 May	27 March-25 May
2017	6 April	19 April	13 May	31 March-4 June
2018	11 April	27 April	18 May	8 April-3 June
2019	17 April	13 May	4 June	12 April-4 June
2020	**23 April**	**5 May**	**27 May**	**10 April-25 June**
Valley Creek				
2011	27 April	14 May	2 June	06 April-16 June
2012	4 April	26 April	22 May	25 March-16 June
2013	18 April	7 May	21 May	14 April-9 June
2014	16 April	28 April	20 May	4 April-3 June
2015	25 April	8 May	21 May	23 April-22 May
2016	13 April	27 April	25 May	31 March-9 June
2017	12 April	25 April	20 May	10 April-31 May
2018	14 April	29 April	26 May	7 April-8 June
2019	10 April	26 April	16 May	1 April-6 June
2020	**26 April**	**8 May**	**24 May**	**9 April-25 June**
Camas Creek				
2011	4 May	15 May	23 May	7 April-11 June
2012[a]	**---**	**---**	**---**	---
2013	5 May	7 May	15 May	5 May-16 May
2014	21 April	30 April	22 May	16 April-26 May
2015	25 April	6 May	24 May	25 April-24 May
2016	22 April	8 May	13 May	18 April-16 May
2017	14 April	19 April	10 May	14 April-10 May
2018[a] 2019[a]	**---**	**---**	**---**	**---**
2020	**25 April**	**13 May**	**28 May**	**22 April-31 May**

Appendix Table 2. Continued.

Year	Percentile passage dates at Lower Granite Dam			
	10th	50th	90th	Range
Loon Creek				
2011	30 April	14-May	19-May	11 April-5 June
2012	22 April	27-Apr	20-May	28 March-6 June
2013	24 April	6-May	13-May	13 April-22 May
2014	21 April	2-May	10-May	17 April-21 May
2015	28 April	2-May	13-May	27 April-12 May
2016	14 April	24-Apr	7-May	5 April-10 May
2017	11 April	25-Apr	11-May	24 March-16 May
2018	19 April	30-Apr	13-May	19 April-19 May
2019[a]	---	---	---	---
2020	**28 April**	**5-May**	**16-May**	**24 April-14 May**
Marsh Creek				
2011	10 April	9 May	16 May	4 April-8 June
2012	18 April	25 April	19 May	1 April-26 May
2013[a]	---	---	---	---
2014	19 April	28 April	22 May	15 April-31 May
2015	19 April	25 April	19 May	19 April-19 May
2016	14 April	27 April	9 May	10 April-18 May
2017	10 April	22 April	10 May	3 April-28 May
2018	14 April	29 April	11 May	10 April-21 May
2019[a]	---	---	---	---
2020	**23 April**	**30 April**	**15 May**	**7 April-15 May**
Sulphur Creek				
2011	18 April	5 May	16 May	4 April-4 June
2012	22 April	28 April	20 May	13 April-4 June
2013	22 April	11 May	15 May	12 April-21 May
2014[a]	---	---	---	---
2015	22 April	3 May	10 May	14 April-21 May
2016	13 April	26 April	14 May	31 March-22 May
2017	17 April	9 May	2 June	15 April-2 June
2018[a] 2019[a]	---	---	---	---
2020	**25 April**	**2 May**	**21 May**	**22 April-1 June**
Cape Horn Creek				
2011	4 April	1 May	14 May	4 April-14 May
2012[a] 2013[a]	---	---	---	---
2014	20 April	2 May	21 May	15 April-9 June
2015	25 April	2 May	11 May	12 April-17 May
2016	13 April	21 April	9 May	8 April-14 May
2017	15 April	27 April	14 May	9 April-27 May
2018	19 April	3 May	18 May	16 April-6 June
2019[a]	---	---	---	---
2020	**4 May**	**19 May**	**3 June**	**2 May-1 June**

Appendix Table 2. Continued.

Year	Percentile passage dates at Lower Granite Dam			
	10th	50th	90th	Range
South Fork Salmon River				
2011	7 April	4 May	22 May	3 April-5 June
2012	20 April	28 April	20 May	7 April-6 June
2013	14 April	29 April	9 May	13 April-21 May
2014	12 April	26 April	23 May	1 April-4 June
2015	4 April	23 April	11 May	4 April-11 May
2016	11 April	15 April	26 April	5 April-25 May
2017	11 April	21 April	9 May	1 April-26 May
2018	14 April	4 May	13 May	4 April-24 May
2019	15 April	5 May	1 June	2 April-6 June
2020	**24 April**	**3 May**	**23 May**	**19 April-1 June**
Big Creek (upper)				
2011	7 May	16 May	24 May	25 April-1 June
2012	24 April	15 May	12 Jun	6 April-20 June
2013	30 April	14 May	30 May	23 April-30 May
2014	24 April	10 May	26 May	16 April-31 May
2015	25 April	9 May	21 May	25 April-24 May
2016	15 April	30 April	20 May	12 April-04 June
2017	20 April	10 May	29 May	13 April-06 June
2018	16 April	8 May	19 May	14 April-27 May
2019	25 April	15 May	2 June	23 April-6 June
2020	**30 April**	**16 May**	**28 May**	**25 April-2 June**
Big Creek (lower)				
2011	9 April	2 May	14 May	6 April-21 May
2012	14 April	25 April	5 May	2 April-22 May
2013	20 April	2 May	11 May	13 April- 18 May
2014	15 April	24 April	6 May	7 April-9 May
2015	20 April	27 April	11 May	29 March-18 May
2016	13 April	17 April	7 May	11 April-20 May
2017	10 April	20 April	12 May	29 March-14 May
2018	14 April	25 April	6 May	9 April-13 May
2019	8 April	14 April	5 May	8 April-5 May
2020	**25 April**	**30 April**	**13 May**	**21 April-15 May**
Secesh River				
2011	7 April	1 May	7 June	3 April-27 June
2012	5 April	23 April	7 May	2 April-26 May
2013	29 April	7 May	18 May	8 April-15 May
2014	11 April	19 April	6 May	3 April-25 May
2015	16 April	27 April	14 May	4 April-12 June
2016	12 April	21 April	10 May	1 April-12 May
2017	4 April	15 April	28 Apr	23 March-25 May
2018	9 April	18 April	10 May	1 April-21 May
2019	9 April	22 April	30 April	28 March-20 May
2020	**22 April**	**27 April**	**23 May**	**4 April-26 May**

Appendix Table 2. Continued.

Year	Percentile passage dates at Lower Granite Dam			
	10th	50th	90th	Range
Lake Creek				
2011	12 April	11 May	16 May	10 April-12 June
2012	21 April	27 April	27 May	9 April-2 July
2013	13 April	29 April	11 May	8 April-22 May
2014	12 April	17 April	28 May	11 April-1 June
2015	12 April	25 April	2 May	12 April- 2 May
2016	10 April	17 April	5 June	24 March-8 June
2017	10 April	16 April	8 May	24 March-4 June
2018	13 April	20 April	10 May	12 April-22 May
2019	11 April	24 April	11 May	1 April-24 June
2020	**22 April**	**2 May**	**4 June**	**9 April-23 June**
Herd Creek				
2011	14 April	12 May	18 May	5 April-31 May
2012	21 April	28 April	17 May	31 March-21 May
2013	14 April	10 May	16 May	08 April-22 May
2014	18 April	26 April	20 May	10 April-10 June
2015	23 April	6 May	7 May	23 April-7 May
2016	15 April	27 April	13 May	13 April-27 May
2017	17 April	25 April	22 May	12 April-2 June
2018	19 April	4 May	15 May	12 April-20 May
2019	12 April	28 April	6 May	10 April-17 May
2020[b]	**---**	**---**	**---**	---
Chamberlain Creek				
2011	19 April	9 May	23 May	3 April-16 June
2012	19 April	30 April	10 May	1 April-12 May
2013	29 April	5 May	22 May	11 April- 23 May
2014	19 April	26 April	10 May	17 April-17 May
2015	23 April	29 April	16 May	25 March-16 May
2016	13 April	19 April	15 May	12 April-15 May
2017	13 April	21 April	15 May	9 April-25 May
2018[a]	**---**	**---**	**---**	**---**
2019	12 April	26 April	19 May	9 April-9 June
2020	**26 April**	**3 May**	**7 June**	**19 April- 5 July**
West Fork Chamberlain Creek				
2011	22 April	9 May	27 May	3 April-27 June
2012	20 April	26 April	19 May	1 April-26 May
2013	29 April	7 May	16 May	11 April- 23 May
2014	18 April	26 April	11 May	12 April-17 May
2015	24 April	27 April	13 May	23 April-18 May
2016	15 April	26 April	9 May	13 April-10 May
2017	14 April	21 April	16 May	14 April-16 May
2018[a] 2019[a]	**---**	**---**	**---**	**---**
2020	**25 April**	**10 May**	**3 June**	**17 April-27 June**

[a] No parr were tagged the summer prior to this migration year.
[b] Insufficient numbers detected to estimate timing.

Appendix Table 3. Detections during 2020 of PIT-tagged smolts by date at Snake and Columbia River dams for 1,000 wild Chinook salmon from Bear Valley Creek released 2-3 August 2019. Release sites were 629-635 km above Lower Granite Dam

	Bear Valley Creek								
Detection date (2020)	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
16 Apr	1		2						
17 Apr	1	1	4						
19 Apr	1		2						
20 Apr		1	2						
21 Apr		1	2						
22 Apr	2	2	9						
23 Apr	1		3						
24 Apr	2		7						
25 Apr	2		7						
26 Apr	4		12						
27 Apr	3		10						
28 Apr	1	1	6						
29 Apr	1		3						
30 Apr	2	1	9						
1 May	1	2	8	2	1	1			
2 May	1		3	1					
3 May	1	1	10						
5 May									2
6 May	1		3				1		
7 May	1	1	6						1
8 May	1		3						
9 May	1		3						
10 May	1	1	5						
11 May					1				1
12 May		1	4			1			
14 May	1	4	15						
15 May		2	6	1					
16 May				1				1	
17 May	1		4						
18 May						1			
19 May			3			1			1
20 May								1	
21 May									1
22 May		1	3						1
25 May		1	3					1	
27 May		1	3						
28 May				1			1		
1 June	3		12						
3 June	1		5						
7 June		1	2						
13 June	1		1						
25 June	1		2		1				
26 June	1		3						
Total	**35**	**22**	**185**	**6**	**3**	**3**	**2**	**3**	**6**

Appendix Table 4. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 619 wild Chinook salmon from Elk Creek released 4-5 August 2019. Release sites were 634-638 km above Lower Granite Dam.

	Elk Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
10 Apr	1		3						
18 Apr	1		2						
19 Apr									
20 Apr	1		2						
21 Apr	3		6						
22 Apr									
23 Apr	3		8						
24 Apr		1	4						
25 Apr	1		4						
26 Apr	3		9						
27 Apr	2		6						
28 Apr	1	1	6				1		
29 Apr									
30 Apr	1		3						
1 May	2	1	8						
2 May				1			1		
3 May	1		5						
4 May	1	1	8						
5 May									1
6 May	1		3						
7 May	2	1	8				1		
8 May	1		3						
9 May							1		1
13 May	2	1	8						
14 May								1	
15 May					1			1	
17 May	1		4						
18 May		1	3						
19 May		1	3	2				2	
20 May									
21 May				1					
22 May		1	3						
23 May		1	3						
24 May		1	2						
25 May	1		3						
26 May	1		3						
28 May									1
30 May								1	
2 June				1					
4 June							1		
5 June	1		3						1
15 June	1		3						
25 June	1		2						
Total	**33**	**11**	**128**	**5**	**1**	**0**	**5**	**5**	**4**

Appendix Table 5. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 1,144 wild Chinook salmon from Valley Creek released 23-24 July 2019. Release sites were 743-750 km above Lower Granite Dam.

	Valley Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
9 Apr	1		2						
19 Apr	1		2						
22 Apr	1		2			1			
23 Apr	1		3						
24 Apr	1		4						
25 Apr	2		7						
26 Apr	1		3						
27 Apr	1		3						
28 Apr	1		3			1			
29 Apr	1		3						
30 Apr	2		6				1		
1 May		1	3						
2 May	2		6			1	1		
3 May	2		10						
4 May		1	4			1	2		
6 May	1	1	6		1				
7 May		1	3						
8 May	3		10						
9 May	1		3						
11 May		2	7						
12 May	2		7						
13 May	1		3						
15 May					1				
16 May	1		3		1				
17 May				1					
18 May	1		3						
19 May								1	
20 May	1	2	9						
22 May							1		
24 May						1			
28 May		1	3						
31 May									1
2 June		1	7						
25 June	1		2						
Total	**29**	**10**	**127**	**1**	**3**	**5**	**5**	**1**	**1**

Appendix Table 6. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 565 wild Chinook salmon from Upper Big Creek released 31 July and 1 August 2019. Release sites were 489-491 km above Lower Granite Dam.

	Upper Big Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
25 Apr	2		7						
28 Apr	1	1	6						
30 Apr	1		3						
1 May				1					
2 May	2		6						
3 May					1			1	
4 May	1								
5 May		1	4				1	1	
7 May	1		3						
8 May									1
9 May	1		3						
10 May	1		3						
11 May		1	3						2
12 May	1	1	7						
13 May	2	2	10					1	
14 May	2	1	9	2	1				
16 May	1	1	7						1
17 May	1	1	8			1			
18 May		1	3	1			1	1	
19 May	2		6	2				3	
20 May		1	3	1	1				
21 May				2					
22 May				1	1	1		2	
23 May	2	1	8	1					
24 May	2		5						1
25 May	1		3			1		1	
26 May	1		3						
27 May				1					
30 May					1				
1 June		1	4						
2 June		1	7						
19 June							1		
7 July								1	
Total	**25**	**14**	**124**	**12**	**5**	**3**	**3**	**11**	**5**

Appendix Table 7. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 193 wild Chinook salmon from Lower Big Creek released 25 August 2019. Release sites were 489-491 km above Lower Granite Dam.

	Lower Big Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
21 Apr	2		4						
22 Apr	1		2						
23 Apr	1		3						
24 Apr	3		11	1					
26 Apr	5		15						
27 Apr	1	1	6		1	1			
29 Apr	1		3						
30 Apr	3	1	12	1			1		
1 May	1		3	1		2			
2 May		1	3		1				
4 May		1	4		1		2		
5 May					1	1		1	
7 May	1		3	1	1				
9 May							1		
10 May		1	3						
11 May	1	1	7						
12 May					1				
15 May		1	3						
19 May				1					1
Total	**20**	**7**	**81**	**5**	**6**	**4**	**4**	**1**	**1**

Appendix Table 8. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 1,241 wild Chinook salmon from South Fork Salmon River released 14 August 2019. Release sites were 467-469 km above Lower Granite Dam.

	South Fork Salmon River								
Detection date (2020)	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
19 Apr	1	1	4						
20 Apr	2		5		1				
21 Apr	1		2						
22 Apr	3	1	9						
23 Apr	3		8						
24 Apr	2		7						
25 Apr	1	1	7						
26 Apr	1		3	2					
27 Apr	1	1	6	1		1			
29 Apr	4	3	22			1			
30 Apr		1	3						
1 May	4		11						
2 May	2		6	2					
3 May		1	5						
4 May	1		4	1			1		
5 May	1		3		1		1		
6 May									1
7 May				2					
8 May	1		3						
10 May									1
11 May							1		
12 May								1	
13 May	3		8						
14 May	1	3	12					1	
15 May		2	6						
16 May		1	3						
19 May	1		3	1				1	
20 May					1				
21 May		1	3	3				1	
23 May	1	1	5	1					
24 May	1		2	1		1			
25 May					1				
26 May				2					
27 May							1	1	
28 May				1					
29 May				1					
31 May	1		2						
1 June	1		4						
3 June				1					
5 June									1
8 June				1					
Total	**37**	**17**	**156**	**20**	**4**	**3**	**4**	**5**	**3**

Appendix Table 9. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 450 wild Chinook salmon from Secesh River released 14 August 2019. Release sites were 429-431 km above Lower Granite Dam.

	Secesh River								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
4 Apr	1		2						
12 Apr	1		3						
17 Apr	1		2						
20 Apr	2		5						
21 Apr	2	1	6						
22 Apr	3		7						
23 Apr	3		8						
24 Apr	1		4						
25 Apr	2		7						
26 Apr	1		3						
27 Apr	2		6		1				
29 Apr	1		3						
30 Apr	2		6				1		
1 May	1		3				1		
4 May							2		
5 May									2
9 May	1		3						
10 May	1		3						
17 May				1					
20 May		1	3						
21 May		1	3	1					
23 May		1	3						
26 May								1	
Total	**25**	**4**	**80**	**2**	**1**	**0**	**4**	**1**	**2**

Appendix Table 10. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 327 wild Chinook salmon from Lake Creek released 15 August 2019. Release site was 451 km above Lower Granite Dam.

	Lake Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
9 Apr	1		2						
17 Apr	1		2						
20 Apr	1		2						
21 Apr	1		2						
22 Apr	3		7						
23 Apr	1		3						
24 Apr	1		7						
26 Apr						1			
29 Apr		1	3						
30 Apr		1	3						
12 May				1					
13 May								1	
17 May		1	4						
21 May								1	
23 May				1					
26 May								1	
2 June	2	1	22						
3 June				1					
9 June								1	
11 June							1		
13 June									1
14 June	1		3						
23 June	1		1						
Total	**13**	**4**	**61**	**3**	**0**	**1**	**1**	**4**	**1**

Appendix Table 11. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 177 wild Chinook salmon from Camas Creek released 17 July 2019. The release site was 529 km above Lower Granite Dam.

	Camas Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
22 Apr	1		2						
23 Apr		1	3						
28 Apr		1	3						
30 Apr	1		3						
8 May	1		3						1
9 May							1		
10 May							1		
11 May									1
13 May		1	3						
14 May		1	3						
16 May	1		3						
18 May				1			1		
25 May		1	3						
31 May	1		2						
Total	**5**	**5**	**28**	**1**	**0**	**0**	**3**	**0**	**2**

Appendix Table 12. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 128 wild Chinook salmon from Cape Horn Creek released 22 July 2019. The release site was 631 km above Lower Granite Dam.

	Cape Horn Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
2 May	1		3						
8 May				1					
10 May				1					
15 May	1		3						
17 May	1		4						
18 May								1	
25 May									1
27 May				1					
01 June	1		4						
Total	**4**	**0**	**14**	**3**	**0**	**0**	**0**	**1**	**1**

Appendix Table 13. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 737 wild Chinook salmon from Chamberlain Creek released 23-24 August 2019. The release site was 437 km above Lower Granite Dam.

	Chamberlain Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
19 Apr	1		2						
22 Apr	1		2						
23 Apr	2	1	8						
24 Apr	1		4						
25 Apr	2		7						
26 Apr	5		15						
27 Apr	2	1	10						
28 Apr		1	3						
29 Apr	2	1	9		1				
30 Apr	3	1	12						
1 May	3		8			1			
2 May		1	3		1		1		
3 May					1			1	
4 May	1		4		1				
5 May				1					
6 May	1	1	6				1		
7 May					2			2	
10 May							1		1
11 May					1				
12 May	2		7				1		
13 May	2		5	1				1	
14 May	1	1	6		1			1	
15 May		1	3						
16 May					1				
17 May									1
19 May				1				1	
20 May		1	3						1
21 May						1		1	
22 May	1		3						
23 May	1		3						
1 June		1	4				1		
3 June		1	5						
4 June				1					
5 June	1	1	7						
7 June					1				
9 June						1			
10 June							1		
12 June							1		
18 June	1		9			1			1
5 July	1		2						
Total	**34**	**13**	**150**	**4**	**10**	**4**	**7**	**7**	**4**

Appendix Table 14. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 500 wild Chinook salmon from West Fork Chamberlain Creek released 22 August 2019. The release site was 438 km above Lower Granite Dam.

	West Fork Chamberlain Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
14 Apr				1					
17 Apr		1	2						
19 Apr	1		2						
23 Apr	2		5						
24 Apr	2		7						
25 Apr	1		4						
26 Apr		1	3						
27 Apr							1		
29 Apr				1					
30 Apr	2		6			1			
2 May	1		3						
3 May	2		10						
5 May				1					
7 May	1		3				1		
8 May	2		7						
10 May							1		1
13 May	1	2	8	1				1	
14 May	3		9						
15 May	1	1	6	1					
18 May		1	3					2	
21 May	1		3					1	
23 May				1					
25 May								1	
29 May						1			
30 May	1		2						
1 June	1		4						
20 June	1		4						
24 June	1		1						
27 June	1		2						
Total	**26**	**6**	**94**	**6**	**0**	**2**	**3**	**4**	**1**

Appendix Table 15. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 255 wild Chinook salmon from Loon Creek released 20 July 2019. The release site was 552 km above Lower Granite Dam.

	Loon Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
24 Apr	1		4						
26 Apr	2	1	9						
27 Apr	1		3						
29 Apr				1					
30 Apr	1	1	6	1					
1 May	1	1	5						
3 May	1		5						
4 May					1		1		
6 May	1		3						
7 May	2		6	1			1		
8 May								1	
9 May						1			
10 May									1
13 May		1	3						
14 May	1	3	12	1					
15 May					1				
16 May								1	
18 May								1	
Total	**11**	**7**	**56**	**4**	**2**	**1**	**2**	**3**	**1**

Appendix Table 16. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 535 wild Chinook salmon from Sulphur Creek released August 2019. The release site was 605 km above Lower Granite Dam.

	Sulphur Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
22 Apr	1		2						
23 Apr	4		11						
24 Apr	2		7						
25 Apr	1		4	1					
26 Apr	1		3						
27 Apr	2		6	1					
28 Apr	2	1	9						
29 Apr	1		3		1				
30 Apr	2		6	1					
1 May	2		5	1					
2 May		1	3	1	1				
3 May						1			
4 May					1				
5 May	1		3						
6 May				1					
7 May	2		6	1					1
9 May	1		3						
10 May									1
11 May				1		1	1		
12 May	1		4						
13 May		1	3		1				
14 May		2	6						
16 May							1		
17 May	1		4	1				1	
19 May	1		3						
22 May								1	
25 May		1	3						
27 May								1	
28 May									1
29 May							1		
30 May					1				
1 June		1	4		1				
5 June				1					
Total	**25**	**7**	**98**	**10**	**6**	**2**	**3**	**3**	**3**

Appendix Table 17. Detections during 2020 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 515 wild Chinook salmon from Marsh Creek released 21-22 July 2019. The release site was 631 km above Lower Granite Dam.

	Marsh Creek								
Detection	Lower Granite			First detections					
date (2020)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
7 Apr	1		2						
16 Apr		2	5						
17 Apr	1		2	1					
21 Apr	2		4						
22 Apr	1		2						
23 Apr	2		5						
24 Apr	2		7						
25 Apr	3		11						
26 Apr	1		3						
27 Apr	3	2	16						
28 Apr	2	2	13				1		
29 Apr	3	1	12	1					
30 Apr	1		3	1					
1 May		2	5				1		
3 May				1					
4 May	2		8		1		2	1	
5 May							1		
6 May	1	1	6						
7 May	1		3						
8 May							1		
9 May					1				
10 May	1		3						
11 May						1			
12 May	1	1	7						
13 May	2	2	10	1		1			
14 May							1		
15 May		1	3		1				
17 May									1
19 May				1					
20 May								1	
21 May				2					
23 May					1	1			
30 May								1	
Total	**30**	**14**	**130**	**8**	**4**	**3**	**7**	**3**	**1**

Appendix Table 18. Daily detections and expanded detection numbers (i.e., estimated detection efficiency) of PIT-tagged wild spring/summer Chinook salmon smolts at Lower Granite Dam during 2020 with associated river conditions at the dam.

	Lower Granite Dam						
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Spill Detections LGS (n)	Bypass Detections LGB (n)	Detections (n)	Expanded detections (n)
4 Apr	38.1	23.2	8.1	1	0	1	2
7 Apr	38.3	23.2	7.9	1	0	1	2
9 Apr	46.8	29.2	9.0	1	0	2	5
10 Apr	49.7	31.6	9.5	1	0	1	3
12 Apr	58.1	36.6	9.9	1	0	1	3
16 Apr	51.2	32.2	9.3	1	2	3	7
17 Apr	52.3	32.2	9.0	4	2	6	12
18 Apr	47.8	29.8	8.8	1	0	1	2
19 Apr	50.6	32.0	8.8	5	1	6	11
20 Apr	50.3	32.8	9.4	7	0	7	16
21 Apr	49.1	30.6	9.8	11	2	13	25
22 Apr	54.5	34.9	10.1	17	3	20	45
23 Apr	63.1	40.4	10.7	23	2	25	68
24 Apr	74.5	47.4	11.2	19	1	20	73
25 Apr	73.1	48.9	11.1	17	1	18	65
26 Apr	74.7	49.0	10.5	24	2	26	77
27 Apr	79.3	51.1	10.3	18	5	23	73
28 Apr	84.3	54.5	10.5	8	8	16	50
29 Apr	88.5	57.5	11.0	14	6	20	62
30 Apr	94.8	59.2	11.0	21	6	27	82
1 May	115.7	61.7	11.1	15	7	22	59
2 May	112.1	60.9	10.6	9	3	12	37
3 May	104.9	61.4	9.9	7	2	9	43
4 May	103.8	61.7	10.1	6	3	9	35
5 May	93.8	60.9	10.3	2	1	3	10
6 May	86.9	55.9	10.3	6	3	9	28
7 May	90.6	59.2	10.3	11	3	14	39
8 May	86.8	57.7	10.5	9	0	9	30
9 May	82.8	53.4	10.5	5	0	5	14
10 May	83.1	53.5	10.9	4	2	6	15
11 May	97.0	60.0	11.2	1	4	5	17
12 May	102.2	63.2	11.7	7	3	10	37

Appendix Table 18. Continued.

	Lower Granite Dam (continued)						
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Spill Detections LGS (n)	Bypass Detections LGB (n)	Detections (n)	Expanded detections (n)
13 May	112.4	64.0	11.9	13	10	23	59
14 May	111.4	64.1	11.3	9	15	24	72
15 May	101.8	64.8	10.4	2	8	10	29
16 May	97.9	64.9	10.2	3	2	5	17
17 May	94.0	61.9	10.2	5	2	7	28
18 May	97.1	63.9	10.4	1	3	4	13
19 May	113.2	71.0	10.6	5	1	6	19
20 May	114.8	65.6	10.7	1	5	6	18
21 May	132.5	68.1	10.0	1	2	3	9
22 May	131.3	77.4	9.9	1	2	3	9
23 May	123.4	60.4	9.9	4	4	8	22
24 May	103.2	59.0	10.1	3	1	4	9
25 May	101.3	58.9	10.3	2	3	5	13
26 May	101.2	62.4	10.5	2	1	3	8
27 May	110.0	60.5	11.1	0	1	1	3
28 May	113.2	60.7	12.0	0	1	1	3
30 May	124.9	60.4	13.0	1	0	1	2
31 May	136.8	64.3	13.4	2	0	2	5
1 Jun	156.9	75.7	13.6	6	3	9	36
2 Jun	166.1	75.5	13.5	2	3	5	36
3 Jun	145.0	74.7	13.0	1	1	2	10
5 Jun	125.3	58.1	12.6	2	1	3	10
7 Jun	115.5	57.3	13.5	0	1	1	2
13 Jun	109.3	69.2	14.0	1	0	1	1
14 Jun	89.3	67.3	13.9	1	0	1	3
15 Jun	93.8	68.7	14.7	1	0	1	3
18 Jun	91.7	59.3	15.0	1	0	1	9
20 Jun	90.2	58.3	13.4	1	0	1	4
23 Jun	85.4	66.4	13.7	1	0	1	1
24 Jun	93.8	25.8	15.1	1	0	1	1
25 Jun	84.4	27.5	15.8	3	0	3	6
26 Jun	82.8	34.7	16.3	1	0	1	3
27 Jun	77.8	38.7	17.1	1	0	1	2
5 Jul	54.6	18.7	15.4	1	0	1	2
Avg/Total	**91.6**	**53.1**	**11.4**	**356**	**142**	**499**	**1514**

Appendix Table 19. Daily detections at Little Goose Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	Little Goose Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
14 Apr	57.8	33.9	9.6	1
17 Apr	51.1	30.6	10.4	1
24 Apr	73.4	49.1	10.3	1
25 Apr	69.7	45.6	10.6	1
26 Apr	72.6	48.0	11.0	2
27 Apr	76.3	50.8	11.6	2
29 Apr	87.6	58.8	11.3	3
30 Apr	92.9	61.1	11.1	4
1 May	113.4	62.9	11.3	5
2 May	110.5	63.6	11.5	5
3 May	99.5	61.9	11.5	1
4 May	106.0	64.2	11.2	1
5 May	89.3	60.4	10.7	2
6 May	86.1	57.6	10.6	1
7 May	87.5	57.4	10.8	5
8 May	85.7	57.6	10.9	1
10 May	78.5	52.6	11.3	1
11 May	96.4	60.0	11.5	1
12 May	98.4	63.6	11.5	1
13 May	107.4	64.6	11.7	3
14 May	110.6	64.9	12.1	3
15 May	96.7	63.7	12.4	2
16 May	95.7	63.6	12.3	1
17 May	91.0	61.3	11.6	3
18 May	96.4	64.2	11.0	2
19 May	108.9	66.1	10.8	8
20 May	112.8	66.9	10.9	1
21 May	128.4	68.6	11.0	9
22 May	125.7	69.3	10.9	1
23 May	119.3	68.2	10.5	4
24 May	100.6	66.2	10.6	1
26 May	96.5	65.4	10.8	2
27 May	106.7	67.0	11.1	2
28 May	111.7	68.1	11.4	2

Appendix Table 19. Continued.

	Little Goose Dam (continued)			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
29 May	121.1	68.8	11.9	1
2 Jun	142.1	66.0	14.0	2
3 Jun	122.4	63.1	13.9	2
4 Jun	110.2	59.6	13.6	1
5 Jun	116.3	60.0	13.4	1
8 Jun	104.2	57.7	13.9	1
Avg/Total	**98.9**	**60.1**	**11.5**	**91**

Appendix Table 20. Daily detections at Lower Monumental Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	Lower Monumental Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
20 Apr	46.3	33.2	11.0	1
27 Apr	77.4	52.2	11.0	2
29 Apr	87.6	59.6	12.0	2
1 May	112.6	75.4	11.7	1
2 May	113.4	76.0	11.4	4
3 May	98.8	66.0	11.7	2
4 May	105.0	70.3	11.7	5
5 May	88.9	61.1	11.8	2
6 May	84.7	58.8	11.5	1
7 May	85.2	57.8	11.1	3
8 May	85.7	58.9	10.9	1
9 May	80.4	55.0	11.1	1
11 May	95.3	63.0	11.4	2
12 May	100.0	68.4	11.7	1
13 May	108.4	73.2	11.7	1
14 May	111.5	76.1	11.8	2
15 May	95.8	65.2	12.0	4
16 May	96.6	66.9	12.4	2
20 May	114.4	78.8	11.1	2
22 May	126.8	85.4	11.0	1
23 May	121.0	80.6	11.1	1
25 May	99.2	67.5	10.9	1
30 May	131.7	90.2	12.2	2
1 Jun	159.5	109.0	13.9	1
7 Jun	101.1	68.3	13.7	1
25 Jun	78.7	17.0	15.3	1
25 Jun	78.7	17.0	15.3	1
Avg/Total	**100.2**	**66.7**	**11.8**	**47**

Appendix Table 21. Daily detections at Ice Harbor Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	Ice Harbor Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
22 Apr	56.6	36.0	11.4	1
26 Apr	76.1	51.5	11.2	1
27 Apr	81.0	55.7	11.2	2
28 Apr	88.0	59.7	11.3	1
29 Apr	90.9	62.9	11.6	1
30 Apr	96.1	66.9	12.0	1
1 May	116.5	86.4	12.5	4
2 May	117.9	86.4	12.4	1
3 May	104.1	74.5	11.9	1
4 May	111.5	81.4	11.9	1
5 May	94.0	65.6	12.2	1
9 May	83.1	58.4	11.8	1
11 May	99.2	70.3	12.0	2
12 May	103.3	73.7	12.1	1
13 May	111.3	82.4	12.2	1
17 May	97.9	69.1	12.7	1
18 May	102.3	73.4	13.0	1
21 May	132.0	95.5	11.8	1
22 May	133.3	106.2	11.4	1
23 May	125.1	93.1	11.5	1
24 May	108.6	79.4	11.8	2
25 May	103.7	74.4	11.9	1
29 May	124.0	91.9	12.1	1
9 Jun	103.3	74.8	14.0	1
18 Jun	90.4	61.6	14.3	1
Avg/Total	**105.2**	**75.7**	**12.1**	**31**

Appendix Table 22. Daily detections at McNary Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	McNary Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
27 Apr	200.3	127.1	11.5	1
28 Apr	224.1	145.0	11.5	2
30 Apr	242.8	162.9	11.6	3
1 May	256.5	172.3	11.5	2
2 May	274.7	187.6	11.8	1
4 May	260.3	179.8	11.9	10
5 May	271.5	188.6	11.9	3
6 May	263.2	184.8	11.8	2
7 May	266.3	183.1	11.8	2
8 May	275.3	187.5	11.7	1
9 May	263.7	177.8	11.8	3
10 May	270.1	184.0	12.0	3
11 May	289.2	207.8	12.0	2
12 May	310.0	221.5	11.9	1
14 May	339.2	234.2	12.0	1
16 May	309.2	218.9	12.3	1
18 May	306.8	219.4	12.5	2
22 May	328.9	261.5	12.1	1
27 May	311.0	217.5	13.2	1
28 May	342.9	238.6	13.3	1
29 May	355.4	239.0	13.6	1
1 Jun	391.2	260.8	13.7	1
4 Jun	356.1	266.5	14.5	1
10 Jun	296.5	193.7	14.0	1
11 Jun	315.8	209.7	14.4	1
12 Jun	321.3	198.9	14.7	1
19 Jun	308.3	162.6	15.3	1
Avg/Total	**294.5**	**201.1**	**12.6**	**50**

Appendix Table 23. Daily detections at John Day Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	John Day Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
2 May	269.7	148.2	12.6	1
3 May	253.1	144.9	12.5	2
4 May	268.1	149.0	12.5	1
5 May	273.3	150.4	12.4	2
7 May	275.3	149.8	12.7	3
8 May	286.9	150.0	13.0	1
12 May	315.9	158.0	12.9	1
13 May	312.3	155.2	12.8	4
14 May	342.8	155.3	12.8	3
15 May	336.7	152.4	12.6	1
16 May	300.4	147.4	12.7	2
17 May	308.2	149.9	12.7	1
18 May	310.2	148.0	12.8	5
19 May	332.8	167.7	12.8	8
20 May	357.9	156.7	12.8	2
21 May	346.4	150.0	12.9	4
22 May	352.4	160.7	12.8	3
25 May	316.8	147.3	12.7	3
26 May	313.4	147.6	12.9	2
27 May	313.3	158.2	13.1	2
30 May	359.5	171.8	14.1	2
9 Jun	330.0	147.6	14.5	1
6 Jul	218.2	76.5	17.2	1
Avg/Total	**308.4**	**149.7**	**13.1**	**55**

Appendix Table 24. Daily detections at Bonneville Dam in 2020 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2019.

	Bonneville Dam			
Date (2020)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
5 May	270.2	132.2	13.0	5
6 May	250.3	132.6	12.9	1
7 May	271.8	133.0	12.8	2
8 May	290.9	132.5	12.8	2
9 May	272.9	133.0	13.3	1
10 May	259.3	133.0	13.6	5
11 May	279.0	132.7	13.6	4
16 May	313.7	133.1	13.1	1
17 May	302.6	132.8	13.0	2
19 May	338.7	148.3	12.9	2
20 May	349.1	148.6	12.9	1
21 May	354.8	148.8	12.9	1
22 May	340.9	148.7	12.9	1
24 May	344.5	147.0	13.1	1
25 May	328.5	148.1	13.1	1
28 May	322.6	136.0	13.7	2
31 May	371.4	148.8	14.3	1
5 Jun	372.0	150.8	14.7	2
13 Jun	287.3	133.2	14.8	1
18 Jun	292.8	96.2	15.6	1
Avg/Total	**310.6**	**137.5**	**13.4**	**37**

Appendix Table 25. Estimated detection efficiencies for the Valley Creek instream PIT-tag monitoring system based on detections at downstream dams, 2003-2020.

Year at Valley Creek	PIT tag size (mm)	Detection efficiency (%)	SE
2003	12	---	--
2004	12	22.6	--
2005	12	34.4	--
2006	12	14.9	--
2007	12	28.9	--
2008	12	21.1	--
2009	12	45.6	--
2010	12	37.7	--
2011	12	75.9	--
2012	12	80.0	--
	9	38.0	--
2013	12	74.2	5.6
	9	49.0	7.0
2014	12	48.9	7.5
	9	15.4	5.0
2015	12	60.5	7.5
2016	12	69.4	5.4
2017	12	82.4	3.8
2018	9 and 12	47.6	5.5
2019	12	82.4	4.2
2020	12	96.4	2.5
Average		**51.26**	

U.S. Secretary of Commerce
Gina M. Raimondo

Acting Under Secretary of Commerce
for Oceans and Atmosphere
Benjamin Friedman

Acting Assistant Administrator for
Fisheries
Dr. Paul N. Doremus

May 2021

fisheries.noaa.gov

OFFICIAL BUSINESS

National Marine
Fisheries Service
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112