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

Survival and Timing, 2022

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U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
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NOAA FISHERIES

Monitoring the Migrations of Wild Snake River Spring/Summer Chinook Salmon Juveniles: Survival and Timing, 2022

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Executive Summary

From late summer 2021 to mid-2022, 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 2021 and monitored through spring 2022. Comprehensive detail on fish collection and tagging is described in our report of December 2021, *Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles: Fish collection and tagging, 2021*.

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 as well as 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 2021-2022 are summarized below:

- During July-August 2021, we PIT-tagged 6,232 wild Chinook salmon parr and released them back into the 11 sample streams from which they were collected.
- For fish from all streams combined, the average estimated rate of parr-to-smolt survival to Lower Granite Dam was 16.8% (range 11.0-41.8%).
- For tagged parr from all 11 stream populations combined, peak detections at Lower Granite Dam occurred during 7-9 May 2022. Respective dates of the 10th, 50th, and 90th passage percentiles at the dam were 29 April, 10 May, and 28 May 2022.
- During 2022, we recaptured 129 study fish using the separation-by-code system at Lower Granite Dam. Recaptures included fish from all 11 Idaho populations sampled in 2021.
- For the 129 recaptured fish, average growth was 41 mm in length and 10.5 g in weight over an average period of 286 d. Mean condition factor declined from 1.13 at release (parr) to 1.07 at recapture (smolt). Among fish tagged and released as parr in 2021, we found no significant difference relating to size (length at tagging) between fish detected during spring and summer 2022 and those that were never detected (P = 0.3740).

Table 1. Numbers and proportions of PIT-tagged wild spring/summer Chinook salmon released during 2021 and detected during 2021-2022 with associated estimates of survival to monitoring systems and to Lower Granite Dam. Results shown are for eight tagging cohorts which migrated past 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 (%)					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	1,000	294*	29.4*	--	--	--	75.6*	38.9*	19.3*	7.3
Upper Big Creek										
Edwardsburg	500	--	--	--	--	--	--	--	--	--
Taylor Ranch	500	29	5.8	34.5	37.9	27.6	16.4	35.4	36.8	20.4
Lake Creek	500	151	30.2	90.1	9.3	0.7	67.8	44.5	50.9	21.7
Secesh River	500	178	35.6	91.0	6.7	2.2	59.4	59.9	46.1	27.4
S Fork Salmon R	750	177	23.6	60.5	24.9	14.7	42.3	55.8	32.2	19.6
Marsh Creek	1,000	551	55.1	87.5	9.1	3.4	93.2	59.2	32.5	19.2
Cape Horn Creek	715	385	53.8	85.4	7.3	7.3	98.4	54.8	128.9	16.0

* The Valley Creek instream system was non-operational during a key portion of the study period (17 Jun-11 Aug).

Contents

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.

Construction and installation of the spillway PIT detection system at Lower Granite Dam was completed in January 2020 allowing for detection of fish that pass via spill bay 1. The spillway detection system was fully operational for data collection in April 2020, and during its inaugural year, successfully detected over 160,000 unique fish, resulting in a 371% increase over detections in the existing juvenile bypass detection system at Lower Granite Dam.

In 2021, the new spillway system detected 251,000 fish resulting in a 977% increase in total project detection. Prior to installation of the spillway detection system, a large number of PIT tagged fish passed Lower Granite without detection. The new system will allow for more precise estimates of survival and timing of the wild Snake River spring/summer Chinook tagged as part of this project.

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 populations and of the environmental status of natal streams and tributaries supporting 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 2021 to spring and early summer 2022 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 2021, we recorded water temperature and depth measured at 14 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 2021. Complete details of this work are reported by Lamb et al. (2023). Briefly, National Marine Fisheries Service (NMFS) personnel tagged fish in 11 Idaho streams (Figure 1). Fish collection followed the safe handling methods developed for this study by Matthews et al. (1990, 1997). Anesthetized fish were randomly selected for tagging, provided they met the minimum fork length (FL) requirement of 55-mm.

In 2021, 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, injury, and disease transmission during the tagging process. After recovery from the anesthetic, fish were released back to the streams where they had been originally captured.

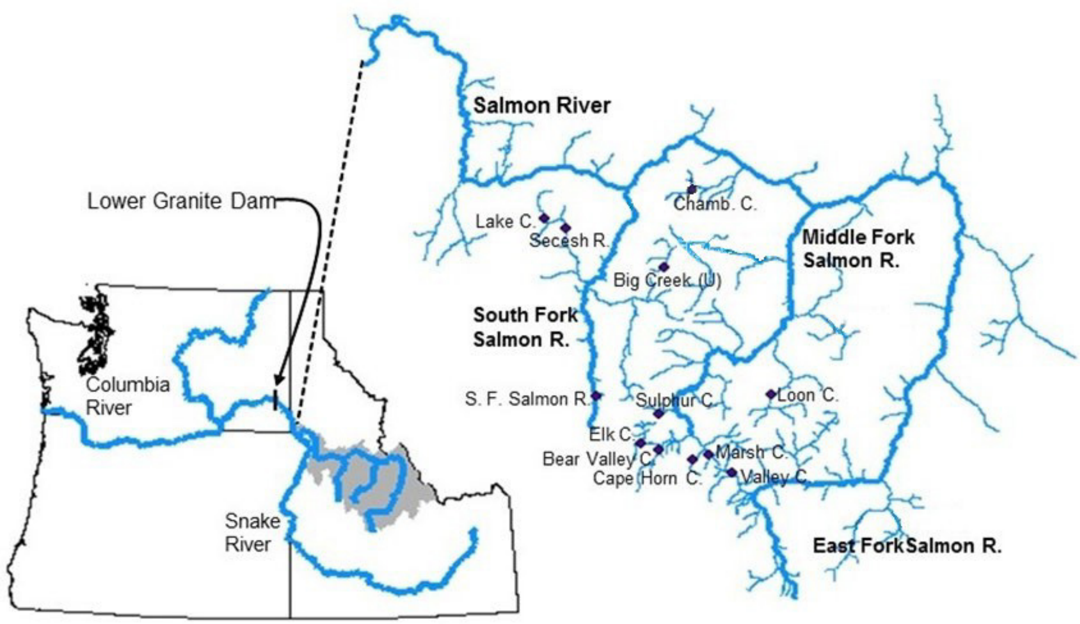


Figure 1. Map showing the streams and sample reaches where wild spring/summer Chinook salmon parr were PIT tagged during 2021.

[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 2021.

	Number of fish		Average fork length (mm)		Average weight (g)			
Tagging location	Collected	Tagged & released	Collected	Tagged	Collected	Tagged	Collection area to stream mouth (km)	Estimated stream area sampled (m^2)
Loon Creek	314	250	64.5	65.4	2.7	2.9	28.0-29.0	9,368
Valley Creek	1,215	1,000	70.1	70.3	3.7	3.7	3.5-5.0	16,406
Marsh Creek	1,275	1,000	63.8	65.4	3.3	3.4	11.0-12.8	16,995
Cape Horn Creek	1,227	715	63.5	64.7	3.3	3.3	0.5-1.5	16,746
Bear Valley Creek	628	594	70.7	70.3	4.4	4.3	8-9.8 & 12.3-13.5	35,661
Elk Creek	183	173	72.0	71.7	4.4	4.3	0.2-1.5	12,742
Big Creek (upper)	552	500	65.3	65.3	3.4	3.3	56.5-59.0	21,547
S Fork Salmon R	816	750	71.3	70.0	4.4	3.9	117.0-120.0	35,067
Secesh River	540	500	68.9	68.4	4.2	4.0	24.2-25.5	14,370
Lake Creek	627	500	64.7	64.6	3.5	3.3	2.0-3.2	20,481
Chamberlain Creek	277	250	67.2	67.2	3.8	3.8	24.0-25.0	6,806
Totals/averages	**7,654**	**6,232**	**67.4**	**67.6**	**3.7**	**3.7**	**19.5**	**206,189**

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. 2013-2021). 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 2021 through June 2022, we collected detection data from wild PIT-tagged Chinook salmon juveniles passing NOAA instream monitoring sites (Table 3).

In October 2019, a new 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. Fish tagged during summer 2021 are the first cohort of this study to be detected passing the Marsh Creek instream site (MAR).

Monitoring systems at dams and in the estuary

During spring and summer 2022, wild Chinook smolts that had been PIT-tagged as parr in 2021 began a directed migration downstream. Of the eight dams encountered by these smolts on the lower Snake and Columbia Rivers, seven have 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.

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, 2021-2022.

Fish collection, tagging, and release areas	Instream monitoring site		
	Description	River or creek (rkm)	Site code*
Valley Creek	Valley Creek	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	Big Creek (rkm 12)	TAY
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

* Site code is an abbreviation designated for monitoring systems listed in the Columbia Basin Pit Tag Information System (PTAGIS) regional database.

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 spillway ogee detection system (GRS) began operation in 2020 (Axel et al. 2021). Similar to migration year 2020, the majority of wild fish from the study that were detected at Lower Granite dam were detected on GRS (295; 66.3%).

Tagged fish have several possibilities for detection in the lower 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 recent years, an autonomous stationary barge detection system has been deployed ~3 km downstream from Bonneville Dam. The barge was not operated in 2022; however, a pilot detection system was operated from April to June on a pile dike at rkm 68 (site code PD6), approximately 166 km downstream of Bonneville on the Washington side of the river.

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 2021 and spring 2022, juvenile migrant traps were operated at the following locations:

- South Fork Salmon River at Krassel Creek
- Secesh River near Calf Creek confluence
- 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 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 was conducted from April through June 2022 in an effort to recapture subsamples of our study fish tagged as parr in summer 2021. Recaptures were obtained by programming the PIT-tag separation-by-code (SbyC) system, which can divert specific, predesignated tagged study fish from the population passing the dam (Downing et al. 2001). The SbyC system was programmed to divert a maximum of 100 fish from each stream at a maximum collection rate of 15 fish/d per stream.

All recaptured fish were handled using water-to-water transfers and other best handling practices. After measuring weight and length, we returned all tagged and non-tagged fish to the river via the bypass system.

In addition to recording fork length (mm) and weight (g) for these wild smolts at Lower Granite Dam, we calculated a Fulton-type condition factor (CF) as:

$$CCCC = \frac{wwwwwwwwhtt\ (ww)}{llwwllwwtth\ (mmmm)^3} \times 10^5$$

Condition factor was calculated both at release and recapture using release data associated with the PIT tag code.

Results and Discussion

A total of 208 wild spring/summer Chinook salmon tagged in summer 2021 were recaptured at traps above Lower Granite Dam from summer/fall 2021 to spring 2022 (Table 4). We recaptured 129 fish in the SbyC system at Lower Granite Dam for examination of length, weight, and condition factor (Table 4). During 2022, the largest numbers of recaptured fish were from Marsh Creek (24 fish).

During 2022, we recaptured study fish from Idaho streams at Lower Granite Dam to measure growth over the entire migration season (April-June). As in past years, we recaptured a maximum of 15 fish/d from each stream. For the 129 recaptured study fish, overall mean growth was 0.14 mm/d during 2021-2022. This was comparable to overall growth rates measured in previous years (Achord et al. 2002-2012; Lamb et al. 2013-2021). Overall mean weight gain of these fish was 0.037 g/d and was also comparable to that measured in previous years.

Table 4. Fork length, weight, and condition factor of wild spring/summer Chinook salmon PIT-tagged in Idaho during summer 2021 and recaptured either in the separation-by-code system at Lower Granite Dam or at traps during summer/fall 2021 and spring/summer 2022. 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 in SbyC at Lower Granite Dam											
Loon Creek	12	290-303	294	12	36-60	48	12	8.5-14.5	12.2	0.99	1.01
Valley Creek	10	289-329	300	10	27-41	34	9	6.2-11.8	8.6	0.97	1.03
Marsh Creek	24	288-319	297	24	17-56	41	18	4.0-14.6	10.2	1.14	1.06
Cape Horn Creek	15	289-326	298	15	31-58	45	13	6.8-14.9	11.0	1.17	1.10
Bear Valley Creek	8	277-314	291	8	21-50	38	8	3.9-16.6	10.5	1.21	1.10
Elk Creek	1	---	288	1	---	33	1	---	9.6	1.12	1.12
Big Creek (upper)	12	274-298	288	12	35-53	42	12	8.0-14.4	10.9	1.09	1.12
S Fork Salmon River	18	259-292	273	17	9-54	40	13	7.9-14.9	10.3	1.11	1.07
Secesh River	10	249-258	271	10	24-48	37	10	4.3-15.5	9.1	1.23	1.04
Lake Creek	8	266-305	276	8	26-59	46	8	6.3-15.3	11.4	1.14	1.07
Chamberlain Creek	11	263-283	270	11	30-53	44	11	6.9-14.9	11.2	1.22	1.07
Totals or averages	**129**	**249-329**	**286**	**128**	**17-60**	**41**	**115**	**3.9-16.6**	**10.5**	**1.13**	**1.07**

Table 4. Continued.

Origin	Recaptured fish n	Days to recapture range	Days to recapture mean	Length gain (mm) n	Length gain (mm) range	Length gain (mm) mean	Weight and condition factor (CF) n	Weight gain (g) range	Weight gain (g) Mean	Mean CF release	Mean CF recapture
Wild spring/summer Chinook salmon recaptured at traps											
S Fork Salmon R (Krassel)											
Fall	20	43-85	70	19	6-18	12	15	0.3-3.1	1.5	1.16	1.01
Spring	4	225-252	232	4	10-27	18	4	1.4-4.8	3.0	1.05	1.00
Marsh Cr											
Cape Horn Cr-fall	50	3-95	60	49	-3-15	8	7	-0.8-1.2	0.3	1.14	1.07
Cape Horn Cr-spring	2	247-248	--	2	20-24	22	0	---	--	1.14	---
Marsh Cr-fall	59	1-100	68	59	-3-24	9	4	-0.2-1.0	0.3	1.15	1.13
Marsh Cr-spring	2	249-254	252	2	7-9	8	0	---	--	1.05	---
Secesh River											
Lake Creek-fall	32	11-80	49	31	-1-16	8	28	-0.5-1.5	0.7	1.24	1.04
Secesh River-fall	38	6-78	40	37	-2-15	6	37	-0.8-1.8	0.3	1.25	1.05
Salmon River-spring	1	---	227	1	---	19	0	---	---	1.06	---
Total or average	208	1-254	66	204	-3-27	9	105	-0.8-4.8	1.1	1.18	1.05

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 specified detection or non-detection at 1) the instream monitor and 2) any downstream dam. This produced four possible detection histories for fish in each release group: 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.

In the past we explored a method to estimate detection and survival in reaches with two instream detection sites based only on detection data from the instream monitors (Connolly et al. 2008). However, detection data from monitoring systems with two antenna arrays have shown that detection probability at an upstream antenna array was not independent of detection probability at a downstream array.

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 for two separate estimates of survival: from release to the instream monitors and from the instream monitors to Lower Granite Dam.

Results

Valley Creek

We released 1,000 tagged wild Chinook parr to Valley Creek on 22 July 2021 (Table 2). All fish were tagged with 12-mm PIT tags and released in natal rearing areas 4-5 km above the Valley Creek instream array (VC2) located in Stanley, Idaho. Due to planned upgrades in 2021, the Valley Creek system was non-operational from 17 June to 11 August. No fish were detected on the system during this period. Of the 1,000 fish released, 294 were detected on the monitors between 14 August 2021 and 17 June 2022 (Table 1; Figure 2).

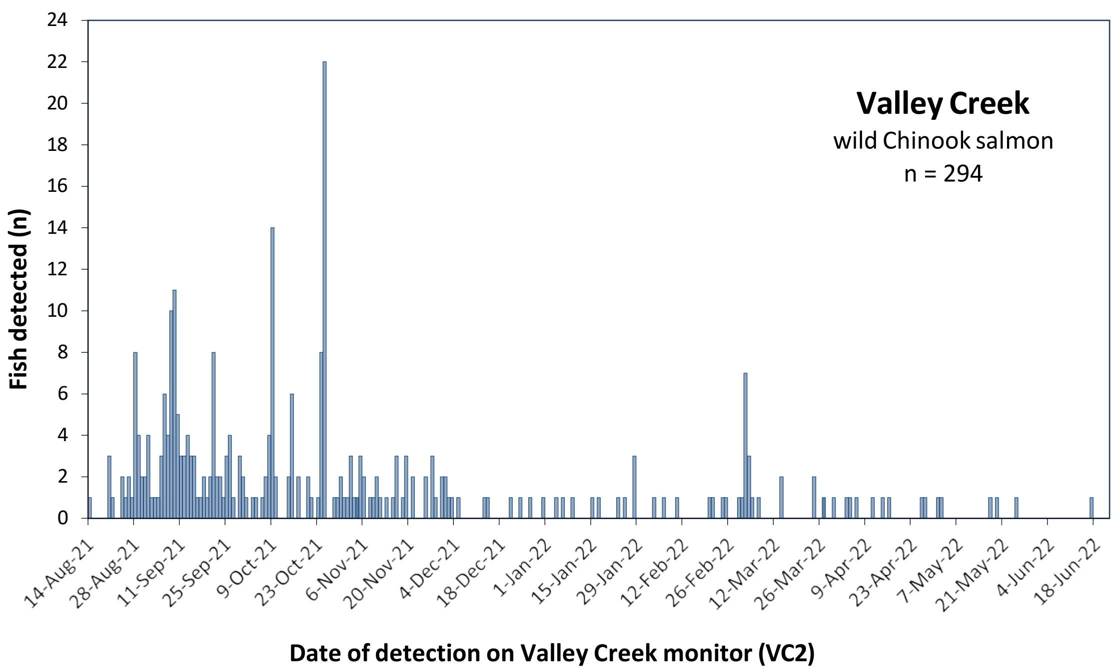


Figure 2. Detections of 294 PIT-tagged wild spring/summer Chinook salmon parr, pre-smolts, and smolts on the monitoring system at Valley Creek (VC2), August 2021-June 2022. A total of 1,000 parr were tagged and released 4-5 km upstream from these antennas during 22 July 2021. Due to scheduled upgrades in 2021, the Valley Creek system was non-operational from 17 June to 11 August.

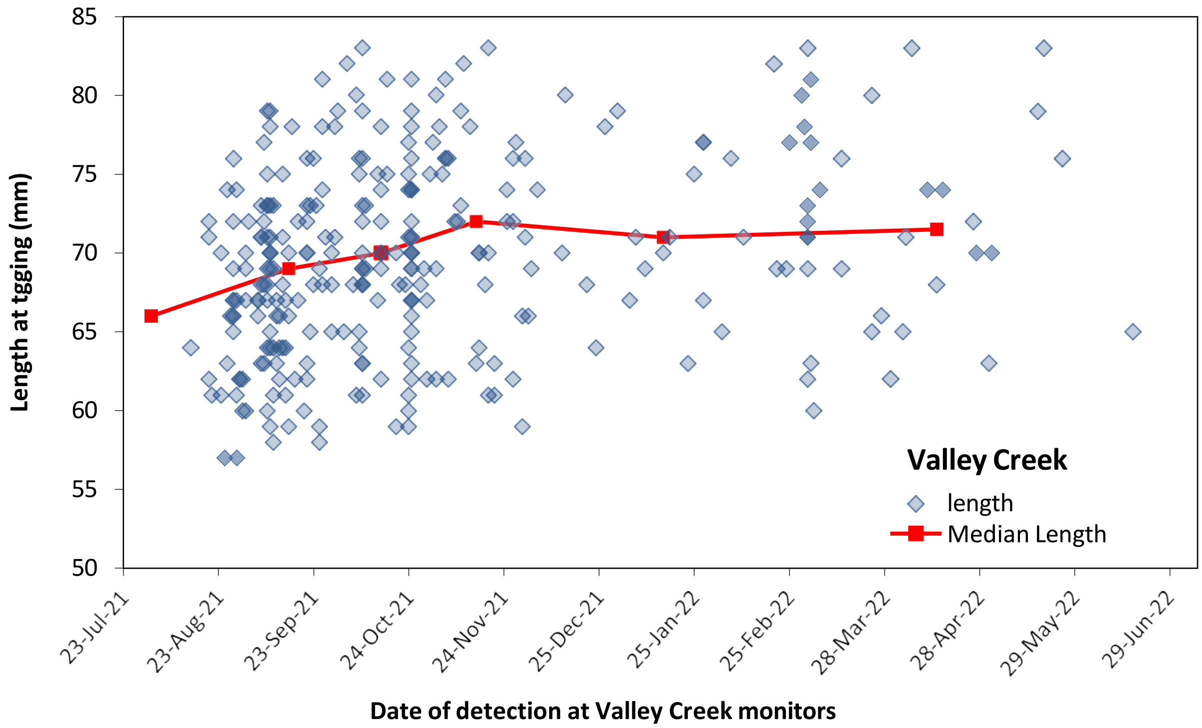


Figure 3. Fork length at tagging vs. date of detection for 294 wild Chinook tagged as parr in Valley Creek. Fish were detected on the PIT-tag monitoring antennas at Valley Creek (VC2).

Upper Big Creek

We released 500 tagged wild Chinook salmon parr to Upper Big Creek on 6 August 2021 (Table 2). All fish were released in natal rearing areas 48 km upstream from the monitoring systems in Lower Big Creek at Taylor Ranch (TAY; rkm 11).

Of the 500 fish released to Upper Big Creek, 29 were detected on one or both instream monitors at Taylor Ranch between August 2021 and May 2022 (Table 1; Figure 4). Based on detections at downstream dams, overall detection efficiency at the Taylor Ranch monitors was 16.4% for Upper Big Creek fish. Based on this detection efficiency, survival to the Taylor Ranch monitors was 35.4%. 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 = 0.12%, P = 0.955; Figure 5).

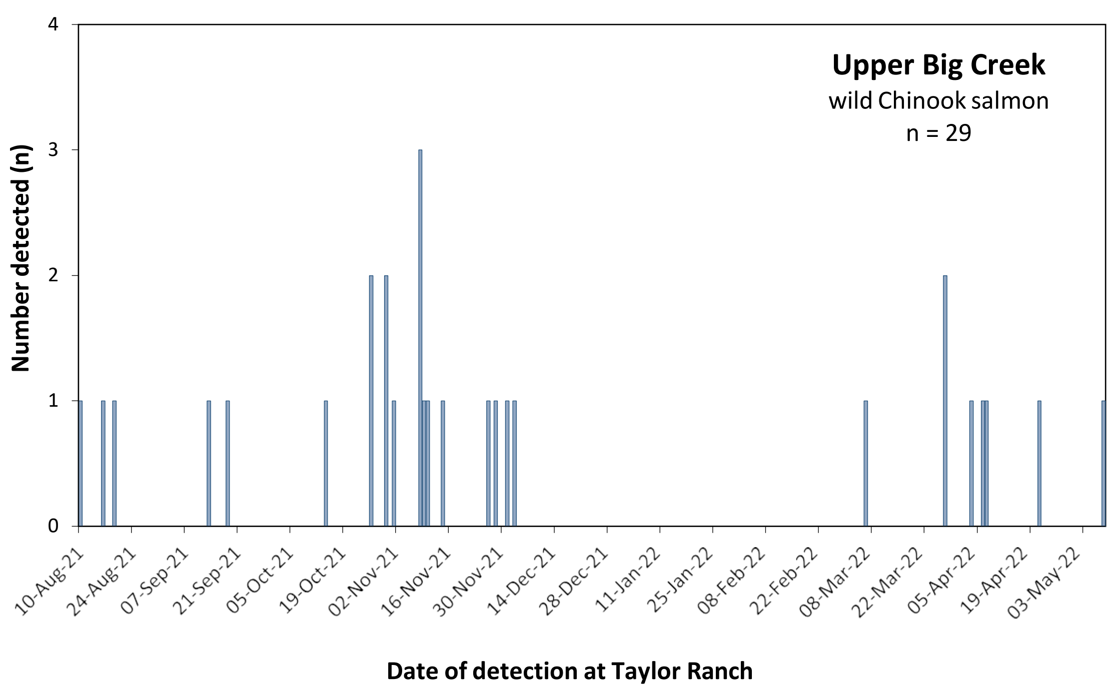


Figure 4. Detections by date of 29 wild spring/summer Chinook parr, pre-smolts, and smolts from Upper Big Creek. A total of 500 parr were tagged and released 48 km upstream from the Taylor Ranch monitoring system on 6 August 2021.

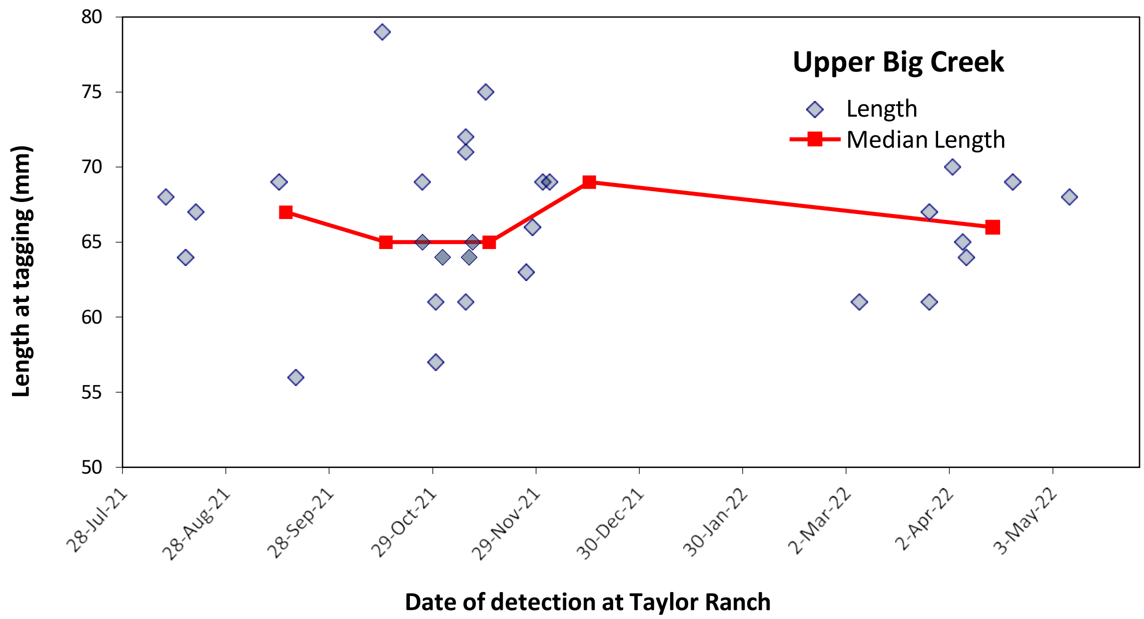


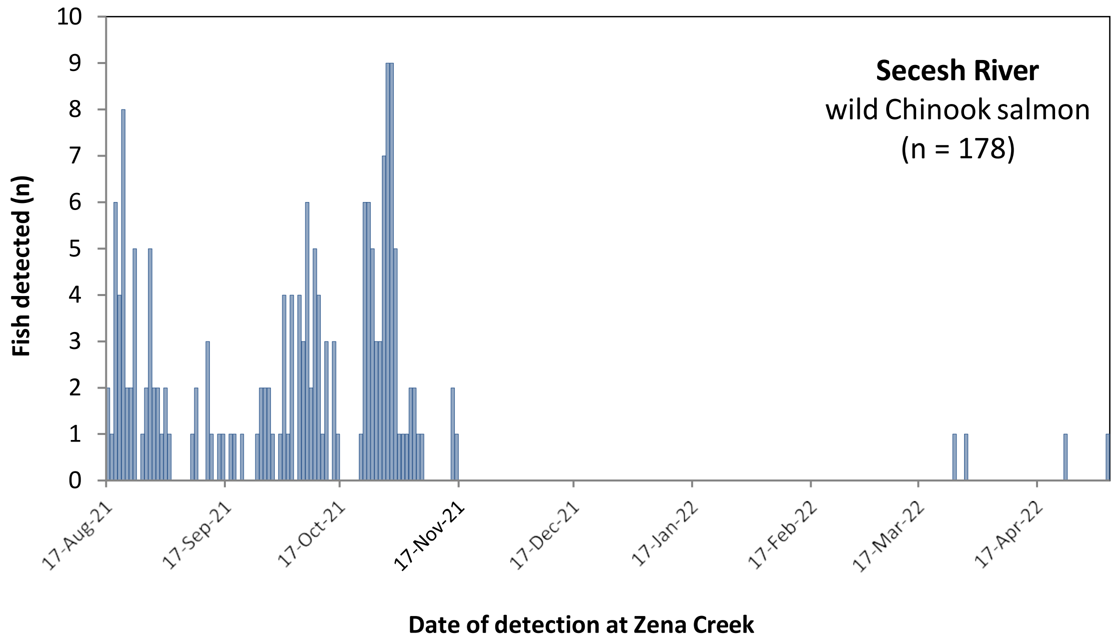
Figure 5. Fork length at tagging vs. date of detection for 29 wild spring/summer Chinook tagged at Upper Big Creek and detected at the Taylor Ranch (TAY) instream PIT-tag monitoring system.

Secesh River and Lake Creek

We collected and tagged 500 wild Chinook salmon parr from the Secesh River on 13 August 2021. We then collected and tagged 500 fish from Lake Creek on 14 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 2021 to May 2022, 178 Secesh River fish and 151 Lake Creek fish were detected near Zena Creek Ranch (Figure 6). Of the 178 detections of Secesh River fish, 162 (91.0%) occurred in late summer/fall, 12 (6.7%) in winter, and four (2.2%) in spring. Of the 151 detections of fish from Lake Creek, 136 (90.1%) occurred in late summer/fall, 14 (9.3%) in winter, and only one in spring (0.7%; Table 1).

Based on detections at downstream dams, overall detection efficiency of the instream monitoring system at Zena Creek was 59.4% for parr from the Secesh River (n = 178) and 67.8% for those from Lake Creek (n = 151; Table 1). Based on these detection efficiencies, we estimated survival to the Zena Creek instream monitoring system at 59.9% for parr from the Secesh River and 44.5% for those from Lake Creek (Table 1).



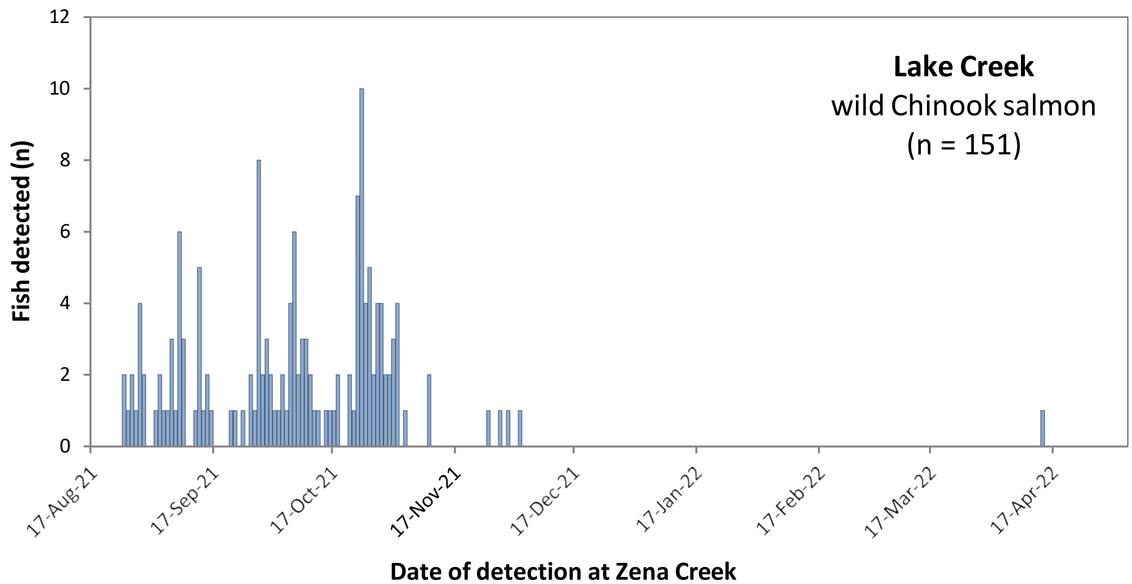


Figure 6. Detections on instream monitors at Zena Creek Ranch from wild spring/summer Chinook salmon from the Secesh River (upper panel) and Lake Creek (lower panel). We tagged and released 500 fish from both the Secesh River and Lake Creek. All fish were released in areas ~21-42 km above the Zena Creek monitors

Data from the Zena Creek monitoring system showed that both Secesh River and Lake Creek fish that had been larger at the time of tagging were detected significantly later than their smaller cohorts (R^2 = 6.51%, P = 0.001 for Secesh River and R^2 = 10.17%, P < 0.001 for Lake Creek; Figure 7).

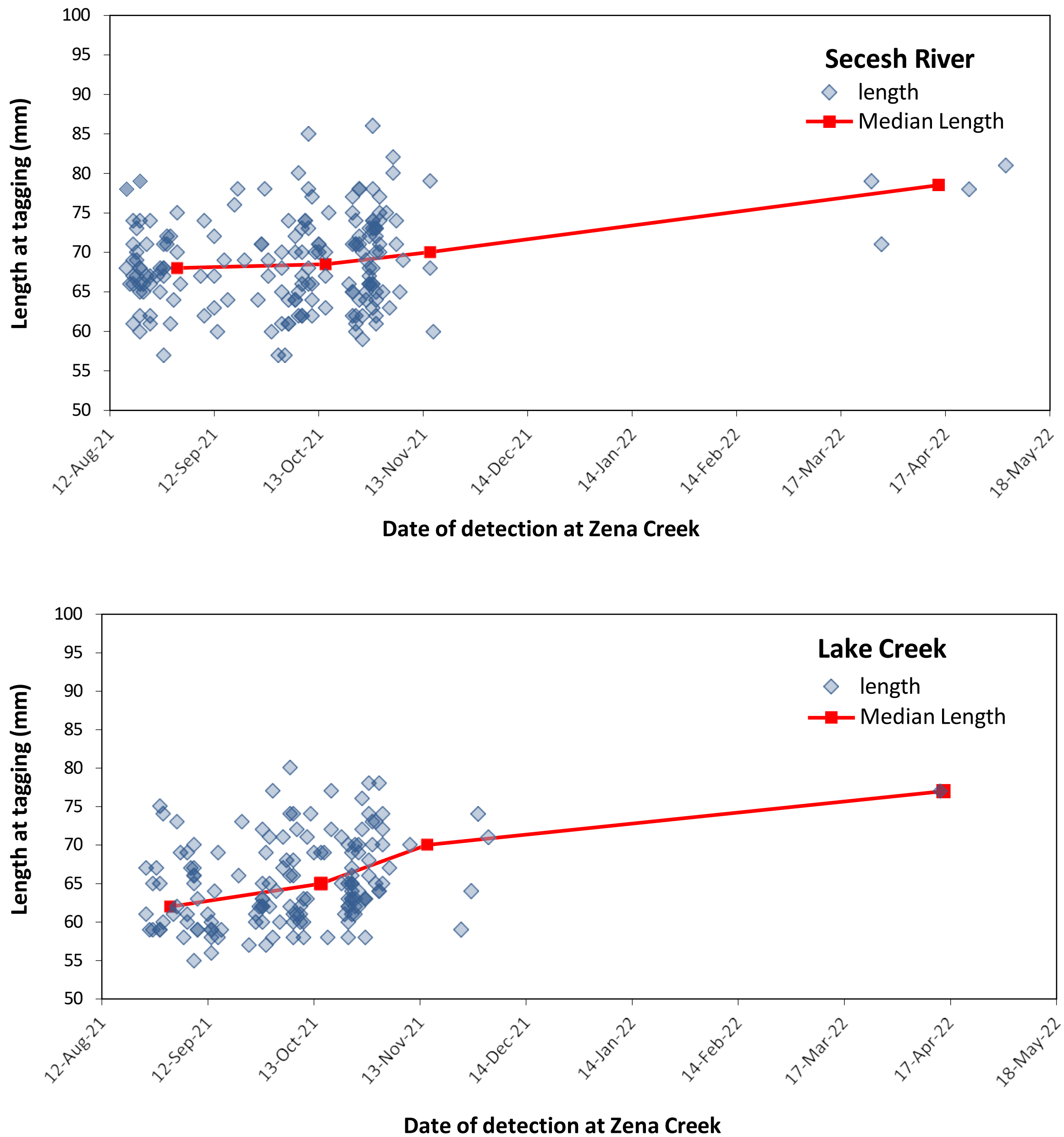
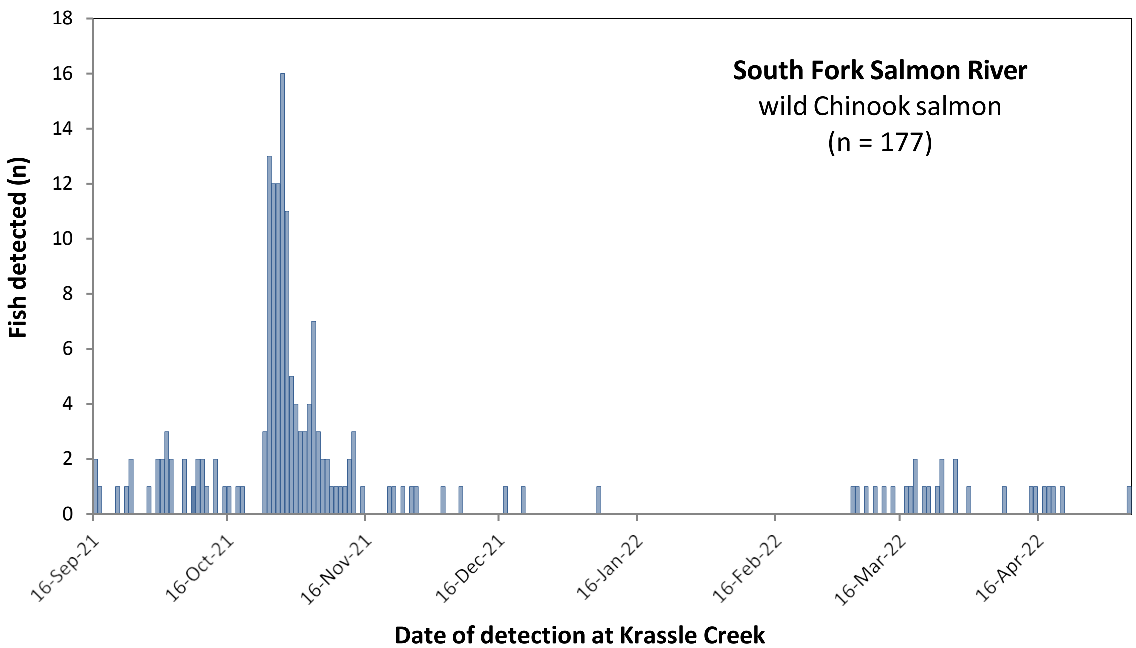


Figure 7. Length at tagging vs. date of detection for fish collected and tagged at the Secesh River (upper panel) and Lake Creek (lower panel). A total of 178 fish from the Secesh River and 151 from Lake Creek were detected at the instream monitoring site in the lower Secesh River near Zena Creek Ranch.

South Fork Salmon River

We released 750 tagged wild Chinook salmon parr to the South Fork Salmon River during 11-12 August 2021 (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, 177 were detected near Krassel Creek from September 2021 through May 2022. Of these 177 detections, 107 (60.4%) occurred during late summer/fall, 44 (24.9%) during winter, and 26 (14.7%) during the following spring (Table 1; Figure 8).



Figure` 8. Detections by date of 177 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 750 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 42.3%. Using this detection efficiency rate, we estimated survival to the Krassel Creek monitoring system at 55.8% 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 = 0.42%, P = 0.395; Figure 9).

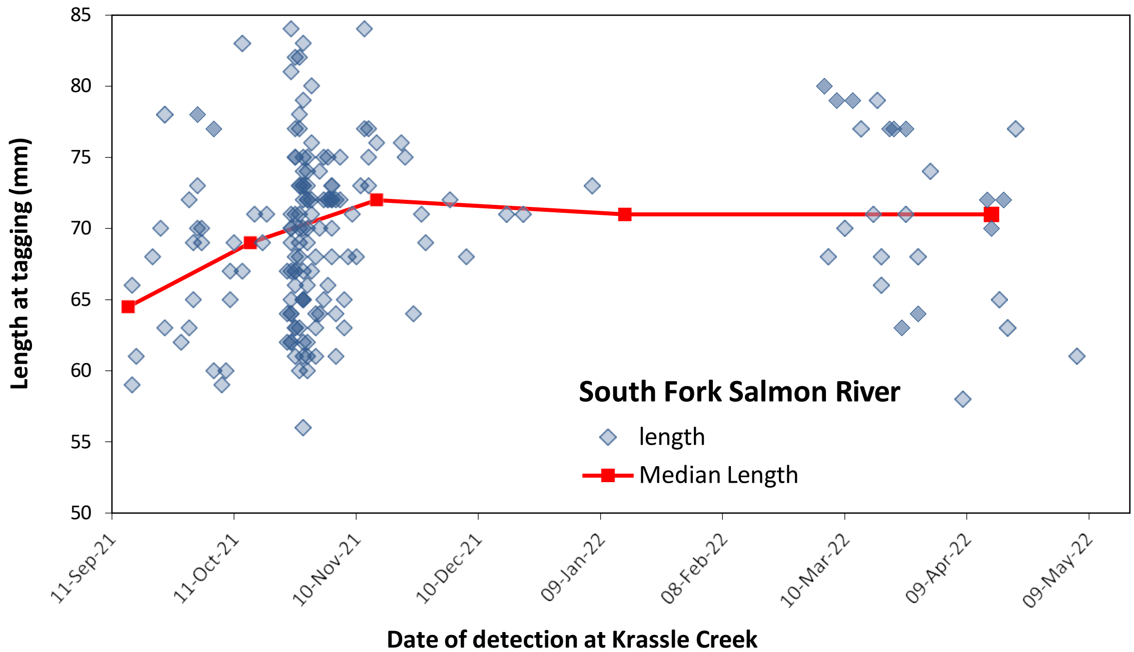


Figure 9. Fork length at tagging vs. date of detection for 177 wild spring/summer Chinook salmon tagged in the South Fork Salmon River and detected at the instream PIT-tag monitoring site at Krassel Creek in the South Fork Salmon River.

Marsh and Cape Horn Creek

We collected and tagged 1,000 wild Chinook salmon parr from Marsh Creek on 23 July 2021. We then collected and tagged 715 fish from Cape Horn Creek on 24 July. Release sites for these fish were 2-3 km upstream from the instream monitoring array near Lola Creek Campground on Marsh Creek.

From July 2021 to May 2022, 551 Marsh and 385 Cape Horn Creek fish were detected on the Marsh Creek instream array (Figure 10). Of the 551 detections from Marsh Creek, 482 (87.5%) occurred in late summer/fall, 50 (9.1%) in winter, and 19 (3.4%) in spring. Of the 385 detections of fish from Cape Horn Creek, 329 (85.4%) occurred in late summer/fall, 28 (7.3%) in winter, and 28 (7.3%) in spring (Table 1).

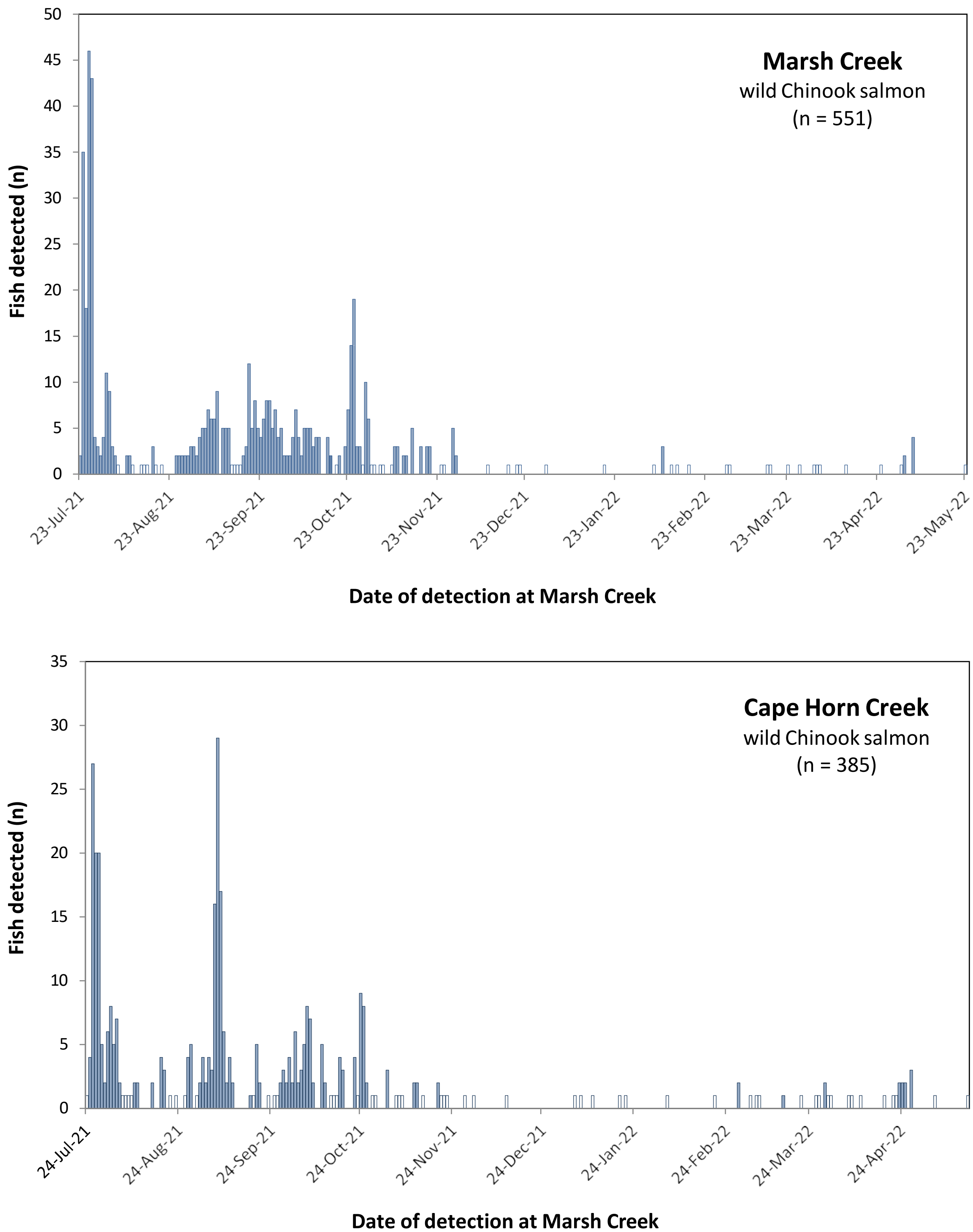


Figure 10. Detections on instream monitors at Marsh Creek from wild spring/summer Chinook salmon from Marsh (upper panel) and Cape Horn Creek (lower panel). We tagged and released 1,000 fish from Marsh and 715 fish from Cape Horn Creek. All fish were released in areas 2-3 km above the Marsh Creek monitors.

Based on detections at downstream dams, overall detection efficiency of the instream monitoring system at Marsh Creek was 93.2% for parr from Marsh Creek (n = 551) and 98.4% for those from Cape Horn Creek (n = 385; Table 1). Based on these detection efficiencies, we estimated survival to the Marsh Creek instream monitoring system at 59.2% for parr from Marsh Creek and 54.8% for those from Cape Horn Creek (Table 1).

Data from the Marsh Creek monitoring system showed that Cape Horn Creek fish that had been larger at the time of tagging were detected significantly later than their smaller cohorts ($R^2 = 5.68\%$, $P < 0.001$). However, for Marsh Creek fish, detection data indicated no significant relationship between fork length at tagging and date of detection ($R^2 = 0.49\%$, $P = 0.100$; Figure 11).

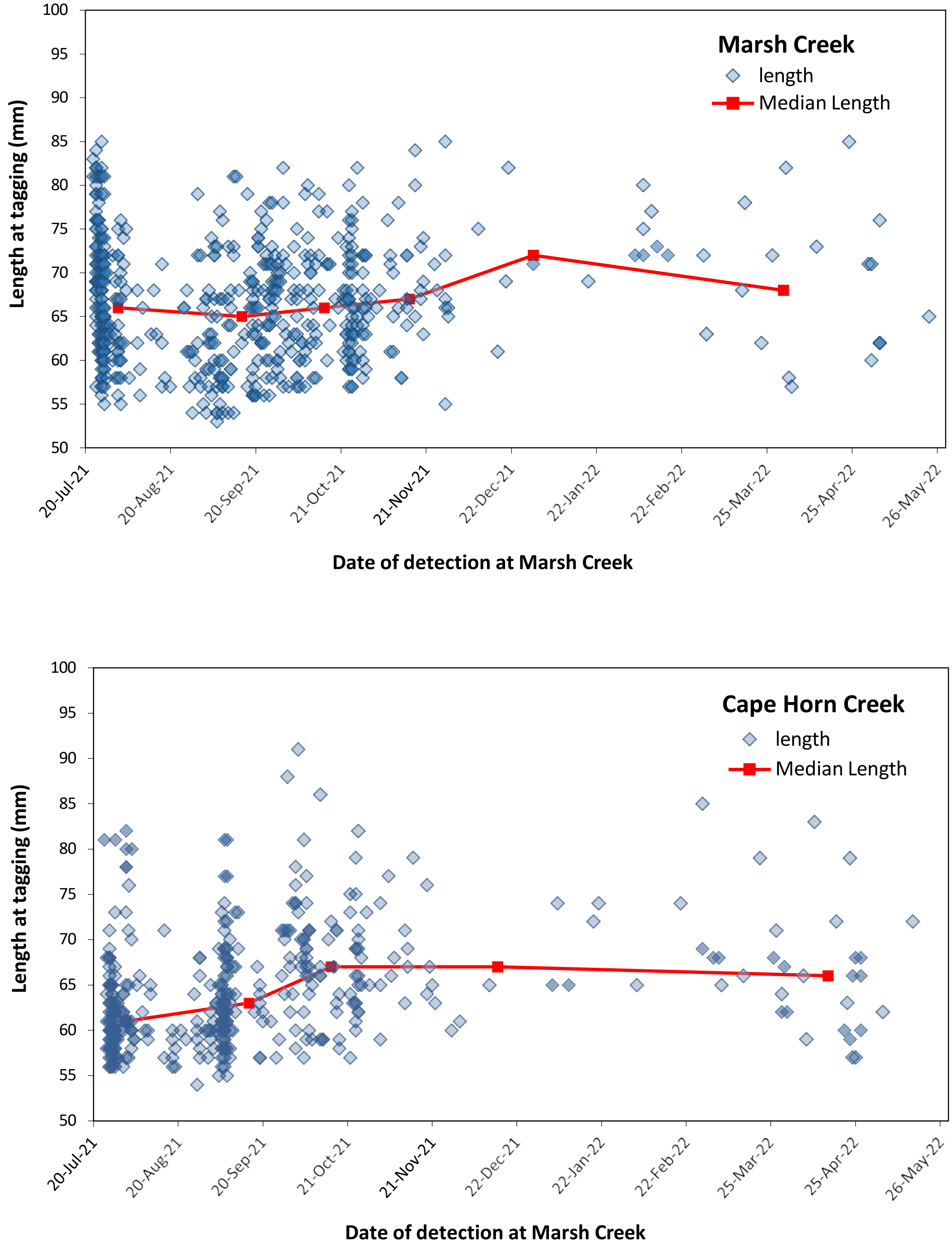


Figure 11. Length at tagging vs. date of detection for fish collected and tagged at Marsh (upper panel) and Cape Horn Creek (lower panel). A total of 551 fish from Marsh and 385 from Cape Horn Creek were detected at the instream monitoring site in Marsh Creek.

Discussion

During August 2021, the Valley Creek PIT-tag monitoring system was overhauled, with the layout changed and electronic equipment updated. These changes were intended to modernize the site with hopes of better overall detection rates for juvenile and adult salmonids. The VC1 and VC2 sites were condensed to a single site at the VC2 location, which now has dual arrays spaced approximately 100 m apart. Biomark technicians provided the following installation comments:

> This site was upgraded from a mux to a Master Controller and six IS1001 readers. The old antennas were removed and replaced with six new antennas in the same general location, although the upstream and downstream arrays are farther apart than the original setup.
>
> The new antennas are all 20' ABS antennas with attached IS1001 nodes. They are laid out in upstream and downstream arrays of three antennas. The two arrays are approximately 300' apart from each other. Each array is connected to the MC with a 200' CAN-bus cable. The original 5060 TEG was replaced by a 5120 TEG (PSMFC 2021).

In Valley Creek, the PIT-tag monitoring system has been operating for 20 years (2002-2022) and is the oldest in-stream detection site in central Idaho. During 2021, the Valley Creek system was non-operational from 17 June to 11 August, when a large portion of early migrants likely left the stream following our release of 22 July. Historically, a large portion of our study fish are detected on the Valley Creek system during the first month after tagging (Achord et al. 2002-2010; Lamb et al. 2012-2021). However, if a large portion of study fish moved downstream between 17 June and 11 August 2021, they would not have been detected on the Valley Creek system.

This data gap probably caused bias in estimates of run timing, in estimated survival to the instream monitors, and in estimated detection efficiency of the Valley Creek site. During 2021-2022, estimated detection efficiency at Valley Creek was 75.6%, based on detections of tagged fish at Lower Granite Dam. This estimate was likely biased low and not representative of the detection efficiency we typically measure at this site. However, we are optimistic that while work to update the site may have interrupted detections in 2021, resulting improvements to the site will contribute to better performance with a higher detection efficiency in future years.

During 2021-2022, the interrogation site near Edwardsburg, Idaho (rkm 57) on Upper Big Creek had intermittent outages, and data was unavailable. Due to its remote location and off-grid power source, operational periods for the Edwardsburg site may vary from year to year.

Detection efficiencies at the Taylor Ranch monitoring system continue to be very low in comparison to other sites (Lamb et al. 2019-2021). With no sampling and tagging done during 2021 at lower Big Creek, we used fish tagged from Upper Big Creek to estimate detection efficiencies of 16.4% for the Taylor Ranch site (Table 1). Physical array location and environmental variables (increased depth due to high flow) most likely contribute to the poor detection efficiency of this site.

For fish from Lake Creek, the Secesh and South Fork Rivers, detection efficiencies continue to be satisfactory. At Zena Creek Ranch, detection efficiencies were 67.8% for fish from Lake Creek and 59.4% for fish from the Secesh River. At Krassel Creek (rkm 65), detection efficiency was 42.3% for South Fork Salmon River fish. These detection efficiencies are most likely attributable to favorable environmental conditions and the use of APT12 tags, which contributed to the increased detection rates seen on instream monitoring sites in 2020 (fish were first tagged with APT12 tags in 2019).

During fall 2019, an instream PIT-tag monitoring system was installed on Marsh Creek below its confluence with Capehorn Creek near Lola Campground (rkm 8; site code MAR). Based on numbers of fish (Marsh and Cape Horn Creek fish) detected at Marsh Creek and subsequently detected at downstream dams, we estimated detection efficiency of the new system at 95.1%. The Marsh Creek system had the highest detection efficiency of all instream monitoring system for fish tagged during 2021. Time will tell if there were environmental factors that played a role in this high detection efficiency or if the system had such a high performance due to its location and the modern PIT technology used in installation of the site. If the Marsh Creek system continues to perform this well, we hope older instream sites will be upgraded with similar components and layout.

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 seven 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 estimate of detection probability for Lower Granite Dam on that day to obtain an *expanded* daily estimate (methods for expanded estimates are explained below in *Estimates of parr to smolt survival*).

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 divided by the total number of fish released from that stream to derive the estimate of survival to Lower Granite Dam.

For the seven sampling sites with monitoring systems, we used the above process for 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, the pertinent totals of expanded daily passage numbers at the dam were 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. For fish from these monitored streams, we estimated overall parr-to-smolt survival by calculating the weighted mean of the three seasonal survival estimates calculated above. Means for each season were weighted according to the proportion of total detections from that season.

Estimates of parr-to-smolt survival

To estimate parr-to-smolt survival, we used daily detection probabilities at Lower Granite Dam to *expand* daily observed detections. Detection probability estimates for this expansion 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.

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 16.8% (SE 0.9%; Table 5). This estimate was based on expanded detections at Lower Granite Dam from 7 April to 5 July 2022 (n = 1,062). An additional 137 first-time detections were recorded at Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dam (Appendix Tables 3-13).

Table 5. Summary of observed vs. expanded detections of wild spring/summer Chinook smolts at Lower Granite Dam in 2021-2022. 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, **2021-2022**				
		Observed		Expanded (parr-to-smolt survival)		
Stream		(n)	(%)	(n)*	(%)	SE (%)
Loon Creek	250	20	8.0	49	19.6	4.5
Valley Creek	1,000	29	2.9	73	7.3	1.4
Marsh Creek	1,000	79	7.9	192	19.2	2.3
Cape Horn Creek	715	46	6.4	114	16.0	2.4
Bear Valley Creek	594	25	4.2	58	9.8	2.0
Elk Creek	173	10	5.8	22	12.8	1.7
Big Creek (upper)	500	39	7.8	102	20.4	3.3
S Fork Salmon River	750	62	8.3	147	19.6	2.7
Secesh River	500	62	12.4	137	27.4	3.6
Lake Creek	500	49	9.8	109	21.7	3.1
Chamberlain Creek	250	24	9.6	58	23.4	4.7
Totals or averages	**6,232**	445	7.1	1,062	16.4	0.9

* Due to rounding, expanded detection numbers may vary slightly from those in Appendix Tables 3-13.

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 19.3% and overall parr-to-smolt survival at 7.3% (Table 6).

Marsh and Cape Horn Creek—For wild juvenile Chinook from Marsh Creek detected on Marsh Creek monitors, we estimated overall survival to Lower Granite Dam at 32.5% and overall parr-to-smolt survival at 19.2% (Table 6).

For wild juvenile Chinook from Cape Horn Creek detected on Marsh Creek monitors, we estimated overall survival to Lower Granite Dam at 28.9% and overall parr-to-smolt survival at 16.0% (Table 6).

Upper Big Creek—For wild juvenile Chinook released to Upper Big Creek and detected on instream arrays near Taylor Ranch, overall estimated survival to Lower Granite Dam was 36.8%, and overall parr-to-smolt survival was 20.4% (Table 6).

Table 6. Estimated survival to Lower Granite Dam for fish detected on instream monitors with overall estimated parr-to-smolt survival for study populations passing instream PIT-tag monitoring arrays, 2021-2022.

		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	19.3	3.9	12.0-27.1	7.3	1.4	4.5-10.1
Marsh Creek	Marsh Creek	32.5	3.7	25.5-39.9	19.2	2.3	15.3-23.9
Cape Horn Creek	Marsh Creek	28.9	4.3	20.9-37.6	16.0	2.4	11.4-21.1
Upper Big Creek	Taylor Ranch	36.8	17.2	8.1-73.3	20.4	3.3	14.5-27.1
Secesh River	Zena Creek	46.1	7.1	32.3-59.4	27.4	3.6	20.8-34.6
Lake Creek	Zena Creek	50.9	8.7	34.3-68.3	21.7	3.1	15.8-27.9
S Fork Salmon R	Krassel Creek	32.2	6.4	20.7-46.0	19.6	2.7	14.8-24.9

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 46.1%, and overall estimated parr-to-smolt survival at 27.4% (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 21.7%.

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 32.2% and overall parr-to-smolt survival at 19.6% (Table 6).

Relationship between Length at Tagging and Detection at Dams

For tagged fish from all streams combined, average fork length at release was 67.6 mm (Table 2; Appendix Table 1). Among these fish, average fork length at release was not significantly different for fish that were detected vs. those not detected the following spring at Lower Granite Dam (67.5 vs. 67.4 mm; $Z = 0.91$; $P = 0.362$; Figure 14)

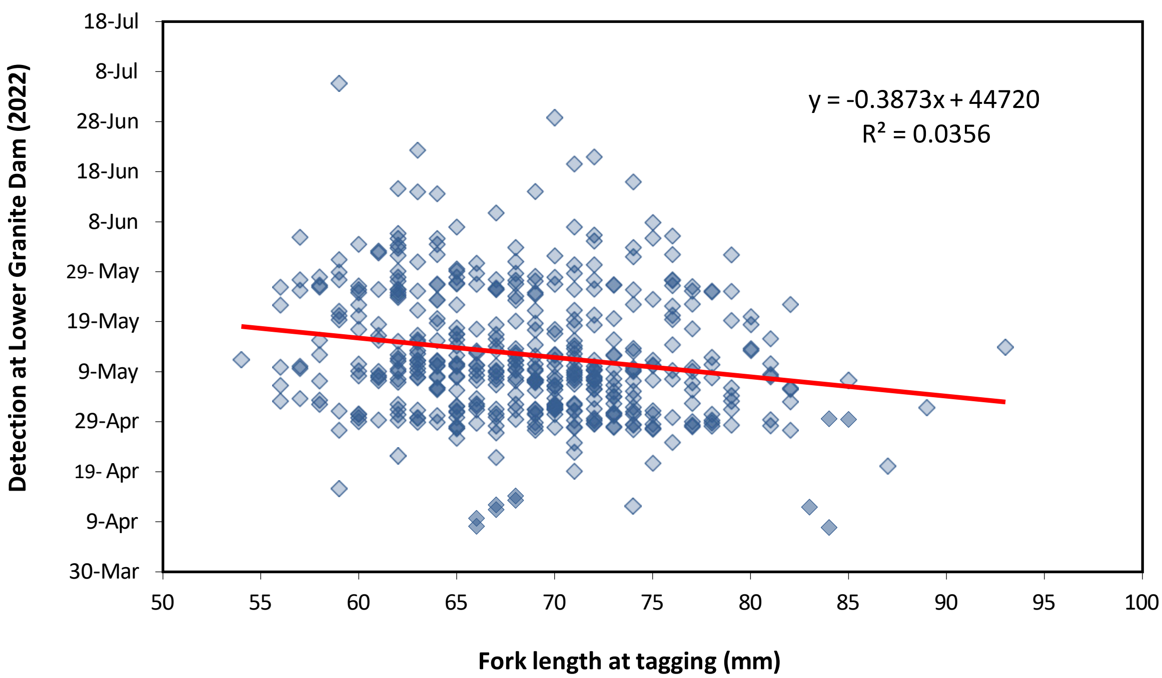


Figure 12. Relationship between fork length of wild Chinook salmon parr at tagging (2021) and detection date at Lower Granite Dam in 2022 (n = 575).

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 64 mm fork length (FL) or smaller, 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).

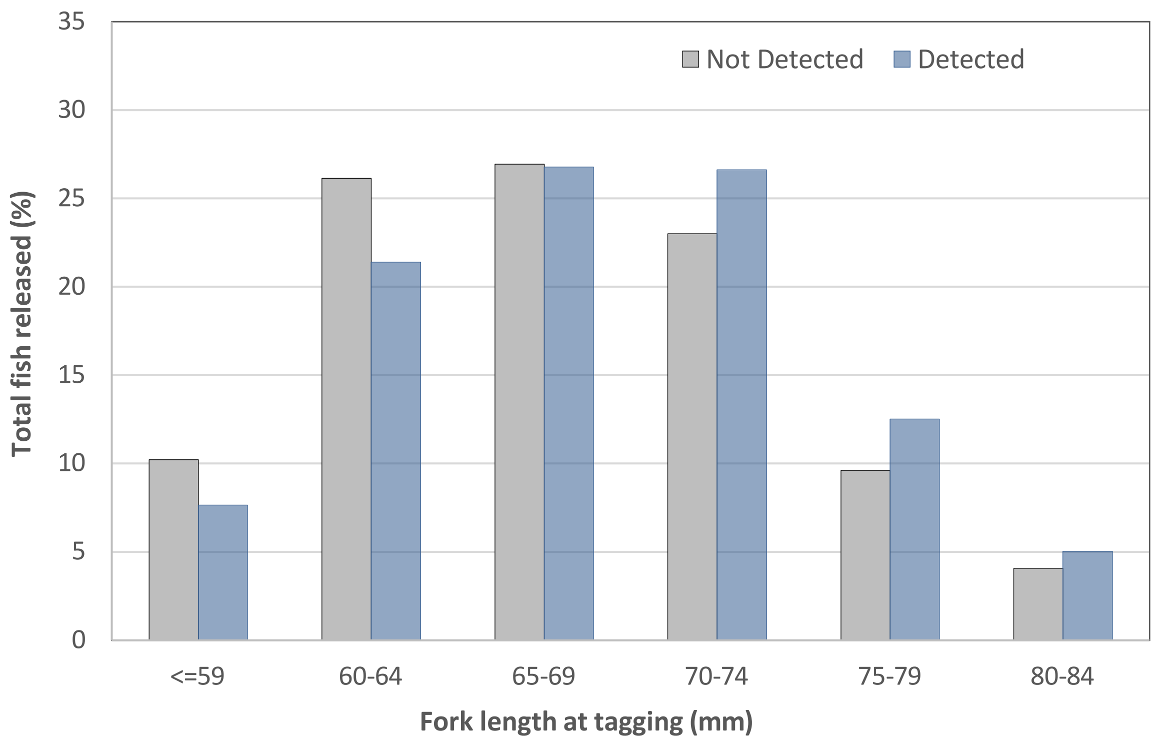


Figure 13. Distributions of fork length by 5-mm length bin for wild spring/summer Chinook salmon parr PIT-tagged and released in Idaho streams, 2021. Gray bars represent percentages not detected (n = 5,633) and blue bars represent percentages detected at Lower Granite Dam in spring/summer 2022 (n = 575).

Discussion

Annual parr-to-smolt survival estimates have ranged 7.9-25.4% for Idaho stream populations studied over the past 29 years. Similar to past years, survival to Lower Granite Dam for fish that were detected on instream monitors was considerably higher than that of fish never seen on the instream monitors (Table 6). Fish from all streams combined had an overall parr-to-smolt survival rate of 15.1% averaged over all years (Figure 12). During 2022, we estimated an overall survival of 16.8%, which was among the highest survival rates recorded during all 29 years of study.

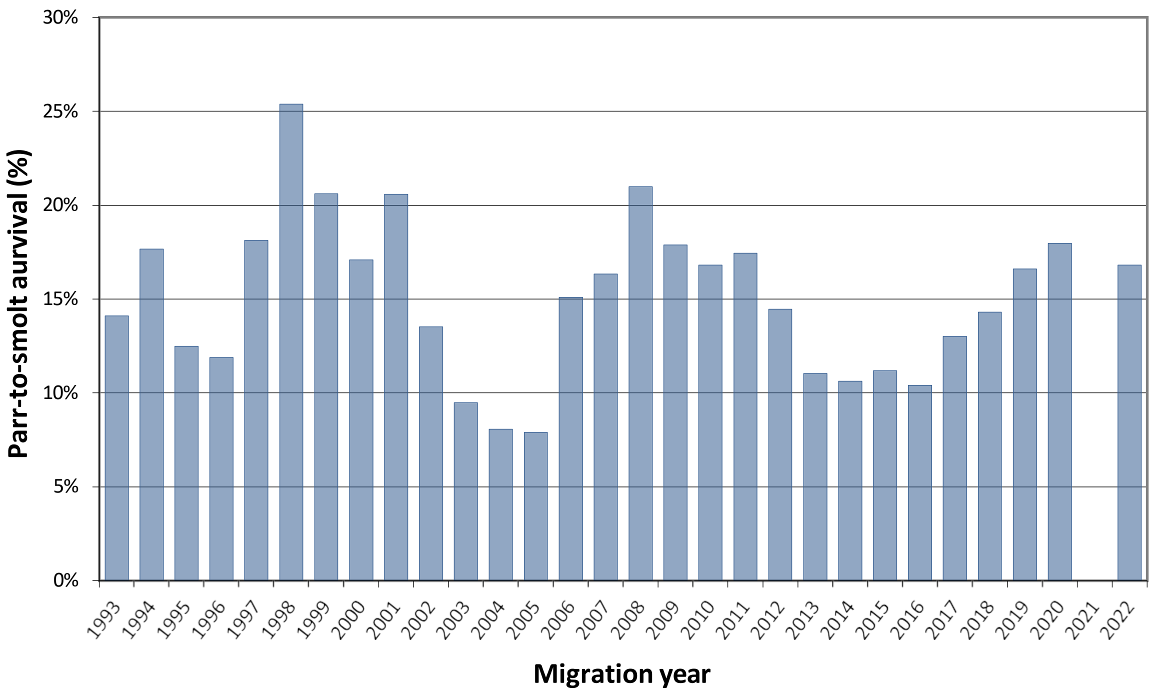


Figure 14. Overall estimated rates of parr-to-smolt survival for wild spring/summer Chinook salmon from all streams combined, 1993-2022. Standard errors ranged 0.3-2.5% over all years and averaged 0.8%.

Annual average data continues to indicate a potential inverse relationship between parr-to-smolt survival and parr density (Figure 15). 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%).

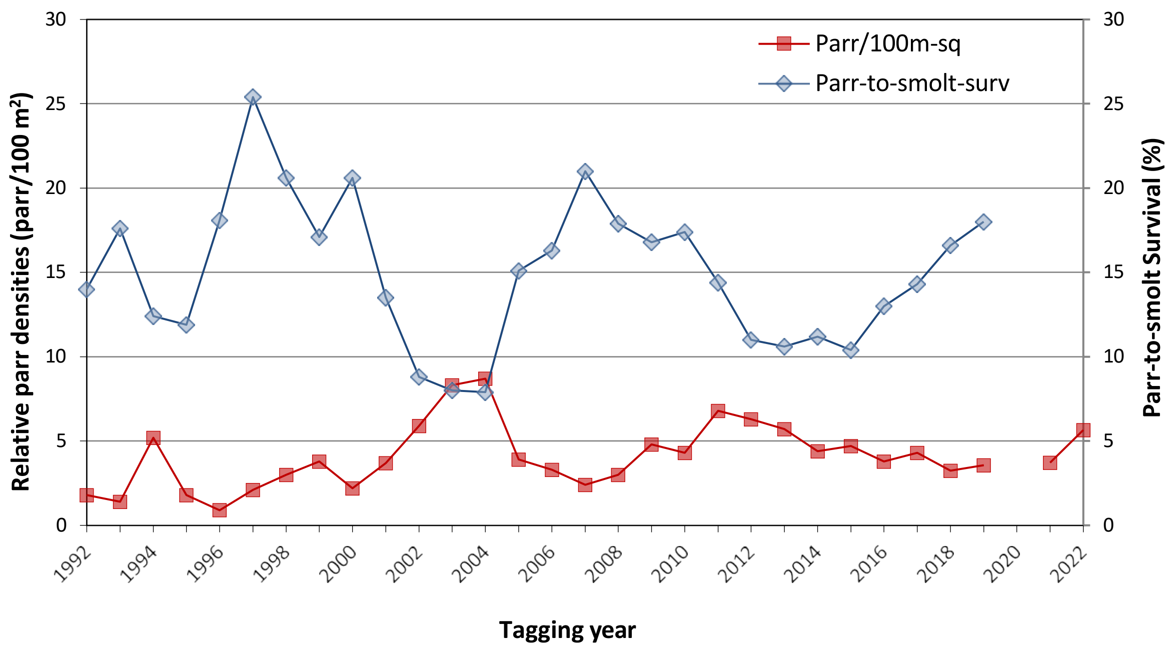


Figure 15. Annual average relative Chinook salmon parr densities (parr/100 m^2) in areas sampled in all streams from 1992 to 2022 vs. annual smolt survival estimate to Lower Granite Dam the following year.

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 2022, arrival timing of tagged fish at Lower Granite Dam varied among Idaho stream populations (Figure 16). Fish from the Secesh River were the first to arrive, while fish from Bear Valley Creek arrived later than fish from all other streams. For populations from all streams combined, the median passage date at Lower Granite was shifted slightly later during 2022, occurring from late April to late May. This later passage date was similar to dates observed in 2020, but different than the 10-year average date or dates observed in prior study years (Figure 16; Tables 7 and 8).

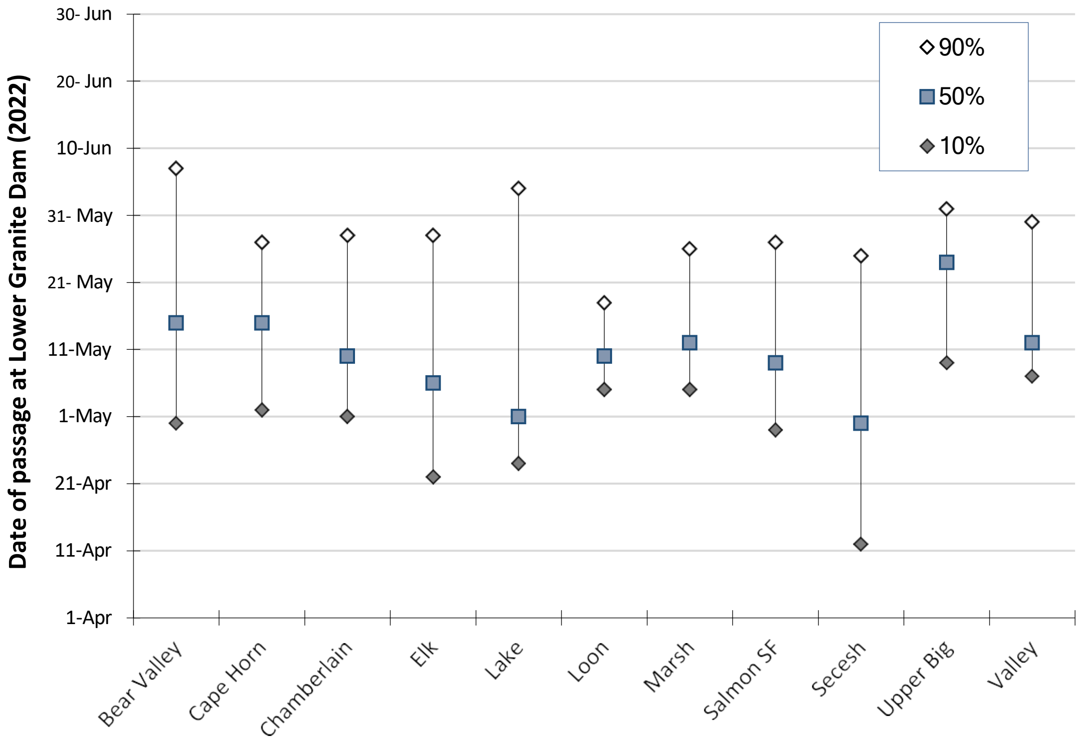


Figure 16. Estimated passage distribution dates at Lower Granite Dam from earliest to latest in 2022 for wild spring/summer Chinook salmon smolts tagged in Idaho streams. See Appendix Tables 3-13 for daily estimated passage numbers.

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 2022, 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 the Valley Creek and South Fork Salmon River populations 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 2022. 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									
	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	32
S Fork Salmon River	18 Apr	15-21 Apr	1	5 May	2-9 May	2	29 May	24 May-3 Jun	2	30
Bear Valley Creek	20 Apr	18-23 Apr	1	6 May	3-8 May	1	28 May	24 May-1 Jun	2	30
Valley Creek	23 Apr	19-26 Apr	2	9 May	6-12 May	2	31 May	27 May-4 Jun	2	30
Elk Creek	19 Apr	16-22 Apr	1	3 May	30 Apr-6 May	1	25 May	22-29 May	2	29
Lake Creek	15 Apr	13-18 Apr	1	28 Apr	25 Apr-1 May	1	26 May	21 May-1 Jun	3	28
Big Creek (upper)	28 Apr	25 Apr-1 May	1	16 May	12-19 May	2	2 Jun	27 May-7 Jun	3	27
Marsh Creek	20 Apr	17-22 Apr	1	3 May	30 Apr-5 May	1	21 May	18-24 May	2	25
Loon Creek	25 Apr	22-28 Apr	2	6 May	2-9 May	2	18 May	14-21 May	2	22
Cape Horn Creek	23 Apr	19-27 Apr	2	8 May	4-12 May	2	25 May	20-31 May	3	21
Chamberlain Creek	20 Apr	17-24 Apr	2	30 Apr	26 Apr-3 May	2	21 May	14-27 May	3	16

Table 8. Mean annual passage dates at Lower Granite Dam for the past 10 years (2013-2022) for combined stream populations of wild spring/summer Chinook salmon smolts PIT tagged the previous summers as parr. For all study years (1989-2022), average dates for the 10th, 50th, and 90th passage percentiles were 20 April, 5 May, and 25 May, respectively.

	Timing of passage percentiles at Lower Granite Dam			
Year	10th	50th	90th	Range
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
2021	---	---	---	---
2022	29 Apr	10 May	28 May	7 Apr-5 Jul
10-year average	**18 Apr**	**30 Apr**	**18 May**	**23 Mar-5 Jul**
All-year average	**20 April**	**5 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 17; Appendix Table 14). Overall, the passage distribution of first detections ranged from early April to early July 2022, with the middle 80th percentile occurring during the 29-d period from 29 April to 28 May (Table 7). Peak passage dates were also estimated using expanded detections, and these occurred from 7 to 9 May during a short period of elevated flow at the dam (Figure 17; Appendix Table 14).

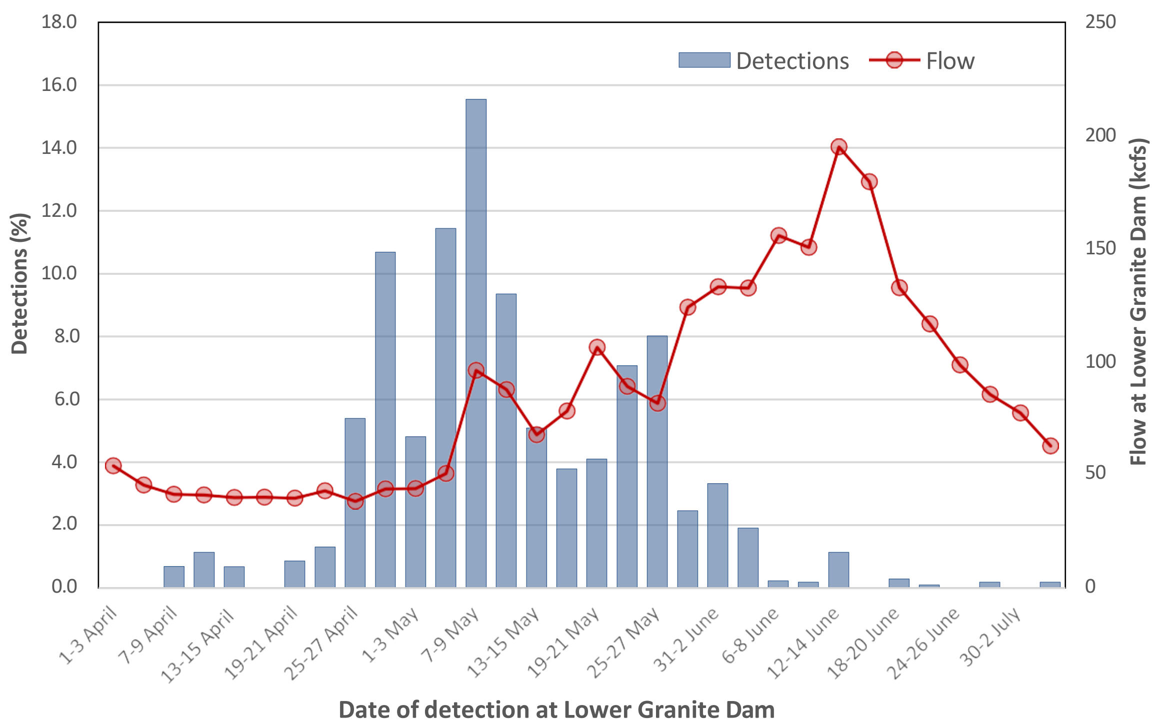


Figure 17. Overall migration timing of PIT-tagged wild spring/summer Chinook salmon smolts with associated river flows at Lower Granite Dam, 2022. Daily detections from all streams were expanded based on daily detection probability and pooled in 3-d intervals. Daily river flows at the dam were averaged 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. 2013-2021). 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 shows some indication of a geographical component (distance from Lower Granite) linked to early arriving populations. 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.

Environmental Information

In 2007, Northwest Fisheries Science Center personnel published 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.

During 2022, we were able to collect hourly water quality measurements from 4 of our 14 environmental sampling sites: Valley, Marsh, Cape Horn, and Bear Valley Creek. Mapped over time, this information, along with weather and climate data, can provide 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

1. During 2022, we continued to see increased detection efficiency at nearly all historical interrogation sites, with phenomenal performance observed at the new Marsh Creek site (95.1% for Marsh and Cape Horn Creek fish combined). After upgrades to the Valley Creek site were complete, we saw relatively high detection efficiency for the portion of fish that passed when the system was operational (i.e., 20 d after release of Valley Creek fish). We were very pleased with the performance of the site during 2021-2022, and we expect it to continue providing quality data.

2. The PIT-tag monitoring system located in the spill bay below the removable spillway weir at Lower Granite Dam detected 295 of our Idaho wild fish (66.3% of fish detected at the dam). Based on a NOAA evaluation done during spring 2022, the estimated detection efficiency of the spillway monitoring system is 65.5% (SE ±1.5%), but will vary depending on seasonal effects (flow, temperature, etc.; Axel et al. 2023). This new interrogation site continues to provide us with sufficient data for more accurate estimates of timing and survival and a better understanding of relationships between environmental conditions and movement of fry, parr, and smolts from natal rearing areas.

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.

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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, 2021. Some length-weight data includes recaptured tagged fish and precocious Chinook.

				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
Loon Creek	314	250	250	49-87	64.5	1.0-7.0	2.7	54-87	65.4	1.6-7.1	2.9
Valley Creek	1,215	1,000	1,000	48-131	70.1	1.2-25.7	3.7	56-110	70.3	1.6-14.6	3.7
Marsh Creek	1,275	1,000	1,000	43-135	63.8	0.9-28.7	3.3	53-85	65.4	1.1-7.5	3.4
Cape Horn Creek	1,227	715	715	42-129	63.5	0.8-28.0	3.3	54-91	64.7	1.4-8.7	3.3
Bear Valley Creek	628	595	594	50-141	70.7	1.1-40.9	4.4	57-89	70.3	2.1-8.5	4.3
Elk Creek	183	173	173	61-126	72	2.4-24.0	4.4	61-85	71.7	2.4-7.6	4.3
Big Creek (upper)	552	500	500	49-124	65.3	1.5-23.0	3.4	55-83	65.3	1.7-6.7	3.3
S Fork Salmon River	816	750	750	51-127	71.3	1.3-25.9	4.4	56-106	70.0	1.6-16.5	3.9
Secesh River	540	500	500	57-118	68.9	1.9-18.4	4.2	57-86	68.4	1.9-8.0	4.0
Lake Creek	627	500	500	44-123	64.7	0.7-24.2	3.5	55-100	64.6	1.6-13.3	3.3
Chamberlain Creek	277	250	250	47-114	67.2	1.4-19.9	3.8	55-88	67.2	2.0-8.1	3.8
Total or mean	7,654	6,233	6,232	42-141	67.4	0.7-40.9	3.7	53-110	67.6	1.1-16.5	3.7

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				
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
2021[a]	---	---	---	---
2022	**30 April**	**15 May**	**7 June**	**28 April-22 June**
Elk Creek				
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
2021[a]	---	---	---	---
2022	**22 April**	**6 May**	**28 May**	**20 April-20 June**
Valley Creek				
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
2021[a]	---	---	---	---
2022	**7 May**	**12 May**	**30 May**	**1 May-15 June**
Loon Creek				
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
2021[a]	---	---	---	---
2022	**5 May**	**10 May**	**18 May**	**3 May-19May**

Appendix Table 2. Continued.

Year	Percentile passage dates at Lower Granite Dam			
	10th	50th	90th	Range
Marsh Creek				
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
2021[a]	---	---	---	---
2022	**5 May**	**12 May**	**26 May**	**27 April-13 June**
Cape Horn Creek				
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
2021[a]	---	---	---	---
2022	**2 May**	**15 May**	**27 May**	**13 April-27 June**
South Fork Salmon River				
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
2021[a]	---	---	---	---
2022	**29 April**	**9 May**	**27 May**	**14 April-1 June**
Big Creek (upper)				
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
2021[a]	---	---	---	---
2022	**9 May**	**24 May**	**1 June**	**30 April-4 June**

Appendix Table 2. Continued.

	Percentile passage dates at Lower Granite Dam			
Year	10th	50th	90th	Range
Secesh River				
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
2021[a]	---	---	---	---
2022	**12 April**	**30 April**	**25 May**	**7 April-2 June**
Lake Creek				
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
2021[a]	---	---	---	---
2022	**24 April**	**1 May**	**4 June**	**8 April-5 July**
Chamberlain Creek				
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
2021[a]	---	---	---	---
2022	**1 May**	**10 May**	**28 May**	**28 April-9 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 2022 of PIT-tagged smolts by date at Snake and Columbia River dams for 594 wild Chinook salmon from Bear Valley Creek released 3-4 August 2021. Release sites were 629-635 km above Lower Granite Dam. One fish was also detected on the lower Columbia River PIT Trawl (TWX) 7 June 2022.

	Bear Valley Creek								
Detection date (2022)	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
28 Apr	1		2						
29 Apr	1		2						
30 Apr	1		2						
1 May	1		2						
2 May				1					
3 May									
4 May	1		2						
5 May	2		4						
6 May									
7 May	1		2						
8 May		1	3						
9 May				1					
10 May		2	6						
13 May		1	2						
14 May									
15 May	1		3						
17 May				1	1				
18 May		1	1						
19 May	1		3						
23 May		1	3						
24 May	1		3						
25 May									
27 May	1		3						
29 May					1				
1 June	1		3						
2 June		1	3				1		
4 June	2		4	1					
7 June		1	2						
14 June		1	3						
15 June						1			
22 June	1		1						
27 June				1					
Total	**16**	**9**	**58**	**5**	**2**	**1**	**1**	**0**	**0**

Appendix Table 4. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 173 wild Chinook salmon from Elk Creek released 5 August 2021. 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
20 Apr	1		2						
28 Apr	1		2						
2 May	1		2						
6 May	1		5						
13 May	1		2						
20 May		1	2						
23 May	1		3						
28 May	1		3						
30 May									1
3 June					1				
18 June							1		
20 June		1	1						
4 July								1	
Total	**8**	**2**	**22**	**0**	**1**	**0**	**1**	**5**	**1**

Appendix Table 5. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 1,000 wild Chinook salmon from Valley Creek released 22 July 2021. Release sites were 743-750 km above Lower Granite Dam.

	Valley Creek								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
1 May	1		2						
2 May									
3 May	1		2						
4 May									
5 May	1		2						
7 May	1	3	10						
8 May	1		3						
9 May		3	8	1					
10 May	1		3						
12 May		3	9						
13 May									
14 May	1		3		1				
15 May	1		3						
16 May									
17 May	1		1						
18 May					1				
19 May				1					
20 May									
22 May									
23 May								1	
24 May	1		3						
25 May	1		3						
26 May	2		5	1					
27 May	2	1	9						
28 May		1	3	1					
29 May				1					
31 May									
1 June		1	3						
4 June				1			1		
5 June	1		2						1
14 June					1				
15 June		1	2						
Total	**16**	**13**	**73**	**6**	**3**	**0**	**1**	**1**	**1**

Appendix Table 6. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 500 wild Chinook salmon from Upper Big Creek released 6 August 2021. Release sites were 489-491 km above Lower Granite Dam. One fish was also detected on the lower Columbia River PIT Trawl (TWX) 4 June 2022.

	Upper Big Creek								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
30 Apr	1		2						
1 May									
2 May									
3 May									
4 May									
5 May									
6 May	1		2						
7 May	1		2						
8 May		1	3						
9 May		1	3						
10 May		1	3						
11 May	2	1	8						
12 May									
13 May									
15 May	1		3		1				
16 May									
17 May	1		1						
18 May	1		1	1	2				
19 May	1		3	1	1				
20 May	1		2						
21 May	1	2	9						
22 May	1	1	6					1	
23 May		1	3						
24 May	1		3						1
25 May	2		5						
26 May	2		5						
27 May	1		3						
28 May	2		6	2					
29 May	3		7		1				
30 May		1	3						
31 May		2	6		2				
1 June	1	1	5						
2 June	1	1	6			1			
3 June				1				1	
4 June	1		2	1					
5 June				1					
6 June					1				
10 June							1		
11 June									1
14 June				1					
Total	**25**	**13**	**102**	**8**	**8**	**1**	**1**	**2**	**2**

Appendix Table 7. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 750 wild Chinook salmon from South Fork Salmon River released 11-12 August 2021. Release sites were 467-469 km above Lower Granite Dam.

	South Fork Salmon River								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
14 Apr	1		3						
20 Apr	1		2						
27 Apr		1	2			1			
28 Apr	2	1	5						
29 Apr	4		8						
30 Apr	3		7						
1 May	2		4	1					
2 May	5		10						
4 May	2		4						
5 May	1		2						
7 May	2	4	14						
8 May	2	2	10						
9 May		5	13						
10 May	2		6		1				
11 May	3		8		1				
12 May		1	3					1	
13 May	1		2						
14 May				1					1
15 May		1	3						1
17 May	2		3						
18 May					1				
19 May		1	3						1
20 May									
21 May									
22 May	2	1	9						1
23 May									
24 May									
25 May	3		8						
26 May	1		3						1
27 May	2		6						
30 May		2	5		1				
31 May									
1 June		1	3						
5 June				1					
7 June				1					
8 June									1
28 June	1		2						
Total	**42**	**20**	**147**	**4**	**4**	**1**	**0**	**1**	**6**

Appendix Table 8. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 500 wild Chinook salmon from Secesh River released 13 August 2021. Release sites were 429-431 km above Lower Granite Dam. One fish was also detected on the lower Columbia River PIT Trawl (TWX) 21 May 2022.

	Secesh River								
Detection date (2022)	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
7 Apr	1		3						
9 Apr		1	2						
11 Apr	1		3						
12 Apr	2		7						
13 Apr		1	2						
17 Apr									
19 Apr		1	2						
20 Apr									
21 Apr	1		2						
22 Apr	1		2	1					
25 Apr	1		3						
26 Apr	1		3						
27 Apr	6	1	12						
28 Apr	6	1	12						
29 Apr	6		12						
30 Apr	4		9						
1 May	7	1	18						
2 May	4		8						
3 May	1		2						
4 May									
5 May	1		2						
6 May	2		5						
7 May	2	2	10						
8 May		1	3						
13 May				1					
14 May									1
18 May									1
20 May				1					
25 May	2		5						
26 May	1		3						
29 May					1				
30 May		1	3						
1 June		1	3						
2 June		1	3						
Total	**50**	**12**	**137**	**3**	**1**	**0**	**0**	**0**	**2**

Appendix Table 9. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 500 wild Chinook salmon from Lake Creek released 14 August 2021. Release site was 451 km above Lower Granite Dam. Two fish were also detected on the lower Columbia River PIT Trawl (TWX) 17&19 May 2022.

	Lake Creek								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
8 Apr	1		3						
11 Apr		1	3						
15 Apr	1		2						
22 Apr	1		2						
23 Apr									
24 Apr	2		4						
25 Apr	1		3						
27 Apr	2		3	1					
28 Apr	4		7						
29 Apr	5		10						
30 Apr	5		11						
1 May	5		11						
2 May	1		2						
3 May	1		2						
5 May	1		2						
6 May	3		7		1				
7 May		2	5	1					
8 May		1	3						
10 May		2	6						
11 May		1	3						
12 May									
13 May		1	2						
15 May					1				1
16 May	1		2						
25 May	1		3						
29 May				1					
3 June		1	2						
4 June		1	2						1
6 June		1	2						
14 June		1	3						
18 June							1		
19 June	1		2						
5 July	1		2						
Total	**37**	**12**	**109**	**3**	**2**	**0**	**1**	**0**	**2**

Appendix Table 10. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 715 wild Chinook salmon from Cape Horn Creek released 24 July 2021. The release site was 631 km above Lower Granite Dam. One fish was also detected on the lower Columbia River PIT Trawl (TWX) 1 June 2022.

	Cape Horn Creek								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
27 Apr	1		2						
28 Apr	1	1	4						
1 May	1		4						
2 May	1		2						
6 May	1		2						
7 May	1		2						
8 May		1	3						
9 May	1	3	11						
10 May	2		6						
11 May	1	1	5						
12 May	1	1	6						
13 May	1	1	5	2					
14 May	1		3	1					
15 May	2		5				1		
16 May	1	1	4	1	1				
17 May	1		1	1	1				
18 May	1		1						
19 May		2	6						
20 May		1	2		1				
22 May		1	3						
23 May		1	3						
24 May	1		3						
25 May	4		10						
27 May	3	1	11						
28 May	1		3						
29 May									1
30 May				1					
2 June				1					
3 June	1	1	5						
4 June						1			
9 June									1
13 June		1	2						
Total	**29**	**17**	**114**	**7**	**3**	**0**	**1**	**0**	**2**

Appendix Table 11. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 250 wild Chinook salmon from Chamberlain Creek released 16 August 2021. The release site was 437 km above Lower Granite Dam.

Detection date (2022)	Chamberlain Creek								
	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
28 Apr	1		2						
30 Apr	1		2						
1 May	1		2						
2 May	1		2						
3 May	2		3						
4 May									
5 May	2		4						
6 May		1	2						
7 May		1	2						
8 May		1	3						
9 May	1	1	5						
10 May	1	1	6						
11 May									
12 May		1	3						
13 May		1	2						
14 May		2	5						
15 May					1				
16 May				1					
18 May					1				
22 May	1		3						
23 May									
26 May	1	1	5						
27 May				1	1				
28 May				1					
30 May				1					1
31 May		1	3						
9 June	1		2						
Total	**13**	**11**	**58**	**4**	**3**	**0**	**0**	**0**	**1**

Appendix Table 12. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 250 wild Chinook salmon from Loon Creek released 21 July 2021. The release site was 552 km above Lower Granite Dam.

	Loon Creek								
Detection date (2022)	Lower Granite			First detections					
	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
3 May	1		2						
4 May									
5 May	2		4						
6 May									
7 May		3	7						
8 May		1	3		1				
9 May	1	2	8						
10 May	1	1	6						
11 May		2	5						
12 May		2	6						
13 May									
14 May									1
15 May									
16 May	1		2						
18 May	2		3	1	1				
19 May		1	3						
22 May					1				
30 May				1					
3 June								1	
6 June					1				
Total	**8**	**12**	**49**	**2**	**4**	**0**	**0**	**1**	**1**

Appendix Table 13. Detections during 2022 of PIT-tagged smolts by date at four Snake River dams and three Columbia River dams for 1,000 wild Chinook salmon from Marsh Creek released 23 July 2021. The release site was 631 km above Lower Granite Dam. Two fish were also detected on the lower Columbia River PIT Trawl (TWX) 18 May and 8 June 2022.

	Marsh Creek								
Detection	Lower Granite			First detections					
date (2022)	Spill	Bypass	Expanded	Little Goose	Lower Monumental	Ice Harbor	McNary	John Day	Bonneville
27 April	1		2						
29 April	2		4						
2 May	1		2						
3 May	2		5						
4 May	1		2						
5 May	4		8						
6 May	1		2						
7 May	1	4	12						
8 May	1	1	5	1					
9 May	3	4	19						
10 May	4	2	19						
11 May	1	2	8						
12 May	3	1	12	1					
13 May	1	2	7	2					
14 May	1	1	5	2					
15 May	1	3	10		1				
16 May	2		4		1				
17 May	2		3		1				
18 May	2		3	1	1				
19 May		1	3		2				
20 May	2		4						
21 May	1		3						
22 May									2
23 May	1		3						1
24 May	3		8						
25 May	2	2	10	1					1
26 May	3	2	13						
27 May	1	1	6	1					
30 May									
4 June	1		2						
5 June	1	1	4						1
6 June		1	2	1				1	
13 June	1		2						
Total	**51**	**28**	**192**	**10**	**6**	**0**	**0**	**1**	**5**

Appendix Table 14. 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 2022 with associated river conditions at the dam.

Lower Granite Dam							
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Spill Detections LGS (n)	Bypass Detections LGB (n)	Detections (n)	Expanded detections (n)
7 Apr	40.9	28.5	7.7	1		1	3
8 Apr	40.5	28.2	7.7	1		1	3
9 Apr	39.0	25.0	7.6		1	1	2
10 Apr	42.2	26.8	7.5				
11 Apr	42.3	25.7	7.5	1	1	2	5
12 Apr	39.7	24.0	7.8	2		2	7
13 Apr	40.0	24.5	7.9		1	1	2
14 Apr	40.5	24.9	7.9	1		1	3
15 Apr	40.2	24.6	7.6	1		1	2
19 Apr	39.4	28.0	6.9		1	1	2
20 Apr	41.5	26.1	7.1	2		2	4
21 Apr	43.3	32.0	7.2	1		1	2
22 Apr	44.4	31.7	7.4	2		2	4
23 Apr	41.2	26.9	7.8				
24 Apr	37.8	23.4	8.6	2		2	4
25 Apr	37.4	23.1	9.2	2		2	5
26 Apr	39.9	25.7	9.2	1		1	3
27 Apr	45.2	26.9	9.5	10	2	12	21
28 Apr	41.9	27.7	10.0	16	3	19	33
29 Apr	44.5	28.1	10.2	18		18	36
30 Apr	44.4	28.0	10.5	15		15	33
1 May	42.9	28.7	10.2	19	1	20	45
2 May	44.7	28.3	10.0	14		14	28
3 May	46.7	29.7	10.0	9		9	16
4 May	50.0	32.1	10.2	4		4	7
5 May	55.5	36.8	10.3	14		14	28
6 May	65.1	44.1	10.3	10	1	11	26
7 May	105.4	56.1	10.4	9	19	28	67
8 May	118.0	59.9	10.5	4	10	14	36
9 May	100.0	60.8	9.8	6	19	25	67
10 May	86.0	56.6	9.2	11	9	20	62
11 May	77.2	50.4	9.0	7	7	14	37
12 May	68.4	44.2	9.0	4	9	13	38
13 May	68.1	43.8	9.2	4	6	10	24
14 May	66.6	43.0	9.5	3	3	6	15

Appendix Table 14. Continued.

	Lower Granite Dam (continued)						
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Spill Detections LGS (n)	Bypass Detections LGB (n)	Detections (n)	Expanded detections (n)
15 May	67.1	43.4	10.2	6	4	10	26
16 May	73.8	49.2	10.7	5	1	6	13
17 May	93.7	59.9	11.1	7		7	10
18 May	105.6	64.9	11.6	6	1	7	10
19 May	108.8	65.1	11.6	2	5	7	20
20 May	104.5	65.8	10.9	3	2	5	11
21 May	93.0	60.4	10.2	2	2	4	13
22 May	91.2	59.6	10.0	4	3	7	20
23 May	82.9	53.2	10.2	2	3	5	13
24 May	79.9	51.6	10.4	7		7	18
25 May	79.7	50.7	10.7	15	2	17	45
26 May	85.0	54.7	11.2	10	3	13	34
27 May	104.3	64.4	11.7	10	3	13	37
28 May	128.1	66.1	12.4	4	1	5	15
29 May	139.4	64.1	11.9	3		3	7
30 May	136.5	61.5	10.9		4	4	10
31 May	136.6	60.7	10.3		3	3	9
1 Jun	126.2	59.5	9.9	2	4	6	16
2 Jun	124.0	60.1	10.6	1	3	4	12
3 Jun	130.9	60.0	11.5	1	2	3	7
4 Jun	142.4	59.7	12.1	4	1	5	10
5 Jun	149.5	59.7	12.2	2	1	3	6
6 Jun	158.7	61.9	11.6		2	2	4
7 Jun	158.9	60.1	11.5		1	1	2
8 Jun	153.5	59.7	11.7			0	0
9 Jun	145.3	59.9	12.1	1		1	2
13 Jun	204.3	93.7	---	1	1	2	4
14 Jun	205.5	99.2	11.08		2	2	6
15 Jun	181.1	80.1	10.97		1	1	2
19 Jun	131.2	73.7	13.26	1		1	2
20 Jun	122.1	72.2	13.1		1	1	1
22 Jun	108.7	20.0	13.26	1		1	1
28 Jun	86.2	22.5	15.42	1		1	2
5 Jul	58.1	18.0	17.28	1		1	2
Avg/Total	**91.0**	**44.6**	**11.1**	**296**	**149**	**445**	**1,059**

Appendix Table 15. Daily detections at Little Goose Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	Little Goose Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
22 Apr	39.5	21.2	8.04	1
27 Apr	42.1	22.8	8.51	1
1 May	40.0	22.1	9.84	1
2 May	42.0	24.2	10.12	1
7 May	98.8	55.9	10.88	1
8 May	111.0	63.4	10.69	1
9 May	96.9	63.0	10.6	2
12 May	63.1	40.2	10.41	1
13 May	63.8	39.6	10.09	5
14 May	62.9	39.6	9.96	4
15 May	62.5	39.4	10.06	0
16 May	68.1	44.5	9.96	2
17 May	87.8	60.1	10.21	2
18 May	100.7	63.2	10.89	3
19 May	104.0	63.2	11.28	2
20 May	98.5	65.3	11.52	1
25 May	75.6	48.8	10.81	1
26 May	80.6	53.8	11.07	1
27 May	99.9	61.7	11.17	2
28 May	120.0	65.0	11.44	4
29 May	131.6	64.6	11.96	2
30 May	131.1	63.0	12.38	3
31 May	129.0	63.4	11.94	0
1 Jun	121.2	63.5	11.3	0
2 Jun	117.3	63.3	10.94	1
3 Jun	124.4	62.9	10.64	1
4 Jun	132.6	62.9	11.28	3
5 Jun	139.1	69.6	12.01	2
6 Jun	154.7	84.4	12.6	1
7 Jun	154.3	82.4	12.52	1
14 Jun	204.6	132.1	11.86	1
27 Jun	80.3	24.3	15.16	1
Avg/Total	**99.3**	**56.0**	**11.0**	**52**

Appendix Table 16. Daily detections at Lower Monumental Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	Lower Monumental Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
6 May	60.0	41.7	10.9	1
7 May	101.7	67.4	11.2	0
8 May	113.4	69.0	11.1	1
9 May	105.9	69.3	10.9	0
10 May	84.4	54.5	10.8	1
11 May	75.7	51.6	10.9	1
12 May	64.2	42.3	11.1	0
13 May	69.4	47.0	11.1	0
14 May	64.1	44.8	11.0	1
15 May	69.7	48.9	10.8	4
16 May	68.1	47.1	10.6	2
17 May	89.1	59.8	10.7	3
18 May	103.8	71.0	10.5	7
19 May	110.3	71.3	10.7	3
20 May	103.1	71.6	11.2	1
21 May	92.6	60.6	11.6	0
22 May	87.0	59.6	11.9	1
27 May	103.9	73.1	11.5	1
28 May	123.0	75.5	11.5	0
29 May	134.2	80.6	11.6	3
30 May	132.1	73.2	11.9	1
31 May	134.7	78.2	12.5	2
3 Jun	125.0	74.4	11.7	1
6 Jun	157.2	78.9	12.3	2
14 Jun	206.8	108.7	12.4	1
Avg/Total	**103.2**	**64.8**	**11.3**	**37**

Appendix Table 17. Daily detections at Ice Harbor Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	Ice Harbor Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
27 Apr	47.6	37.1	9.6	1
2 Jun	124.3	106.4	13.1	1
3 Jun	123.4	107.5	12.9	0
4 Jun	143.6	111.1	12.3	1
15 Jun	185.3	118.9	12.6	1

Appendix Table 18. Daily detections at McNary Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	McNary Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
27 Apr	200.3	127.1	11.5	1
15 May	239.3	182.9	11.3	1
2 Jun	299.7	241.8	12.9	1
3 Jun	311.6	246.4	13.2	0
4 Jun	345.7	265.7	13.4	1
10 Jun	412.0	267.0	13.7	1
18 Jun	419.5	274.4	13.3	2

Appendix Table 19. Daily detections at John Day Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	John Day Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
12 May	245.8	155.4	11.5	1
22 May	270.7	164.3	12.3	1
23 May	260.1	166.0	12.3	1
3 Jun	344.9	190.5	12.9	2
6 Jun	384.2	199.8	13.9	1
4 Jul	258.5	90.4	16.9	1

Appendix Table 20. Daily detections at Bonneville Dam in 2022 of wild spring/summer Chinook salmon smolts with river conditions at the dam. Fish were PIT-tagged and released in streams during summer 2021.

	Bonneville Dam			
Date (2022)	Average flow (kcfs)	Average spill (kcfs)	Water temperature (°C)	Numbers detected (n)
14 May	259.2	148.5	11.6	3
15 May	258.7	148.8	11.8	2
19 May	275.8	149.0	12.4	1
22 May	285.0	149.8	12.8	3
23 May	262.2	149.7	13.0	1
24 May	255.7	150.1	13.0	1
25 May	279.2	149.9	13.0	1
26 May	285.5	149.5	13.1	1
29 May	306.4	149.1	12.9	1
30 May	321.3	149.3	13.1	2
4 Jun	360.0	150.3	13.4	1
5 Jun	374.5	154.1	13.5	2
8 Jun	395.7	196.2	--	1
9 Jun	416.6	213.1	--	1
10 Jun	432.8	223.1	--	0
11 Jun	441.3	234.7	--	1
18 Jun	439.7	238.5	--	1
Avg/Total	**332.3**	**170.8**	**12.8**	**23**

Appendix Table 21. Estimated detection efficiencies for the Valley Creek instream PIT-tag monitoring system based on detections at downstream dams, 2003-2022.

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
2021	--	---	--
2022	12	75.6[a]	--

[a] Estimates for 2022 are biased low due to an outage of the instream site from 17 June – 11 Aug

U.S. Secretary of Commerce
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Under Secretary of Commerce for
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