Atascadero Creek Sedimentation Analysis and Fish Passage Restoration 65% Design Project: Coho Salmon Monitoring Report

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1. Contents

2. Background

The Coho Salmon monitoring summarized in this report was conducted by California Sea Grant (CSG) in support of restoring salmonid habitat in the Atascadero Creek watershed and was part of a larger project coordinated by Gold Ridge Resource Conservation District (GRRCD) and funded by the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Prop 1) through a grant from the California Department of Fish and Wildlife (CDFW Contract #Q2096007). The monitoring for this project was designed to increase our understanding of Coho Salmon use of Atascadero Creek and help determine whether the lower reaches of Atascadero Creek, where significant sediment accumulation is thought to decrease salmonid habitat and water quality conditions, pose a bottleneck to Coho Salmon migration and survival. Data collection for this study was conducted between fall 2020 and spring 2023; however, results from ongoing monitoring efforts by CSG and Sonoma Water (SW) in the Russian River watershed were also included for context and to expand some of the datasets.

2.1. Coho Salmon recovery in the Russian River watershed

The Russian River Coho Salmon population (which includes the Green Valley Creek watershed encompassing Atascadero Creek), is part of the Central California Coast Evolutionarily Significant Unit (CCC ESU) of Coho Salmon which is listed as endangered under state and federal endangered species acts. Russian River populations, once thought to be in the tens of thousands, dropped to fewer than 10 adults known to return each year in the early 2000s (NMFS 2012). In response to this decline, extensive efforts to improve habitat conditions have, and continue to be, conducted throughout the watershed. In addition, a conservation hatchery program called the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program), was initiated in 2001 and began releasing juvenile Coho Salmon bred from local genetic stock into Russian River tributaries in 2004. Releases have continued annually and approximately 150,000 – 200,000 juveniles are released into the Russian River watershed each year. The long-term goal of the conservation hatchery program is to restore self-sustaining runs of Coho Salmon that can complete their life cycle independently (i.e., without hatchery support). Although hundreds of Coho Salmon adults are now returning to the Russian River each year, on average over 98% of the adult returns are hatchery-origin fish (California Sea Grant and Sonoma Water 2023), suggesting that existing habitat (freshwater and marine) is still not sufficient to support the full life cycle of Coho Salmon in the Russian River watershed. The study summarized in this report supports the larger Coho Salmon recovery effort by helping to identify bottlenecks to survival.

2.2. Green Valley and Atascadero Creek watersheds

Atascadero Creek falls within the Green Valley Creek watershed which is listed as a core watershed for recovery in NMFS' recovery plan for the CCC ESU of Coho Salmon (NMFS 2012) and Green Valley Creek is a focus stream for the California Department of Fish and Wildlife (CDFW) North Coast Salmon Project. Green Valley Creek is also one of four life cycle monitoring streams for the Broodstock Program and the Coastal Monitoring Program. During the extreme Coho Salmon decline in the early 2000s, Green Valley Creek was the last remaining Russian River tributary to support three year classes of Coho Salmon and these fish were the basis of the captive broodstock program. By 2005, no Coho Salmon were documented returning to Green Valley Creek after which the Broodstock Program began stocking fish into Green Valley and Purrington creeks.

Despite the intensive Coho Salmon monitoring that has occurred in Green Valley Creek over the last two decades, little was known about salmonid presence in and use of Atascadero Creek, which comprises approximately 60% of the Green Valley watershed area. In large part, this has been due to the difficulty of implementing standard fish monitoring protocols (e.g., snorkeling, spawner surveys, trapping) in the low-gradient, wide-channeled, low-visibility, swampy habitat characteristic of lower Atascadero Creek. Based on salmonid life history strategies observed in other Pacific Northwest watersheds that utilize extensive low-gradient habitat for overwinter survival and growth, it is likely that the Atascadero watershed historically provided important overwinter habitat for juvenile salmonids that originated from spawning reaches within the larger Green Valley watershed and other Russian River tributaries. Low-gradient overwinter rearing habitat is important because it provides refuge from high-velocity winter flows and can enhance feeding opportunity and growth which are related to higher marine survival. However, land-use activities appear to have caused a high-level of impairment in the Atascadero watershed (Dawson 2021), and recent water quality monitoring indicates that conditions are not sufficient to support survival and growth of salmonids, and may even trigger mortality events such as one observed by GRRCD during a storm event in May 2019 (GRRCD and OEI 2021). GRRCD and a number of other partners are specifically evaluating habitat and water quality in a lower reach of Atascadero Creek that flows through the 44-acre Atascadero Creek Ecological Reserve (ACER), and they are proposing actions that would improve conditions for salmonids through that reach. We hereafter refer to this reach as the “project reach”.

2.3. Monitoring goals and objectives

The primary goal of this study was to document use of the lower Atascadero project reach by CCC ESU Coho Salmon. Specific objectives were to:

1) Document use of and passage through the lower Atascadero project reach by Coho Salmon that originated from Redwood Creek (within Atascadero watershed upstream of the project reach)
2) Document entry and use of the lower Atascadero project reach by Coho Salmon that originated from other Russian River tributaries (e.g., Green Valley and Purrington creeks)

2.4. Coho Salmon life history

In the Russian River watershed, the prevalent Coho Salmon life history strategy is to emerge from the gravel as a young-of-year (YOY) (a.k.a., fry) in a tributary stream in early-spring, rear in that stream as a parr for a little over a year, migrate to the ocean during the second spring as a smolt, feed and grow for 0.5 – 1.5 years in the ocean, and then return to spawn in the tributaries in December-February as an age-2 or age-3 adult. Alternative, though less common, life history patterns include early juvenile emigration from tributaries during the winter months and/or remaining in the stream environment as a juvenile for two years instead of one.

2.5. Coho Salmon releases from Don Clausen Fish Hatchery

The Broodstock Program supplements the Russian River Coho Salmon population by releasing juveniles at the spring (YOY), fall (parr), presmolt, and smolt stages into different tributaries each year. The number and age of fish that are released into each tributary each year depends on multiple factors that include the level of hatchery production, environmental and climatic conditions, and natural production.

The Broodstock Program first released juvenile Coho Salmon into the Atascadero watershed in 2017 and continued to release fish annually through 2021 (Table 1). All hatchery fish were released into Redwood Creek, a tributary to Jonive Creek which flows into Atascadero Creek (Figure 1). Redwood Creek was selected as a release stream for its characteristically cool summer temperatures and high surface flow connectivity relative to other Russian River tributaries. While biologists suspected relatively high summer survival of rearing juveniles in Redwood Creek, habitat and water quality in the main channel of Atascadero Creek was questionable and there was uncertainty if fish released into Redwood Creek would be able to successfully migrate through Atascadero Creek as smolts during their migration to the ocean. The releases into Redwood Creek, in combination with the present study, were a means of learning more about the potential for Coho Salmon survival in the Atascadero watershed.

During the five years of juvenile Coho Salmon releases into Redwood Creek, fish were stocked as parr in late fall. In 2019 and 2020, fish were also stocked as young-of-year (YOY) in late-spring. In addition to the Redwood Creek releases, juvenile hatchery Coho Salmon were released into Green Valley Creek and Purrington Creek (Table 1).

A fraction of all hatchery Coho Salmon released into the Russian River watershed are marked with passive integrated transponder (PIT) tags which provides populations of fish that can be tracked using PIT antennas placed in strategic locations throughout the watershed. In this study, tracking of these PIT-tagged fish allowed us to characterize emigration patterns of the fish released into Redwood Creek and immigration patterns of PIT-tagged fish entering Atascadero Creek from other Russian River streams.

During the project period, juvenile Coho Salmon were released into Redwood Creek in 2020 and 2021, and these cohorts are the focus of this report. When possible, we also included results from previous cohorts.

Table 1. Number of hatchery Coho Salmon released into the Green Valley Creek watershed and proportion PIT-tagged for cohorts 2017 - 2022. Releases specifically into the Atascadero watershed (Redwood Creek) are highlighted in bold.

Cohort (Hatch year)	Release tributary	Release group	Release date range	Total number released	PIT number released	Percent PIT-tagged
2017	Green Valley Creek	spring	6/16/2017	454	454	100%
		fall	12/6/2017	8,069	1,610	20%
		smolt	3/28/2018 - 5/22/2018	14,066	2,859	20%
	Purrington Creek	fall	12/4/2017	3,041	610	20%
	Redwood Creek	**fall**	**12/1/2017**	**3,041**	**609**	**20%**
2018	Green Valley Creek	fall	12/6/2018	7,063	1,401	20%
		presmolt	3/7/2019	8,054	1,599	20%
		smolt	4/1/2019 - 4/29/2019	5,077	1,016	20%
	Purrington Creek	fall	12/7/2018	3,016	609	20%
	Redwood Creek	**fall**	**12/7/2018**	**3,005**	**609**	**20%**
2019	Green Valley Creek	fall	12/10/2019	11,635	1,735	15%
		smolt	3/24/2020 - 4/27/2020	15,610	2,339	15%
	Purrington Creek	fall	12/9/2019	4,041	605	15%

	Redwood Creek	**spring**	**6/17/2019**	**2,018**	**406**	**20%**
		fall	**12/11/2019**	**2,050**	**305**	**15%**
2020	Green Valley Creek	fall	12/14/2020 - 12/15/2020	16,150	2,428	15%
		presmolt	2/23/2021	10,079	1,521	15%
		smolt	4/9/2021	3,634	549	15%
	Purrington Creek	fall	12/7/2020	2,537	385	15%
	Redwood Creek	**spring**	**6/22/2020**	**2,072**	**310**	**15%**
		fall	**11/25/2020**	**3,039**	**460**	**15%**
2021	Green Valley Creek	fall	12/1/2021	11,467	1,722	15%
	Purrington Creek	fall	11/30/2021	2,041	302	15%
	Redwood Creek	**fall**	**11/26/2021**	**2,000**	**305**	**15%**
2022	Green Valley Creek	smolt	3/20/2023 - 5/1/2023	24,291	6,427	26%
	Purrington Creek	presmolt	1/26/2023	3,539	785	22%

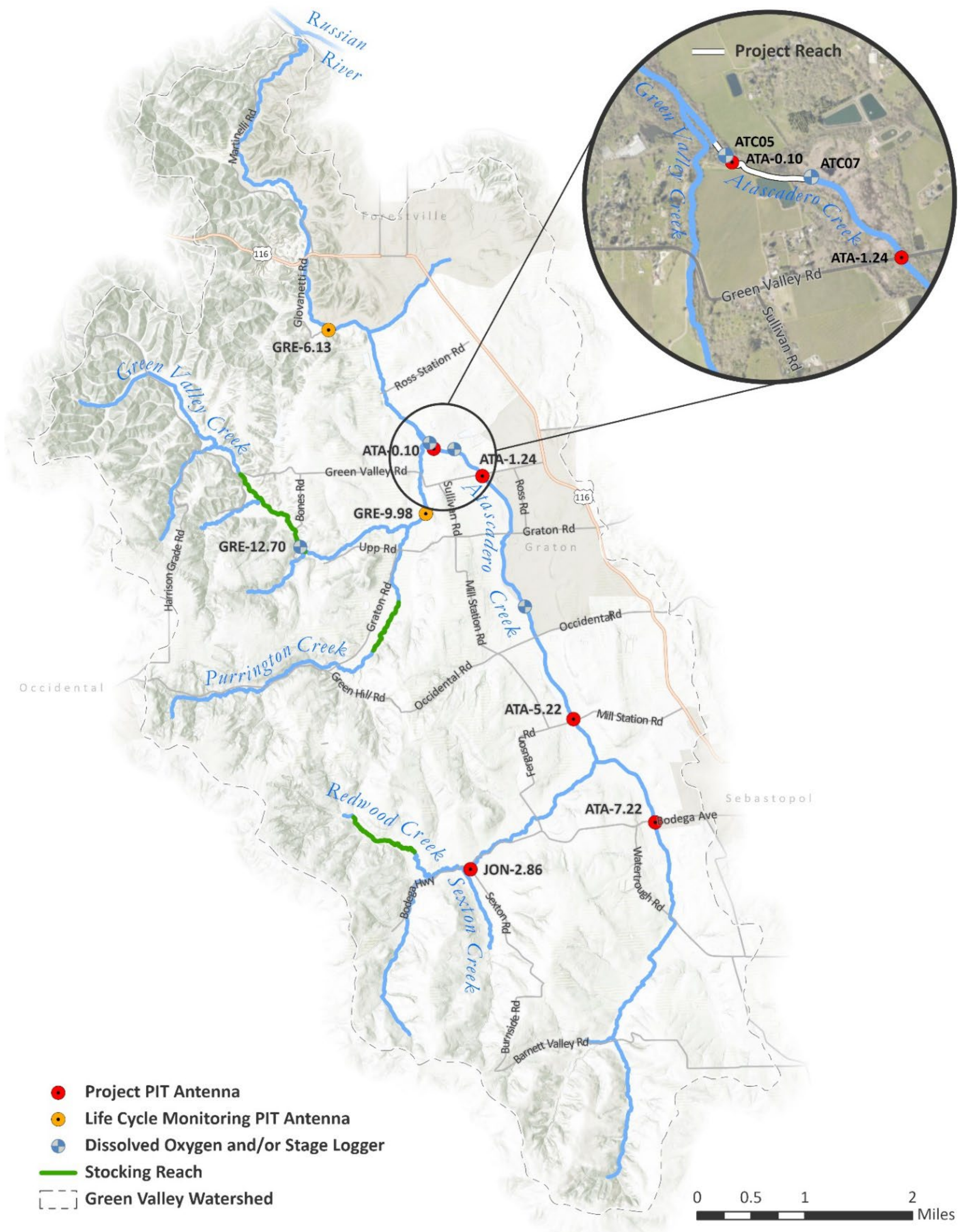

Figure 1. Location of PIT antennas, loggers, and stocking reaches in relation to the project reach. Site codes consist of the first three letters of the tributary in which the site is located and the approximate river kilometer distance upstream from the mouth of that tributary. Note that the ATA-0.10 antenna array was actually located 0.33 km upstream of the confluence with Green Valley Creek (not 0.10 km as indicated by its site code).

Methods

2.6. Passive integrated transponder (PIT) antenna arrays

Our primary means of documenting juvenile Coho Salmon use of and migration through the project reach was to establish stationary FDX PIT detection systems (antenna arrays) upstream and downstream of the project reach (Figure 1) to track movement patterns of PIT-tagged Coho Salmon. The low elevation of the watershed, lack of suitable conditions for antenna operation (riffle habitat with high stream banks), and limited access to private land made site selection for antenna placement a challenge so we attempted antenna operation at multiple sites (Table 2, Figure 2, Figure 3).

For the duration of the project we continued operation of two antenna arrays that CSG had previously installed through other funding sources; one on Jonive Creek upstream of the project reach (JON-2.86; Figure 1, Figure 3) and one on the mainstem of Green Valley Creek (GRE-6.13), located downstream of the confluence of Atascadero Creek. During the fall of 2020, we installed two new arrays in lower Atascadero Creek; one immediately below the project reach, approximately 0.33 river km upstream of the mouth of Atascadero (ATA-0.10; Figure 3) and one at the closest site upstream of the project reach where it was possible to operate an antenna (ATA-1.24; Green Valley Road crossing) (Figure 1). CSG operated these new arrays for two wet seasons, and GRRCD continued operation of ATA-0.10 for a third season. To try to gain more information about finer scale movement patterns in Atascadero Creek, we installed and operated antenna arrays at two additional locations during the wet season of 2021-2022. One site was located in Atascadero Creek upstream of the confluence with Jonive Creek (ATA-7.22; Bodega Ave crossing) and the other was located at river km 5.22 (ATA-5.22; Mill Station Road crossing) (Figure 1, Table 2).

Following antenna and transceiver installation, all antenna sites were checked approximately biweekly during the wet season and powered off during the dry season when there was no flow over the antennas. Biweekly checks consisted of data downloads and changing batteries at battery-powered sites. More frequent antenna checks were conducted during storm events. When extreme storm events were forecast, electronic equipment was removed in flood-prone areas. Data download files were converted to Microsoft Excel, error checked, and uploaded to a SQL database where antenna detections could be related to information collected at the time of tagging, such as species and year, season, and stream of release.

Due to the high water depths and wide channels in Atascadero Creek, particularly during high flow events, it is very likely that we did not detect all PIT-tagged fish that passed over each of the antenna sites. Detection data should therefore be considered minimum counts of fish passing over each site.

Table 2. PIT antenna sites and specifications. Site codes consist of the first three letters of the tributary in which the site is located and the approximate river kilometer upstream from the mouth of that tributary. Note that the ATA-0.10 antenna array was actually located 0.33 km upstream of the confluence with Green Valley Creek (not 0.10 km as indicated by its site code).

Site code	Tributary	Site description	Antenna specifications	Number of antennas	Power source	Comments	Installation date	Retrieval date
JON-2.86	Jonive Creek	Located immediately downstream of the confluence with Redwood Creek.	10' flat-plate; IS1001s	2	solar	Installed through other funding sources.	11/1/2018	NA - ongoing
ATA-7.22	Atascadero Creek	Located at the Bodega Ave bridge crossing.	15' upright; IS1001	1	battery		10/27/2021	6/15/2022
ATA-5.22	Atascadero Creek	Located at Mill Station Rd bridge crossing. Approximate location where Atascadero shifts from flowing stream with riffle habitat to very low gradient, still water.	10' flat-plate, then 10' upright; IS1001	1	solar, battery	Initial setup was solar with a flat-plate but due to power issues, we converted it to an upright with batteries on 11/24/21. Better coverage than ATA-1.24 and ATA-0.10.	10/18/2021	6/30/2022
ATA-1.24	Atascadero Creek	Located at a Green Valley Rd bridge crossing.	3' disc, then 15' upright with IS1001	1	battery	Initially installed as a submerged "disc" antenna, but following power issues, we converted it to a 15' upright on 11/10/20. The antenna did not span the channel and the water level was often 2-5' above the antenna in winter and spring.	12/3/2019	6/30/2022
ATA-0.10	Atascadero Creek	Located 0.33 km upstream of the confluence with Green Valley Creek.	15' upright; IS1001s	2	solar	Site is flood prone and was electronic equipment was removed on multiple occasions during high flow events.	10/21/2020	NA - ongoing
GRE-6.13	Green Valley Creek	Located on the mainstem of Green Valley Creek downstream of the confluence with Atascadero Creek.	12' and 15' flat-plate; MC and IS1001s	6	solar	Operated by CSG initially through the Thomas Creek Ranch habitat restoration project and then through the Coho Broodstock Program monitoring effort.	11/13/2013	NA - ongoing

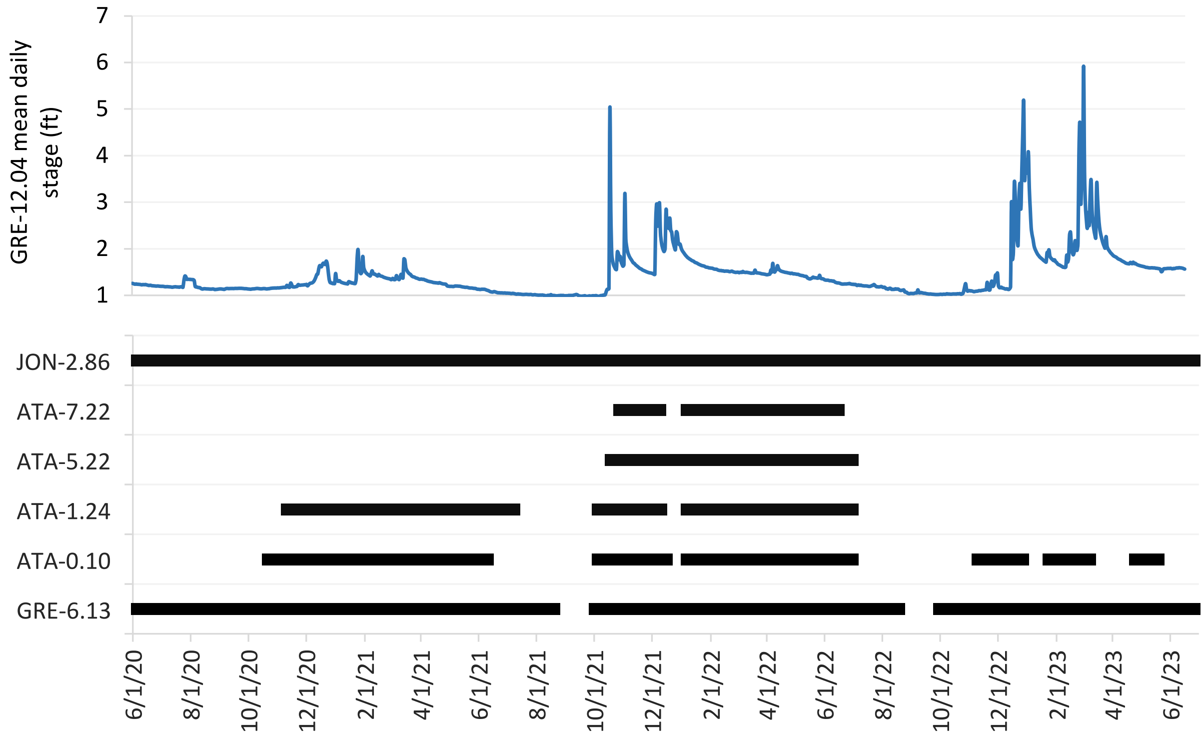

Figure 2. Dates of antenna operation (black bars) in relation to stream stage between June 1, 2020 and June 30, 2023.

Figure 3. PIT antenna arrays on lower Atascadero Creek (left; ATA-0.10) and Jonive Creek (right; JON-2.86).

3. Results

3.1. Redwood Creek releases

3.1.1. Detections of PIT-tagged Coho Salmon at each antenna array

For all but the 2017 cohort, the majority of the detections of PIT-tagged Coho Salmon from the Redwood Creek releases were on the Jonive Creek antenna array (JON-2.86) and there were far fewer detections at the other sites (Table 3). The Jonive Creek array was installed a full year after the 2017 cohort of fish was released so it is likely that many fish from the 2017 cohort moved past the site prior to antenna installation. The proportion of each release detected on the Jonive antenna array varied among years, ranging from 5 - 69%. Very few fish were detected on the Atascadero Creek antennas in any year in which antennas were operated. For the 2020 cohort, the number of detections declined progressively downstream in Atascadero and for the 2021 cohort, no PIT-tagged fish were detected in Atascadero. Only one fish was detected on the ATA-7.22 antenna array, which indicated an upstream movement from the confluence with Jonive Creek. Fish from only two of five cohorts of Redwood Creek releases (2017 and 2018) were detected on the Green Valley Creek array (GRE-6.13), representing 2% and 12% of the PIT-tagged fish released for those respective cohorts. Although we were unable to account for antenna efficiency in this study and generate estimates of survival, we can presume that survival through Atascadero was extremely low in most years; a minimum of 2% for the 2017 cohort and likely zero for the 2019-2021 cohorts. The highest survival documented was 12% in 2018.

Table 3. Number of unique PIT-tagged Coho Salmon originating from Redwood Creek hatchery releases and detected on PIT antenna arrays in the Atascadero watershed and/or in lower Green Valley Creek.

Cohort	Release group	PIT-tagged fish released	Number of unique PIT-tagged fish detections (proportion of release)					
			JON-2.86	ATA-7.22	ATA-5.22	ATA-1.24	ATA-0.10	GRE-6.13
2017	fall	609	5 (NA for most of first year)	NA	NA	NA	NA	15 (2%)
2018	fall	609	386 (63%)	NA	NA	3 (0.5%)	NA	73 (12%)
2019	spring	406	122 (30%)	NA	NA	0 (0%)	NA	0 (0%)
	fall	305	211 (69%)	NA	NA	0 (0%)	NA	0 (0%)
2020	spring	310	48 (15%)	1 (0.3%)	21 (7%)	1 (0.3%)	0 (0%)	0 (0%)
	fall	460	79 (17%)	0 (0%)	25 (5%)	9 (2%)	0 (0%)	0 (0%)
2021	fall	305	14 (5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

3.1.2. Timing of PIT tag detections

To gain a better understanding of Coho Salmon emigration timing in the Atascadero watershed, we plotted the first detection of each PIT-tagged fish detected at each antenna site for each cohort of hatchery-released Coho Salmon over a two year period following release from the hatchery (Figure 4 - Figure 9). We compared the timing data with stage data collected by Trout Unlimited on Green Valley Creek and dissolved oxygen data collected by GRRCD for years it was available.

3.1.2.1. Jonive Creek site

For most cohorts of fish, the majority of the PIT-tagged Coho Salmon were detected on the Jonive Creek antenna array during their first spring following release, presumably emigrating from Redwood Creek as age-1 smolts. However, for all cohorts except 2021, a proportion of the Coho Salmon were detected emigrating during their second spring, presumably as age-2 smolts. The greatest proportion of age-2 emigrants occurred with the spring 2020 release group. While age-2 smolts have been documented in other Russian River tributaries (CSG unpublished data), it appears to occur more frequently with the Redwood Creek hatchery releases.

For the 2018 and 2019 fall releases and the 2019 spring release, we observed a pulse of movement immediately following release from the hatchery. We have observed this behavior during the first few days after releases in other tributaries when fish are stocked at flow conditions that allow them to move freely. We attribute these pulses of movement as a “flight” response triggered by the abrupt change from a hatchery environment to a stream environment.

For most cohorts, in addition to spring movement, we also observed fish emigrating from Redwood Creek (JON-2.86 detections) during the winter season. For the 2021 cohort, there were very few fish detected on the Jonive array and all but one detection occurred during the winter season.

3.1.2.2. Atascadero Creek sites

The timing of first PIT tag detections at the Atascadero Creek antenna sites generally occurred during the spring season with occasional detections during the fall and winter. The one detection of a fish moving upstream in Atascadero (ATA-7.22) occurred in late October following an unseasonably high October storm event in 2021 (Figure 7).

3.1.2.3. Green Valley Creek site

For the two cohorts in which PIT-tagged Coho Salmon from Redwood Creek were detected at this site (cohorts 2017 and 2018), the majority occurred between March and May, with only one detection in late December.

3.1.2.4. Relationships to flow and dissolved oxygen

We did not observe any strong patterns between timing of first detection and stage. The majority of the detections occurred during the spring season, a typical window of time that Coho Salmon smolts emigrate to the ocean when the hydrograph is receding in coastal California streams. A late spring spate during May of 2019, however, appeared to trigger movement, as evidenced by the pulse of fish detected at both the Jonive site and the lower Green Valley site at that time (Figure 5). Winter detections of fish occurred when flows were higher, but there were too few detections during that time to determine the strength of correlation with flow.

Suitable dissolved oxygen (DO) concentrations are essential for fish survival, growth and migration and the North Coast Regional Water Quality Control Board (NCRWQCB) has listed 6.0 mg/L as a daily minimum DO objective for the Russian River Hydrologic Unit (NCRWQCB 2015). Decreases in swimming speed and growth rate can occur below this concentration (U.S. Environmental Protection Agency 1986), and juvenile salmonids consistently avoid waters with DO concentrations below 5.0 mg/L (Washington State University 2002). The lower limit to avoid mortality of salmonids is 3.0 mg/L (U.S. Environmental Protection Agency 1986). Dissolved oxygen (DO) levels in Atascadero Creek were generally poor when fish were emigrating from Redwood Creek past the Jonive antenna array (Figure 6, Figure 8, Figure 9). Although mean DO levels increased briefly during some high flow events, these storms did not typically coincide with spring smolt migration. In the case of the May 2019 storm which did coincide with smolt migration, DO must have been high enough for some Coho Salmon to reach the lower Green Valley antenna site (Figure 4, Figure 5); however, GRRCD documented a Coho Salmon mortality event in Atascadero in conjunction with low DO during this storm, suggesting that some smolts that were attempting to migrate were unable to complete their journey.

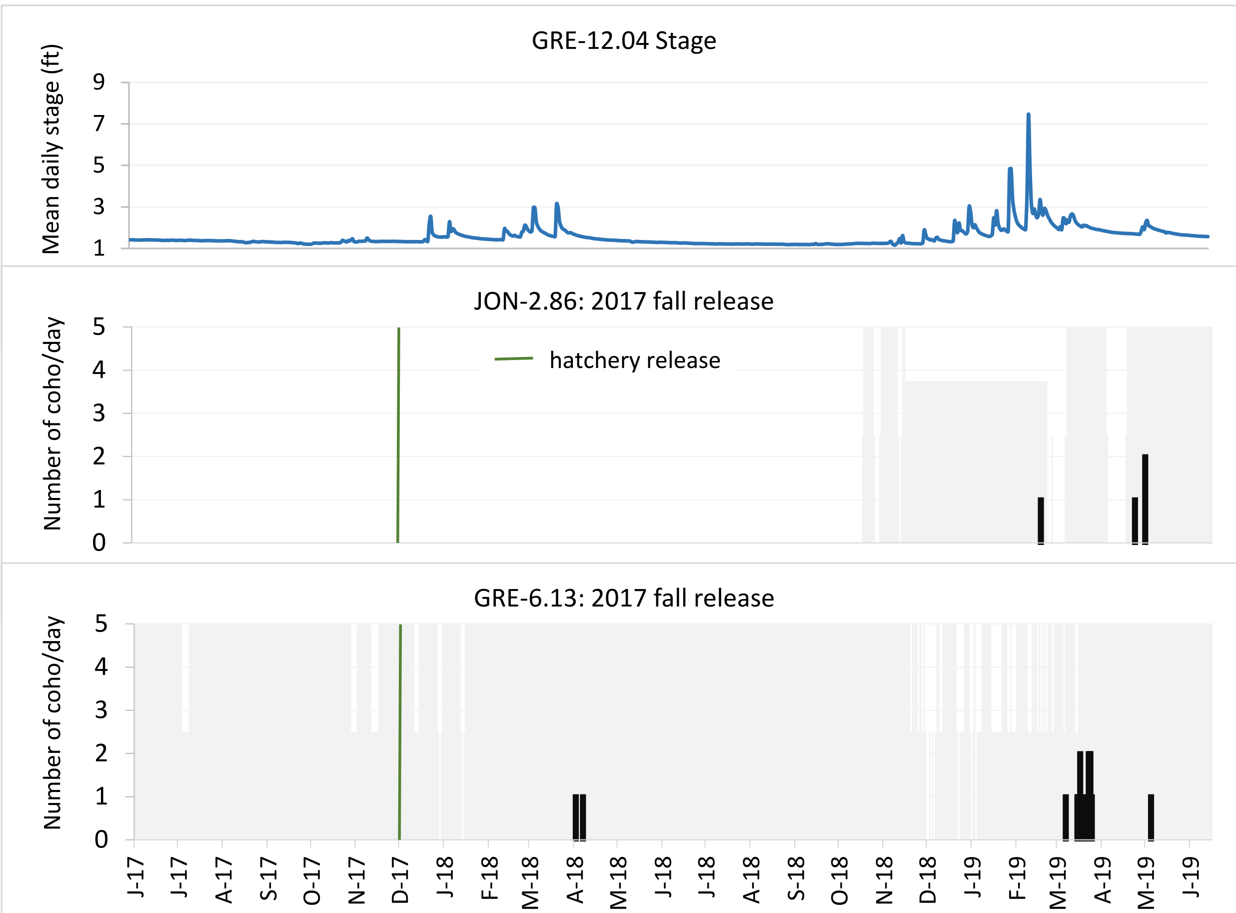

Figure 4. Emigration timing of the 2017 cohort of Redwood Creek fall-released hatchery Coho Salmon in relation to Green Valley Creek stage. Shaded background indicates when PIT antennas were in operation. Stage data was provided by Trout Unlimited.

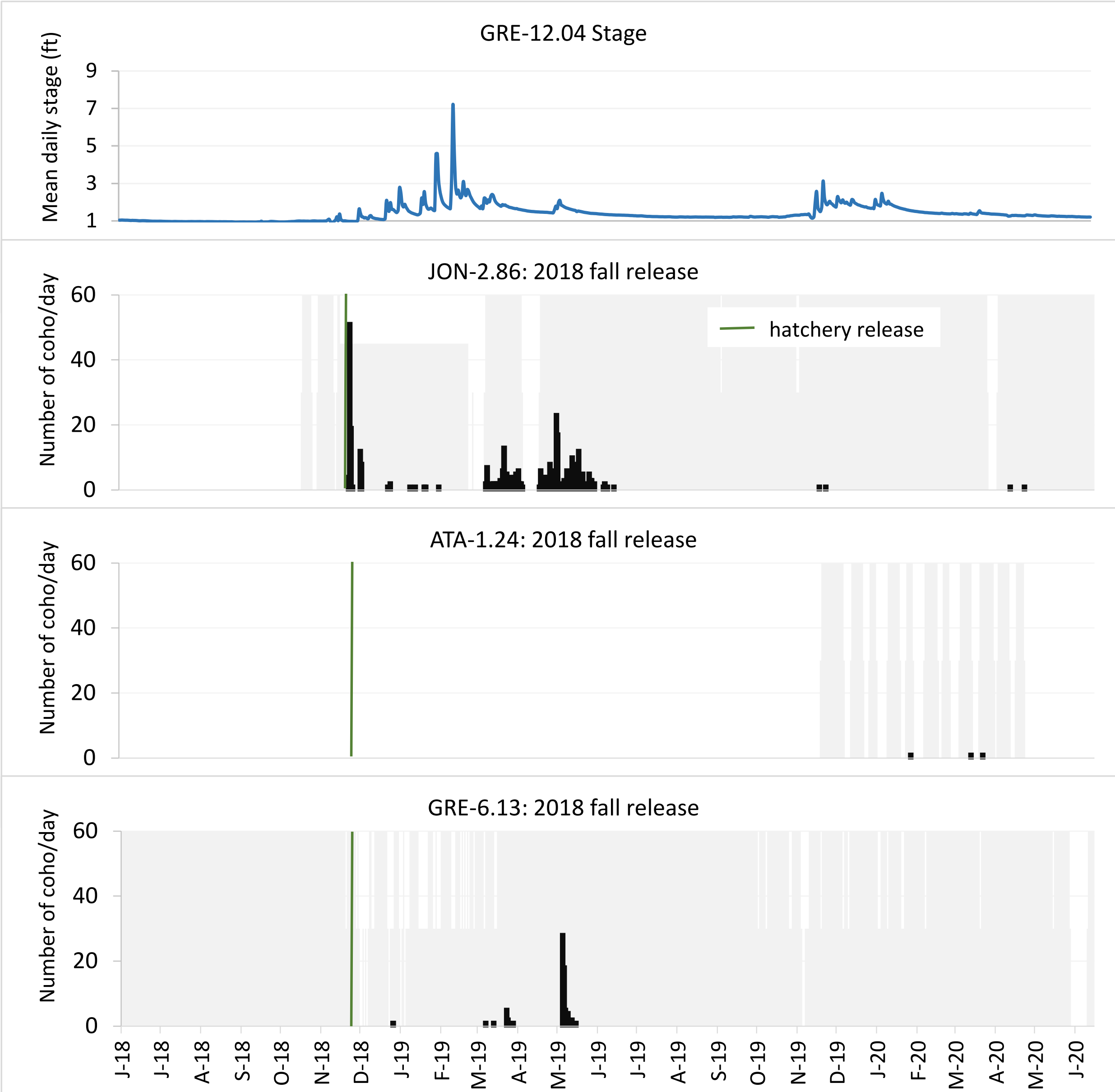

Figure 5. Emigration timing of the 2018 cohort of Redwood Creek fall-released hatchery Coho Salmon in relation to Green Valley Creek stage. Shaded background indicates when PIT antennas were in operation. Stage data was collected by Trout Unlimited.

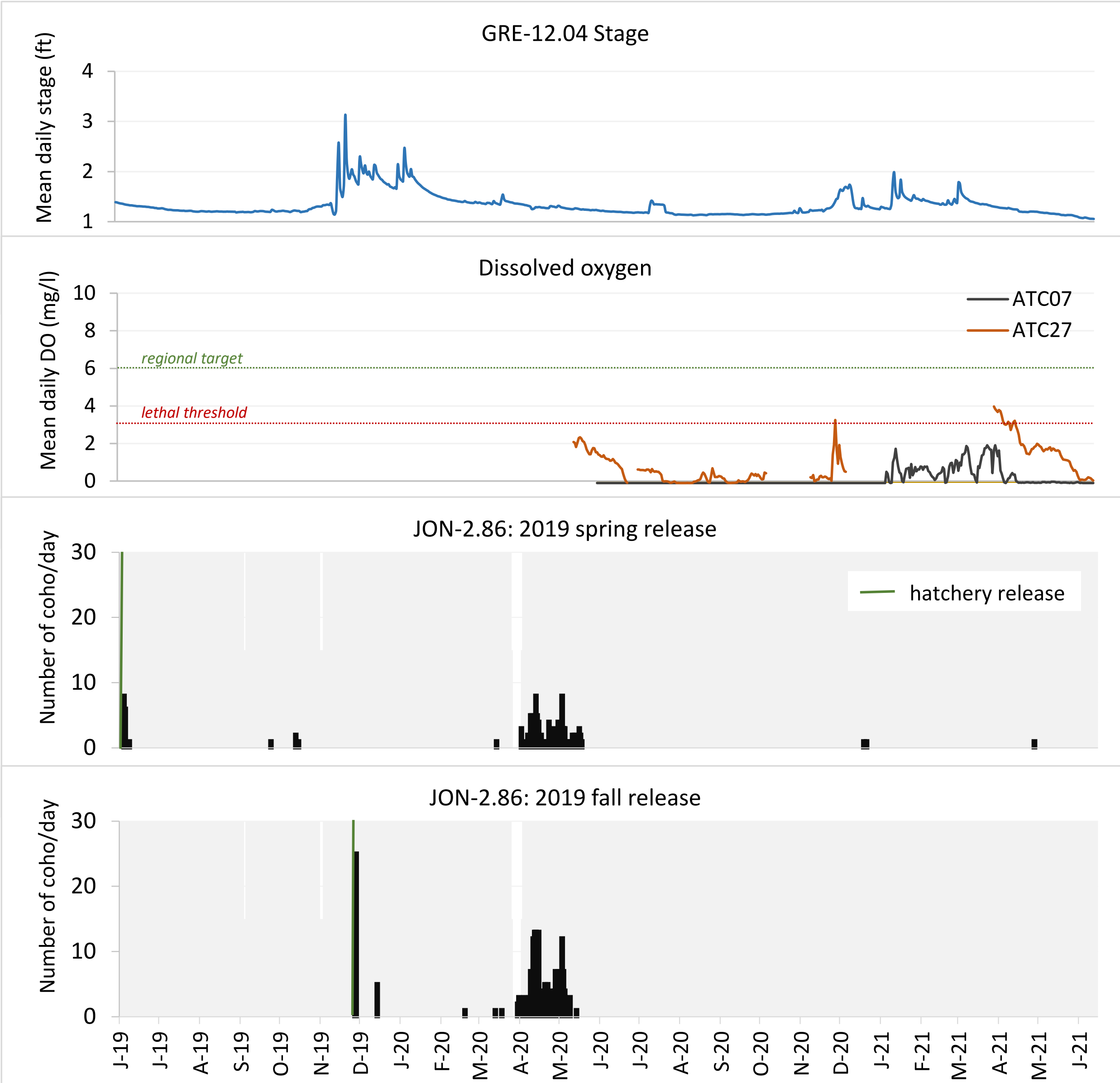

Figure 6. Emigration timing of the 2019 cohort of Redwood Creek spring- and fall-released hatchery Coho Salmon in relation to Green Valley Creek stage and dissolved oxygen at multiple sites. Shaded background indicates when PIT antennas were in operation. Stage data was collected by Trout Unlimited and dissolved oxygen data was collected by GRRCD. 2019 cohort fish were only detected at antenna site JON-2.86.

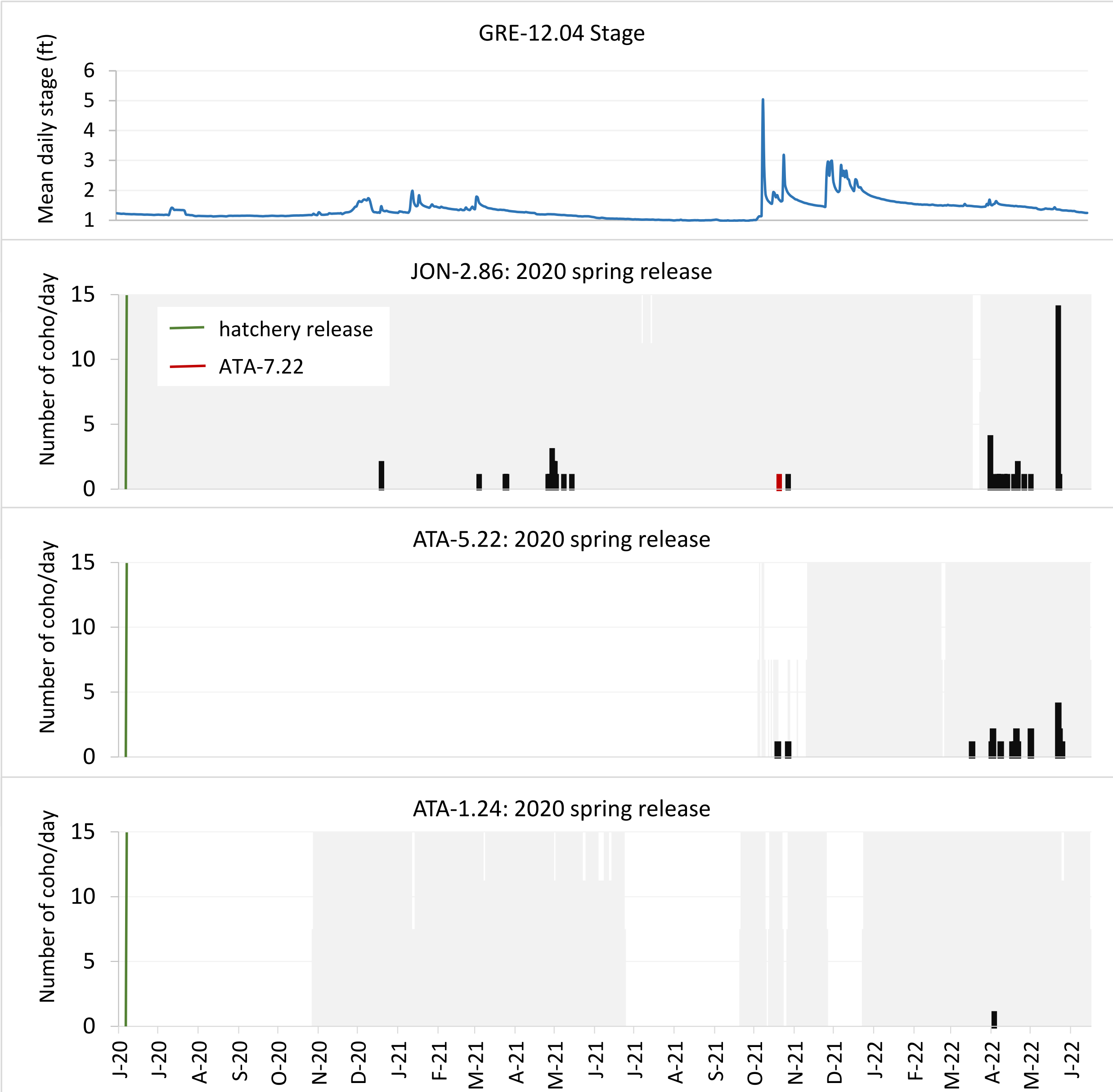

Figure 7. Emigration timing of the 2020 cohort of Redwood Creek spring-released hatchery Coho Salmon in relation to Green Valley Creek stage. Shaded background indicates when PIT antennas were in operation. Stage data was collected by Trout Unlimited. 2020 spring-release fish were not detected at antenna sites ATA-0.10.

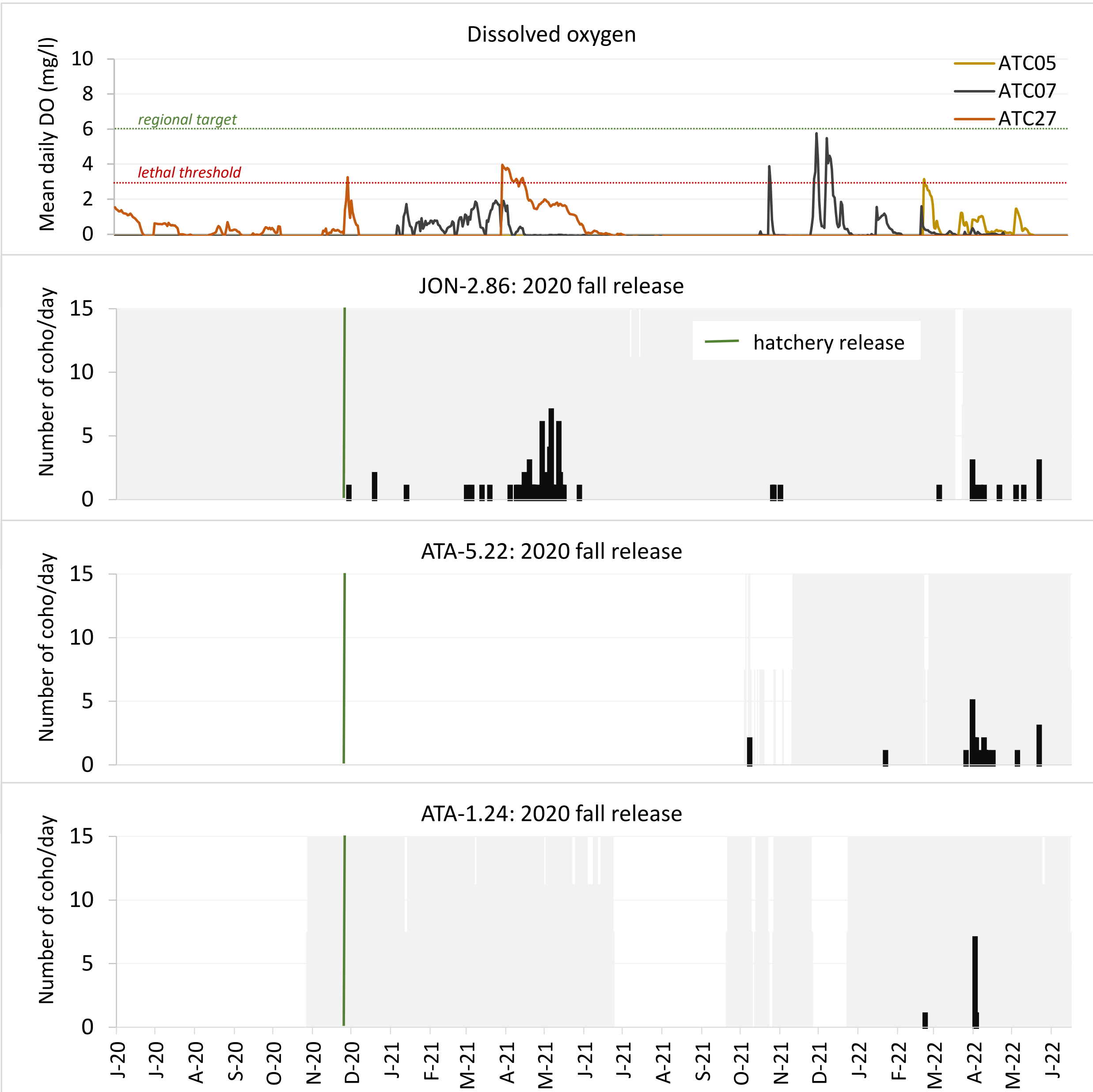

Figure 8. Emigration timing of the 2020 cohort of Redwood Creek fall-released hatchery Coho Salmon in relation to dissolved oxygen in lower Atascadero. Shaded background indicates when PIT antennas were in operation. Dissolved oxygen data was collected by GRRCD. 2020 fall-release fish were not detected at antenna sites ATA-7.22, ATA-0.10 or GRE-6.13.

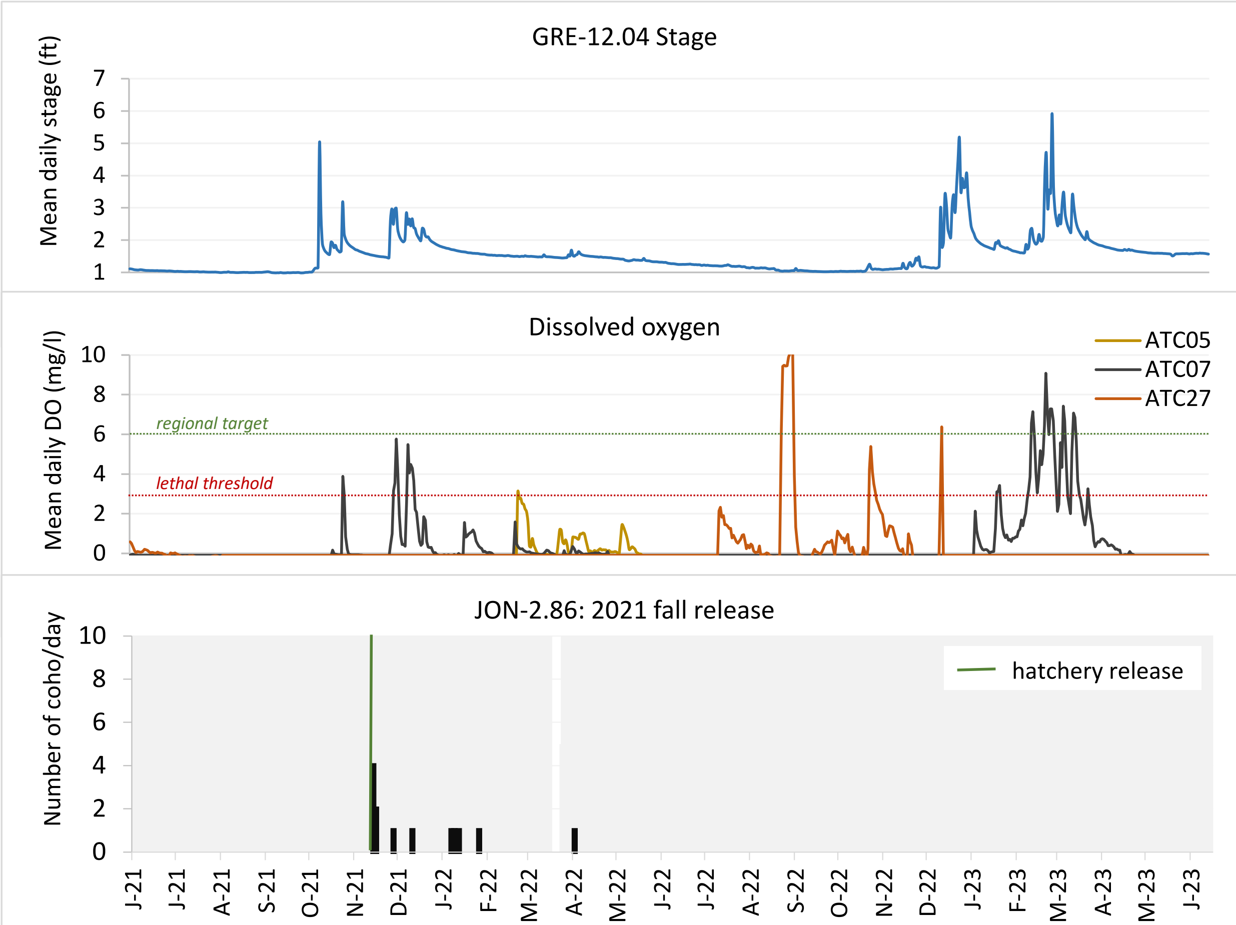

Figure 9. Emigration timing of the 2021 cohort of Redwood Creek fall-released hatchery Coho Salmon in relation to Green Valley Creek stage and dissolved oxygen at multiple sites. Shaded background indicates when PIT antennas were in operation. Stage data was collected by Trout Unlimited and dissolved oxygen data was collected by GRRCD. 2021 fall-release fish were only detected at site JON-2.86.

3.1.3. Age-2 life history strategy

In four of the five cohorts of fish released into Redwood Creek (2017-2020), we detected fish emigrating as age-2 fish (Figure 4 - Figure 8) and the majority of these fish were from the 2020 cohort. To explore where in the Atascadero watershed these fish were rearing during their two years in freshwater, we extracted individuals from the PIT tag dataset that were stocked in Redwood Creek and later detected at the JON-2.86, ATA-5.22 and ATA-1.24 sites and plotted their detection timing at each site (Figure 10). A total of 10 fish were detected at all three sites. Nine of the fish were from the fall release group and were detected at JON-2.86 (emigrating from Redwood Creek) during their age-1 spring. These fish remained in the upper reaches of Atascadero Creek (between the confluence with Jonive Creek and Atascadero at river km 5.22) for a full year until their second spring when they were detected in rapid succession at the ATA-5.22 and ATA-1.24 sites. The tenth fish was from the 2020 spring release into Redwood Creek and this fish remained in Redwood Creek until its second spring and then emigrated from Jonive Creek to ATA-5.22 over a three-day period. None of the 10 fish were detected downstream (or anywhere in the Russian River watershed) after their final detections on the ATA-1.24 antenna.

Juvenile Coho Salmon were observed during CMP snorkeling surveys in Redwood Creek each year from 2019 through 2023 and counts ranged from three in 2019 to 124 in 2021 (CSG unpublished data). All of these fish are thought to be hatchery-origin fish that remained in Redwood Creek for an additional year (as opposed to resulting from natural spawning). In August of 2021, CDFW conducted an electrofishing survey in Redwood Creek and captured juvenile Coho Salmon (Will Boucher, personal communication). They observed two distinct size classes of Coho Salmon and scanning for PIT tags revealed the presence of both spring and fall cohort 2020 Redwood Creek release fish (Figure 11).

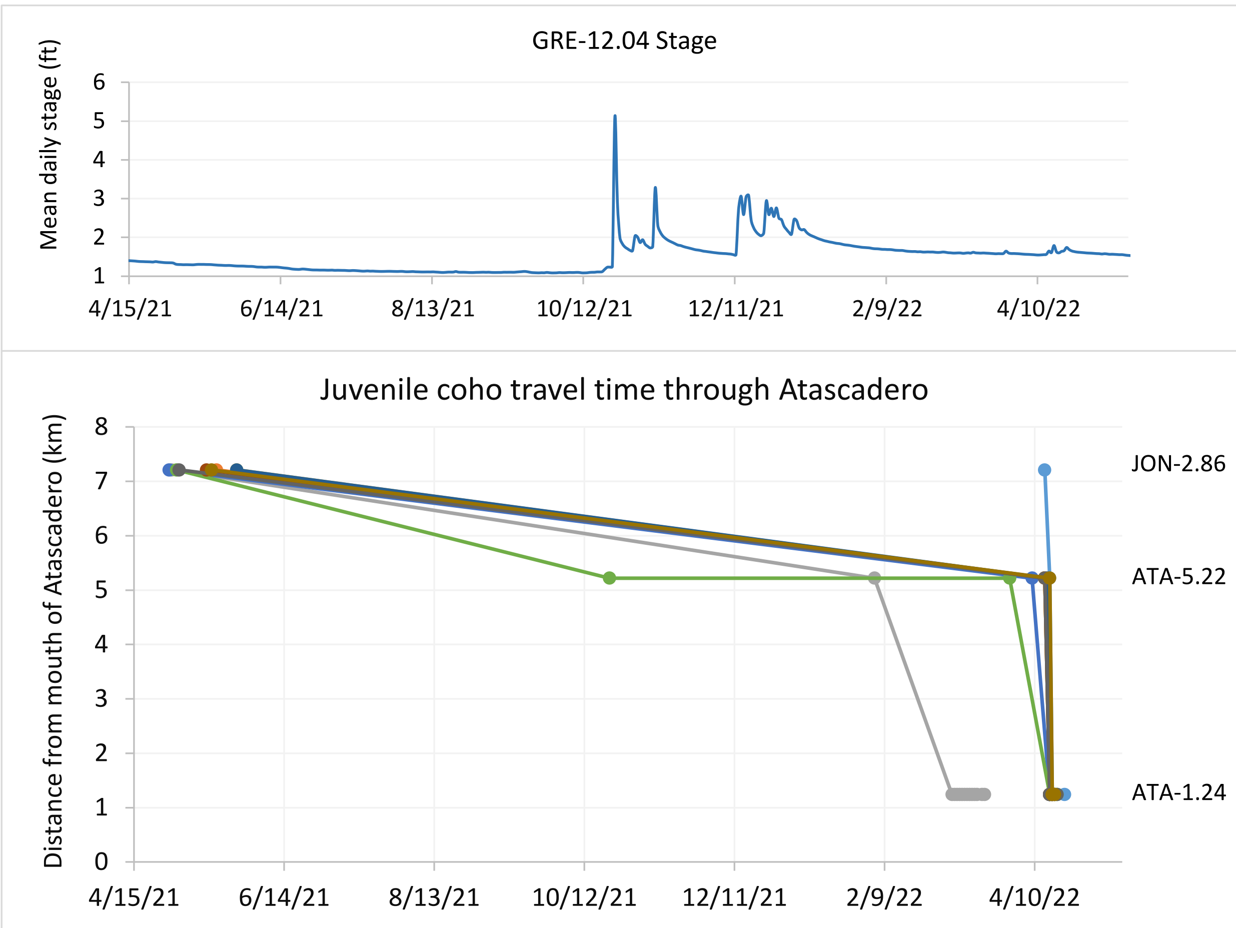

Figure 10. Detection timing of ten individual Coho Salmon released into Redwood Creek in spring or fall of 2020 and later detected on Jonive Creek and Atascadero Creek PIT antenna arrays. Green Valley Creek stage data was provided by Trout Unlimited.

Figure 11. Hatchery Coho Salmon juveniles captured during a CDFW summer electrofishing survey in 2021. The fish on the left is from the 2020 spring release into Redwood Creek and the fish on the right is from the 2020 fall release into Redwood Creek.

3.2. Detections of fish from other Russian River tributaries in Atascadero watershed

To examine use of Atascadero Creek by fish that originated from other streams, we queried the Russian River PIT tag database that includes all records of PIT-tagged fish released from Don Clausen Fish Hatchery at Warm Springs Dam as well as any fish PIT-tagged during field surveys. We extracted all PIT tag detections on the Jonive and Atascadero antenna arrays and summarized the number of unique individuals by species, and stream and year of tagging or release (Table 4).

A total of 305 individual Coho Salmon originating from outside the Atascadero watershed were detected on the antenna array below the project reach (ATA-0.10), 58 were detected at ATA-1.24 upstream of the project reach, and one was detected in Jonive Creek at the JON-2.86 site. The majority of these Coho Salmon were of hatchery-origin, but detections included a few natural-origin Coho Salmon that were tagged during Coastal Monitoring Program (CMP) electrofishing surveys in Purrington Creek. Fish from fall, presmolt and smolt Coho Salmon hatchery release groups were detected on the lower Atascadero arrays, while the one Coho Salmon detected on the Jonive array was from a fall release group into Purrington Creek. One Coho Salmon originated from a fall release into Dutch Bill Creek (outside of the Green Valley Creek watershed) on 12/13/22. This fish was detected on an antenna array in Dutch Bill Creek (river km 6.51 at Westminster Woods) on 12/16/22 and 1/10/23, then in Green Valley Creek at site GRE-6.13 on 1/26/23 and finally at the mouth of Atascadero Creek at site ATA-0.10 on 2/23/23. Between 1/10/23 and 1/26/23, this fish swam upstream in the mainstem of the Russian River when flow ranged from 3,100 to 33,100 ft^3/s at the USGS Hacienda gage.

Of the 305 non-natal Coho Salmon detected at the downstream-most Atascadero antenna array (ATA-0.10), the majority (223) were not detected further upstream. These fish may not have swam any further upstream into Atascadero (i.e., briefly swam up into the lowest antenna array and then turned around) or they may have swam further up into Atascadero and never returned. Seventeen of the 305 were later detected upstream on the ATA-1.24 antenna and then never observed again. Sixty-five of the

305 were detected at a later date at Green Valley Creek antenna sites downstream and/or upstream of the confluence with Atascadero Creek, indicating their survival after entering Atascadero. The fate of the remaining 240 fish is unknown.

Natural-origin steelhead were also detected entering Atascadero Creek, with 19 individuals detected at ATA-0.10 and seven at ATA-1.24. All of the PIT-tagged steelhead originated from CMP electrofishing surveys conducted during the summer season, and all were tagged in Purrington Creek with the exception of one fish that was tagged in Green Valley Creek.

To explore the timing of entry of non-natal salmonids into Atascadero, we plotted the first detection of each individual Coho Salmon and steelhead at the ATA-0.10 antenna array in relation to flow and hatchery release timing for cohorts 2020 through 2022 (Figure 12 - Figure 14). The distribution of Coho Salmon and steelhead detections spanned multiple months across a range of flows, including relatively low flows, suggesting that fish intentionally swam upstream into Atascadero. If we had only detected fish during extreme storm events when the confluence of Atascadero with Green Valley was flooded, we might have concluded that fish traveling through Green Valley were simply bumping up against the lower Atascadero antenna array.

Table 4. Number, species and origin of PIT-tagged fish detected on antenna arrays in the Atascadero watershed.

					Stream of origin or release			
Species	**Antenna site**	**Cohort (Hatch year)**	**Release group**	**Tagging location**	**Green Valley**	**Purrington**	**Dutch Bill**	**Total individuals**
Coho Salmon	ATA-0.10	2019	smolt	hatchery	1			305
		2020	fall	hatchery	46			
			presmolt	hatchery	102			
			smolt	hatchery	10			
		2021	fall	hatchery	33	15		
		2022	fall	hatchery			1	
			presmolt	hatchery		93		
			smolt	hatchery	3			
			NA	spring downstream migrant trap	1			
	ATA 1.24	2018	presmolt	hatchery	1			58
		2019	fall	hatchery	8	2		
			NA	summer electrofishing	2	3		
		2020	fall	hatchery	7			
			presmolt	hatchery	5			
		2021	fall	hatchery	26	4		
	JON-2.86	2021	fall	hatchery		1		1

steelhead	ATA-0.10	2019	NA	summer electrofishing		1		19
		2020	NA	summer electrofishing		17		
		2022	NA	summer electrofishing		1		
	ATA 1.24	2019	NA	summer electrofishing	1	2		7
		2020	NA	summer electrofishing		4		

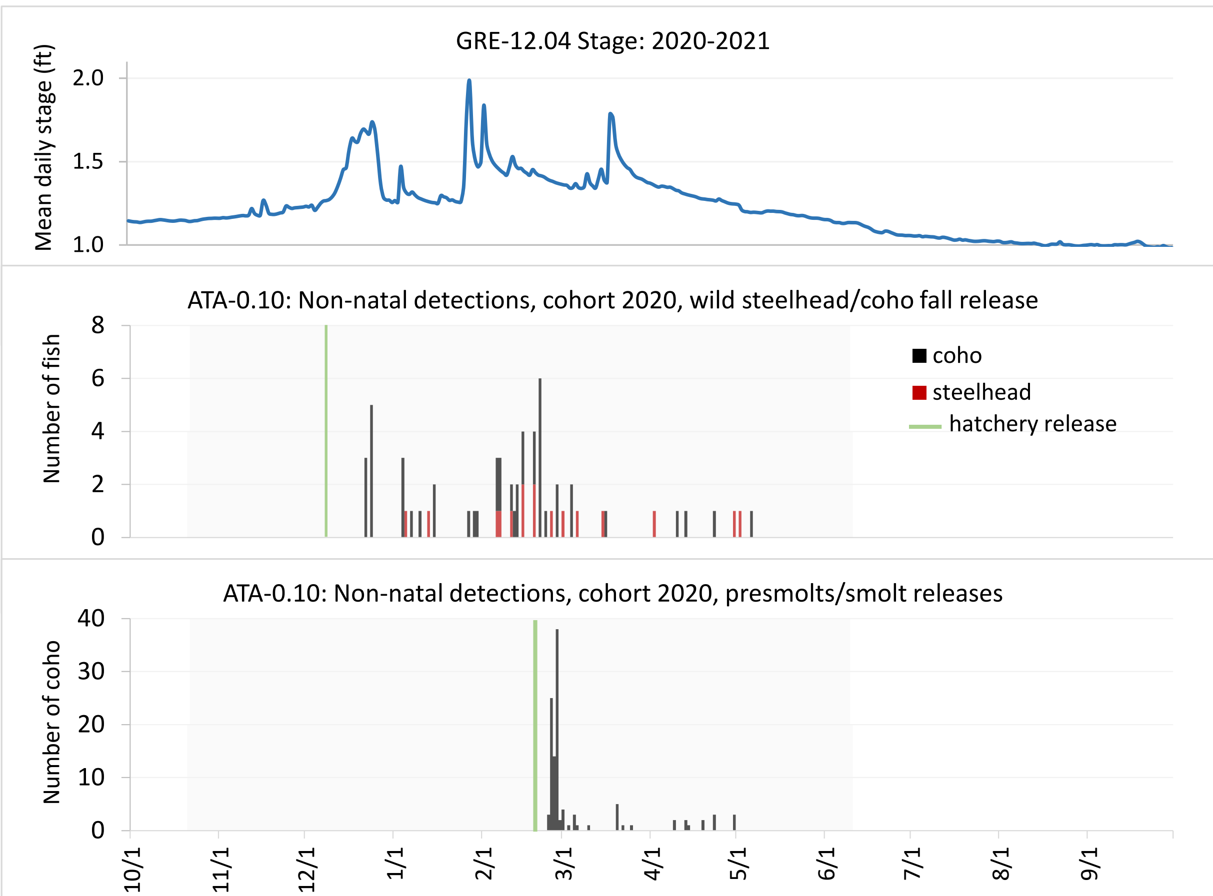

Figure 12. Timing of non-natal PIT-tagged salmonid detections in Atascadero in relation to flow, 2020-2021. Shaded background indicated when antennas were in operation. Stage data was provided by Trout Unlimited.

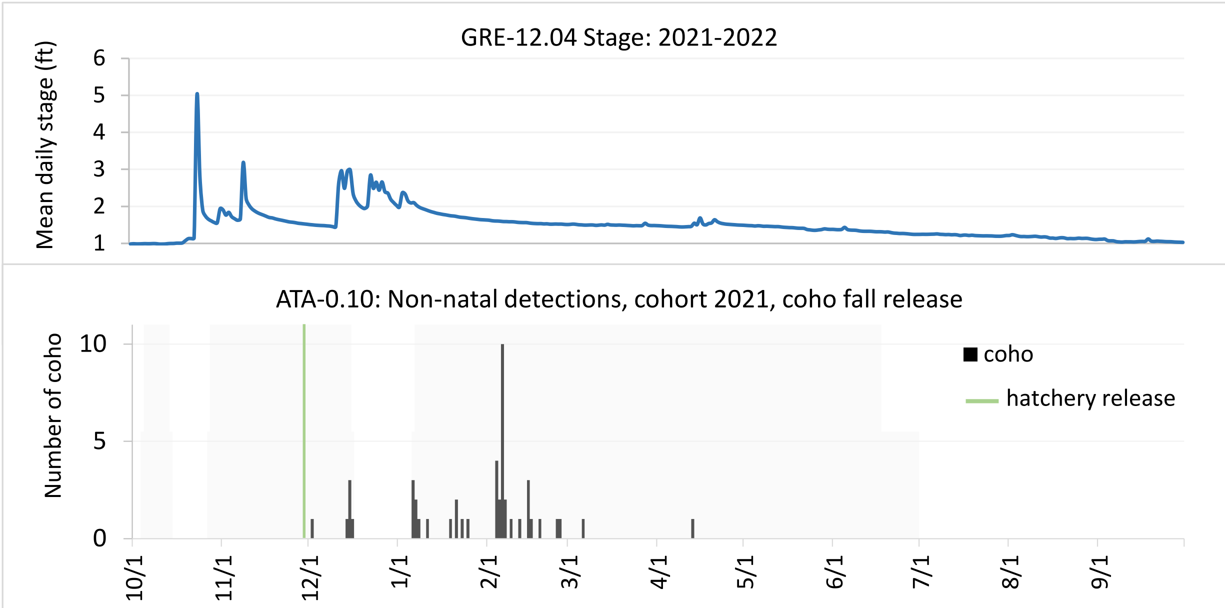

Figure 13. Timing of non-natal PIT-tagged Coho Salmon detections in Atascadero in relation to flow, 2021-2022. Shaded background indicated when antennas were in operation. Stage data was provided by Trout Unlimited.

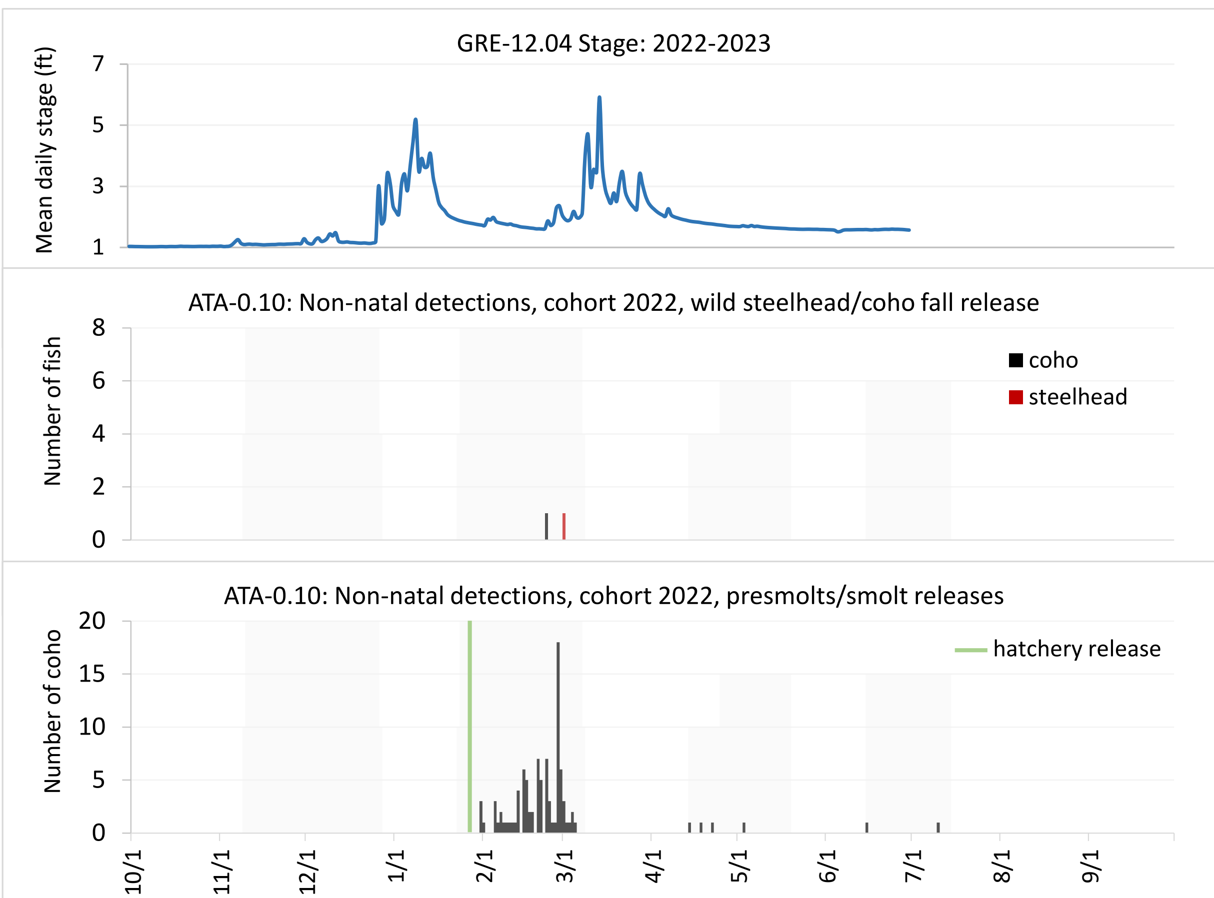

Figure 14. Timing of non-natal PIT-tagged Coho detections in Atascadero in relation to flow, 2022-2023. Shaded background indicated when antennas were in operation. Stage data was provided by Trout Unlimited.

4. Residence time in Atascadero reaches

4.1. Residence time in the lower Atascadero project reach (ATA-0.10 – ATA-1.24)

To calculate residence time in the project reach, we extracted fish from the PIT tag dataset that were detected on both ATA-0.10 and ATA-1.24, the arrays located immediately upstream and downstream of the project reach. There were a total of 21 individual fish detected at both sites. None of these fish originated from Redwood Creek releases and all of them were immigrating from Green Valley or Purrington creeks into Atascadero Creek. The 21 fish included 15 Coho Salmon originating from Green Valley Creek, two Coho Salmon originating from Purrington Creek, and four steelhead originating from Purrington Creek. All except one of these fish were detected on ATA-0.10, then ATA-1.24, and then never observed again. One was detected on ATA-0.10 then ATA-1.24 and then ATA-0.10. None of the 21 were detected on any arrays in the Russian River watershed following their detections in Atascadero. The majority (18) of the fish moved through the project reach within one day, while three remained in the project reach for 22 days, between 12/15/21 and 1/6/22 (Figure 15).

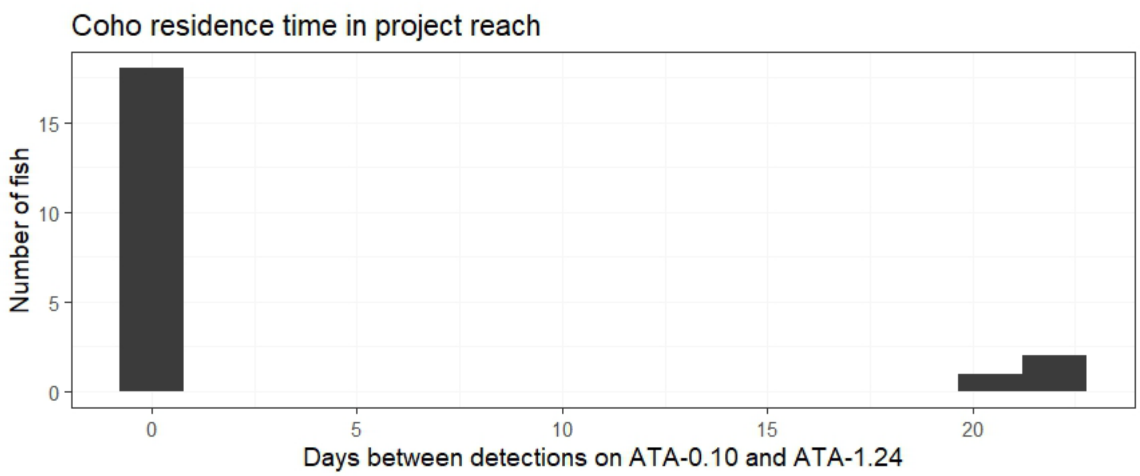

Figure 15. Frequency of Coho Salmon residence time in the project reach for juvenile Coho Salmon detected on both the ATA-0.10 and ATA-1.24 antenna arrays.

4.2. Residence time in the upper Atascadero reach (JON-2.86 – ATA-5.22)

A total of 46 Coho Salmon were detected on both the JON-2.86 and ATA-5.22 antenna arrays. All fish were Coho Salmon that originated from Redwood Creek releases and were moving in a downstream direction. Twenty-six of the individuals moved through the reach in less than one week, 16 remained in the reach between eight and 281 days, and 12 remained in the reach for over 300 days (Figure 16).

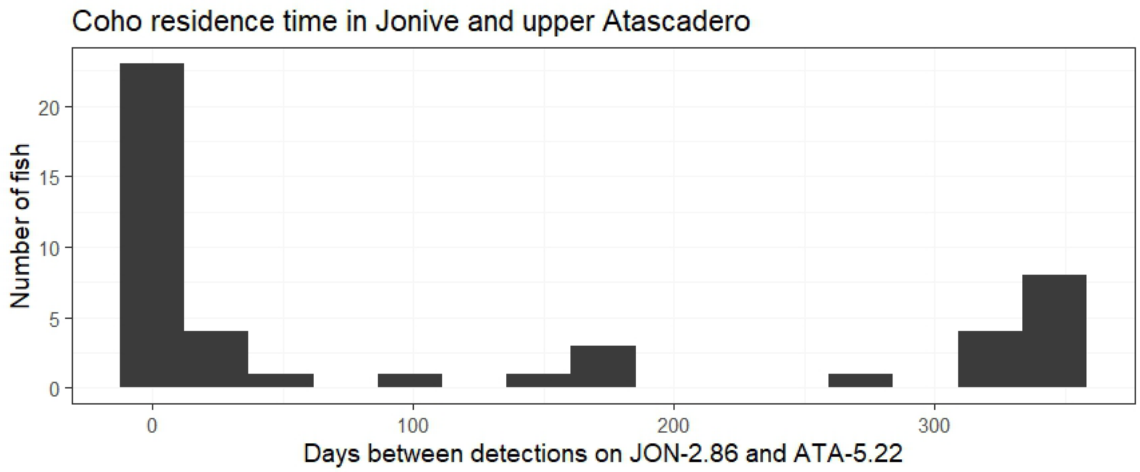

Figure 16. Frequency of juvenile Coho Salmon residence time between the JON-2.86 and ATA-5.22 antenna arrays.

4.3. Residence time in the middle Atascadero reach (ATA-5.22 – ATA-1.24)

A total of 10 Coho Salmon were detected on both the ATA-5.22 and ATA-1.24 antenna arrays. All fish were Coho Salmon that originated from Redwood Creek releases and were moving in a downstream direction. Seven Coho Salmon moved through the reach in one to two days, and the remaining three moved through in 7, 16, or 31 days (Figure 17).

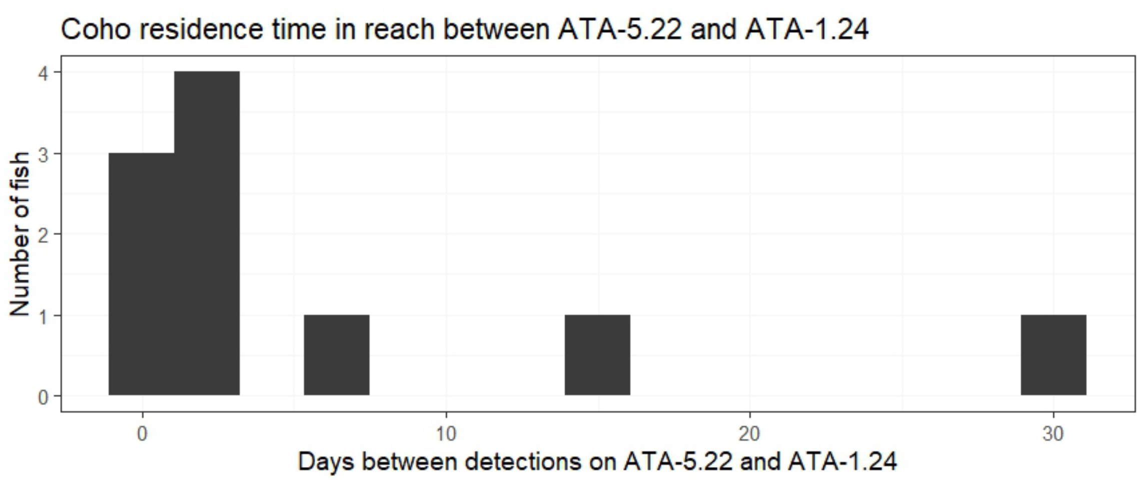

Figure 17. Frequency of juvenile Coho Salmon residence time between the ATA-5.22 and ATA-1.24 antenna arrays.

4.3.1. Adult returns

Two age-3 adult returns resulted from PIT-tagged hatchery Coho Salmon releases into Redwood Creek (Table 5). The first fish (3DD.003BF26B6F) was released on 12/1/17, prior to installation of any PIT antennas in the Atascadero watershed. It was detected returning as an age-3 adult during the winter of

2019-2020 and was first observed moving upstream and downstream in Green Valley during the month of December before moving into Atascadero Creek on December 31 and was then detected at the Jonive Creek antenna array two weeks later.

The other age-3 adult originated from the 2018 fall release into Redwood Creek. Fish number 3DD.003D358698 was detected leaving Redwood Creek on December 17, just 10 days after it was released as a juvenile. It was not detected at the GRE-6.13 site in lower Green Valley until May of the following year, when it was presumably emigrating as a smolt. We did not have antenna arrays in Atascadero during the winter/spring of 2018-2019 so we have no indication of where this fish overwintered as a juvenile, but can conclude that it resided between the JON-2.86 and GRE-6.13 sites. This fish was detected as an age-3 fish during the winter of 2020-2021 on the mainstem of the Russian River at Mirabel dam as well as on an antenna array located on Dry Creek near its confluence with the Russian River. This fish was not documented returning to Redwood Creek.

Fish number 3DD.003D3586AA emigrated as a juvenile from Redwood Creek on 3/22/19 and was then detected as an age-2 fish on November 27 at Mirabel dam. We are unable to determine whether this fish was an age-2 juvenile moving downstream in the mainstem of the Russian River or an age-2 adult moving upstream.

Table 5. PIT antenna detection histories of three PIT-tagged Coho Salmon released into Redwood Creek that returned to the Russian River watershed as adults.

PIT Number	Date(s)	Antenna site	Comments
3DD.003BF26B6F	12/1/2017	NA	released into Redwood Creek as fall parr
	12/3/19 - 12/18/19	GRE-6.13	age-3 adult
	12/18/19 - 12/19/19	GRE-9.98	
	12/22/2019	GRE-6.13	
	12/30/2019	GRE-9.98	
	12/31/2019	ATA-1.24	
	1/13/20 - 1/26/20	JON-2.86	
3DD.003D358698	12/7/2018	NA	released into Redwood Creek as fall parr
	12/17/2018	JON-2.86	presumably emigrating from Redwood Creek as a parr
	5/19/2019	GRE-6.13	presumably emigrating from Green Valley Creek as a smolt
	12/13/20 - 12/15/20	Mirabel fish ladder	age-3 adult; Russian River mainstem: river km 28.14
	12/26/20 - 1/4/21	DRY-0.36	antennas located near USGS gage
	1/17/2021	Mirabel fish ladder	
3DD.003D3586AA	12/7/2018	NA	released into Redwood Creek as fall parr
	3/22/2019	JON-2.86	
	11/27/2019	Mirabel fish ladder	age-2 fish; unable to determine whether it was a juvenile or an adult

Discussion

4.4. Coho Salmon migration and survival through Atascadero Creek

The results of this monitoring work demonstrate that, in some circumstances, it is possible for both juvenile and adult Coho Salmon to navigate the lower Atascadero project reach. In most years of the study, however, the Atascadero corridor posed a severe bottleneck to migration and survival. For five cohorts of juvenile hatchery Coho Salmon released into Redwood Creek, very few fish completed their migration to Green Valley Creek, and most of them were never observed again following their entry into Atascadero Creek.

With the exception of 2021, an extreme drought year, a high proportion of Coho Salmon that were released into Redwood Creek were detected on the Jonive antenna array (JON-2.86), emigrating from Redwood Creek (Table 3). For the 2018 – 2020 cohorts, an average of 39% (range 15 – 69%) of the fish survived in Redwood Creek and were detected on the Jonive array. For the 2017 cohort, only five fish were detected on the Jonive array, but this was not surprising because the antennas were not in place for the first year after the 2017 release. The percentage of Coho Salmon detected on the Jonive array for the 2021 cohort was also low (5%), and this is likely attributed to the extreme drought conditions of 2021. Extensive wetted habitat surveys conducted throughout the Russian River watershed during late summer of 2021 documented extreme stream drying and poor water quality conditions in most tributaries surveyed (see CSG wetted habitat dashboard) so it is possible that the fish released into Redwood Creek in late-November of 2021 experienced less than suitable conditions that impacted their survival. This cohort also experienced record hot temperatures in the hatchery environment prior to release which may have also impacted their survival.

While in most years a high proportion of Coho Salmon released into Redwood Creek survived and emigrated past the Jonive antenna array, very few detections of these fish on the Atascadero and lower Green Valley antenna arrays suggest a bottleneck to migration and survival in Atascadero Creek. Successful passage through Atascadero Creek occurred only for a small proportion of Coho Salmon from only two of the five cohorts of fish released into Redwood Creek (Table 3). No fish from the 2019 or 2021 cohorts were detected downstream of the Jonive array, and for the 2020 cohort, the number of detections on the antenna arrays declined progressively downstream, with no detections at the mouth of Atascadero or in lower Green Valley. This pattern closely mirrors a spatial pattern of declining DO from upstream to downstream measured at grab sample sites in Atascadero Creek by CDFW in 2019 (GRRCD and OEI 2021).

At least nine fish from the 2020 cohort survived a full year downstream of the Jonive antenna array and upstream of the Atascadero array at Mill Station Road (ATA-5.22) (Figure 10, Figure 16) suggesting that survival is possible in upper reaches of the Atascadero watershed. From the extremely low number of detections on the antennas in lower Atascadero and the progressively poorer water quality conditions moving downstream, we can infer that survival is likely progressively worse in the lower reaches of Atascadero, including the project reach.

One Coho Salmon adult originating from the 2017 cohort of Coho Salmon released into Redwood Creek survived and completed its migration to and from the ocean and back to Redwood Creek as an age-3 adult (Table 5). While it was only a single fish, it does suggest that when conditions are suitable, it is possible for fish to complete their life cycle in the Atascadero watershed. It also lends support for the Atascadero bottleneck being a water quality barrier rather than a complete physical passage barrier.

4.5. Use of project reach by fish from other streams

Over 300 juvenile Coho Salmon individuals and over 20 juvenile steelhead individuals from outside of the Atascadero watershed were detected entering Atascadero Creek. The majority originated from Green Valley or Purrington creeks and included both natural- and hatchery-origin fish (Table 4). One hatchery Coho Salmon originated from Dutch Bill Creek. Depending on the cohort, a range of 1.8 – 5% of the PIT-tagged hatchery fish released into Green Valley or Purrington in the fall were detected entering Atascadero, and the range for presmolts was 6.7% - 11.8%.

Most of the non-natal fish were detected only on the lowest antenna array (ATA-0.10), located approximately 0.33 river km upstream of Atascadero's confluence with Green Valley Creek, so we are unsure how far upstream those fish swam into the project reach. Of 305 Coho Salmon that were detected at the lowest Atascadero array, 21% were later detected on an array in Green Valley indicating that they survived, but we are uncertain of the fate of the remaining fish. For the few fish (21) that were detected at the two antenna arrays bounding the project reach (ATA-0.10 and ATA-1.24) almost all of them moved through the project reach on the same day (Figure 15) and none of them were observed again. This data provides evidence that non-natal juvenile salmonids are attempting to utilize habitat in Atascadero, and while at least 21% survived after entering, it is likely that the remainder were impacted by the poor water quality conditions in the Atascadero creek/marsh habitat.

4.6. Life history patterns

The age-2 smolt life history is unusual in Russian River tributaries and we were surprised to observe such a high proportion of the Redwood Creek Coho Salmon releases express this strategy. The pattern appeared most strongly with the spring releases which spend a longer period of time in the stream environment.

During the summer of 2021, 124 juvenile Coho Salmon were observed during CMP snorkel surveys on Redwood Creek. The fish observed were of similar size to young-of-year in other Russian River tributaries; however, subsequent electrofishing surveys in Redwood Creek by CDFW revealed that these fish were hatchery releases from 2020 (as evidenced by the presence of coded wire and/or PIT tags). The fish were surprisingly small for their age (Figure 11) and this is likely attributable to low growth rates. Low growth could have resulted from stocking at densities too high for the level of productivity (i.e. food) available in Redwood Creek. On average, Redwood Creek is cooler than most Russian River tributaries (Figure 18) which could influence primary productivity and, in turn, growth opportunity of rearing juveniles and age at smolting. For example, Metcalfe and Thorpe (1990) found that cooler temperatures are associated with lower growth rates and older age at smolting.

Although less likely, it is also possible that the presence of barriers (physical or water quality-related) may have contributed to the higher proportion of age-2 smolts (i.e., if fish were unable to emigrate in their first year due to barriers, they may have remained in Redwood or Jonive creeks for an additional year and then attempted emigration during their second year).

4.7. Considerations for restoration

Because of its high surface flows and cool temperatures during the summer season relative to other Russian River tributaries, Redwood Creek offers high potential for oversummer survival of rearing juvenile salmonids, and this was validated by the high proportion of Coho Salmon emigrating from Redwood Creek in most years of our study. However, the small size of the fish captured during CDFW electrofishing surveys suggests that growth potential is limited in this creek.

Low-gradient stream habitat typically supports high overwinter survival and high growth of juvenile salmonids by providing refuge from high flows and high prey availability. While Atascadero Creek has the potential to provide suitable overwinter rearing habitat, the low water quality conditions appear to be preventing this from being realized. Recent studies have highlighted the importance of habitat heterogeneity as a key factor in supporting life history diversity and production, which, in turn, allows populations to respond to environmental change and increase overall population stability. If water quality and habitat conditions in the lower reaches of Atascadero could be improved to the point of supporting salmonids, the complex of habitat within the Atascadero (and larger Green Valley) watershed could more capably support the salmonid life cycle. Redwood Creek could provide adult spawning habitat and juvenile oversummer rearing habitat and Atascadero Creek could provide overwinter habitat and the growth opportunity necessary to increase their size prior to entering the marine environment.

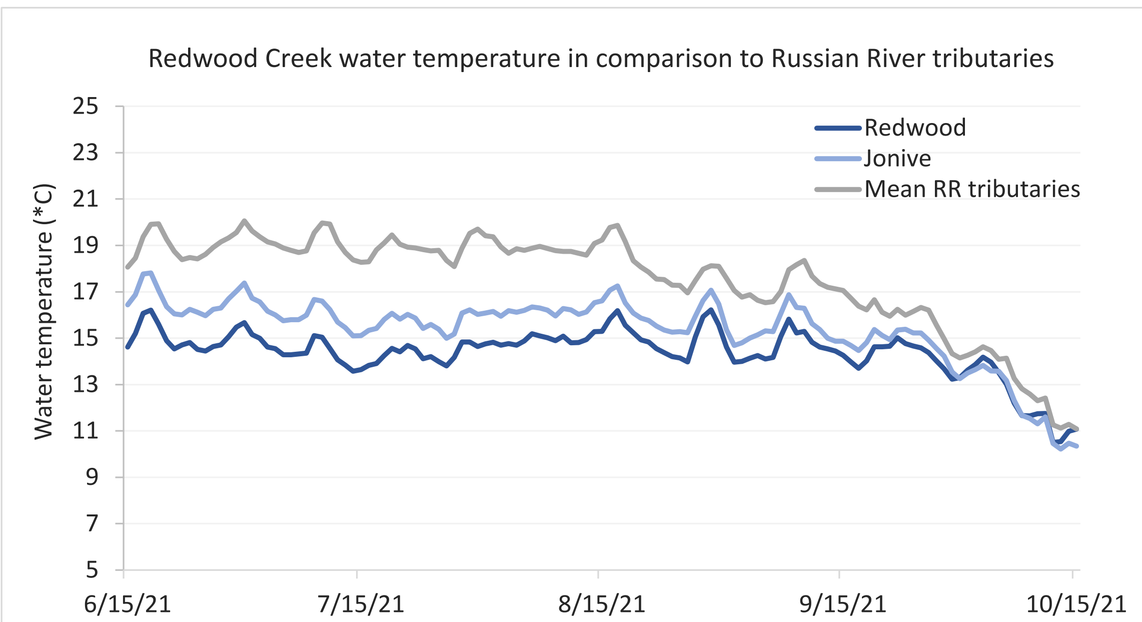

Figure 18. Mean daily water temperatures in Redwood Creek, Jonive Creek and the mean of 24 Russian River tributaries in 2021.

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