# 2021 Progress Report: Using acoustic telemetry to estimate reach-specific riverine and estuarine salmonid survival in the Russian River watershed

## Introduction

In 2021, Sonoma Water and California Sea Grant (CSG) partnered with the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC) to conduct a pilot project using acoustic telemetry to estimate reach-specific travel time and survival of Coho Salmon smolts through the migration corridor from Dry Creek to the lower Russian River estuary. This portion of the watershed encompasses the majority of current and historic coho habitat in the basin and provides habitat for a significant portion of the Chinook Salmon and steelhead populations in the basin. Our intention is to use results from this pilot year to help guide efforts for similar work in future years. Methods and results from data collected in 2021 are provided in this document.

Overall project goals are to:

- Inform questions related to release strategies of hatchery-reared Coho Salmon (e.g., when to release, where to release, what life stages to release).
- Provide a broad scale context to better validate targeted management and recovery measures in freshwater (e.g., Dry Creek habitat enhancement).
- Allow the decoupling of riverine smolt migration survival from estuarine and ocean survival.

Objectives in the 2021 pilot project year were to:

- Evaluate performance of acoustic tags and receivers for meeting overall project goals
- Choose and evaluate receiver location (gates)
- Develop estimates of reach-specific travel time and survival for hatchery-reared Coho Salmon smolts

## Methods

### Fish tagging and release

Coho salmon reared at Don Clausen Warm Springs Fish Hatchery were used for this study. These fish were part of the annual group of fish produced to augment coho populations in the Russian River watershed. Individuals were tagged on two separate dates: Apr 23 for the first group and Apr 29 for the second group. Fish ranged in size from 110 to 160 mm FL (mean, 131.8 mm) and there was no difference in FL between groups (t-test; $P = 0.26$).

To check for tag loss and mortality, fish were held in the hatchery prior to release (group 1: 6 d; group 2: 7 d). There was 1 mortality observed from group 1 during the post-tagging period. That tag was re-applied to a fish in group 2 making a total of 49 fish in group 1 and 51 fish in group 2. Group 1 was released on Apr 29 at 1100 hours and group 2 was released on May 6 at 1200 hrs.

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All fish were released at the wellfield (river km 21.27, Figure 1) immediately downstream of the hatchery.

## Equipment

Acoustic tags and receivers were manufactured by Innovasea. All fish were tagged intraperitoneally with a 307 kHz, 4 mm diameter by 15 mm long acoustic tag (Innovasea V3 acoustic tag). We used the HR3 autonomous cableless receiver (Innovasea HR3 receiver). Tags and receivers were configured to use the HTI coding structure. Receivers were mounted on 23 kg anchors and generally placed in deeper portions of gate locations.

## Study location

Acoustic receivers were deployed at eight locations from the mouth of Dry Creek to Patty's Rock at the downstream end of the Russian River estuary (Figure 1, Table 1). The distance from the release site in Dry Creek to ocean entry is 73.19 km. The upstream-most 21.27 km of the migration route is through Dry Creek. The next 61.63 km are through the mainstem Russian River and the final 11.56 km are through the Russian River estuary. There is year-round juvenile coho rearing habitat in Dry Creek but, because of warm temperatures, rearing habitat for coho in the mainstem Russian River is likely restricted to winter through spring.

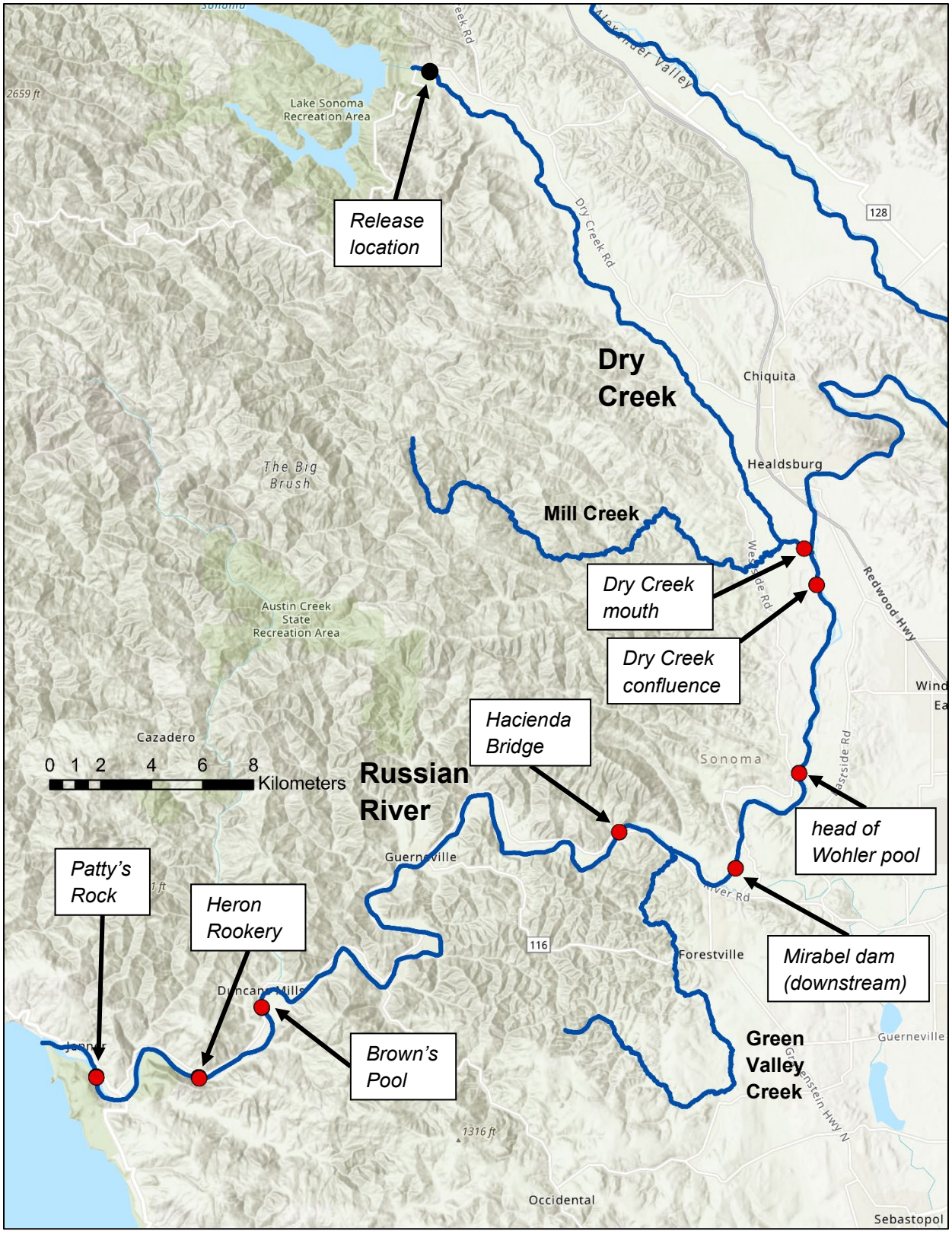


**Figure 1. Acoustic receiver gate and release locations, 2021.**

**Table 1. Release and acoustic receiver gate information in the Coho Salmon smolt migration corridor for fish acoustic-tagged and released in upper mainstem Dry Creek, 2021.**

| Tributary | Site | Number of receivers | Distance from (river km) | | Date | |
|---|---|---|---|---|---|---|
| | | | Release | Ocean | Deploy | Retrieval |
| Dry Creek | wellfield | | 0 | 73.19 | Apr 29, May 6 | n/a |
| | Dry Creek mouth | 1 | 21.27 | 51.92 | Apr 26 | Jun 7 |
| Russian River | Dry Creek confluence | 2 | 22.58 | 50.61 | Apr 26 | Jun 7 |
| | head of Wohler pool | 2 | 29.02 | 44.17 | Apr 26 | Jun 7 |
| | Mirabel dam (downstream) | 2 | 33.90 | 39.29 | Apr 26 | Jun 7 |
| | Hacienda Bridge | 2 | 38.45 | 34.74 | Apr 26 | Jun 21 |
| Estuary | Brown's Pool | 2 | 62.22 | 10.97 | Apr 27 | Jun 23 |
| | Heron Rookery | 3 | 65.88 | 7.31 | Apr 27 | Jun 23 |
| | Patty's Rock | 4 | 70.94 | 2.25 | Apr 27 | Jun 23 |

## Travel time

Travel time (number of days) from the release site and travel rate (km*d$^{-1}$) was calculated for each individual detected on the upper and lower gates bounding the following reaches: release site to Dry Creek mouth; Dry Creek mouth to Hacienda Bridge; Hacienda Bridge to Brown's Pool; Brown's Pool to Patty's Rock. The median travel time for all fish was calculated to represent reach-specific travel times and rates for each release group.

## Detection probability and survival

We deployed a total of 18 receivers in the eight gates to facilitate survival estimation. Each receiver served as an encounter occasion in a Cormack Jolly Seber capture-mark-recapture model. In addition to detection probability of individual receivers, we calculated the combined detection probability of all receivers within a gate as:

$d_g^* = 1 - [(1 - d_1) * (1 - d_2) \ldots * (1 - d_r)]$;

where *g* refers to gate and *r* refers to receiver within a gate.

Between receivers within a gate, we fixed survival probability to 1 but allowed the model to estimate survival between gates (Figure 2). Including the release occasion, there were a total of 19 digits in the encounter history. Consequently, there were 18 detection probabilities estimated (one for each gate) but only eight survival probabilities (one for each stream reach between gates) for each release group. Cumulative survival from release to the successive downstream

gates was calculated as the product of the preceding (upstream) reach-specific survival probability estimates.

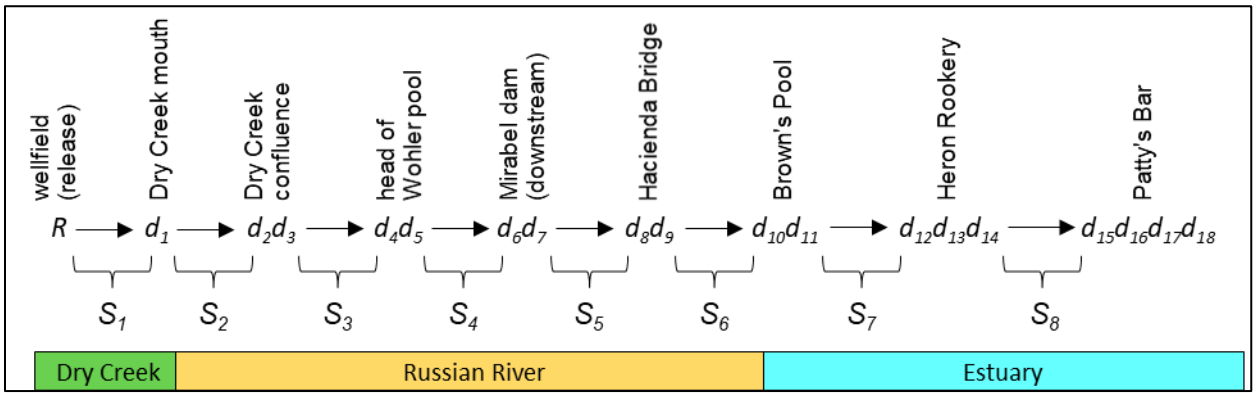


**Figure 2. Structure of capture-mark-recapture model to estimate detection probability and true survival of Coho Salmon smolts released on two different dates (Apr 29 and May 6) in Dry Creek, 2021.**

# Results

## Travel time

Median travel times were similar between release groups but more variable among individuals for the early release group (Figure 3, upper panels). Travel rate was also similar but noticeably longer through the Dry Creek mouth to Hacienda reach as compared to other reaches (Figure 3, lower panels).

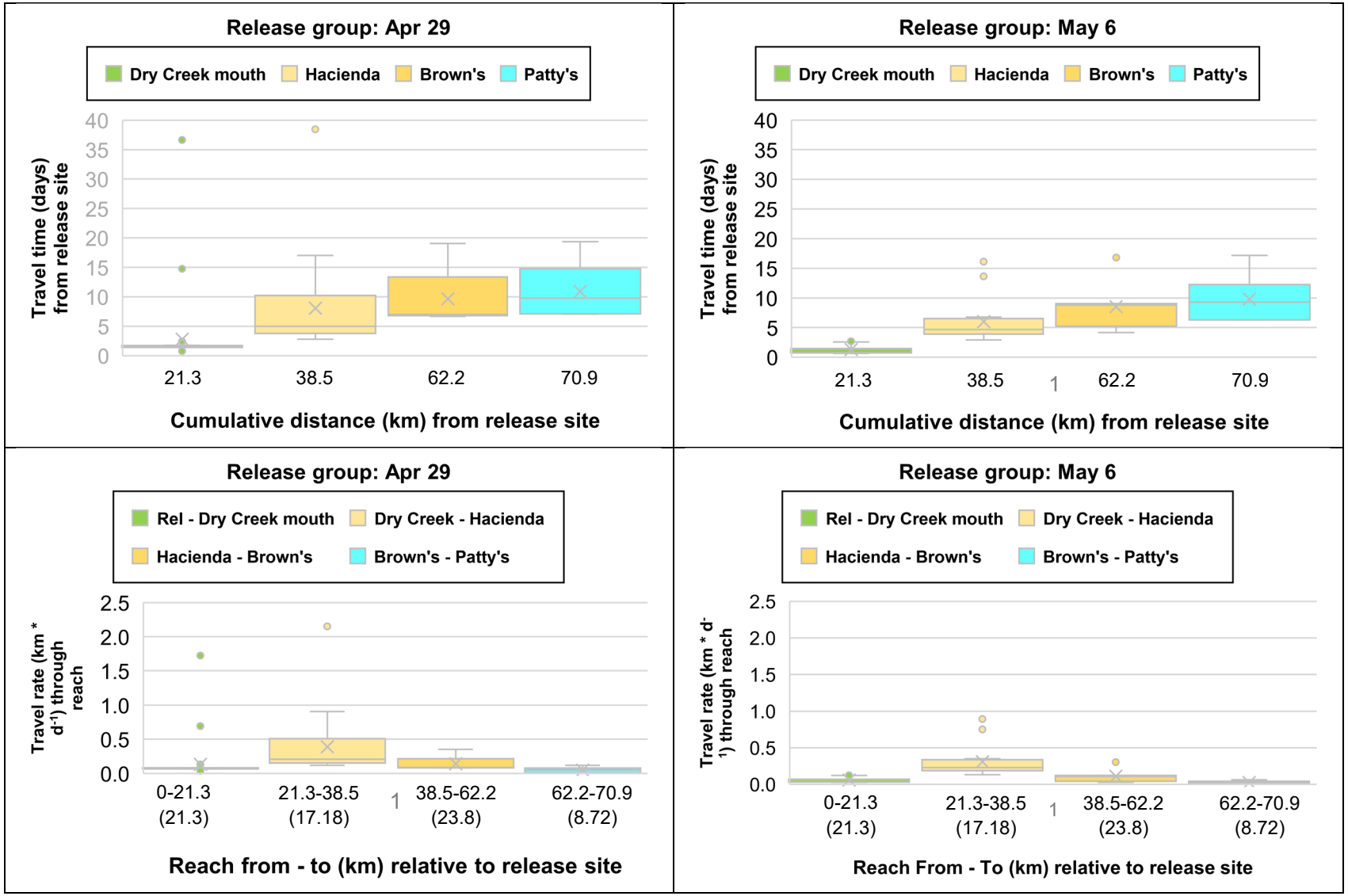


**Figure 3. Travel time from release site (top panels) and reach-specific travel rates (bottom panels, numbers in parentheses are reach lengths) for two groups of Coho Salmon smolts released on two different dates (Apr 29 and May 6) in Dry Creek, 2021. Bar heights and horizontal lines are quartiles, X's are means and whiskers are minimums and maximums irrespective of outliers (points).**

## Detection probability and survival

Detection probability of individual receivers was generally high, ranging between 0.61 and 1.00 and combined detection probabilities within a gate ($d_g^*$), were also high (range 0.87 to 1.00; Figure 4).

Reach-specific survival estimates (i.e., survival between gates) was high in Dry Creek and the estuary for both release groups, but notably lower between Dry Creek and Mirabel dam as well as between Hacienda Bridge and Brown's Pool (Figure 5). Survival was notably lower in the mainstem Russian River for the later release group as compared to the early release group, especially between the head of Wohler pool and Mirabel dam. From the release site in Dry Creek to the lower end of the estuary at Patty's Rock, cumulative survival was estimated at less than 0.19 for both groups.

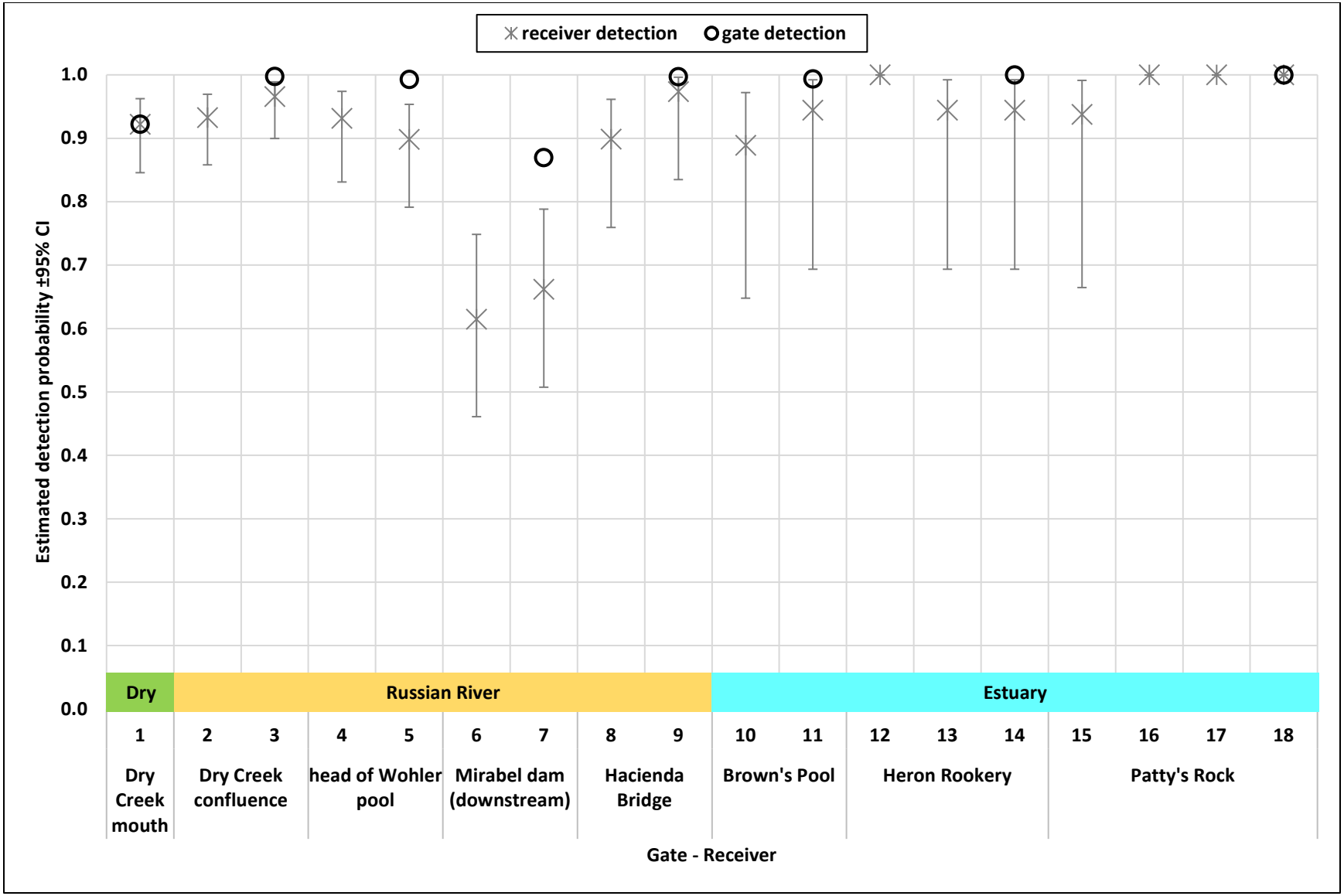


**Figure 4. Receiver-specific and gate-specific estimated detection probabilities of hatchery-reared Coho Salmon smolts released on two different dates (Apr 29 and May 6) in Dry Creek, 2021.**

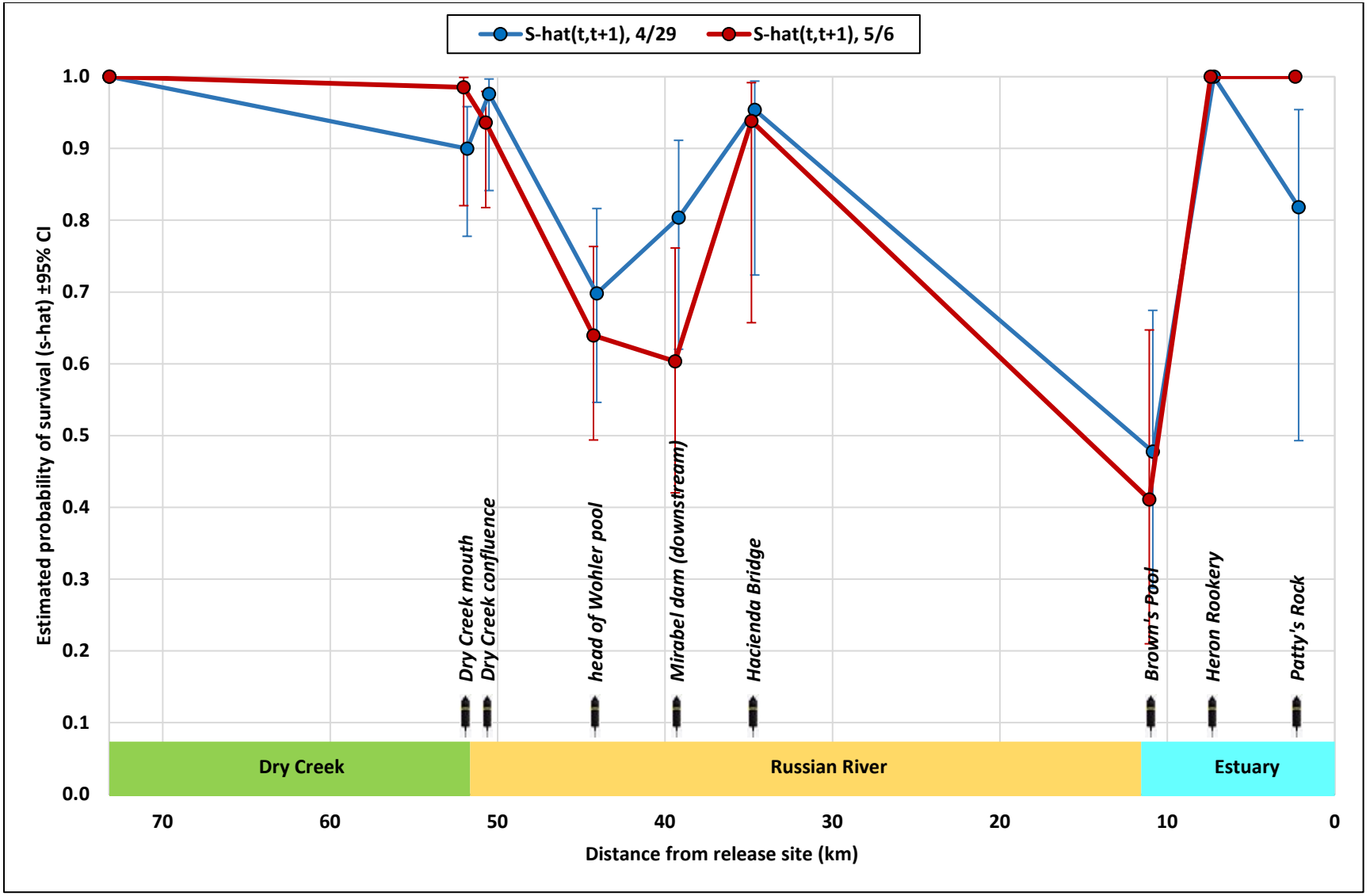


**Figure 5. Reach-specific estimated survival probabilities of hatchery-reared Coho Salmon smolts released on two different dates (Apr 29 and May 6) in Dry Creek, 2021. A given point represents survival between that point and the upstream point (i.e., the preceding or upstream reach). Therefore, the slope of each line represents the estimated proportion of fish lost per kilometer for that reach.**

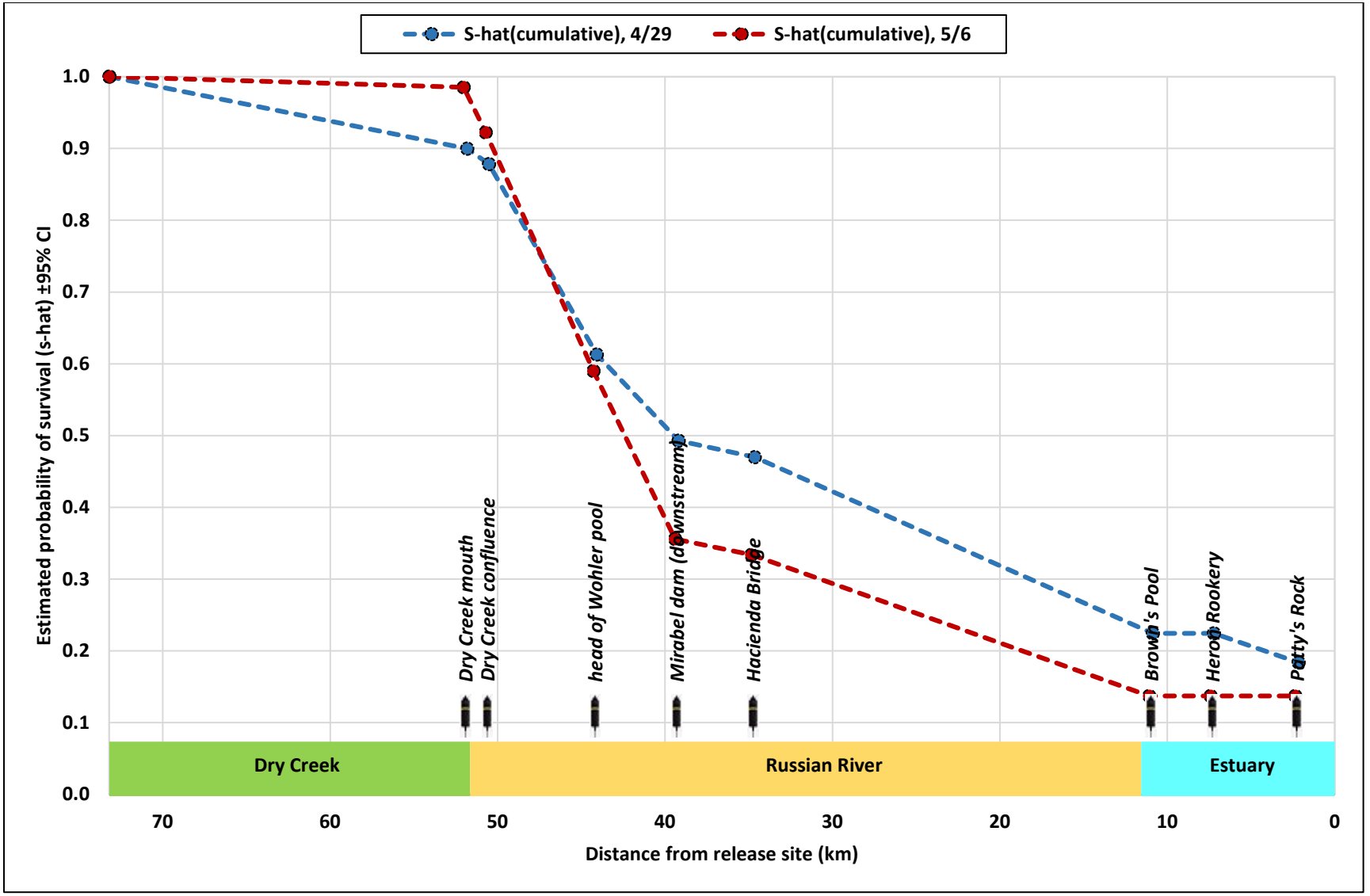


**Figure 6. Cumulative estimated survival probabilities of hatchery-reared Coho Salmon smolts released on two different dates (Apr 29 and May 6) in Dry Creek, 2021. Cumulative survival is calculated as the product of all survival probabilities up to and including the current reach.**

# Discussion

The acoustic tags, receivers and HTI coding structure we employed at the selected gate locations performed very well, giving us confidence that a similar study design in the future should allow us to continue along the path to better understanding Coho Salmon smolt survival during their seaward migration through the lower portion of the Russian River watershed. Deploying multiple receivers within a gate not only helps increase overall detection probability for the gate (site), but receiver redundancy within a gate also helps guard against failure of a receiver in the gate. Such high detection probabilities lend confidence that the capture-mark-recapture model will result in robust estimates of true survival. The locations we selected for receiver deployment were deliberately chosen to encompass reaches where we were interested in evaluating bottlenecks to survival. Such information will help guide strategies for future releases of hatchery-reared Coho Salmon smolts while allowing a straightforward way to decouple broad-scale processes (e.g., ocean survival, migration survival) from specific management and recovery actions.

The estimated survival from Dry Creek to the lower Russian River estuary from this study is alarming. To put it into context, the approximate 0.16 cumulative survival we observed (combined survival for both groups), means that for every 10,000 smolts we release in Dry Creek, we can expect only 1,600 to survive until ocean entry. While this is striking, it is important to note that conditions in 2021 were at near historic low levels in terms of stream discharge in the mainstem Russian River. For example, the cumulative daily flow at the Hacienda gage in 2021 during Mar 1-Jun 15 (the typical smolt emigration period in the Russian River watershed) was the second lowest during the period of record since 1941 (Figure 7). For this reason, it is important to conduct similar work in future years under different conditions.

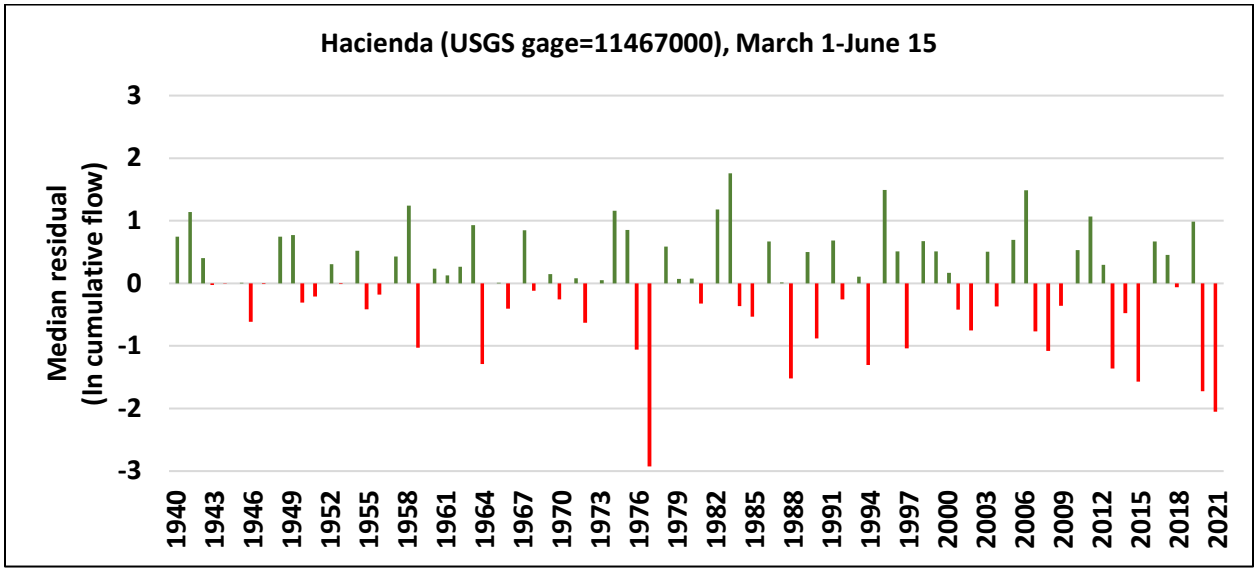


**Figure 7. Annual residual flow calculated as the difference between the cumulative daily flow during the typical Coho Salmon smolt emigration period in the Russian River watershed (Mar 1-Jun15) in a given year and the long-term median flow at the USGS gage station at Hacienda on the mainstem Russian River (11467000).**

We can only speculate on the main sources of mortality for emigrating Coho Salmon smolts in the Russian River. Sonoma Water has been conducting boat electrofishing in the mainstem between Mirabel dam and the head of Wohler pool since the early 2000's. Though somewhat anecdotal, this effort has revealed a robust population of native and non-native piscivorous fish including Sacramento Pikeminnow, Smallmouth Bass and Striped Bass. Though we cannot quantitatively say with any certainty what the population levels of these species are in this reach of the mainstem nor how widely distributed they are elsewhere in the mainstem, it is reasonable to assume that they are predating on salmonid smolts as they make their downstream migration.

Based on patterns of tag movement, we strongly suspect that at least some of the individuals tagged in this study were predated upon by piscivorous fish. We offer two lines of evidence to support that. First, there were a few tags that made multiple upstream movements of several kilometers which is inconsistent with the typical downstream migration behavior we attribute to the smolt life stage. Second, we recorded detections of a few tags that were moving around in the vicinity of a receiver for several hours but then the tag stopped moving as if lying on the stream bed after being defecated by a predator. Although there are other possible explanations for these unusual movement patterns, we suspect that, at least in some of these cases, predation was the source of mortality.

Again, it is important to point out that the 2021 smolt migration period exhibited extreme low flow conditions, meaning that the extent to which smolts were delayed in making their downstream migration (e.g., because of low flows) may have led to higher predation than may occur in a more normal or high flow year. Because the candidate piscivores in the Russian are sight feeders, the predation risk may be even higher when turbidity is low – a condition that is associated with the low flows present in the mainstem Russian River in spring, 2021.

## Recommendations

We recommend continuing the work begun in 2021 by repeating some aspects of that work in spring, 2022. Specifically, we recommend deploying a receiver array similar to that deployed in 2021 and again releasing hatchery-reared Coho Salmon smolts in Dry Creek to evaluate travel and survival through the same reaches along the migration corridor where these two metrics were evaluated in 2021. We recommend continuing to use the same non-predator V3 tag that was used in 2021, but tagging additional fish with the predator V3D tags that was recently developed by Innovasea with nearly identical dimensions to the V3 tag (Innovasea Predator Transmitter). The V3D tag can signal when a fish predator has ingested a tag thus indicating death by predation. This would help us begin to ascribe mortality sources (i.e., predation vs. non-predation). To begin evaluating the relationship between release time and survival, we also recommend releasing additional tag groups (perhaps four groups) over a broader time range. In future years, we may also consider tagging Coho Salmon smolts captured in the wild to evaluate whether their reach-specific survival is similar to hatchery-reared smolts. Good choices for fish capture are downstream migrant traps operated by CSG on Mill Creek and Green Valley Creek with the additional possibility of tagging fish at the Dry Creek downstream migrant trap operated by Sonoma Water (Figure 1).