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Estimation of juvenile Steelhead survival and routing migrating through the Delta
2024 Six-Year Steelhead Survival Study: Statistical Methods and Results

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Executive summary

The 2024 San Joaquin River (SJR) steelhead acoustic telemetry study is a continuation of the Six-Year Steelhead Survival Study from 2011-2016. We used acoustic telemetry to assess survival, routing, and migration characteristics of juvenile steelhead from the SJR at Durham Ferry through the South Delta to ocean entry at Golden Gate (Figure 1). In 2024, a multiagency collaboration between UCSC and USFWS-Lodi surgically implanted 906 juvenile steelhead from the Mokelumne River Hatchery with JSATS acoustic transmitters in March, April, and May.

This report outlines the analytical methods used to address the six objectives outlined in our study plan:

i. Provide overall Delta outmigration survival estimates to Chipps Island, for all release weeks combined, as well as per release week.
ii. Provide overall outmigration survival per major migratory route, for all release weeks combined, as well as per release week.
iii. Provide reach-specific survival estimates through the SJR and OR migratory routes, for all release weeks combined, as well as per release week.
iv. Provide route entrainment estimates at important junctions, including Head of Old River (HOR) and Turner Cut (TC), for all release weeks combined, as well as per release week.
v. Perform a multivariate analysis to determine how environmental variables and water operations may have influenced routing probabilities and reach-specific survival.
vi. Provide these above estimates in such a way to be comparable to past study years, to the extent possible.

We modified the multistate mark-recapture model from 2021 and 2022 to estimate survival and routing for juvenile steelhead migrating from the SJR through the California Delta to Ocean entry utilizing the space-for-time substitution. The space-for-time substitution links each capture occasion to a spatial location (e.g., river reach) to help account for the complex routing options and fixed receiver locations used in the system. We used a mixed effects structure with random effects applied to reach-specific survival, receiver detections, and routing. Coupled with multiple release locations to bolster survival estimates downstream of Durham Ferry (i.e., the HOR and Dos Reis releases), these methods present updated analytical methods compared to previous South Delta methods presented by Buchanan and coauthors. In addition, we developed a simulation to assess bias in parameter estimation across different sample sizes to infer the appropriate release sizes for each release group and release locations. Updates to the 2024 multistate mark-recapture model included adjustments to active receiver locations along the Old River route, but otherwise the model was nearly identical to the prior versions.

Survival for outmigrating steelhead smolts was higher in 2024 than 2021 or 2022. Through-Delta survival in 2024 ranged from 20-29%, was 10-13% in 2022, and <5% in 2021, and well within the range of estimates from 2011-2016 (5-63%). Routing estimates at the HOR were comparable to the 2011 wet year, with about half of the fish taking the SJR route at the HOR. Finally, detection rates were also comparable between studies with most detection estimates >80% for all studies. The 2024 water year was classified as above normal, with mean SJR inflows from 4,950-5,443 cfs and exports ranging from 1,799-3,115 cfs. Additionally, water temperatures at Mossdale were 15.4-16.7°C during the study period. Future efforts will seek analytical methods to account for multiple covariates within the survival model.

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Acknowledgements

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Introduction

The 2024 San Joaquin River (SJR) steelhead acoustic telemetry study is a continuation of the Six-Year Steelhead Survival Study from 2011-2016 (U.S. Bureau of Reclamation (USBR) et al. 2018c, 2018a, 2018b; Buchanan 2018a, 2018b, 2018c) and is included as action 3.4.11 of the 2019 NMFS Biological Opinion (U.S. National Marine Fisheries Service 2019). Like the original study, we used acoustic telemetry to assess survival, routing, and migration characteristics of juvenile steelhead from the SJR at Durham Ferry through the South Delta to ocean entry at Golden Gate (Figure 1). In 2024, a multiagency collaboration between UCSC and USFWS-Lodi, surgically implanted 906 juvenile steelhead from the Mokelumne River Hatchery with JSATS acoustic transmitters in March, April, and May (Table 1).

The NMFS Biological Opinion (BiOp) includes actions that influence Central Valley Project (CVP)/State Water Project (SWP) export and discharges through the SJR and Old and Middle River (OMR) corridor during the study period (U.S. National Marine Fisheries Service 2019). Action 3.4.4 identified target OMR flows of no more negative than -5000 cfs from roughly January through June (the OMR season). In addition, Action 3.4.5 stipulates single-year and cumulative loss thresholds based on historic loss from 2010-2018. This threshold is no greater than 90% of the highest annual loss from 2010-2019. If 50% of the single-year threshold is exceeded, OMR flows will be reduced to a 14-day moving average of -3,500 cfs. If 75% of the threshold is exceeded, OMR flows will be reduced to a 14-day moving average of -2,500 cfs. Under both scenarios, these actions will remain in place for the remainder of the OMR season unless a risk assessment based on real-time fish monitoring data finds the risk is no longer present (U.S. National Marine Fisheries Service 2019).

State-wide, the 2024 water year was classified as above normal, compared to critically low for the 2021 and 2022 water years (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST). Previous studies were conducted during critically low water years 2013-2015, with additional dry water years in 2012 and 2016, along with a wet year in 2011. In addition to the export reduction actions to meet OMR flow standards and SJR discharge (outlined in U.S. National Marine Fisheries Service 2019), the releases for 2024 were planned to utilize and estimate the effects of a spring pulse flow in mid-May. Thus, this study was intended to refine measures for protecting CA Central Valley steelhead, including those outlined above and explicitly stated in the 2019 BiOp.

Experienced taggers surgically implanted acoustic transmitters and PIT tags into the body cavity of steelhead. Fish were released over two 1-week periods upstream of the Delta at Durham Ferry, in Old River (OR) just below splitting from the SJR, and in the SJR near Dos Reis Regional Park. Acoustic tags were detectable on a telemetry array deployed in the SJR downstream of Durham Ferry and throughout the California Delta, Delta exit (Chipps Island), Benicia, Ocean entry (Golden Gate Bridge), and upstream on the Sacramento River (Figure 1). This array was similar to last year’s study and the historical 6-year survival studies (Buchanan 2018c) and allows for comparable inferences with the prior studies. We developed a multistate mark-recapture model to estimate survival and routing for juvenile steelhead migrating from the SJR through the California Delta to Ocean entry.

This report outlines the analytical methods used to address the six objectives outlined in our study plan:

vii. Provide overall Delta outmigration survival estimates to Chipps Island, for all release weeks combined, as well as per release week.

viii. Provide overall outmigration survival per major migratory route, for all release weeks combined, as well as per release week.

ix. Provide reach-specific survival estimates through the SJR and OR migratory routes, for all release weeks combined, as well as per release week.

x. Provide route entrainment estimates at important junctions, including Head of Old River (HOR) and Turner Cut (TC), for all release weeks combined, as well as per release week.

xi. Perform a multivariate analysis to determine how environmental variables and water operations may have influenced routing probabilities and reach-specific survival.

xii. Provide these above estimates in such a way to be comparable to past study years, to the extent possible.

Field Methods

Tagging Protocol

An experienced staff from UCSC and USFWS performed the tagging operations during the two weeks of tagging. This included two taggers, two data recorders (one per tagger), and one fish manager (who ensured a steady, controlled flow of fish getting processed by the taggers). In addition, two fish release teams of two persons each released fish daily, for a total of nine staff per day of the project (with the exception of Mondays when release teams were not needed or Fridays when tagging team was not needed; see weekly schedule below). One release team performed two of the daily releases, while the other release team performed the third release.

Experienced taggers performed surgery in as sterile an environment as possible. Fish were placed ventral-side up on a surgery cradle and had water diffused with a maintenance anesthesia solution passed over gill membranes continuously throughout the procedure. A sterilized, individually-coded, JSATs tag was inserted through an incision into the peritoneal cavity of the fish. The incision was closed with two simple sutures and fish were transferred to an aerated recovery tank as soon as possible post-surgery. PIT tags were also inserted into the peritoneal cavity, which allowed the detection of acoustic-tagged steelhead captured in the CVP or SWP salvage tanks.

Receiver Array

Between existing realtime JSATs receivers managed by USGS and UCSC, along with realtime and autonomous receivers maintained by UC Davis, and receivers deployed and maintained by USGS/Environmental Science Associates (under contract by DWR), the receiver array depicted in colors red, blue and orange (Figure 1) represent the receivers operational during the 2024 steelhead telemetry project. No receivers were deployed at Medford Island, in contrast to some previous years' studies (Buchanan 2018c). Through conversations with R. Buchanan (University of Washington), we believed that Medford Island was not a critical site for a South Delta routing and survival analysis. UCSC ensured that receivers for the 2024 study were deployed before the first releases of tagged steelhead. The receiver array in 2024 was similar to 2022, except that no SJ_BCA receiver was deployed for 2024. This analysis utilized Old River – Victoria River (OR_Victoria) receivers in place of OR_hwy4 receivers and the Middle River Railroad Bridge (MR_RRB) in place of MR_hwy4 receivers for detecting fish volitionally migrating through the Delta to Chipps Island.

Schedule

The fish were tagged and released over a 1-week period in each of March, April, and May. Tagging occurred Tuesday-Thursday and releases occurred approximately 24 hours after tagging Wednesday-Friday. These fish were released upstream of the Delta at Durham Ferry (DF release), in Old River just below splitting from the SJR (HOR release), and in the SJR at Dos Reis Regional Park (DR release; Figure 1; Table 1).

Sample Size

In total, USBR supplied 1000 JSATs tags for this study, along with 50 tags for battery life tests. An additional 300 Vemco PDAT tags were available to supplement the Durham Ferry release groups, but were not analyzed as part of this report. Fewer fish were tagged and released for the May release (236) compared to the March and April releases (335 each), due to limited availability of taggable fish at the hatchery. Daily fish released were distributed 44% to DF, 28% to HOR, and 28% to DR. Therefore, in total, 906 fish were used over three weeks with 95-126 fish tagged per day using JSATS tags (see Table 1).

In 2024, there were issues with the tag technology where tags with firmware version 7 malfunctioned. In total, 501 version 7 tags were implanted into fish during this study. There were no version 7 tags used in March, 226 version 7 tags used in April (79% of this release group), and all but one tag (235 tags) used in the May release were version 7 (Table 2 and Table 3). Failure rates were estimated around 62% for these tags (R. Robinson; unpublished report titled: ATS JSATS Version 7 Tag Failure Report provided to USBR).

Release Protocol

Fish were held at the hatchery overnight after tagging. Fish were transported via coolers to release sites. Fish were tempered with river water (at a rate not to exceed 3°C change per hour), until cooler temperature was within 2°C of river water temperature. Fish were then released directly into the river from the shore. The maximum tempering rate for 2024 was the same as 2022, which was 1°C higher than 2021 to ensure fish were released close to their scheduled release times when water temperatures were high.

For sites with tidal influence (HOR and Dos Reis), fish were released during a slack tide that occurred during daylight (at least 1.5 hours after sunrise and no later than 2 hours before sunset). Slack tides were offset by 2-4 hours between these sites, so releases were not simultaneous. For sites with no tidal influence (Durham Ferry), fish were released in the morning, no earlier than 1.5 hours after sunrise (so as to avoid periods of high predation risk), and no later than noon (to avoid warmer waters). For 2024, we no longer used the Stockton release site and used the Dos Reis Regional Park boat ramp instead.

Statistical Methods

We developed a multistate mark-recapture model to estimate survival and routing for juvenile steelhead migrating from the SJR through the California Delta to ocean entry (Figures 2-4). Similar to other models developed for estimating survival and routing through the California Central Valley (U.S. Bureau of Reclamation (USBR) et al. 2018c; Perry et al. 2018; Buchanan et al. 2021), we utilized the space-for-time substitution. The space-for-time substitution links each capture occasion to a spatial location (e.g., river reach) to help account for the complex routing options and fixed receiver locations used in the system. This means that detections for fish i at receiver j indicate passage from upstream reach k into reach j (see model assumptions described in the next paragraph). There is no time component inherent for how long a fish can remain in reach j, therefore they can move through quickly or can remain for an unlimited time (i.e., have non-detections listed for the remaining capture occasions).

We followed the previous year's analytical methods (Matthias et al. 2024; 2025) and used a mixed effects structure with random effects applied to reach-specific survival, receiver detections, and routing. Coupled with using multiple release locations to bolster survival estimates downstream of Durham Ferry (i.e., the HOR and Dos Reis releases), these methods present updated analytical methods compared to previous South Delta methods used by Buchanan and coauthors (see Buchanan 2018c; Buchanan et al. 2021 and citations within).

The model estimates reach-specific survival rates and detection probabilities, along with routing probabilities for the different routes outmigrating steelhead may take to get from Delta entry at Mossdale to Delta exit at Chipps Island. The model was developed in Template Model Builder (TMB; Kristensen et al. 2016), which is a frequentist methodology that is very effective estimating large numbers of random effects. The TMB models and all data processing were run through program R version 4.3.2 (R Core Team 2023).

Data Processing

JSATS California Fish Tracking databases for this study were obtained from ERDDAP on January 30, 2025. These databases, which are under development, include information related to receiver deployments, tagging of salmonids, and salmonid detections.

The tagging database was obtained from https://oceanview.pfeg.noaa.gov/erddap/tabledap/FED_JSATS_taggedfish.html, with optional constraint study_id specified as "SJ_Steelhead_2024". Relevant data collected on tagged Mokelumne River Hatchery steelhead smolts included fish ID, fish release date-time, fish length (mm), release location, and release latitude and longitude. The tagged fish database contains a fish ID (i.e., tag) key that links to the detections database.

The detection database was downloaded from https://oceanview.pfeg.noaa.gov/erddap/tabledap/FED_JSATS_detects.html, with optional constraint study_id specified as "SJ_Steelhead_2024". An acoustic transmitter can register repeated detections of an individual tagged fish over a short time interval, some of which are false detections. Moreover, these repeated detections are not necessary for survival and movement analyses. Therefore, prior to public release of data on ERDDAP, acoustic detection data were filtered to remove false detections and reduce repeated detections. The initial filtering process applied to the raw detection data is described by NMFS (U.S. National Marine Fisheries Service 2021), and also included the collating of individual detections into detection events. Unique detection events were defined by the detection of an individual fish ID at a specific receiver, until the fish was detected at a new receiver, or there was a 60-minute time delay before being detected again at the same receiver. Two time stamps of the detection event correspond to the first time of tag transmission for the event (one is PST and one is UTC). Another time stamp corresponds to last time of tag transmission for the event in PST. Hereafter, detection events are referred to as "detections" for succinctness.

After data were obtained from ERDDAP, another round of data cleaning made additional corrections to the data prior to use in the predator filter and survival model analyses. Release times as recorded in the data were averages across individual batches of fish released on a specific date for a release site. Therefore, actual release times for release groups could be up to 30 minutes earlier than the listed time stamp in the detection data. This presented a problem when there were detections for a fish prior to the listed release time. Adjustments were made to reflect true release times.

The Mossdale telemetry receiver had inaccurate GPS coordinates, and were corrected (corrected latitude = 37.79228, corrected longitude = -121.307). Old River Quimby and Holland Cut Quimby receivers were removed from the analyses to maintain consistency with the 2022 study (see Figure 1). In 2024, Old River RR Bridge was not installed, but Old River Victoria was available nearby as a substitute receiver. Detection histories were scrutinized for individual implausible tag transmissions, and those detections were removed. Implausible detections were recorded at many receivers, although CVP Trash Rack was particularly noisy.

The detections database contains a deployment ID key that links deployments of individual receivers to corresponding detections of tagged fish at those sites. The deployment ID was used as key because individual receiver serial numbers could be removed from a site and redeployed at a new site within a single migration season.

The receiver database was accessed at https://oceanview.pfeg.noaa.gov/erddap/tabledap/FED_JSATS_receivers.html with no defined optional constraints. Once downloaded, the receiver database was filtered to receivers only within the SJR, South Delta, West Delta, Carquinez Strait, and SF Bay receiver regions, along the outmigration path for SJR steelhead. In addition to region, receivers in ERDDAP are labeled at two other spatial scales: receiver location (location for a single receiver) with corresponding latitude and longitude coordinates, and receiver general location (location of one or more receivers) with corresponding receiver general latitudes and longitudes (see Table 4). Receiver general locations often distinguish between upstream (typically designated "1") and downstream (typically "2") lines of receivers or gates, which otherwise have the same site name (e.g., OR_HOR_1 and OR_HOR_2). Detections per tag, collated at receiver general locations, were analyzed by the multistate model to estimate survival and migration probabilities.

Distinguishing between Steelhead and Predator Detections

During migration to the estuary, *O. mykiss* smolts may be consumed by a number of predatory fish species, including Striped Bass *Morone saxatilis*, Largemouth Bass *Micropterus salmoides*, Channel Catfish *Ictalurus punctatus*, and White Catfish *Ameiurus catus* (Michel et al. 2018). Once consumed, the tag originally belonging to the smolt may continue to be acoustically detected while in the predator. These predated tag detections, if not omitted from the analyzed capture histories, could in certain circumstances bias the estimated state-specific survival rates for steelhead smolts. In particular, tags that are consumed by predators that migrate will introduce bias into a mark-recapture model. The longer/farther a tag remains in a predator, the greater the bias introduced into survival estimates. If a smolt is eaten in reach k and the tag remains in reach k, the mark-recapture model will correctly "assign" that mortality to reach k. If the predator moves to reach j, then the model will assign mortality to reach j, introducing a slight bias. The farther that predator travels, the more bias introduced. Thus, if the predator remains in the Delta, bias will not necessarily be introduced into the estimate of through-Delta survival. However, if the predator makes it past Chipps Island with the tag, this could bias the estimate of through-Delta survival high (i.e., true survival is lower than what we estimated). To address this potential source of bias, we developed a predator filter that identified and removed "predator-type" detections from the dataset of migrating tags, leaving only "smolt-type" detections to be analyzed by the mark-recapture model. The full, unfiltered dataset of all tag detections (including both predator-type and smolt-type detections) comprised a second dataset for analysis.

Previous studies have identified a number of behavioral metrics that could be indicative of salmonid predator movements in the SJR and Delta (U.S. Bureau of Reclamation (USBR) et al. 2018c; Buchanan and Whitlock 2022). It should be noted that we did not attempt to incorporate all metrics into the predator filter developed for this study, but instead relied on expert advice (e.g., R. Buchanan and conversations within the Central Valley Tag Predation SOP working group) to highlight key metrics toward a simplified filter that may change as predator filtering approaches evolve.

The predator filter applied in this study focused on four metrics as potential indicators of predator behavior, including upstream movement past Mossdale, repeated detections near the HOR or at water export facilities, and migration rate. First, as with Chinook Salmon smolts, steelhead smolts were not expected to move either upstream or against flow for very long distances. In particular, a movement back upstream after previously moving downstream of Mossdale may be associated with steelhead predators. This is because once steelhead smolts pass the Delta entrance at the HOR, it can be assumed that subsequent upstream migrations will be minimal (R. Buchanan, pers. comm.; U.S. Bureau of Reclamation (USBR) et al. 2018c). The HOR itself may also be a site of increased predation risk for salmonids, particularly when temperatures increase to coincide with the thermal preferences of piscine predators such as striped bass (Michel et al. 2020). A third potential indicator of predator behavior related to detections at the CVP and/or SWP export facilities (hereafter, “facilities”; corresponds to receiver general locations CVP Trash Rack, CC intake, Clifton Court). Once smolts reached the facilities, it was expected that they would only leave through salvage and transport (Buchanan et al. 2018c). Steelhead predators cannot fit through the louvers at SWP to enter salvage, and therefore tags that are detected entering SWP and next at sites in the Western Delta (after transport) can be considered smolts. Although most steelhead predators are also too large to enter the CVP holding tanks, the trash rack preceding the holding tanks is occasionally cleaned and predators may swim through at those times (R. Buchanan, pers. comm.). However, repeated detections of a tag at the facilities are more likely the result of tag consumption by a predator than resident smolts. The fourth metric, migration rate (km/hr), is often used to identify salmonid predators. The swimming speeds of these predators can greatly exceed those of weaker, migrating steelhead smolts (see U.S. Bureau of Reclamation (USBR) et al. 2018c). Although previous studies (e.g., U.S. Bureau of Reclamation (USBR) et al. 2018c) have used both minimum (representing resident predators) and maximum migration rate thresholds to define predator-type transitions, we focused on maximum migration rates. Consumption of tags by faster moving, highly migratory predators, such as striped bass (see Michel et al. 2020) would be more likely to bias survival estimates of outmigrating steelhead.

Metrics were calculated using data summarized per tag at the array level. Detections at receiver general locations were further collated to the broader, site level array to help identify potential predator movements and behaviors. Averaged latitudes and longitudes estimated for each array, along with receiver general location coordinates are provided in Table 5. An appropriate parametric distribution was fit to each metric, as needed. Thresholds for predator-type detections were quantified based on bootstrap estimates of parameters and corresponding uncertainty for the fitted parametric distribution. Those detections that were equal to or exceeded the 0.95 quantile were labeled as predator-type detections for the purposes of this study. An advantage to using the data to establish thresholds for predator-type detections is that environmental conditions (e.g., flow, temperature, and other water quality metrics; see Lehman et al. 2017) fluctuate temporally, which could lead to differences in predator (and smolt) movements across years. Instead, in the absence of data on known predator movements during the 2024 water year, we used the complete distribution of each metric to identify atypical behaviors that were more likely to be predator movements while assuming that the majority of values in the distribution resulted from migratory smolts.

For the HOR sites (which included the SJR and OR sites nearest to HOR, plus Mossdale) and facility detection metrics, we fit a statistical distribution to each using a truncated dataset for fish with at least one detection at the location of interest. We then transformed each dataset by subtracting one to better fit known count distributions with low values and a larger quantity of zeros (e.g., negative binomial, Poisson, zero-inflated distributions). Distributions were fit to data using the R package **fitdistrplus** (Delignette-Muller and Dutang 2015). Chi-square tables of observed versus theoretical counts of detections and corresponding goodness-of-fit tests revealed no significant differences between actual facilities detections and the negative binomial fit to the data (χ^2= 4.47; p = 0.11). Of the three distributions tested (negative binomial, Poisson, and zero-inflated negative binomial), the zero-inflated negative binomial and negative binomial distributions could not be fit. To maintain continuity with the approach from 2021 and 2022, the fit of the Poisson distribution to the observed HOR count data was used to guide the threshold for predator-type detections, despite significant differences between the observed and theoretical count distributions (χ^2= 25.14, p < 0.05). The estimated 0.95 quantile from the fit negative binomial distribution corresponded to a median value of five detections at the facilities (μ= 1.39; Figure 5), and the fit Poisson distribution corresponded to a median of three detections at HOR sites ($lambda$ = 0.64; Figure 6) for the back transformed datasets. Thus, ≥ 5 facility detections and ≥ 3 HOR site detections were used as the lower threshold values for predator-type detections in the predator filter.

Migration rates were calculated by estimating the transition distances between sequential pairs of detections at arrays and dividing those distances by time. The process involved snapping detections at receivers to nodes along a flow network of the Delta created with the R package **riverdist** (functions and flow network provided by the Delta predator filter R package **DPF,** forthcoming). Several steps were taken to ensure that calculated migrations rates were realistic and reflected study questions. For example, very short transitions between release and adjacent receivers (e.g., HOR release to HOR sites on the SJR or OR, or Durham Ferry release to the downstream Durham Ferry site) were excluded from migration rate calculations. Recorded release times had been approximated per group of releases and therefore could contribute to inaccurate movement rates. Following Buchanan (2018c), intermediate visits (i.e., multiple trips back and forth to same array) were also removed and only final routes retained to better reflect the rates at which steelhead were outmigrating. The same final routes were used as inputs to the multistate mark-recapture model, and only those transitions analyzed by the model were used to establish predator filter thresholds. Finally, several transitions were composed of detections at non-adjacent receivers but were still considered useful data for establishing the distribution of migration rates for each transition. For those cases, we used the broader migration rate calculated on non-adjacent receiver transitions in place of the missing migration rates for adjacent receiver transitions.

Once relevant transitions and data were identified, we visualized continuous distributions of log migration rates per transition within a region and estimated the 0.95 quantile per transition as the threshold for predator-type distributions using the R package **ggridges** (see Figures 7-10; Table 6). The distributions were computed from kernel density estimates, where the bandwidth used in the smoothed estimate varied jointly per region based on the data. Bandwidth directly affects smoothing, with higher bandwidth corresponding to more smoothing. Because each tagged fish had a different number of transitions between detection events, we calculated per fish the proportion of transitions at very high migration rates (i.e., at or above the 0.95 quantile for each transition). We found that relatively few fish had more than one-quarter of their transitions correspond to these very high migration rates; 0.25 was a fairly consistent break in the migration rate histograms across the nine release groups (Figure 11). We explored this threshold as a potential indicator of predator behavior for the predator filter.

Two variants of predator filter were applied to remove predator-type detections prior to the construction of capture histories and subsequent analysis by the mark-recapture model.

(1) A 1-hit filter that identified a predator-type detection based on any one of the following metric thresholds:
    (a) At least three HOR site visits
    (b) At least five visits to the CVP and/or SWP facilities
    (c) At least 1 upstream migration from downstream of Mossdale back up to Mossdale or upstream
    (d) More than one-quarter of transitions between arrays exceed the 95th percentile of log migration rate.
(2) A multi-hit filter based on the following previously defined criteria:
    (a) Either (c), or two of the following: (a), (b), or (d).

These two filters, along with the unfiltered data, were intended to represent book-ends for potential predators and subsequent survival estimates, and therefore results are provided for all three datasets. The unfiltered data assumes all detections are smolts and provides the upper bounds for survival estimates. The data using the 1-hit filter represents the lower bounds for survival as it takes the least amount of questionable actions to be classified as a predator. Finally, the multi-hit filter represents a middle-range between the unfiltered data and the 1-hit-filtered data. For either predator filter variant, any detection corresponding to the threshold value for each metric was flagged in the predator-filtered datasets. The flagged detection and any subsequent detections were labeled as predator-type detections and removed from the tag's detection history.

Constructing Capture Histories

Capture (detection) histories (CH) were created for all tags to enable analysis by the multistate mark-recapture model with space-for-time substitution. A capture history provided the release location and the sequence of detections at receiver general locations as a tag migrated downstream along a route through the reaches of the study area. Although the capture histories were generally compiled using receiver general locations, there were a few cases where detections at receiver general locations were aggregated to simplify routing and/or increase sample sizes of analyzed reaches. CliftonCourtRadialGates_1 and Clifton_Court_Radial_Gates_2 were combined. Detections for sites around the CVP Trash Rack (CentralValleyProjectTrashRack_1, CentralValleyProjectSalvageTank) were also combined.

Once the detection locations and adjacent reaches for analysis were determined, numbered states were assigned to the reaches. A full model of all releases included 28 total states/reaches across 14 capture occasions. State numbers were generally increased by one compared to 2021 and 2022 (Matthias et al. 2024, 2025) due to the new release location of Dos Reis for 2025. See also description in *Survival Model* for release-specific routing and states. Because a number of Dos Reis released tags were observed to move upstream from the release site through Howard and around the HOR, Dos Reis released tags were allowed to follow this route or move downstream toward MAC or Turner_Cut. Capture histories were tailored to exclude illegal transitions between states in the model structure (see lines between states for allowed transitions in Figures 2-4, and description in *Survival Model*). Tags were also expected to advance to one of the possible downstream states at each subsequent capture occasion (see Figures 2-4) to fit the space-for-time multistate model assumptions.

Three different versions of capture histories were generated for model analysis corresponding to the full (unfiltered) dataset, the multi-hit predator-filtered dataset, and the 1-hit predator-filtered dataset. We present model results from these three applications to provide a range of reach-specific survival and route entrainment estimates for consideration.

Survival Model

Reach-specific survival $\phi_{i,k}$ represents the probability of individual i surviving from reach k to j. Survival was estimated using a mixed effects linear model

$$logit(\phi_{i,k}) = \mathrm{B}_{k,g_i} + \beta_1 L_i \qquad 1$$

where B_{k,g_i} is the random intercept for release group g_i and β_1 is the regression coefficient for length-at-tagging L_i. The B_{k,g_i} is a normally distributed random effect following

$$\mathrm{B}_{k,g_i} \sim \begin{matrix} if\ k \leq 3 & N(\mu_{\mathrm{B,g_i}}, \sigma_{\mathrm{B,1}}) \\ else & N(\mu_{\mathrm{B,g_i}}, \sigma_{\mathrm{B,2}}) \end{matrix} \qquad 2$$

with a release-group-specific mean of $\mu_{\mathrm{B,g}}$and a standard deviation of $\sigma_{\mathrm{B},x}$ shared across release groups. We assumed immediate post-release survival (reaches $k = (1,2,3)$) may be different than survival in subsequent reaches $k > 3$, which is represented by different standard deviations $\sigma_{\beta,x}$ for the random effect. By setting $\mathrm{B}_{k,1} = \mathrm{B}_{k,2}$, we are assuming survival for an individual of length L_i remains constant between the March and April releases. By setting $\mathrm{B}_{k,1} \neq \mathrm{B}_{k,2}$, we are allowing reach-specific survival for an individual of length L_i to be different across each release group.

Multistate mark-recapture models rely on transition matrices to describe how individuals move, and ultimately survive, from capture occasion x to occasion $x + 1$. For this model, we developed three transition matrices that represent each release site (Durham Ferry, HOR, and Stockton in Figures 2-4, respectively). Each matrix is based off of the Durham Ferry transition matrix, but has slight differences based on the release location. We start by describing routing for fish released at Durham Ferry, then touch on the differences in the transition matrix for HOR and ST releases. Before jumping into details, it is important to discuss two major assumptions for fish movement. The first is that fish cannot swim upstream, so a fish with $CH = (1,4,5,6, \dots)$ cannot move back upstream to state 5 after state 6 (i.e., $CH = (1,4,5,6,5 \dots)$ is not allowed). All capture histories are based on the most downstream state reached. Second, capture histories for fish that pass a junction multiple times are based on final route selection. For example, a fish detected moving from Durham Ferry to Middle River, back up to the Head of OR and down the SJ route (e.g., detections at (1,4,5,6,12,13,12,6,7,8…) will utilize the SJ route for $CH = (1,4,5,6,7,8 \dots)$. These assumptions and decisions for creating capture histories are common for multistate mark-recapture models utilizing the space-for-time substitution (e.g., Perry et al. 2010).

Within the transition matricies, there are several dummy states used. Effectively there are two types of dummy states

1) Pre-release dummy states with a detection rates of 100% and survival of 100% and
2) Unseen dummy states with detection rates of 0% and survival of 100%.

These states are used for keeping the different routing options consistent such that a fish taking any route will reach Chipps Island on capture occasion 11. These dummy states do not influence the likelihood because detection rates and survival are known values. Pre-release dummy states are used in the HOR releases (states 31, 32, and 33; Figure 3) and Stockton releases (states 39; Figure 4). The unseen dummy states are scattered throughout each movement matrix (states 13, 16, 18, 28, 29, and 30; Figures 2-4), with additional states (34-38) immediately post-release for the Stockton releases for individuals heading toward MacDonald Island or TC.

- The 2021 model was developed to estimate migration characteristics along five major routing options for fish released at Durham Ferry once they enter the Delta at Mossdale (reach 6). The two SJR routes consist of the SJR Mainstem and TC Routes. The three OR Routes include Middle River (MR), OR mainstem, and Grant Line Canal (GLC) Routes. Both SJR routes have fish remaining in the SJR past the HOR where $CH = (1,4,5,6,7,8,9, \dots)$.
    - SJR Mainstem Route: fish remain in the SJR at the HOR and make it to MacDonald Island $CH = (\dots,9,10, \dots)$. Once they make it to state 10, they have four options to reach Chipps Island, take Three-Mile Slough or Jersey Point (states 22 and 23) or head towards the CVP or SWP (states 19 and 20).
    - TC Route: fish remain in the SJR at the HOR and take TC into the interior Delta $CH = (\dots,9,11, \dots)$. Similar to the SJR Mainstem Route, once they make it to state 11, they have four options to reach Chipps Island, take Three-Mile Slough or Jersey Point (states 22 and 23) or head towards the CVP or SWP (states 19 and 20).
- The three OR routes have fish moving into OR after reach 6 where $CH = (1,4,5,6,12, \dots)$.
    - Fish may take MR route $CH = (1,4,5,6,12,13,0, \dots)$, which includes an unseen dummy state (0), and may volitionally make it to Chipps Island via the Middle or Old River Railroad bridge (reaches 14 or 17) and pass Three-mile Slough or Jersey Point (reaches 22 or 23). Alternatively, fish may get salvaged at the CVP or SWP pumping facilities (reaches 19 or 20).
    - Fish remain in OR at both the junctions with MR and GLC $CH = (1,4,5,6,12,15,16, \dots)$. After reach 16, fish may go to Chipps Island via the Middle or Old River Hwy-4 bridge (reaches 14 or 17) and pass Three-mile Slough or Jersey Point (reaches 22 or 23). Alternatively, fish may get salvaged at the CVP or SWP pumping facilities (reaches 19 or 20).
    - Fish remain in OR at the junction with MR and become entrained into GLC $CH = (1,4,5,6,12,15,18, \dots)$. After reach 18, fish may go to Chipps Island via the Middle or Old River Hwy-4 bridge (reaches 14 or 17) and pass Three-mile Slough or Jersey Point (reaches 22 or 23). Alternatively, fish may get salvaged at the CVP or SWP pumping facilities (reaches 19 or 20).

Due to differences in the receiver array along the Old River corridor in 2022, we were unable to estimate separate routing and survival probabilities associated with the Old River and GLC routes. Therefore, these two routes were combined into a single route within the model by assuming survival was equal between these two routes (i.e., estimating B_{15,g_i} and setting $\mathrm{B}_{16,g_i} = \mathrm{B}_{18,g_i} = 1.0$), arbitrarily assigning a 50% routing probability (i.e., $\rho_{12} = 0.5$), and assigning a 0% detection probability for these reaches (i.e., $p_{13} = p_{15} = 0.0$). In addition, there was no receiver along the Middle River route (i.e., $p_{10} = 0.0$), but we were still able to estimate routing into and survival through the MR route. These changes allowed us to keep the same model structure and routing probabilities as the 2021 model, while accounting for differences in receiver deployments.

For the DF transition matrix, we have three non-detection dummy states (Detection = 0% and survival = 100%; reaches 16, 18, 28, 29, and 30). In addition, we explicitly modeled dual-line receiver gates (i.e., two receiver lines located in close proximity) with 100% survival in reach 26 (i.e., Golden Gate East). This allowed us to obtain an estimate of survival for reach 25 (from Benicia Bridge to Golden Gate East), as opposed to the joint probability of surviving and being detected.

For fish released at HOR, individuals can utilize any of the SJ or OR routes (Figure 3). The only difference for these fish is the capture histories contain known dummy states (Detection = 100% and Survival = 100%). These dummy states are represented by states 31-33 and HOR releases into reach 2, $CH = (31,32,33,2, \dots)$. These represent pre-release states in order to match capture occasions represented by the Durham Ferry releases. After selection of the ST or OR routes (i.e., after reach 2), the HOR release transition matrix is identical to the DF transition matrix (Figures 3, 2).

The structure for ST releases is slightly different and incorporate both pre-release dummy states (39) and unseen dummy reaches (Detection = 0% and Survival = 100%, reaches 34-38). Fish are allowed to swim downstream towards MacDonald Island and TC (reaches 10 and 11) to take either SJ route. Fish taking the SJ routes have additional unseen dummy reaches after release in reach 3 $CH = (39,3,0,0,0,0,0,10,\ldots)$ or $CH = (39,3,0,0,0,0,0,11,\ldots)$. Additionally, fish may swim upstream toward the HOR and select the OR routes $CH = (39,3,7,6,12,\ldots)$. Routing after reaches 10, 11, and 12 are identical to the DF routing along both SJ and OR routes (Figures 4, 2). For the ST release groups, structuring the model this way allowed us to utilize data for individuals that swam upstream toward the HOR to improve estimates of survival and routing in the OR routes.

Route entrainment probabilities $\psi_{g_i,r_i,k,j}$ for release group g_i and release location r_i describe the probability a fish will transition from reach k to reach j. Similar to Buchanan (2018c), we modeled the main outmigration paths that fish migrating from the SJR can take. For routing options at 2-way junctions, such as fish released at Durham Ferry that reach the HOR (reach 6), they can remain in the SJR route

$$\psi_{g_i,1,6,7} = \rho_{g_i,x=3} \tag{3}$$

or take the OR route

$$\psi_{g_i,1,6,12} = \left(1 - \rho_{g_i,x=3}\right) \tag{4}$$

where $\rho_{g_i,x=3}$ is the probability of remaining in the SJR at the HOR (parameters defined in Tables 18-20). As you will note when looking at the routing map, there are instances where fish have >2 route selection options (e.g., states 10, 11, 16, 18, and 28 have 3-4 routing options; Figures 2-4). We modeled these parameters as 2-part functions, or joint probabilities, where we broke up individual transition probabilities into easier-to-handle components that can be easily integrated in TMB. For example, fish i in state 10 (they remained in the SJR route past MacDonald Island, MAC) could

1. stay in the central Delta and take Three-mile Slough to get to Chipps Island
$$\psi_{g_i,r_i,10,22} = \left(1 - \rho_{g_i,6}\right) * \rho_{g_i,2} \tag{5}$$
2. stay in the central Delta and swim past Jersey Point to get to Chipps Island
$$\psi_{g_i,r_i,10,23} = \left(1 - \rho_{g_i,6}\right) * \left(1 - \rho_{g_i,2}\right) \tag{6}$$
3. head towards the pumping facilities and get entrained into the CVP
$$\psi_{g_i,r_i,10,19} = \rho_{g_i,6} * \rho_{g_i,1} \tag{7}$$
4. or head towards the pumping facilities and get entrained into the SWP
$$\psi_{g_i,r_i,10,20} = \rho_{g_i,6} * \left(1 - \rho_{g_i,1}\right) \tag{8}$$

where $\rho_{g_i,x}$ is the probability of taking routing option x (see Tables 18-20). We modeled $\rho_{g_i,x}$ as a logit-transformed normally distributed random effect. Because the probability of taking route x or route y is arbitrary from a fish's perspective relative to a statistical model and to avoid any unintentional bias, we estimated the mean hyperprior μ_ρ and used an informative standard deviation of log(1.75) to approximate a uniform prior at mean hyperprior values of zero. The hypermean μ_ρ was shared across all release groups. Similar to survival, by setting routing probabilies $\rho_{1,x} = \rho_{2,x} = \rho_{3,x}$, we are holding routing at each junction constant across release group g_i or allowing routing to vary between each release group by having $\rho_{1,x} \neq \rho_{2,x} \neq \rho_{3,x}$.

Detection probabilities (P_j) represent the probability a tagged fish will be detected transitioning from reach k to reach j given the fish is alive and acoustic transmitter is functional. Detection probability for each receiver gate p_j was treated as a logit-transformed normally distributed random effect with a mean of zero and standard deviation of σ_p. In order to reduce the complexity of the model, we condensed most dual-line receivers into a single detection event (except at the Golden Gate dual-line receivers; Figures 2-4). For fish passing these condensed dual-line receivers, we classified a "detection" within the model as the transmitter being detected by at least one of the gates. Therefore, the detection probability for condensed dual-line gates was estimated as

$$P_j = 1 - \left(1 - p_j\right)^2 \qquad 9$$

and for standard single-line gates $P_j = p_j$. This allowed us to minimize bias in the random effect structure for detection by explicitly accounting for the increased detection probabilities at the condensed dual-line receivers. Detection probabilities for each reach were held constant over each release group as it seems likely that detection at a given site would remain relatively stable over time. This also reduces the number of parameters to be estimated and reduces model complexity.

A multinomial distribution was used to calculate the likelihood. With the multinomial likelihood, the probability of being observed in reach j is the product of survival in reach k, the detection probability entering reach j and the probability of transitioning from reach k to reach j. This is a multiplicative process for each capture occasion. For example, a fish released at Durham Ferry (1), detected at DF_DS (4), SJ_BCA (5), SJ_HOR (7), MAC (10), CCF_inlet (20), Chipps (24), and Golden Gate East (26) would have a capture history of $CH = (1,4,5,0,7,0,0,10,20,0,24,0,26,0)$. This likelihood would be

$$l = \phi_1 P_4 * \phi_4 P_5 * \phi_5(1 - P_6) * \phi_6 \psi_{g_i,1,6,7} P_7 * \phi_7(1 - P_8) * \phi_8(1 - P_9) * \phi_9 \psi_{g_i,1,9,10} P_{10} * \phi_{10} \psi_{g_i,1,10,20} P_{20} * \phi_{20}(1 - P_{21}) * \phi_{21} P_{24} * \phi_{24}(1 - P_{25}) * \phi_{25} P_{26} * (1 - P_{27}) \qquad 10$$

and needs to be calculated for every fish.

Analysis of Tag Battery Life and Retention

Approximately 5% of the tags available were randomly selected for use in a battery life and tag retention study. This study was lead by UCSC staff and details of the methods can be found in (Notch et al. *unpublished*). Briefly, a total of 41 tags were tested for battery life and and 44 for tag retention. All tags made it to the estimated run-time of 79 days. Mean run time was 167 days with a tags dying as early as 110 days. A total of 5 tags were shed (11.4%), with tags shed between 27-38 days post-surgery. Given the high battery life and low tagging mortality, we did not incorporate this information into the model. Further, incorporating tag loss into the model would require integrating time back into the model, similar to methods outlined in Hance et al. (2022) by incorporating travel time into a space-for-time multistate model.

Analysis of Travel Time to Chipps Island

Travel times (in days) for all tags that made it to Chipps Island, including the 37 fish that were trucked from the facilities to the Western Delta, were calculated. Following Buchanan (2018a), the harmonic mean was used as a summary of travel times. Estimates of travel time encompassed all release months but were segregated by both release location and route (SJR vs. OR routes). Travel times to Chipps Island across both routes were also calculated. Importantly, because release times were not considered reliable for individual tags, release times were excluded from the calculated rate. In addition to calculating travel times based on all tags (i.e., the unfiltered dataset), travel times to Chipps were also calculated based on the multi-hit and 1-hit predator-filtered datasets.

Multivariate Analysis on Survival & Routing

To assess the effects of environmental conditions on through-Delta survival and routing at the HOR, we used estimates from 2011-2016 for each release group reported in Buchanan et al. (2021), reports (Buchanan 2018a, 2018b, 2018c, USBR 2018a, 2018b, 2018c), estimates from the 2021 study (Matthias et al. 2024) and the 2022 results from this study. All data utilized a predator filter, with the 2021 and 2022 data using the multi-hit filter (Tables B2, B3). Covariates assessed were related to environmental conditions (Delta inflow, Delta outflow, SJR inflow, Sacramento River Inflow, and Temperature) along with management-based covariates (exports, Inflow:Exports [IE] ratio for total Delta Inflow, SJR Inflow:Export ratio, Sacramento River Inflow:Export ratio, and the presence of a rock barrier at the Head of Old River [HORB]; Table 19). Flow and export related covariates were obtained from the Dayflow database (reported on a daily time-step; https://data.cnra.ca.gov/dataset/dayflow) and temperature was recorded at Mossdale (recorded on a 15-minute interval; https://wdl.water.ca.gov/waterdatalibrary/). Covariates were averaged over the release period and represent general conditions fish experienced during outmigration. This time period may not represent the exact conditions fish experienced when migrating through the Delta, but represent a simple approximation of their experienced conditions.

We performed a multivariate analysis on survival using a generalized logistic model

$$logit(\hat{S}_i) = \mathrm{A} + \frac{\mathrm{K} + \mathrm{A}}{1 + e^{-(\beta_0 + \beta_1 * B_i + \beta_2 * x_i + \beta_3 * T_i)}} \qquad 11$$

where $\hat{S}_i$ is the predicted survival from release group i, A is the left horizontal asymptote, K is the right horizontal asymptote, $\beta_0, \dots, \beta_3$ are the regression coefficients, B_i represents barrier status with $B_i = 1$ represents conditions in which the HORB was completed prior to release for group i and $B_i = 0$ when the HORB was not installed or under construction, x_i is the inflow/outflow/export covarites (discussed above), and T_i is the temperature at Mossdale. Except the presence of the HORB, the covariates were centered (subtracting the covariate by the mean of that covariate) to help with model fitting. We used a generalized logistic function for the analysis because survival appeared to reach an asymptote of less than 100% through-Delta survival (survival range from 3-69%; Figures 17-18). We used a maximum likelihood framework with a normal likelihood

$$NLL = -\sum_{i=1}^{n} \log\left(\frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(S_i - \hat{S}_i)^2}{2\sigma^2}}\right) \qquad 12$$

where NLL is the negative log likelihood, σ is the standard error, and S_i are the observed survival estimates for each release group. Finally, we used optim in R to minimize the NLL.

Multivariate analysis for routing used similar methods for survival with $\mathrm{A} = 1$ and $\mathrm{K} = 1$ (i.e., a standard logistic regression). Attempts at fitting the model with covarates did not produce reasonable results. The exception was the covariates for presence/absence of the HORB. Therefore, no formal multivariate analysis for routing was pursued.

Results

Detections

A total of 396 fish were released at Durham Ferry. Of the 180 fish that were detected downstream of HOR, over half of the fish selected SJR routes (n = 98) compared to OR routes (n = 82). A total of 46 fish were detected at Chipps Island. Of these fish, 13 were detected at Chipps Island, one taking the SJR mainstem route, 12 remaining in OR past MR. Of the fish that made it to Chipps Island, four took 3-Mile Slough, 28 went past Jersey Point, six were entrained into the CVP and six in the SWP, and two via an unknown route. More fish made it past Chipps Island in March (n = 19) compared to April (n = 11) or May (n = 16).

A total of 255 fish were released at HOR and most remained in the OR route (n = 147) compared to taking the SJR routes (n = 13). A total of 35 fish were detected at Chipps Island, 21 from the March, 12 from the April, and two from the May release groups. Of the fish that made it past Chipps Island, five fish took the SJR mainstem route and 30 took OR routes. Twenty of the fish released at HOR that made it to Chipps Island were detected at the pumping facilities, 14 detected at Jersey Point, and one detected at Three-Mile Slough.

A total of 255 fish were released at Dos Reis, with 44 detected at downstream of Chipps Island (23 in March, 16 in April, and five in May). A total of 151 fish were detected downstream of release and 28 went upstream towards the HOR routes. Most fish that made it to Chipps Island were detected moving past Jersey Point (n = 36) and few taking Three-Mile Slough (n = 2), the pumps (four at the CVP), or unknown routes (n = 2).

Environmental Conditions During Releases

We calculated weekly mean flow, temperature, and exports for the three release weeks; daily averages are visually represented in Figures 12-15. Flow and temperature data near Vernalis were downloaded from the California Data Exchange Center. Weekly mean flow was 5,250 cfs in March, 5,373 cfs in April, and 4,519 cfs in May. Weekly mean temperature in March was 14.6°C, 15.5°C in April, and 17.3°C in May. The daily range for the study period (March 13 – May 16) for flow was 4,219 cfs to 7,392 cfs and for temperature was 12.2°C to 18.8 °C.

Exports data were downloaded from the California Department of Water Resources dayflow website. Weekly mean exports at the Central Valley Project were 1,828 cfs in March, 922 cfs in April, and 917 cfs in May. For the State Water Project, weekly mean exports were 1,134 cfs in March, 594 cfs in April, and 591 cfs in May. Weekly mean total exports were 3,057 cfs in March, 1,855 cfs in April, and 1,794 in May. The daily export range for the study period (March 13 – May 16) was 908 cfs to 2,721 cfs for the Central Valley Project, 580 cfs to 3,798 cfs for the State Water Project, and total exports from 1,771 cfs to 4,855 cfs. Weekly mean export to inflow ratio was 0.06 for March, 0.05 for April, and 0.04 for May. The daily export to inflow ratio for the study period was 0.04 to 0.10.

Model Results – All data

Release/reach-specific Survival

All release groups combined

Survival from Durham Ferry to Delta-entry at Mossdale was 0.48, through-Delta (Delta entry at Mossdale to Chipps Island) survival was 0.24, and through-Bay (Chipps Island to Golden Gate West) was 0.72 (Table 9). Fish taking the SJR Routes had survival rates of 0.25, with higher survival for fish staying in the SJR (0.28) than those taking the TC route (0.18; Table 9). Fish taking the OR routes had survival rates of 0.22, with similar survival of fish taking the MR routes (0.20) or remaining to take the OR/GLC routes (0.23; Table 9). Post-release survival was about 0.60 for all release groups (Table 13). Reach-specific survival rates for an average-sized fish were >0.90 for many reaches along the SJR between Mossdale and the Turner Cut junction (reaches 7-10) and in the OR routes from Mossdale to the pumping facilities (reaches 13, 14, 16-18; Table 13). Lowest survival (<0.51) was in the interior Delta region (reaches 11, 12, 15, and 18) and around the pumping facilities (reaches 20-22; Table 13).

March

Survival from Durham Ferry to Delta-entry was 0.78, through-Delta survival was 0.22, and through-Bay was 0.70 (Table 10). For fish taking the SJR Routes, survival was 0.24 and was higher for fish staying in the SJR compared to TC routes (0.26 and 0.17 respectively; Table 10). Fish taking the OR routes had survival rates of 0.21, with similar survival of fish taking the MR routes (0.21) compared to those staying in the OR/GLC routes (0.21; Table 10). Post-release survival was high for all three March releases locations (0.97; Table 14), note that no version 7 tags were released in March (Table 3). Reach-specific survival rates for an average-sized fish were >0.90 for many reaches along the SJR between Mossdale and the Turner Cut junction (reaches 7-10) and in the OR routes from Mossdale to the pumping facilities (reaches 13, 14, 16-18; Table 14). Lowest survival (generally <0.64) was in the interior Delta region (reaches 11, 12, 15, and 18) and around the pumping facilities (reaches 20-22; Table 14).

April

Survival from Durham Ferry to Delta-entry was 0.32, through-Delta survival was 0.21, and through-Bay was 0.69 (Table 11). Survival for fish taking the SJR Routes was 0.21 with higher survival for fish staying in the SJR (0.22) compared to those taking the TC route (0.17; Table 11). Fish taking the OR routes had survival rates of 0.20, with lower survival of fish taking the MR routes (0.18) compared to those staying in the OR/GLC routes (0.20; Table 11). Post-release survival ranged from 0.17-0.32 (Table 15) and this low survival can be attributed, in part, to the high prevalence of version 7 tags in this release group (Table 3). Reach-specific survival rates for an average-sized fish were >0.90 for many reaches along the SJR between Mossdale and the turner cut junction (reaches 7-10) and in the OR routes from Mossdale to the pumping facilities (reaches 13, 14, 16-18; Table 15). Lowest survival (generally <0.45) was in the interior Delta region (reaches 11, 12, 15, and 18) and around the pumping facilities (reaches 20-22; Table 15).

May

Survival from Durham Ferry to Delta-entry was 0.33, through-Delta survival was 0.29, and through-Bay was 0.77 (Table 12). Survival for fish taking the SJR Routes was 0.32 with higher survival for fish staying in the SJR (0.36) compared to those taking the TC route (0.19; Table 12). Fish taking the OR routes had survival rates of 0.26, with lower survival of fish taking the MR routes (0.23) compared to those staying in the OR/GLC routes (0.27; Table 12). Post-release survival ranged from 0.17-0.44 (Table 16) and this low survival can be attributed, in part, to the high prevalence of version 7 tags in this release group (Table 3). Reach-specific survival rates for an average-sized fish were >0.90 for many reaches along the SJR between Mossdale and the turner cut junction (reaches 7-10) and in the OR routes from Mossdale to the pumping facilities (reaches 13, 14, 16-18; Table 16). Lowest survival (generally <0.57) was in the interior Delta region (reaches 11, 12, 15, and 18) and around the pumping facilities (reaches 20-22; Table 16).

Covariates

We incorporated a mixed-effects regression to estimate survival, including fixed effects representing a length-based survival covariate in the model. Overall mean tagging length was 237.6 mm (range 135-324 mm). Monthly size distributions showed increasing mean sizes over time, with mean tagging length of 226.7 mm (range 135-295 mm) in March, 240.8 mm (range 153-309 mm) in April, and 248.4 mm (range 138-324 mm) in May. The mean survival random effect, which can be interpreted as the mean release-specific intercept, had highest values for March and lower values for the April and May releases (values of 1.48, 1.07, and 1.03, respectively; Tables 13-14). The length-survival relationship was assumed to be constant over all release groups. We found a significant (i.e., 95% confidence intervals did not overlap zero; mean estimate 0.37 with 95% confidence intervals of 0.32-0.43) positive relationship between length and survival (Tables 13-14).

Release/reach-specific Routing

All release groups combined

Routing probabilities across all release groups (reported in Table 17) showed about half of DF released fish took SJR routes at the Head of OR (55%) compared to taking OR routes (45%). For fish that took the SJR routes, most remained in the SJR past TC (71%) and few of these fish headed towards the pumps after passing MacDonald Island (11%). Most fish that took the TC route went towards the pumps (57%). Few fish took the MR route (16%) and 62% of those fish headed towards the pumps. Fish that took the OR/GLC routes often ended up at the pumping facilities (64%). Most fish released at the HOR took the OR routes (93%) and most fish released at DR took SJR routes (i.e., went downstream; 86%).

Given the model structure, we modeled entrainment by the SWP or CVP as a constant across all routing options. For fish that were entrained at the pumping facitlies, we estimated roughly half of fish were entrained by the CVP (48%) compared to the SWP (52%; Table 17). Route selection from the interior Delta to Chipps Island via Three-Mile Slough or Jersey Point was also constant across routing options. Most fish took Jersey Point (88%) to get to Chipps Island via the interior Delta (Table 17).

March

Routing probabilities for March (reported in Table 18) showed that half of DF released fish took SJR routes at the Head of OR (51%) compared to taking OR routes (49%). For fish that took SJR routes, most remained in the SJR past TC (69%) and few headed towards the pumps after passing MacDonald Island (8%). Roughly half of the fish that took the TC route went towards the pumps (53%). Few fish took the MR route (11%) and 48% of those fish headed towards the pumps. Fish that took the OR/GLC routes often ended up at the pumping facilities (73%). Most fish released at the HOR remained in OR (89%) and just over half of fish went downstream in the DR releases (86%).

Given the model structure, we modeled entrainment by the SWP or CVP as a constant across all routing options. For the fish entrained at the pumping facilities, we estimated less than half of fish were entrained by the CVP (34%) compared to the SWP (66%; Table 18). Route selection from the interior Delta to Chipps Island via Three-Mile Slough or Jersey Point was also constant across routing options. Most fish took Jersey Point (86%) to get to Chipps Island via the interior Delta (Table 18).

April

Routing probabilities for April (reported in Table 19) showed few DF released fish took SJR routes at the Head of OR (66%) compared to taking OR routes (44%; Table 19). For fish that took SJR routes, half remained in the SJR past TC (68%) and few of these fish headed towards the pumps after passing MacDonald Island (12%). Less than half of the fish that took the TC route went towards the pumps (45%). Few fish took the MR route (14%) and 56% of those fish that took the MR route headed towards the pumps. Fish that took the OR/GLC routes often ended up at the pumping facilities (66%). Most fish released at the HOR remained in OR (95%) and most fish went downstream in the DR releases (93%; Table 19).

Given the model structure, we modeled entrainment by the SWP or CVP as a constant across all routing options. For fish that were entrained at the pumping facitlies, we estimated roughly half of fish were entrained by the CVP (50%) compared to the SWP (50%; Table 19). Route selection from the interior Delta to Chipps Island via Three-Mile Slough or Jersey Point was also constant across routing options. Most fish took Jersey Point (87%) to get to Chipps Island via the interior Delta (Table 19).

May

Routing probabilities for May (reported in Table 20) showed about half of the DF released fish took SJR routes at the Head of OR (47%) compared to taking OR routes (53%; Table 20). For fish that took SJR routes, half remained in the SJR past TC (76%) and few of these fish headed towards the pumps after passing MacDonald Island (12%). Most of the fish that took the TC route went towards the pumps (71%). Few fish took the MR route (28%) and 15% of those fish headed towards the pumps. Fish that took the OR/GLC routes often ended up at the pumping facilities (69%). Most fish released at the HOR remained in OR (94%) and most fish went downstream in the DR releases (75%; Table 20).

Given the model structure, we modeled entrainment by the SWP or CVP as a constant across all routing options. For fish that were entrained at the pumping facitlies, we estimated over half of fish were entrained by the CVP (60%) compared to the SWP (40%; Table 20). Route selection from the interior Delta to Chipps Island via Three-Mile Slough or Jersey Point was also constant across routing options. Most fish took Jersey Point (90%) to get to Chipps Island via the interior Delta (Table 20).

Detection Probabilities

Detection probabilities for single-line receiver gates were often >80% (13 of 20 gates; Table 21). Some locations had <80% single-line detection rates, but were often associated with combined-dual lines, resulting in the detection probability for the combined gates being >82% (i.e., the probability of being detected at the upstream gate, downstream gate, or both gates; e.g., OR_HOR = 80%, Chipps Island = 94%, etc.; Table 21). Four exceptions with low detection probabilities were downstream of Durham Ferry (DF_DS; single-line detection rate of 58%), OR_MidR (single-line detection rate of 56%), MR_RRB (single-line detection rate of 55%), and Golden Gate W (single-line detection rate of 69%; Table 21). Detection probabilities were held constant over each release group.

Model Results – Predator Filters

We developed two predator filters for these data, a 1-hit filter and a multi-hit filter. A total of 51 fish had detections that were removed due to exceeding predator thresholds for the 1-hit filter and six had detections removed for the multi-hit filter. Nine tags that made it to Chipps Island were identified as having predator-type detections (SJSH2024-0016, SJSH2024-0167, SJSH2024-0205, SJSH2024-0250, SJSH2024-0251, SJSH2024-377, SJSH2024-397, SJSH2024-702, SJSH2024-827). Two fish released at DF were classified as exhibiting predator-type behaviors for the 1-hit filter, as were two fish from the DR releases and five fish from the HOR releases. No fish identified as predators by the multi-hit filter made it to Chipps Island.

Derived survival estimates (e.g., survival to Delta Entry, through-Delta survival, through-Bay survival, etc.) were very similar between the models using predator filtered data compared to unfiltered data (Tables 9-12, A1-A4, B1-B4). Derived survival estimates using the 1-hit filter were generally lower (1-3% lower probabilities) to those using the unfiltered data (Tables 9-12, A1-A4). We consistently predicted survival rates 1-3% lower across all SJR and OR routes when using the multi-hit filter dataset. There were some exceptions, maninly survival to Delta entry across all months were very similar between datasets. For the multi-hit filter, most derived survival rates showed little differences (estimates from the multi-hit filter within $\pm$0.01 of the unfiltered data; Tables 9-12, B1-B4).

Reach-specific differences in reach-specific survival rates were generally within $\pm$0.05 units between the model with unfiltered data compared to model results using either predator filter (Tables 13-16, A5-A8, B5-B8). A few reaches in each release group had larger differences in survival between the unfiltered data and the 1-hit predator filter, especially in April/May when we used mostly the faulty version 7 tags (Tables 13-16, A5-A8, B5-B8). Based on the implementation of the predator filter, differences in the survival rates between the unfiltered vs. predator filtered data occurred at the reach-level, but didn't propagate over larger spatial scales for the multi-hit filter (e.g., through-Delta estimates) because no fish flagged as predators made it to Chipps Island. Nine of the 51 fish classified as predators using the 1-hit filter made it to Chipps Island, and we see larger differences in derived survival estimates.

Estimates of routing and detection were also similar between models using all datasets (Tables 17-21, A9-A13, B9-B13). The only notable differences in routing was the probability of heading to the pumps after Turner Cut (ρ_9). With the unfiltered data, 72% of the TC route fish headed towards the pumps and 54% of these fish with the 1-hit filter for the May releases (Tables 20 and A12). It should be noted that the 95% confidence intervals for these estimates overlap and are thus not statistically significant (Tables 20 and A12). Detection estimates were within $\pm$0.03 units between models using unfiltered vs. predator filtered data (Tables 21, A13, B13).

Travel Time

Travel times for the 118 tagged fish that made it to Chipps Island, based on the unfiltered dataset, are provided in Table 7. Across release months, fish released at Dos Reis that traveled along the OR routes to Chipps Island had the longest average travel time at 28.88 days (SE = 8.41 days). However, it should be noted that only three fish detected at Chipps Island took the OR routes after release at Dos Reis. The next longest average travel time to Chipps Island corresponded to HOR released fish that used the SJR routes (mean = 22.98 days; SE = 6.77 days). Durham Ferry released fish traveled the fastest to Chipps Island overall, regardless of whether they traveled through the SJR routes (mean = 7.37; SE = 2.75 days) or OR routes (mean = 8.26 days; SE = 1.82 days). Dos Reis released fish traveling through the SJR route and HOR released fish traveling along the OR routes spent 1-2 more days to arrive at Chipps Island than did the Durham Ferry fish (Table 7).

Seven fish spent less than 4 days enroute to Chipps Island, across a variety of release locations and routes, with one of those fish making it in 2.3 days from release at HOR along the OR routes. The distribution of travel times for each combination of release location and route is provided as cumulative frequency plots (Figure 16). Two fish spent more than 50 days traveling to Chipps Island, by moving through the SJR routes, less than in 2022 when the maximum travel time to Chipps was 69 days (Matthias et al. 2025) but more than in 2021 when maximum travel time barely exceeded 30 days (Matthias et al. 2024).

Once the capture histories of the tags classified as predator based on the 1-hit filter were removed, travel times to Chipps Island only reduced slightly for the following groups: Durham Ferry and HOR releases moving through the OR routes, Durham Ferry releases moving through the SJR routes, and for fish released at Dos Reis traveling along the SJR routes. Travel time increased slightly for the HOR release group moving down the SJR routes (see Table 8).

Multivariate Analysis on Survival & Routing

Through-Delta survival estimates from 2024 (21-29%) were within the range estimated by Buchanan et al. (2021) between 2011 and 2016 (6-69%), and higher than those estimated in 2021 or 2022 (2-13%; Figure 17). The 2024 study was the only above normal water year and environmental (SJR inflow and temperature) and managed (exports and IE ratio) conditions during 2024 were intermediate between the wet year (2011) and dry or critallly dry years (all other years; Figures 17, 18). The multivariate analysis indicated that inflow (total Delta, SJR, and SAC inflow), Delta outflow , and exports were the best models describing variation in survival (i.e., ΔAIC < 6; Table 20), with the Delta inflow model having the lowest AIC. Across all models, the presence of the HORB was associated with higher survival and there was a negative relationship between survival and temperature (Figure 18; Table 20).

Routing at the HOR was highly dependent on the presence/absence of the HORB (rock barrier at the head of Old River; Figure 19). When the HORB was in place, most fish (>90%) took the SJR route. Routing in 2024 matched closely with estimates from 2011 (a wet year), in which approximately half the fish took the SJR route (Figure 19). During dry and critically dry water years without the HORB, most fish took the OR route (Figure 19), except for the April release in 2012 when the HORB was partially in place. It should be noted the HORB was under construction from March 15 to April 11 and fish were released from April 4-7 in 2012. There was no correlation between routing at the HOR and covariates assessed (see Figure 20 for examples).

Discussion

Survival was higher for outmigrating steelhead smolts in 2024 (21-29%) than other recent years (<13% in 2021 and 2022; Matthias et al. 2024, 2025). The 2024 survival rates were within the range of estimates from 2011-2016 (5-63%; from Buchanan et al. 2021). Interestingly, the 2024 study occurred during the only above normal water year, but survival rates were lower than those observed during dry water years (average 39%, 2012 and 2016 compared to 24% from 2024) and only slightly higher than the critically dry years from 2013-2015 (average 20%). Routing estimates at the HOR were comparable the wet year in 2011, with about 50% remaining in the SJR. Finally, detection rates were also comparable between studies with most detection estimates >80% for all studies (see Buchanan 2018a, 2018b, 2018c, USBR 2018a, 2018b, 2018c; Matthias et al. 2024; 2025), except for downstream of Durham Ferry and MR_RRB (57% and 55% respectively; Table B10). Note, the discussion focuses on results obtained from the multi-hit predator filter because they are comparable to results presented in Buchanan et al. (2021).

The 2024 water year was classified as above normal, with mean SJR inflows from 4,950-5,443 cfs and exports ranging from 1,799-3,115 cfs, resulting in lower export rates than SJR inflow for each release group (SJR inflow/exports were 1.7 to 2.9 for the release groups). Additionally, OMR flows did not exceed -5000 cfs during the release weeks (the tidally averaged flows across the release groups were -155 to -836 cfs). Water temperatures at Mossdale increased from 15.4-16.7°C during the study period. Similar to previous years, it will be very challenging to detect any survival benefits of the spring pulse flow with the existing model structure. This is a consistent issue with these analysis methods when we are unable to incorporate multiple covariates into the survival components of the mark-recapture model. Future efforts will seek analytical methods to account for multiple covariates within the survival model.

Incorporating covariates within the multistate modeling framework is challenging across the temporal and spatial extent of this study. Therefore we only incorporated a fixed length-effect and random reach effects within the model. Similar to work by Buchanan et al. (2021), we found a positive relationship between smolt length and survival. Although we did not directly incorporate temperature into the multistate models, no apparent trend in survival with Mossdale temperature was evident during the release weeks, as temperatures were within 1.5°C range for each release group, nor did they exceed 20°C (as seen during 2012-2015 and 2021). The negative trend in survival and temperature were present when comparing to previous studies (Table 20; Figure 18; Buchanan et al. 2021; Matthias et al. 2024; 2025). Correlating the other covariates with survival showed higher survival with higher inflows, exports and IE ratios, similar to results from Buchanan et al. (2021). In the future, we will investigate methods to estimate the effects of temperature, inflow and exports on survival within the multistate mark-recapture model framework.

Buchanan et al. (2021) and the 2021-2022 studies (Matthias et al. 2024; 2025) demonstrated that survival rates were not appreciably different for fish taking either the SJR and OR routes. The results from 2024 consistenly show slightly higher survival of fish taking the SJR routes across all release groups, although confidence intervals overlap. For the SJR routes, prior studies for both steelhead and fall-run Chinook consistently show lower survival of fish taking the TC route (Buchanan et al. 2021). Looking at through-Delta survival for these routes, we found 5-17% lower survival for fish that were entrained into Turner Cut than those that remained in the SJR (Table B3). Survival was consistent across all OR routes, ranging from 20-27% (Tables B2-B4). Overall, we detected similar route-specific patterns of survival compared to previous studies when no barrier at HOR was installed (i.e., no detectable differences in survival between the SJR or OR routes).

Similar to studies by R. Buchanan (Buchanan 2018a, 2018b, 2018c, USBR 2018a, 2018b, 2018c), the biggest driving factor in routing at the HOR was the presence/absence of the rock barrier (HORB). There was no HORB installed for the 2024 study and roughly half of the fish released at Durham Ferry took the OR routes, similar to the wet year in 2011. This is different than routing observations from the 2021-2022 studies, where most fish took OR at HOR (Matthias et al. 2024, 2025). Although, this was similar to observations in May 2021 release where a higher proportion of fish (42%) remained in the SJR. The May 2021 estimate was similar to 2011 (the only wet water year), 2024 (the only above normal water year), and several releases where the HORB was partially installed (April 2012 and late-March 2015). As noted in the 2021 report (Matthias et al. 2024), the Durham Ferry release in May experienced very low survival from release to Delta-entry (12%, compared to >54% for the other releases that year) and this low sample size likely contributed to the high proportion of fish taking the SJR route for the May release.

We developed two different predator filters for this effort. As a reminder the multi-hit needs multiple hits on the predator filter to be considered a predator and the 1-hit filter needs a single hit to be classified as a predator. The unfiltered data and the 1-hit filtered data can be considered bookends on the survival estimates. These predator filters differ from prior filters developed by R. Buchanan on steelhead (USBR 2018c). The Buchanan predator filter was developed based on expert opinion across multiple lines of evidence (surpassing thresholds for at least two of the following criteria at a station: fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow; U.S. Bureau of Reclamation (USBR) et al. 2018c). Our predator filter is slightly different in that we utilize statistical distributions to classify individual metrics as being a predator-type or smolt-type metric. For simplicity, we only utilized the upper extreme values for classifying predators (i.e., the upper 95% of observations were classified as predator types). Thus it is important to note that the predator classifications from 2011-2016 data are different than those reported in this document.

In 2024, a proportion of the tags suffered from a software issue resulting resulting in the tags deactivating before bing implanted into the fish (i.e., version 7 tags). Thus, an unknown subset of our tags were not functioning when the fish were released. As a result, this decreased apparent survival rates estimated for reaches 1,2, and 4 (i.e., the release states). Therefore, these estimates can actually be referred to as the joint probability a fish successfully transitioned to a downstream reach (i.e., survived and migrated towards the Delta exit) and the tag was functioning properly. Additionally, differences in survival estimates between each release group is a function of the proportion of version 7 tags released each month at a given release site (see Table 3 for numbers of version 7 tags deployed with each release group). Taking a look at release-specific survival rates across months, we had no version 7 tags released in March (high survival rates; 97%), all but one version 7 tag released in May (very low survival rates; 17-44%), and a mixture of tag versions in April (mostly version 7, intermediate survival rates; 37-66%; Tables 14-16). The tag failure likely influenced post-release survival rates in reaches immediately downstream of release because we didn’t know which version 7 tags were active. Attempts at incorporating an additional parameter on survival of fish with version 7 tags (e.g., a version 7 tag mortality factor) were not successful because we didn’t have adequate overlap between the different tag types across releases and the parameter was unestimable.

Our study provides an updated study design utilizing multiple release groups and associated analytical methods to estimate survival, routing, and detection probabilities of juvenile steelhead migrating through the Sacramento – San Joaquin River Delta. While the model structure differed from prior models by R. Buchanan, our results are directly comparable to the prior studies. Results show that through-Delta outmigrating survival of juvenile steelhead was intermediate for fish taking either the SJR or OR routes in 2024. Survival estimates were comparable to those from the previous study from 2011-2016, even though 2024 was the only above nomal water year. Further advancements to the methods outlined here, in particular those designed to incorporate additional covariates into the estimates of survival and routing, should provide better insight into the effects of water operations on juvenile steelhead outmigration characteristics.

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Tables

Table 1. Release numbers for each day and release location. A total of 906 fish were released during the study.

Rlease Site	20-Mar	21-Mar	22-Mar	17-Apr	18-Apr	19-Apr	8-May	9-May	Total
Durham Ferry	30	55	55	30	55	55	50	66	396
Head of Old River	39	26	39	26	39	26	36	24	255
Dos Reis	26	39	26	39	26	39	24	36	255
Total	95	120	120	95	120	120	110	126	906

Table 2. Release numbers for non-version 7 tags for each day and release location. A total of 405 fish with these tags were released during the study.

Rlease Site	20-Mar	21-Mar	22-Mar	17-Apr	18-Apr	19-Apr	8-May	9-May	Total
Durham Ferry	30	55	55	2	0	0	0	0	142
Head of Old River	39	26	39	25	0	1	0	0	130
Dos Reis	26	39	26	39	1	1	1	0	133
Total	95	120	120	66	1	2	1	0	405

Table 3. Release numbers for version 7 tags for each day and release location. A total of 501 fish with these tags were released during the study.

Rlease Site	20-Mar	21-Mar	22-Mar	17-Apr	18-Apr	19-Apr	8-May	9-May	Total
Durham Ferry	0	0	0	28	55	55	50	66	254
Head of Old River	0	0	0	1	39	25	36	24	125
Dos Reis	0	0	0	0	25	38	23	36	122
Total	0	0	0	29	119	118	109	126	501

Table 4. Receiver general locations, and latitude and longitude coordinates used in 2024 study.

Receiver general location	Latitude	Longitude
DurhamFerry_Rel	37.68780	-121.2622
Durhamferry	37.68949	-121.27556
Mossdale	37.79184	-121.3072
Head_of_Old_River	37.80789	-121.3295
SJ_HOR_1	37.81155	-121.3187
OldRiverHOR_1	37.81359	-121.3354
SJ_HOR_2	37.81377	-121.3184
OldRiverHOR_2	37.81545	-121.3342
CVP_Trash_Rack	37.81629	-121.5589
Old_River_at_Middle_River_Head_1	37.82061	-121.3776
GoldenGateW	37.82052	-122.4683
GoldenGateE	37.82523	-122.4616
Clifton_Court	37.82990	-121.5569
CC_intake_J	37.82824	-121.5942
SJ_Howard_1	37.87361	-121.3318
SJ_Garwood_1	37.93627	-121.3339
SJ_Garwood_2	37.93820	-121.3356
Dos_Rios_Rel	37.83051	-121.3112
MiddleRiver_RR_Bridge (MR_RRB)	37.93935	-121.5330
Old_River_Victoria_1	37.87739	-121.5773
Old_River_Victoria_2	37.88039	-121.5756
TurnerCut_1	37.98843	-121.4649
TurnerCut_2	37.99008	-121.4609
SJMac_1	38.02206	-121.4653
SJMac_2	38.02615	-121.4687
BeniciaW	38.04067	-122.1235
BeniciaE	38.04336	-122.1226
ChippsE	38.04593	-121.9099
ChippsW	38.04640	-121.9155
JerseyPoint_2	38.05018	-121.6938
JerseyPoint_1	38.05364	-121.6905
Three_Mile_South	38.10734	-121.6841
Three_Mile_North	38.11069	-121.6822

Table 5. Receiver locations, arrays used for the 2024 predator analysis, and the corresponding averaged latitude and longitude coordinates.

Receiver general location	Array	Averaged Latitude	Averaged Longitude
DurhamFerry_Rel	DurhamFerry_Rel	37.68780	-121.2622
Durhamferry	Durhamferry	37.68865	-121.2689
Mossdale	Mossdale	37.79184	-121.3072
Head_of_Old_River	Head_of_Old_River	37.80789	-121.3295
SJ_HOR_1	SJ_HOR	37.81266	-121.3185
OldRiverHOR_1	OR_HOR	37.81452	-121.3348
SJ_HOR_2	SJ_HOR	37.81263	-121.3185
OldRiverHOR_2	OR_HOR	37.81452	-121.3348
CVP_Trash_Rack	CVP_Trash_Rack	37.81629	-121.5589
Old_River_at_Middle_River_Head_1	Old_River_at_Middle_River	37.82061	-121.3776
GoldenGateW	GoldenGate	37.82287	-122.4650
GoldenGateE	GoldenGate	37.82287	-122.4650
Clifton_Court	Clifton_Court	37.82990	-121.5569
CC_intake_J	CC_intake	37.82824	-121.5942
SJ_Howard_1	Howard	37.87360	-121.3319
SJ_Garwood_1	SJG	37.93723	-121.3347
SJ_Garwood_2	SJG	37.93723	-121.3347
Dos_Rios_Rel	Stockton	37.83051	-121.3111
MiddleRiver_RR_Bridge (MR_RRB)	MiddleRiver_RR_Bridge	37.93935	-121.5330
Old_River_Victoria_1	Old_River_Victoria	37.93947	-121.5605
Old_River_Victoria_2	Old_River_Victoria	37.93947	-121.5605
TurnerCut_1	TurnerCut	37.98925	-121.4629
TurnerCut_2	TurnerCut	37.98925	-121.4629
SJMac_1	Mac	38.02410	-121.4670
SJMac_2	Mac	38.02410	-121.4670
BeniciaW	Benicia	38.04201	-122.1230
BeniciaE	Benicia	38.04201	-122.1230
ChippsE	Chipps	38.04617	-121.9127
ChippsW	Chipps	38.04617	-121.9127
JerseyPoint_2	Jersey_Point	38.05191	-121.6919
JerseyPoint_1	Jersey_Point	38.05191	-121.6919
Three_Mile_South	Three_Mile	38.10902	-121.6831
Three_Mile_North	Three_Mile	38.10902	-121.6831

Table 6. The estimated 0.95 quantile for log migration rate for each transition between arrays. These quantiles are the minimum migration rates identified as predator-type detections by the predator filter.

Transition between arrays	Log migration rate threshold (km/hr)	Migration Rate threshold (km/hr)
Benicia to GoldenGate	0.727	2.069
CC intake to Chipps	0.451	1.570
CVP Trash Rack to Chipps	1.025	2.787
CVP Trash Rack to Jersey Point	-1.114	0.328
Chipps to Benicia	1.580	4.855
Clifton Court to CC intake	-0.370	0.691
DurhamFerry to Mossdale	0.970	2.638
Howard to SJG	0.710	2.034
Howard to SJ HOR	0.036	1.037
Jersey Point to Chipps	1.555	4.735
Mac to Jersey Point	0.177	1.194
Mac to Middle River RR Bridge	-0.215	0.807
Mac to Three Mile	0.400	1.492
Middle River RR Bridge to Jersey Point	-0.078	0.925
Mossdale to Old River HOR	0.966	2.627
Mossdale to SJ HOR	0.764	2.147
Old River HOR to Old River Victoria	0.124	1.132
Old River HOR to Old River at Middle River	0.596	1.815
Old River Victoria to Jersey Point	-0.704	0.459
Old River Victoria to Three Mile	0.049	1.050
Old River at Middle River to CVP Trash Rack	0.277	1.319
Old River at Middle River to Clifton Court	0.378	1.459
Old River at Middle River to Old River Victoria	0.265	1.303
SJG to Mac	0.081	1.084
SJG to TurnerCut	-0.137	0.872
SJ HOR to Howard	0.768	2.155
SJ HOR to Old River HOR	-0.344	0.709
Three Mile to Chipps	0.0508	1.052
TurnerCut to Jersey Point	-0.845	0.430
TurnerCut to Middle River RR Bridge	0.213	1.237
TurnerCut to Old River Victoria	-1.193	0.303

Table 7. Summary statistics for travel times (days) to Chipps Island, by route and release location for the unfiltered dataset.

Release location	Route	Mean travel time (days)	Travel time standard error (days)
Durham Ferry	Old River	8.26	1.82
Durham Ferry	San Joaquin River	7.37	2.75
Head of Old River	Old River	9.40	2.02
Head of Old River	San Joaquin River	23.0	6.77
Dos Reis	Old River	28.88	8.41
Dos Reis	San Joaquin River	9.30	1.18

Table 8. Summary statistics for travel times (days) to Chipps Island, by route and release location for the 1-hit predator filtered dataset.

Release location	Route	Mean travel time (days)	Travel time standard error (days)
Durham Ferry	Old River	8.45	1.25
Durham Ferry	San Joaquin River	7.55	2.38
Head of Old River	Old River	10.11	2.65
Head of Old River	San Joaquin River	15.83	13.63
Dos Reis	Old River	28.21	NA
Dos Reis	San Joaquin River	9.24	1.27

Table 9. Mean derived survival estimates for all releases combined. Parameter estimates were obtained from the model using data without a predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.08	0.11	0.48	0.43	0.53
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-0.94	0.17	0.28	0.22	0.35
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.54	0.27	0.18	0.11	0.27
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.36	0.23	0.20	0.14	0.29
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.23	0.16	0.23	0.18	0.29
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.23	0.16	0.23	0.18	0.29
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.09	0.15	0.25	0.20	0.31
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.25	0.16	0.22	0.17	0.28
Through-Delta Survival	lphi_TD	-1.17	0.12	0.24	0.20	0.28
Through-Bay Survival	lphi_TB	0.96	0.29	0.72	0.59	0.82
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.76	0.18	0.68	0.60	0.75
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.25	0.12	0.10	0.08	0.12
Survival from Head of Old River Release to Benicia	lphi_HORtB	-2.11	0.16	0.11	0.08	0.14
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.88	0.15	0.13	0.10	0.17
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.33	0.03			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.35	0.03			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table 10. Derived survival estimates for the March releases. Parameter estimates were obtained from the model using data without a predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	1.26	0.20	0.78	0.70	0.84
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.02	0.21	0.26	0.19	0.35
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.58	0.30	0.17	0.10	0.27
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.33	0.36	0.21	0.12	0.35
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.34	0.19	0.21	0.15	0.28
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.34	0.19	0.21	0.15	0.28
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.18	0.19	0.24	0.18	0.31
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.33	0.19	0.21	0.15	0.28
Through-Delta Survival	lphi_TD	-1.25	0.14	0.22	0.18	0.27
Through-Bay Survival	lphi_TB	0.85	0.36	0.70	0.54	0.83
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.36	0.18	0.59	0.50	0.67
Survival from Durham Ferry to Benicia	lphi_DFtB	-1.61	0.15	0.17	0.13	0.21
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.33	0.17	0.21	0.16	0.27
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.16	0.17	0.24	0.18	0.30
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	0.04	0.03			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	0.02	0.03			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table 11. Derived survival estimates for the April releases. Parameter estimates were obtained from the model using data without a predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.77	0.18	0.32	0.24	0.40
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.24	0.26	0.22	0.15	0.33
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.56	0.37	0.17	0.09	0.30
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.55	0.40	0.18	0.09	0.32
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.37	0.26	0.20	0.13	0.30
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.37	0.26	0.20	0.13	0.30
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.34	0.23	0.21	0.14	0.29
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.39	0.26	0.20	0.13	0.29
Through-Delta Survival	lphi_TD	-1.36	0.19	0.20	0.15	0.27
Through-Bay Survival	lphi_TB	0.79	0.45	0.69	0.48	0.84
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.83	0.25	0.70	0.58	0.79
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.72	0.21	0.06	0.04	0.09
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.93	0.24	0.13	0.08	0.19
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.80	0.21	0.14	0.10	0.20
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.31	0.07			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.32	0.05			

[1]These routes were combined in the analysis, but separate in the 2021 study
[2]Not estimated in 2024, but estimated in 2021

Table 12. Derived survival estimates for the May releases. Parameter estimates were obtained from the model using data without a predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.73	0.20	0.33	0.25	0.42
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-0.56	0.38	0.36	0.21	0.54
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.49	0.64	0.18	0.06	0.44
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.21	0.41	0.23	0.12	0.40
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-0.98	0.35	0.27	0.16	0.43
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-0.98	0.35	0.27	0.16	0.43
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-0.76	0.34	0.32	0.19	0.48
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.04	0.34	0.26	0.15	0.41
Through-Delta Survival	lphi_TD	-0.90	0.26	0.29	0.19	0.41
Through-Bay Survival	lphi_TB	1.22	0.60	0.77	0.51	0.92
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	1.08	0.43	0.75	0.56	0.87
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.41	0.27	0.08	0.05	0.13
Survival from Head of Old River Release to Benicia	lphi_HORtB	-3.08	0.39	0.04	0.02	0.09
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-2.68	0.34	0.06	0.03	0.12
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.72	0.07			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.74	0.07			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table 13. Mean reach-specific survival random effects estimates (Est.), standard errors (SE), and lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) across all release groups for an average-sized fish. Parameter estimates were obtained from the model using data without a predator filter.

Parameter Description	Est.	SE	L_{95}	U_{95}
RE for Reach 1: DF release	0.59	0.03	0.54	0.64
RE for Reach 2: HOR release	0.59	0.02	0.54	0.64
RE for Reach 3: ST release[1]				
RE for Reach 4: DR release	0.61	0.02	0.57	0.66
RE for Reach 5: DF_DS to SJ_BCA	0.81	0.04	0.74	0.88
RE for Reach 6: SJ_BCA to Mossdale[1]				
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	0.92	0.02	0.87	0.97
RE for Reach 8: SJ-HOR to Howard	0.96	0.02	0.93	1.00
RE for Reach 9: Howard to SJG	0.94	0.02	0.91	0.97
RE for Reach 10: SJG to MAC or TC	0.81	0.03	0.76	0.87
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.51	0.05	0.41	0.60
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.49	0.08	0.33	0.65
RE for Reach 13: OR_HOR to OR_MR junction	0.92	0.03	0.87	0.97
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	0.84	0.11	0.63	1.06
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	0.36	0.13	0.10	0.63
RE for Reach 16: OR_MidR to OR_Tracy or GLC	0.95	0.02	0.91	0.99
RE for Reach 17: OR_Tracy to MR_RRB , OR_Victoria, CVP, or SWP[1]				
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.38	0.08	0.22	0.53
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]				
RE for Reach 20: CVP trash rack to Chipps Island	0.37	0.06	0.26	0.49
RE for Reach 21: CCF_inlet to CCF_intake	0.40	0.07	0.27	0.53
RE for Reach 22: CCF_intake to Chipps Island	0.36	0.10	0.18	0.55
RE for Reach 23: 3-mile to Chipps Island	0.70	0.12	0.47	0.94
RE for Reach 24: Jersey Point to Chipps Island	0.92	0.03	0.86	0.98
RE for Reach 25: Chipps Island to Benicia	0.93	0.03	0.87	0.98
RE for Reach 26: Benicia to Golden Gate E	0.78	0.06	0.67	0.89

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table 14. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the March release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	3.35	0.74	0.97	0.87	0.99
RE for Reach 2: HOR release	3.51	0.66	0.97	0.90	0.99
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	3.64	0.71	0.97	0.90	0.99
RE for Reach 5: DF_DS to SJ_BCA	1.42	0.24	0.81	0.72	0.87
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.59	0.39	0.93	0.86	0.97
RE for Reach 8: SJ-HOR to Howard	3.16	0.67	0.96	0.86	0.99
RE for Reach 9: Howard to SJG	2.07	0.28	0.89	0.82	0.93
RE for Reach 10: SJG to MAC or TC	1.06	0.21	0.74	0.66	0.81
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.19	0.26	0.55	0.42	0.67
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.11	0.40	0.53	0.34	0.71
RE for Reach 13: OR_HOR to OR_MR junction	2.21	0.39	0.90	0.81	0.95
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.70	1.52	0.85	0.22	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.03	0.64	0.49	0.22	0.77
RE for Reach 16: OR_MidR to OR_Tracy or GLC	2.37	0.43	0.91	0.82	0.96
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-1.08	0.51	0.25	0.11	0.48
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.34	0.37	0.41	0.25	0.59
RE for Reach 21: CCF_inlet to CCF_intake	-0.55	0.28	0.37	0.25	0.50
RE for Reach 22: CCF_intake to Chipps Island	0.06	0.44	0.52	0.31	0.72
RE for Reach 23: 3-mile to Chipps Island	0.89	0.81	0.71	0.33	0.92
RE for Reach 24: Jersey Point to Chipps Island	2.14	0.51	0.89	0.76	0.96
RE for Reach 25: Chipps Island to Benicia	3.15	0.64	0.96	0.87	0.99
RE for Reach 26: Benicia to Golden Gate E	1.00	0.39	0.73	0.56	0.86
Mean of survival RE	1.48	0.44			
Slope for the survival-length relationship*	0.37	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.60	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table 15. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.55	0.19	0.37	0.28	0.46
RE for Reach 2: HOR release	0.51	0.22	0.63	0.52	0.72
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	0.65	0.21	0.66	0.56	0.74
RE for Reach 5: DF_DS to SJ_BCA	1.84	0.52	0.86	0.69	0.95
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.64	0.63	0.93	0.81	0.98
RE for Reach 8: SJ-HOR to Howard	3.64	1.00	0.97	0.84	1.00
RE for Reach 9: Howard to SJG	3.24	0.56	0.96	0.89	0.99
RE for Reach 10: SJG to MAC or TC	1.36	0.27	0.80	0.70	0.87
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	-0.37	0.29	0.41	0.28	0.55
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	-0.24	0.42	0.44	0.26	0.64
RE for Reach 13: OR_HOR to OR_MR junction	2.56	0.68	0.93	0.77	0.98
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.50	1.38	0.82	0.23	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.93	0.97	0.28	0.06	0.73
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.76	0.93	0.98	0.87	1.00
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-0.60	0.40	0.35	0.20	0.55
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.94	0.46	0.28	0.14	0.49
RE for Reach 21: CCF_inlet to CCF_intake	0.13	0.47	0.53	0.31	0.74
RE for Reach 22: CCF_intake to Chipps Island	-1.39	0.67	0.20	0.06	0.48
RE for Reach 23: 3-mile to Chipps Island	0.30	0.91	0.57	0.18	0.89
RE for Reach 24: Jersey Point to Chipps Island	2.38	0.65	0.91	0.75	0.97
RE for Reach 25: Chipps Island to Benicia	2.99	0.77	0.95	0.81	0.99
RE for Reach 26: Benicia to Golden Gate E	0.96	0.49	0.73	0.50	0.87
Mean of survival RE	1.07	0.42			
Slope for the survival-length relationship*	0.37	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.60	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table 16. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.26	0.22	0.44	0.33	0.54
RE for Reach 2: HOR release	-1.58	0.33	0.17	0.10	0.28
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	-1.31	0.30	0.21	0.13	0.33
RE for Reach 5: DF_DS to SJ_BCA	1.09	0.41	0.75	0.57	0.87
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.11	0.56	0.89	0.73	0.96
RE for Reach 8: SJ-HOR to Howard	3.09	1.08	0.96	0.73	0.99
RE for Reach 9: Howard to SJG	3.39	1.03	0.97	0.80	1.00
RE for Reach 10: SJG to MAC or TC	2.24	0.67	0.90	0.72	0.97
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.27	0.45	0.57	0.35	0.76
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.05	0.78	0.51	0.19	0.83
RE for Reach 13: OR_HOR to OR_MR junction	2.71	0.94	0.94	0.70	0.99
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.77	1.28	0.86	0.32	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.79	1.40	0.31	0.03	0.88
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.01	1.02	0.95	0.73	0.99
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.09	0.77	0.52	0.19	0.83
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.30	0.51	0.43	0.21	0.67
RE for Reach 21: CCF_inlet to CCF_intake	-0.80	0.65	0.31	0.11	0.62
RE for Reach 22: CCF_intake to Chipps Island	-0.49	1.00	0.38	0.08	0.81
RE for Reach 23: 3-mile to Chipps Island	1.55	1.56	0.82	0.18	0.99
RE for Reach 24: Jersey Point to Chipps Island	2.87	1.12	0.95	0.66	0.99
RE for Reach 25: Chipps Island to Benicia	1.92	0.66	0.87	0.65	0.96
RE for Reach 26: Benicia to Golden Gate E	2.05	0.93	0.89	0.56	0.98
Mean of survival RE	1.03	0.48			
Slope for the survival-length relationship*	0.37	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.60	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table 17. Mean routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from all release groups. Parameter estimates were obtained from the model using data without a predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.10	0.18	0.48	0.39	0.57
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.96	0.34	0.12	0.07	0.22
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.18	0.16	0.55	0.47	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.58	0.40	0.07	0.03	0.14
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.80	0.26	0.86	0.78	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.90	0.18	0.71	0.63	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.14	0.39	0.11	0.05	0.20
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.28	0.49	0.57	0.34	0.78
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.65	0.39	0.16	0.08	0.29
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-0.47	0.51	0.38	0.19	0.63
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.65	0.71	0.34	0.11	0.68
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.68	0.19	0.34	0.26	0.43
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.15	0.36	0.24	0.14	0.39
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.68	0.19	0.34	0.26	0.43
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.15	0.36	0.24	0.14	0.39

Table 18. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L95 and U95, respectively) from the March release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.68	0.23	0.34	0.25	0.44
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.82	0.42	0.14	0.07	0.27
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.03	0.20	0.51	0.41	0.61
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.05	0.31	0.11	0.07	0.19
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.78	0.30	0.86	0.77	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.82	0.23	0.69	0.59	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.40	0.61	0.08	0.03	0.23
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.11	0.53	0.53	0.28	0.76
ρ_{10}	Prob. of taking MR @ MR-OR split	-2.15	0.60	0.10	0.03	0.27
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.10	0.82	0.53	0.18	0.85
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	0.01	0.91	0.50	0.14	0.86
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-1.00	0.24	0.27	0.19	0.37
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-0.65	0.45	0.34	0.18	0.56
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-1.00	0.24	0.27	0.19	0.37
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-0.65	0.45	0.34	0.18	0.56
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.59	0.26			

Table 19. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.01	0.30	0.50	0.35	0.64
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.89	0.50	0.13	0.05	0.28
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.64	0.31	0.66	0.51	0.78
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.97	0.58	0.05	0.02	0.14
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	2.53	0.45	0.93	0.84	0.97
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.76	0.25	0.68	0.57	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-1.99	0.63	0.12	0.04	0.32
ρ_9	Prob. of heading to pumps after entering Turner Cut	-0.20	0.57	0.45	0.21	0.72
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.85	0.59	0.14	0.05	0.33
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.22	0.85	0.56	0.19	0.87
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.96	1.09	0.28	0.04	0.76
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.22	0.27	0.44	0.32	0.57
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.70	0.54	0.15	0.06	0.35
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.22	0.27	0.44	0.32	0.57
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.70	0.54	0.15	0.06	0.35
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.59	0.26			

Table 20. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data without a predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	0.39	0.40	0.60	0.41	0.76
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-2.18	0.77	0.10	0.02	0.34
ρ_3	Prob. of remaining in SJ @ HOR for DF release	-0.13	0.32	0.47	0.32	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.72	1.02	0.06	0.01	0.33
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.08	0.58	0.75	0.49	0.90
ρ_7	Prob. of remaining in SJ @ Turner Cut	1.13	0.44	0.76	0.57	0.88
ρ_8	Prob. of heading to pumps after passing MAC	-2.03	0.79	0.12	0.03	0.38
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.94	1.24	0.72	0.18	0.97
ρ_{10}	Prob. of taking MR @ MR-OR split	-0.94	0.48	0.28	0.13	0.50
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-1.75	0.97	0.15	0.03	0.54
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-1.01	1.55	0.27	0.02	0.88
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.82	0.45	0.31	0.15	0.52
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.11	0.77	0.25	0.07	0.60
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.82	0.45	0.31	0.15	0.52
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.11	0.77	0.25	0.07	0.60
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.59	0.26			

Table 21. Detection probability estimates (Est.) and standard errors (SE) on the logit-scale and and transformed estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively). The bottom two parameters represent the hyperparameter mean and standard deviation (SD) for the distribution of random effects. Detection estimates represent detection at a single-line and detection of combined dual-line receivers so detection across both lines is $P = 1 - \left(1 - 1/e^{-lgt_p}\right)^2$. Parameter estimates were obtained from the model using data without a predator filter.

		Logit-Scale		Transformed Est.			Dual-
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}	Line Est.
p_1	Logit Detection: DF_DS	0.31	0.14	0.58	0.51	0.64	
p_2	Logit Detection: SJ_BCA[1]			0.00			
p_3	Logit Detection: Mossdale	2.07	0.23	0.89	0.83	0.93	
p_4	Logit Detection: SJ_HOR (Combined dual-line)	0.43	0.24	0.61	0.49	0.71	0.84
p_5	Logit Detection: Howard	1.82	0.18	0.86	0.81	0.90	
p_6	Logit Detection: SJG (Combined dual-line)	1.78	0.28	0.86	0.77	0.91	0.98
p_7	Logit Detection: MAC (Combined dual-line)	2.41	0.69	0.92	0.74	0.98	0.99
p_8	Logit Detection: Turner Cut (Combined dual-line)	1.54	0.56	0.82	0.61	0.93	0.97
p_9	Logit Detection: OR_HOR (Combined dual-line)	0.21	0.12	0.55	0.49	0.61	0.80
p_{10}	Logit Detection: MR_OR[1]			0.00			
p_{11}	Logit Detection: MR_RRB	0.21	0.12	0.55	0.49	0.61	
p_{12}	Logit Detection: OR_MidR	0.22	0.57	0.56	0.29	0.79	
p_{13}	Logit Detection: OR_Tracy (Combined dual-line) [1]			0.00			
p_{14}	Logit Detection: OR_Victoria (Combined dual-line)	1.89	0.86	0.87	0.55	0.97	0.98
p_{15}	Logit Detection: GLC (Combined dual-line) [1]			0.00			
p_{16}	Logit Detection: CVP_trash_rack	2.51	0.64	0.92	0.78	0.98	
p_{17}	Logit Detection: CCF_Inlet	2.67	0.63	0.93	0.81	0.98	
p_{18}	Logit Detection: CCF_Intake	2.89	0.61	0.95	0.84	0.98	
p_{19}	Logit Detection: 3-mile Slough (Combined dual-line)	1.51	1.13	0.82	0.33	0.98	0.97
p_{20}	Logit Detection: Jersey Point (Combined dual-line)	1.60	0.45	0.83	0.67	0.92	0.97
p_{21}	Logit Detection: Chipps Island (Combined dual-line)	1.08	0.23	0.75	0.65	0.82	0.94
p_{22}	Logit Detection: Benicia (Combined dual-line)	2.54	0.66	0.93	0.78	0.98	0.99
p_{23}	Logit Detection: Golden Gate E	2.56	0.80	0.93	0.73	0.98	
p_{24}	Logit Detection: Golden Gate W	0.79	0.27	0.69	0.56	0.79	
μ_p	Hyperparameter mean detection probability in logit space	1.63	0.27				
$log(\sigma_p)$	Hyperparameter log(SD) for detection random effect	0.01	0.26				

[1]No receivers were deployed to monitor entry into these reaches and detection was set to zero in the model. Receivers were deployed and parameters were estimated in the 2021 model.

Table 22. Through-Delta (Mossdale to Chipps Island) survival with 95% confidence intervals from 2011-2016 and 2021 with environmental and management covariates. Covarates were averaged between the first release (day start) to last release (day end) for each release group. Inflow, outflow, exports and Inflow:Export ratios (IE) were obtained from Dayflow for San Joaquin River (SJR), Sacramento River (SAC) and system-wide (overall). A physical rock barrier was in place for some release groups at the head of Old River (HORB fully installed = 1, no HORB = 0).

Year	Month	Day Start	Day End	Surv.	Lower 95%	Upper 95%	Delta Inflow	SJR Inflow	SR Inflow	Delta Outflow	Exports	Overall IE	SJR IE	SR IE	Temp C	HORB 1=Yes
2011	3	22	26	0.69	0.63	0.75	195,971	16,740	84,560	197,773	3,122	206.8	17.8	86.4	10.9	0
2011	4	3	7	0.52	0.46	0.58	128,724	29,840	70,400	121,139	5,804	22.2	5.1	12.1	15.3	0
2011	4	17	21	0.44	0.38	0.50	73,121	26,380	40,100	64,954	6,330	11.6	4.2	6.3	16.2	0
2011	5	11	26	0.60	0.54	0.66	51,945	11,669	36,381	47,605	3,261	16.5	3.7	11.6	15.9	0
2011	6	15	18	0.38	0.28	0.48	57,248	10,525	43,475	43,723	9,766	5.9	1.1	4.5	17.9	0
2012	4	4	7	0.26	0.22	0.30	28,923	1,950	25,750	25,717	1,938	15.0	1.0	13.4	15.6	0
2012	5	1	6	0.35	0.29	0.41	28,221	2,963	23,800	23,405	2,809	10.3	1.1	8.7	18.3	1
2012	5	18	23	0.33	0.25	0.41	13,685	2,515	9,987	6,481	4,716	2.9	0.5	2.1	20.1	1
2013	3	6	9	0.15	0.11	0.19	14,746	1,733	12,300	8,116	5,823	2.5	0.3	2.1	14.1	0
2013	4	3	6	0.09	0.05	0.13	19,452	1,483	16,950	19,829	1,523	12.8	1.0	11.1	20.2	0
2013	5	8	11	0.20	0.16	0.24	15,723	3,573	11,150	11,355	2,223	7.1	1.6	5.0	17.1	0
2014	4	24	27	0.43	0.37	0.49	10,292	2,935	6,488	8,067	3,155	3.3	0.9	2.1	15.7	1
2014	5	21	24	0.06	0.02	0.10	8,017	757	6,365	4,052	1,392	5.8	0.5	4.6	21.5	1
2015	3	4	7	0.15	0.09	0.21	11,221	586	9,403	5,359	4,845	2.3	0.1	1.9	15.9	0
2015	3	25	28	0.35	0.29	0.41	10,966	820	6,940	7,558	1,863	5.9	0.4	3.7	19.3	0
2015	4	22	25	0.20	0.12	0.28	7,985	610	5,768	5,254	1,609	5.0	0.4	3.6	20.2	1
2016	2	24	27	0.39	0.33	0.45	20,344	858	18,775	13,552	5,904	3.4	0.1	3.2	16.2	0
2016	3	16	19	0.42	0.38	0.46	112,114	3,868	76,300	104,086	7,711	14.4	0.5	9.9	16.7	0
2016	4	27	30	0.59	0.55	0.63	17,038	2,830	12,925	12,526	2,916	5.8	1.0	4.4	15.9	1
2021	3	23	26	0.05	0.03	0.09	11,842	842	10,480	9,115	1,276	9.3	0.7	8.2	15.5	0
2021	4	13	16	0.04	0.02	0.06	10,538	1,300	8,688	7,119	1,600	6.6	0.8	5.4	18.6	0
2021	5	4	7	0.02	0.01	0.04	6,834	672	5,608	3,357	1,448	4.7	0.5	3.9	21.8	0
2022	3	15	18	0.13	0.10	0.19	10,796	846	9,525	7,719	2,512	4.8	0.4	4.3	16.9	0
2022	4	19	22	0.10	0.08	0.14	11,374	1,320	8,460	9,815	1,795	6.3	0.7	4.7	17.8	0
2024	3	20	22	0.22	0.18	0.28	51,403	5,217	42,267	47,057	3,115	16.5	1.7	13.6	15.4	0
2024	4	17	19	0.21	0.15	0.27	41,076	5,443	32,700	39,262	1,846	22.3	2.9	17.7	16.6	0
2024	5	8	9	0.29	0.19	0.40	36,085	4,950	29,350	33,906	1,799	20.1	2.8	16.3	16.7	0

Table 23: Generalized logistic multivariate model comparison on correlating through Delta survival with the presence of the head of Old River Barrier (HORB), covariates, and Mossdale water temperature. Covariates, HORB, and temperature values were averaged over the release period and maximum likelihood covariate estimates with standard errors in parentheses.

Covariate	NLL	AIC	ΔAIC	Right Asymptote A	Left Asymptote κ	Intercept β_0	Barrier β_1	Covariate β_2	Temperature β_3	$\log(\sigma)$
Delta Inflow	25.8	65.6	0.0	-25.48 (88.71)	2.48 (3.48)	1.84 (3.33)	0.38 (0.44)	0.27 (0.34)	-0.05 (0.06)	-0.46 (0.14)
Delta Outflow	26.3	66.7	1.0	-22.48 (124)	3.4 (7.04)	1.48 (4.82)	0.34 (0.75)	0.18 (0.41)	-0.04 (0.10)	-0.44 (0.14)
Exports	27.2	68.4	2.8	-14.68 (81.96)	-0.47 (0.22)	4.34 (4.86)	0.65 (0.77)	3.75 (3.28)	-0.13 (0.13)	-0.41 (0.14)
IE ratio	32.7	79.4	13.8	-96.03 (256)	2.12 (3.41)	3.31 (2.82)	0.35 (0.35)	0.12 (0.16)	-0.09 (0.09)	-0.21 (0.14)
SJR Inflow	27.9	69.8	4.2	-45.26 (315)	8.31 (30.95)	1.51 (6.26)	0.13 (0.45)	0.07 (0.24)	-0.03 (0.09)	-0.39 (0.14)
SJR IE	32.3	78.7	13.1	-63.83 (163)	3.07 (5.85)	2.66 (2.83)	0.25 (0.33)	0.08 (0.11)	-0.07 (0.10)	-0.22 (0.14)
SAC Inflow	27.9	69.7	4.1	-6.53 (23.22)	3.22 (14.17)	0.08 (2.00)	0.57 (2.25)	0.34 (1.36)	-0.08 (0.32)	-0.39 (0.14)
SAC IE	33.5	80.9	15.3	-80.04 (379)	2.58 (5.29)	3.00 (4.85)	0.30 (0.40)	0.07 (0.12)	-0.09 (0.12)	-0.18 (0.14)

Figures

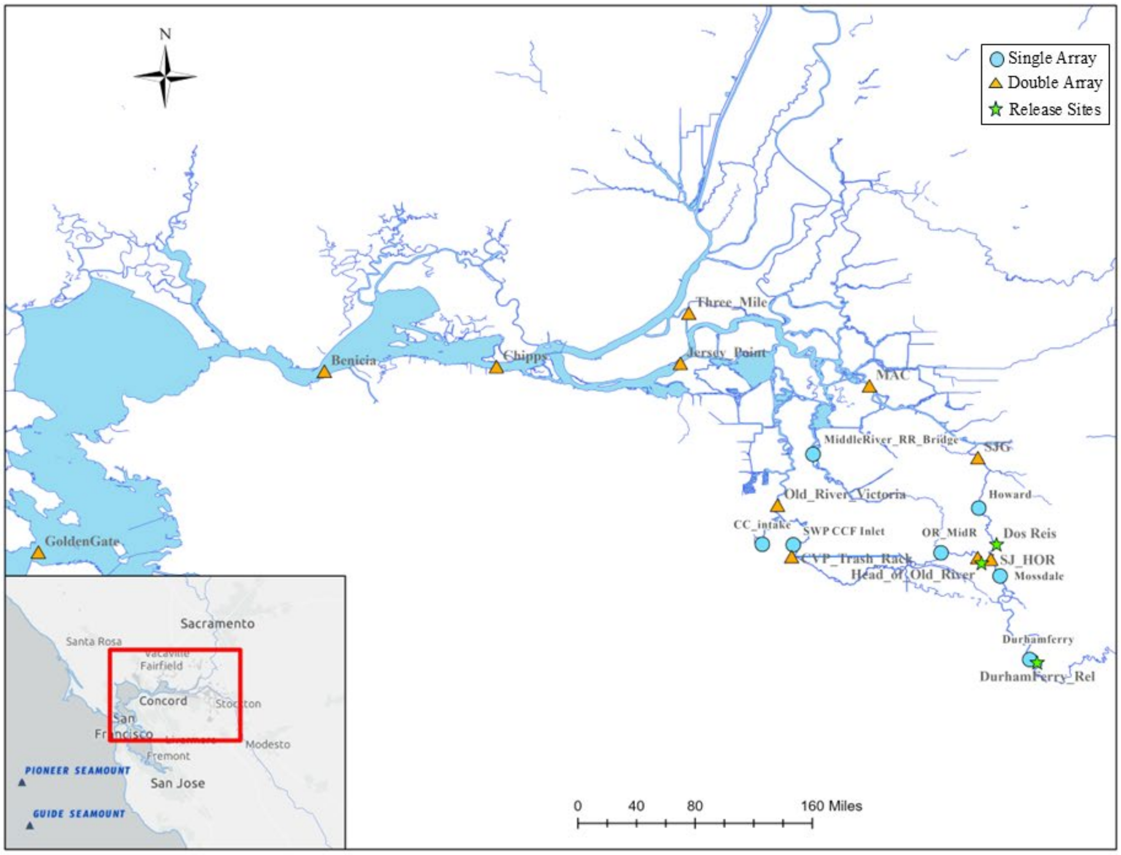

Figure 1. Receiver distribution and release locations in 2024.

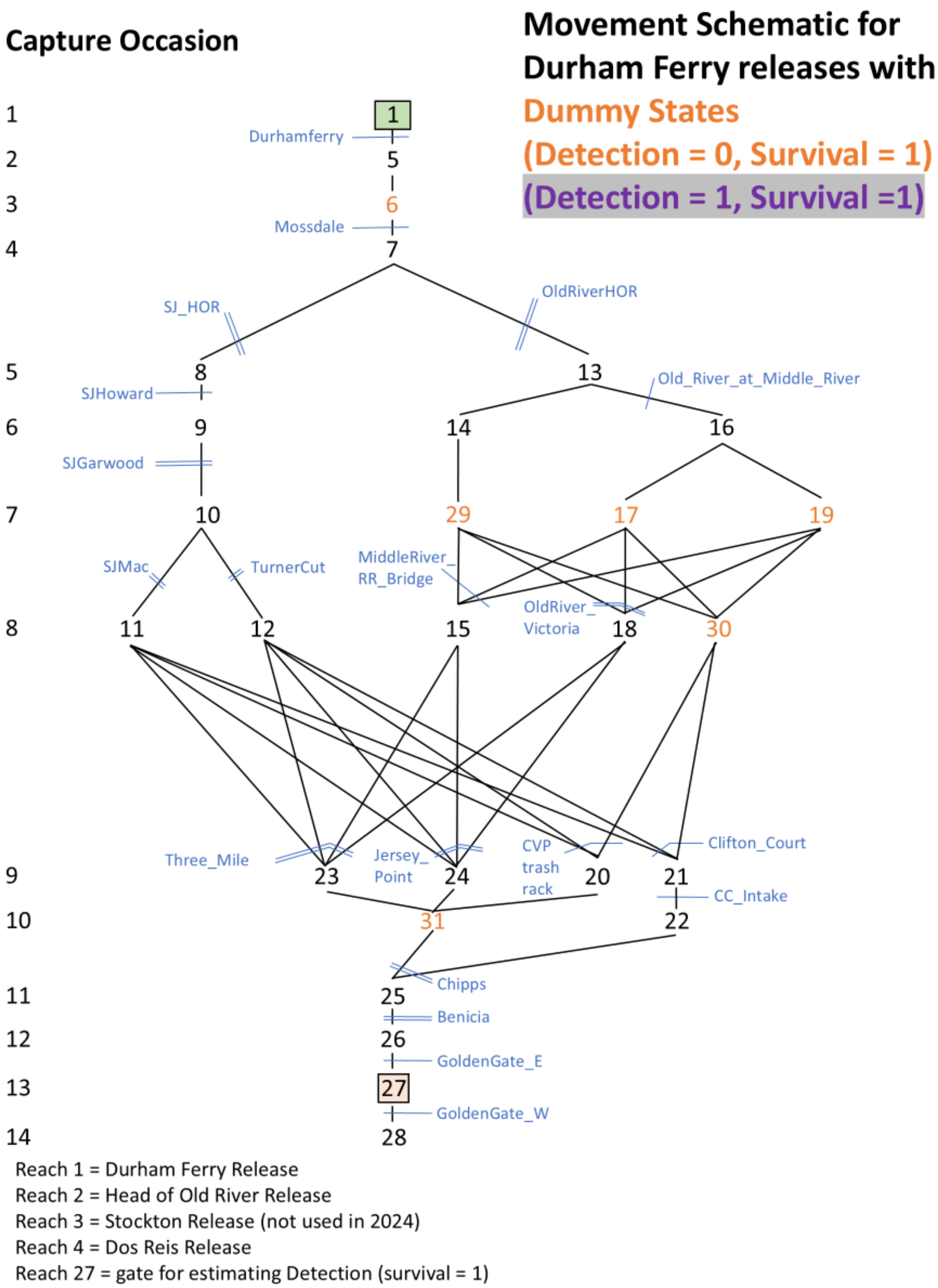

Figure 2. Movement schematic for 2024 releases at Durham Ferry. Numbers within the routing schematic are reaches (states) between receiver general locations indicated by blue single lines (single-arrays) or double lines (dual-arrays). Connecting (black) lines show downstream route options between states. Potential states for the capture histories were limited to those horizontally aligned with the capture occasions listed on the left. Dummy states were added to ensure consistency in capture histories at any given capture occasion (e.g., regardless of route taken, fish would make it to Chipps Island (reach 25) at capture occasion 11). Dummy states in orange had detection rates of 0 and survival of 1. Dummy states in purple were assigned detection and survival of 1 representing pre-release states.

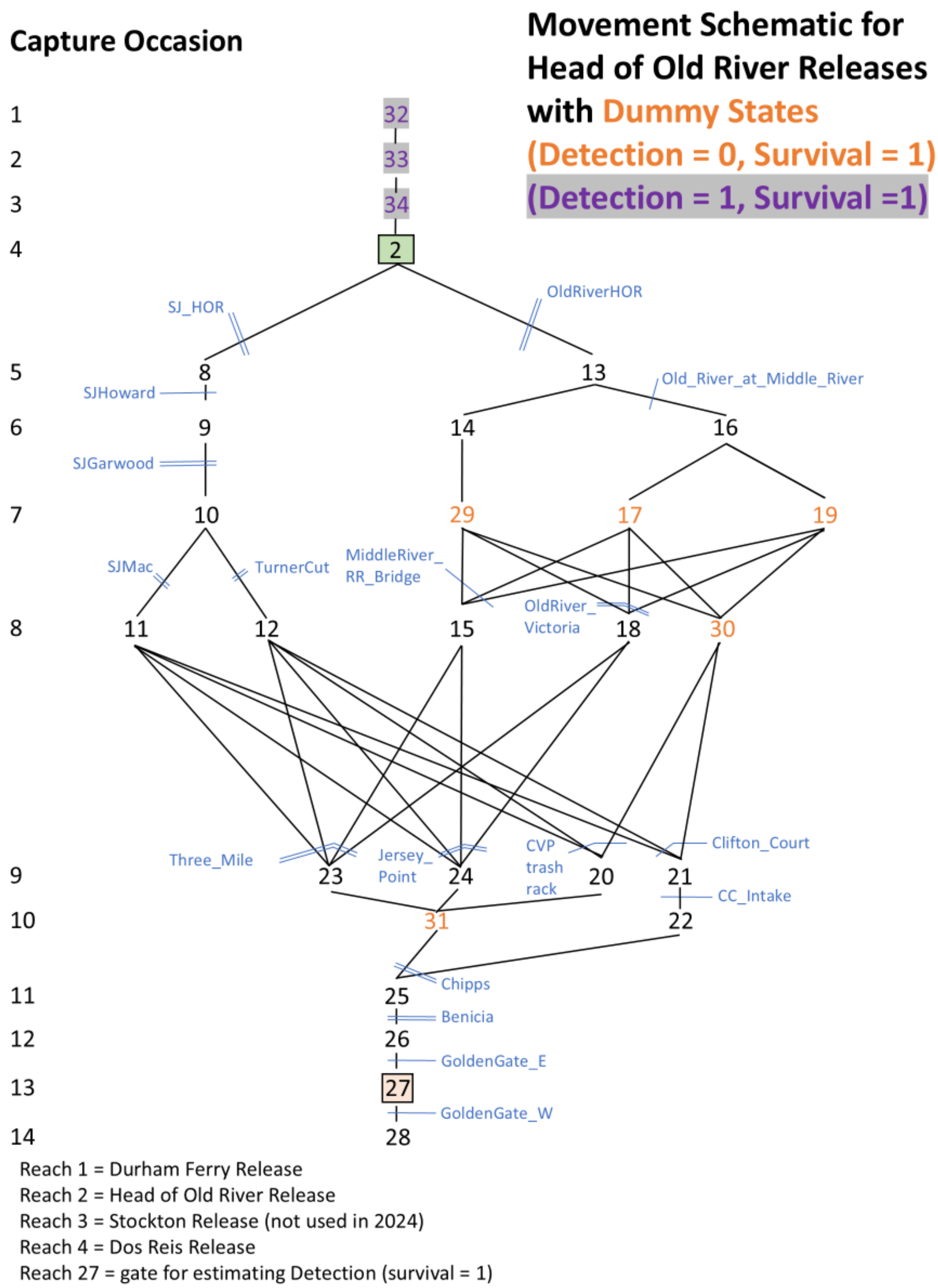

Figure 3. Movement schematic for 2024 releases at Head of Old River. Numbers within the routing schematic are reaches (states) between receiver general locations indicated by blue single lines (single-arrays) or double lines (dual-arrays). Connecting (black) lines show downstream route options between states. Potential states for the capture histories were limited to those horizontally aligned with the capture occasions listed on the left. Dummy states were added to ensure consistency in capture histories at any given capture occasion (e.g., regardless of route taken, fish would make it to Chipps Island (reach 25) at occasion 11). Dummy states in orange had detection rates of 0 and survival of 1. Dummy states in purple were assigned detection and survival of 1 representing pre-release states.

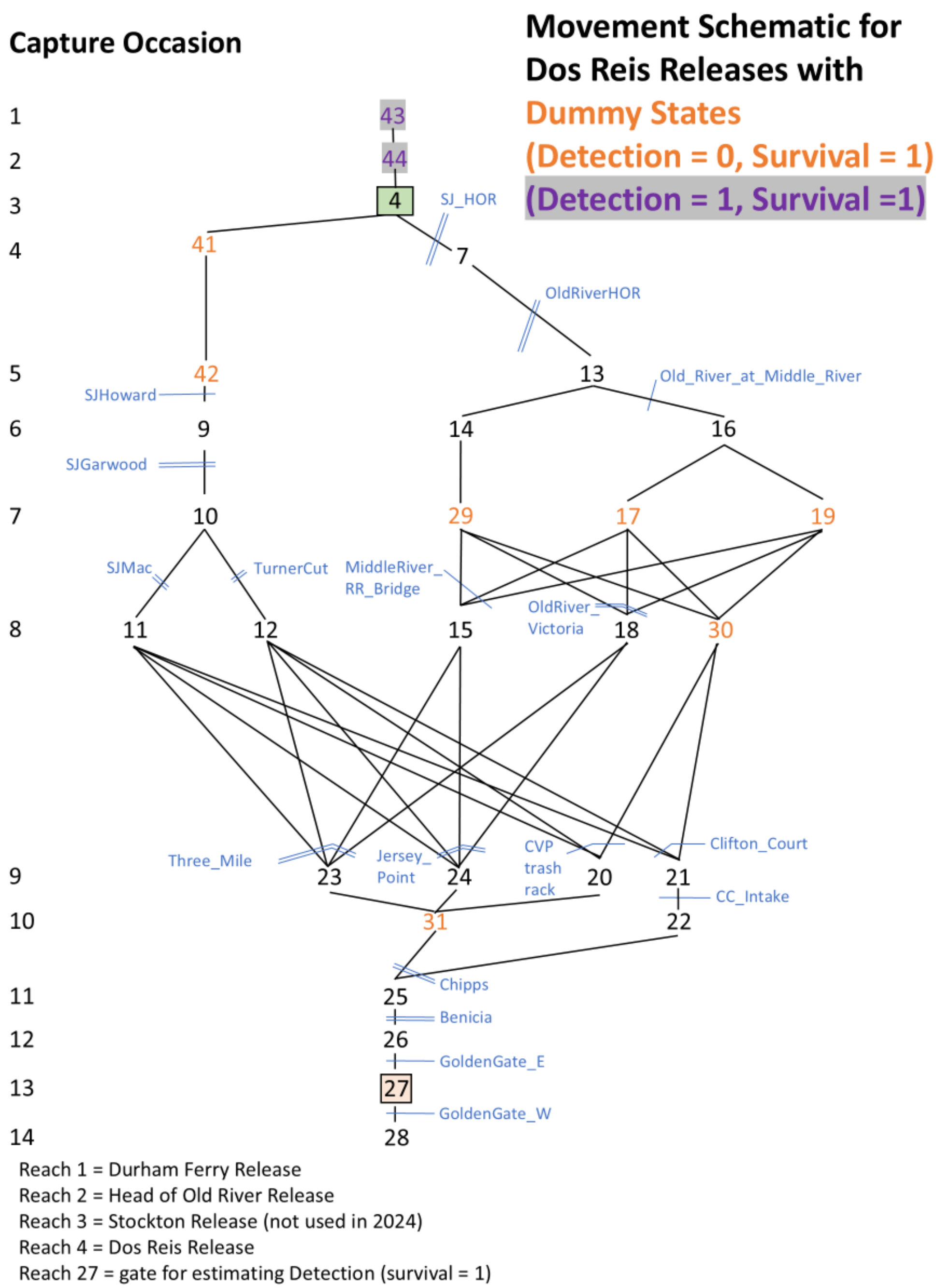

Figure 4. Movement schematic for 2024 releases at Dos Reis. Numbers within the routing schematic are reaches (states) between receiver general locations indicated by blue single lines (single-arrays) or double lines (dual-arrays). Connecting (black) lines show route options between states. Potential states for the capture histories were limited to those horizontally aligned with the capture occasions listed on the left. Dummy states were added to ensure consistency in capture histories at any given capture occasion (e.g., regardless of route taken, fish would make it to Chipps Island (reach 25) at occasion 11). Dummy states in orange had detection rates of 0 and survival of 1. Dummy states in purple were assigned detection and survival of 1 representing pre-release states.

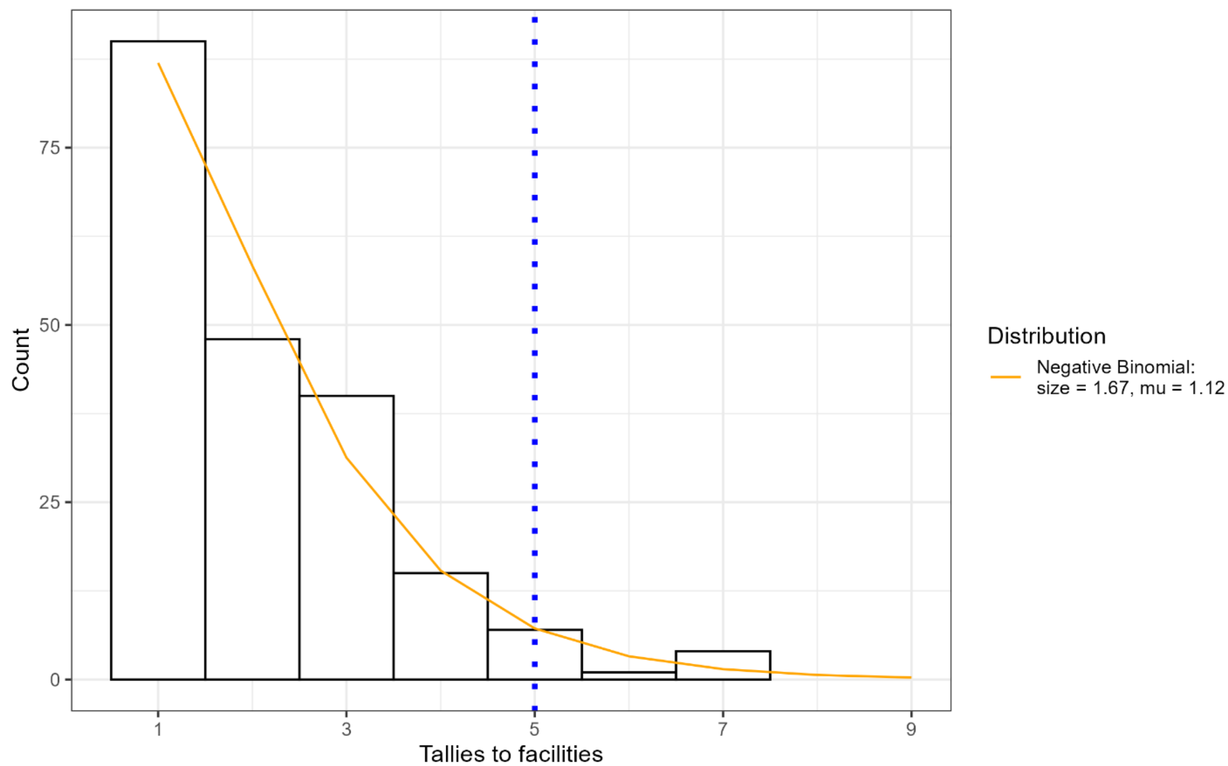

Figure 5. Negative binomial distribution (orange line) fit to the histogram of the number of detections of a tag at the SWP or CVP water export facilities. Estimated parameters for the fitted distribution are provided in the legend. The blue dotted line corresponds to 0.95 quantile for the number of detections.

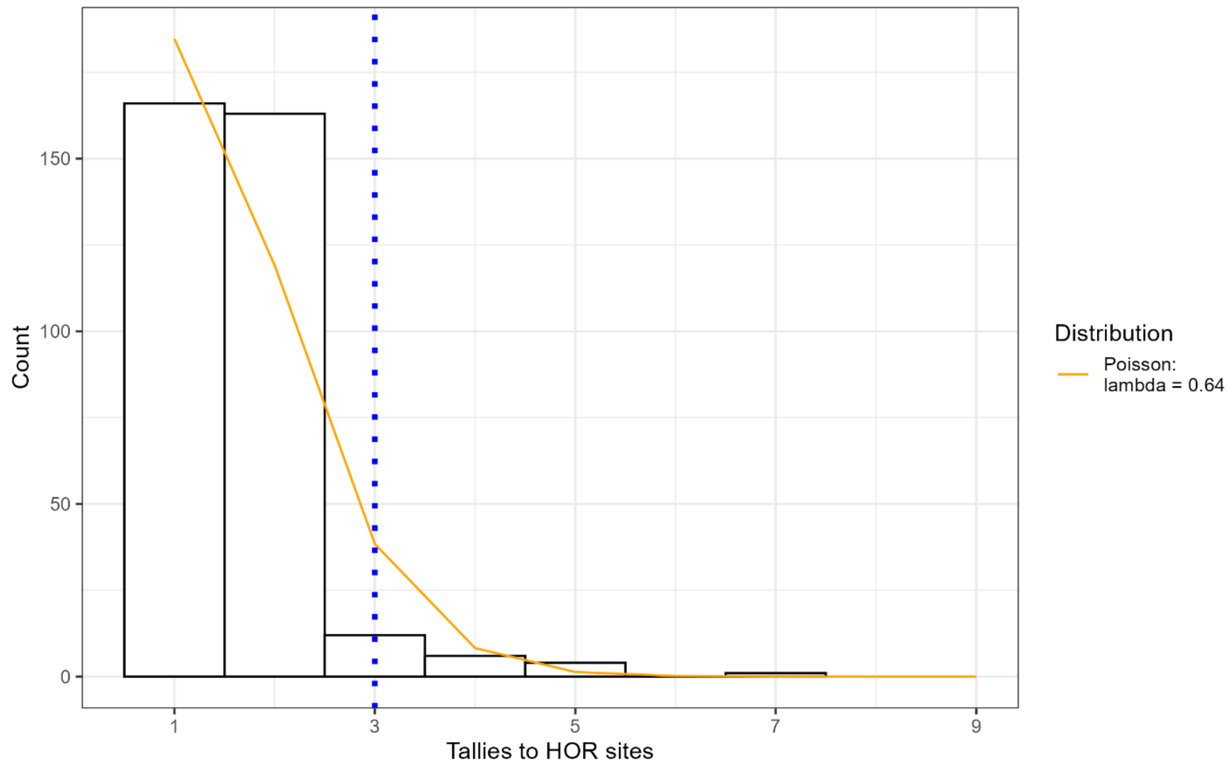

Figure 6. Poisson distribution (orange line) fit to the histogram of the number of detections of a tag at sites around the Head of Old River (HOR). Estimated parameters for the fitted distribution are provided in the legend. The blue dotted line corresponds to 0.95 quantile for the number of detections.

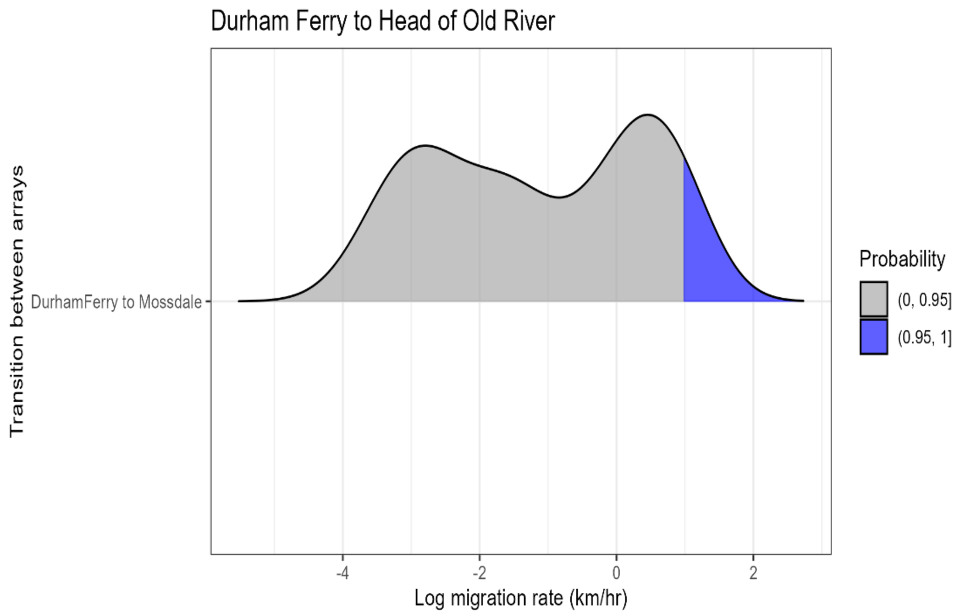

Figure 7. Smoothed histogram of counts of log migration rates (km/hr) between Durham Ferry and Mossdale receiver arrays for the region between Durham Ferry and the Head of Old River. Shaded blue area is the upper 0.05 quantile of migration rates observed.

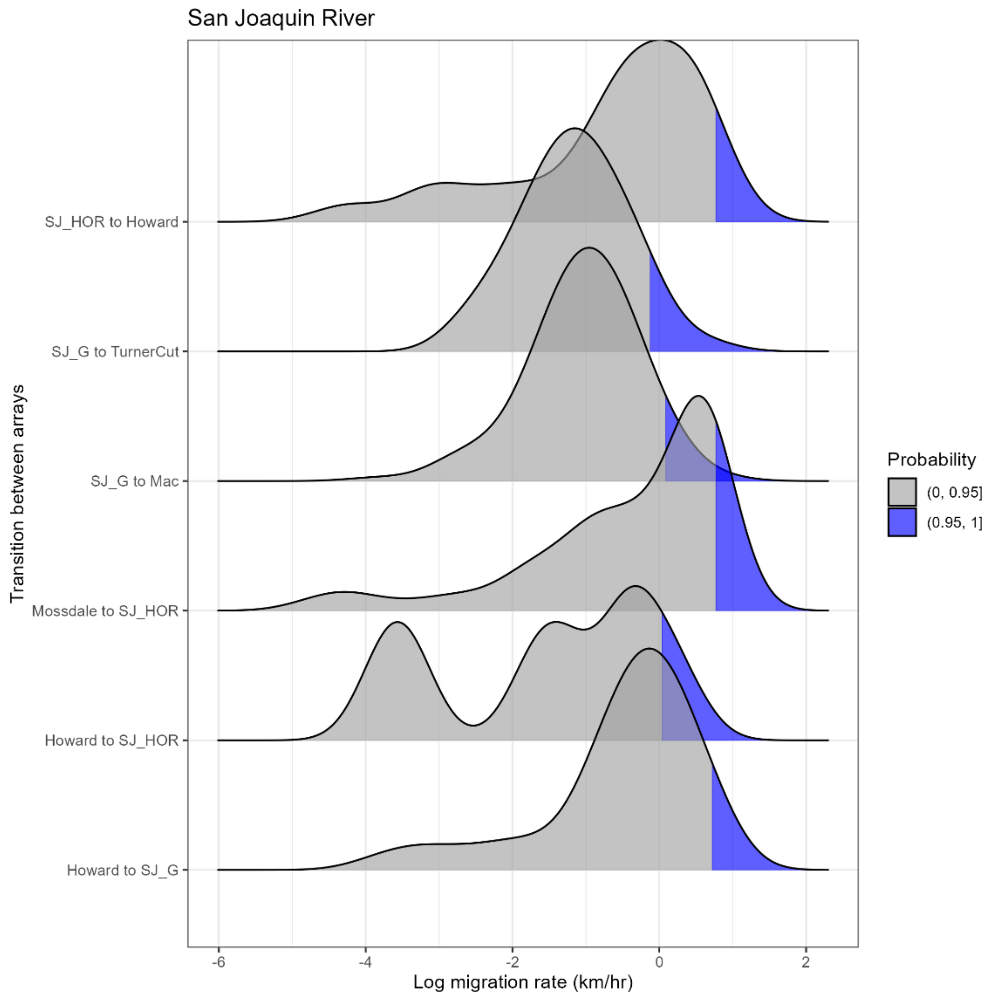

Figure 8. Smoothed histograms of counts of log migration rates (km/hr) at each transition between receiver arrays for the San Joaquin River region. Shaded blue areas are the upper 0.05 quantile of migration rates observed per transition.

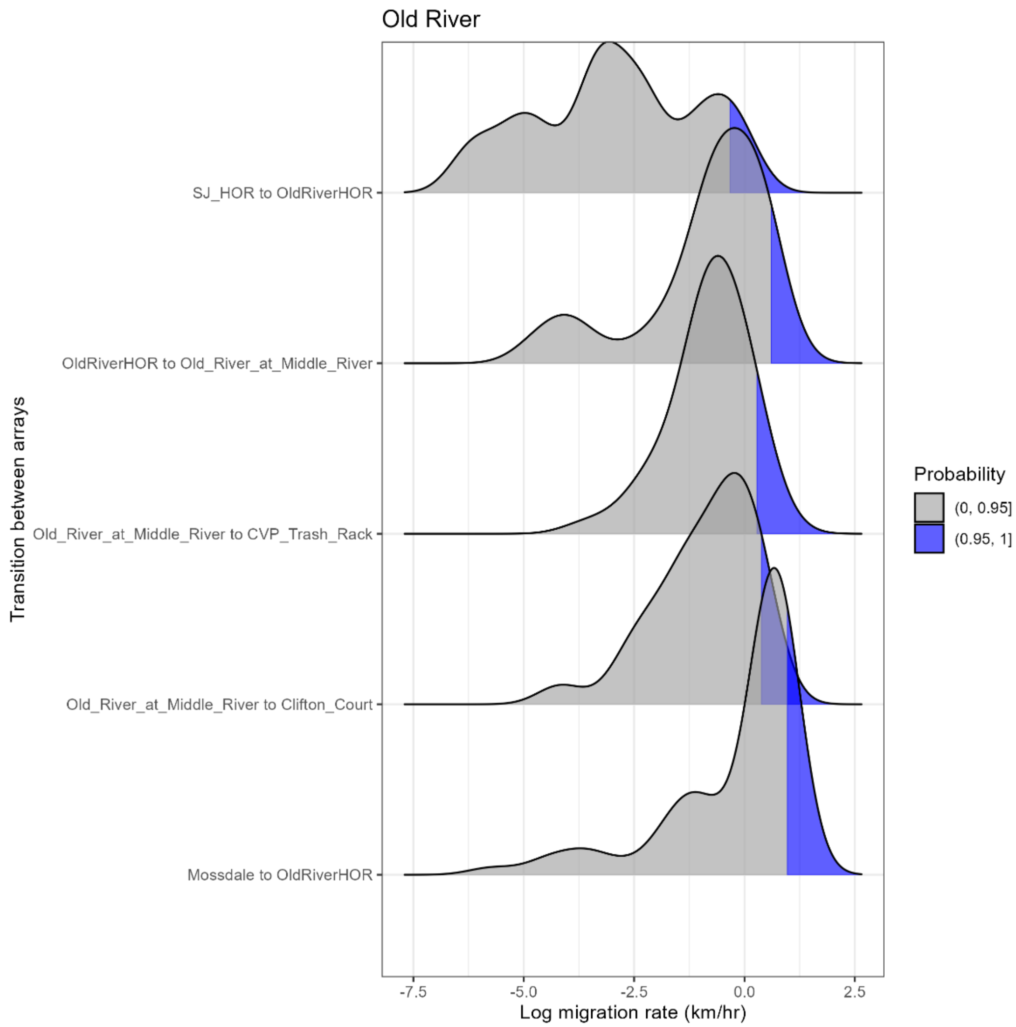

Figure 9. Smoothed histograms of counts of log migration rates (km/hr) at each transition between receiver arrays for the Old River region. Shaded blue areas are the upper 0.05 quantile of migration rates observed per transition.

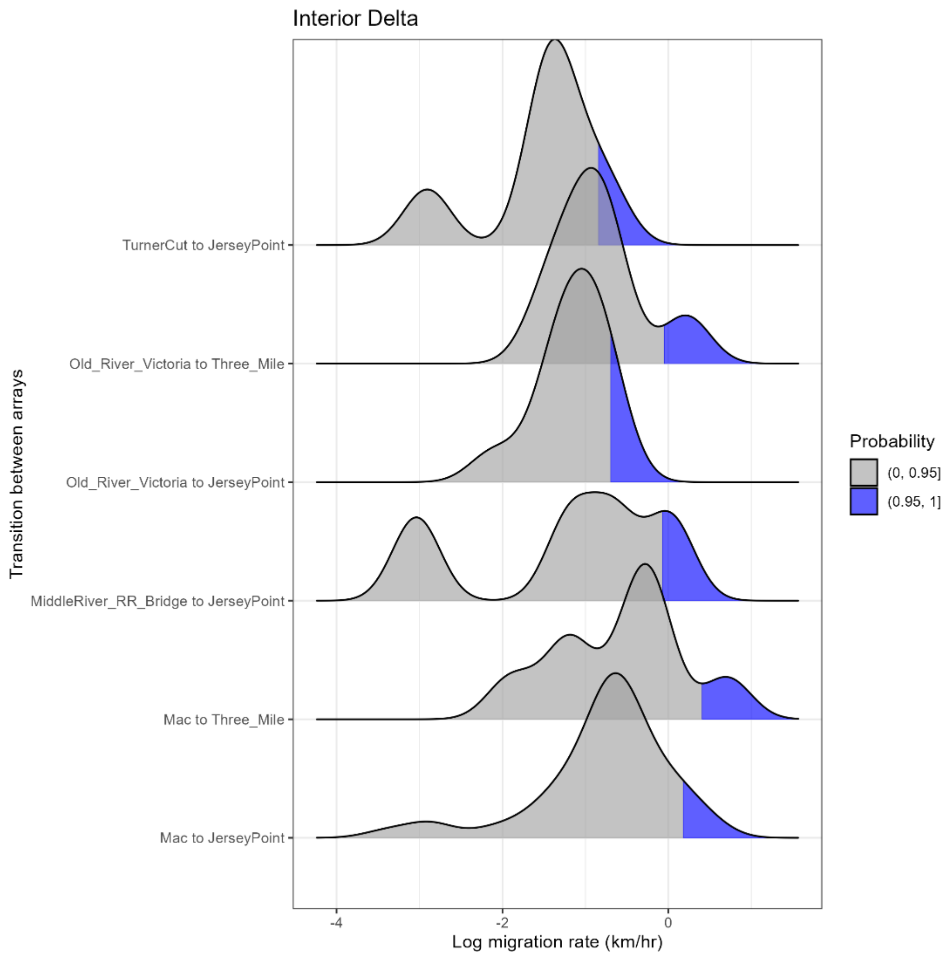

Figure 10. Smoothed histograms of counts of log migration rates (km/hr) at each transition between receiver arrays for the Interior Delta region. Shaded blue areas are the upper 0.05 quantile of migration rates observed per transition.

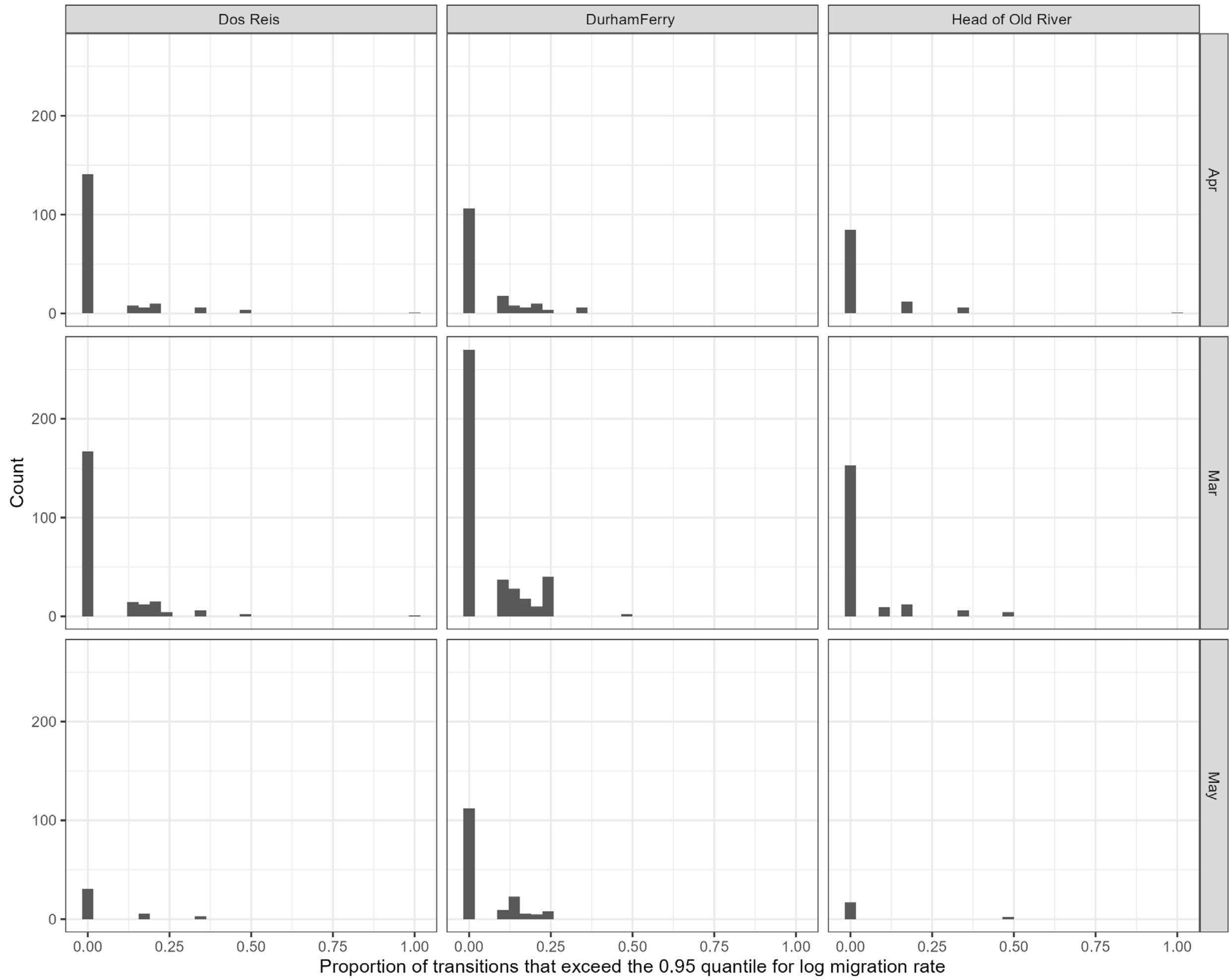

Figure 11. Histograms of the proportion of a tag's transitions between arrays that exceed the 0.95 quantile for log migration rate (km/hr), for each release group.

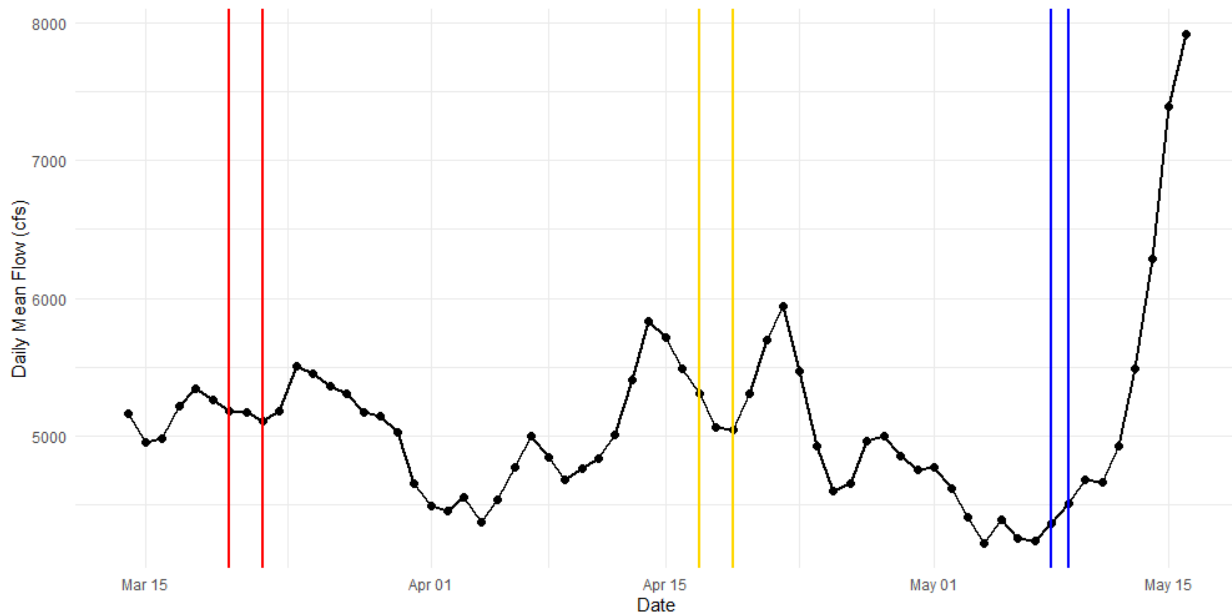

Figure 12. Daily mean flow (cubic feet per second, cfs) at Vernalis. Release weeks denoted by colors: March (red), April (yellow), May (blue).

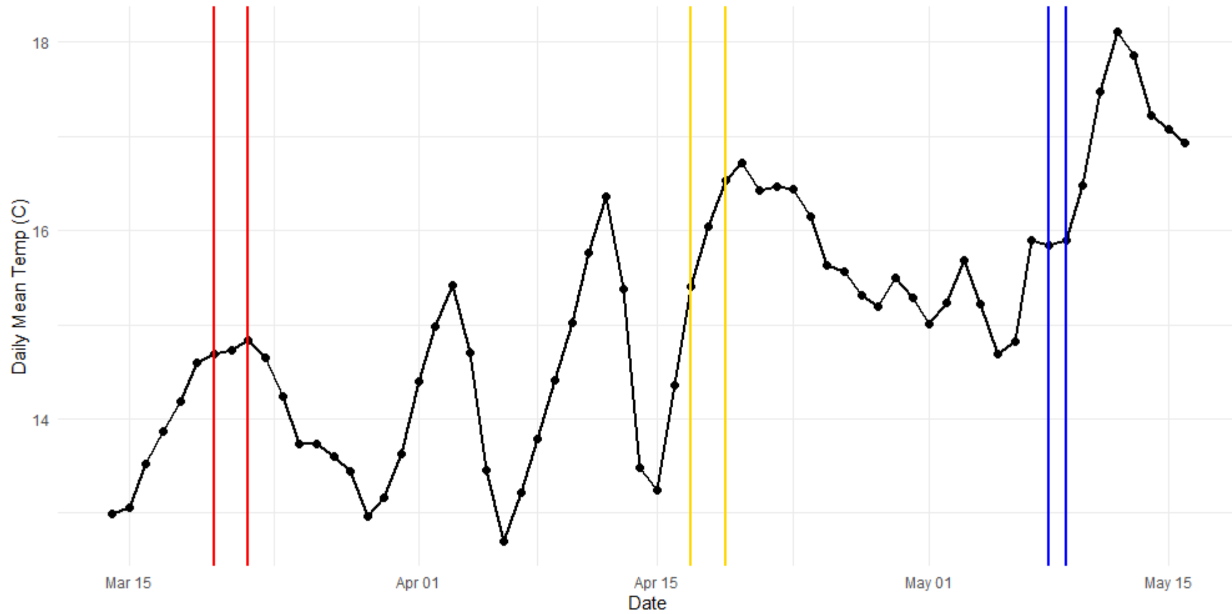

Figure 13. Daily mean water temperature (°C) at Vernalis. Release weeks denoted by colors: March (red), April (yellow), May (blue).

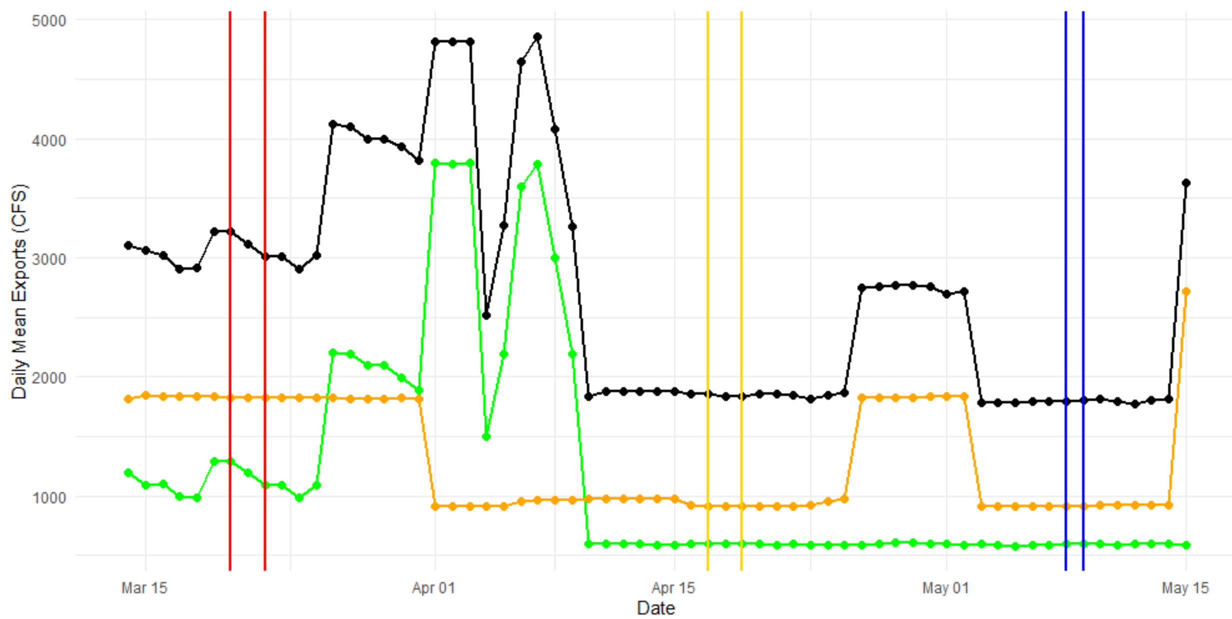

Figure 14. Daily mean Central Valley Project (orange), State Water Project (green), and total exports (black). Release weeks denoted by colors: March (red), April (yellow), May (blue).

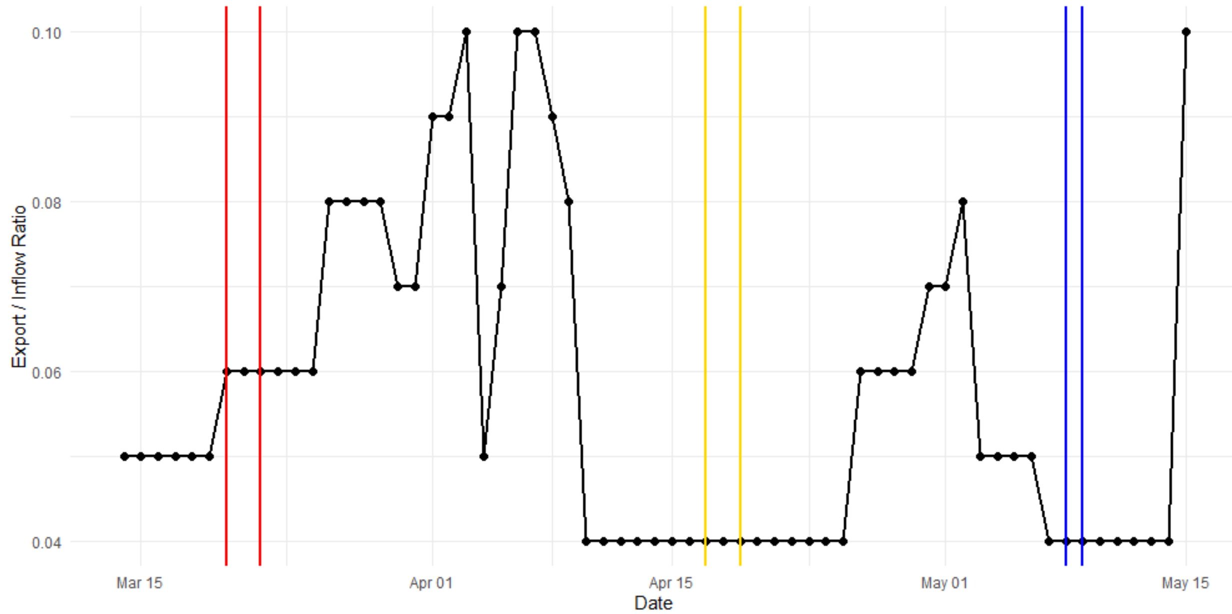

Figure 15. Daily mean export/inflow ratio. Release weeks denoted by colors: March (red), April (yellow), May (blue).

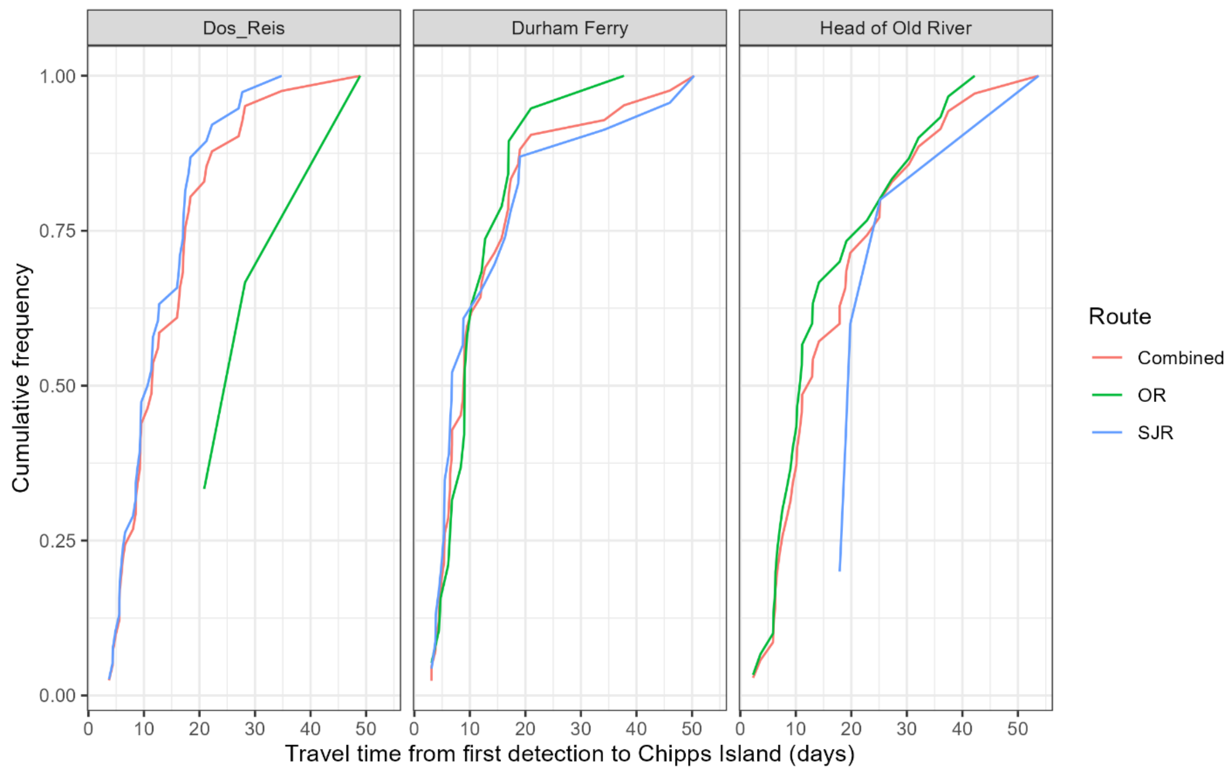

Figure 16. For those fish that made it to Chipps Island, the cumulative frequency of travel times (in days) from release to Chipps Island, based on the unfiltered dataset. Cumulative frequencies of travel times are displayed by route (San Joaquin River (SJR), Old River (OR), or Combined SJR and OR) and release location (Durham Ferry, Head of Old River, or Dos Reis).

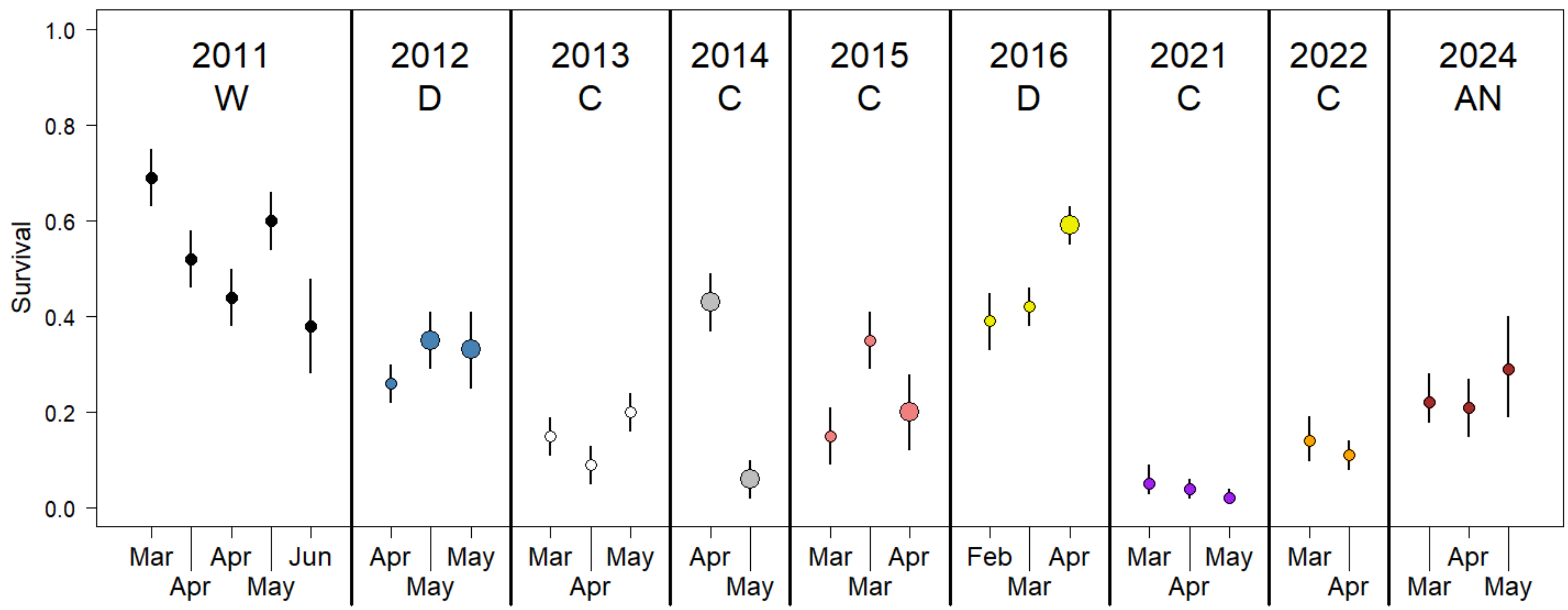

Figure 17. Juvenile steelhead through-Delta survival with 95% confidence intervals (from Mossdale to Chipps Island) from 2011-2016 (reported in Buchanan et al. 2021), 2021 (Matthias et al. 2024), 2022 (Matthias et al. 2025), and 2024. Water year types for the San Joaquin River Basin were wet (W), dry (D), critically dry (C), and above normal (AN) during the studies. Point colors represent year and size represents the presence (large points) or absence (small points) of the head of Old River barrier (HORB).

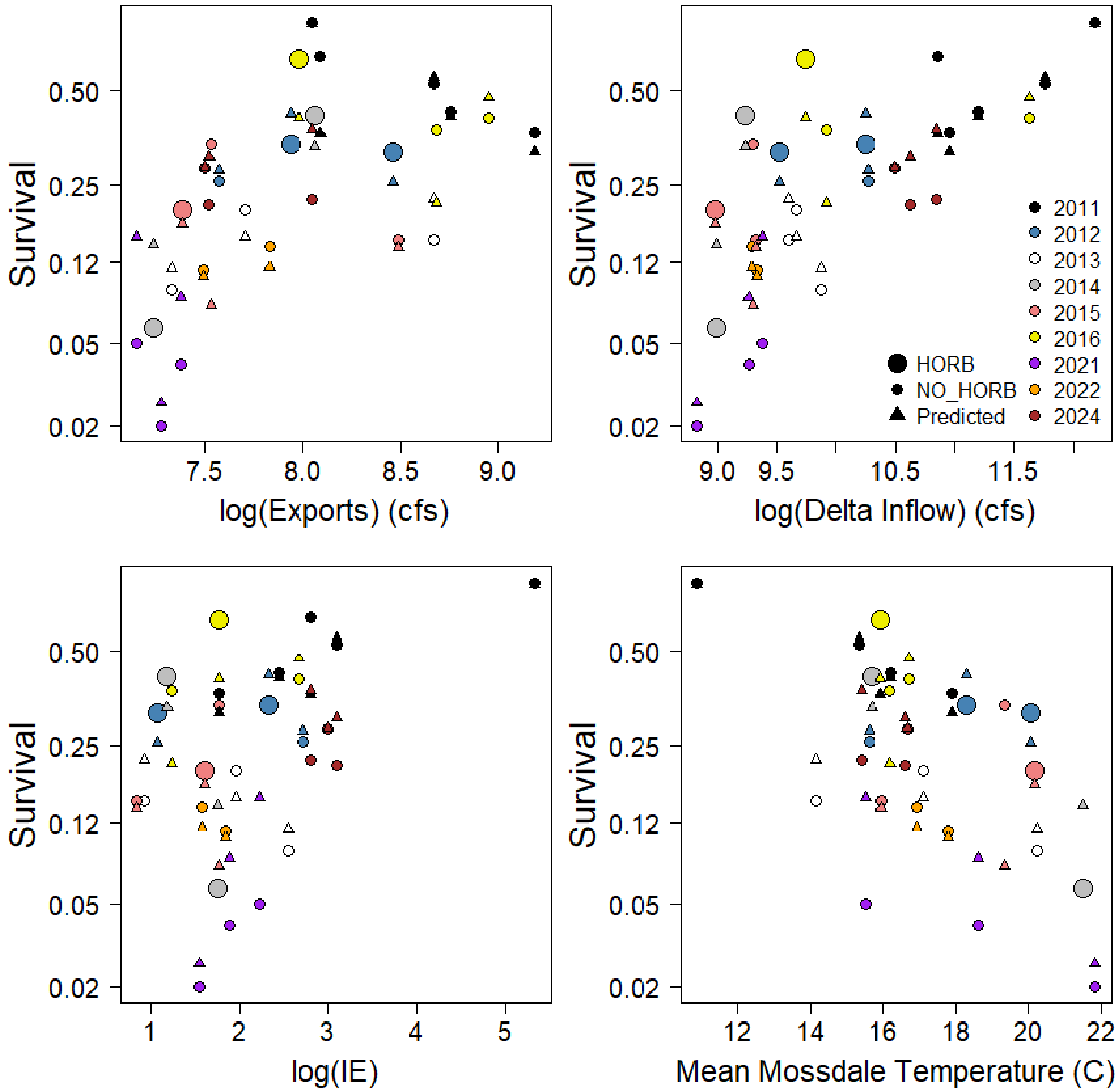

Figure 18. Juvenile steelhead through-Delta survival (from Mossdale to Chipps Island) from 2011-2016 (reported in Buchanan et al. 2021), 2021 (Matthias et al. 2024), 2022 (Matthias et al. 2025), and 2024. Environmental (total Delta inflow and mean temperature at Mossdale) and management (exports and Inflow:Export (IE) ratio) conditions were calcaulated as the mean values over the release period. The head of Old River barrier (HORB) was not installed in some years (2011, 2013, 2021, and 2022).

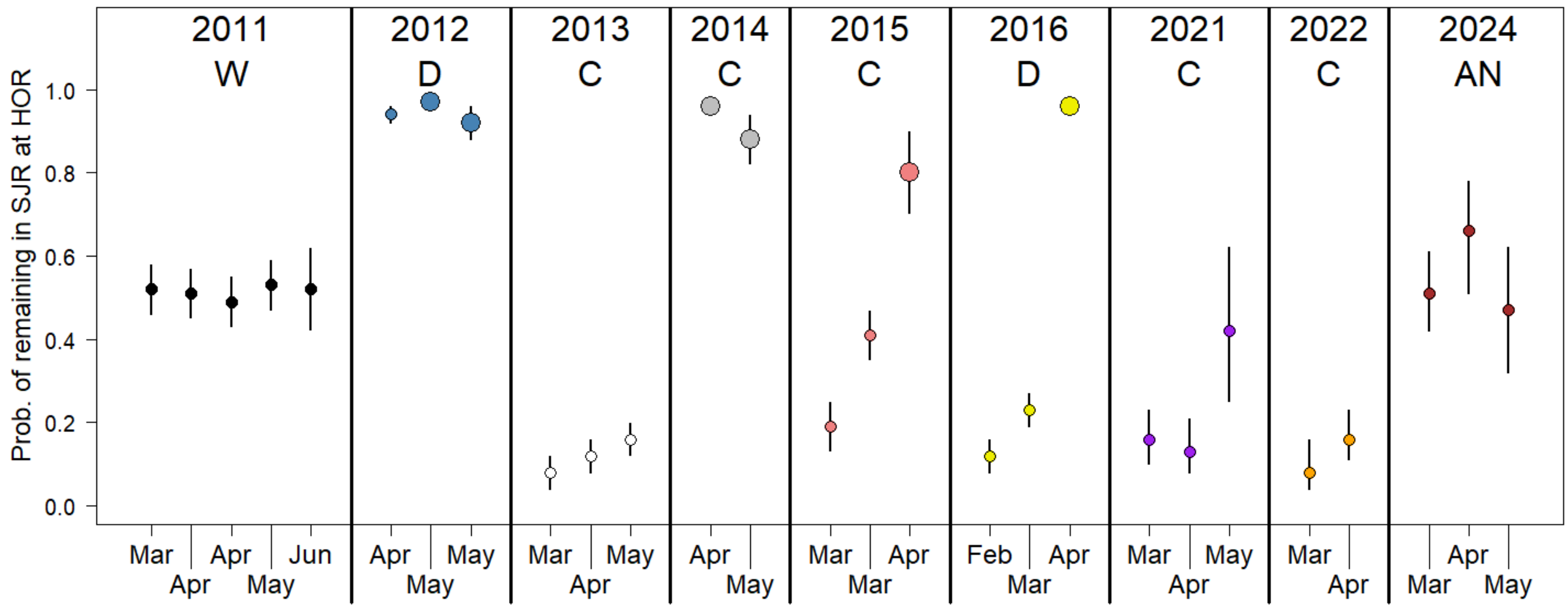

Figure 19. Juvenile steelhead routing at the Head of Old River (probability of remaining in the San Joaquin River) with 95% confidence intervals from 2011-2016 (reported in Buchanan 2018a, 2018b, 2018c, USBR 2018a, 2018b, 2018c), 2021 (Matthias et al. 2024), 2022 (Matthias et al. 2025), and 2024. Water year types for the San Joaquin River Basin were wet (W), dry (D), critically dry (C), and above normal (AN) during the studies. Point colors represent year and size represents the presence (large points) or absence (small points) of the head of Old River barrier (HORB).

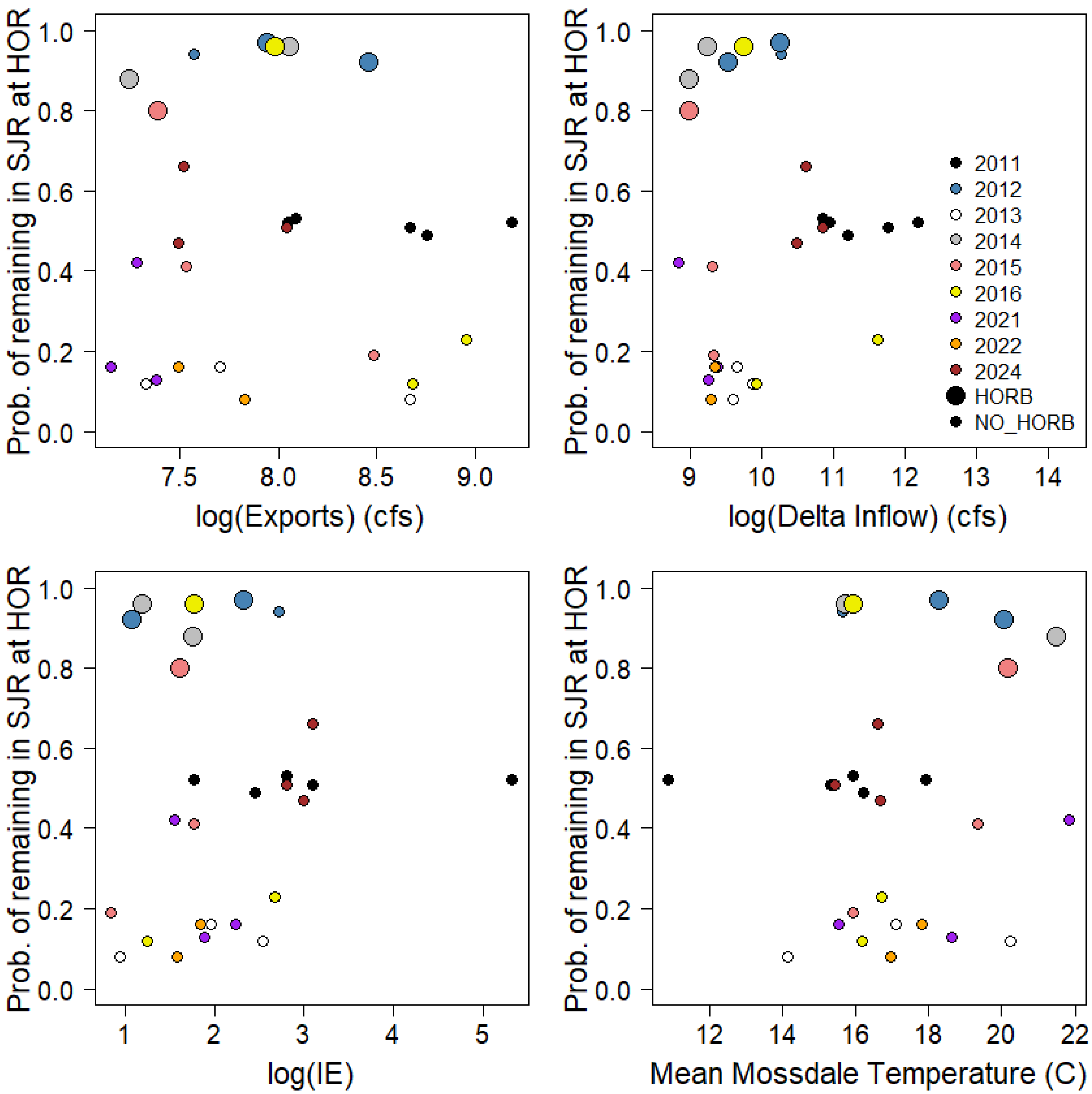

Figure 20. Juvenile steelhead routing at the Head of Old River from 2011-2016 (reported in Buchanan et al. 2021), 2021 (Matthias et al. 2024), 2022 (Matthias et al. 2025), and 2024.. Environmental (total Delta inflow and mean temperature at Mossdale) and management (exports and Inflow:Export (IE) ratio) conditions were calcaulated as the mean values over the release period. The head of Old River barrier (HORB) was not installed in some years (2011, 2013, 2021, 2022).

Appendix

Appendix A: Model Results from the 1-hit Predator Filter

Table A1. Mean derived survival estimates for all releases combined. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.08	0.11	0.48	0.43	0.54
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.06	0.17	0.26	0.20	0.33
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.65	0.30	0.16	0.10	0.26
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.52	0.26	0.18	0.12	0.27
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.33	0.17	0.21	0.16	0.27
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.33	0.17	0.21	0.16	0.27
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.20	0.15	0.23	0.18	0.29
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.37	0.16	0.20	0.16	0.26
Through-Delta Survival	lphi_TD	-1.29	0.12	0.22	0.18	0.26
Through-Bay Survival	lphi_TB	0.93	0.30	0.72	0.59	0.82
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.54	0.17	0.63	0.55	0.71
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.35	0.13	0.09	0.07	0.11
Survival from Head of Old River Release to Benicia	lphi_HORtB	-2.20	0.17	0.10	0.07	0.13
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.94	0.15	0.13	0.10	0.16
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.31	0.04			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.32	0.03			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table A2. Derived survival estimates for the March releases. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	1.22	0.20	0.77	0.70	0.83
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.15	0.21	0.24	0.17	0.32
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.67	0.31	0.16	0.09	0.26
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.46	0.45	0.19	0.09	0.36
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.46	0.21	0.19	0.13	0.26
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.46	0.21	0.19	0.13	0.26
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.30	0.19	0.21	0.16	0.28
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.46	0.20	0.19	0.14	0.26
Through-Delta Survival	lphi_TD	-1.38	0.15	0.20	0.16	0.25
Through-Bay Survival	lphi_TB	0.90	0.38	0.71	0.54	0.84
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.16	0.18	0.54	0.45	0.63
Survival from Durham Ferry to Benicia	lphi_DFtB	-1.74	0.15	0.15	0.11	0.19
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.44	0.18	0.19	0.14	0.25
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.22	0.17	0.23	0.17	0.29
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	0.06	0.03			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	0.06	0.04			

[1]These routes were combined in the analysis, but separate in the 2021 study
[2]Not estimated in 2024, but estimated in 2021

Table A3. Derived survival estimates for the April releases. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.77	0.18	0.32	0.24	0.40
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.42	0.28	0.20	0.12	0.29
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.60	0.38	0.17	0.09	0.30
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.69	0.45	0.16	0.07	0.31
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.45	0.27	0.19	0.12	0.28
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.45	0.27	0.19	0.12	0.28
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.47	0.24	0.19	0.13	0.27
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.48	0.26	0.19	0.12	0.28
Through-Delta Survival	lphi_TD	-1.48	0.19	0.19	0.14	0.25
Through-Bay Survival	lphi_TB	0.70	0.45	0.67	0.45	0.83
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.48	0.24	0.62	0.50	0.72
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.83	0.22	0.06	0.04	0.08
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.99	0.25	0.12	0.08	0.18
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.88	0.22	0.13	0.09	0.19
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.28	0.07			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.29	0.06			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table A4. Derived survival estimates for the May releases. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.68	0.20	0.34	0.26	0.43
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-0.60	0.37	0.35	0.21	0.53
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.67	0.74	0.16	0.04	0.44
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.42	0.45	0.19	0.09	0.37
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.08	0.37	0.25	0.14	0.41
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.08	0.37	0.25	0.14	0.41
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-0.82	0.35	0.31	0.18	0.46
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.18	0.35	0.23	0.13	0.38
Through-Delta Survival	lphi_TD	-1.01	0.27	0.27	0.18	0.38
Through-Bay Survival	lphi_TB	1.18	0.60	0.77	0.50	0.91
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.98	0.41	0.73	0.54	0.86
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.47	0.28	0.08	0.05	0.13
Survival from Head of Old River Release to Benicia	lphi_HORtB	-3.17	0.40	0.04	0.02	0.08
Survival from Stockton Release to Benicia	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-2.72	0.35	0.06	0.03	0.11
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.70	0.08			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.74	0.07			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table A5. Mean reach-specific survival random effects estimates (Est.), standard errors (SE), and lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) across all release groups for an average-sized fish. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

Parameter Description	Est.	SE	L_{95}	U_{95}
RE for Reach 1: DF release	0.59	0.02	0.54	0.64
RE for Reach 2: HOR release	0.59	0.02	0.55	0.64
RE for Reach 3: ST release[1]				
RE for Reach 4: DR release	0.62	0.02	0.57	0.66
RE for Reach 5: DF_DS to SJ_BCA	0.81	0.04	0.75	0.88
RE for Reach 6: SJ_BCA to Mossdale[1]				
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	0.90	0.03	0.85	0.95
RE for Reach 8: SJ-HOR to Howard	0.94	0.02	0.89	0.99
RE for Reach 9: Howard to SJG	0.92	0.02	0.88	0.95
RE for Reach 10: SJG to MAC or TC	0.81	0.03	0.75	0.86
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.49	0.05	0.40	0.59
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.44	0.08	0.29	0.59
RE for Reach 13: OR_HOR to OR_MR junction	0.88	0.04	0.81	0.95
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	0.78	0.14	0.51	1.06
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	0.39	0.14	0.11	0.67
RE for Reach 16: OR_MidR to OR_Tracy or GLC	0.94	0.02	0.91	0.98
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]				
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.40	0.08	0.24	0.56
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]				
RE for Reach 20: CVP trash rack to Chipps Island	0.33	0.06	0.21	0.45
RE for Reach 21: CCF_inlet to CCF_intake	0.39	0.07	0.25	0.52
RE for Reach 22: CCF_intake to Chipps Island	0.42	0.10	0.23	0.61
RE for Reach 23: 3-mile to Chipps Island	0.72	0.12	0.48	0.96
RE for Reach 24: Jersey Point to Chipps Island	0.93	0.03	0.87	0.99
RE for Reach 25: Chipps Island to Benicia	0.92	0.03	0.86	0.98
RE for Reach 26: Benicia to Golden Gate E	0.78	0.06	0.66	0.89

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table A6. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the March release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	3.41	0.78	0.97	0.87	0.99
RE for Reach 2: HOR release	3.75	0.80	0.98	0.90	1.00
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	3.68	0.74	0.98	0.90	0.99
RE for Reach 5: DF_DS to SJ_BCA	1.37	0.24	0.80	0.71	0.86
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.44	0.39	0.92	0.84	0.96
RE for Reach 8: SJ-HOR to Howard	2.40	0.48	0.92	0.81	0.97
RE for Reach 9: Howard to SJG	1.94	0.27	0.87	0.80	0.92
RE for Reach 10: SJG to MAC or TC	1.01	0.21	0.73	0.64	0.81
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.16	0.26	0.54	0.41	0.66
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.01	0.40	0.50	0.32	0.69
RE for Reach 13: OR_HOR to OR_MR junction	1.75	0.36	0.85	0.74	0.92
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.30	1.53	0.79	0.15	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.05	0.74	0.49	0.18	0.80
RE for Reach 16: OR_MidR to OR_Tracy or GLC	2.14	0.38	0.89	0.80	0.95
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-1.06	0.51	0.26	0.11	0.48
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.52	0.39	0.37	0.22	0.56
RE for Reach 21: CCF_inlet to CCF_intake	-0.71	0.30	0.33	0.22	0.47
RE for Reach 22: CCF_intake to Chipps Island	0.58	0.51	0.64	0.40	0.83
RE for Reach 23: 3-mile to Chipps Island	0.66	0.83	0.66	0.27	0.91
RE for Reach 24: Jersey Point to Chipps Island	2.31	0.56	0.91	0.77	0.97
RE for Reach 25: Chipps Island to Benicia	3.03	0.62	0.95	0.86	0.99
RE for Reach 26: Benicia to Golden Gate E	1.08	0.42	0.75	0.56	0.87
Mean of survival RE	1.33	0.42			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.66	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.53	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table A7. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.55	0.19	0.37	0.28	0.46
RE for Reach 2: HOR release	0.53	0.23	0.63	0.52	0.73
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	0.66	0.21	0.66	0.56	0.75
RE for Reach 5: DF_DS to SJ_BCA	1.87	0.53	0.87	0.69	0.95
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.36	0.56	0.91	0.78	0.97
RE for Reach 8: SJ-HOR to Howard	2.93	0.80	0.95	0.80	0.99
RE for Reach 9: Howard to SJG	2.38	0.39	0.91	0.83	0.96
RE for Reach 10: SJG to MAC or TC	1.26	0.27	0.78	0.68	0.86
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	-0.51	0.30	0.38	0.25	0.52
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	-0.24	0.44	0.44	0.25	0.65
RE for Reach 13: OR_HOR to OR_MR junction	2.18	0.61	0.90	0.73	0.97
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.22	1.38	0.77	0.18	0.98
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.88	0.95	0.29	0.06	0.73
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.62	0.87	0.97	0.87	1.00
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-0.56	0.42	0.36	0.20	0.57
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-1.07	0.48	0.26	0.12	0.47
RE for Reach 21: CCF_inlet to CCF_intake	-0.08	0.46	0.48	0.27	0.69
RE for Reach 22: CCF_intake to Chipps Island	-1.25	0.67	0.22	0.07	0.52
RE for Reach 23: 3-mile to Chipps Island	0.70	1.04	0.67	0.21	0.94
RE for Reach 24: Jersey Point to Chipps Island	2.68	0.77	0.94	0.76	0.98
RE for Reach 25: Chipps Island to Benicia	2.87	0.75	0.95	0.80	0.99
RE for Reach 26: Benicia to Golden Gate E	0.87	0.49	0.71	0.48	0.87
Mean of survival RE	0.97	0.40			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.66	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.53	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table A8. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.28	0.22	0.43	0.33	0.54
RE for Reach 2: HOR release	-1.57	0.33	0.17	0.10	0.29
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	-1.31	0.30	0.21	0.13	0.33
RE for Reach 5: DF_DS to SJ_BCA	1.27	0.44	0.78	0.60	0.89
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	1.95	0.54	0.88	0.71	0.95
RE for Reach 8: SJ-HOR to Howard	3.01	1.03	0.95	0.73	0.99
RE for Reach 9: Howard to SJG	3.31	0.98	0.96	0.80	0.99
RE for Reach 10: SJG to MAC or TC	2.24	0.67	0.90	0.72	0.97
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.28	0.45	0.57	0.36	0.76
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	-0.50	0.77	0.38	0.12	0.73
RE for Reach 13: OR_HOR to OR_MR junction	2.07	0.86	0.89	0.59	0.98
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.37	1.31	0.80	0.23	0.98
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.45	1.36	0.39	0.04	0.90
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.19	1.00	0.96	0.77	0.99
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.37	0.84	0.59	0.22	0.88
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.54	0.53	0.37	0.17	0.62
RE for Reach 21: CCF_inlet to CCF_intake	-0.59	0.67	0.36	0.13	0.67
RE for Reach 22: CCF_intake to Chipps Island	-0.42	0.98	0.40	0.09	0.82
RE for Reach 23: 3-mile to Chipps Island	1.52	1.48	0.82	0.20	0.99
RE for Reach 24: Jersey Point to Chipps Island	2.80	1.07	0.94	0.67	0.99
RE for Reach 25: Chipps Island to Benicia	1.88	0.66	0.87	0.64	0.96
RE for Reach 26: Benicia to Golden Gate E	2.02	0.92	0.88	0.55	0.98
Mean of survival RE	1.04	0.45			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.66	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.53	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table A9. Mean routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from all release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.07	0.19	0.48	0.39	0.57
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-2.06	0.36	0.11	0.06	0.20
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.16	0.16	0.54	0.46	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.57	0.40	0.07	0.03	0.15
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.80	0.26	0.86	0.78	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.90	0.19	0.71	0.63	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.24	0.42	0.10	0.04	0.19
ρ_9	Prob. of heading to pumps after entering Turner Cut	-0.09	0.54	0.48	0.24	0.72
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.52	0.38	0.18	0.09	0.32
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-0.43	0.51	0.39	0.19	0.64
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.60	0.71	0.35	0.12	0.69
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.80	0.20	0.31	0.23	0.40
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR Victoria _ from OR	-1.28	0.38	0.22	0.12	0.37
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.80	0.20	0.31	0.23	0.40
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.28	0.38	0.22	0.12	0.37

Table A10. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.64	0.24	0.35	0.25	0.46
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.91	0.45	0.13	0.06	0.26
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.01	0.20	0.50	0.40	0.60
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-1.97	0.30	0.12	0.07	0.20
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.78	0.30	0.86	0.77	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.81	0.24	0.69	0.58	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.35	0.61	0.09	0.03	0.24
ρ_9	Prob. of heading to pumps after entering Turner Cut	-0.05	0.55	0.49	0.24	0.74
ρ_{10}	Prob. of taking MR @ MR-OR split	-2.01	0.59	0.12	0.04	0.30
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.39	0.84	0.60	0.22	0.88
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	0.09	0.86	0.52	0.17	0.85
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-1.06	0.25	0.26	0.17	0.36
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.14	0.55	0.24	0.10	0.49
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-1.06	0.25	0.26	0.17	0.36
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.14	0.55	0.24	0.10	0.49
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.64	0.26			

Table A11. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.06	0.31	0.49	0.34	0.63
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-2.07	0.55	0.11	0.04	0.27
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.60	0.31	0.65	0.50	0.77
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.99	0.58	0.05	0.02	0.14
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	2.54	0.45	0.93	0.84	0.97
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.76	0.26	0.68	0.56	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.34	0.76	0.09	0.02	0.30
ρ_9	Prob. of heading to pumps after entering Turner Cut	-0.41	0.61	0.40	0.17	0.69
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.77	0.59	0.15	0.05	0.35
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.05	0.82	0.51	0.17	0.84
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.82	1.09	0.31	0.05	0.79
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.34	0.27	0.42	0.29	0.55
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.61	0.55	0.17	0.06	0.37
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.34	0.27	0.42	0.29	0.55
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.61	0.55	0.17	0.06	0.37
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.64	0.26			

Table A12. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	0.47	0.41	0.62	0.42	0.78
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-2.19	0.78	0.10	0.02	0.34
ρ_3	Prob. of remaining in SJ @ HOR for DF release	-0.15	0.32	0.46	0.32	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.74	1.02	0.06	0.01	0.32
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.08	0.58	0.75	0.49	0.90
ρ_7	Prob. of remaining in SJ @ Turner Cut	1.12	0.43	0.75	0.57	0.88
ρ_8	Prob. of heading to pumps after passing MAC	-2.04	0.79	0.11	0.03	0.38
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.18	1.37	0.54	0.08	0.95
ρ_{10}	Prob. of taking MR @ MR-OR split	-0.73	0.49	0.33	0.16	0.56
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-1.73	0.93	0.15	0.03	0.53
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-1.09	1.53	0.25	0.02	0.87
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.99	0.48	0.27	0.13	0.48
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.09	0.79	0.25	0.07	0.61
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.99	0.48	0.27	0.13	0.48
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.09	0.79	0.25	0.07	0.61
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.64	0.26			

Table A13. Detection probability estimates (Est.) and standard errors (SE) on the logit-scale and and transformed estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively). The bottom two parameters represent the hyperparameter mean and standard deviation (SD) for the distribution of random effects. Detection estimates represent detection at a single-line and detection of combined dual-line receivers so detection across both lines is $P = 1 - \left(1 - 1/e^{-lgt_p}\right)^2$. Parameter estimates were obtained from the model using data processed with the 1-hit predator filter.

		Logit-Scale		Transformed Est.			Dual-
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}	Line Est.
p_1	Logit Detection: DF_DS	0.31	0.14	0.58	0.51	0.64	
p_2	Logit Detection: SJ_BCA			0.00			
p_3	Logit Detection: Mossdale	2.00	0.23	0.88	0.82	0.92	
p_4	Logit Detection: SJ_HOR (Combined dual-line)	0.35	0.25	0.59	0.47	0.70	0.83
p_5	Logit Detection: Howard	1.84	0.19	0.86	0.81	0.90	
p_6	Logit Detection: SJG (Combined dual-line)	1.67	0.32	0.84	0.74	0.91	0.98
p_7	Logit Detection: MAC (Combined dual-line)	1.90	0.31	0.87	0.78	0.92	0.98
p_8	Logit Detection: Turner Cut (Combined dual-line)	2.45	0.75	0.92	0.73	0.98	0.99
p_9	Logit Detection: OR_HOR (Combined dual-line)	1.50	0.58	0.82	0.59	0.93	0.97
p_{10}	Logit Detection: MR_OR			0.00			
p_{11}	Logit Detection: MR_RRB	0.16	0.12	0.54	0.48	0.60	
p_{12}	Logit Detection: OR_MidR	0.21	0.65	0.55	0.26	0.82	
p_{13}	Logit Detection: OR_Tracy (Combined dual-line)			0.00			
p_{14}	Logit Detection: OR_Victoria (Combined dual-line)	1.86	0.99	0.87	0.48	0.98	0.98
p_{15}	Logit Detection: GLC (Combined dual-line)			0.00			
p_{16}	Logit Detection: CVP_trash_rack	2.66	0.69	0.93	0.79	0.98	
p_{17}	Logit Detection: CCF_Inlet	2.84	0.75	0.94	0.80	0.99	
p_{18}	Logit Detection: CCF_Intake	3.31	0.79	0.96	0.85	0.99	
p_{19}	Logit Detection: 3-mile Slough (Combined dual-line)	1.50	1.30	0.82	0.26	0.98	0.97
p_{20}	Logit Detection: Jersey Point (Combined dual-line)	1.48	0.43	0.81	0.65	0.91	0.97
p_{21}	Logit Detection: Chipps Island (Combined dual-line)	1.04	0.23	0.74	0.64	0.82	0.93
p_{22}	Logit Detection: Benicia (Combined dual-line)	2.59	0.72	0.93	0.77	0.98	1.00
p_{23}	Logit Detection: Golden Gate E	2.67	0.87	0.94	0.72	0.99	
p_{24}	Logit Detection: Golden Gate W	0.74	0.28	0.68	0.55	0.78	
μ_p	Hyperparameter mean detection probability in logit space	1.65	0.30				
$\log(\sigma_p)$	Hyperparameter log(SD) for detection random effect	0.10	0.28				

Appendix B: Model Results from the Multi-hit Predator Filter

Table B1. Mean derived survival estimates for all releases combined. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.09	0.11	0.48	0.42	0.53
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-0.96	0.17	0.28	0.22	0.35
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.55	0.27	0.18	0.11	0.26
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.34	0.23	0.21	0.14	0.29
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.23	0.16	0.23	0.18	0.29
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.23	0.16	0.23	0.18	0.29
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.10	0.15	0.25	0.20	0.31
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.25	0.16	0.22	0.17	0.28
Through-Delta Survival	lphi_TD	-1.17	0.12	0.24	0.20	0.28
Through-Bay Survival	lphi_TB	0.96	0.29	0.72	0.60	0.82
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.72	0.17	0.67	0.59	0.74
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.25	0.12	0.10	0.08	0.12
Survival from Head of Old River Release to Benicia	lphi_HORtB	-2.10	0.16	0.11	0.08	0.14
Survival from Stockton Release to Benicia[2]	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.87	0.15	0.13	0.10	0.17
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.32	0.03			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-1.05	0.15			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table B2. Derived survival estimates for the March releases. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	1.22	0.20	0.77	0.70	0.83
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.03	0.21	0.26	0.19	0.35
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.58	0.30	0.17	0.10	0.27
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.26	0.38	0.22	0.12	0.37
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.33	0.20	0.21	0.15	0.28
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.33	0.20	0.21	0.15	0.28
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.18	0.19	0.24	0.18	0.31
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.33	0.19	0.21	0.15	0.28
Through-Delta Survival	lphi_TD	-1.25	0.14	0.22	0.18	0.28
Through-Bay Survival	lphi_TB	0.86	0.36	0.70	0.54	0.83
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.35	0.18	0.59	0.50	0.67
Survival from Durham Ferry to Benicia	lphi_DFtB	-1.62	0.15	0.16	0.13	0.21
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.32	0.17	0.21	0.16	0.27
Survival from Stockton Release to Benicia[2]	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.16	0.17	0.24	0.18	0.30
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	0.04	0.03			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	0.02	0.03			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table B3. Derived survival estimates for the April releases. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.77	0.18	0.32	0.24	0.40
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-1.24	0.26	0.22	0.15	0.33
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.55	0.37	0.18	0.09	0.30
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.59	0.42	0.17	0.08	0.32
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-1.36	0.26	0.20	0.13	0.30
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-1.36	0.26	0.20	0.13	0.30
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-1.33	0.23	0.21	0.14	0.29
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.39	0.26	0.20	0.13	0.29
Through-Delta Survival	lphi_TD	-1.35	0.19	0.21	0.15	0.27
Through-Bay Survival	lphi_TB	0.79	0.45	0.69	0.48	0.84
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.83	0.25	0.70	0.58	0.79
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.72	0.21	0.06	0.04	0.09
Survival from Head of Old River Release to Benicia	lphi_HORtB	-1.93	0.24	0.13	0.08	0.19
Survival from Stockton Release to Benicia[2]	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-1.80	0.21	0.14	0.10	0.20
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.31	0.07			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.32	0.05			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table B4. Derived survival estimates for the May releases. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter. Parameter estimates (Est.) and standard errors (SE) were estimated on the logit-scale and transformed into mean probabilities with lower and upper 95% confidence intervals (L_{95} and U_{95} respectively).

		Logit-Scale		Probabilities		
Parameter Description	Parameter	Est.	SE	Mean	L_{95}	U_{95}
Survival from Durham Ferry to Delta Entry (Mossdale)	lphi_DE	-0.72	0.20	0.33	0.25	0.42
Survival from Delta Entry to Chipps via San Joaquin Route	lphi_SJSJ	-0.60	0.37	0.35	0.21	0.53
Survival from Delta Entry to Chipps via Turner Cut Route	lphi_SJTC	-1.51	0.64	0.18	0.06	0.43
Survival from Delta Entry to Chipps via Middle River Route	lphi_ORMR	-1.16	0.39	0.24	0.13	0.40
Survival from Delta Entry to Chipps via Old River Route[1]	lphi_OROR	-0.98	0.34	0.27	0.16	0.42
Survival from Delta Entry to Chipps via Grant Line Canal Route[1]	lphi_ORGL	-0.98	0.34	0.27	0.16	0.42
Survival from Delta Entry to Chipps via San Joaquin River Routes (SJ and TC)	lphi_SJ	-0.79	0.34	0.31	0.19	0.47
Survival from Delta Entry to Chipps via Old River Routes (MR, OR, GLC)	lphi_OR	-1.03	0.34	0.26	0.16	0.41
Through-Delta Survival	lphi_TD	-0.92	0.27	0.29	0.19	0.40
Through-Bay Survival	lphi_TB	1.23	0.60	0.77	0.51	0.92
Survival from SJ downstream of HOR to Turner Cut	lphi_SJtTC	0.96	0.40	0.72	0.54	0.85
Survival from Durham Ferry to Benicia	lphi_DFtB	-2.42	0.27	0.08	0.05	0.13
Survival from Head of Old River Release to Benicia	lphi_HORtB	-3.05	0.38	0.05	0.02	0.09
Survival from Stockton Release to Benicia[2]	lphi_STtB					
Survival from Dos Reis Release to Benicia	lphi_DRtB	-2.67	0.34	0.06	0.03	0.12
Difference HOR release survival and HOR-reach survival *not logit space	dphi_HOR	-0.69	0.07			
Difference in ST release survival and ST-reach survival[2] *not logit space	dphi_ST					
Difference in DR release survival and DR-reach survival *not logit space	dphi_DR	-0.74	0.07			

[1]These routes were combined in the analysis, but separate in the 2021 study

[2]Not estimated in 2024, but estimated in 2021

Table B5. Mean reach-specific survival random effects estimates (Est.), standard errors (SE), and lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) across all release groups for an average-sized fish. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

Parameter Description	Est.	SE	L_{95}	U_{95}
RE for Reach 1: DF release	0.59	0.02	0.54	0.64
RE for Reach 2: HOR release	0.59	0.02	0.54	0.64
RE for Reach 3: ST release[1]				
RE for Reach 4: DR release	0.61	0.02	0.57	0.66
RE for Reach 5: DF_DS to SJ_BCA	0.80	0.04	0.73	0.87
RE for Reach 6: SJ_BCA to Mossdale[1]				
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	0.91	0.03	0.86	0.96
RE for Reach 8: SJ-HOR to Howard	0.96	0.02	0.93	1.00
RE for Reach 9: Howard to SJG	0.94	0.02	0.91	0.97
RE for Reach 10: SJG to MAC or TC	0.81	0.03	0.76	0.87
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.51	0.05	0.41	0.60
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.50	0.08	0.34	0.65
RE for Reach 13: OR_HOR to OR_MR junction	0.92	0.03	0.87	0.97
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	0.84	0.11	0.62	1.06
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	0.39	0.14	0.12	0.66
RE for Reach 16: OR_MidR to OR_Tracy or GLC	0.95	0.02	0.91	0.99
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]				
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.38	0.08	0.22	0.53
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]				
RE for Reach 20: CVP trash rack to Chipps Island	0.38	0.06	0.26	0.49
RE for Reach 21: CCF_inlet to CCF_intake	0.41	0.07	0.28	0.54
RE for Reach 22: CCF_intake to Chipps Island	0.37	0.10	0.18	0.55
RE for Reach 23: 3-mile to Chipps Island	0.70	0.12	0.47	0.94
RE for Reach 24: Jersey Point to Chipps Island	0.92	0.03	0.86	0.98
RE for Reach 25: Chipps Island to Benicia	0.93	0.03	0.87	0.98
RE for Reach 26: Benicia to Golden Gate E	0.78	0.06	0.67	0.89

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table B6. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the March release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	3.41	0.78	0.97	0.87	0.99
RE for Reach 2: HOR release	3.52	0.67	0.97	0.90	0.99
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	3.65	0.71	0.97	0.90	0.99
RE for Reach 5: DF_DS to SJ_BCA	1.37	0.24	0.80	0.71	0.86
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.58	0.39	0.93	0.86	0.97
RE for Reach 8: SJ-HOR to Howard	3.15	0.67	0.96	0.86	0.99
RE for Reach 9: Howard to SJG	2.07	0.28	0.89	0.82	0.93
RE for Reach 10: SJG to MAC or TC	1.06	0.21	0.74	0.66	0.81
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.19	0.26	0.55	0.42	0.67
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.11	0.40	0.53	0.34	0.71
RE for Reach 13: OR_HOR to OR_MR junction	2.20	0.39	0.90	0.81	0.95
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.68	1.52	0.84	0.22	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	0.26	0.70	0.56	0.25	0.83
RE for Reach 16: OR_MidR to OR_Tracy or GLC	2.30	0.41	0.91	0.82	0.96
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-1.08	0.51	0.25	0.11	0.48
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.34	0.37	0.41	0.25	0.59
RE for Reach 21: CCF_inlet to CCF_intake	-0.55	0.28	0.37	0.25	0.50
RE for Reach 22: CCF_intake to Chipps Island	0.06	0.44	0.52	0.31	0.72
RE for Reach 23: 3-mile to Chipps Island	0.89	0.81	0.71	0.33	0.92
RE for Reach 24: Jersey Point to Chipps Island	2.14	0.51	0.89	0.76	0.96
RE for Reach 25: Chipps Island to Benicia	3.15	0.64	0.96	0.87	0.99
RE for Reach 26: Benicia to Golden Gate E	1.00	0.39	0.73	0.56	0.85
Mean of survival RE	1.48	0.44			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.62	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table B7. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.55	0.19	0.37	0.28	0.46
RE for Reach 2: HOR release	0.52	0.23	0.63	0.52	0.72
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	0.65	0.21	0.66	0.56	0.74
RE for Reach 5: DF_DS to SJ_BCA	1.84	0.52	0.86	0.69	0.95
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	2.67	0.64	0.94	0.80	0.98
RE for Reach 8: SJ-HOR to Howard	3.64	1.00	0.97	0.84	1.00
RE for Reach 9: Howard to SJG	3.23	0.56	0.96	0.89	0.99
RE for Reach 10: SJG to MAC or TC	1.36	0.27	0.80	0.70	0.87
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	-0.37	0.29	0.41	0.28	0.55
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	-0.23	0.42	0.44	0.26	0.64
RE for Reach 13: OR_HOR to OR_MR junction	2.40	0.68	0.92	0.74	0.98
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	1.34	1.44	0.79	0.19	0.98
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.94	0.97	0.28	0.06	0.72
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.74	0.92	0.98	0.87	1.00
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	-0.60	0.40	0.35	0.20	0.55
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.94	0.46	0.28	0.14	0.49
RE for Reach 21: CCF_inlet to CCF_intake	0.25	0.48	0.56	0.33	0.77
RE for Reach 22: CCF_intake to Chipps Island	-1.38	0.66	0.20	0.06	0.48
RE for Reach 23: 3-mile to Chipps Island	0.30	0.91	0.57	0.18	0.89
RE for Reach 24: Jersey Point to Chipps Island	2.37	0.65	0.91	0.75	0.97
RE for Reach 25: Chipps Island to Benicia	2.98	0.77	0.95	0.81	0.99
RE for Reach 26: Benicia to Golden Gate E	0.96	0.49	0.72	0.50	0.87
Mean of survival RE	1.06	0.42			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.62	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table B8. Reach-specific survival random effects estimates (Est.) and standard errors (SE) on the logit-scale and derived reach-specific survival estimates for an average-sized fish with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. Bottom four parameters represent the fixed effects intercept, effect of length on survival, and standard deviation (SD) hyperparameters for the reach-specific random effects. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

	Logit-Scale		Derived Reach-Specific Est.		
Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
RE for Reach 1: DF release	-0.25	0.22	0.44	0.33	0.55
RE for Reach 2: HOR release	-1.58	0.33	0.17	0.10	0.28
RE for Reach 3: ST release[1]			1.00		
RE for Reach 4: DR release	-1.30	0.30	0.21	0.13	0.33
RE for Reach 5: DF_DS to SJ_BCA	1.10	0.42	0.75	0.57	0.87
RE for Reach 6: SJ_BCA to Mossdale[1]			1.00		
RE for Reach 7: Mossdale to SJ_HOR or OR_HOR	1.85	0.50	0.86	0.70	0.94
RE for Reach 8: SJ-HOR to Howard	3.10	1.08	0.96	0.73	0.99
RE for Reach 9: Howard to SJG	3.40	1.03	0.97	0.80	1.00
RE for Reach 10: SJG to MAC or TC	2.25	0.67	0.90	0.72	0.97
RE for Reach 11: MAC to 3-mile, Jersey Point, CVP or SWP	0.27	0.45	0.57	0.35	0.76
RE for Reach 12: Turner Cut to 3-mile, Jersey Point, CVP or SWP	0.06	0.78	0.52	0.19	0.83
RE for Reach 13: OR_HOR to OR_MR junction	3.00	0.95	0.95	0.76	0.99
RE for Reach 14: MR_OR to MR_RRB, OR_Victoria, CVP, or SWP	2.10	1.23	0.89	0.42	0.99
RE for Reach 15: MR_RRB to 3-mile or Jersey Point	-0.72	1.39	0.33	0.03	0.88
RE for Reach 16: OR_MidR to OR_Tracy or GLC	3.02	1.02	0.95	0.73	0.99
RE for Reach 17: OR_Tracy to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 18: OR_Victoria to 3-mile or Jersey Point	0.10	0.77	0.52	0.20	0.83
RE for Reach 19: GLC to MR_RRB, OR_Victoria, CVP, or SWP[1]			1.00		
RE for Reach 20: CVP trash rack to Chipps Island	-0.28	0.51	0.43	0.22	0.67
RE for Reach 21: CCF_inlet to CCF_intake	-0.79	0.65	0.31	0.11	0.62
RE for Reach 22: CCF_intake to Chipps Island	-0.47	1.00	0.38	0.08	0.82
RE for Reach 23: 3-mile to Chipps Island	1.57	1.56	0.83	0.19	0.99
RE for Reach 24: Jersey Point to Chipps Island	2.88	1.12	0.95	0.66	0.99
RE for Reach 25: Chipps Island to Benicia	1.93	0.66	0.87	0.65	0.96
RE for Reach 26: Benicia to Golden Gate E	2.06	0.93	0.89	0.56	0.98
Mean of survival RE	1.07	0.48			
Slope for the survival-length relationship*	0.36	0.06			
Log(SD) for Release-specific random effect hyperparameter*	0.62	0.28			
Log(SD) for Reach-specific random effect hyperparameter*	0.60	0.14			

[1]Survival in these reachs were not estimated, but were estimated in the 2021 study.

Table B9. Mean routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from all release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.08	0.18	0.48	0.39	0.57
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.96	0.34	0.12	0.07	0.22
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.19	0.16	0.55	0.47	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.58	0.40	0.07	0.03	0.14
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.80	0.26	0.86	0.78	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.90	0.18	0.71	0.63	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.14	0.39	0.11	0.05	0.20
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.28	0.49	0.57	0.33	0.78
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.64	0.39	0.16	0.08	0.30
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-0.48	0.51	0.39	0.19	0.63
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.66	0.71	0.34	0.11	0.67
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.69	0.19	0.33	0.26	0.42
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.21	0.36	0.23	0.13	0.38
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.69	0.19	0.33	0.26	0.42
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.21	0.36	0.23	0.13	0.38

Table B10. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the March release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	-0.68	0.23	0.34	0.25	0.44
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.82	0.42	0.14	0.07	0.27
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.05	0.20	0.51	0.42	0.61
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.05	0.31	0.11	0.07	0.19
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.78	0.30	0.86	0.77	0.91
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.82	0.23	0.69	0.59	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-2.40	0.61	0.08	0.03	0.23
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.11	0.53	0.53	0.28	0.76
ρ_{10}	Prob. of taking MR @ MR-OR split	-2.13	0.59	0.11	0.04	0.27
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.11	0.82	0.53	0.18	0.85
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	0.01	0.90	0.50	0.15	0.85
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-1.05	0.24	0.26	0.18	0.36
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-0.82	0.47	0.31	0.15	0.53
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-1.05	0.24	0.26	0.18	0.36
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-0.82	0.47	0.31	0.15	0.53
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.60	0.26			

Table B11. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the April release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	0.04	0.31	0.51	0.36	0.66
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-1.90	0.50	0.13	0.05	0.28
ρ_3	Prob. of remaining in SJ @ HOR for DF release	0.64	0.31	0.66	0.51	0.78
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.98	0.58	0.05	0.02	0.14
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	2.53	0.45	0.93	0.84	0.97
ρ_7	Prob. of remaining in SJ @ Turner Cut	0.76	0.25	0.68	0.57	0.78
ρ_8	Prob. of heading to pumps after passing MAC	-1.99	0.63	0.12	0.04	0.32
ρ_9	Prob. of heading to pumps after entering Turner Cut	-0.20	0.57	0.45	0.21	0.72
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.78	0.59	0.14	0.05	0.35
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	0.22	0.84	0.55	0.19	0.86
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-0.94	1.09	0.28	0.04	0.77
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.19	0.27	0.45	0.33	0.58
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.69	0.54	0.16	0.06	0.35
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.19	0.27	0.45	0.33	0.58
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.69	0.54	0.16	0.06	0.35
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.60	0.26			

Table B12. Routing random effects estimates (Est.) and standard errors (SE) on the logit-scale and mean transformed routing estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively) from the May release. The * indicates parameter held constant over release groups. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

		Logit-Scale		Transformed Est.		
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}
ρ_1	Prob. of entering CVP vs. SWP	0.39	0.40	0.60	0.41	0.76
ρ_2	Prob. of taking 3-mile vs. Jersey Point to Chipps Island	-2.18	0.77	0.10	0.02	0.34
ρ_3	Prob. of remaining in SJ @ HOR for DF release	-0.13	0.32	0.47	0.32	0.62
ρ_4	Prob. of taking SJ route for HOR release vs. OR route	-2.72	1.02	0.06	0.01	0.33
ρ_5	Prob. of going downstream @ ST release			0.50		
ρ_6	Prob. of going downstream @ DR release	1.08	0.58	0.75	0.49	0.90
ρ_7	Prob. of remaining in SJ @ Turner Cut	1.13	0.44	0.76	0.57	0.88
ρ_8	Prob. of heading to pumps after passing MAC	-2.03	0.79	0.12	0.03	0.38
ρ_9	Prob. of heading to pumps after entering Turner Cut	0.93	1.24	0.72	0.18	0.97
ρ_{10}	Prob. of taking MR @ MR-OR split	-1.00	0.48	0.27	0.13	0.49
ρ_{11}	Prob. of heading to interior delta vs. pumps from MR	-1.77	0.98	0.15	0.02	0.54
ρ_{12}	Prob. of heading to interior via MR_RRB vs OR_Victoria from MR	-1.06	1.54	0.26	0.02	0.88
ρ_{13}	Prob. of taking OR @ OR-GLC split			0.50		
ρ_{14}	Prob. of heading to interior delta vs. pumps from OR_Victoria	-0.82	0.45	0.31	0.15	0.52
ρ_{15}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from OR	-1.12	0.77	0.25	0.07	0.60
ρ_{16}	Prob. of heading to interior delta vs. pumps from GLC	-0.82	0.45	0.31	0.15	0.52
ρ_{17}	Prob. of heading to interior delta via MR_RRB vs. OR_Victoria from GLC	-1.12	0.77	0.25	0.07	0.60
μ_ρ	Hyperparameter mean of transition probability in logit space*	-0.60	0.26			

Table B13. Detection probability estimates (Est.) and standard errors (SE) on the logit-scale and and transformed estimates with lower and upper 95% confidence intervals (L_{95} and U_{95}, respectively). The bottom two parameters represent the hyperparameter mean and standard deviation (SD) for the distribution of random effects. Detection estimates represent detection at a single-line and detection of combined dual-line receivers so detection across both lines is $P = 1-\left(1-1/e^{-lgt_p}\right)^2$. Parameter estimates were obtained from the model using data processed with the multi-hit predator filter.

		Logit-Scale		Transformed Est.			Dual-
Par.	Parameter Description	Est.	SE	Mean	L_{95}	U_{95}	Line Est.
p_1	Logit Detection: DF_DS	0.31	0.14	0.58	0.51	0.64	
p_2	Logit Detection: SJ_BCA			0.00			
p_3	Logit Detection: Mossdale	2.06	0.24	0.89	0.83	0.93	
p_4	Logit Detection: SJ_HOR (Combined dual-line)	0.43	0.24	0.60	0.49	0.71	0.84
p_5	Logit Detection: Howard	1.82	0.18	0.86	0.81	0.90	
p_6	Logit Detection: SJG (Combined dual-line)	1.69	0.32	0.84	0.74	0.91	0.98
p_7	Logit Detection: MAC (Combined dual-line)	1.78	0.28	0.86	0.77	0.91	0.98
p_8	Logit Detection: Turner Cut (Combined dual-line)	2.41	0.69	0.92	0.74	0.98	0.99
p_9	Logit Detection: OR_HOR (Combined dual-line)	1.54	0.56	0.82	0.61	0.93	0.97
p_{10}	Logit Detection: MR_OR			0.00			
p_{11}	Logit Detection: MR_RRB	0.20	0.12	0.55	0.49	0.61	
p_{12}	Logit Detection: OR_MidR	0.20	0.58	0.55	0.28	0.79	
p_{13}	Logit Detection: OR_Tracy (Combined dual-line)			0.00			
p_{14}	Logit Detection: OR_Victoria (Combined dual-line)	1.90	0.86	0.87	0.55	0.97	0.98
p_{15}	Logit Detection: GLC (Combined dual-line)			0.00			
p_{16}	Logit Detection: CVP_trash_rack	2.52	0.65	0.93	0.78	0.98	
p_{17}	Logit Detection: CCF_Inlet	2.69	0.64	0.94	0.81	0.98	
p_{18}	Logit Detection: CCF_Intake	2.89	0.61	0.95	0.84	0.98	
p_{19}	Logit Detection: 3-mile Slough (Combined dual-line)	1.51	1.14	0.82	0.33	0.98	0.97
p_{20}	Logit Detection: Jersey Point (Combined dual-line)	1.59	0.45	0.83	0.67	0.92	0.97
p_{21}	Logit Detection: Chipps Island (Combined dual-line)	1.08	0.23	0.75	0.65	0.82	0.94
p_{22}	Logit Detection: Benicia (Combined dual-line)	2.54	0.66	0.93	0.78	0.98	0.99
p_{23}	Logit Detection: Golden Gate E	2.58	0.81	0.93	0.73	0.98	
p_{24}	Logit Detection: Golden Gate W	0.79	0.27	0.69	0.56	0.79	
μ_p	Hyperparameter mean detection probability in logit space	1.63	0.27				
$\log(\sigma_p)$	Hyperparameter log(SD) for detection random effect	0.02	0.26				