Salmonid Monitoring of Habitat Restoration Sites in the Upper Sacramento River in 2018-2019

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SUMMARY

One aspect of the Upper Sacramento River Anadromous Fish Habitat Restoration Project (hereafter, the Project) is the restoration of historic off-channel juvenile salmonid habitat in the upper Sacramento River through the reconnection of historic side channel habitat to the main stem of the river. The Project operates under the assumption that if channels are connected at a range of flows, the physical and biological characteristics of the habitat will support a greater abundance of juvenile salmonids that are larger and in better condition to out-migrate. This report summarizes the efforts of the Project Monitoring Team from project inception to the end of the 2018-19 monitoring year. By the end of July 2019, four side channels had been restored. In order to evaluate the restoration, the Monitoring Team collected pre-restoration data (baseline), post-restoration data (impact), and data from control sites. To choose control sites, the team used previously conducted surveys to choose areas thought to be the highest-quality habitat geographically located near restoration (or future restoration) sites. Analyses reported here compare impact and control site data, due to limited availability of pre-restoration data. Because of this, we use the creation of additional high-quality habitat that performs similarly, or better, to these controls as a benchmark for successful restoration. Analyses of snorkel survey data shows that restored sites had similar juvenile salmonid densities for all runs. Average fish densities over the duration of the project were a function of run, with fall run Chinook exhibiting the highest densities, and winter run Chinook having the lowest densities. Fish densities were higher at more northern sites, though the strength of this relationship varies with run. Analyses of habitat mapping data shows that restored and control sites had similar levels of suitable and optimal habitat (as defined by Goodman et al. 2015). Restoration of Lake California, North Cypress, and Painter's Riffle side channels created approximately 5.23 acres of habitat classified as suitable or optimal for juvenile salmonids when mapped at flows ranging between 3,250 and 3,700 cfs, and 5.08 acres at flows ranging between 7,400 and 8,000 cfs. Kapusta side channel was not yet mapped at these flows, but is expected to add to this acreage. Chinook fry in restored sites showed a significant preference for habitat with fine woody debris. Analyses show that fall run Chinook salmon juveniles captured via seining within side channels had a higher condition factor and/or greater fork length than those caught in the mainstem of the river in the vicinity of side channels between February and June 2019. Winter run Chinook juveniles in side channels exhibited greater fork lengths in December 2018, than those caught in the mainstem of the river. December of 2018 was the only month comparisons were feasible due to data limitations. No differences in fork length existed for late-fall run juveniles in May and June of 2019, however sample sizes were limited in June 2019. Together, this information suggests that the Project has been successful in adding a significant amount of high-quality juvenile salmonid habitat to the Upper Sacramento River.

INTRODUCTION

Problem Statement

Central Valley anadromous salmonid populations have seen marked declines in the past century, with many populations listed as endangered, threatened, or of special concern under the California and Federal endangered species acts (Katz *et al.*, 2013; NMFS, 2014). The reasons for this are numerous, and are outlined in the Central Valley Chinook Salmon and steelhead Recovery Plan (NMFS, 2014). Stressors that have been ranked as high or very high for rearing and out-migrating juvenile salmonids in the upper Sacramento River include loss of floodplain habitat; loss of natural morphologic function; loss of riparian habitat and instream cover; and competition and predation (NMFS, 2014). Anadromous salmonids that spawn in the Sacramento River generally use the upper Sacramento River as rearing habitat, with the middle and lower portions of the river primarily serving as a migration corridor (NMFS, 2014).

The Upper Sacramento River Anadromous Fish Habitat Restoration Project (hereafter, the Project) aims to restore spawning and juvenile rearing habitat in the upper Sacramento River. This report focuses on monitoring data related to the latter. The majority of historic off-channel habitat in the upper Sacramento River has been lost as a result of controlled flow regimes in conjunction with natural geologic formations and flood control levees, resulting in a scarcity of juvenile rearing habitat (NMFS, 2014). The Upper Sacramento River Anadromous Fish Habitat Restoration Project (hereafter, the Project) restores this habitat through the reconnection of historic side channel habitat to the main stem of the river, under the assumption that if channels are connected at a range of flows, the physical and biological characteristics of the habitat will support a greater abundance of juvenile salmonids that are larger and in better condition to out-migrate. The conceptual model underlying this hypothesis, and which forms the basis for the monitoring plan approach, is provided below (Figure 1). An in-depth discussion of this conceptual model is available in the Upper Sacramento River Anadromous Fish Habitat Restoration Project Monitoring Plan and Protocols (Tussing and Banet, 2017), hereafter referred to as the Monitoring Plan.

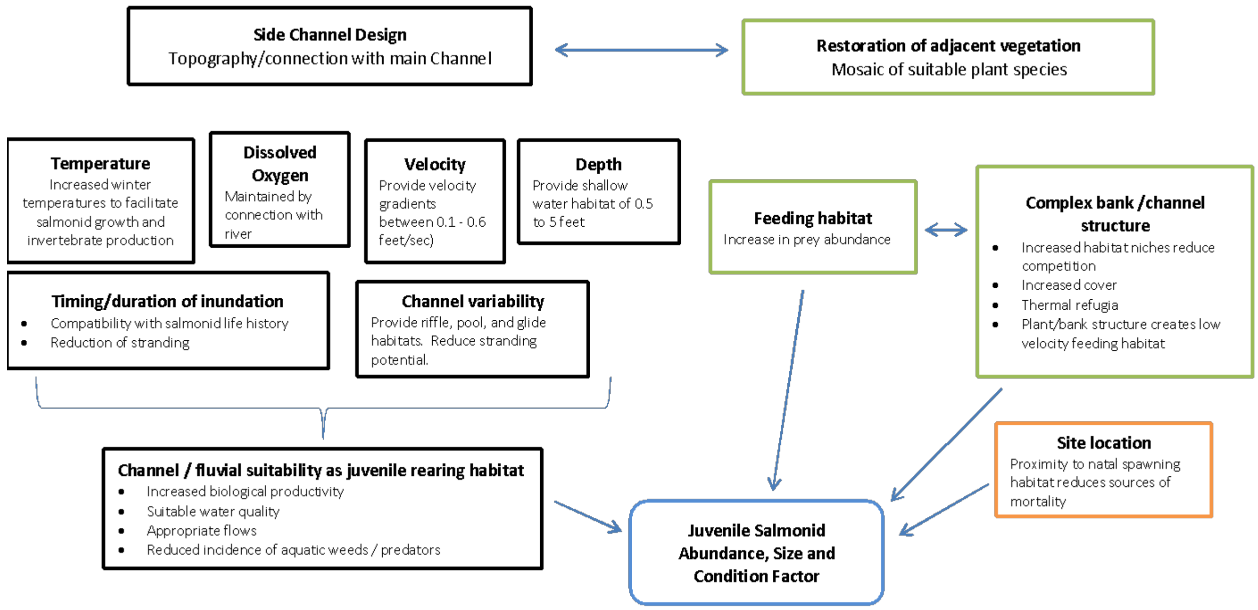


Figure 1. Conceptual model of design-related elements and their influence on biotic and abiotic juvenile salmonid habitat elements.

Restoration Goals and Objectives

The primary goals of the Project, as stated in the Monitoring Plan (Tussing and Banet, 2017), are to:

1. Increase the availability, quality and quantity of spawning and rearing habitat for Sacramento River Basin Chinook salmon and steelhead trout
2. Restore, maintain or enhance natural system processes whenever possible
3. Determine project effectiveness, including cost, project longevity and maintenance requirements, with an efficient and scientifically-robust monitoring program
4. Demonstrate a positive, detectable salmonid population response to habitat enhancement activities
5. Contribute to the long-term health of the river ecosystem (water quality, invertebrate and fish assemblages, riparian and floodplain habitat function, etc.)
6. Incorporate information learned to improve future projects (adaptive management)
7. Contribute to scientific understanding of aquatic ecology
8. Work collaboratively with partners to identify and implement projects that are cost effective and benefit aquatic resources, emphasizing anadromous salmonids, in the short and long term.

The primary objectives of the Project, as stated in the Monitoring Plan (Tussing and Banet, 2017) are to provide:

1. An increase in the areal extent of spawning habitat meeting suitability criteria and the use of spawning habitat.

2. An increase in the areal extent of rearing habitat meeting juvenile salmonid rearing habitat suitability criteria.
3. Increase in salmonid juvenile abundance/density at restoration sites after implementation, as compared to before implementation.
4. Improved size and average condition of salmonids using the side channels, as compared to those that have not been documented using the side channels.
5. An increase in available prey abundance, including both drift and benthic macroinvertebrates.
6. Increased extent and quality of riparian habitat at Sand Slough.

Purpose of Annual Reporting

The purpose of annual reporting, as described in the Monitoring Plan (Tussing and Banet, 2017) is to determine if monitoring data collection methods are effective at achieving data objectives; modify field protocols as needed to effectively meet those objectives; perform preliminary tests of hypotheses as data allows; and, to inform restoration efforts where a biological response to restoration can be established. More extensive and thorough analysis and reporting are to be performed when there is sufficient data to analyze the full suite of hypotheses as described in the primary study design and provide more robust feedback to inform possible modifications. To that end, this report focuses on a subset of activities that address Project objectives 2 and 3, and 4 using data collected between December 2015 and July 2019. Monitoring activities for other Project objectives were either implemented more recently, or are in the process of being quality checked, and will be included in a future report when a more robust dataset is available. Objectives 2 and 3 now have several years of monitoring data for a subset of the study sites, and objective 4 has data from the most recent reporting year. However, because of the number of confounding factors that can influence field data, we advise caution with the interpretation of the reported analyses until a larger dataset can be gathered. It may require additional years of monitoring to fully evaluate the success of these objectives with an acceptable level of certainty.

METHODS

The methods described below are derived from the Monitoring Plan (Tussing and Banet, 2017) with modifications as needed due to crew safety concerns, crew availability, or other logistical constraints. Methods were designed to monitor the effects of restoration on native juvenile salmonids, including all present runs of Chinook salmon and steelhead/Rainbow trout.

Monitoring Site Selection

Project sites (Figure 2, Table 1) were identified and prioritized for construction through the CVPIA habitat restoration process. Restoration sites are side channels that were either previously connected to the river and have since been cut off to fish due to increased channelization, or side channels that are only available to juvenile fish during certain times of year (i.e. during high releases from Keswick dam). The Project prioritized sites for construction based on a multitude of factors which may include but are not limited to: stranding potential at lower Keswick releases, feasibility of construction, land-owner cooperation, site longevity and maintenance requirements, and overall perceived benefit to juvenile salmonids, with emphasis on benefits to listed species. Baseline snorkel data was taken from restoration sites when possible, but this data is limited because many restored sites were not consistently connected to the mainstem prior to restoration.

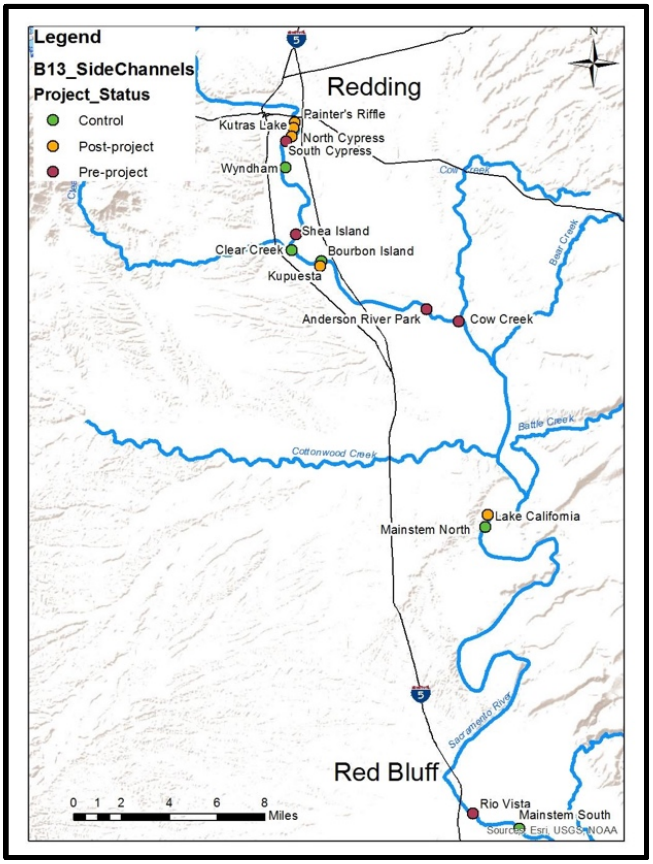


Figure 2. Map of control, pre-project (pre-restoration) and post-project (restored) side channels surveyed as part of the Project.

Table 1. Name, status, and approximate river mile of Project Sites.

Site Name	Status	RM
Painter's Riffle	Post-project	296
Kutras Lake	Post-project	296
North Cypress	Post-project	295.5
South Cypress	Pre-project	294
Wyndham	Control	293.5
Shea Island	Pre-project	290
Clear Creek	Control	289
Bourbon Island	Control	287.5
Kapusta	Post-project	287.5
Anderson River Park	Pre-project	282
Cow Creek	Pre-project	280
Lake California	Post-project	269.5
Mainstem North	Control	268.5
Rio Vista	Pre-project	247
Mainstem South	Control	242

In order to examine the performance of the restored side channels, the monitoring team identified five control sites. To select control sites, we consulted with area experts to identify habitat geographically located near restoration (or future restoration) sites that was thought to be the highest quality nearby habitat. When possible, currently functioning side channels were selected as controls. In areas of the river where functioning side channels were not available to use as controls, mainstem control sites were selected. This process resulted in three side channel controls, and two mainstem controls (Figure 2, Table 1).

Fish Abundance Index

Snorkel Surveys

An index of fish abundance was collected via snorkel surveys when conditions permitted. Surveys were conducted at each site between 9AM and 3PM, generally every two weeks. Data was classified as control, baseline (pre-restoration), or impact (restored). The order in which control, impact, and baseline sites were surveyed were randomized whenever possible, in order to reduce the likelihood that data is confounded with time of day. We recorded several physical variables each time a site was surveyed (Table 2). Visibility, weather, and water temperature were recorded on site. Flow was calculated in the office using data from nearby gauging stations.

Table 2. Physical variables collected in conjunction with snorkel counts.

Variable	Description
Visibility	Visibility is measured using a secchi disk. A member of the crew submerges his or her face into the water and extends the pole upstream along the plane of their eye level until the disc can no longer be seen. The distance from the disc to the swimmer's eye is recorded in feet.
Weather	Weather is measured on a numeric scale as follows: 1- Clear, 2 - Partly Cloudy, 3 - Cloudy, 4 - Rain, 5 - Snow, 6 - Fog. For this report, monthly weather scores are reported both as mean and mode numeric values.
Water Temperature	Water temperature is measured in Fahrenheit during each survey.
Calculated Flow	Flow is determined using data from nearby gauging stations. Lake California, Mainstem North, Mainstem South, and Rio Vista use data from the Bend Bridge (BND) gauging station in Red Bluff, CA. All other sites use data from the Keswick (KWK) gauging station in Keswick, CA.

Each swimmer calibrated his or her vision prior to commencing a snorkel survey in order to account for the visual distortion that occurs in water. To do this, the swimmer submerged their face and mask in the water, and another crew member held a calibration tool equipped with a model fish of known lengths in front of the swimmer for a short period of time. This process was repeated until the swimmer was comfortable with the calibration.

Flows and conditions at some sites were not amenable to snorkeling upstream. Because of this, all surveys were conducted downstream to maintain consistency. Swimmers formed a line perpendicular to flow prior to the start of the survey and recorded the start time of the survey. At most sites, two snorkelers were used to survey edge habitat along each bank of a side channel. For mainstem sites, one snorkeler surveyed the edge of the main river bank. Swimmers maintained their line in order to reduce the likelihood of double counting fish. Juvenile salmonids were identified to species, classified by size, and counted as they passed by the snorkeler. Other fish species were noted and counted as well, in order to gather information on species richness and the presence of predators. After the survey was completed, an end time was recorded. For analysis, steelhead and Rainbow Trout juveniles were classified together, and Chinook salmon were categorized into runs using the Central Valley length-to-date chart (See Appendix A).

Juvenile Habitat Mapping and Suitability

Juvenile habitat mapping was implemented on a schedule that allowed us to map a range of flows. Targets were as follows: low, or winter flows (3,250-4,500 cfs); intermediate, or fall flows (4,500-7,000 cfs); and high, or summer flows (10,000+ cfs) for each site. When crew safety or limited flow regimes prevented measuring a site at all target flows, we mapped at the widest range of flows possible given these constraints. When possible, all habitat mapping protocols described below were implemented on the same day in order to maintain consistency between the flows at which date were collected.

Habitat Types

At each site, cross sections for discharge measurement were established following the Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California (CDFW, 2013). Cross sections were benchmarked for future use. Habitat typing and mapping followed methods from the California Stream Habitat Restoration Manual (CDFW, 2010). Surveys began at the downstream end of side channels, and proceeded upstream to the side channel inlet. Habitats were classified to level III using the habitat types hierarchy provided in CDFW (2010). The wetted perimeter and breaks between habitat types were mapped for the entire length of the channel using a Trimble Geo7x Handheld GPS. The maximum depth was recorded for each habitat type (habitat unit), and average depth was calculated using data taken by a stadia rod across several transects. Dominant and codominant substrate within he wetted area was identified following classification of CDFW (2010). Tree canopy cover was measured as percent stream area covered with a spherical densiometer.

Depth, Velocity, and Cover

Juvenile habitat mapping efforts followed the juvenile habitat suitability criteria of Goodman *et al.* (2015) and apply to age-0 presmolt (>50mm) Chinook salmon. These criteria include depth, velocity and distance to cover (Table 3). Cover types mapped followed the primary cover types previously identified during the study of Flow-Habitat Relationships for Chinook Salmon Rearing in the Sacramento River between Keswick Dam and Battle Creek (USFWS, 2005; Holmes *et al.*, 2014; Table 4).

Table 3. Juvenile Chinook Salmon Habitat Suitability Criteria (Goodman *et al.*, 2015)

Parameter	Upper Range (m)	Upper Range (ft)
Depth	1	3.3
Velocity (m/s)	0.24	0.8
Distance to Cover	0.6	2.0
Definitions		
Unsuitable habitat	Does not meet depth, velocity, or cover criteria	
Suitable habitat	Meets depth and velocity criteria ***or*** cover criteria	
Optimal habitat	Meets depth, velocity, and cover criteria	

Table 4. Juvenile Salmonid Habitat Cover Types (USFWS, 2005; Holmes *et al.*, 2014)

Cover Type	Definition
No cover	No cover
Cobble	3”-12” particle size, < 50% embedded
Boulder	>12” particle size
Fine wood vegetation	<1” Diameter
Branches, small woody debris	< 12” Diameter
Log, large woody debris	> 12” Diameter
Overhead cover	> 2’ above substrate, < 1.5’ off water surface
Undercut banks	Undercut banks
Aquatic vegetation	In-water vegetative cover
Rip rap	Rip rap

To map depth and velocity, the field crew used a Trimble Geo7x Handheld GPS. Data was collected when the accuracy of the Trimble unit allowed mapping to occur at a scale of one meter or less. Using juvenile depth and velocity suitability criteria identified in Table 5, the crew outlined areas of suitable habitat by measuring depth and velocity using hand-held flow meters on top-setting rods. This allowed identification of discrete polygons throughout the side channel that simultaneously met both depth and velocity criteria (i.e. depth and velocity were not mapped independently). We excluded small habitat areas less than $2m^2$ from perimeter mapping in order to reduce geo-spatial error.

The Trimble GPS was also used to map cover. Using juvenile cover suitability criteria identified above (Table 3), the crew outlined the perimeter of in-water escape cover, and geo-referenced locations of this outline using the Trimble GPS. The in-water escape cover was mapped separately for each of the cover types without overlapping polygons. In some cases where cover types overlapped, and separate mapping of types was not feasible (e.g. minimum size criteria), the polygon was classified by the dominant cover type. The mapping of unembedded cobble as a cover type is the one exception to the general rule, and was mapped independently and often overlapped with other cover types. Similar to the depth and velocity mapping, we excluded small areas of cover less than $2m^2$ to reduce geo-spatial error from perimeter mapping.

Microhabitat Use

We used stratified random sampling to select habitats for inclusion in data collection for microhabitat use, in order to ensure the full range of available habitat types were captured, and that a commensurate amount of surface area was sampled for each habitat type. Surveys focused on both suitable and unsuitable habitat (as defined in Table 2) in order to establish the difference between fish use of preferred vs. available habitat.

For selected habitat units, snorkelers worked in an upstream direction and at a slow pace to observe the point locations of undisturbed fish. The location of fish observed was marked with a weighted tag on the stream bottom. The species, run, size, and number of the juveniles were recorded on tags for any observed salmonid juveniles less than 201mm in fork length. Estimates of fish size and selection of the appropriate size class bin was aided by the use of a dive cuff with photographs of salmonids at bin lengths. Size class bins included <41mm, 41-50mm, 51-60mm, and then by 20mm bin widths up to a maximum of 200mm. After the habitat unit was surveyed, flagged locations were revisited, and data was collected on fish attributes, GPS point location, habitat type, depth (total water column), distance to bank, distance to cover, cover type, mean water column velocity, and substrate.

Fish Size and Condition

Fish size and condition data was collected through the use of seining at a variety of sites both within side channels and in the mainstem Sacramento River in the vicinity of side channels. Within each side channel, three permanent seining sites were established that were free of in-water obstructions, would be seinable at the range of targeted flows (3,250 to 13,000 cfs Keswick releases), and represented a riffle, flatwater and a pool habitat type. Three permanent seining sites were also selected in the mainstem river in the vicinity of side channels that met the same criteria and captured the diversity of velocity and depth characteristics present rather than specific habitat types, which occur on much larger spatial scales.

Each pair of side channel/mainstem sites were sampled on the same day, and it took approximately 10 days to sample all side channel/mainstem paired sites for each sampling event. Two seine pulls were applied at each permanent sampling site and all salmonids captured were identified to run, enumerated, measured for fork lengths (mm) and weights (to the nearest 0.01 g). Seines used were of a wandering pole type with a purse and 30’ in total length. Surface area seined and average depths were measured and recorded. Where seining at fixed sites did not yield sufficient numbers of fish to establish size and condition, roving seining consisting of single seine sets were applied anywhere that was conducive to sampling in side channels and the mainstem.

Data Analysis

Fish Abundance

Statistical analyses were conducted using R (R Core Team, 2016). The area observed per snorkel survey was calculated as the length of the channel surveyed multiplied by the visibility distance recorded on the day of the survey and the number of snorkelers. This information was then used to estimate the number of fish per acre for each survey. The geographic location of a survey was classified as "North" if it was above river mile 287 and "South" if it was below river mile 287. Monthly averages over the duration of the study were graphed for visualization purposes, but time series analysis was not possible because the large number of zeros in the data affected model fit. Instead, fish per acre was used as the dependent variable in a mixed effects multiple regression model that pooled data over time. This model included control and impact data. Baseline data was excluded because we lacked enough pre-project surveys of restored sites to make comparisons. The model included fixed effects of run, channel status (restored vs. control), and geographic location, as well as random effects of site, and the interaction between site and run. The fixed effects allow us to directly estimate the influence the variables have on fish per acre. The random effects take into account repeated measurements on the same sites and for the same runs. The random effect for the site in this model allows for correlation within sites, and the random effects on the interaction between site and run attempts to account for the variation due to specific runs preferring specific sites. All estimated means are the approximation made by the model after accounting for the fixed and random effects above. Bootstrap estimated confidence intervals provide measures of uncertainty in the model's estimates. Each confidence interval was developed by conditioning on the estimated random effects and resampling 10001 times.

Juvenile Habitat Mapping and Suitability – Depth, Velocity, and Cover

The analyses reported below exclude cobble and aquatic vegetation as cover types. For cobble, this is because we believe our early estimates of cobble may have been biased due to difficulty detecting cobble in deeper water. Aquatic vegetation was excluded because it created a relationship between flow and cover that was an artifact of seasonal changes in vegetation, it was often non-native, and field crew reported that they rarely saw fish using it as cover. Analyses that included aquatic vegetation had only minor differences from those reported below, and can be found in Appendix C.

As described above, a Trimble Geo7x Handheld GPS was used to map discrete polygons throughout the side channel that simultaneously met both depth and velocity criteria. Similarly, the in-water escape cover was mapped separately for each of the cover types without overlapping polygons. This data was processed using Trimble GPS Pathfinder Office software, and imported into ArcGIS in order to determine the proportion of each side channel that met the Goodman *et al.* (2015) criteria for depth & velocity, cover, suitable habitat, and optimal habitat for age-0 presmolt (>50mm) Chinook salmon.

Statistical analyses were conducted using R (R Core Team, 2016). The proportion of each habitat classified as suitable or optimal was calculated for each side channel mapped (Goodman *et al.*, 2015). We used linear mixed models to determine the effect of restoration status (control vs restored) and flow from Keswick Dam on the proportion of optimal habitat, suitable habitat, and the sum of the two. Because each side channel was measured at multiple flows, these models included side channel ID as a random effect in order to account for correlations between measurements within sites. We used similar linear mixed models to determine the effect of restoration and flow on suitable depth and velocity, and suitable cover, which are the component habitat characteristics used to define suitable and optimal habitat. Because flow is a continuous variable, we used the lsmeans package in R to conduct post-hoc analyses that examined how habitat availability is expected to change in response to flow. Attempts to fit a model that allowed predictions of the acres of each habitat classification gained across a range of flows yielded extremely low adjusted R^2 values (not reported) and would not provide reliable predictions; thus, we instead report on the actual amount of habitat measured at each site in the field.

Juvenile Habitat Mapping and Suitability – Microhabitat Use

As with the depth, velocity, and cover analyses, the microhabitat-use analyses reported below exclude cobble and aquatic vegetation as cover types. Fish preference for different cover types was explored by comparing the proportion of fish found in each cover type with the proportion of area each cover type occupies at a specific site. We assume that a higher proportion of fish found in cover types that make up relatively less square footage of a site indicates preference for that cover type. Thus, preference is defined as:

$$\text{Preference} = \frac{F_{cover}}{F_{total}} - \frac{A_{cover}}{A_{total}}$$

where F_{cover} represents the number of fish in observed in a given cover type, F_{total} represents the number of fish observed in all cover types, A_{cover} represents area of a given cover type, and A_{total} represents the total area surveyed.

Analysis of this data was constrained due to the inherent issues of analyzing groups that make up a proportion of a whole. Because of this, we ran an ANOVA that examined whether fish preference was a function of the interaction between channel status and cover type. Separate tests were run for Chinook fry, Chinook juveniles, steelhead/Rainbow trout fry, and steelhead/Rainbow trout juveniles. When an ANOVA identified at least one significant difference amongst the means of the levels of the interaction between cover type and channel status, we performed additional post-hoc pairwise comparisons of combinations of cover type and channel status to determine which mean(s) are different. Combinations that are of interest are reported below. All p-values were adjusted to control for multiple comparisons and maintain a family-wise confidence level of 95% using Tukey's Honest Significant Difference.

Fish Size and Condition

As a preliminary look at fish condition, we calculated Fulton's condition factor (Ricker, 1975) and relative condition factor (Le Cren, 1951) for fall run Chinook and late-fall Chinook. Fulton's Condition Factor is represented by the equation:

$$\text{Fulton's Condition Factor} = 100\left(\frac{L}{w^3}\right)$$

where L equals the length of the fish and w is the mass of the fish. Relative Condition Factor is calculated use the equation:

$$\text{Relative Condition Factor} = \frac{w}{W}$$

Where w is the observed mass of an individual is divided by its predicted mass W, which is obtained from the linear regression of the weight-length relationship of the respective population sample.

We then used two-sample t-tests to compare differences in condition between fish captured in side channels, and those captured in nearby sections of the mainstem of the Sacramento River for each run. Due to our relatively small sample size, data from the entire sampling period (February -June 2019) was pooled, and control and impact side channels were considered together for this preliminary analysis.

Additionally, we took a preliminary look at potential size differences (fork lengths) for winter, fall, and late-fall Chinook fry and juveniles. We used two-sample t-tests to compare differences for Chinook of each run in side channel vs. mainstem Sacramento River habitats for each sampling period that occurred between December 2018 and June 2019 (n=5). Control and impact side channels were considered together for this preliminary analysis.

RESULTS

Fish Abundance Index

Using the length-to-date chart, snorkelers observed juvenile fall run, late-fall run, and winter run Chinook salmon, as well as steelhead/Rainbow trout. A small number (<10) of fish were classified as spring run Chinook based on the length-to-date chart (Appendix A). It is unclear whether these fish indicate a small presence of spring-run juvenile salmonids in the upper Sacramento River, or whether they represent errant classifications. These observations are excluded from the following analyses due to the small sample size. Monthly averages of fish-per-acre for each site over the duration of the project are graphed for visualization purposes in figures 3 and 4. A mixed effects multiple regression model showed that there was no significant difference in estimates of fish-per-acre for restored and control sites (Table 5, Figure 5). As expected, the density of fish observed was a factor of run (Table 5, Figure 5). Fish-per-acre was higher at northern sites than southern sites, though the strength of this influence varied by run (Table 5, Figure 6). Figure 7 shows mean density of fish at each site for each run over the course of the study.

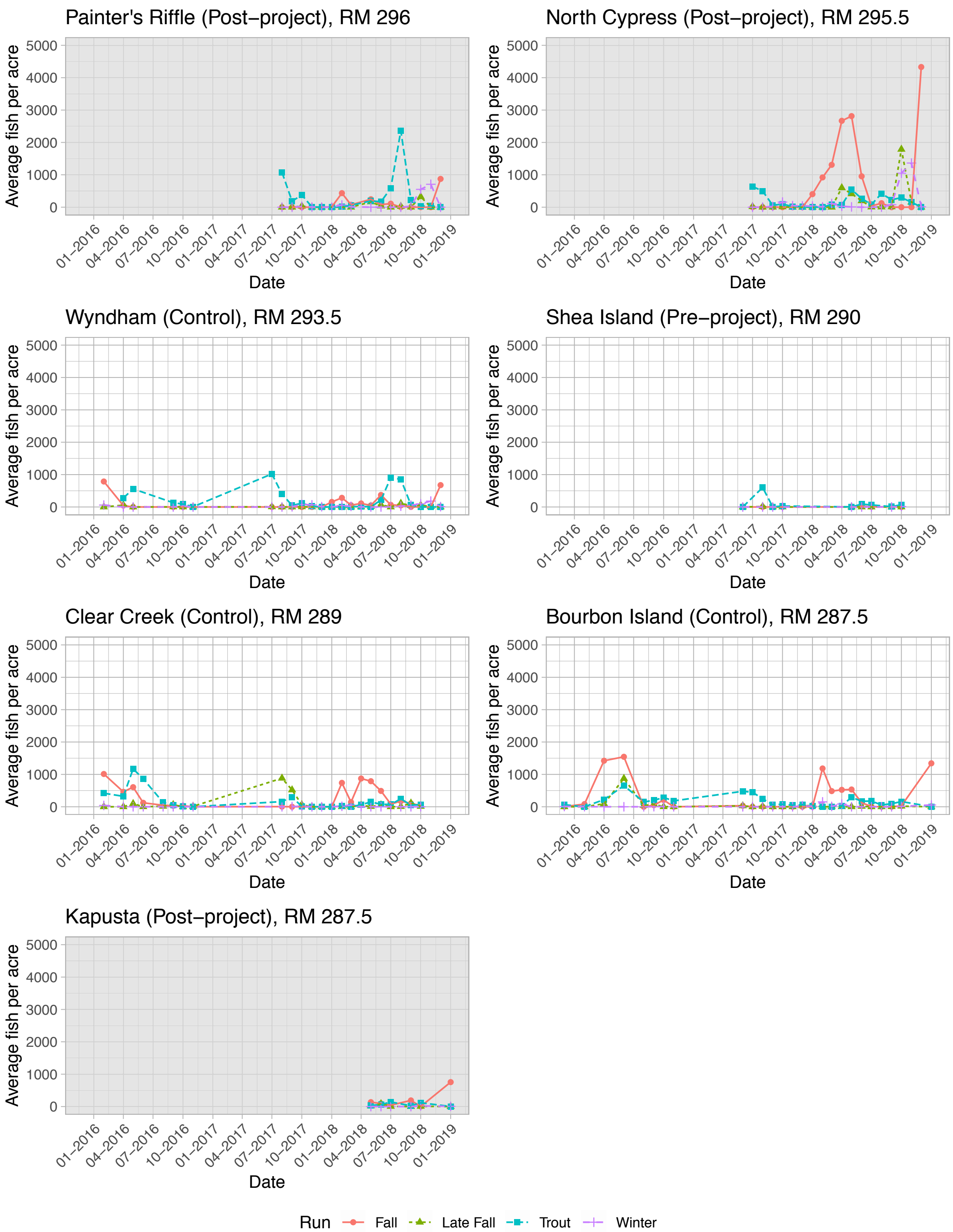


Figure 3. Monthly averages of fish-per-acre for northern sites (above RM 287). Light gray shading indicates data taken after restoration (post-project). No shading indicates control or baseline data. Note that the y-axis scale for this figure differs from figure 4.

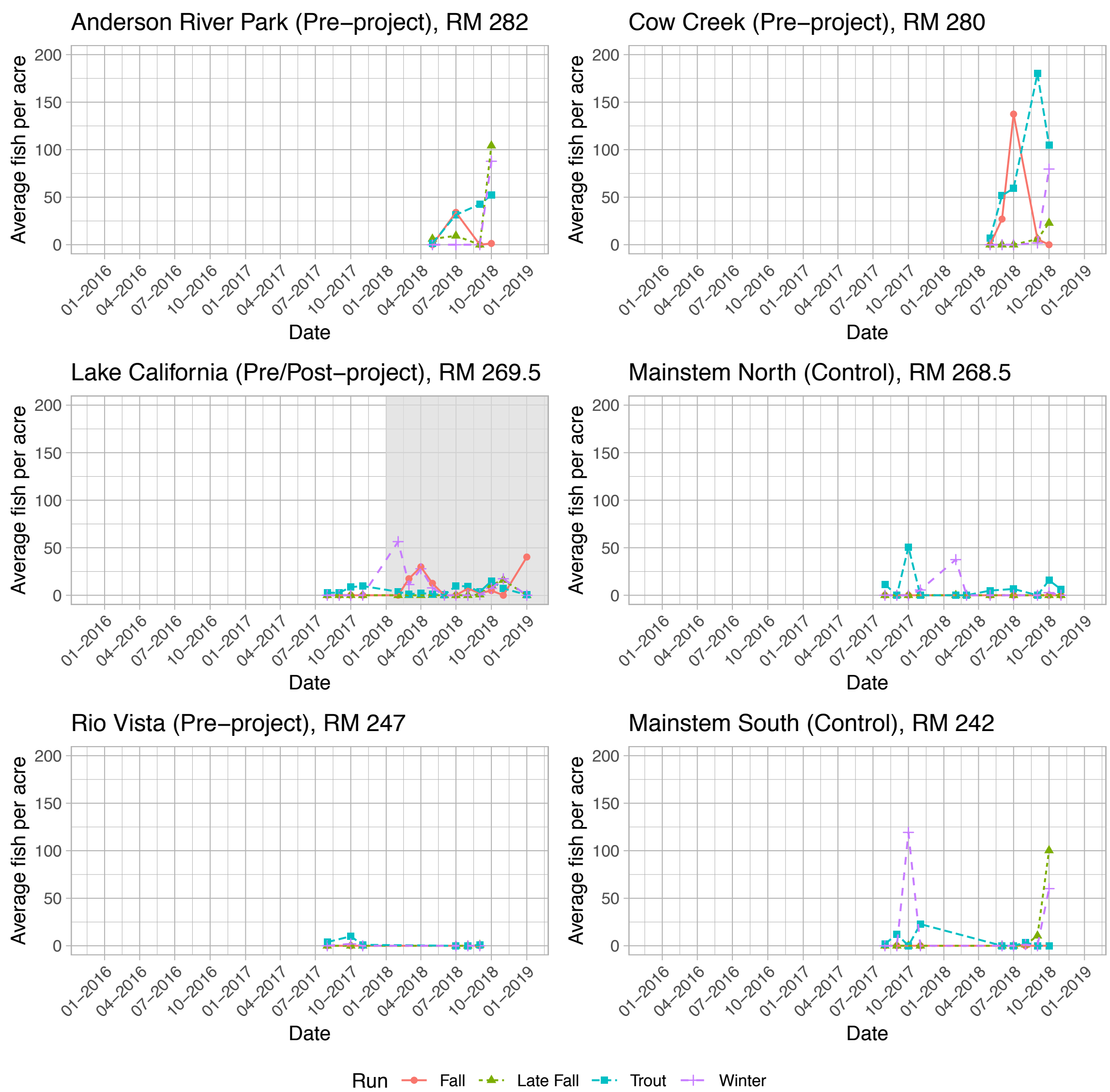


Figure 4. Monthly averages of fish-per-acre for southern sites (below RM 287). Gray shading indicates data taken after restoration (post-project). No shading indicates control or baseline data. Note that the y-axis scale for this figure differs from figure 3.

Table 5. Results of the mixed effects multiple regression model, showing the influence of fixed and random effects on fish-per-acre. P-values were estimated with Kenward-Rogers degrees of freedom.

	F-statistic	DF	P-Value
Channel Status	1.11	1, 6.85	0.327
Run	**7.38**	**3, 21.66**	**0.001**
Geographic Location	**11.29**	**1, 7.82**	**0.010**
Geographic Location * Run	**3.11**	**3, 30.71**	**0.040**

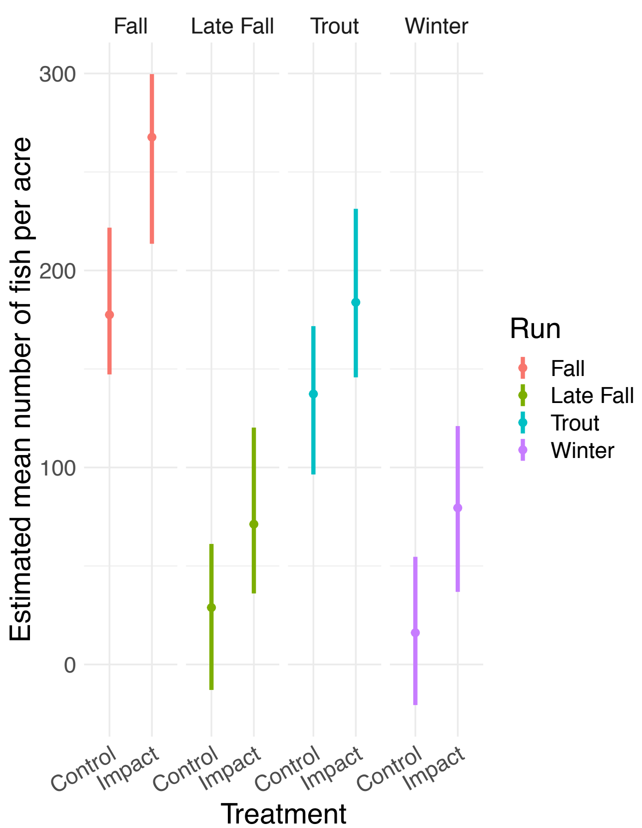


Figure 5. Estimated density of fish as a function of channel status and run. Error bars represent 95% confidence intervals. Estimated densities of fish varied by run. There was no significant difference in fish densities between control and impact sites. Control sites were chosen because they represented some of the best, pre-existing habitat near the restoration sites.

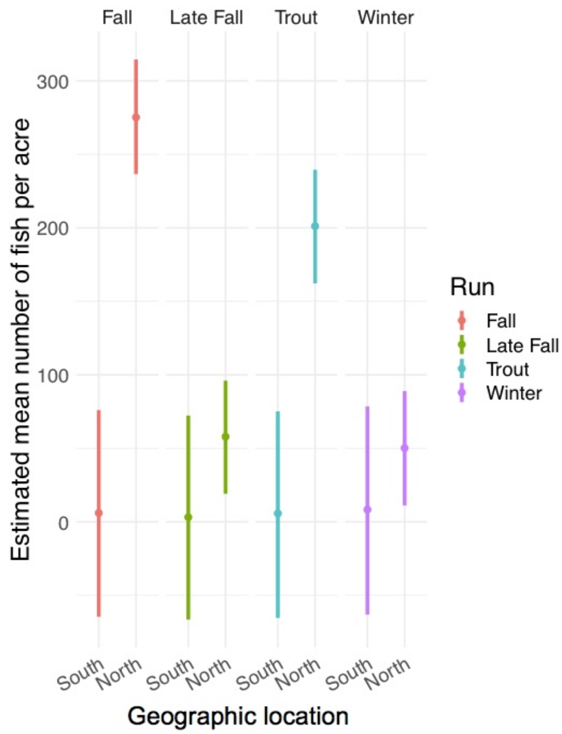
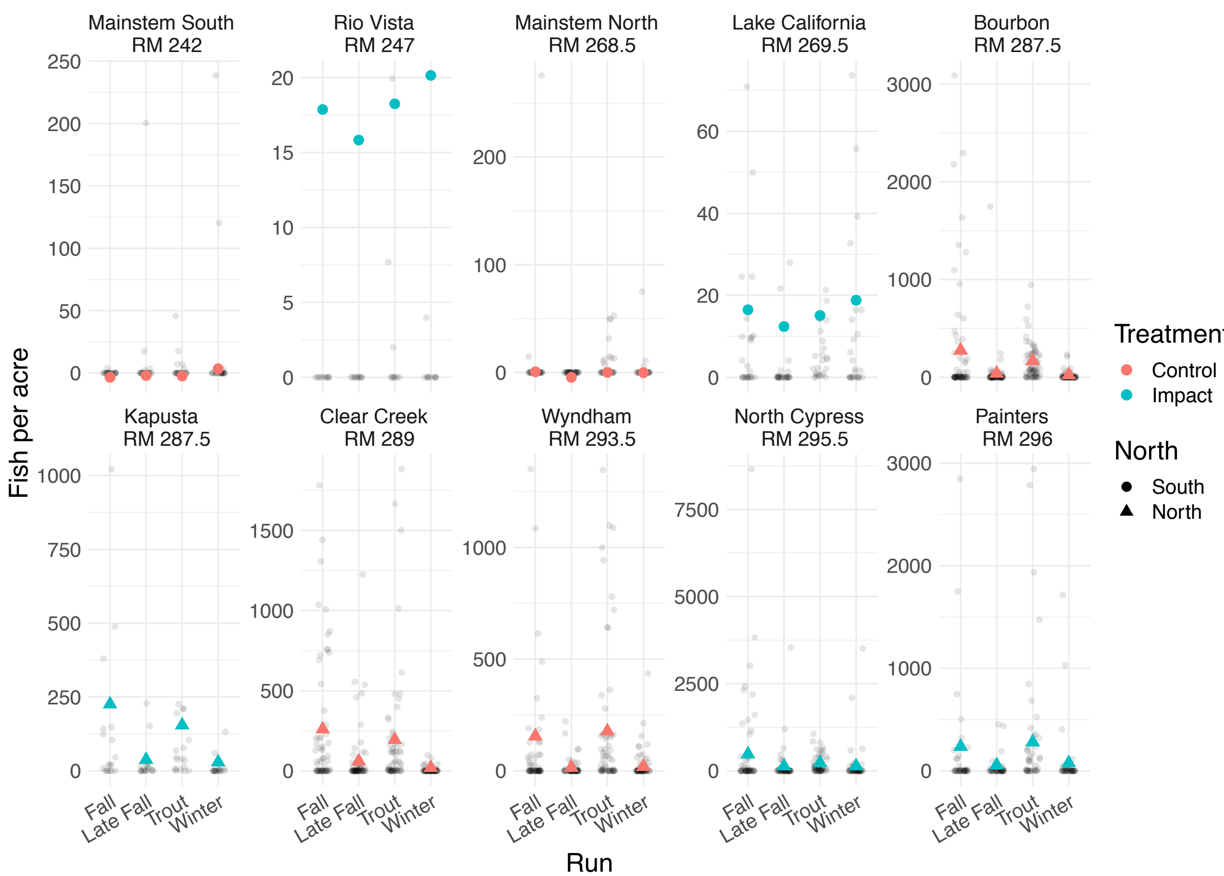


Figure 6 (left). Estimated density of fish as a function of geographic location. Error bars represent 95% confidence intervals. Higher densities of fish were observed at northern sites (above RM 287), but the strength of this relationship varied by run.

Figure 7 (below). Density of fish at each site for each run. Colored circles and triangles indicate means of surveys. Gray dots represent densities from individual surveys. Some dots are offset from vertical lines in order reveal overlapping data. Note that due to drastic differences in density observations, the y-axis varies greatly between graphs.



Juvenile Habitat Mapping and Suitability

Depth, Velocity, and Cover
By the end of July 2019, three control sites and three restored side channels had been mapped for depth, velocity, and cover at three flows. Control sites included Bourbon, Clear Creek, and Wyndham side channels, and restored sites included Lake California, North Cypress, and Painter's Riffle side channels. Mapping covered a range a flows, but did not always meet the full range of target flows due to logistical constraints. Another restored site, Kapusta side channel, was mapped at 7,500 cfs only; we chose to exclude it from statistical analyses until a wider range of flows are mapped. Maps for all side channels, including Kapusta, are presented in the Appendix B.

Linear mixed model analyses show that restored and control sites have similar proportions of available habitat for all habitat classifications examined (Table 6, Figure 8), and that flow from Keswick Dam significantly influenced the proportion of suitable habitat; optimal habitat; suitable and optimal habitat combined; and suitable depth and velocity. Flow did not have a significant influence on the proportion of suitable cover. Post-hoc analyses using the lsmeans package in R showed that as flow increased, there were lower proportions of suitable habitat; optimal habitat; suitable and optimal habitat combined; and suitable depth and velocity (Table 7).

Table 6. Linear mixed model analyses of the effects of channel status (restored vs control) and flow from Keswick on the amount of habitat available. Habitat classification criteria are defined in table 3. Analyses include three restored sites and three control sites, each measured at a range of flows. Details are in text. P-values were estimated using Kenward-Rogers degrees of freedom.

Habitat Classification	Channel Status	Flow
All Suitable	$F_{1,4.12} = 2.16$ $p = 0.214$	**$F_{1,11.16} = 11.16$** **$p < 0.001$**
All Optimal	$F_{1,4.01} = 0.0875$ $p = 0.782$	**$F_{1,11.01} = 17.05$** **$p = 0.002$**
Suitable & Optimal	$F_{1,4.07} = 1.50$ $p = 0.288$	**$F_{1,11.09} = 39.46$** **$p < 0.001$**
Suitable Depth & Velocity	$F_{1,4.08} = 1.33$ $p = 0.312$	**$F_{1,11.12} = 39.52$** **$p < 0.001$**
Suitable Cover	$F_{1,4.02} = 0.05$ $p = 0.838$	$F_{1,11.03} = 0.01$ $p = 0.942$

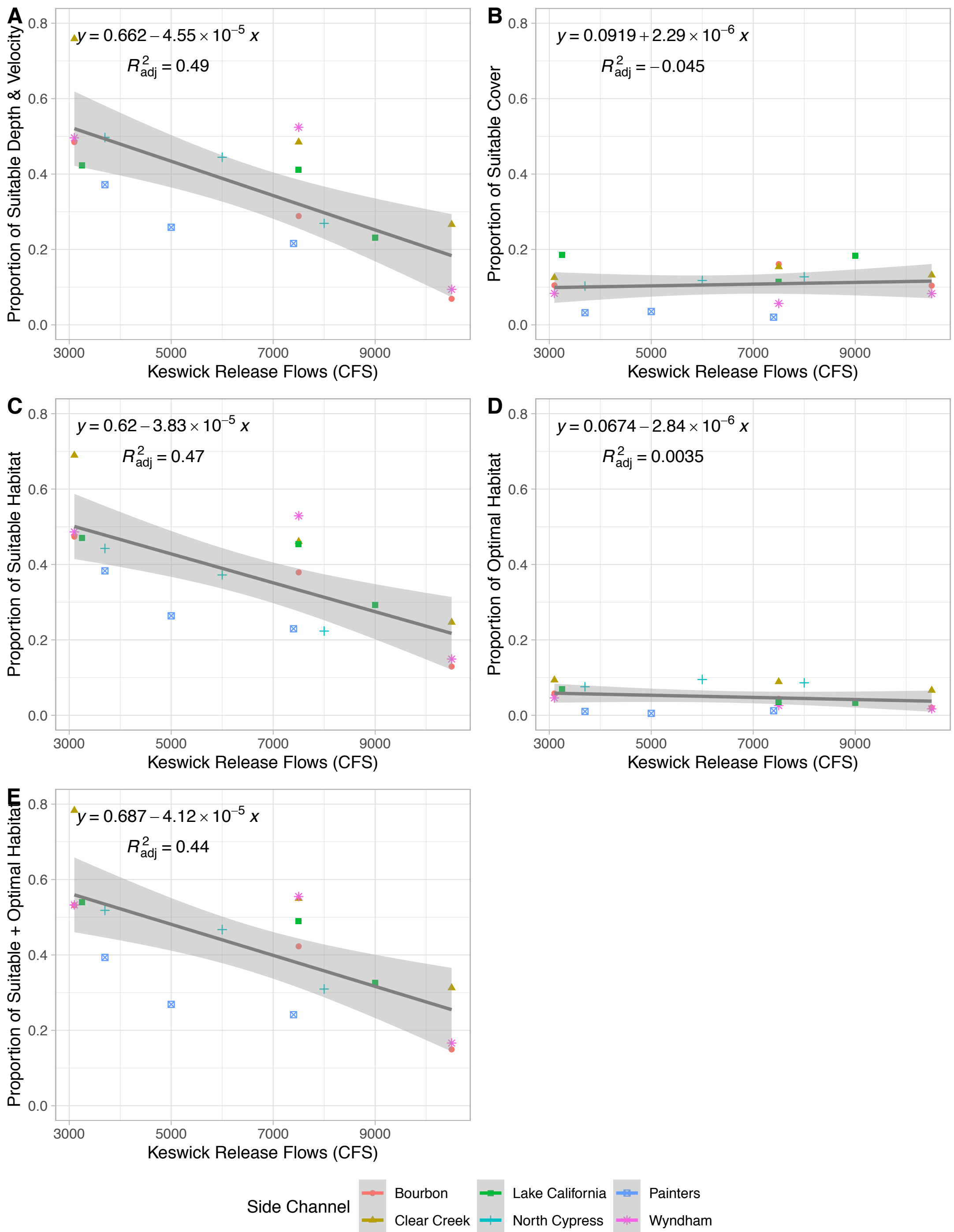


Figure 8. Proportion of habitat that has (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat, (D) optimal habitat, and (E) suitable + optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). All side channels were pooled because channel status (control vs. restored) did not have a significant effect on the proportion of available habitat. Points represent individual sampling days and sites. Shading represents the 95% confidence bands.

Table 7. Post-hoc analyses showing the estimated proportion of habitat that meets the habitat classification criteria for variables found to have a significant relationship with flow. 95% confidence intervals are shown in parentheses. Estimates are derived from a linear model fit to the data from all six channels. Control and restored side channels were pooled because linear mixed models (described in text) showed that channel status did not significantly affect the proportion of available habitat in any of our analyses.

Flow (cfs)	Suitable Depth & Velocity	Suitable Habitat	Optimal Habitat	Suitable + Optimal Habitat
3,250	0.53(0.42-0.64)	0.51(0.42-0.60)	0.06(0.02-0.10)	0.57(0.46-0.69)
4,000	0.49(0.38-0.60)	0.48(0.39-0.57)	0.06(0.02-0.10)	0.54(0.43-0.65)
5,000	0.43(0.33-0.55)	0.44(0.35-0.52)	0.05(0.02-0.09)	0.49(0.38-0.60)
6,000	0.39(0.28-0.50)	0.39(0.31-0.48)	0.05(0.01-0.09)	0.44(0.33-0.56)
7,000	0.34(0.23-0.45)	0.35(0.26-0.44)	0.05(0.01-0.09)	0.40(0.33-0.51)
8,000	0.29(0.18-0.40)	0.31(0.22-0.39)	0.04(0.00-0.08)	0.35(0.24-0.46)
9,000	0.24(0.13-0.35)	0.26(0.18-0.35)	0.04(0.00-0.08)	0.30(0.19-0.41)
10,000	0.19(0.08-0.30)	0.22(0.13-0.31)	0.04(0.00-0.07)	0.25(0.14-0.37)
11,000	0.14(0.02-0.26)	0.18(0.07-0.28)	0.03(-0.01-0.07)	0.20(0.09-0.33)

Attempts to fit a model that allowed predictions of the acres of each habitat classification gained across a range of flows yielded extremely low adjusted R^2 values (not reported) and would not provide reliable predictions. Additional work on the creation of these models will continue as more data is collected. Figure 9 shows the number of acres of habitat that were classified as suitable depth and velocity; suitable cover; suitable habitat; optimal habitat; and suitable plus optimal habitat at each site in the field. In order to visualize the total acres of habitat gained from the three restored sites included in the habitat mapping analyses (Lake California, North Cypress, and Painter's Riffle), we looked at data collected at the lowest and highest flows for each restored side channel (Figure 10). Due to logistic constraints during data collection, the range of these flows does not align perfectly with the target ranges set out in the Monitoring Plan. Instead, low flows ranged from 3,250-3,700 cfs, and intermediate flows ranged from 7,400-8,000 cfs. The total acres of habitat deemed suitable or optimal in the three restored side channels included in this analysis (Lake California, North Cypress, and Painter's Riffle) was 5.23 acres at low flows and 5.08 acres at intermediate flows. Kapusta side channel, which was not included in this analysis due to limited mapping, is expected to increase this number.

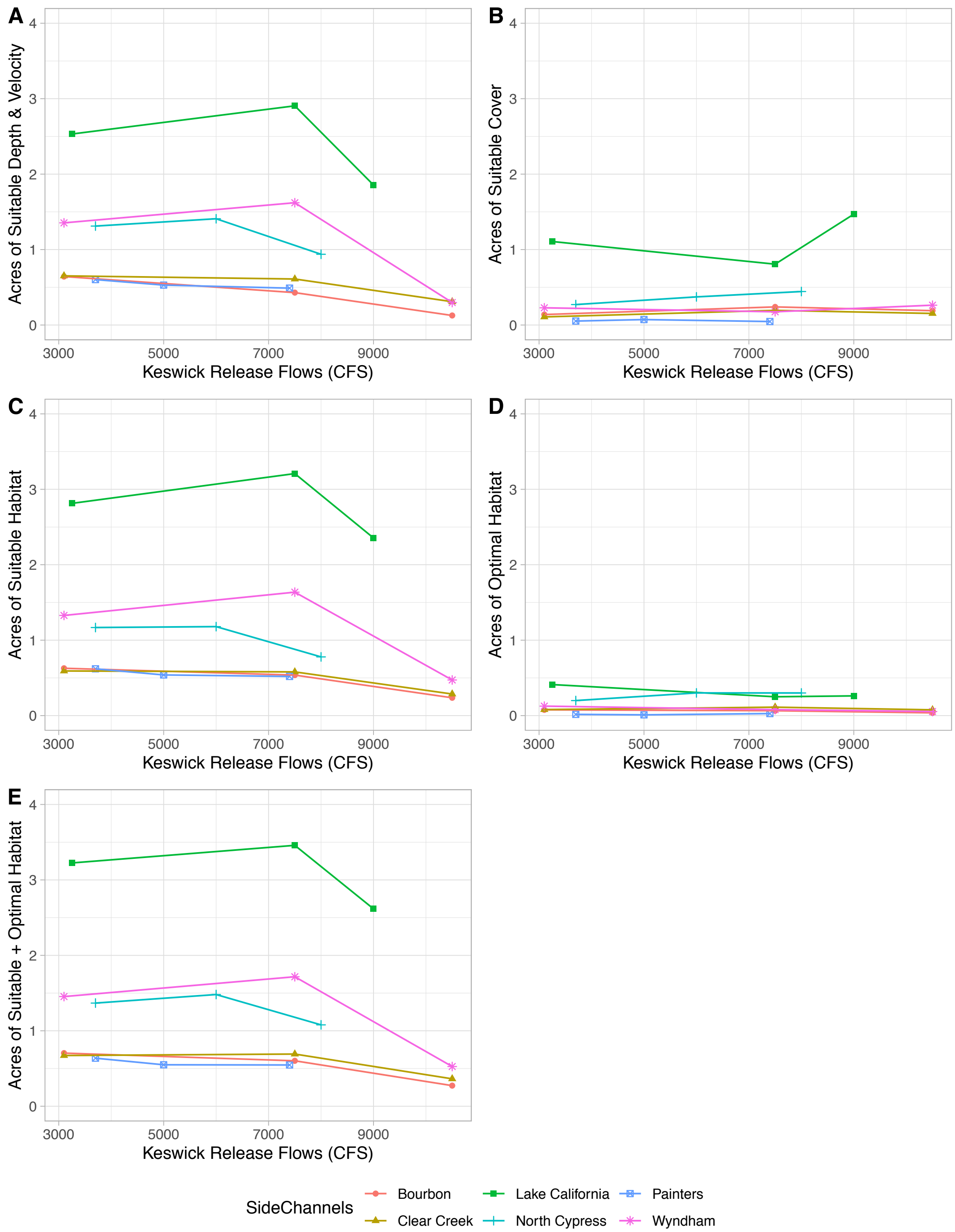


Figure 9. Acres of (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat (D) optimal habitat, and (E) suitable and optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). Points represent individual sampling days and sites.

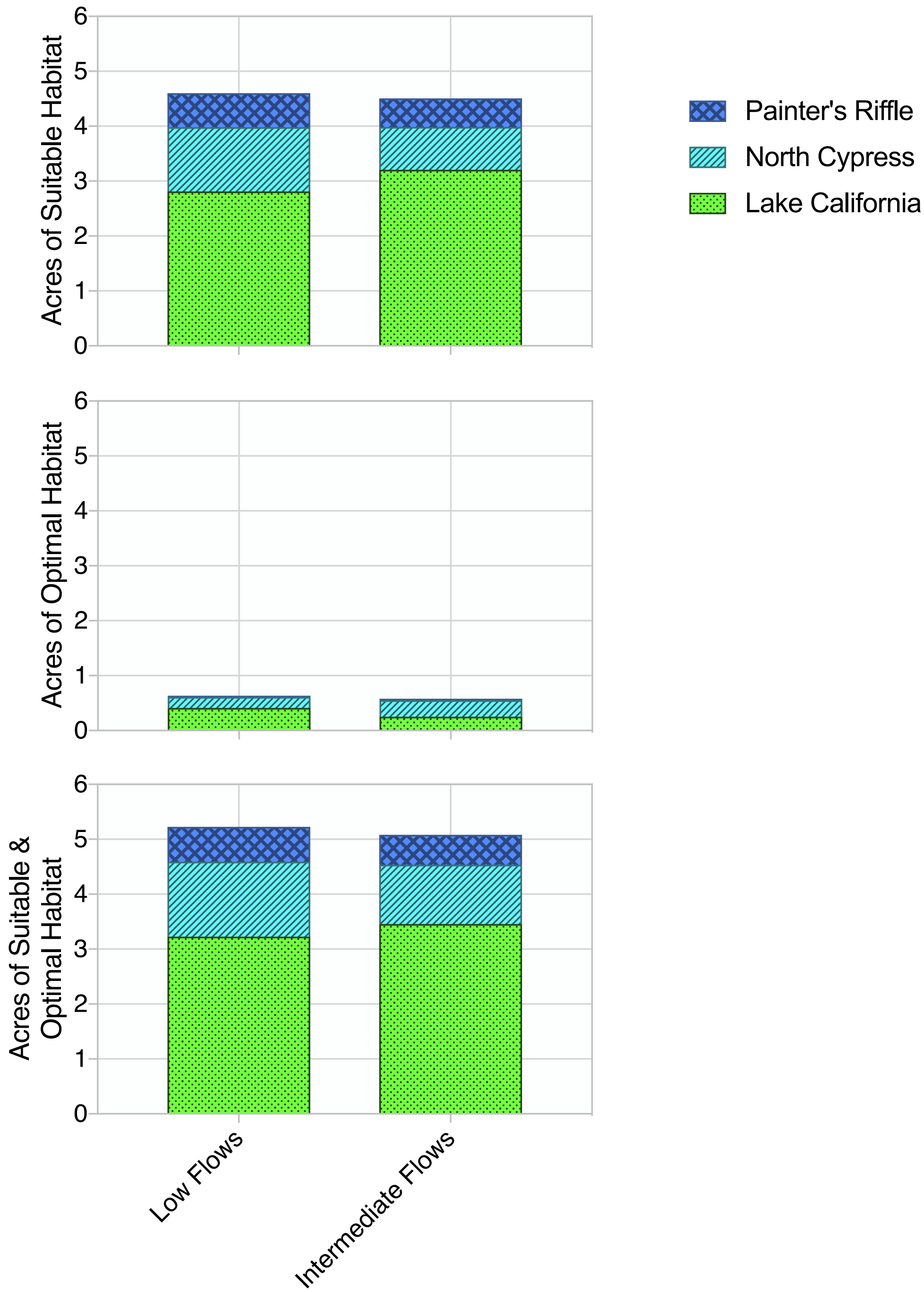


Figure 10. Acres of habitat available in restored sites at high and low flows from three restored sites. Due to logistic constraints during data collection, the range of these flows do not align perfectly with the target ranges set out in the Monitoring Plan. Instead, low flows ranged from 3,250-3,700 cfs, and intermediate flows ranged from 7,400-8,000 cfs.

Microhabitat Use

Microhabitat use associations for Chinook salmon and steelhead/Rainbow trout of less than 201mm in fork length (FL) were sampled in pool, riffle and flatwater habitats on six separate occasions between March 2018 and January of 2019. High turbidity conditions prohibited microhabitat use sampling from February through June 2019. Approximately 60% of all Chinook salmon observed were fall run fish and the juvenile life stage (> 50mm FL) accounted for approximately 65% of all Chinook salmon observations (Table 8, Figure 11). A total of 271 steelhead/Rainbow trout were observed with similar proportions of fry and juvenile life stages present (Table 8, Figure 11). The 50mm fork length threshold for the distinction between life stages is tentative pending further data collection and formal analysis of differences in selection of habitat attributes for the two life stages.

Table 8. Number and life stage of Chinook salmon and steelhead/Rainbow trout observations from March 2018 through January 2019.

Species /Stock	**Observations**	**% Fry (</= 50mm)**	**% Juvenile (> 50mm)**
Fall run Chinook Salmon	176	38%	62%
Late-Fall run Chinook Salmon	24	46%	54%
Winter run Chinook salmon	96	28%	72%
steelhead/Rainbow trout	271	49%	51%

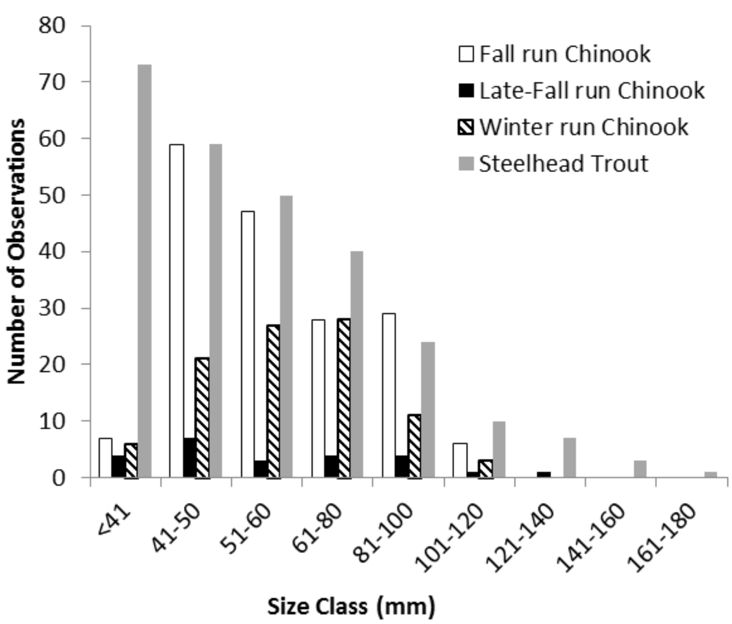


Figure 11. Size class distributions for Chinook salmon and steelhead/Rainbow trout observations within control and restored side channels from March 2018 through January of 2019.

Microhabitat use sampling provides an opportunity to determine if fish habitat mapping criteria are representative of habitat characteristics where fish are actually being observed, as well as visualization of the habitats being used that can be applied to the design of future projects. Habitat mapping criteria identify suitable habitat as meeting either: both a depth and velocity criteria; or, a distance to cover criteria. Optimal habitat is defined as areas meeting all depth, velocity and cover criteria.

Habitat mapping criteria for suitable mean water column velocities ranges from 0.0 to 0.8 ft./sec. Across all control and restored side channels, this range captures 93% of Chinook fry and 73% of juvenile observations, and for steelhead/Rainbow trout, this range captures 97% of fry and 71% of juvenile observations (Figure 12). As the 0.8 fps velocity criteria only captures 71% to 73% of the juvenile life stage for trout and Chinook salmon observations, the actual fish numbers within observations are investigated to determine if the 0.8 fps criteria is under-representing suitable habitat velocities. The actual numbers of juvenile fish within a single microhabitat use observation varies between one and 220 for data collected from March 2018 through June 2019. The 0.8 fps velocity criteria captures 90% of the actual juvenile numbers within Chinook salmon observations. Velocities of 0.8 fps and below have an average of 24 juvenile fish per observation, while velocities greater than 0.8 fps average 7 fish per observation. The 0.8 fps velocity criteria also captures 81% of the actual juvenile numbers within trout observations.

Criteria for suitable water depths range from 0 to 3.3 feet and this range captures more than 95% of all Chinook and steelhead/Rainbow trout life stages observed. (Figure12). Habitat mapping criteria for distance to cover range from 0.0 to 2.0 feet. This range captures 87% of Chinook fry and 83% of juvenile observations. For steelhead/Rainbow trout, this range captures 95% of fry and 86% of juvenile observations (Figure 12). The majority of all fish observations for all species and life stages (50-55% of observations) occur below or within a cover element (i.e. distance to cover = 0). Relative to habitat mapping criteria applied to all salmonid observations (n = 567, consisting of one to 220 fish per observation), 71% are observed in optimal habitats, 23% in suitable habitats, and 5% in unsuitable habitats.

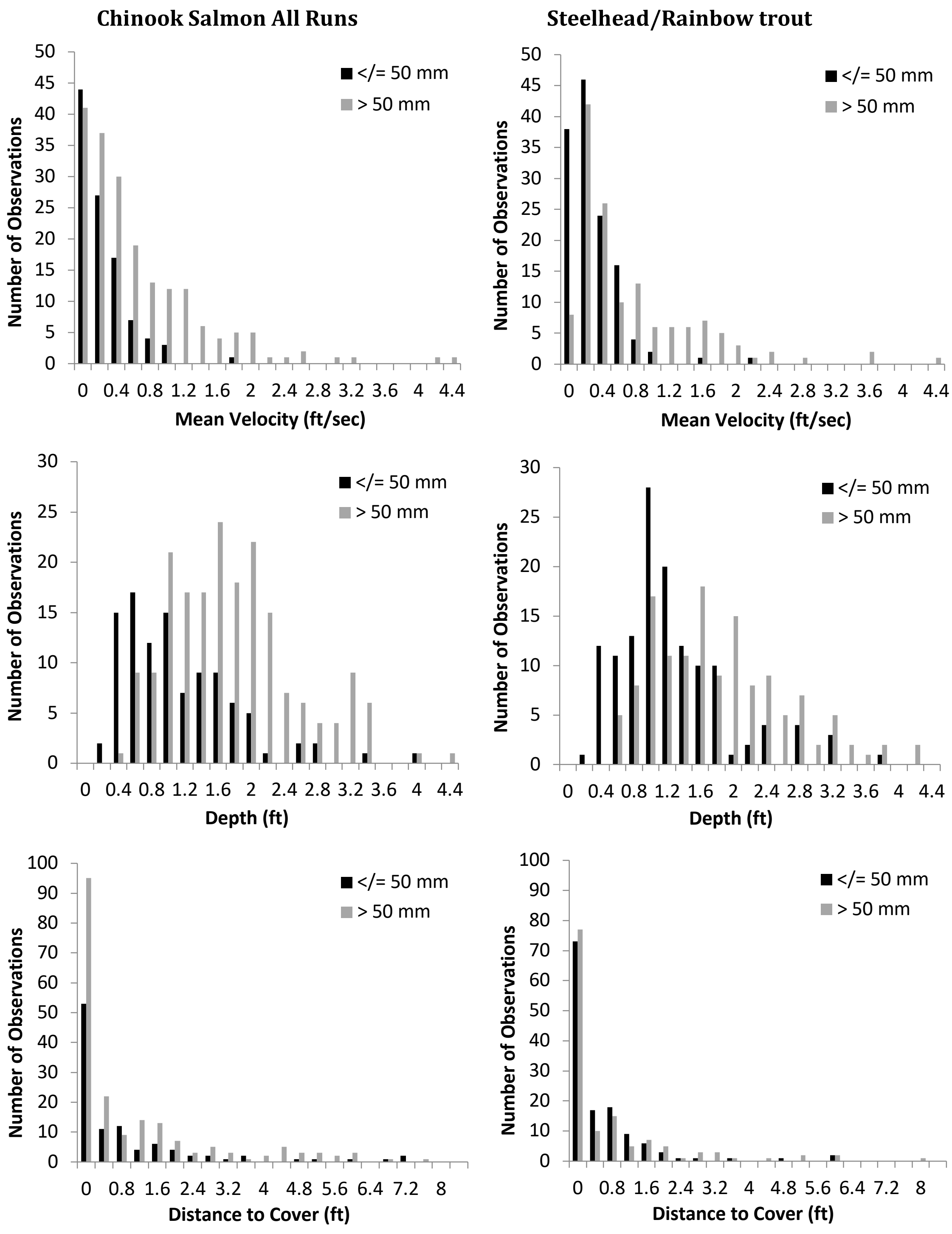


Figure 12. Mean velocity, depth and distance to cover associations for observations of fry (</= 50mm FL) and juvenile (> 50mm FL) Chinook salmon and steelhead/Rainbow trout within control and restored side channels from March 2018 through January of 2019. Note that these are raw data, and are not adjusted for availability of each habitat classification. Because of this, higher numbers do not necessarily indicate strength of preference.

Chinook Fry and steelhead/Rainbow trout juveniles showed significant differences in cover preferences (defined as the difference between the proportion of fish found in each cover type and the proportion of square footage of that cover type at each site) between restored and control channels (Table 9, Figure 13). Tukey HSD was conducted for Chinook fry and steelhead/Rainbow trout juveniles to determine what these differences were. Significant preference differences are shown in Tables 10-13, below.

*Table 9. ANOVA examining the effect of channel status*cover type on cover preference for Chinook fry, Chinook juveniles, steelhead/Rainbow trout fry, and steelhead/Rainbow trout juveniles.*

	Chinook Fry	**Chinook Juveniles**	**Trout Fry**	**Trout Juveniles**
Channel Status* Cover Type	**$F_{14,28}$= 7.68 p <0.001**	$F_{14,28}$= 1.12 p = 0.385	$F_{14,28}$= 0.90 p = 564	**$F_{14,28}$= 2.71 p = 0.012**

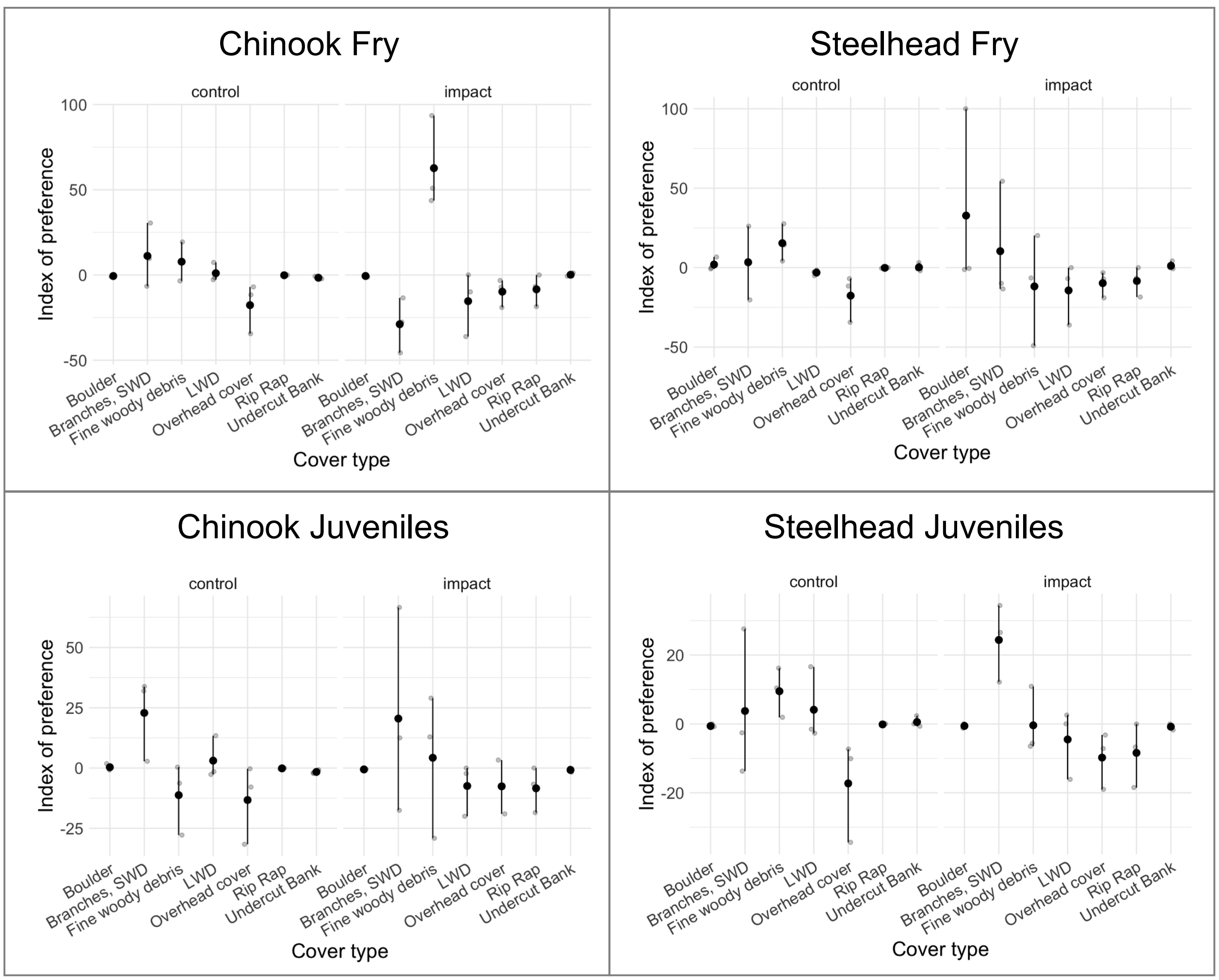


Figure 13. Cover preference index for Chinook and steelhead/Rainbow trout fry and juveniles in control and impact habitat. Chinook fry and steelhead/Rainbow trout juveniles differed significantly in preference between control and impact sites.

Table 10: Results of Tukey's Honest Significant difference test comparing Chinook fry preference for cover types within impact sites

Impact \ Impact	Boulder	Branches, SWD	Fine woody debris	LWD	Overhead cover	Rip rap	Undercut bank
Boulder							
Branches, SWD	NS						
Fine woody debris	**p<0.001**	**p<0.001**					
LWD	NS	NS	**p<0.001**				
Overhead cover	NS	NS	**p<0.001**	NS			
Rip rap	NS	NS	**p<0.001**	NS	NS		
Undercut bank	NS	NS	**p<0.001**	NS	NS	NS	

Table 11: Results of Tukey's Honest Significant difference test comparing Chinook fry preference for cover types between control and impact sites

Control / Impact	Boulder	Branches, SWD	Fine woody debris	LWD	Overhead cover	Rip rap	Undercut bank
Boulder	NS	NS	NS	NS	NS	NS	NS
Branches, SWD	NS	**p=0.029**	NS	NS	NS	NS	NS
Fine woody debris	**p<0.001**	**p=0.002**	**p=0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
LWD	NS	NS	NS	NS	NS	NS	NS
Overhead cover	NS	NS	NS	NS	NS	NS	NS
Rip rap	NS	NS	NS	NS	NS	NS	NS
Undercut bank	NS	NS	NS	NS	NS	NS	NS

Table 12: Results of Tukey's Honest Significant difference test comparing steelhead/Rainbow trout juvenile preference for cover types within impact sites

Impact \ Impact	Boulder	Branches, SWD	Fine woody debris	LWD	Overhead cover	Rip rap	Undercut bank
Boulder							
Branches, SWD	NS						
Fine woody debris	NS	NS					
LWD	NS	NS	NS				
Overhead cover	NS	**p=0.011**	NS	NS			
Rip rap	NS	**p=0.017**	NS	NS	NS		
Undercut bank	NS	NS	NS	NS	NS	NS	

Table 13: Results of Tukey's Honest Significant difference test comparing steelhead/Rainbow trout juvenile preference for cover types between control and impact sites

Impact \ Control	Boulder	Branches, SWD	Fine woody debris	LWD	Overhead cover	Rip rap	Undercut bank
Boulder	NS	NS	NS	NS	NS	NS	NS
Branches, SWD	NS	NS	NS	NS	**p=0.001**	NS	NS
Fine woody debris	NS	NS	NS	NS	NS	NS	NS
LWD	NS	NS	NS	NS	NS	NS	NS
Overhead cover	NS	NS	NS	NS	NS	NS	NS
Rip rap	NS	NS	NS	NS	NS	NS	NS
Undercut bank	NS	NS	NS	NS	NS	NS	NS

Early life history occurrences of Chinook salmon and steelhead/Rainbow trout are often observed along side channel habitat margins. Across all habitat types surveyed, 82% and 80% of fry life stage observations of Chinook salmon and steelhead/Rainbow trout respectively, occur within six feet of the bank (Figure 14). For juvenile size fish (>50mm), 91% of Chinook salmon and 82% of steelhead/Rainbow trout observations occur within 14 feet of the bank (Figure 14).

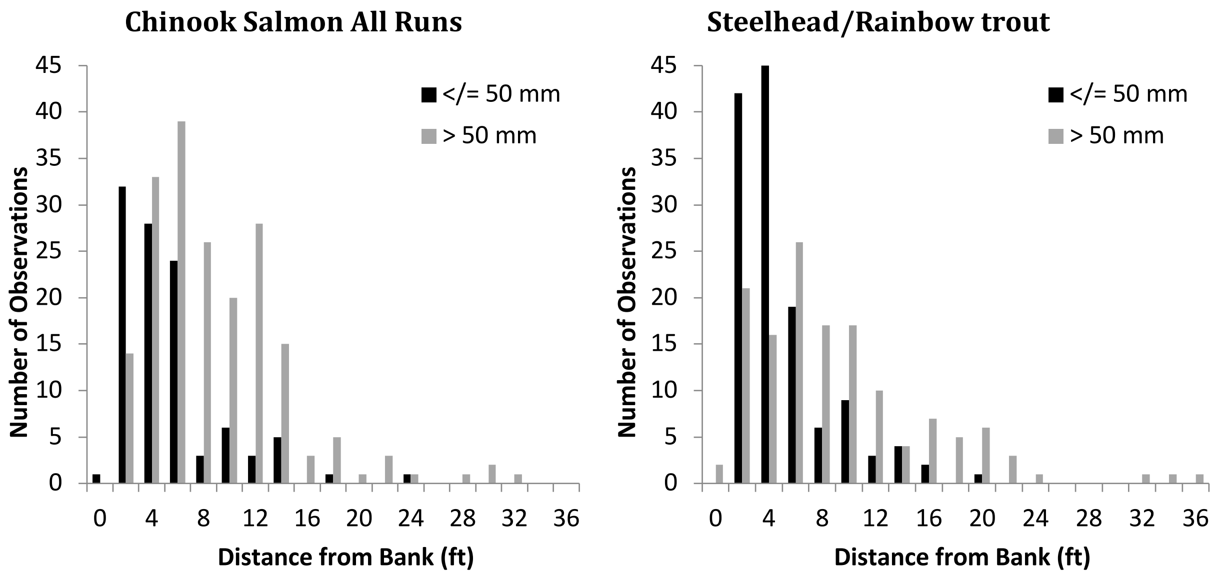


Figure 14. Distance to bank observations of fry (</= 50mm FL) and juvenile (> 50mm FL) Chinook salmon and steelhead/Rainbow trout across all habitat types and control/restored side channels from March 2018 through January of 2019.

For each micro-habitat use sampling event, equal surface areas of pool, flatwater, and riffle habitats were surveyed. The percent of total fish observations in each of these three habitat types is presented in Table 14 below.

Table 14. Percent use of habitat types by Chinook salmon and steelhead/Rainbow trout fry (</= 50mm FL) and juveniles (> 50mm FL) from March 2018 through January of 2019.

	Chinook salmon		**steelhead/Rainbow trout**	
Habitat Type	Fry	Juvenile	Fry	Juvenile
Pool	55%	43%	40%	38%
Flatwater	12%	24%	39%	37%
Riffle	34%	33%	20%	25%

Fish Size and Condition

Analyses show that winter run Chinook salmon juveniles within side channels captured via seine in the Mid-December 2018 sampling period had greater fork lengths than those caught in the mainstem of the river (Table 15, Figure 15). Additionally, fall run fry and juveniles from side channels had greater fork lengths than those caught in the mainstem river in February and April 2019. No differences existed for late-fall run fry in the May or June 2019 sampling periods, however sample sizes were limited in June 2019. Data from both control and restored side channels were pooled for theses analyses.

Table 15. Results of two-sample t-tests comparing differences in fork length between Chinook salmon captured in side channels, and those captured in nearby sections of the mainstem of the Sacramento River for each run and sampling period.

	Sampling Period	Fork Length
Winter run	12/17/18 to 12/20/18	**t_{89} = 1.987, p < 0.001**
Fall run	12/17/18 to 12/20/18	t_{264} = 1.969, p = 0.409
	1/9/19 to 1/18/19	t_{460} = 1.965, p = 0.464
	2/12/19 to 2/20/19	**t_{257} = 1.969, p = 0.007**
	4/30/19 to 5/14/19	**t_{288} = 1.968, p < 0.001**
	6/10/19 to 6/20/19	t_{124} = 1.979, p = 0.663
Late-fall run	4/30/19 to 5/14/19	t_{249} = 1.970, p = 0.296
	6/10/19 to 6/20/19	t_{43} = 2.017, p = 0.378

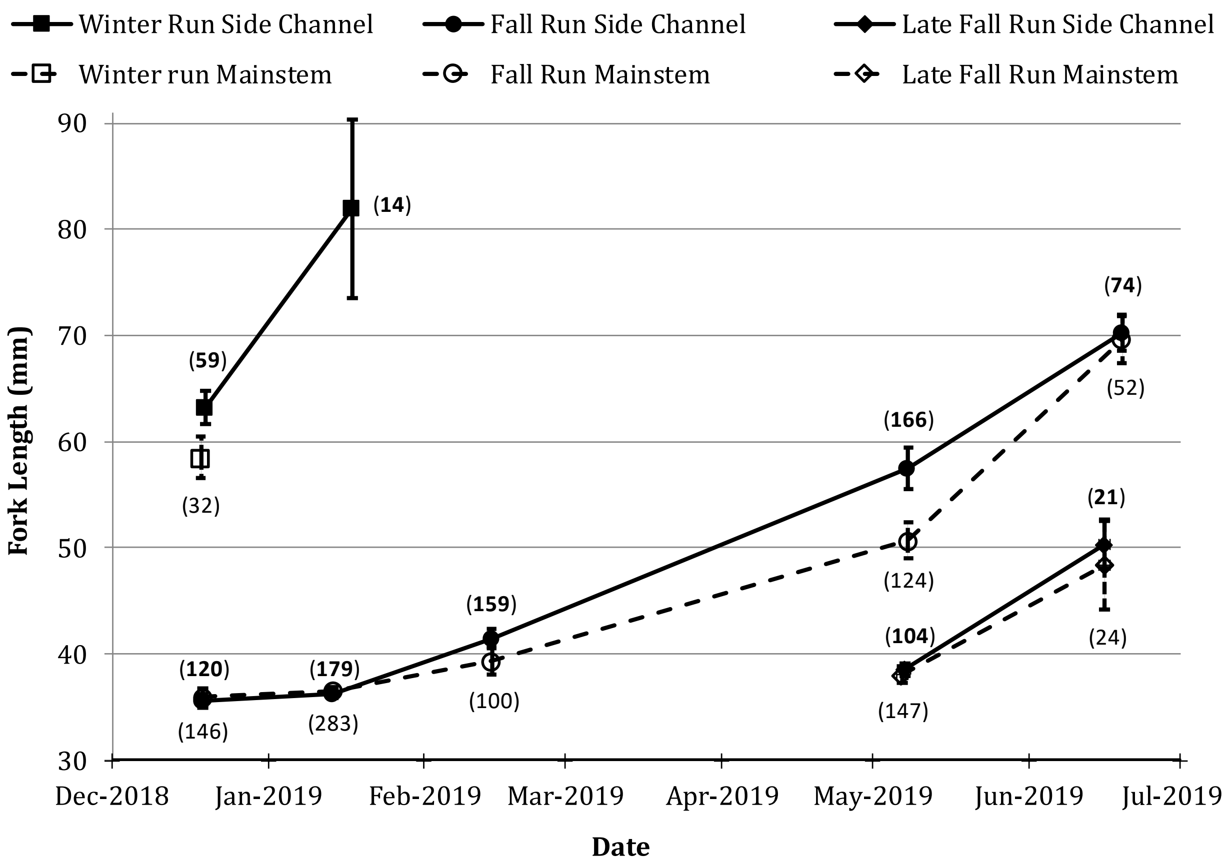


Figure 15. Mean fork lengths (mm) for Chinook salmon fry and juveniles captured in side channels, and those captured in nearby sections of the mainstem of the Sacramento River for each run and sampling period. Mean lengths and 95% CI are plotted against mean date of capture within five sampling events between mid-December 2018 and mid-June 2019. Sample sizes are provided in parentheses with side channel values in bold font.

Analyses show that fall run Chinook salmon juveniles captured via seine within side channels had a higher Fulton's condition factor and a higher relative condition factor than those caught in the mainstem of the river (Table 16, Figure 16). While condition factors for fall run fish captured in side channels during the May sampling event had similar condition to mainstem fish (Figure 16), fork lengths were on average 7mm greater (Table 15, Figure 15). No differences existed for late-fall run juveniles for either metric. Data from both control and restored side channels were pooled for these analyses.

Table 16. Results of two-sample t-tests comparing differences in condition between fish captured in side channels, and those captured in nearby sections of the mainstem of the Sacramento River for each run. See methods for description of condition factors.

	Fulton's Condition Factor	**Relative Condition Factor**
Fall run	**$t_{611} = 1.647$** **$p < 0.001$**	**$t_{611} = 1.964$** **$p < 0.001$**
Late-fall run	$t_{122} = 0.194$ $p = 0.847$	$t_{122} = 0.141$ $p = 0.888$

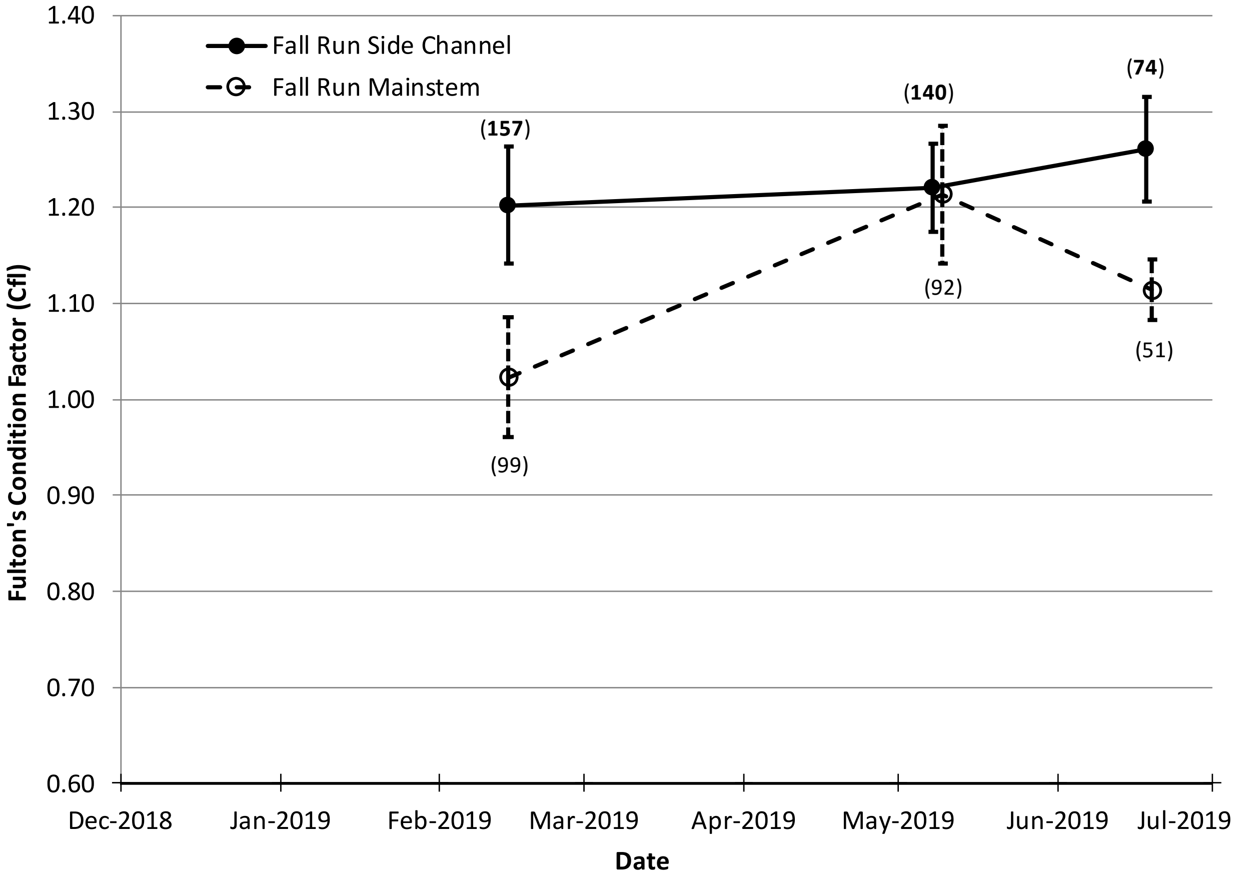


Figure 16. Mean Fulton's Condition Factor (Cfl) for Chinook salmon fry and juveniles captured in side channels, and those captured in nearby sections of the mainstem of the Sacramento River for each run and sampling period. Mean Cfl and 95% CI are plotted against mean date of capture within three sampling events between mid-February 2019 and mid-June 2019. Sample sizes are provided in parentheses with side channel values in bold font.

DISCUSSION

In order to evaluate the restoration conducted as part of the Upper Sacramento River Anadromous Fish Habitat Restoration Project, we compared data collected from restored side channels to nearby control sites. Control sites were chosen based on preliminary surveys, and are thought to be some of the highest-quality habitat geographically located near restoration (or future restoration) sites. This comparison provides a benchmark to determine whether restoration was successful. If restored sites perform comparably to, or better than, control sites, this would suggest that the Project has been successful in adding a significant amount of high-quality juvenile salmonid habitat to the Upper Sacramento River.

Restored sites and control sites had similar densities of fall run Chinook, late-fall run Chinook, winter run Chinook, and steelhead/Rainbow trout. Geographic location had a strong influence on fish density. More northern sites exhibited higher fish densities, though this relationship was strongest for fall run Chinook and steelhead/Rainbow trout.

Restored sites and control sites also had similar proportions high-quality habitat for every habitat criterion we examined. This similarity suggests that the Project has been successful at creating restored side channels that mirror the depth, velocity, and cover of pre-existing side channel habitat. Flow from Keswick Dam had a significant, negative influence on the proportion of suitable depth and velocity, suitable habitat (which met depth/velocity criteria *or* cover criteria), optimal habitat (which met all criteria), and total habitat considered suitable or optimal. Despite this, intermediate flows often had the highest acreage of high-quality habitat, because the area of the side channels increased as flows increased. Intermediate flows typically only occur for short periods in early fall, and late spring. Flow did not influence the proportion of suitable cover. This trend is likely driven by the fact that cover includes biotic elements such as aquatic vegetation, which can be affected by factors other than flow. All classifications that had a significant relationship with flow were variables that included depth and velocity as a component.

The CVPIA Science Integration Team (SIT) Chinook carrying capacity calculator (Gill, n.d.) estimates in-channel habitat for Chinook salmon fry in the Upper Sacramento River to be 26 acres at median flows (8311 cfs). The CVPIA SIT model uses slightly different criteria than our analyses, but does allow for rough comparison. Using the habitat suitability criteria from Goodman *et al*. (2015), we found that restoration of Lake California, North Cypress, and Painter's Riffle side channels added 5.23 acres of high-quality habitat at flows ranging from 3,250-3,700 cfs, and 5.08 acres of high-quality habitat at flows ranging from 7,400-8,000 cfs. Kapusta side channel, which was not included in this report due to limited mapping during the reporting period, is expected to increase this number. This information, while a rough comparison, indicates that side channel restoration has substantially increased the available juvenile salmonid habitat in the upper Sacramento River.

Microhabitat analyses showed that fine woody debris was strongly preferred by Chinook salmon fry in restored sites, but no such relationship was found in control sites. It is possible that this relationship was a function of specific characteristics of the fine woody debris found in restoration sites that was not captured in our data collection. Other small trends were observed (e.g. steelhead/Rainbow trout juveniles preferred branches and small woody debris to overhead cover), but in general no other strong trends in preference for cover types were observed.

Our data on juvenile size and condition was limited for this report, consisting of metrics from seined fish sampled between mid-December 2018 and mid-June 2019. Analyses suggest that winter run juveniles found in side channels in December 2018 have greater fork lengths than those found in the mainstem. Analyses also suggest that fall-run juveniles found in side channels are in better condition, and at times significantly longer in fork length, than those found in the mainstem of the river. Seining gives only a snapshot of habitat use, and does not guarantee that the capture location is where the fish has spent most of their time. Data collection is ongoing, and should enable future analyses to examine potential differences between restored and control side channels, and among years.

Restored and control sites performed similarly on every metric we examined, suggesting that the Project has been successful in adding a significant amount of high-quality juvenile salmonid habitat to the Upper Sacramento River. After the end of the reporting period covered in this document, two additional restorations at Anderson River Park and Rio Vista have occurred. Continued monitoring of these, and other sites, will provide additional insight into the effectiveness of restoration, and information about how side channel characteristics evolve over time.

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APPENDIX A. Salmon Length -to-Date Chart (1-page example)

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
1-Jan	0-41	42-55	56-111	112-202	203-270	1-Jan
2-Jan	0-41	42-55	56-112	113-230	231-270	2-Jan
3-Jan	0-41	42-56	57-112	113-205	206-270	3-Jan
4-Jan	0-41	42-56	57-113	114-206	207-270	4-Jan
5-Jan	0-42	43-56	57-114	115-207	208-270	5-Jan
6-Jan	0-42	43-57	58-115	116-209	210-270	6-Jan
7-Jan	0-42	43-57	58-115	116-210	211-270	7-Jan
8-Jan	0-43	44-58	59-116	117-211	212-270	8-Jan
9-Jan	0-43	44-58	59-117	118-213	214-270	9-Jan
10-Jan	0-43	44-58	59-118	119-214	215-270	10-Jan
11-Jan	0-43	44-59	60-119	120-216	217-270	11-Jan
12-Jan	0-44	45-59	60-119	120-217	218-270	12-Jan
13-Jan	0-44	45-59	60-120	121-218	219-270	13-Jan
14-Jan	0-44	45-60	61-121	122-220	221-270	14-Jan
15-Jan	0-45	46-60	61-122	123-221	222-270	15-Jan
16-Jan	0-45	46-61	62-123	124-223	224-270	16-Jan
17-Jan	0-45	46-61	62-123	124-224	225-270	17-Jan
18-Jan	0-45	46-61	62-124	125-226	227-270	18-Jan
19-Jan	0-46	47-62	63-125	126-227	228-270	19-Jan
20-Jan	0-46	47-62	63-126	127-229	230-270	20-Jan
21-Jan	0-46	47-63	64-127	128-230	231-270	21-Jan
22-Jan	0-47	48-63	64-127	128-232	233-270	22-Jan
23-Jan	0-47	48-64	65-128	129-233	234-270	23-Jan
24-Jan	0-47	48-64	65-129	130-235	236-270	24-Jan
25-Jan	0-48	49-64	65-130	131-236	237-270	25-Jan
26-Jan	0-48	49-65	66-131	132-238	239-270	26-Jan
27-Jan	0-48	49-65	66-132	133-239	240-270	27-Jan
28-Jan	0-49	50-66	67-133	134-241	242-270	28-Jan
29-Jan	0-49	50-66	67-133	134-243	244-270	29-Jan
30-Jan	0-49	50-67	68-134	135-244	245-270	30-Jan
31-Jan	0-50	51-67	68-135	136-246	247-270	31-Jan
1-Feb	0-50	51-67	68-136	137-247	248-270	1-Feb
2-Feb	0-50	51-68	69-137	138-249	250-270	2-Feb
3-Feb	0-50	51-68	69-138	139-251	252-270	3-Feb
4-Feb	0-50	51-69	70-139	140-252	253-270	4-Feb
5-Feb	0-51	52-69	70-140	141-254	255-270	5-Feb
6-Feb	0-51	52-70	71-141	142-256	257-270	6-Feb
7-Feb	0-52	53-70	71-142	143-257	258-270	7-Feb
8-Feb	0-52	53-71	72-143	144-259	260-270	8-Feb
9-Feb	0-53	54-71	72-143	144-261	262-270	9-Feb
10-Feb	0-53	54-72	73-144	145-262	263-270	10-Feb
11-Feb	0-53	54-72	73-145	146-264	265-270	11-Feb
12-Feb	0-54	55-72	73-146	147-266	267-270	12-Feb
13-Feb	0-54	55-73	74-147	148-268	269-270	13-Feb
14-Feb	0-54	55-73	74-148	149-269	270-270	14-Feb
15-Feb	0-55	56-74	75-149	150-270	end lg fall	15-Feb

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
16-Feb	0-55	56-75	76-150	151-270	*	16-Feb
17-Feb	0-55	56-75	76-151	152-270	*	17-Feb
18-Feb	0-56	57-75	76-152	153-270	*	18-Feb
19-Feb	0-56	57-76	77-153	154-270	*	19-Feb
20-Feb	0-56	57-76	77-154	155-270	*	20-Feb
21-Feb	0-57	58-77	78-155	156-270	*	21-Feb
22-Feb	0-57	58-77	78-156	157-270	*	22-Feb
23-Feb	0-58	59-78	79-157	158-270	*	23-Feb
24-Feb	0-58	59-78	79-158	159-270	*	24-Feb
25-Feb	0-58	59-79	80-159	160-270	*	25-Feb
26-Feb	0-59	60-79	80-160	161-270	*	26-Feb
27-Feb	0-59	60-80	81-161	162-270	*	27-Feb
28-Feb	0-59	60-80	81-163	164-270	*	28-Feb
29-Feb	0-60	61-81	82-164	165-270	*	29-Feb
1-Mar	0-60	61-82	83-165	166-270	*	1-Mar
2-Mar	0-61	62-82	83-166	167-270	*	2-Mar
3-Mar	0-61	62-83	84-167	168-270	*	3-Mar
4-Mar	0-61	62-83	84-168	169-270	*	4-Mar
5-Mar	0-62	63-84	85-169	170-270	*	5-Mar
6-Mar	0-62	63-84	85-170	171-270	*	6-Mar
7-Mar	0-63	64-85	86-171	172-270	*	7-Mar
8-Mar	0-63	64-85	86-172	173-270	*	8-Mar
9-Mar	0-64	65-86	87-174	175-270	*	9-Mar
10-Mar	0-64	65-87	88-175	176-270	*	10-Mar
11-Mar	0-64	65-87	88-176	177-270	*	11-Mar
12-Mar	0-65	66-88	89-177	178-270	*	12-Mar
13-Mar	0-65	66-88	89-178	179-270	*	13-Mar
14-Mar	0-66	67-89	90-179	180-270	*	14-Mar
15-Mar	0-66	67-89	90-181	182-270	*	15-Mar
16-Mar	0-67	68-90	91-182	183-270	*	16-Mar
17-Mar	0-67	68-91	92-183	184-270	*	17-Mar
18-Mar	0-67	68-91	92-184	185-270	*	18-Mar
19-Mar	0-68	69-92	93-185	186-270	*	19-Mar
20-Mar	0-68	69-92	93-187	188-270	*	20-Mar
21-Mar	0-69	70-93	94-188	189-270	*	21-Mar
22-Mar	0-69	70-94	95-189	190-270	*	22-Mar
23-Mar	0-70	71-94	95-190	191-270	*	23-Mar
24-Mar	0-70	71-95	96-192	193-270	*	24-Mar
25-Mar	0-71	72-95	96-193	194-270	*	25-Mar
26-Mar	0-71	72-96	97-194	195-270	*	26-Mar
27-Mar	0-72	73-97	98-195	196-270	*	27-Mar
28-Mar	0-72	73-97	98-197	198-270	*	28-Mar
29-Mar	0-72	73-98	99-198	199-270	*	29-Mar
30-Mar	0-73	74-99	100-199	200-270	*	30-Mar
31-Mar	0-73	74-99	100-201	202-270	Late-Fall	31-Mar
1-Apr	34-74	75-100	101-202	203-270	0-33	1-Apr

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
2-Apr	35-74	75-101	102-203	204-270	0-34	2-Apr
3-Apr	35-75	76-101	102-205	206-270	0-34	3-Apr
4-Apr	35-75	76-102	103-206	207-270	0-34	4-Apr
5-Apr	35-76	77-103	104-207	208-270	0-34	5-Apr
6-Apr	35-76	77-103	104-209	210-270	0-34	6-Apr
7-Apr	36-77	78-104	105-210	211-270	0-35	7-Apr
8-Apr	36-77	78-105	106-211	212-270	0-35	8-Apr
9-Apr	36-78	79-105	106-213	214-270	0-35	9-Apr
10-Apr	36-78	79-106	107-214	215-270	0-35	10-Apr
11-Apr	37-79	80-107	108-216	217-270	0-36	11-Apr
12-Apr	37-79	80-107	108-217	218-270	0-36	12-Apr
13-Apr	37-80	81-108	109-218	219-270	0-36	13-Apr
14-Apr	37-80	81-109	110-220	221-270	0-36	14-Apr
15-Apr	38-81	82-110	111-221	222-270	0-37	15-Apr
16-Apr	38-82	83-110	111-223	224-270	0-37	16-Apr
17-Apr	38-82	83-111	112-224	225-270	0-37	17-Apr
18-Apr	38-83	84-112	113-226	227-270	0-37	18-Apr
19-Apr	39-83	84-112	113-227	228-270	0-38	19-Apr
20-Apr	39-84	85-113	114-229	230-270	0-38	20-Apr
21-Apr	39-84	85-114	115-230	231-270	0-38	21-Apr
22-Apr	39-85	86-115	116-232	233-270	0-38	22-Apr
23-Apr	40-85	86-115	116-233	234-270	0-39	23-Apr
24-Apr	40-86	87-116	117-235	236-270	0-39	24-Apr
25-Apr	40-87	88-117	118-236	237-270	0-39	25-Apr
26-Apr	40-87	88-118	119-238	239-270	0-39	26-Apr
27-Apr	41-88	89-119	120-239	240-270	0-40	27-Apr
28-Apr	41-88	89-119	120-241	242-270	0-40	28-Apr
29-Apr	41-89	90-120	121-243	244-270	0-40	29-Apr
30-Apr	41-89	90-121	122-244	245-270	0-40	30-Apr
1-May	41-90	91-122	123-246	247-270	0-40	1-May
2-May	42-91	92-123	124-247	248-270	0-41	2-May
3-May	42-91	92-123	124-249	250-270	0-41	3-May
4-May	42-92	93-124	125-251	252-270	0-41	4-May
5-May	42-92	93-125	126-252	253-270	0-41	5-May
6-May	43-93	94-126	127-254	255-270	0-42	6-May
7-May	43-94	95-127	128-256	257-270	0-42	7-May
8-May	43-94	95-127	128-257	258-270	0-42	8-May
9-May	44-95	96-128	129-259	260-270	0-43	9-May
10-May	44-95	96-129	130-261	262-270	0-43	10-May
11-May	44-96	97-130	131-262	263-270	0-43	11-May
12-May	45-97	98-131	132-264	265-270	0-44	12-May
13-May	45-97	98-132	133-266	267-270	0-44	13-May
14-May	45-98	99-133	134-268	269-270	0-44	14-May
15-May	45-99	100-133	134-269	270-270	0-44	15-May
16-May	46-99	100-134	135-270	*	0-45	16-May
17-May	46-100	101-135	136-270	*	0-45	17-May

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
18-May	46-101	102-136	137-270	*	0-45	18-May
19-May	47-101	102-137	138-270	*	0-46	19-May
20-May	47-102	103-138	139-270	*	0-46	20-May
21-May	47-103	104-139	140-270	*	0-46	21-May
22-May	47-103	104-140	141-270	*	0-46	22-May
23-May	48-104	105-141	142-270	*	0-47	23-May
24-May	48-105	106-142	143-270	*	0-47	24-May
25-May	48-105	106-143	144-270	*	0-47	25-May
26-May	49-106	107-143	144-270	*	0-48	26-May
27-May	49-107	108-144	145-270	*	0-48	27-May
28-May	49-107	108-145	146-270	*	0-48	28-May
29-May	50-108	109-146	147-270	*	0-49	29-May
30-May	50-109	110-147	148-270	*	0-49	30-May
31-May	50-110	111-148	149-270	*	0-49	31-May
1-Jun	51-110	111-149	150-270	0-50	end sm late fall	1-Jun
2-Jun	51-111	112-150	151-270	0-50	*	2-Jun
3-Jun	51-112	113-151	152-270	0-50	*	3-Jun
4-Jun	51-112	113-152	153-270	0-50	*	4-Jun
5-Jun	52-113	114-153	154-270	0-51	*	5-Jun
6-Jun	52-114	115-154	155-270	0-51	*	6-Jun
7-Jun	52-115	116-155	156-270	0-51	*	7-Jun
8-Jun	53-115	116-156	157-270	0-52	*	8-Jun
9-Jun	53-116	117-157	158-270	0-52	*	9-Jun
10-Jun	54-117	118-158	159-270	0-53	*	10-Jun
11-Jun	54-118	119-159	160-270	0-53	*	11-Jun
12-Jun	54-119	120-160	161-270	0-53	*	12-Jun
13-Jun	55-119	120-161	162-270	0-54	*	13-Jun
14-Jun	55-120	121-163	164-270	0-54	*	14-Jun
15-Jun	55-121	122-164	165-270	0-54	*	15-Jun
16-Jun	56-121	122-165	166-270	0-55	*	16-Jun
17-Jun	56-123	124-166	167-270	0-55	*	17-Jun
18-Jun	56-123	124-167	168-270	0-55	*	18-Jun
19-Jun	57-124	125-168	169-270	0-56	*	19-Jun
20-Jun	57-125	126-169	170-270	0-56	*	20-Jun
21-Jun	57-126	127-170	171-270	0-56	*	21-Jun
22-Jun	58-127	128-171	172-270	0-57	*	22-Jun
23-Jun	58-127	128-172	173-270	0-57	*	23-Jun
24-Jun	59-128	129-174	175-270	0-58	*	24-Jun
25-Jun	59-129	130-175	176-270	0-58	*	25-Jun
26-Jun	59-130	131-176	177-270	0-58	*	26-Jun
27-Jun	60-131	132-177	178-270	0-59	*	27-Jun
28-Jun	60-132	133-178	179-270	0-59	*	28-Jun
29-Jun	60-133	134-179	180-270	0-59	*	29-Jun
30-Jun	61-133	134-181	182-270	0-60	Winter	30-Jun
1-Jul	61-134	135-182	183-270	34-60	0-33	1-Jul
2-Jul	62-135	136-183	184-270	34-61	0-33	2-Jul

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
3-Jul	62-136	137-184	185-270	35-61	0-34	3-Jul
4-Jul	62-137	138-185	186-270	35-61	0-34	4-Jul
5-Jul	63-138	139-187	188-270	35-62	0-34	5-Jul
6-Jul	63-139	140-188	189-270	35-62	0-34	6-Jul
7-Jul	64-140	141-189	190-270	35-63	0-34	7-Jul
8-Jul	64-141	142-190	191-270	36-63	0-35	8-Jul
9-Jul	65-142	143-192	193-270	36-64	0-35	9-Jul
10-Jul	65-143	144-193	194-270	36-64	0-35	10-Jul
11-Jul	65-143	144-194	195-270	36-64	0-35	11-Jul
12-Jul	66-144	145-195	196-270	37-65	0-36	12-Jul
13-Jul	66-145	146-197	198-270	37-65	0-36	13-Jul
14-Jul	67-146	147-198	199-270	37-66	0-36	14-Jul
15-Jul	67-147	148-199	200-270	37-66	0-36	15-Jul
16-Jul	68-148	149-201	202-270	38-67	0-37	16-Jul
17-Jul	68-149	150-202	203-270	38-67	0-37	17-Jul
18-Jul	68-150	151-203	204-270	38-67	0-37	18-Jul
19-Jul	69-151	152-205	206-270	38-68	0-37	19-Jul
20-Jul	69-152	153-206	207-270	39-68	0-38	20-Jul
21-Jul	70-153	154-207	208-270	39-69	0-38	21-Jul
22-Jul	70-154	155-209	210-270	39-69	0-38	22-Jul
23-Jul	71-155	156-210	211-270	39-70	0-38	23-Jul
24-Jul	71-156	157-211	212-270	40-70	0-39	24-Jul
25-Jul	72-157	158-213	214-270	40-71	0-39	25-Jul
26-Jul	72-158	159-214	215-270	40-71	0-39	26-Jul
27-Jul	73-159	160-216	217-270	40-72	0-39	27-Jul
28-Jul	73-160	161-217	218-270	41-72	0-40	28-Jul
29-Jul	73-161	162-218	219-270	41-72	0-40	29-Jul
30-Jul	74-163	164-220	221-270	41-73	0-40	30-Jul
31-Jul	74-164	165-221	222-270	41-73	0-40	31-Jul
1-Aug	75-165	166-223	224-270	42-74	0-41	1-Aug
2-Aug	75-166	167-224	225-270	42-74	0-41	2-Aug
3-Aug	76-167	168-226	227-270	42-75	0-41	3-Aug
4-Aug	76-168	169-227	228-270	42-75	0-41	4-Aug
5-Aug	77-169	170-229	230-270	43-76	0-42	5-Aug
6-Aug	77-170	171-230	231-270	43-76	0-42	6-Aug
7-Aug	78-171	172-232	233-270	43-77	0-42	7-Aug
8-Aug	78-172	173-233	234-270	44-77	0-43	8-Aug
9-Aug	79-174	175-235	236-270	44-78	0-43	9-Aug
10-Aug	79-175	176-236	237-270	44-78	0-43	10-Aug
11-Aug	80-176	177-238	239-270	44-79	0-43	11-Aug
12-Aug	80-177	178-239	240-270	45-79	0-44	12-Aug
13-Aug	81-178	179-241	242-270	45-80	0-44	13-Aug
14-Aug	81-179	180-243	244-270	45-80	0-44	14-Aug
15-Aug	82-181	182-244	245-270	46-81	0-45	15-Aug
16-Aug	83-182	183-246	247-270	46-82	0-45	16-Aug
17-Aug	83-183	184-247	248-270	46-82	0-45	17-Aug

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
18-Aug	84-184	185-249	250-270	46-83	0-45	18-Aug
19-Aug	84-185	186-251	252-270	47-83	0-46	19-Aug
20-Aug	85-187	188-252	253-270	47-84	0-46	20-Aug
21-Aug	85-188	189-254	255-270	47-84	0-46	21-Aug
22-Aug	86-189	190-256	257-270	48-85	0-47	22-Aug
23-Aug	86-190	191-257	258-270	48-85	0-47	23-Aug
24-Aug	87-192	193-259	260-270	48-86	0-47	24-Aug
25-Aug	88-193	194-261	262-270	49-87	0-48	25-Aug
26-Aug	88-194	195-262	263-270	49-87	0-48	26-Aug
27-Aug	89-195	196-264	265-270	49-88	0-48	27-Aug
28-Aug	89-197	198-266	267-270	50-88	0-49	28-Aug
29-Aug	90-198	199-268	269-270	50-89	0-49	29-Aug
30-Aug	90-199	200-269	270-270	50-89	0-49	30-Aug
31-Aug	91-201	202-270	*	51-90	0-50	31-Aug
1-Sep	92-202	203-270	0-50	51-91	end sm Winter	1-Sep
2-Sep	92-203	204-270	0-50	51-91	*	2-Sep
3-Sep	93-205	206-270	0-50	51-92	*	3-Sep
4-Sep	93-206	207-270	0-51	52-92	*	4-Sep
5-Sep	94-207	208-270	0-51	52-93	*	5-Sep
6-Sep	95-209	210-270	0-51	52-94	*	6-Sep
7-Sep	95-210	211-270	0-52	53-94	*	7-Sep
8-Sep	96-211	212-270	0-52	53-95	*	8-Sep
9-Sep	96-213	214-270	0-53	54-95	*	9-Sep
10-Sep	97-214	215-270	0-53	54-96	*	10-Sep
11-Sep	98-216	217-270	0-53	54-97	*	11-Sep
12-Sep	98-217	218-270	0-54	55-97	*	12-Sep
13-Sep	99-218	219-270	0-54	55-98	*	13-Sep
14-Sep	100-220	221-270	0-54	55-99	*	14-Sep
15-Sep	100-221	222-270	0-55	56-99	*	15-Sep
16-Sep	101-223	224-270	0-55	56-100	*	16-Sep
17-Sep	102-224	225-270	0-55	56-101	*	17-Sep
18-Sep	102-226	227-270	0-56	57-101	*	18-Sep
19-Sep	103-227	228-270	0-56	57-102	*	19-Sep
20-Sep	104-229	230-270	0-56	57-103	*	20-Sep
21-Sep	104-230	231-270	0-57	58-103	*	21-Sep
22-Sep	105-232	233-270	0-57	58-104	*	22-Sep
23-Sep	106-233	234-270	0-58	59-105	*	23-Sep
24-Sep	106-235	236-270	0-58	59-105	*	24-Sep
25-Sep	107-236	237-270	0-58	59-106	*	25-Sep
26-Sep	108-238	239-270	0-59	60-107	*	26-Sep
27-Sep	108-239	240-270	0-59	60-107	*	27-Sep
28-Sep	109-241	242-270	0-59	60-108	*	28-Sep
29-Sep	110-243	244-270	0-60	61-109	*	29-Sep
30-Sep	111-244	245-270	0-60	61-110	*	30-Sep
1-Oct	111-246	247-270	0-61	62-110	*	1-Oct
2-Oct	112-247	248-270	0-61	62-111	*	2-Oct

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

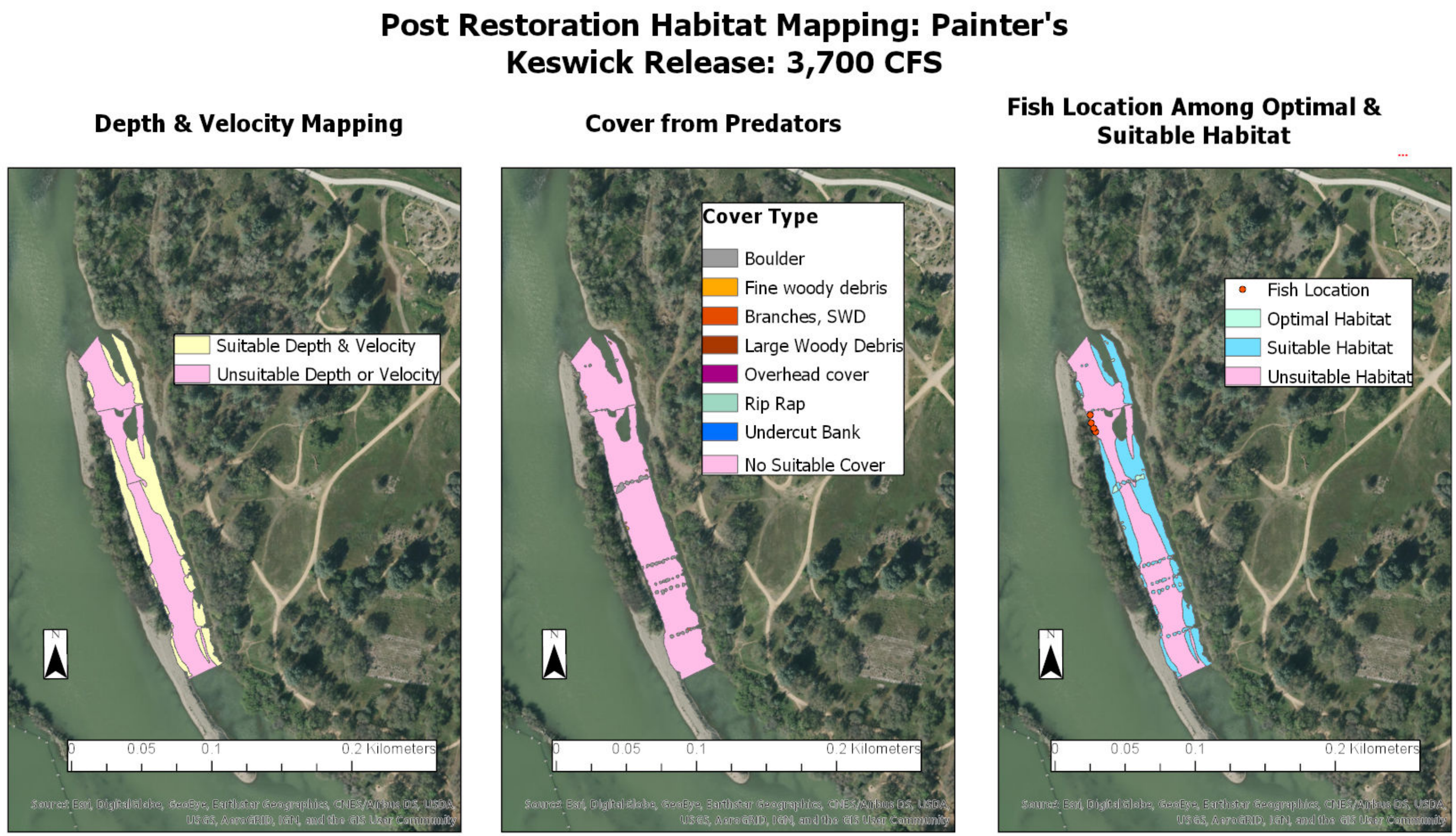
DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
3-Oct	113-249	250-270	0-61	62-112	*	3-Oct
4-Oct	113-251	252-270	0-62	63-112	*	4-Oct
5-Oct	114-252	253-270	0-62	63-113	*	5-Oct
6-Oct	115-254	255-270	0-63	64-114	*	6-Oct
7-Oct	116-256	257-270	0-63	64-115	*	7-Oct
8-Oct	116-257	258-270	0-64	65-115	*	8-Oct
9-Oct	117-259	260-270	0-64	65-116	*	9-Oct
10-Oct	118-261	262-270	0-64	65-117	*	10-Oct
11-Oct	119-262	263-270	0-65	66-118	*	11-Oct
12-Oct	120-264	265-270	0-65	66-119	*	12-Oct
13-Oct	120-266	267-270	0-66	67-119	*	13-Oct
14-Oct	121-268	269-270	0-66	67-120	*	14-Oct
15-Oct	122-269	270-270	0-67	68-121	*	15-Oct
16-Oct	123-270	0-33	34-67	68-122	*	16-Oct
17-Oct	124-270	0-33	34-67	68-123	*	17-Oct
18-Oct	124-270	0-34	35-68	69-123	*	18-Oct
19-Oct	125-270	0-34	35-68	69-124	*	19-Oct
20-Oct	126-270	0-34	35-69	70-125	*	20-Oct
21-Oct	127-270	0-34	35-69	70-126	*	21-Oct
22-Oct	128-270	0-34	35-70	71-127	*	22-Oct
23-Oct	128-270	0-35	36-70	71-127	*	23-Oct
24-Oct	129-270	0-35	36-71	72-128	*	24-Oct
25-Oct	130-270	0-35	36-71	72-129	*	25-Oct
26-Oct	131-270	0-35	36-72	73-130	*	26-Oct
27-Oct	132-270	0-36	37-72	73-131	*	27-Oct
28-Oct	133-270	0-36	37-72	73-132	*	28-Oct
29-Oct	134-270	0-36	37-73	74-133	*	29-Oct
30-Oct	134-270	0-36	37-73	74-133	*	30-Oct
31-Oct	135-270	0-37	38-74	75-134	*	31-Oct
1-Nov	136-270	0-37	38-74	75-135	*	1-Nov
2-Nov	137-270	0-37	38-75	76-136	*	2-Nov
3-Nov	138-270	0-37	38-75	76-137	*	3-Nov
4-Nov	139-270	0-38	39-76	77-138	*	4-Nov
5-Nov	140-270	0-38	39-76	77-139	*	5-Nov
6-Nov	141-270	0-38	39-77	78-140	*	6-Nov
7-Nov	142-270	0-38	39-77	78-141	*	7-Nov
8-Nov	143-270	0-39	40-78	79-142	*	8-Nov
9-Nov	144-270	0-39	40-78	79-143	*	9-Nov
10-Nov	144-270	0-39	40-79	80-143	*	10-Nov
11-Nov	145-270	0-39	40-79	80-144	*	11-Nov
12-Nov	146-270	0-40	41-80	81-145	*	12-Nov
13-Nov	147-270	0-40	41-80	81-146	*	13-Nov
14-Nov	148-270	0-40	41-81	82-147	*	14-Nov
15-Nov	149-270	0-40	41-82	83-148	*	15-Nov
16-Nov	150-270	0-41	42-82	83-149	*	16-Nov
17-Nov	151-270	0-41	42-83	84-150	*	17-Nov

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
18-Nov	152-270	0-41	42-83	84-151	*	18-Nov
19-Nov	153-270	0-41	42-84	85-152	*	19-Nov
20-Nov	154-270	0-42	43-84	85-153	*	20-Nov
21-Nov	155-270	0-42	43-85	86-154	*	21-Nov
22-Nov	156-270	0-42	43-85	86-155	*	22-Nov
23-Nov	157-270	0-43	44-86	87-156	*	23-Nov
24-Nov	158-270	0-43	44-87	88-157	*	24-Nov
25-Nov	159-270	0-43	44-87	88-158	*	25-Nov
26-Nov	160-270	0-43	44-88	89-159	*	26-Nov
27-Nov	161-270	0-44	45-88	89-160	*	27-Nov
28-Nov	162-270	0-44	45-89	90-161	*	28-Nov
29-Nov	164-270	0-44	45-89	90-163	*	29-Nov
30-Nov	165-270	0-45	46-90	91-164	Fall	30-Nov
1-Dec	0-33	34-45	46-91	92-165	166-270	1-Dec
2-Dec	0-33	34-45	46-91	92-166	167-270	2-Dec
3-Dec	0-34	35-45	46-92	93-167	168-270	3-Dec
4-Dec	0-34	35-46	47-92	93-168	169-270	4-Dec
5-Dec	0-34	35-46	47-93	94-169	170-270	5-Dec
6-Dec	0-34	35-46	47-94	95-170	171-270	6-Dec
7-Dec	0-34	35-47	48-94	95-171	172-270	7-Dec
8-Dec	0-35	36-47	48-95	96-172	173-270	8-Dec
9-Dec	0-35	36-47	48-95	96-174	175-270	9-Dec
10-Dec	0-35	36-48	49-96	97-175	176-270	10-Dec
11-Dec	0-35	36-48	49-97	98-176	177-270	11-Dec
12-Dec	0-36	37-48	49-97	98-177	178-270	12-Dec
13-Dec	0-36	37-49	50-98	99-178	179-270	13-Dec
14-Dec	0-36	37-49	50-99	100-179	180-270	14-Dec
15-Dec	0-36	37-49	50-99	100-181	182-270	15-Dec
16-Dec	0-37	38-50	51-100	101-182	183-270	16-Dec
17-Dec	0-37	38-50	51-101	102-183	184-270	17-Dec
18-Dec	0-37	38-50	51-101	102-184	185-270	18-Dec
19-Dec	0-37	38-50	51-102	103-185	186-270	19-Dec
20-Dec	0-38	39-51	52-103	104-187	188-270	20-Dec
21-Dec	0-38	39-51	52-103	104-188	189-270	21-Dec
22-Dec	0-38	39-51	52-104	105-189	190-270	22-Dec
23-Dec	0-38	39-52	53-105	106-190	191-270	23-Dec
24-Dec	0-39	40-52	53-105	106-192	193-270	24-Dec
25-Dec	0-39	40-53	54-106	107-193	194-270	25-Dec
26-Dec	0-39	40-53	54-107	108-194	195-270	26-Dec
27-Dec	0-39	40-53	54-107	108-195	196-270	27-Dec
28-Dec	0-40	41-54	55-108	109-195	196-270	28-Dec
29-Dec	0-40	41-54	55-109	110-198	199-270	29-Dec
30-Dec	0-40	41-54	55-110	111-199	200-270	30-Dec
31-Dec	0-40	41-55	56-110	111-201	202-270	31-Dec

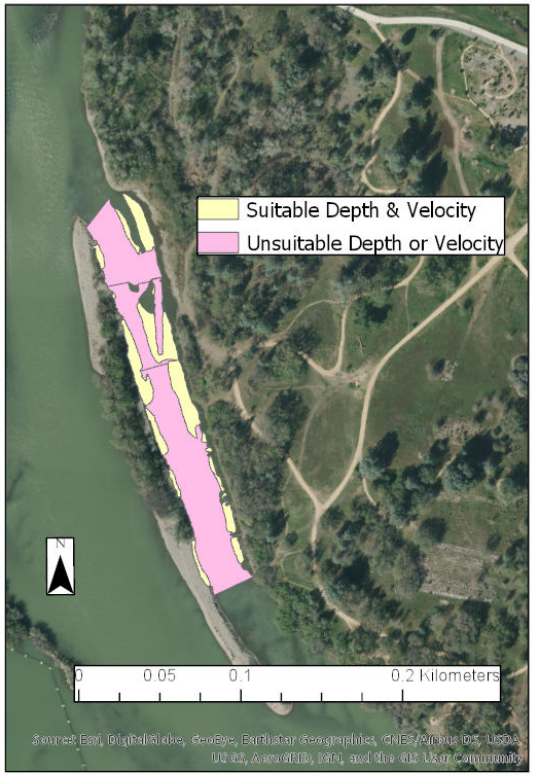
APPENDIX B. Juvenile Habitat Mapping and Suitability Maps

The maps in in this appendix show the mapping data that was used for the juvenile habitat mapping and suitability analyses reported in the main text.

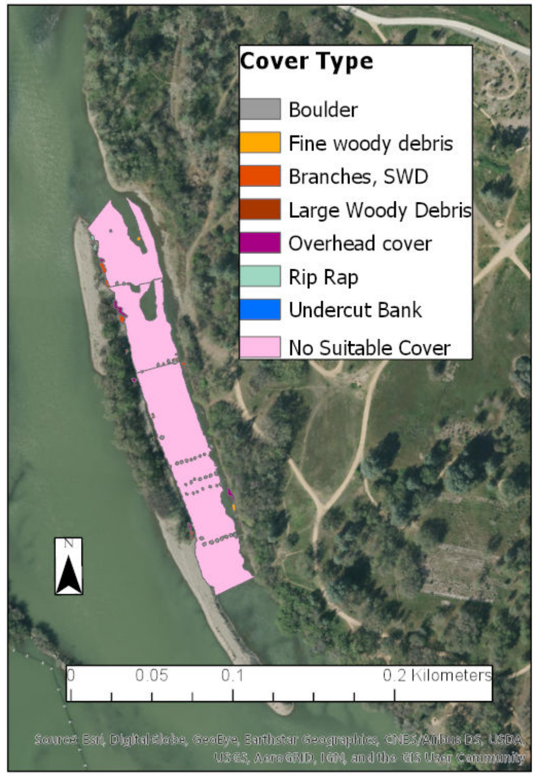


Post Restoration Habitat Mapping: Painter's
Keswick Release: 5,000 CFS

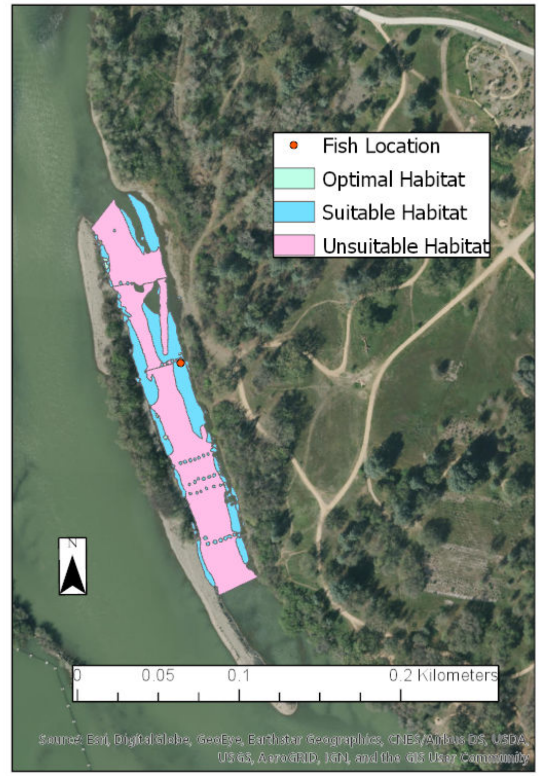
Depth & Velocity Mapping



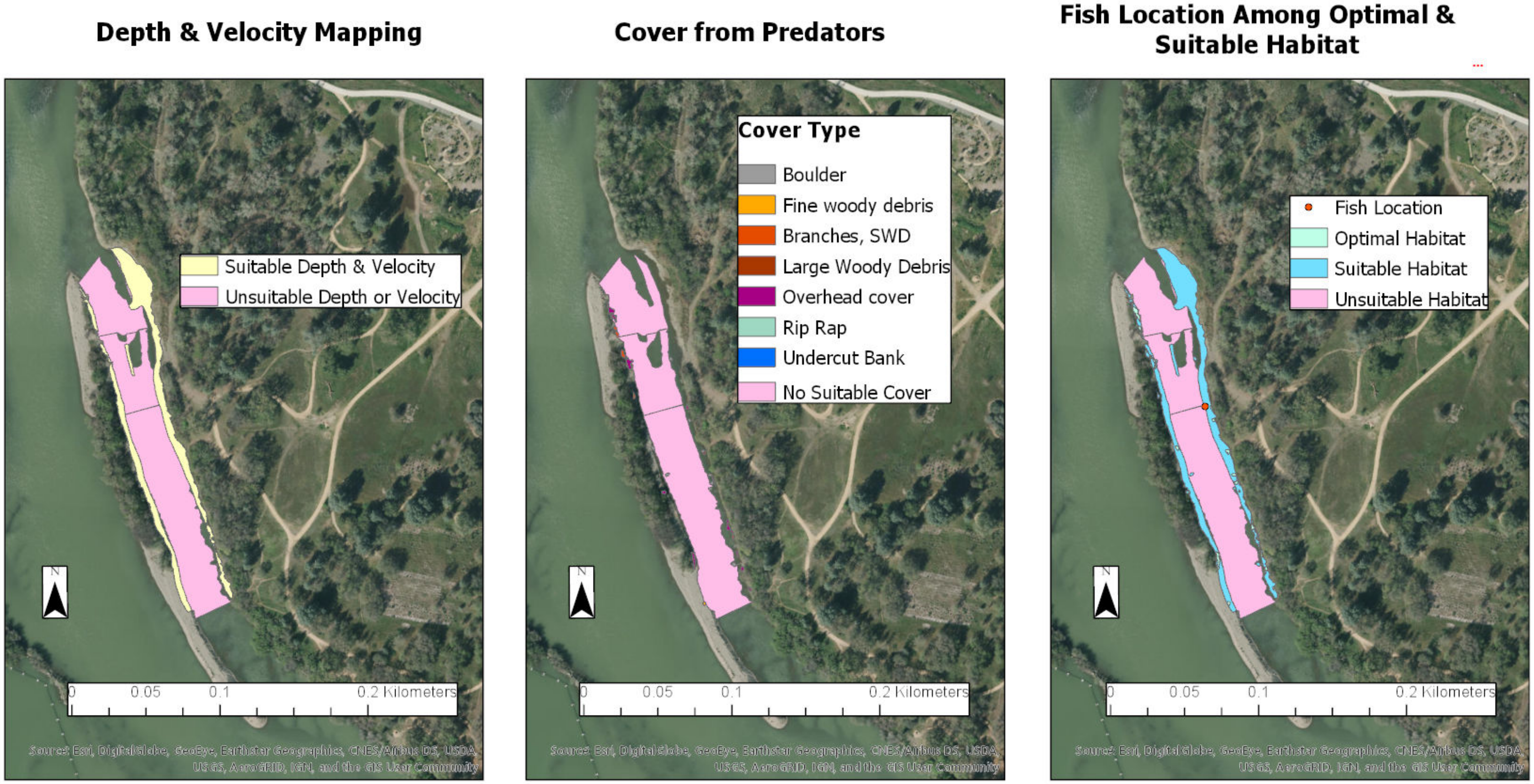
Cover from Predators



Fish Location Among Optimal & Suitable Habitat

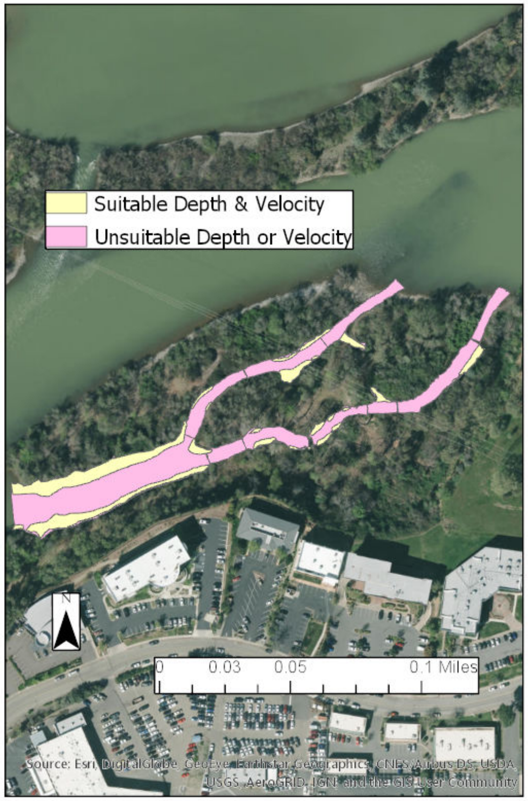


Post Restoration Habitat Mapping: Painter's
Keswick Release: 7,400 CFS

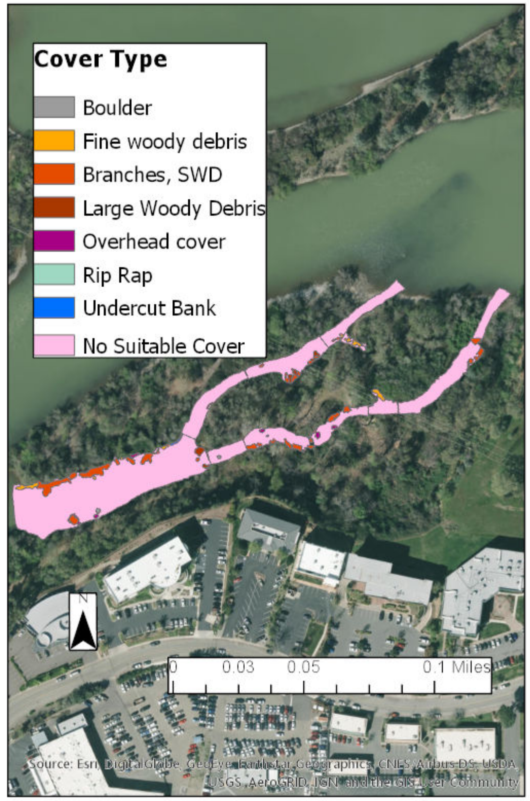


Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release: 3,700 CFS

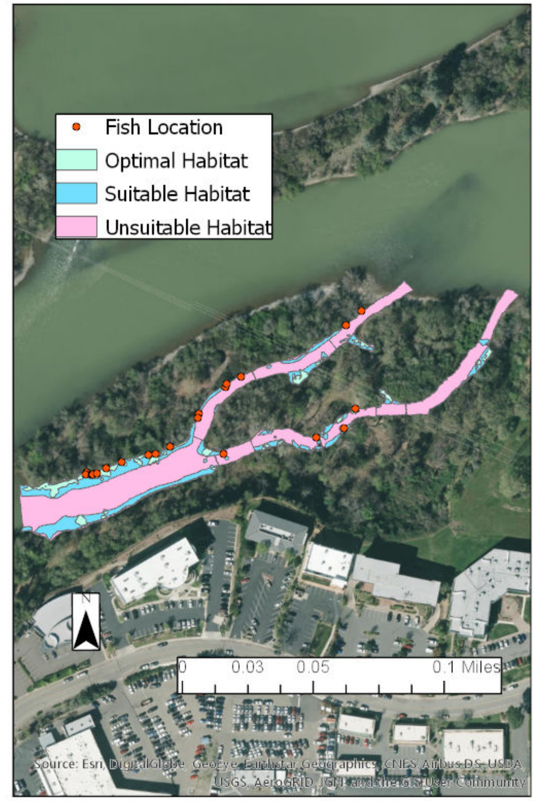
Depth & Velocity Mapping



Cover from Predators

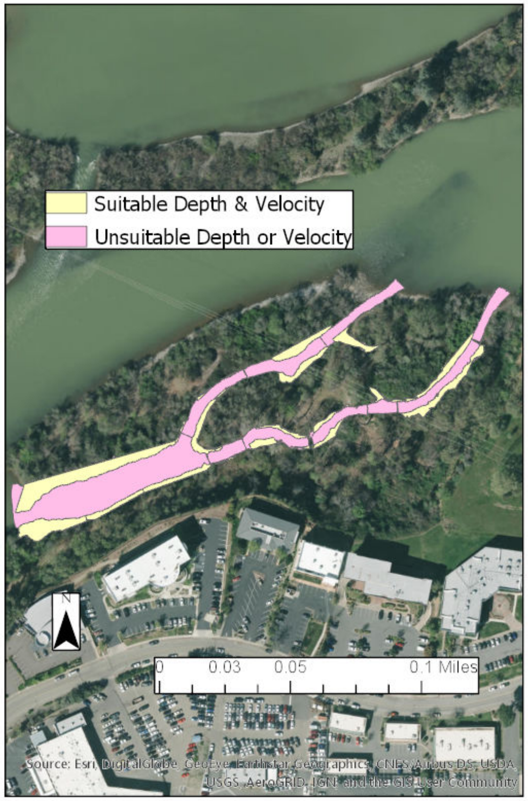


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release: 6,000 CFS

Depth & Velocity Mapping



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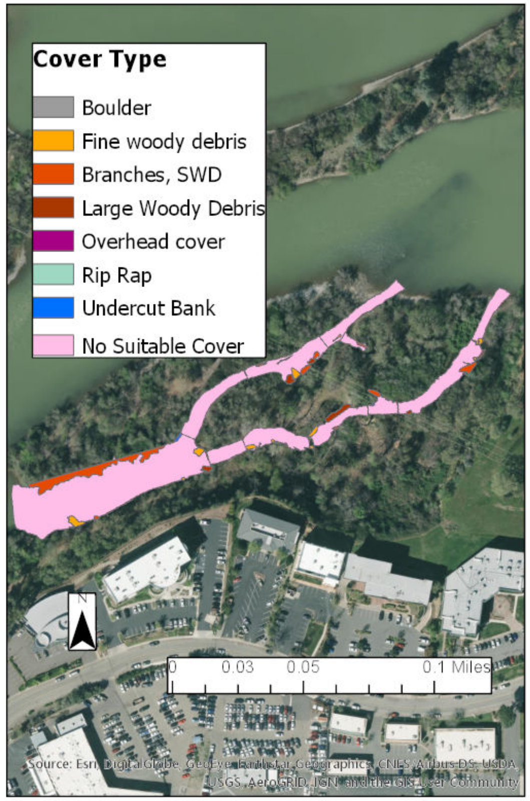
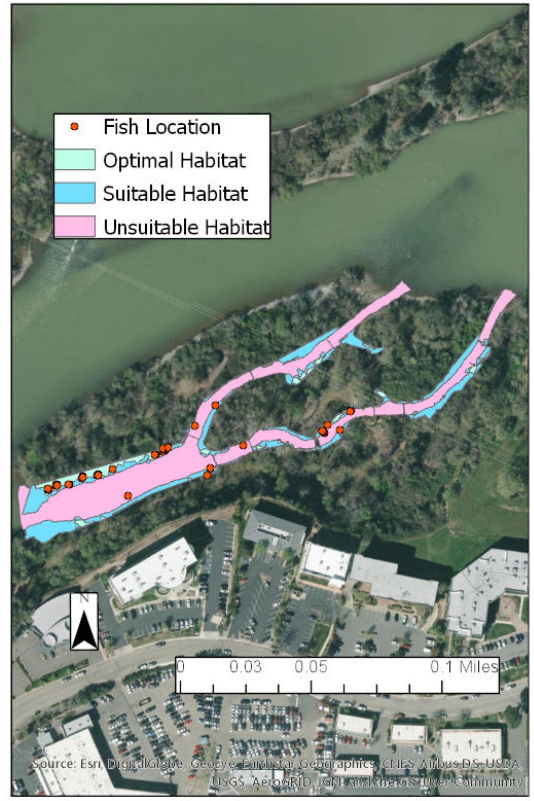
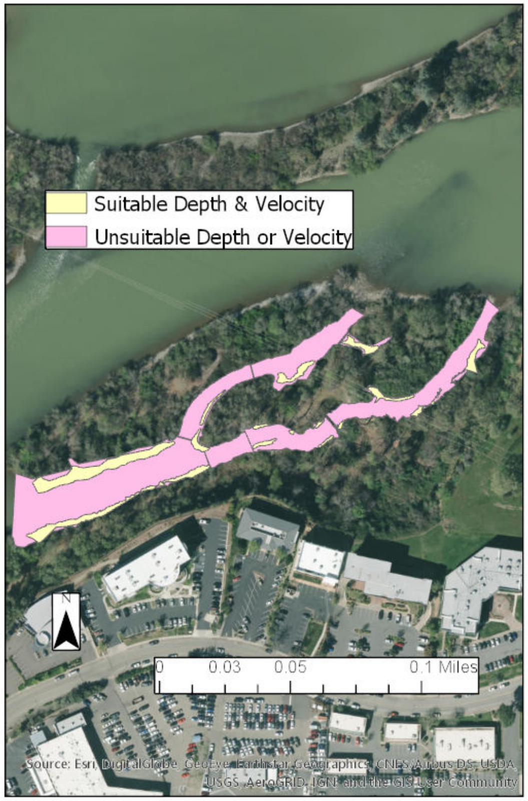


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release: 8,000 CFS

Depth & Velocity Mapping



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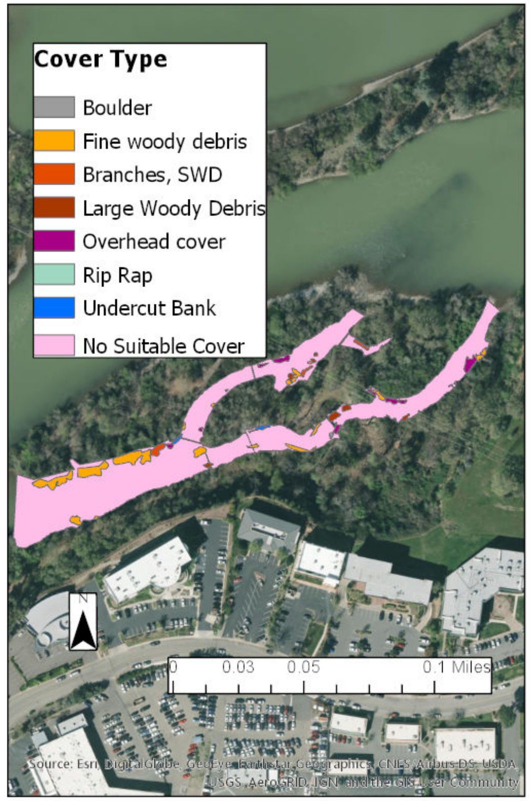
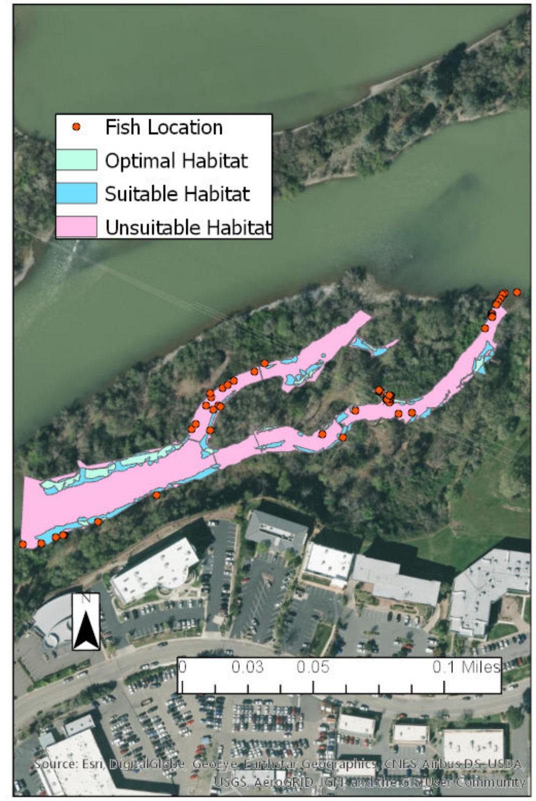
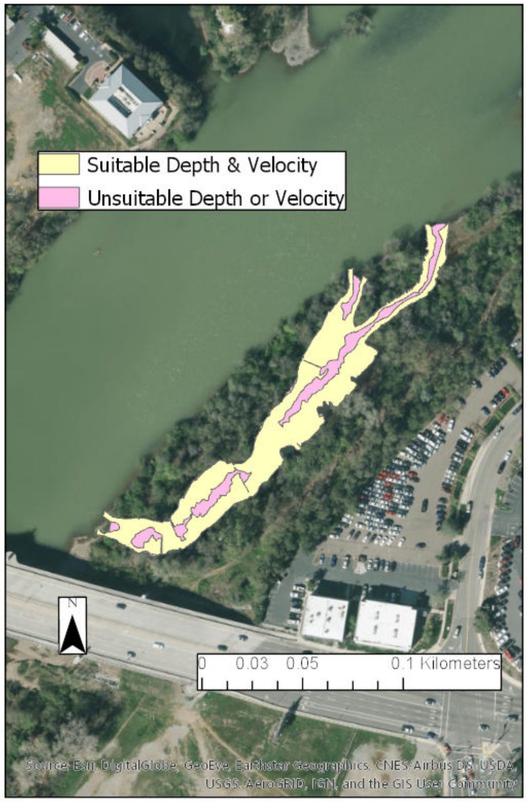


Fish Locations Among Optimal & Suitable Habitat

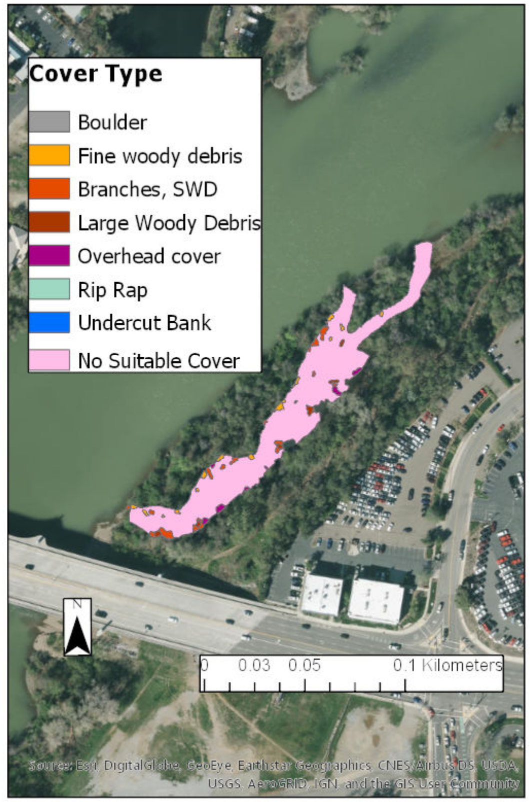


Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release: 3,700 CFS

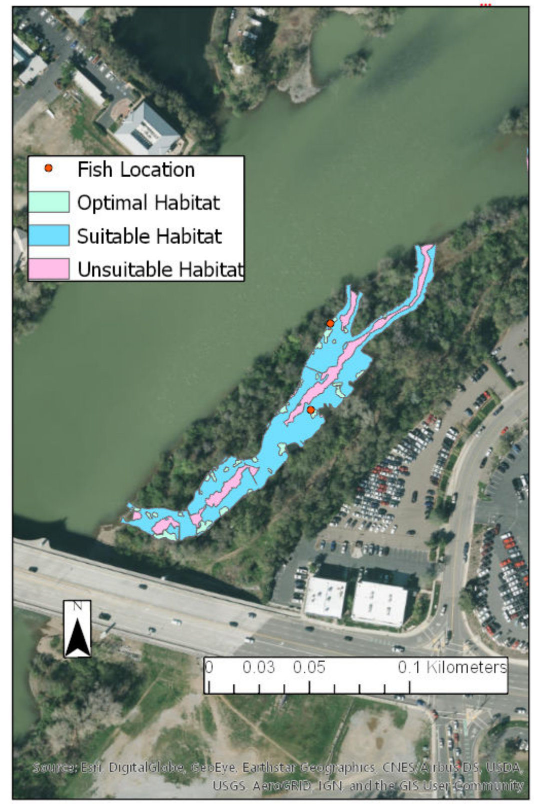
Depth & Velocity Mapping



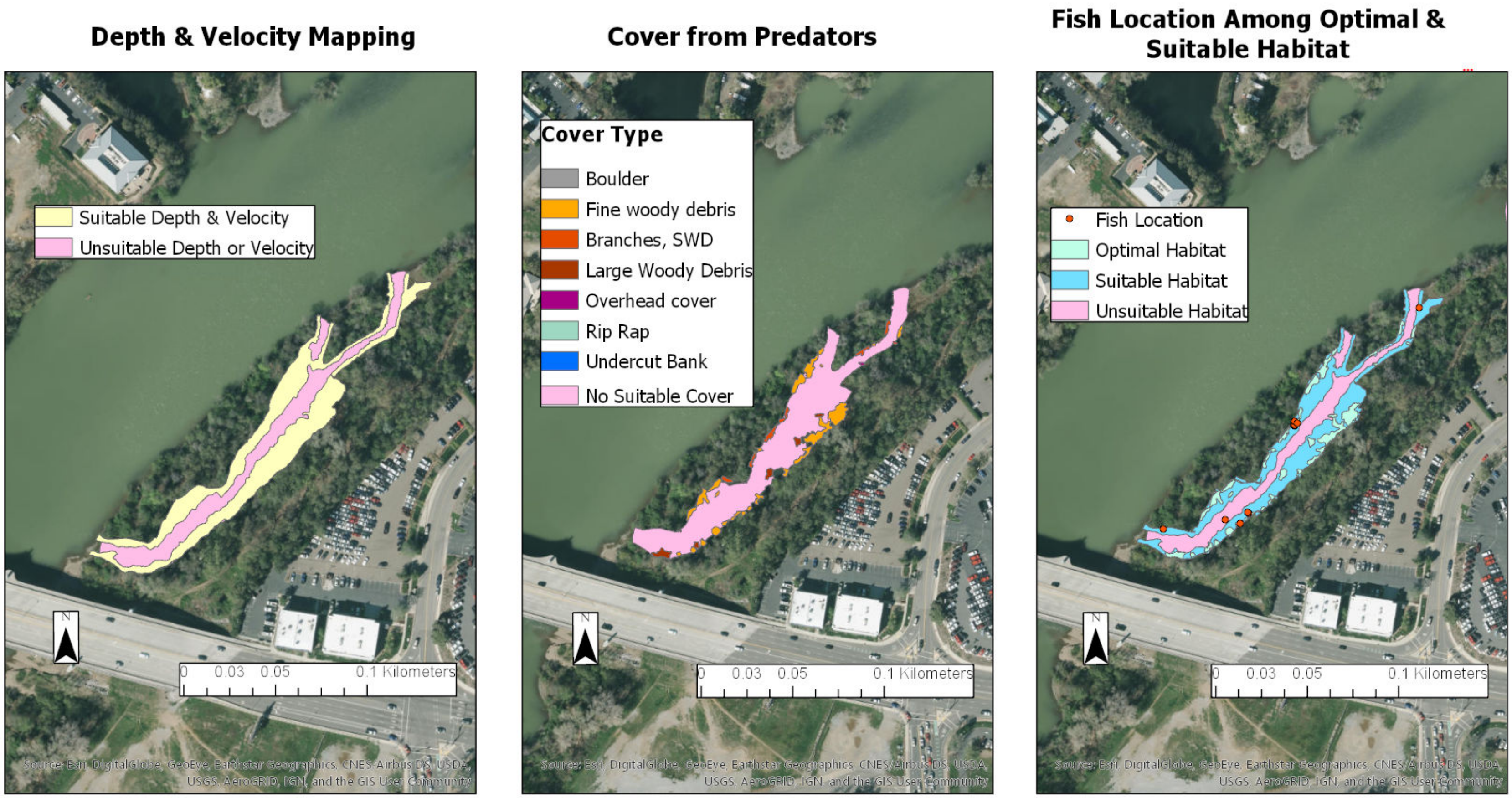
Cover from Predators



Fish Location Among Optimal & Suitable Habitat

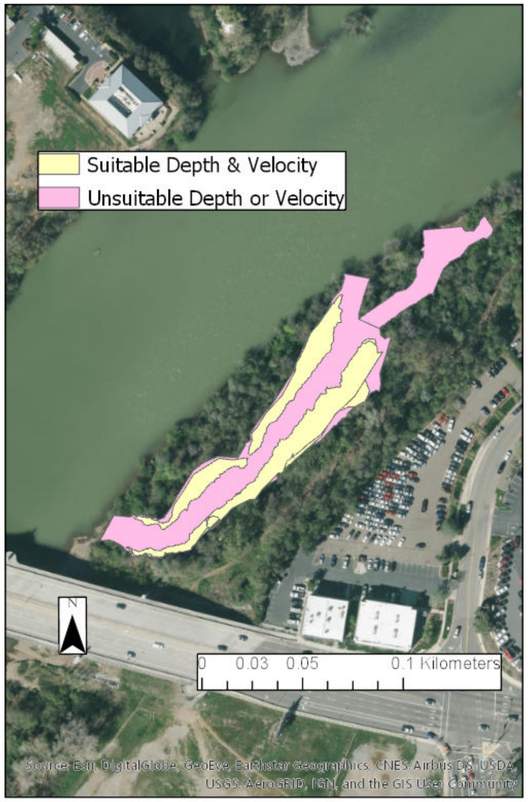


Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release: 6,000 CFS

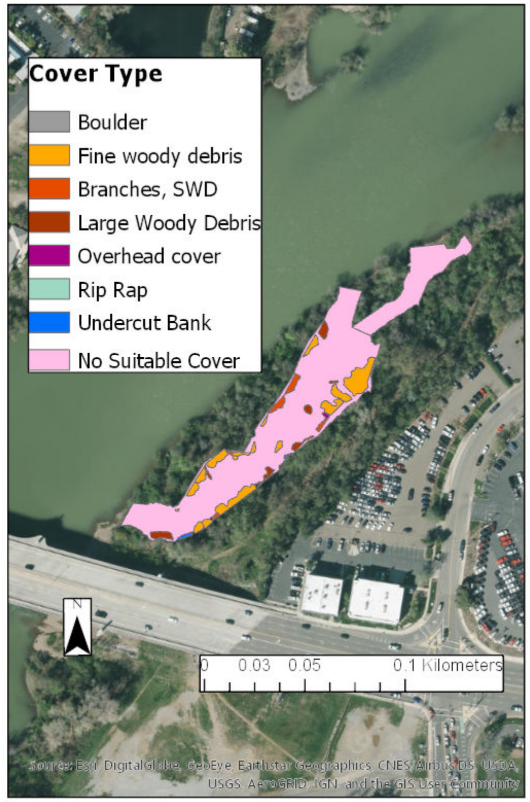


Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release: 8,000 CFS

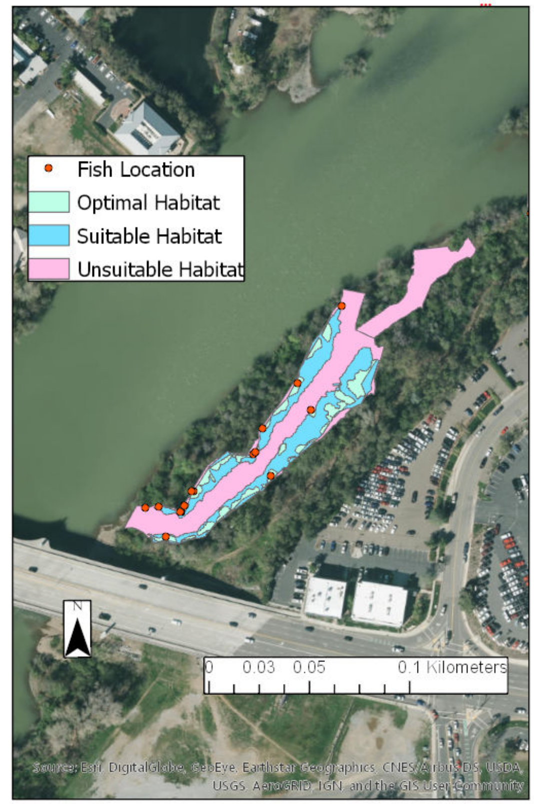
Depth & Velocity Mapping



Cover from Predators

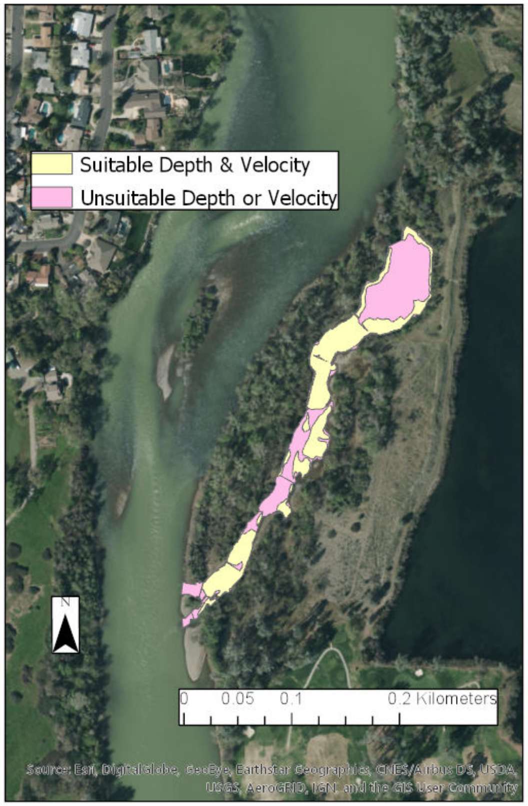


Fish Location Among Optimal & Suitable Habitat



Control Site Habitat Mapping: Wyndham
Keswick Release: 3,100 CFS

Depth & Velocity Mapping



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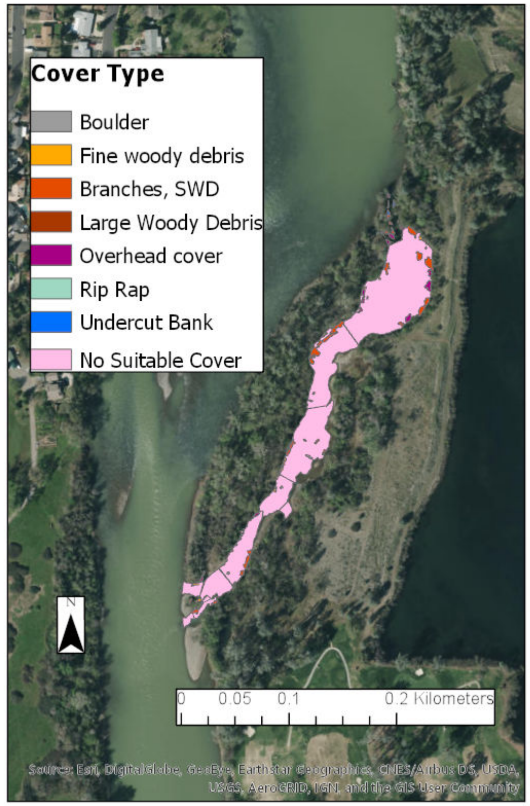
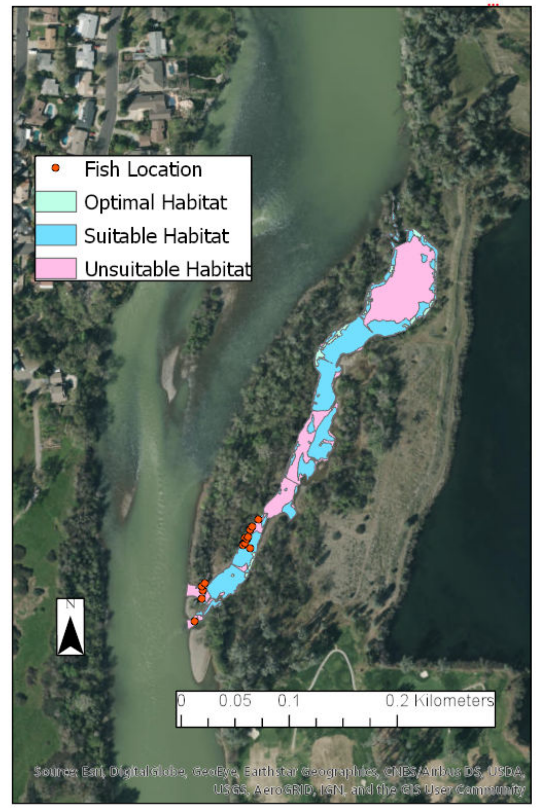
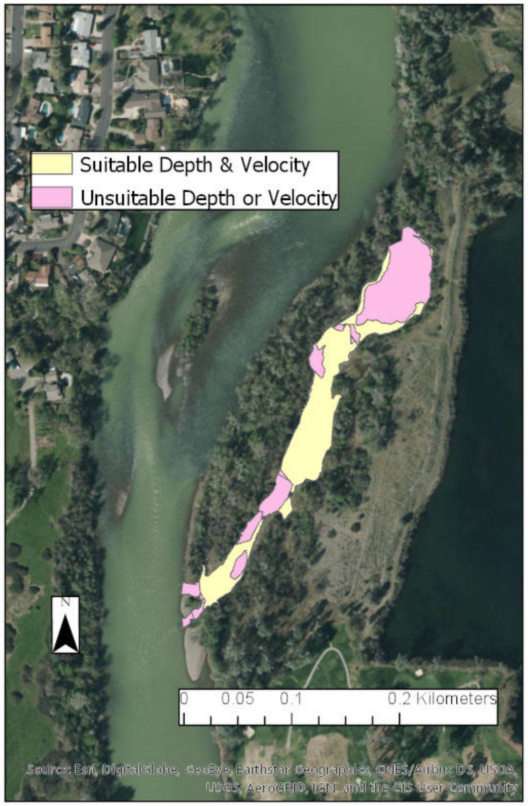


Fish Locations Among Optimal & Suitable Habitat



Control Site Habitat Mapping: Wyndham
Keswick Release: 7,500 CFS

Depth & Velocity Mapping



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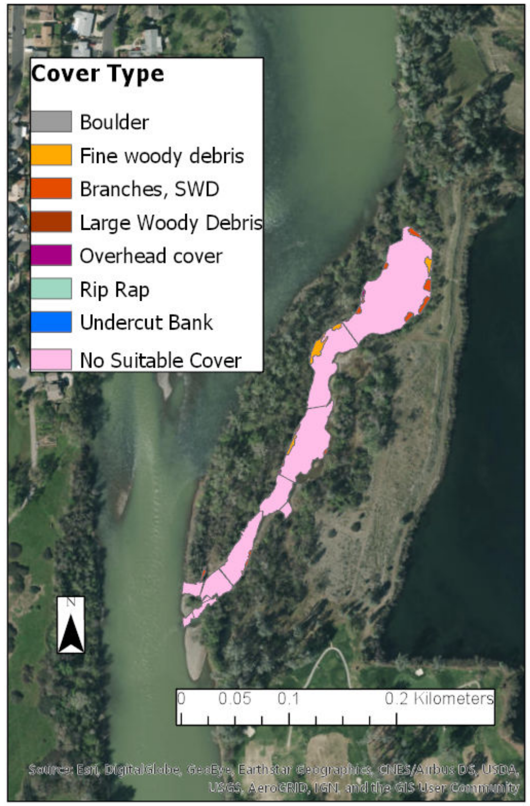
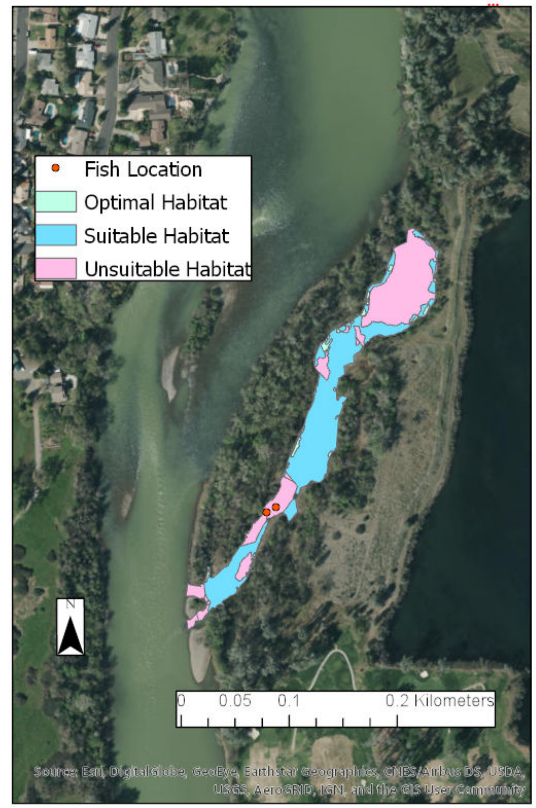
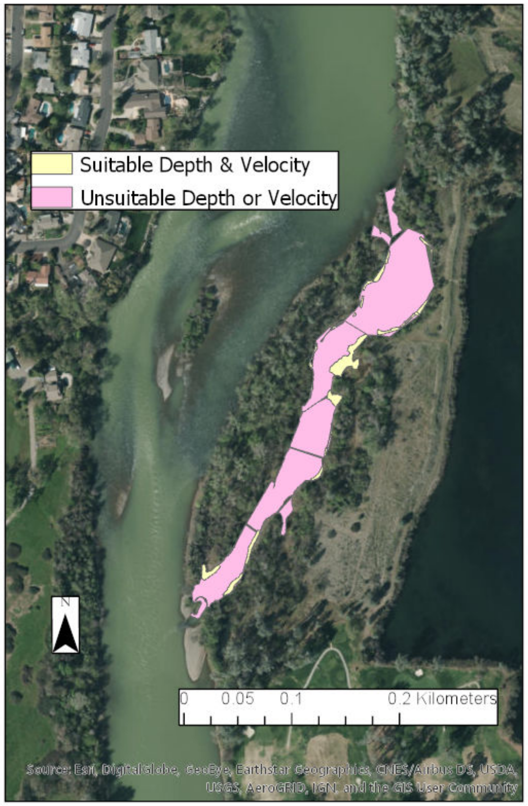


Fish Locations Among Optimal & Suitable Habitat

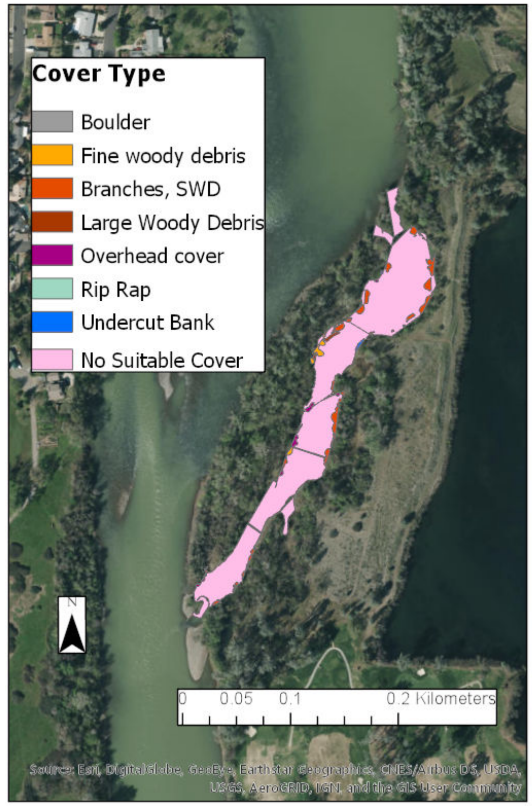


Control Site Habitat Mapping: Wyndham
Keswick Release: 10,500 CFS

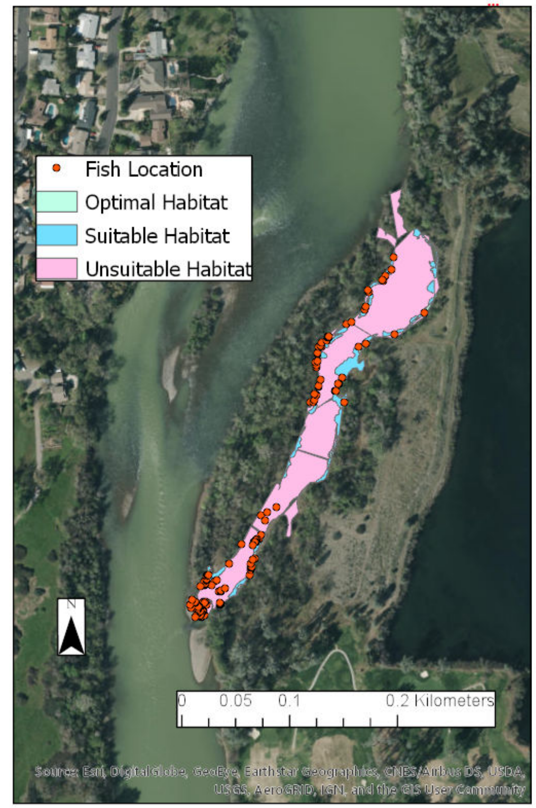
Depth & Velocity Mapping



Cover from Predators

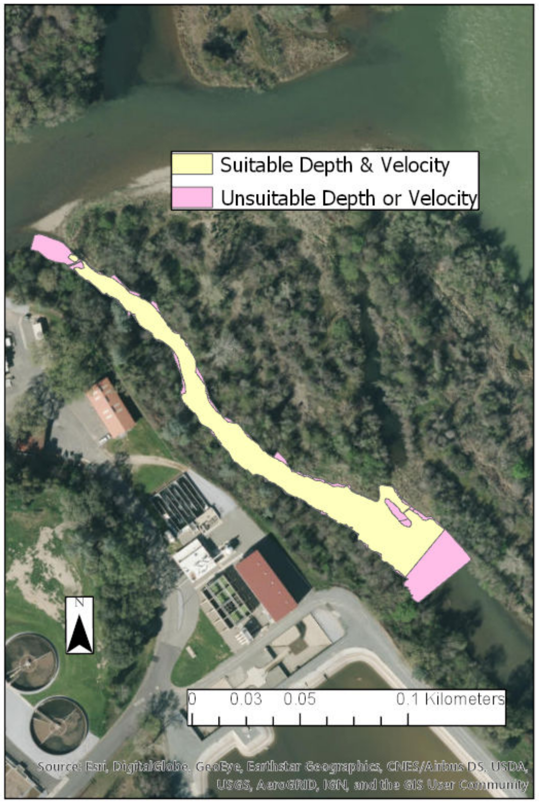


Fish Locations Among Optimal & Suitable Habitat



Control Site Habitat Mapping: Clear Creek
Keswick Release: 3,100 CFS

Depth & Velocity Mapping



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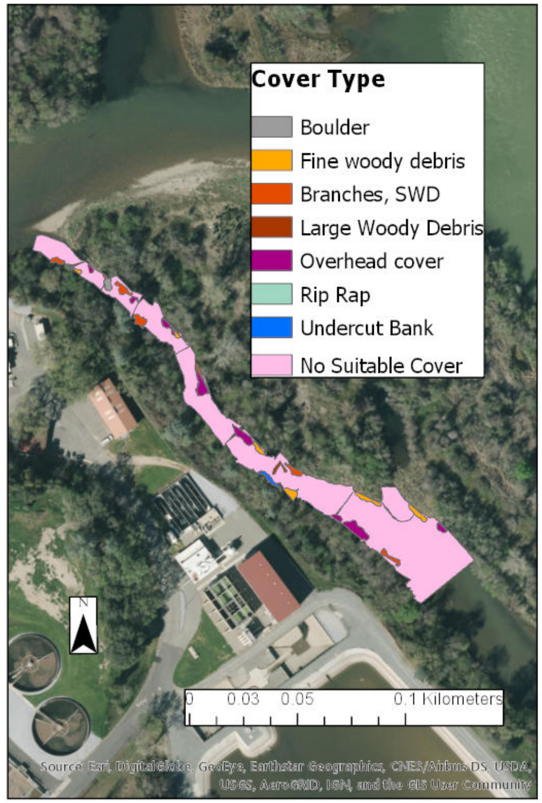
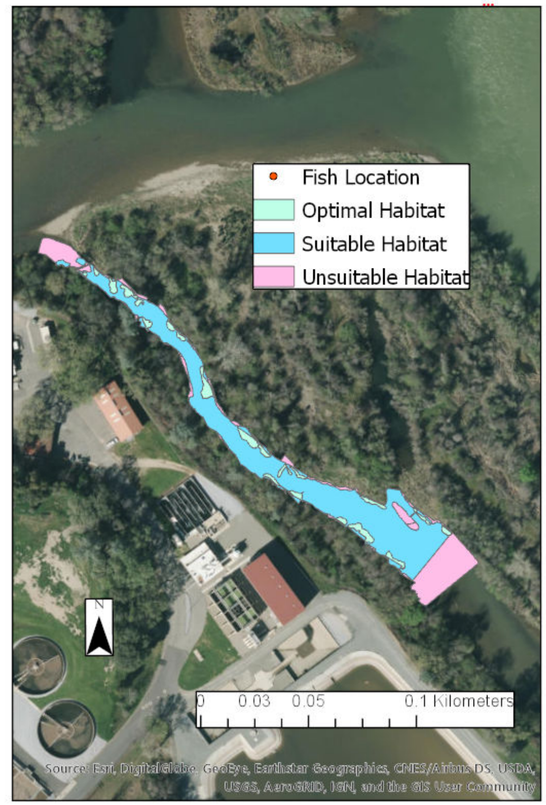
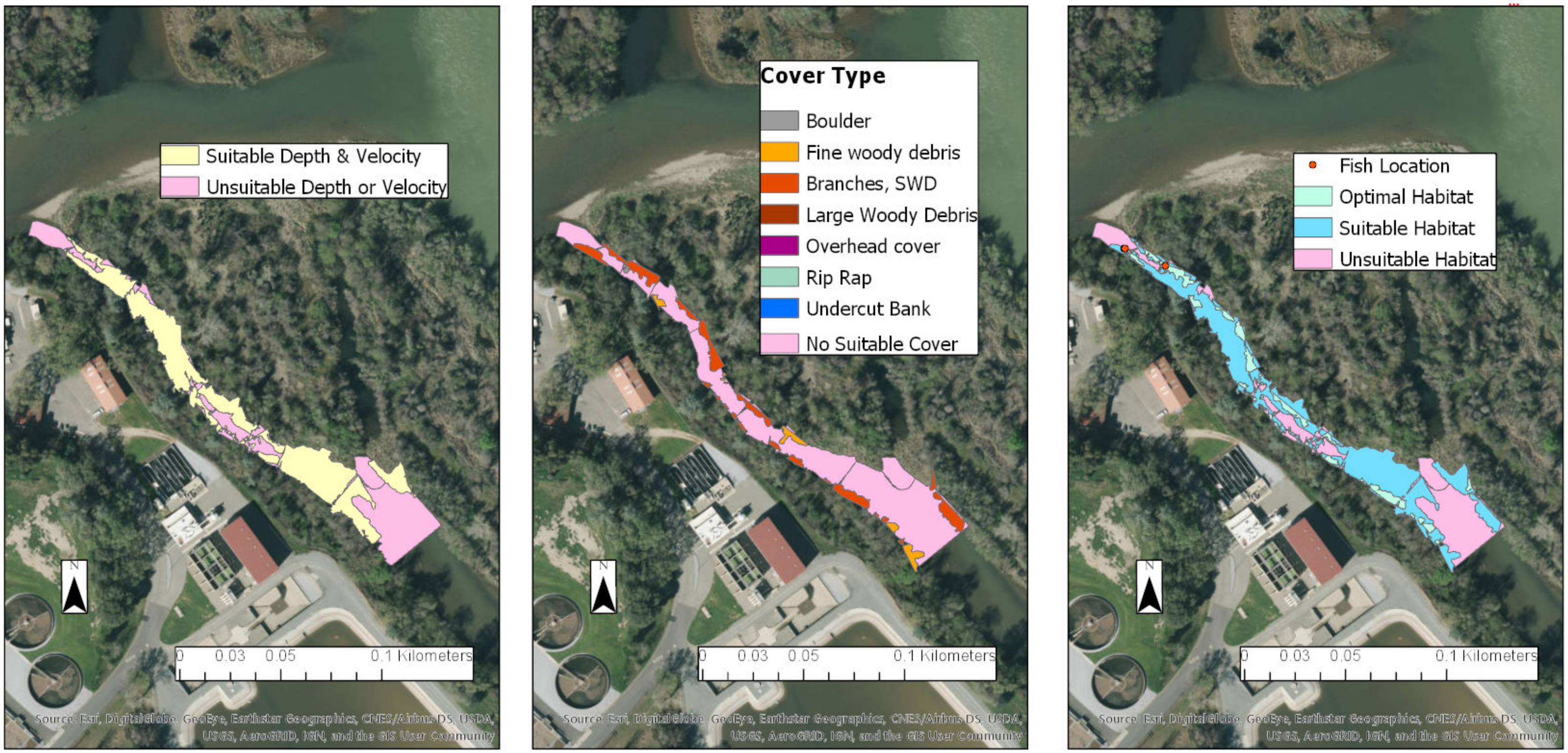


Fish Locations Among Optimal & Suitable Habitat



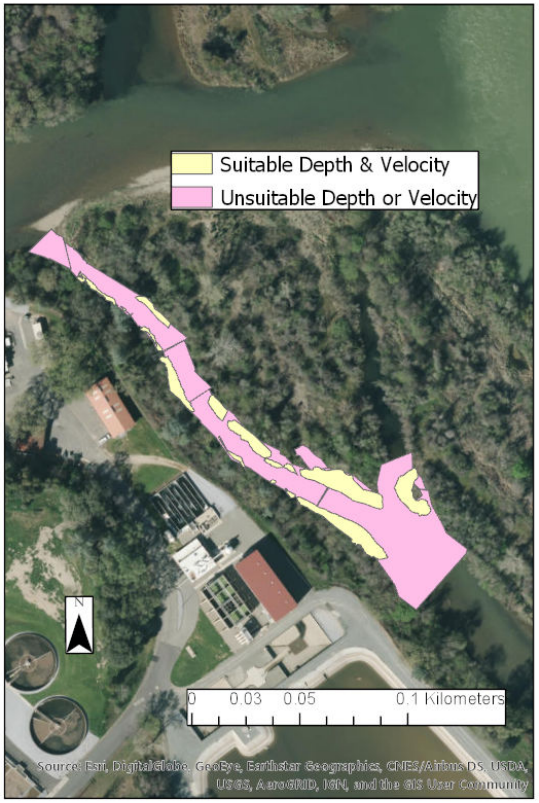
Control Site Habitat Mapping: Clear Creek
Keswick Release: 7,500 CFS

Depth & Velocity Mapping | **Cover from Predators** | **Fish Locations Among Optimal & Suitable Habitat**

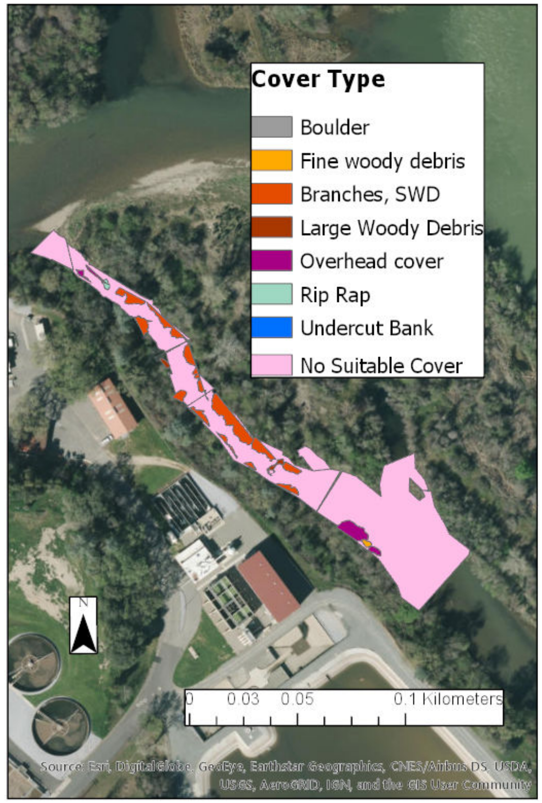


Control Site Habitat Mapping: Clear Creek
Keswick Release: 10,500 CFS

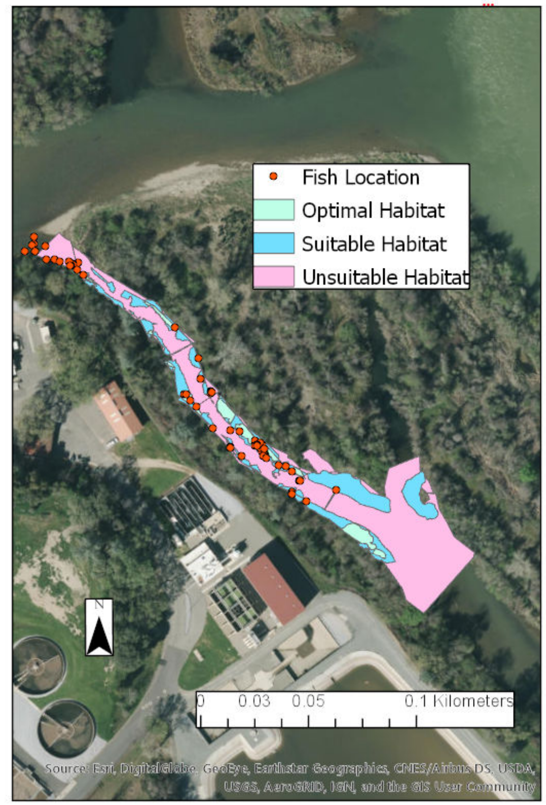
Depth & Velocity Mapping



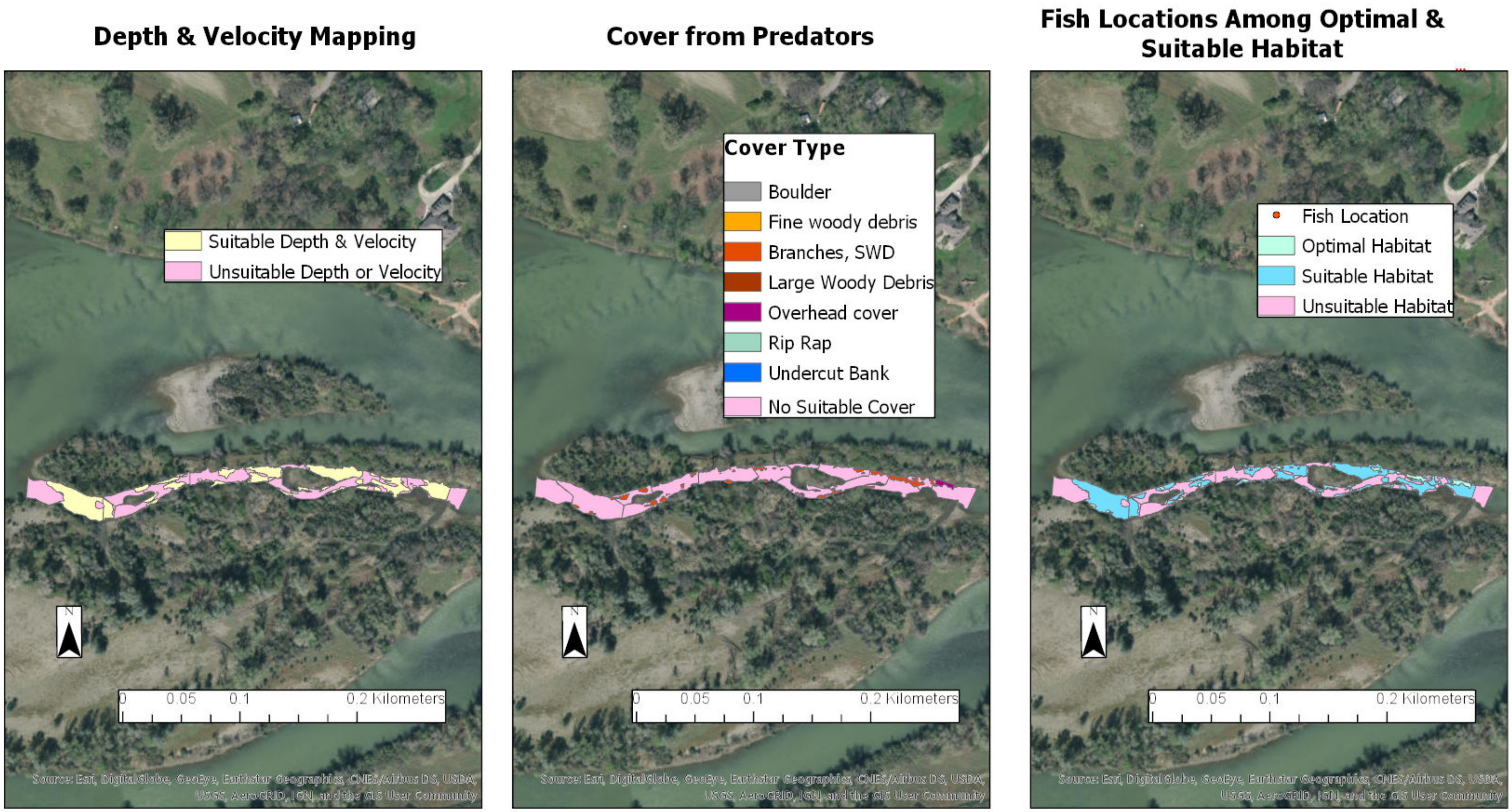
Cover from Predators



Fish Locations Among Optimal & Suitable Habitat

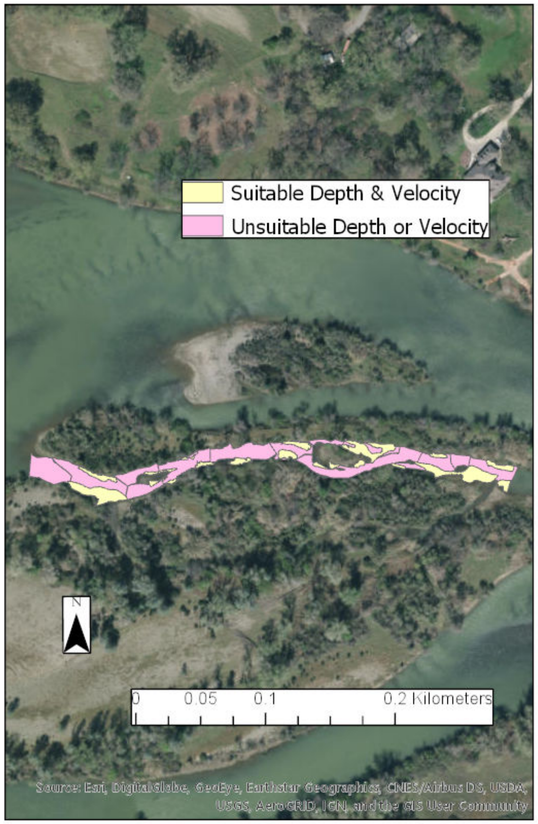


Control Site Habitat Mapping: Bourbon
Keswick Release: 3,100 CFS

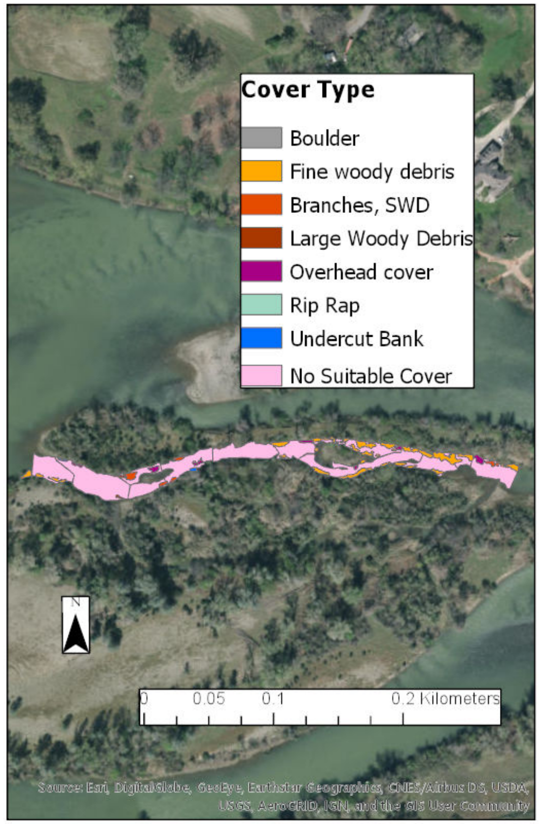


Control Site Habitat Mapping: Bourbon
Keswick Release: 7,500 CFS

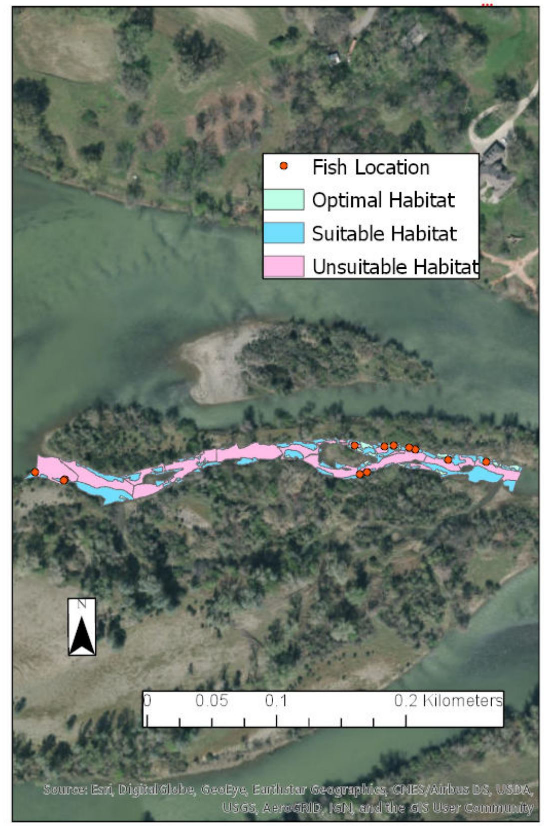
Depth & Velocity Mapping



Cover from Predators

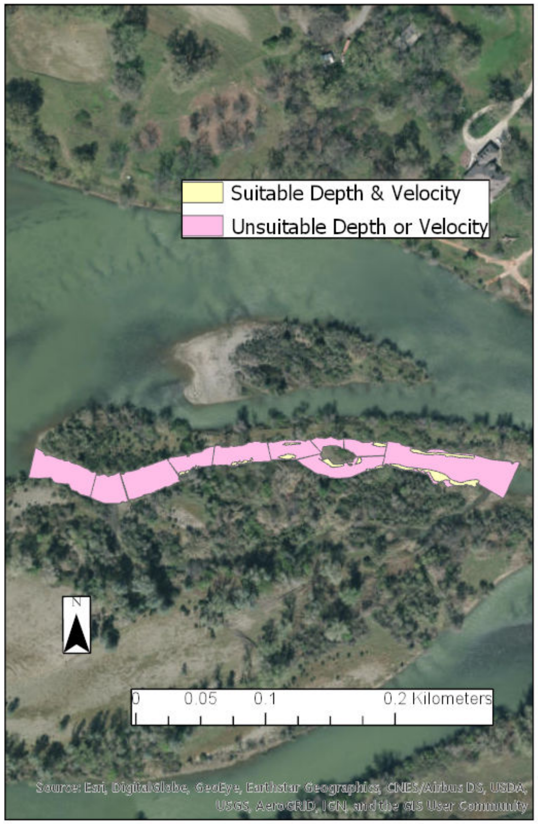


Fish Locations Among Optimal & Suitable Habitat



Control Site Habitat Mapping: Bourbon
Keswick Release: 10,500 CFS

Depth & Velocity Mapping



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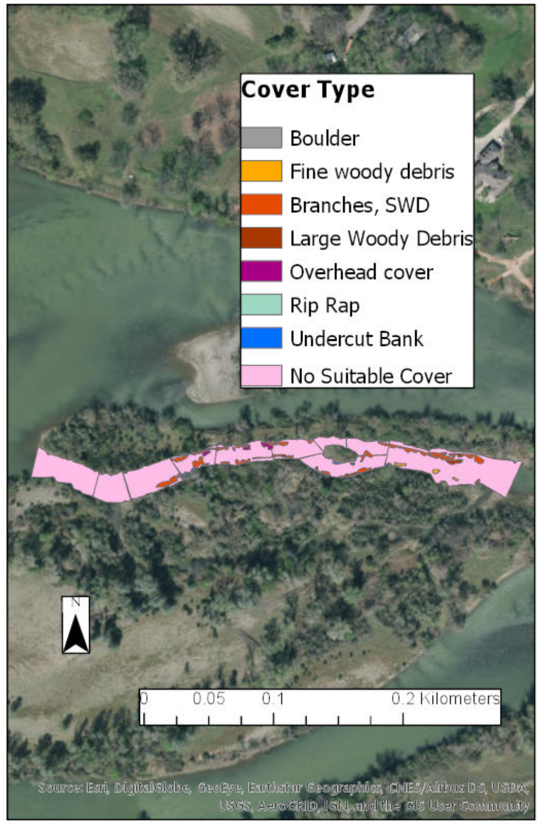
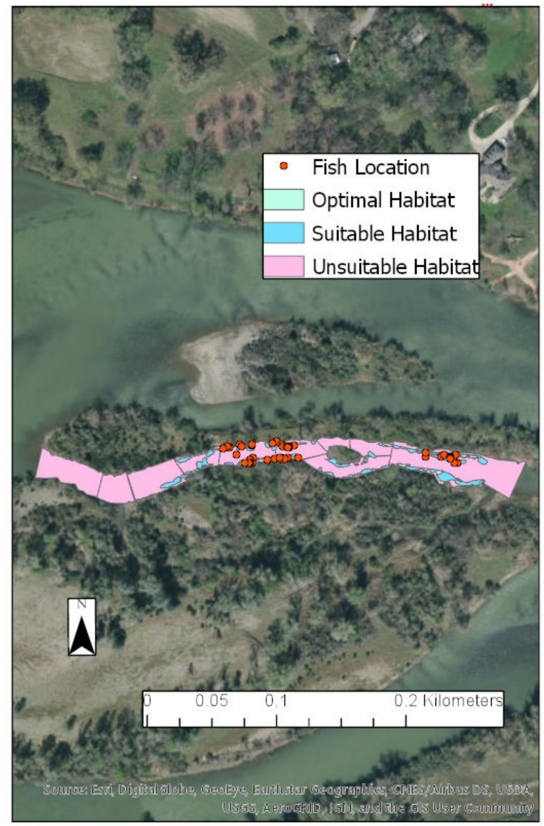
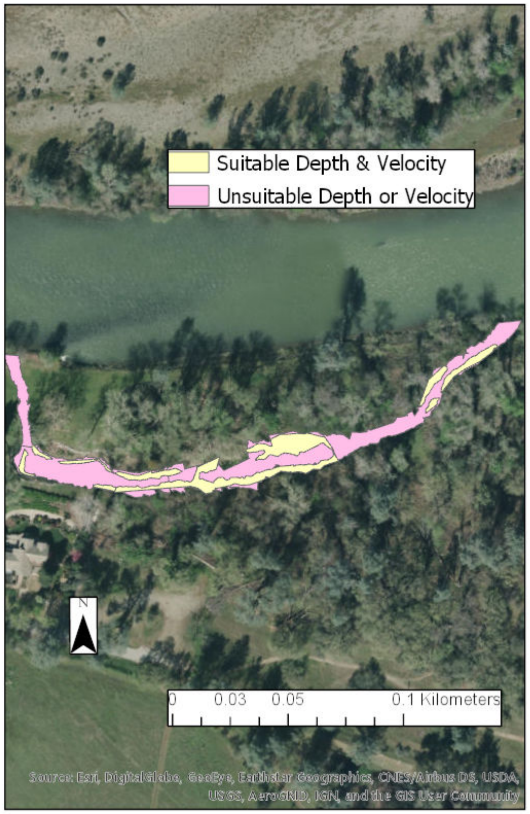


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: Kapuesta
Keswick Release: 7,500 CFS

Depth & Velocity Mapping



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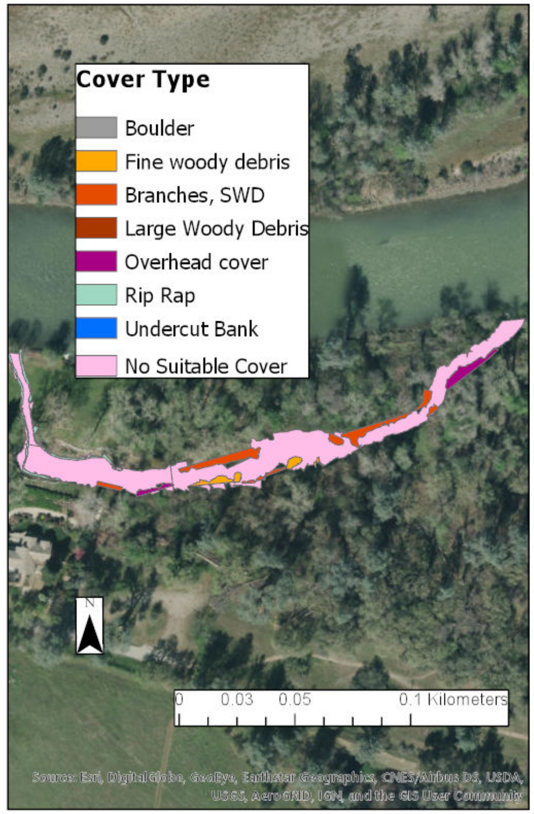
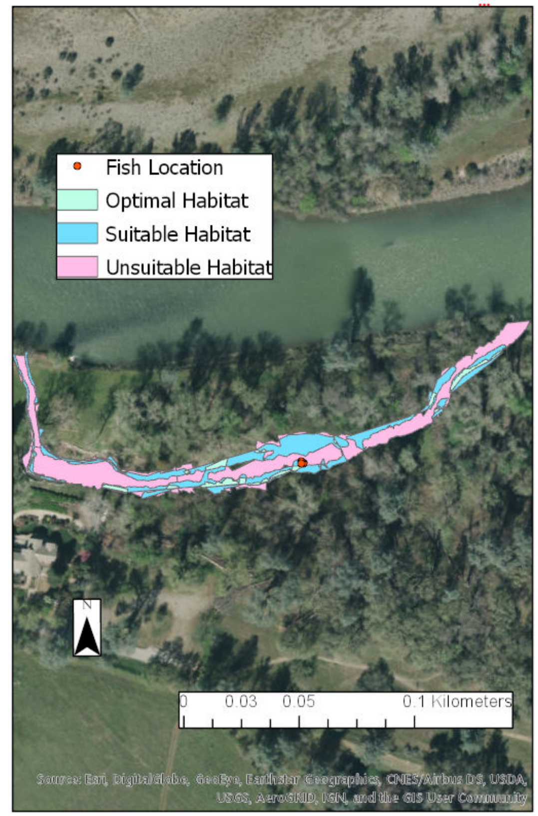
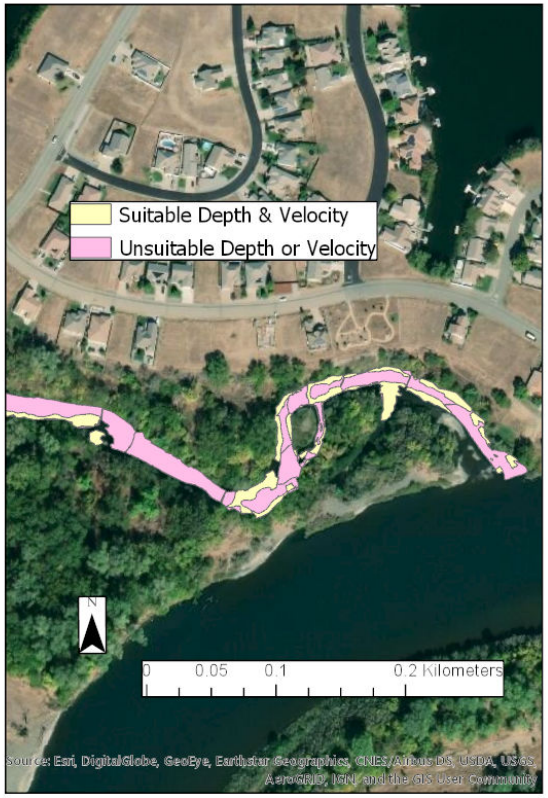


Fish Locations Among Optimal & Suitable Habitat

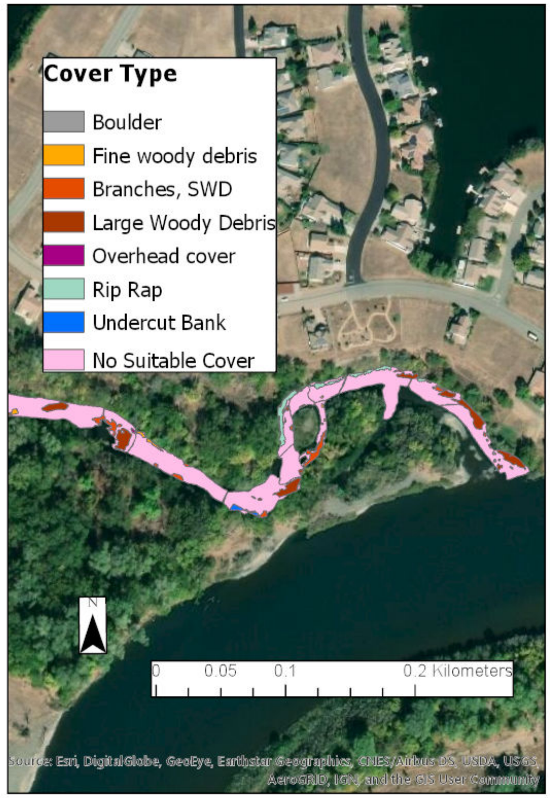


Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release: 3,250 CFS

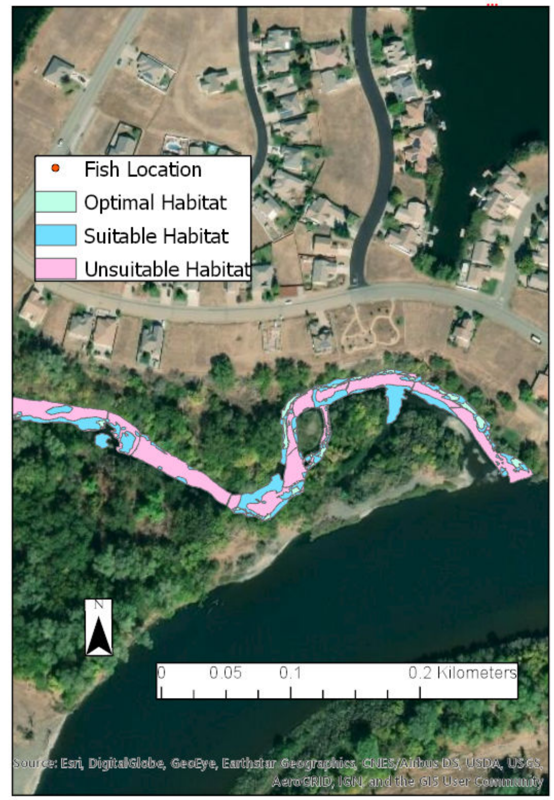
Depth & Velocity Mapping



Cover from Predators

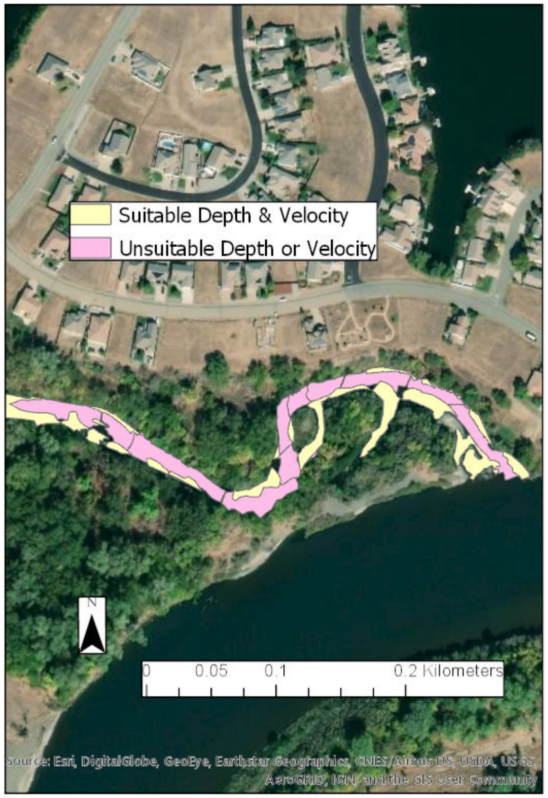


Fish Locations Among Optimal & Suitable Habitat

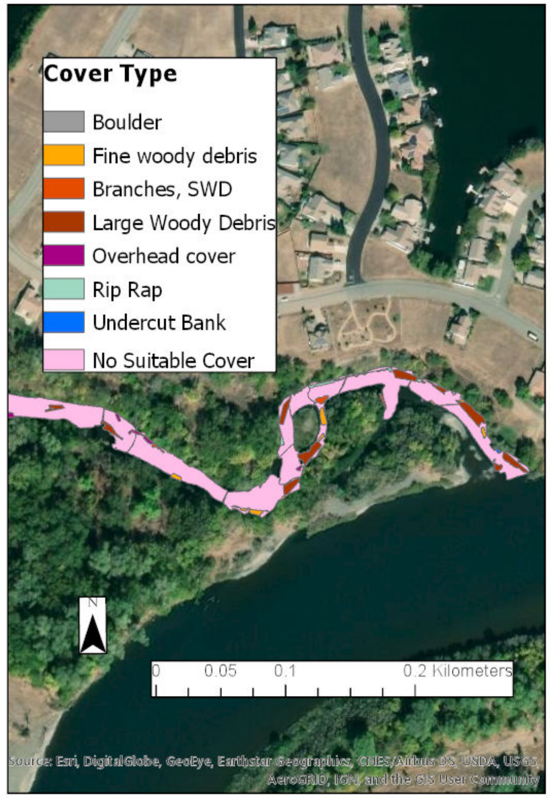


Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release: 7,500 CFS

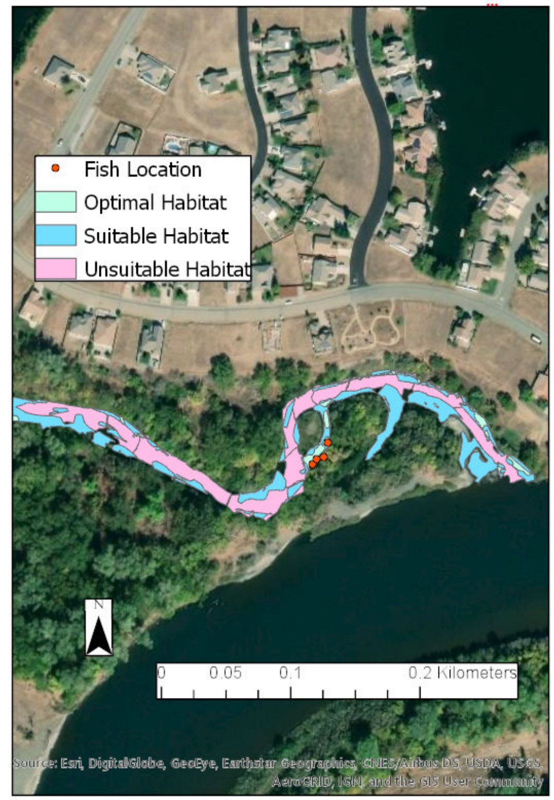
Depth & Velocity Mapping



Cover from Predators

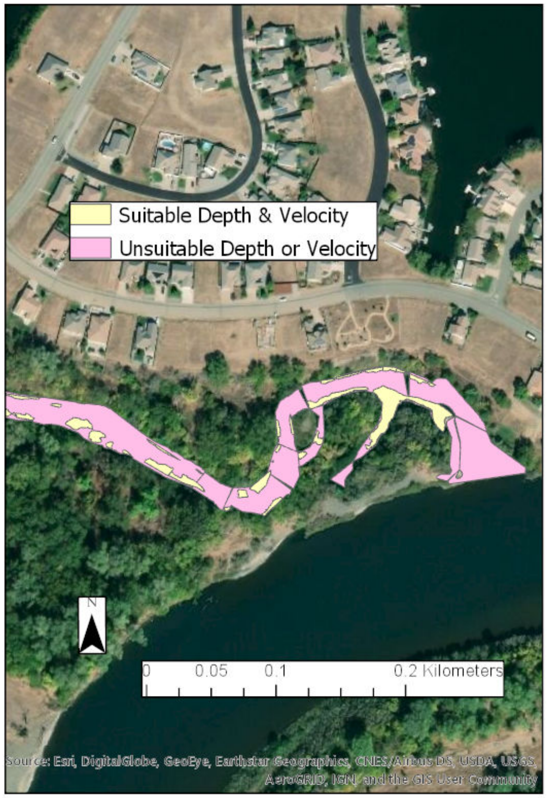


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release: 9,000 CFS

Depth & Velocity Mapping



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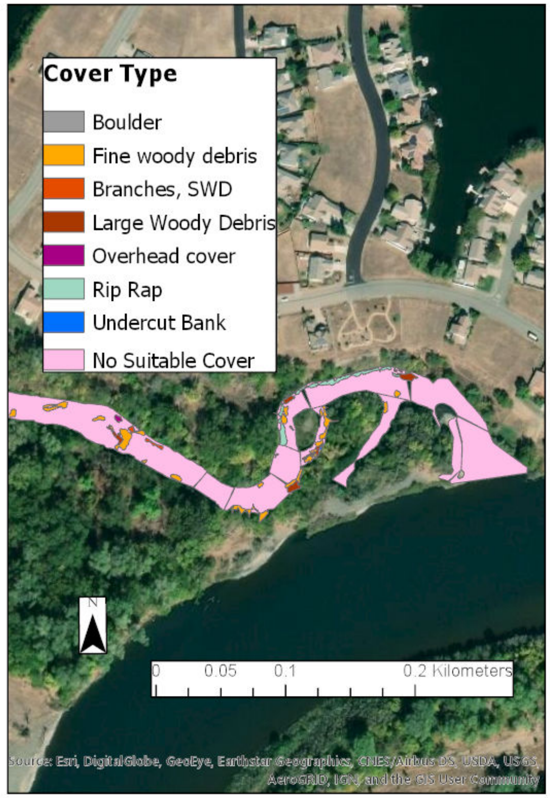
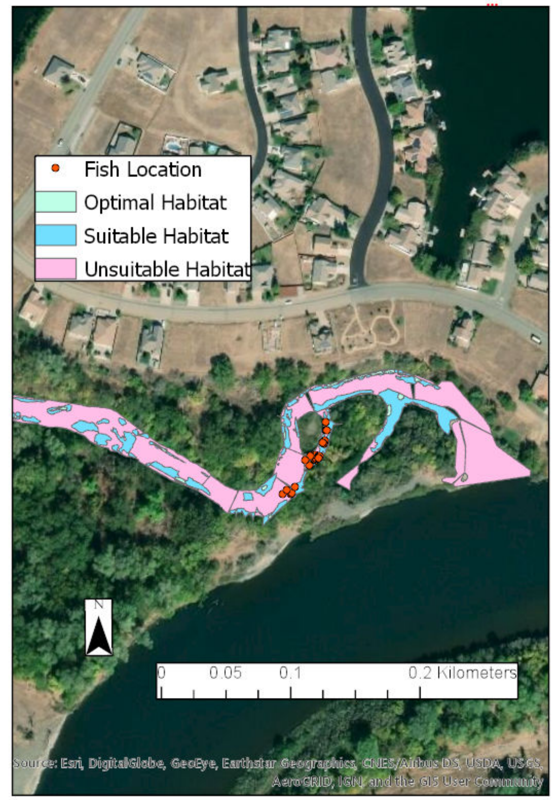
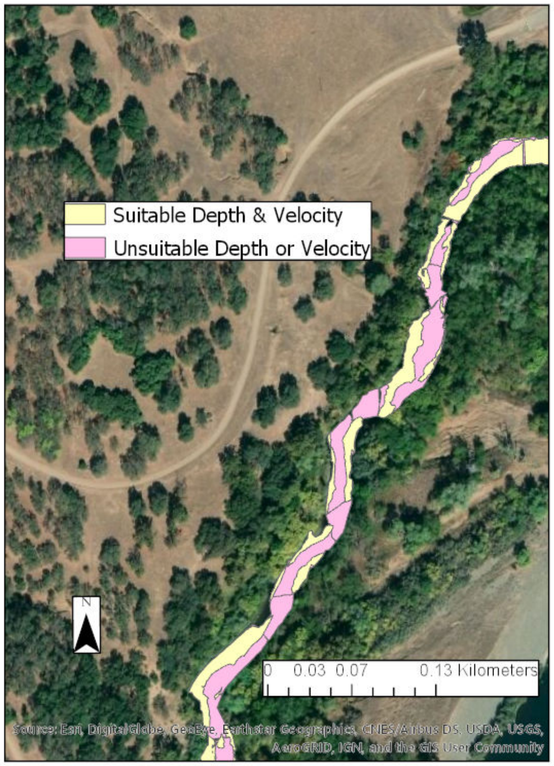


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release: 3,250 CFS

Depth & Velocity Mapping



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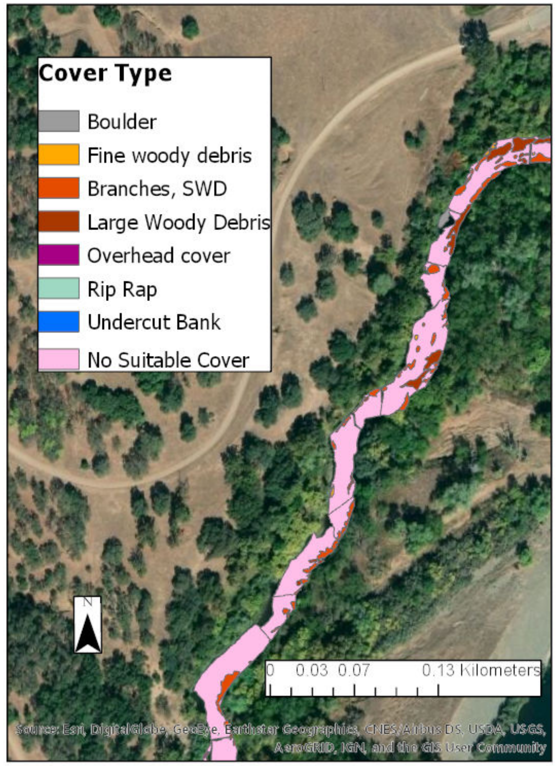
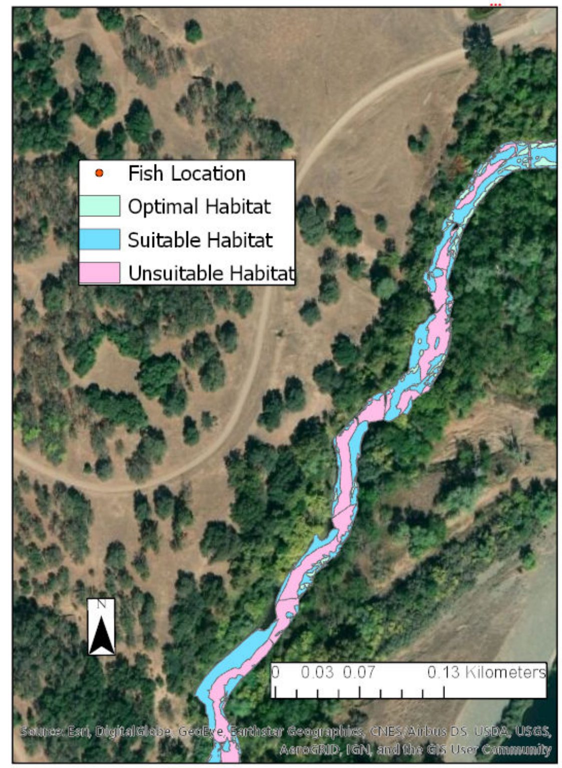
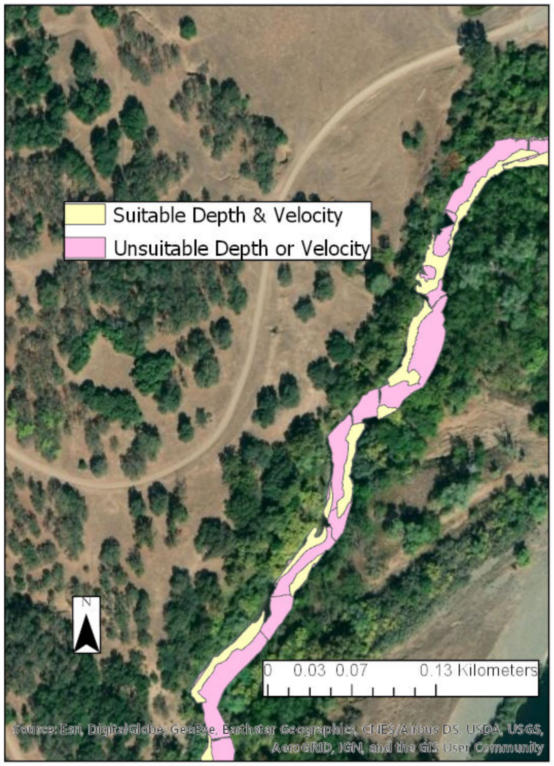


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release: 7,500 CFS

Depth & Velocity Mapping



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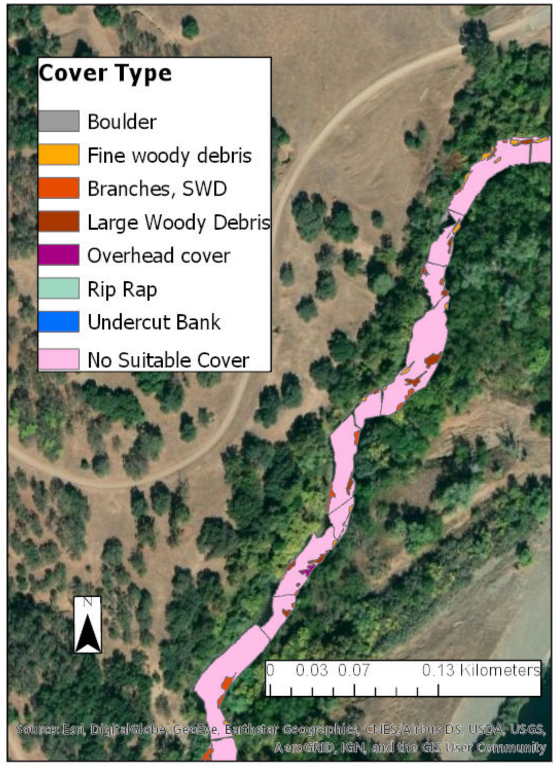
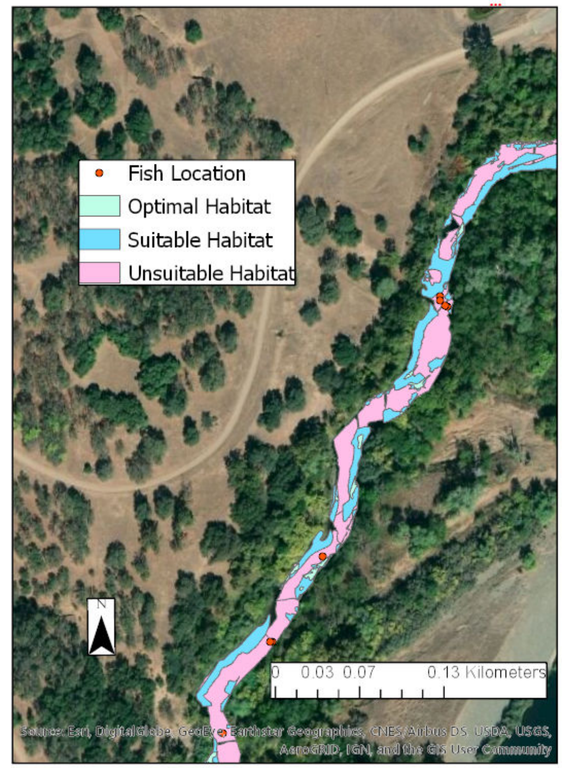
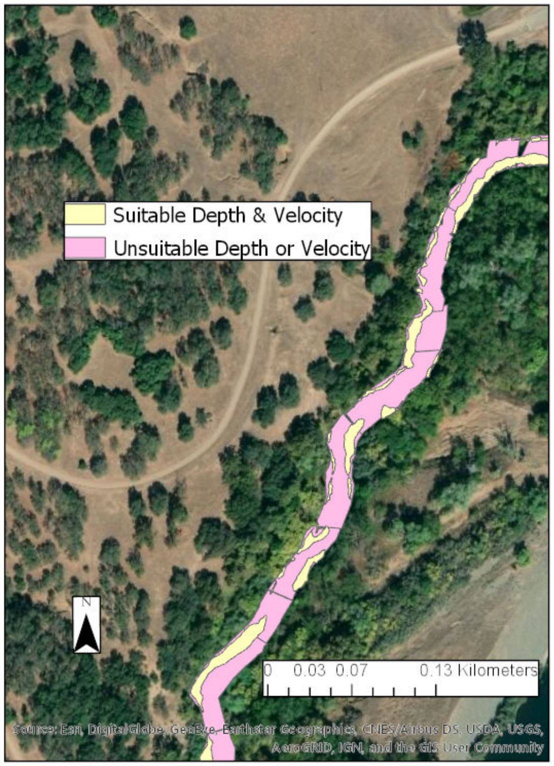


Fish Locations Among Optimal & Suitable Habitat



Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release: 9,000 CFS

Depth & Velocity Mapping



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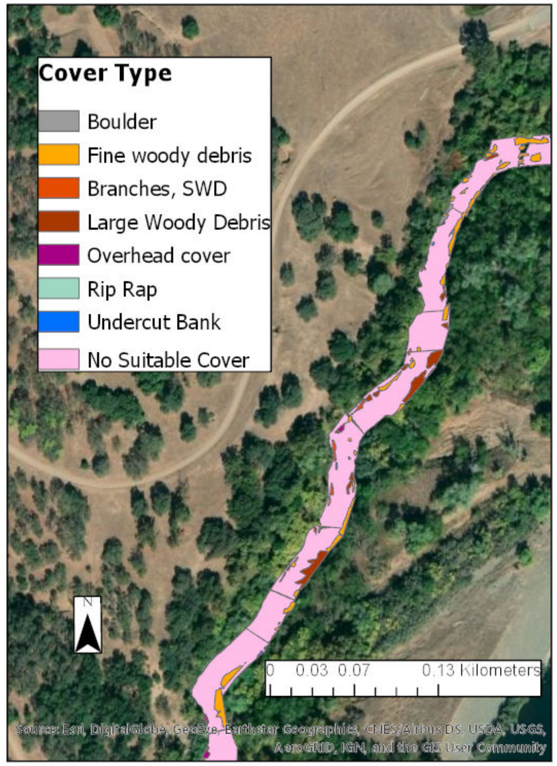
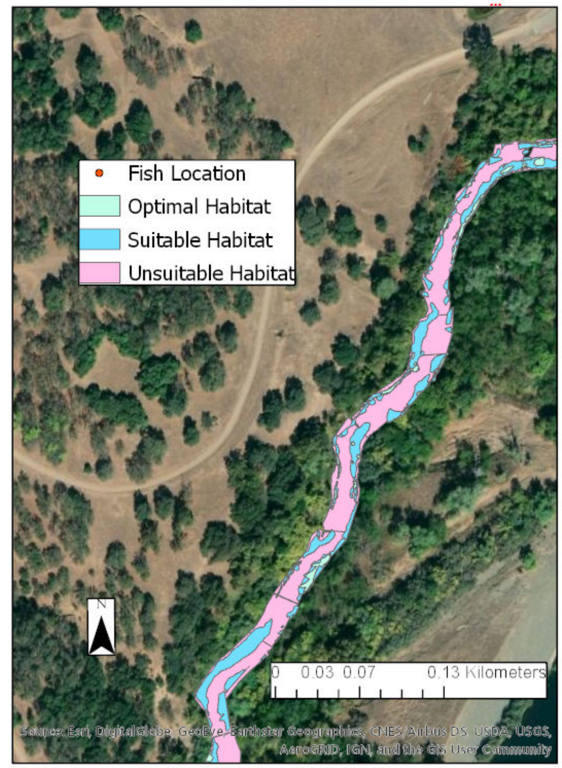
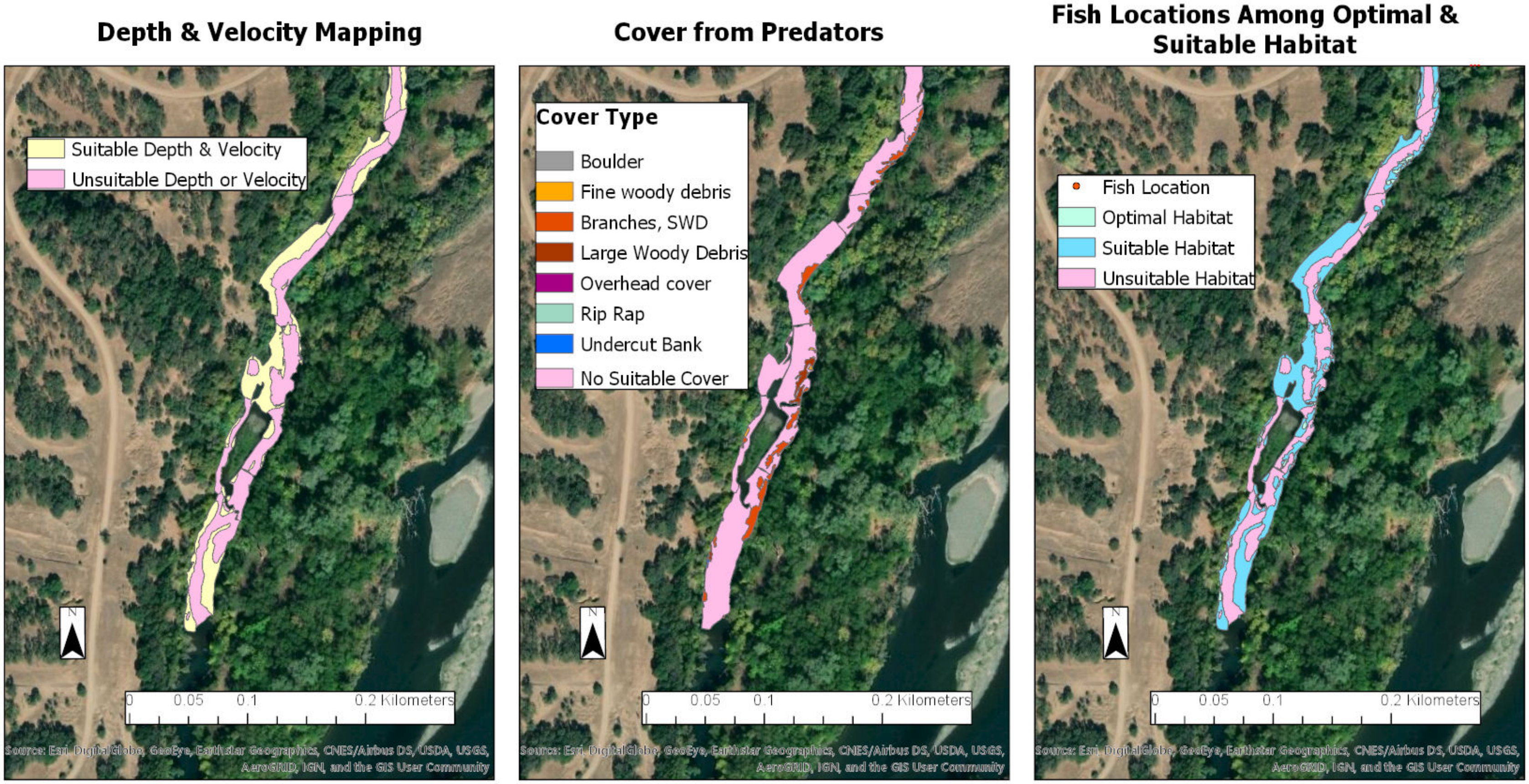


Fish Locations Among Optimal & Suitable Habitat

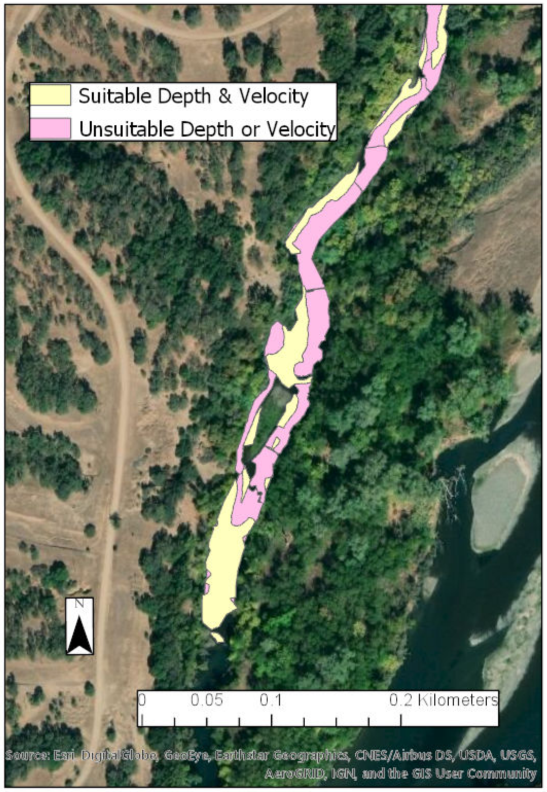


Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release: 3,250 CFS

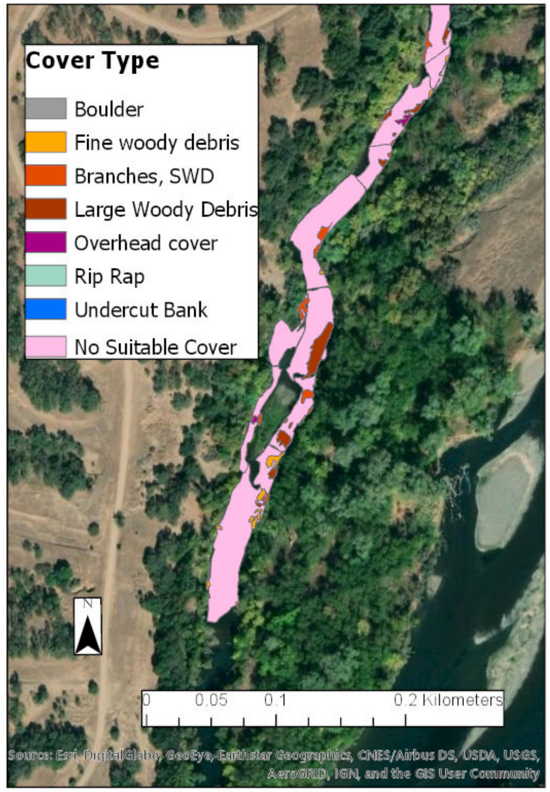


Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release: 7,500 CFS

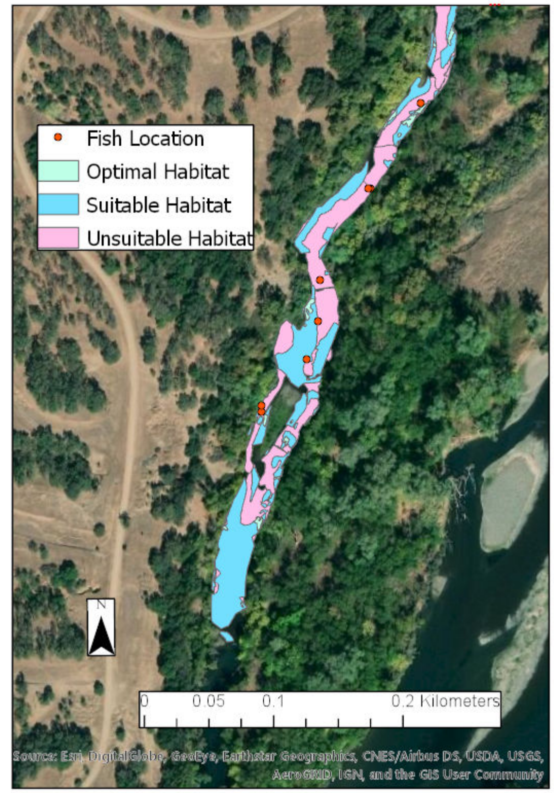
Depth & Velocity Mapping



Cover from Predators

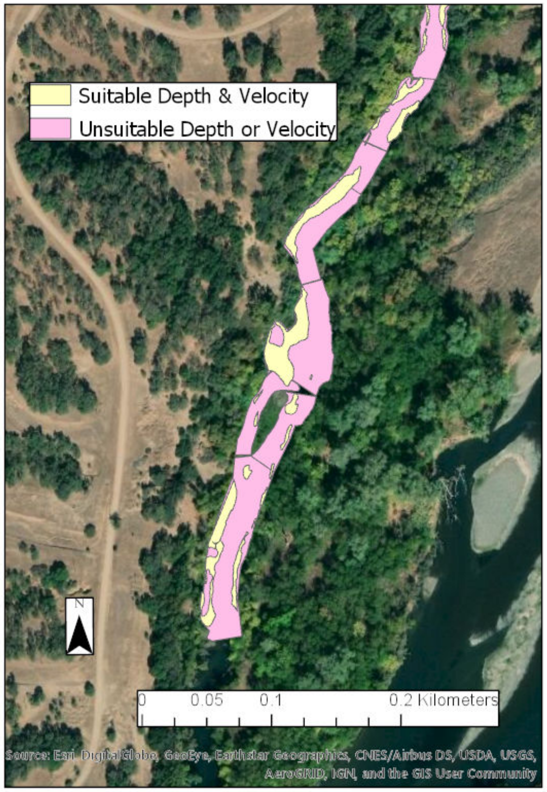


Fish Locations Among Optimal & Suitable Habitat

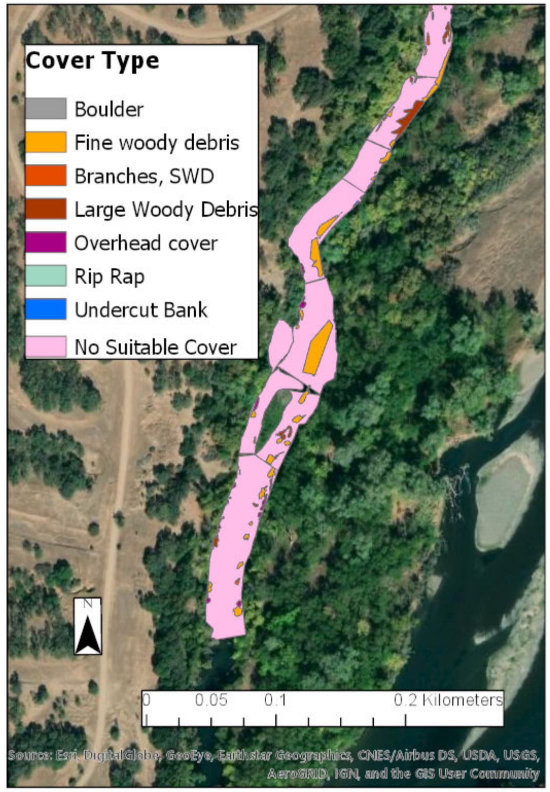


Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release: 9,000 CFS

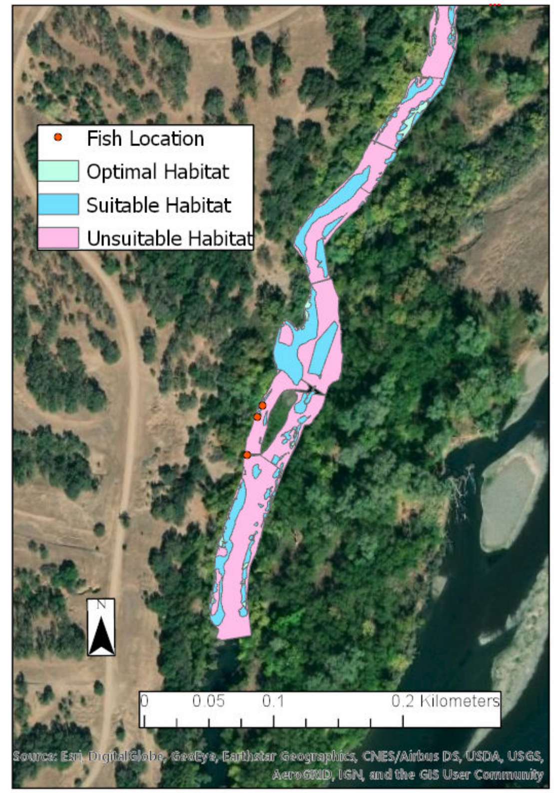
Depth & Velocity Mapping



Cover from Predators



Fish Locations Among Optimal & Suitable Habitat



APPENDIX C. Juvenile Habitat Mapping: Depth, Velocity, and Cover Analyses with Aquatic Vegetation Included

The results described in this section use the same statistical methods described in the main text. They differ from the main text in that aquatic vegetation is included as a cover type. The only difference the inclusion of aquatic vegetation makes in terms of statistical significance is in the linear mixed model that examines the effect of channel status and flow on the amount of optimal habitat. For this model, inclusion of aquatic vegetation changes the effect of flow from significant to not significant. This is because optimal habitat is a composite variable that includes cover, and the presence of aquatic vegetation has a seasonal component that masks the effect of flow.

Habitat Classification	Channel Status	Flow
All Suitable	$F_{1,4.31} = 2.66$ $p = 0.173$	**$F_{1,11.41} = 11.41$** **$p = 0.006$**
All Optimal	$F_{1,4.11} = 1.00$ $p = 0.3719$	$F_{1,11.15} = 1.64$ $p = 0.226$
Suitable + Optimal	$F_{1,4.20} = 2.36$ $p = 0.196$	**$F_{1,11.26} = 11.41$** **$p = 0.006$**
Suitable Depth & Velocity	$F_{1,4.08} = 1.33$ $p = 0.312$	**$F_{1,11.11} = 39.53$** **$p < 0.001$**
Suitable Cover	$F_{1,4.31} = 2.14$ $p = 0.212$	$F_{1,11.41} = 0.04$ $p = 0.838$

Table C1. Linear mixed model analyses of the effects of channel status (restored vs control) and flow from Keswick on the amount of habitat available. Habitat classification criteria are defined in text. Analyses include three restored sites and three control sites, each measured at a range of flows. Details are in main text. P-values were estimated using Kenward-Rogers degrees of freedom.

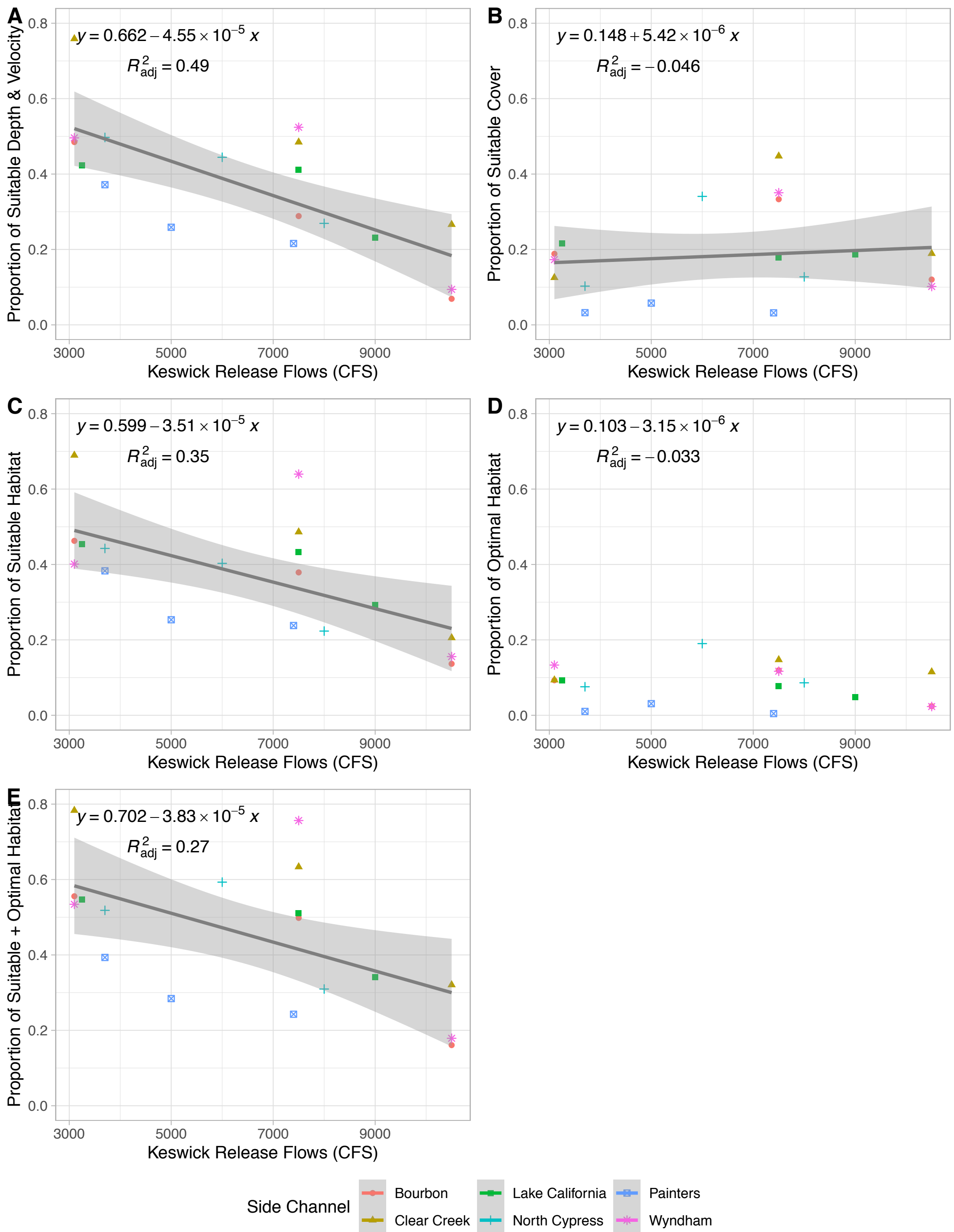


Figure C1. Proportion of habitat that has (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat, (D) optimal habitat, and (E) suitable + optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). All side channels were pooled because channel status (control vs. restored) did not have a significant effect on the proportion of available habitat. Points represent individual sampling days and sites. Shading represents the 95% confidence bands.

Flow (cfs)	Suitable Depth & Velocity	Suitable Habitat	Suitable & Optimal Habitat
3,250	0.530(0.419-0.641)	0.497(0.397-0.596)	0.597(0.469-0.726)
4,000	0.492(0.382-0.601)	0.468(0.380-0.556)	0.564(0.444-0.684)
5,000	0.441(0.332-0.551)	0.429(0.349-0.509)	0.520(0.405-0.635)
6,000	0.391(0.280-0.502)	0.390(0.310- 0.471)	0.475(0.358-0.592)
7,000	0.340(0.229-0.451)	0.351(0.271-0.432)	0.431(0.314-0.548)
8,000	0.290(0.180-0.399)	0.312(0.232-0.393)	0.386(0.271-0.502)
9,000	0.239(0.130-0.349)	0.274(0.186-0.362)	0.342(0.222-0.462)
10,000	0.189(0.076-0.301)	0.235(0.132-0.338)	0.298(0.165-0.430)
11,000	0.138(0.019-0.258)	0.196(0.074-0.317)	0.253(0.102-0.404)

Table C2. Post-hoc analyses showing the estimated proportion of habitat that meets the habitat classification criteria for variables found to have a significant relationship with flow. 95% confidence intervals are shown in parentheses. Estimates are derived from a linear model fit to the data from all six channels. Control and restored side channels were pooled because linear mixed models (described in text) showed that channel status did not significantly affect the proportion of available habitat in any of our analyses.

Attempts to fit a model that allowed predictions of the acres of each habitat classification gained across a range of flows yielded extremely low adjusted R^2 values (not reported) and would not provide reliable predictions. Additional work on the creation of these models will continue as more data is collected. Figure C3 shows the number of acres of habitat that were classified as suitable depth and velocity; suitable cover; suitable habitat; optimal habitat; and suitable plus optimal habitat at each site in the field. In order to visualize the total acres of habitat gained from the three restored sites included in the habitat mapping analyses (Lake California, North Cypress, and Painter's Riffle), we looked at data collected at low and intermediate flows for each restored side channel (Figure C4). Due to logistic constraints during data collection, the range of these flows does not align perfectly with the target ranges set out in the Monitoring Plan. Instead, low flows ranged from 3,250-3,700 cfs, and intermediate flows ranged from 7,400-8,000 cfs. The total acres of suitable habitat deemed suitable or optimal in Lake California, North Cypress, and Painter's Riffle side channels was 5.27 acres at low flows and 5.24 acres at intermediate flows.

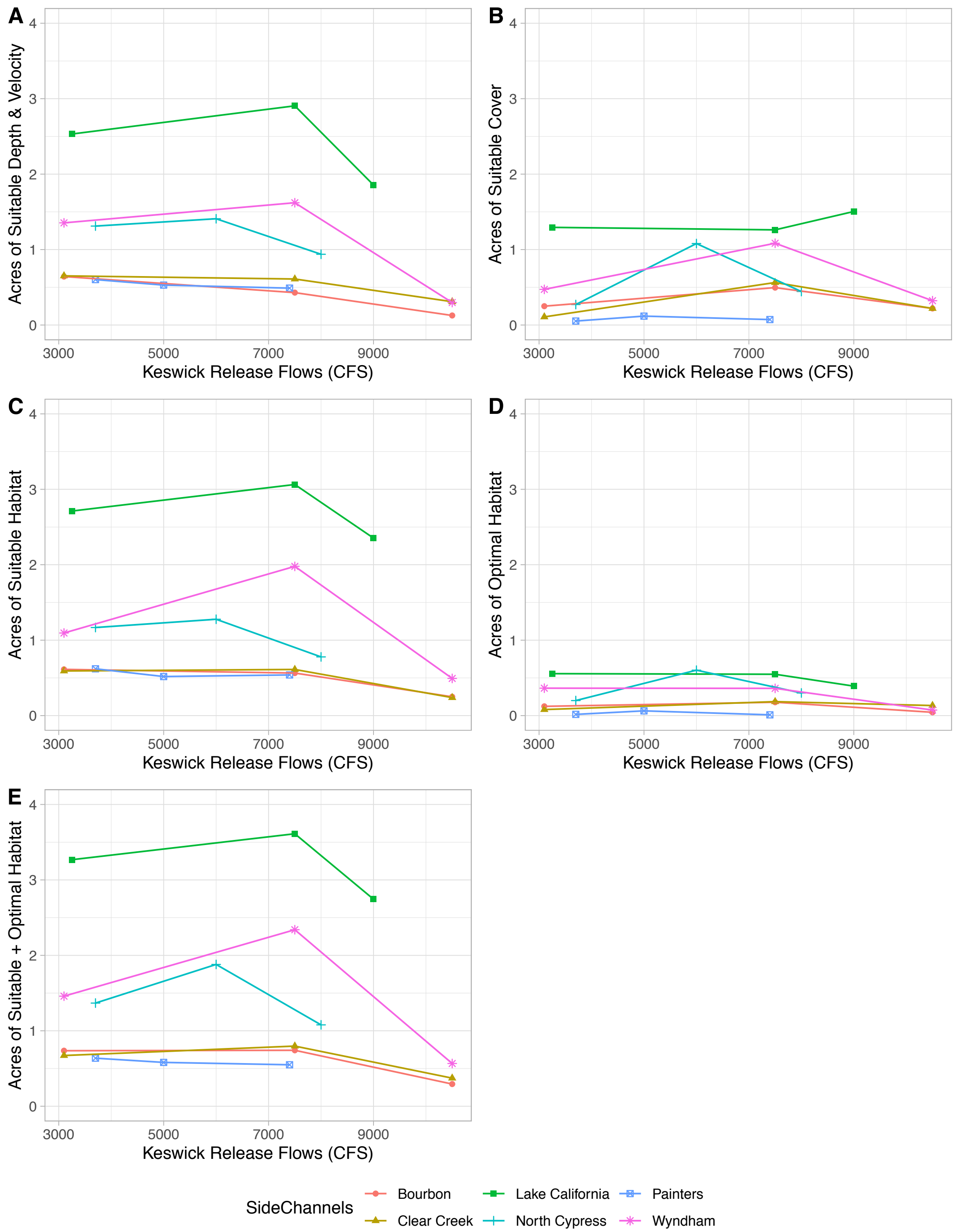


Figure C2. Acres of (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat (D) optimal habitat, and (E) suitable and optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). Points represent individual sampling days and sites.

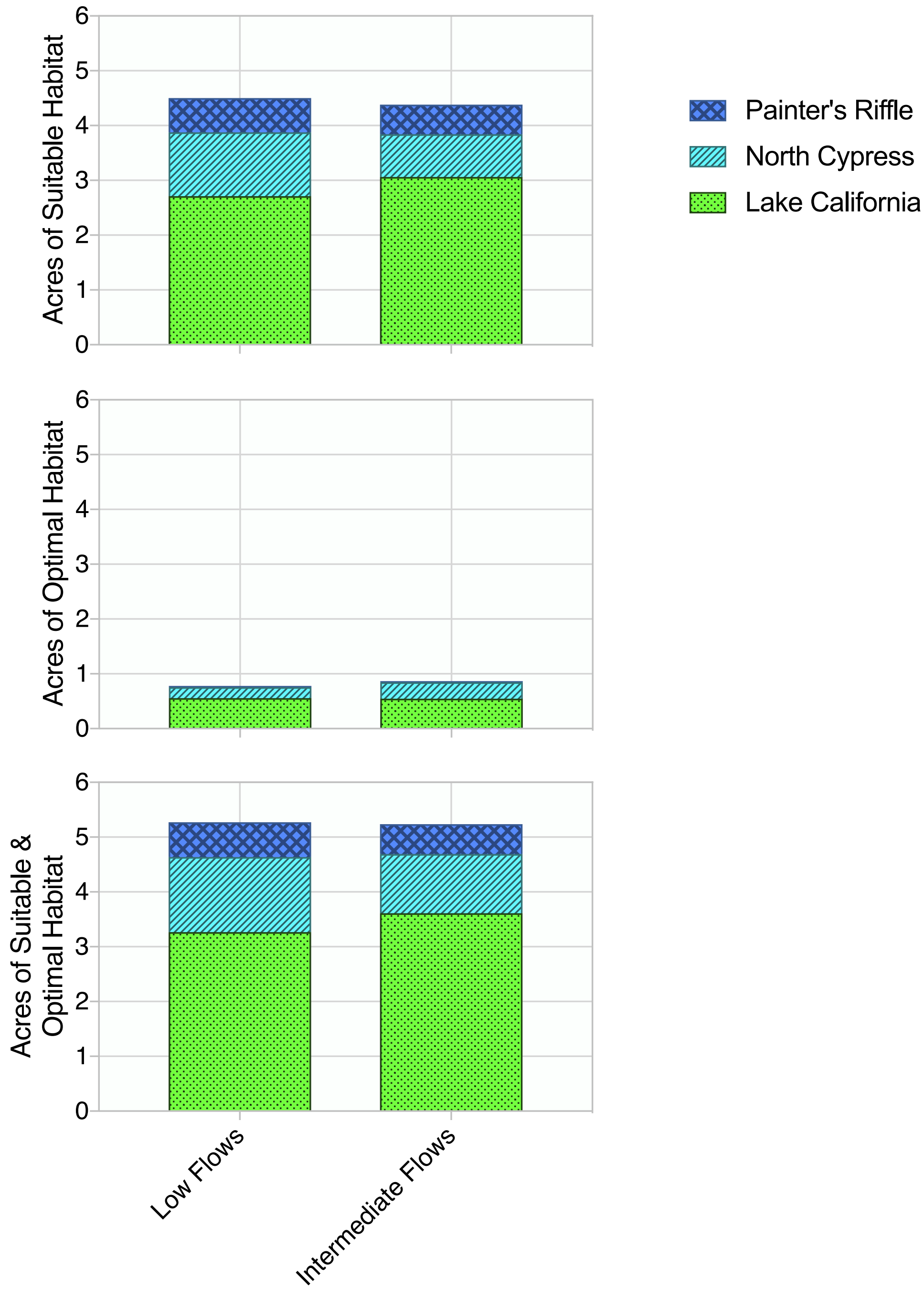


Figure C3. Acres of habitat available in restored sites at high and low flows from three restored sites. Due to logistic constraints during data collection, the range of these flows do not align perfectly with the target ranges set out in the Monitoring Plan. Instead, low flows ranged from 3,250-3,700 cfs, and intermediate flows ranged from 7,400-8,000 cfs.