Salmonid Monitoring of Habitat Restoration Sites in the Upper Sacramento River in 2019-2020

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SUMMARY

The Upper Sacramento River Anadromous Fish Habitat Restoration Project restores spawning and juvenile rearing habitat in the Upper Sacramento River. The project approach assumes that restoring or creating side channels that are connected at a range of flows will recreate the historical biological and geologic characteristics that support salmon populations, leading to increased survival and condition. This report presents data from monitoring efforts from project inception through the end of the 2019-2020 monitoring year (including and adding to data from previous annual reports) and addresses project objectives 2-4: increasing the areal extent of rearing habitat meeting juvenile salmonid rearing habitat suitability criteria; increasing salmonid juvenile abundance/density at restoration sites after implementation, as compared to before implementation; and improving size and average condition of salmonids using the side channels, as compared to those that have not been documented using the side channels.

At the time of reporting, six side channels had been restored between 2014 and December 2019. Control sites near the restorations were chosen from historical side channels, which are thought to be the highest quality habitat nearest the restoration sites. When side channel controls were not available, mainstem controls were chosen from nearby areas that exhibited characteristics that could support juvenile salmon. The monitoring team aimed to collect data from project and control sites before and after restoration. However, due to logistic constraints, before data is limited a subset of data types from the three most recent restorations.

To analyze fish abundance, we first used a BACI (before-after-control-impact) approach to analyze total observed fish number from the restoration sites and their nearby controls that had adequate before data (restoration sites: Anderson River Park, Lake California, and Rio Vista; control sites: Bourbon Island, Mainstem North, and Mainstem South). A zero-inflated linear mixed model showed that restoration sites had a significantly larger increase in observed fish number after restoration, as compared to the controls, indicating a positive effect of the restoration. When broken down by run, this pattern was significant for fall run Chinook salmon and steelhead/rainbow trout. Winter run and late-fall run Chinook salmon showed similar, non-significant trends. We used a similar model to analyze fish density (fish-per-acre) in these same sites. Steelhead/rainbow trout showed a significant increase in density in response to restoration. Fall run Chinook, late-fall run Chinook, winter run Chinook, and all salmonids pooled together showed similar, non-significant trends. We then analyzed the full dataset (including those sites without before data) with a Bayesian approach, using a zero-inflated lognormal mixed effects model. The lack of data taken before restoration makes it more challenging to make decisive conclusions. Fish counts, in particular, are difficult to analyze and interpret without adequate before data for comparison, so our dependent variable in these analyses is estimated fish density (fish-per-acre). The trends for estimated density show that control sites and restored sites are similar, and consistently have more estimated fish than baseline sites. However, due to the large error in the estimates, we cannot statistically detect differences between any of the site types. This inability to distinguish whether the mean estimates between site types differ from one another points to the importance of collecting adequate data before restoration.

Linear mixed models applied to habitat mapping data shows that restored and control sites had similar levels of suitable and optimal habitat (as defined by Goodman et al. 2015). Microhabitat data shows that depth, velocity, and distance-to-cover preferences were similar between Chinook and steelhead/rainbow trout. The majority of fish (80.5%) are found in habitat classified as optimal, followed by suitable (17.5%) and unsuitable (2.5%) habitats. Analysis of variance and Tukey HSD tests showed that juvenile Chinook and steelhead/rainbow trout (>50mm) both preferred some cover types over others; preferences varied slightly, with the most notable preference being for fine woody debris. Fry (</= 50mm) of these same taxa showed no significant discernment between cover types.

Examination of fish size and condition using seining and enclosure studies yielded differing results. Limited data from fish seining only allowed statistical analysis of fall and spring run Chinook fork length. Fall run chinook caught in restored sites had significantly larger fork lengths than fish from control side channels or the mainstem of the Sacramento River. No differences were detected between control side channels and the mainstem sites. Spring run had a much smaller sample size, and no differences in fork length were detected from any of the sites. The enclosure study showed higher growth rates in the mainstem of the river as compared to control and restored side channels. However, these data should be interpreted with extreme caution. Mainstem sites had greater fish loss from the enclosures, either through mortality or escape, than either of the side channel sites. This means that mainstem sites had lower mean densities of fish in each enclosure for a large duration of the study. Growth has been shown to have a strong negative correlation with density, so it is likely that the differences found in this dataset are an artifact of density, rather than site type.

The datasets used in the analyses reported above vary in quality and size. Results obtained from the highest quality datasets all suggest that the Upper Sacramento River Anadromous Fish Habitat Restoration Project has effectively produced additional high quality juvenile salmonid habitat and increased fish numbers in the upper Sacramento River. However, some metrics need additional data collection in order to draw definitive conclusions. For future restorations, we emphasize the need for data collection before restoration occurs, in order to increase our ability to detect differences between sites. Continued monitoring of completed and future restorations will provide additional insight into the effectiveness of side channel restoration, as well as information about how side channel characteristics evolve over time.

INTRODUCTION

Project Overview

Central Valley anadromous salmonid populations have seen dramatic declines in the past century, largely due to anthropogenic habitat alterations (Katz *et al.*, 2013). In the upper Sacramento River, the largest impacts have been attributed to loss of floodplains, riparian habitat, and instream cover; increased competition and predation; and alterations to morphologic function (NMFS, 2014). Historic off-channel habitat has largely been lost due to flood control and associated geologic processes; the Central Valley Project Improvement Act Science Integration model (CVPIA SIT) estimates in-stream habitat to be 26 acres at median flows (8311 cfs), far below the number needed to aid in recovery of threatened and endangered populations of Central Valley salmonids (Gill, n.d.).

The Upper Sacramento River Anadromous Fish Habitat Restoration Project (hereafter, the Project) restores spawning and juvenile rearing habitat in the Upper Sacramento River. The project approach assumes that restoring or creating side channels that are connected at a range of flows will recreate the historical biological and geologic characteristics that support salmon populations, leading to increased survival and condition. The conceptual model underlying this hypothesis, 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.

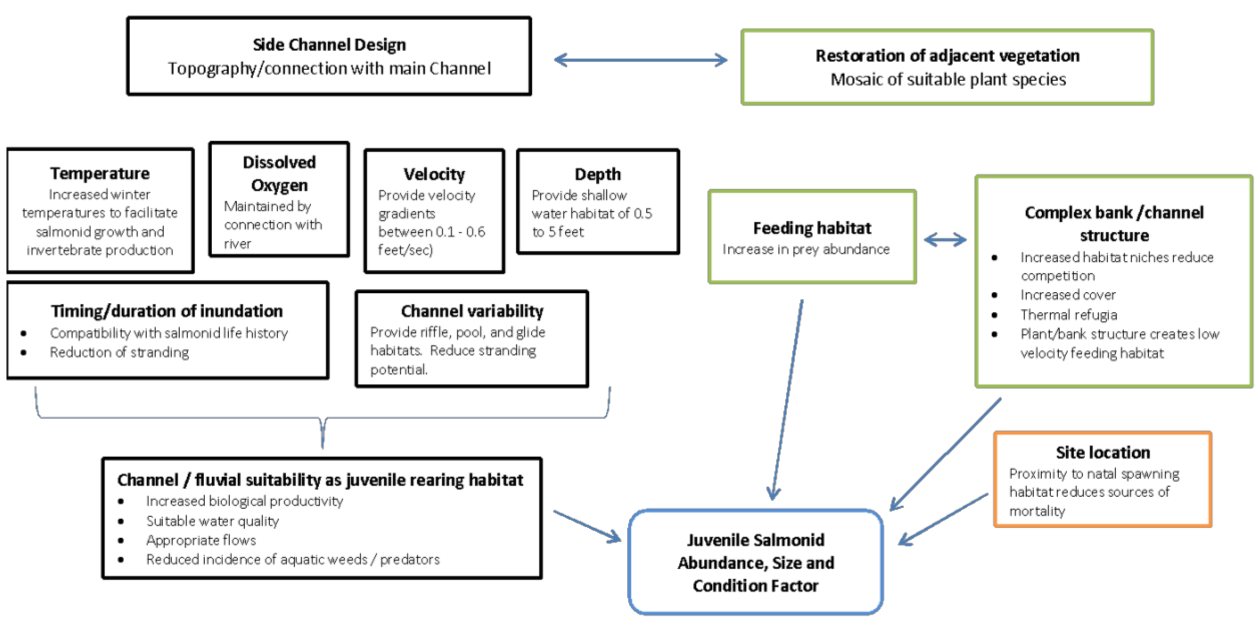

Figure 1. Conceptual model of design-related elements and their influence on biotic and abiotic juvenile salmonid habitat elements, from Banet and Tussing (2017).

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/rainbow 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; to modify field protocols as needed to effectively meet those objectives; to perform preliminary tests of hypotheses as data allows; and, to inform restoration efforts where a biological response to restoration can be established. More extensive analyses 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. This annual report addresses objectives 2, 3, and 4 using data collected between December 2015 and July 2020. Data has been collected for project objectives 1 and 5, but processing and QA/QC for analysis has not yet been completed.

METHODS

The methods described below are derived from the Monitoring Plan (Tussing and Banet, 2017) and the 2018-19 annual report (Banet *et al.*, 2020), with minor modifications made for crew safety concerns, crew availability, and other logistical constraints. Methods that have remained consistent between years may be excerpted from these earlier documents without alteration. 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, either due to logistical constraints, or because many restored sites were not consistently connected to the mainstem prior to restoration.

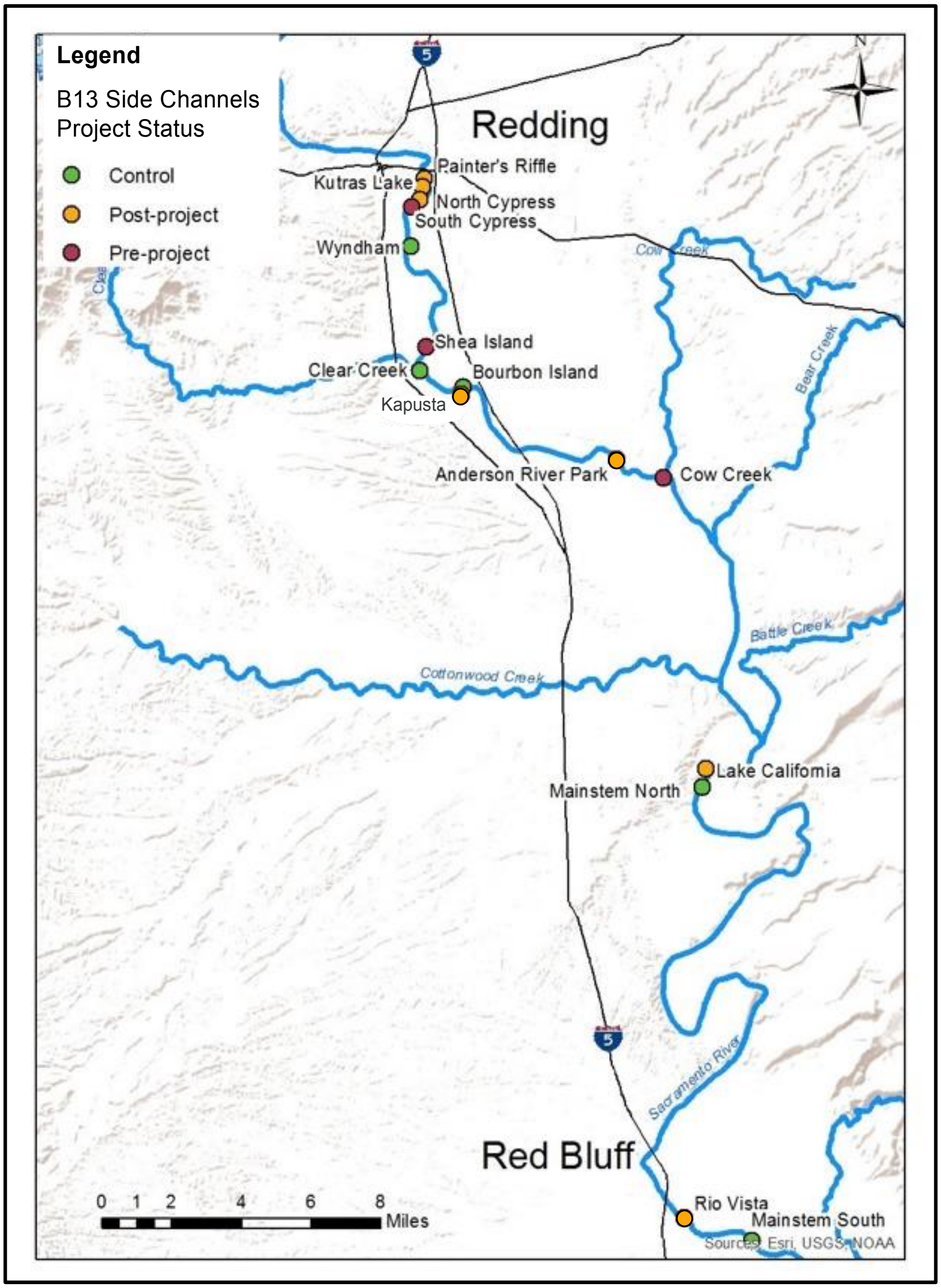

Figure 2. Map of control, pre-project (pre-restoration) and post-project (restored) side channels surveyed as part of the Project.

Table 1. Name, status, and approximate river mile (RM) of Project Sites. Note that Kutras Lake is not a side channel, and is not addressed in this report. Pre-project status refers to project sites that are slated for restoration, but were not restored at the end of this reporting period. Post-project status refers to sites that have been restored. Control status refers to existing habitat that is not scheduled for restoration.

Site Name	Status	Restoration Date(s)	RM
Painter's Riffle	Post-project	2014	296
Kutras Lake	Post-project	May 2017	296
North Cypress	Post-project	December 2016	295.5
South Cypress	Pre-project	N/A	294
Wyndham	Control	N/A	293.5
Shea Island	Pre-project	N/A	290
Clear Creek	Control	N/A	289
Bourbon Island	Control	N/A	287.5
Kapusta	Post-project	May 2018 (Kapusta 1A only)	287.5
Anderson River Park	Post-project	December 2019	282
Cow Creek	Pre-project	N/A	280
Reading Island	Post-project	August 2019 (Phase I) December 2019 (Phase II)	274
Lake California	Post-project	January 2018	269.5
Mainstem North	Control	N/A	268.5
Rio Vista	Post-project	October 2019	247
Mainstem South	Control	N/A	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 (based on estimated depth, velocity, cover, and prior fish observations). When possible, currently functioning side channels with flow year-round 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 Estimates

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 the 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 (SWD)	< 12” Diameter
Log, large woody debris (LWD)	> 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 3, 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 and cover types listed in Tables 3 and 4, 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 3) 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

Seining

Fish size and condition data were 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.

Enclosure study

Enclosure studies were used to examine juvenile growth and diet. Six enclosures were placed in two control side channels, two mainstem sites and two restored side channels, with a total of 36 enclosures. Enclosures from one channel of each type were disturbed, and the data could not be used in the experiment. Analyses were conducted on data from the remaining three sites, shown in Table 5. Twenty juvenile Chinook Salmon were placed into each enclosure (initial fork length: mean 6.47 cm, range 4.8 to 8.4 cm). Factors impacting growth rates such as flow velocity, temperature, and prey abundance, were recorded (Rosenfeld and Taylor, 2009; Scrivener *et al.*, 2011; Tiffan *et al.*, 2014). The enclosures were constructed with 0.6 x 0.6 x 1.2 meter PVC frames with 6.3mm extruded plastic netting attached. This netting allowed for macroinvertebrates and other larval fish to pass through and be eaten by the Chinook salmon yet did not allow study fish to exit. The enclosures were anchored to the riverbed with an arrowhead anchor, and the anchor line was supported by placing cobble on top. Fork length and mass of the salmon were measured weekly to determine growth rates and condition factor. Temperature loggers were attached to each enclosure, monitoring temperature hourly. Each enclosure was placed for roughly 50 days. At the end of the study, fish were euthanized via an overdose of MS222 (Tricaine methanesulfonate) following guidelines from the American Veterinary Medical Association (Leary *et al.*, 2013). Fish stomachs were dissected, and the contents were enumerated and identified to order.

Table 5. Locations used in the enclosure study

Site Name	Habitat Type	NAD 83 UTM E (m)	NAD 83 UTM N (m)
Bourbon Island	Control Side Channel	567042.14	4464344.15
Lake California	Restored Side Channel	567312.23	4466126.05
Lake California Adjacent	Mainstem	567474.62	4465975.12

Data Analysis

Fish Abundance

In an ideal study, we would have data on all restoration sites and nearby controls before and after restoration. This approach allows analysis of the data using a before-after-control-impact (BACI) design, which can be used to disentangle effects of restoration from that of natural variation (Smith, 2014). For our early restorations, logistical constraints prevented us from collecting adequate "before" data to employ a BACI analysis. Previous annual reports focused after-control-impact data, which provides less power to detect differences. This year, for the first time, we have a BACI fish abundance dataset for three restoration and three nearby control sites (Restoration Sites: Anderson River Park, Lake California, Rio Vista, Control sites: Bourbon Island, Mainstem North, Mainstem South), allowing us to employ a BACI analysis. We chose data that overlapped from each control/restoration pair. All surveys from each restored site had a complementary survey taken at its nearby control within a short time frame (typically within two days from one another, but never more than a week). Fish count and fish density data were analyzed using the glmmTBD package in R (R Core Team, 2016), which allows analysis of datasets with large numbers of zeros. A zero-inflated linear mixed model with was used to examine the effects of site classification (restoration/control), restoration timeline (before/after), visibility, and the interaction between site classification and restoration timeline on fish number. Note that restoration timeline applies to both a restoration site and its nearby control; "before" refers to data collected before restoration at both the restoration site and its nearby control, while "after" data refers to data collected after restoration at both a restoration site and its nearby control. Because seasonal variability can affect fish number, we classified the year into quarters (October-December, January-March, April-June, and July-September) and included this as a random effect in the model. Likewise, because geographic location may impact fish number, we paired restoration sites with their nearest control (Anderson River Park with Bourbon Island, Lake California with Mainstem North, and Rio Vista with Mainstem South) and used these pairs as a random effect in the model. We used a type I negative binomial distribution in the model, which had the lowest AIC score of all distributions available in the glmmTBD package (Magnusson *et al.*, 2020). The interaction term in this model (site classification * restoration timeline) is the key output for understanding the effect of restoration. A greater increase in fish number in the restored side channels after restoration, relative to the control sites, would indicate that the restoration was successful in increasing fish numbers.

The full dataset is more challenging to analyze due to lack of before and after data at many of the study sites. Fish counts, in particular, are difficult to analyze and interpret without adequate before data for comparison, so our dependent variable in these analyses is estimated fish density (fish-per-acre). 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. For this dataset, we fit a zero-inflated lognormal mixed effects model. We chose to use Bayesian statistics for this model (as opposed to the frequentist model fit to the BACI data). This is because zero-inflated models are a relatively new approach, and the current software available allows a greater choice of distributions when using Bayesian statistics, which was beneficial for this dataset. We are aware that many readers of this report may be more familiar with the interpretation of frequentist statistics; in the future we will reassess and may switch to a frequentist approach for this dataset as the analysis software becomes more developed.

Bayesian statistics do not produce classical p-values, and as such do not encourage binary decision making. Bayesian statistics instead focuses on inference of trends via means and confidence intervals. These confidence intervals can be used to make similar conclusions if necessary. A lognormal hurdle model was fit to the data. The lognormal distribution is appropriate for data that are, by nature, nonnegative valued, such as fish per acre. The lognormal distribution is more appropriate that the Normal distribution, which allows negative values. A hurdle model is a relatively new feature of models that allows for more observed zeros in the data than otherwise would occur with a lognormal distribution. By statistically modeling the increased number of observed zeros, we allow the model to better fit the data and thus to give a more accurate estimate of the magnitude of effects of the explanatory variables. This model functions like a Normal mixed effects model, despite the change in distribution (from Normal to lognormal), and the modification to account for the increased number of zeros. The fixed effect variables are geographic location, run, year, and channel status (baseline, control, or impact). Geographic location helps account for the fact that northern sites and southern sites might just inherently have more (or less) fish per acre. 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. Accounting for run allows us to make predictions of estimated mean fish per acre for each of the runs. We use year as a fixed effect to act as a proxy for various biological circumstances, relative to either the fish themselves, the river, or both, unique to each year. We include site as a random effect, to account for the fact that we are looking at just a subset of the geographic regions of the Sacramento river which could have been restored or even just measured. We include date as random variable to account for correlation amongst time periods.

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, rather than flow itself.

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.* 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. We used linear mixed effects 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 (Lenth, 2018). 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. We ran an ANOVA that examined whether fish preference was a function of cover type or 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 a significant difference, we performed additional post-hoc pairwise comparisons of 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 - Seining Data

As a preliminary look at fish condition, we examined for length and Fulton's condition factor (Ricker, 1975) from measurements taken on seined fish. Fulton's Condition Factor is represented by the equation:

$$\text{Fulton's Condition Factor} = 10^5 \left(\frac{w}{L^3}\right)$$

where L equals the length of the fish in centimeters and w is the mass of the fish in grams. Data from the 2018-19 reporting year is presented separately from data collected during the 2019-20 reporting year. We used a mixed model to analyze the effect of site type (control side channel, mainstem, and post-restoration side channel) on fork length, with month and year included as nested random effects to account for temporal correlations within the dataset.

Fish Size and Condition – Enclosure Study

We used an Analysis of Variance (ANOVA) to examine whether juvenile salmon growth rates differed among habitat types (control side channels, mainstem, and restored side channels). Tukey's Honest Significance Difference was used to determine the direction of these differences.

RESULTS

Fish Abundance Index

Fish reported below are classified by run using the Central Valley length-to-date chart (Appendix A). In data used in previous reports, we observed a small number of fish (<10) that were classified as spring run based on size. We excluded those observations due to small sample size and uncertainty whether those classifications were correct. More recent data has had larger numbers of fish classified as spring run. Thus, we include spring run in the graphs and analyses below. We caution the reader from drawing strong conclusions for that run, due to the still relatively small sample size and uncertainty surrounding the data.

Fish Abundance in Habitats with Before, After, Control, Impact Data

As described in the methods, the analyses below focus on three restored side channels that have sufficient before/after data (Anderson River Park, Lake California, and Rio Vista), and the three control sites nearest each of those restored channels (Bourbon Island, Mainstem North, and Mainstem South). We first examine total number of observed fish, followed by estimated density of fish-per-acre using observations from 186 snorkel surveys from July 2017 through June 2020. Results of the zero-inflated linear mixed models used for the BACI analyses of total observed fish are shown in Table 6 and Figure 3. The interaction term (site classification * restoration timeline) indicates whether the restoration was successful in increasing fish number. Restoration significantly increased fish number in restored sites relative to control sites when examining all salmonids, fall run Chinook salmon, and steelhead/rainbow trout. Late-fall and winter run Chinook salmon showed similar, non-significant trends. Our limited data on spring run Chinook salmon did not allow a reliable model fit and is thus not included in this analysis. Note that the main effects of site classification and restoration timeline in each model cannot be interpreted directly when the interaction is significant. Note that because the above model includes comparison of paired control and restored sites within the same time frame, variation in escapement across years is accounted for.

Table 6. BACI (before-after-control-impact) analyses of ***fish counts*** *for three restoration sites (Anderson River Park, Lake California, and Rio Vista) and nearby controls (Bourbon Island, Mainstem North, and Mainstem South). Details of the zero-inflated linear mixed models used in these analyses are provided in the methods. Note that the main effects of site classification and restoration timeline in each model cannot be interpreted directly when the interaction is significant. Because the model includes comparison of paired control and restored sites within the same time frame, variation in escapement across years is accounted for.*

Run	**Site Classification**	**Restoration Timeline**	**Visibility**	**Site Classification * Restoration Timeline**
All salmonids	**z = -1.971** **p <0.001**	**z = 3.357** **p <0.001**	**z = 2.034** **p = 0.042**	**z = -2.777** **p = 0.005**
Fall run Chinook	z = 1.347 p = 0.179	**z = 3.287** **p = 0.001**	z = 0.418 p = 0.675	**z = -2.415** **p = 0.016**
Late-fall run Chinook	z = -1.428 p = 0.153	**z = 3.451** **p < 0.001**	**z = 2.139** **p = 0.032**	z = -1.302 p = 0.192
Winter run Chinook	z = -1.794 p = 0.073	**z = 4.527** **p <0.001**	**z = 2.844** **p = 0.004**	z = -1.599 p = 0.110
Steelhead/ rainbow trout	**z = -2.787** **p = 0.005**	z = -0.872 p = 0.383	z = 0.585 p = 0.559	**z = -4.234** **p <0.001**

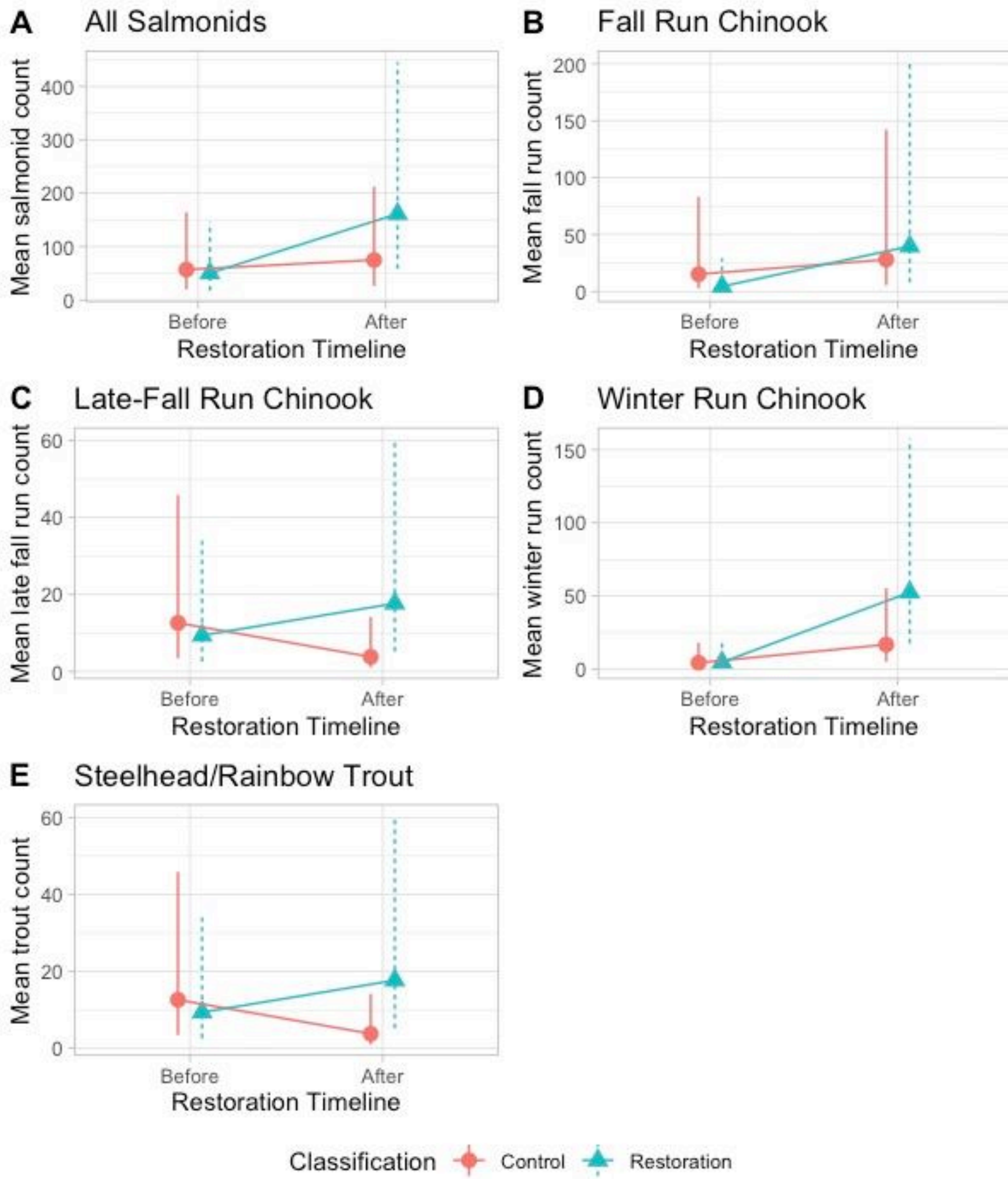

Figure 3. Estimated marginal means of fish count before and after restoration for three restoration sites (Anderson River Park, Lake California, and Rio Vista) and nearby controls (Bourbon Island, Mainstem North, and Mainstem South). A larger slope in restoration sites, as compared to control sites, indicates a positive effect of restoration on fish number. Error bars are 95% confidence intervals. Details of the zero-inflated linear mixed models used to generate this data are provided in the methods. Output from the model is in Table 6.

Results of the zero-inflated linear mixed models used for the BACI analysis of fish-per-acre are shown in Table 7 and Figure 4. The interaction term (site classification * restoration timeline) indicates whether the restoration was successful in increasing fish number. Restoration significantly increased fish number in restored sites relative to control sites when examining all salmonids, fall run Chinook, and Trout. Late-fall and winter run Chinook showed similar, non-significant trends. Our limited data on spring run Chinook salmon did not allow a reliable model fit and is thus not included in this analysis. Note that the main effects of site classification and restoration timeline in each model cannot be interpreted directly when the interaction is significant.

Table 7. BACI (before-after-control-impact) analyses of ***fish densities*** *for three restoration sites (Anderson River Park, Lake California, and Rio Vista) and nearby controls (Bourbon Island, Mainstem North, and Mainstem South). Details of the zero-inflated linear mixed models used in these analyses are provided in the methods. The interaction term (site classification * restoration timeline) indicates whether the restoration was successful in increasing fish number. Note that the main effects of site classification and restoration timeline in each model cannot be interpreted directly when the interaction is significant. Because the model includes comparison of paired control and restored sites within the same time frame, variation in escapement across years is accounted for.*

Run	**Site Classification**	**Restoration Timeline**	**Visibility**	**Site Classification * Restoration Timeline**
All salmonids	z = 0.765 p =0.504	**z = 2.784** **p = 0.005**	z = 0.310 p = 0.757	z = -0.667 p = 0.505
Fall run Chinook	**z = 2.487** **p =0.0129**	**z = 2.981** **p = 0.003**	z = -0.936 p = 0.349	z = -1.407 p = 0.159
Late-fall run Chinook	z = -0.910 p =0.363	**z = 3.141** **p = 0.002**	z = 1.899 p = 0.056	z = -0.716 p = 0.474
Winter run Chinook	z = -0.867 p =0.381	**z = 4.357** **p < 0.001**	**z = 1.980** **p = 0.047**	z = -1.247 p = 0.214
Steelhead/ rainbow trout	z = -1.180 p =0.237	z = -1.492 p = 0.135	z = 0.239 p = 0.811	**z = -3.480** **p < 0.001**

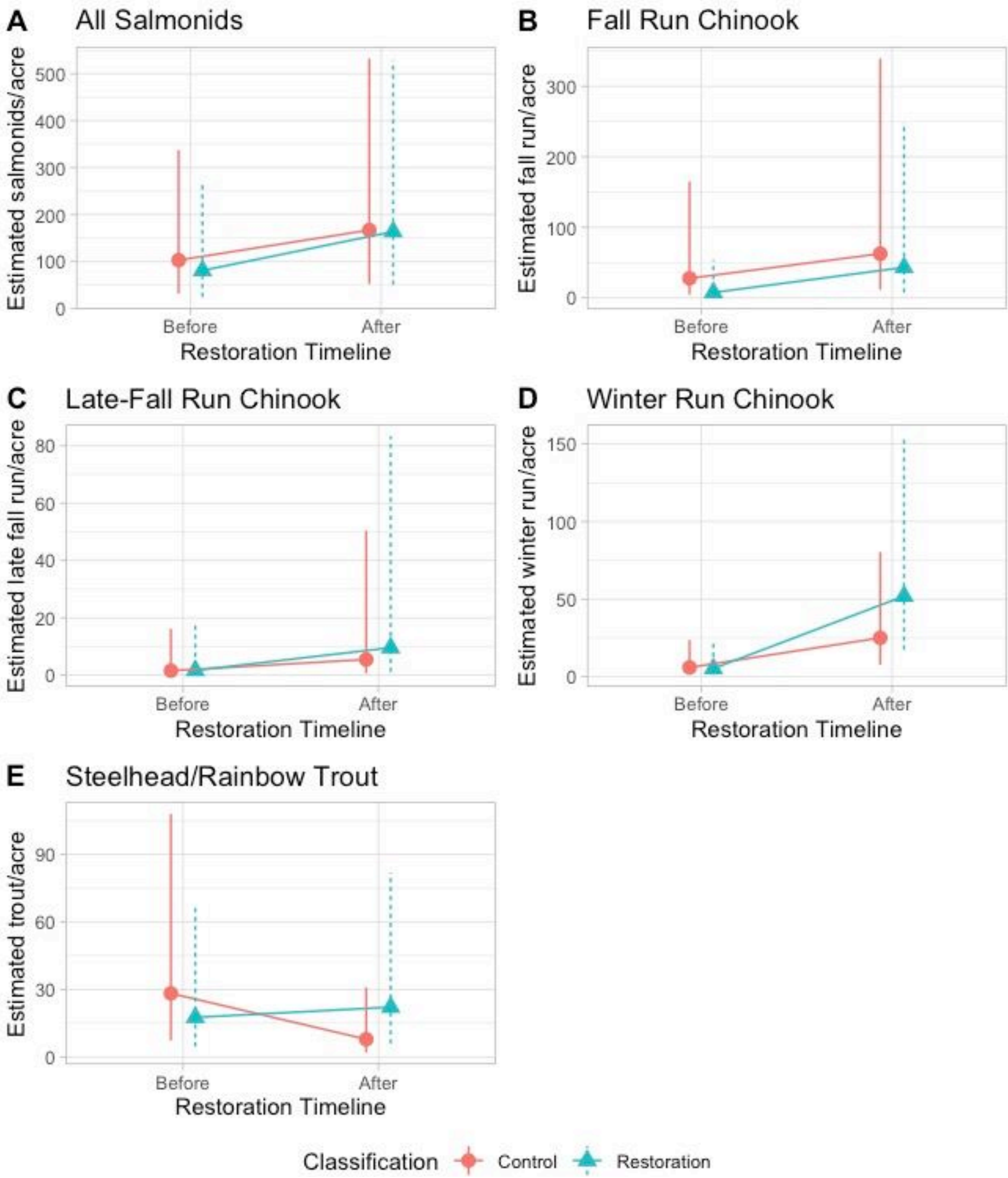

Figure 4. Estimated marginal means of fish-per-acre before and after restoration for three restoration sites (Anderson River Park, Lake California, and Rio Vista) and nearby controls (Bourbon Island, Mainstem North, and Mainstem South). A larger slope in restoration sites, as compared to control sites, indicates a positive effect of restoration on density. Error bars are 95% confidence intervals. Details. of the zero-inflated linear mixed models used to generate this data are provided in the methods. Output from the model is in Table 7.

Fish Density (Using Full Dataset)

We also examined fish density of the full data set, include those sites that did not have before restoration data to include in the BACI analysis. Results of the lognormal hurdle model described in the methods section are presented below. Fixed effects of the model are presented in Table 8. Bayesian analyses do not have p-values, but coefficients can be compared to one another using their confidence intervals. However, the estimates themselves should not be interpreted as the actual value of estimated fish per acre, as is common in Normal models. These predicted fish per acre *do* allow comparison in order to judge the effects of interest. Information extracted from this model are presented Figures 5-10 and Tables 9-15.

Table 8. Fixed effects of the lognormal hurdle model that were used to examine fish density. Comparisons of interest are broken out in Table 9-15 and Figures 5-10, below.

	Estimate	Est. Error	Lower 95% CI	Upper 95% CI	R hat	Bulk effective sample size	Tail effective sample size
Group-level effects							
Site name	0.85	0.20	0.54	1.31	1.00	1029	2057
Channel status	3.34	3.06	0.11	11.09	1.00	1344	1639
Channel status * Date	0.65	0.07	0.51	0.78	1.00	1316	1920
Population-level effects							
Intercept	1.87	4.44	-8.95	10.23	1.0	1442	1161
Year 2016	0.95	0.98	-0.97	2.82	1.00	973	1202
Year 2017	0.94	0.97	-0.97	2.80	1.00	927	1261
Year 2018	0.99	0.97	-0.96	2.86	1.00	932	1294
Year 2019	1.51	0.98	-0.47	3.41	1.00	938	1238
Year 2020	1.34	0.97	-0.63	3.22	1.00	940	1322
Location	1.80	0.48	0.89	2.74	1.00	1311	2056
Late-fall run Chinook	-1.45	0.28	-2.01	-0.91	1.00	2031	2791
Spring run Chinook	-0.68	0.30	-1.26	-0.08	1.00	2655	2843
Steelhead/rainbow trout	-1.23	0.23	-1.66	-0.80	1.00	2009	2902
Winter run Chinook	-0.54	0.25	-1.01	-0.04	1.00	2018	2621
Control	-1.05	6.17	-14.98	11.26	1.00	1607	1218
Impact	-1.32	5.95	-15.12	11.25	1.00	1462	1115
Location * Late-fall run Chinook	-0.46	0.33	-1.10	0.18	1.00	2158	2688
Location * Spring run Chinook	-0.88	0.41	-1.67	-0.09	1.00	2880	2655
Location * Steelhead/rainbow trout	0.27	0.27	-0.26	0.79	1.00	1895	3147
Location * Winter Run	-1.13	0.30	-1.73	-0.54	1.00	1755	2565
Family Specific Parameters							
sigma	1.62	0.04	1.55	1.69	1.00	2673	2694
hu	0.62	0.01	0.61	0.64	1.00	5479	2723

Table 9. Note that baseline and impact data are not available for all restoration sites. Some only have data for one of those categories, which reduces our power to detect differences between treatments. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences in fish density between treatments.

Site Type	**Mean**	**Lower 95% CI**	**Upper 95% CI**
Baseline	30.6	3.55	935
Control	59.5	6.97	564
Impact	57.5	3.25	768

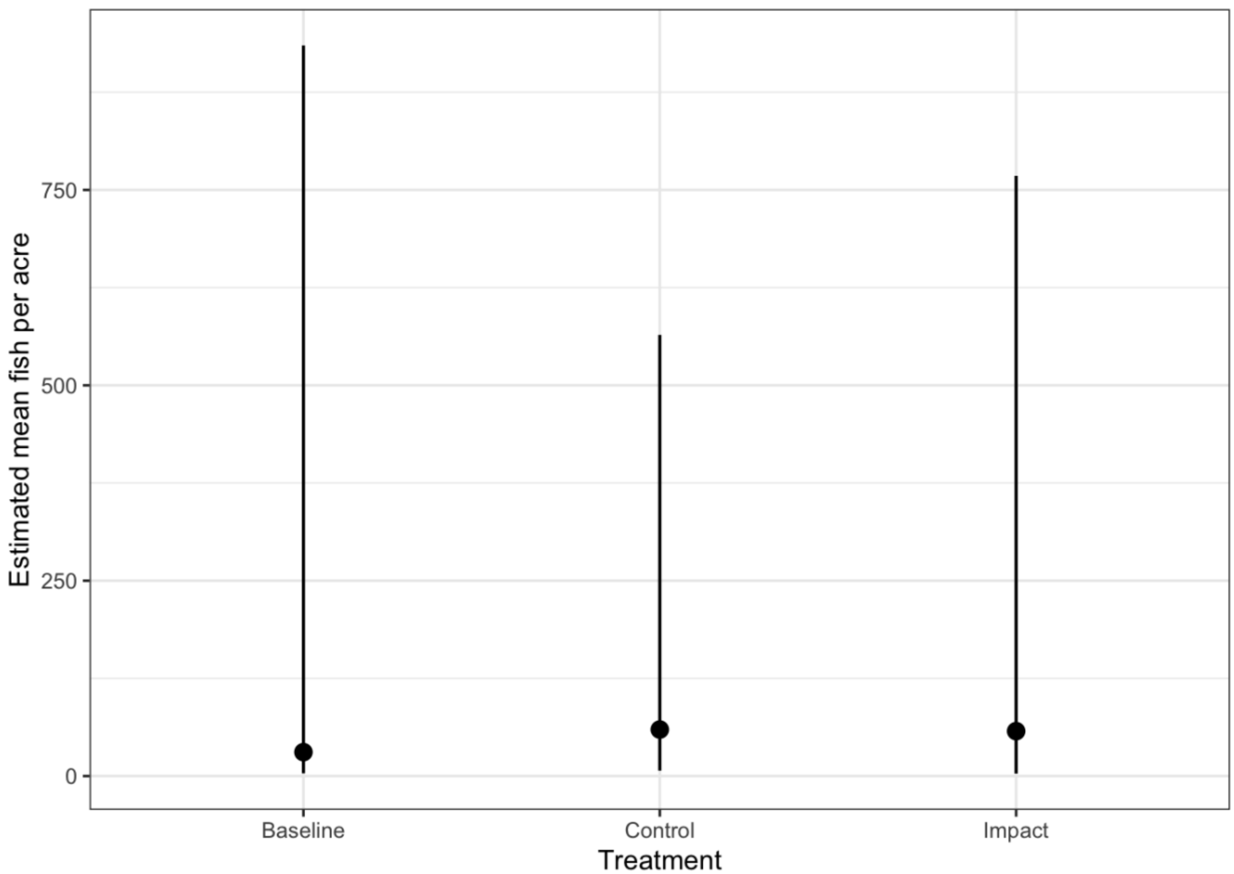

Figure 5. Estimated mean fish per acre for baseline, control, and impact sites. Note that baseline and impact data are not available for all restoration sites. Some only have data for one of those categories, which reduces our power to detect differences between treatments. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences in fish density between treatments.

Table 10. Comparison of baseline data and impact data to control sites. Note that baseline and impact data are not available for all restoration sites. Some only have data for one of those categories, which reduces our power to detect differences between treatments. The confidence intervals below show strong overlap with zero, suggesting that the mean fish per acre in restored sites, relative to control, is not obviously different from the mean fish per acre in baseline sites relative to control.

Comparison	Estimate	Est. Error	Lower 95% CI	Upper 95% CI
Impact - Control	-0.27	5.86	-12.89	12.52
Baseline - Control	2.91	9.94	-18.66	23.94

Table 11. Estimated mean fish per acre for baseline, control, and impact sites, reported by run. Note that baseline and impact data are not available for all restoration sites. Some only have data for one of those categories, which reduces our power to detect differences between treatments. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences in fish density between treatments.

	Mean	Lower 95% CI	Upper 95% CI
Fall run Chinook			
Baseline	75.2	11.4	2709
Control	214	19.5	986
Impact	221	9.04	1464
Late-fall run Chinook			
Baseline	15.2	2.41	409
Control	33.3	4.43	148
Impact	33.4	2.07	218
Spring run Chinook			
Baseline	29.4	4.08	609
Control	50.5	8.75	226
Impact	49.1	4.37	324
Steelhead/ rainbow trout			
Baseline	24.1	3.51	1038
Control	80.6	5.76	376
Impact	84.4	2.65	558
Winter run Chinook			
Baseline	31.8	4.21	562
Control	47.8	9.86	196
Impact	46.3	5.21	278

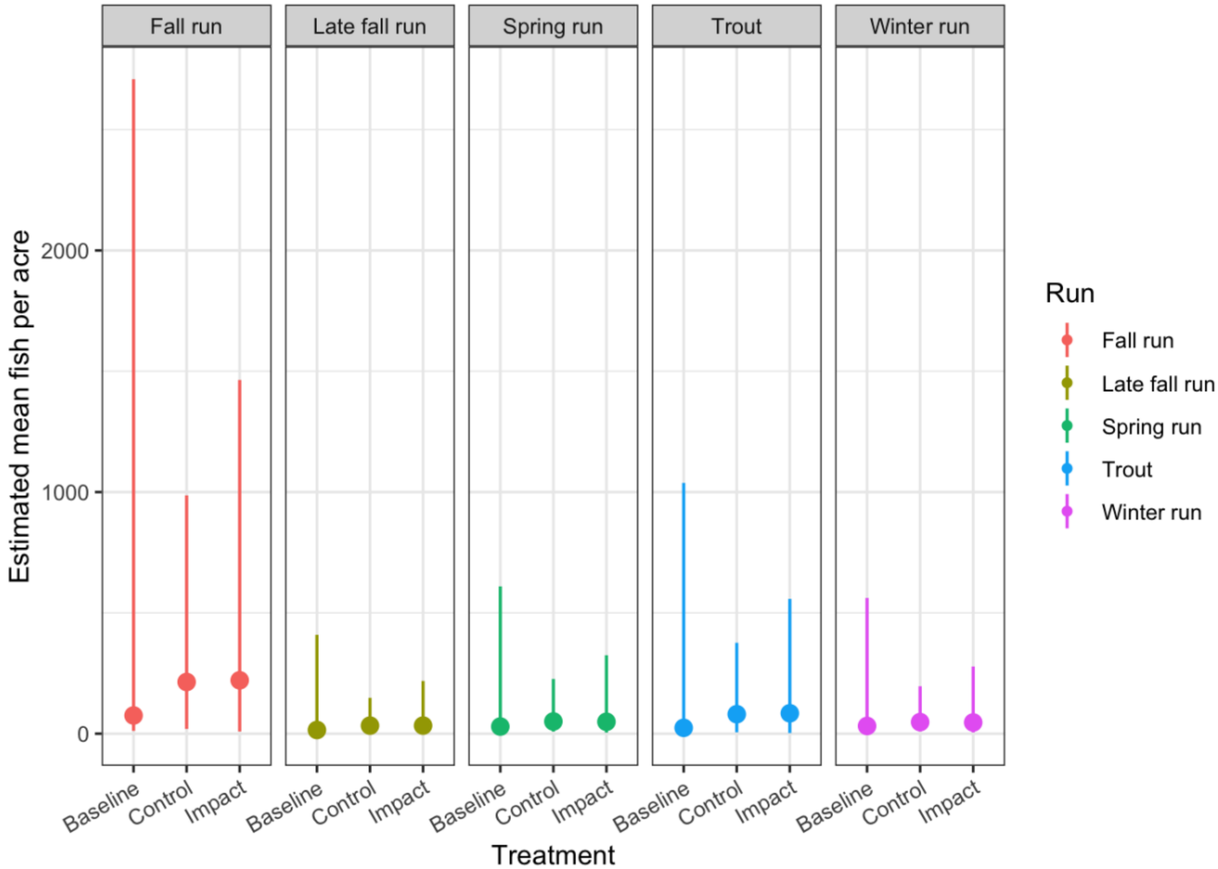

Figure 6. Estimated mean fish per acre for baseline, control, and impact sites, reported by run. Note that baseline and impact data are not available for all restoration sites. Some only have data for one of those categories, which reduces our power to detect differences between treatments. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences in fish density between treatments. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

Table 12. Estimated mean fish per acre in sites classified as northern (above RM 287) and southern (below RM 287). While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between northern and southern sites.

Site Type	Mean	Lower 95% CI	Upper 95% CI
Southern	22.1	2.84	206
Northern	80.8	8.87	859

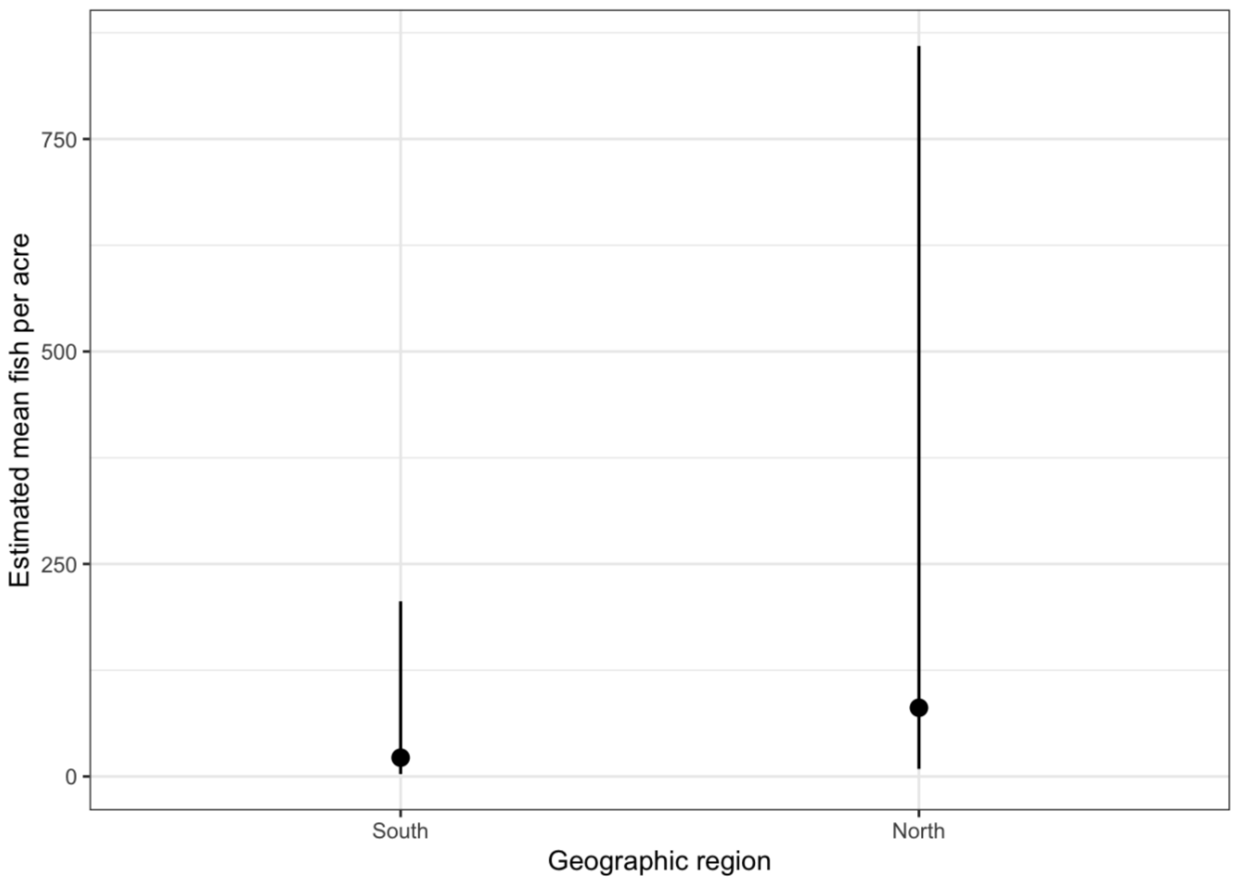

Figure 7. Estimated mean fish per acre in sites classified as northern (above RM 287) and southern (below RM 287). While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between northern and southern sites.

Table 13. Estimated mean fish per acre in sites classified as northern (above RM 287) and southern (below RM 287), reported by run. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between northern and southern sites.

	Mean	Lower 95% CI	Upper 95% CI
Fall run Chinook			
Southern	48.2	8.14	350
Northern	295	39.6	1743
Late-fall run Chinook			
Southern	11.3	1.87	84.4
Northern	43.7	5.85	260
Spring run Chinook			
Southern	24.6	3.92	186
Northern	62.0	8.01	385
Steelhead/rainbow trout			
Southern	14.1	2.41	103
Northern	113	15.2	664
Winter run Chinook			
Southern	28.1	4.72	207
Northern	55.7	7.47	331

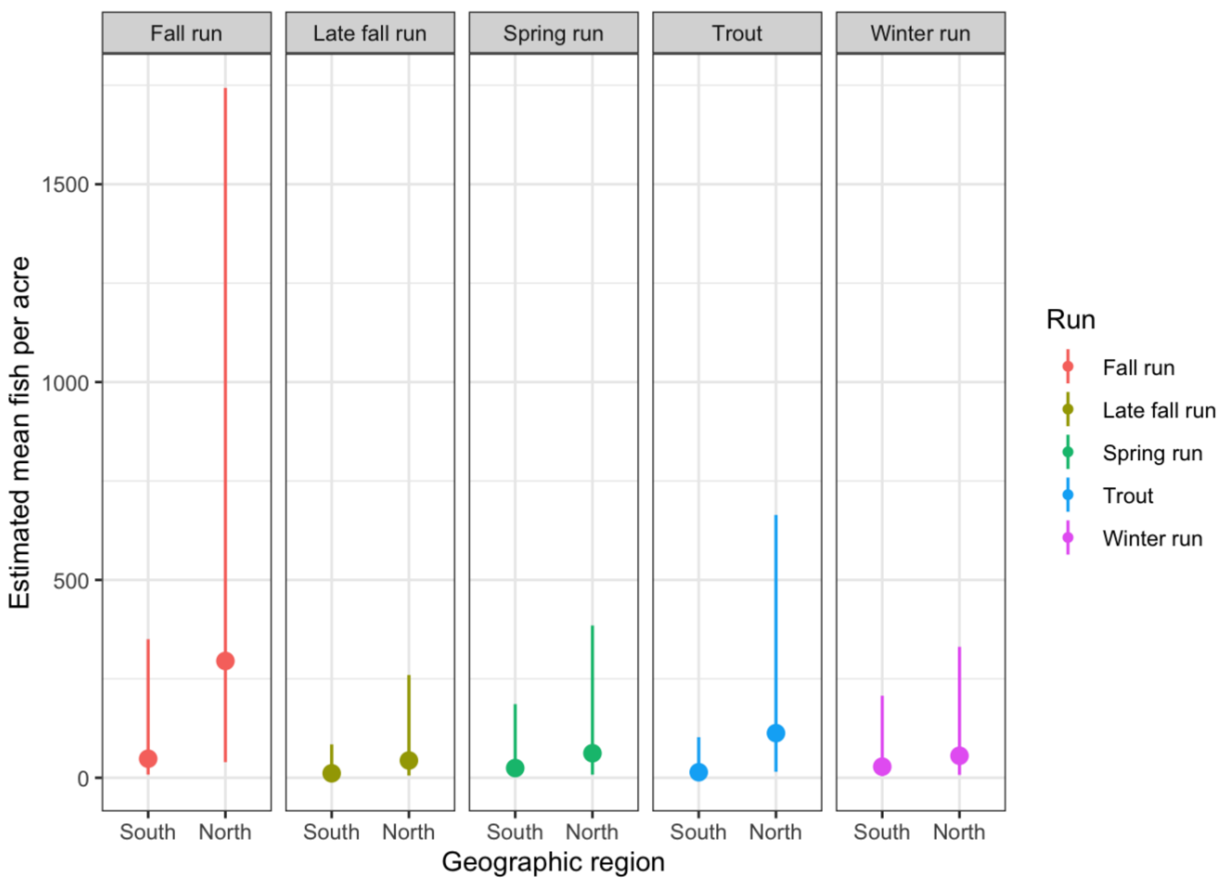

Figure 8. Estimated mean fish per acre in sites classified as northern (above RM 287) and southern (below RM 287), reported by run. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between northern and southern sites. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

Table 14. Estimated mean fish per acre across calendar years of the monitoring program. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between in fish density between years.

Year	**Mean**	**Lower 95% CI**	**Upper 95% CI**
2015	27.2	3.26	298
2016	61.2	6.37	588
2017	45.3	4.05	562
2018	45.7	3.74	575
2019	64.7	5.21	786
2020	58.4	4.19	959

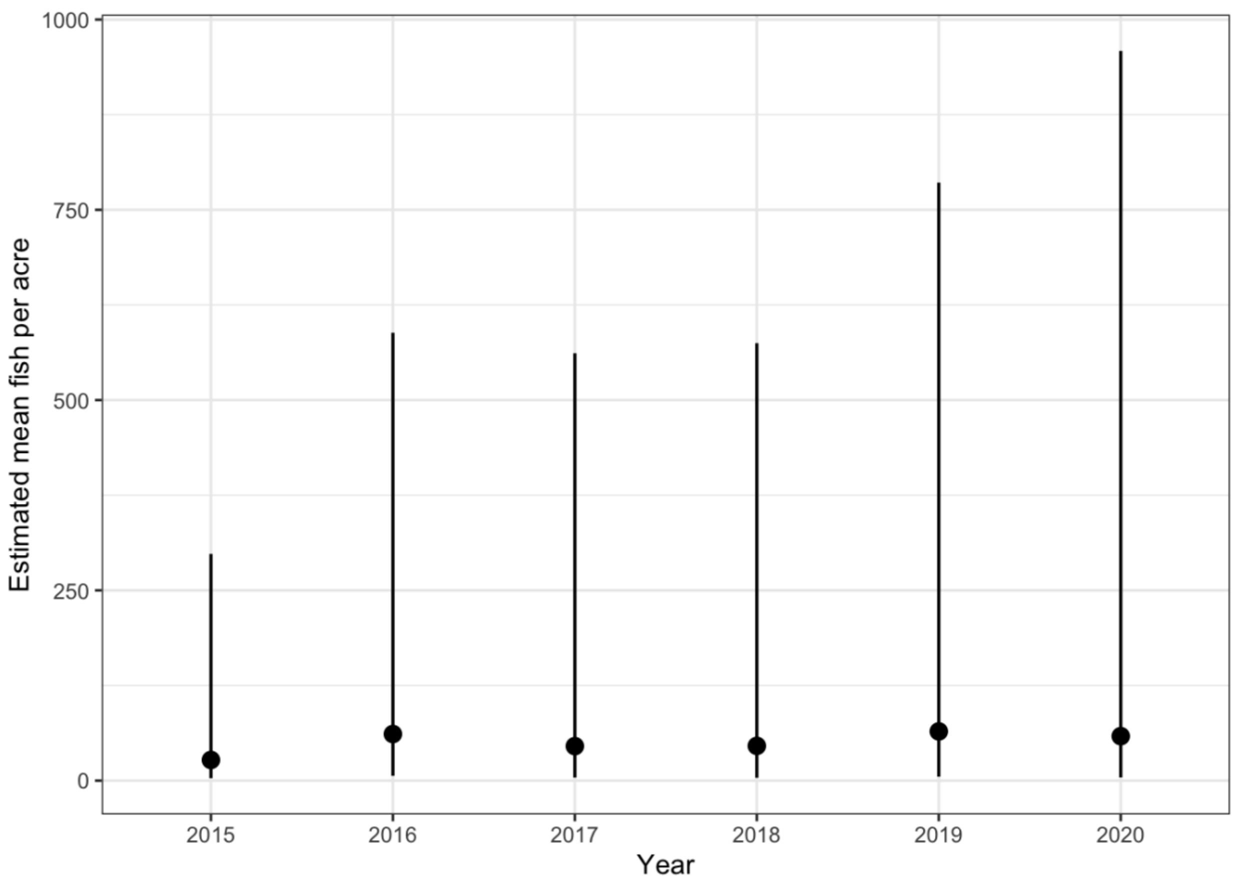

Figure 9. Estimated mean fish per acre across calendar years of the monitoring program. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between in fish density between years.

Table 15. Estimated mean juvenile fish per acre across calendar years of the monitoring program, reported by run. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between in fish density between years. Preliminary numbers of successful female spawners for winter run Chinook salmon are included courtesy Doug Killam, CDFW.

Year	**Mean Number of Juveniles**	**Lower 95% CI**	**Upper 95% CI**	**Number of Successful Female Spawners**
Fall run Chinook				
2015	96.9	15.3	594	
2016	225	20.2	1031	
2017	159	12.1	1063	
2018	154	10.7	1131	
2019	213	14.0	1518	
2020	166	11.6	2235	
Late-fall run Chinook				
2015	14.5	2.24	86.1	
2016	33.6	4.06	154	
2017	25.3	2.66	157	
2018	25.5	2.42	169	
2019	35.9	3.23	227	
2020	31.4	2.63	341	
Spring run Chinook				
2015	20.3	3.05	129	
2016	48.5	6.84	235	
25.5	39.5	4.95	237	
2018	40.5	4.71	254	
2019	57.9	6.56	345	
2020	54.6	5.41	514	
Steelhead/rainbow trout				
2015	37.4	5.92	223	
2016	86.0	6.25	391	
2017	60.0	3.69	400	
2018	56.1	3.18	432	
2019	77.0	4.14	580	
2020	55.3	3.41	855	
Winter Run Chinook				
2015	18.3	2.93	109	2022
2016	44.2	7.06	200	653
2017	38.4	5.45	202	367
2018	39.5	5.29	221	1080
2019	56.7	7.63	298	4884
2020	55.4	6.12	476	2904

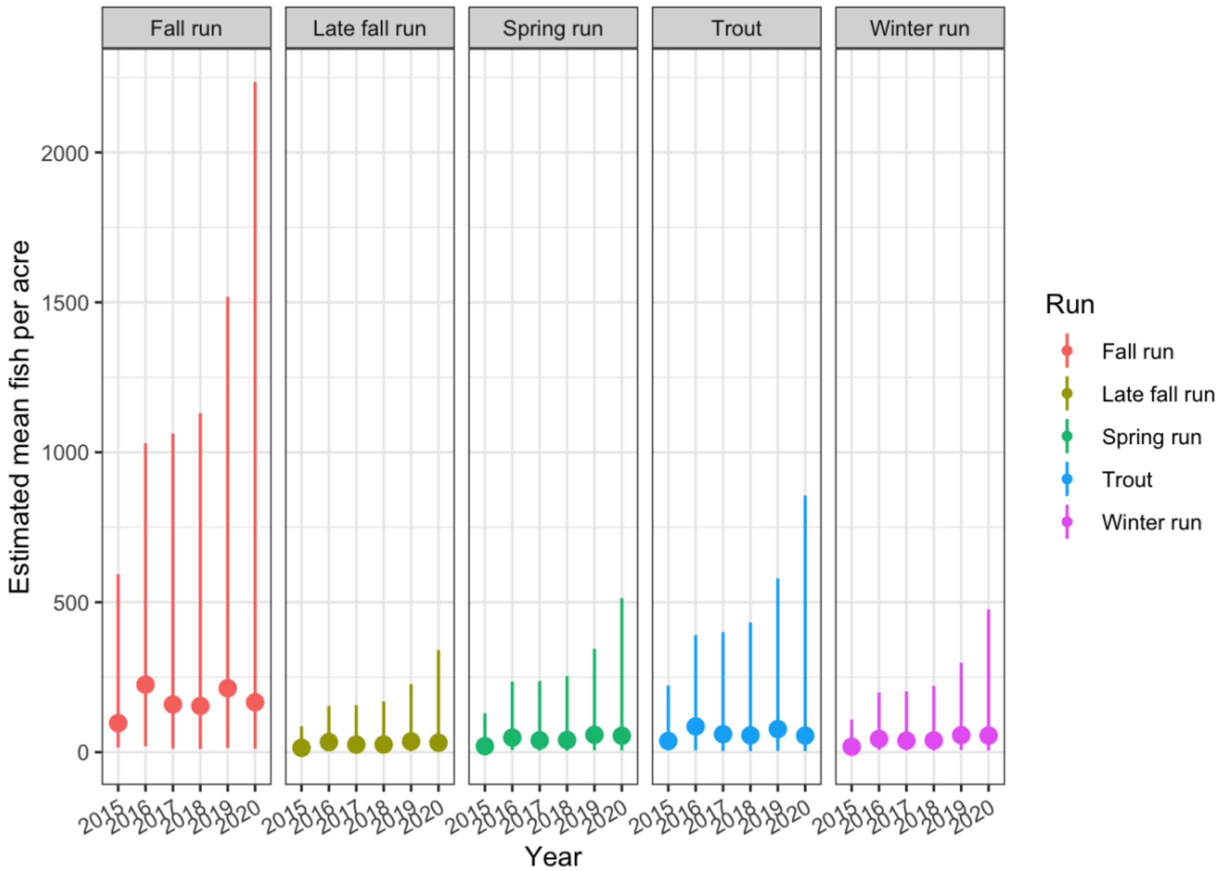

Figure 10. Estimated mean fish per acre across calendar years of the monitoring program, reported by run. While means differ, the large 95% confidence intervals do not allow us to conclude that there are differences between in fish density between years. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

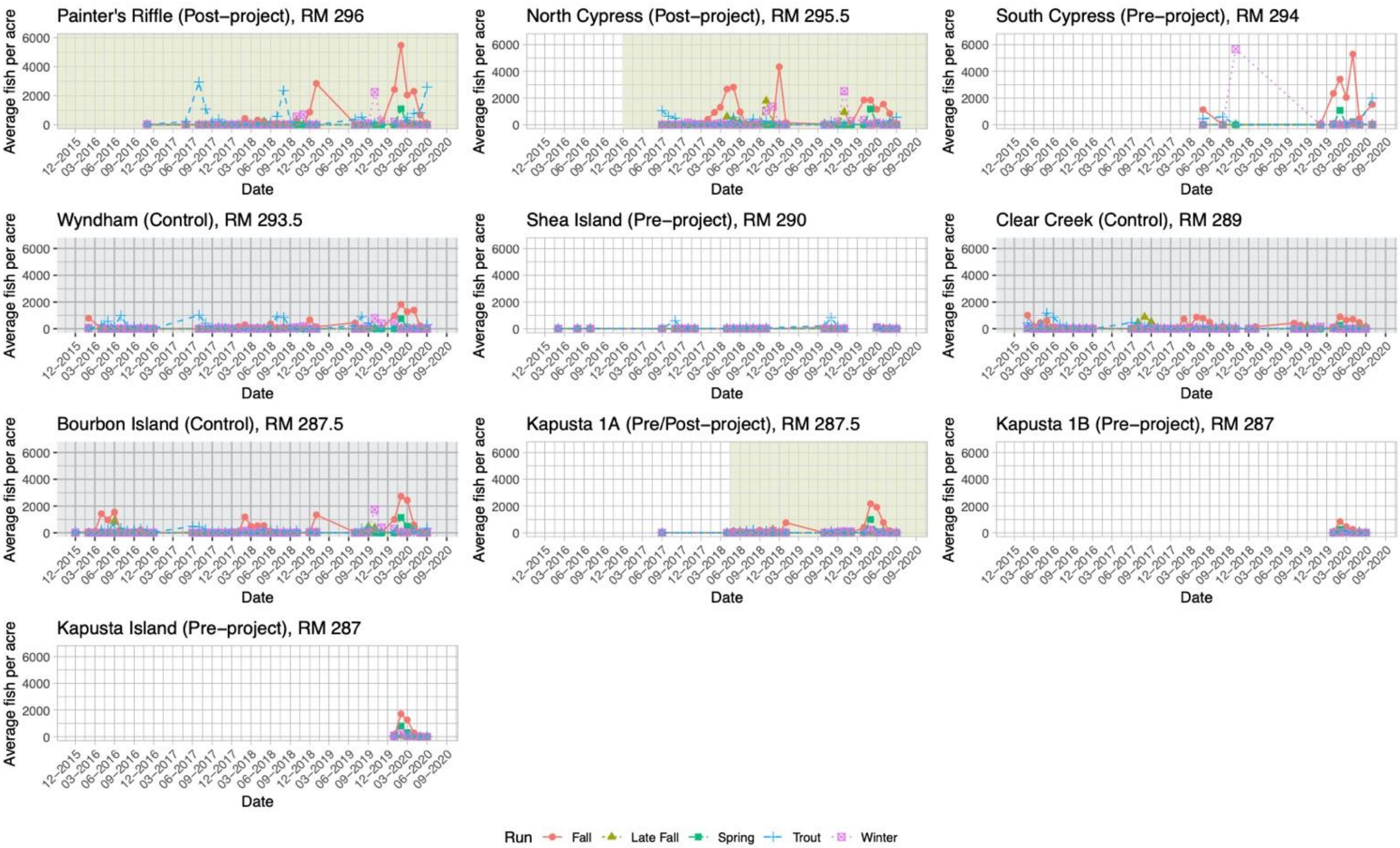

Figure 11. Monthly averages of fish-per-acre for northern sites (above RM 287). Light gray shading control sites, white shading indicates baseline data in restored sites (pre-project), and khaki shading represents impact data in restored sites (post-project). Large panels from each site are available in Appendix B, to allow better examination of detailed trends. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

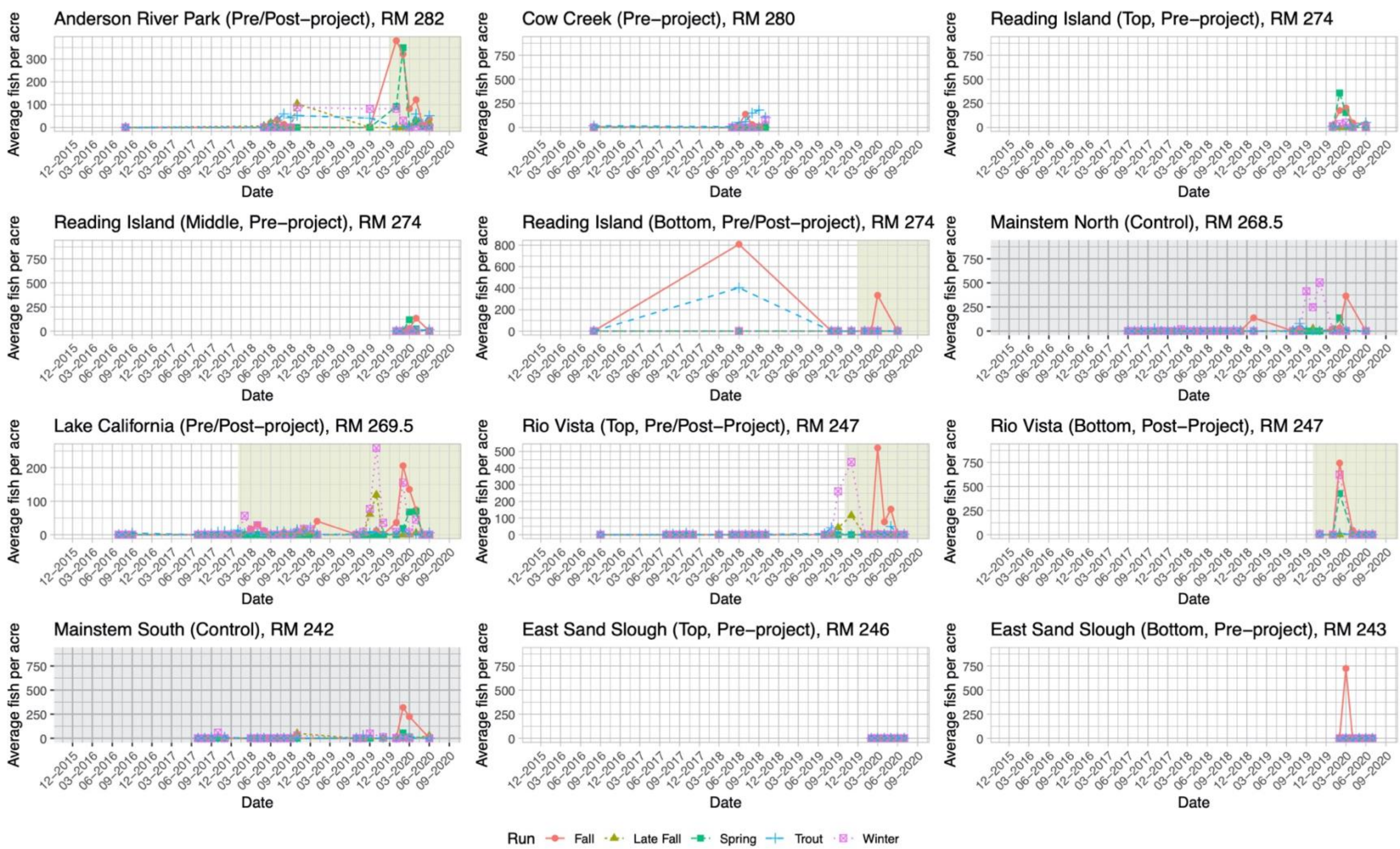

Figure 12. Monthly averages of fish-per-acre for southern sites (below RM 287). Light gray shading control sites, white shading indicates baseline data in restored sites (pre-project), and khaki shading represents impact data in restored sites (post-project). Large panels from each site are available in Appendix B, to allow better examination of detailed trends. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

Juvenile Habitat Mapping and Suitability

Depth, Velocity, and Cover

By the end of July 2020, three control sites and six 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, Painter's Riffle, Kapusta, Rio Vista, and Anderson River Park side channels. Mapping covered a range a flows, but did not always meet the full range of target flows due to logistical constraints. The statistical 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, making the results of the model misleading. Appendix C presents maps without cobble and aquatic vegetation for all side channels mapping completed by the end of the reporting period. Appendix D presents a complementary set of maps that exclude cobble, but include vegetation.

Linear mixed model analyses show that restored and control sites have similar proportions of available habitat for all habitat classifications examined, 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 (Table 16, Figure 13). 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 at the sites studied (Table 17).

Table 16. 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	$F_{1,6.70} = 0.0425$ $p = 0.8427$	**$F_{1,19.82} = 46.82$** **$p < 0.001$**
All Optimal	$F_{1,6.76} = 0.0699$ $p = 0.799$	$F_{1,19.64} = 2.23$ $p = 0.1511$
Suitable & Optimal	$F_{1,6.75} = 0.0083$ $p = 0.9302$	**$F_{1,19.69} = 42.86$** **$p < 0.001$**
Suitable Depth & Velocity	$F_{1,6.66} = 0.0251$ $p = 0.879$	**$F_{1,19.95} = 45.76$** **$p < 0.001$**
Suitable Cover	$F_{1,6.87} = 0.0752$ $p = 0.793$	$F_{1,19.33} = 1.502$ $p = 0.793$

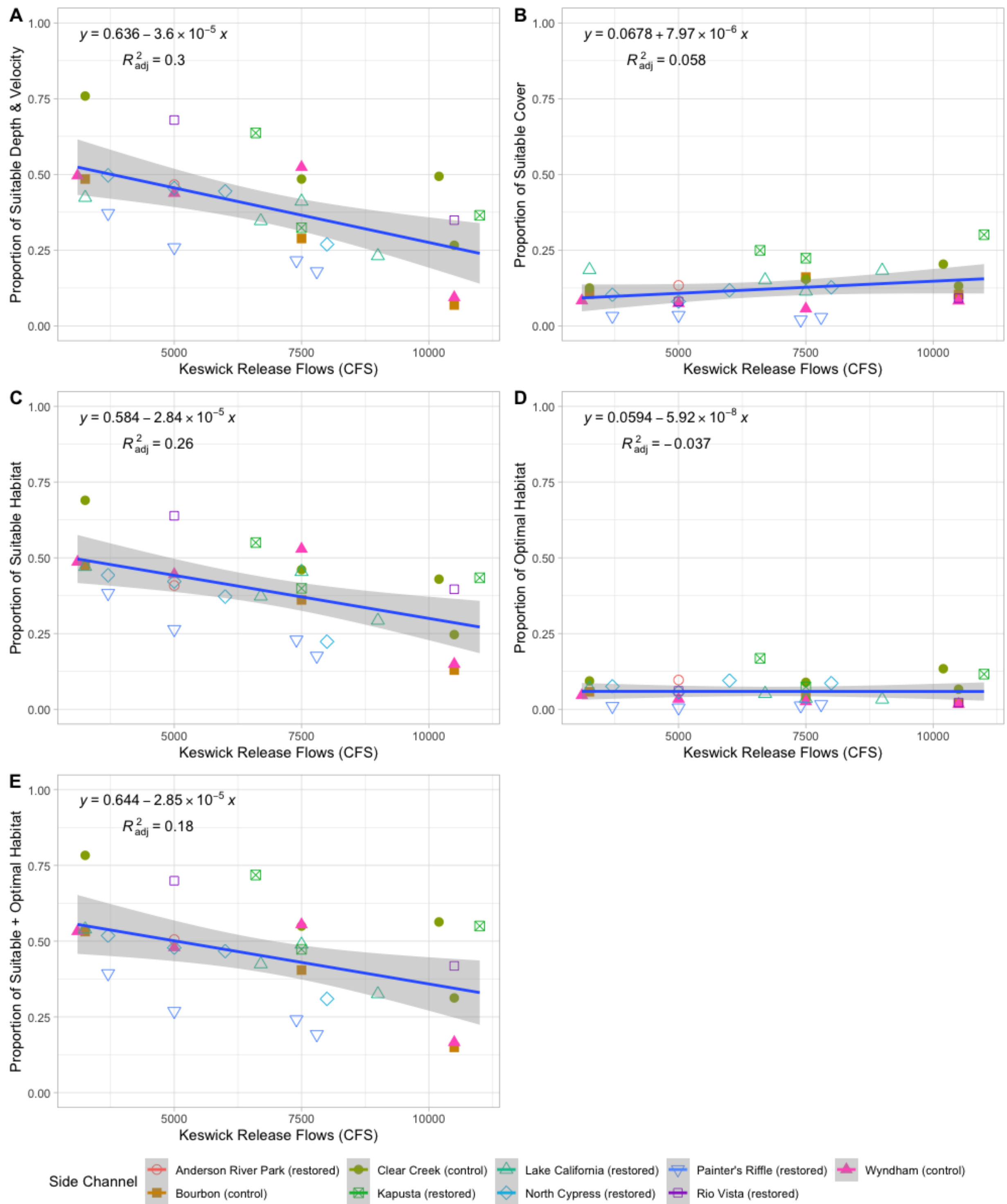

Figure 13. Proportion of habitat that has (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat, (D) optimal habitat, and (E) suitable + optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). All side channels were pooled because channel status (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 17. 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	Suitable + Optimal Habitat
3,250	0.57(0.45-0.68)	0.54(0.42-0.60)	0.61 (0.49-0.73)
4,000	0.53(0.42-0.64)	0.51(0.39-0.57)	0.58(0.46-0.70)
5,000	0.49(0.38-0.59)	0.47(0.35-0.52)	0.54(0.42-0.66)
6,000	0.44(0.33-0.55)	0.43(0.31-0.48)	0.49(0.38-0.61)
7,000	0.39(0.28-0.50)	0.39(0.26-0.44)	0.45(0.33-0.57)
8,000	0.35(0.24-0.45)	0.35(0.22-0.39)	0.41(0.29-0.53)
9,000	0.30(0.19-0.41)	0.31(0.18-0.35)	0.37(0.25-0.49)
10,000	0.25(0.14-0.36)	0.27(0.13-0.31)	0.33(0.20-0.45)
11,000	0.21(0.09-0.32)	0.24(0.07-0.28)	0.28(0.16-0.41)

Figure 14 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 available from the six restored sites included in the habitat mapping analyses (Lake California, North Cypress, Painter's Riffle, Kapusta, Rio Vista, and Anderson River Park), we looked at data collected at low, intermediate, and high flow classifications for each restored side channel (Figure 15). 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 5,000-7,800 cfs, and high flows range from 8,000-11,000 cfs. Some sites had data available at multiple intermediate flows (Lake California - 6,700 and 7,500 cfs; North Cypress - 5000 and 6000 cfs; Painter's Riffle - 5000, 7,400, and 7,800 cfs; and Kapusta – 6,600 and 7,500 cfs). Data was averaged in these cases.

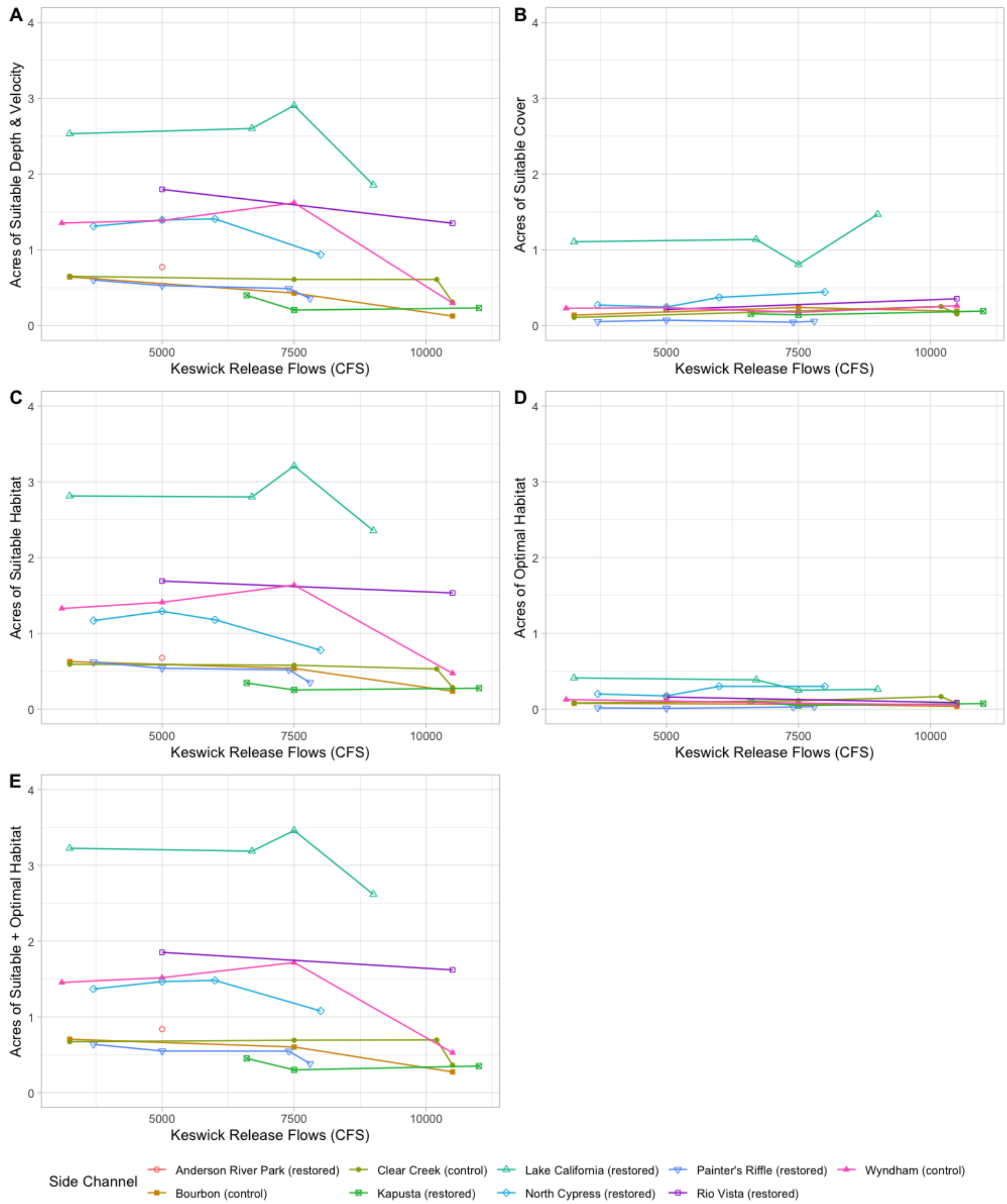

Figure 14. Acres of (A) suitable depth and velocity, (B) suitable cover, (C) suitable habitat (D) optimal habitat, and (E) suitable and optimal habitat found across a range of flows. Habitat criteria are from Goodman et al. (2015). Points represent individual sampling days and sites.

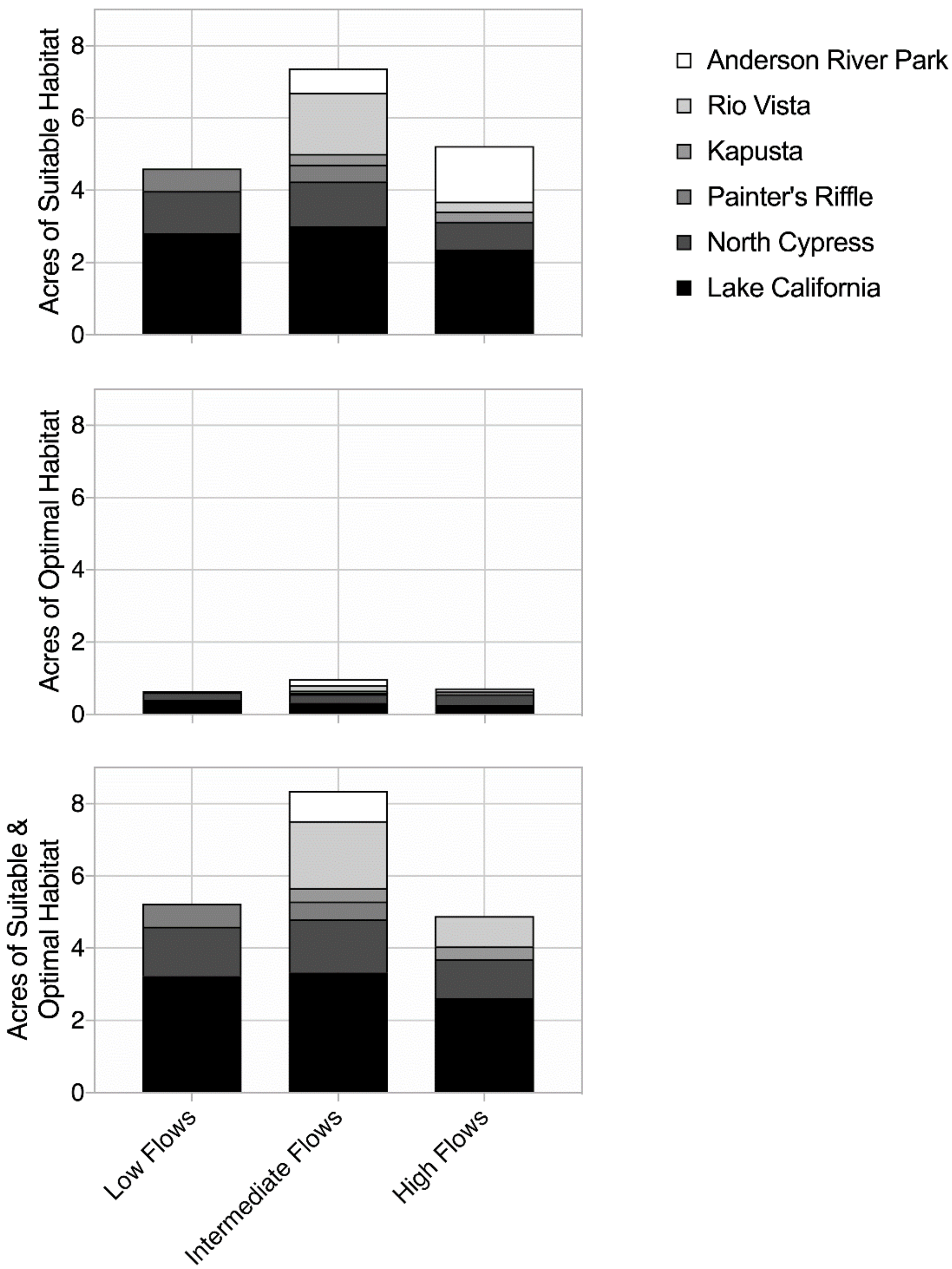

Figure 15. Acres of habitat available across flows from six restored sites. Due to logistic constraints during data collection, the range of these flows do not align perfectly with the target ranges set out in the Monitoring Plan. Instead, low flows ranged from 3,250-3,700 cfs, and intermediate flows ranged from 5,000-7,800 cfs, and high flows range from 8,000-11,000 cfs. Anderson River Park, Rio Vista, and Kapusta were not mapped at low flows by the end of the reporting period. Painter's Riffle was not mapped at high flows by the end of the reporting period. Some sites had data available at multiple intermediate flows (Lake California - 6,700 and 7,500 cfs; North Cypress - 5000 and 6000 cfs; Painter's Riffle - 5000, 7,400, and 7,800 cfs; and Kapusta – 6,600 and 7,500 cfs). Data was averaged in these cases.

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 thirteen separate occasions between March 2018 and June of 2020. High turbidity conditions prohibited microhabitat use sampling from February 2019 through June 2019. Approximately 61% of all Chinook salmon observed were fall run fish and the juvenile life stage (> 50mm FL) accounted for approximately 59% of all Chinook salmon observations (Table 18, Figure 16). A total of 642 steelhead/rainbow trout were observed with similar proportions of fry and juvenile life stages present (Table 18, Figure 16). 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 18. Number and life stage of Chinook salmon and steelhead/rainbow trout observations from March 2018 through June of 2020.

Species /Stock	Observations	% Fry (</= 50mm)	% Juvenile (> 50mm)
Fall run Chinook Salmon	618	51%	49%
Late-Fall run Chinook Salmon	103	53%	47%
Spring run Chinook Salmon	79	5%	95%
Winter run Chinook salmon	216	25%	75%
steelhead/rainbow trout	642	53%	47%

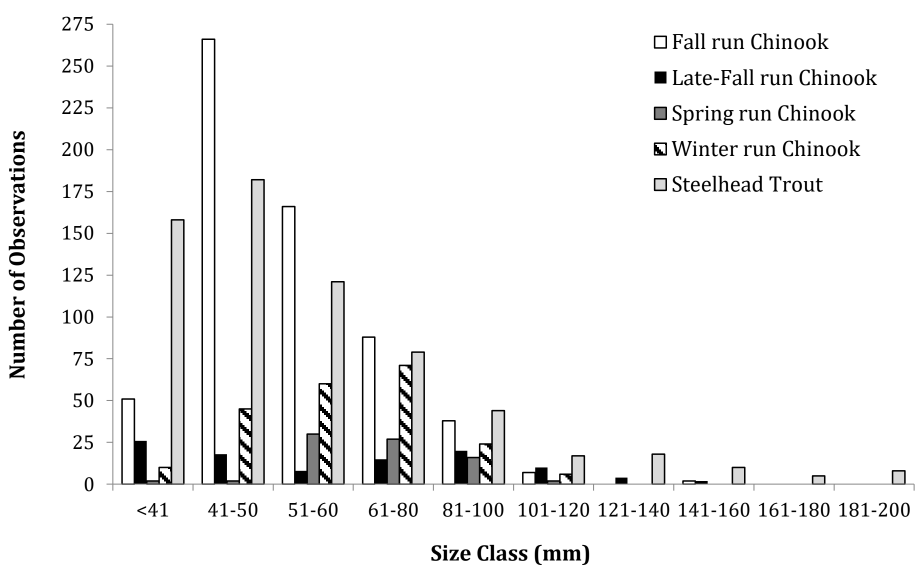

Figure 16. Size class distributions for Chinook salmon and steelhead/rainbow trout observations from March 2018 through June of 2020.

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 95% of Chinook fry and 83% of juvenile observations, and for steelhead/rainbow trout, this range captures 97% of fry and 76% of juvenile observations (Figure 17). 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. (Figure 17). Habitat mapping criteria for distance to cover range from 0.0 to 2.0 feet. This range captures 92% of Chinook fry and 90% of juvenile observations. For steelhead/rainbow trout, this range captures 98% of fry and 91% of juvenile observations (Figure 17).

Relative to habitat mapping criteria applied to all salmonid observations (n = 1,658, consisting of one to 355 fish per observation), 80.5% are observed in optimal habitats, 17% in suitable habitats, and 2.5% in unsuitable habitats. Percentages among Chinook salmon (all runs) and steelhead/rainbow trout are very similar. For Chinook salmon (all runs combined, n = 1016), 79% of fish are observed in optimal habitats, 18% in suitable habitats and 3% in unsuitable habitats. Steelhead/rainbow trout observations (n = 642) consisted of 82.5% of fish observed in optimal habitats, 15% in suitable habitats and 2.5% in unsuitable habitats.

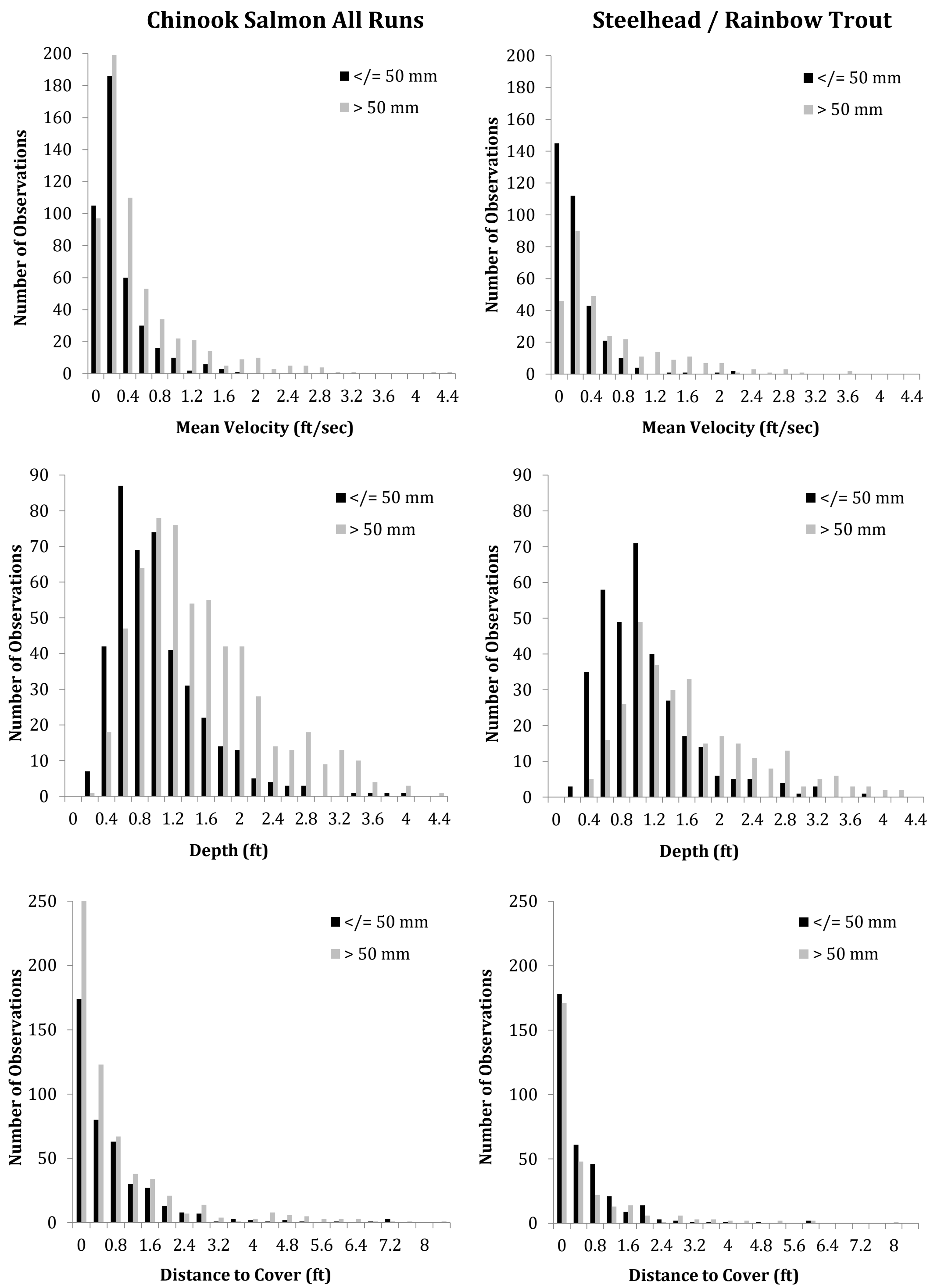

Figure 17. Mean velocity, depth and distance to cover associations for observations of fry (</= 50mm FL) and juvenile (> 50mm FL) Chinook salmon and steelhead/rainbow trout from March 2018 through June of 2020. Note that these are raw data, and are not adjusted for availability of each habitat classification. 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 19, Figure 18). 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 20 and 21, below.

*Table 19. 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 (all runs)	**Chinook juveniles (all runs)**	**Steelhead/ rainbow trout fry**	**Steelhead/ rainbow trout juveniles**
Cover Type	$F_{7,28}$= 1.64 p = 0.166	**$F_{7,28}$= 3.47** **p = 0.008**	$F_{7,28}$= 1.62 p = 0.168	**$F_{7,28}$= 4.21** **p = 0.011**
Channel Status* Cover Type	$F_{7,28}$= 0.19 p = 0.948	$F_{7,28}$= 0.4191 p = 0.882	$F_{7,28}$= 0.574 p = 0.770	$F_{7,28}$= 1.31 p = 0.282

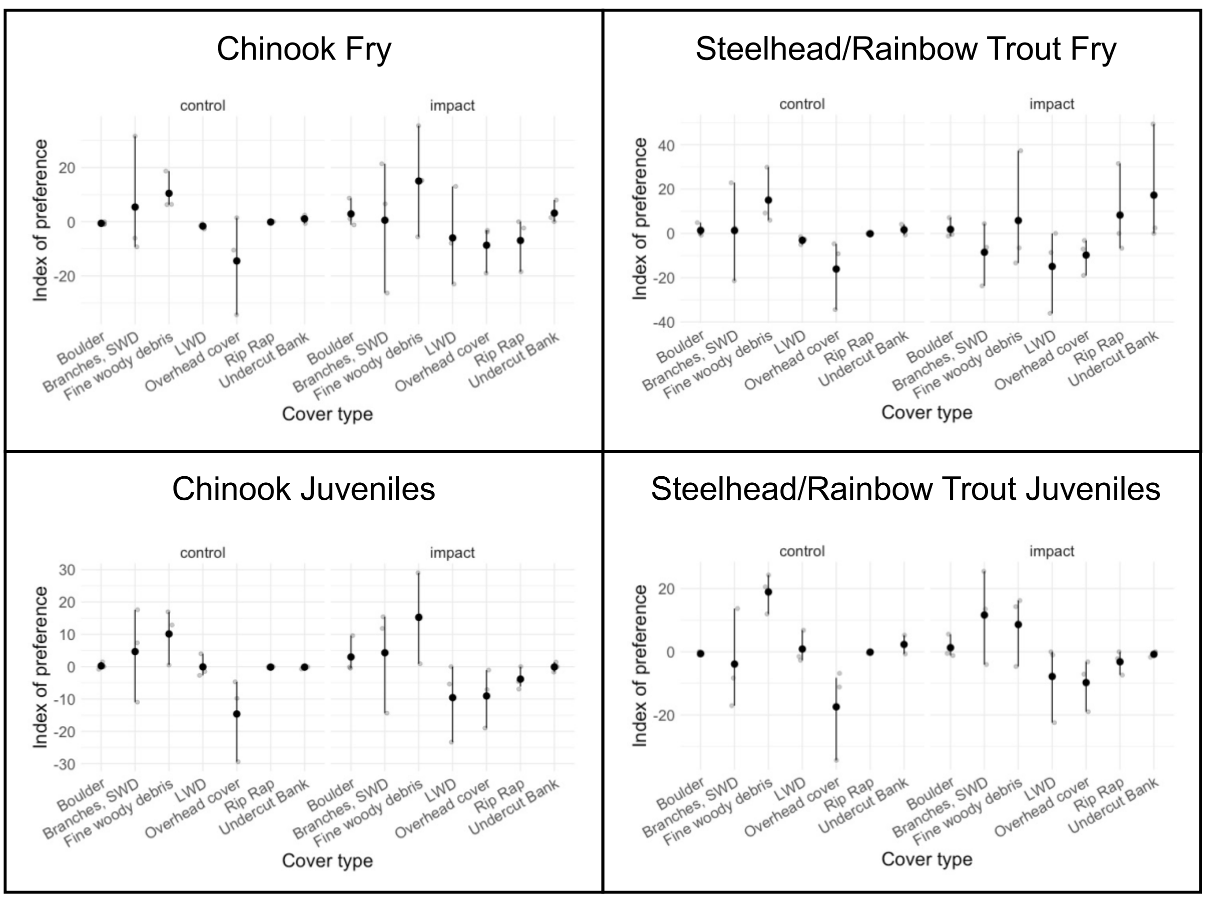

Figure 18. Cover preference index for Chinook salmon (all runs) and steelhead/rainbow trout fry and juveniles in control and impact habitat. Values above zero indicate fish were found at those cover types more than expected based on a random distribution, indicating a positive preference. Negative values suggest the inverse relationship.

Table 20: Results of Tukey's Honest Significant difference test comparing juvenile Chinook salmon preference for cover types. Cover types are defined in Table 4.

	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	**p=0.041** Fine woody debris preferred				
Overhead cover	NS	NS	**p=0.002** Fine woody debris preferred	NS			
Rip rap	NS	NS	NS	NS	NS		
Undercut bank	NS	NS	NS	NS	NS	NS	

Table 21: Results of Tukey's Honest Significant difference test comparing juvenile steelhead/rainbow trout preference for cover types. Cover types are defined in Table 4.

	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=0.035** Branches, SWD preferred	**p<0.001** Fine woody debris preferred	NS			
Rip rap	NS	NS	NS	NS	NS		
Undercut bank	NS	NS	NS	NS	NS	NS	

Fish Size and Condition

Seining Data

Fish fork lengths obtained from seined fish are shown in Figure 19 (2019-20 reporting year, total n = 1950). Late fall run, winter run, and steelhead/rainbow trout need additional data in order to compare size between site types. For fall run Chinook salmon, there was a significant effect of site type on fork length (linear mixed effects model, month included as a random effect: $F_{2,1672.8}$=25.065, p<0.001, total n=1678). Post hoc analysis (Table 22) shows that post-restoration side channels had larger fish than control side channels or mainstem sites. Mainstem and control sides were not significantly different than one another. Fish classified as Spring run showed no significant relationship between site type and growth (linear mixed effects model, month included as a random effect: $F_{2,119.35}$=0.0694, p<0.933, total n=118). Fulton's condition factor, calculated from the length and weight of seined fish is shown in Figure 20. Sample sizes are smaller in this dataset (Total n=713, split between 27 run/site/month groups) because weights could not accurately be captured from small fish or windy sampling days. Because of this, statistical analyses were not completed.

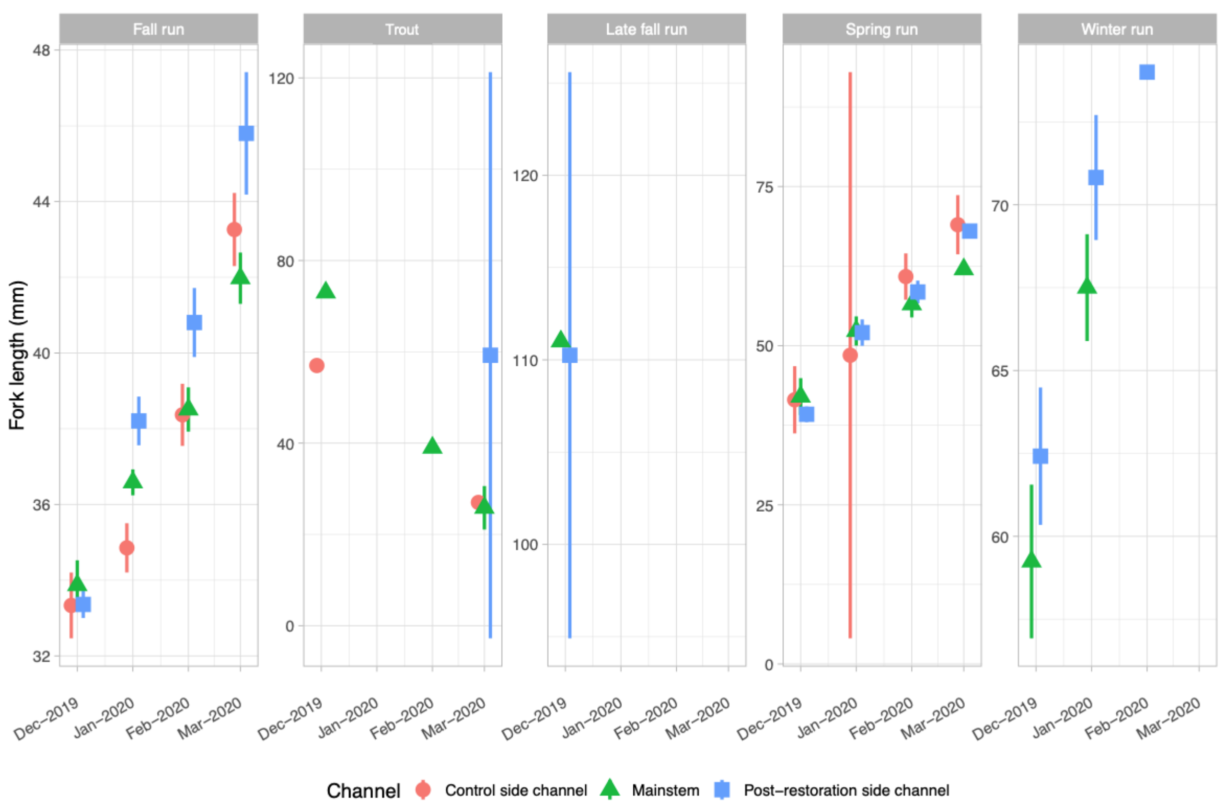

Figure 19. Fork length of seined fish from each run captured between December 2019 and March 2020. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

Table 22. Post-hoc analyses of fall run fork lengths, estimated using the glht function from the multcomp package in R. Post-restoration side channels had larger fish that control side channels or mainstem sites. Mainstem sites and control side channels were not significantly different than one another.

Comparison	z-value	p-value
Mainstem – Control Side Channel	-0.766	0.444
Post-restoration – Control Side Channels	5.452	**< 0.001**
Post-restoration Side Channel – Mainstem	6.924	**< 0.001**

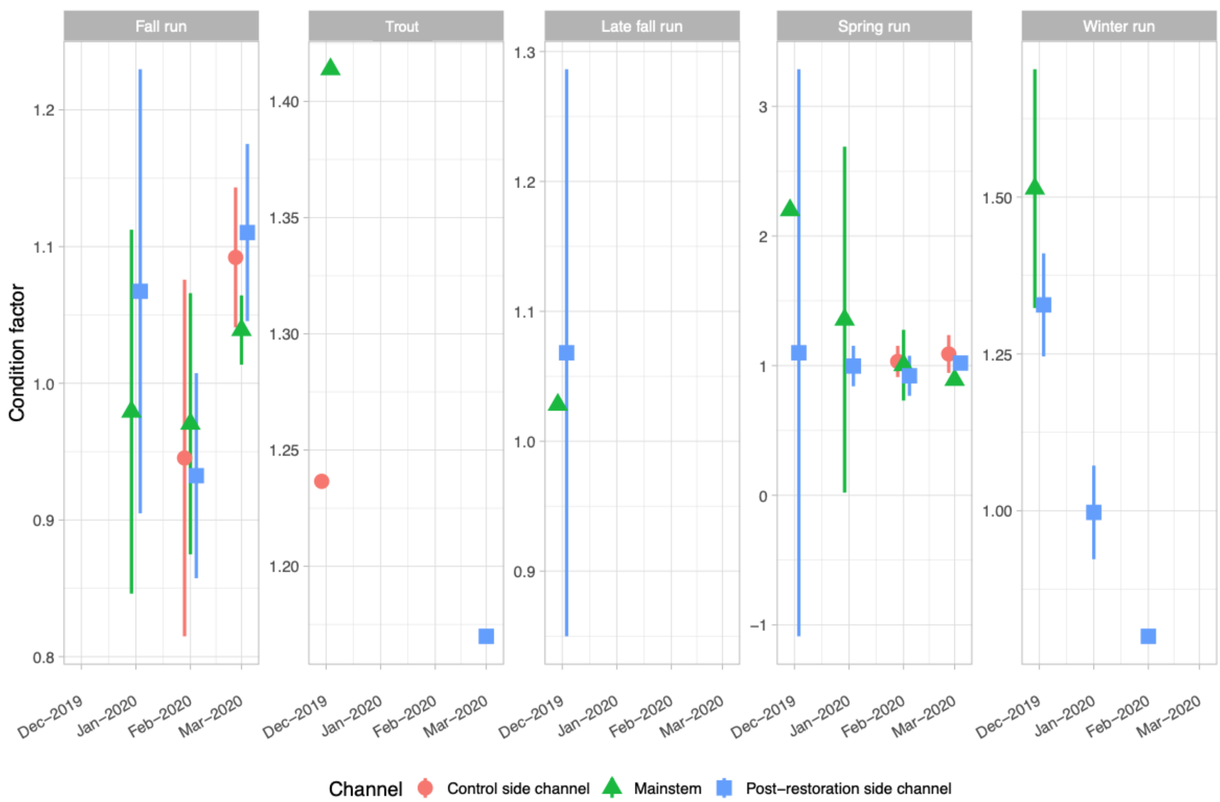

Figure 20. Fulton's condition factor of seined fish from each run captured between December 2019 and March 2020. Note that fall run, late-fall run, spring run, and winter run refer to Chinook salmon. Trout refers to steelhead/rainbow trout.

Enclosure Study

Enclosures in each habitat had different survival (or retention) rates (Figure 21), which lead to different mean densities in enclosures in the different habitat types. Fish growth rates were significantly higher in mainstem sites than historic or restored sites (ANOVA: $F_{2,253}=7.773$, $p<0.001$, Figure 22, Table 23), but note that this may be a function of lower densities in mainstem sites due to lower survival. Fish diets, as determined by stomach dissection at the end of the experiment, are shown in Figure 23.

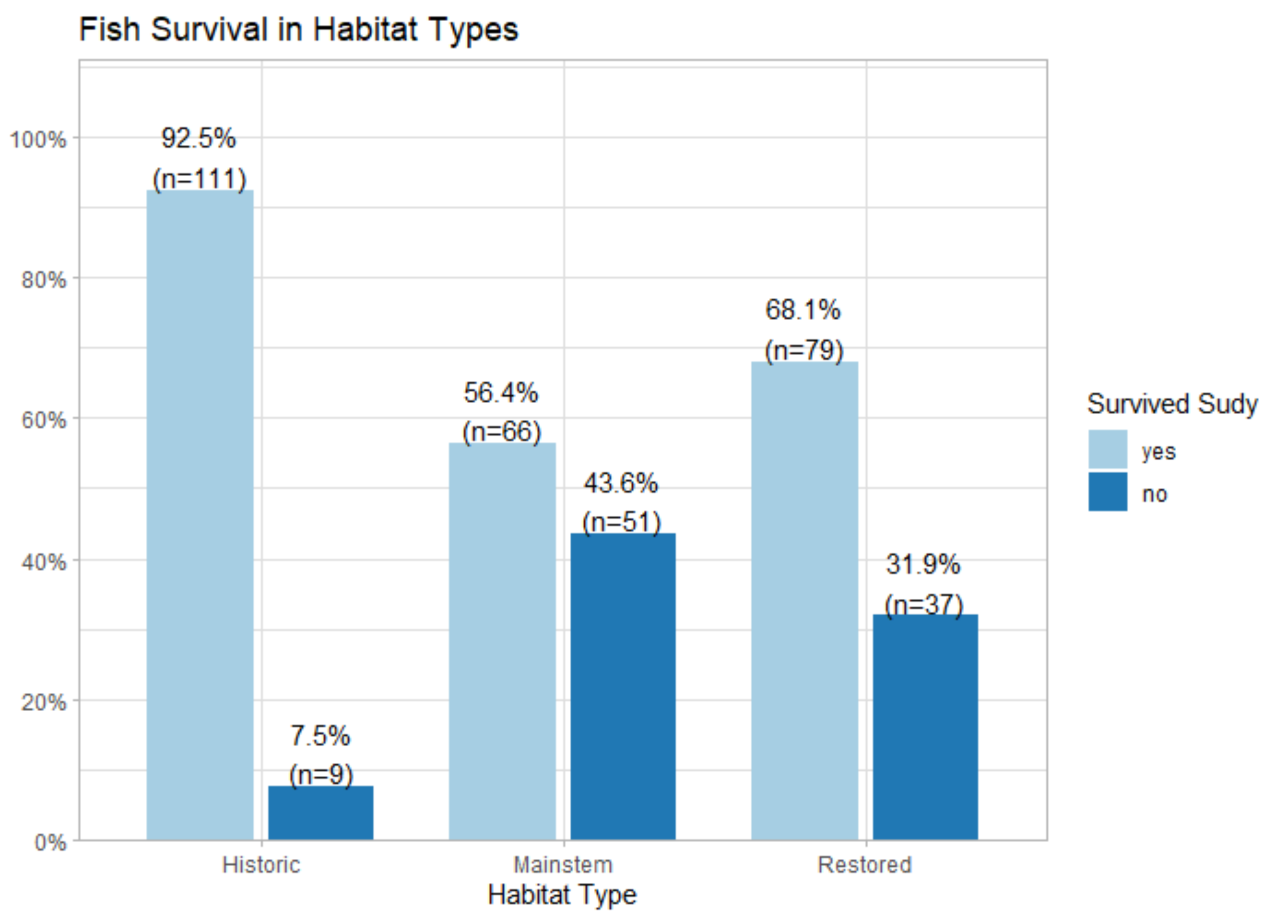

Figure 21. Fish survival across habitat types in the enclosure study. Note that what we refer to as survival may be a function of both survival and retention within the enclosure. Missing fish, regardless of whether carcasses were recovered, were marked as non-survivors.

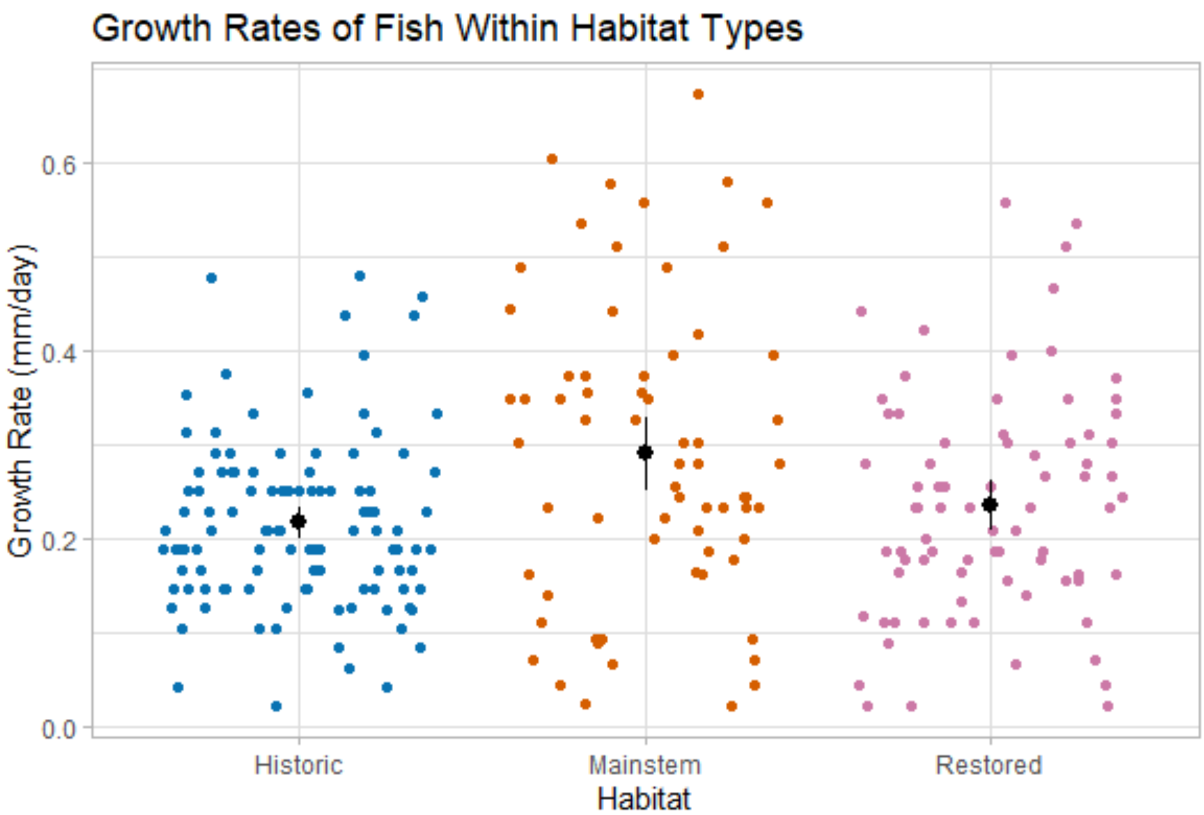

Figure 22. Fish growth rates from historic control side channels, mainstem controls, and restored side channels in the enclosure study. Note that mainstem habitats had lower fish retention/survival over the course of the study, which led to low average fish density in each enclosure. This, the results seen here may be in part a function of fish density.

Table 23. Tukey Honest Significance Difference results. Note that mainstem habitats had lower fish retention/survival over the course of the study, which led to low average fish density in each enclosure. Thus, the results seen here may be in part a function of fish density.

Comparison	Difference	Lower 95% CI	Upper 95% CI	Adjusted P Value
Restored-Historic	0.018	-0.024	0.06	0.581
Mainstem-Historic	**0.073**	**0.029**	**0.118**	**p <0 .001**
Mainstem-Restored	**0.056**	**0.008**	**0.103**	**0.017**

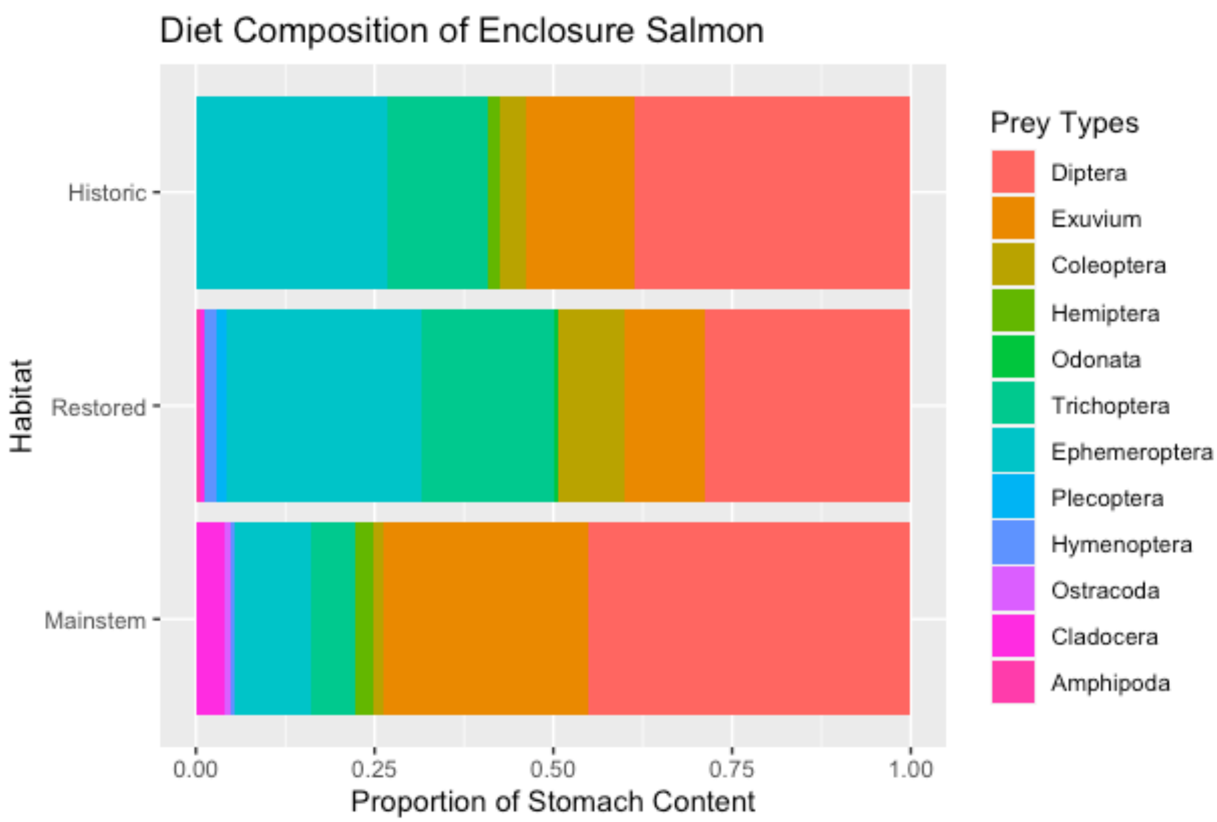

Figure 23. Proportion of fish diet made up of various invertebrate orders. Data was collected by dissecting fish stomachs at the end of the enclosure study. Proportions were calculated using count data.

DISCUSSION

The overarching goal of this monitoring report is to examine the effect of restoration on juvenile salmonids in the upper Sacramento, and to provide information that can help inform future restoration efforts. The data presented in this annual report allow for a stronger evaluation of the effects of restoration than data from previous years, but some analyses still need additional data in order to make concrete conclusions.

This is the first year that adequate data from before and after restoration was available to do BACI (before-after-control-impact) analyses to determine the effects of restoration on fish abundance. The BACI design greatly increases our ability to detect differences between treatment groups. The three restoration sites (Anderson River Park, Lake California, and Rio Vista) show an increase in observed fish number after the restoration relative to the three nearest control sites (Bourbon Island, Mainstem North, Mainstem South), providing strong support for the effectiveness of the side channel restorations. This increase was significant in models that include all salmonids, fall run Chinook, and steelhead/rainbow trout. Winter run and late fall run showed similar, non-significant trends, which may be in part be due to a smaller number of observed fish in the dataset. Comparable trends were seen when examining fish density (fish-per-acre). Steelhead/rainbow Trout showed a significant increase in fish density in restored sites relative to control sites. Similar non-significant trends were seen in fall run Chinook, late fall run Chinook, winter run Chinook, and all salmonids when pooled. Fish classified as spring-run Chinook did not show any response to the restoration for either metric, though observations of this run are extremely limited, and there is some concern that these fish may be mis-classified individuals from other runs. Genetic analysis of a subset of fish could help confirm whether these fish are appropriately classified. Together, these results suggest overall positive effects of restoration on fish abundance, though the extent of the benefit varies depending on which metric and runs are examined.

We also analyzed fish abundance in the full suite of side channels, including those that do not have data from before and after restoration. The lack of data taken before restoration makes it more challenging to make decisive conclusions, in part because of reduced power to detect differences between treatments. Fish counts, in particular, are difficult to analyze and interpret without adequate data taken before restoration for comparison, so our dependent variable in these analyses is estimated fish density (fish-per-acre). The trends for estimated density show that control sites and restored sites are similar, and consistently have more estimated fish than baseline sites. However, due to the large error in the estimates, we cannot statistically detect differences between any of the site types. This inability to distinguish whether the mean estimates between site types differ from one another points to the importance of collecting adequate data before restoration. However, another reason we may not be seeing statistically detectable differences is because these analyses focuses on estimated dish density, rather than fish number. The creation of additional habitat in a side channel may increase fish number, even if there is no measurable change in fish density.

Consistent with results from previous annual reports, restored and control side channels had similar proportions of high-quality habitat for every criterion we examined, suggesting that the restoration has successfully recreated the depth, velocity, and cover characteristics of historical side channels. Flow from Keswick Dam had a significant negative effect on all criteria whose estimations were strongly driven by velocity: all suitable habitat, suitable + optimal habitat, and suitable depth and velocity. Optimal habitat and suitable cover, which are both largely influenced by the proportion of suitable cover, did not show a significant relationship with flow from Keswick at our study sites.

While we do have limited pre-restoration mapping for Anderson River Park and Rio Vista, this data was not included in the statistical analyses for two reasons. First, the flows mapped before restoration and the flows mapped after restoration do not overlap, making comparison difficult. Additional mapping is planned. Second, comparing the proportion of high-quality habitat between pre-restoration baseline mapping and post-restoration mapping in a single site can be misleading. Disconnected pre-restoration sites can sometimes show large proportions of suitable habitat due to artifacts of classification. For example, a small backwater habitat with near-zero velocity will appear to have a high proportion of suitable habitat. Because of this, baseline and impact data within a site are best compared using absolute values of habitat availability at similar flows, particularly when the pre-restoration side channel was not connected to the mainstem river on both ends at all flows.

In previous years, we used information obtained by mapping post-restoration sites to estimate the amount of high-quality habitat gained at different flows. This year, we also report on Anderson River Park and Rio Vista side channels. These side channels both had considerable habitat available prior to restoration, which means that the high-quality habitat mapped after restoration is not an accurate measure of habitat gained. Because of this, we are not reporting habitat gained in this report. Figure 15 shows the total amount of habitat available in restored sites, but for reasons just described, these numbers are an overestimate of habitat gained. As mentioned above, we do have limited pre-restoration mapping of each of these sites, but we do not currently have post-restoration maps at the same flows. Once these flows are mapped, we can create estimates of the amount of habitat gained for each of these sites.

Microhabitat data shows that depth, velocity, and distance-to-cover preferences were similar between Chinook and steelhead/rainbow trout. The majority of fish (80.5%) are found in habitat classified as optimal, followed by suitable (17.5%) and unsuitable (2.5%) habitats, as defined by Goodman *et al.* (2015). When cover types are broken down by type, we see that juvenile Chinook and steelhead/rainbow trout (>50mm) both preferred some cover types over others, though significant differences between cover types were limited. Juvenile Chinook had a preference index for fine woody debris that was significantly higher than indices for large wood debris or overhead cover. Juvenile steelhead/rainbow trout a significantly higher preference indices for fine wood debris and branches/small woody debris than for overhead cover. Neither taxa had juveniles that showed different cover preferences between control and restored sites. Fry (<= 50mm) from both taxa showed no difference in preference between cover types, nor in preference for cover types between control and restored sites.

Fish condition and growth was examined through two complementary datasets: size and weight of seined fish, and growth rates in the enclosure study. Limited data from fish seining only allowed statistical analysis of fall and spring run Chinook fork length. Fall run Chinook caught in restored sites had significantly larger fork lengths than fish from control side channels or the mainstem of the Sacramento River. No differences were detected between control side channels and the mainstem sites. Spring run had a much smaller sample size, and no differences in fork length were detected from any of the sites. One caveat to drawing conclusions from this data is that fish were classified into run base on fork lengths – if these classifications have error, they may produce misleading results in these analyses. The enclosure study, which used late fall run fish from Coleman National Fish Hatchery, showed different trends than the seining data. This dataset showed higher growth rates in the mainstem of the river as compared to control and restored side channels. However, these data should be interpreted with extreme caution. Mainstem sites had greater fish loss, either through mortality or escape, than either of the side channel sites. This means that mainstem sites had lower mean densities of fish in each enclosure for a large duration of the study. Growth has been shown to have a strong negative correlation with density (Cowan *et al.*, 2000; Grant and Imre, 2005; Einum *et al.*, 2006), so it is likely that the differences found in this dataset are an artifact of density, rather than the site type. To address this, we planned a second season of enclosure studies where missing fish would be replaced regularly throughout the study to keep the density consistent. Unfortunately, this study had to be abandoned shortly after the enclosures were deployed due to COVID-19 restrictions.

Juvenile salmon stomach contents, which were dissected from euthanized fish at the end of the initial enclosure study, showed that diptera was a dominant food item for juvenile salmon in all site types. Fish in restored side channels had eaten the highest proportion of ephemeroptera, plecoptera and tricoptera (EPT) orders, followed by control side channels, and then mainstem habitats. EPT are sensitive taxa that are often used as an indicator of water quality (Mazor *et al.*, 2016). Various EPT indices exist, but the commonality between them is that higher proportions of EPT richness indicates higher water quality. Currently, we cannot tell whether the higher proportions of EPT in gut contents of fish in restored side channels are a result of prey availability or diet preference. Invertebrate drift sampling data was also collected at each site in conjunction with the enclosure studies. Those samples, which may distinguish between these two alternatives, are currently with the CDFW Aquatic Bioassessment Lab (ABL) for identification.

The datasets used in the analyses reported above vary in quality and size. Results obtained from the highest quality datasets all suggest that the Upper Sacramento River Anadromous Fish Habitat Restoration Project has effectively produced additional high quality juvenile salmonid habitat and increased fish numbers in the upper Sacramento River. However, some metrics need additional data collection in order to draw definitive conclusions. For future restorations, we emphasize the need for data collection before restoration occurs, in order to increase our ability to detect differences between sites. Continued monitoring of completed and future restorations will provide additional insight into the effectiveness of side channel restoration, as well as information about how side channel characteristics evolve over time.

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APPENDIX A – SALMON LENGTH-TO-DATE CHART

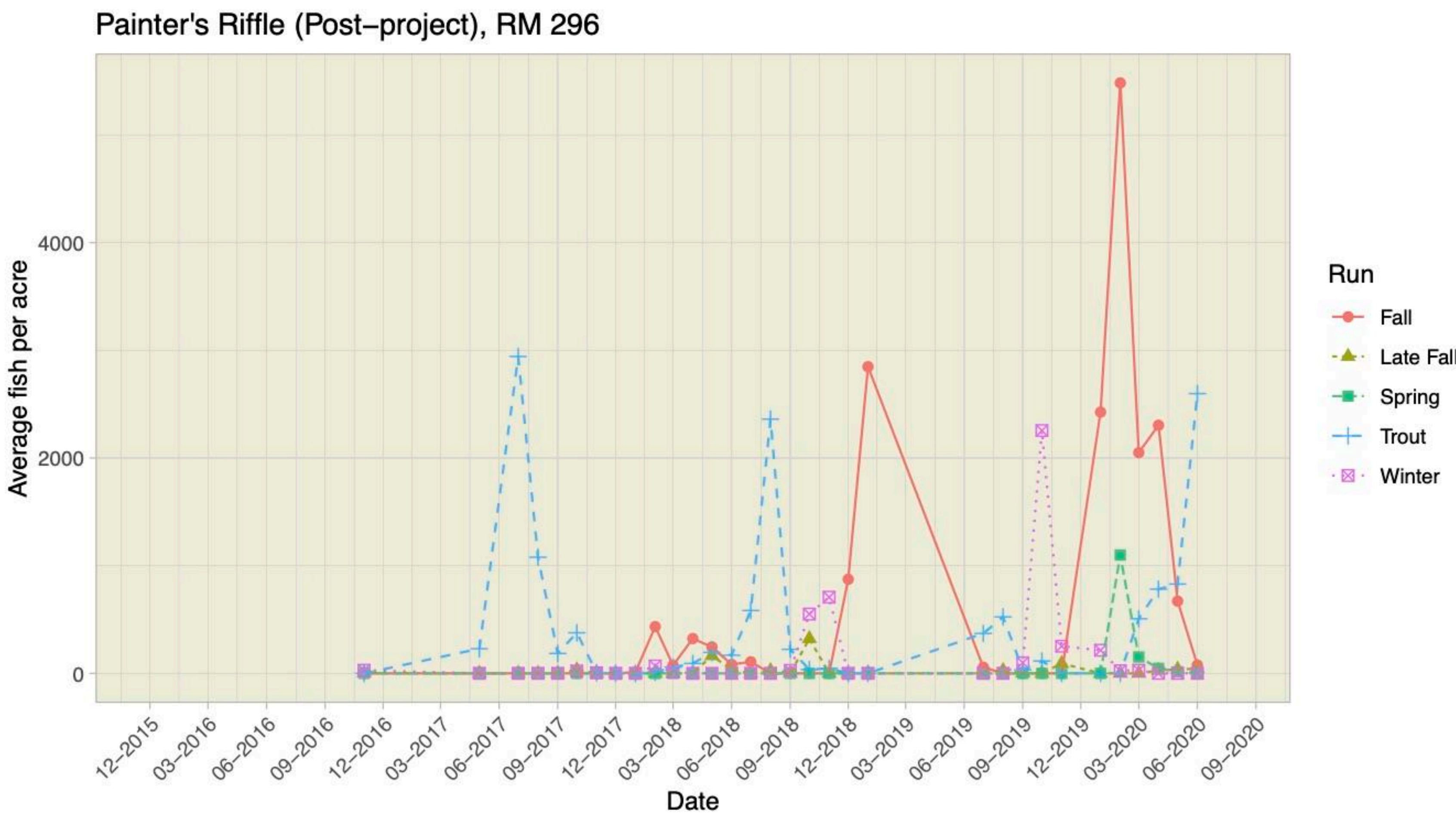
One-page example

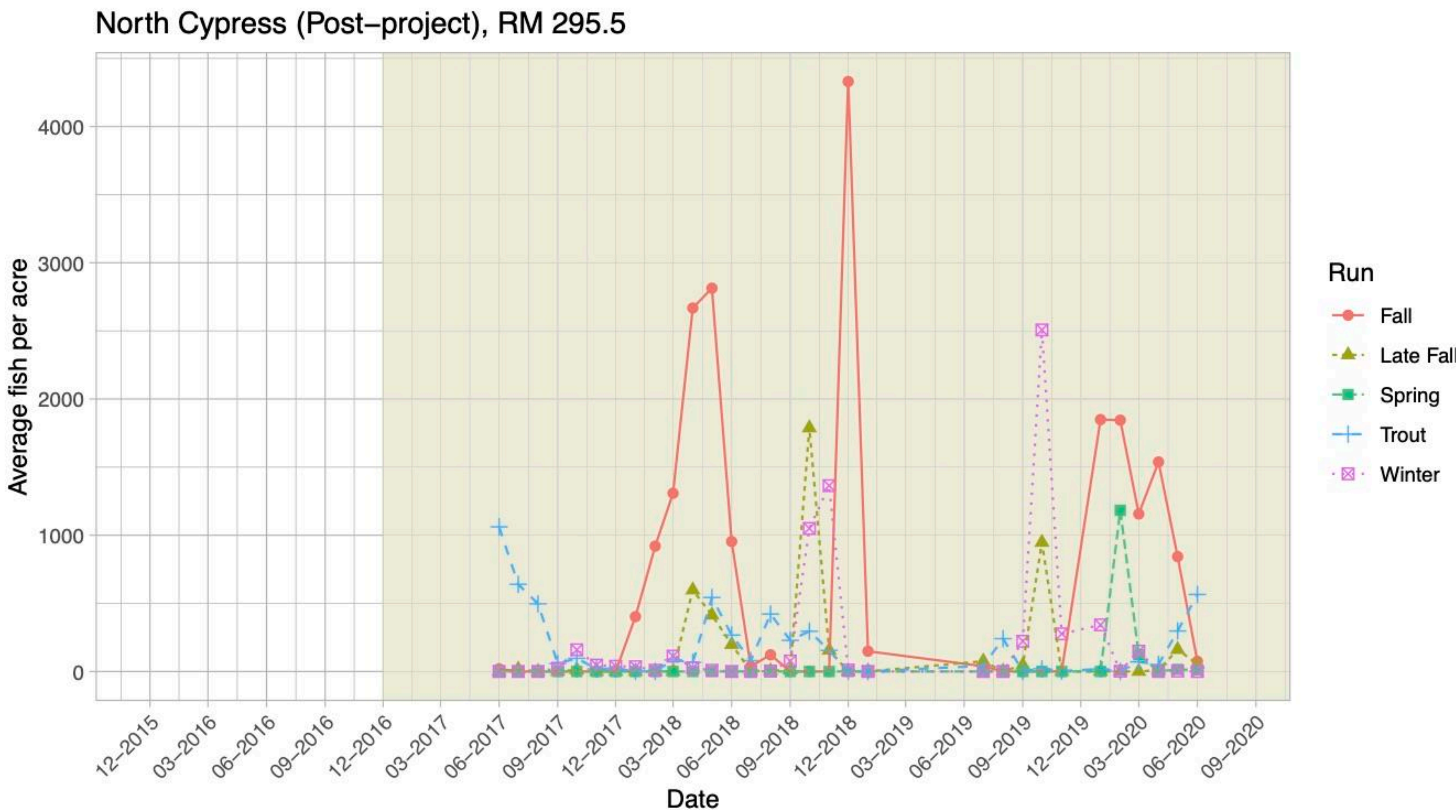
RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

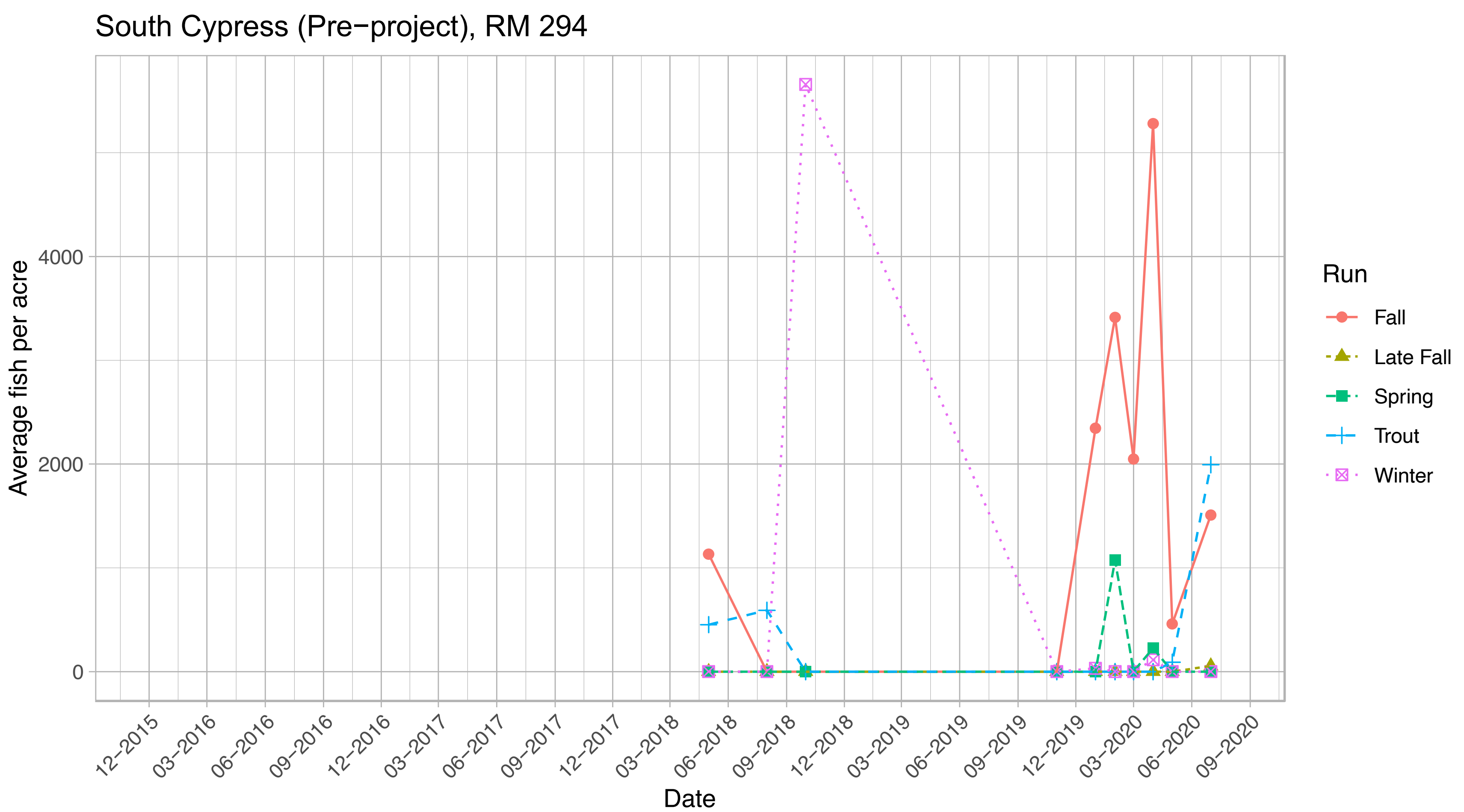
DATE	FALL	SPRING	WINTER	LATE-FALL	All runs SEE BELOW	DATE
1-Jan	0-41	42-55	56-111	112-202	203-270	1-Jan
2-Jan	0-41	42-55	56-112	113-230	231-270	2-Jan
3-Jan	0-41	42-56	57-112	113-205	206-270	3-Jan
4-Jan	0-41	42-56	57-113	114-206	207-270	4-Jan
5-Jan	0-42	43-56	57-114	115-207	208-270	5-Jan
6-Jan	0-42	43-57	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

APPENDIX B – SNORKEL FISH DENSITY GRAPHS BY SITE

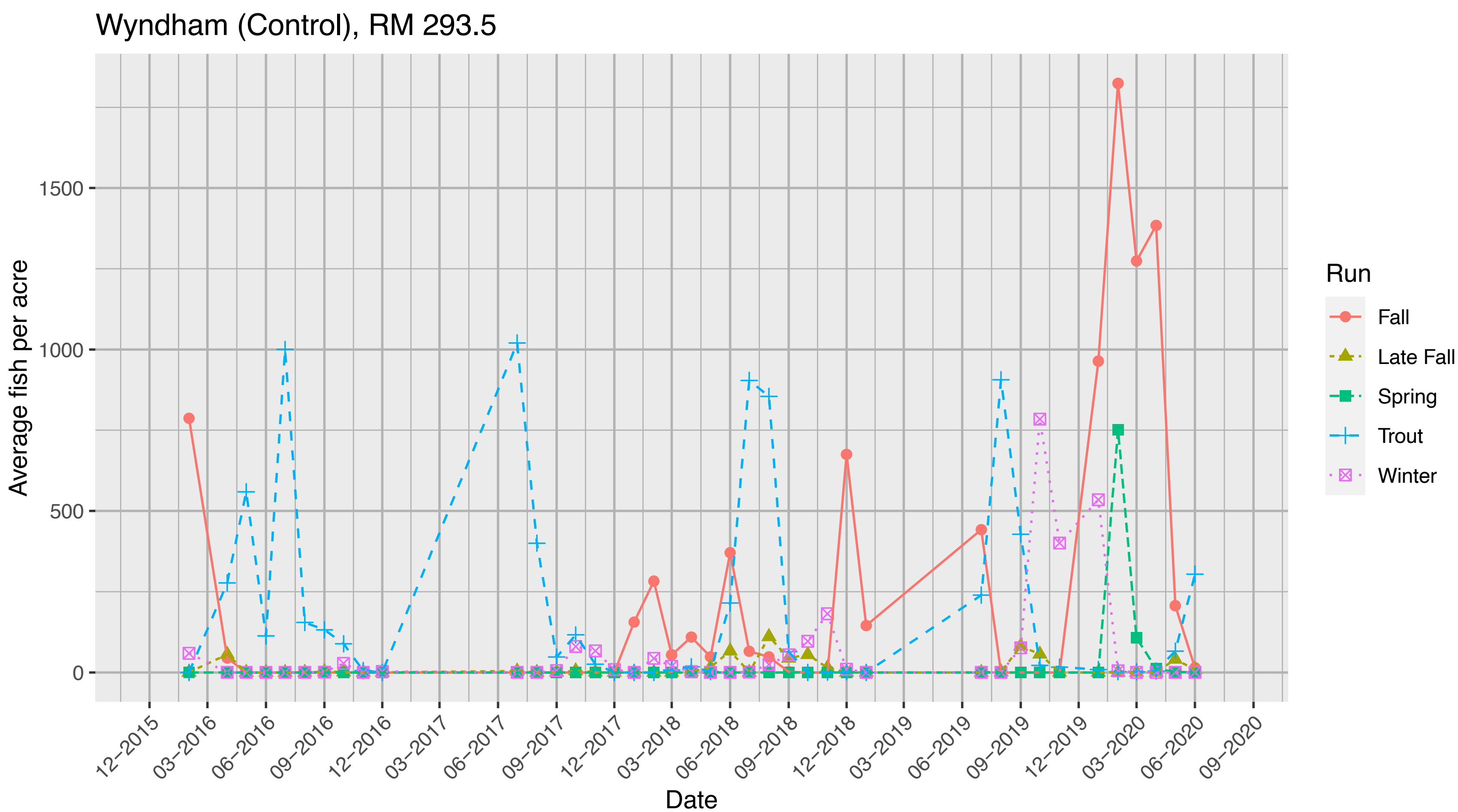
Organized north to south

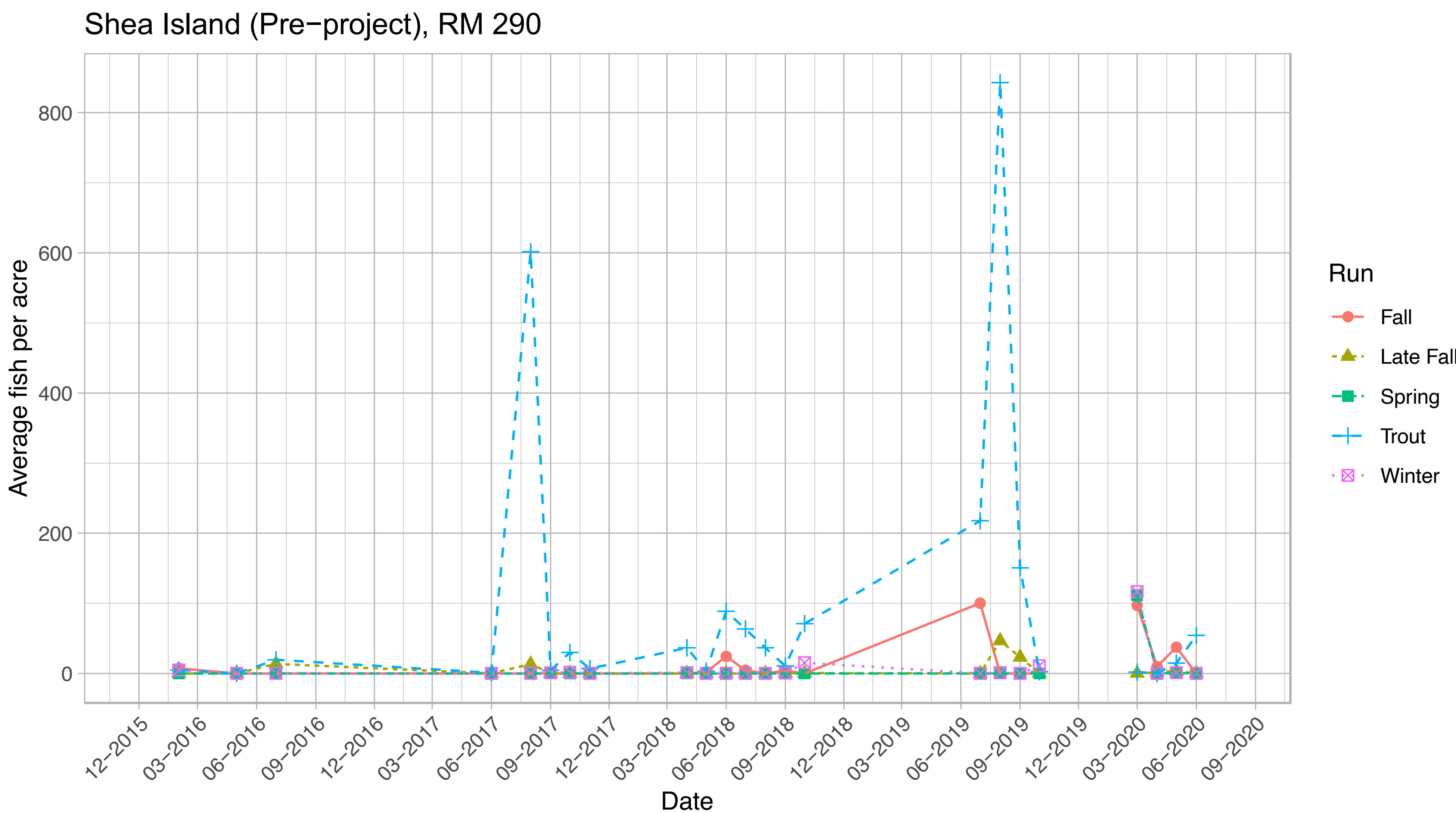


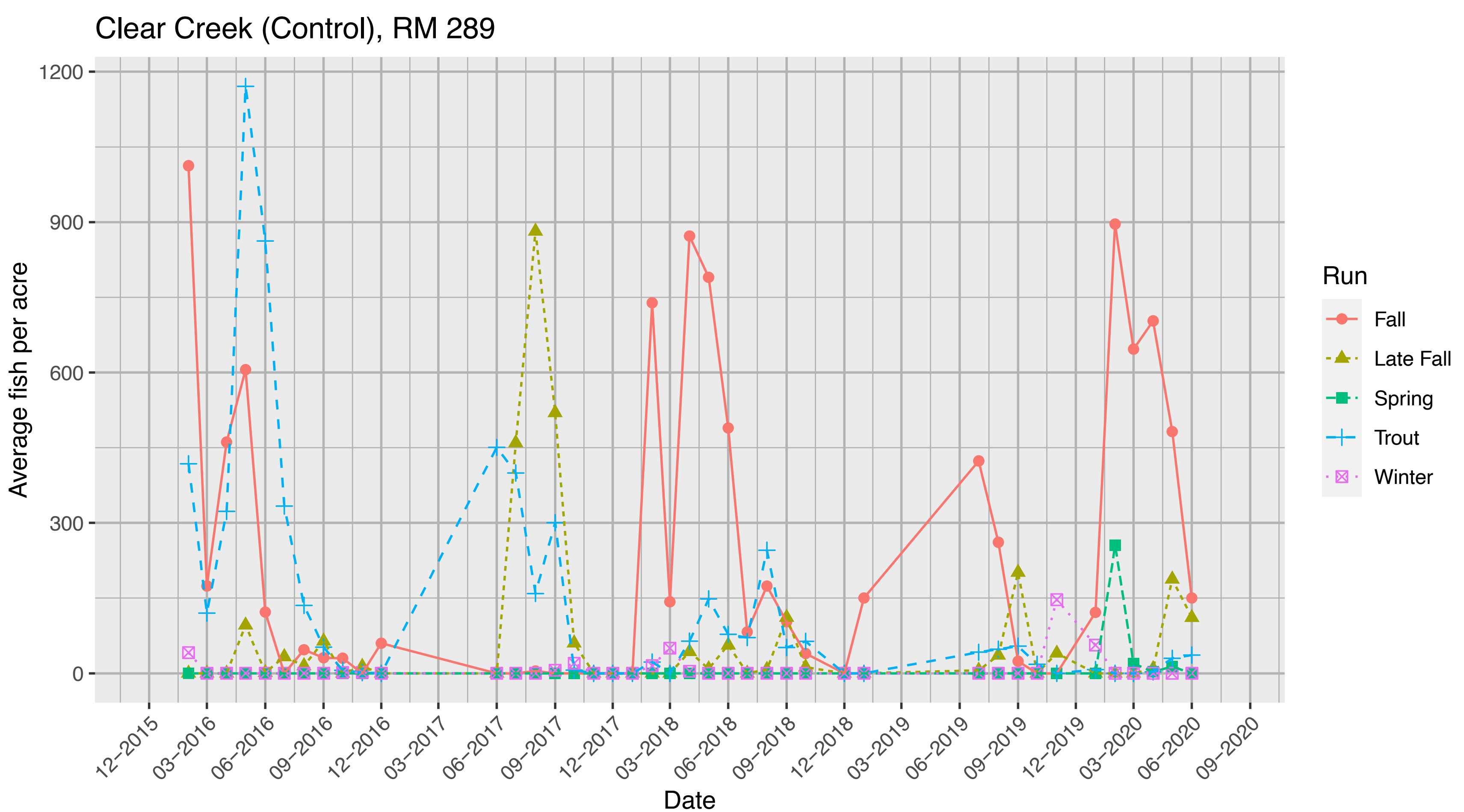

North Cypress (Post–project), RM 295.5
Average fish per acre
4000
3000
2000
1000
0
Date
12–2015
03–2016
06–2016
09–2016
12–2016
03–2017
06–2017
09–2017
12–2017
03–2018
06–2018
09–2018
12–2018
03–2019
06–2019
09–2019
12–2019
03–2020
06–2020
09–2020
Run
Fall
Late Fall
Spring
Trout
Winter



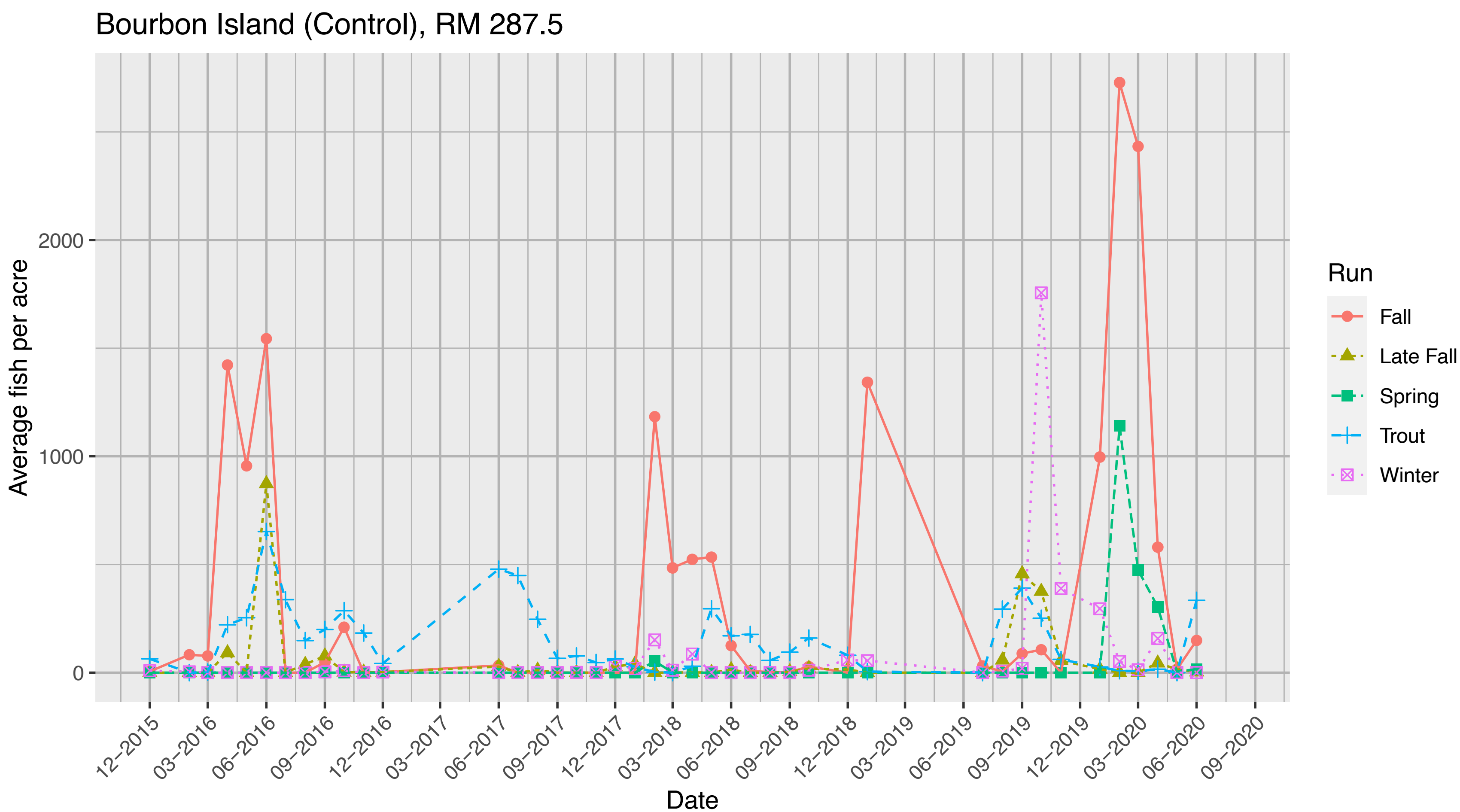
South Cypress (Pre−project), RM 294
Average fish per acre
0
2000
4000
Date
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Run
Fall
Late Fall
Spring
Trout
Winter

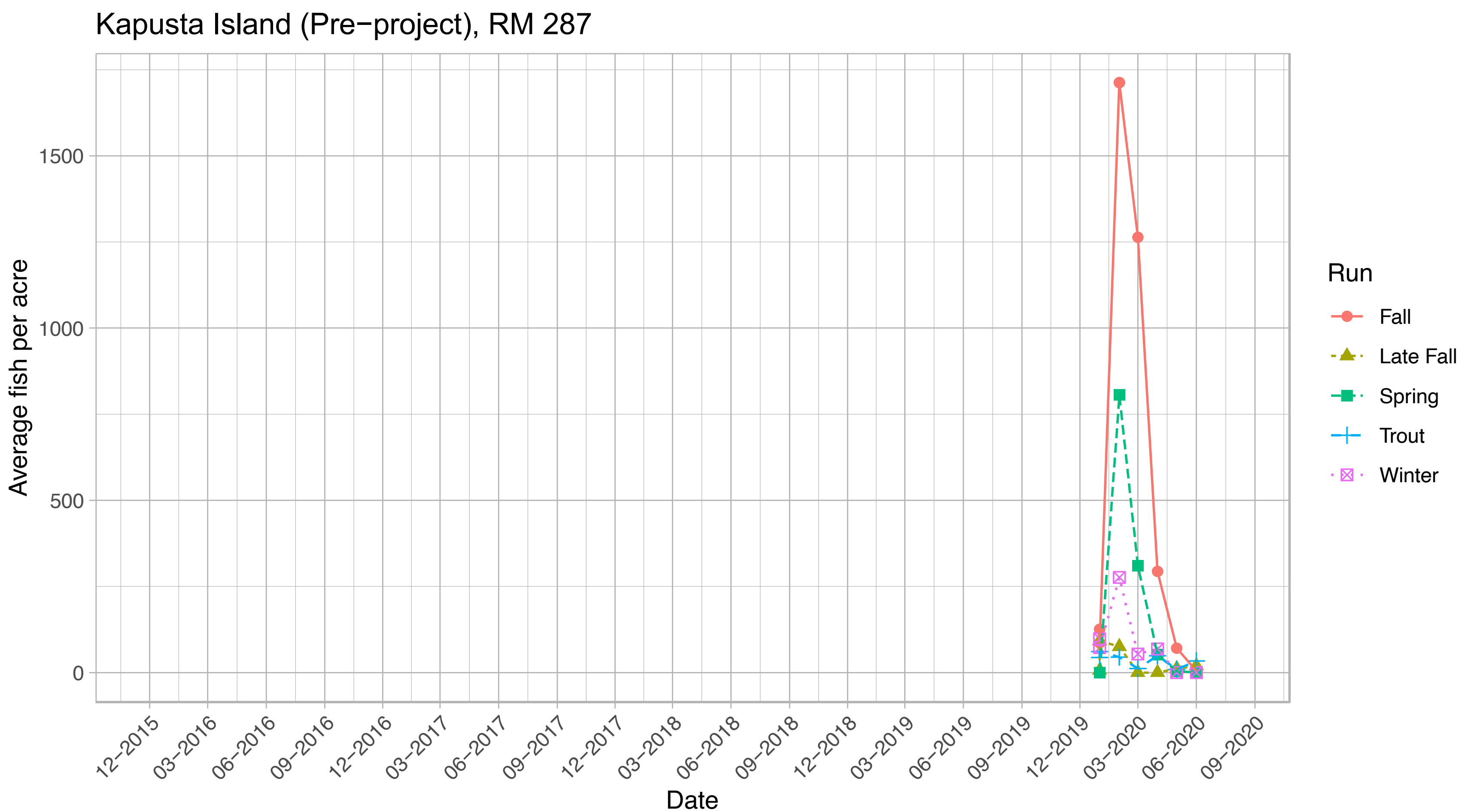

Wyndham (Control), RM 293.5
Average fish per acre
0
500
1000
1500
Date
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Run
Fall
Late Fall
Spring
Trout
Winter

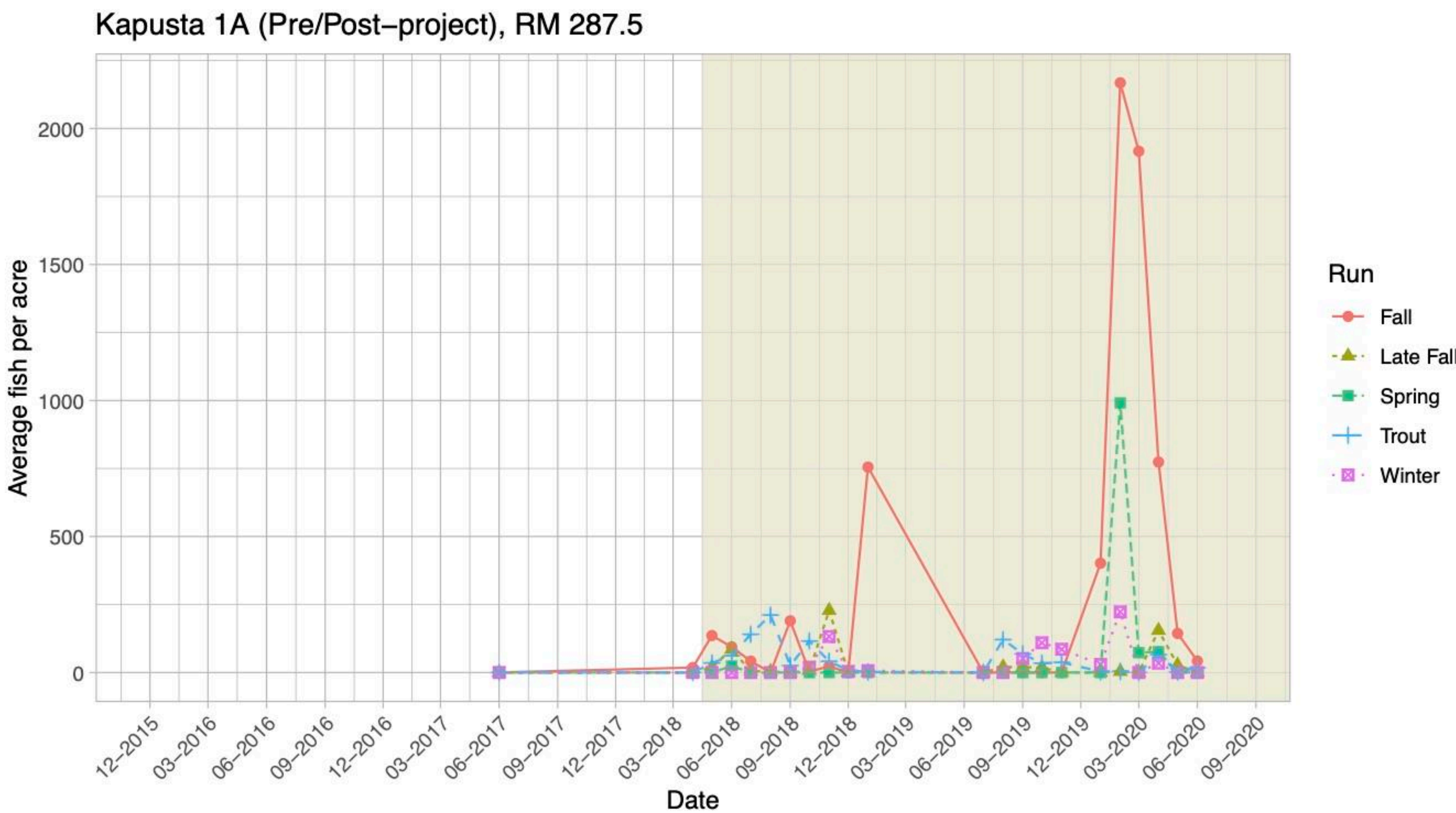

Shea Island (Pre−project), RM 290
Average fish per acre
800
600
400
200
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter



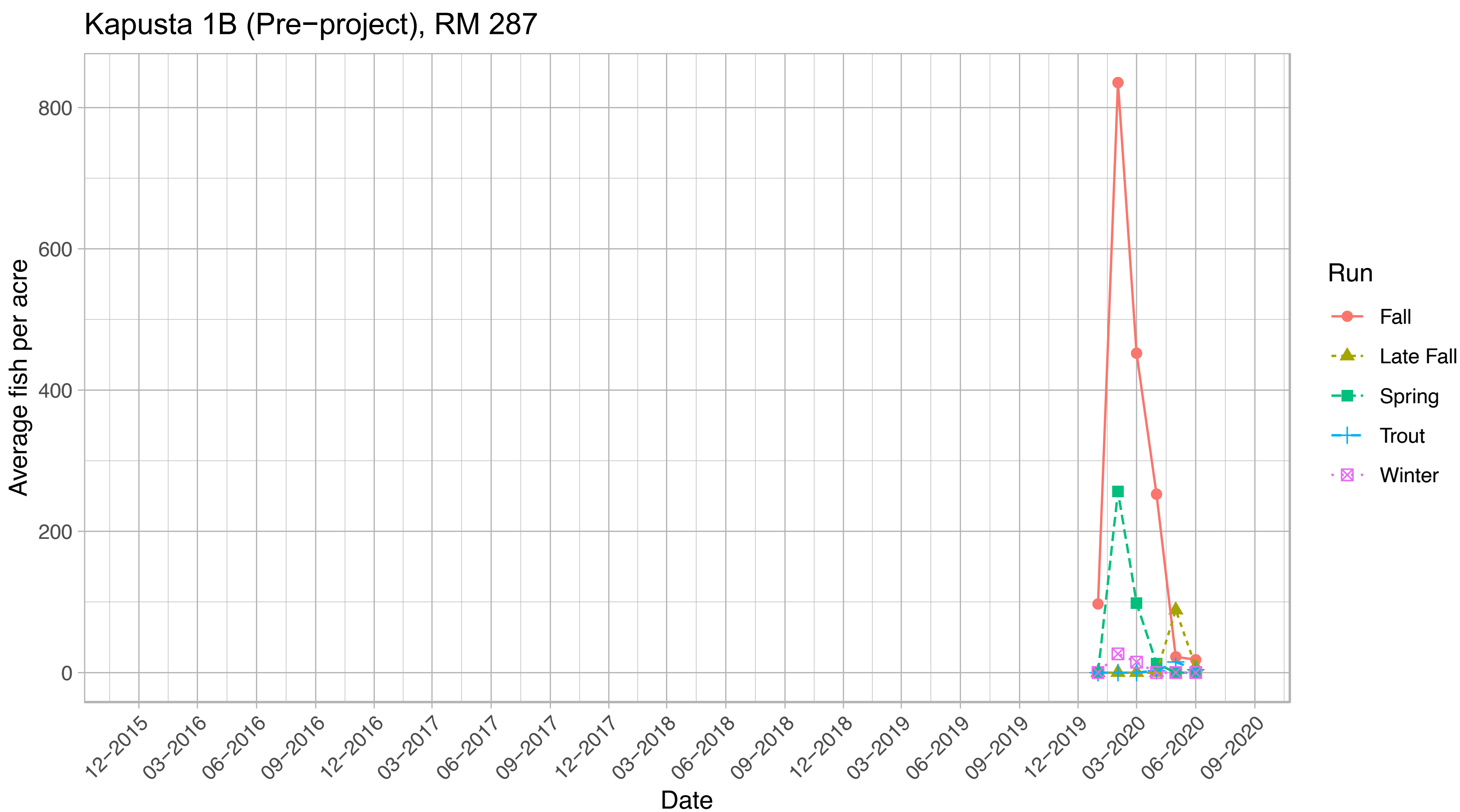
Clear Creek (Control), RM 289
Average fish per acre
1200
900
600
300
0
12–2015
03–2016
06–2016
09–2016
12–2016
03–2017
06–2017
09–2017
12–2017
03–2018
06–2018
09–2018
12–2018
03–2019
06–2019
09–2019
12–2019
03–2020
06–2020
09–2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

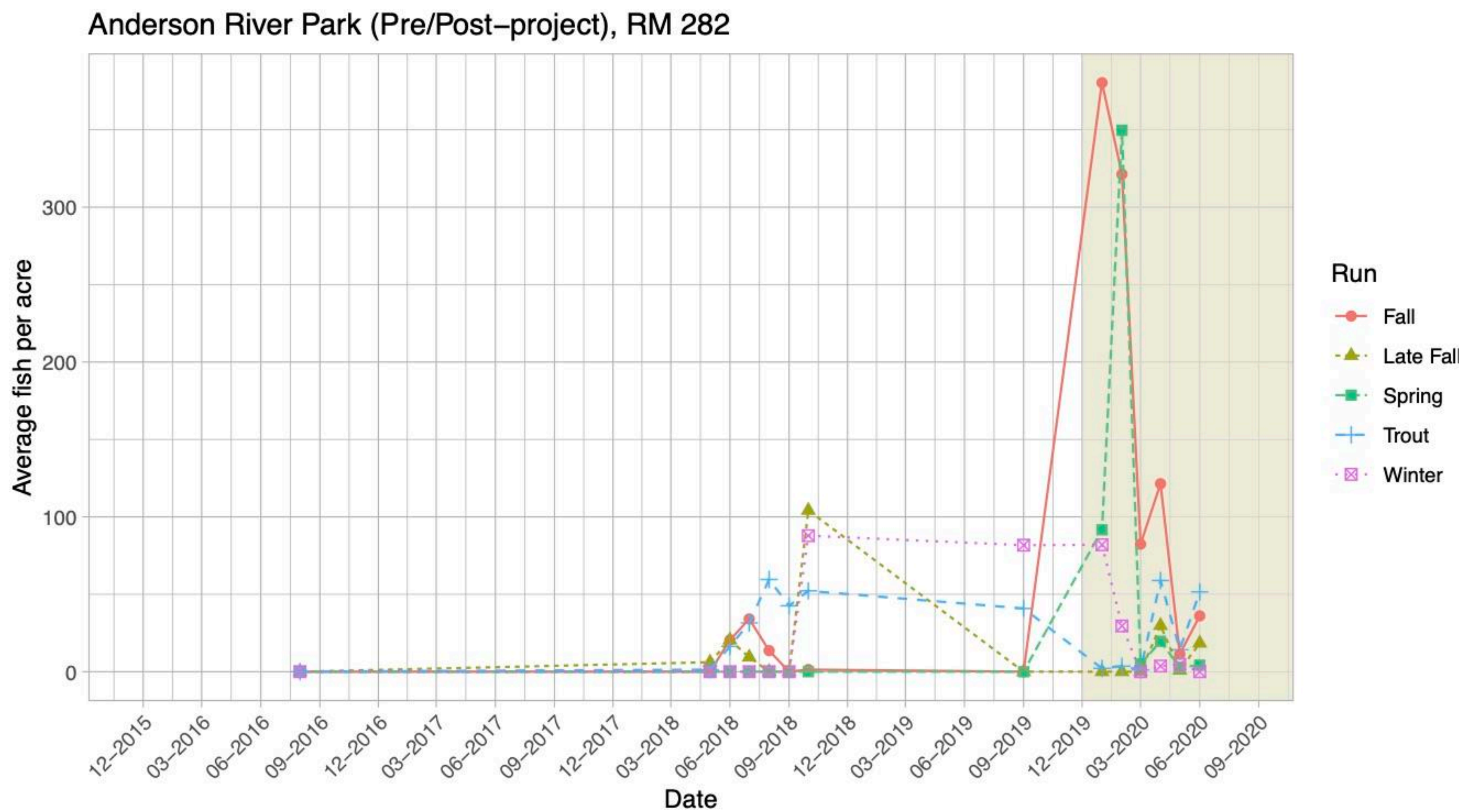

Bourbon Island (Control), RM 287.5
Average fish per acre
2000
1000
0
12–2015
03–2016
06–2016
09–2016
12–2016
03–2017
06–2017
09–2017
12–2017
03–2018
06–2018
09–2018
12–2018
03–2019
06–2019
09–2019
12–2019
03–2020
06–2020
09–2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter


Kapusta Island (Pre−project), RM 287
Average fish per acre
0
500
1000
1500
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

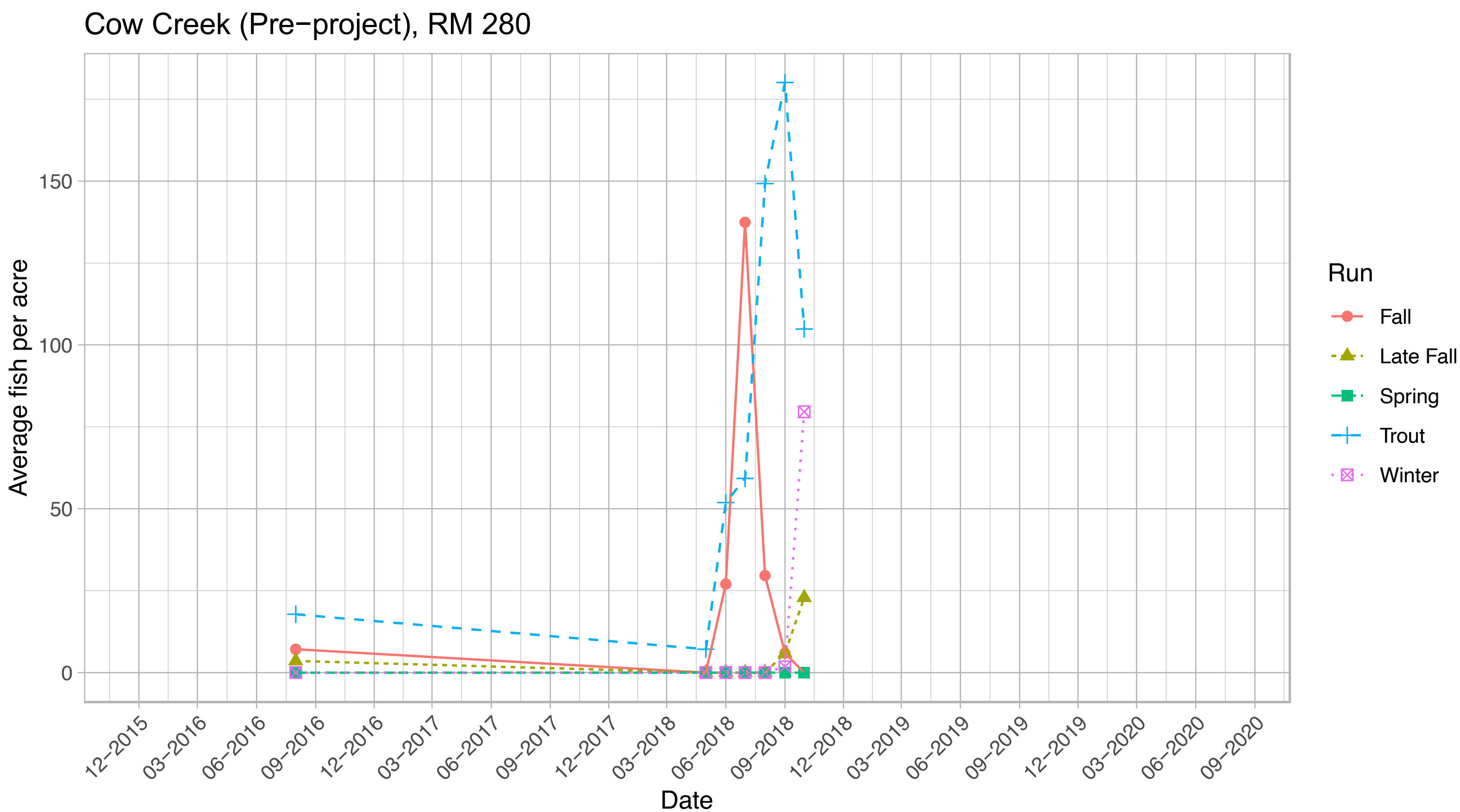


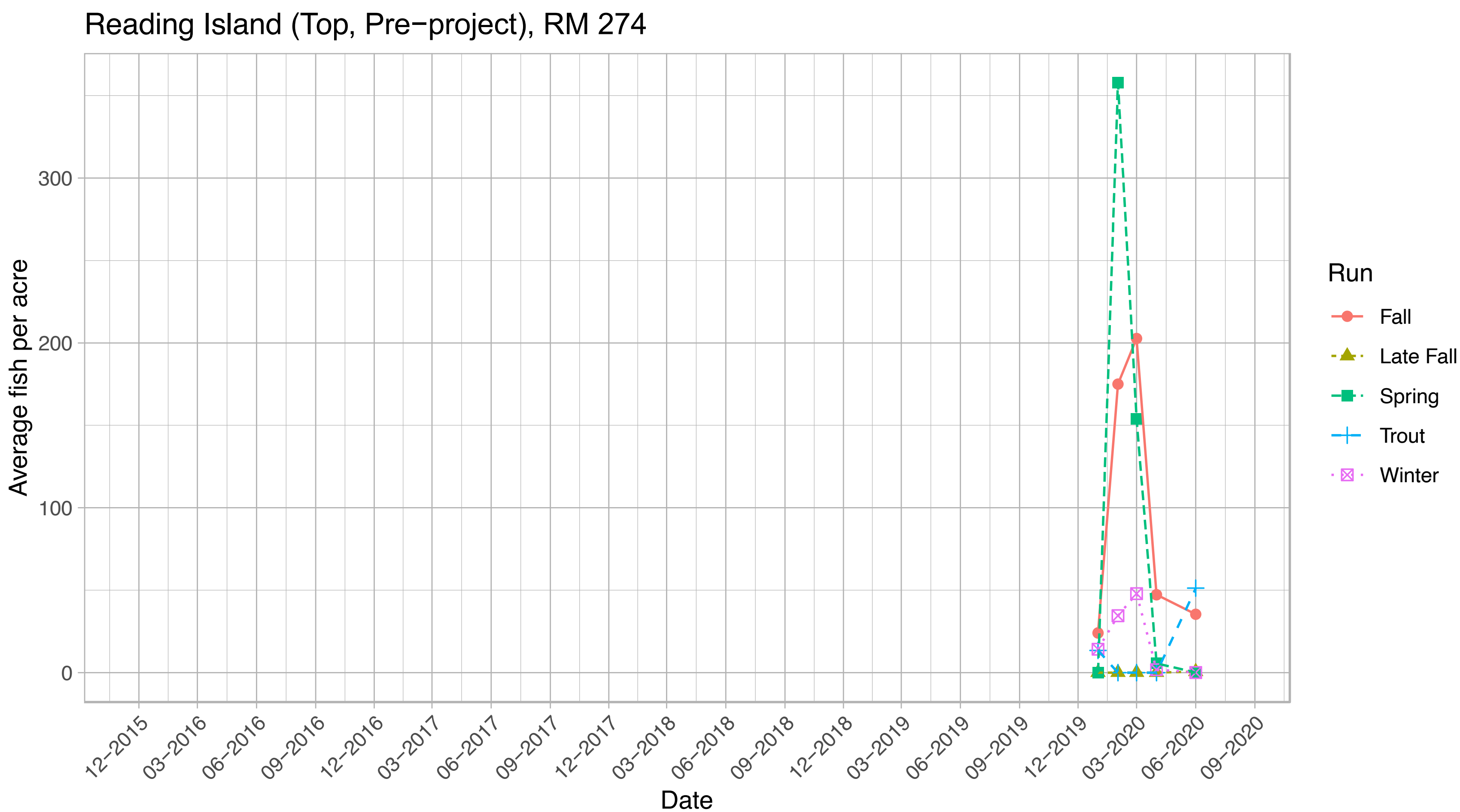
Kapusta 1A (Pre/Post–project), RM 287.5
Average fish per acre
2000
1500
1000
500
0
Date
12–2015
03–2016
06–2016
09–2016
12–2016
03–2017
06–2017
09–2017
12–2017
03–2018
06–2018
09–2018
12–2018
03–2019
06–2019
09–2019
12–2019
03–2020
06–2020
09–2020
Run
Fall
Late Fall
Spring
Trout
Winter

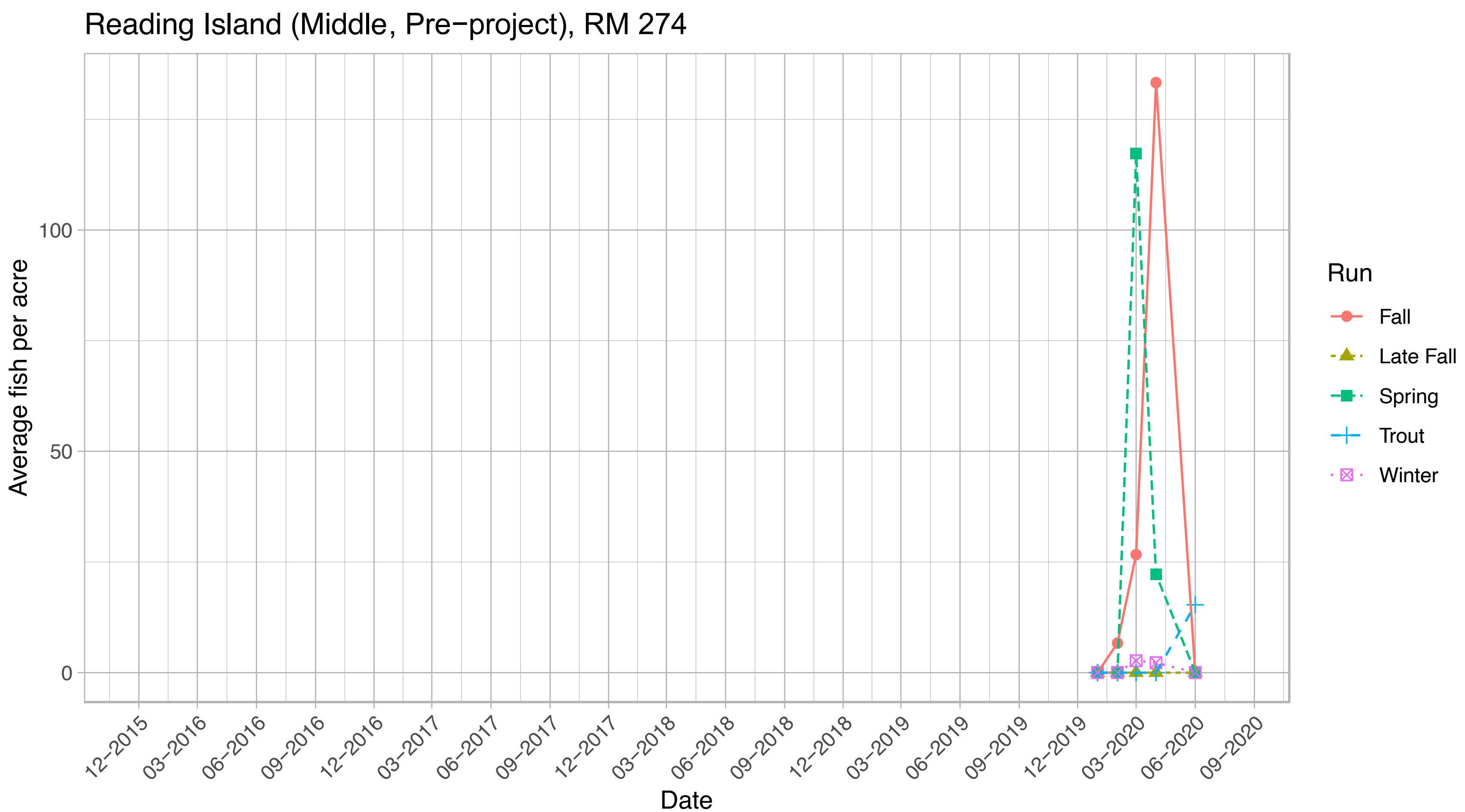

Kapusta 1B (Pre−project), RM 287
Average fish per acre
0
200
400
600
800
Date
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Run
Fall
Late Fall
Spring
Trout
Winter



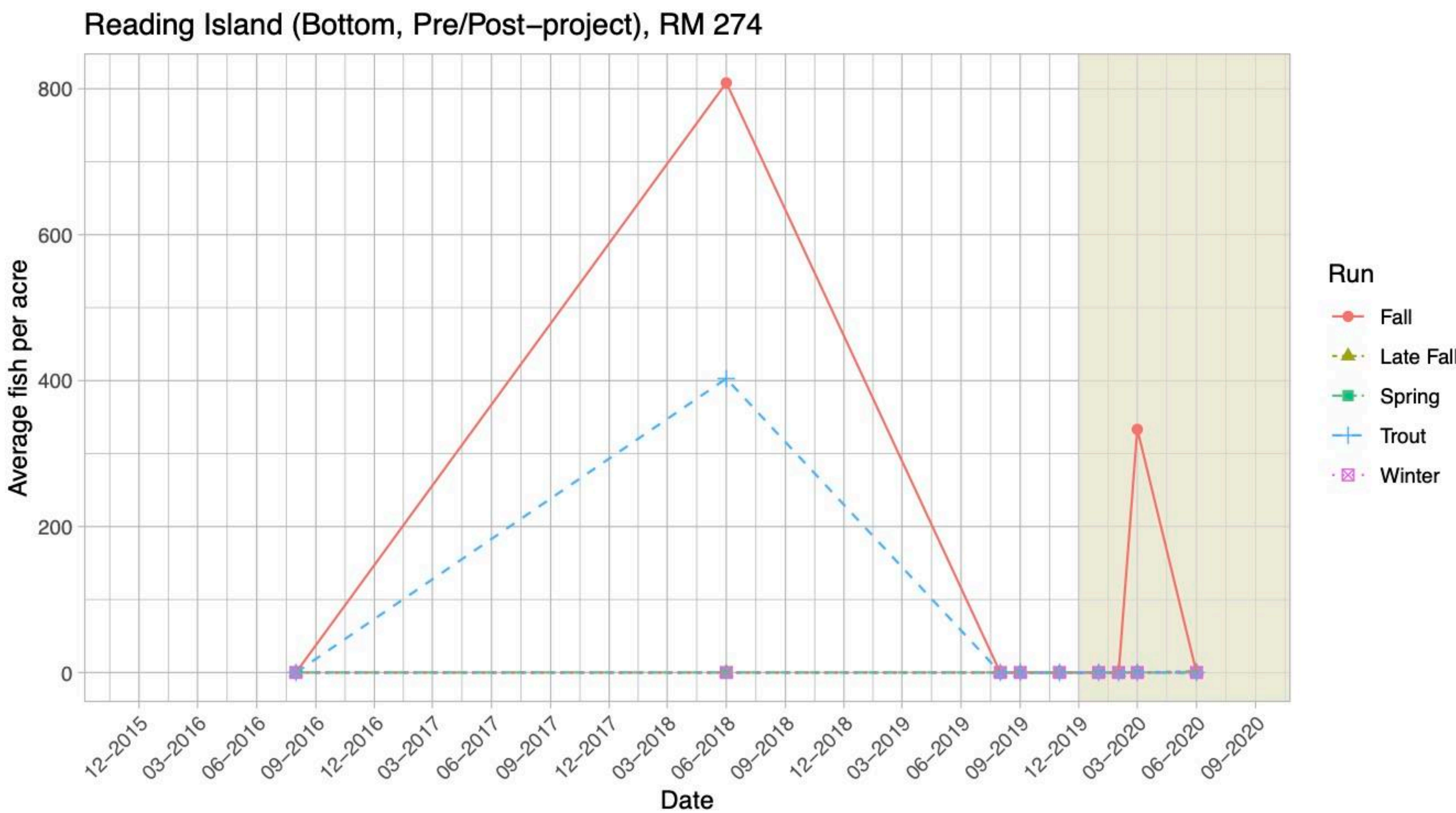
Anderson River Park (Pre/Post−project), RM 282
Average fish per acre
300
200
100
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter


Cow Creek (Pre−project), RM 280
Average fish per acre
150
100
50
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

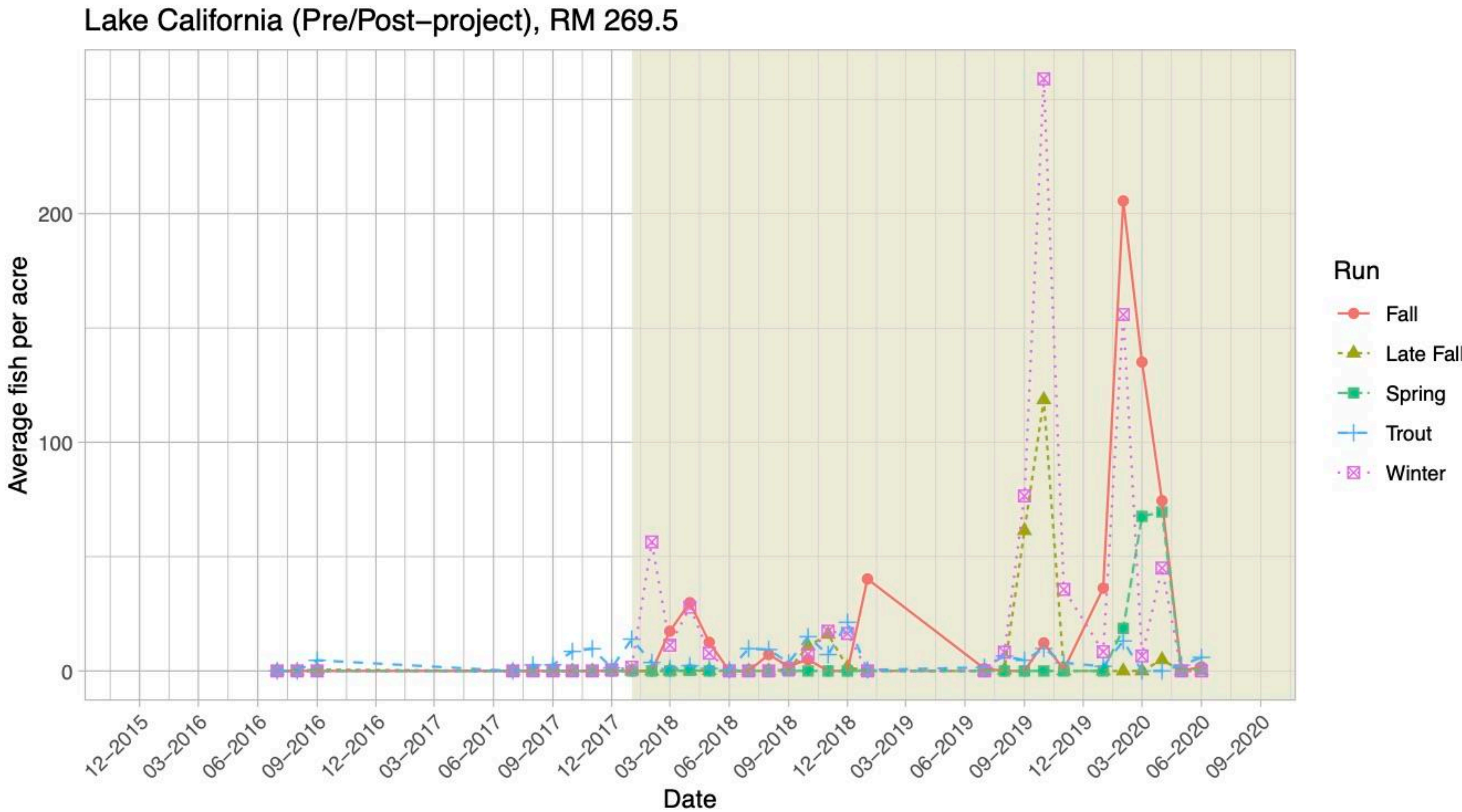

Reading Island (Top, Pre−project), RM 274
Average fish per acre
300
200
100
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter



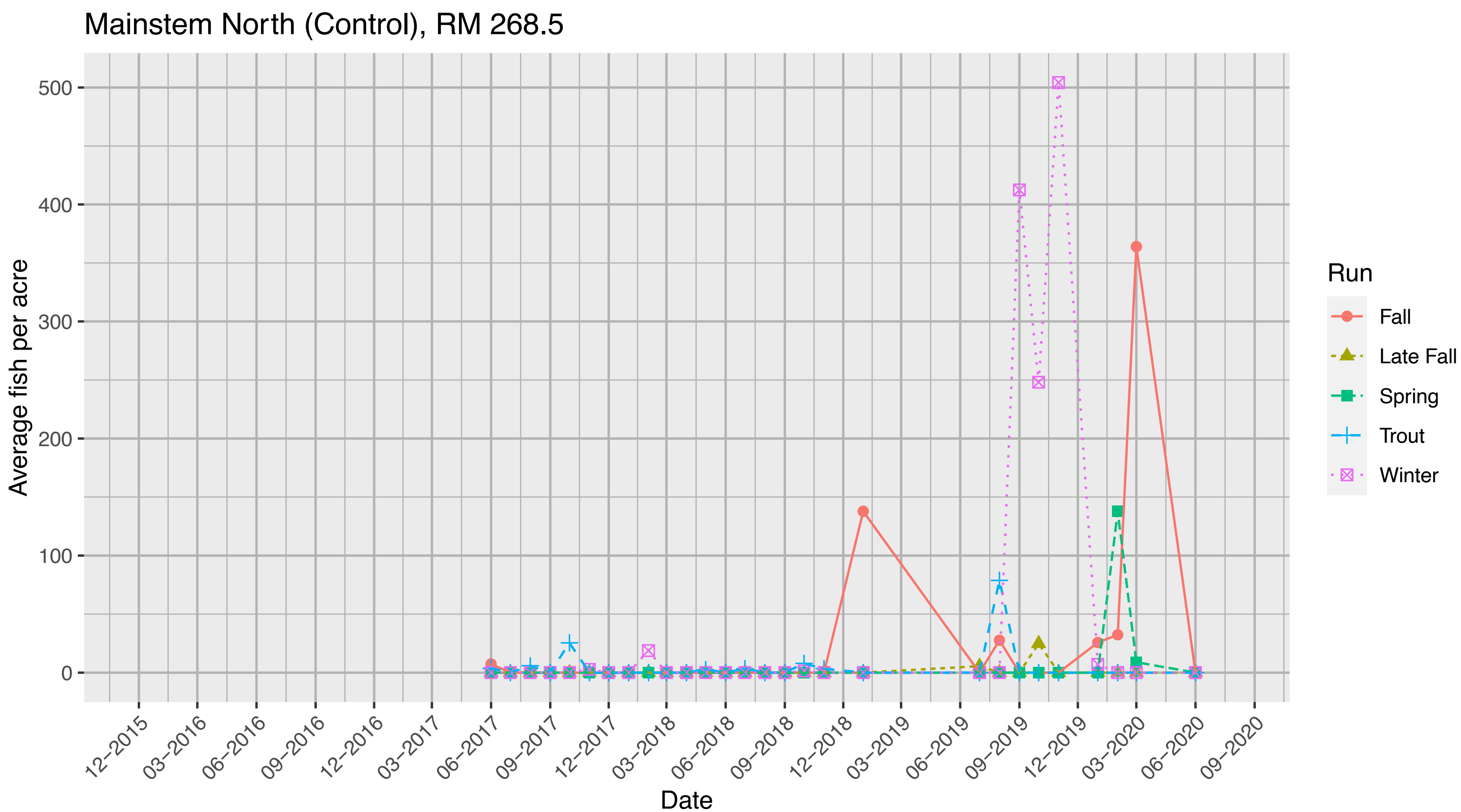
Reading Island (Middle, Pre−project), RM 274
Average fish per acre
100
50
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter



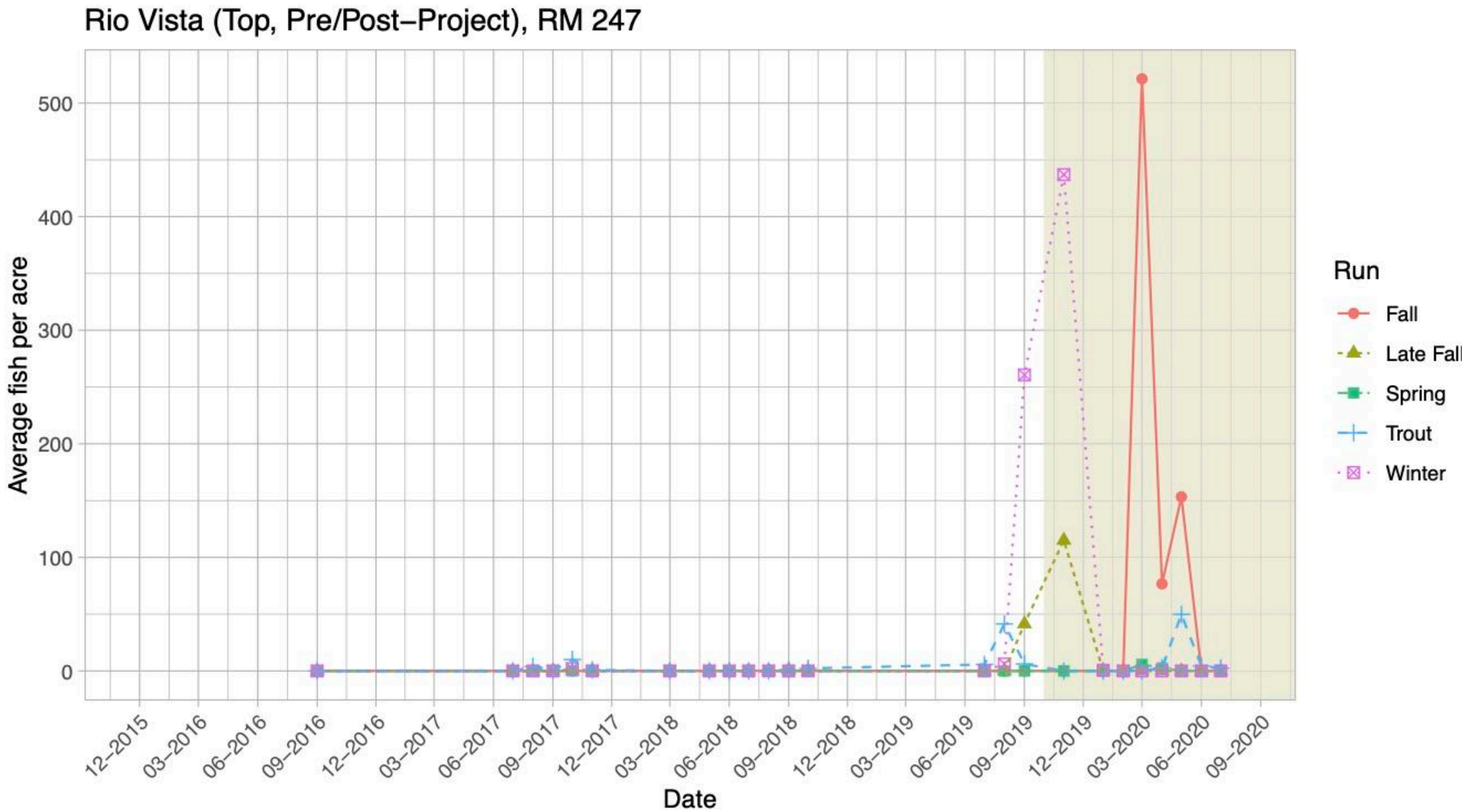
Reading Island (Bottom, Pre/Post−project), RM 274
800
600
400
200
0
Average fish per acre
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter



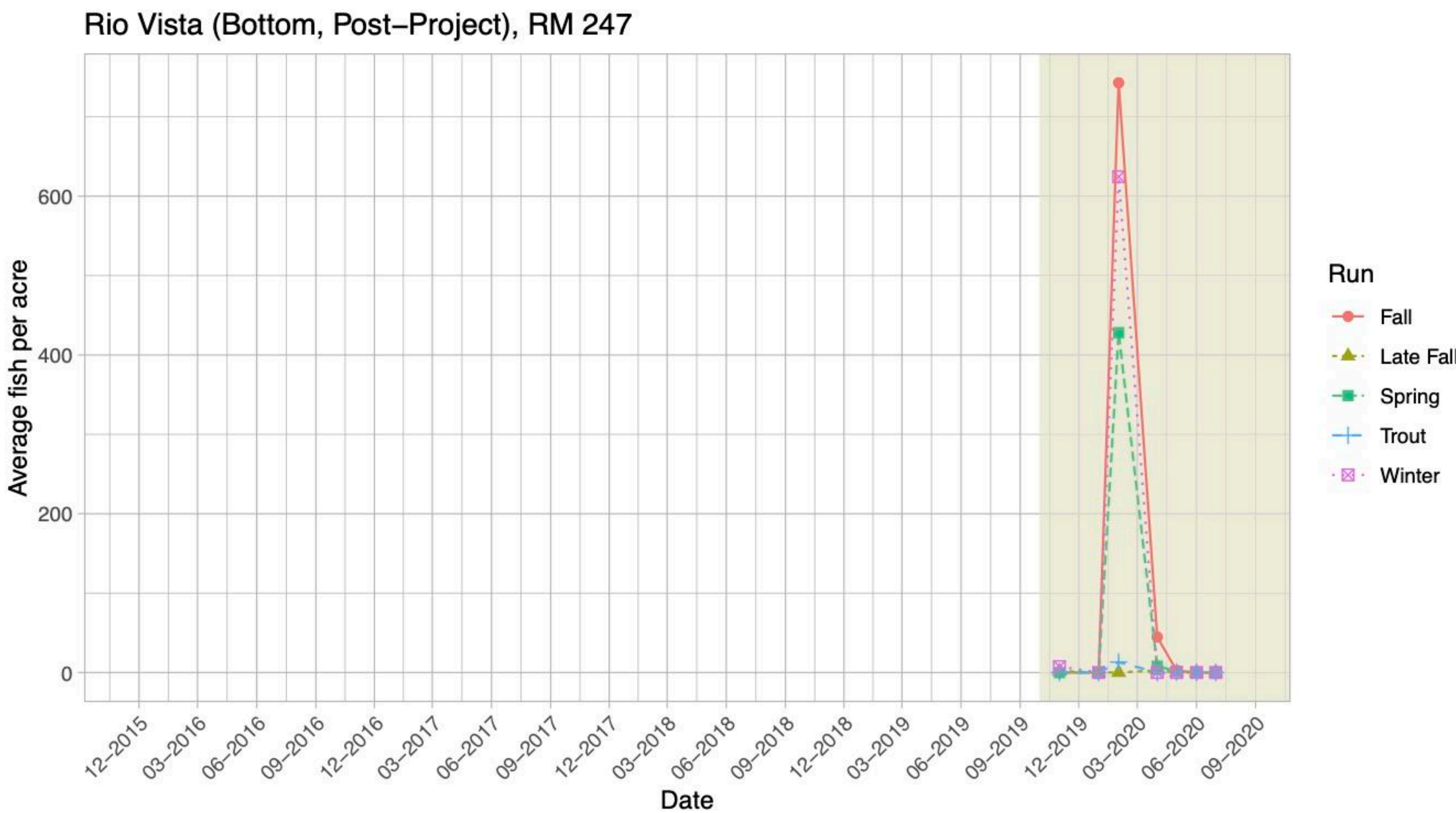
Lake California (Pre/Post−project), RM 269.5
Average fish per acre
200
100
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

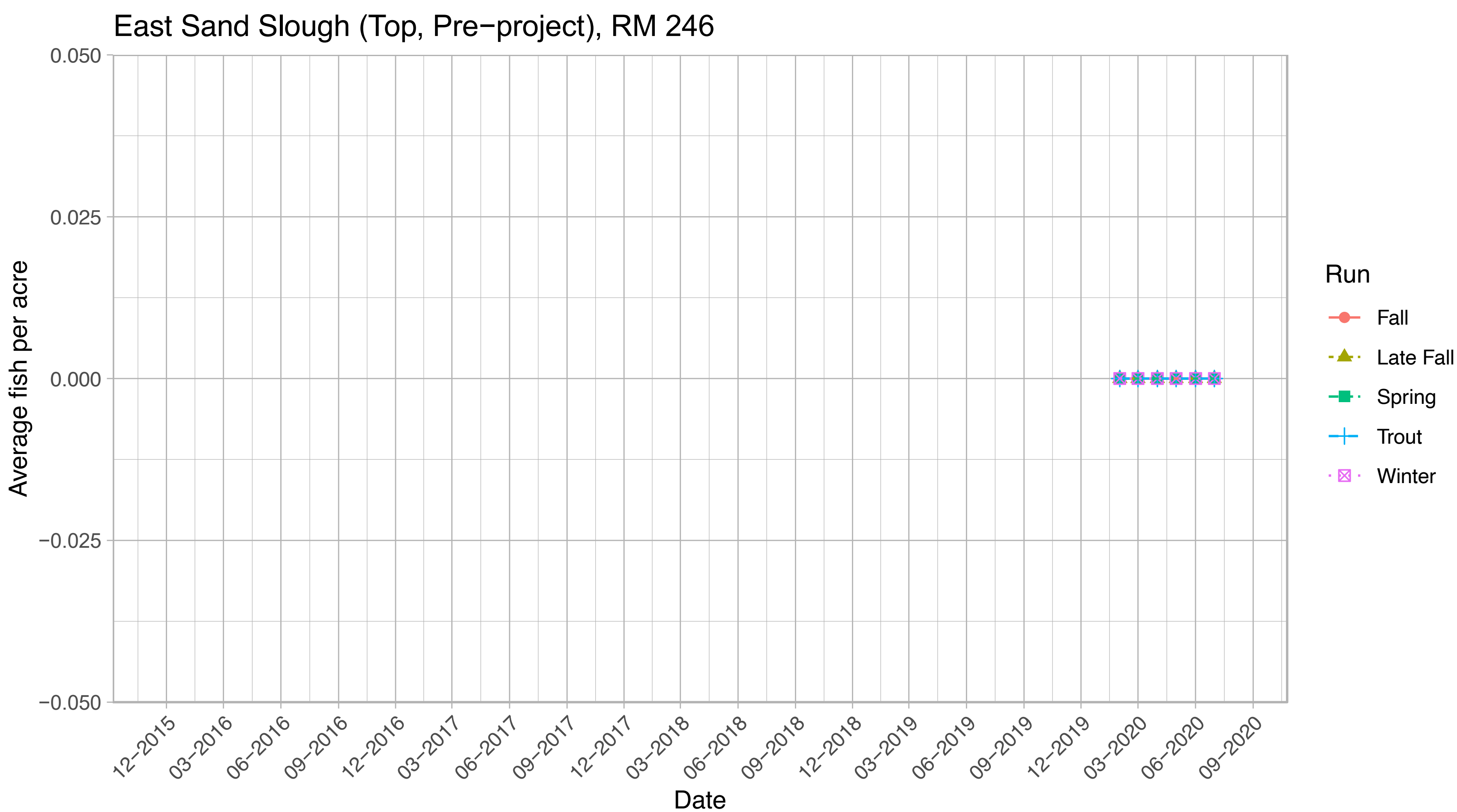


Mainstem North (Control), RM 268.5
Average fish per acre
500
400
300
200
100
0
12–2015
03–2016
06–2016
09–2016
12–2016
03–2017
06–2017
09–2017
12–2017
03–2018
06–2018
09–2018
12–2018
03–2019
06–2019
09–2019
12–2019
03–2020
06–2020
09–2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

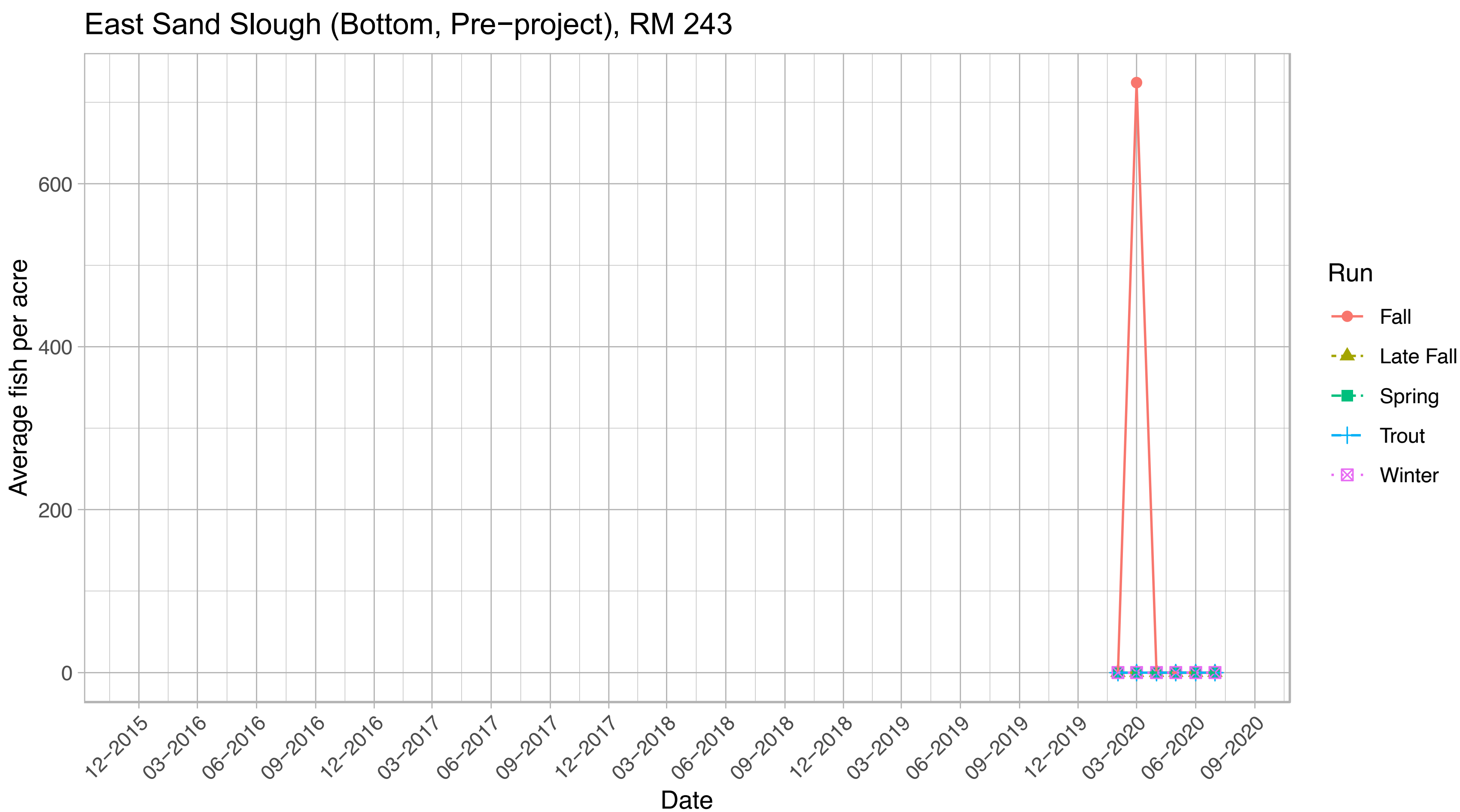


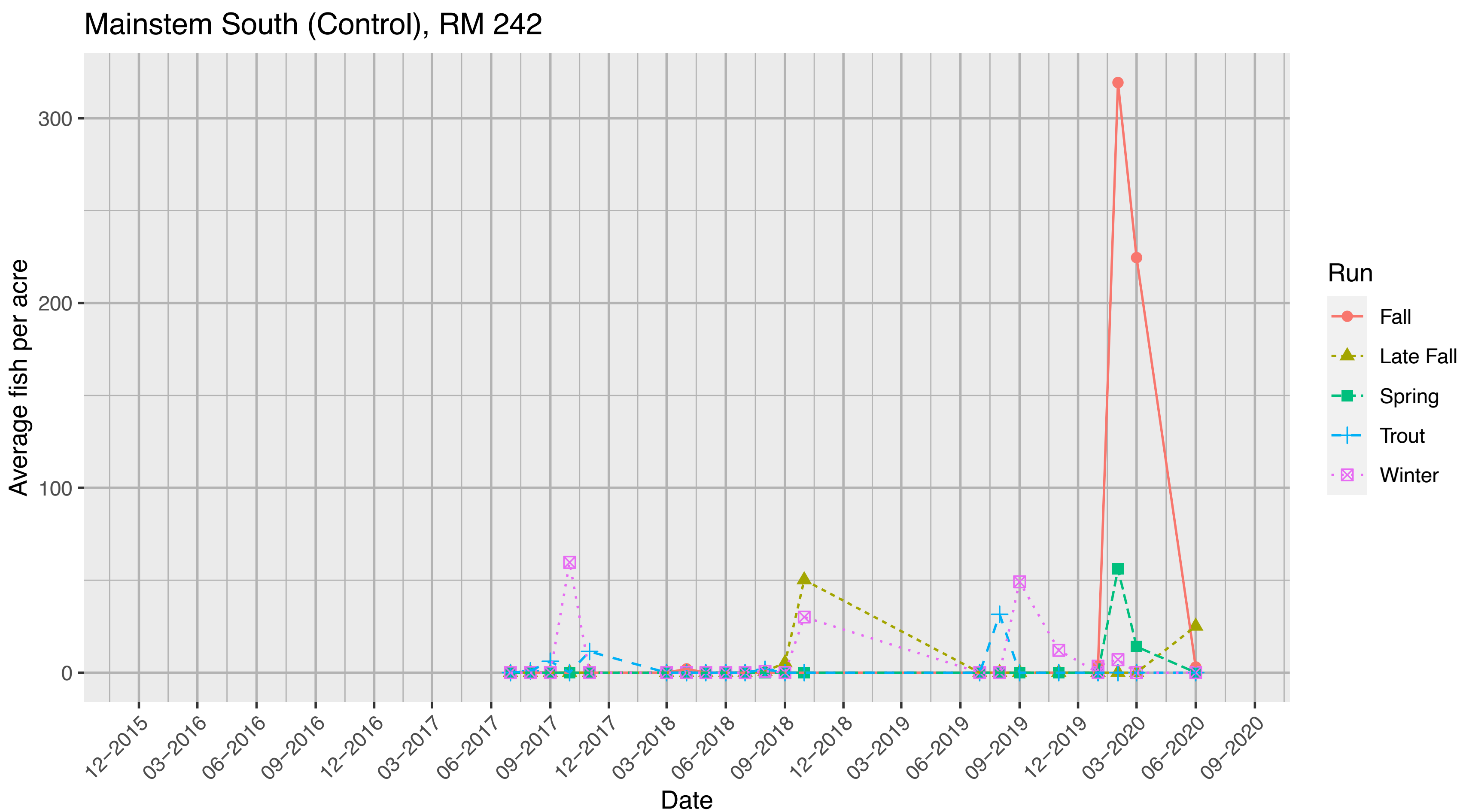
Rio Vista (Top, Pre/Post−Project), RM 247
Average fish per acre
500
400
300
200
100
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter


Rio Vista (Bottom, Post−Project), RM 247
600
400
200
0
Average fish per acre
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter



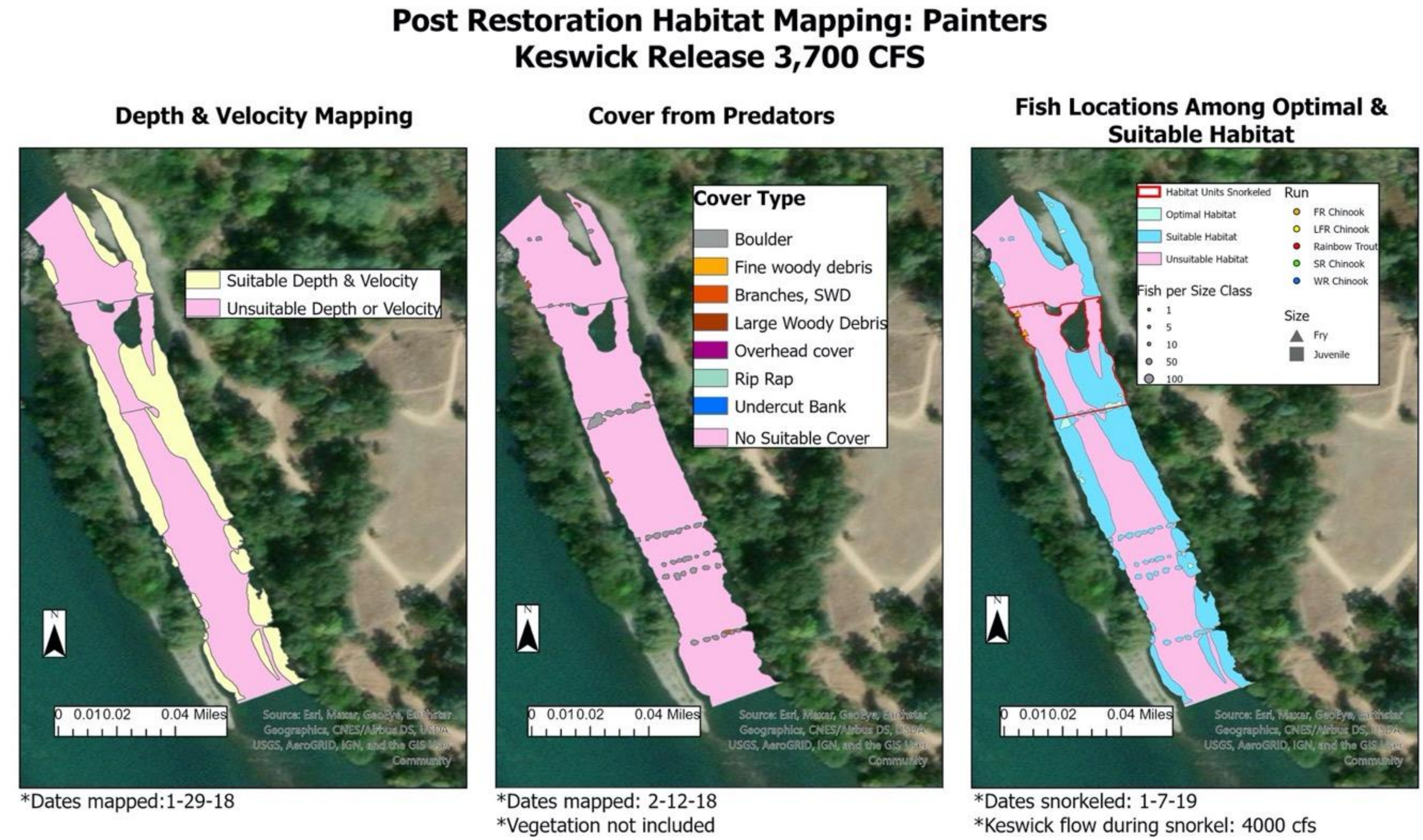
East Sand Slough (Top, Pre−project), RM 246
0.050
0.025
0.000
−0.025
−0.050
Average fish per acre
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter


East Sand Slough (Bottom, Pre−project), RM 243
Average fish per acre
600
400
200
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter


Mainstem South (Control), RM 242
Average fish per acre
300
200
100
0
12−2015
03−2016
06−2016
09−2016
12−2016
03−2017
06−2017
09−2017
12−2017
03−2018
06−2018
09−2018
12−2018
03−2019
06−2019
09−2019
12−2019
03−2020
06−2020
09−2020
Date
Run
Fall
Late Fall
Spring
Trout
Winter

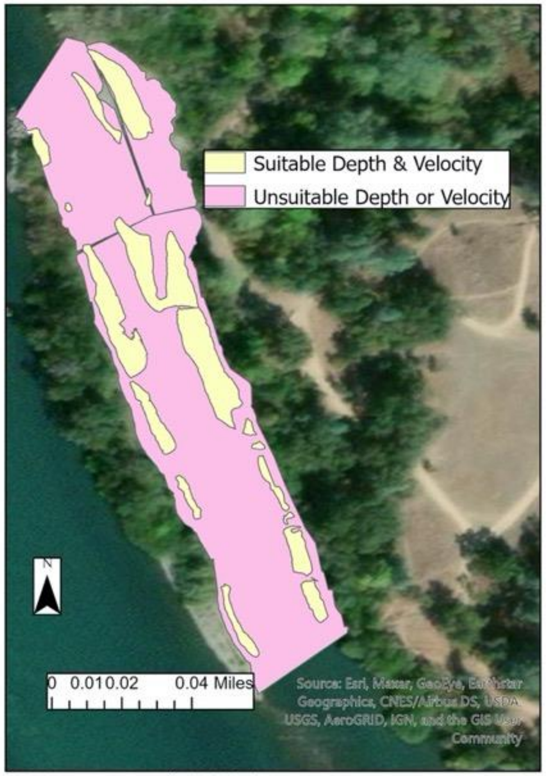
APPENDIX C – HABITAT MAPS (NO COBBLE OR VEGETATION)

Cobble and vegetation excluded, organized north to south, pre-restoration to post-restoration, and low flow to high flow.



Post Restoration Habitat Mapping: Painters
Keswick Release 5,000 CFS

Depth & Velocity Mapping



*Dates mapped: 12-5-17

Cover from Predators

*Dates mapped: 10-27-17
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat

*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

Post Restoration Habitat Mapping: Painters
Keswick Release 7,400 CFS

Depth & Velocity Mapping

*Dates mapped: 9-26-18 & 10-10-18

Cover from Predators

*Dates mapped: 9-26-18 & 10-10-18
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat

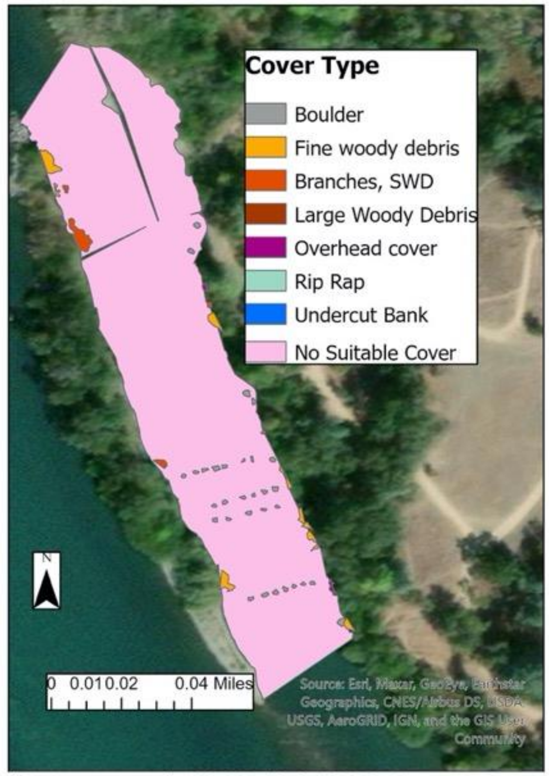
*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

Post Restoration Habitat Mapping: Painters
Keswick Release 7,800 CFS

Depth & Velocity Mapping

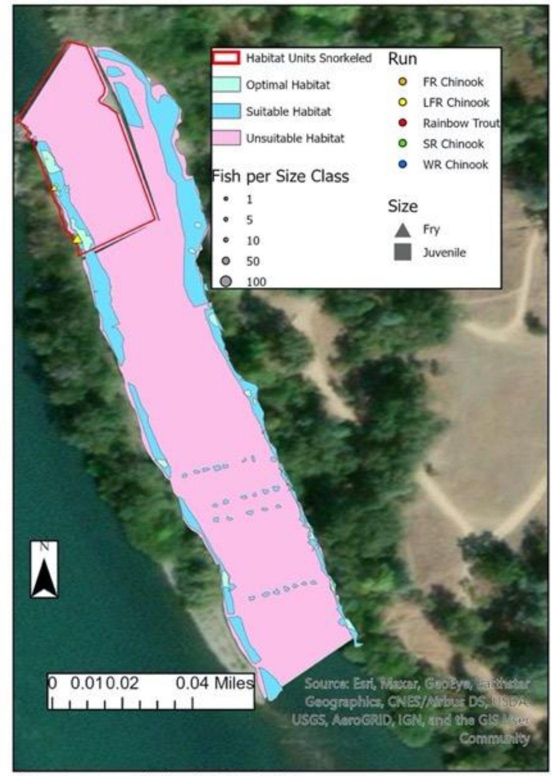
*Dates mapped: 10-28-19 & 10-30-19

Cover from Predators



*Dates mapped: 10-28-19 & 10-30-19
*Vegetation not included

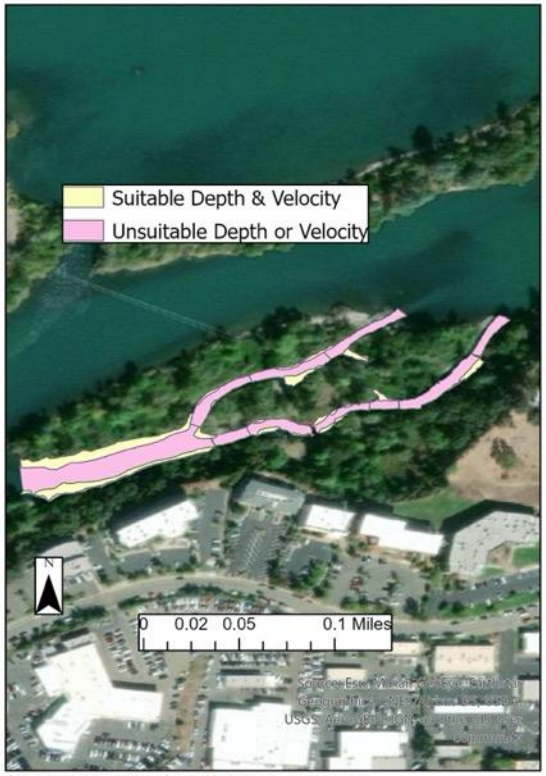
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-26-19
*Keswick flow during snorkel: 11000 cfs

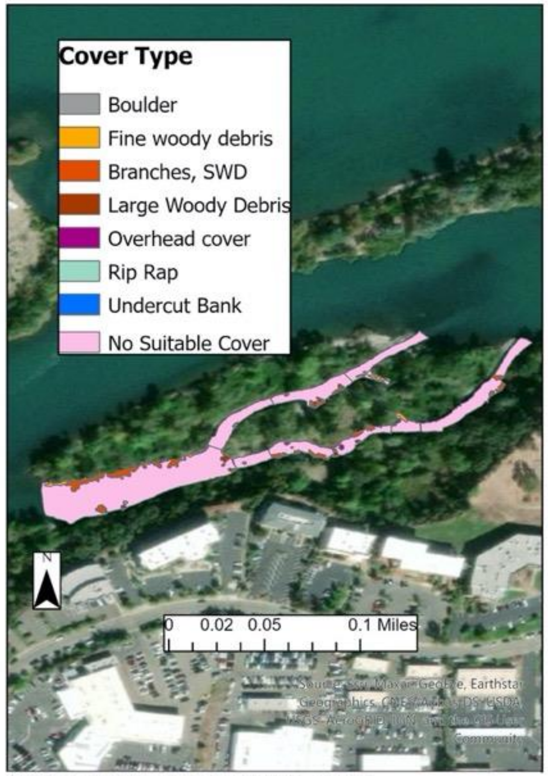
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 3,700 CFS

Depth & Velocity Mapping



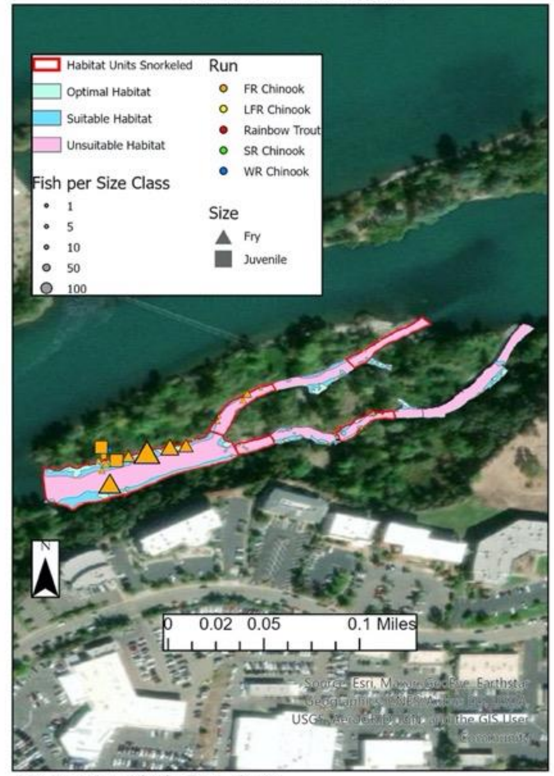
*Dates mapped: 2-9-18 & 2-12-18

Cover from Predators



*Dates mapped: 2-9-18 & 2-12-18
*Vegetation not included

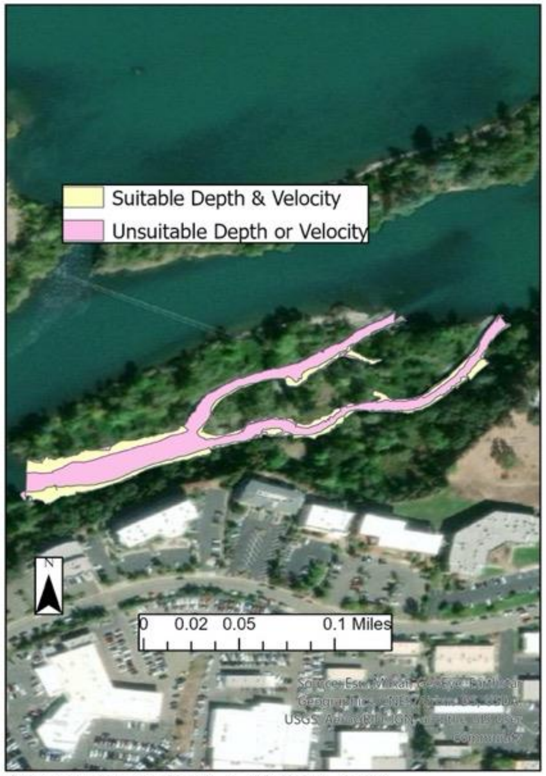
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-7-19
*Keswick flow during snorkel: 4000 cfs

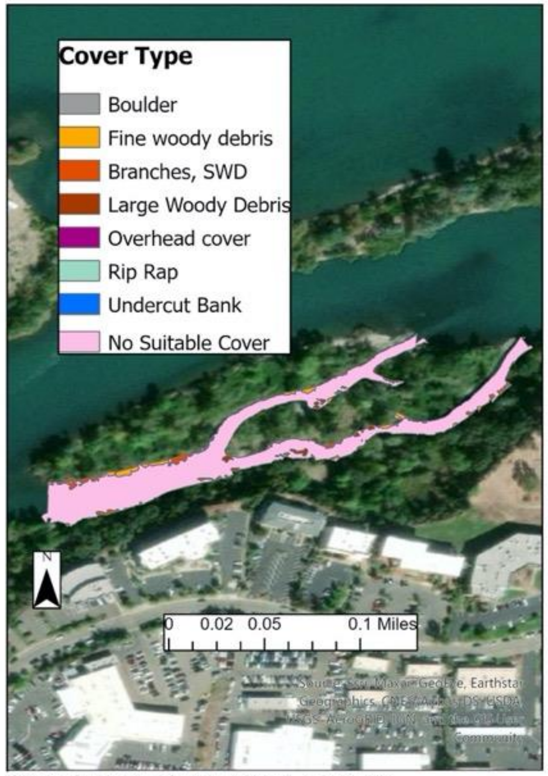
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



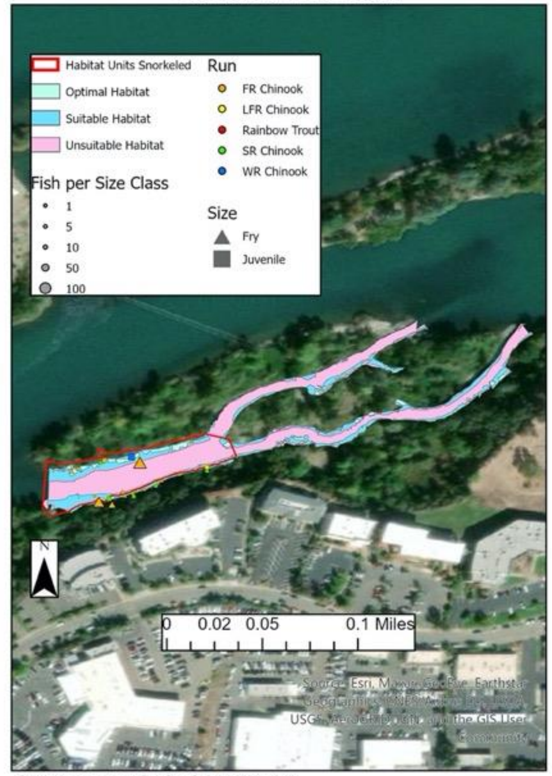
*Dates mapped: 11-4-19 & 11-6-19

Cover from Predators



*Dates mapped: 11-4-19 & 11-6-19
*Vegetation not included

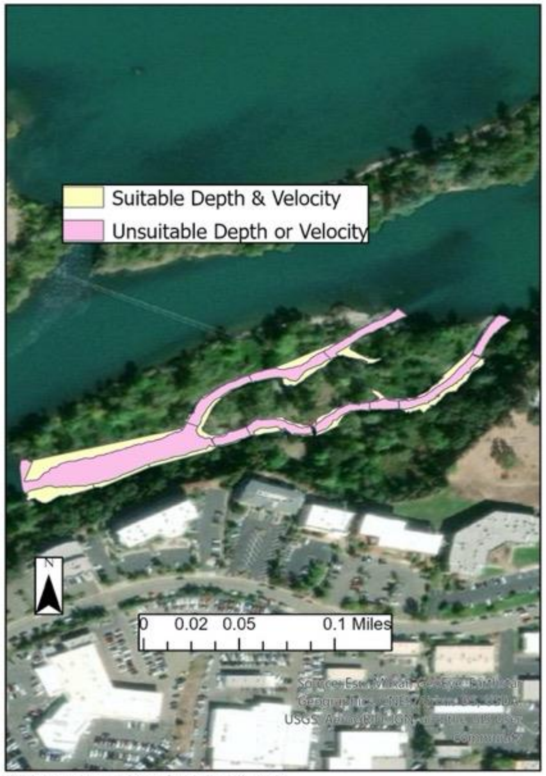
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-28-20
*Keswick flow during snorkel: 5000 cfs

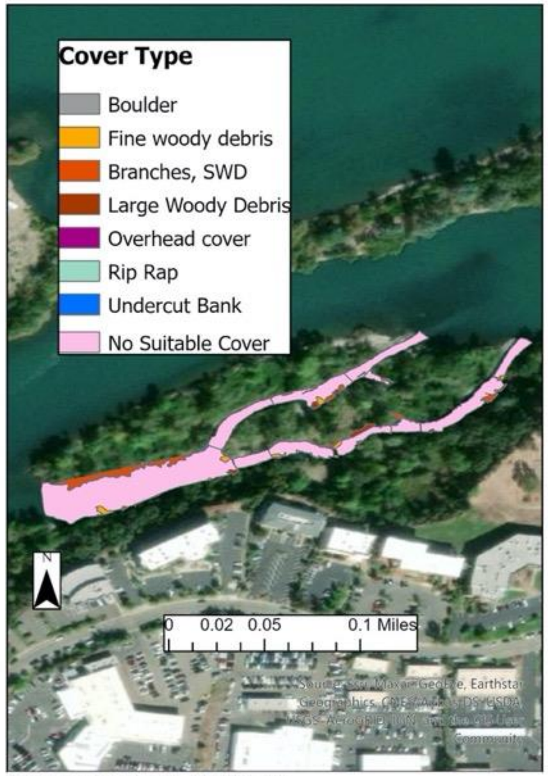
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 6,000 CFS

Depth & Velocity Mapping



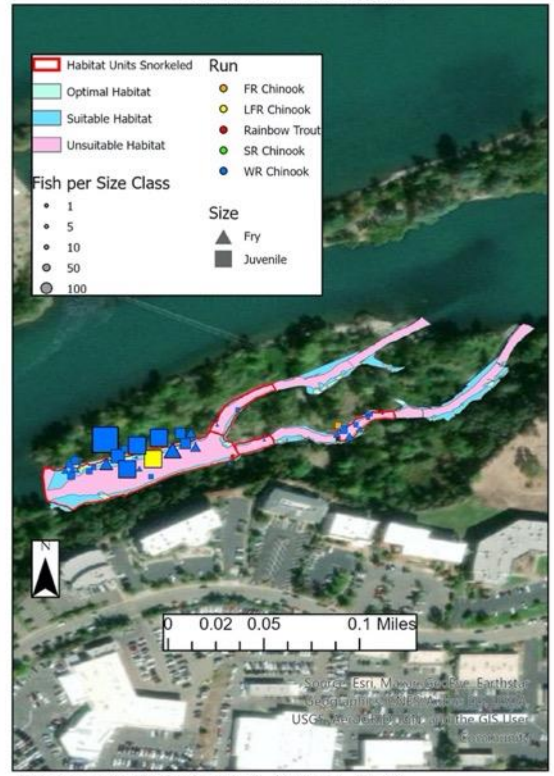
*Dates mapped: 10-24-18

Cover from Predators



*Dates mapped: 10-24-18
*Vegetation not included

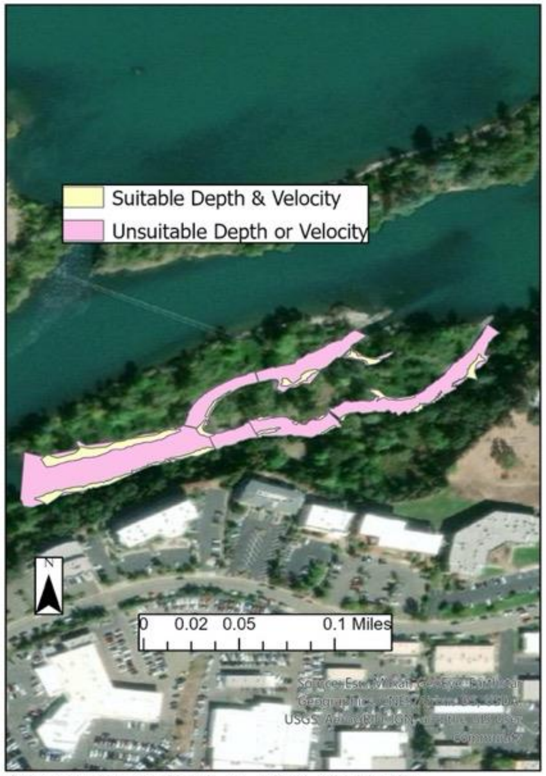
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-6-18 &11-7-18
*Keswick flow during snorkel: 4600 cfs

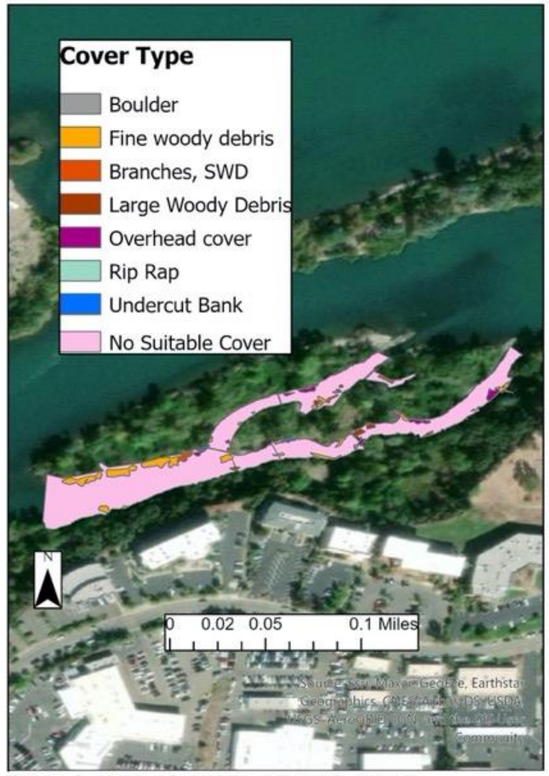
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 8,000 CFS

Depth & Velocity Mapping



*Dates mapped: 10-11-17 & 10-12-17

Cover from Predators



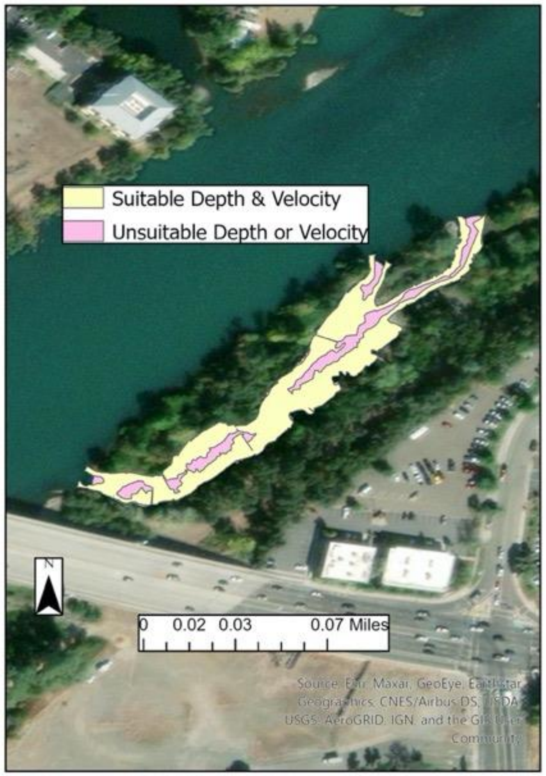
*Dates mapped: 10-11-17 & 10-12-17
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat

*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

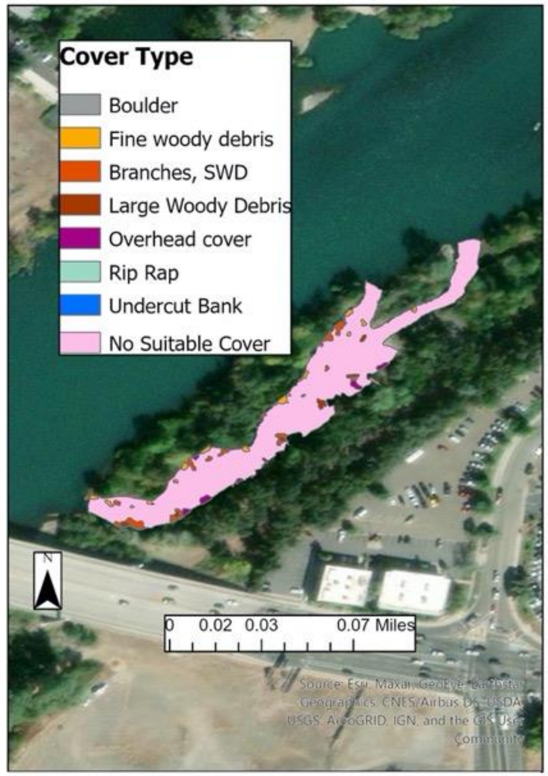
Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 3,700 CFS

Depth & Velocity Mapping



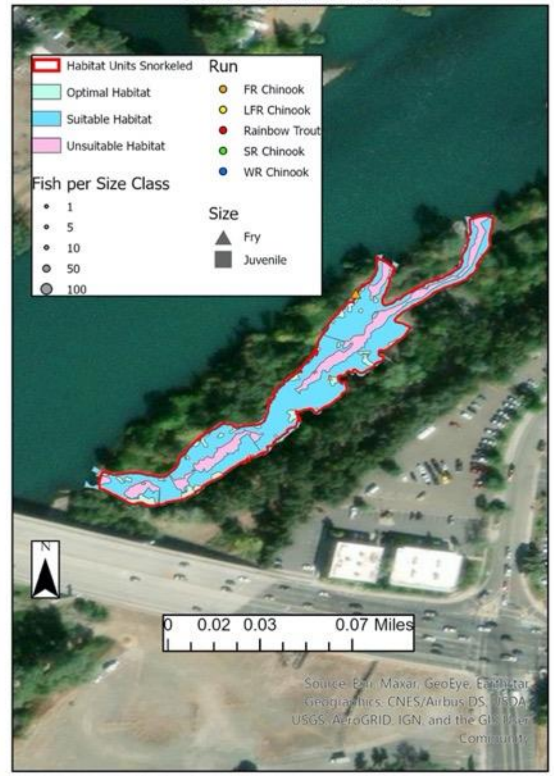
*Dates mapped: 2-9-18 & 2-12-18

Cover from Predators



*Dates mapped: 2-9-18 & 2-12-18
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat



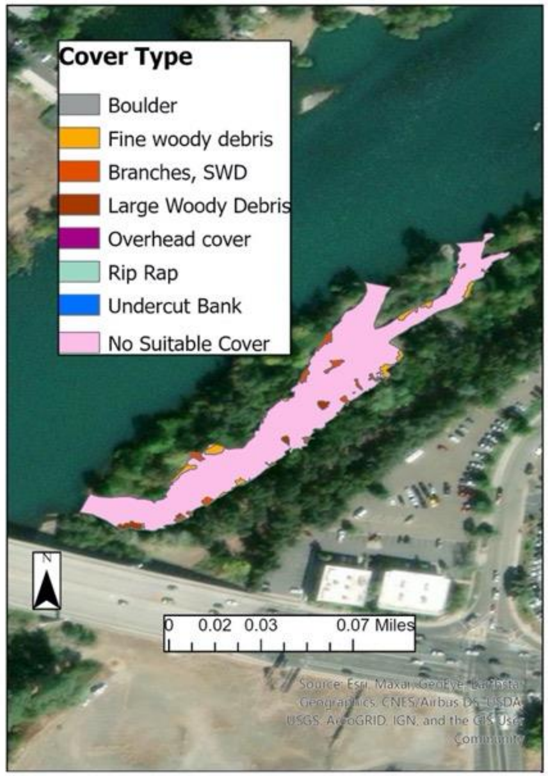
*Dates snorkeled: 1-7-19
*Keswick flow during snorkel: 4000 cfs

Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping

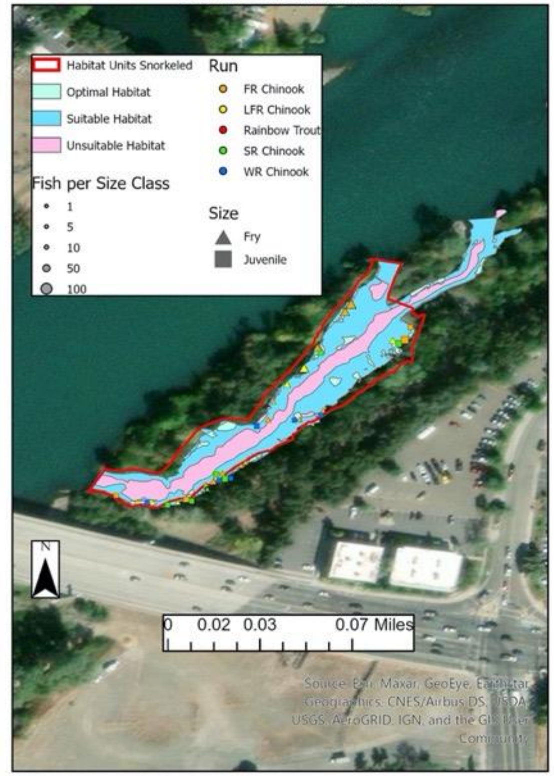
*Dates mapped: 11-4-19 & 11-6-19

Cover from Predators



*Dates mapped: 11-4-19 & 11-6-19
*Vegetation not included

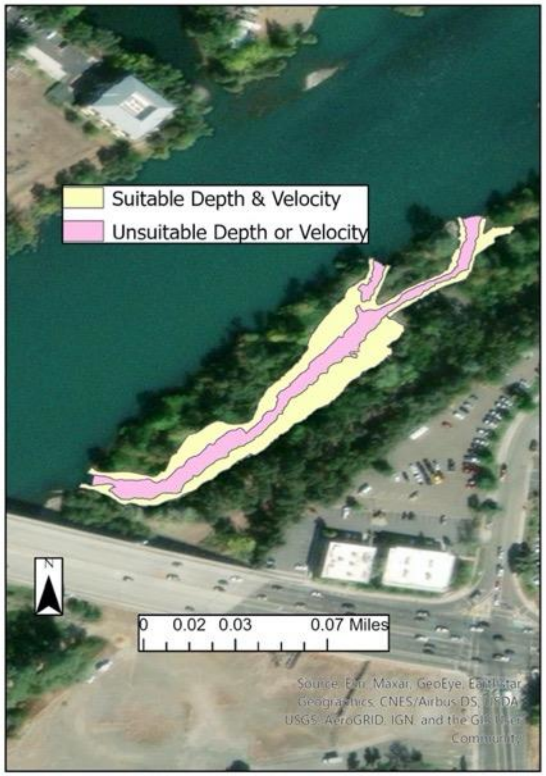
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-28-20
*Keswick flow during snorkel: 5000 cfs

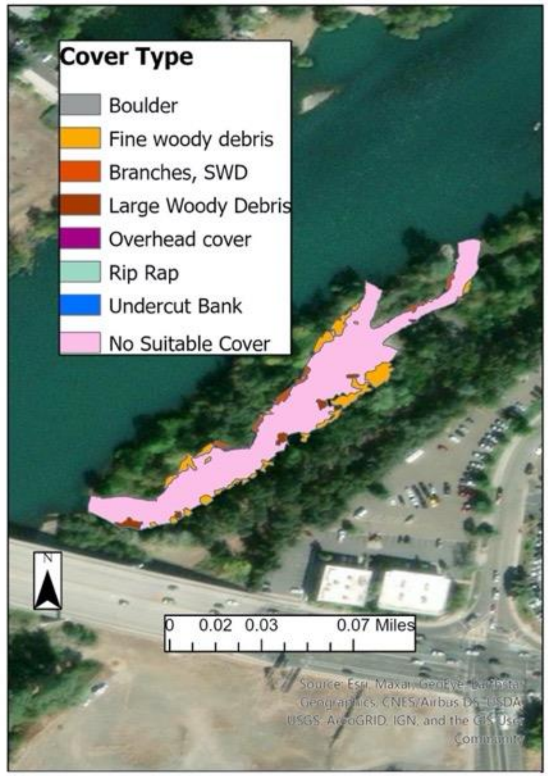
Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 6,000 CFS

Depth & Velocity Mapping



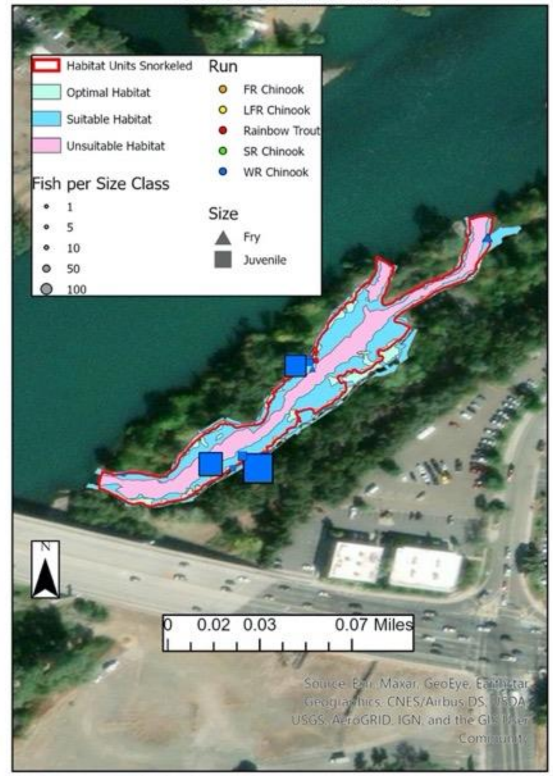
*Dates mapped: 10-24-18

Cover from Predators



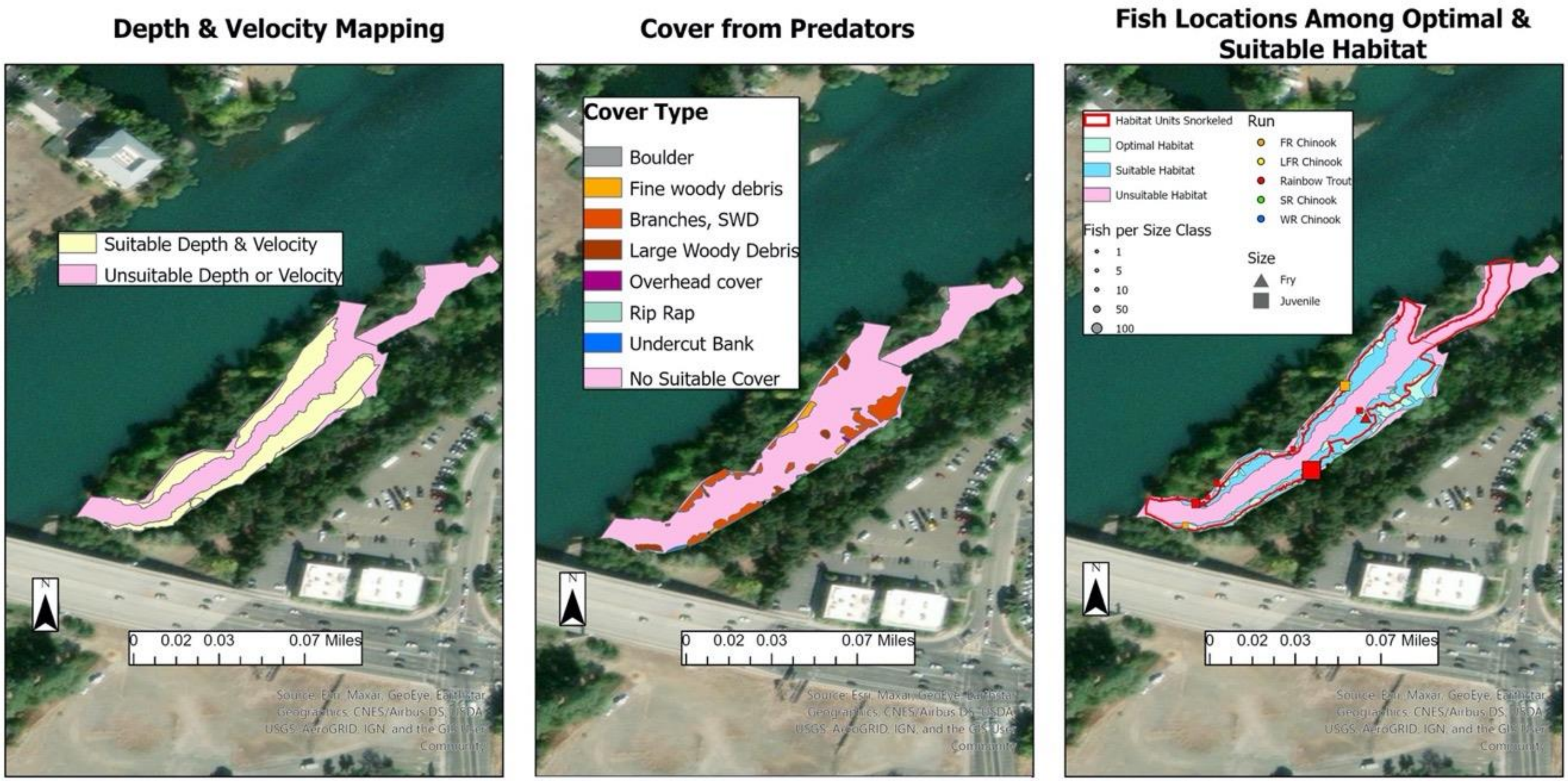
*Dates mapped: 10-24-18
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-6-18 &11-7-18
*Keswick flow during snorkel: 4600 cfs

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



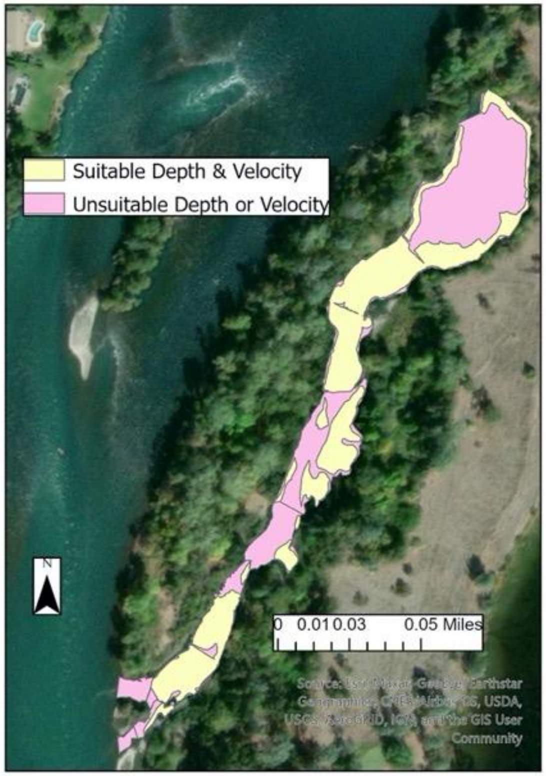
*Dates mapped: 10-11-17 & 10-12-17

*Dates mapped: 10-11-17 & 10-12-17
*Vegetation not included

*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

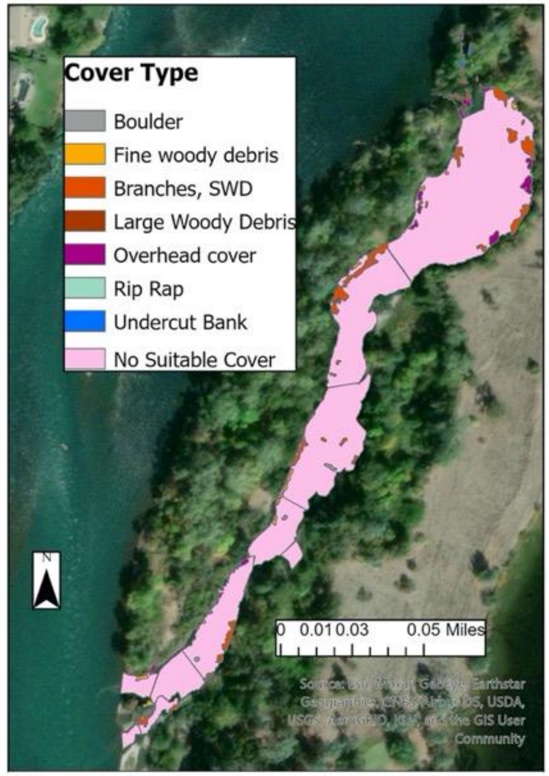
Control Site Habitat Mapping: Wyndham
Keswick Release 3,250 CFS

Depth & Velocity Mapping



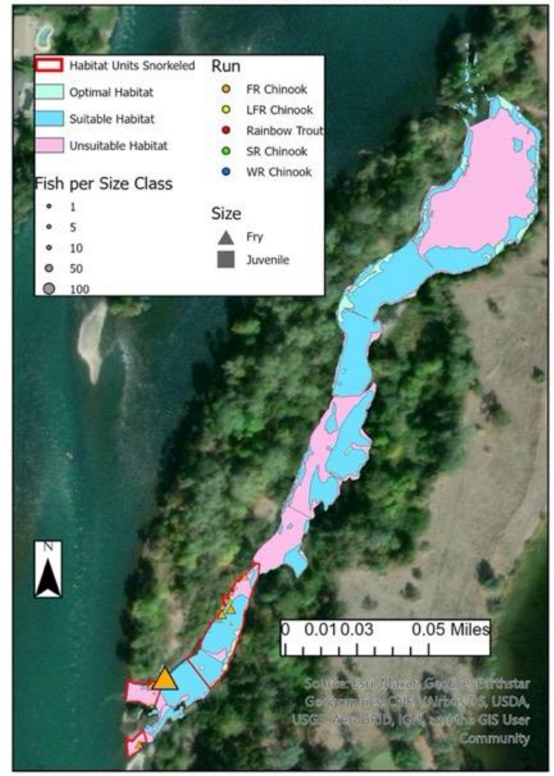
*Dates mapped: 3-7-18 & 3-9-18

Cover from Predators



*Dates mapped: 3-7-18 & 3-9-18
*Vegetation not included

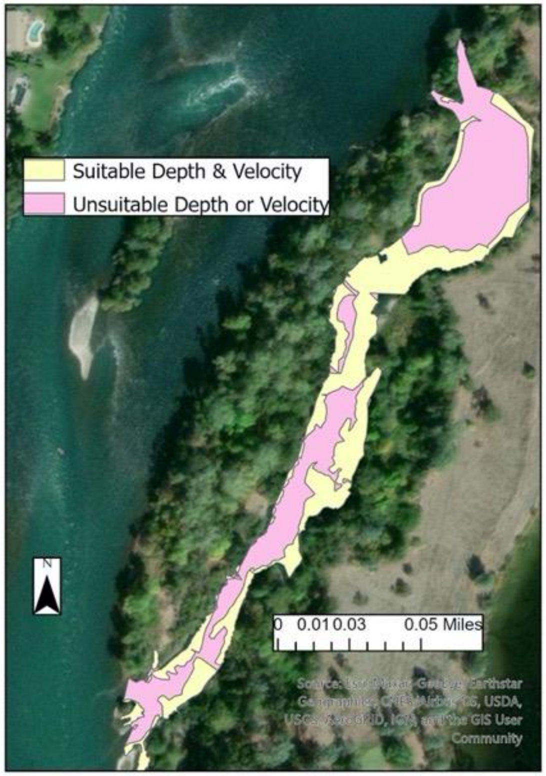
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-8-19
*Keswick flow during snorkel: 4000 cfs

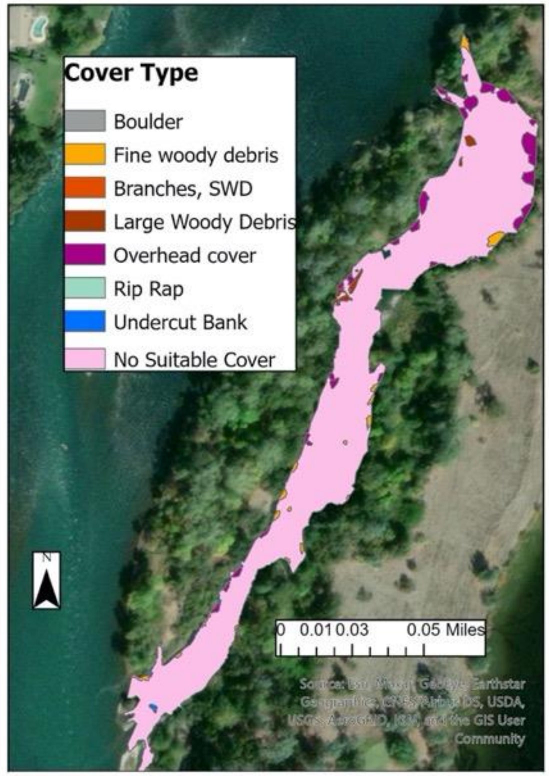
Control Site Habitat Mapping: Wyndham
Keswick Release 5,000 CFS

Depth & Velocity Mapping



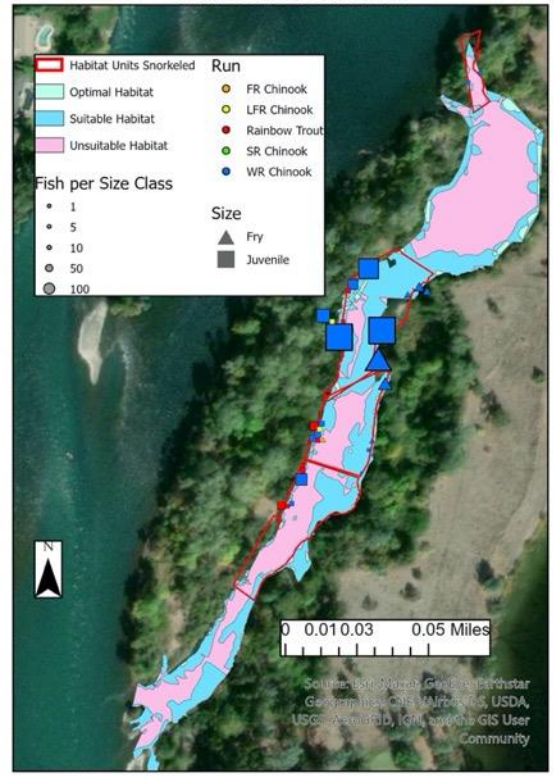
*Dates mapped: 11-4-19

Cover from Predators



*Dates mapped: 11-5-19, 11-7-19, & 11-21-19
*Vegetation not included

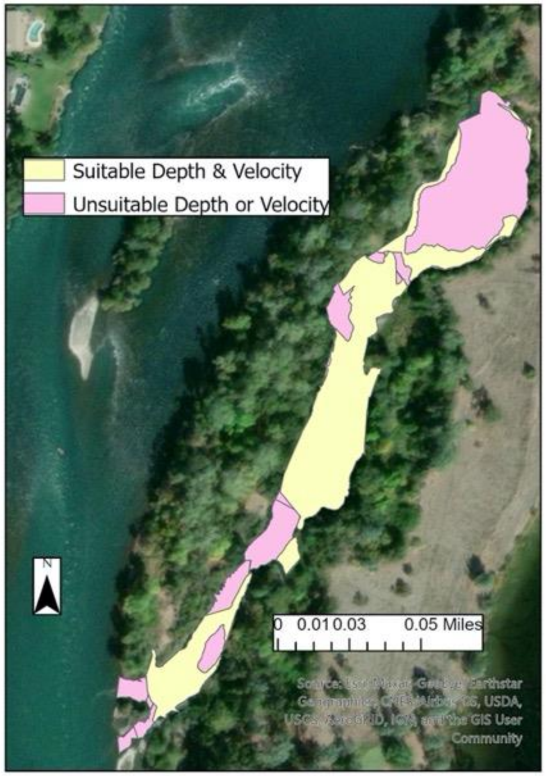
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-8-19, 10-24-19, & 10-28-19
*Keswick flow during snorkel: 7000 cfs

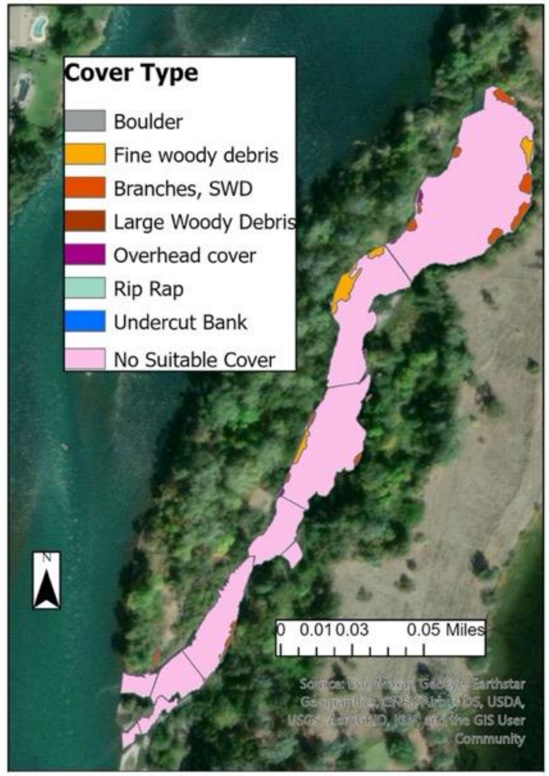
Control Site Habitat Mapping: Wyndham
Keswick Release 7,500 CFS

Depth & Velocity Mapping



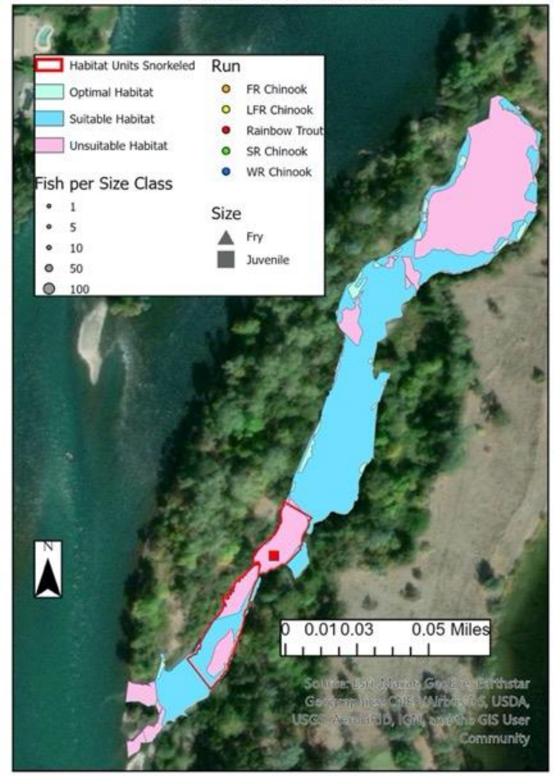
*Dates mapped: 10-9-18

Cover from Predators



*Dates mapped: 10-9-18
*Vegetation not included

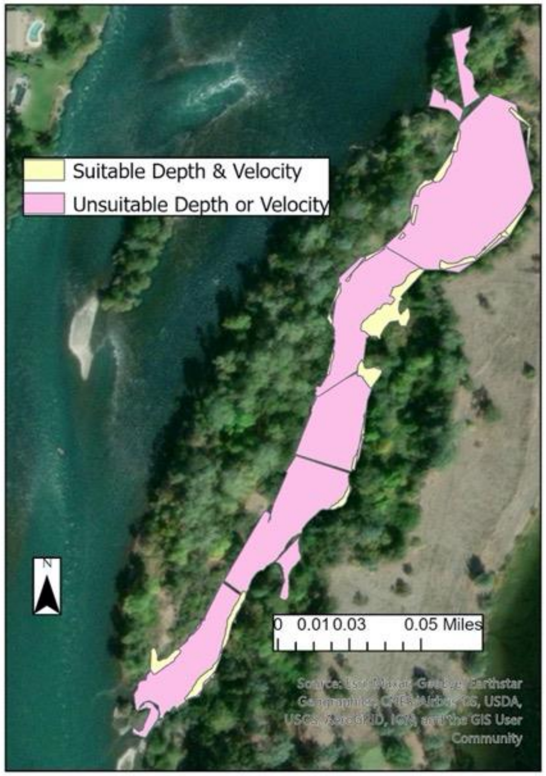
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

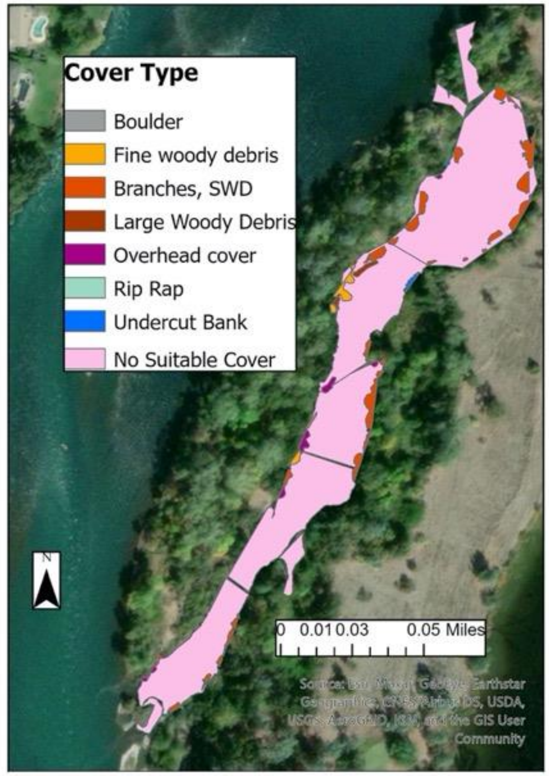
Control Site Habitat Mapping: Wyndham
Keswick Release 10,500 CFS

Depth & Velocity Mapping



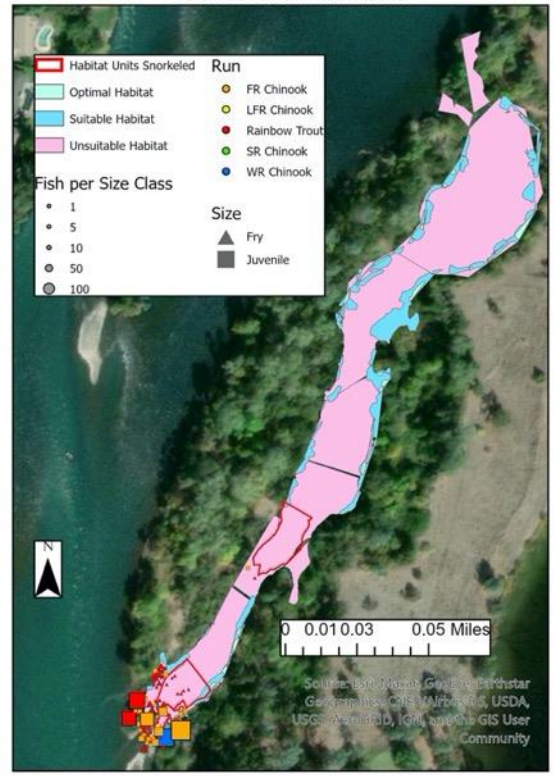
*Dates mapped: 7-26-17 & 7-31-17

Cover from Predators



*Dates mapped: 7-31-17
*Vegetation not included

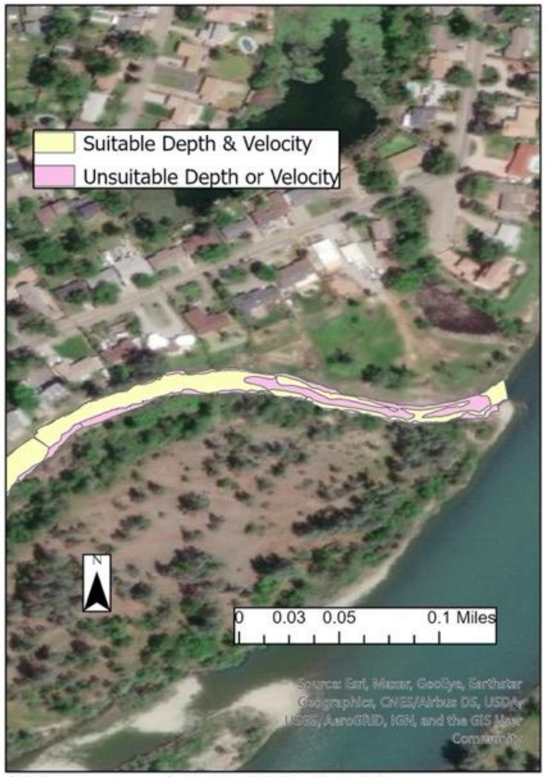
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

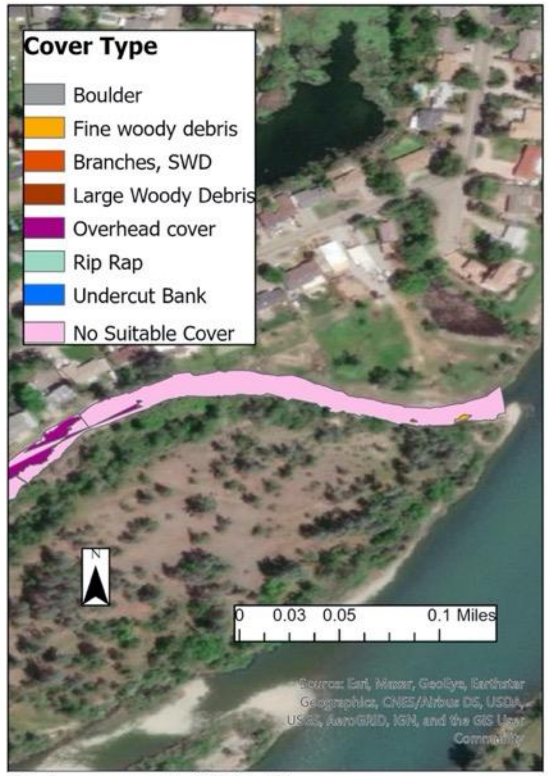
Pre Restoration Habitat Mapping: Shae Island (Upper)
Keswick Release 7,400 CFS

Depth & Velocity Mapping



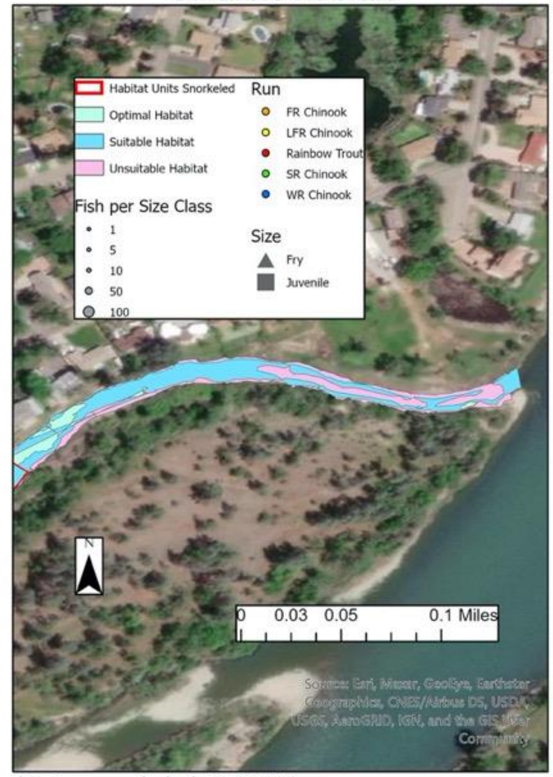
*Dates mapped: 9-28-18 & 10-9-18

Cover from Predators



*Dates mapped: 10-22-18
*Vegetation not included

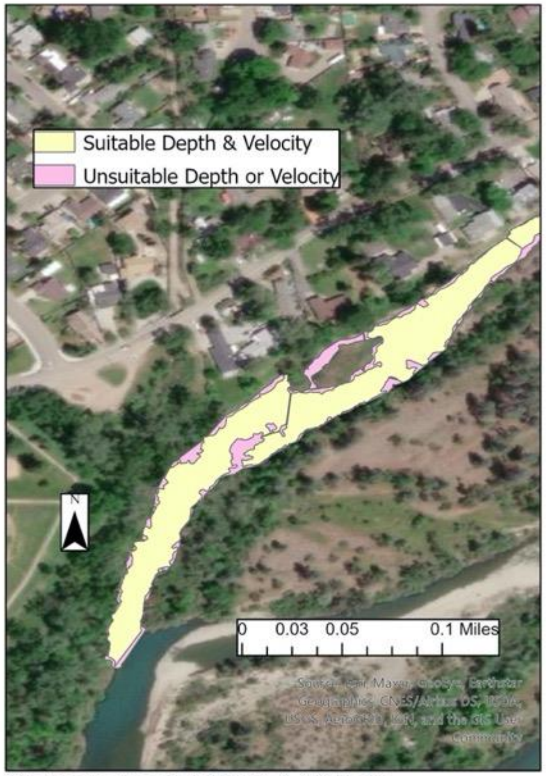
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-26-19
*Keswick flow during snorkel: 7600 cfs

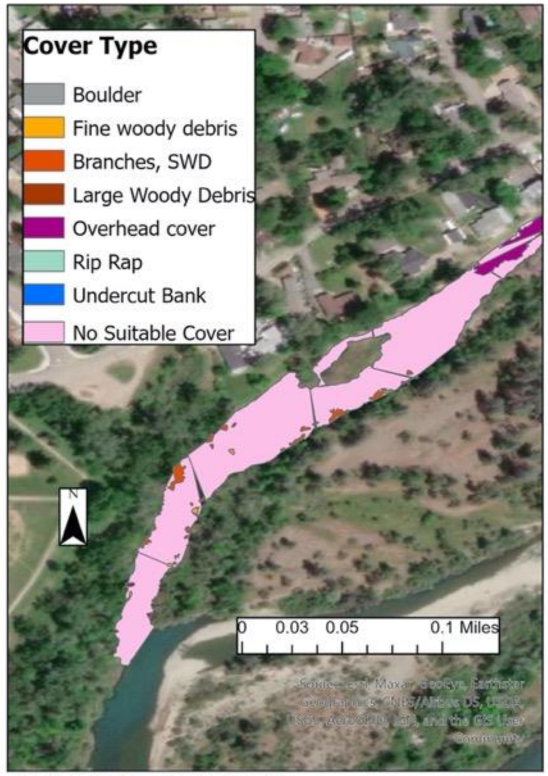
Pre Restoration Habitat Mapping: Shae Island (Lower)
Keswick Release 7,400 CFS

Depth & Velocity Mapping



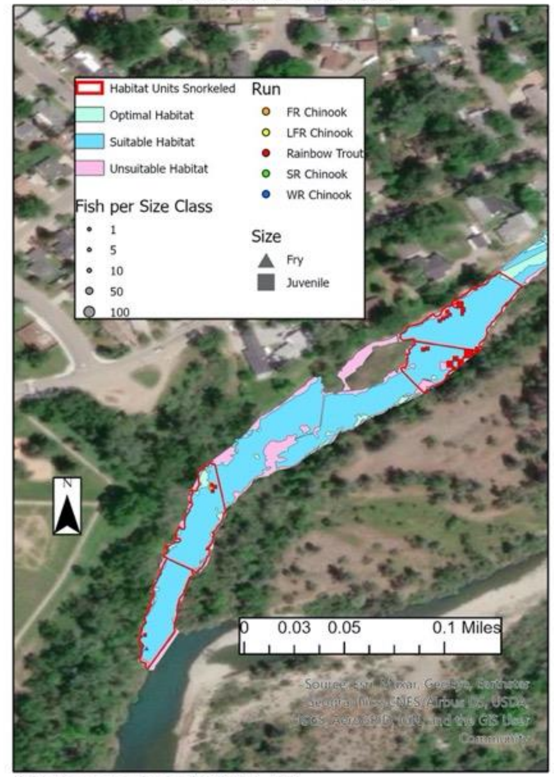
*Dates mapped: 9-28-18 & 10-9-18

Cover from Predators



*Dates mapped: 10-22-18
*Vegetation not included

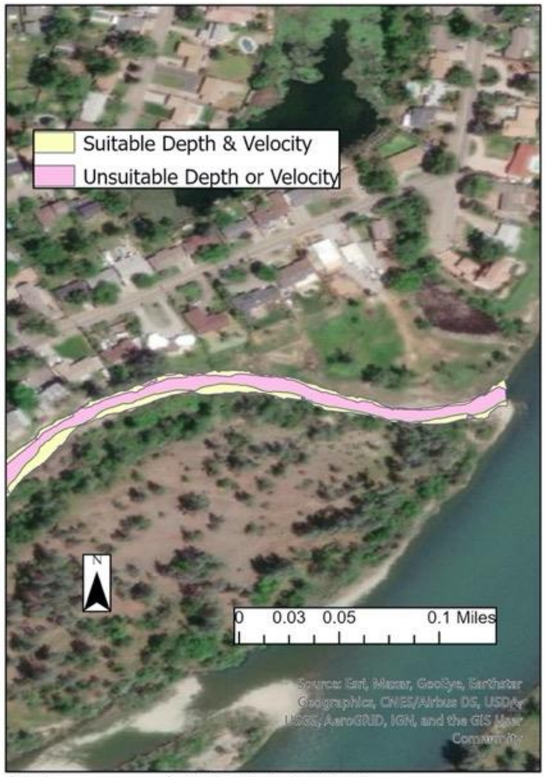
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-26-19
*Keswick flow during snorkel: 7600 cfs

Pre Restoration Habitat Mapping: Shae Island (Upper)
Keswick Release 9,000 CFS

Depth & Velocity Mapping

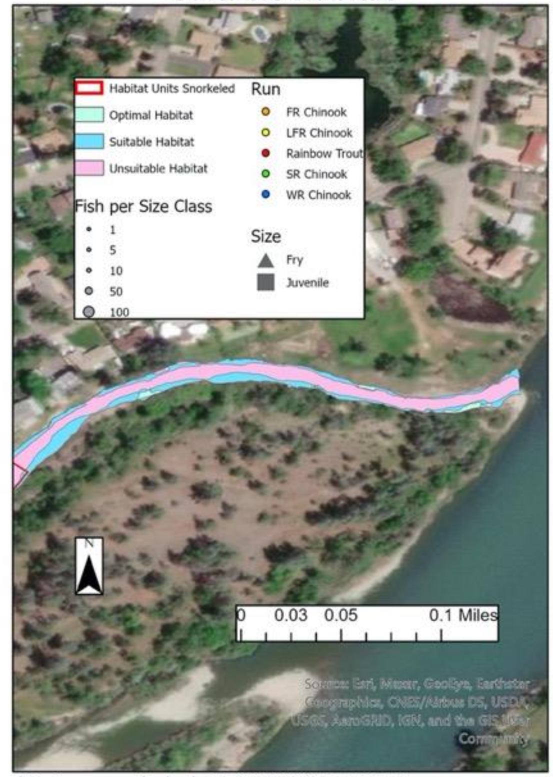


*Dates mapped: 9-5-19 & 9-10-19

Cover from Predators

*Dates mapped: 9-3-19 & 9-5-19
*Vegetation not included

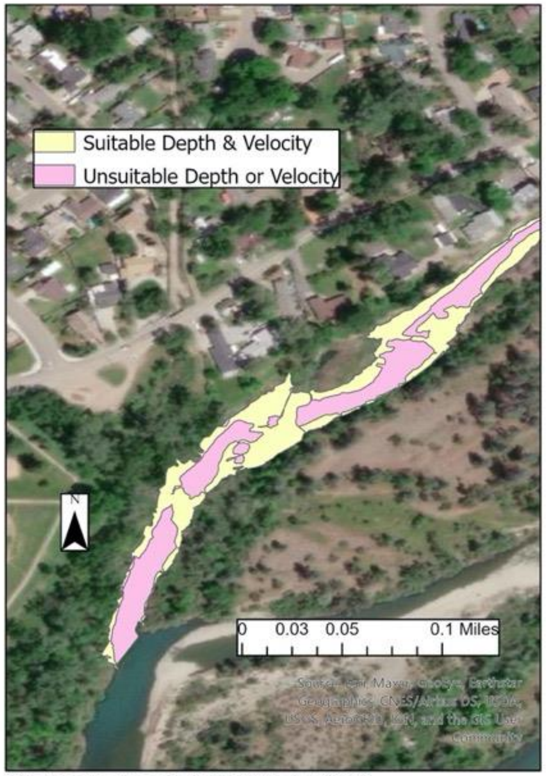
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-23-19 & 7-26-19
*Keswick flow during snorkel: 11000 cfs

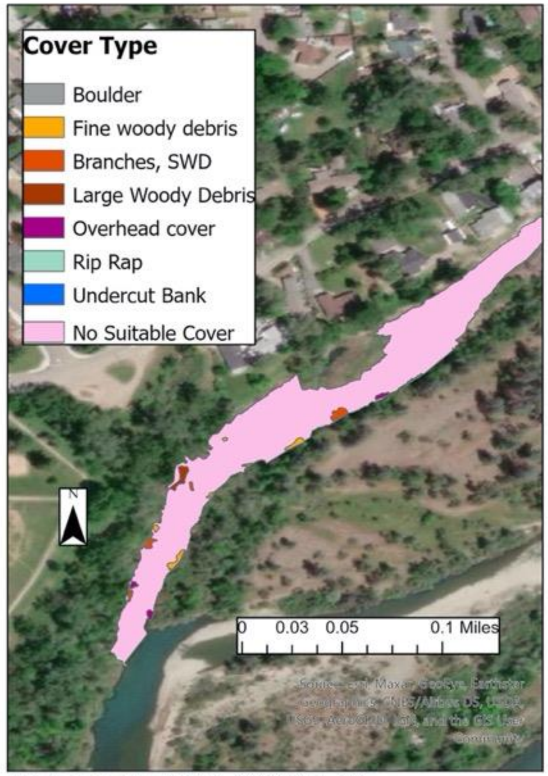
Pre Restoration Habitat Mapping: Shae Island (Lower)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



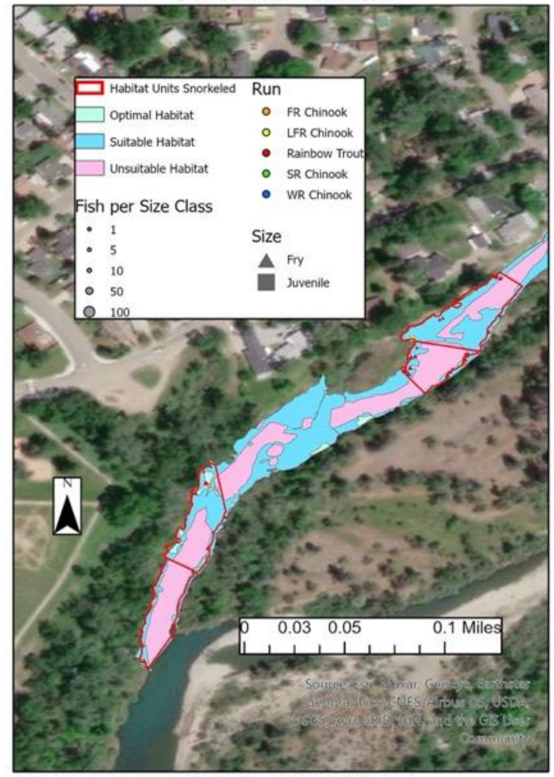
*Dates mapped: 9-5-19 & 9-10-19

Cover from Predators



*Dates mapped: 9-3-19 & 9-5-19
*Vegetation not included

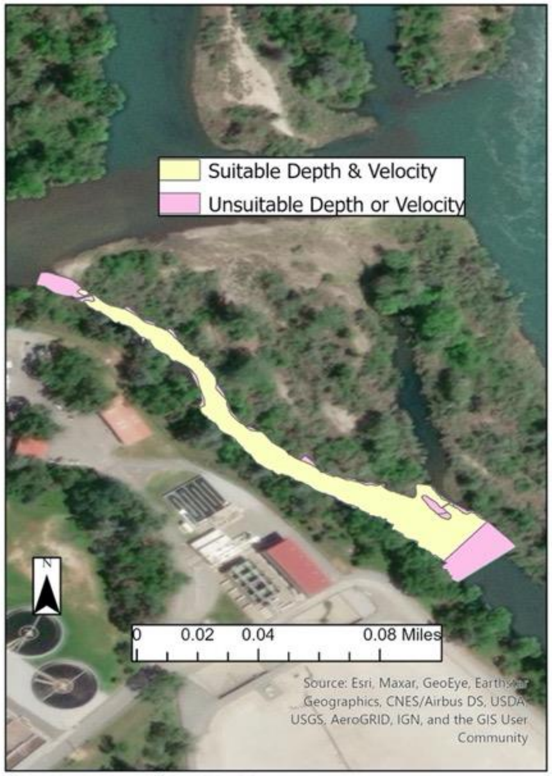
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-23-19 & 7-26-19
*Keswick flow during snorkel: 11000 cfs

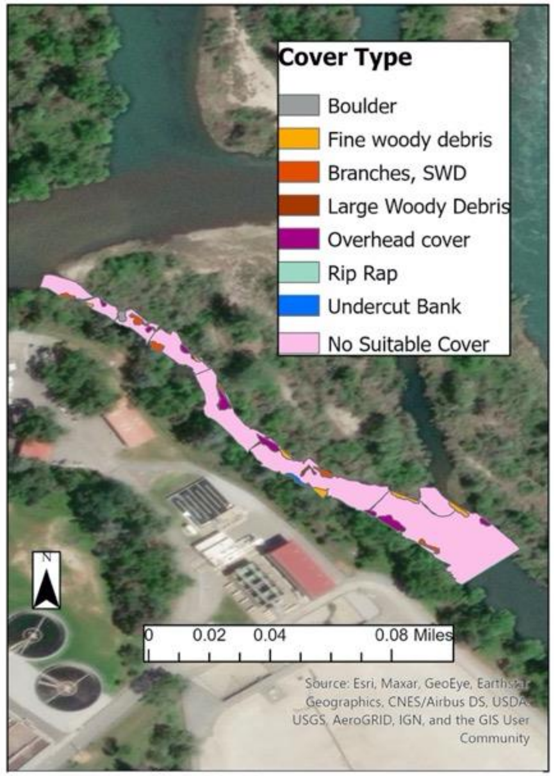
Control Site Habitat Mapping: Clear Creek
Keswick Release 3,250 CFS

Depth & Velocity Mapping



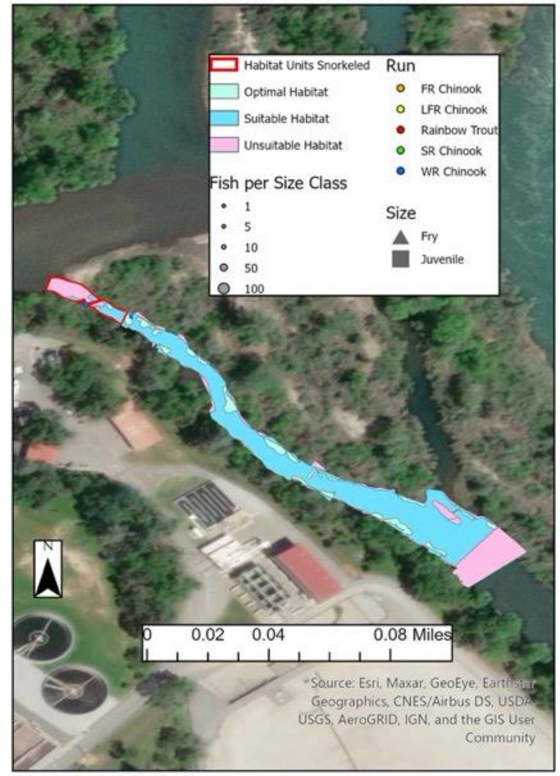
*Date mapped: 2-28-18

Cover from Predators



*Date mapped: 2-28-18
*Vegetation not included

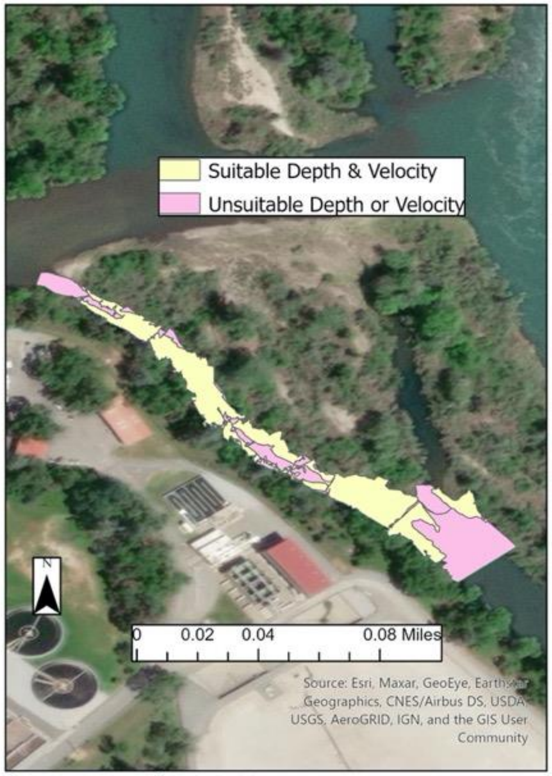
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 11-20-18
*Keswick flow during snorkel: 4400 cfs

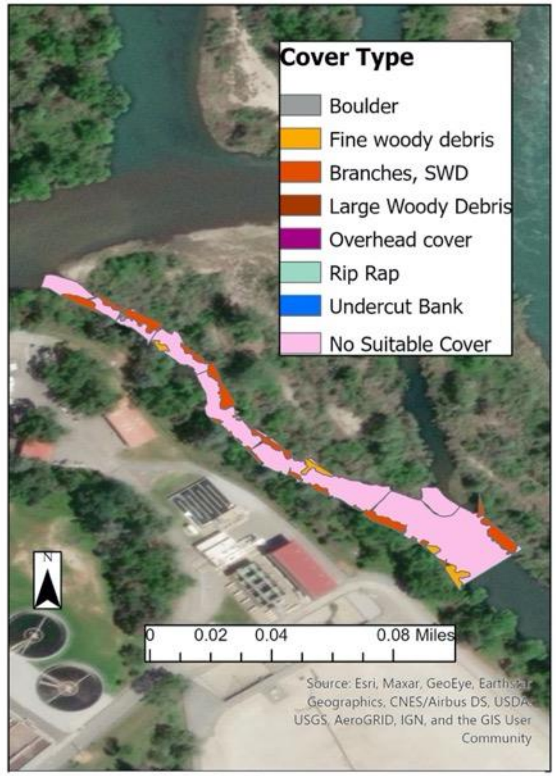
Control Site Habitat Mapping: Clear Creek
Keswick Release 7,500 CFS

Depth & Velocity Mapping



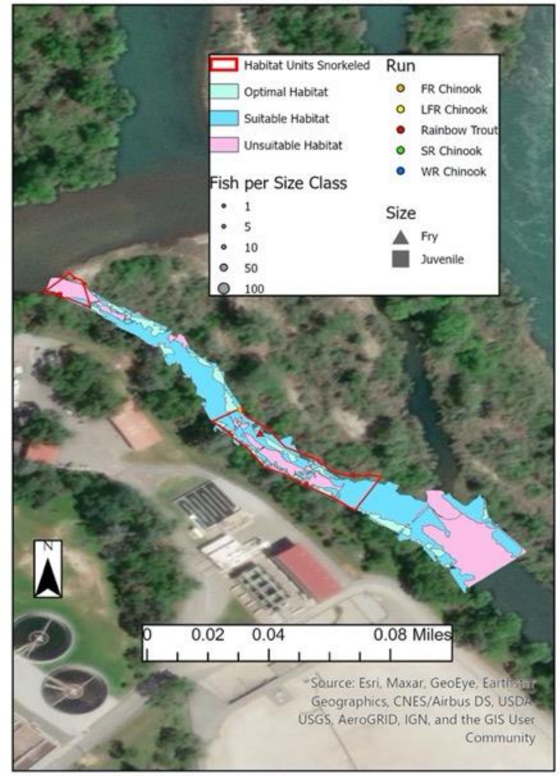
*Date mapped: 10-9-18

Cover from Predators



*Date mapped: 10-9-18
*Vegetation not included

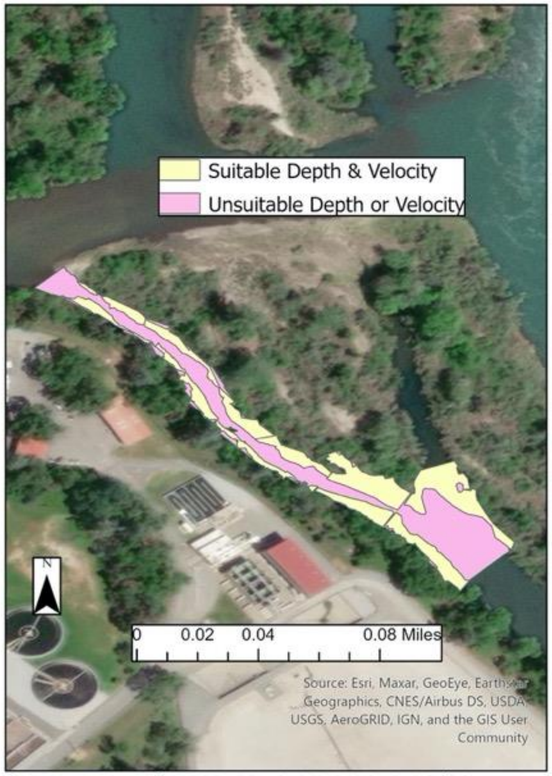
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 10-1-19
*Keswick flow during snorkel: 7600 cfs

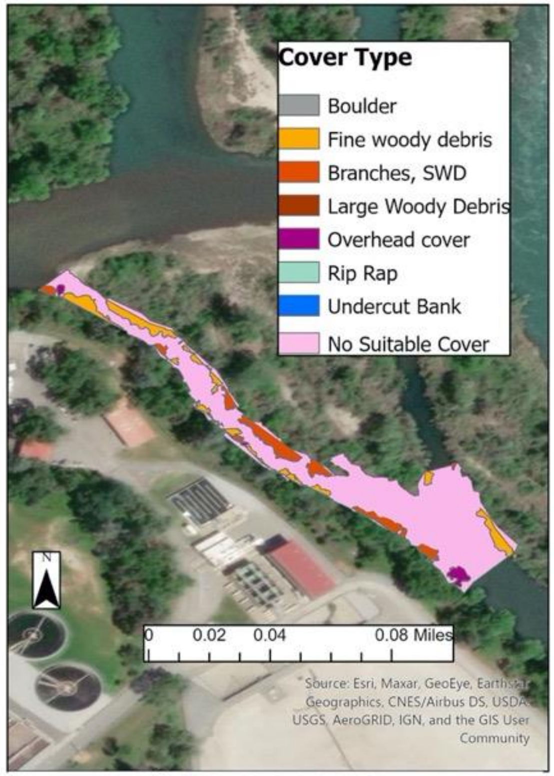
Control Site Habitat Mapping: Clear Creek
Keswick Release 10,200 CFS

Depth & Velocity Mapping



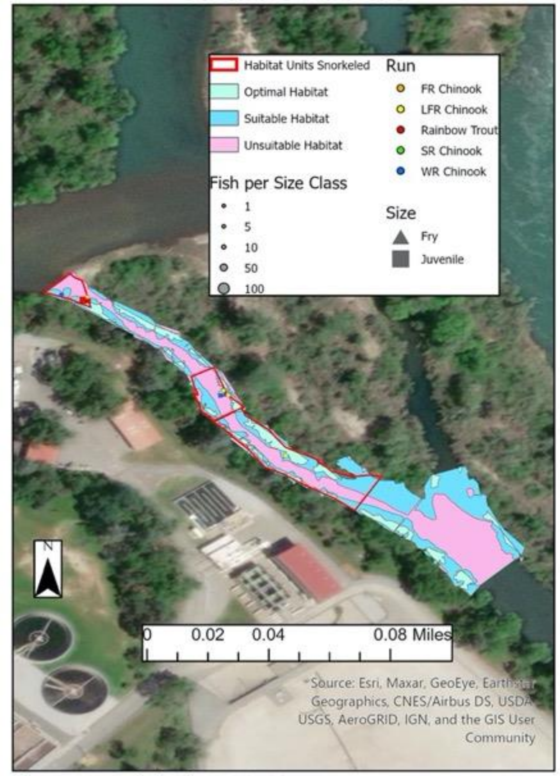
*Date mapped: 8-23-19, 8-27-19 & 8-28/19

Cover from Predators



*Date mapped: 8-23-19 & 8-26-19
*Vegetation not included

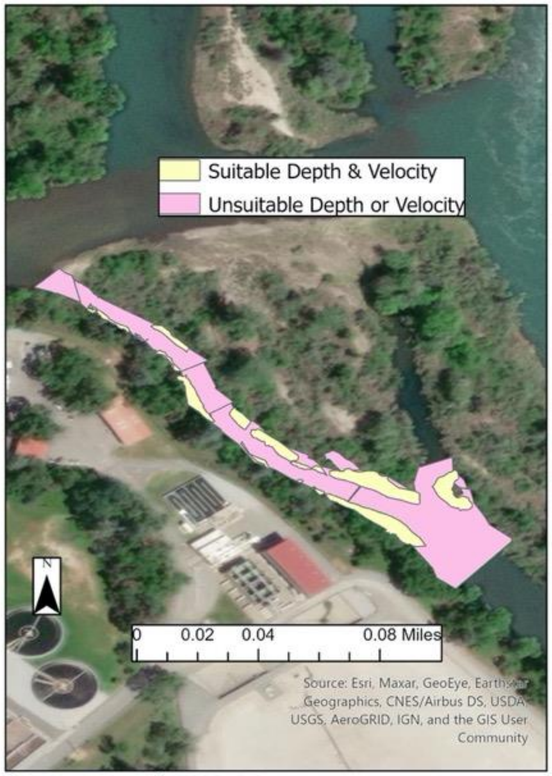
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 7-31-19
*Keswick flow during snorkel: 10500 cfs

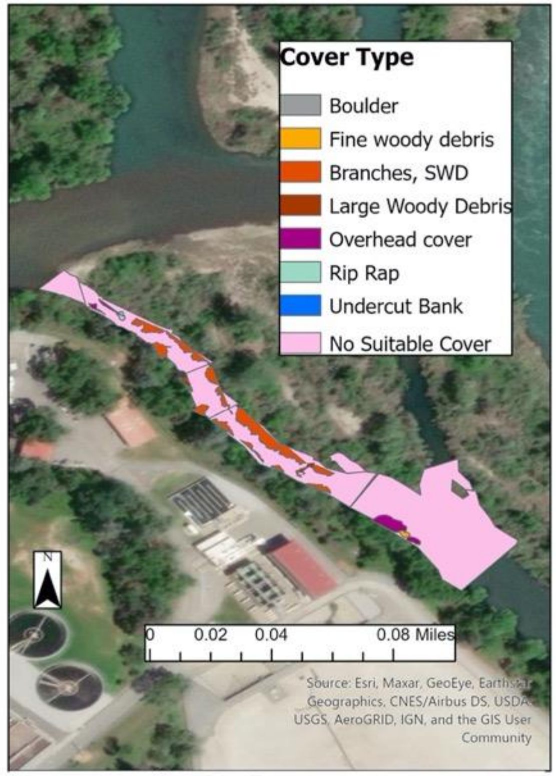
Control Site Habitat Mapping: Clear Creek
Keswick Release 10,500 CFS

Depth & Velocity Mapping



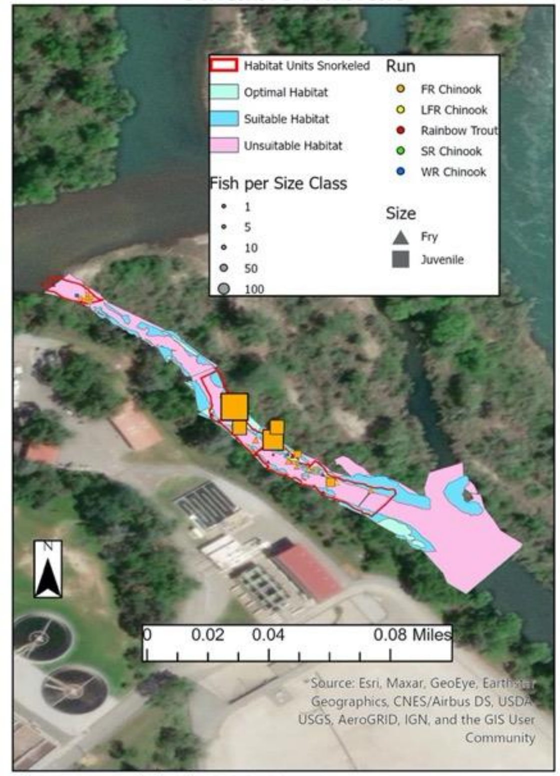
*Date mapped: 7-20-17

Cover from Predators



*Date mapped: 7-20-17
*Vegetation not included

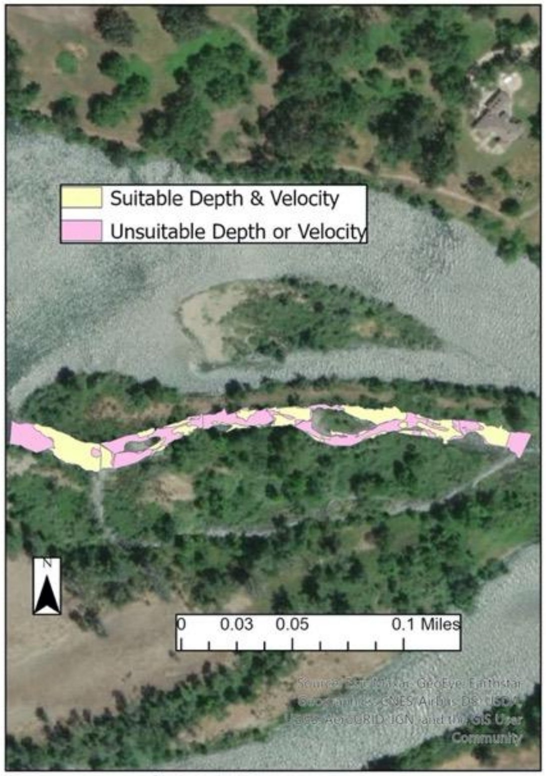
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

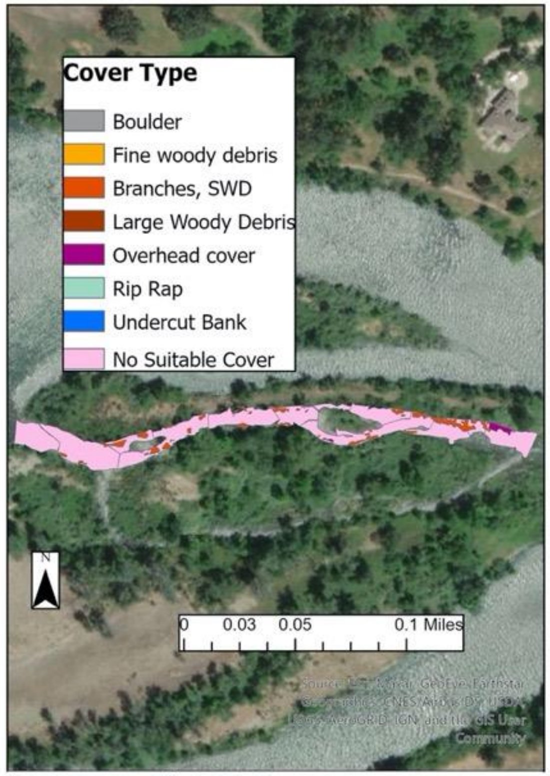
Control Site Habitat Mapping: Bourbon
Keswick Release 3,250 CFS

Depth & Velocity Mapping



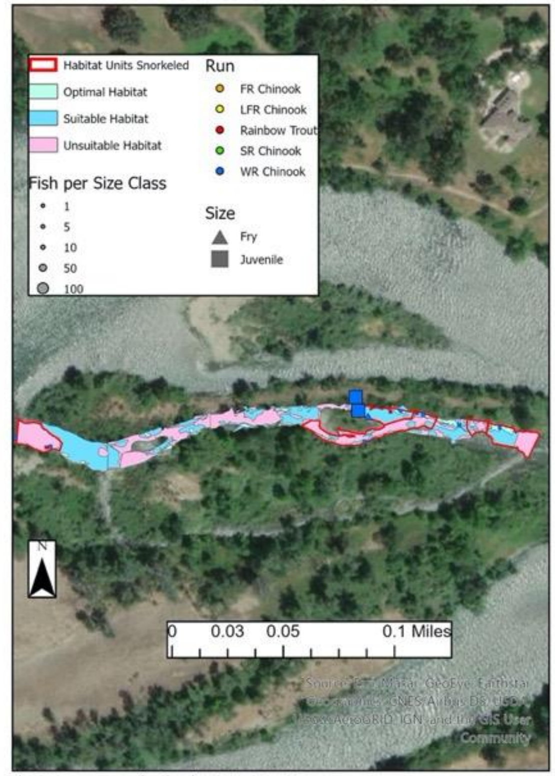
Dates mapped: 2-26-18

Cover from Predators



*Dates mapped: 2-26-18
*Vegetation not included

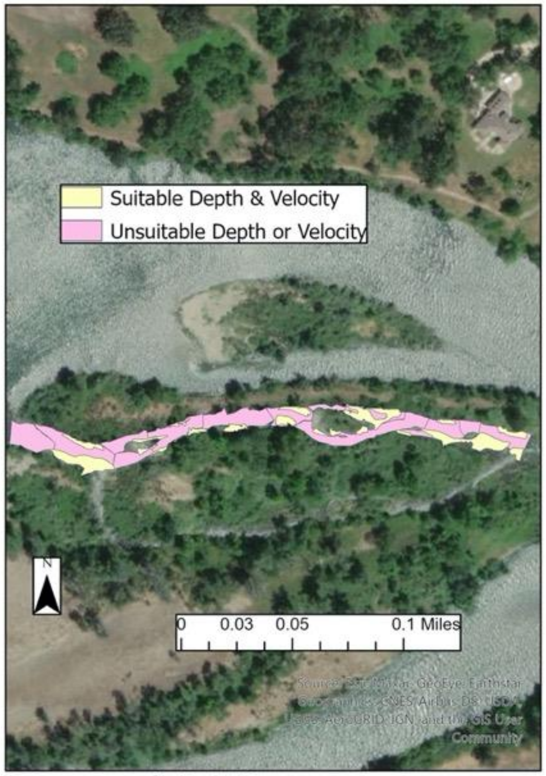
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-16-18
*Keswick flow during snorkel: 4400 cfs

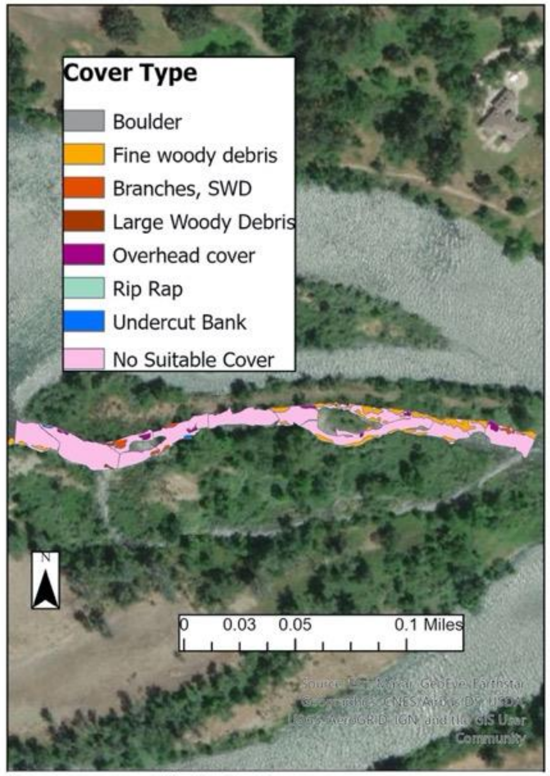
Control Site Habitat Mapping: Bourbon
Keswick Release 7,500 CFS

Depth & Velocity Mapping



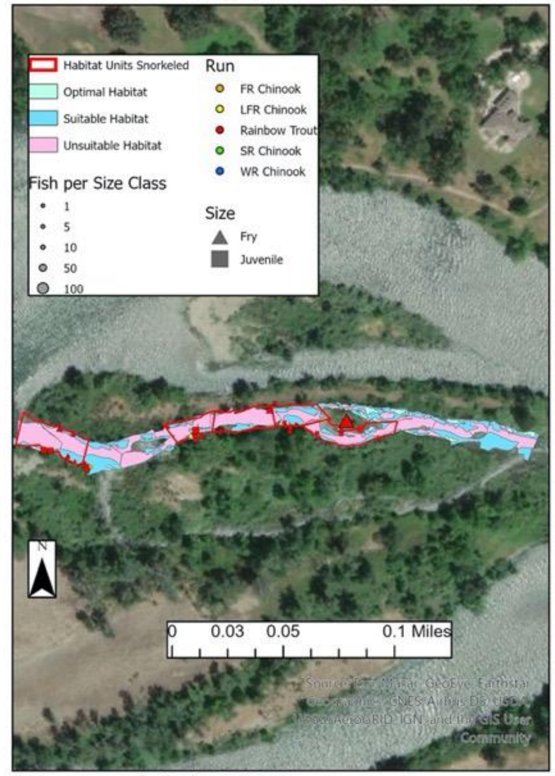
Dates mapped: 10-9-18

Cover from Predators



*Dates mapped: 10-9-18
*Vegetation not included

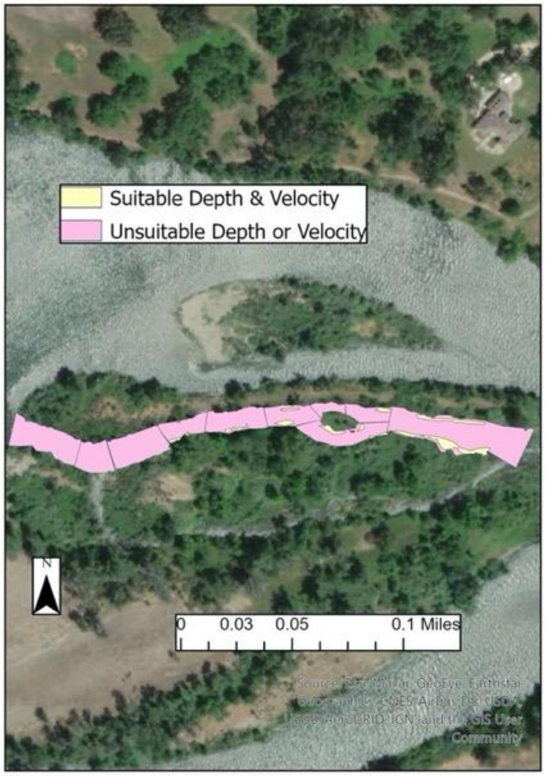
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-25-19
*Keswick flow during snorkel: 11,000 cfs

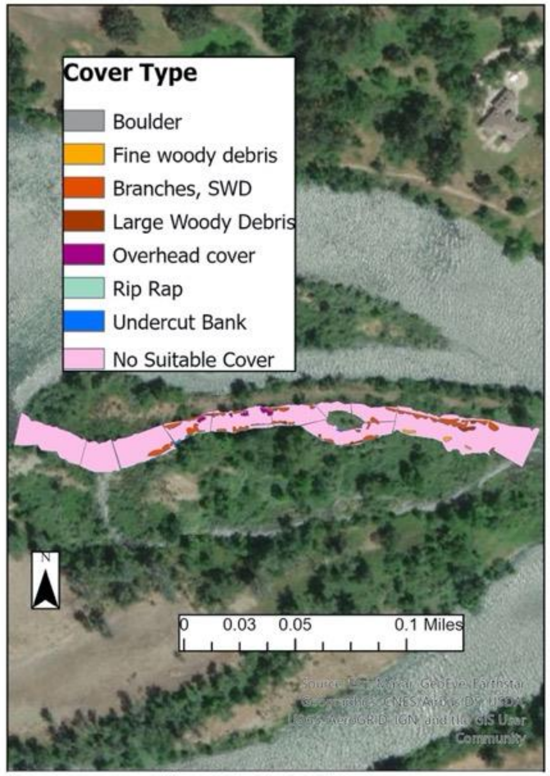
Control Site Habitat Mapping: Bourbon
Keswick Release 10,500 CFS

Depth & Velocity Mapping



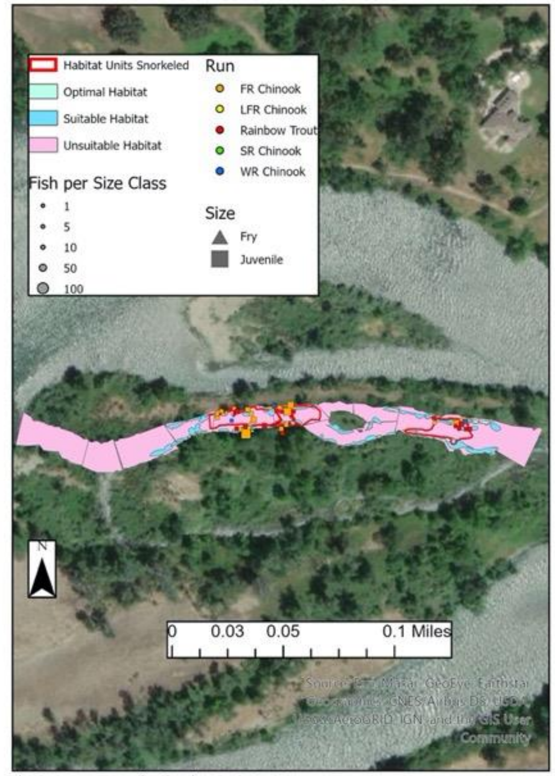
*Dates mapped: 7-18-17 & 7-19-17

Cover from Predators



*Dates mapped: 7-18-17 & 7-19-17
*Vegetation not included

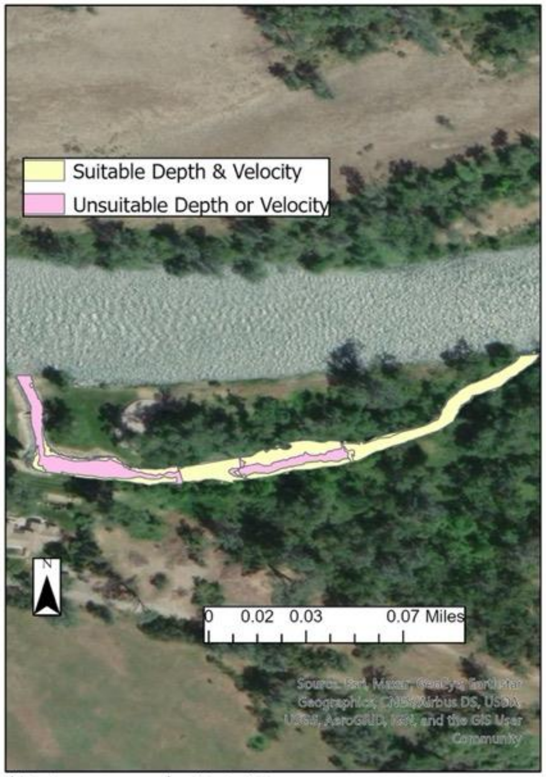
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

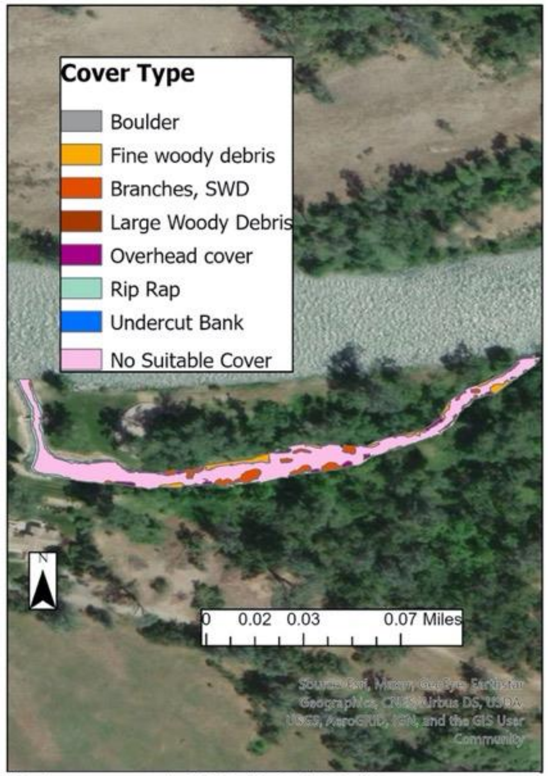
Post Restoration Habitat Mapping: Kapuesta
Keswick Release 6,600 CFS

Depth & Velocity Mapping



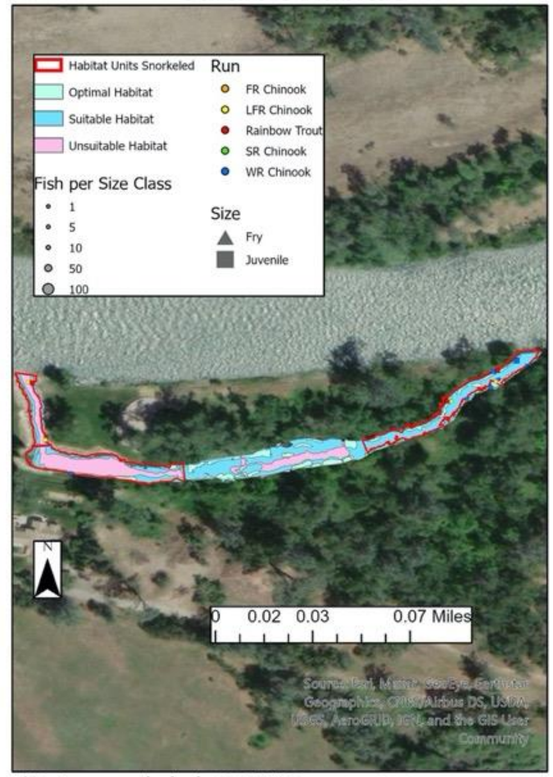
*Dates mapped: 10-2-19

Cover from Predators



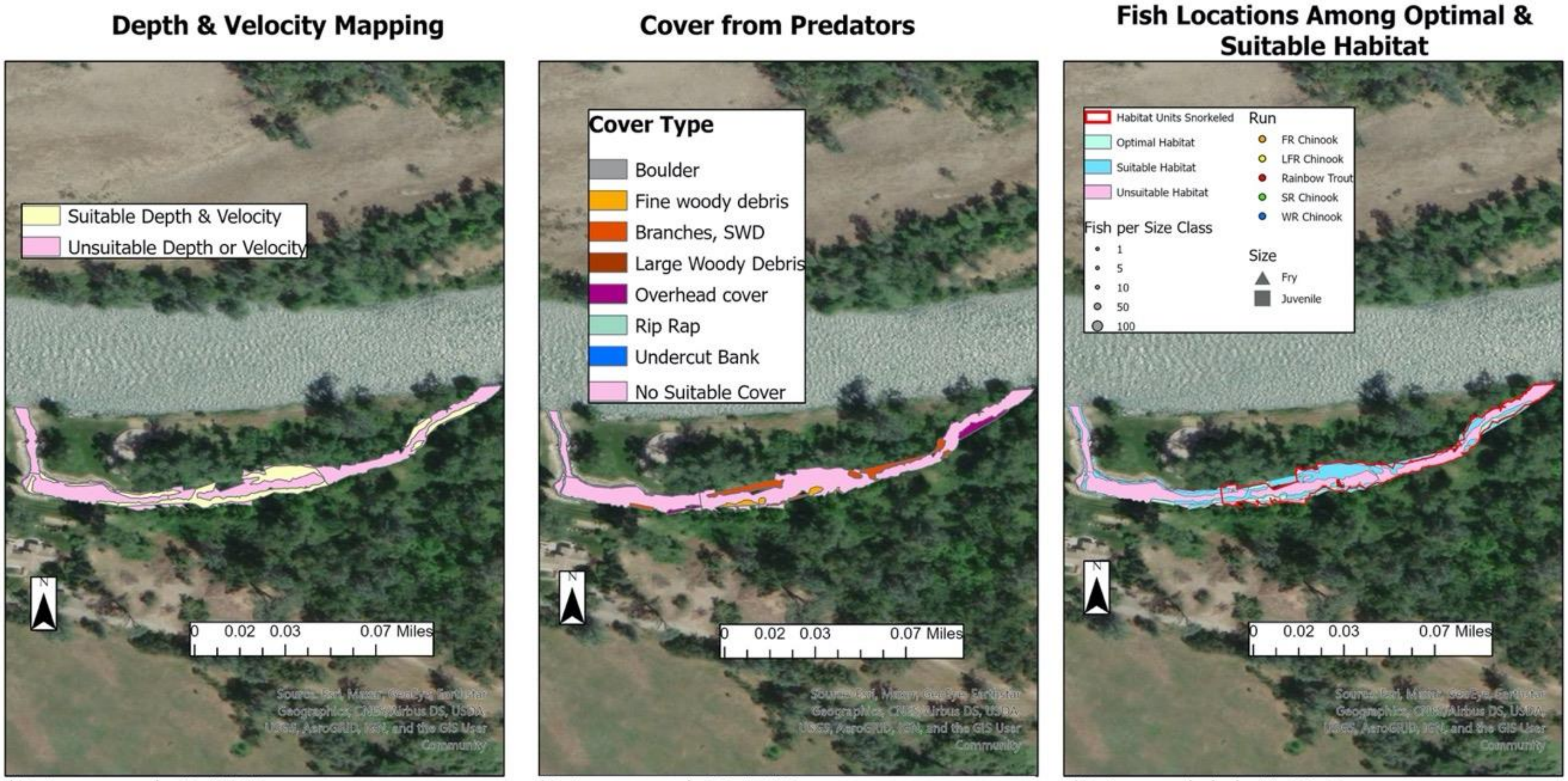
*Dates mapped: 10-2-19 & 10-3-19
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-25-19
*Keswick flow during snorkel: 7600 cfs

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



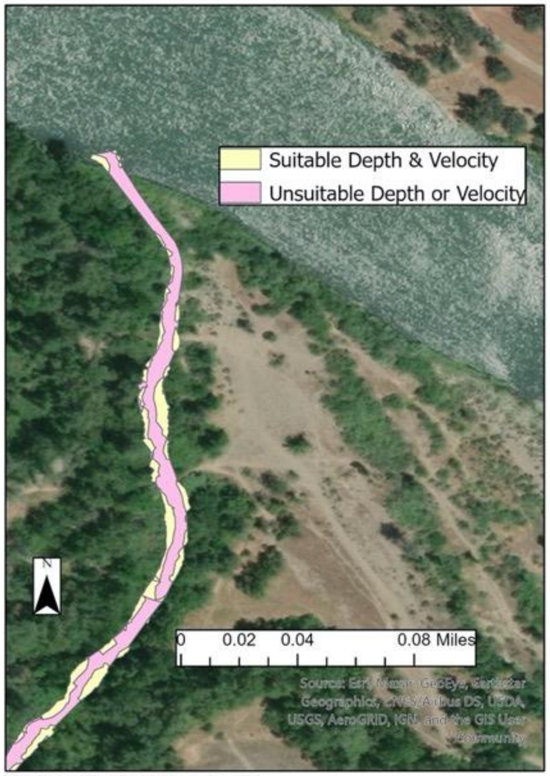
*Dates mapped: 10-17-18

*Dates mapped: 10-17-18
*Vegetation not included

*Dates snorkeled: 11-20-18
*Keswick flow during snorkel: 4400 cfs

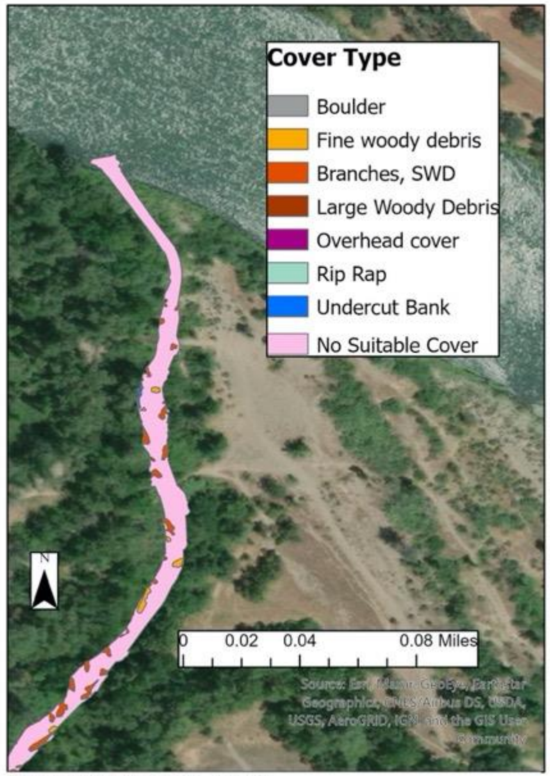
Post Restoration Habitat Mapping: Anderson River Park (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



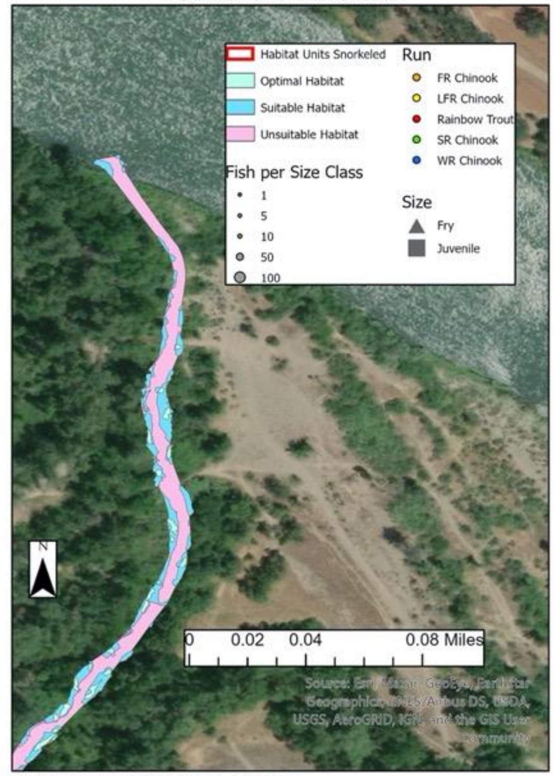
*Dates mapped: 1-9-20

Cover from Predators



*Dates mapped: 1-15-20
*Vegetation not included

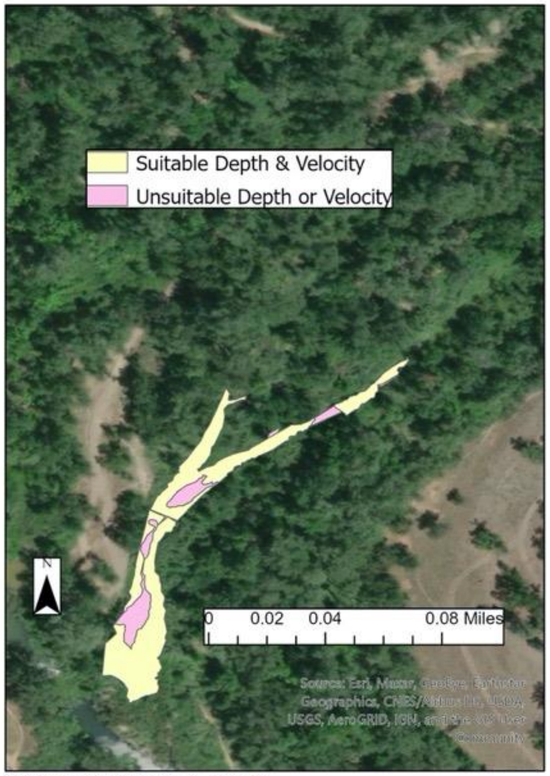
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-30-20
*Keswick flow during snorkel: 5000 cfs

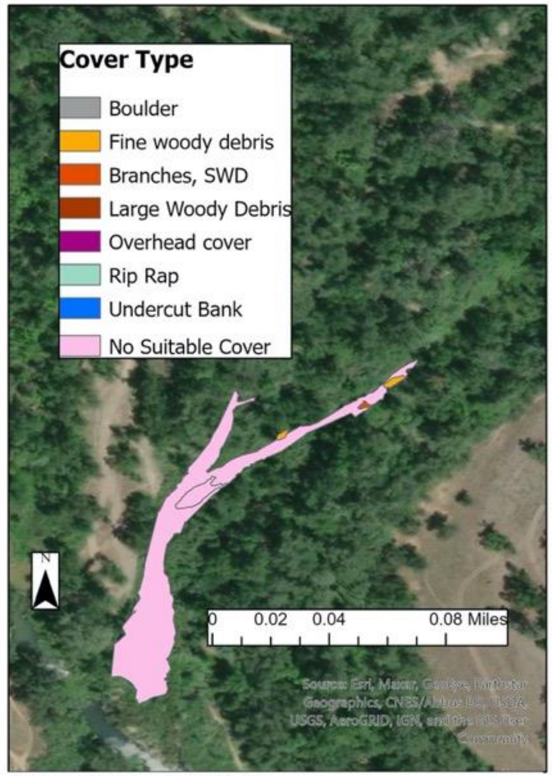
Pre Restoration Habitat Mapping: Anderson River Park (Lower)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



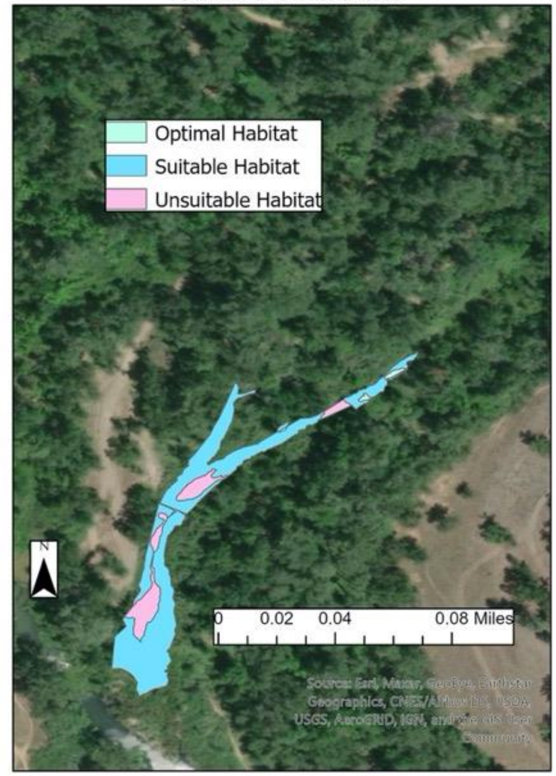
*Dates mapped: 1-22-19

Cover from Predators



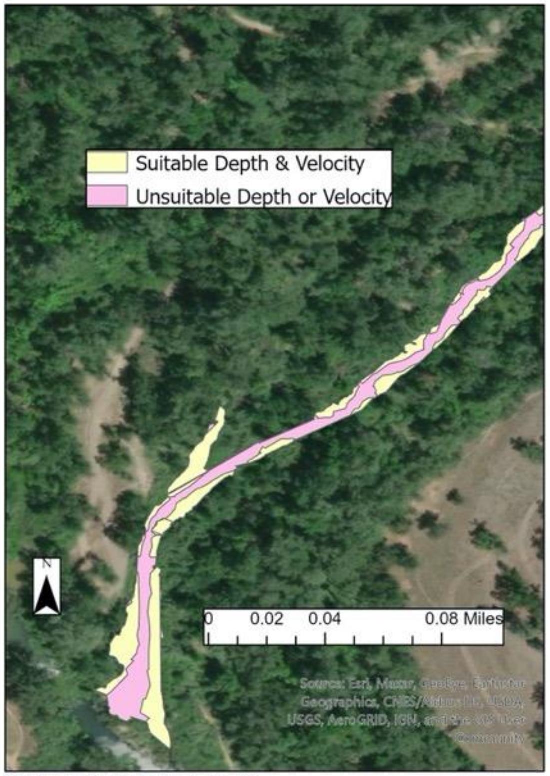
*Dates mapped: 1-22-19
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat



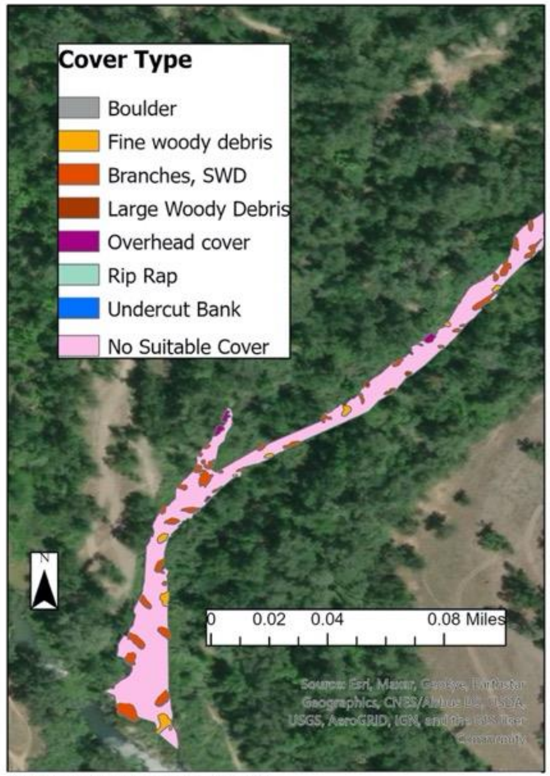
Post Restoration Habitat Mapping: Anderson River Park (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



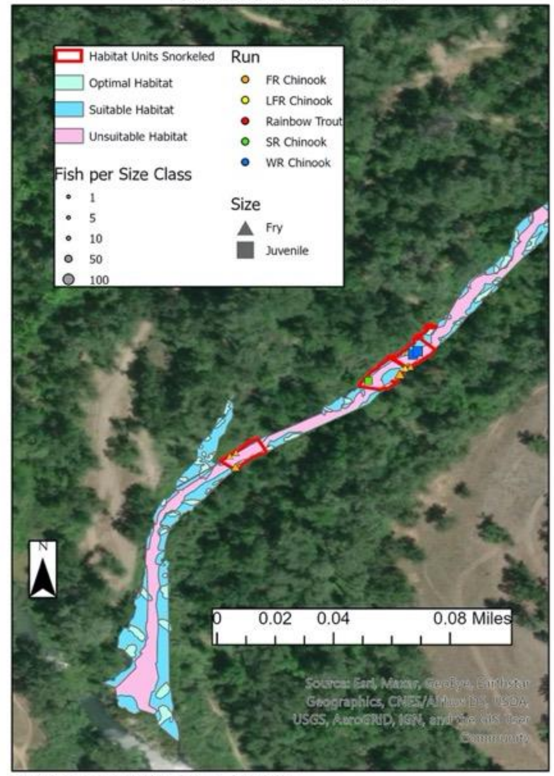
*Dates mapped: 1-9-20

Cover from Predators



*Dates mapped: 1-15-20
*Vegetation not included

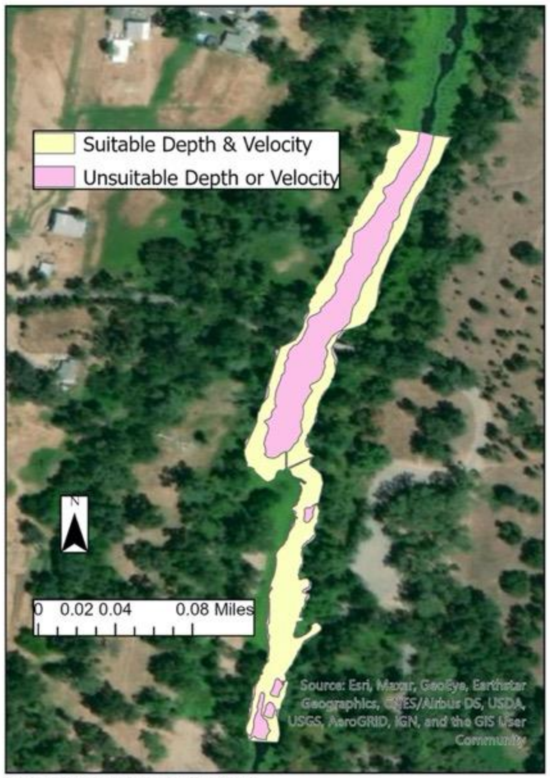
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-30-20
*Keswick flow during snorkel: 5000 cfs

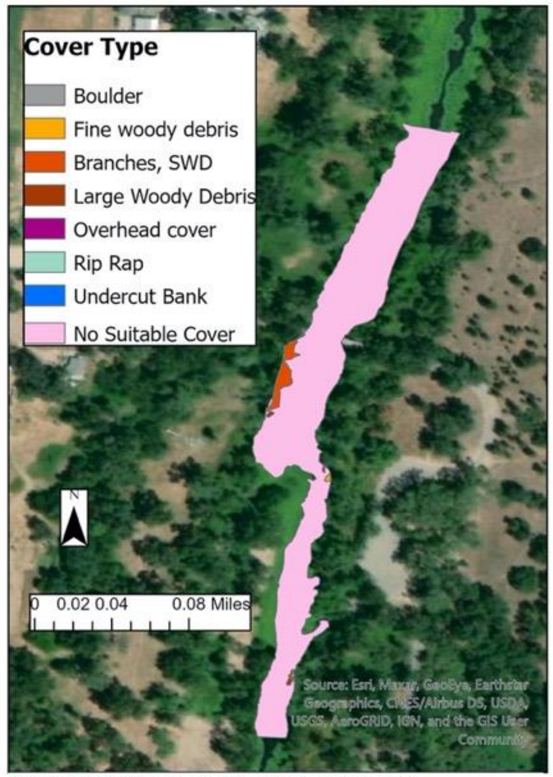
Pre Restoration Habitat Mapping: Reading Island
Keswick Release 3,250 CFS

Depth & Velocity Mapping



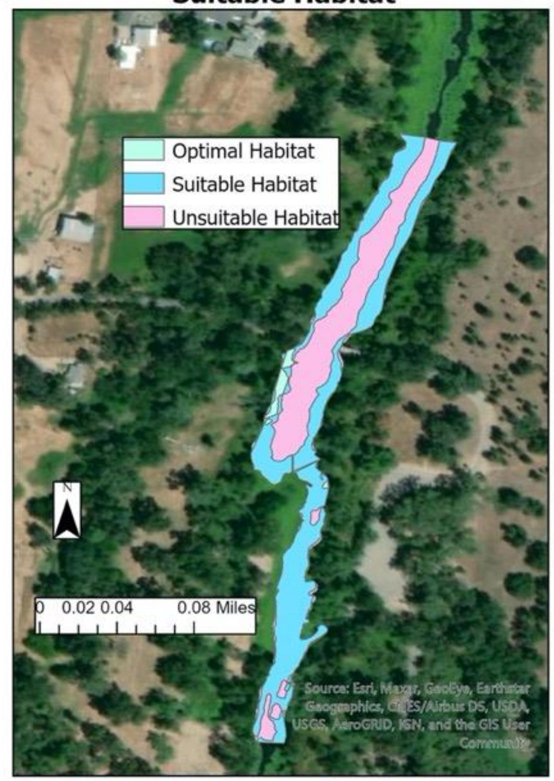
*Dates mapped: 2-7-19

Cover from Predators



*Dates mapped: 12-16-19 & 12-17-19
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat

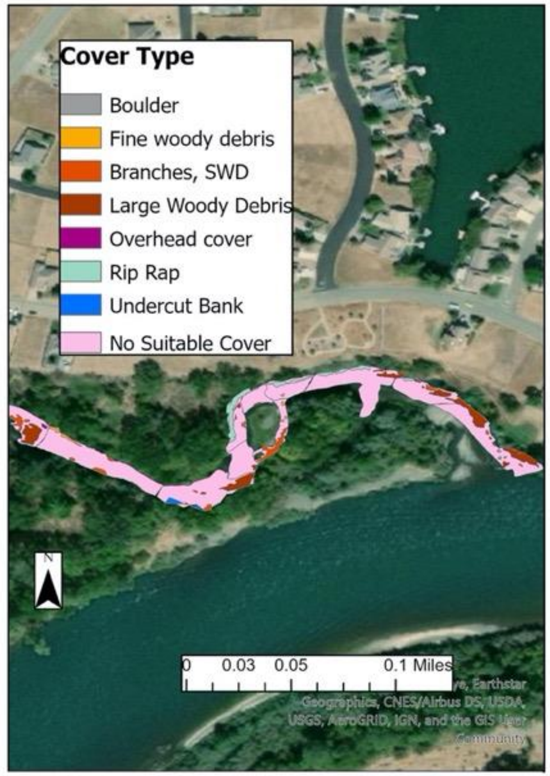


Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release 3,250 CFS

Depth & Velocity Mapping

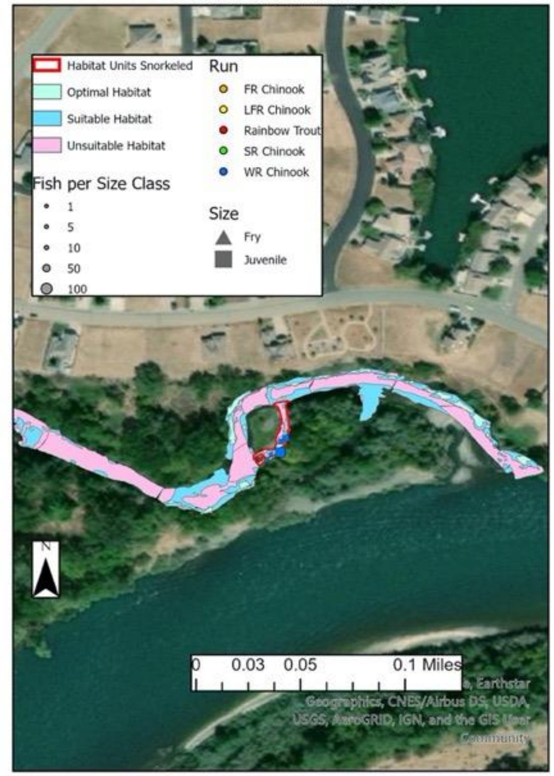
*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators



*Dates mapped: 2-13-18, 2-15-18, 2-20-18
*Vegetation not included

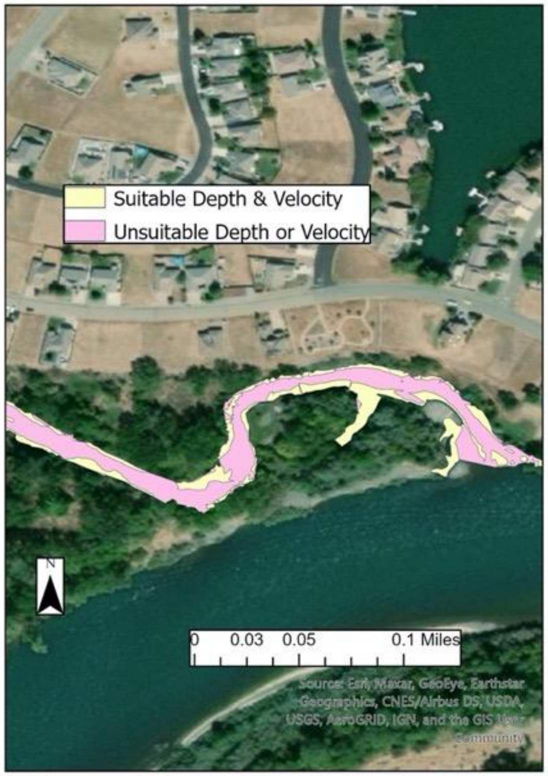
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

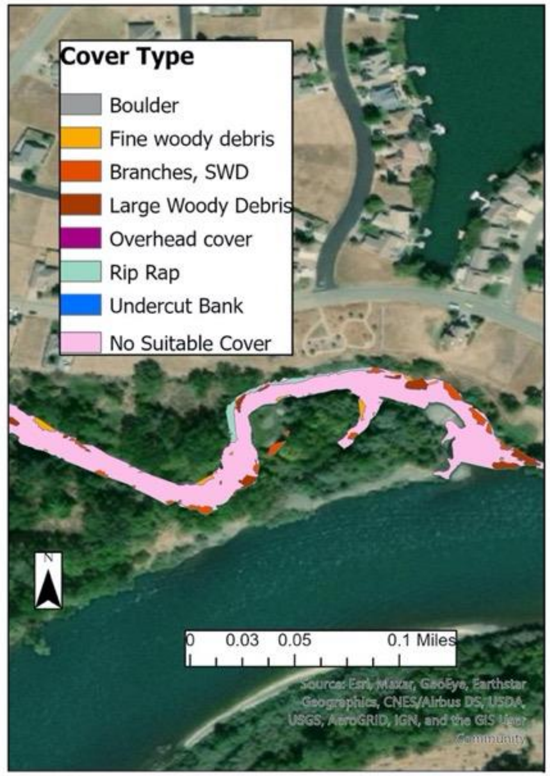
Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release 6,700 CFS

Depth & Velocity Mapping



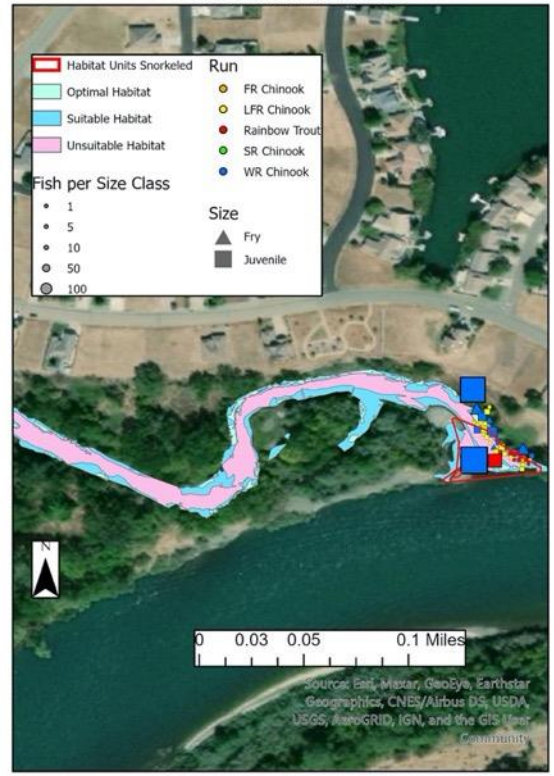
*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

Cover from Predators



*Dates mapped: 10-14-19 & 10-16-19
*Vegetation not included

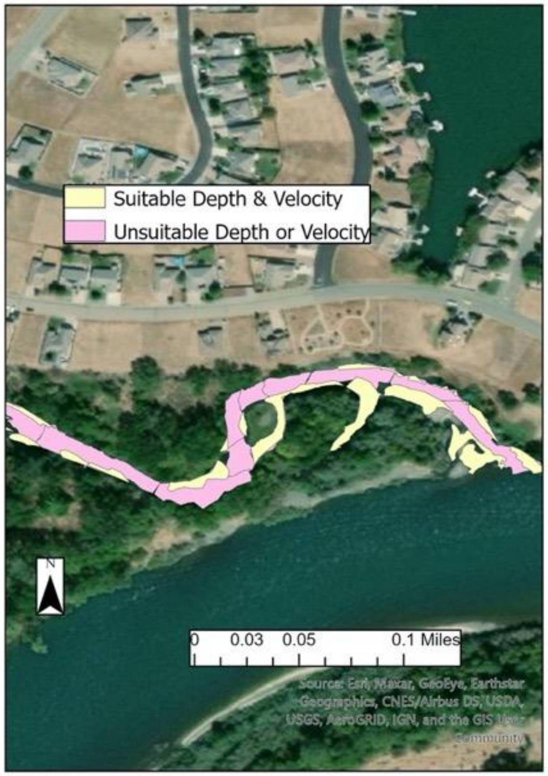
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

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

Depth & Velocity Mapping

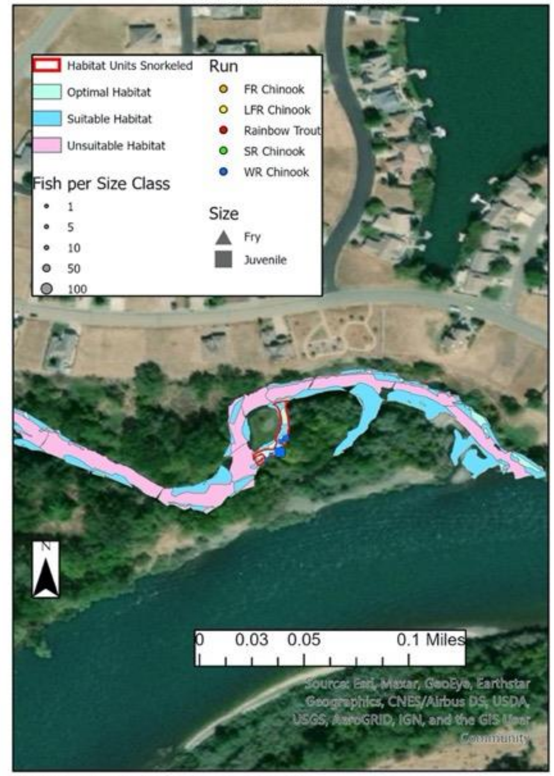


*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators

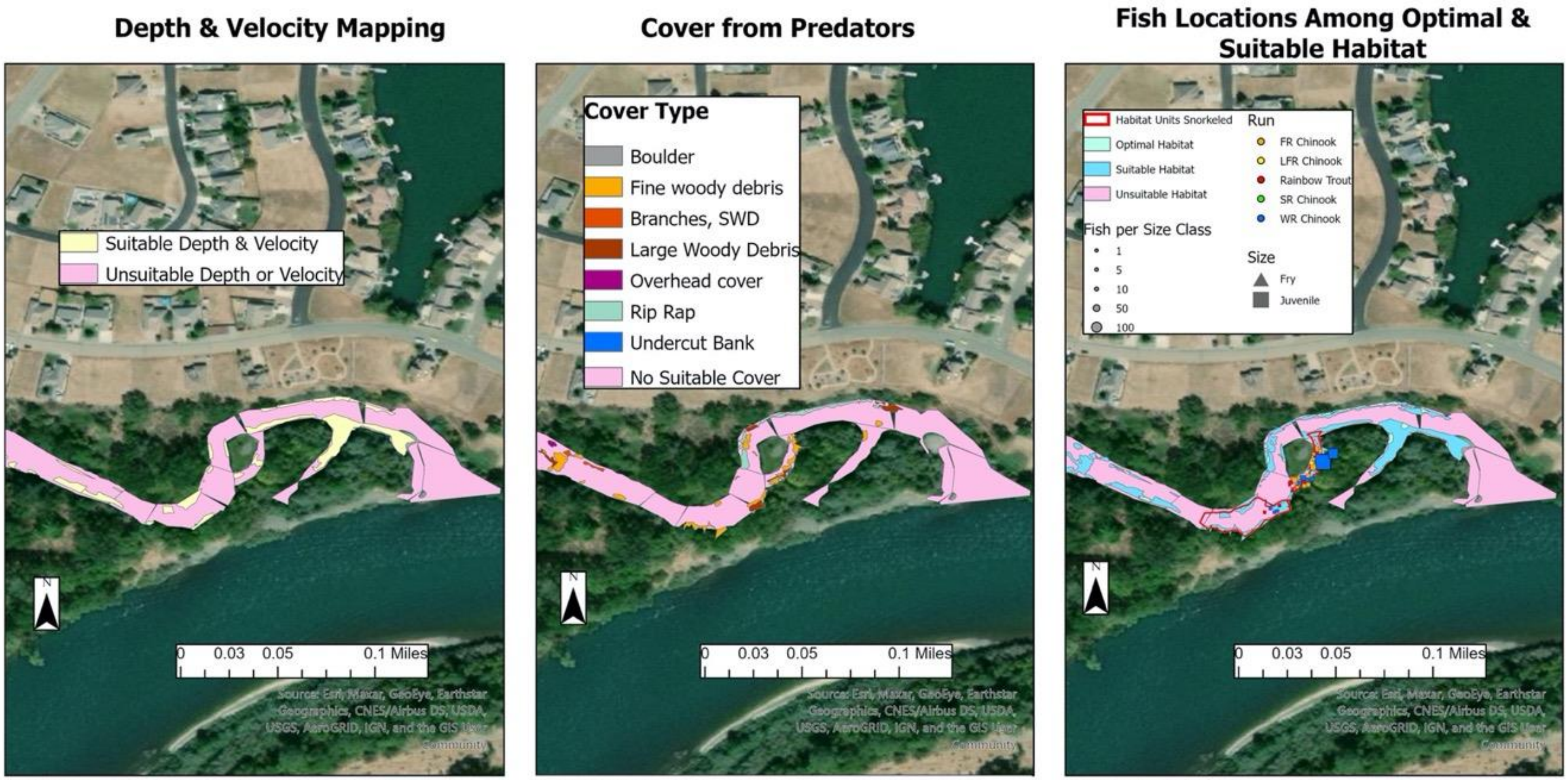
*Dates mapped: 10-8-18 & 10-10-18
*Vegetation not included

Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

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



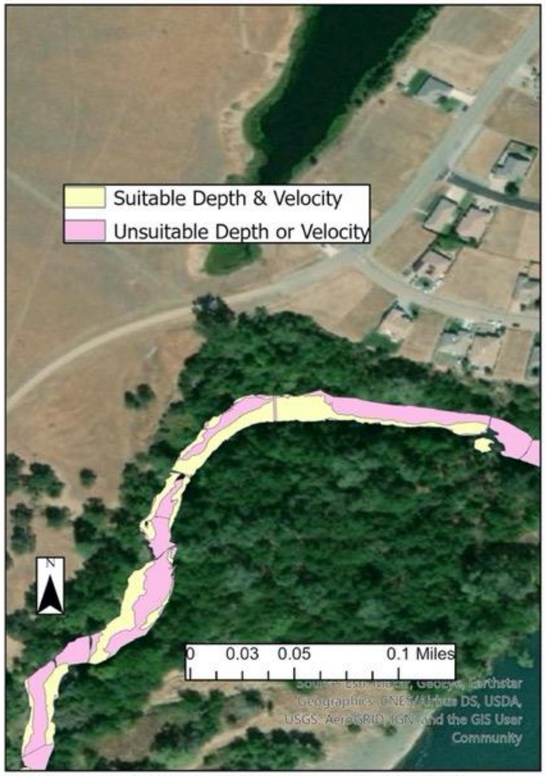
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17 *Vegetation not included

*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

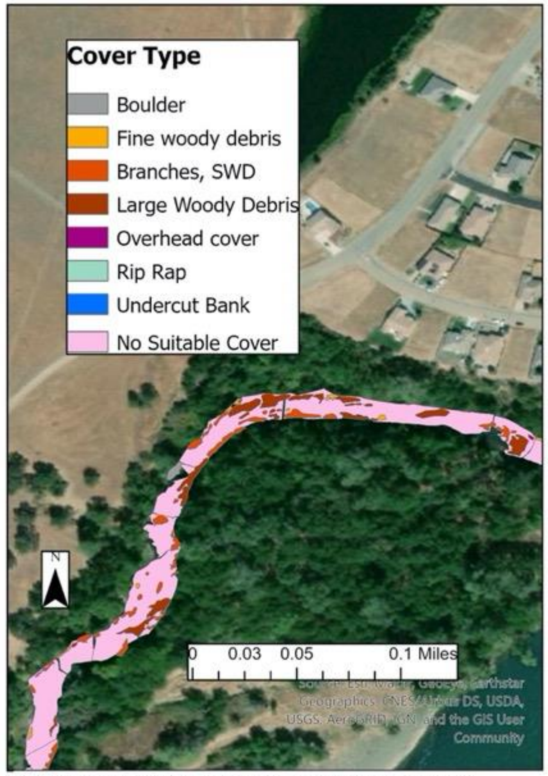
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



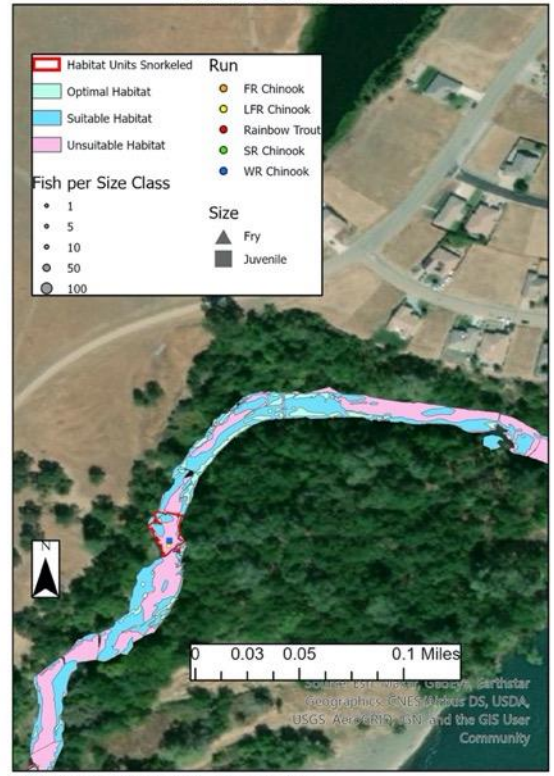
*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators



*Dates mapped: 2-13-18, 2-15-18, 2-20-18
*Vegetation not included

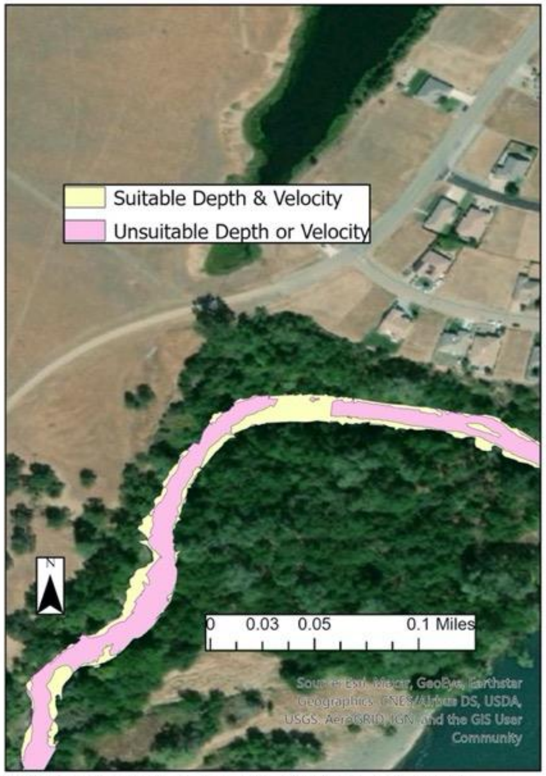
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

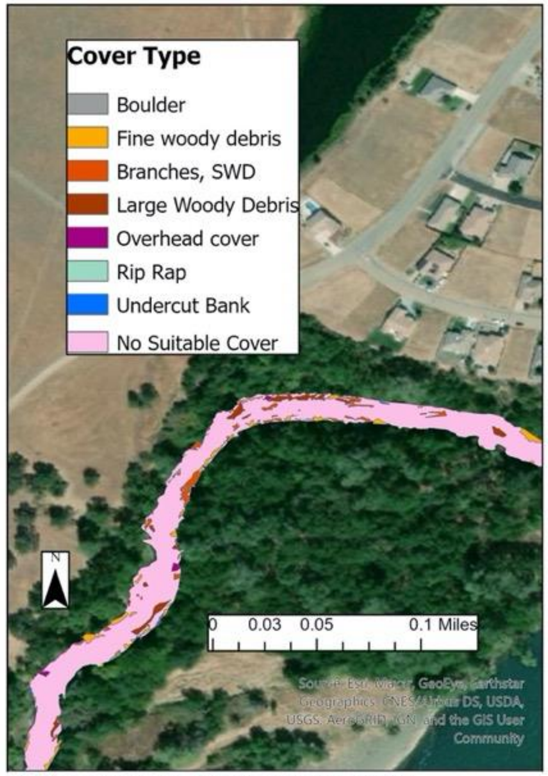
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 6,700 CFS

Depth & Velocity Mapping



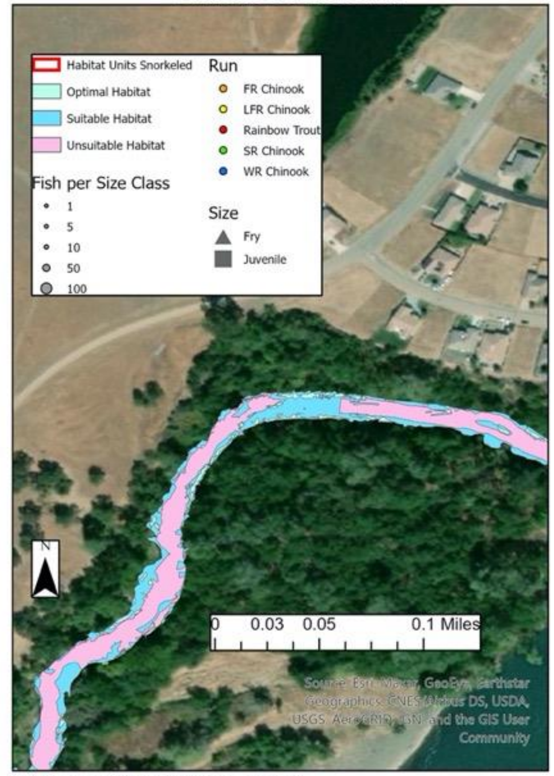
*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

Cover from Predators



*Dates mapped: 10-14-19 & 10-16-19
*Vegetation not included

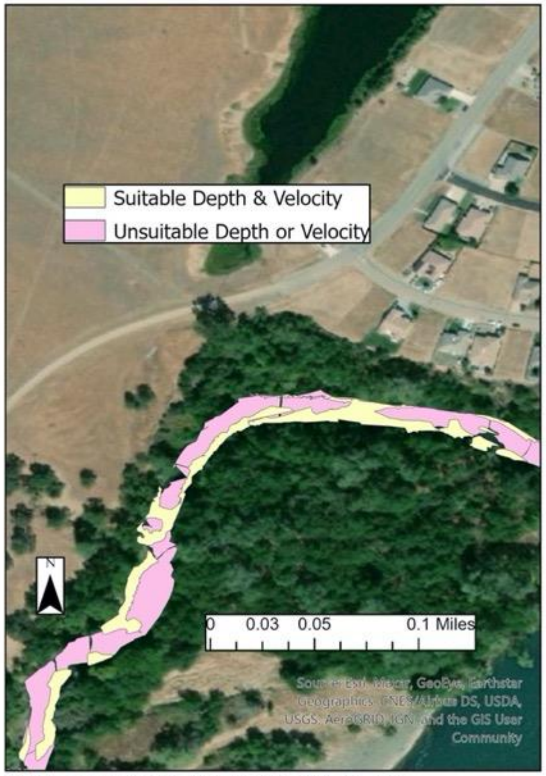
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

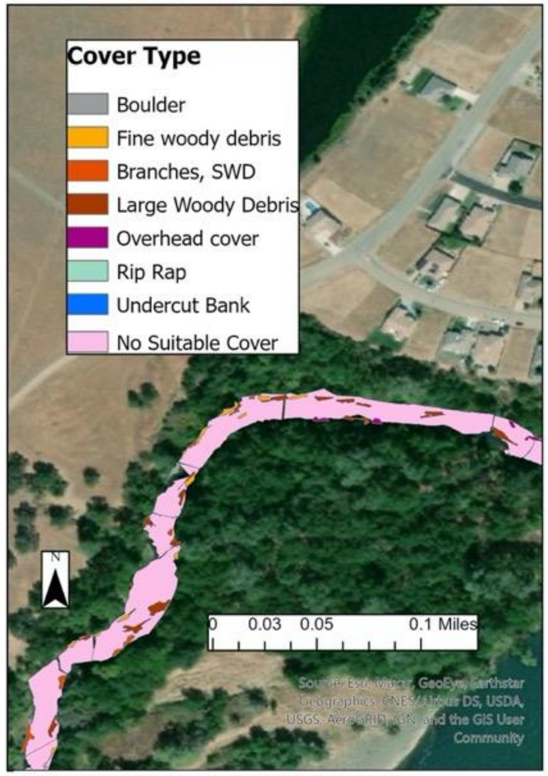
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 7,500 CFS

Depth & Velocity Mapping



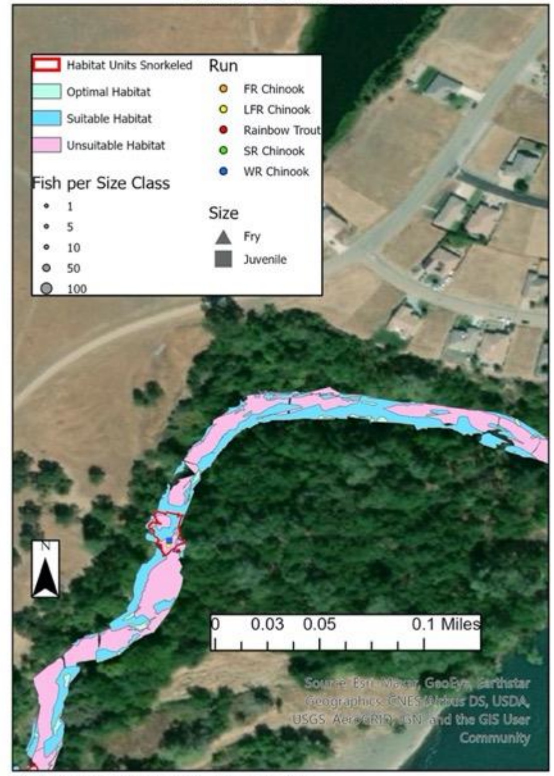
*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators



*Dates mapped: 10-8-18 & 10-10-18
*Vegetation not included

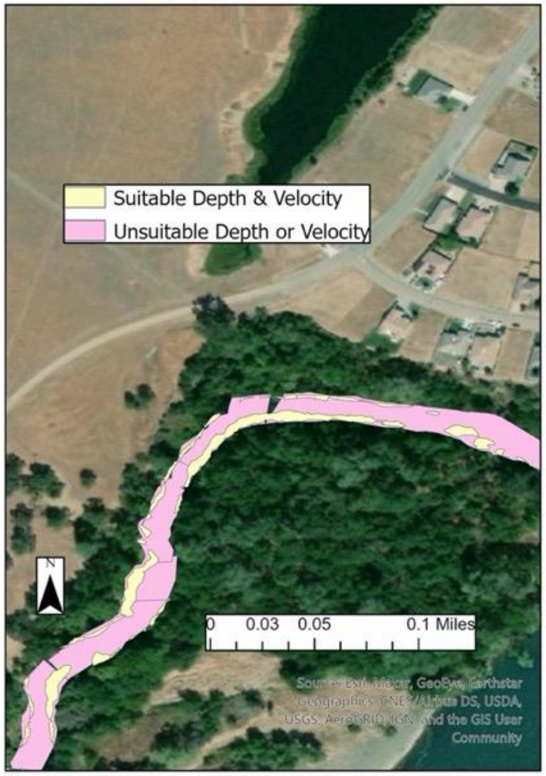
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

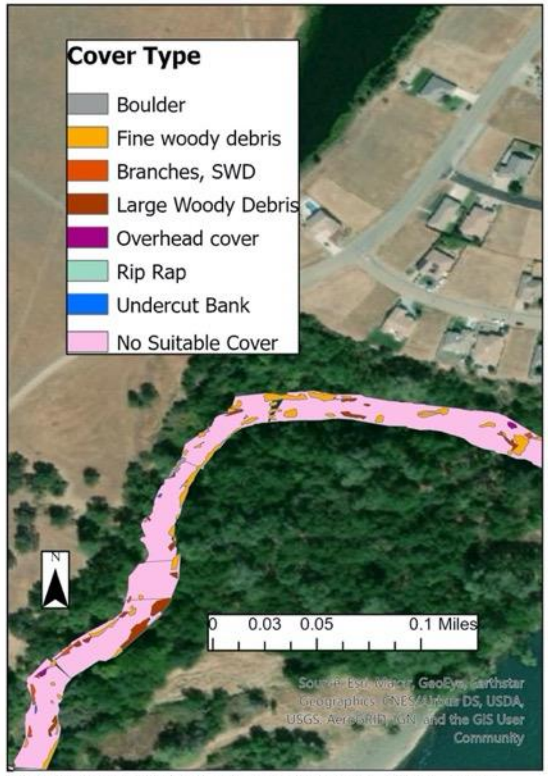
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



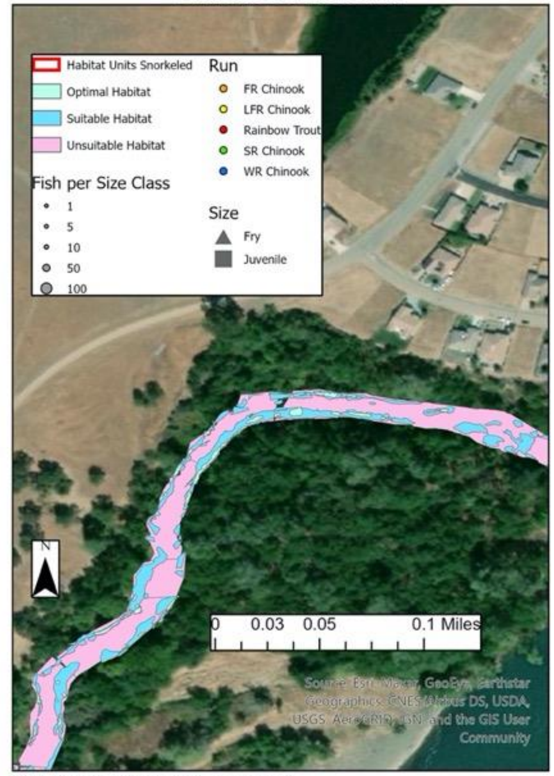
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

Cover from Predators



*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17 *Vegetation not included

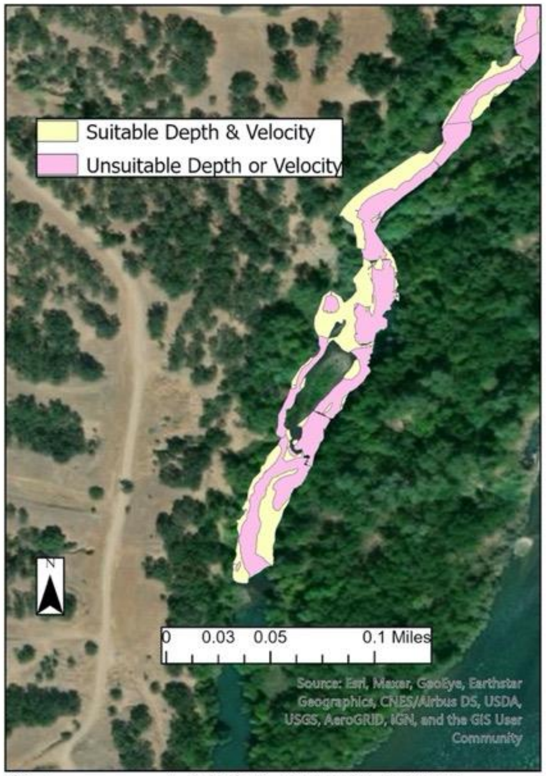
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

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

Depth & Velocity Mapping

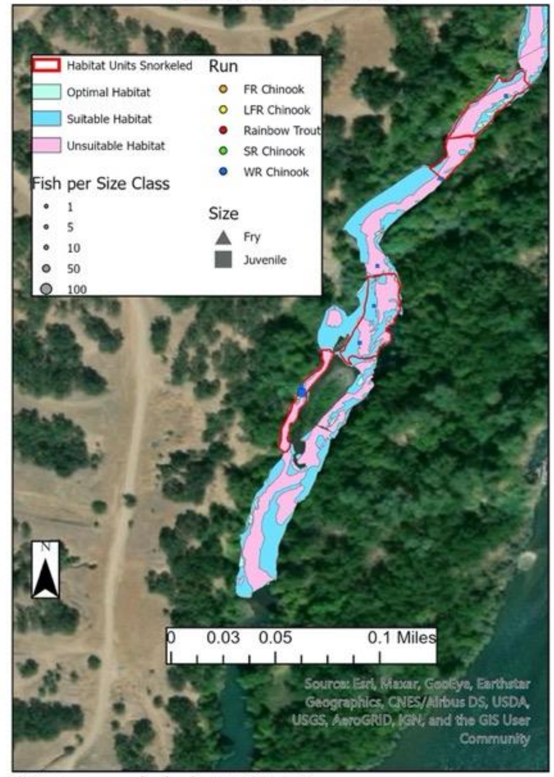


*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators

*Dates mapped: 2-13-18, 2-15-18, 2-20-18
*Vegetation not included

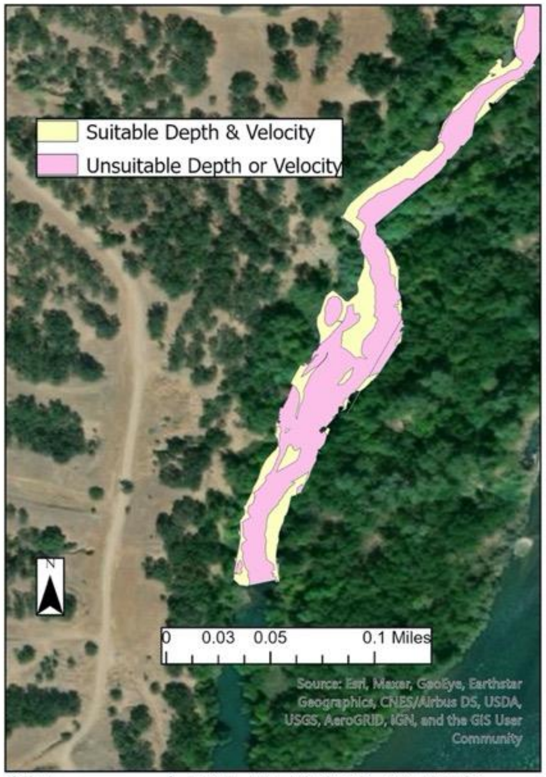
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

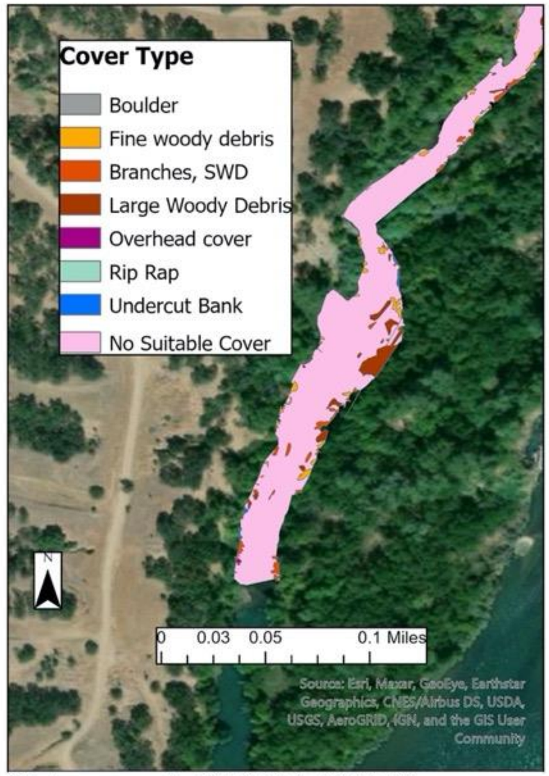
Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 6,700 CFS

Depth & Velocity Mapping



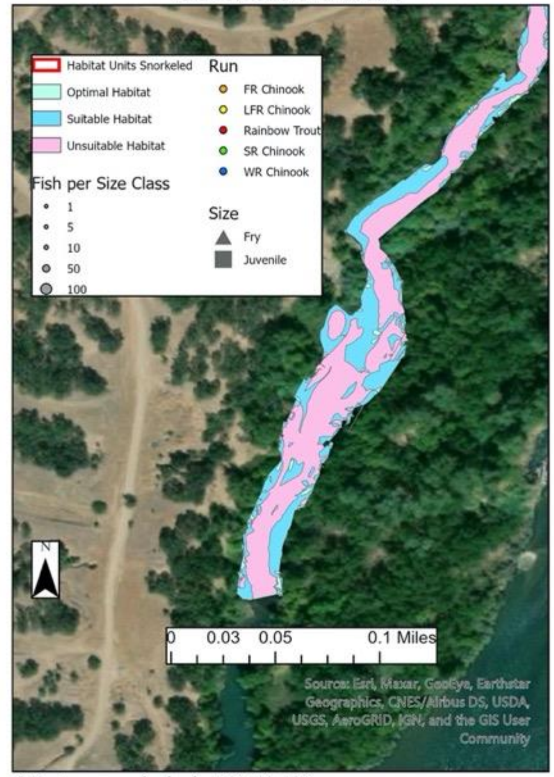
*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

Cover from Predators



*Dates mapped: 10-14-19 & 10-16-19
*Vegetation not included

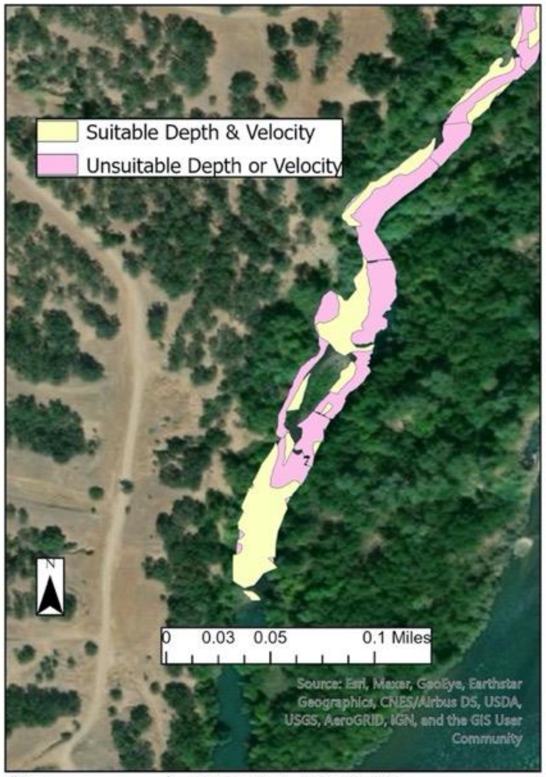
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

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

Depth & Velocity Mapping

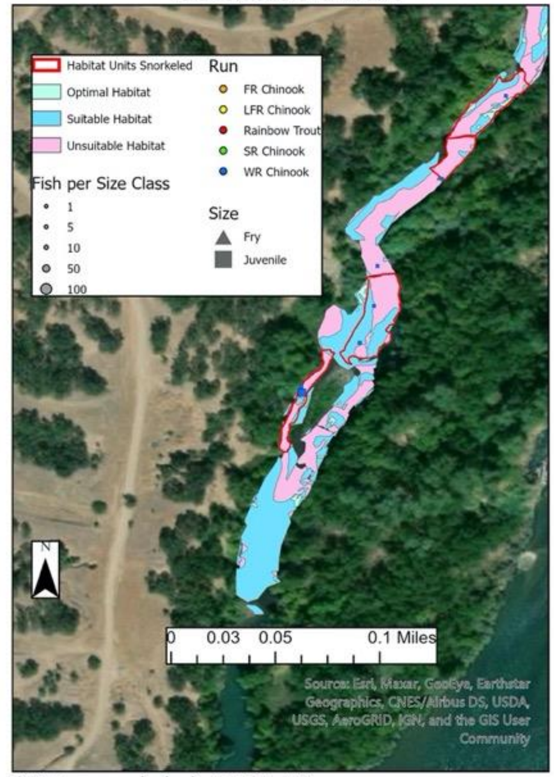


*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators

*Dates mapped: 10-8-18 & 10-10-18
*Vegetation not included

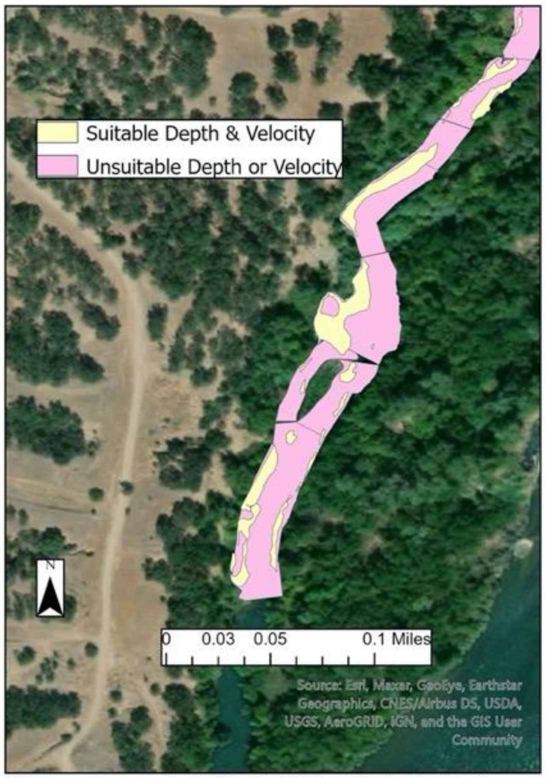
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

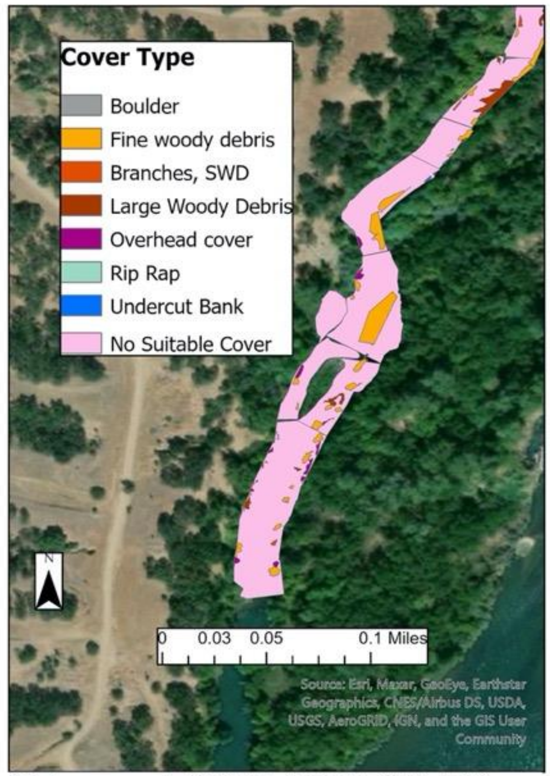
Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



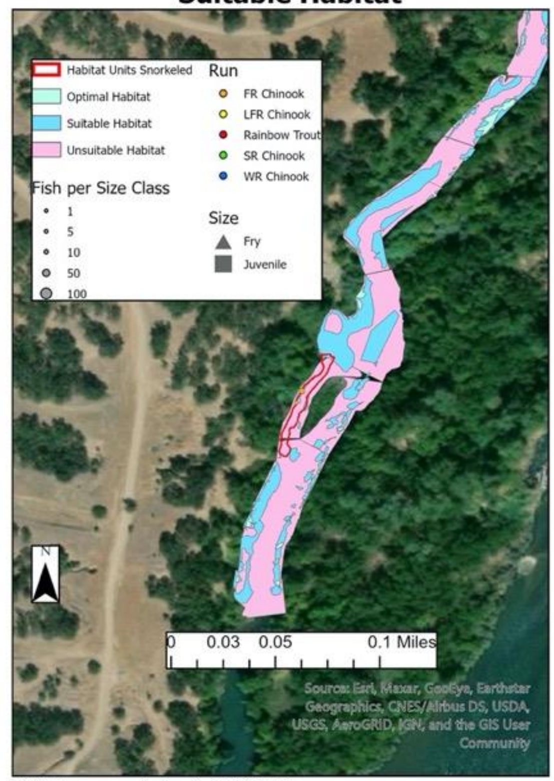
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

Cover from Predators



*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17 *Vegetation not included

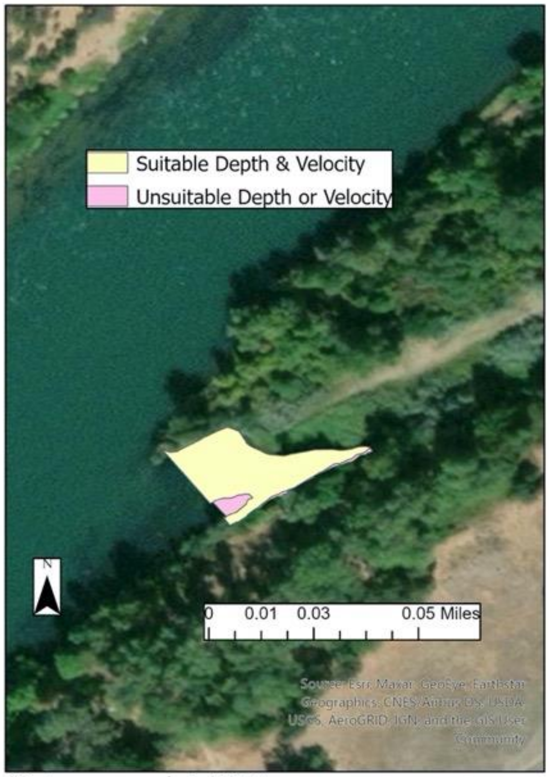
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

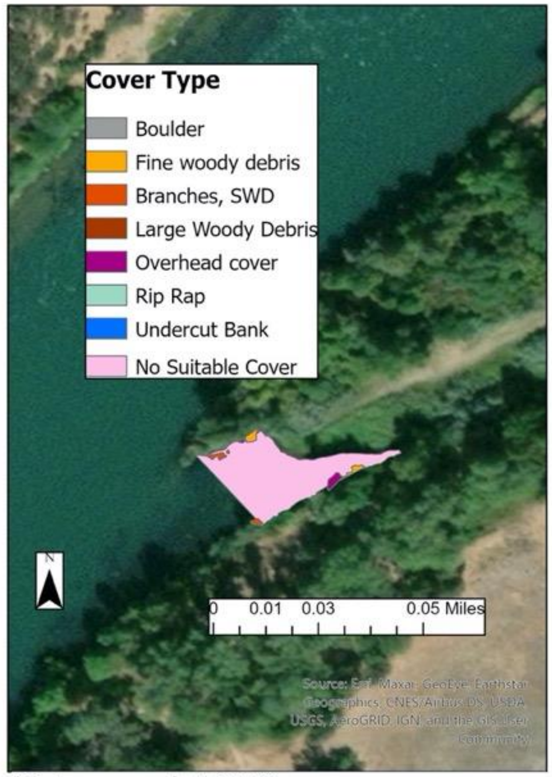
Pre Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



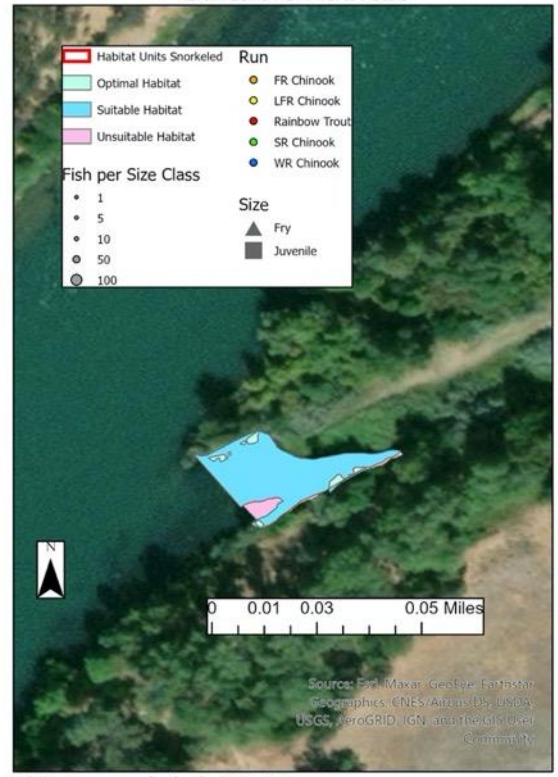
*Dates mapped: 1-22-19

Cover from Predators



*Dates mapped: 1-24-19
*Vegetation not included

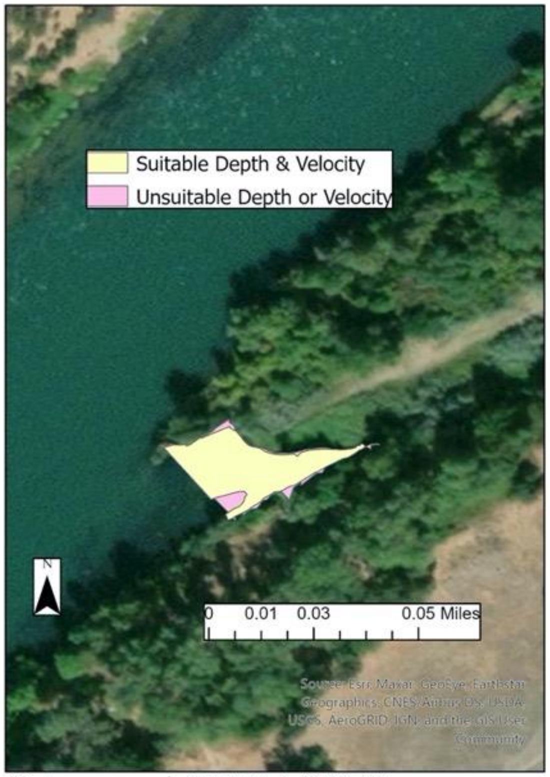
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

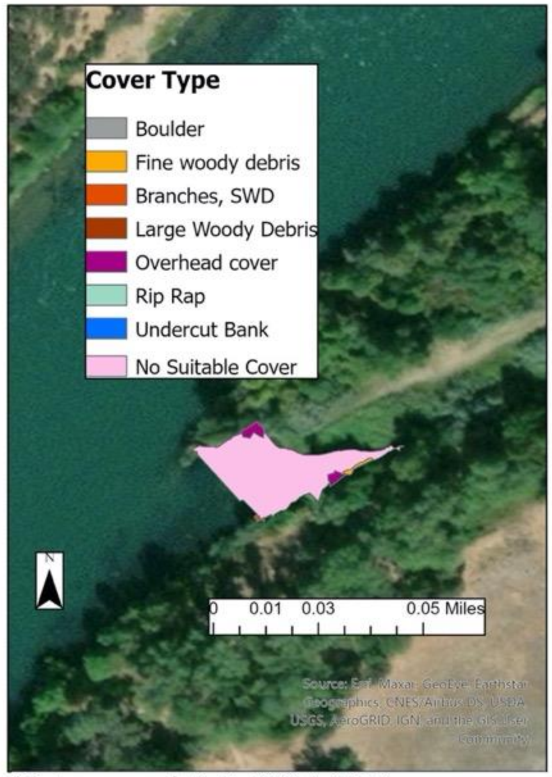
Pre Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 8,600 CFS

Depth & Velocity Mapping



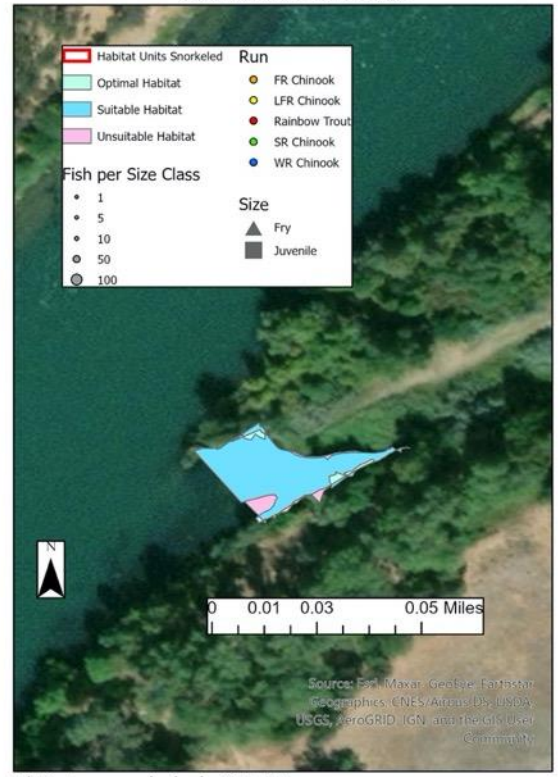
*Dates mapped: 9-11-19 & 9-12-19

Cover from Predators



*Dates mapped: 9-11-19 & 9-12-19
*Vegetation not included

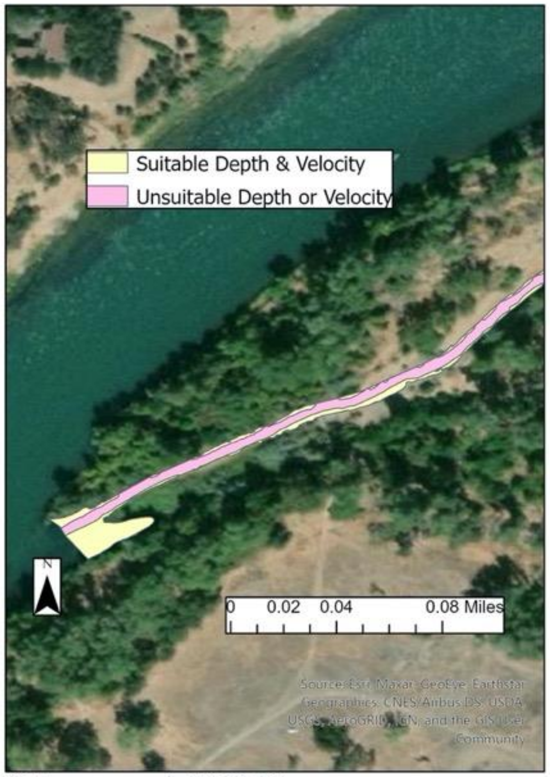
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

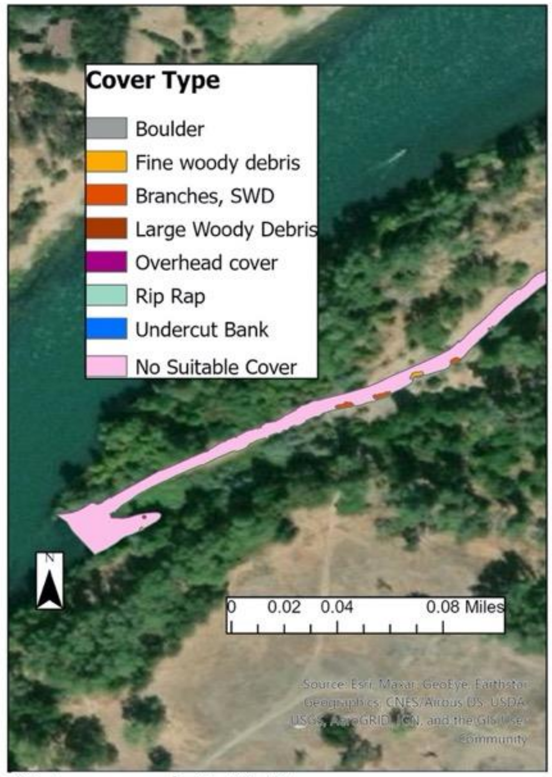
Post Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



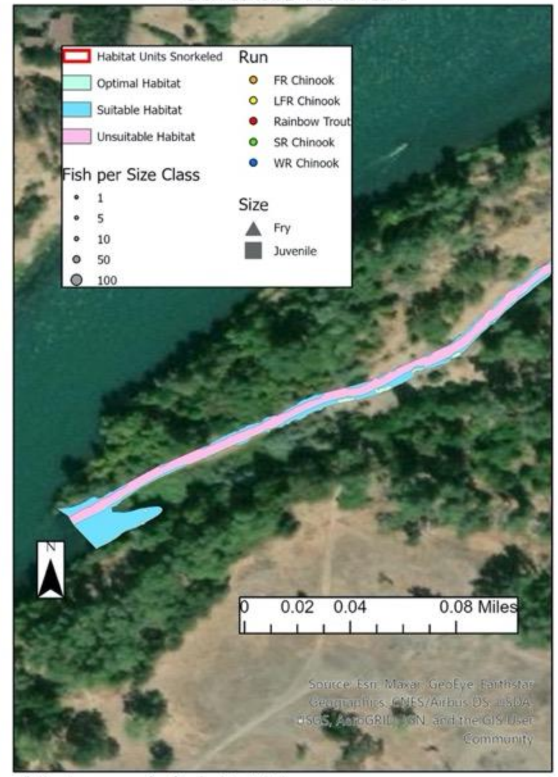
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19
*Vegetation not included

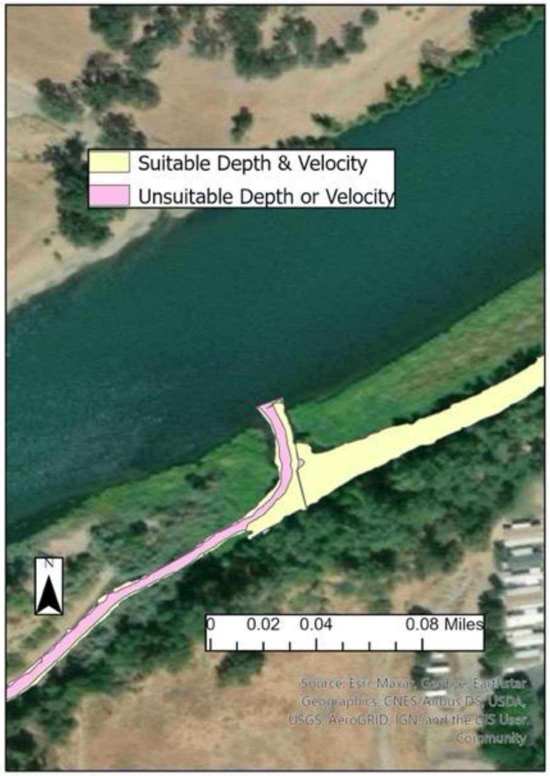
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

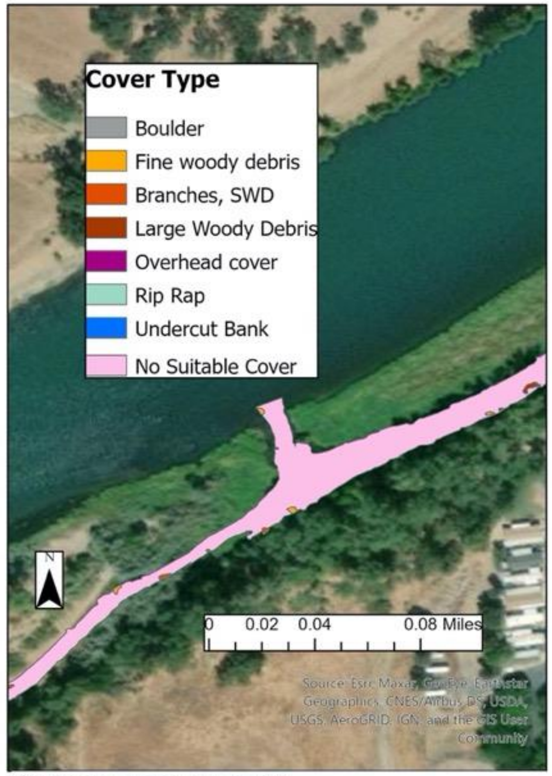
Post Restoration Habitat Mapping: Rio Vista (Middle)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



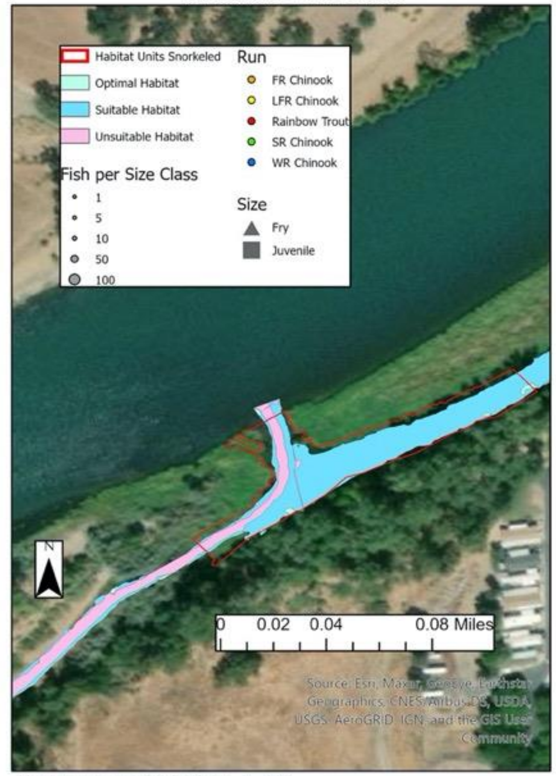
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19
*Vegetation not included

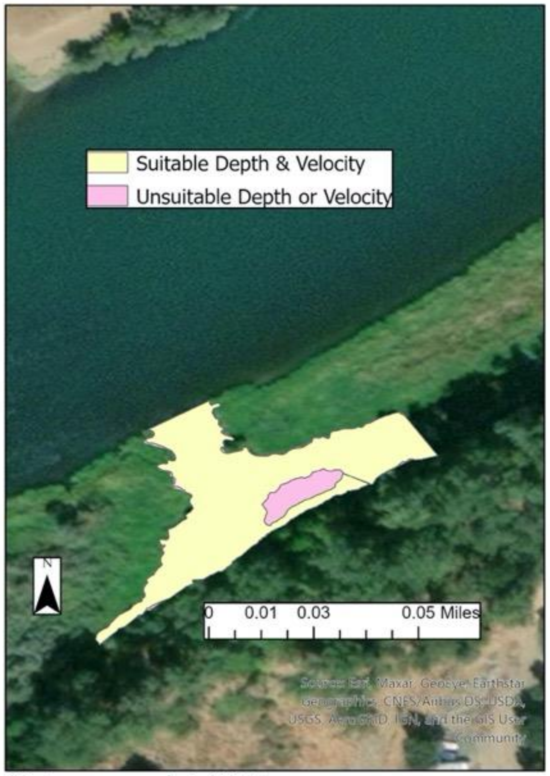
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

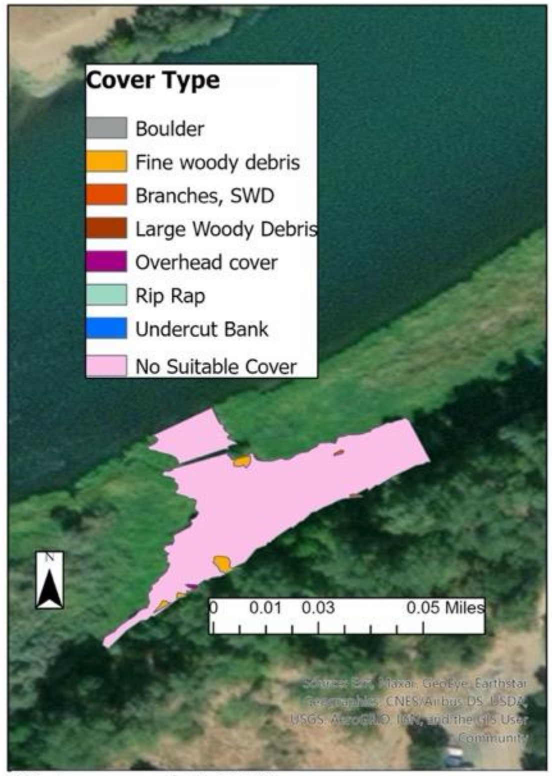
Pre Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



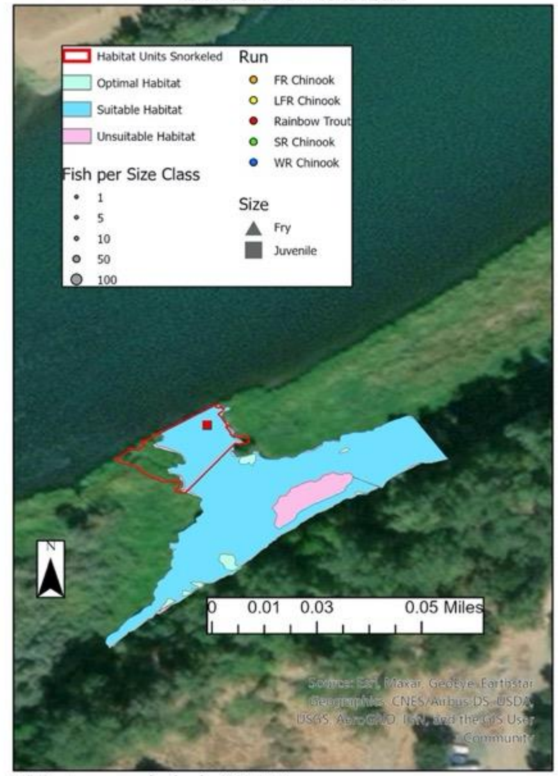
*Dates mapped: 1-22-19

Cover from Predators



*Dates mapped: 1-24-19
*Vegetation not included

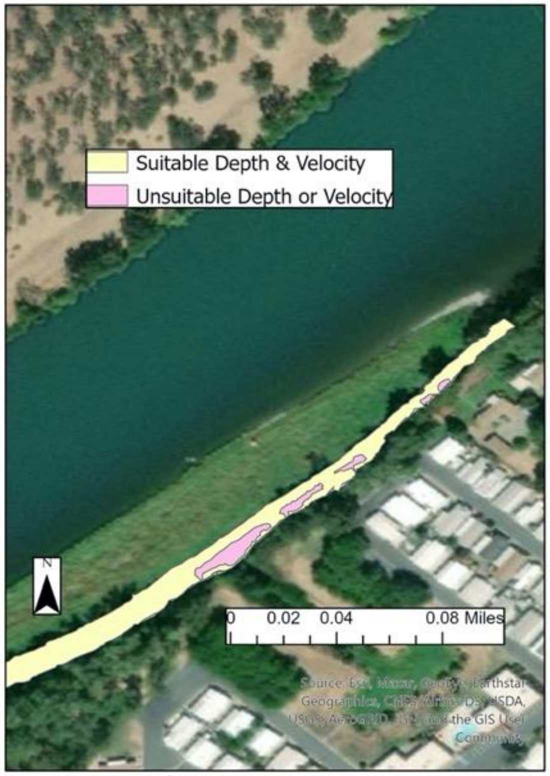
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

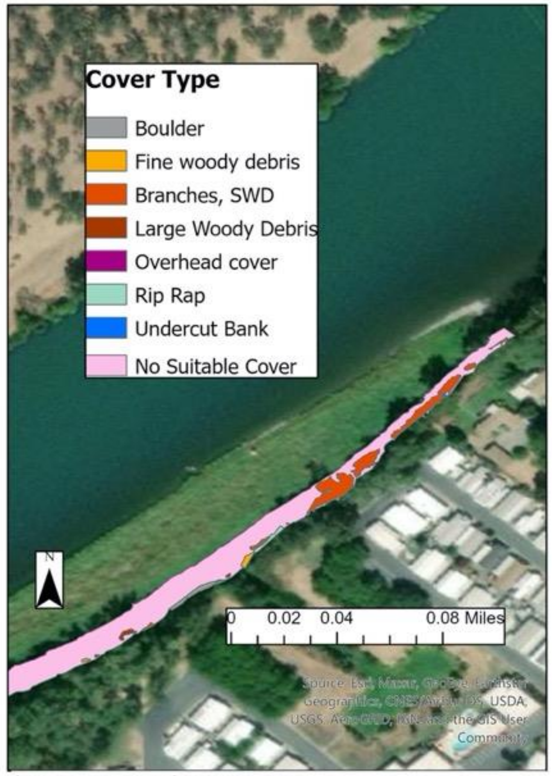
Post Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



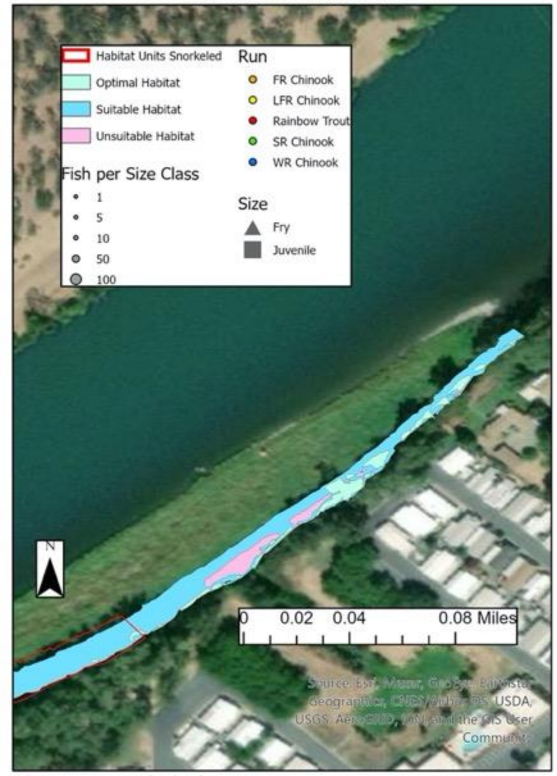
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19
*Vegetation not included

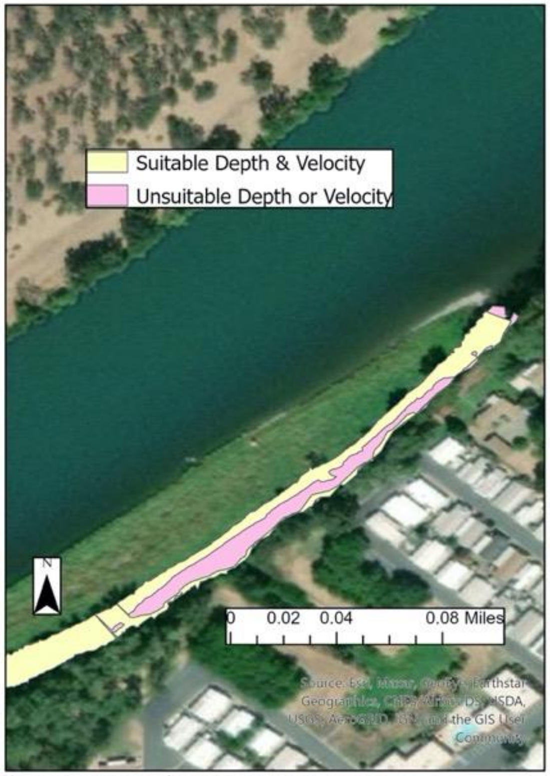
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

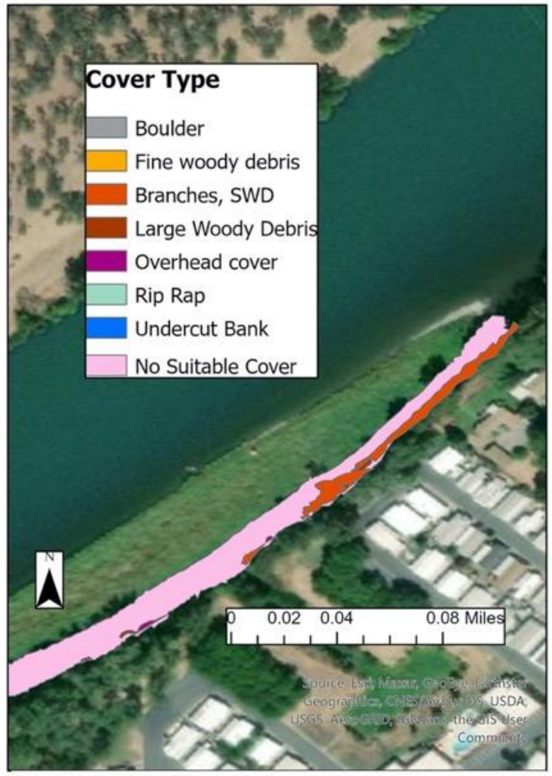
Pre Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 8,600 CFS

Depth & Velocity Mapping



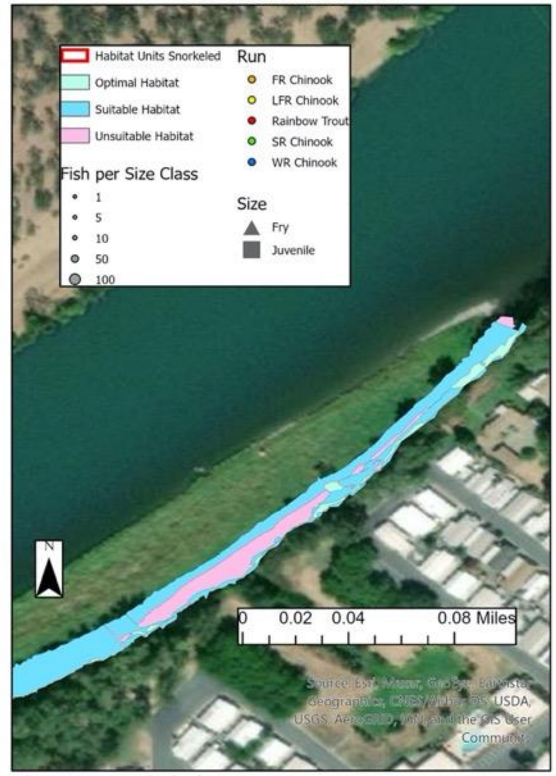
*Dates mapped: 9-11-19 & 9-12-19

Cover from Predators



*Dates mapped: 9-11-19 & 9-12-19
*Vegetation not included

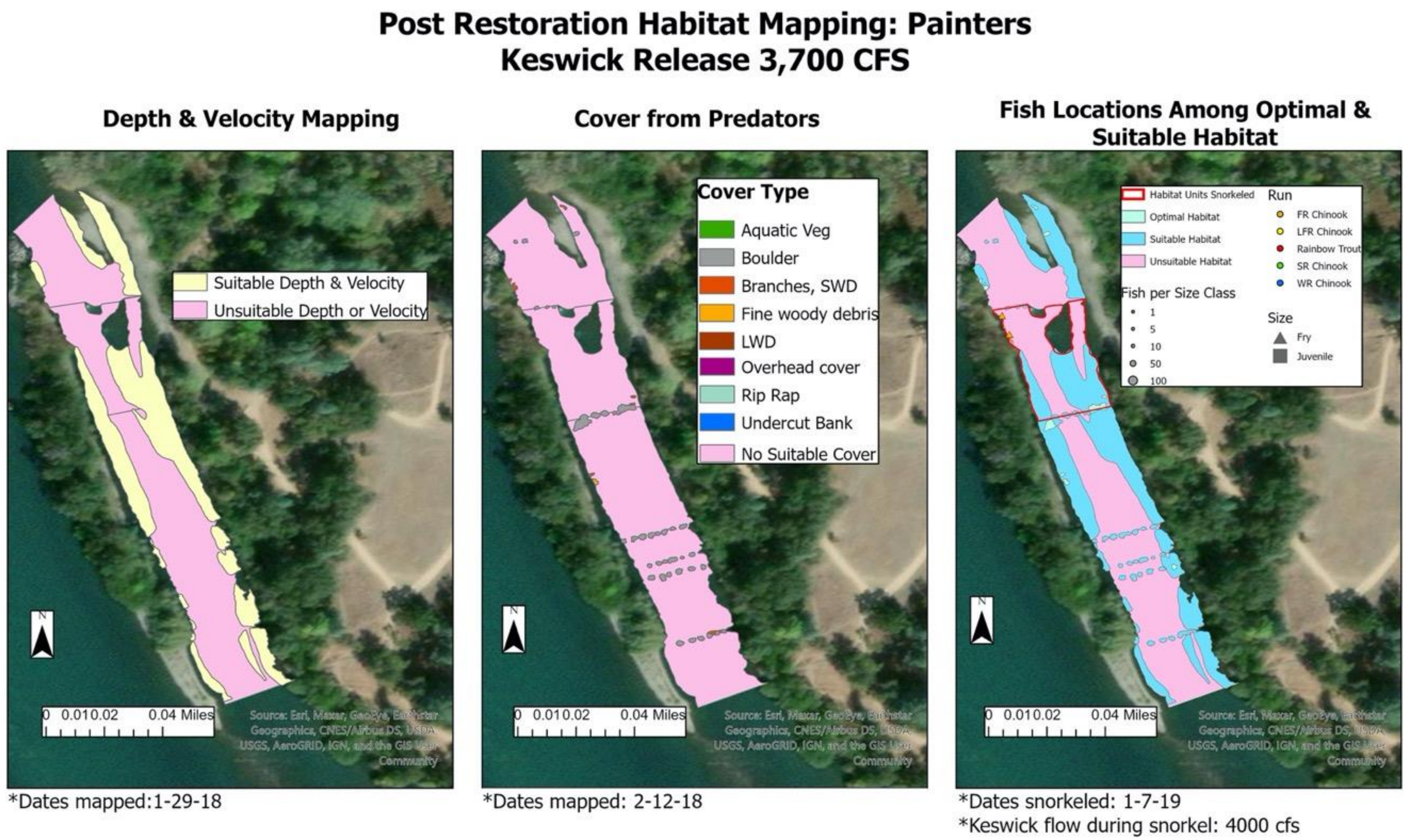
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

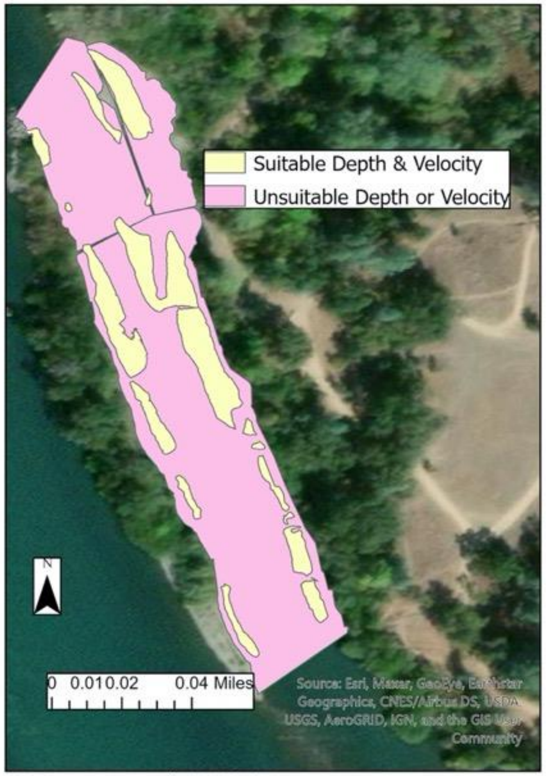
APPENDIX D – HABITAT MAPS (NO COBBLE, INCLUDES VEGETATION)

Cobble and vegetation excluded, organized north to south, pre-restoration to post-restoration, and low flow to high flow.



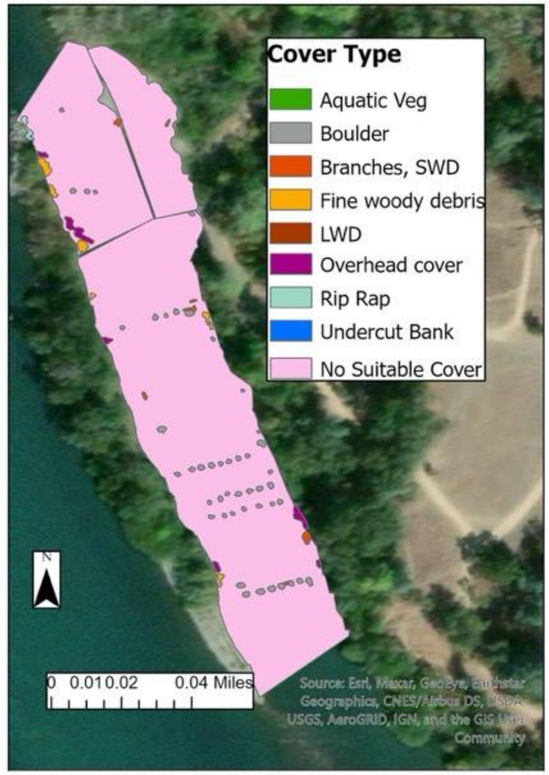
Post Restoration Habitat Mapping: Painters
Keswick Release 5,000 CFS

Depth & Velocity Mapping



*Dates mapped: 12-5-17

Cover from Predators



*Dates mapped: 10-27-17

Fish Locations Among Optimal & Suitable Habitat

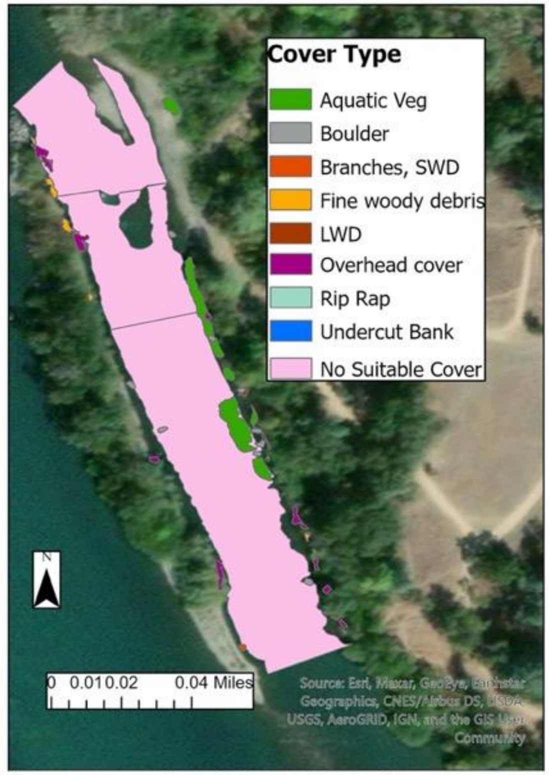
*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

Post Restoration Habitat Mapping: Painters
Keswick Release 7,400 CFS

Depth & Velocity Mapping

*Dates mapped: 9-26-18 & 10-10-18

Cover from Predators



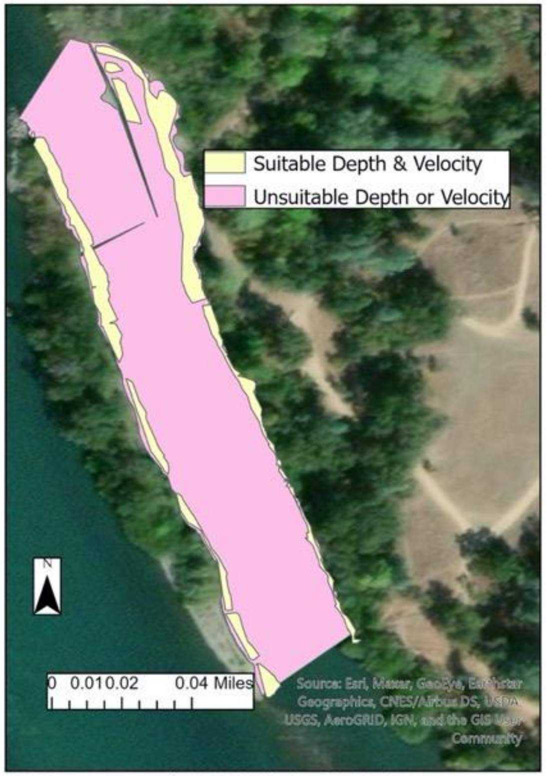
*Dates mapped: 9-26-18 & 10-10-18

Fish Locations Among Optimal & Suitable Habitat

*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

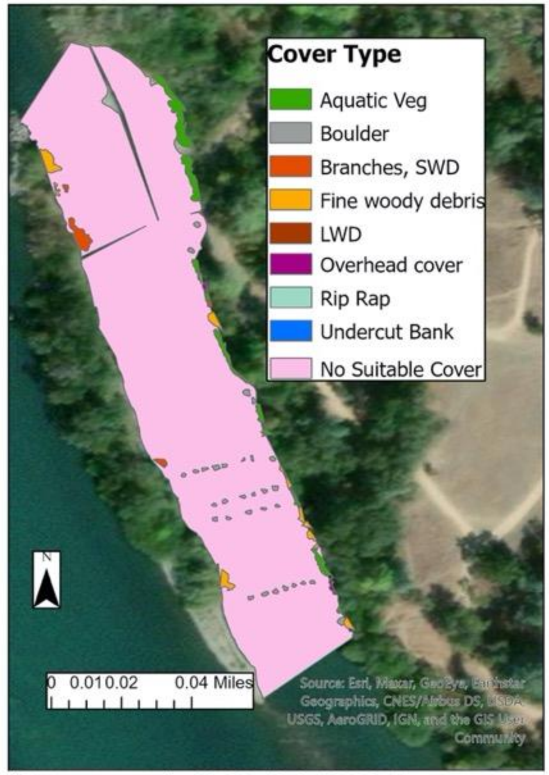
Post Restoration Habitat Mapping: Painters
Keswick Release 7,800 CFS

Depth & Velocity Mapping



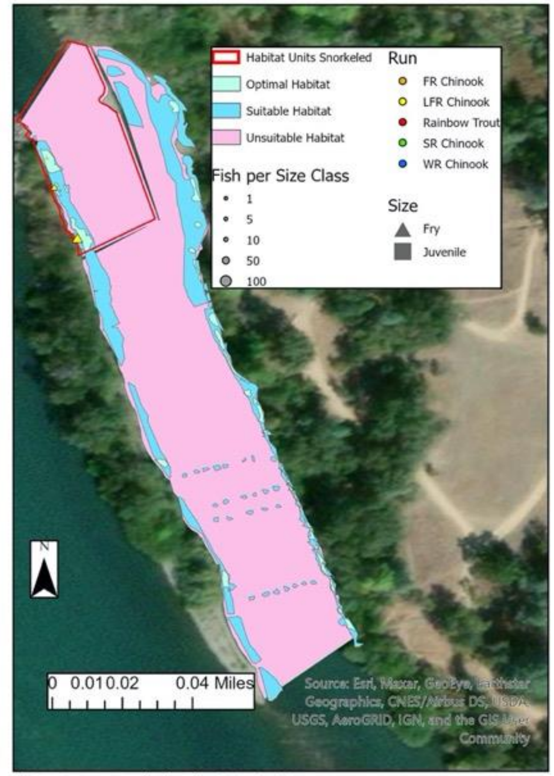
*Dates mapped: 10-28-19 & 10-30-19

Cover from Predators



*Dates mapped: 10-28-19 & 10-30-19

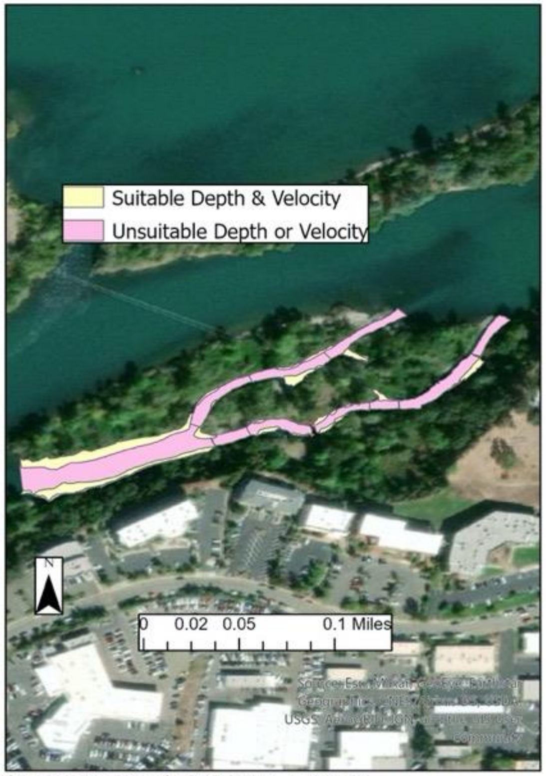
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-26-19
*Keswick flow during snorkel: 11000 cfs

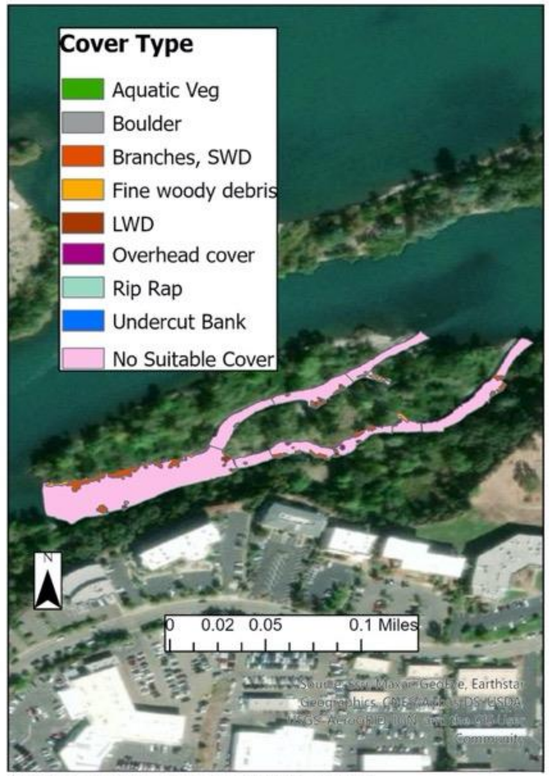
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 3,700 CFS

Depth & Velocity Mapping



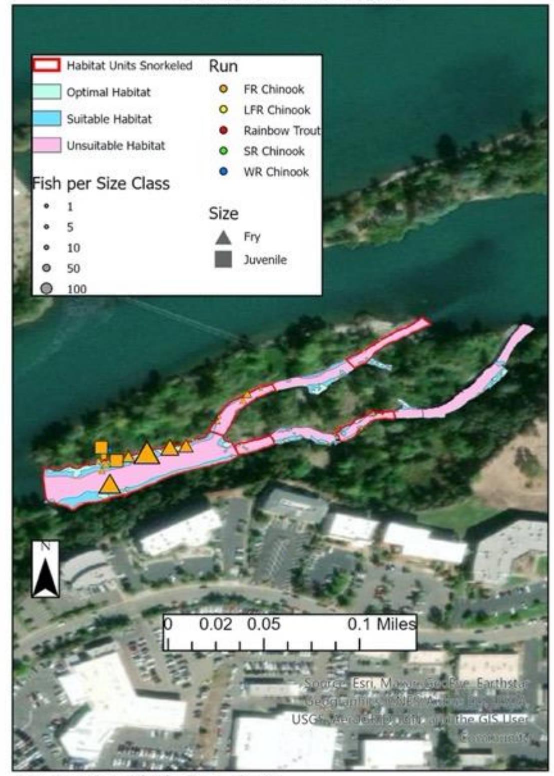
*Dates mapped: 2-9-18 & 2-12-18

Cover from Predators



*Dates mapped: 2-9-18 & 2-12-18

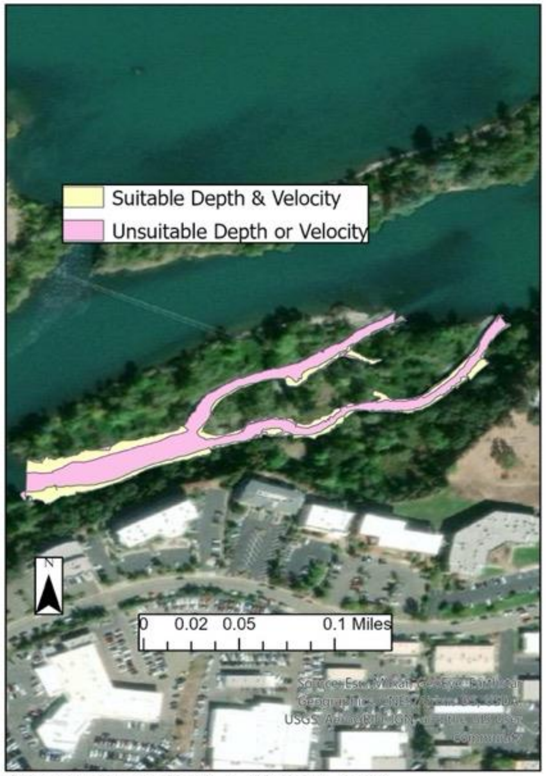
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-7-19
*Keswick flow during snorkel: 4000 cfs

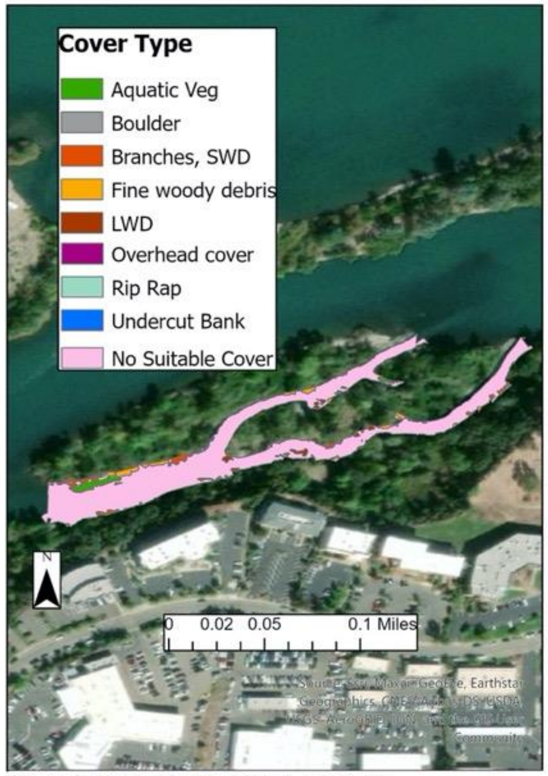
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



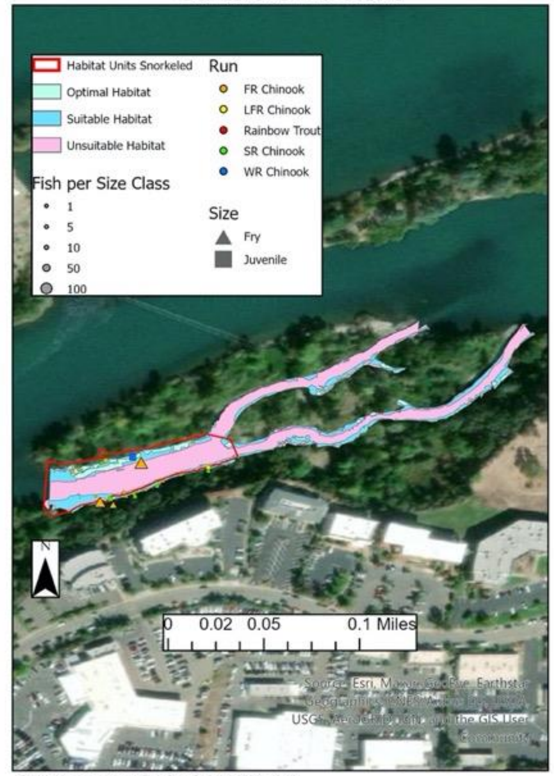
*Dates mapped: 11-4-19 & 11-6-19

Cover from Predators



*Dates mapped: 11-4-19 & 11-6-19

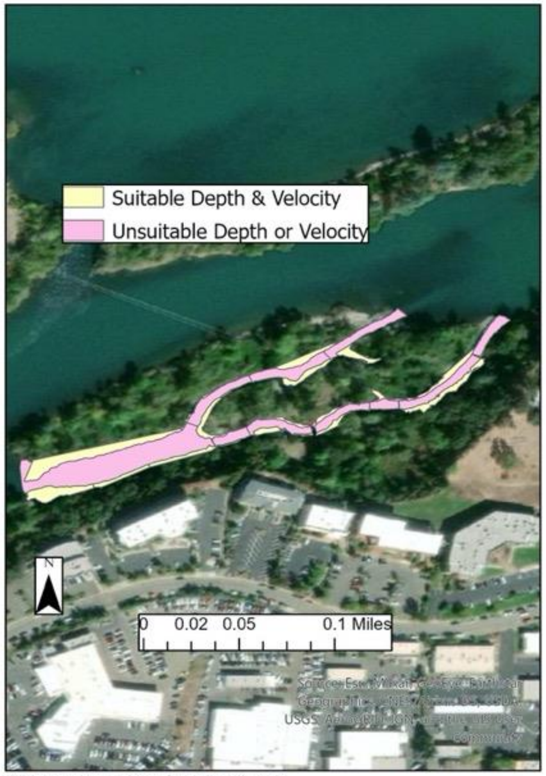
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-28-20
*Keswick flow during snorkel: 5000 cfs

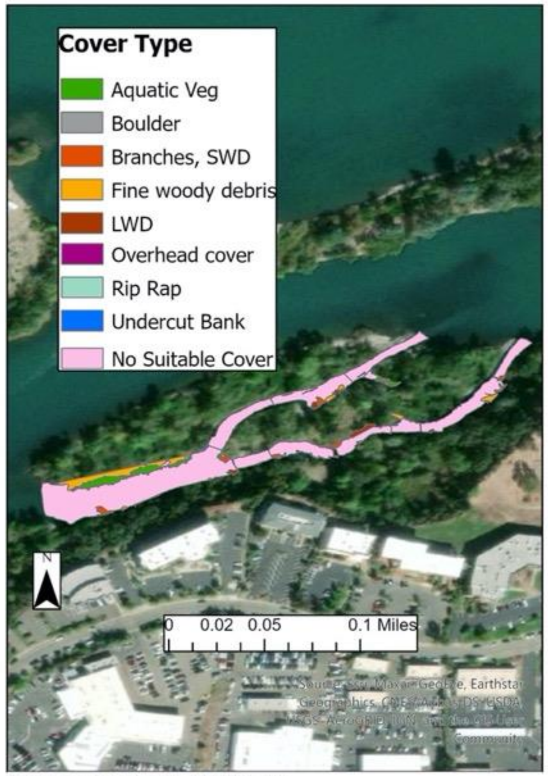
Post Restoration Habitat Mapping: North Cypress (Upper)
Keswick Release 6,000 CFS

Depth & Velocity Mapping



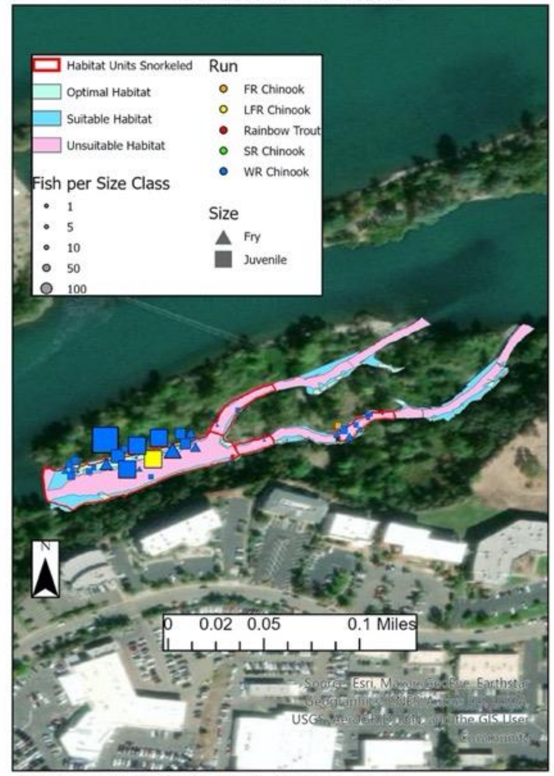
*Dates mapped: 10-24-18

Cover from Predators



*Dates mapped: 10-24-18

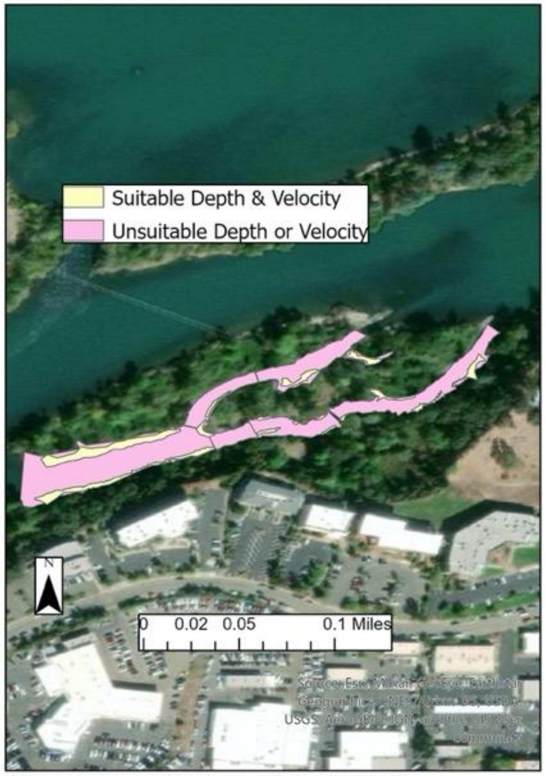
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-6-18 &11-7-18
*Keswick flow during snorkel: 4600 cfs

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

Depth & Velocity Mapping



*Dates mapped: 10-11-17 & 10-12-17

Cover from Predators

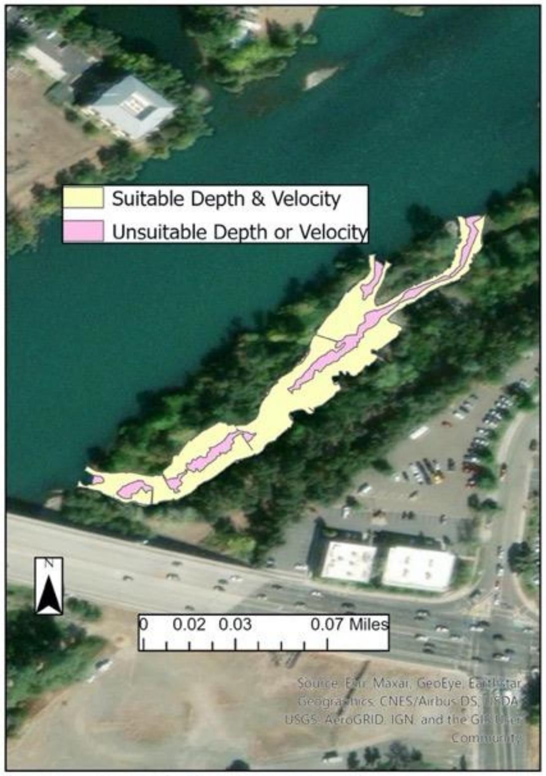
*Dates mapped: 10-11-17 & 10-12-17

Fish Locations Among Optimal & Suitable Habitat

*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

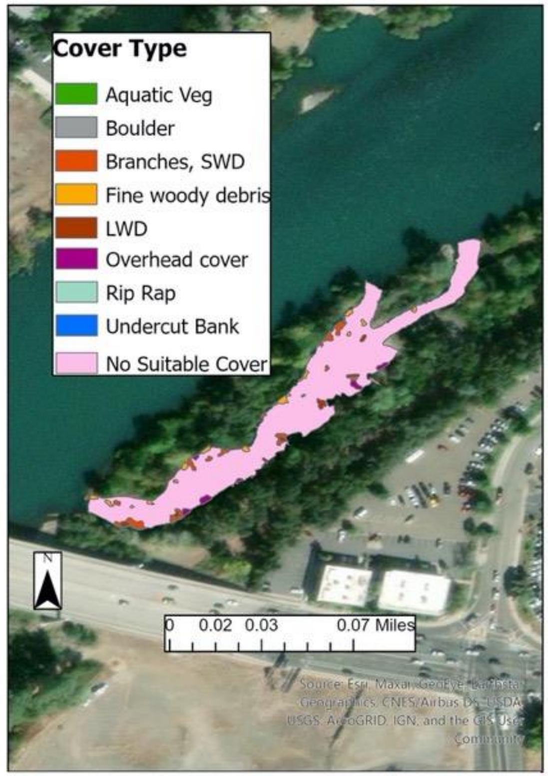
Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 3,700 CFS

Depth & Velocity Mapping



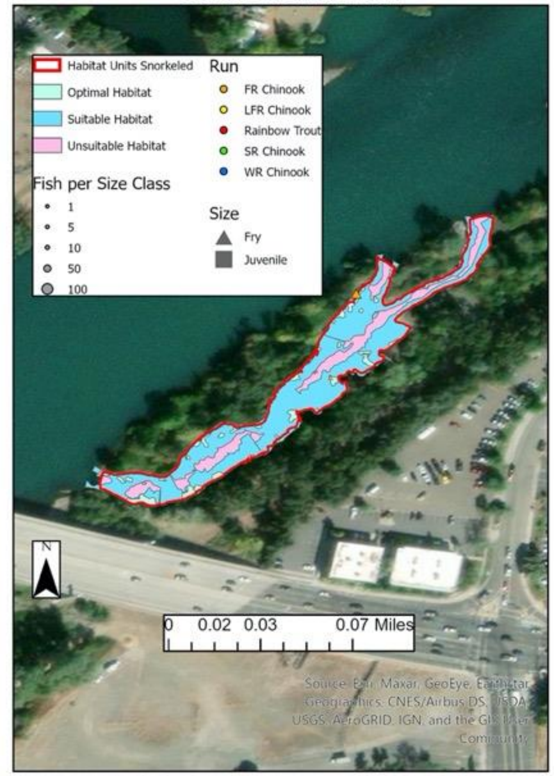
*Dates mapped: 2-9-18 & 2-12-18

Cover from Predators



*Dates mapped: 2-9-18 & 2-12-18

Fish Locations Among Optimal & Suitable Habitat



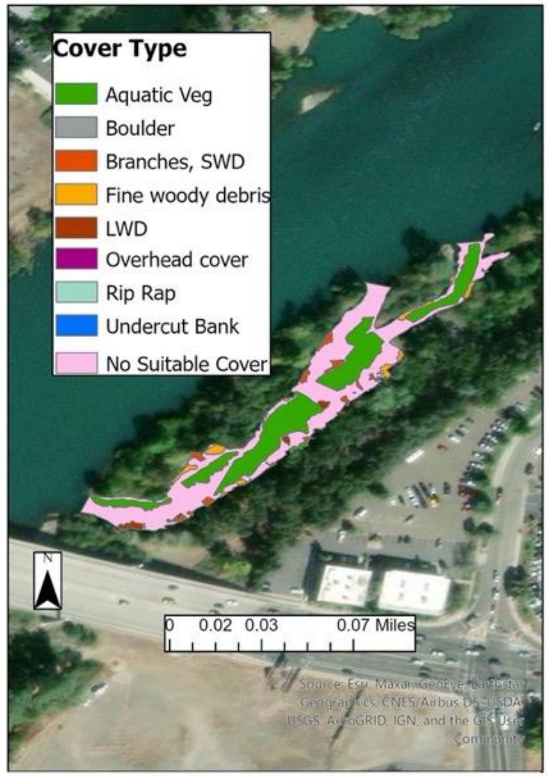
*Dates snorkeled: 1-7-19
*Keswick flow during snorkel: 4000 cfs

Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping

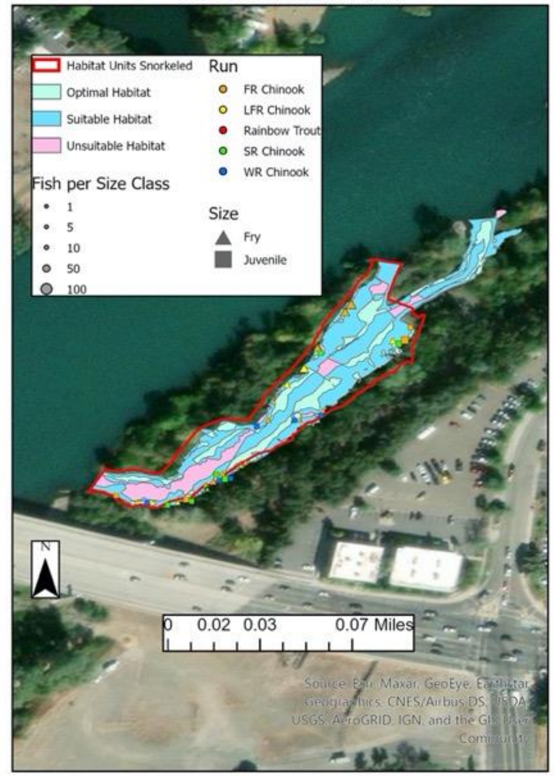
*Dates mapped: 11-4-19 & 11-6-19

Cover from Predators



*Dates mapped: 11-4-19 & 11-6-19

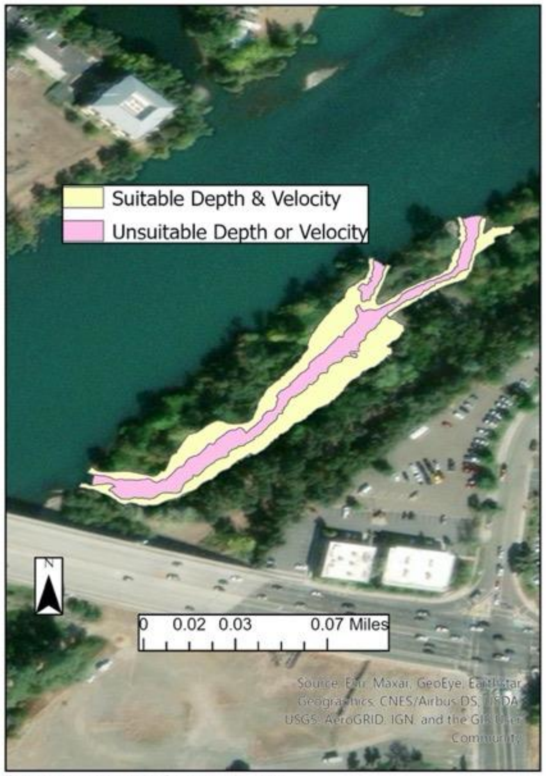
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-28-20
*Keswick flow during snorkel: 5000 cfs

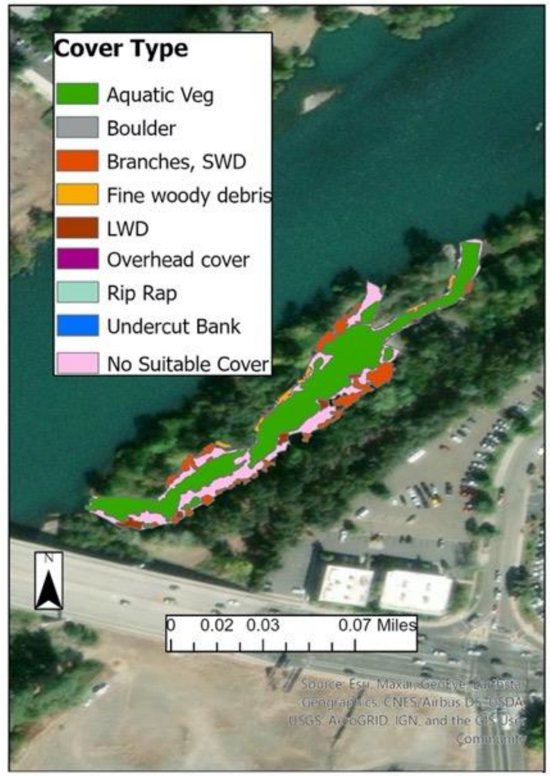
Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 6,000 CFS

Depth & Velocity Mapping



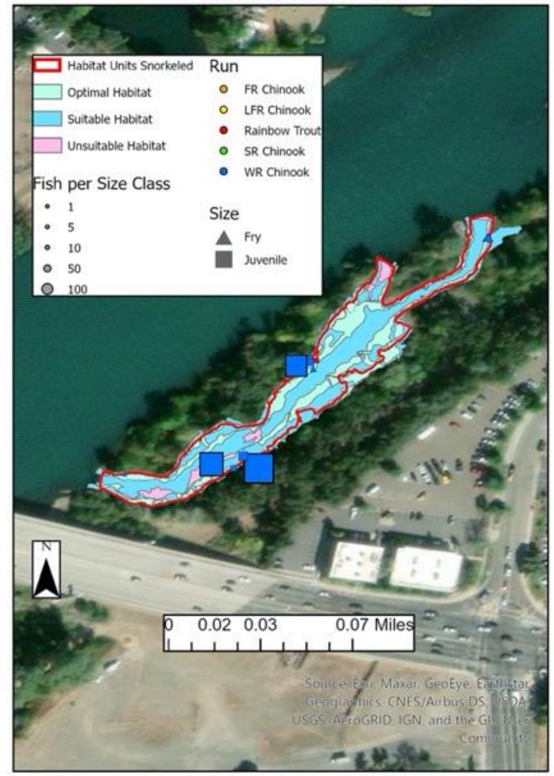
*Dates mapped: 10-24-18

Cover from Predators



*Dates mapped: 10-24-18

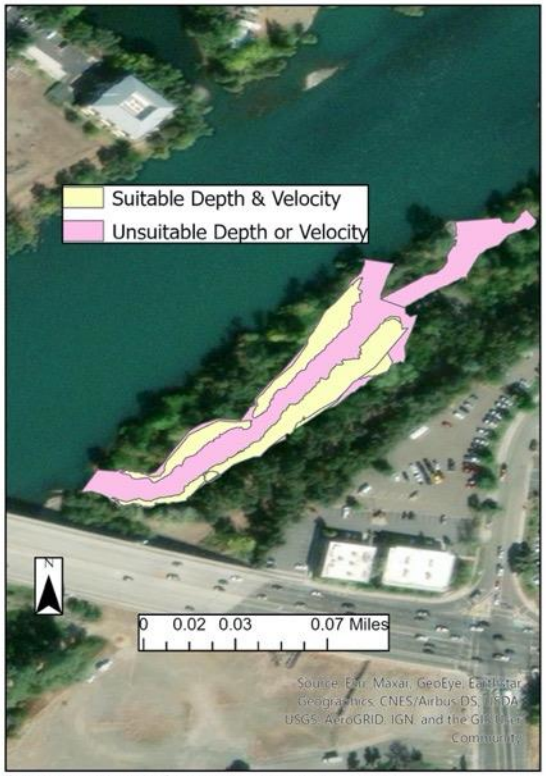
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-6-18 &11-7-18
*Keswick flow during snorkel: 4600 cfs

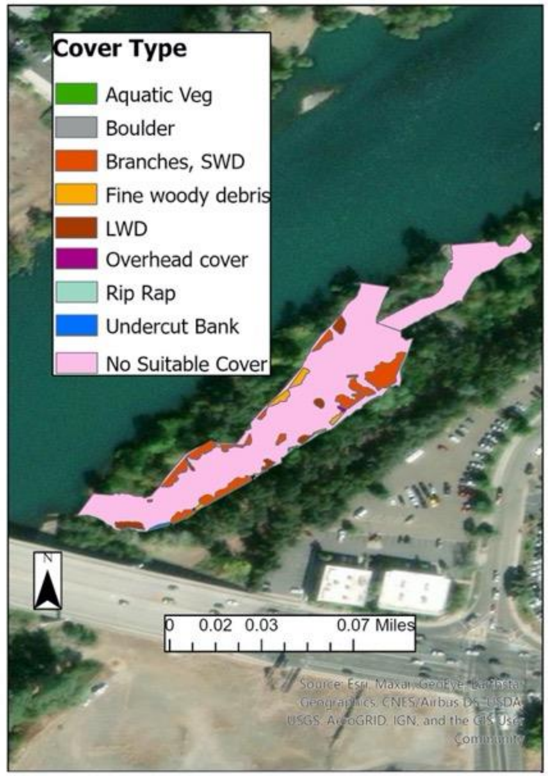
Post Restoration Habitat Mapping: North Cypress (Lower)
Keswick Release 8,000 CFS

Depth & Velocity Mapping



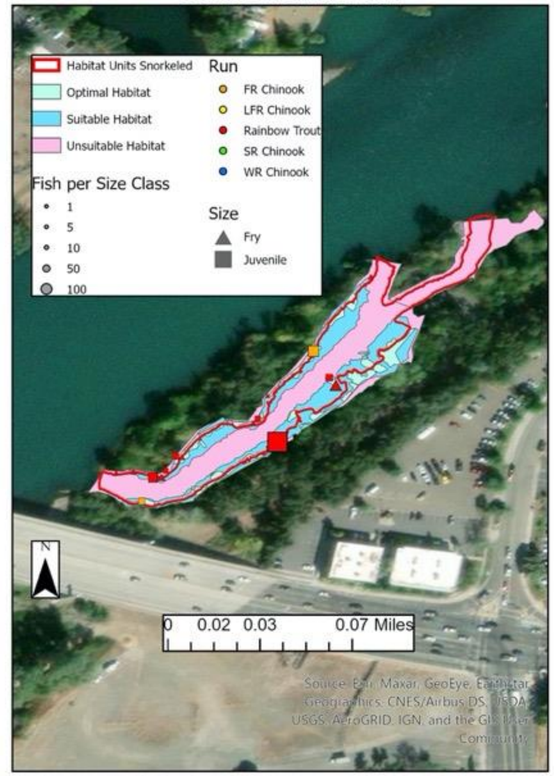
*Dates mapped: 10-11-17 & 10-12-17

Cover from Predators



*Dates mapped: 10-11-17 & 10-12-17

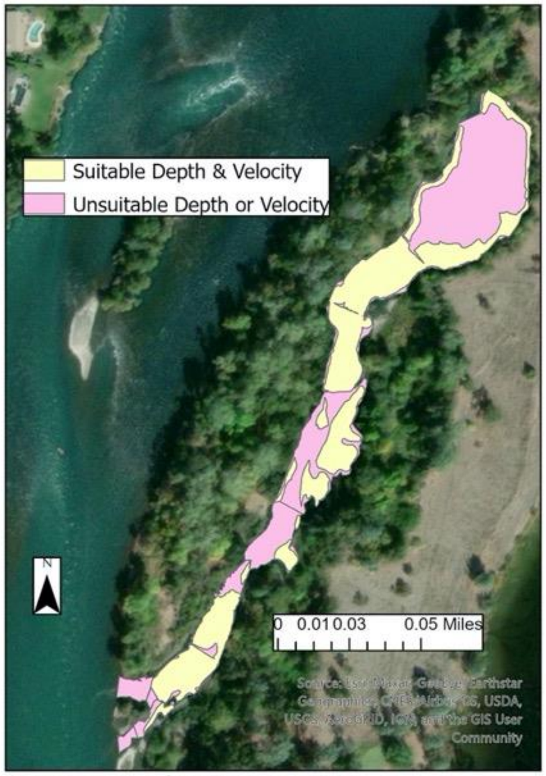
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

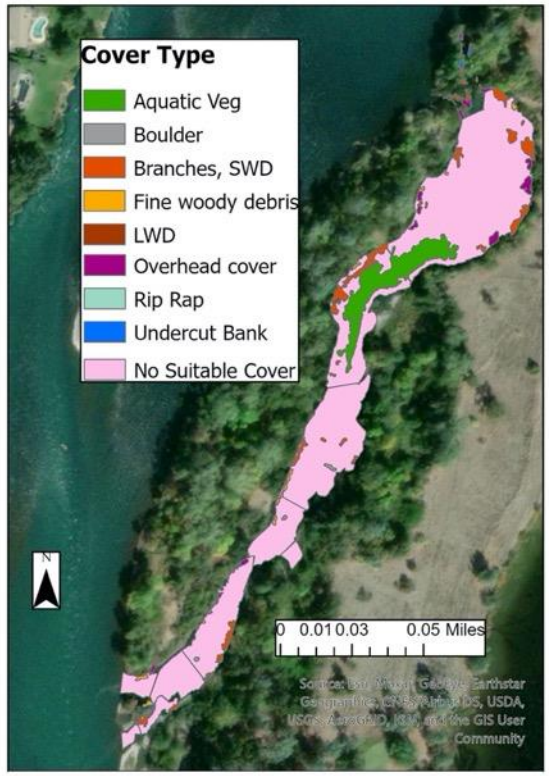
Control Site Habitat Mapping: Wyndham
Keswick Release 3,250 CFS

Depth & Velocity Mapping



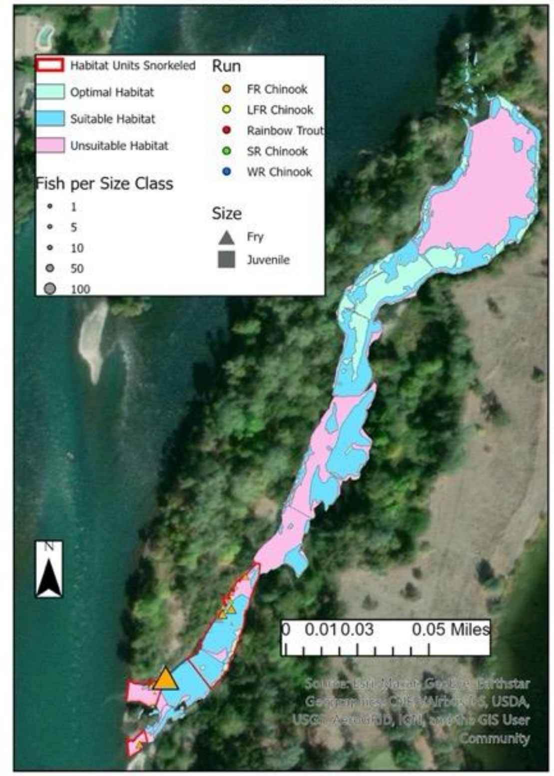
*Dates mapped: 3-7-18 & 3-9-18

Cover from Predators



*Dates mapped: 3-7-18 & 3-9-18

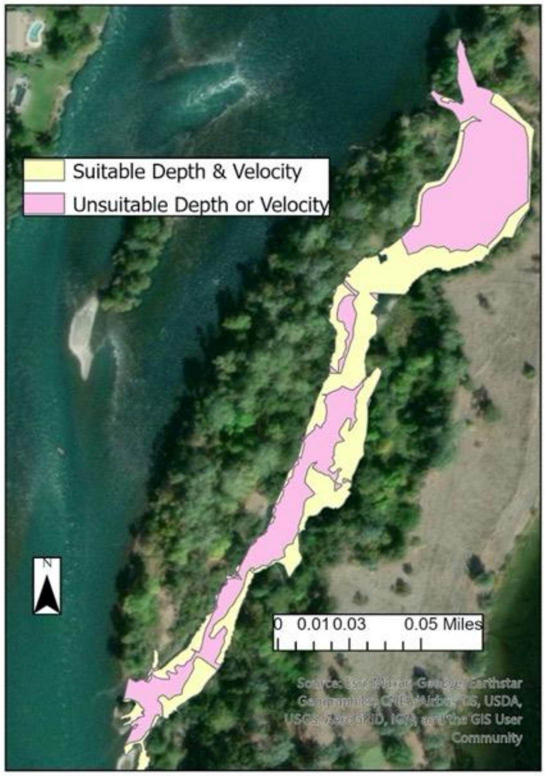
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-8-19
*Keswick flow during snorkel: 4000 cfs

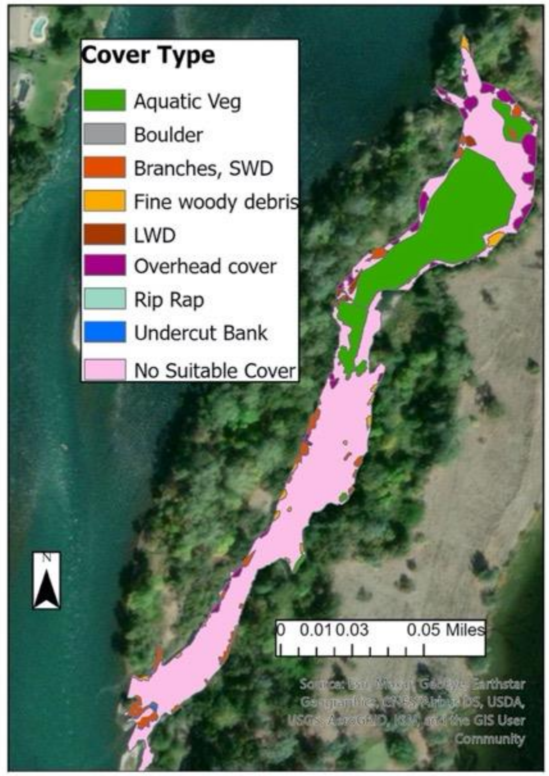
Control Site Habitat Mapping: Wyndham
Keswick Release 5,000 CFS

Depth & Velocity Mapping



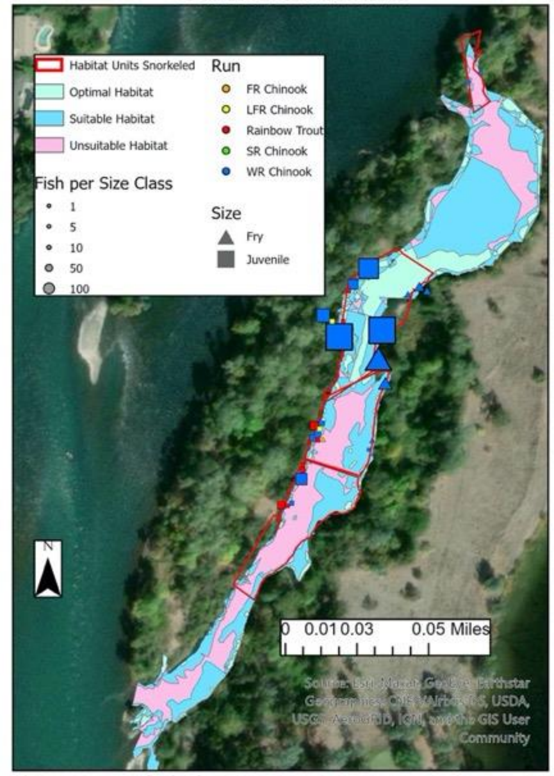
*Dates mapped: 11-4-19

Cover from Predators



*Dates mapped: 11-5-19, 11-7-19, & 11-21-19

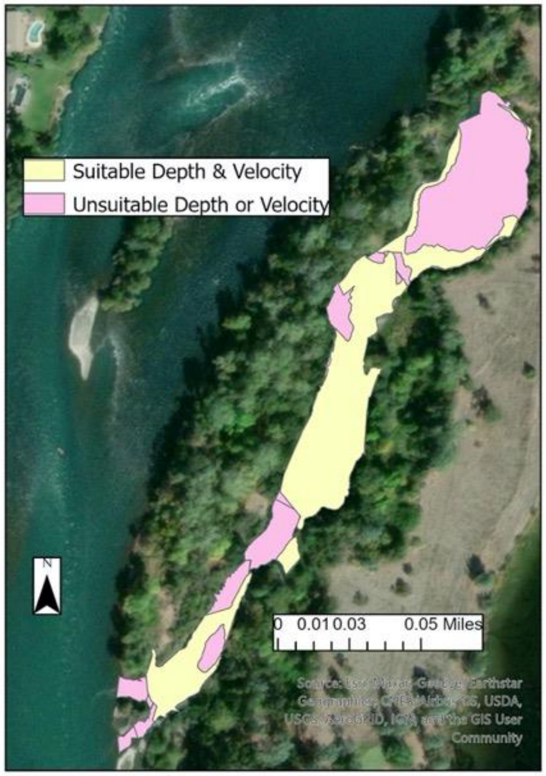
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-8-19, 10-24-19, & 10-28-19
*Keswick flow during snorkel: 7000 cfs

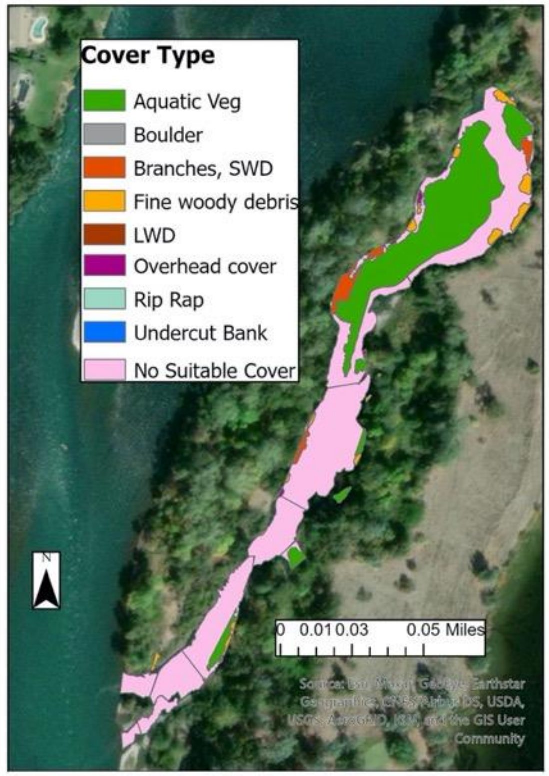
Control Site Habitat Mapping: Wyndham
Keswick Release 7,500 CFS

Depth & Velocity Mapping



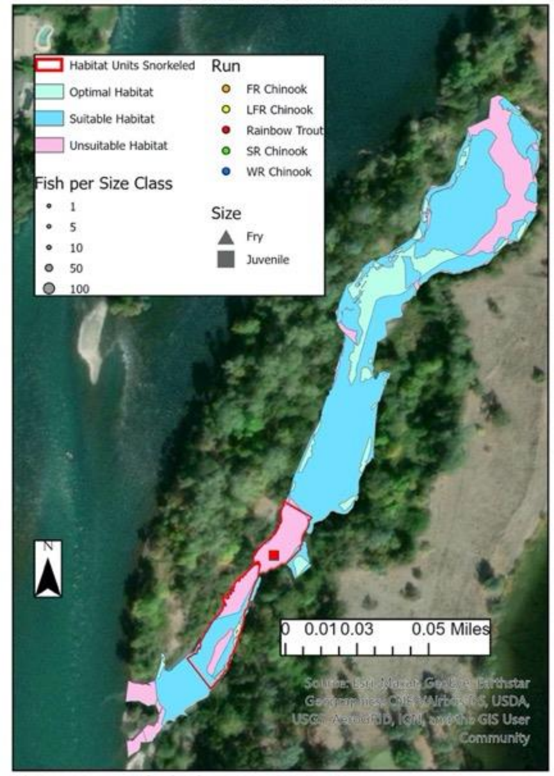
*Dates mapped: 10-9-18

Cover from Predators



*Dates mapped: 10-9-18

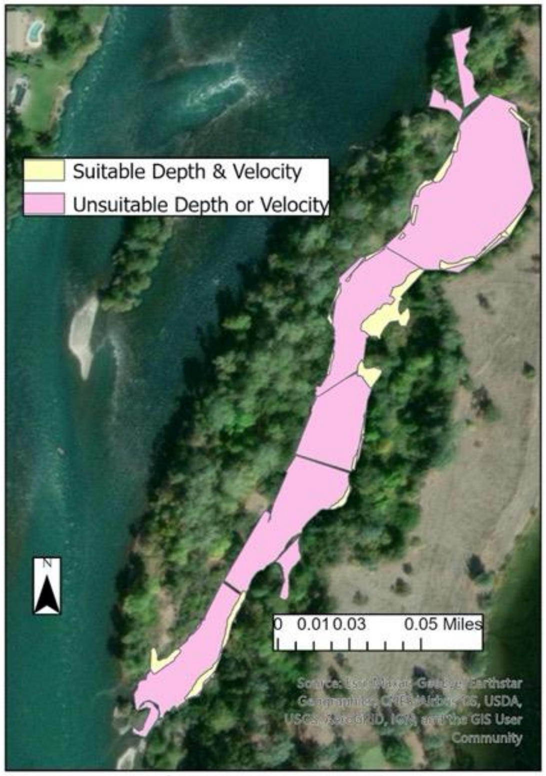
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-19-18
*Keswick flow during snorkel: 4400 cfs

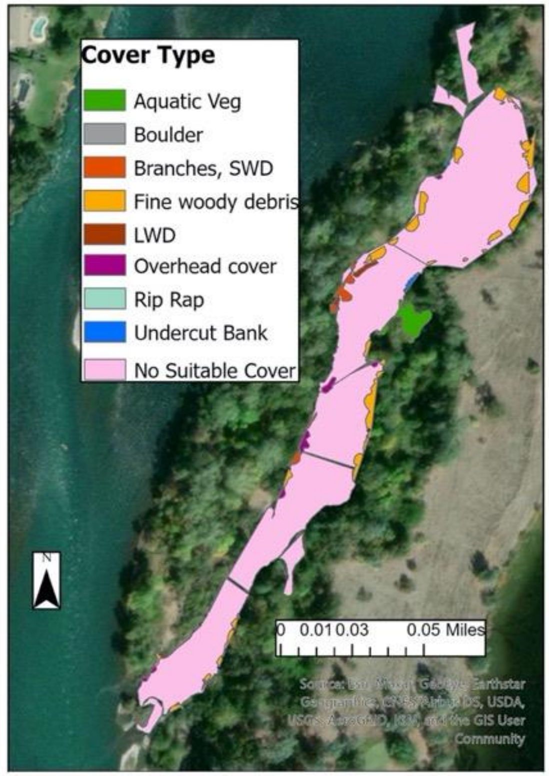
Control Site Habitat Mapping: Wyndham
Keswick Release 10,500 CFS

Depth & Velocity Mapping



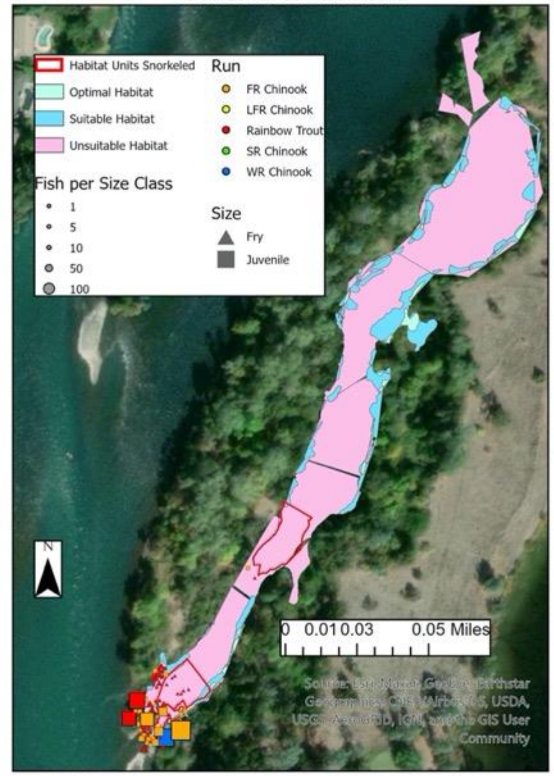
*Dates mapped: 7-26-17 & 7-31-17

Cover from Predators



*Dates mapped: 7-31-17

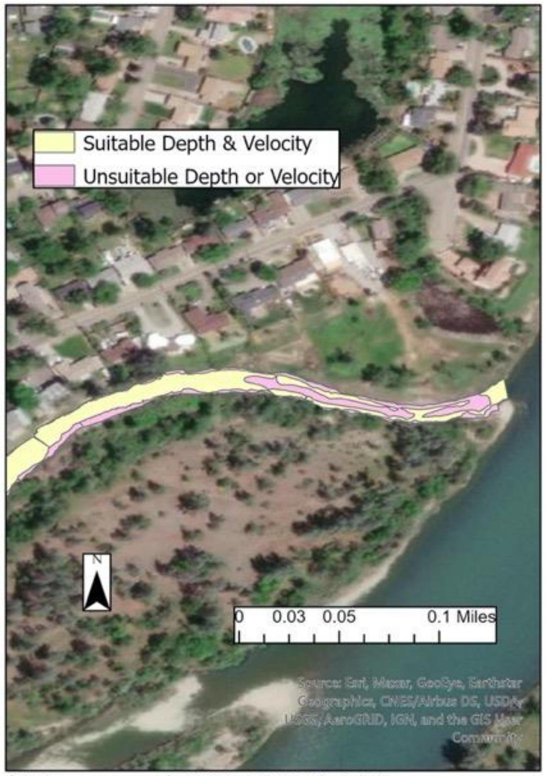
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

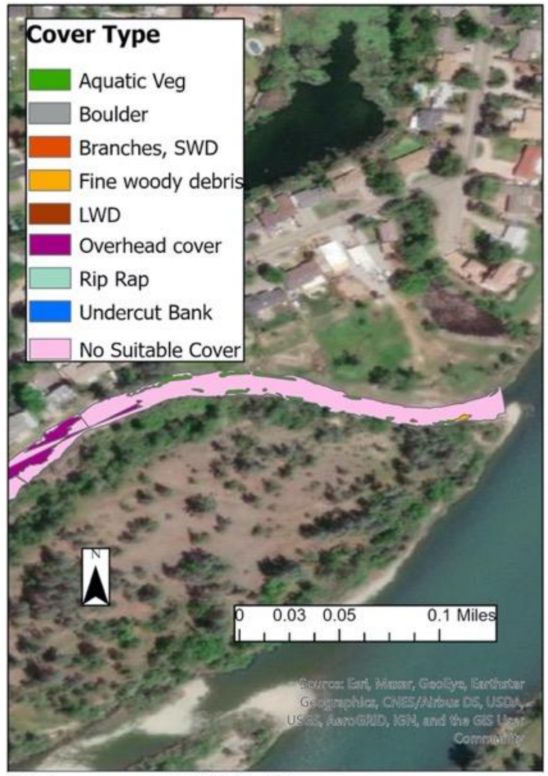
Pre Restoration Habitat Mapping: Shae Island (Upper)
Keswick Release 7,400 CFS

Depth & Velocity Mapping



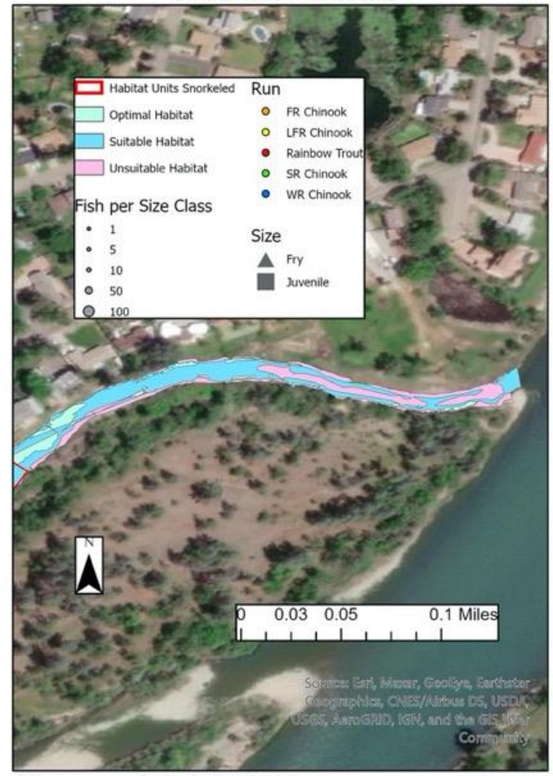
*Dates mapped: 9-28-18 & 10-9-18

Cover from Predators



*Dates mapped: 10-22-18

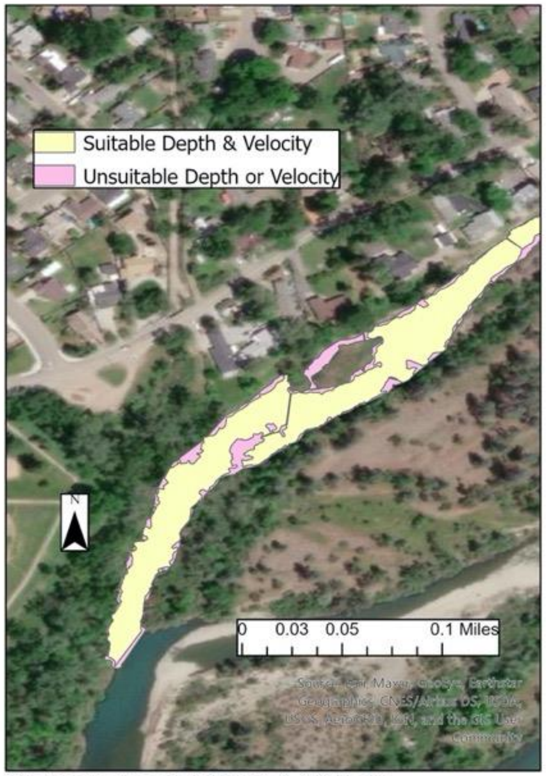
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-26-19
*Keswick flow during snorkel: 7600 cfs

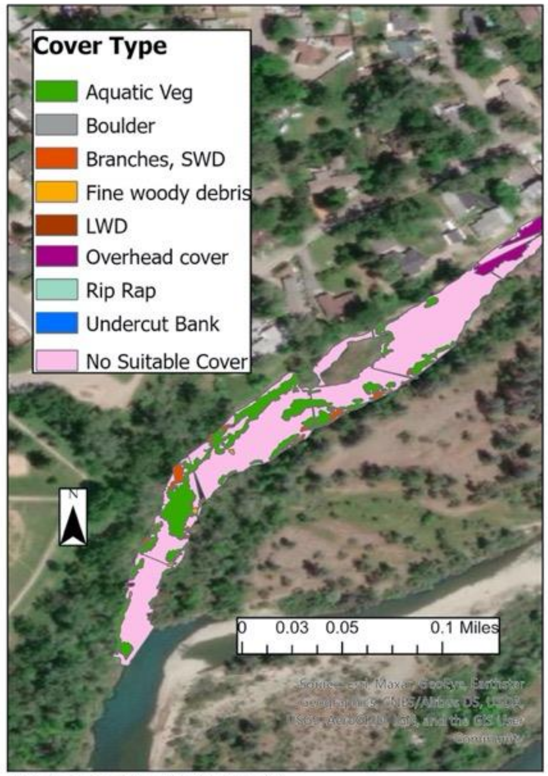
Pre Restoration Habitat Mapping: Shae Island (Lower)
Keswick Release 7,400 CFS

Depth & Velocity Mapping



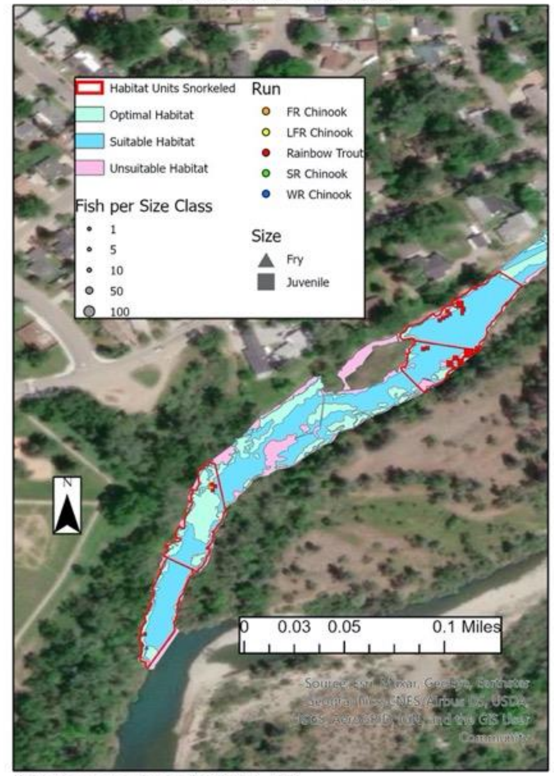
*Dates mapped: 9-28-18 & 10-9-18

Cover from Predators



*Dates mapped: 10-22-18

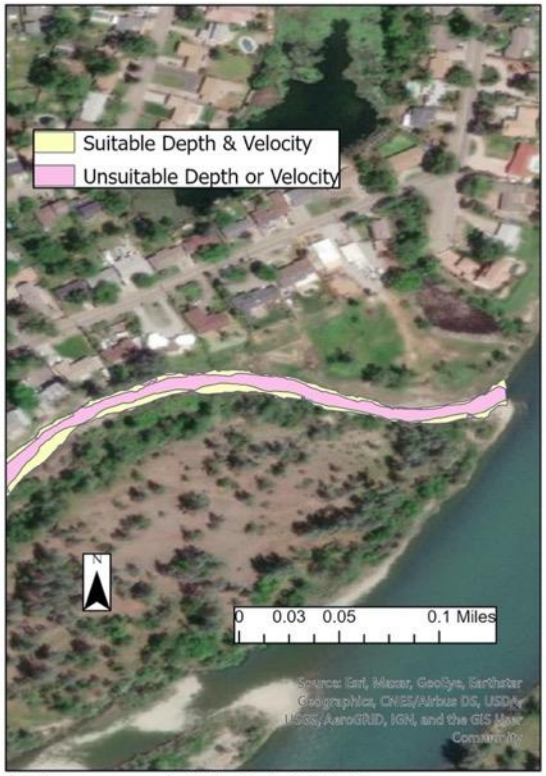
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-26-19
*Keswick flow during snorkel: 7600 cfs

Pre Restoration Habitat Mapping: Shae Island (Upper)
Keswick Release 9,000 CFS

Depth & Velocity Mapping

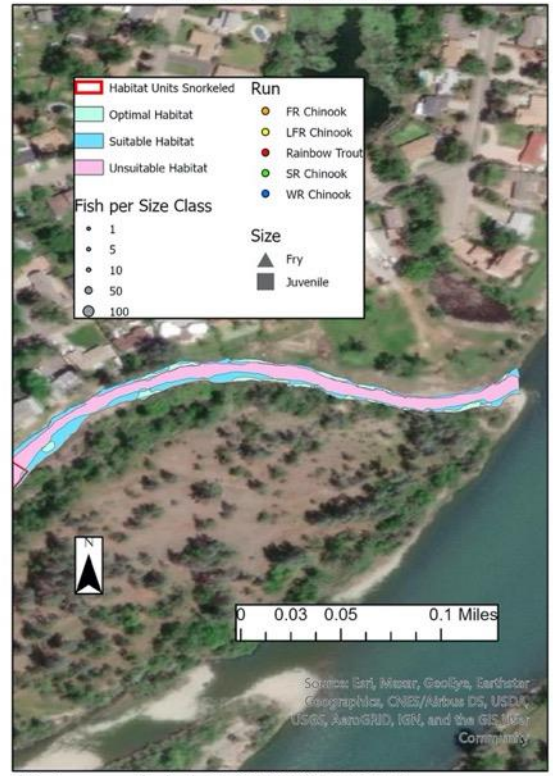


*Dates mapped: 9-5-19 & 9-10-19

Cover from Predators

*Dates mapped: 9-3-19 & 9-5-19

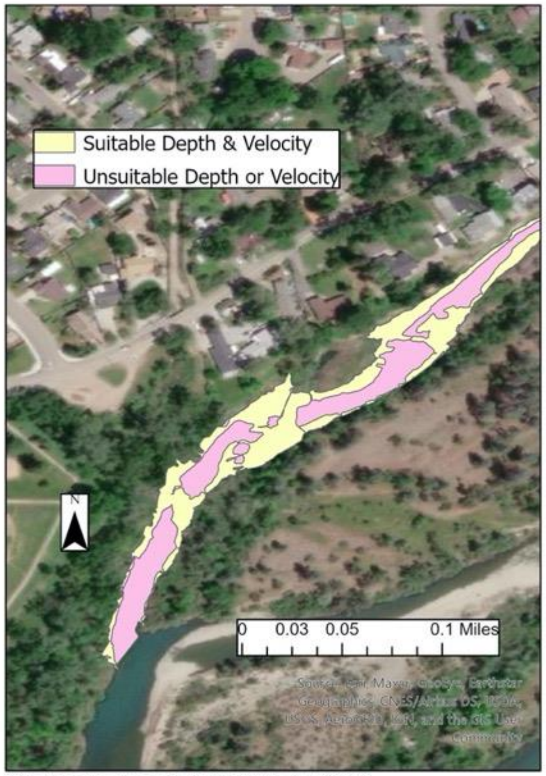
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-23-19 & 7-26-19
*Keswick flow during snorkel: 11000 cfs

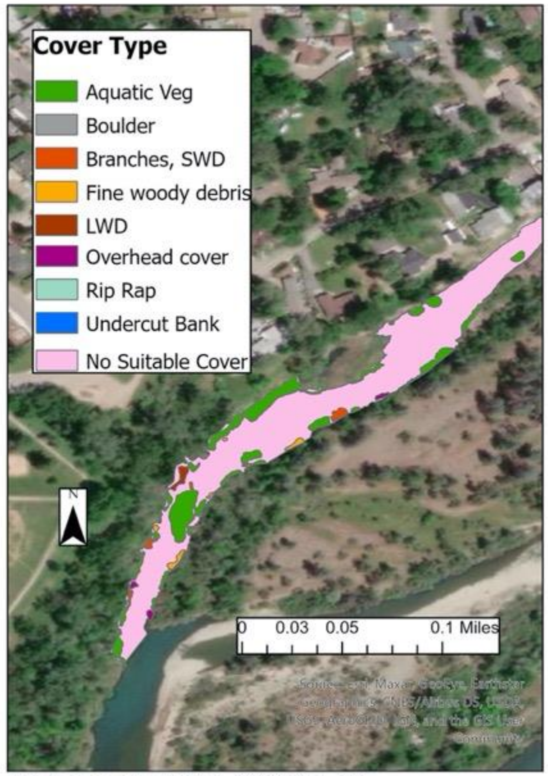
Pre Restoration Habitat Mapping: Shae Island (Lower)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



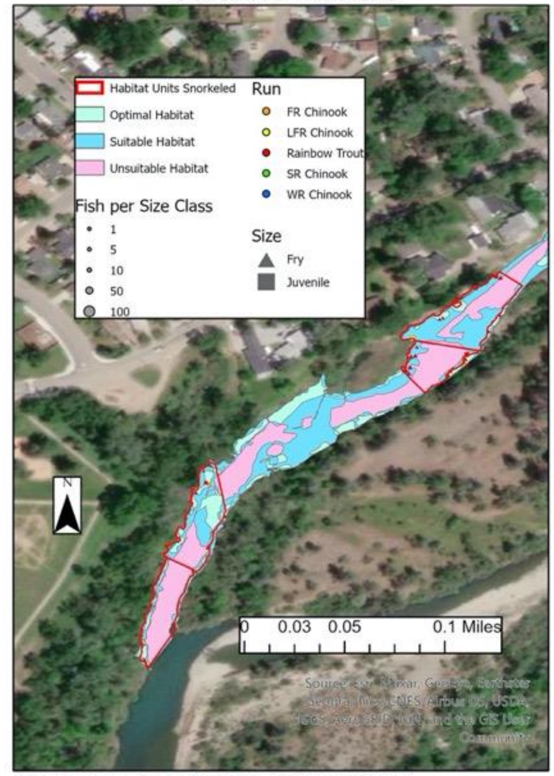
*Dates mapped: 9-5-19 & 9-10-19

Cover from Predators



*Dates mapped: 9-3-19 & 9-5-19

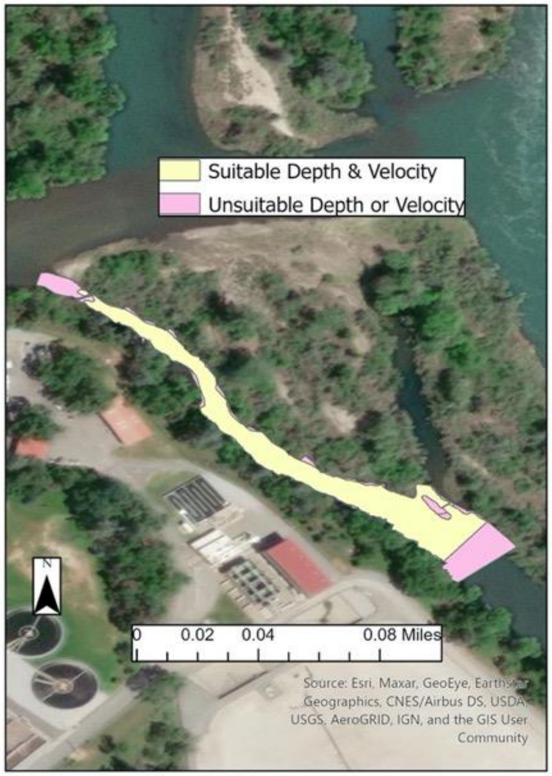
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-23-19 & 7-26-19
*Keswick flow during snorkel: 11000 cfs

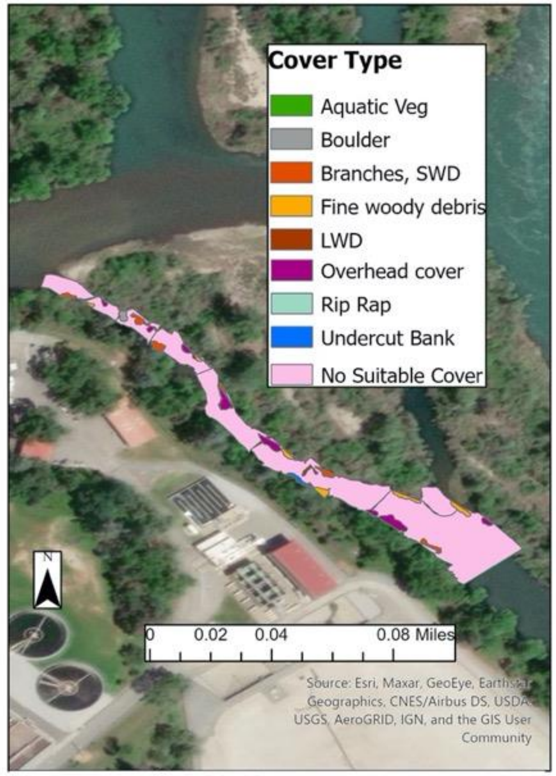
Control Site Habitat Mapping: Clear Creek
Keswick Release 3,250 CFS

Depth & Velocity Mapping



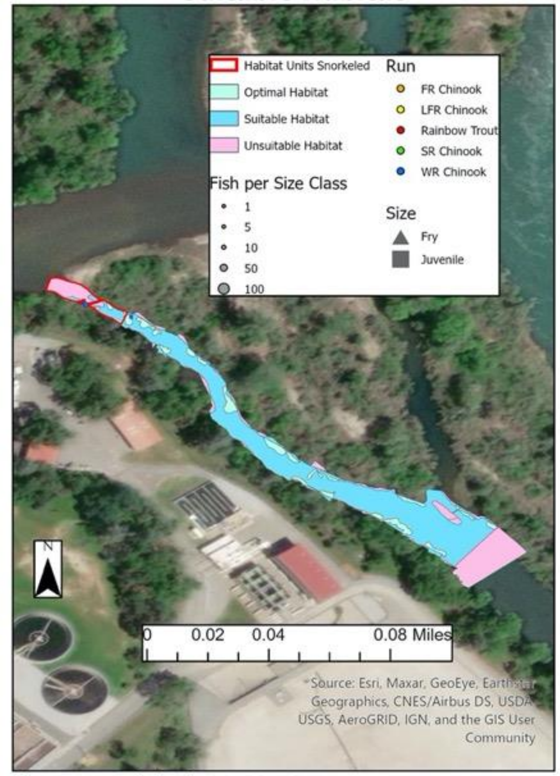
*Date mapped: 2-28-18

Cover from Predators



*Date mapped: 2-28-18

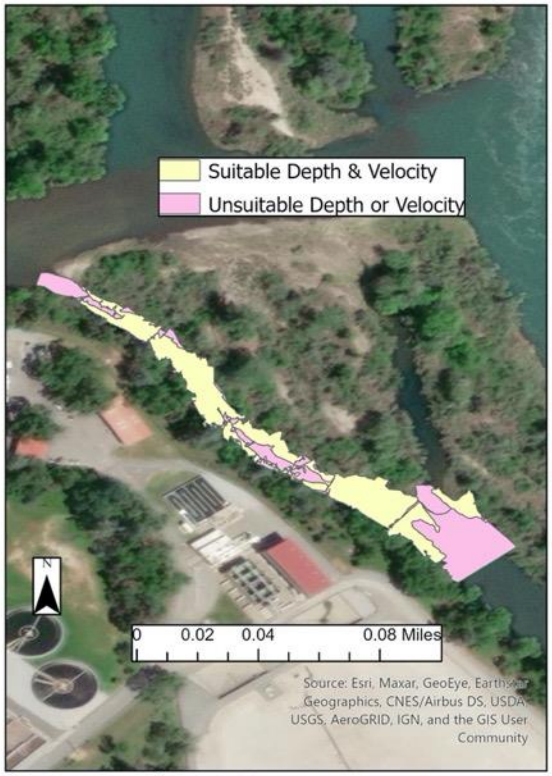
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 11-20-18
*Keswick flow during snorkel: 4400 cfs

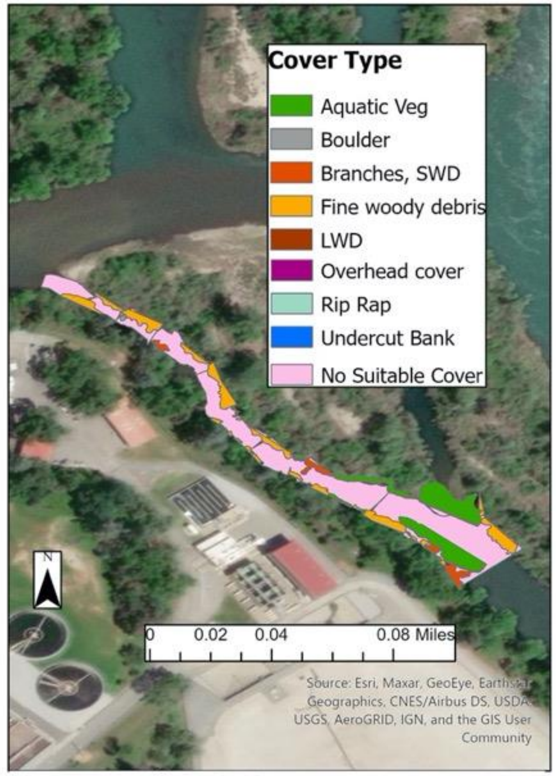
Control Site Habitat Mapping: Clear Creek
Keswick Release 7,500 CFS

Depth & Velocity Mapping



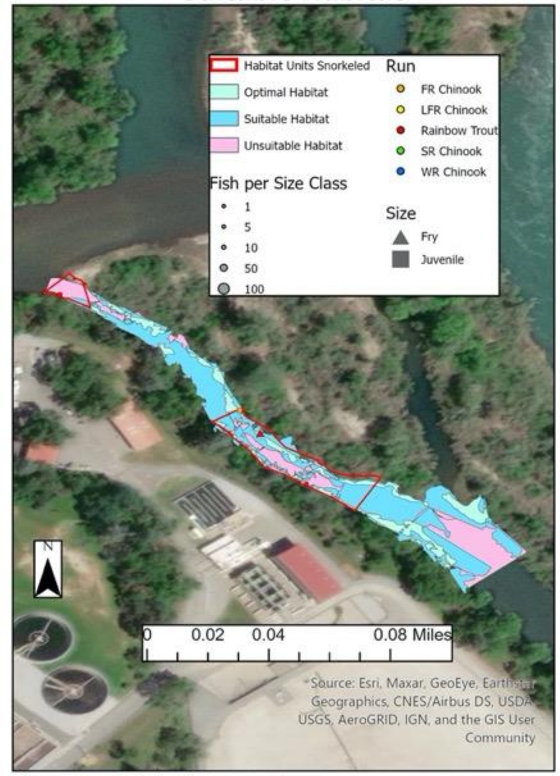
*Date mapped: 10-9-18

Cover from Predators



*Date mapped: 10-9-18

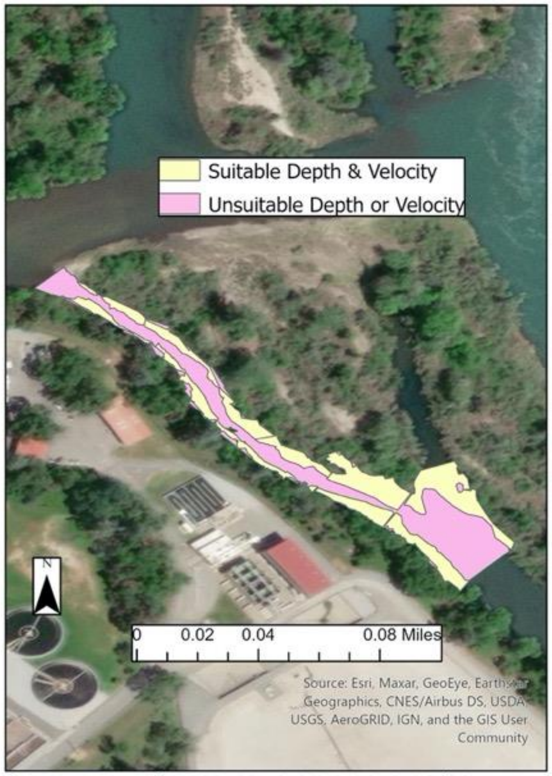
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 10-1-19
*Keswick flow during snorkel: 7600 cfs

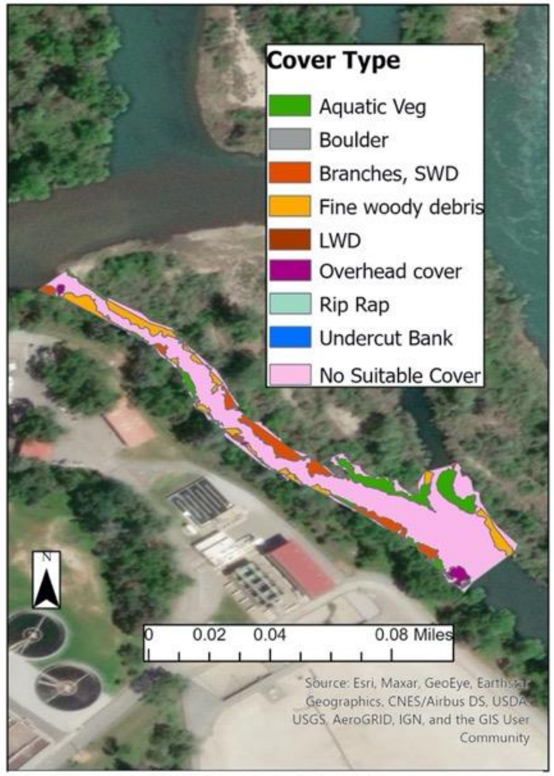
Control Site Habitat Mapping: Clear Creek
Keswick Release 10,200 CFS

Depth & Velocity Mapping



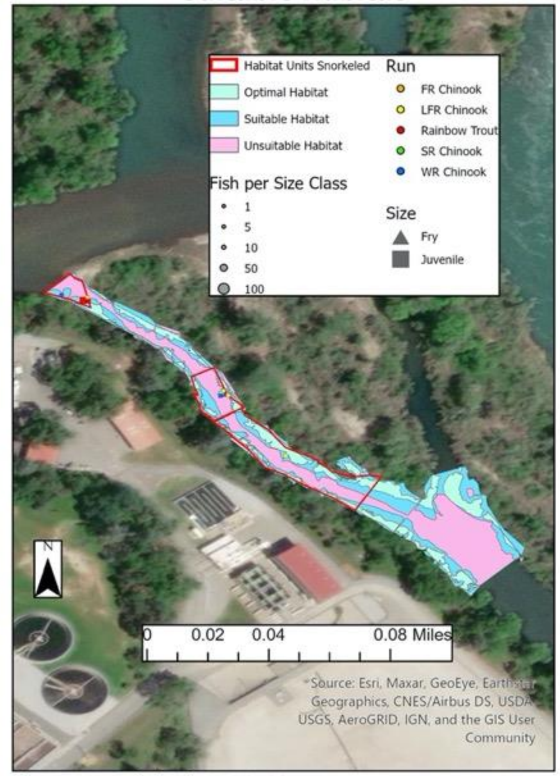
*Date mapped: 8-23-19, 8-27-19 & 8-28/19

Cover from Predators



*Date mapped: 8-23-19 & 8-26-19

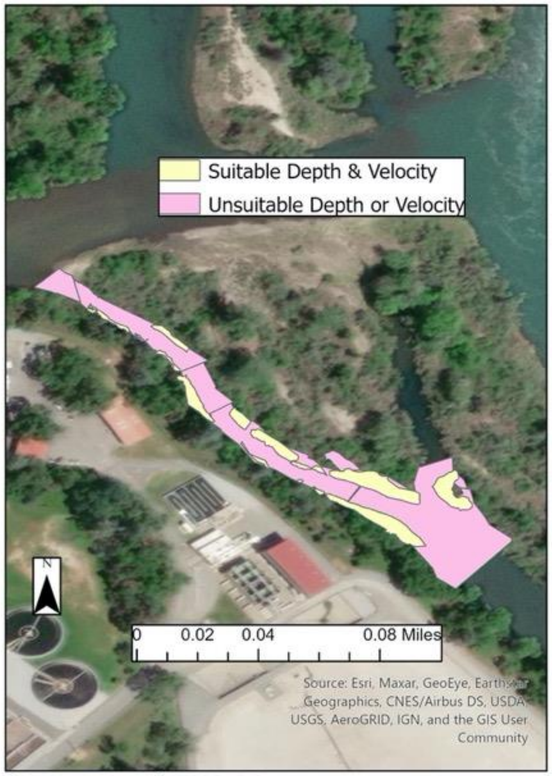
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 7-31-19
*Keswick flow during snorkel: 10500 cfs

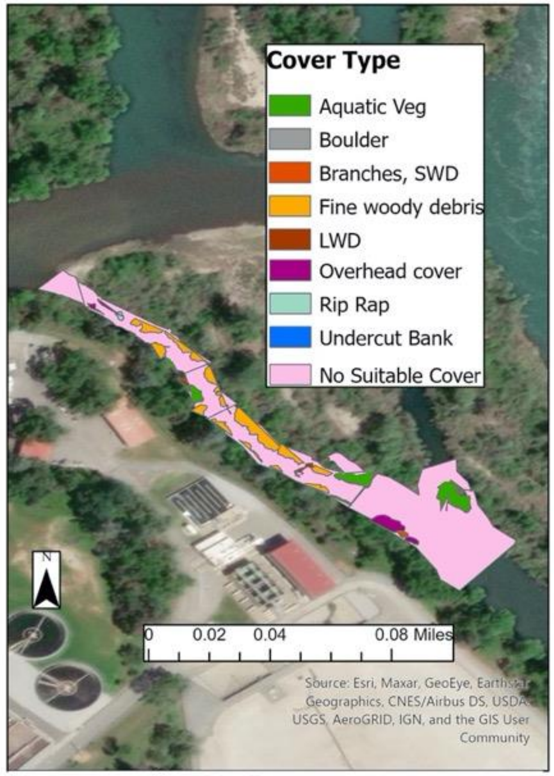
Control Site Habitat Mapping: Clear Creek
Keswick Release 10,500 CFS

Depth & Velocity Mapping



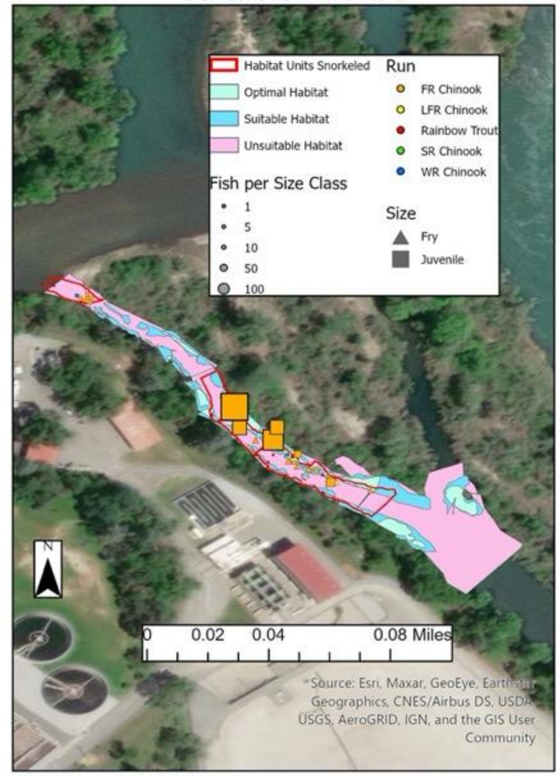
*Date mapped: 7-20-17

Cover from Predators



*Date mapped: 7-20-17

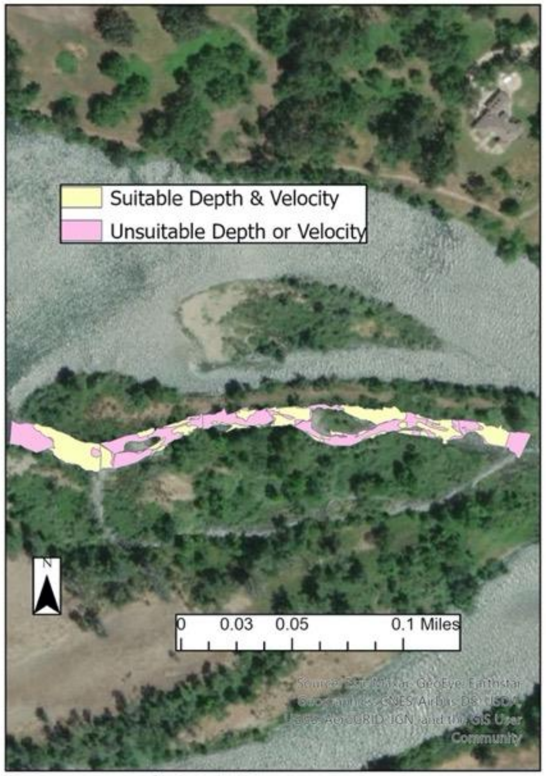
Fish Locations Among Optimal & Suitable Habitat



*Date snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

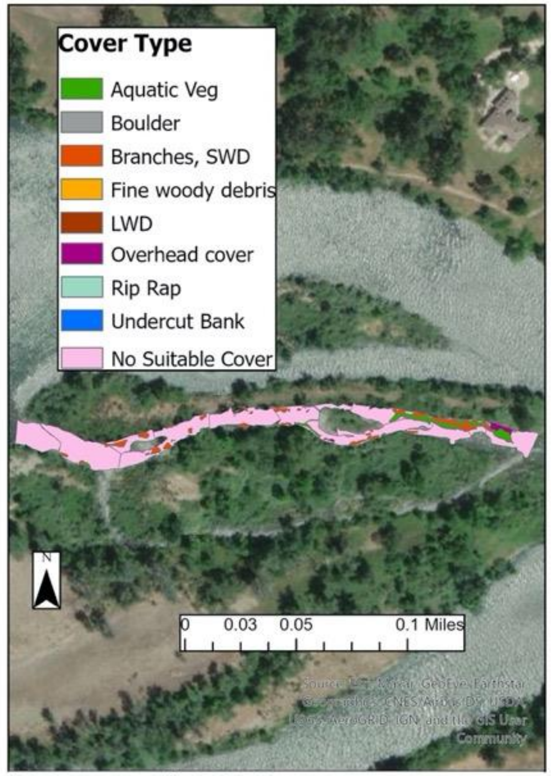
Control Site Habitat Mapping: Bourbon
Keswick Release 3,250 CFS

Depth & Velocity Mapping



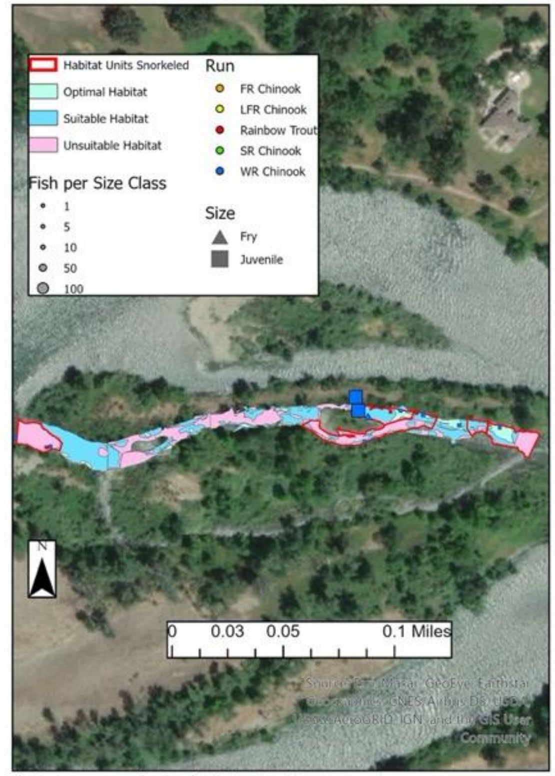
Dates mapped: 2-26-18

Cover from Predators



*Dates mapped: 2-26-18

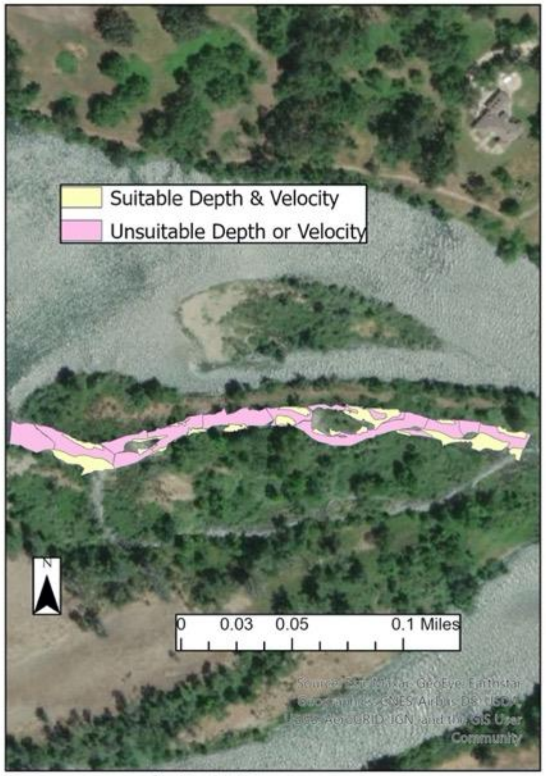
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-16-18
*Keswick flow during snorkel: 4400 cfs

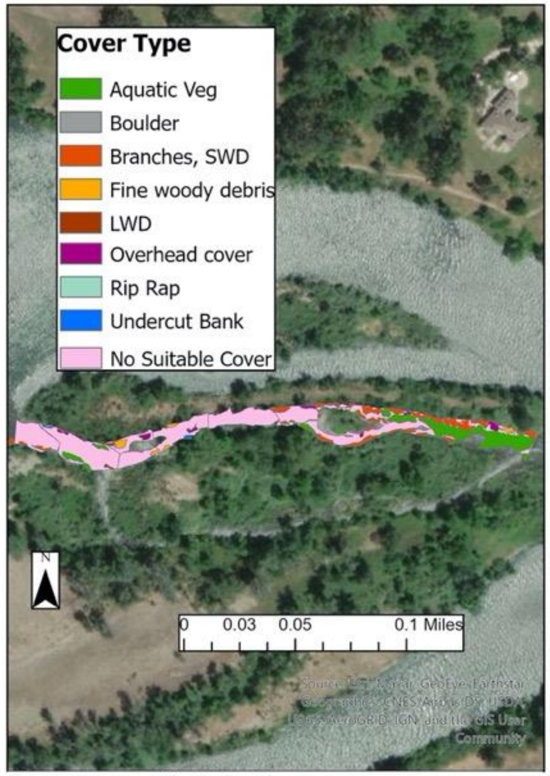
Control Site Habitat Mapping: Bourbon
Keswick Release 7,500 CFS

Depth & Velocity Mapping



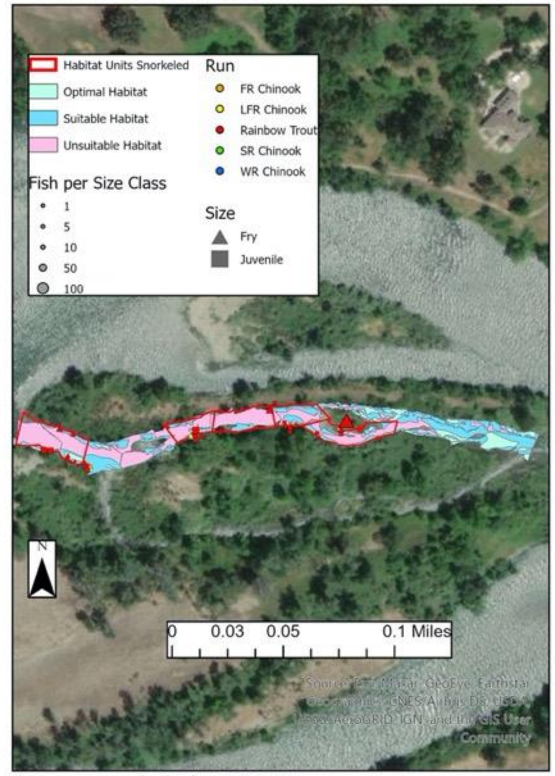
Dates mapped: 10-9-18

Cover from Predators



*Dates mapped: 10-9-18

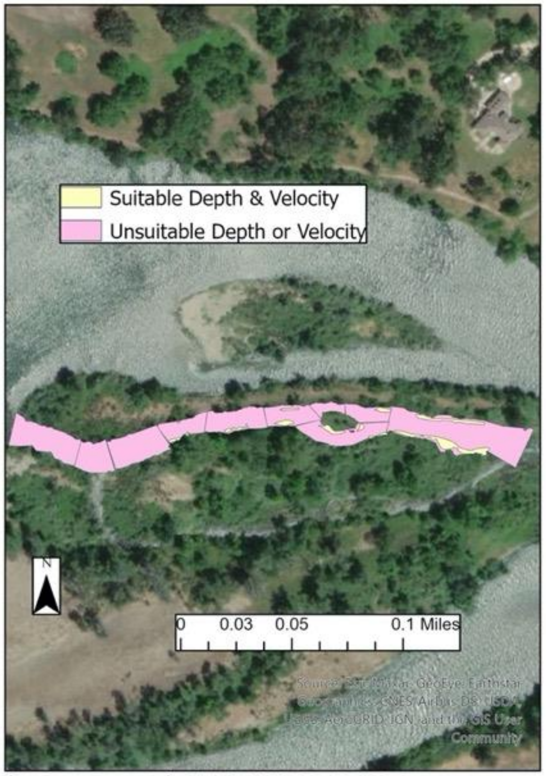
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 7-25-19
*Keswick flow during snorkel: 11,000 cfs

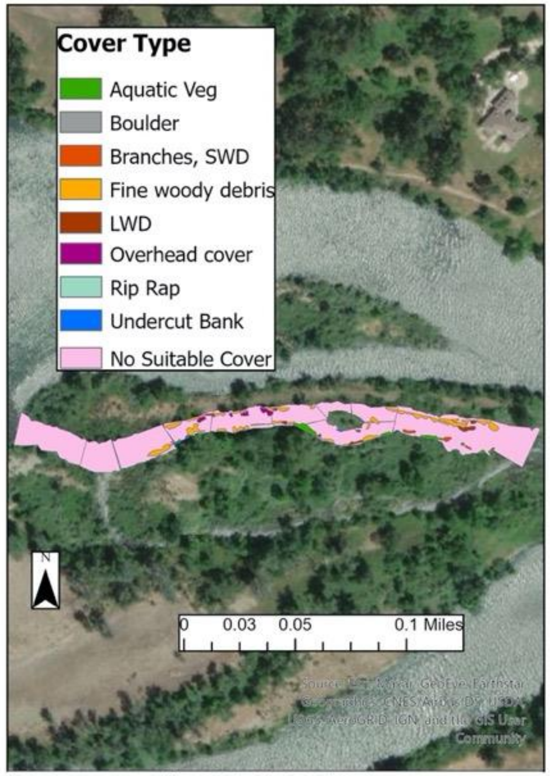
Control Site Habitat Mapping: Bourbon
Keswick Release 10,500 CFS

Depth & Velocity Mapping



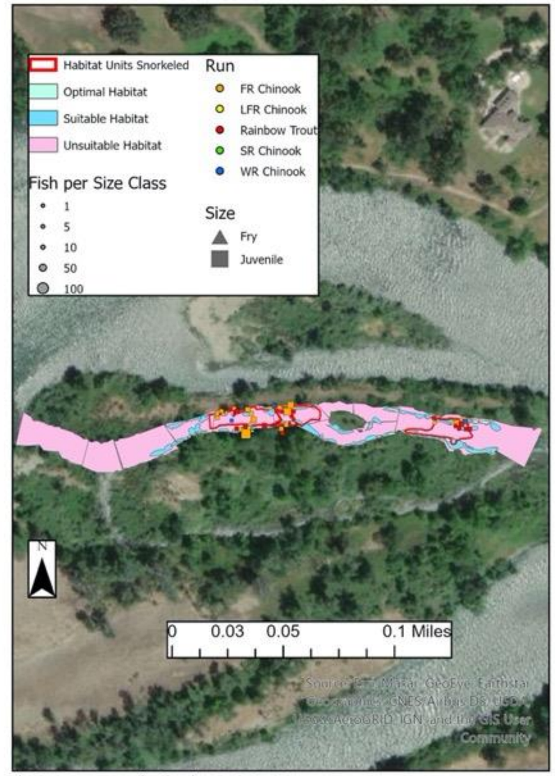
*Dates mapped: 7-18-17 & 7-19-17

Cover from Predators



*Dates mapped: 7-18-17 & 7-19-17

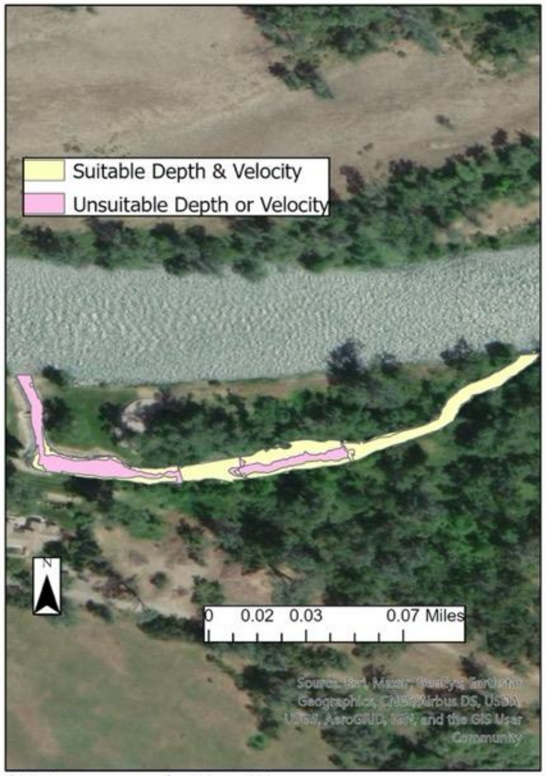
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

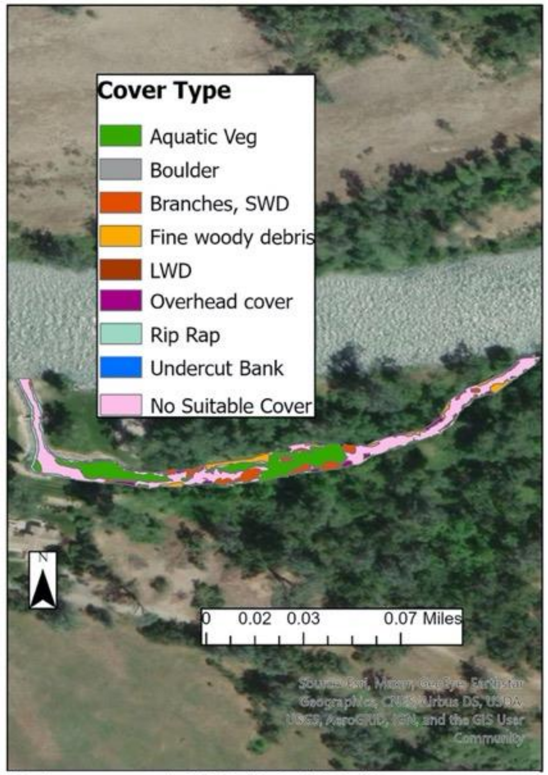
Post Restoration Habitat Mapping: Kapuesta
Keswick Release 6,600 CFS

Depth & Velocity Mapping



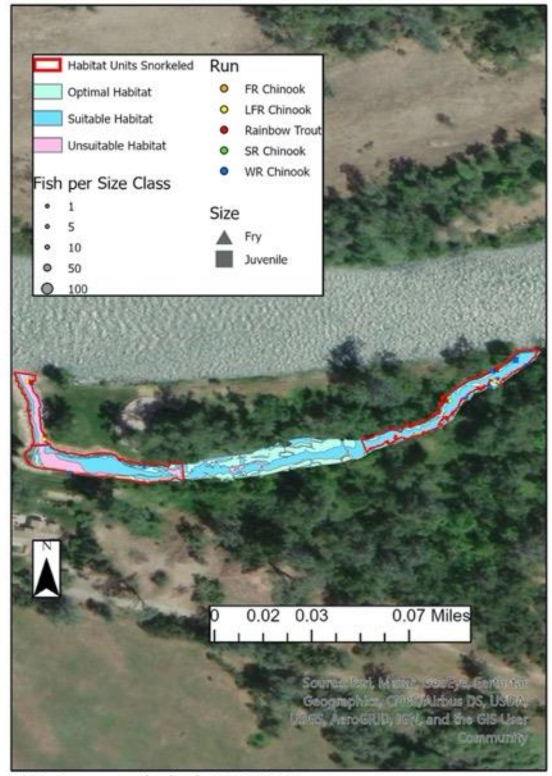
*Dates mapped: 10-2-19

Cover from Predators



*Dates mapped: 10-2-19 & 10-3-19

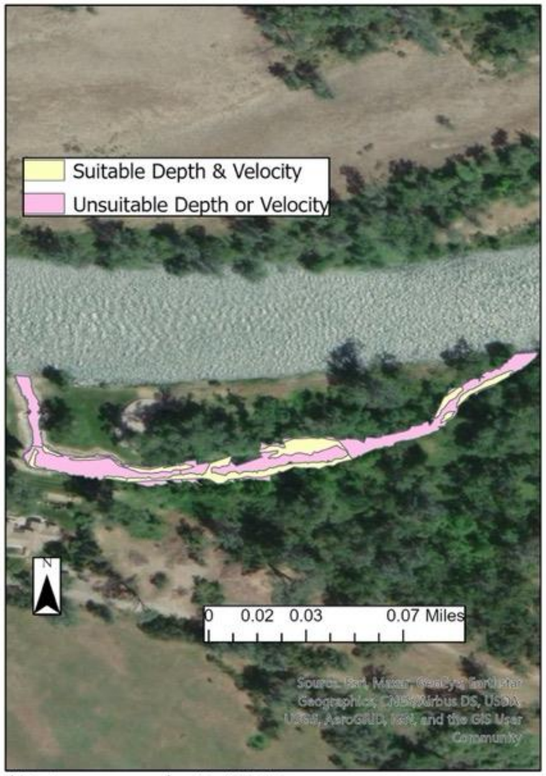
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 9-25-19
*Keswick flow during snorkel: 7600 cfs

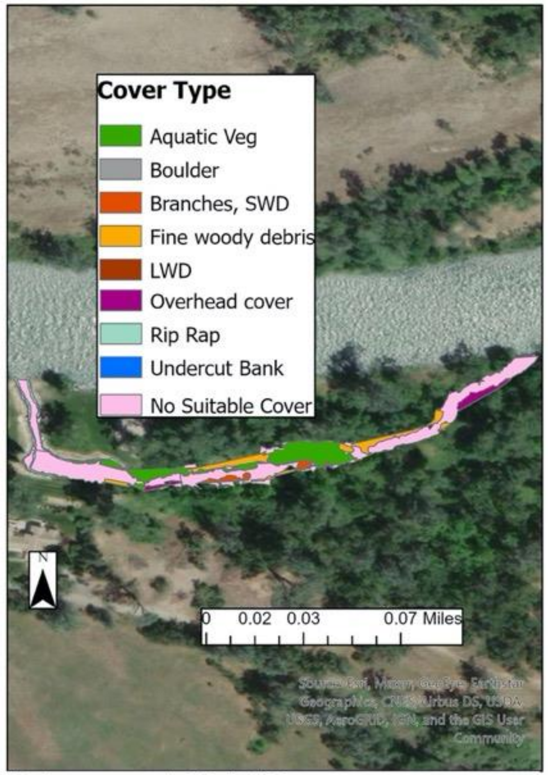
Post Restoration Habitat Mapping: Kapuesta
Keswick Release 7,500 CFS

Depth & Velocity Mapping



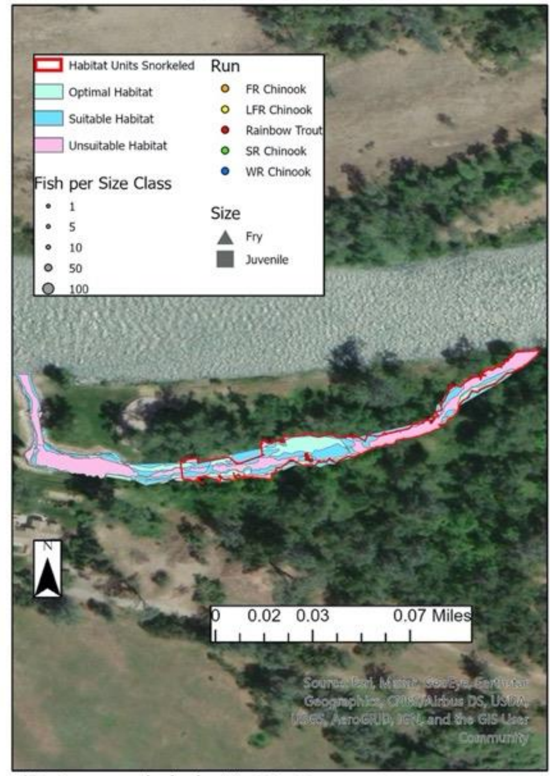
*Dates mapped: 10-17-18

Cover from Predators



*Dates mapped: 10-17-18

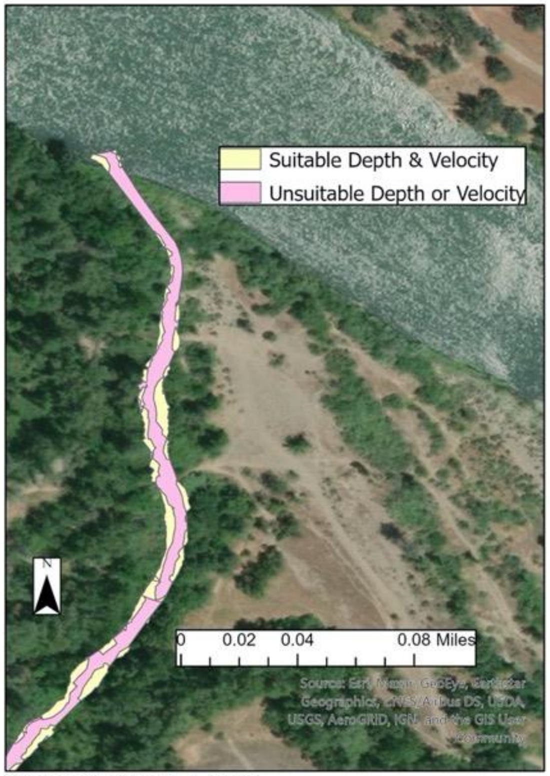
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-20-18
*Keswick flow during snorkel: 4400 cfs

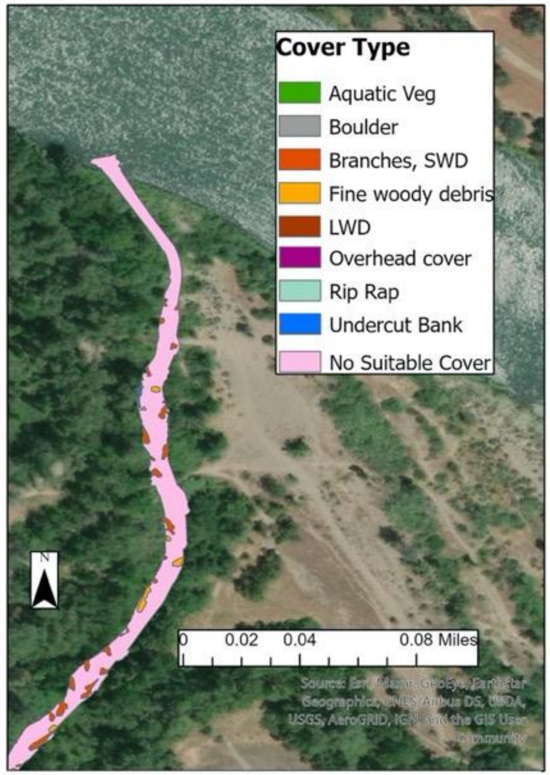
Post Restoration Habitat Mapping: Anderson River Park (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



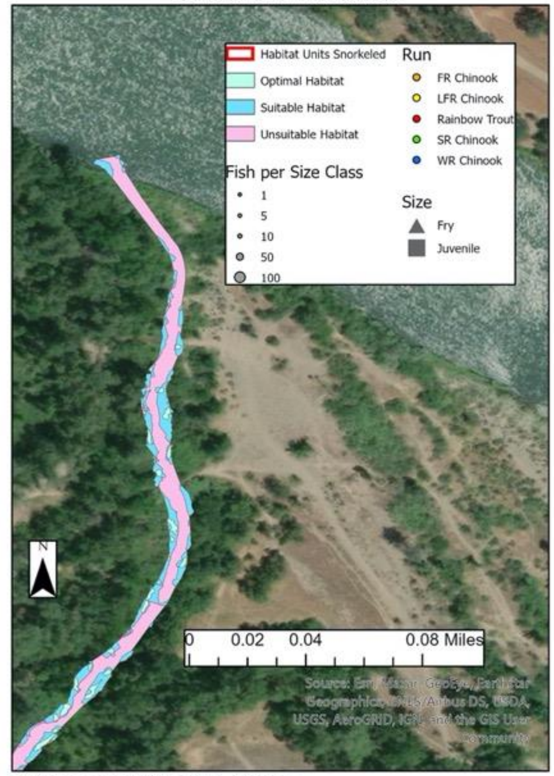
*Dates mapped: 1-9-20

Cover from Predators



*Dates mapped: 1-15-20

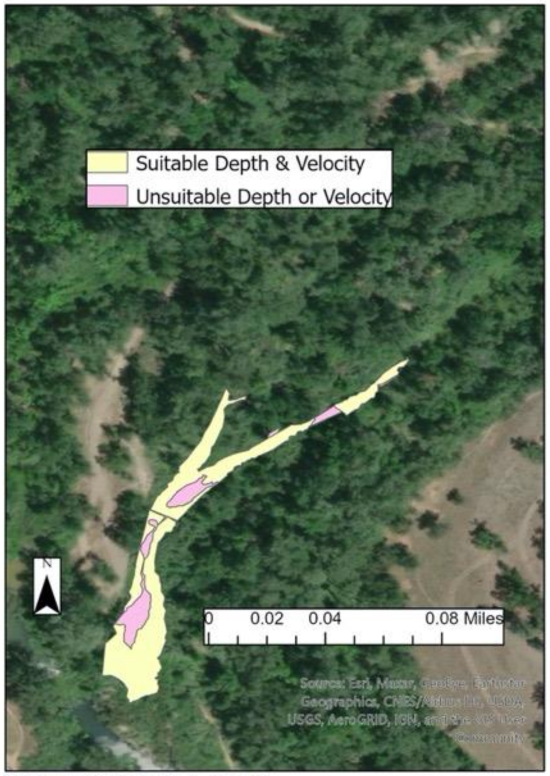
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-30-20
*Keswick flow during snorkel: 5000 cfs

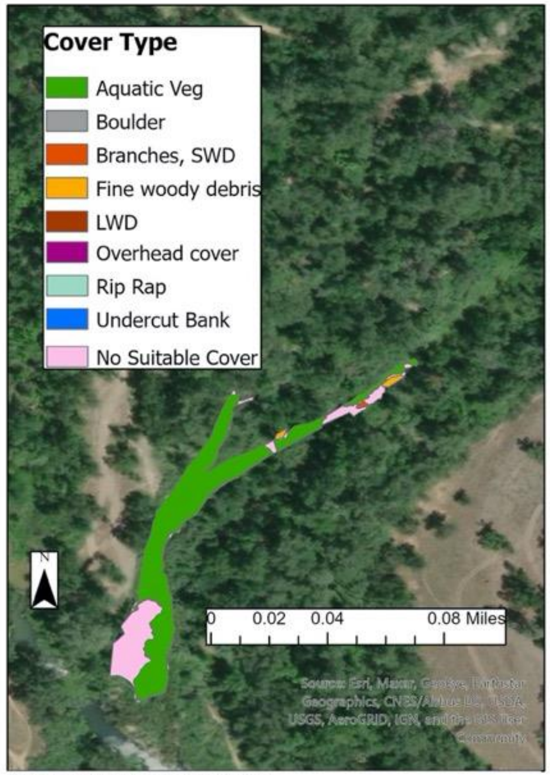
Pre Restoration Habitat Mapping: Anderson River Park (Lower)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



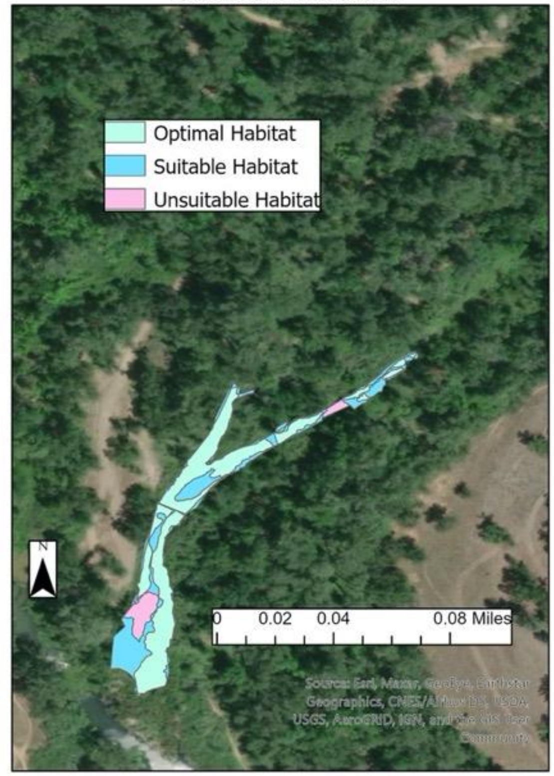
*Dates mapped: 1-22-19

Cover from Predators



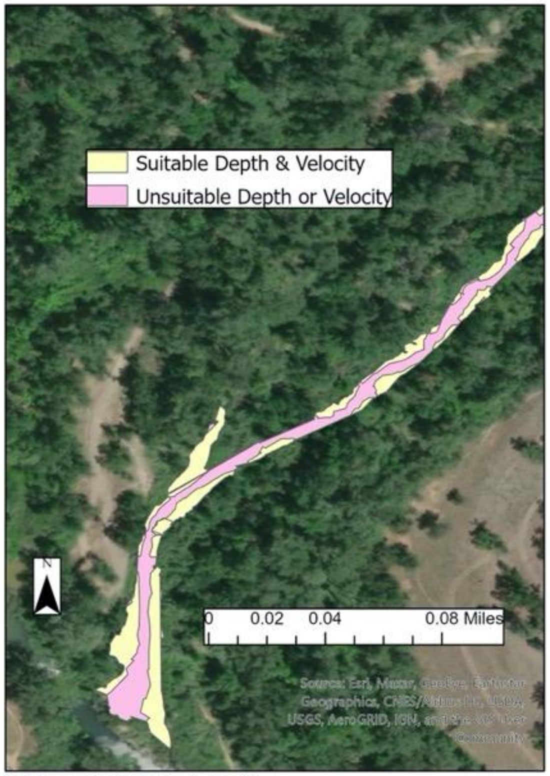
*Dates mapped: 1-22-19

Fish Locations Among Optimal & Suitable Habitat



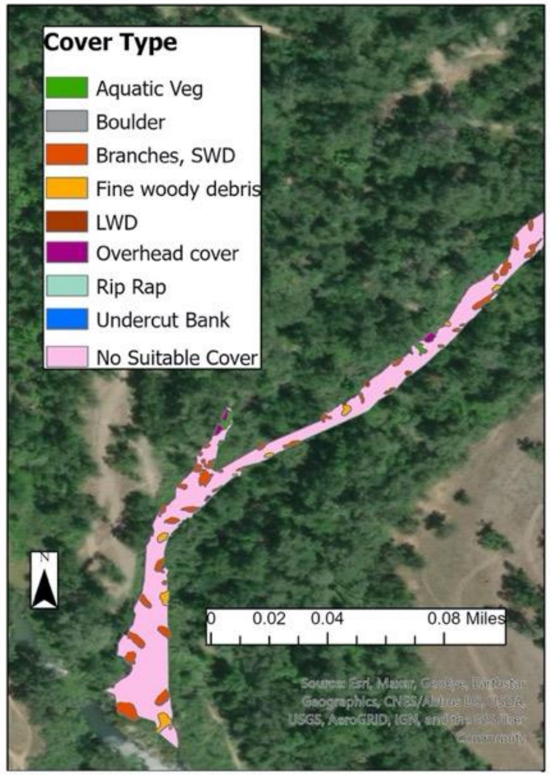
Post Restoration Habitat Mapping: Anderson River Park (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



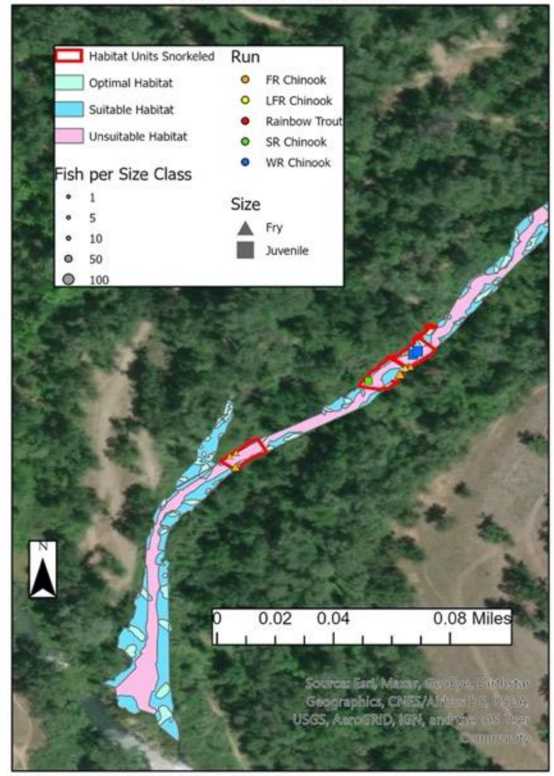
*Dates mapped: 1-9-20

Cover from Predators



*Dates mapped: 1-15-20

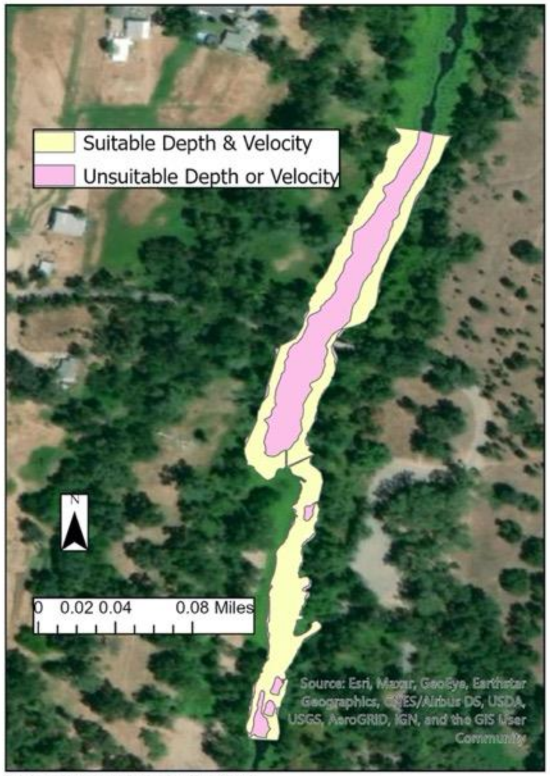
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 1-30-20
*Keswick flow during snorkel: 5000 cfs

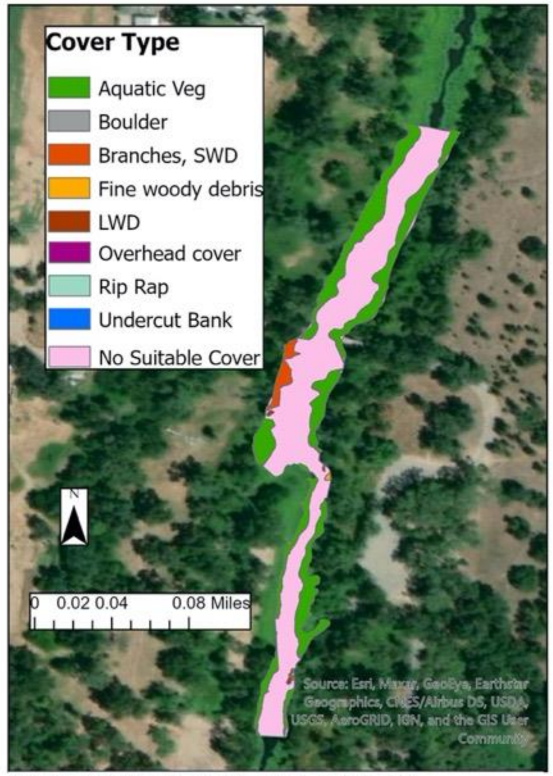
Pre Restoration Habitat Mapping: Reading Island
Keswick Release 3,250 CFS

Depth & Velocity Mapping



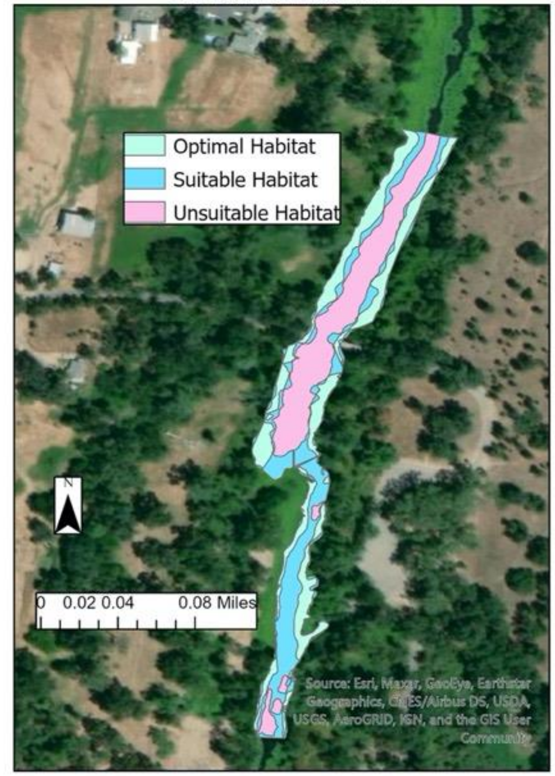
*Dates mapped: 2-7-19

Cover from Predators



*Dates mapped: 12-16-19 & 12-17-19

Fish Locations Among Optimal & Suitable Habitat



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

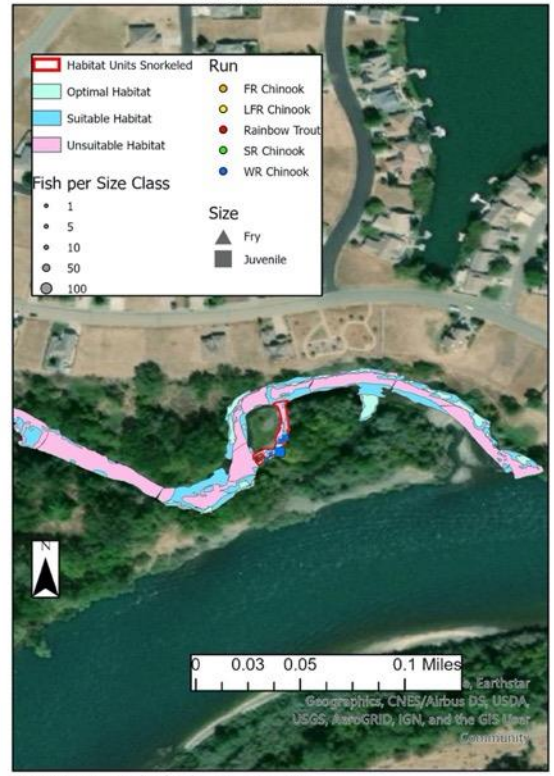
Depth & Velocity Mapping

*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators

*Dates mapped: 2-13-18, 2-15-18, 2-20-18

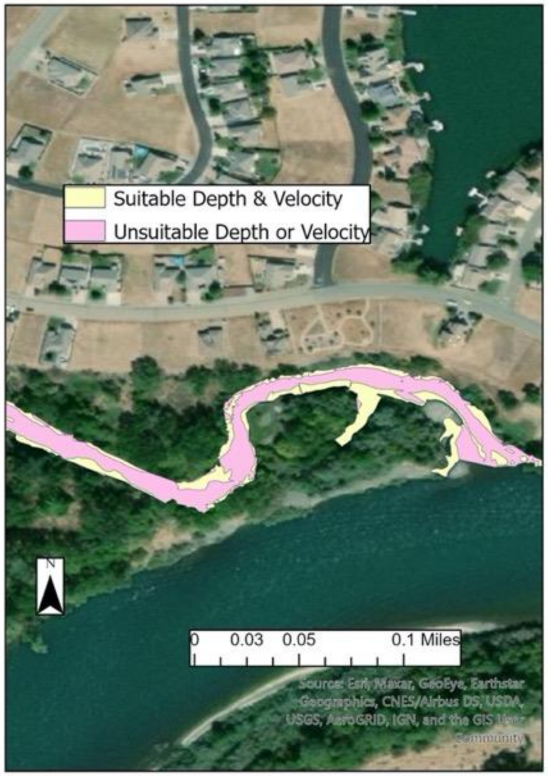
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

Post Restoration Habitat Mapping: Lake California (Upper)
Keswick Release 6,700 CFS

Depth & Velocity Mapping

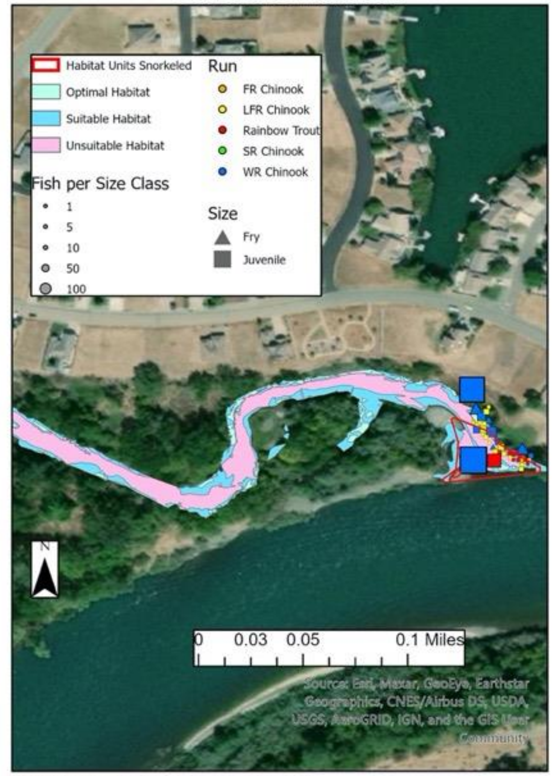


*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

Cover from Predators

*Dates mapped: 10-14-19 & 10-16-19

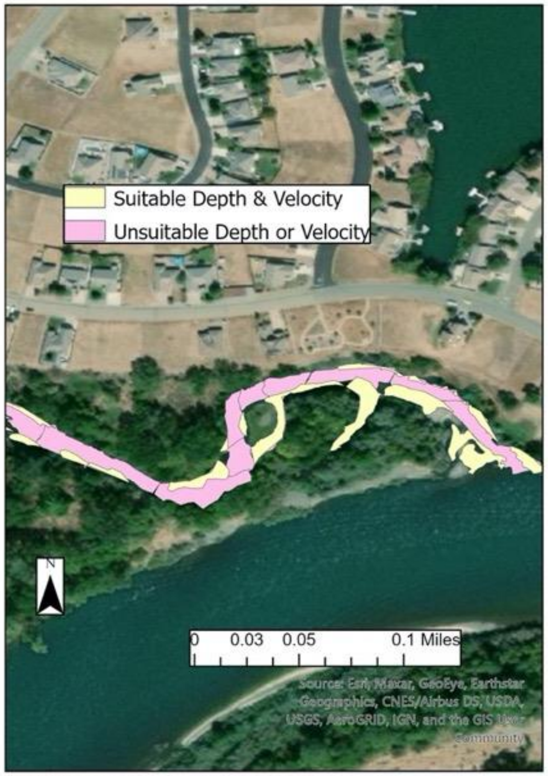
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

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

Depth & Velocity Mapping

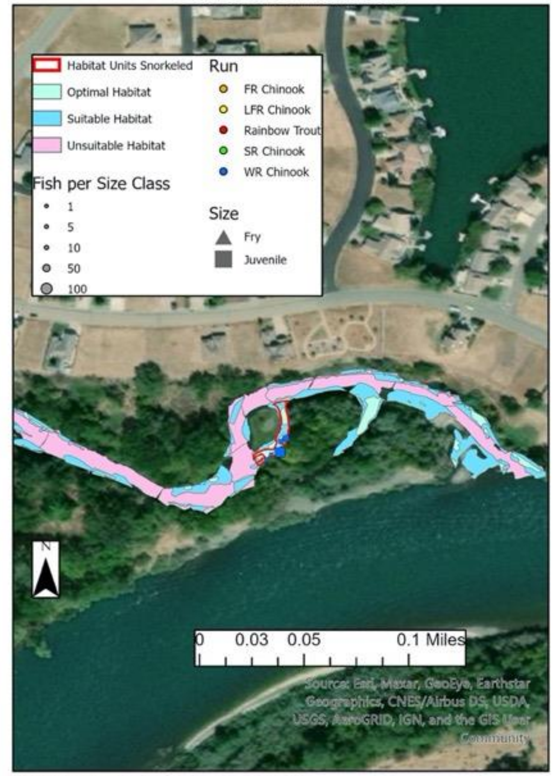


*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators

*Dates mapped: 10-8-18 & 10-10-18

Fish Locations Among Optimal & Suitable Habitat



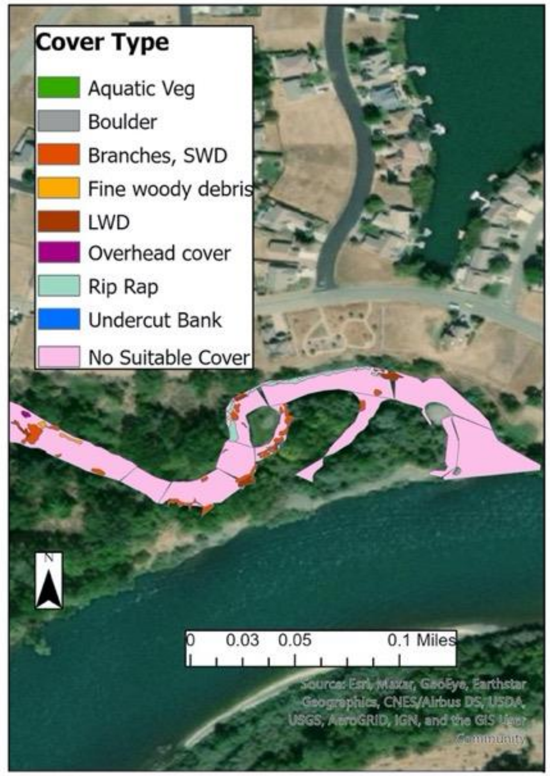
*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

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

Depth & Velocity Mapping

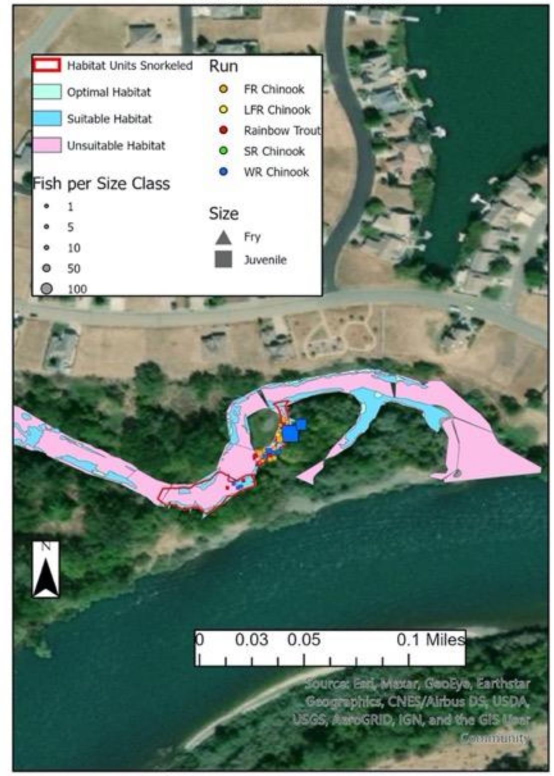
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

Cover from Predators



*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

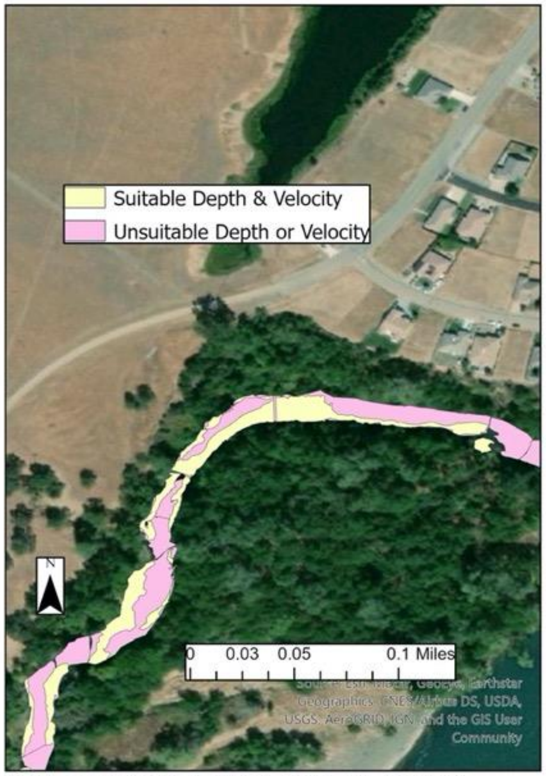
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

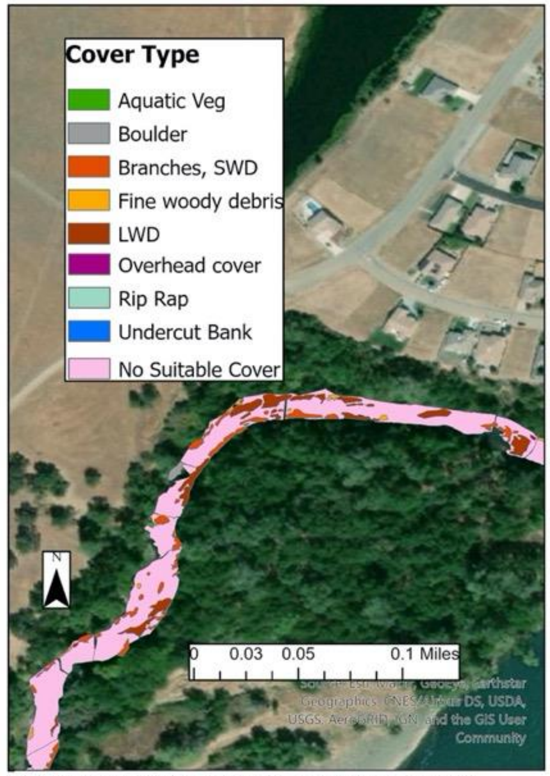
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



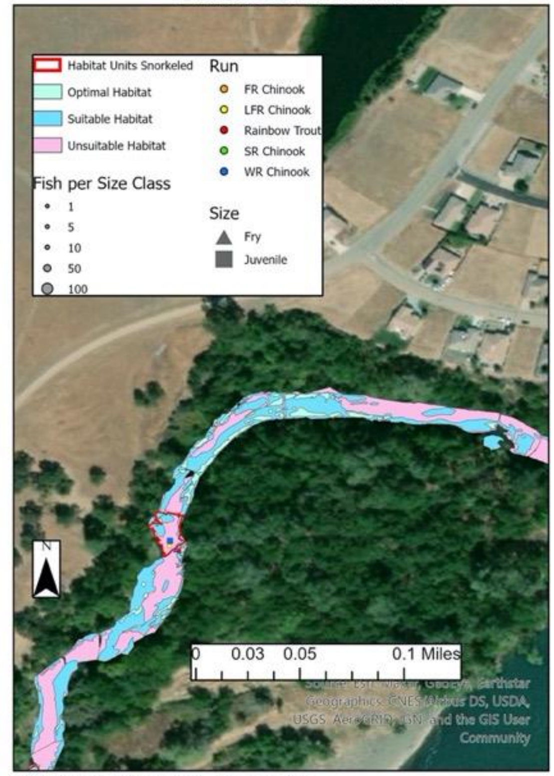
*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators



*Dates mapped: 2-13-18, 2-15-18, 2-20-18

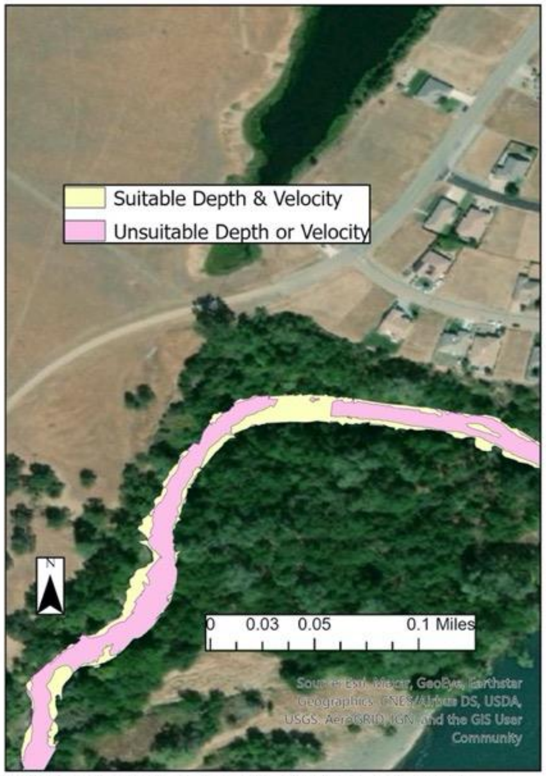
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

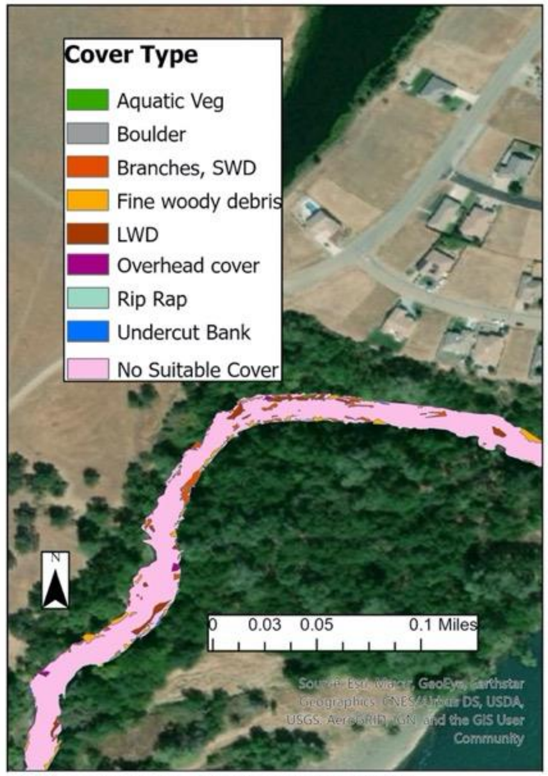
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 6,700 CFS

Depth & Velocity Mapping



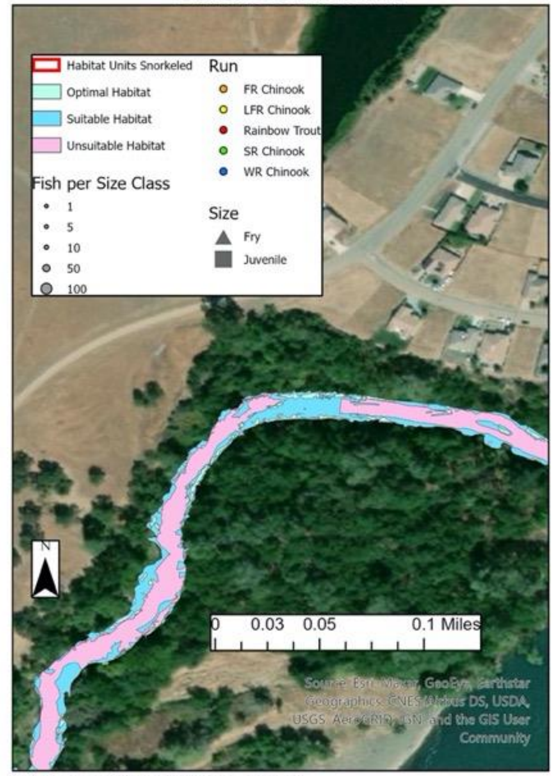
*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

Cover from Predators



*Dates mapped: 10-14-19 & 10-16-19

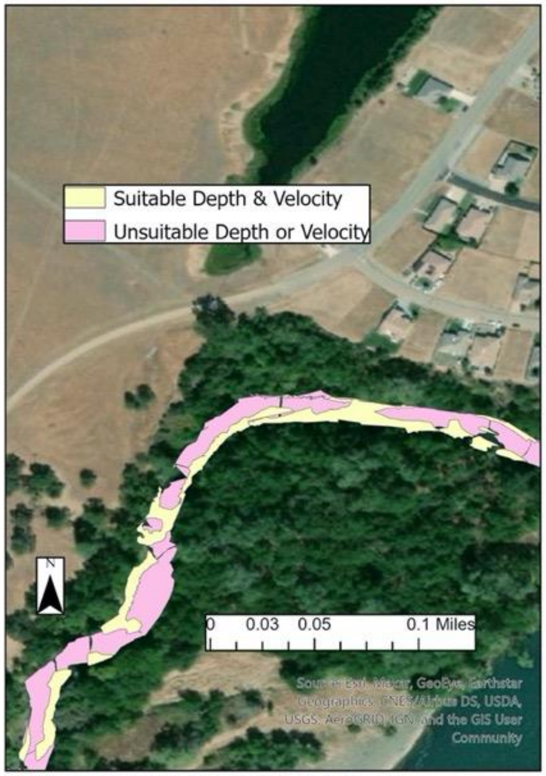
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

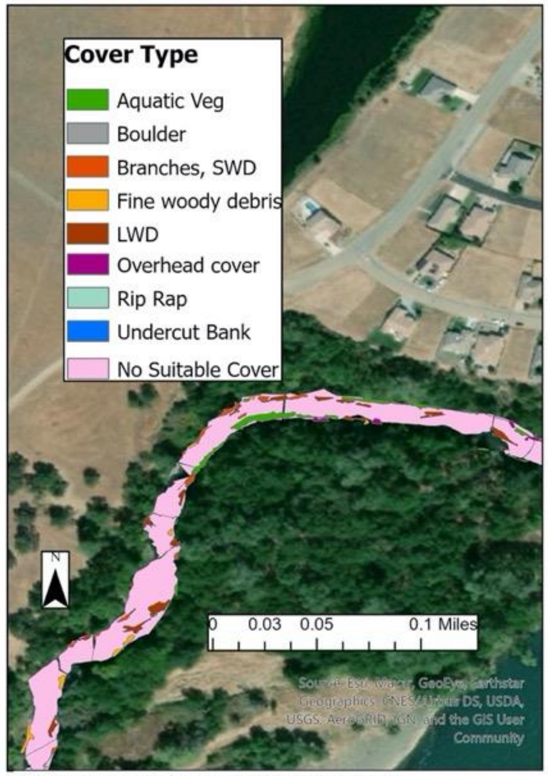
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 7,500 CFS

Depth & Velocity Mapping



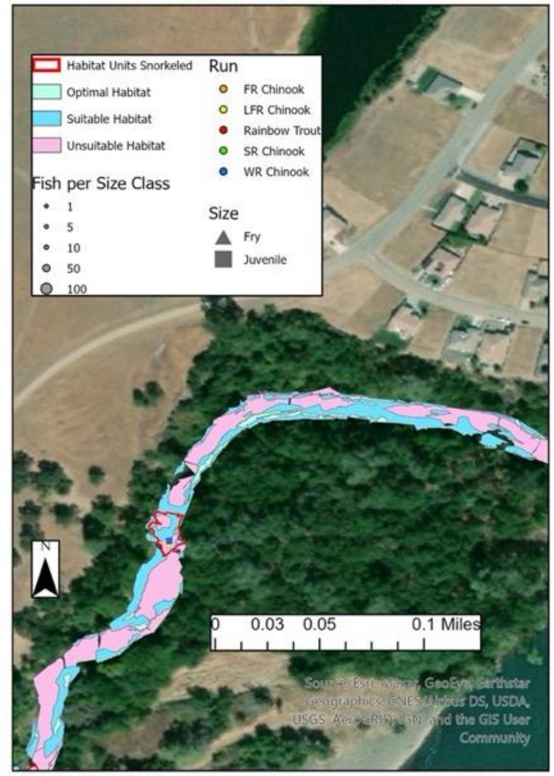
*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators



*Dates mapped: 10-8-18 & 10-10-18

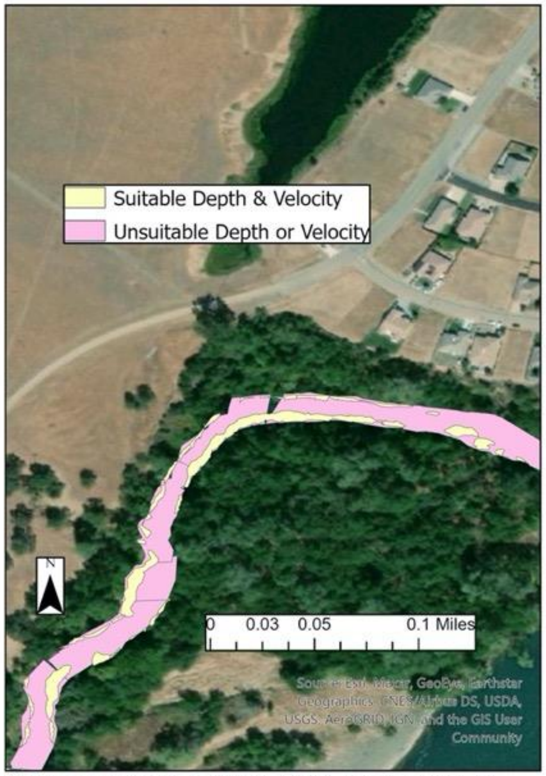
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

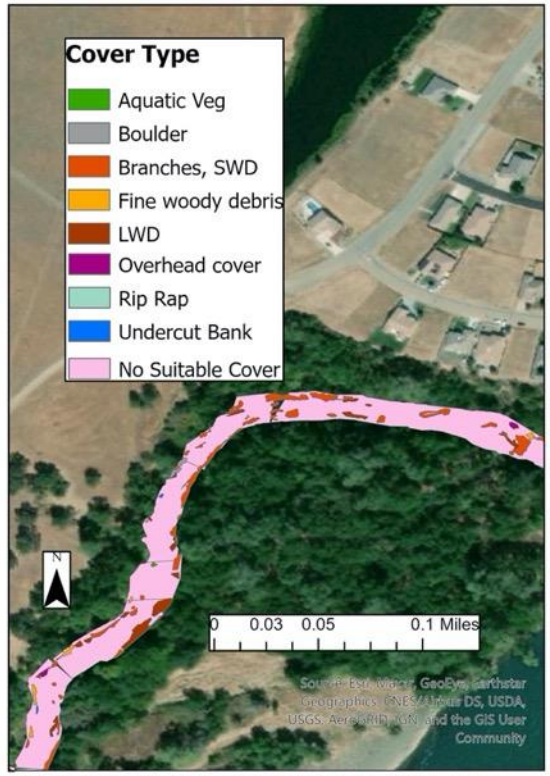
Post Restoration Habitat Mapping: Lake California (Middle)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



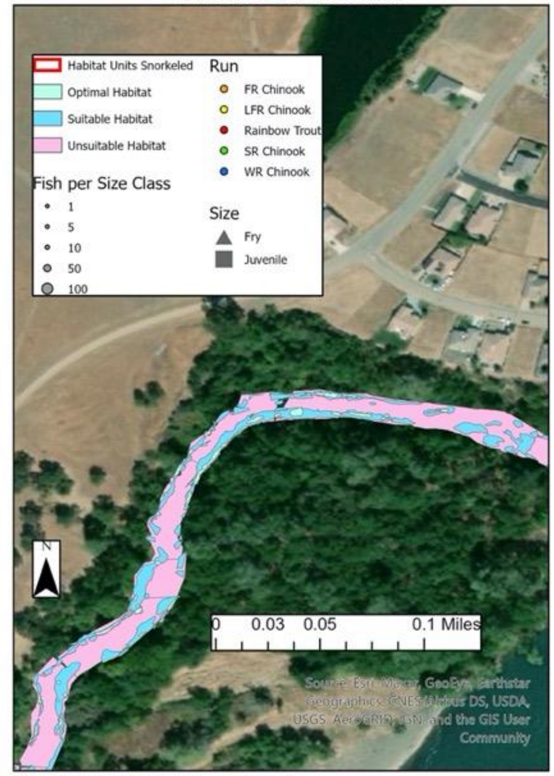
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

Cover from Predators



*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

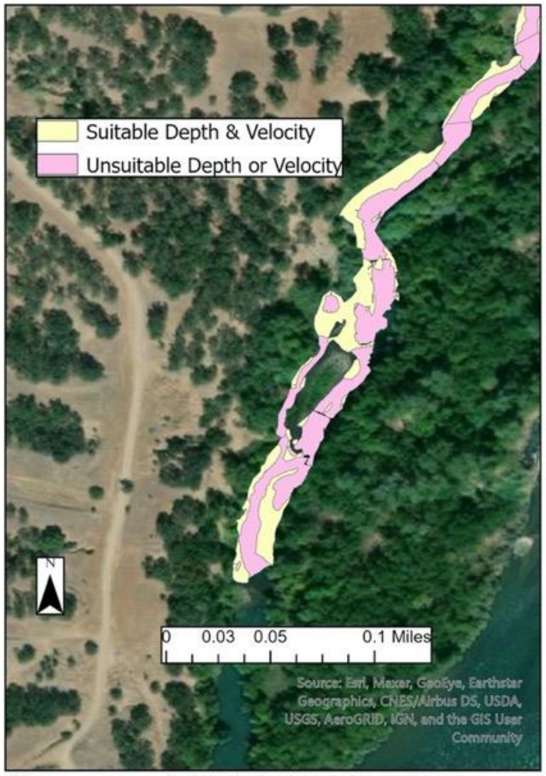
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

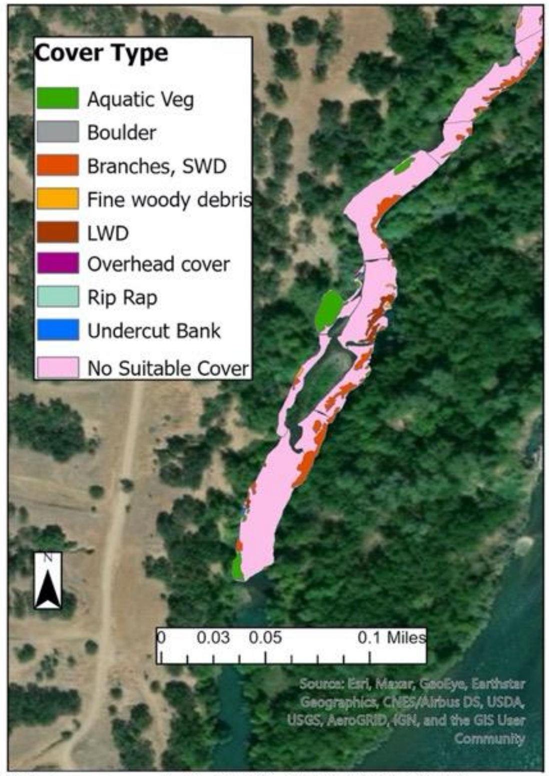
Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



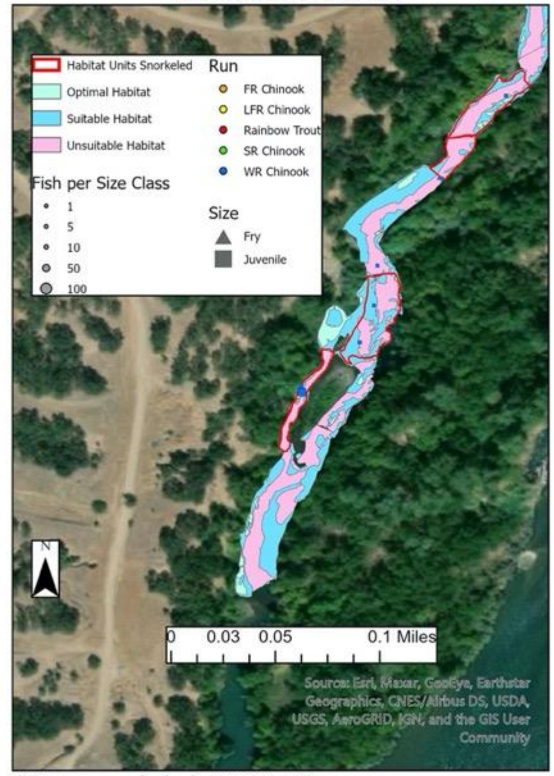
*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Cover from Predators



*Dates mapped: 2-13-18, 2-15-18, 2-20-18

Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 6,700 CFS

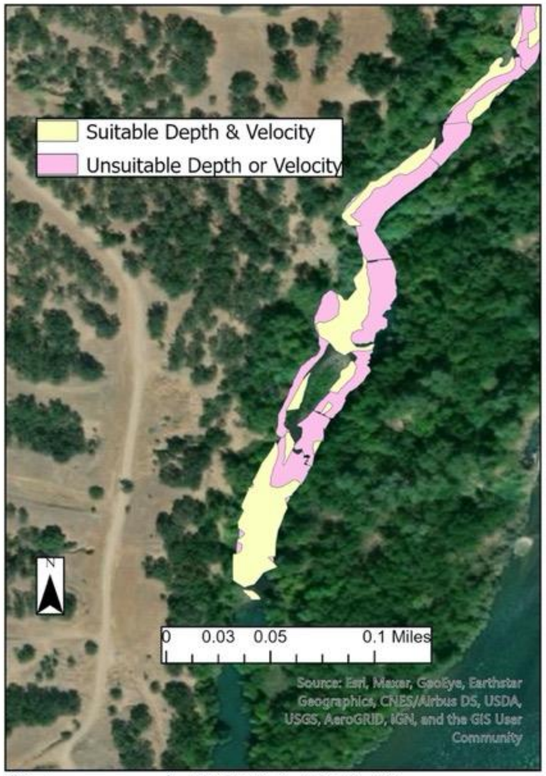
*Dates mapped: 10-7-19, 10-9-19, 10-17-19, 10-25-19 & 10-29-19

*Dates mapped: 10-14-19 & 10-16-19

*Dates snorkeled: 10-10-19
*Keswick flow during snorkel: 6600 cfs

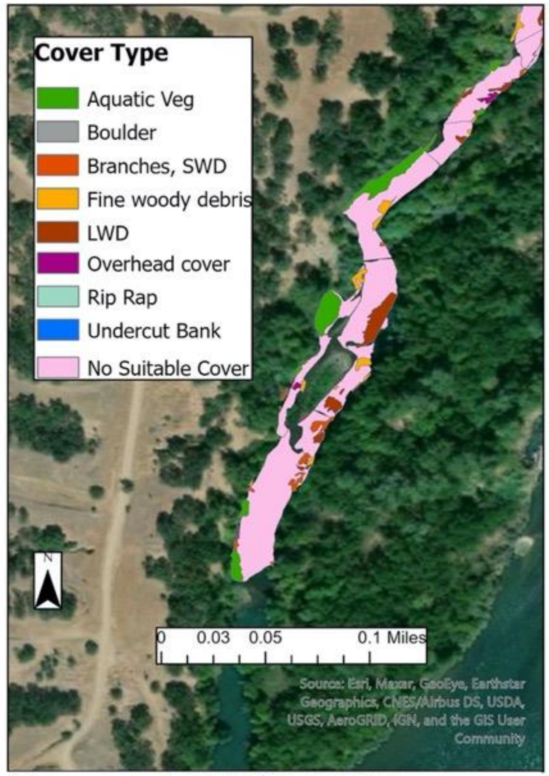
Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 7,500 CFS

Depth & Velocity Mapping



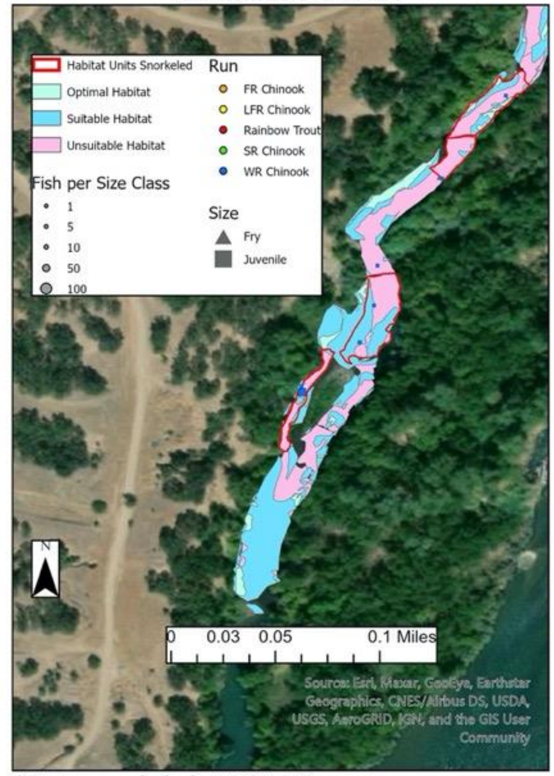
*Dates mapped: 10-8-18 & 10-10-18

Cover from Predators



*Dates mapped: 10-8-18 & 10-10-18

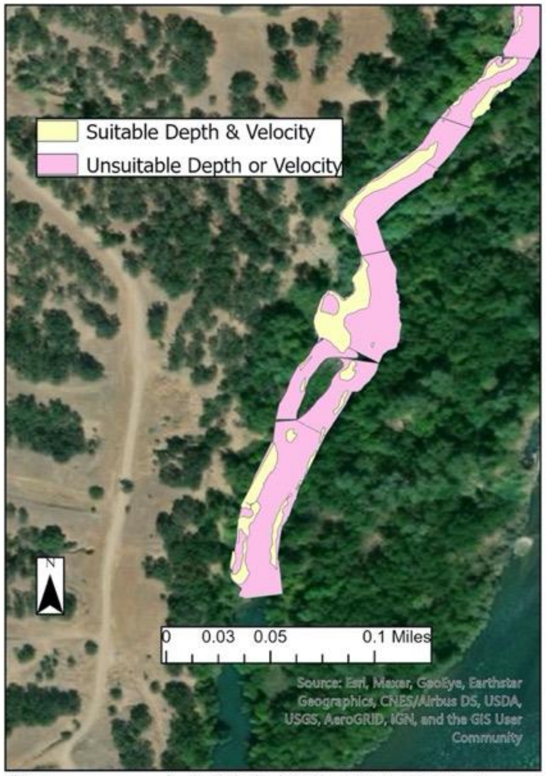
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 11-21-18
*Keswick flow during snorkel: 4400 cfs

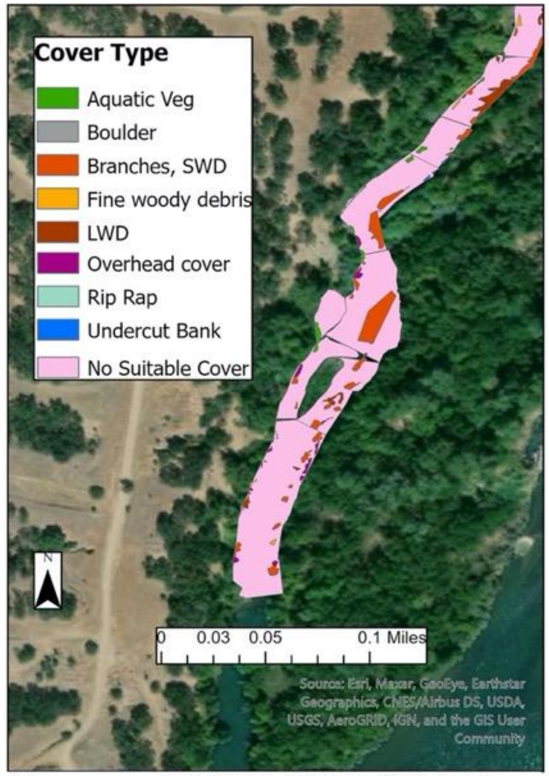
Post Restoration Habitat Mapping: Lake California (Lower)
Keswick Release 9,000 CFS

Depth & Velocity Mapping



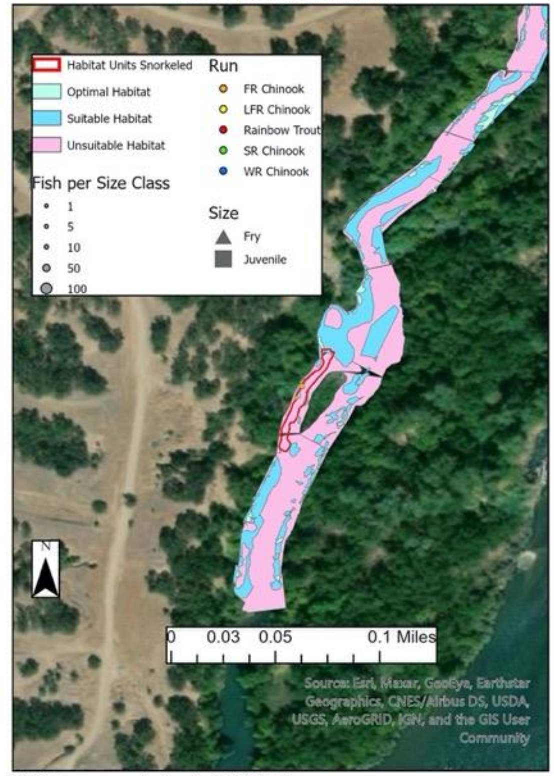
*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

Cover from Predators



*Dates mapped: 8-30-17, 9-11-17, 9-13-17, & 9-14-17

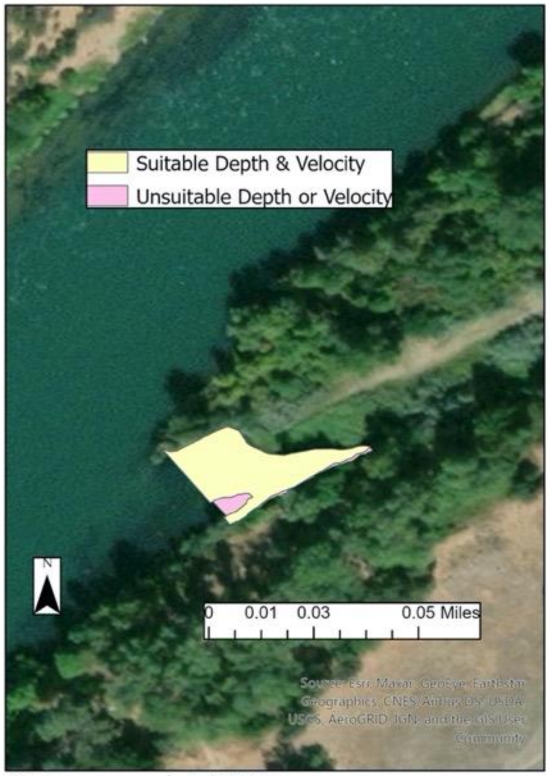
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 6-20-18
*Keswick flow during snorkel: 11000 cfs

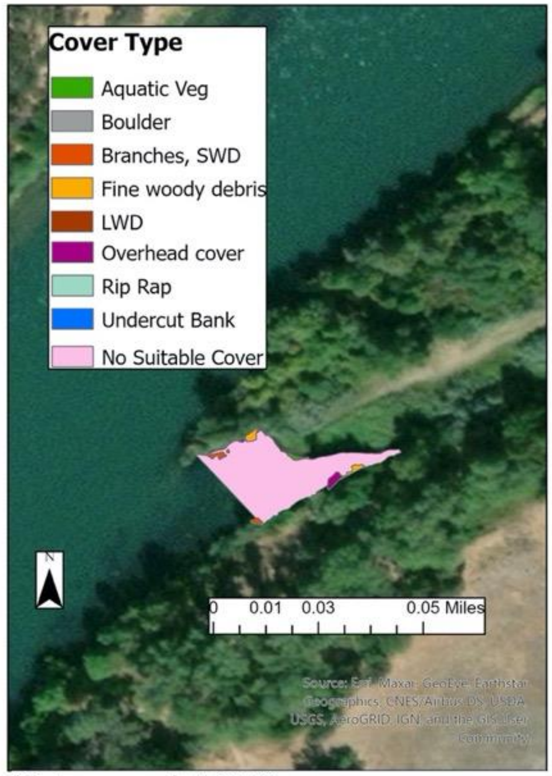
Pre Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



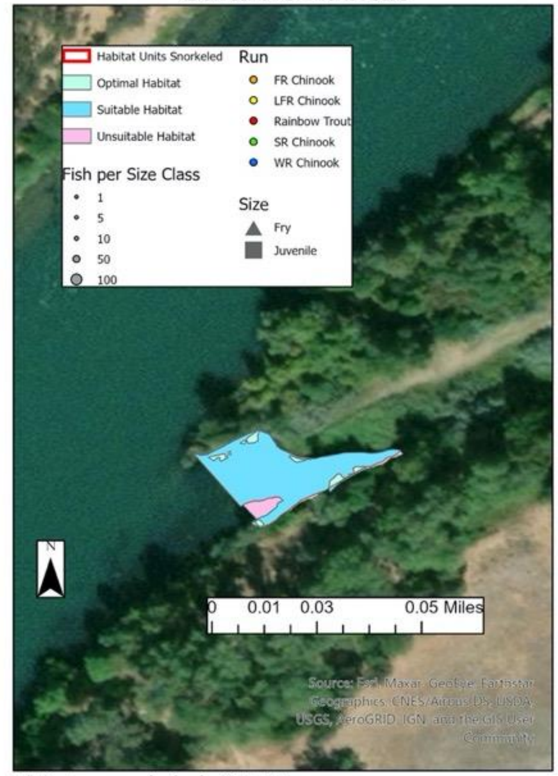
*Dates mapped: 1-22-19

Cover from Predators



*Dates mapped: 1-24-19

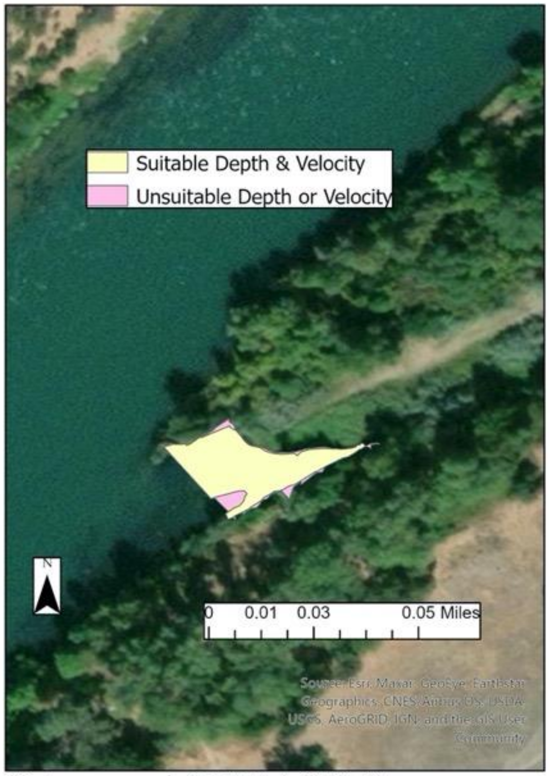
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

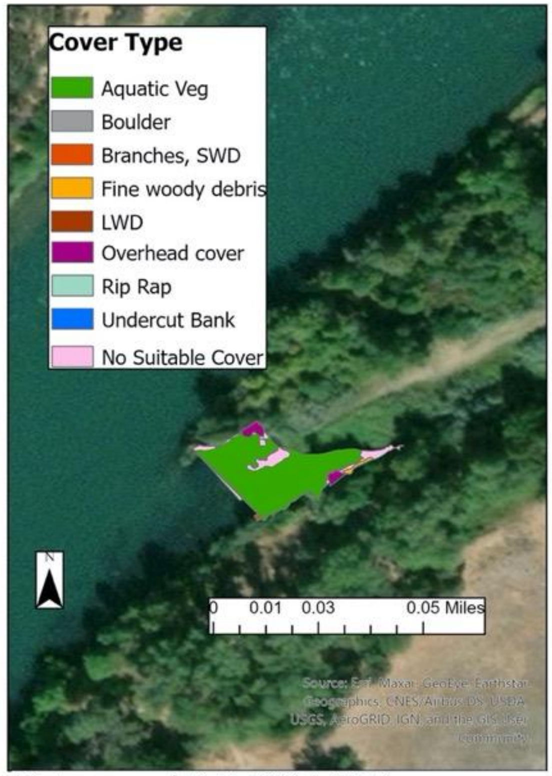
Pre Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 8,600 CFS

Depth & Velocity Mapping



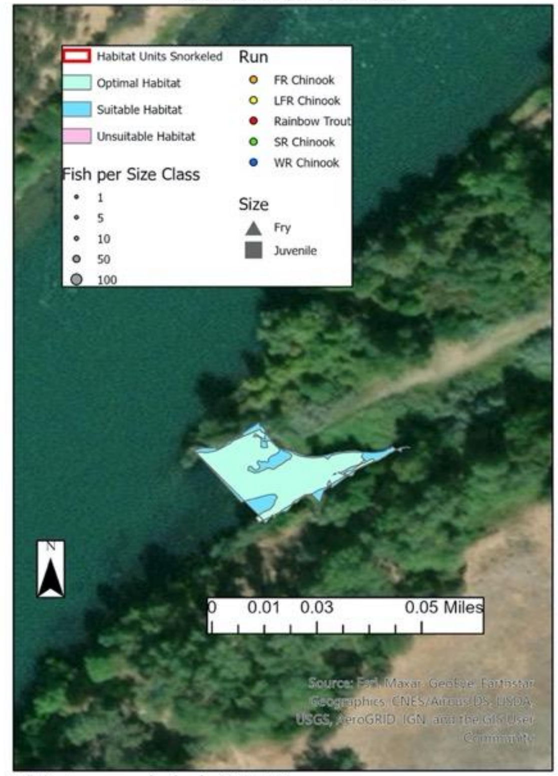
*Dates mapped: 9-11-19 & 9-12-19

Cover from Predators



*Dates mapped: 9-11-19 & 9-12-19

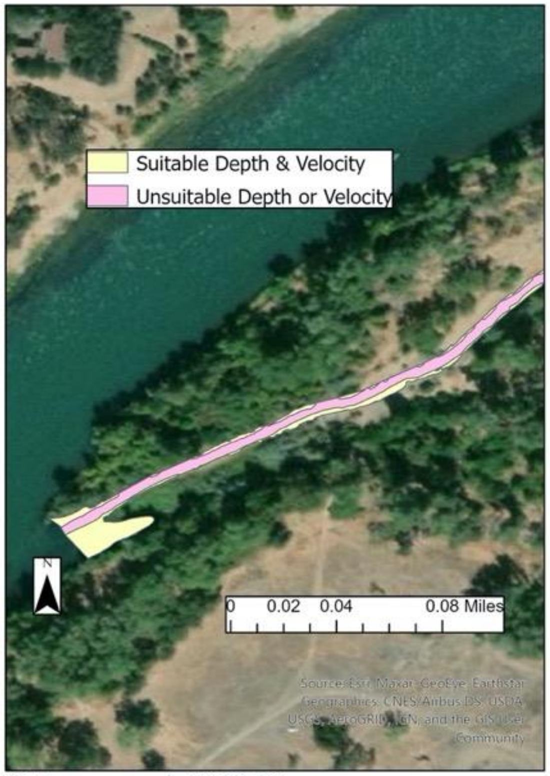
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

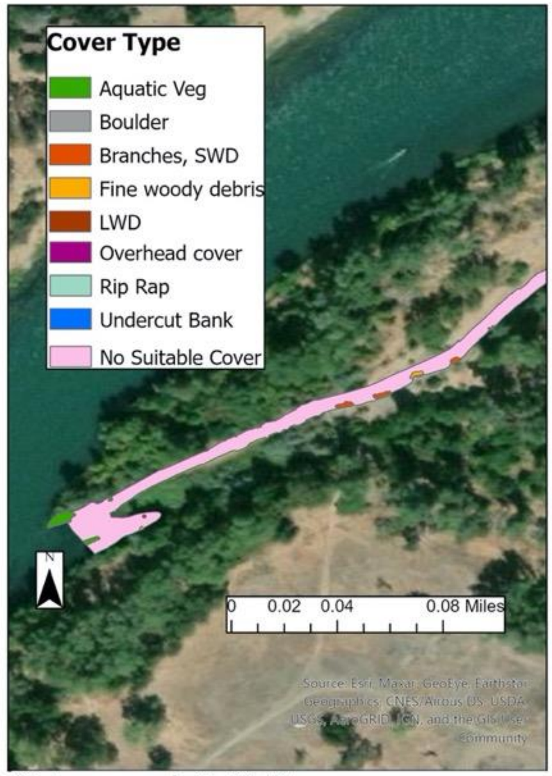
Post Restoration Habitat Mapping: Rio Vista (Lower)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



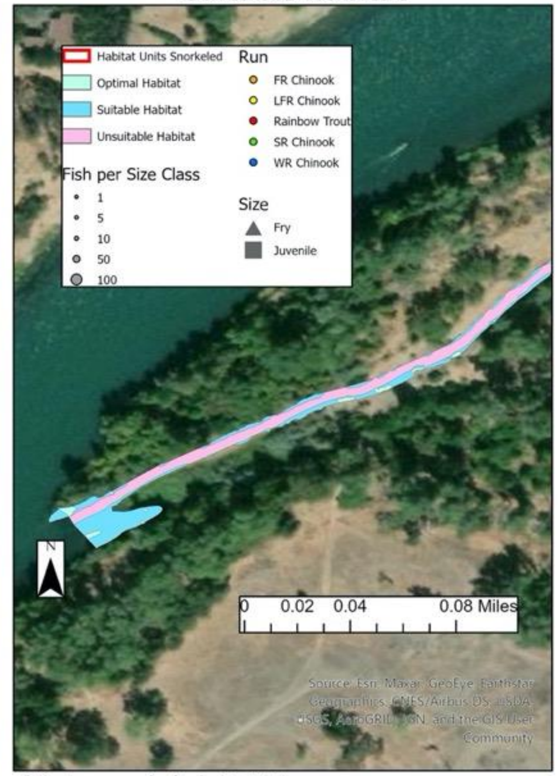
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19

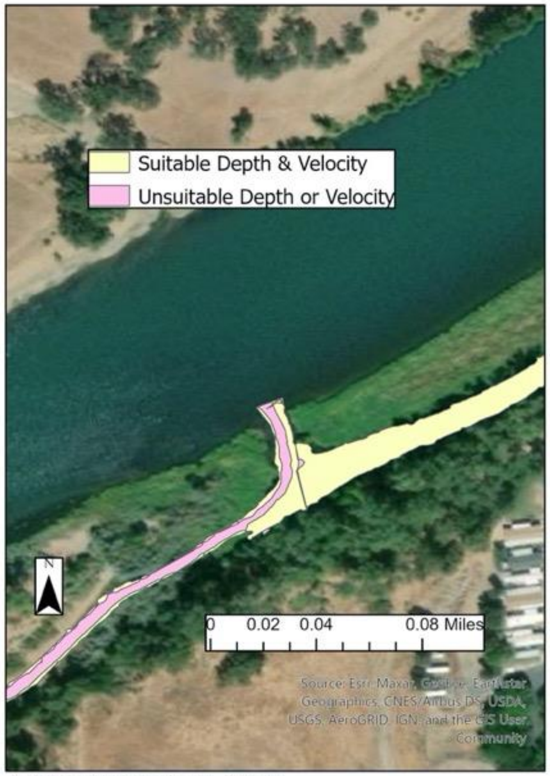
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

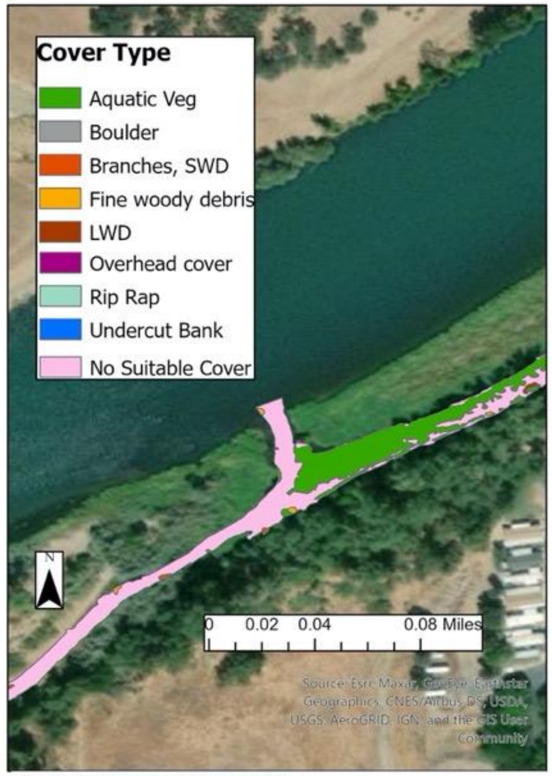
Post Restoration Habitat Mapping: Rio Vista (Middle)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



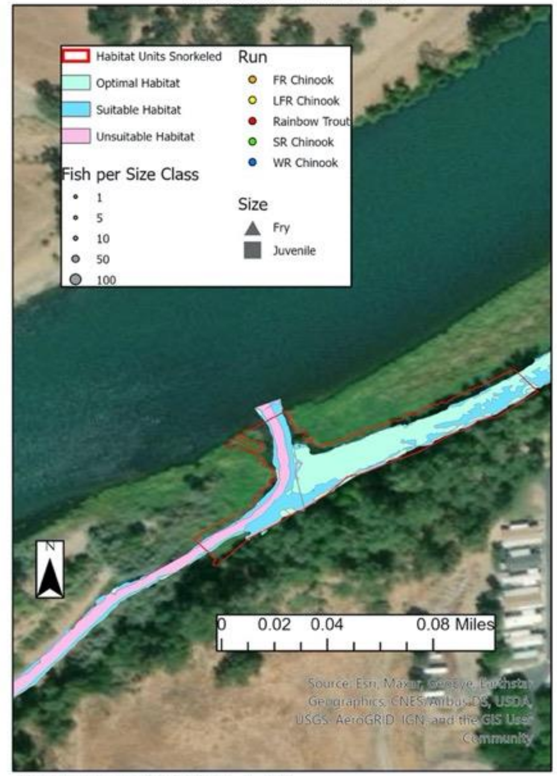
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19

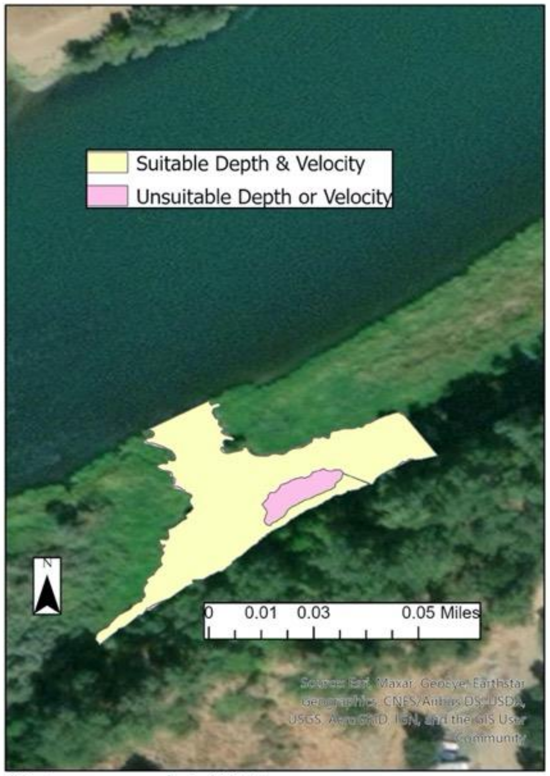
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

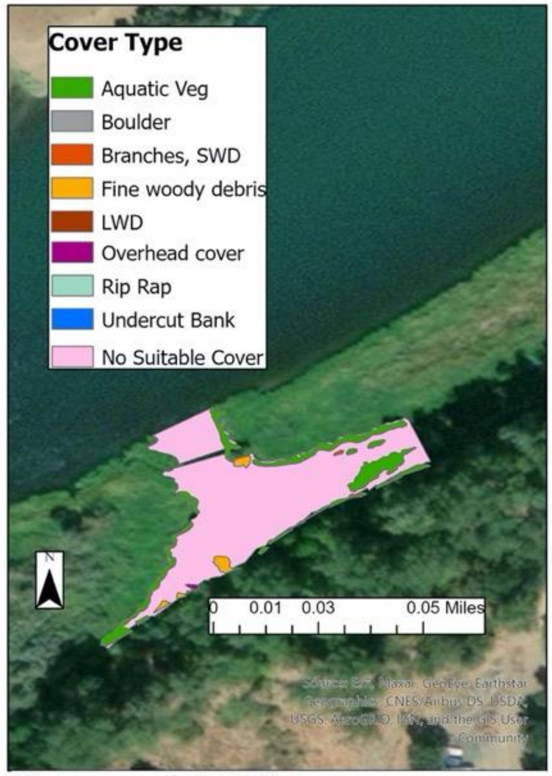
Pre Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 3,250 CFS

Depth & Velocity Mapping



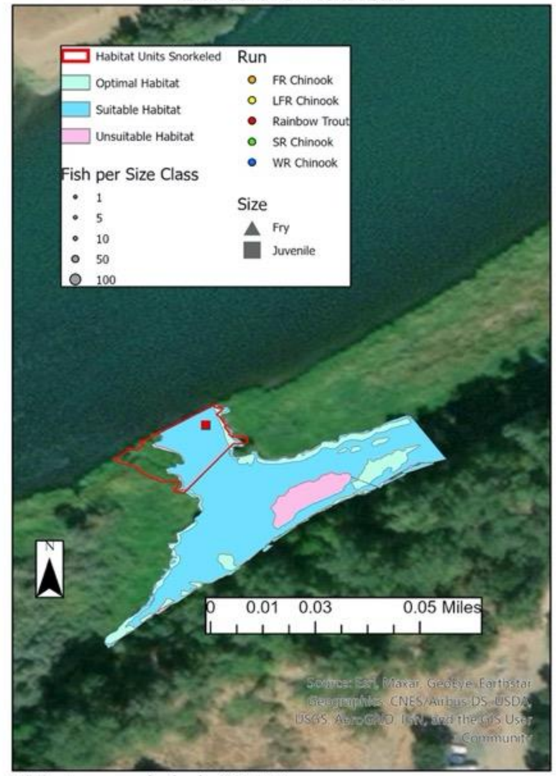
*Dates mapped: 1-22-19

Cover from Predators



*Dates mapped: 1-24-19

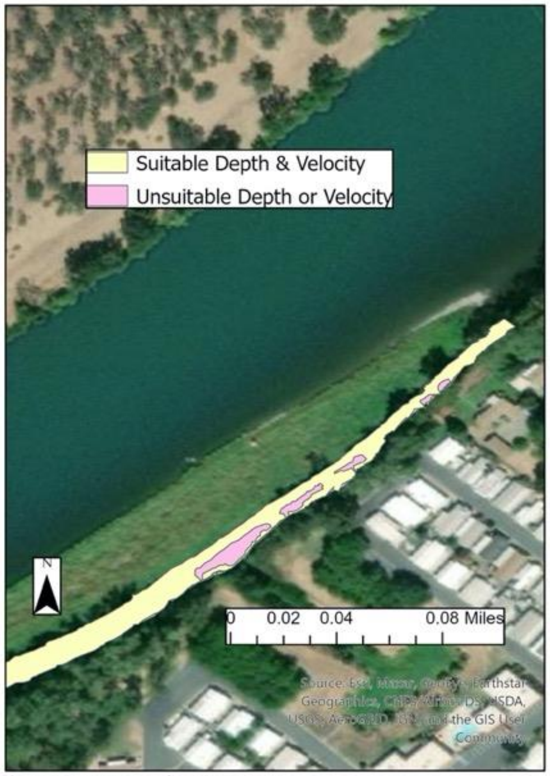
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs

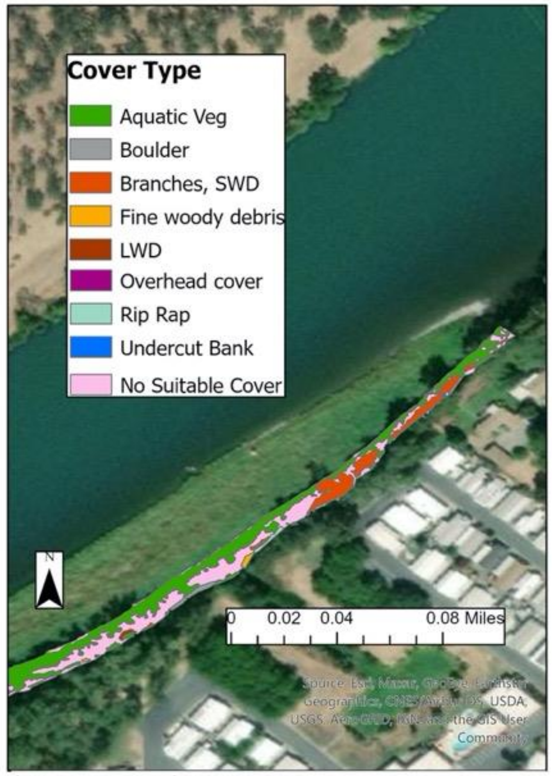
Post Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 5,000 CFS

Depth & Velocity Mapping



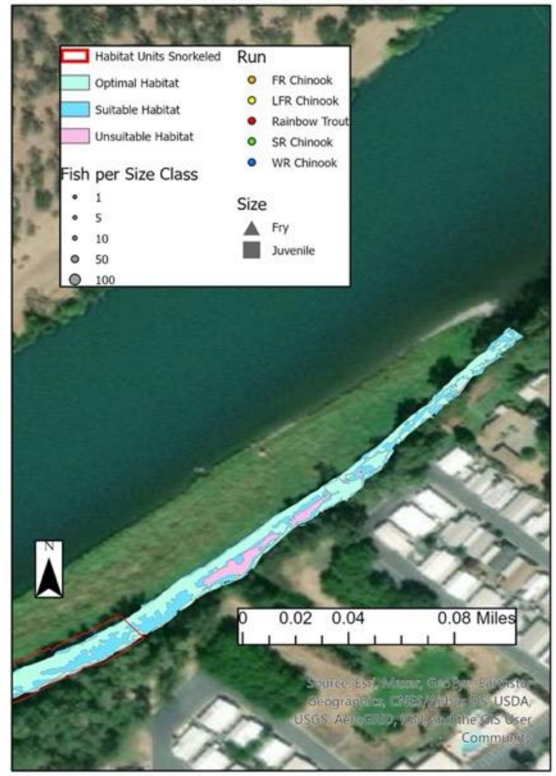
*Dates mapped: 11-20-19

Cover from Predators



*Dates mapped: 11-18-19

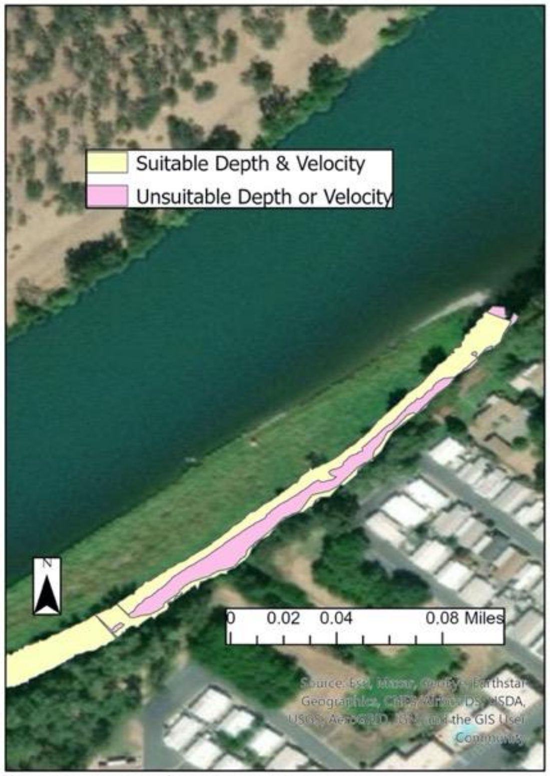
Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 2-4-20
*Keswick flow during snorkel: 4500 cfs

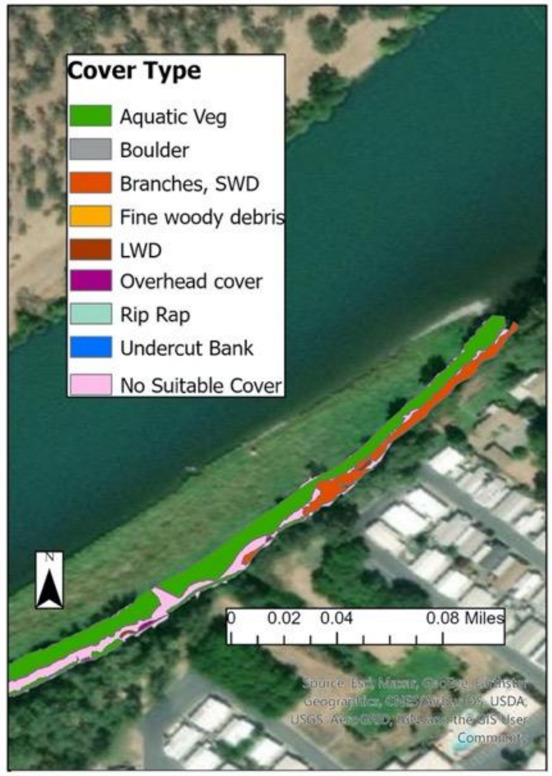
Pre Restoration Habitat Mapping: Rio Vista (Upper)
Keswick Release 8,600 CFS

Depth & Velocity Mapping



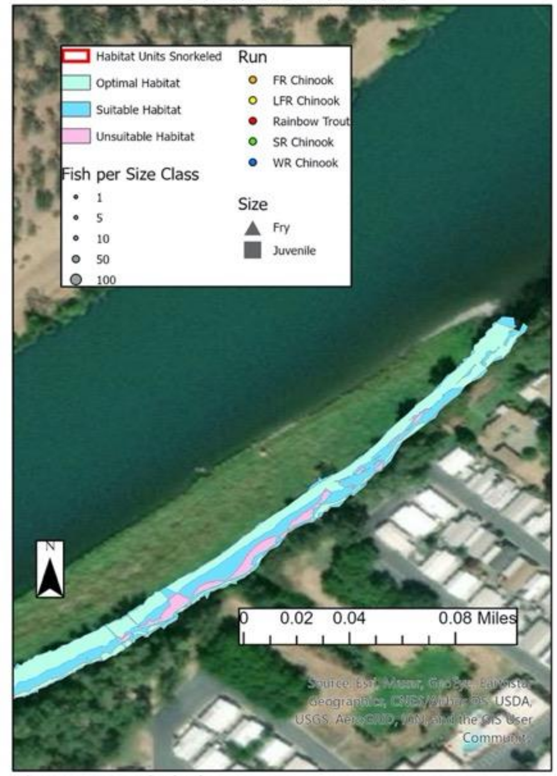
*Dates mapped: 9-11-19 & 9-12-19

Cover from Predators



*Dates mapped: 9-11-19 & 9-12-19

Fish Locations Among Optimal & Suitable Habitat



*Dates snorkeled: 8-1-19
*Keswick flow during snorkel: 11000 cfs